PROCEEDINGS

Volume 1

Editors

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FOREWORD

On behalf of the organising committee, I am delighted to welcome delegates to Brisbane, Australia for the Second World Fisheries Congress. The congress is an important opportunity for fisheries scientists, managers and commercial and recreational industry representatives to meet and address the theme Developing and Sustaining World Fisheries Resources: the State of Science and Management.

The response to the call for papers was quite overwhelming – more than 600 abstracts were received and reviewed. This volume of proceedings contains the abstracts of the oral and poster presentations which will occur during the four days of the congress. While some abstracts were submitted too late to be included in this volume of proceedings, a complete list of the oral and poster presentations can be found in the congress handbook. A second volume of proceedings, which will contain the full papers of the oral presentations, will be published after the congress.

I would like to thank the sponsors of Proceedings Volume 1 – their support has enabled us to produce this high quality document – which I am confident will become a valuable reference document and comprehensive record of the Second World Fisheries Congress.

DR JOHN GLAISTER
Congress Chairman
28 July 1996

CONTENTS
2nd World Fisheries Congress

Theme One

Presenter	Title	Page
Mace, Pamela **(Keynote speaker)**	Developing and sustaining world fisheries resources: the state of science and management	1
Sinclair, Michael **(Theme speaker)**	Why do some fisheries survive while others collapse?	2
Al-Hossaini, Mohsen	Age validation of nagroor, *Pomadasys kaakan* (Cuvier, 1830) (Family: Pomadasidae) in Kuwait Waters	2
Augustyn, Johann	Squid fisheries of the world: chaos or pattern? (Author: Marek Lipinski)	22
Bacalbasa-Dobrovici, Nicholae	Lower Danube fisheries collapse and prediction	2
Booth, John	Geographic variation in productivity and a prognosis for the New Zealand rock lobster fishery	3
Bortone, Stephen	Stock identification of red snapper, *Lutjanus campechanus* (Lutjanidae), from the Gulf of Mexico using mtDNA and year-class data	3
Bossy, Simon	Joint management initiatives in the English Channel	3
ındt, Stephen	Spatial and temporal complexity in aquatic environments: a key to fluctuating fisheries?	4
Brown, Ian	Development and mangement of the Queensland spanner crab fishery	4
Burridge, Charis	A comparison of interreef benthic communities in zones open and closed to trawling in the northern Great Barrier Reef	5
Calderon Aguilera, Luis	Assessment of shrimp postlarvae as a proxy variable of stock recruitment in the Gulf of California	5
Cappo, Mike	An overview of Australian fisheries habitat research	6
Castilla, Juan Carlos	The Chilean dived-invertebrate resources: fishery collapse, stock rebuilding and the role of coastal management areas and national parks	6
Chauvet, Claud	Existence of a sex-ratio regulation mechanism in Tunisian stocks of sea bream *Sparus auratus*	7
	Destruction of juvenile coconut crabs' environment (Author: Thourya Kadiri-Jan)	20
Chopin, Frank	Understanding technological impacts of capture technologies and sources of unaccounted fishing mortality	7
Chu, Ka Hou	Crustacean fisheries in the Zhujiang (Pearl River) Estuary, China	7
Clark, Malcolm	New Zealand orange roughy: steps towards a sustainable fishery	8
Connell, Mark	Cross shelf distribution of surfical sediments in the far nothern Great Barrier Reef, Australia	8
.t, Jose	The bluefin tuna *(Thunnus thynnus* L.) fishery in the Cantabrian Sea (Northeast Atlantic)	9
Dauble, Dennis	Rebuilding strategies for endangered stocks of Pacific salmon	9
Del Piero, Donatella	The striped venus and the razor clam fishery in the Gulf of Trieste: different life strategies and different fishery perspectives	10
Dulepova, Elena	Salmon in ecosystems of the Far-Eastern seas and North-western Pacific	10
	Biological resources of Far Eastern seas and North-western Pacific Ocean: the structure, status and long term dynamics of pelagic and demersal communities	11
Ehrhardt, Nelson	Sustainability of fisheries supported by dynamic surplus production: the case of the Chilean pelagic fisheries	11
Elliott, Nicholas	Evidence for two depth-separated stocks of the deepwater oreo Neocyttus *rhomboidalis* (Oreosomatidae) off Southern Australia	12
	An update on marine oil research in Australia	12
Englund, Ronald	Decline of Oahu's stream fisheries: identifying causes and planning restoration	12
Everett, John	World fisheries and climate change: impacts and adaptation measures	13
Fang, Lee-Shing	The environmental biology of an endemic fresh water fish, *Varicorhinus alticorpus,* in Taiwan	13
Ferreri, Paola	Role of fishing and sea lamprey induced mortality in the rehabilitation of lake trout in the US waters of Lake Superior	13
Filbert, Randall	Decline of Oahu's stream fisheries: identifying causes and planning restoration	12

Fonteneau, Alain	A critical review of tuna stocks and fisheries trends worldwide and why most tuna stocks are not yet overexploited	14
Francis, Malcolm	Prediction of snapper *(Pagrus auratus)* recruitment from sea surface temperature	14
Gehrke, Peter	Effects of urban development on fish and fisheries of the Hawkesbury-Nepean River System, Australia	15
Gilbert, David	A hypothesis to explain fish recruitment	15
Gillman, David	Integrated management in the Great Lakes: the sea lamprey program	16
Giussi, Analia Rosa	Southwest Atlantic long tail hake *(Macruronus magellanicus)*: state of stock and management	16
Gracia, Adolfo	Brown shrimp sequential fisheries in the Gulf of Mexico	17
Gribble, Neil	Spatial variation in the distribution of penaeidea (shrimp) species on the northern Great Barrier Reef: potential effects on management	17
Hare, Steven	Effects of interdecadal climate variability on the oceanic ecosystems of the north Pacific	18
Hilborn, Ray	The frequency and severity of fish stock declines and increases	18
Hudson, Elodie	Marine fish and the IUCN red list of threatened animals	18
Ibrahim, Sakri	Distribution of Benthic organisms around different designed artificial reefs	19
Jones, Keith	The effect of oceanographic variability on the recruitment of two species of juvenile arripid fish to a nursery area and subsequently to the hauling net fishery in South Australia	19
Jordan, Alan	Recruitment and size structure of jackass morwong (Nemadactylus macropterus) and tiger flathead *(Neoplatycephalus richardsoni)* populations in eastern and south-eastern Tasmania, Australia	19
Kanamoto, Ziyusei	Daily changes in the catch of *Parapristipoma trilineatum* at the hook and line fishing ground of Toshima Fishery Co-op in the Uwa Sea, Japan	20
Klyashtorin, Leonid	Global climate cycles and pelagic fish stock fluctuations in the Pacific	20
Knight, Scott	Habitat and fisheries restoration of incised stream channels	21
Koslow, Tony	Management of Australia's orange roughy fishery	22
Kroese, Marcel	Elasmobranch stocks in South Africa – improved utilization or increasing catches?	22
Lluch-Belda, Daniel	Perspectives of the lobster and abalone fisheries on the northwest coast of Mexico and their management, exploited under a limited access system	40
	The signal of global interdecadal Regime variation on temperate sardine and anchovy populations	23
Loesch, Joseph	Development and application of a juvenile index of abundance for anadromous river herring	23
Lozano-Alvarez, Enrique	Fluctuations in population parameters of the spiny lobster *Panulirus argus* in a fishery based on artificial shelters	24
Manyala, Julius Otieno	Effect of variability in some population parameters of *Rastrineobola argentea* (Pellegrin 1904) on the yield and biomass in Lake Victoria	24
Mapstone, Bruce	The effect of reopening Bramble Reef to bottom fishing on fishing behaviour and catch rates of commercial and recreational line fishers on fishing	24
Mathisen, Ole	The fall and rise of Pacific Salmon in North America	25
Mathur, Sushil Chand	Protozoan parasites of freshwater food fishes of Punjab India, with special reference to gregarines, microsporidians and amoebae	25
McClatchie, Sam	Demersal fish community diversity off New Zealand is related to depth, latitude and regional surface phytoplankton	26
McKenzie, Jeremy	Biomass estimation of New Zealand snapper stocks by Petersen Mark recapture using cryptic (coded wire) tags	26
Megrey, Bernard	Applied fisheries oceangraphy: guiding fisheries management by relating environmental and recruitment variability to forecast year-class strength of Alaska Walli Pollock	27
Moran, Michael	Effects of fishing gear on benthic habitat	27
Muchiri, Mucai	Fluctuations in the fisheries of Kenya's Rift Valley lakes: causes and prospects for the future	27
Muhlia-Melo, Arturo	The Robalo Fishery in Mexico: management, enhancement and aquaculture	28
Nance, James	Bycatch in the Gulf of Mexico shrimp fishery	28
O'Dor, Ron	Squid recruitment in the genus *Illex*	29
Palmisano, John	Regional abundance variation in Washington's salmonid fisheries	29
Papaconstantinou, Costas	The distribution of larval scombrids in the Aegean Sea (Greece)	30
Penn, James	Protecting vulnerable stocks in multi-species prawn fisheries	30

Pikitch, Ellen	Mortality estimation of trawl-caught and discarded Pacific halibut *(Hippoglossus stenolepis)*	31
Pitcher, Tony	Fish social behaviour as the keystone factor in the resilience of fisheries	31
	An individually-based model of fish school dynamics	32
Rawlinson, Nick	Survival of selected fish species after escaping from square mesh codends	32
Reid, Dennis	Decline of freshwater fisheries in a large semi-arid floodplain river system	32
Reynolds, James	Relative length: a comparative approach to fish growth	33
Rinne, John	Factors contributing to the collapse yet maintenance of a native fish community in the desert southwest (USA)	33
Robins, Carolyn	Factors influencing fishing power in the northern prawn fishery	33
Robins, Julie	Is it true what they say about trawling and sea turtles?	34
Rowling, Kevin	The collapse of the eastern Australian gemfish stock – a case of putting all your eggs in one basket?	34
Sanaullah, Muhammad	*Myxobolus* spp. (myxozoa: Myxosporea) as primary causative agents of epizootic ulcerative syndrome (EUS) in fishes from Beel Mahmoodpur, Faridpur, Bangladesh	34
Sanchez, Pilar	Catch composition of the otter bottom trawl fishery on the Catalan Coast, northwestern Mediterranean	35
Slotte, Aril	Spawning of Norwegian spring spawning herring *(Clupea harnegus* L.) related to geographical location and population structure	35
ley, Brian	Data sets and environmental indicators used to manage Pacific salmon for sustainable fisheries on Canada's west coast	36
Stephenson, Peter	Relating fishing mortality to fish trawl effort on the north-west shelf of Western Australia	36
Stephenson, Robert	Successes and failures in the management of Atlantic herring fisheries: do we know why some have collapsed and others survived?	37
Stevens, John	Are southern Australian shark fisheries sustainable?	37
Sunnane, Knut	The North-East Euro-Arctic ecosystem – successes and failures of managing multispecies and multifleet fisheries	38
Thorncraft, Garry	Assessment of rock-ramp fishways	38
Twagilimana, Landoald	Problems of fisheries in developing countries: example of degradation of the aquatic environment by Rwandese war (Africa)	39
Tzeng, Wann-Nian	Short- and long-term fluctuation in catches of the Japanese eel, *Anguilla japonica,* elvers on the coast of Taiwan	39
Vega, Armando	Perspectives of the lobster and abalone fisheries on the northwest coast of Mexico and their management, exploited under a limited access system	40
Williams, Robert	Estuarine rehabilitation studies in New South Wales, Australia: from intensive to extensive	40

Theme Two

bowen, Bernard **(Theme speaker)**	What are the roles of science, economics, sociology and politics in fisheries management?	41
Arimoto, Takafumi	Use of artificial stimuli for fish harvesting and controlling purposes	41
Armantrout, Neil	Using remote sensing to locate aquatic habitat	41
Baker, David	Your work is of value, prove it or perish	42
Barker, John	Co-management – fact or fiction?	42
Barrington, Jonathon	"All quiet on the western front" – the application of war and peace strategies in fisheries management	43
Brown, Bonnie	Use of ecological and genetic data as a basis for multi-jurisdictional fisheries management	43
Brown, Deborah	Incorporating risk in a bioeconomic analysis of the Orange roughy fishery (Author: Robert Curtotti)	45
Bundy, Alida	Conflicts in fisheries: an integratic approach with management options	44
Coleman, Anne	Fishcount '95: an innovative design for collection of recreational fisheries data	44
Cooper, Jon	Environmental impact assessment and other regulatory mechanisms: approaches to fisheries protection and mitigation in Senegal and Indonesia	45
Dayaratne, Pauline	Bio-socio-economic approach in the assessment and management of the purse-seine fishery in the south-west coast of Sri Lanka	46
Derbyshire, Kurt	Geographical Fisheries System (GFS): visualising fisheries data	46
Du Plessis, Pieter	The socioeconomic effects of longlining versus trawling and of exploiting bycatch in the South African economy and grassroots fishing communities	47

	The socioeconomic effect and implications of fishermen's community trusts in South Africa	47
Dudley, Sheldon	The effect of netting strategy on shark attack risk: is it predictable?	48
Foale, Simon	Ownership and management of traditional trochus fisheries at West Gela, Solomon Islands	48
France, Murray	Industry must be a part of the fisheries management system	49
Gomes, Charmaine	The use of DNA markers in determination of stock structure of the four-wing flyingfish, *Hirundichthys affinis*, and its implications for fisheries management in the central western Atlantic	49
Hammond, Donald	The joining of provincial government, sportfishing industry and fishery management to help conserve istiophorid stocks	50
Higginbottom, Ian	The EchoListener: a low cost and high resolution acoustic data logger for fishers, marine scientists and hydrographers	50
Higgs, James	Can the recreational fishing community be used to collect information suitable for fisheries management decision making?	51
Hutton, Trevor	Post-apartheid fisheries management policy in South Africa: the need for a change in management philosophy	51
Kailis, George	Sustainably managing sustainable management	52
Kangas, Mervi	Review of the effectiveness of a total closure in the Gulf St Vincent prawn industry	53
Kaplan, Ilene	Policy, compliance and ecology: a case study of New England fishers	53
Karavellas, Demetres	Fisheries and the conservation of biodiversity: the case of the Mediterranean monk seal *Monachus monachus* in Greece	54
Kirschbaum, Frank	Need for further study on environmental control of cyclic reproduction of tropical freshwater fishes	54
Knuckey, Ian	Good management and/or good luck? Timely introduction of input controls in the Northern Territory Mud Crab Fishery	55
Lane, Daniel	Fisheries management science: integrating the roles of science, economics, sociology and politics in effective fisheries management	55
Lassen, Hans	Biological advice on fishery management in the North Atlantic 1970-1995: structure, principles and results	56
Marshall, Philip	New technology for fisheries management – implementing a satellite based vessel monitoring system	56
McDonald, David	An empirical evaluation of important sources of price risk for Tasmanian southern rock lobster	57
McPhee, Daryl	Cooperative tagging programs: scientists and anglers working together	57
Meaden, Geoffery	Monitoring fisheries effort and catch using a geographical information system and a global positioning system	57
Michael, Dinakaran	Differential immunomodulatory effect of nickel compounds in *Oreochromis mossanbicus* (Peters)	
Nathanael, Shirani	The role of science, economics, sociology and politics in the sustainable management of the fishery at the Victoria Reservoir, Sri Lanka	58
Neitzel, Duane	Setting objectives: lessons learned from Pacific Northwest, United States of America	59
Nicolas, Jose	Database management: the application of Lotus Macro for on-farm economic analysis of rice-fish data	59
Nielsen, Dr Larry	The stakeholder satisfaction triangle: a model for successful management	59
O'Boyle, Robert	A comparison of the benefits and costs of quota versus effort based fisheries management	60
	Strategic planning in fisheries management – a blueprint for sustainable harvesting	60
Pierce, Bryan	Integrated fisheries management: structured solutions to managing political, economic and scientific chaos in degraded wild stock fisheries	61
Pitcher, Tony	Exploration of a multi-disciplinary taxonomy of fisheries	61
Punt, Andre	Advances in Bayesian stock assessment and decision analysis – application to orange roughy off Tasmania	62
Ransom, Bruce	Counting migrating juvenile and adult salmonids (*Oncorhyachus* and *Salmo* spp.) in rivers using split-beam hydroacoustics and target tracking	62
Rawlinson, Peter	Structural adjustment and fisheries in Australia: sustainability and economic efficiency. Policy considerations for a national fisheries adjustment program	63
Rayns, Nick	Effective consultation and its impact on the management of eastern Australian gemfish	63
Rettig, Bruce	Cost-effective recovery of endangered Snake River salmon	64

Roberts, Michael	Fisheries management: developing an environmentally driven predictive capability (EDPC) for the South African squid fishery	65
Robertson, John	Fisheries management in the Great Barrier Reef Marine Park	65
Ross, Darby	The Australian orange roughy fishery: a process for better resource management	65
Saila, Saul	Fuzzy control theory applied to American lobster management	66
Sauer, Warwick	Squid fishers and scientists – creating a symbiotic environment	66
Sawynok, Bill	Sportfish tagging data and its role in a recreational fishing database in Queensland	67
Scandol, James	Converting research results into improved management using Bayesian statistics: the example of Pacific salmon gauntlet fisheries	67
Smith, Tony	Quantification of objectives, strategies and performance criteria for fishery management plans – an Australian perspective	68
Starr, Rick	Can fishery catch data supplement research cruise data? A geographic comparison of research and commercial catch data	68
Sumaila, Ussif	Co-operative and non co-operative exploitation of the Arcto-Norwegian cod stock	69
Thompson, Bruce	Louisiana striped mullet: Integration of science, fishery and management	69
Trumble, Bob	When science isn't enough: improving survival of discarded Pacific halibut	70
Van Zyl, Jacques	The roles of science, economics, sociology and politics in fisheries management - the South African experience	70
Williams, Lew	Effect of feedback on commercial fisher data collection in remote area fisheries	71

Theme Three

Van Der Elst, Rudy **(Theme speaker)**	Fisheries access rights: dishing out what remains of the South African fish pie	72
Ali, Md Islam	"As nets belong to fishers, fisheries belong to them" (Jaal Jar Jala Taar)	72
Augustyn, Johann	Management of offshore marine resources in the new South Africa	73
Ault, Jerald	The role of protected marine areas in fisheries management: Florida Keys National Marine Sanctuary	74
Brown, Bonnie	Critical tests for variation indicate mtDNA characters are powerful for mixed stock analysis	74
Butcher, Adam	Development of the stout whiting fishery in southeast Queensland	74
Cameron, Darren	Management considerations for the dusky flathead fishery in Moreton Bay, Queensland, Australia	75
Castro, Refugio	Brown shrimp *(Penaeus aztecus)* fisheries resources in the Mexican waters of the Gulf of Mexico	75
Davies, Campbell	Appropriate spatial scales for marine fishery reserves for management of coral trout, *Plectropomus leopardus,* on the Great Barrier Reef	76
Dean, John	International bio-political fisheries management: sashimi on the cutting edge	76
Fennessy, Sean	South African east coast trawling – what's the (by) catch?	76
[illegible], Wes	The division of access in a fully exploited fishery: restructuring the Tasmanian rock lobster fishery	77
Hanek, George	Towards management of Lake Tanganyika's fisheries	77
Hart, Paul	Controlling illegal fishing in closed areas: the case of mackerel off Norway	78
Kinloch, Martine	Resource allocation in the South Australian marine inshore fishery	78
Mapstone, Bruce	Design of experimental manipulations of line fishing and area closures on the Great Barrier Reef	79
Millington, Peter	Franchising fisheries resources, an alternative model for defining access rights in Western Australian fisheries	79
Morgan, Gary	Optimal allocation of fisheries quotas under a transferable quota management system	80
Nielsen, Jesper R	Fisheries co-management: a comparative analysis	89
O'Boyle, Robert	Strategic planning in fisheries management a blueprint for sustainable harvesting	60
Page, Ray	The Victorian Recreational Fishing Peak-Body	80
Palmer, Bill	Property rights in fishery resources	80
Passer, Jeff	Enforcing quotas in Alaska	81
Pitcher, Tony	The benefits of recreational fisheries: cases from Kenya, South Africa and British Columbia	81
Pollard, David	Marine harvest refugia as a tool for inshore fish population enhancement	82
Shallard, Bruce	Concepts and practice of individual transferable quotas for the management of fisheries – an overview	82

Sheshappa, Subbanna	A novel approach for rebuilding fish stock and ecological balance to help small scale and traditional fisheries	83
Slooten, Elisabeth	Risk and uncertainty – implications for the sustainable management of bycatch mortality of Hector's dolphin	83
Smith, John	Octopus fishing at Eaglehawk Bay: a case study of conflict and resource management	83
Sullivan, Kevin	Management of New Zealand's snapper fishery: allocation of a limited resource between commercial and non-commercial users	84
Sumpton, Wayne	Problems associated with the assessment of offshore multi-user fisheries	85
Taylor-Moore, Noel	The allocation of marine inshore and estuarine fish resources in Australia: the need for a precautionary decision making paradigm?	85
Tilzey, Richard	Allocation issues between recreational and commercial fishers: the Australian experience	86
Turnbull, Clive	Research-directed management or management-directed research? The Torres Strait Prawn Fishery	86
Van Bueren, Martin	An economic assessment of reallocating salmon and herring stocks from the commercial sector to the recreational sector in Western Australia	87
Van Zalinge, Nicolaas	Fisheries of Cambodia: the Tonle Sap Great Lake and River ecosystem under threat	87
Wallner, Bruce	Sustainable management of northern Australian fisheries resources – access and catch sharing with traditional Indonesian fishers	
Watson, Reginald	Computer simulation of fisheries closures	88
Wright, Steven	Institutional reforms: realigning the roles and responsibilities of fishers and the government	89

Theme Four

Liao, I Chiu **(Theme speaker)**	How can aquaculture help sustain world fisheries?	90
Bence, James	Evaluation of the relative importance of hatchery-reared and wild fish in the restoration of Lake Superior lake trout	90
Bianchini, Marco	An Italian enhancement program for slipper lobster, *Scyllarides latus*	91
Blankenship, Lee	A responsible approach to marine stock enhancement	91
Chao, Nai-Hsien	Can cryopreservation of sperm gametes help sustain aquaculture diversity?	91
Cheah, Michael	Preliminary trials on larval rearing of the Australian eel tail catfish, *Neosilurus ater* (Perugia)	92
Chien, Yew-Hu	Ecological consideration for the planning, implementation and practice of pond mariculture	92
DeAlteris, Joseph	Transient gear, shellfish aquaculture, an innovative socially acceptable complement to the wild stock capture fishery	93
Fagbenro, Oyedapo	Biopreservation of fish by-products for aquaculture feed in tropical Africa	
Felix-Pico, Esteban	Clam and scallop fisheries and culture in Baja California Sur, Mexico	94
Green, Trellis	The myth of sustainability in managed wild fisheries: the economic case for aquaculture subsidies	94
Hart, Anthony	Can aquaculture help restore and sustain production of giant clams?	95
Hickman, Robert	The fisheries aquaculture relationship in New Zealand: is it competitive or complementary?	95
Chung, Huu-Yun	Review of epizootics in cultured fish in Taiwan	95
Ingram, Brett	Progress towards development of culture methods for glass eels of the Australian short-finned eel *(Anguilla australis)*	96
	Hormone induced spawning of the threatened Macquarie perch *(Macquaria australasica)*: an Australian native freshwater fish	97
	Evaluation of two electronic juvenile fish counters	97
John, George	Indian aquaculture: where does it stand?	98
Kahn, James	The myth of sustainability in managed wild fisheries: the economic case for aquaculture subsidies	94
Kikuchi, Kotaro	Intensive production of Japanese flounder with a closed recirculating culture system	98
Liao, David	Demand for recreational fishing and stock enhancement programs in the northeast region of Taiwan	99
Liao, I-Chiu	Survey of leptocephalus of Japanese eel in the western Pacific Ocean	99
McKinnon, Lachlan	A pilot evaluation of aquaculture integration with irrigated farming systems	99
McLoughlin, Richard	Coastal planning and aquaculture: regional marine farming development plans	100

McMeniman, Neil — Estimation of *in vivo* digestibility of diets fed to barramundi *(Lates calcarifer)* 100
Michael, Dinakaran — Immunoindicators of environmental stress and disease-outbreak in aquaculture 101
Palmegiano, Giovanni — Intensive fishculture and its impact on the environment: the role of natural zeolites in the reduction on the ammonium content in the effluents 101
Preece, Peter — Feasibility of abalone stock enhancement and rehabilitation by larval reseeding: new developments in South Australia 102
Pullin, Roger — Conservation of genetic resources for aquaculture 103
Ramachandran, Alappat — Strategic planning to tide over the present crisis and sustain the brackish water aquaculture industry in India 103
Robinette, Randy — Influence of channel catfish, *Ictalurus punctatus,* size-class distribution on protein ulitization 103
Russell, John — Assessment of stock enhancement of barramundi *(Lates calcarifer)* in a coastal river system in far northern Queensland, Australia 104
Scarsbrick, Joanne — Towards sustainability – the aquaculture industry 104
Shiau, Chyuan-Yuan — Effects of growth and starvation on the concentration of free histidine in the muscle of milkfish *(Chanos chanos)* 105
Soares, Joseph — Improved dietary phosphorus utilization by striped bass fed phytase 105
Su, Mao-Sen — Status and prospects of small abalone culture in Taiwan 105
Welcomme, Robin — World inland fisheries and aquaculture – changing attitude to management 106
liams, Kevin — Improved grow-out diets for farmed barramundi *Lates calcarifer* (Bloch) 106
Woods, Curry — Nutritional requirements of domestic striped bass broodstock 107
Zaitsev, Viatcheslav — Processes of membrane digestion in reared fish species 107

Theme Five

Beddington, John **(Theme speaker)** — Limits to the exploitation of capture fisheries 108
Bax, Nicholas — Quantitative assessment and forecasting of Australia's orange roughy stocks 108
Brewer, David — A comparison between diamond and square mesh codend selectivity in the northern prawn fishery of Australia 109
Assessment of an environmentally friendly, semi-pelagic fish trawl 109
An assessment of eight bycatch reduction devices in Australia's northern prawn fishery 109
Recent advancements in environmentally friendly trawl gear research in Australia ... 110
Cannizzaro, Leonardo — Catch and abundance in areas with different exploitation rates in the Sicilian Channel 110
Caputi, Nick — Relationships between different life history stages of the western rock lobster, *Panulirus cygnus,* and implications for management 111
Chotiyaputta, Cherdchinda — Distribution, abundance, reproductive biology, age and growth of *Loligo chinensis* and *Loligo duvauceli* in the western Gulf of Thailand 111
Danaher, Karen — Documenting fisheries habitat resources - mapping mangroves with remote sensing in Queensland, north-east Australia 112
Day, Robert — The value of research to age abalone, and how to time-stamp them 112
DeAlteris, Joseph — Bycatch reduction in Northwest Atlantic bottom trawl fisheries: myth or reality 113
Die, David — Can biological research influence management decisions in a trawl fishery for tropical prawns? The Australian northern prawn fishery 113
Dijkstra, Lucette — Genetic origins of rainbow trout and chinook salmon transferred to New Zealand from California at the turn of the century 113
Douglas, John — Development and validation of a fish index of biotic integrity as part of an evaluation of aquatic ecosystem condition 114
Eayrs, Steve — Headline height modifications to improve prawn trawl performance 114
Ely, Bert — Evidence for genetic differentiation among striped bass populations in eastern North America 115
Franks, Jim — Age, growth and reproduction of cobia, *Rachycentron canadum,* from the northern Gulf of Mexico 115
Fuentes, Hector — Depletion experiments and estimation of abundance in reef fish stocks of Solomon Islands and Fiji 116
Harris, Aubrey — A cross-check of catch data collected by a traditional fishing community 116
He, Xi — Estimating fisheries impacts using commercial fisheries data: simulation models and time series analysis of Hawaii's tuna fisheries 117
Jiang, Shann-Tzong — Effects of cathepsin B on the disintegration of minced mackerel 117

Kemp, Darrell	Development and validation of an index to evaluate the condition of aquatic habitat	117
Kennelly, Steve	A framework for solving by-catch problems: examples from New South Wales, Australia, the eastern Pacific and the northwest Atlantic	118
Kline, Tom	Natural stable isotope abundance used for assessment of anadromous and amphidromous migrations in fish ecology: implications for fisheries management and habitat protection	118
Koehn, John	The key criteria to sustaining the wild stock Murray cod fishery in Lake Mulwala	119
Lavery, Shane	Molecular genetic markers in discriminating stocks of Australian penaeid prawns	119
Liu, Hsi-Chiang	The management implication for the Indian albacore stock when production model analyses result in discrepancies in estimated parameters	120
Loneragan, Neil	Structure of seagrasses and their carrying capacity for juvenile penaeid prawns: studies of the effects of prawn density and predation	120
Matsuoka, Tatsuro	Selectivity of deep water prawn Danish seine assessed by experimental net with infrared underwater video	121
Matsushita, Yoshiki	Multi species separation in the Japanese coastal trawl fishery	121
McKinnon, Lachlan	Assessment of the potential of glass eel resources in South-Eastern Australia for commerical aquaculture	121
Mohan, Ramasamy	Spiny lobster fisheries and management concerns in Sultanate of Oman	122
Montgomery, Steven	Developing a strategy for measuring the relative abundance of Pueruli of the spiny lobster *Jasus verreauxi*	122
Navodaru, Ion	Danube delta fisheries in transitive period from economic exploitation to sustainable use	123
Pauly, Tim	Hydroacoustic methods and results of krill stock surveys for three consecutive years in east Antarctica	123
Pitcher, Roland	Research for management of the ornate rock lobster fishery in Torres Strait	124
Pitcher, Tony	A new family of empirical models for the potential yield of lake fisheries	124
Quinn, Terrance	Performance of transect and point count underwater visual census methods for reef fish assessments	124
Rimmer, Mike	Development of improved techniques for the transport of live finfish	125
Robins, Julie	Trawl industry considers new AusTED design	125
Schiller, Craig	Population size-structure and recruitment of freshwater fish species in the Murray-Darling River system, Australia	126
Simpfendorfer, Colin	Gauntlet fisheries for large, long-lived sharks: approaches to research and management	126
Suuronen, Petri	Usefulness of mesh size management in pelagic trawl fishery	127
Sylvia, Gilbert	Intrinsic quality and fisheries management: bioeconomic analysis of the Pacific whiting fishery	127
Tanabe, Toshiyuki	Study on the early life of skipjack tuna, *Katsuwonus pelamis,* in the tropical western Pacific	128
Thomas, Gary	Development of a multi-species, ecosystem model for managing fisheries resources in the Greater Prince William Sound	128
Treble, Rodney	Stock assessment of southern rock lobster *(Jasus edwardsii)* at Apollo Bay, Victoria, Australia	129
Troynikov, Vladimir	Estimation and prediction of growth heterogeneity in the context of fish stock assessment problems	129
Vance, David	How far do prawns and fish move into mangroves? Distribution of juvenile banana prawns, *Penaeus merguiensis,* and fish in a tropical mangrove forest in Northern Australia	130
Virgona, John	Assessment of stocks of sea mullet *(Mugil cephalus)* in New South Wales and Queensland waters	130
Wadley, Vicki	Squid stocks in south-east Australian waters	131
Wang, You-Gan	A bioeconomic analysis of seasonal closures in Australia's multispecies northern prawn fishery	131
Warburton, Kevin	Applying bioenergetic models to fisheries management: a simulation of prawn consumption by juvenile barramundi	131
Ward, Robert	Comparison of molecular genetic techniques for assessing the global populations structure of yellowfin tuna	132
Whitelaw, Wade	Fishing characteristics of tuna longlines - from theory to practice	132
Yamaguchi, Yasuhiro	The falling velocity of cuttlefish eggs in water	133

Yamane, Takeshi — The pot fishery for cuttlefish *(Sepia esculenta)* in Nagasaki, Japan 133
Yu, Swee Yean — Utilization of *Leiognathus equulus*, a low-value fish species in fishball processing 133

Theme Six

Garcia, Serge **(Theme speaker)** — Fisheries management and sustainability: a new perspective on an old problem? 135
Arenas-Fuentes, Pablo — How to achieve sustainable fisheries development in a developing country: a look at some of the possible solutions. The case of Mexico 135
Ayvazian, Suzanne — Quantifying hook-release mortality in marine recreational fisheries: working toward more effective fishery management 136
Ballantine, Bill — "No-take" marine reserve networks support fisheries 136
Boje, Jesper — Management regimes for the main Greenland fishery resources 137
Brayford, Heather — Co-operative management - a fisheries ecosystem approach to jurisdiction 142
Brethes, Jean-Claude — Conservation when fisheries collapse: the Canadian Atlantic experience 137
Camhi, Merry — Fishing in Darwin's paradise: can the Galapagos Islands survive commercial export fisheries? 138
Campbell, David — Role of economic performance indicators in ensuring fish resource use management objectives 138
Chesson, Jean — Evolution of a fishery assessment process 139
:s, Robert — The impact of urban drain management on fisheries habitat in north Queensland, Australia 139
Conides, Alexis — Effects of bottom sediment type, salinity and temperature on the dynamics of 0⁻ fry population of European sea bass, *Dicentrarchus labrax* (Linnaeus, 1758) used as seed for aquaculture 140
Cryer, Martin — The development of techniques for estimating the recreational harvest of marine fish species in New Zealand 140
Fenton, Gwen — Fish ageing: validation by radiometric analysis for oreo dories (Family Oreosomatidae) 141
Fisher, Douglas — Legal regimes for fisheries management 141
Fowler, Jane — Co-operative management: a fisheries ecosystem approach to jurisdiction 142
Fox, William — Sustainability and living marine resource management in the United States of America 142
Gomes, Charmaine — Responses of an over-exploited Caribbean trap fishery to the introduction of a larger mesh size (Author: Hazel Oxenford) 156
Harris, John — Towards sustainable management of NSW riverine fish: developing knowledge on diversity, distribution and biotic integrity 143
Hemming, Brian — Fisheries enforcement: our last fisheries management frontier! 143
Inoue, Yoshihiro — Conservation technology research in Japanese coastal fisheries 144
:nto, Eusebio Jr — Sustainable coastal area development: a framework for sustainable fisheries (Author: Ephraim Batungbacal) 137
Japp, Dave — Longlining or trawling - managing change in the demersal fisheries of a new South Africa 144
Johnson, Graham — Giving an old fishery a new lease of life 145
Keenan, Clive — Genetics and morphology distinguish three species of mud crab, genus *Scylla* 145
Kuronuma, Yoshihiro — Key conditions for community based fisheries management: a case study on self-imposed management in Alfonsino fishing ground off Katsuura, Japan 146
Lamberth, Stephen — An evaluation of fishers' perceptions, and management, of the South African marine linefishery 146
Larkin, Peter — The costs of fisheries management information and fisheries research (Presenter: Tony Pitcher) 147
Lindholm, James — The biology of yearling groundfish on Georges Bank: a spatially explicit dynamic model and its policy implications 147
Lopez, Rizalito — Sustainable coastal area development: a framework for sustainable fisheries 137
Lupton, Chris — Fisheries resources assessment of coastal rivers in the Wide Bay-Burnett region of Queensland, Australia - a base-line for fisheries management 148
Manning, Peter — Managing Namibia's fisheries sector: optimal resource use and national development objectives 148
Matthews, Kathleen — To manage fisheries sustainably, new philosophies are required 149
McCaughran, Donald — 100 years of fishing Pacific halibut: why do we still have a fishery? 149

McColl, James	Australian Fisheries Management Authority organisational structures and management philosophy	150
McLoughlin, Kevin	Australian fisheries resources - the status of Commonwealth managed fisheries	150
McPhee, Daryl	Comparing the introductions of trawl excluders and bycatch excluders in Australia and the USA	151
Meehan, James	Modern fisheries research vessels	151
Mojtabavi, Hamid Reza	Sustainable development and fisheries management in Islamic Republic of Iran	151
Morison, Sandy	Central Ageing Facility	152
Morvell, Gerry	Managing fisheries sustainably: the Australian solution	153
Mtsambiwa, Morris	New approaches to fisheries management in Lake Kariba (Southern Africa)	153
Murphy, Brian	Freshwater fisheries management conflicts in Cuban reservoirs	153
Nao, Thuok	Role of local fisher communities in the sustainable management of the Great Lake fisheries, Cambodia	154
Narayanan, Muthuswamy	Effect of size and density on the rates of ammonia excretion in freshwater prawn *Caridina weberi*	155
	Acute toxicity of mercuric chloride on respiratory metabolism and tissue pathology of the freshwater prawn, *Caridina weberi* (de man)	155
Officer, Rickard	Changes to fish communities in Port Phillip Bay, Victoria, Australia, over two decades: 1970-1991	?
Pajaro, Marivic	Community based management for a sustainable seahorse fishery	165
Pease, Bruce	The headaches and benefits of compiling an historial summary of industry based fisheries statistics	156
Pokrant, Bob	Traditional fishers and the "New fisheries management policy", Bangladesh, 1986-96	157
Pownall, Peter	Management of Australia's northern prawn fishery: a delicate balancing act	157
Prince, Jeremy	Spatiality, stock assessment and property rights in Indo-Pacific fisheries	158
Rodhouse, Paul	Use of a marine GIS to examine variability in squid fisheries over the Patagonian Shelf in relation to remotely-sensed oceangraphic variables (Author: Philip Thrathan)	162
Safina, Carl	Decline of world fisheries	158
Schmidt, Dana	Alaska's sockeye salmon fishery management: can we learn from success?	159
Schofield, Martin	The Natal Parks Board and small-scale fisheries along the coast of KwaZulu-Natal	159
Sharp, Gary	It's about time: rethinking fisheries management	160
Smale, Malcolm	Conservation and management of chondrichythyans	160
Staples, Derek	Sustainability indicators for fisheries development	161
Stevens, Richard	Australian Fisheries Management Authority organisational structures and management philosophy	150
Sutton, Michael	A new paradigm for managing marine fisheries in the next millennium	-
Taylor, William	Great Lakes fisheries futures: using an ecosystem approach to balancing the demands of a binational resource	162
Tsamenyi, Martin	International environmental instruments and their impact on the fishing industry	163
Vincent, Amanda	Community-based management for a sustainable seahorse fishery	163
Walker, Terry	Can shark stocks be harvested sustainably - a question revisited	164
Zacharin, William	Management arrangements for developing fisheries: the precautionary principle and use of adaptive management strategies	164

Developing and sustaining world fisheries resources: the state of the science and management

Keynote presentation: P.M. Mace

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The popular characteristic of the world's fisheries is that they are on the brink of disaster. FAO data suggest that the supply from marine capture fisheries (about 78 million t in total but only about 50 million t available for direct human consumption) and inland capture fisheries (about 6.5 million t) may have peaked, with almost 70% of marine capture fisheries classified as fully – or over-exploited. World fishing fleets are operating at an estimated net loss of about US$54 billion, mainly offset by government subsidies. Each year, commercial marine fisheries result in about 28.7 million t of bycatch and 27 million t of discards, equivalent to about one third of landings from marine capture fisheries. Aquaculture has exhibited phenomenal growth but also

ctacular failures in some sectors. Debate exists about whether aquaculture production (almost 16 million t of animal products and 5.5 million t of plant products) can expand sufficiently to meet projected increasing demand for food and income that probably cannot be provided by natural systems. Poor science, poor management, poor data, poor policy and a host of other factors have been implicated in this "crisis". However, a small set of fundamental problems surpasses all others in requiring immediate and focussed remedial action; indeed, they are the key to solving many of the other problems. For capture fisheries, fleet overcapacity is the single most important factor threatening the long-term viability of exploited fish stocks and the fisheries that depend on them. Global fleet capacity must be reduced substantially, perhaps by as much as 50%, to levels that more closely match sustainable resource productivity. For aquaculture, the most pressing need is to solve the dilemma of promoting expansion, while at the same time demanding the development of environmentally-sound technologies and farming practices.

But perhaps the state of the world's fisheries is not as bad as the popular portrayal. There have been considerable advances in fisheries science, particularly computer modelling and other methods of quantitative analysis; a number of innovative management systems are now being tested; several depleted stocks have been rebuilt; there is considerable room for expansion in aquaculture; scientists, environmentalists and fishers are beginning to have a major positive impact on management objectives and practices that will enhance prospects for sustainability; and several revolutionary international agreements have recently been concluded. The challenge for the future is to build on existing successes to effect a transition to environmentally and economically sound fisheries on a global and local basis. This is a formidable task. The transition will have a high price in monetary terms, and probably also in social terms. Therefore, the transition will be resisted and there will be no pressure to preserve the *status quo*. Unfortunately, except in rare cases, the *status quo* is no longer a viable option. The groundrules that have brought fisheries to a crossroad must be abandoned in favour of new paradigms that emphasize long-term sustainability over short-term gain. The model for the future must incorporate global conservation standards, formulation of holistic national policies focussing on long-term objectives, and greater involvement of fishers and other stakeholders in the management process. All players need to be united in their determination to implement effective management and to be responsible and accountable for their decisions and actions. The transition has already begun.

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Why do some fisheries survive while others collapse?

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The objective of the paper is to use the experience of fisheries management off Nova Scotia, Canada, since the extension of jurisdiction to 200 miles (in 1977), to generate some conclusions on "why some fisheries survive while others collapse". Groundfish, scallop and lobster management units are included.

The conservation objectives for groundfish were to rebuild the stocks, and to subsequently prevent both growth and recruitment overfishing. The strategy was to harvest the resources at $F_{0.1}$. The control tactic chosen was quota management of single species within specified management units. The tactics for the economic performance and employment objectives included limited entry and the control of harvesting capacity, as well as an income support programme. The results of management between 1977 and 1993 led to initial rebuilding in the early 1980s, followed by sharp declines. Most of the management units have been growth overfished, and some may have been recruitment overfished. The quotas were sometimes set higher than the scientific advice, the landings frequently exceeded the quotas, and the scientific advice was often optimistic. It has not proven possible to enforce at-sea activities without observers, and as a result there have been substantial levels of misreporting, discarding and highgrading. As TACs were reached, fishing continued under bycatch rules and/or trip limits. The tactics for economic performance and employment compromised the ability to control fishing effort by quota. It is concluded that the single species quota management tactic, for an industry using multi-species harvesting technology, was not capable of controlling fishing effort at the strategic target. Without effective controls on fishing effort by the tactic of quota management, the fishery, in essence, operated at the "open access equilibrium point". Given the efficiency of the harvesting technology (i.e., the ability of some sectors of the industry to fish profitably at very low stock levels), at this equilibrium point the resources may be below their minimum spawning stock levels.

The tactics to meet the conservation objectives for lobster have involved input controls (limited entry, seasons and trap limits) rather than TACs. Participation levels have been steady, and the resource appears to be sustainable although exploitation levels generate growth overfishing. Even if the lobster fisheries are operating at the open access equilibrium point, at these effort levels recruitment overfishing does not appear to be occurring. The offshore scallop fishery is managed with quotas under a property rights regime (predominantly output controls). In contrast, the inshore scallop fishery is managed by input controls. The offshore regime is meeting both the conservation and socio-economic objectives, whereas the inshore fishery is not.

The observations from Nova Scotia lead to a tentative framework of choices of management regimes dependent on the social fabric of the participants, the technology in use, the knowledge of the populations and the life history characteristics of the species.

Age validation of nagroor, *Pomadasys kaakan* (Cuvier, 1830) (Family Pomadasidae) in Kuwait waters

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Daily increments in sagittal otoliths of young nagroor, *Pomadasys kaakan* (Family Pomadasidae) were validated using alizarin complexone (ALZ). Counts of the daily increments between annual marks of adult wild fish were used to validate the annuli and time of their formation. The ALZ fluorescent marks were observable under UV light, the highest survival being obtained with immersion in 75-100 mg/l ALZ solution for 24 hours. Young nagroor deposit daily increments in laboratory conditions at 17-20 degrees C. Increments of the wild fish are relatively easy to discern and count. The annulus consists of checks aggregated all around the thin transverse sections. The average number of d: increment counts between the annuli was 266, 326 and 276 for the first three years respectively. The recent annuli formed on the otolith edge were observed in most of March-May otolith samples. All data pooled for years 1992-95 indicate that the peak formation of the annuli is during March-May, although few samples showed formation in January and February. The data also indicate that juvenile and immature fish (14-22 cm total length) form annuli before the onset of ovary maturation.

Lower Danube fisheries collapse and prediction

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The Lower Danube includes the Danube Delta Biosphere Reserve and the river upstream to the dam of the hydropower plant "Iron Gates II".

The most frequent and valuable fish were the halfmigrat.. y (*Cyprinus carpio, Stizostedion lucioperca, Leuciscus idus,* and *Silurus glanis*) and the migratory species (*Huso huso, Acipenser gueldenstaedti, Acipenser stellatus* and *Alosa pontica*). The Danube floodplain, especially its stretch between the mouth of the Rivers Prut and Argesh, covered more than 200,000 ha – a spawning zone for the halfmigratory fishes. Their fry remained partially on the spot, but the bulk populated the Danube Delta. The fingerlings which reached the Delta were in sufficient numbers to escape the big number of predatory fishes, which was significantly greater than in the upper part of the river.

The Danubian fisheries, well known from antiquity, were maintained up to the sixties of this century. In the first two decades of the present century, under the leadership of Grigore Antipa, these were amongst the best organised fisheries of the world.

During the last thirty years, due to eutrophic factors, the Lower Danubian fisheries collapsed. The endykements of its floodplains were made simultaneously with the rising of the river water pollution. This situation contributed decisively to the eutrophication of the North-West Black Sea region, very important for the migratory species. Till 1989 these elements were determinant.

After the political changes in Central and South-East Europe, the crisis in industry and agriculture contributed to a decrease in pollutant effluents. At the same time the former centralized management of fisheries by the state was abolished. Thus the coordination and enforcement of the existing fisheries regulations and the international cooperation of the Danubian countries were weakened. At the same time a wrong licensing system was partially introduced : short stetches of only 1 – 5 km of the river are licensed for only one year. The consequence of this was a numerical excess of fishers and fishing gears and disrespect for the fisheries regulations. Even the fingerlings of the halfmigratory species were directly and indirectly destroyed. Gradually the catches of valuable fish species diminished and were replaced by other less appreciated species.

The most frequent species are now *Rutilus rutilus* and *Carassius auratus*. These are more resistant and have less stringent requirements for spawning. The introduced *Hypophtalmichthys molitrix, Aristichthys nobilis* and *Ctenopharyngodon idella* are spawning in the river and normally escape from the traditional fishing gears.

The partial recovery of the halfmigratory fish species and sturgeons depends on the lowering of the actual level of pollution, including the eutrophication, and the improvement of management, including the enforcement of the fisheries regulations, as well as a better collaboration of riverine countries.

Geographic variation in productivity and a prognosis for the New Zealand rock lobster fishery

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In the New Zealand fishery for the red rock lobster, *Jasus edwardsii,* largest catches and high catch per unit of effort (cpue) are on the east coast of the North Island south of East Cape (= SENI) and in the southern half of the South Island. These areas do not, however, exactly correspond with areas with other high indices of abundance and productivity. Compared with areas to the south, SENI has higher reproductive potential, based on earlier age at first breeding and at least as high female abundance. In recent years, it has had tens to hundreds of times the abundance offshore of advanced phyllosoma larvae and, level nearshore, of puerulus settlement. The southern area is currently more heavily exploited than the northern areas: vulnerable biomass is less than 10% virgin vulnerable biomass and βcurrent is less than 50% βmsy. 'Insurance' against fishery collapse seems better secured for SENI than for farther south.

If excess fishing pressure does not reduce breeding stocks to very low levels, shelter and food limitations would appear, intuitively, to be important in SENI. There is no evidence for larval drift or seafloor migration south from SENI, so the south of the South Island may be more larval recruitment-limited. However, high density-dependent mortality and a different array of predators could reduce the significance of the high larval and settlement indices of SENI. Ocean climate may influence levels of larval recruitment everywhere through its influence on the abundance of phyllosomas and pueruli.

Local abundance and productivity indices may not have always been like this. It will be instructive to note any change in these as stocks in the south rebuild.

Stock identification of red snapper, *Lutjanus campechanus* (Lutjanidae), from the Gulf of Mexico using mtDNA and year-class data

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A total of 882 specimens of red snapper were collected from a wide range of its distribution from the Gulf of Mexico. Otoliths were removed and sectioned or whole mounted for age determination so that year class could be assigned to each fish. Liver or heart tissues were also removed and preserved and prepared for mtDNA analysis using the PCR technique to be able to multiply the DNA material available. The age and growth analysis indicated that fish grew in a manner similar to that found by other researchers studying red snapper. There were few differences among red snapper relative to year class regarding the otolith-length relationship or the backcalculated size at age relationship. There were some differences in these variables relative to the zone or part of the Gulf from which they were captured. There was an especially large difference in the body proportion (i.e. length-otolith relationship) as well as the size at age relationship between a population off the coast of Texas and the remaining red snapper from the Gulf. The mtDNA analysis showed similar results. While there was little evidence of a distinct genetic group of red snapper between year classes, there were some differences in genetic makeup relative to the geographical place of capture. These results somewhat contradict other studies that have indicated that red snapper form a relatively homogeneous population of panmictic organisms within the Gulf of Mexico. Future studies that use microsatellites may shed more light on the question of distinct stocks within the Gulf.

Joint management initiatives in the English Channel

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Jersey is on the southern side of the English Channel, 15 km west of the Cherbourg Peninsula. Its waters are relatively shallow (max 40 m datum). Maximum tidal range is 13 m and gives rise to strong currents.

Although part of Britain, Jersey is not part of the UK and the local government is autonomous. No representatives are sent to the UK Parliament. Jersey relies on the UK only for Defence and Foreign Affairs.

90% by weight of catches are shellfish. Clawed lobster (*Homarus gammarus*), brown crab (*Cancer pagurus*) and spider crab (*Maia squinado*) predominate landings. Fin fish

landings are of sea bass (*Dicentrachus labrax*) and black sea bream (*Spondyliosoma cantharus*). Shellfish are caught in baited traps although tangle nets are also used. Vessels vary in size between 6 and 12 m and may work up to 800 traps per day.

Jersey has a 3 mile exclusive limit. Exclusive limits along the French coast are approximately 3 miles in some parts but unclear in others. The limits and management of the common waters are subject to a regime agreed between British and French governments in 1839 based on an oyster fishery which collapsed in the late 1800s. Up until now the national governments have been unwilling to re-negotiate a modern regime.

The trap fishery is open access and unlimited. Fishers have been allowed to re-invest profits in more traps with increasingly efficient designs using modern materials. Fishing is done with increasingly sophisticated vessels. Catch per unit of effort (cpue) using traditional traps had dropped by a factor of ten in the last thirty years and halved in the last three years and profitability is dropping.

Giving fishers some form of limited property right may be the ultimate solution but it is impractical at present. Convincing fishers that excess effort should be relocated outside the fishery is still difficult. The enforcement associated with allocating individual quotas for small vessels on such a large area of coastline (Jersey and the adjacent coast of France) is not supported by central government. Interim solutions are based upon the formation of a joint Jersey/French management advisory group. The group consists of local fishers (50%), administrators (35%) and biologists (15%) and will advise respective governments on limiting access and agreed conservation measures. The formation of a bilateral management group is a novel initiative from the Jersey and French governments. It comes about from a wish to preserve employment in artisanal fisheries from the French side and a wish for a profitable fishery from the Jersey side. The high proportion of fishers in the group is intended to involve all the participating fishing communities in decision making and promote some form of 'ownership' of the fishery. Involving the fishers at this level also enables continual minor conflicts in resource exploitation to be discussed openly before escalation to major conflict occurs. Both sociological and political skills have been important in setting up this initiative.

Spatial and temporal complexity in aquatic environments: a key to fluctuating fisheries?

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Spatial and temporal complexity are inherent and scale-dependent attributes of aquatic systems, yet they are often ignored in estimates of fish growth and habitat carrying capacity. Fish production can be significantly affected by biological processes that occur at relatively small spatial scales (1-100 m3) or over relatively short (minutes-days-months) time intervals. Until recently, it was difficult to evaluate these types of effects . High-frequency underwater acoustics provides a tool to measure spatial and temporal heterogeneities in biological features of the environment. Spatial modelling approaches (which maintain the spatio-temporal integrity of the habitat) have recently been developed, and use the strengths of underwater acoustics (continuous measures of the spatial and temporal distributions of prey) and bioenergetics models (quantitative growth rate determinations) to evaluate how physical and biological heterogeneity affects habitat quality and fish growth rates in the pelagic zone. This approach subdivides the habitat into small homogeneous volumes of water. Data are input across a two dimensional grid composed of cells (e.g. depth X distance). High-resolution spatial data on prey abundances and sizes are collected with underwater acoustics that measure organism abundance throughout the water column on a near-continuous basis. Data on light, temperature and oxygen define the physical conditions. Foraging and fish growth models are run in each cell but are parameterized according to the habitat conditions of each cell. The foraging model estimates consumption rate from measured prey densities and sizes. The growth model estimates fish growth rate from the consumption rate and is based on fish physiology and prevailing physical conditions. This spatial modelling results in cross-sectional maps of potential fish growth rates that would be achieved in each cell if the predator occupied that particular cell for specified unit of time. Recent developments in interact. data visualization and Geographic Information Systems (GIS) are used to display and evaluate spatial patterns of fish growth rates and production.

This approach has been applied to the Great Lakes of North America and the Chesapeake Bay. Model simulations demonstrate how biological processes interact with spatial/temporal heterogeneity in the physical and biological habitat to affect predator-prey interactions, fish growth rates, and ultimately, fish production. The effects are non-linear and complex. Up to a four-fold decrease in estimates of fish production was found when physical and biological heterogeneity were included in the analyses as opposed to when average conditions were used. These types of differences are generally unacceptable in highly managed ecosystems. In both aquatic environments, potential fish production was often concentrated in small regions and reductions in prey resources could be compensated for by small improvements in habitat (e.g. oxygen and temperature) conditions. It is concluded that explicit consideration of space and time in both sampling and modelling improves evaluations of food web interactions and estimates fisheries production in aquatic environments.

Development and management of the Queensland spanner crab fishery

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It is suggested that the evolution of fisheries management strategies is frequently driven by contemporary issues rather than long-term perspectives. The development of the Queensland spanner crab *(Ranina ranina)* fishery is an example.

Spanner crabs were virtually unknown in Australia before the late 1970s, when a fishery developed in nearshore waters of southern Queensland. The key industry issues at the time related to investment and marketing questions. Research and management focused on nurturing a fledgling fishery based on a stock about which very little was known,

and a domestic market which had suffered initially from poor product handling practices.

The fishery gradually expanded south into northern New South Wales and north along the Sunshine Coast, and during the 1980s annual catches increased to about 500 t. The fleet comprised small (6-10 m) high-speed runabouts, with spanner crabbing a part-time activity in a multi-species fishery targeting portunid mud crabs *(Scylla serrata)* and sand crabs *(Portunus pelagicus)*. Increased landings were due largely to increases in individual effective effort (more net sets and more fishing days) rather than to substantial changes in the demography of the fleet. Early in this period of expansion a need was seen for the introduction of some conservative management controls, including a minimum legal size and a prohibition on taking ovigerous females. These static precautionary measures were based both on biological and marketing considerations.

The early 1990s saw a significant increase in the size of the fleet – from 85 to 219 vessels – together with a trend towards larger craft that could remain on the fishing grounds for extended periods and operate in more inclement weather. ıdings of spanner crabs increased significantly tnroughout this period, to 2200 t in 1993 and 3300 t in 1994. Increased financial returns resulted from the successful establishment of a single Asian market for live crabs, and the simultaneous development of low-temperature transportation systems which vastly improved in-transit survival rates. Landings continued to increase, despite declines in catch per unit of effort in established parts of the fishery, due to the exploitation of previously lightly-fished or unexploited grounds and by fleet efficiency changes.

As there are probably few new grounds left to be exploited, the need to control the influx of new vessels into the fishery has become critical and has led to the development of a different management philosophy for the fishery. Extensive public consultations have resulted in new management arrangements including constraints on fleet size, individual daily quotas, and fishery-wide output controls (Total Allowable Catches – TACs).

A comparison of interreef ' :nthic communities in zones open and closed to trawling in the northern Great Barrier Reef

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Prawn trawling is prohibited in a large cross-shelf zone in the far northern section of the Great Barrier Reef Marine Park. A large scale survey of the interreef benthic communities was carried out inside this zone, and in adjacent areas where trawling is permitted. One aim of this survey was to provide a baseline description of benthic communities in this region, to aid in designing an impact experiment inside the closed zone. The other aim of the survey, discussed here, was to compare the benthos of areas open and closed to trawling.

Benthos were sampled using a 3m beam trawl during two cruises (May 1992 and March-April 1993): 102 stations in the closed zone and 83 to the north and south of the closed zone. The communities were expected to vary in an east-west direction, reflecting cross-shelf changes in sediment composition. Stations were therefore grouped into five cross-shelf strata so that this background effect could be taken into account when comparing the species composition and abundance of the open and closed zones.

Multivariate analysis of variance of log-transformed weight was used to examine the extent to which benthic communities differed among cross-shelf strata, between the two cruises, and between the open and closed zones. For the most frequently found species (more than 50 stations), cruise and stratum effects were dominant. Stratum effects differed between cruises. The overall difference between the open and closed zones was negligible, though significant north-south trends were detected.

When less common species were also included, stratum and cruise effects continued to be highly significant. However, the difference between the open and closed zones became highly significant and the north-south trend became negligible.

Assessment of shrimp postlarvae as a proxy variable of stock recruitment in the Gulf of California

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The shrimp fishery is the most profitable fishery in Mexico. It provides employment for more than 300,000 on the Pacific Coast and it is the second most profitable export. The catch per unit of effort (cpue) has been decreasing during the last decade, presumably due to overfishing, but other factors such as global changes could be affecting it. The open sea fishers argue that the stock is decreasing because of the capture of postlarvae (PL) in estuaries and coastal zones, for culture purposes. To assess the distribution and abundance of postlarvae, samples were collected (plankton net 0.505 mesh size) during the flood tide in full moon and new moon, during the spawning period of the shrimp in the upper Gulf of California (April – October 1993, April – November 1994), as well as intensive sampling from July 12 to July 27, 1995. Two species were identified: *Penaeus californiensis* and *P. stylirostris*. A peak of abundance was found in July (60 Pl/m^3) and from mid-October Pl are almost absent (0.02 Pl/m^3). Postlarvae were more abundant in the night and at full moon. The correlation between abundance and temperature was not significant ($P>0.05$), but the mean size of PL increases through the season, coinciding with higher temperature. Formerly *P. stylirostris* was dominant in landings, but since 1989 *P. californiensis* has increased in abundance. In 1993, there was 8% *R. californiensis* postlarvae and 20% *P. stylirostris*, and in 1994 60% *P. californiensis* postlarvae and 40% *P. stylirostris*. Even when the annual yield is largely a function of the annual level of recruitment, there was a weak correlation between the abundance of postlarvae and captures. This could be due to uncertainty of place of catches and because of migration of the shrimp in the adult stage. The capture of postlarvae for culture should be regulated to avoid conflicts.

An overview of Australian fisheries habitat research

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As a first step in refining a national strategy for investment in its Ecosystem Protection Program, the Fisheries Research and Development Corporation commissioned the Australian Institute of Marine Science to undertake a one year review and synthesis of all previous Australian research related to fisheries and their links with habitats. The objectives of the review (to be completed in late 1996) are:

1 To identify generic, national and regional research issues relevant to the sustainable use of fisheries ecosystems, especially a) Natural Dynamics, b) Modification of nearshore, estuarine and wetland habitats, c) Effects of Fishing, d) Change in drainage, e) Introduction of marine pests and f) Nutrient inputs.

2 To describe the current state of knowledge of the priority issues including the scale, impact, significance, threats and opportunities and to collate the literature into a freely accessible bibliography.

Oligotrophic shelf waters and the proximity of intense drought, flood and variable wind conditions induced by El Niño and La Niña events have amplified the downstream effects of agriculture, industry and urban development on nearby estuaries and coastal embayments in Australia. These events also have influence on the recruitment and demography of many of our finfish and shellfish, but such natural variability cannot be fully scaled yet against anthropogenic change in fisheries ecosystems, due to lack of long term data.

The enclosed nature of many subtropical lake, estuary and bay environments is coupled generally with low tidal flushing near Australia's expanding urban centres. As a consequence, freshwater flows have been reduced by diversion, sedimentation rates have been raised and eutrophication at local scales is now evident through nuisance algal blooms. The nature and extent of sources of primary and secondary production for nearshore fisheries have changed as a result, but the signals in catch records are rarely clear — being obscured by fleet behaviour, movement of fished species, unknown levels of catch in the recreational sector and natural variation in recruitment.

The links between fisheries production and obvious sources of primary production, such as mangroves, seagrass, macroalgae and coral reefs, have been well documented in the direct sense for relatively few commercially important species, but distant, indirect links from these sources up through food chains are not well understood and will require innovative use of biomarkers and other tracers.

Multi-disciplinary research has improved the identification and protection of sources and sinks of fisheries production and is extending into habitat modification at small scales – mainly through restoration of tidal flow in lower catchments.

Inshore nursery habitats in Australia are often characterised more by the influence of sheltered conditions than single specific sources of primary production or fresh and saltwater interfaces. In contrast the habitat requirements and sources of recruitment variation of many important shelf species are unknown for major trawl fisheries, yet these have shown greater declines in production than those perceived for nearshore fisheries. Experimental manipulation of gears and fishing effort and subsequent study of recovery of benthic communities and their associated fisheries, has enabled the various effects of fishing to be distinguished — and for some undesirable effects to be reduced.

The Chilean dived-invertebrate resources: fishery collapse, stock rebuilding and the role of coastal management areas and national parks

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In Chile, the extraction of benthic invertebrates is ba. exclusively on small-scale (artisanal) fishing-diving operations. There are over 10,000 registered divers, a small-scale fleet of more than 15,000 artisanal boats and over 60 species of invertebrates ("mariscos") marketed either locally or exported. The annual landing of "mariscos" amounts to approximately 150,000t, representing 2.5-3% of the total Chilean marine landings. Nevertheless, their annual export marketable value represents 12-14% of the total of US$1200-1400 million of marine resource exports.

The elevated aggregate value and international market demands on some of these invertebrates, in particular on the unique gastropod muricid *Concholepas concholepas* ("loco"), which represents about 30% of the total Chilean "mariscos" export value, have resulted in overexploitation and signs of stock collapses. As a consequence year-round total closures of several fisheries have been in operation.

The paper describes these fishery collapses, with emphasis on the *Concholepas* case, benthic invertebrate resource extraction switching, responding to external markets demands, and cases of stock rebuilding processes, particularly in scientifically-oriented Coastal Ma. Preserves. Further, it describes the institutionalization of the benthic resource management tools introduced recently into Chilean Fishery and Aquaculture Law and involving the use of adaptive-experimental management procedures and co-management steps at the level of Chilean units of production, or "Caletas Artesanales". In the latter the "users", the artisanal fisher communities at the "Caletas", have been incorporated into management plans experimenting with common-property rights.

Finally, the future role of large National Coastal Marine Parks or Preserves, as well as the more reduced Coastal Management Areas considered in the Law, allocated exclusively to the small-scale fisher communities, and their connection with conservation and the management of benthic invertebrates in the country, are highlighted. It is argued that these incipient Chilean benthic invertebrate management tools and models, based on small-scale fishing community common property and co-management schemes, can be extrapolated to other countries in Latin America and around the world.

Existence of a sex-ratio regulation mechanism in Tunisian stocks of sea bream *Sparus auratus*

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The influences of demographic structure and social behaviour on the sex-reversal of hermaphroditic fish are well known in many species, especialy in the families Labridae and Pomacentridae. Sex-reversal determinism is more or less difficult to observe in territorial fish, but, when fish have a large erratic trophic area and no permanent school, it is nearly impossible to experiment in the wild. Nevertheless it has been possible to point out such sex-reversal mechanisms (without explaning them) in the exploited stocks of *Sparus auratus* (Sparidae) in Tunisia, where this protandrous species has been studied during four years.

From a fisheries point of view, three representative zones were selected in Tunisia: North, South-East and the bahiret El Biban, a coastal lagoon close to Zarzis (35,000 ha in the far South-East). The rocky shore North coast of Tunisia is bad for trawling and it is not very populated. On the contrary the East and the South-East shores are sedimentary and the coastline more densely populated. Coastal fishing activities are getting less intensive from the North to the East and the South-East. Consequently exploited stock demography is different in each area. Moreover the younger age classes of *Sparus auratus* live in coastal lagoons in preference to the shore. So the *Sparus auratus* stocks in El Biban have a demographic structure modified by the peculiar population dynamics specific to this kind of inshore situation. In this lagoon there is a very big wear (i.e. 3.1 km long fish traps crosswise the opening to the sea) which catches nearly the whole inside stock.

In the North, the total mortality rate (Z) is nearly equal to 0.35 , in the South-East it is close to 0.5, and in the El Biban lagoon it is higher than 0.8 . Concurrently to the total mortality rate estimation, (1) the average age of primary sexuality, which indicates the average age of sex-reversal, was calculated. This parameter decreases when Z increases: in the North, the average age of primary sexuality is 3.5 years , in the South-East it is 3.1 years, and in the El Biban lagoon it is 2.5 years. (2) The logarithmic conversion of the male proportion of each year class was plotted against the age which gave three distinct linear slopes. Each slope showed the sex-reversal rate of each stock: in the North, the average sex-reversal rate is 0.6 , in the South-East it is 0.9, and in the El Biban lagoon it is 1.2. This second sexual parameter decreases when Z decreases. (3) Finally, it was observed that the global sex-ratio of each stock remains constant.

When mortality increases, the average age of sex-reversal decreases and sex-reversal rate of the stock increases. On the other hand the global sex-ratio remains constant. Therefore, it seems that in the stocks of this hermaphroditic fish mechanisms, (social mechanisms?) take place to react against mortality increase, to maintain global sex-ratio in a constant rate.

Understanding technological impacts of capture technologies and sources of unaccounted fishing mortality

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Discarding of non-target species and sizes of fish is a common practice in many fisheries around the world and is currently estimated at 27 million t globally. With uncertainty regarding whether current levels of global catches are in excess of theoretical potential ocean fish yields and with the prospect that global population expansion will put additional stresses on marine resources, the need to eliminate all forms of marine resource waste is becoming critical. One traditional approach to reducing resource waste has been to reduce the capture of non-target species and sizes of fish by developing species and size selective fishing gears. In recent years, research into fish mortality after escape has shown that mortalities vary by gear type and species, may be immediate or delayed and due to injuries or stressors associated with capture – escape trauma. Fishing-induced mortalities include non-reported catches, recreational and artisanal catches, discards, avoidance, drop out, ghost fishing, escape and predation where:

$$F = [F_{CL} + F_{AL} + F_{RL}] + F_B + F_D + F_O + F_A - F_E + F_G + F_P + F_P + F_H$$

The level of each component of F varies with different capture technologies and the probability of mortality is a function of stresses and injuries received during the capture and/or escape process. This paper reviews sources of accounted and unaccounted fishing mortality, identifies gaps that exist in data and experimental methodologies and recent efforts to estimate various components of F.

Crustacean fisheries in the Zhujiang (Pearl River) Estuary, China

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The Zhujiang (Pearl River) estuary (22°00'–22°45'N; 113°30'–114°00'E) which covers an area of more than 2,000 km² is one of the largest estuarine systems in the South China Sea. The estuary has been under intense fishing pressure for decades. In recent years, destruction of coastal habitats and water pollution associated with

industrialization and urbanization in the Zhujiang delta have posed additional threat to fishery production in the estuary.

A survey was conducted on the species composition and abundance of the crustacean fisheries catch in the estuary. Samples were collected between 1991 and 1995 by beam trawling. The estuary contained a diverse fauna of crustaceans, which made up 40–80% of the total catch by weight. Other trawl catches included teleosts and molluscs. Penaeid shrimp which is the major commercially important component comprised 0–52% of the crustacean catch. A total of 14 species were found; 13 are in the genera *Penaeus, Metapenaeus* and *Parapenaeopsis*. The dominant species were *Metapenaeus joyneri* and *Parapenaeopsis hungerfordi*. Larger *Penaeus* species were relatively rare. Caridean shrimp belonging to the families Palaemonidae and Alpheidae made up 5–41% of the crustacean catch. Five species were identified in the samples with *Exopalaemon carinicauda* and *Palaemon guangdongensis* being the most abundant. Shrimps belonging to the families Solenoceridae and Sergestidae were also included in the samples. Brachyuran crabs constituted 30–75% of the crustacean catch and comprised 13 species. The dominant crab species in the catch were *Charybdis affinis* and *Charybdis japonica*. Economic species such as *Charybdis feriatus, Portunus sanguinolentus* and *Scylla serrata* were sparse. Other crustaceans in the trawl samples were mainly stomatopods, comprised 1–22% of the crustacean catch and represented by 9 species in 5 genera. The dominant species was *Oratosquilla interrupta*.

Our results show that most crustaceans in the catch are subeconomic species. The low catch of major economic species is probably the result of overfishing as well as destruction and deterioration of habitats, including the nursery ground for larvae and juveniles. Proper fisheries management, stock enhancement programmes and protection of nursery habitat are suggested measures for the restoration of fisheries in the Zhujiang estuary.

New Zealand orange roughy: steps towards a sustainable fishery

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New Zealand orange roughy fisheries developed rapidly in the early and mid 1980s. New stocks were discovered as the fishery expanded, and there are currently eight main fishing areas within the EEZ. Catches have generally been between 30,000t and 50,000t, and for much of the period orange roughy has been New Zealand's single most valuable fish species.

Orange roughy presented fisheries managers with the difficult task of balancing commercial pressure to develop a new and valuable resource, and very limited research data on a little-known fish species. Catch limits were initially set using the best available research information, but were much higher than sustainable in the longterm. A number of stocks have been overexploited, and reduced to levels below their optimal size. Valuable lessons have been learnt, which are being applied to new fisheries.

In the early years of orange roughy research, assumed productivity values proved too liberal, and there was considerable uncertainty in biomass estimation. Productivity is now thought to be well estimated, but abundance continues to be difficult to measure reliably. Trawl survey, commercial catch per unit effort, acoustic survey and egg production techniques have been applied in various degrees to New Zealand orange roughy stocks. Emphasis in the 1980s was on use of time series of trawl surveys, combined with analyses of commercial catch and effort data. Both methods involve the use of relative abundance indices, and so require several years of data before results can be used in stock reduction analyses to estimate biomass and yields. Orange roughy are vulnerable to rapid overfishing and this has lead to increasing interest in acoustic surveys and egg production methods with the potential to provide one-off estimates of absolute biomass. All methods have their advantages and disadvantages and no single method has proven generally applicable.

Some of the lessons learnt about orange roughy have been applied recently in two situations where in 1994 new spawning grounds were discovered off the North Island of New Zealand.

1 East Cape fishery. A 'best guess' estimate of stock size was made by experienced scientific staff on the grounds winter 1994. A catch limit of twice the long-term consta... yield expected from the assumed stock size was applied for a two year period. A research programme was instituted in 1995 based on an egg production survey of the area. Catch levels would be reduced after two years, taking into account results of the research programme.

2 Bay of Plenty fishery. Before any change was made to the existing Total Allowable Catch, an adaptive management programme was prepared and discussed by a wide range of interested parties. This involves a moderate increase in catch levels for a five year period, with a trawl survey series built in. Changes in stock size indicated by the trawl surveys and a pre-agreed set of 'decision rules' will determine catch levels during the five year period.

These examples illustrate a much more controlled approach to development of new orange roughy fisheries. Key points are that catch levels are kept relatively low until more is known about likely stock size, appropriate research is instituted at an early stage and there is a clearly defined management strategy to enable appropriate commercial planning. This sort of approach recognises the vulnerabi... of orange roughy to overexploitation and their l... productivity, meaning low long-term sustainable yields and slow recovery from overfishing, thereby avoiding some of the problems of the past.

Cross shelf distribution of surfical sediments in the far northern Great Barrier Reef, Australia

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Surfical sediment samples from the Shelburne Bay area of the Great Barrier Reef, Australia, were analysed to give particle size distributions, Ca CO_3 content and visual estimates of composition. The samples were collected as part of a larger study of the fauna of the study area for the Effects of Prawn Trawling project being carried out by QDPI Fisheries and CSIRO. Except for a band of terrigenous muddy sediment close to the coast, the sediments were dominated by sand (>63μm) high in Ca CO_3 (>80%) and

biogenic in origin. The sediments were stratified in bands that parallelled the coast. The complex bathymetry of the area is also described. These results will be incorporated in studies of the distribution of fauna in the area and provide a baseline for further studies.

The bluefin tuna (*Thunnus thynnus* L.) fishery in the Cantabrian Sea (Northeast Atlantic)

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The artisanal surface fishery for bluefin tuna with live bait in the Cantabrian Sea began at the end of the 1940s. In the present paper an attempt is made to describe, firstly, the general characteristics of this fishery based on a study whose historical series spans 20 to 30 years of information ı ding to: total catches; fishing effort; abundance indices; demographic structure of catches; biological, ecological and tagging/recovery data. Furthermore, the current situation of the fishery is analysed, taking as a reference the general state of the bluefin tuna stock in the North Atlantic obtained from scientific assessments carried out by the International Commission for the Conservation of Atlantic Tuna (ICCAT) scientific committee.

Bluefin tuna migration from the southern Atlantic and Mediterranean Sea towards the Cantabrian Sea is of a trophic nature; the youngest fish make their appearance at the end of spring, coinciding with the northward displacement of the surface water isotherms. Their presence comes at the same time as the abundance of food in the area. The return to wintering areas takes place at the beginning of autumn or even later if environmental conditions are favourable. Medium-sized tuna appear in summer and their presence is usually shorter. In the tagging surveys carried out between 1978 and 1991, 5,663 specimens were tagged, of which 359 were recovered. The observed movements and migrations of these specimens e ›blish a clear interaction among the diverse fisheries v. ch concentrate their effort on these groups of fish: Mediterranean Sea, northeast Atlantic, and the Cantabrian Sea, the object of this study.

The age of specimens caught was determined through annual reading of the hard parts (dorsal fin). The demographic composition of catches shows that the fishery is made up, almost wholly, of juveniles aged 1 to 4 years (5-35 kg). Medium-sized tuna aged 5 to 9 (40-120 kg) are also observed, though to a lesser extent.

The total catches in the surface fishery have remained stable for the last thirty years, as has fishing effort which, following the reduction in the number of boats at the end of the 1960s, remains constant.

Using the historical series of catch and catch per unit of effort (cpue) of age group 2 (8-14 kg) as an abundance index, stable values are obtained for the last 26 years, during which recruitment fluctuated without a tendency, reaching maximum values every nine years.

The importance of the international commerce which this species sustains is the reason for the many investigations and assessments carried out of the state of stocks (eastern and western Atlantic) to manage the resource rationally. The last analysis of the eastern Atlantic stock, made in 1994, provides results on levels of fishing mortality and recruitment and points to a situation in which the biomass of spawners is at a high level of exploitation; nevertheless, the tendency of recruitment appears to be unaffected, since this has shown an increase in recent years. With the Cantabrian Sea, it must be taken into account that this fishery depends directly on recruitment of juveniles of the eastern stock which come to this area. Thus, though the degree of uncertainty associated with these analyses must be considered, it may be concluded that the situation of stability of this fishery is in accordance with the actual situation of the resource.

Rebuilding strategies for endangered stocks of Pacific salmon

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Historically, as many as 12 million Pacific salmon (*Oncorhynchus* spp.) may have returned to the Columbia and Snake Rivers to spawn. These runs included all five species and a wide range of life history types. Today, fewer than two million adult salmon return to their natal streams within the Columbia River system. The reasons for this decline are many, including overfishing, loss of freshwater habitat, operation of the hydroelectric power system, ocean conditions. The purpose of this paper is to compare the influence of environmental factors on two populations of fall chinook salmon (*O. tshawytscha*): 1) stable populations from the Hanford Reach of the Columbia River, and 2) weak stocks from the Snake River that were recently listed for protection under the Endangered Species Act (ESA). Strategies for rebuilding weak stocks must address questions of scale or habitat relationships between the two major river systems (Columbia and Snake Rivers) and relative population size.

By 1994, numbers of adult salmon returning to spawning grounds in the Snake River had declined to less than 500 fish annually. In contrast, average escapement of fall chinook salmon to the Hanford Reach of the Columbia River since 1988 has remained stable at >50,000 adults annually. Both populations exist within an area of regulated flow and bounded by run-of-river reservoirs. Snake River fish spawn over a 200 km stretch while Hanford Reach fish spawning is confined to about 80 km of river. Remaining historical spawning habitat for both stocks has been inundated by the extensive hydroelectric dam complex developed in the Columbia River system from 1938 to 1975.

Recent studies suggest that present production of fall chinook salmon is not limited by spawning habitat availability as described by traditional measures. Suitable spawning habitat in large rivers is likely to be more limited than superficial observations of traditional measures, e.g., depth, velocity and substrate, would suggest. Thus a conceptual model has been developed that incorporates additional information on physical habitat features that influence the production of fall chinook salmon in large, free-flowing rivers. The model includes a description of spawning habitat based on different spatial scales (i.e., basin, reach and channel) and hydraulic processes (i.e., longitudinal, lateral and vertical). This approach indicates that comparisons between river systems cannot be made unless landform processes are considered. For example, it has been found that comparisons between the Snake and

Columbia River systems, based on longitudinal slope, may only be appropriate for the lower 20 km of the Snake River spawning areas. However, microhabitat characteristics are similar, suggesting that accurate production estimates are possible. The landform-based approach for predicting potential spawning habitat will be applied to rebuilding strategies for Endangered Snake River runs and could be used in other systems for estimating production potential of salmonid populations.

The striped venus and the razor clam fishery in the Gulf of Trieste: different life strategies and different fishery perspectives

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The clam fishery in the Northern Adriatic suffers periodic crises, the last (1995) being particularly heavy. Two coastal species, the razor clam, *Ensis minor,* and the striped venus, *Chamelea gallina,* show different patterns of partial recovery due to the different patterns of growth and recruitment. The exerted fishing effort (if computable) seems not to be the decisive factor, because fishers usually fish as long as they have some economic yield, often in spite the imposed limits. The razor clam lives in the depth range 1.5 – 3.5m and grows faster than the striped venus (depth range 3 – 6m). The recruitment pattern is fairly clear in the razor clam and seems connected with the physical space for settlement and the demographic composition of the parent stock. So the abundance is driven by cycles repeating every two or three years as the fishing activity that can of course emphasise this pattern. The striped venus grows slowly and no clear recruitment pattern can be discovered. In fact the spawning season of the razor clam is relatively short and occurs in springtime and almost all recruits settle in the same period. The reproductive season of the striped venus starts in June and lasts sometimes till October, November, but the last outburst has in general scarce probability to survive during the winter season and the survivors' growth is low. In addition this species suffers periodic mass mortalities.

Despite this, the fishing pressure is very high and the landings decreased from 100,000t in past years to 38,000t in 1994. The decline of the stock seems to be irreversible and only a total fishery closure could permit a stock recovery. The exploitation strategies, however, have to be revised carefully for both species, especially for the striped venus. Some improvisation (called also flexibility) in fishers' decisions (this year the species is abundant so I can fish it till exhaustion) is no longer practicable nor tolerable, but reflects the problems of the clam fishery very well. The innovative constitution, under public scientific control, of fishers' unions with exclusive fishery rights over fishing grounds, could lead to better management and mutual surveillance of the fishery activities, but on the other hand there are local interests that can compromise a really satisfactory application of this new management criterion. The real problem seems to be the capacity of the fleet . In the Gulf of Trieste for example, there are 88 fishing boats equipped with hydraulic dredges and here can be found the highest density per km² over the entire Adriatic Sea. If a rigorous reduction programme in vessel numbers could be achieved, stock restoration could be a reality.

Salmon in ecosystems of the Far-Eastern Seas and the North-Western Pacific

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Since the beginning of the 1990s a new direction in the study of the Pacific salmon life cycle has been developed by the Pacific Research Institute of Fisheries and Oceanography (TINRO). Trawl surveys for salmon sampling are conducted twice annually – during the catadromous migration in fall and the anadromous run in summer. Usually these investigations are carried out by comprehensive ecological monitoring of pelagic waters by the application of conventional methods. Hydrological parameters, plankton biomass and composition, status of salmon food supply, abundance of other fishes and squid, including competitors and predators were assessed simultaneously.

During the investigation of the entire area of the Russian Economic Zone, unique data on Pacific salmon ecology, ontogenesis and physiology have been collected. Recorded features of spatial distribution (especially within the water column) allow consideration of the inherent diversity of salmon species to different biotopes within pelagic waters. Previously established migration patterns for the most abundant Asian salmon (pink and chum) were revised.

Round-the-year observations have extended the known limits of the ecological parameters suitable for salmon species. It now appears that large numbers of pink salmon spend the winter feeding within the southern Okhotsk Sea. Pink salmon aggregations occurred until March even in areas with sub-zero sea surface temperatures. However, while pink salmon are so eurybiotic, physical factors can still affect the nature and direction of their migrations. In the summer of 1993 the possibility of large-scale redistribution of anadromous pink salmon in the Sakhalin-Kuriles region was indicated as a consequence of current pattern anomalies and steep gradients of the water properties across the migration route. This supports the hypothesis that variations in pink salmon stocks are the result of environmental changes.

The temporal and interregional dynamics of the feeding habits of salmon during its marine phase were studied in detail. Trophic specialisation is more evident for salmon which spend several years at sea. It is mostly demonstrated in the active stage of the feeding period preceding seasonal migrations. For example, chum salmon specialise in feeding on pteropods and sluggish jellylike organisms. In the Bering Sea, pteropods contribute 45 – 78% to chum salmon diets. In contrast actively migrating interzonal plankton (hyperiids, euphasiids) and juvenile squid dominate the diet of sockeye salmon.

As a result of detailed statistical analyses, estimates of salmon mortality have been revised. Mean mortality rates of Asian pink salmon are approximately 50% from the beginning of their anadromous migrations to the return to rivers. In unfavourable years mortality rates can be considerably higher.

Concurrent observation on the dynamics of climatic and oceanic factors have provided evidence of patterns of abundance for salmon species. Increased intensity of water movements in the sub-Arctic current system determines the extent of the southward shift of waters within the sub-Arctic

water mass, thereby extending the area suitable for salmon within oceanic waters. In such periods (e.g. 1935-1955 and since 1980) salmon stocks were notable for their high productivity. In recent years some regional stocks of pink salmon have yielded significant increases in numbers (more than 3 to 5 times the mean level). However, by 1994-95 an increase in the mortality rates of pink salmon was observed. This may indicate that conditions for extended reproduction of pink salmon will again become worse.

Biological resources of far eastern seas and the north-western Pacific Ocean: the structure, status and longterm dynamics of pelagic and demersal communities

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After the establishment of the 200 mile zones, active regulation of fishing activity on the basis of catch became possible. Soon after this, ecosystem research of bioresources was organised on a large scale within the Russian economic zone. As a result of a large number of expeditions, a detailed assessment of the composition and structure of demersal and pelagic communities of the Far-Eastern Seas and adjacent Pacific waters has been made.

As the scientific research continued, the status of stocks of many commercial hydrobionts was estimated. Patterns of stock recruitment were determined in relation to recovery of ecosystems by incorporating the influence of global changes in climatic and oceanic conditions since the beginning of the 1990s.

After fishing became regulated, stocks of almost all hydrobiont species, previously reduced, recovered. The extent of recovery varied across the different regions. For example, in the most productive region of the Russian zone – the western Kamchatkan Shelf – the resources of demersal fish and crabs increased to approximately the level of the carrying capacity of the 1980s. In Terpenya Bay (Sakhalin), where the resources of flounder were previously exhausted by long term fishing, the comparatively rapid recovery of their abundance started only at the beginning of the 1990s. At the beginning of the 1980s on the western Kamchatkan Shelf, the biomass of demersal fish and predatory benthos was estimated as 4.22 million t. Consumption of organic matter by these stocks was estimated at 16.0 million t while production of non-predatory benthos was 27.0 million t. At the end of the 1980s, biomass of benthos consumers (fish and crabs) increased to 5.5 million t. As a result the consumption of non-predatory benthos also increased (22.0 million t), but its production remained at its previous level.

The success in regulating the harvesting of the demersal bioresources of the Far Eastern Seas offers hope for the future if catch quotas are to be maintained, especially if the principles of rational multispecific fisheries management are implemented.

Significant recoveries in pelagic communities (not only nektonic but also planktonic ones) of the Far Eastern Seas were confirmed from numerous data. Recoveries mostly occurred in this pattern; decline of biomass of the most abundant pelagic species (pollock – in the north, Japanese sardine – in the south); decrease in pressure from consumers on planktonic communities; increase in zooplankton production, especially by predatory ones; reduction of production of non-predatory zooplankton; decline of fish productivity; commencement of growth in abundance of alternate nekton species (herring, Japanese anchovy, Pacific squid); reduction of biomass and production of predatory plankton. At present, the ecosystems of many regions of the Pacific Ocean are developing according to the above pattern and are in a transition state.

Experience in analysing the dynamics of pelagic communities shows the importance of climatic, oceanic and biocenologic factors (i.e. natural but not anthropogenic ones). It can be concluded that the present time is the beginning of a period analogous to that of the 1940-1960s which came between those of the 1920-1930s and the 1970-1980s.

Sustainability of fisheries supported by dynamic surplus production: the case of the Chilean pelagic fisheries

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Chilean anchovy (*Engraulis ringens*), Chilean pilchard (*Sardinops sagax*) and horse mackerel (*Trachurus murphy*) support a major Chilean fish meal industry. Since 1985, the combined sustained landings of these species have averaged 5.5 million t, representing 86% of the total Chilean landings or 5.8% of the total world marine landings. However, the percentage contribution of each species to the total catch has changed dramatically over the years. Variability in species abundance is the consequence of marked species-specific recruitment responses to ENSO (El Nino Southern Oscillation) events. Larval survivorship during these events is reduced in anchovy while it is enhanced in pilchards and horse mackerel.

As a result of the strong 1972 and 1982 ENSO, anchovy stocks were reduced by over 80% and landings dropped from about 1 million t in 1971 to less than 20,000 t in 1977. Landings fluctuated between 50 and 200 thousand t during 1978-1985. With the cooling of the Humbolt Current system since 1986, the anchovy stock has recuperated considerably. In 1993, landings exceeded 1.4 million t.

The same two ENSO events contributed significantly to the outburst of the pilchard stock that peaked at maximum population abundances in 1982. At that time, pilchards had utilised most of the habitat space left by the collapsed anchovy. Cooling of the Humbolt Current system in the late 1980s contracted pilchard habitat, reducing the stock to isolated school formations in discrete areas of the littoral. Therefore the evolution of pilchard landings is one of a steadily increasing trend from 0.1 million t in 1971 to a historic maximum of 2.9 million t in 1985 and then a steady increase resulting in less than 0.5 million t in 1993.

Horse mackerel is a more open ocean species that supported modest landings of about 100 thousand t prior to 1972. Since the 1972 ENSO, horse mackerel recruitment has increased steadily – a trend that was further enhanced by

the 1982 ENSO. The successful 1983 through 1985 year classes produced an extraordinary large spawning stock during 1998-1990 that outburst population biomass in the early 1990s. Concomitant with this population increase, landings have increased continuously, reaching 1.5 million t in 1982, 2.1 million t in 1988, and 3.2 million t in 1993. During that period, stock distribution expanded to over 1500 miles offshore.

Given the recruitment dynamics and the character of the species biomass replacements observed in the pelagic fishery of Chile, the general exploitation strategy has been to utilise the resources to their maxima. This strategy is supported by the industrial sector in view of the observed results and the unproven theory that the ecosystem, as influenced by ENSO events, will replenish overall ecosystem surplus production. However, the history of this fishery is not long enough to adequately draw these generalisations. Clearly, the horse mackerel population outburst is not related to the anchovy-sardine species replacement scheme. If overfishing of horse mackerel spawning biomass occurs, this may reverse the overall pelagic abundance trend observed since the 1972 ENSO event. The consequences of such a condition has yet to be quantified. Thus, fishery management is generally weak, consisting of limiting access to avoid further overcapitalisation, seasonal closures of the anchovy and pilchard fisheries to protect spawning and recruitment, and a 20 and 24 cm minimum size established for pilchard and horse mackerel respectively. However, these management strategies may not be effective under the extraordinary fishing power of the existing fleets.

Evidence for two depth-separated stocks of the deepwater oreo *Neocyttus rhomboidalis* (Oreosomatidae) off southern Australia

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The spikey oreo, *Neocyttus rhomboidalis*, is one of four commercial oreosomatid species taken on the continental slopes and seamounts off southern Australia and New Zealand. Once caught only as bycatch to the orange roughy and blue grenadier fisheries, the oreos are now targeted with over 1,000 t taken annually in the Australian South East Fishery, and over 20,000 t per year off New Zealand. Little is known about these deepwater fish, although it has been suggested that they have a long larval duration, late maturity (20 to 30 years of age) and may live for over 100 years. A stock structure study examining allozyme and mitochondrial DNA variation, as well as meristic variation, was undertaken on four species of oreo, including the spikey oreo. Striking separation of two groups of spikey oreo samples was found at the *sSOD** locus, with differentiation of samples within one of these groups at two other loci. The highly significant differentiation at *sSOD** was found to be based not on geography, but rather depth of capture (above 700 m and below 700 m). No mitochondrial DNA nor meristic/morphology differences could be detected between these two depth-separated groups of samples. The *sSOD** differences may reflect recent reproductive isolation of two stocks or selection for particular genotypes at the different depths.

An update on marine oil research in Australia

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The waste, bycatch and by-products generated by the fishing industry may be value-added through various procedures to yield a range of marine oil products. In 1938 in the first CSIRO Fisheries report, the oil and vitamin content of a range of shallow and mid-water Australian fish was examined and the potential of several species recognised. After the second world war the availability of synthetics produced vitamins saw the use of fish-derived oils diminish.

By the late 1980s, CSIRO research began to focus on the oil from deepwater fish and several companies had commenced production of marine oils for export and local use. A range of uses for the oils exists, including as lubricants, in degreaser and hand cleaner products, in health and nutritional products and in cosmetics. Oils of current interest include:

1. wax esters derived from orange roughy, oreos and other species,
2. shark liver oils containing squalene (which can also be converted to squalane) and diacylglycerol ethers, and
3. triacylglycerol oils rich in the essential omega-3 fatty acids.

Research conducted within CSIRO currently centres on the detailed characterisation of marine oils from a range of species, searching for new sources for the various commercially sought-after oils and development of new or refinement of existing processing conditions suitable for use with the Australian oils. The research has established strong ties with local industry to transfer this knowledge and thereby allow an increasing return to the fishing industry, without an increase in catching effort.

Decline of Oahu's stream fisheries: identifying causes and planning restoration

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The objectives of this study were 1) to evaluate the current distribution and abundance of native fish in Oahu streams, 2) to correlate species composition and abundance with habitat quality and extent of environmental disturbance, and 3) to evaluate the efficacy of stream restoration alternatives. The Hawaiian archipelago includes five major islands with 376 streams that support fish populations. The ichthyofauna is composed of five amphidromous gobiids including four species of Gobiidae and one species of Eleotridae. A number of estuarine fish species use the lower elevations of streams to complete their life cycles. At one time, these fish comprised an important food source for Hawaiians.

Adult gobies and estuarine species were captured throughout the year and upstream runs of post-larval gobies returning from the ocean were exploited on a seasonal basis. Although no quantitative estimates of historical fish abundance exist, Hawaiian written and oral histories indicate that fish were extremely abundant. However, fish populations on Oahu declined substantially in response to urban development associated with the explosive increase in the human population after World War II. Oahu represents less than 10% of the land mass of the islands but supports 80% of Hawaii's 1,000,000 people. The result is that Oahu's streams have been extensively altered by diversion, channelization, water quality degradation and introduction of alien biota. Research has shown that native gobies are adversely affected by parasites disseminated by introduced fishes. Species composition and abundance data were collected from 40 Oahu streams between 1992 and 1995.

Below an elevation of about 100 m, native stream gobies were uncommon while alien fish were abundant. Although estuarine fish are more tolerant of environmental disturbance, their abundance was low relative to that of other Hawaiian Islands. Of the three high-elevation gobies, *Lentipes concolor* and *Sicyopterus stimpsoni* were rare. *Awaous guamensis* accounted for more than 90% of gobies sampled during the study. Water temperature, stream depth and the presence of alien fish appeared to be the most important factors influencing goby abundance and species composition. Differences in flow did not explain inter-stream variability in goby abundance. In contrast, densities of estuarine fish were strongly correlated with volume of freshwater. Temporal monitoring of one stream in which flow was substantially augmented revealed increases in the density of native estuarine fish and a concomitant decline in abundance of introduced species. However, no significant changes in goby abundance were noted at higher elevations. This may be due to the duration of monitoring; a longer period may be required to observe changes. Moreover, initial flow-related declines in introduced fish species at higher elevations were short-lived. The data indicate that exotic species have adjusted to the higher flow. It is believed that flow enhancement alone will not lead to substantial increases in goby abundance. Other factors, particularly the presence of introduced species, appear to have an influence. Rotenone treatment prior to flow release is recommended to remove fish from the system. Subsequently, amphidromous native species will recolonize the vacant streams, whereas introduced freshwater fish will have no means of dispersal into these systems.

World fisheries and climate change: impacts and adaption measures

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The author formed an international team of authors, contributors and reviewers to assess the impacts of climate change on world freshwater and marine fisheries and on aquaculture, and to suggest adaption measures, as a member of Working Group II of the Intergovernmental Panel on Climate Change (IPCC). The findings of the team were that climate-change effects interact with those of pervasive overfishing, diminishing nursery areas, and extensive inshore and coastal pollution. Globally, marine fisheries production is expected to remain about the same; high-latitude freshwater and aquaculture production are likely to increase, assuming that natural climate variability and the structure and strength of ocean currents remain about the same. The principal impacts will be felt at the national and local levels as species mix and centers of production shift. The positive effects of climate change, such as from longer growing seasons, lower natural winter mortality and faster growth rates in higher latitudes, may be offset by negative factors such as changes in established reproductive patterns, migration routes and ecosystem relationships (Everett *et al.* 1995). The author reviews these findings and the possible adaptation measures, and suggests a possible strategy for bringing the findings to the attention of policy makers.

The environmental biology of an endemic freshwater fish, *Varicorhinus alticorpus,* in Taiwan

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High body Ku fish, *Varicorhinus alticorpus,* is an endemic primary freshwater fish in Taiwan. This fish is already on the list of endangered wildlife in Taiwan, yet very little is known about them. During the past nine years, the distribution of this fish in Taiwan was surveyed and mapped. Furthermore, their equivalent biology in one of their major river habitats was studied. The results showed that deep pools with inlets of rushing water are their favourite habitats. Physical conditions for their occurrence are: 16.7–28.2°C, pH 8.02–8.82, D.O. 60% saturation up, conductivity 284.4–601.3ms, flow rate 0.1–0.8m/sec. Their major diet is benthic algae with opportunistic ingestion of insects. Their breeding season is estimated to be between October and February. In some cases it may extend to May. The shift of the breeding season to winter-spring is obviously an adaptation to avoid the summer flood-typhoon season in Taiwan. Adult fish reveal regional migration between middle and upper sections of the river in different seasons.

The role of fishing and sea lamprey-induced mortality in the rehabilitation of lake trout in the U.S. waters of Lake Superior

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Lake trout (*Salvelinus namaycush*) in Lake Superior supported an important commercial fishery averaging two million kg annually until 1949. Commercial yields of lake trout declined by 90% during the 1950s as a result of overexploitation and sea lamprey (*Petromyzon marinus*) predation. Efforts to rehabilitate lake trout populations in Lake Superior began in the 1950s with stocking of hatchery reared lake trout and chemical control of sea lampreys. Additionally, severe harvest restrictions were placed on the commercial fishery in 1962 in an effort to reduce lake trout

mortality. Although progress toward rehabilitation of lake trout populations has been slow, abundance of wild lake trout in the U.S. waters of Lake Superior has generally increased from 1970 to 1993 and is currently at moderate levels. However, excessive mortality due to sea lamprey predation and fishing continue to hinder lake trout populations from reaching historical levels of abundance. The objective of this study was to evaluate the impact of fishing and sea lamprey-induced mortality on current lake trout rehabilitation efforts in the U.S. waters of Lake Superior.

The roles of fishing and of sea lamprey-induced mortality in lake trout population dynamics were evaluated using a life table approach. Age-specific fecundity and survival schedules of lake trout currently found in the U.S. waters of Lake Superior were incorporated into a Leslie projection matrix to calculate the finite rate of population growth (λ). Elasticity analysis was used to determine the proportional contribution of age-specific fecundity and survival to the population growth rate. Survival, particularly during the pre-reproductive ages, made a greater contribution than fecundity to the population growth rate of lake trout in Lake Superior. Using sensitivity analysis, the response of the population growth rate to changes in fishing and sea lamprey-induced mortality was evaluated. The model clearly shows that for lake trout rehabilitation goals to be met in the U.S. waters of Lake Superior, mortality rates need to be significantly reduced. Further, it was found that reducing fishing mortality had a greater effect on the population growth rate than reducing sea lamprey-induced mortality by an equal percentage; a result related to fishing mortality being greater than sea lamprey-induced mortality for lake trout of pre-reproductive ages. Lake trout in Lake Superior mature at approximately 60 cm in length while fishing begins to target lake trout that are approximately 51 cm in length. Sea lamprey, on the other hand, are size-selective predators that target the largest prey item available. Thus, fishing mortality is greatest during the pre-reproductive years when survival is most important in driving the population growth rate. Fishery managers can reduce fishing mortality of pre-reproductive lake trout by increasing the legal size limit. Such an action has the potential to increase the population growth rate of lake trout in Lake Superior and facilitate their rehabilitation to historic levels of abundance.

A critical review of tuna stocks and fisheries trends world wide and why most tuna stocks are not yet overexploited

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This paper will summarize the results obtained at the end of a two year programme targeting on a world wide comparison of the stock status of the various tuna species and stocks exploited in the Atlantic, Indian and Pacific Oceans, taking into account their ecology and their oceanographic environment.

Most tuna species are still showing increasing catches world wide, especially of the tropical species. Extensive and seasonally mobile oceanic habitat is the major cause for this surprising low exploitation rate and constant increase in most tuna catches observed world wide. Most tunas are conducting seasonally extensive migrations, for instance between their feeding and spawning zones; the thermoregulation capabilities of the tunas, especially efficient for the adults of the largest species, allow them to migrate and feed in cold waters. The high individual spawning potential and the large numbers of tunas spawning in large time and area strata help explain the good stability of most tuna stocks. Furthermore, it appears that most tuna stocks may have significant fractions of stocks which are still not available to the fisheries, being located in a remote zone, too scattered or too deep. Those fractions of tuna stocks (potentially large?) mostly unavailable to the fisheries, may often be acting as natural refuges for various tuna stocks because of their incomplete mixing with the fully exploited fraction of stock; however, their importance is presently difficult to evaluate quantitatively. Those conditions explain well why most tuna stocks have shown in the past little recruitment variability and very few cases of recruitment overfishing.

However, this positive conclusion probably cannot be extrapolated to the future. Various bluefin tuna stocks are already in bad shape. The bad condition of this temperate tuna can easily be explained by various factors, amc others a large size and a very high value on the sashimi market (allowing a sustainable fishery, even at very low catch per unit of effort), low levels of recruitment and a fish which is often easy to catch because of its behaviour.

For most tuna species and stocks, the exploitation rates have been constantly increasing as shown by the trends of their catches. However most tuna stock assessments have been quite inefficient in past years in estimating the real Maximum Sustainable Yield (MSY) of those underexploited tuna stocks. Various tuna stocks may probably soon join the large group of already overfished resources, as very few potential fishing zones now remain unexploited for the major tuna stocks. This danger of tuna overexploitation may be linked to the increase in fishing effort and to the recent spectacular increase in fishing efficiency observed for most tuna fleets (due to technological and other improvement). It may be difficult to prevent this overfishing because of the geographical distribution of tuna, within and outside Exclusive Economic Zones (EEZs), and the multiple practical and legal difficulties faced world wide (at various degrees, depending on the tuna commissions active in ea·h area) to develop an efficient international managemen. .. such highly migratory resources.

Prediction of snapper (*Pagrus auratres*) recruitment from sea surface temperature

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The snapper population along the north-east North Island coast (SNA 1) supports New Zealand's most important inshore demersal fishery. Commercial catches (5,000–6,000t per year) have been constrained since 1986 by Individual Transferable Quotas and the recreational catch is currently 3,000t per year. In the absence of major changes in fishing mortality, natural mortality and growth rates, recruitment variability is likely to be the main factor affecting future population sizes. The present study aimed to assess the magnitude of recruitment variability, determine whether recruitment is related to sea surface temperature (SST) and predict future recruitment for use in population forecasting models.

Trawl surveys were conducted annually between 1984 and 1994 (except 1991) in the Hauraki Gulf, the main nursery area for SNA 1, to estimate the Year Class Strength (YCS) of 1+ snapper. YCS varied eight-fold over the 11-year period. Nearly all of the variation in YCS (R^2 = 95%) was explained by mean SST during February–June of the 0+ year. The mechanism underlying the temperature-recruitment relationship is unknown, but may result from the observed reduction in larval duration at higher temperatures and consequent reduced exposure to larval predators.

The temperature-recruitment model was used to predict YCS for the period 1931–1995. YCS predictions for the 1981–1988 year classes were strongly correlated with YCS estimates for recruited snapper derived from commercial longline age-frequency data using an age-structured model. This shows that the trawl survey estimates of YCS at age 1+ are valid indices of recruitment to the adult population. YCS predictions also agreed well with qualitative estimates of YCS obtained from age-frequency data for the year classes 1938–1976, providing further validation of the temperature-recruitment model.

A , year cycle in mean February–June SST, and hence in YCS predictions, over the last three decades appears to be driven by the El Niño – Southern Oscillation: there is a significant positive correlation (r = 0.65) between SST and the Southern Oscillation Index.

Snapper recruit to the adult population at 3–5 years, enabling prediction of YCS 2–4 years before recruitment. Based on recent SST data, the 1991–1993 year classes are predicted to be weak, the 1994 year class average and the 1995 year class strong. Forward projection of the SNA 1 population model suggests that population size will decline at the current level of fishing.

Effects of urban development on fish and fisheries of the Hawkesbury-Nepean River system, Australia

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Major cities of the world are commonly built around rivers and estuaries which provide both a source of fresh water for domestic and industrial purposes and an avenue for disposal of wastewater. Use of rivers for these purposes usually leads to degradation of fish habitats and riverine ecosystems in general and affects fish populations that support commercial and recreational fisheries. With increasing populations in many cities, deterioration of river systems is likely to continue, placing fish populations and fisheries at risk.

The Hawkesbury-Nepean River system supplies 97% of the drinking water for Sydney's population. Much of the sewage from western Sydney is discharged into the middle and lower reaches of the system. As a result of this disturbance, the river and its fish communities are showing signs of environmental stress. Current projections estimate that the human population in the river valley may increase by a further million people over the next two or three decades, placing additional stresses on the river system. The Hawkesbury is the second most important estuary in New South Wales by value of the total fishery catch and is the fourth most important NSW estuary for oyster production. Recreational angling in both estuarine and freshwater reaches of the system is also an important fishery. This study assessed the impact of water supply development and related activities on the fish and fisheries of the system to ensure water resources are used in an ecologically sustainable way, to relieve environmental stress and to secure the survival of fisheries in the system.

Regulation of stream flow by dam operations for domestic, industrial and agricultural water supply modifies the flow of water from the natural pattern within the system, with implications for fish that rely on environmental cues for reproduction and migration. Fifty-five sites, including sites above and below dams on regulated tributaries, reference sites on unregulated tributaries and main channel sites in the lowland reaches of the Hawkesbury River were studied. Fish communities were sampled using backpack and boat-mounted electrofishers as well as gillnets in sites inaccessible for electrofishing.

Fish catches were analysed by multi-dimensional scaling to identify patterns in fish communities and to establish which sites were most affected by river regulation. Discontinuities in species distributions among sites were detected using analysis of variance. Fish communities downstream of dams and weirs are depauperate compared with equivalent sites in unregulated rivers. Operation of dams in a more ecologically sensitive manner, by providing environmental streamflows that preserve critical elements of the natural flow regime, has the potential to restore fish communities affected by river regulation. In many cases, such flows can be provided without compromising operating requirements for water storage and distribution.

A hypothesis to explain fish recruitment

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Time series of recruitment (R) to fish stocks often contain successive periods of high and low values. A "recruitment states" hypothesis is proposed in which recruitment switches between states from time to time. Each state has a different level of mean R. R varies randomly around each mean. Using a meta-analysis methodology, the recruitment states hypothesis can explain recruitment time series, for a meta-dataset of 153 marine-spawning bony fishes, significantly better than the null hypothesis of random recruitment. In contrast, the null hypothesis cannot be rejected for a meta-dataset of 31 salmon stocks.

The conventional "stock recruitment paradigm", is that R is positively related to the Spawning Stock Biomass (SSB) of the stock, at low SSB. Some (SSB, R) datasets appear to support this paradigm, showing low R at low SSB. These apparent relationships may be spurious. Under the recruitment states hypothesis, when a stock occupies a low recruitment state for a period, SSB will almost inevitably fall to a low level. Low R and low SSB will tend to occur together, not because low SSB causes low R, but because a period in a low R state, causes a (lagged) period of low SSB. For this reason, any analysis which treats (SSB, R) datasets as though they were independent observations, is capable of producing misleading results.

To avoid this problem, a hypothesis test has been developed, based on estimating derivatives from the first differences of the SSB and R time series. Essentially, the test asks whether a fall in SSB generally corresponds to a fall in R and whether a rise in SSB generally corresponds to a rise in R. That is, are the derivatives of the postulated relationship positive? This test could not reject the null hypothesis for the marine-spawning bony fishes. The observed derivatives were not significantly more often positive than negative, as they are postulated to be under the paradigm. The test did reject the null hypothesis for the salmon stocks. It follows that the relationships, where low SSB apparently causes low R, observed in some (SSB, R) datasets, are generally fallacious for the marine-spawning bony fishes.

The recruitment states hypothesis goes one step towards explaining patterns of recruitment to marine-spawning bony fish stocks. It is speculated that there are environmental correlates to the recruitment states of a fish stock. They may not be easy to find.

It is concluded that for salmon stocks it is important to adopt management measures that reduce the occurrence of low SSB. Such measures will increase mean R and hence mean yield. For marine-spawning bony fishes, periods of low R appear to be natural phenomena which cannot be avoided by fisheries management measures. Managing such stocks may be comparable to managing water in hydroelectric dams. Good management will involve husbanding the resource during periods of drought (like periods of low recruitment). But good management cannot avert the drought itself.

Integrated management in the Great Lakes: the sea lamprey programme

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The North American Great Lakes enjoy a reputation for valuable sport, aboriginal and commercial fisheries as well as providing quality destinations for tourism. These thriving fisheries were not always so, as in the 1950s stocks were at their historic low. Overfishing, predation by the exotic Atlantic sea lamprey and loss of habitat contributed to this decline. Concern for the wellbeing of the fishery prompted Canada and the United States to strike a Convention on Great Lakes Fisheries in 1955 which created the Great Lakes Fishery Commission. The bi-national Commission has resulted in joint and coordinated management efforts by two nations, one province, eight states and native and tribal authorities. Charged with the general improvement of fisheries, the Commission has focused on lake trout rehabilitation and the control of sea lamprey.

This presentation examines the objective of controlling the lamprey, describes the chemical technology chosen to accomplish that objective and evaluates the success to date. A second objective is to examine the change in focus of the Commission as it reacts to the changing needs of the cooperating member agencies of the Commission and the interests of the public within the Great Lakes basin. A third objective is to describe the Strategic Vision of the Great Lakes Fishery Commission as it enters the 21st century with particular emphasis on integrated pest management approaches and the development of alternative technology to replace the long-term chemical control effort.

Findings to date indicate that the original chemical control effort developed and implemented by the Commission in the 1960s was immediately successful and resulted in the reduction of parasitic phase lamprey in the Great Lakes by as much as 90%. This has contributed to the rehabilitation effort for lake trout on most of the Great Lakes where indications of naturally reproducing populations have been confirmed. The control effort also assisted the creation and maintenance of a dynamic sport fishery for stocked salmon.

During the last decade public and agency focus in the Great Lakes has been on reduction of chemical inputs into the system and a much greater awareness of the effects of toxins in the food chain. The Commission, and its cooperating agencies, have reacted by expanding programme objectives to encompass more holistic and ecosystem approaches and to implement integrated and cooperative delivery mechanisms. Efforts to combine fishery management objectives with sea lamprey control measures are described and the target levels for control on each lake provided. Findings indicate that desired levels are being achieved on three of the five Great Lakes at present.

The five principal objective statements of the Strategic Vision are examined with emphasis on the target of 50% chemical use reduction by the year 2000. Alternative control methods such as spawning population barriers are described emphasizing the velocity barrier design and inflatable crest design. Successful use of these designs occurred in 1994 and 1995 and may provide chemical reduction levels of 50 to 100% per stream.

Conclusions are offered indicating that the establishment of the Commission contributed directly to the present success of Great Lakes fisheries. Secondly, that the current revamped approach within the Commission Vision statement for this decade will enable the Commission to continue to successfully address the needs of the client group and assist in the sustaining of Great Lakes fishery resources.

Southwest Atlantic long tail hake (*Macruronus magellanicus*): state of stock and management

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This communication aims mainly to glance at one of the most important SW Atlantic fishery resources. The effort made by Argentina to manage the stock on the basis of continuously improved scientific information is also stressed.

Long tail hake is a demersal, semi-pelagic gadiform, widely distributed within the SW Atlantic from 35° southwards. Main concentrations occur south of 45°S, no deeper than 200 m.

This species is one of the most abundant finfish resources of the region. Assessments of long tail hake biomass off Argentina have been conducted since 1973. A systematic series of demersal trawl surveys (swept area method, stratified random sampling) was started in 1992. Survey results suggest total long tail hake biomasses ranging from 926 to 1,544 thousand t.

As a result of a recent review, the design-based approach hitherto used to estimate long tail hake abundance will be replaced for future surveys by a model-based approach (delta-distribution).

Long tail hake feeds mainly on zooplankton (94.6% frequency (F) of occurrence), having fish only as secondary prey (12.5%F). Among zooplankton species, the most important are those of hyperid amphipods and euphausiids. Cannibalism was mostly exhibited by large individuals (above 70 cm TL). Only a few species were found to predate on long tail hake: southern hake (*Merluccius australis*, 66%F), spiny dogfish (*Squalus acanthias*, 10%F) and Argentine hake (*Merluccius hubbsi*, 2%F).

Typically, the youngest fish are distributed south of 52°S, while the oldest are caught between 45° and 52°S. The oldest observed was 12 and the maximum total length was 121 cm.

Fishery activities on long tail hake began during the middle 1970s, when Polish and former USSR vessels reported some small annual catches. Long tail hake yields were not significant until the middle 1980s, but sharply increased to reach about 145,000 t in 1988. This was a result of fishing boats from Bulgaria and the USSR operating under joint ventures with Argentinian enterprises. Total catches decreased again and currently average about 35,000 t/year (1989-1994).

Cc ..nercial yields are mainly based upon 4-8 year old individuals. Results of a Gulland's VPA (tuned by commercial cpues) run over the catch data from 1983-1993 were used as input for a Thompson and Bell model. Two important biological reference points ($F_{0.1}$ and $F_{0.3\ SSBo}$) were identified and indications of biological risk associated with different management options were given. Accordingly, Argentine fishery authorities have set a Total Allowable Catch of 165,000 t for 1995.

Brown shrimp sequential fisheries in the Gulf of Mexico

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Brown shrimp, *Penaeus aztecus*, in Mexican waters of the Gulf of Mexico is the most important stock that currently ' ›ports the Mexican shrimp fleet in the Gulf. Brown ... ..mp is subjected to artisanal inshore and industrial offshore fisheries. Mean annual shrimp production is about 10,000 t. Almost half of brown shrimp landings are obtained from nursery grounds in coastal lagoons. Artisanal catch is composed of juvenile shrimp with a mean size between 60 and 90 mm. Total length corresponds to 2.3 months old. Artisanal exploitation has reduced brown shrimp stock to a state of growth overfishing. Yield per recruit models suggest that standing stock offshore could be enhanced in a ratio of 1:3 if juvenile shrimp are protected in the nursery grounds. On the other hand, offshore fishing pressure has also been increasing in the last years due to improvement of shrimp fleet fishing power and to directing fishing effort to the brown shrimp fishery.

A resource use conflict exists between artisanal and industrial brown fisheries. An inshore and offshore closure has been set to improve brown shrimp yield. During 1993 this fishery regulation reduced artisanal catch by about 25% and resulted in a yield enhancement of more than 300% offshore. The gain in weight exceeding shrimp mortality seems to favour the offshore fishery over the artisanal fishery. Competition between the two fisheries for larger catches in the following years resulted in lower total catch. Offshore yield obtained in 1993 was 72% above the mean catch of the last ten years, whereas during 1994 it was only 10% above the mean annual offshore catch. Industrial fishing effort in the open season increased 1.7-1.9 above average value. The possibility of a closed season also cause artisanal fishing effort to increase 1.5 times above mean value. Apparently the fishery regulation is promoting an undesirable effect as it is increasing total fishing effort on brown shrimp stock. The constant increase of fishing effort in both fisheries may eventually affect the remaining spawning biomass and add a problem of recruitment overfishing to the brown shrimp stock.

Spatial variation in the distribution of Penaeidae (shrimp) species on the northern Great Barrier Reef: potential effects on management

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Spatial heterogeneity is a general characteristic of complex reef systems. This paper reports the effects of this complexity on the distribution of Penaeidae species of the far northern Great Barrier Reef and how such complexity potentially impacts on management strategies. Multi-dimensional scaling (MDS) shows a definite gradient in abundance and biomass from the inshore lagoon on to the mid-shelf reef-shoal zone; with a relatively low number of large-bodied species in the inshore lagoon and a larger nmber of smaller-bodies species offshore in the reef-shoal zone. Isopleth plots of abundance and biomass overlaid on a map of the cross-shelf habitat showed a mosaic of interlocking species distributions along this inshore-offshore gradient. A Kriging method, incorporating spatial structure, was used to estimate the total abundance and biomass of the fifteen most abundant species. Canonical correspondence analysis (CCA) was used to explore and partition the variance in the abundance into spatial and environmental components. Approximately 9% of the variance was attributed to intrinsic spatial effects, 9% to purely environmental effects and 29% of the total variance to spatially structured environmental effects. The residual 53% of the variation was due to unknown factors or simple random stochasticity.

Inherently high levels of variation, due to temporal (seasonal and lunar) and spatial factors, indicate that predicting the magnitude and spatial distribution of penaeid abundance will be imprecise. Management methods such as area or seasonal closures, and the research sampling on which these closures are often based, need to accommodate, on the one hand, distinct gradients and spatial patterns in species distribution, and on the other, high variance which makes statistical evaluation difficult.

Effects of interdecadal climate variability on the oceanic ecosystems of the north Pacific

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It is increasingly apparent that a major reorganization of the North Pacific biota transpired following a climatic 'regime shift' in the mid 1970s. The effects of interdecadal climate forcing on the oceanic ecosystems of the Northeast Pacific Ocean have been characterized. The approach is to first reflect on a number of recent studies relating climate to marine ecosystem dynamics. These studies have focused on most major components of marine ecosystems: primary and secondary producers; primary, secondary and top-level predators. They have been undertaken at different time and space scales. However, taken together, they reveal a more coherent picture of how decadal scale climate forcing may affect the large oceanic ecosystems of the Northeast Pacific. The insight gained from these studies has been synthesized with what is known about the atmospheric and oceanic physics and their effect on these marine ecosystems.

The frequency and severity of fish stock declines and increases

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Trends in spawning stock biomass, recruitment and catch have been examined for 129 stocks of fish for which over twenty years of data were available. These data show that dramatic declines and increases in abundance are common. 10% of all stocks examined showed a ten fold decline in spawning stock biomass and recruitment using a five-year running average. 6% of stocks showed a ten-fold increase in both spawning stock biomass and recruitment. 19% of stocks exhibited a five-fold decline and 15% showed a five-fold increase.

Of 24 stocks of the order Clupiformes 38% showed a ten-fold decline in spawning stock biomass, while 29% showed a ten-fold increase. 41 stocks of Gadiformes were examined; 38% showed a ten-fold decline and none showed a ten-fold increase. Of the 15 Pleuronectiformes stocks examined none showed a ten-fold decline or increase. Of 44 Salmoniformes stocks examined 17% showed a ten-fold decline while 21% showed a ten-fold increase.

These data illustrate that large scale fluctuations in fish stocks are widespread, and that in general, increases are not quite as common as declines. The results by taxonomic group indicate that Clupiformes are the most variable, while Pleuronectiformes seem to be the most stable.

Marine fish and the IUCN red list of threatened animals

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The World Conservation Union (IUCN) categories and criteria have been used to compile threatened species lists (red lists) for almost 30 years. Marine fish have never been well represented in such lists. If the IUCN criteria are applicable to marine fish species, then they may provide a way of flagging those fisheries which have or have not collapsed, in terms of extinction risk. This process may help identify factors which are important in the collapse of fisheries, and help raise public awareness of the importance of sustainable fisheries management.

The first aim is to assess the applicability of the IUCN threatened species criteria to marine fish. In 1994, IUCN accepted new criteria for listing species in red lists, and these are being applied to all animals for the first time in the 1996 red list. These new criteria were primarily tested on terrestrial species, and there has been concern about how applicable they are to marine species, including fish.

At a workshop in London in April 1996, held by the Zoological Society of London, WWF and IUCN, 148 species of marine fish were evaluated, including coral reef fish, seahorses, pipefish, sharks, tunas and many others. 80% of these were classified as threatened, and are summarised here. This list has been submitted to the World Conservation Monitoring Centre for consideration for the 1996 red list. A set of future recommendations and guidelines were produced to address problems encountered with the criteria. One problem was felt to be sufficiently important that the participants requested that it be included with the threatened species list, as a caveat to listing. The caveat recognises that the criteria provide relative assessments of trends in the population status of a species, and that this does not always lead to an equally robust assessment of extinction risk, which can depend upon the life-history of the species. In particular, the criteria may be inappropriate for assessing extinction risk in species with high reproductive potential, fast growth, and broad geographic ranges.

The second aim is to examine the consequences of using the IUCN criteria to evaluate and compare fisheries which have and have not collapsed, in terms of which categories of threat the species fall into, and the impact this may have for flagging conservation concern in collapsed fisheries.

Historical fisheries data is used to evaluate a range of species for which there are collapsed and stable fisheries. Fisheries may show as threatened in the early stages of exploitation which are associated with a rapid reduction in numbers, however if the fishery stabilises, the population will no longer qualify as threatened.

For the majority of species evaluated, the IUCN criteria system was flexible enough to accommodate for the wide variety of marine fish life-histories and for the type of data available. The IUCN criteria are a viable tool for highlighting concern in stocks undergoing rapid decline, however some important problems relating threat assessment to real extinction risk remain to be solved.

Distribution of benthic organisms around different designed artificial reefs

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Artificial reefs provide shelter, spawning and nursery areas for reef fishes. Algae and invertebrates which rapidly colonize the submerged structures provide a food source for some species. The structures are also known to cause an increase in benthic organisms in the surrounding areas. A study was conducted to observe the abundance and distribution of benthic organisms around newly installed artificial reefs. Artificial reefs having five module designs and built from combinations of concrete, discarded tyres and bamboo poles with two replicates for each were installed in coastal waters of West Malaysia in the South China Sea. Sampling of the bottom sediment was conducted before and after the installation of the reef modules, at distances of 0m, 5m and 10m from the reefs. Samples collected were taken to the laboratory for analysis of benthic organisms. Species were identified under a microscope. The study shows that the density of benthic organisms changes with the distance from the reefs and the design of the modules. Important benthic organisms with respect to fish feeding were observed around the reefs.

The effects of oceanographic variability on the recruitment of two species of juvenile arripid fish to a nursery area and subsequently to the hauling net fishery in South Australia

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The link between temporal variability in large scale oceanographic conditions and population dynamics of marine species has long been thought to be an important process. It is only recently that these links are becoming documented through the use of long term biological data sets and the importance of these processes for fisheries in particular is now being understood.

For the Australian salmon and tommy ruff, two sympatric arripid species *Arripis truttacea* and *A. georgiana* (Order Perciformes) found in southern Australian waters, an attempt has been made to relate oceanographic conditions at time of spawning to recruitment to a nursery area and subsequently to the fisheries, based on the results from a long-term beach seine survey in a mangrove/seagrass ecosystem in South Australia. Between 1981 and 1995, beach seine shots were carried out at 3 sites within the Barker Inlet estuary, an embayment on the eastern side of Gulf St. Vincent, and it was found that recruits of *A. truttacea* entered the estuary between July and September (average: August), and the fish of that year class remained for 11–14 months before moving out of the estuary to a part of the hauling net fishery in SE Gulf St. Vincent. *A. georgiana* entered Barker Inlet on average two months later; however, the year class remained in the estuary for up to two years, before entering the hauling net fishery. For both species recruitment indices were expressed as the $\log_e$ of the average number of 0 group fish per shot, and these were significantly correlated with sea level heights (mm) at the known time of spawning for each species (April for *A. truttacea* and June for *A. georgiana*) for Albany, Western Australia, adjacent to the only known spawning areas for both species. Although the recruitment index for *A. truttacea* also correlated with the Southern Oscillation Index (SOI), the relationship for *A. georgiana* was not as clear, and it appears that local oceanographic/meteorological conditions in the spawning area, manifested as sea level height, may play a major role in determining the recruitment strength for the latter species. The annual catches in the fishery were also correlated with a one and two year lag with the respective recruitment indices and these were also found to be significant ($P < 0.05$). The study has also demonstrated, for these two species at least, that simple beach seines are an effective sampling method for obtaining recruitment indices for predicting recruitment variability in the hauling net fisheries in South Australia.

Recruitment and size structure of jackass morwong (*Nemadactylus macropterus*) and tiger flathead (*Neoplatycephalus richardsoni*) populations in eastern and south-eastern Tasmania, Australia

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In south-eastern Australian waters a multi-species demersal fishery operates on the shelf and mid slope waters. Landings from this fishery peaked at over 60,000 t in 1990. Two of the main target species on the shelf are jackass morwong (*Nemadactylus macropterus*) and tiger flathead (*Neoplatycephalus richardsoni*) which had combined landings of approximately 3,200 t in 1993. The same species are targeted by a small fleet of otter board trawlers and danish seiners in Tasmanian fishing waters with recent catches ranging from 160 to 250 t p.a.. Small catches are also made in New South Wales and Victorian State waters.

Despite a long history of commercial fishing for these shelf species, little is known about their early life history and recruitment processes. Since January 1992 seasonal demersal trawl surveys have been conducted on the shelf in depths of 15-200m adjacent to eastern and south-eastern Tasmania to determine the size structure of the demersal populations by depth, principally to identify nursery areas for the species. Additional to this, sampling has been conducted with small mesh beam trawls and gill nets in the 0-15m depth range to provide coverage of the shallow inshore waters.

Jackass morwong have shown a consistent pattern of increasing fish size with depth with mature fish restricted mainly to the mid and outer shelf. In south-eastern Tasmania, spawning takes place on the shelf between January and May with recruitment to shallow inshore waters occurring after an extended pelagic post-larval, or 'paperfish', phase of approximately 9-12 months. Recruitment occurs during spring and summer (October-March) at around 6-8 cm, with settlement occurring primarily

in inshore waters < 50m depth. They utilize the shallow unvegetated habitats as a nursery area for up to two years before moving into deeper water with the onset of maturity.

Tiger flathead show less size structuring by depth with mature fish found across the shelf, although the majority of fish >40cm were on the outer shelf. The size structure also varied seasonally with the appearance of large mature fish (>50cm) on the outer shelf during the spawning season (December to March). While larvae are pelagic on the shelf the distribution of the 0+ cohort (i.e. ~2-18cm) is still unknown. While mesh selectivity may account for the lack of this cohort in the 15-200m depth range, the absence of juveniles in small mesh nets inshore indicates that they do not utilize shallow inshore waters as a nursery area. In contrast, a closely related species, sand flathead (*Platycephalus bassensis*) recruit to shallow inshore waters, primarily seagrass beds and mud dominated bays at around 5-6cm.

While there is a consistent pattern in the size structuring of the major demersal species by depth, with juveniles more common inshore and larger fish in deeper water, the duration of the pre-settlement phase, habitat preference of juveniles and age-based migration from nursery areas appear to be species specific.

Destruction of the environment of juvenile coconut crabs

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The cocount crab, *Birgus latro* (L) *Coenobitidae* is the largest land arthropod which lives on the islands, coral islets and atolls of the Indo-Pacific tropical region.

Since the beginning of the century, numerous studies have been carried out on the adults of the species but none centred on juveniles. The rare observations have been fleeting.

Despite having widely adapted to the land environment, *Birgus latro* is dependent on the marine environment for the laying of eggs and larval development. Larval growth goes through 4 to 5 pelagic zoea stages over a total of between 17 and 28 days, and then through an amphibian glaucothoe stage, lasting 21 to 28 days. At this stage, the crab takes to the land.

A study was carried out on Lifou. Juveniles were looked for in a zone situated between the ocean and the cliff, corresponding to the first destination of the land-bound juveniles. Traps were placed at various points in this zone and at the same time a careful investigation was carried out of the piles of vegetation found in the area.

Around a hundred crabs were observed exclusively under the piles of vegetation at the foot of coconut palms, piles made up essentially of coconuts and palm branches. The crabs found here were all smaller than the size at sexual maturity (ie 25mm). The smallest amongst them protect their abdomen by way of a gastropod shell which they change every four months and which they abandon at one year, at a size of 8 mm.

The coastal zones, which are vital for the development of *Birgus latro* juveniles also have an economic interest. It is here that the majority of the tribes live and where the island's main road is found. Uninhabited land can also be put to use by the inhabitants of Lifou, being used for slash and burn culture or animal farming. Seaside areas also attract tourist outlets. All these activities constitute the main causes of juvenile habitat destruction and explain the often drastic diminution of crab stocks in the world. Rivalry for space is far greater than the exploitation in other regions. This phenomenon will become more acute with the demographic and economic growth of the islands.

Daily changes in the catch of *Parapristipoma trilineatum* at the hook and line fishing ground of the Toshima Fishery Co-op in the Uwa Sea, Japan

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Daily changes in the catch of threeline grunt, *Parapristipoma trilineatum*, at the Toshima hook and line fishing ground were studied during the period April 1988 to March 1989. Hook and line fishing of *P. trilineatum* is one of the Japanese traditional fishing methods which has been continued by contemporary fishers. Total catch (TC) and catch of grunts (CP) changed seasonally and were higher in summer and poor in the winter season. The CP/TC ratio was more than 30% between May and September. Daily changes in CP were related closely to the number of fishing boats which caught *P. trilineatum* (NFB) during June and September. Daily changes of CP and fluctuations in daily tidal level (FTL) were positively related from June to September (except for August); the same relationship was also found between NFB and FTL. Catch per unit of effort of *P. trilineatum* was not related to FTL. It appears that daily changes in catch at the Toshima hook and line fishing ground were influenced by periodic changes in the tidal cycle. Good catches are taken during the spring tide but they are poor during the neap so there is no fishing during the neap tide.

Global climate cycles and pelagic fish stock fluctuations in the Pacific

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The impact of large-scale climate change on the biological productivity of oceans is a problem of great scientific and economical importance. Long term decisions, such as those pertaining to the scheduling of fleet replacement or the construction of processing plants, would be greatly facilitated by improved knowledge of the mechanisms underlying long-term fluctuations in commercial fish populations.

The main purposes of this research are: 1) to identify the main Pacific commercial stocks involved in long-term climate-governed fluctuations, and 2) to determine reliable global climate indices which could make it possible to forecast the long-term dynamics of main commercial stocks.

The main Pacific commercial fish species (Peruvian, Japanese and Californian sardine, anchovy, Pacific salmon, walleye pollock, Chilean jack mackerel, Pacific herring, Pacific cod, tunas and some others) are involved in long-term simultaneous oscillations in tropical, subtropical, subarctic

and arctic zones. The total catch of these species adds up to about 45 percent of the total Pacific marine fish harvest.

Global and North Hemispheric surface air temperature anomaly (dT°) and Aleutian Low Index (ALPI) trends being strongly smoothed, demonstrate the general direction of Global Climate changes, though without reliable predictive meaning for Pacific fish production . The climatic indicator most closely related to long-term fluctuations of main commercial stock trends is the so-called Atmospheric Circulation Index (ACI) characterizing the principal direction of aerial mass transport (meridional or latitudinal). This index has been recorded in the Northern Hemisphere for more than one hundred years, since 1891.

Correlation coefficients between unsmoothed commercial catches and ACI trends for the period 1900-1992 constitute for Peruvian, Japanese and Californian sardine 0.90-0.92, Chilean jack mackerel 0.94, Pacific salmon 0.84, walleye pollock 0.80, Pacific cod 0.82, Pacific tunas 0.90 and for the total commercial Pacific catch 0.93.

ACI long-term dynamics are in phase with general smoothed trends for Global and Northern Hemisphere air surface temperature anomalies and are likely to reflect long-term atmospheric circulation processes on a global scale. This is confirmed by the strong correlation between time series of ACI and global geophysical characteristics, the Earth Rotation Velocity Index (ERVI) for more than one hundred years.

Cyclic variation at a period of 50-60 years was observed in the stock dynamics of the main commercial species, ACI and ERVI trends.

Good correspondence is detected in phases between ACI, ERVI and Japanese sardine abundance trends since early 1800s. Periodicity of Japanese sardine bursts is approximately sixty years. Such a type of long-term cyclic fluctuation is confirmed by data on reconstruction of stock abundance variation of Californian sardine and anchovy over the past two millenia. Similar long-term periodicity of stock abundance has been observed in Pacific salmon over the past 200 years and in Icelandic cod over the past 350 years.

Variations in commercial species production in the Pacific over the last century can be pictured as two sequential climate-governed production cycles. The first took place in the 1920s-50s with a maximum in the late 1930s. The second one developed from the early 1970s with maximum in the late 1980s-early 90s. The latter cycle is not completed yet but now it comes to a final climate-production phase, similar to the phase of 1940s-50s. The climatic (dT° ,ALPI , ACI) and geophysical (ERVI) indices also come to a final descending phase.

The evolution of a new climatic phase in the Pacific will have serious consequences for oceanic biota as well as for terrestrial.

Close correlations between commercial species production and some climatic (and geophysical) characteristics such as CI and ERVI make it possible to consider main commercial stock dynamics as a sensitive indicator of large-scale climatic change.

The results obtained provide a basis on which to elaborate new approaches for a predictive "climate regime model". The adaptation of longterm ACI (and ERVI) variation permit the forecasting general trends main Pacific commercial stocks for 2-15 years and correct them timely if necessary.

The information gained on long-term climate-governed dynamics of certain fish stocks calls into question the use of regulatory concepts such as Maximal Sustainable Yield (MSY).

Habitat and fisheries restoration of incised stream channels

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Stream channel incision typically results in physical instability and a corresponding loss of habitat features such as pools, riffles, large woody debris and stream-floodplain interaction. Because habitat availability, heterogeneity and stability greatly influence numbers and species of animals in aquatic habitats, stream rehabilitation efforts that enhance stream habitat features, while preventing stream channel erosion and incision, may repair damaged aquatic ecosystems. Planting dormant willow (*Salix* sp.) and addition of stone spurs and weirs were coupled with existing erosion control structures in an effort to increase pool habitat availability and physical heterogeneity in four incised Mississippi streams. Fish collections and physical habitat data were compared with pre-construction information and with data collected concurrently on two control streams and one reference stream. Study sites were warmwater streams draining watersheds ranging from 12 to 205 km^2.

Dormant willow posts were successfully established along stream channels and sand bars where soil conditions were aerobic and where sufficient water was available. Woody cover along the bank of one treatment stream increased from 38% to 66%. Generally, posts contributed only slightly to debris habitat, mostly in streams where woody debris was most scarce. Kudzu (*Pueraria lobata*), an exotic vine, and beavers (*Castor canadensis*) contributed significantly to willow post mortality in all four streams. In one stream competition with Kudzu increased willow post mortality from 40% to 66%. Weir and spur dike construction increased pool habitat in all four treatment streams with greatest increases occurring in streams fitted with stone weirs. Pool habitat comprised 0% to 11% of water area before restoration and 14% to 61% afterwards, while baseflow mean depths ranged from 8 to 17 cm before restoration and 12 to 58 cm following restoration.

Deeper water provided habitats for both larger individual fish and larger species of fishes. Average length of fish increased 40% in one stream. In treatment streams located near rivers or tributaries that provided a source for re-establishment of fish stocks, species richness increased by as much as 74%. In more isolated streams species richness was unchanged. As pool habitat increased, composition of all treatment streams shifted from cyprinid domination to a more uniform mix of cyprinids, centrarchids, catostomids and ictalurids. Catch per effort also improved in the least isolated stream, increasing from 0.70 kg/hr to 8.68 kg/hr, in part, because of shifts in fish communities from small, shallow-water cyprinids to taxa which attain a larger adult size. This study showed that channel stabilization measures which create pools interspersed with riffles can improve biomass and diversity, especially in streams where immigration occurs.

Management of Australia's orange roughy fishery

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Orange roughy, *Hoplostethus atlanticus*, is the focus of one of the world's deepest fisheries, being fished at 700-1200m off New Zealand and southeastern Australia. Orange roughy is exceptionally vulnerable to overfishing due to a combination of life-history and behavioural characteristics that it shares with other exploited deepwater species: extreme longevity (well over 100 years), slow growth, extended age of maturity (25-30 years) and occurrence in aggregations around seamounts. Orange roughy is therefore highly susceptible to a 'mining' operation and a stock can be severely overfished in less than a decade.

Recognizing orange roughy's vulnerability to overfishing, an intensive research programme was instituted within a year of the discovery of the first major aggregations off southeast Australia in 1989. Egg and acoustic surveys were carried out initially to obtain absolute estimates of stock biomass. These initial assessments of resource size indicated that sustainable yield would be <10,000t. Catches peaked in 1990 at ~50,000t, and Total Allowable Catches (TACs) were introduced thereafter to manage the fishdown period and reduce catches to sustainable levels. By 1993 the time series of acoustic surveys was combined with the catch history to produce a relative biomass index. These data were combined with the egg survey results in a stock reduction model.

The goal for the fishdown was to maintain the stock at 30% of its virgin biomass (B_O). By 1994, it was estimated that the stock was at 25-35% B_O. The catch in 1994 was 6600t, approximately 10% above the estimated sustainable yield of 6000t. A schedule of TACs agreed to by industry and management in 1994 for 1995-1998 should ensure that stock biomass equals or exceeds the management goal of 30% B_O with a 50% probability by 2004. Good agreement between results of the several survey methods and models considerably enhanced the confidence of industry, scientists and management in the stock assessment. Following the rapid initial increase in the fishery to a level that was unsustainable over the longer term, the stock assessment process and confidence in it enabled quotas to be reduced within several years to sustainable levels.

Elasmobranch stocks in South Africa – improved utilization or increasing catches?

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Are present elasmobranch stocks in South Africa underexploited or already fully exploited? The fisheries of South Africa are discussed and their impact on elasmobranch stocks evaluated.

South Africa has abundant pelagic and demersal resources, primarily attributable to the highly productive Benguela and Agulhas current systems that dominate the coastline. As a result, fishing is a major industry in South Africa; however, with the reconstruction and development programme underway there is a growing demand to utilize marine resources to their maximum potential. Elasmobranchs are thought to be underexploited and are receiving increasing fisheries attention. Longterm elasmobranch fisheries have never seriously been established apart from the vitamin A boom period between 1940 and 1952. Catches for this period are estimated at 250 000 sharks, roughly 3750 t per annum and consisted mostly of soupfin sharks (*Galeorhinus galeus*). Catches of this species since then have averaged less than 1,000 ton.

Presently ten commercial fisheries operate in Southern African waters. Of these the purse-seine, abalone, crayfish, squid and tuna poling fishery have little or no impact on elasmobranchs. Of the remaining fisheries, the demersal trawl industry reports the largest landings of elasmobranchs, approximately 3,102 t in 1993, skates being the largest component (65%) of the landed elasmobranch catch. Apart from those elasmobranchs landed as a bycatch, a large number are discarded. Sharks are targeted in three ways: the commercial handline, longline and gill net fisheries. The commercial handline and longline fisheries direct their effort at the soupfin shark (*G. galeus*) and hound shark (*Mustelus mustelus*), with a limited catch of pelagic sharks, while gill net fishers target St Joseph sharks (*Callorhincus capensis*). The commercial handline fishery is responsible for the largest reported landings (carcass weight), 524 t, followed by the gill netters, 452 t and longliners with 156 t in 1993. Foreign vessels with permits to longline in South African waters land large numbers of sharks, although few data are available. Overall, the reported landed catches are increasing at about 100 t annually. Fluctuations in catch over the years appear to be a result of market demands rather that changes in stock abundance, and the recent targeting of *G. galeus* and *Mustelus* spp. is as a result of the growing international demand for shark meat.

Problems in evaluating the impact of the various fisheries on elasmobranch stocks include: what percentage of total bycatch is landed?; b) discrepancies in landing reports; c) inaccurate species identification; and d) limited enforcement of regulations. Preemptive measures to manage chondrichthyan stocks include effort limitation, prohibiting finning in S.A waters and the complete protection of the great white shark. Potential for expansion of the chondrichthyan fishery exists, but inadequate knowledge of the biology, stock size and movements make predictions of sustainable fishing impact impossible at present. In order to develop an operational management procedure for the elasmobranch resource in South Africa, projects have been proposed and initiated to investigate each of the different fisheries which land elasmobranchs in S.A. waters.

Squid fisheries of the world: chaos or pattern?

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This paper reviews squid fisheries for loliginids (mainly inshore), ommastrephids (within shelf) and ommastrephids (oceanic). The following differences between these three groups, which may help managers to plan their actions in the long run, were found.

Loliginid and oceanic ommastrephid fisheries are fairly stable and are more amenable to proper organization and

management. Loliginid fisheries are mainly based on spawning concentrations (with some exceptions, notably *Loligo gahi*) and are therefore much more predictable with regard to availability than are oceanic fisheries. Loliginids spawn on the bottom, usually inshore, and they tend to use the same spawning sites every year. Once spawning commences, they remain on the site for a number of days. Ommastrephid oceanic fisheries are based on more dispersed, smaller aggregations comprising of animals of mixed maturity, that usually feed and migrate freely. Their availability may be severely limited at times, fishing success depending largely upon the fishing gear and the skill and knowledge of the fishers. Loliginids are more easily targeted but are much more vulnerable than oceanic ommastrephids. The abundance of both loliginid and oceanic ommastrephid stocks is governed by multi-factor, chaotic responses to environmental and biological variables. Both have well balanced, regional structures on a supra-population level. They migrate and hunt in small but very numerous schools which may aggregate and split according to circumstances.

Demersal-based ommastrephid fisheries, however, rely on a highly unstable resource and therefore their organization and management are more difficult. These ommastrephids form large aggregations, mainly during feeding migrations. They are known to spawn in the deep water but the character of these concentrations is unknown. A highly unbalanced (big differences in numbers of separate populations) supra-population structure as well as strong, well-structured influences of environmental and biological variables upon the stocks (e.g. Gulf Stream), contribute to periodic stock crashes that have led to complete collapse or severe limitation of the fisheries.

Paradoxically, the chaotic and multi-factored influences of external variables upon a complicated species structure result in stability of both stocks and fisheries. On the other hand, a highly structured, dominant influences of the same factors results in unstable, unpredictable stocks and fisheries.

The signal of global interdecadal Regime variation on temperate sardine and anchovy populations

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Extreme variability in the abundance and/or availability of fishery resources, particularly the most massive ones of small pelagic fishes in temperate areas, result in great losses to some countries and jeopardise the goal of sustainable development. Sudden collapses of fisheries populations have occurred recurrently in the past, and although formerly blamed on overfishing, it is becoming evident that a natural, low frequency environmental component has a major influence on these phenomena.

The synchrony in these variations in widely separated marine coastal areas of major oceans strongly suggests links to global climate forcing factors, although seemingly operating locally through various environmental processes. Sardine population abundance correlates positively (and anchovy abundance inversely) with global air surface temperature anomalies, but it seems evident that temperature is not the only governing factor. Sardine and anchovy populations off California, Japan, Chile-Peru (the Humboldt Current) and the Benguela Current have shifted from high to low abundance levels of each of the two species at the same time, the Benguela Current being out of phase with the others. This variation has been called the Regime Problem, and has been particularly addressed by a group of scientists now participating in SCOR Working Group 98.

Regime shifts have occurred at various times during the present century, leading to high and low sardine population abundance, with inversely high or low periods of anchovy population abundance. Some environmental indices show similar patterns of change in some of the coastal areas, the Regime signal being most evident in temperate and cold ecosystems. Paleoecological indices in some of the areas show that Regime variation has take place during at least the last 2,000 years, shifts occurring some 60 years on average.

The last high abundance period for sardine populations in the Humboldt Current and Japan occurred between the mid-1970s and mid-1980s. Since about 1985 there has been a new Regime shift and anchovy populations in these areas are growing while sardines are becoming less abundant. The California Current sardine population, however, seems to be still growing, while in the past this population has been in phase with others in the Pacific.

Regime changes, of far greater magnitude than interannual variation, present fundamentally different problems than usually considered by fisheries science; existing approaches are inadequate for the management of at least sardine and anchovy fisheries and associated economic development. It seems evident that these variations affect not only small pelagic fish populations, but the whole ecosystem.

In the light of this evidence, major revisions of the *sustainable yield* and *carrying capacity* concepts are badly needed.

Development and application of a juvenile index of abundance for anadromous river herring

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The stocks of anadromous river herring (the alewife, *Alosa pseudoharengus*, and the blueback herring, *A. aestivalis*) and their fisheries have steadily declined along the east coast of the United States over the last two decades. To better understand spawning success and recruitment, a juvenile (young-of-the-year) index of abundance was developed for anadromous river herring in the Mattaponi and Pamunkey Rivers, Virginia. The objectives were to: 1) develop juvenile *Alosa* indices that are sensitive to varying degrees of reproductive success; 2) determine if the two species-specific *Alosa* indices exhibited a common pattern of change in a river system; 3) determine if species-specific *Alosa* index changes are common to both river systems; and 4) assess the utility of *Alosa* juvenile indices in stock-recruitment models.

Experimental sampling in 1977 and 1978 indicated that a bow-mounted pushnet used at night had the greatest fishing power relative to the trawls tested. The maximal catch per unit of effort (cpue) for a series of weekly sampling in the freshwater nursery grounds was chosen as the estimate of relative abundance. This index occurs relatively early in the natal year and thus reduces the problems of emigration and increased gear avoidance that occur with increased growth. Also, the index is attained before the saline encroachment upriver that concentrates the fishes into a confined area; the

encroachment varies annually and results in high but spurious index values. Finally, it is much less costly to establish a maximal cpue than to sample throughout the full season of juvenile river herring availability.

Sampling commenced in 1979 and continues to the present. The two species indices were strongly correlated within the Mattaponi and Pamunkey Rivers (r = 0.85 and 0.89). The blueback herring and alewife indices between rivers were also reasonably strong (r = 0.83 and 0.69). The maximal cpue was strongly correlated with the cpue of all weekly samples (> 0.90 for both species), but the relative variation (cv) for the maximal cpue was lower in all comparisons. The maximal cpue values for alewife in the Pamunkey and Mattaponi Rivers were strongly correlated with the recruitment of their respective year classes to the York River pound net fishery (0.93 and 0.99). The correlation of the index to recruitment for blueback herring was reasonably strong for the Pamunkey River (r = 0.75), but weak for the Mattaponi River (r = 0.42). When the data are combined, the recruitment correlation for the Pamunkey and Mattaponi Rivers is reasonably strong (0.78 and 0.87). When the data are combined for species and rivers, as in commercial landings reports, the correlation between the maximal cpue and year class recruitment is strong (r = 0.86). The relationship of the maximal cpue to year-class recruitment indicates that the index is determined after year class strength is established. The utility of the maximal cpue in spawner-recruit models can not be evaluated until values are obtained for a wider spectrum of stock densities.

Fluctuations in population parameters of the spiny lobster *Panulirus argus* in a fishery based on artificial shelters

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In the past few years, there has been an increasing interest in introducing and evaluating the use of artificial shelters in spiny lobster fisheries. In Bahía de la Ascensión, a large (ca. 740 km^2 in area), shallow (<6m in depth) bay on the Mexican Caribbean coast, a fishery for subadult *Panulirus argus* has been using artificial shelters, called "casitas", for several decades. A large portion of the bay is covered with seagrass and algal beds, reported to be prime habitat for postlarvae and juvenile survival. A large tagging programme to estimate several population parameters was conducted from 1985 to 1987. Here are presented previously unpublished results on lobster biomass, fishing mortality, and immigration and emigration rates during the fishing seasons 16 July 1985-15 March 1986 (year 1), when the catch was average, and 16 July 1986-15 March 1987 (year 2), when the catch was above average, based both on tagging results and cpue data. During year 2, the initial, total and average biomass of lobsters, as well as the emigration and immigration rates, were higher, but the fishing mortality was lower, than during year 1. The immigration and emigration rates suggest a high turnover rate of juveniles in the bay. These results, together with the fast growth rates of juveniles in the bay, could indicate that the biomass of lobsters in a given fishing season may be related to the magnitude of postlarval influx into the bay two years before. A programme to monitor postlarval influx into the bay, by means of artificial collectors, was implemented in 1987. Preliminary results show large annual fluctuations in the postlarval influx index, with indications of a positive relationship with the lobster abundance index (catch of the first month of the fishing season) two years later. Because this relationship is not so clear in another, different segment of the coast, it is proposed that in Bahía de la Ascensión, both the vast areas with suitable habitats for postlarval settlement and young juvenile survival and the use of casitas that provide critical shelter for larger juveniles, are the main factors sustaining the success of this fishery.

Effect of variability in some population parameters of *Rastrineobola argentea* (Pellegrin 1904) on the yield and biomass in Lake Victoria

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There has been great variability in the population parameters of *Rastrineobola argentea* (Pellegrin 1904) determined by different workers in Lake Victoria. Estimates of L_{CO} are 52 mm SL, 64.5 mm SL and 67.8 mm TL, while K estimates are 1.14 yr^{-1}, 0.92 yr^{-1} and 0.94 yr^{-1} in Tanzania, Kenya and Uganda respectively. These differences led to different estimates of mortality rates (Kenya: M=0.88 yr^{-1}, F=1.98 yr^{-1} and Z=2.86 yr^{-1}. Uganda: M=2.37 yr^{-1}, F=1.22 yr^{-1} and Z=3.59 yr -1). It is necessary to analyse the effects of these differing estimates on other population parameters such as yield per recruit and average biomass per recruit which are used to formulate management decisions. An attempt has been made to compare graphically the growth patterns associated with different areas and their effect on estimates of yield/biomass. Response to natural mortality was found to be critical in determining the maximum permissible fishing mortality coefficient at various rates of growth. An objective model is still required for testing the validity of the growth parameters using a similar response analysis to the one outlined here.

The effect of re-opening Bramble Reef to bottom fishing on fishing behaviour and catch rates of commercial and recreational line fishers

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Bramble Reef is the closest midshelf reef to the mainland in the Central Section of the Great Barrier Reef Marine Park. It was closed to bottom fishing on 1 January 1992 in response to concern within the fishing community that the reef fish stocks had declined to an unacceptable level. It was re-opened to fishing on 1 July 1995.

The re-opening of Bramble Reef provided an opportunity to study the effects of reef closure and re-opening on catch

rates, fish stocks and the behaviour of fishers. It also presented the ideal opportunity to develop a study to test, around a focussed issue, a number of catch and effort sampling methodologies.

The study involved collecting catch and effort information from one month prior, and for two months after, the opening of Bramble Reef using 6 methodologies: i) traditional, and ii) "bus route" style boat ramp surveys; iii) fishing diaries maintained by recreational anglers; iv) roving creel surveys; and catch surveys conducted by, v) commercial fishers, and vi) club boat anglers.

Fishing effort at Bramble Reef on opening day was high, with more recreational (64) than commercial (26-40) fishers present. The recreational anglers were in 19 boats, whilst the commercial fishers were based on 14 primary vessels, with 26 dories. Effort by both recreational and commercial fishers dropped sharply after opening day. Over the remaining eight days there were on average two recreational boats and five commercial primary vessels (15 dories) on Bramble Reef on each day. Fishing at Bramble and nearby reefs was negligible by either fishing sector between late July and September because of persistent strong winds.

Recreational catch rates exhibited no clear trends over the duration of the study. Catch rates were highly variable, and both good and poor catches were reported on opening day and throughout July. The same was true of an adjacent reef, which has always been open to fishing. Catch rates from research surveys on a commercial fishing vessel declined rapidly on Bramble Reef after the re-opening. Catch rates immediately prior to July 1 were approximately twice as great on Bramble Reef as on control reefs, but within two weeks of re-opening catch rates at Bramble Reef had dropped to very similar levels to catch rates on control reefs. Data from the commercial fleet indicate that other commercial vessels experienced rapid drops in catch rates on Bramble Reef in the first few days it was open to fishing. Catch rates from Bramble Reef are now similar to catch rates on other reefs.

One of the major features of this programme was the inter-departmental and community cooperation that it involved. Agencies involved in the study included the CRC Reef Research Centre, James Cook University, Great Barrier Reef Marine Park Authority, Department of Primary Industries and substantial staff commitments in the field by Queensland Department of Environment and Heritage Marine Parks, and Queensland Boating and Fisheries Patrol. The research was substantially assisted by the cooperation of the recreational and commercial fishing sectors.

The fall and rise of Pacific salmon in North America

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Most of the Pacific salmon of the genus *Oncorhynchus* have a two stage life history, in fresh and in salt water, and they display strong racial segregation. The population structure of salmon, both at the macro and molecular level, is better known than in most other families of fishes. The fall and rise of Pacific salmon can be interpreted on this basis. The emerging principles also have applications for some exploited species of marine fishes like herring.

Pacific salmon occupies the coastal range from 40 to 70°N, but its abundance has been drastically reduced in California, Oregon, and Washington. In a few places, some races are on the verge of becoming extinct. In contrast, all species of salmon in Alaska are enjoying the highest recorded abundance level, with catch records covering more than one hundred years of fishing. A decline can be attributed to one or more of the four H's; hydro, habitat, harvest, and hatcheries.

As the demand for cheap electric power increased in the three southern states listed above, incentives to build hydroelectric dams grew in proportion. This resulted in higher dams with larger impoundments behind them than seen during the intial period of dam building. In the end, upriver races were brought almost to extinction or complete anihilation. The Columbia – Snake River systems present the most grotesque example.

Habitat destruction through dam building, logging, highway and logging projects together with industrial pollution have reduced many races.

Historically, harvest through fishing operations has decimated salmon races; but the economics of harvesting brings about a stop in operations when the abundance falls below a certain threshold level.

Hatcheries have for many decades been resorted to for compensation of lost habitat. Many results from earlier operations represent a dismal story of failures and frustrations. Today, with an understanding of the genetic basis of salmon races, hatchery enhancements show progress and at times with impressive results.

The present high abundance of wild salmon in Alaska is due to three factors. The first one is the low population pressure, which has left most streams and lakes in their pristine state. Secondly, a management strategy which not only has preserved numerically strong escapements, but which also considers the genetic structure of spawners. Finally, the warming trend of the climate today brings about higher water temperatures and shorter icecover of nursery lakes. Warm and cold climatic periods seem to follow a fifty year cycle.

Protozoan parasites of freshwater food fishes of Punjab India, with special refrence to gregarines, microsporidians and amoebae

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Fishes suffer from various types of diseases caused by protozoan parasites. Pathogonic protozoans are generally thought to be host-specific. Many species exhibit some degree of tissue specificity but in some cases, protozoans do infect different tissues in different hosts. Many parasites, both of freshwater and sea fishes which are well known in natural ecosystems and are looked upon as harmless or moderately pathogenic, may convert into causative agents of serious epizootic outbreaks. This is specially so for protozoans.

Pathogenic parasites, while nourishing on fishes, cause mortality, inferior quality of fish product and systematic poisoning of the fish with their metabolic products. All these factors clearly show the importance of parasitological assessment in planning rational fishery management and improving the quality and productivity of the fish economy. The government is unaware of this infection of

protozoans which is a great threat to fishing industry. It is imperative for fish farming or fish as an amenity that there is a knowledge of the occurrence of parasites that adversely affect fishes. Thorough systematic study of taxonomy and histopathology would enable the immense damage they cause to be controlled.

Fishes were collected from fishery ponds, rivers and culture units of Punjab. The live fishes were brought to the laboratory and examined for parasites. Infected tissues were fixed in aqueous Bouin's, alcoholic Bouin's, Schaudinn's and Carnoy's fixatives. Sections were cut at 7 um for histology and stained with Eosin and Heidenhain's iron haematoxylin. Photomicrographs were taken with a Pentax camera.

In this study twenty-seven species of fishes belonging to eighteen genera were examined for Protozoa, twenty six species of protozoan parasites belonging to twenty-three genera were identified and described. Seventeen species were new to science.

The gregarine, *Monoductus mastacembeli* n. sp., was recorded from the intestine of host fish *Mastacembelus armatus* (Lacepede). It was observed that in the early stages of development, this parasite damaged the epithelial cells where they grow. Cephalins, sporodins, cysts and spores with eight sporozoites were noticed. Invertebrates play a major role as mode of transmission from parasites to fish. The parasite passes to the fish with infested arthropods on which the fish feeds. Gregarines have been recorded for the first time in India from fishes.

The microsporidian *Pleistophora hoffmani* n.sp. was observed from a section of the middle region of the intestine of host fish *Catla catla* (Hamilton); out of 30 fish examined 50% were infected with microsporidian. Various stages of cycle of development were noticed and compared with all previously known species. Parasites caused atrophy, degeneration and vacuolisation of associated cytoplasm. The damage to muscular layers and submucosa was extensive. The infected fish were dwarfs with stunted growth. They were sluggish in movement and died early when brought to the laboratory aquarium.

Entamoeba rohitae n.sp. was observed from intestinal smear and histological sections of gills of *Labeo rohita* (Hamilton). Trophozoite, precystic and uninucleated cysts were seen. The new species is compared with all the other known species. The gill of the host fish exhibited prominent epithelial hyperplasia. Amoebae were observed to have a damaging effect on the fish population.

Demersal fish community diversity off New Zealand is related to depth, latitude and regional surface phytoplankton

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Recent studies of basin–scale patterns of diversity of benthic macrofauna reported strong latitudinal gradients of diversity in the deep North Atlantic, in contrast to regionally variable patterns in the Southern Hemisphere. Here data from fisheries research trawl surveys are used to examine spatial patterns of species richness, Shannon–Wiener diversity index and evenness of demersal fish communities in relation to latitude and depth from 80 to 898 m off south east New Zealand. Species richness was found to decrease latitudinally within regions in the poleward direction and increase with depth. Areas of high species richness were concentrated along the margins of the Chatham Rise and were associated with current intensification in regions of enhanced surface phytoplankton pigment concentration. Species richness was highest between the 500 and 1,000 m contours on the Chatham Rise, where enhanced surface phytoplankton pigment is associated with a major oceanographic feature, the sub–tropical convergence. A predominance of species-rich locations was found on the more steeply shelving northern margin of the Chatham Rise. The regional latitudinal effect on diversity appears to be related to regional production and to be influenced by mesoscale oceanographic features constrained by the bathymetry.

Biomass estimation of New Zealand snapper stocks by Petersen mark recapture using cryptic (coded wire) tags

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The east coast North Island snapper stock (SNA 1) is New Zealand's largest snapper resource. An age-structured population model was developed for this stock, incorporating biomass, catch and growth information. By 1993 it became paramount to obtain an updated estimate of SNA 1 absolute biomass for input to the model so as to maintain model accuracy and precision. A Petersen mark-recapture experiment was developed to provide this biomass estimate. Internal coded wire tags were used as the marking method. A simulation approach was used to determine appropriate tag and recapture sample sizes according to desired precision. A two-phase stratified design was developed to optimise the geographical distribution tags in relation to snapper abundance and length structure. Sources of bias and associated variance in the input parameters of the Petersen equation were investigated experimentally, these being: tag loss; initial release mortality; length composition of examined catch; movement; fish growth; and tag detection success. Release and recapture data corrected for the main sources of bias were used to calculate separate Petersen estimates of snapper numbers within particular length strata. Stratification of the data with respect to fish length, sub-stock areas (east Northland, Hauraki Gulf, Bay of Plenty) and season was considered in relation to variation in recapture probabilities and *a priori* demographic requirements. Estimated mean weights of snapper in respective strata were used to calculate biomass in each sub-stock area from the Petersen estimates. A simulation approach was used to calculate precision of the biomass estimates according to levels of observation and analytical error. Stock size was estimated to be 52,819t with precision within the bounds targeted for in the experimental design. This programme represents only the second documented application of coded wire tag technology for the purpose of assessing absolute stock biomass of a commercial marine species.

Applied fisheries oceanography: guiding fisheries management by relating environmental and recruitment variability to forecast year-class strength of Alaska Walleye Pollock

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NOAA's Fisheries-Oceanography Coordinated Investigations (FOCI) provides guidance through the National Marine Fisheries Service to the North Pacific Fishery Management Council for the management of walleye pollock in the Gulf of Alaska. The National Marine Fisheries Service's quantitative estimates of recruitment are obtained from models of stock assessment and stock projection based on classic methods of survey and estimation. Using scientific methods of fisheries oceanography, FOCI augments the information available for assessment and projection. To generate its information FOCI convenes disciplinary specialists in marine biology, physical and fisheries oceanography, meteorology, and statistics to assemble and analyse relevant time series of biological and physical parameters with respect to recruitment of fish. With a conceptual model of the recruitment process as a basis, statistical methods (nonlinear regression, transfer function modeling, nonlinear response surface analysis, and tree-modeling regression) and empirical models produce results from which a composite recruitment forecast is made. The environmental database consists of over 30 years of information, and analyses have identified factors that affect ocean stratification and circulation during spring and summer of the fish's birth year as being important to recruitment. Actual recruitments during the past three years have corroborated FOCI's predictions.

Effects of fishing gear on benthic habitat

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Foreign pair-trawling for fish off the Australian North-west Shelf from the early 1970s to the late 1980s led to concerns about the effect of fish trawling on the benthic habitat and its fauna of sponges, alcyonarians, gorgonians etc. CSIRO research indicated that this habitat damage may also have affected the species composition of demersal finfish by changing the proportions of habitat types which favour different fish species.

While the access of the foreign fleet to the NW Shelf fishery was progressively reduced and then terminated altogether during the late 1980s, the subsequent increase in demersal stern trawling by the Western Australian domestic fleet raised the question of whether stern trawling as operated from these boats is also damaging to the habitat in the same way as pair trawling. An experimental investigation was therefore instigated of the level of destruction of benthic habitat by a various fishing methods including stern trawling.

The level of habitat destruction was determined by repeatedly fishing an area and monitoring the abundance of benthos using underwater video prior to and throughout the repeated fishing process. The design involved using two replicates (fishing blocks) of each of four fishing treatments, consisting of standard demersal trawl; semi-pelagic trawl; fish trap; and unfished control.

The fishing blocks were quantitatively surveyed with a video camera before and after each treatment to estimate the density of various size classes of benthic fauna. It was decided to count only the benthos higher than 20 cm as smaller ones were sometimes unclear on the videotape. The standard commercial trawl was estimated to destroy 15% of the benthos >20 cm tall in a single pass. Extrapolation of this destruction rate to the whole of the fished area and using the total commercial trawling effort, resulted in an estimated removal rate of the benthos in the fishery of 3% per year in 1993.

The semi-pelagic trawl and fish traps inflicted no measurable habitat damage but the semi-pelagic net took low catches.

Fluctuations in the fisheries of Kenya's Rift Valley lakes: causes and prospects for the future

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Lakes Turkana, Baringo and Naivasha are lakes in the eastern arm of the Great Rift Valley that provide important commercial fisheries and to a small extent provide recreation. The fishery of Lake Turkana is based on 12 main species of fish out of a total of 48 species. Tilapias, *Hydrocinus, Lates* spp., *Citharinus, Distichodus* and *Labeo* are the most important. In Lake Baringo three species (*Oreochromis niloticus, Clarias gariepinus* and *Protopterus aethiopicus*) are the more important out of the seven species present in the lake. Lake Naivasha hosts a total of five species of which *Oreochromis leucostictus, Tilapia zillii* and *Micropterus salmoides* are of commercial importance.

The three fisheries support an estimated 10,000 fishers plus people engaged in fish industry related services. Yet these fisheries are subject to wide fluctuations in fish landings. An analysis of the fisheries is made in this paper to identify factors that have influenced their fluctuations over the years and to elucidate reasons for their persistence.

Habitat variability has been identified as one of the most important factors influencing the fisheries of the three lakes. Lake level fluctuations are shown to be closely followed by similar fluctuations in fish catches. The observed fluctuations in lake levels are as a result of climatic factors combined with human activities which include damming of rivers and extraction of water for irrigation.

Variability in submerged vegetation cover has also been important in the three lakes. Changes in vegetation cover as well as lake level fluctuations are shown to impact more on the fish populations through loss of breeding grounds than through food availability. As the lake water recedes, breeding grounds of littoral zone substrate spawners are lost.

Other anthropogenic influences on the fishery of Lake Naivasha take the form of fishing pressure and species introductions, while in Lake Baringo, catchment degradation, leading to excessive silt loading in the lake, has played a more important role.

The persistence of these fisheries in the face of besetting environmental and anthropogenic factors is attributable, for the greater part, to the resilience of the tilapias that constitute the most important catch in each of the three Rift Valley lakes. Tilapias, particularly of the genus *Oreochromis*, which are mouth brooders have continued to dominate all the three fisheries because of their ability to reproduce even with receding water levels. In addition, Lakes Turkana and Baringo tilapias contribute indirectly to the fishery by being forage fish for the predatory species. The ability of fish to utilize detritus as a food source (as seen in the tilapias of the three lakes, and catfish and *Labeo* of Turkana and Baringo) also dampens out effects of food limitation in aquatic ecosystems.

It is suggested that an integrated approach to catchment management is necessary for the achievement of maximum sustainable fisheries in the Rift Valley lakes.

The robalo fishery in Mexico: management, enhancement and aquaculture

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The purpose of this study is to describe the current state of the robalo fishery of Mexico and to propose management and aquaculture policies.

Coastal fisheries of Mexico developed in the early 1950s. An example of these fisheries is the "robalo" (snook) fishery which developed on both coasts of Mexico, the Gulf of Mexico and the Caribbean Sea in the Atlantic and the Pacific coast of Mexico.

Twelve species of the genus *Centropomus* are distributed in Mexican waters. *Centropomus poeyi* "robalo prieto" and *C. undecimalis* "robalo blanco" for the Atlantic, and *C. nigrescens* and *C. robalito* for the Pacific, are the species that mainly support the Mexican fishery. According to F.A.O. statistics the robalo production of Mexico reached about 4,000 mt in 1971. Considerable increase occurred in 1982, with total production of about 7,500 mt, but production of this fishery decreased from 6,000 mt in 1983 to 2,750 mt in 1991.

C. undecimalis is one of the most studied species in the Atlantic. Larval and juvenile stages are well known, and physiology, reproduction and some parameters of the population dynamics have been studied. However, a stock assessment analysis has not been undertaken. Catch distribution and seasonality, as well as productivity of each species of the fishery are related to environmental factors such as sea surface temperature and salinity in different areas. In order to establish a national research programme in Mexico for management purposes, three geographical areas for research are proposed: A) The Gulf of Mexico and Caribbean area, which involves primarily *Centropomus poeyi* and *C. undecimalis;* B) The central Pacific area (from Nayarit to Chiapas) which involves primarily *C. medius, C. nigrescens* and *C. robalito;* C) The Northwest area which includes the Gulf of California and the west coast of the Baja California peninsula, involves primarily *C. medius* and *C. nigrescens*.

Due to the fact that a drastic decline in production of the Mexican fishery has occurred and demand of the national market has not been satisfied, aquaculture and enhancement projects are proposed. Technologies for culturing these species in Mexico are not well developed. Aquaculture experiences to grow this fish in Mexico are limited, primarily in the states of Tabasco and Campeche in the Gulf of Mexico. However, experiences obtained in Florida (USA) and Brazil, as well as those of the Indopacific countries for the Asiatic snook can be useful in developing appropriate technologies in Mexico.

Bycatch in the Gulf of Mexico shrimp fishery

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Shrimp fishery bycatch in the Gulf of Mexico and the U.S. southeastern Atlantic shrimp fishery has been estimated at around ten billion fish per year, with most of the catch composed of groundfish such as croaker, seatrout, porgies and spot. The principal gear used in this fishery is the ot trawl, a relatively non-selective bottom trawl tha incidentally catches a variety of fish and invertebrate species.

As one of the largest and most valuable U.S. fisheries, the impact on the shrimp industry could be severe if effective solutions to the bycatch problem are not found. Additionally, major long-term harvest reductions could be imposed on other important commercial and recreational fisheries targeting finfish species affected by trawler bycatch (e.g. red snapper). While these actions would be required to protect and in some cases rebuild affected fish populations, their implementation would not be without economic and social disruptions to those fisheries.

The project goals and objectives for this ongoing research are to: 1) collect bycatch characterization data from commercial shrimp vessels operating in the U.S. Gulf of Mexico; and 2) create a credible and usable shrimp bycatch characterization database for the use of all interested parties.

Over one hundred bycatch research trips have been completed during the period from April 1992 through August 1994. A total of 2,745 tows were sampled. Six hundred and sixty two of the tows were along the U.S. e coast, while the other 2,083 tows were in the Gulf of Mexico. A total of 2,603 sea days were used to collect the data. Three hundred and sixty one of the sea days were along the U.S. east coast, while the other 2,242 sea days were in the Gulf of Mexico.

Overall (all areas and seasons combined) the majority of the catch (biomass and number) found in a shrimp trawl was composed of fish and non-penaeid crustaceans. Atlantic croaker and longspine porgy were the two most abundant species by weight and number. Atlantic croaker made up 25% of the total weight and 21% of the total number. Longspine porgy made up 13% of the total weight and 16% of the total number.

In Florida, pink shrimp was the dominant species by weight and number. In Alabama / Mississippi, Atlantic croaker was the most abundant species by weight during all seasons and depths. In Louisiana and Texas, Atlantic croaker was the dominant in the nearshore area during the summer, while longspine porgy was the dominant in the offshore area during both summer and fall, and in the nearshore area during the fall.

The greatest catch of red snapper by weight was in the offshore area of Louisiana during summer and the offshore

area of Texas during the fall period. The largest-sized snapper were found in Louisiana in the winter (174.0 mm), while the smallest-sized snapper were found in Alabama / Mississippi during the same period. No red snapper were found in the trawl samples in Florida.

Squid recruitment in the genus *Illex*

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Squid are among the short-lived species that are replacing traditional fisheries as they decline. Unlike many alternate species, squid often have a higher value in the global market than the traditional species. Larger, more valuable catches potentially possible with squid and other cephalopods because they grow rapidly and have higher production to biomass ratios. The downside is that most cephalopods are annual species with no young of the year as reserves when a year class has been overfished. Thus, knowledge of stock structure and highly variable recruitment dynamics will be even more crucial to protect cephalopods as they move from being bycatch to directed fisheries.

The IOC/FAO's International Recruitment Programme (IREP) began encouraging studies of this problem at its 1981 meeting in Halifax, and in 1987 the FAO commissioned the Cephalopod International Advisory Council (CIAC) to produce a volume on squid recruitment. Authors gathered at the ICES Shellfish Life Histories Symposium in 1990 and began the task of organizing information on three commercial species in the same genus: *Illex coindetii, I. illecebrosus* and *I. argentinus*. The resultant volume is now in press and as editors, it is believed that its perspectives will be a useful addition to this Congress. The concept was to focus on a genus of closely related commercial squid that is widely distributed in the eastern and western boundary currents of both the North and South Atlantic and then to look for generalizations. Twenty-five authors from a dozen countries assembled data from unpublished or grey literature sources and then provided synthetic reviews. The volume demonstrates advances over the last decade that provide the necessary basis for a comprehensive understanding of recruitment in cephalopods, making them a prime target for advancing knowledge of marine recruitment processes in general.

Hard structure increment analysis for age and growth, combined with stomach contents, show that these squid are tremendously flexible in their seasonality and feeding strategies, allowing them to occupy a wide range of habitats. *I. coindetii* occupies marginal habitats in the Mediterranean, Caribbean and along the Atlantic eastern margin from 55°N to 20°S, but never reaches densities adequate to sustain major fisheries. On the more productive western boundary, *I. illecebrosus* collapsed after a few seasons of intense, widely-distributed fishing, while *I. argentinus* remained stable over a much longer period, despite becoming the world's largest squid fishery. Unlike loliginid squids, often fished on spawning grounds, ommastrephids are typically fished on feeding grounds. In contrast to *I. illecebrosus*, the *I. argentinus* fishery appears to have been stabilized by a complex mix of stocks which breed widely dispersed in space and time. As these stocks move rapidly through feeding areas to breeding areas, fishing with selective gears in feeding areas is probably self-limiting, allowing adequate escapement, provided squid are not pursued into breeding areas. This may now be affecting these stocks. Total recruitment is limited both by production (e.g. *I. coindetii*) and by stability of the interactions between adult migrations and ocean physics, which strongly influence early growth and survival (e.g. *I. illecebrosus*).

Regional abundance variation in Washington's salmonid fisheries

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Available information was studied to identify major environmental and management factors that have differentially affected the abundance of Washington's wild anadromous stocks of salmon and trout in the state's three regional salmonid fisheries, which occur in the Columbia River, Puget Sound, and along the Pacific Ocean coast. Subsequent findings of the Washington study help to illustrate why some fisheries survive while others collapse. Regional environmental factors have affected the success of migration, spawning, growth and survival of wild fish. Factors include water-use and land-use practices, human-influenced biological interactions and natural phenomena. Regional management factors have affected abundance and genetic makeup of wild fish that return to spawn in rivers and streams. Factors include fishery agency harvest policies and hatchery practices. Columbia River fisheries have been affected most severely. Water-use practices, primarily hydroelectric dams, irrigation diversions and human-influenced biological interactions, are the primary factors contributing to stream blockage, degradation of freshwater and estuarine habitat, increased mortality and markedly reduced run size. Fewer than 25 percent of these salmonids are wild fish. Puget Sound fisheries are in better condition, and more than 50 percent of these salmonids are wild fish. However, past water-use and land-use practices and a growing and sprawling human population have eliminated productive lower-river and estuarine habitat. Washington's coastal fisheries have been least affected, although important freshwater and estuarine habitat has been lost. Forest and agricultural practices and localized urban-industrial impacts are the primary adverse factors along the coast. However, more than 75 percent of coastal salmonids are wild fish.

Recent fishery statistics, including in-river run size, compliance with established spawning escapement goals, and stock composition, confirm these effects. Many, but not all, of Washington's salmonid stocks have a dominant hatchery component. Sockeye (*Oncorhynchus nerka*) and pink (*O. gorbuscha*) salmon are almost exclusively wild fish. Stocks of chum salmon (*O. keta*) and sea-run cutthroat trout (*O. clarki*) have more wild than hatchery fish, while stocks of coho (*O. kisutch*) and chinook (*O. tshawytscha*) salmon and steelhead trout (*O. mykiss*) are mostly hatchery fish. Reallocation in catch from ocean mixed-stock preterminal fisheries to coastal and Puget Sound terminal fisheries has helped protect declining wild stocks, even though Canadian interception of Washington chinook and coho salmon has increased the total harvest rates above desired levels for these species. However, Washington's interception of Canadian sockeye and pink salmon has partially compensated for these numerical losses. Pink salmon,

whose juveniles spend less than 8 days in fresh water, and sockeye salmon, almost exclusively from Canada, account for almost 60 percent of Washington's commercial salmon harvest. The majority of this catch, therefore, is composed of wild fish little influenced by the state's freshwater environment. Thus the harvest of hatchery-produced fish and continued interception of Canadian stocks have enabled the statewide commercial salmon harvest to remain near historical levels of about 22 million kg annually, despite the decline in some regional fisheries.

The distribution of larval scombrids in the Aegean Sea (Greece)

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The seasonal and spatial distribution of larval scombrids were studied for the first time in the Aegean Sea (Greece) to determine onshore-offshore migration patterns, spawning seasons and relative abundance.

Eight cruises were performed throughout the spawning period of the scombrids (June to September) between 1992 and 1994. A grid of 106 stations was designed over the whole study area and parts of this were sampled on each cruise. Scombrid larvae were sampled by oblique and horizontal hauls from 70m depth to surface with a BONGO net, fitted with 500μ and 300μ mesh size gauzes. Additional data on larval occurrence were compiled from surface-tows, using a midwater METHOT TRAWL sampler, fitted with a 3mm size net. Because the survey catches of scombrid larvae were too small to support standardization, their absolute number taxon possible, enumerated and measured to the nearest 0.1mm standard length.

A total of 373 larvae, belonging to four species of scombrids (*Thunnus alalunga, Euthynus alleteratus, Auxis rochei* and *Xiphias gladius*) was caught. *A.rochei* contained the highest number of specimens (354) and contributed approximately 95% of all scombrid larvae caught. *E.alleteratus* was represented by 16 specimens, whilst only two specimens belonged to *X.gladius* and one to *T.alalunga*. Both swordfish larvae were collected by Methot trawl. No *Thunnus thynnus* or *Sarda sarda* larvae were caught in the Aegean Sea. The fact that *T.thynnus* has the larvae with the greatest dependence on high temperature among scombrids, coupled with the high abundance of this species in the Aegean Sea, suggest that the relatively low water temperature in this area does not favour its reproduction. The data available are inadequate for interpreting the distribution of *A.rochei,* while only indications exist for *E.alleteratus*. Collections of larvae of both species were most abundant close to the shore of continental Greece and on the leeward side of the Sporades Isles. The high concentration of larvae near shores may be related to habitat characteristics that promote higher larval survival than the open sea water. No evidence was found for migratory behaviour. The physical structure of the water column, particularly temperature and salinity, seems to alter the spatial and temporal distribution patterns of larvae on the time and space scales and also on the seasonal scale. Seasonal patterns of spawning were likely to be dependent upon availability of appropriate thermal habitat, with spatial ones upon salinity. The Sporades Isles area, in which were caught 91% of larvae, was characterized by relatively higher salinity concentration. Larvae of *A.rochei* were most abundant between the middle of August and early September, the warmest period of Greek seas. *E.alleteratus* larvae were found over a wider range of temperature, from mid-June to early September, than the later species. The larvae of *A.rochei* were generally small, ranging between 2.5 and 10mm with the bulk from 4.0 to 6.5mm. Size-frequency data combined with the distributional information suggest that spawning or at least hatching of *A.rochei* eggs was concentrated around the Sporades Isles area and the adjacent continental shelf.

Protecting vulnerable stocks in multi-species prawn fisheries

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Historically, penaeid prawn stocks have been regarded as highly resilient to overfishing. However, with continuous advances in fishing technology, this situation may not continue. The purpose of this paper is to prov information on the unusual collapse and rebuilding of individual penaeid stocks within the Western Australian multi-species trawl fisheries. These case studies are presented to assist in developing population models for penaeids and techniques to identify prawn stocks which may be at risk.

A series of studies on the Western Australia (W.A.) prawn fisheries have shown that the Exmouth Gulf fishery for the white prawn (*P. merguiensis*) collapsed in the 1960s and has not recovered. Similarly, the tiger prawn stocks (*P. esculentus*) in the Shark Bay and Exmouth Gulf multi-species fisheries suffered recruitment overfishing during the early 1980s, flowing from an escalation in "effective" fishing effort. Significant reductions in effort directed at tiger prawns, firstly in Exmouth Gulf, then later in Shark Bay have resulted in increased breeding stock levels and subsequent improvements in catches.

Predictive Spawning Stock-Recruitment (SRR) and recruitment to spawning stock relationships have been developed and are presented for the two W.A. tiger prawn stocks. Examination of similar data for western king pra (*P.latisulcatus*) stocks in Shark Bay, fails to demonstrate any clear SRR, but does indicate a within-season environmentally-driven catchability relationship.

Study of the array of species taken in the W.A. and some other Australian prawn fisheries has suggested that a number of factors including behavioural characteristics and the level of aggregation at spawning times which affect catchability, are common to a stock that has declined under heavy fishing. Data from field experiments in Shark Bay and Exmouth Gulf have confirmed a previous hypothesis that differences in behaviour between the major W.A. species can account for much of the differential impact of fishing exhibited in the historical data base.

As a result of the decline in the tiger prawn stocks, radical controls on fishing effort were introduced in the mid 1980s, and over time these have evolved into a system of seasonal and spatial closures. These closures, together with fleet-reducing buy-back schemes have brought fleet capacity back into balance with the reproductive capacity of these stocks. In Exmouth Gulf these management controls now result in a constant escapement of recruits to the tiger prawn spawning stock, while diverting excess fishing effort onto the more resilient king prawn stock.

These fisheries, for which detailed catch and effort data have been recorded since their inception in the early 1960s, are described to assist in the development of precautionary management strategies for other penaeid stocks subject to increasing fishing pressure.

Mortality estimation of trawl-caught and discarded Pacific halibut (*Hippoglossus stenolepis*)

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Retention of trawl-caught Pacific halibut (*Hippoglossus stenolepis*) is prohibited in U.S. coastal waters. Therefore, trawl-caught halibut are discarded at sea. Estimates of trawl-bycatch mortality for this species have reached 6,400t during certain years in the Gulf of Alaska. The objective of this research is to identify fishing and handling practices that reduce mortality of discarded individuals.

A sea-bed cage methodology was used to provide mortality estimates. Research was conducted near Kodiak Island in the Gulf of Alaska during August 1992, 1993, and 1994, and April-May 1995. Trawl-caught halibut were placed into cages that were returned to the sea-bed. These cages were subsequently retrieved one to seven days later for quantification of mortality.

The effects of halibut density (two *versus* six per cage) and caging duration (1, 3, 5, or 7 days) were examined during 1992, 1993, and 1994. Results indicated that 3+ caging days were required to detect most trawl-induced mortality, and that as many as six halibut could be held in cages without influencing results. Baited pots were used to determine whether confinement within cages caused mortality. These pots (i.e. controls) were allowed to "fish" on the sea-bed for a period of 24 hours. After the initial 24 hours of "fishing", tunnels were blocked to prevent additional fish from entering and to prevent captured fish from exiting. Pots were left on the sea bed for a period of 4 to 8 days. Mortality of control halibut was 0%.

Fishing and handling procedures that could affect mortality were examined using data collected during 1994 (summer) and 1995 (spring). Towing duration was 1 or 3 hours, and deck exposure (i.e. amount of time halibut spent out of water) ranged from 10 to 40 minutes. Halibut lengths were 34 to 113 cm, and catch volumes ranged from 0.5 to 12t. Mortality was significantly highest during the summer field season ($p < 0.05$), when air-temperatures were warmest. Mortality also was higher for 3 hour tows than for 1 hour tows ($p < 0.05$), whereas catch size (to 12t) did not significantly affect mortality. Mortality decreased with increasing body length, and increased with increasing deck exposure duration ($p < 0.05$).

Fish social behaviour as the keystone factor in the resilience of fisheries

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The concept of fisheries resilience applies to the collapse and rebuilding of fisheries. Rapid depletion, or collapse, may be caused by over-exploitation by human fisheries or by natural environmental factors. Many historical fisheries collapses have entailed both of these factors. Two critical processes in fisheries resilience are (1) catchability-led stock collapse and (2) range collapse: the former process has been documented for some time but its generality underestimated, while the latter remains ill-understood. The thesis of this paper is that the dynamics of fish social behaviour is the keystone in determining resilience of fisheries in terms of collapse and rebuilding times, and further insight into shoaling behaviour is essential to enhance our understanding of both these processes.

Production models of the resilience of fisheries can illuminate the dangers of collapse but generally subsume these behavioural processes. The paper compares the resilience of model fisheries obeying simple Schaefer, Caddy & Csirke production functions with a recently published model by the author where catch rates are held constant through behavioural responses of the fish and fishers.

The essential behavioural responses of fish in shoals to fishing, predators, food, and ocean habitat occur at spatial and temporal scales where we have least knowledge and which present severe technical problems. Although much work on fish shoaling behaviour has been done in the laboratory or in microcosms, and the general behavioural rules of shoaling are relatively well-understood, there is little precise information from wild fish with which to tune models to actual ocean conditions. Recent work by the author and others using high-resolution sidescan sonar has revealed adaptive behaviour in herring schools towards predators and fishing vessels that may be used to improve the laboratory-based information.

Certain shoal behaviours may act to mitigate stock collapse and hasten rebuilding. Shoal fidelity and shoal relatedness are two candidates for such a function. There is no convincing evidence for the former, but relatedness has recently been reported by the author and others for anchovy shoals. Sardine shoals exhibited no such relatedness. A model is developed that encompasses shoal size, stock range and the number of refugia from which stocks may rebuild. A corollary of this model is that fisheries for cannibalistic fish, such as hake, should be more resilient to human fishing, a prediction that is supported by the data on world hake fisheries.

During stock collapse, many recent examples show that traditional fisheries information flow is too slow to guide management responses towards holding or rebuilding strategies before it is too late to halt collapse. Such fisheries invariably end up closed with the consequent loss of economic benefits and jobs. This paper suggests that the monitoring of key parameters of fish social behaviour might be employed in the preventative and precautionary management of stocks that are sensitive to periodic collapse.

An individually-based model of fish school dynamics

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This poster reports progress with a simulation model of fish shoal dynamics using algorithms based on the behaviour of individual fish, an 'IBM' model. The model aims to mimic shoal behaviours and group size dynamics in relation to food, predators and ocean habitat so that the impact of environmental change and fisheries exploitation on shoaling fish my be explored.

Movement and swimming direction of individual fish is simulated, together with a detection range within which conspecifics that are encountered may be reacted to by turning on to a common track, simulating joining a shoal. The decision as to whether to join an encountered fish is determined by subtracting costs from benefits of belonging to a group of that size. An analogous decision, to leave or stay with the group, is taken at each time step by each fish that is already a member of a travelling group. The costs and benefit curves with shoal numbers are tuned using information from earlier laboratory experiments.

When threat of attack from a predator is perceived, the benefit curves of grouping increase altering the join/leave rules. Results include a comparison of the distribution of group sizes with and without the presence of a threat from a predator.

Information from group sizes observed in the wild might be used to further tune the model. For example, the frequency with which simulated groups join and split may be compared to field data on herring shoals. The model may be extended to include foraging success and hunger.

Survival of selected fish species after escaping from square mesh codends

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Australia's commitment to ecologically sustainable fisheries management has led to the development and testing of bycatch reduction devices to exclude non-target species from prawn trawl catches. Although there are several promising devices that allow substantial amounts of bycatch to escape, there is still concern from the fishing industry and scientists that these escapees may not survive. Previous studies to assess the survival of fish bycatch escaping from codends have all been undertaken in northern hemisphere, temperate water fisheries.

It has been shown that square mesh codends can reduce bycatch while retaining catches of prawns. However, the survival of escapees was unknown. We investigated the survival of selected fish species that had escaped through a square mesh codend. This study was the first assessment of fish bycatch survival in Australian and tropical waters and is a collaborative project between the CSIRO, Australian Maritime College and Northern Territory Department of Primary Industry and Fisheries.

To assess the survival of escapees we towed a trawl constructed with a 45mm square mesh codend in the Gulf of Carpentaria. Two separate experiments were carried out: one with full sized commercial gear and a second with small scale gear designed to be used in shallow water. Survival was compared between fish that had passed through the square mesh with those that had not. Escapees were collected in a fine mesh, 16mm codend cover and transferred to either submerged sea cages or large round tanks. Species retained for the study had a range of body forms and were held for eight to ten days. The fish in tanks were monitored daily. Most mortality occurred in the first three days of the experiment.

A total of 24 taxa were used in the experiments but of these, 12 consisted of less than nine individual escapees for any one experiment. For square mesh escapees, of the nine more abundantly captured taxa, six had survival rates of over 75%. These included *Leiognathus splendens*, *Terapon puta*, *Cynoglossus* spp., *Sillago* spp., *Upeneus* spp. and *Gerres* spp. Three species – *Saurida* spp., *Sardinella* spp., and *Secutor* spp. – showed much lower rates of survival. These survival rates should be interpreted conservatively due to the extra handling that these species were subjected to during collection (hauled to the surface, transported to cages/pools). We conclude that the survival of most fish t escape from square mesh codends is generally high, but is dependent on the species and body form, as well as their size. The loss of bycatch from square mesh codends can therefore be considered an effective mechanism for reducing trawl impact on those species.

Decline of freshwater fisheries in a large semi-arid floodplain river system

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A commercial freshwater fishery for finfish and crustaceans has operated through the 20th Century in the western waters of New South Wales, Australia. The number of licences was reduced from a postwar peak of 280 in 1971, to 44 in 1995, while total production peaked at 840t in 1977/78 and is currently around 300t. The total product figures mask the decline of the dominant species of the 1950s – Murray cod, golden and silver perch – and the rapid rise in catches of carp. The fishery for silver perch and catfish collapsed in the last decade. This period of decline in catches of the formerly dominant and highly-valued native species coincided with a rapid increase in river regulation, and consequent increases in barriers to fish migration, changes in river flow and temperature regimes, and reduction in water quality. Operation of the commercial fishery has been contentious because of perceived resource conflicts with anglers, but the basis for these conflicts is uncertain and the commercial fishery can provide valuable monitoring data on the status of fish stocks.

This study shows the utility of the commercial fisheries data as a stock-monitoring tool. By evaluating the relationships between fish stocks and environmental factors such as droughts, floods, streamflows and anthropogenic changes, the study indicates the usefulness of the commercial data as a measure of the well-being of the ecosystem that supports the fishery.

Relative length: a comparative approach to fish growth

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Fishes grow indeterminately throughout their lives, adding successively smaller increments of size each year until they die. When expressed as a function of initial length each year, these increments tend to decrease at a linear rate (i.e., constant growth deceleration). Growth of fish was examined in terms of length, expressed as a proportion of their ultimate (i.e. asymptotic) length to learn if various species grow at similar relative rates. World Record Length (WRL) was used as an estimate of ultimate length for a species. Relative length was defined as the percentage of WRL attained at any annulus and relative length increment as the percentage of WRL attained during the year subsequent to the same annulus. Growth of various fish species with a WRL between 500 and 1700 mm were compared and gave a declining relationship between relative length increment (Y) and relative length (X): $Y = 15 - 0.2X$. Thus, of those fish examined, most attained 15 percent of WRL for their species in their first year and never exceeded 75 percent of WRL in their lifetime. Short-lived fishes tended to attain only 50 percent of WRL, probably due to higher natural mortality rates compared with long-lived fishes. Relative length attained may serve as an indicator of natural mortality rates among fish species and their populations. Further investigations should include species representing a larger range of length and age and a comparison of ultimate length and world record length as the basis for calculation of relative length.

Factors contributing to the collapse yet maintenance of a native fish community in the desert southwest (USA)

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The native fishes of the southwestern United States are presently in a precarious state. Although the number of species is few, all are currently under consideration for listing or are listed by the federal government as threatened or endangered. These fishes have evolved under the harsh conditions of a desert environment with alternating drought and floods. In addition, over the past century many non-native fishes have been introduced into the area for sport fishing. These introduced, mostly predatory species, along with habitat modification primarily through construction of mainstream dams, have resulted in the endangered status of the fauna.

The relative roles of introduced fishes and natural stream hydrographs comprised of drought and flood conditions were tested in one large desert watercourse in Arizona, the Verde River. This river contains seven species of native fishes. A study was initiated following a 75-year flood event in the winter of 1993. Populations of all fishes, native and introduced, were low in spring 1994. However, because of reproductive strategies consisting of multiple spawning events, the native fish community rapidly rebounded. By spring 1994, sampling over 60 km of river revealed that four of the seven species have increased remarkedly in numbers. Over 8,700 fish were captured in 67 habitat types at seven sample sites. Numbers of fish varied from 451 to 2,800 at the seven sampling sites and species selected specific habitat types (i.e. glides, runs, high and low gradient riffles, and pools). Sampling in October 1995 revealed a dramatic increase in one introduced cyprinid species relative to one threatened native species. In the winter of 1995 a ten-year flood event again occurred. Sampling at the same sites as spring 1994 revealed a seven-fold decrease in fish populations. Non-native fishes were drastically reduced from the previous year.

The dynamics of a native fish community in this desert river relative to flooding suggests the validity of the hypothesis that natural stream hydrographs are critical for sustaining native fish stocks in southwestern desert rivers and streams. Although native species are reduced, non-native species are reduced to a greater extent. However, additional data to be collected over the next 7-10 years will more reliably confirm or reject this hypothesis.

Factors influencing fishing power in the northern prawn fishery

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The Northern Prawn Fishery (NPF) extends from Cape York (Qld) to Cape Londonderry (WA) and has an annual production of between 8,000 and 10,000 t of prime quality export product. It currently earns around $100 million annually in export dollars.

The NPF is divided into two components – the banana prawn fishery and the tiger prawn fishery. At present the banana prawn fishery shows no signs of overfishing. In contrast, over the history of the NPF the tiger prawn fishery has exhibited evidence of a fishery-induced decline. As a consequence the fishing fleet has been subjected to severe management restrictions, which included a 60% reduction in the number of trawlers. Catches, although holding steady over the last few years, have not returned to the levels anticipated by industry.

Assessments of the fishery have not been able to explain the reason for such a lack of response to the restrictions. One possible reason is that the management regulations have not had the expected impact on fishing effort, and thus on fishing mortality.

An analysis has been made of current factors that affect fishing power and subsequently fishing mortality. These include: gear size, vessel size, skipper skill and new technology. Two different methods to determine the fishing power of each trawler were used and compared. One method is an analysis of catch data using generalised linear modelling and the other an iterative mathematical approach using catch rates of boats in the same area at the same time. Even though these methods are very different, they produced similar fishing power estimates.

One technological innovation studied, Global Positioning Systems (GPS), increased the fishing power of the fleet by around 5%, but for individual boats this increase ranged from almost nothing to around 40%.

Is it true what they say about trawling and sea turtles?

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Trawlers working off the Queensland east coast catch sea turtles. To quantify how many turtles, which species, where it happens and what proportion die is the objective of a monitoring programme by the Queensland Department of Primary Industries. This programme monitored the catch and kill of sea turtles by the Queensland east coast otter trawl fishery, which has eight identifiable sub-components. Monitoring has been conducted for four years involving about 50 reliable commercial fishers. They have provided information on date, turtle size, species, location of capture, target species, tow time and tow depth. The condition of each turtle was recorded as either healthy, comatose or dead. From the initial data (i.e. 1991 and 1992), about 5,000 sea turtles were estimated to be caught annually on the Queensland east coast. Turtle catch per unit of effort was different for each sub-component fishery. About 1% of all turtles caught died before being landed on the boat. If all comatose turtles are assumed to die, mortality increases to about 7%.

A voluntary code of fishing ethics and turtle recovery procedures have been provided to all trawl fishers in an attempt to minimise the numbers of turtles caught and to return those caught to the water in the best condition possible. Additional mortalities may occur after turtles are returned to the water because of predation or capture stress. The magnitude of post-trawl mortality is unknown. To determine the fate of trawl-caught turtles, ultrasonic tracking is being undertaken to provide information on the behaviour of these turtles and their post-trawl survival. This information will be used to estimate more accurately the mortality associated with trawl fisheries in eastern Australia.

The collapse of the eastern Australian gemfish stock – a case of putting all your eggs in one basket?

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During the 1970s the New South Wales demersal trawl fishery changed from Danish seining to otter trawling and began fishing in waters deeper than 200m along the upper continental slope. A number of deepwater species were targeted, the most prominent being gemfish, *Rexea solandri,* which formed migratory pre-spawning aggregations at depths of 350 to 450m during the winter months. These aggregations were easily targeted using demersal trawls and catches of five to ten tonnes for single trawl shots were common. Landings of gemfish increased rapidly and peaked at just over 5000t in the 1980 season.

In the mid 1980s gemfish catches declined to 3,000t before reaching a secondary peak of 4,300t in 1987. Research results, which showed falling catch rates and a significant decline in the average size of fish in the catch, were made available to industry and fishery managers. In 1988 a Total Allowable Catch (TAC) of 3,000t was implemented, with the aim of stabilising the annual catch at what was thought at the time to be a sustainable level. However, monitoring of the 1989 catch gave the first indication of a decline in recruitment of maturing four year old fish to the gemfish spawning stock. From 1990 to 1992 the TAC was progressively reduced in response to a series of poor recruitments from cohorts spawned in the years 1985 to 1989.

In 1993 and subsequent seasons gemfish have been subject to a zero TAC, with restrictions on the landing of gemfish incidentally taken whilst targeting other species. It appears that there has been a substantial decline in the abundance of mature fish as the poorly recruited cohorts have reached those ages which once dominated the mature population (5 to 10 year olds). Recently there have been indications of improved recruitment from fish spawned in 1990 and 1991, although data from monitoring of the 1995 catch suggest that this improvement in recruitment may not be sufficient to allow recovery of the spawning stock to previous levels of abundance.

A cohort analysis of the gemfish stock showed that the collapse in recruitment occurred at a time when the spawning stock had only declined to about 40 per cent of its pre-exploitation level. This, combined with the prolonged period of poor recruitment and the apparent improvem[illegible] from the 1990 and 1991 spawnings, indicates that [illegible] underlying cause of the recruitment failure is likely to be unsuitable environmental conditions. Many of the species taken by the deepwater fishery spawn in the winter period. However, gemfish is the only species which is known to undertake a directed migration to spawn during a short period of time (early – mid August) in a restricted geographical area between about 32 and 33 degrees S latitude. This suggests that the prevailing oceanographic conditions in the spawning area, which is dominated by the East Australian Current, may hold the key to the collapse of recruitment to the gemfish stock.

Myxobolus spp. (Myxozoa: Myxosporea) as primary causative agents of Epizootic Ulcerative Syndrome (EUS) in fishes from Beel Mahmoodpur, Faridpur, Bangladesh

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Epizootic ulcerative syndrome is the most dreaded freshwater and estuarine fish disease ever to sweep the south east Asian countries, and possibly Australia, since the 1980s. After several years of environmental, biological and histological investigations on different species of wild fishes in the lake Beel Mahmoodpur, Faridpur, Bangladesh, it has been discovered that *Myxobolus* spp. are organo-cosmopolitan muscle parasites developing intracellularly within the skeletal muscle fibres, apparently with no host reactions, except the presence of some leucocytes, initially affecting the fish. On maturation, the plasmodium splits up, the freshly liberated trophozoites seriously degenerating the surrounding sarcolemma so as to disappear quickly from the site of liberation, either forming another mini-plasmodium in nearby fresh muscle fibre and connective tissues or entering into the blood stream, possibly through the lymphatic system. The spores also form sporoblasts in the gill epithelia, cyst-like structures/pseudoplasmodia within the vein wall of liver tissue, hepatopancreas and

adjacent liver parenchyma with conspicuous degeneration/lysis, and also form pseudocysts near blood vessels or capillaries with massive alterations of spleen and other soft connective tissues like the peritoneal wall of the kidney and liver tissue. Gradually, they finally accumulate in the kidney where they also form plasmodia within the wall of the blood vessels, tubuli wall or in the adjacent kidney interstitial cells. On maturation and splitting up, the plasmodia also massively destroy the tubuli wall as well as the whole kidney parenchyma with severe alterations. Such types of evidence in any form and stage were 98% consistent in different organs like muscle, liver, spleen and the kidney, in most of the EUS affected wild fish species under investigation for two seasons (years). The initial muscle lesions formed during the breakdown of the plasmodial wall may have made the fish osmoregulatorily imbalanced and opened the corridors as mini-scars (pathecia) for secondary infections by fairly consistent aseptate fungi, *Aeromonas sobria,* flexibacter type bacteria or adherence of protozoans on the lesion surfaces. These organisms, separately or together, may further expand the mini-scars into gruesome ulcers in the affected muscle that mately might have caused the devastating fish mortality.

Several histological techniques with HES, PAS and Gram stains were used to detect the parasite's organo-cosmopolitan characteristics in different stages of its lifestyle, as well as its quick appearance, which still left some evidence to enable detection of such tiny organisms by PAS/Gram stains. These had been overlooked for the past several years. It was generally observed that the developing stages, plasmodia, the trophozoites and microspores are PAS positive. The study further revealed that only the polar filaments of the mature spores are Gram positive; the rest of the parasite body as well as the whole immature spores, trophozoites or plasmodia itself are Gram negative while existing in different organs of the hosts. Photomicrographs of the pathogens *in situ* in different forms and stages, with details of pathogenicity supplement the observations.

Catch composition of the otter bottom trawl fishery on the Catalan Coast, northwestern Mediterranean

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During 1991, monthly sampling was undertaken with otter bottom trawl throughout the Catalan coast (Northwestern Mediterranean), which is approximately 550 km long and has 28 ports, 18 of which have daily and regular fishing activity. The Catalan coast can be divided into three different topographic units. The northern zone consists mainly of rocky coast, with a predominance of muddy sand bottoms. Its platform is very narrow, between 8 and 11 miles, and it can reach depths of 800m on the slope at only 3 or 4 miles from the coast, owing to the presence of underwater canyons. The southern zone has very different characteristics. Its platform is very wide (at some points over 35 miles), with a predominance of muddy bottoms inherent to the continental platform. It is a zone of influence of continental waters from the River Ebro. In the central zone of the coast the platform is not very wide and it too has some underwater canyons. The bottoms are intermediate between muddy and muddy sand, with sand and gravel of organic-detritus origin. In order to sample this diversity of coast as thoroughly as possible, the most representative ports of each zone were chosen: three in the north; four in the central zone and two in the southern zone. The depths at which fish were taken ranged between 12 and 522m, though most were taken between 50 and 150m. The species composition, frequency of occurrence and abundance of fish were recorded. Analysis of data was carried out by cluster analysis applied to hauls and species.

A total of 139 species of fishes from 60 families, was recorded in 377 hauls. The three most abundant species in the catches (with abundance expressed as the number of individuals per hour of trawling) were the pilchard, *Sardina pilchardus* (1333.32); the goby, *Lesuerigobius suerii* (428.66); and the anchovy, *Engraulis encrasicholus* (423.94). None of these species, however, is a target species of bottom trawling. The three most abundant target species were the hake, *Merluccius merluccius;* the blue whiting, *Micromesistius poutassou;* and the silver scabbard fish, *Lepidopus caudatus.* The ten species (commercial and bycatch) which showed the highest percentage appearance in catches were the hake (77%); the spotted flounder, *Citharus macrolepidotus* (61.19%); the scaldfish, *Arnoglossus laterna* (55.22%); the red mullet, *Mullus barbatus;* brown comber, *Serranus hepatus;* black goby, *Gobius niger* (47.76%); anchovy (46.27%); Spanish bream, *Pagellus acarne;* four-spotted goby, *Deltentosteus quadrimaculatus;* and red bandfish, *Cepola macrophtalma* (41.79%). Size frequency distributions of the most abundant species have been prepared. Catches were dominated generally by immature individuals. The cluster analysis of the trawl results grouped the samples according to trawl depth. The species analysis grouped the species on the deep slope and continental shelf. This last group can be divided into two different subgroups according to the characteristic habitat. Thus we have more coastal species of rocky habitat and sand bottoms and the species of deeper distribution inherent to muddy bottoms.

Spawning of Norwegian spring spawning herring (*Clupea harengus* L.) related to geographical location and population structure

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Prior to the decline in abundance of Norwegian spring spawning herring in the mid-1960s, spawning grounds were common along the coast of Norway from Lindesnes to Lofoten. From the mid-1940s to the mid-1960s a northward displacement of the spawning areas was observed and after 1959 the southwestern spawning grounds were abandoned. Ever since, spawning has been mainly restricted to coastal grounds and offshore banks off mid-Norway, primarily off the Møre district. Occasionally spawning also took place in the Lofoten-Vesterålen area. After the stock size was severely reduced in the late 1960s and for nearly thirty years, traditional feeding and wintering areas in the Norwegian Sea were also abandoned and the stock spent the entire year in coastal and outer shelf waters. Since 1991, an increasing portion of the stock has again taken up feeding in the areas of the Norwegian Sea.

A gradual rebuilding of the stock during the last 25 years has brought the stock to a size level of about 3 million tons compared with a maximum of about 10 million tons in the 1950s. In recent years the mature stock has wintered in fjords of northern Norway and the southward spawning migration has started in January. The main spawning still takes place off Møre, but from 1989 onwards Norwegian spring spawners reoccurred at traditional sites at the southwestern grounds. In addition, spawning has also been recorded in the northern shelf area (Halten – Vesterålen). In this study, data on catch, distribution and age composition of the spawners are analysed for the period 1992 – 1995. Geographical location of spawning grounds, arrival of spawners and spawning period are described. In recent years spawning time has been delayed with rejuvenation of the stock. Initiation of within-season spawning has also been delayed with increasing migration distance. Consequences of the geographical location of spawning grounds, spawning period and population structure are discussed in relation to future recruitment.

Data sets and environmental indicators used to manage Pacific salmon for sustainable fisheries on Canada's west coast

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Canada has accumulated time series data sets for Pacific salmon stocks that originate from Canada's west coast because salmon are: (i) relatively ubiquitous in marine and freshwater ecosystems, (ii) highly valued from both economic and cultural perspectives, (iii) reasonably diverse in terms of species and especially with respect to life history and genetic variations within species, and (iv) highly sensitive to environmental change at each of several life history stages. In addition, Pacific salmon are commonly the subject of long term assessment programmes that support many Simple Feature Data Sets (SFDS) and a few Rich Feature Data Sets (RFDS). Taken together, these datasets are allowing us to draw inferences and report changes in the state of various stocks and their associated aquatic ecosystems, on temporal scales ranging from weeks to decades and spatial scales from metres to thousands of km.

Largely because of salmon's economic and cultural importance, data sets now assembled constitute some of the longest time series available for any aquatic organism of Canada's west coast region. Systematic recording and assembly of vital statistics on some species began in the mid 1800s and at coastwide locations by the early 1900s. SFDS include thousands of long time series that permit tracking and reporting of Simple Features such as total numbers of fish in annual catches and escapements (spawning) by species and by area. On the other hand, there are only a few RFDS that allow us to follow more Rich (or complex) Features such as the salmon's size at age, sex ratio, survival of eggs/fry/smolts/adults and distribution of these different life history stages at various temporal (weeks to years) and spatial scales (metres to hundreds of km).

As part of Canada's National Environmental Indicators Program for State of the Environment Reporting (SOER), some key Simple Feature Data Sets have been selected to address the issue of sustaining Pacific salmon. These SFDS describe and portray patterns or trends over decades in coastwide stocks at risk, landed catch in commercial/recreational/aboriginal fisheries, fish returning to spawn and so on. Although these SFDS adequately answer the SOER question "What is happening?", they can only make weak inferences to the other questions "Why is it happening?" and "Why is it significant ecologically?". To answer the latter questions, we have been compelled to rely on the few existing Rich Feature Data Sets associated with a limited number of stocks.

These RFDS are playing a disproportionately important role as "precision instruments", since they are being employed repeatedly to tease out and explain the geographical, temporal and other causal mechanisms driving the trends. This poses an always difficult, and sometimes perilous, scientific challenge to fisheries biologists, as they attempt to explain the relative roles of human stresses and natural factors in sustaining Pacific salmon and associated ecosystems in the Pacific region. The demand for scientifically defensible answ continues to grow and place even more urgency and priority in maintaining, developing and interpreting both types of Data Sets.

Relating fishing mortality to fish trawl effort on the north-west shelf of Western Australia

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The importance of using direct tests, either natural occurring events or experimental manipulation, to obtain information on fisheries management , has been long recognised. There have been numerous studies of the effects of different levels of fishing on the size, age structure, and biomass of fish species but few direct measurements. Fortuitous changes in fishing patterns have also given some insight into the effects of different levels fishing effort on tropical multi-species fisheries. For many years the need has been expressed for the use of manipulative experiments to subject fishing grounds to different levels of fishing effort, and sample fish by a method independent of the fishery. This paper presents information from a unique manipulative experiment aimed at determining the fishing mortality of several key fish species by subjecting a portion of the fishery to intense fishing effort for one year.

The trawl fishery studied, on the North-west Shelf of Western Australia, is a tropical multi-species fishery which was subject to extensive habitat modification and change in species composition due to foreign trawling for ten years from 1971. Domestic fish trawling began in 1987, and reliable catch and effort information is available only for the last few years. Setting appropriate levels of effort in this fishery required a direct measurement of fishing mortality and this was obtained by the manipulation of fishing effort.

The fishing fleet was restricted to a small portion of the fishing area for fourteen months to induce a high level of fishing mortality for comparison with the untrawled control areas. Two extensive experimental trawl surveys were conducted one year apart in the area open to fishing and in two adjacent areas closed to fishing. The change in the age

structure of five fish species, between the fished and unfished areas over a period of one year has enabled fishing mortality to be calculated. The results indicated that the long lived species suffered high levels of fishing mortality and appropriate levels of effort have now been provided, to allow an adaptive management arrangement to be developed for the fishery.

Successes and failures in the management of Atlantic herring fisheries: do we know why some have some collapsed and others survived?

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Atlantic herring fisheries have been important historically on both sides of the North Atlantic. As a result, herring has been the subject of considerable scientific study and herring fisheries have received a high degree of attention with respect to regulation and management.

Atlantic herring are evaluated and managed in approximately 30 units around the North Atlantic. These management units span a considerable range in size, stock structure, timing of spawning, assessment forum and structure and fisheries management approach. The fisheries for herring in these areas are diverse. The suite includes several that are very old and well studied, and some that have been the subject of innovative management (including early experiments in limited entry, catch restrictions and quotas, and Individual Transferable Quotas ITQs). Together, they provide a very useful case study for evaluation of fisheries management.

In spite of early and often innovative management and considerable regulation, there have been several instances of failure of herring fisheries – including notable collapses in the North Sea and Georges Bank fisheries. This paper examines the successes and failures in the management of Atlantic herring fisheries to address the question of whether we know why some have some collapsed and others have survived.

The herring fisheries span considerable ranges in most major elements of management: underlying biological stock structure (from single stocks to complexes), degree of biological understanding, fishery type and intensity (low fishing effort by passive gear through intense effort by sophisticated vessels), assessment forum and structure (both sides of the Atlantic), management context (single nation control through transboundary situations to complex jurisdictions), management structure and suite of management measures. Failures have been attributed in whole or in part to several of these factors as well as to externalities such as environmental or ecosystem changes. While high fishing pressure has been a major contributor, the evaluation reveals that collapse has most often been considered to be the result of a complex rather than a single cause – making it difficult to anticipate or to arrest it. In the same way, the rate of recovery has been variable, and has involved several elements of the fishery system.

This review shows the need to continue to work toward a management approach which considers multiple relevant factors and which can react quickly to complex and changing conditions. It emphasizes the importance of structured decision making, which makes the best use of all available data, in a climate of uncertainty, and with explicit consideration of risk.

Are southern Australian shark fisheries sustainable?

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Historically, shark fisheries have been characterised as 'boom or bust' operations with the specialised life history strategies of sharks making them particularly vulnerable to overexploitation. Often cited examples are the Porbeagle fishery in the North Atlantic which showed a sudden increase from some 2,000t in the 1950s to a peak of 11,000t in 1964, followed by a drop to below 2,000t in the late 1960s and 1970s. Catches in the Californian school shark fishery increased dramatically during the late 1930s to around 3500 t and then plummeted after 1941 and have apparently never fully recovered. Case histories such as these prompted a paper by M. Holden in the 1970s questioning whether long-term sustainable fisheries for elasmobranchs were possible. More contemporary examples of shark fisheries, such as on the west coast of the USA, have done nothing to alter this thinking. Current concerns over global overfishing of shark stocks caused largely by massive increases in the shark fin trade have highlighted the need for rational management of elasmobranch stocks.

Australia is one of the few countries with integrated research and management plans for its shark fisheries. Unlike most countries, shark meat is an important, relatively high priced product on the domestic market. The south-eastern fishery which targets school and gummy sharks with demersal gillnets and longlines has a long history of exploitation, with school sharks fished since the 1930s. School sharks are a low productivity resource being particularly long lived (maximum longevity around 60 years), late maturing and slow growing. Despite concerns expressed since the 1950s, the stock of school sharks has not collapsed, although current assessments put the current biomass at about 25% of virgin levels. Prior to the introduction of a management plan in 1988. survival of the stock may have been fortuitously aided by several factors, including exploitation of gummy shark. Gummy sharks are relatively productive and current catches are considered sustainable. A current management measure is aimed at reducing mesh sizes and targeting a restricted range of young year classes while allowing escapement of the larger, more fecund adult breeding stock.

The Western Australian shark fishery targets gummy, whiskery and dusky sharks. The fishery for dusky sharks expanded during the 1970s and is based on new-born fish in the inshore nursery areas. The adult stock is not subjected to any significant fishing pressure. The sustainability of this fishery will not be apparent for a few more years until the first-fished age classes recruit into the breeding population. Stock assessment indicates that the whiskery shark stocks are currently at 25% of virgin levels. Management measures to reduce fishing effort are currently in place.

The north-east Euro-Arctic ecosystem – successes and failures of managing multispecies and multifleet fisheries

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The Barents Sea and the Norwegian Sea constitute the North-East Euro-Arctic Ecosystem. This area has eight major fleet groups and several multispecies fisheries. A total catch of 1.9 million t was reported in 1994 to ICES in Sub-Areas I and II.

Landings of 1.1 million t were from the demersal stocks of Atlantic cod, haddock, saithe, redfish and Greenland halibut where Atlantic cod accounted for 775,000 t. These are all species for which assessments are carried out and quotas given. In addition, approx. 100,000 t of demersal species not being assessed or regulated by quotas, are landed, such as northern shrimp, wolffish, Norway pout, ling, tusk and flatfishes.

The major pelagic species are capelin, herring and polar cod. Both capelin and herring are managed by quotas and the landings in 1994 were almost zero for capelin and 480,000 t for herring. The polar cod is not assessed or managed by quotas and the landings were 6,000 t in 1994.

The main production occurs in the areas where inflowing Atlantic water meets polar water. The seasonal and year-to-year movement of this "polar front" is very important and causes changes in the total productive area of the ecosystem. Invertebrate species of krill, copepods, amphipods and cephalopods are important food resources for the fish stocks. Marine mammals such as seals and whales play an important role as predators and are to a certain degree harvested.

Both coastal and offshore fisheries are important and bottom trawl, pelagic trawl, purse-seine, Danish seine, gillnet, longline, handline and shrimp trawl are used. Most fleet groups have restrictions due to quotas, but some may also conduct non restricted fisheries. Changes in catch per unit of effort (cpue) due to changes in efficiency and increased directed effort are found.

In this paper the histories of the major stocks and fisheries are described back to the 1960s. Both collapses and rebuilding of stocks are described together with the management principles used. Strong stock recruitment relationships and heavy influence on these by environmental and biotic factors are found for several stocks. Cannibalism is shown to influence recruitment to the cod stock. Predation of herring and cod on capelin is shown to have a dramatic effect on the capelin stock and its recruitment.

The fisheries have a very strong influence on the stock levels of most stocks and are the most important single factor in the depletion of several stocks. Reducing the fishing mortality leads to increased stock size almost independent of environmental conditions for some stocks, e.g. cod and haddock. However, even if no fishing takes place, some stocks do not recover, e.g. capelin.

Most of the stocks are managed on the basis of scientific assessments and both single and multi-species approaches are used in successful management. However, failures occur, indicating that both approaches may have their shortcomings. Biological reference points and management levels are used for most of the stocks.

Assessment of rock-ramp fishways

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Even small barriers to fish migration can have a major effect on the fish populations in freshwater habitats. While large dams often extinguish migratory species upstream, the impact of individual low barriers such as weirs, floodgates, road crossings and culverts on fish passage is usually not so extreme. However their cumulative impact may be large, because of the prevalence of these structures. This is especially important in Australia because of the abundance of catadromous and amphidromous fishes whose juveniles migrate upstream. In low or moderate stream flows fish congregate in large numbers downstream of barriers. H mortality rates from predation, competition and disease often result. It is only during higher flows, when the barriers are drowned-out, that fish have the opportunity to migrate upstream. However, small larvae or juveniles of catadromous species may not possess sufficient swimming ability to negotiate drowned-out tidal barriers and species may become locally extinct upstream.

The cost of providing formal pool-type fishways on existing low barriers is often prohibitive and alternative, low-cost solutions are needed. In Europe and North America, 'Nature-like' bypass channels have been used extensively in providing low-level fish passage. But these structures, which mimic the structure of natural stream riffles, have not been tested in Australia. The aim of the study has been to assess the effectiveness of rock-ramps in providing passage for Australian migratory fish. Experimental rock-ramp fishways were built on two tidal and two inland rivers. The species and size-classes of fish sampled below each rock-ramp were then compared with those fish caught successfully swimming upstream.

The rock-ramp design has so far proved effective, with to 600 fish per day caught moving upstream through the fishway. The physical construction and layout of the rock-ramp, particularly the entry and exit areas and movement of the rocks under high flows were found to be critical to a fishway's success. However, the limiting factor in providing fish passage at these sites was generally found to be the management of stream flows rather than the effectiveness of the fishway.

Problems of fisheries in developing countries: example of degradation of the aquatic environment by Rwandese war (Africa)

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The Rwandese civil war started in October 1990 and ended in July 1994, and caused deforestation of more than 70% of the country. During these four years, the quality of surface waters has been polluted by wastes from refugees and the army, destruction of industries, demolition of electric transformers accompanied by release of polychloro biphenyls (PCBs). Fisheries suffer from these kinds of .ution. This paper reports the results of a study designed to evaluate the war impact on water quality and on fisheries in the eastern part of Rwanda, and the impact on living forms in Lake Victoria which receive these contaminated waters.

The production of fishes in lakes (North and South Cyohoha) and rivers (Nyabugogo, Nyabarongo) which serve as recipients of these liquid and solid wastes has declined. These wastewaters cause damage to fisheries and biodiversity in Lake Victoria at the estuary of Kagera River which collects these waters and which is the most important tributary of the Lake.

Lake Cyohoha has became eutrophic because it receives varying amounts of organic and inorganic nutrients from a diversity of anthropogenic activities; and during the dry season, massive fish death occurs. Physico-chemical analysis (Electrical Conductivity, BOD, COD), heavy metallic ions in sediments and the water column (Cd, Cu, Cr, Hg, Mn, Zn and Al) are above the recommended values. Some of these xenobiotics accumulate in fish tissues and the analysis of muscle, nerve tissue and bones of fishes provided directly from the market of Kigali provide evidence of that umulation. So, the quality, particularly the quality of fishes in these lakes and rivers, is not satisfactory because of lack of management. In Lake Cyohoha, there is a loss of some benthic species and *Oreochromis niloticus* has become rare. There is a serious threat to biodiversity. This results in reduced energy transfer, increase of sensitivity, disturbance and diseases of remaining species. There is also loss of habitat accompanied by a loss of fisheries due in part to lake eutrophication. The analysis of sediments established the presence of high concentrations of persistent chemicals such as Al > 4000 mg/L, Mn > 0.6mg/L, Cu > 0.07mg/L, Zn> 0.08mg/L, Pb > 0.7mg/L, Cr> 0.01mg/L not only at the discharge points but also at 50 km downstream, and provided evidence of influence of urban and industrial effluents.

In Lake Victoria which receives these waters, recent investigations provide evidence of mass extinction in progress. Since 1982, there has been a loss of 200 taxa including a significant decline in fish species composition. These waters create a real hazard to Lake Victoria biodiversity.

It is important to focus on the lack of social and economic attention to Rwandan fisheries in comparison with resource studies in the context of the whole country. The results provide an example of the need for cooperation and harmonization of research projects on inland water quality for the sustainable management of fisheries at the regional level (Burundi, Kenya, Rwanda, Tanzania, Uganda).

Short- and long-term fluctuation in catches of the Japanese eel, *Anguilla japonica*, elvers on the coast of Taiwan

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The Japanese eel, *Anguilla japonica* Temminck & Schlegel, is one of the most important culture species in Taiwan, Japan and Mainland China. The eel larvae, leptocephali, drift with currents from the oceanic spawning ground, metamorphose into transparent glass eels on the continental shelf and become elvers in estuaries. They migrate upstream to become yellow eels and live in rivers for 5-20 years. During the late autumn, the maturing eels migrate downstream to spawn in the ocean. Since the eel culture industry was developed in Taiwan in 1965, the supply of elvers has been insufficient to meet the needs of eel farming. To increase the elver production has become an important fisheries policy of Taiwan.

Large numbers of elvers are harvested from November to March in the estuaries. The geographic cline of daily ages of elvers increasing from north to south suggests that the elvers on the western coast of Taiwan come with the cold China Coast Current from the north. The daily maximum catch occurs on the day or several days after the seawater temperature decreases to 15~16°C. The instantaneous maximal catch occurs at the time when elvers in the estuaries are most active, seawater influx is maximum, and the salinity is the highest. In coastal waters the rhythm of biological activity of elvers follows the lunar cycle with the peak catch once a month around the time of new moon. In estuaries, a semilunar rhythm was observed; one around full moon and the other around new moon. Moonlight seems to play a role in inhibiting elver activity in the coastal waters. Annual catch data of elvers from 1964 to 1993 were analysed using autocorrelation function analysis. The result revealed an approximately nine year periodic fluctuation with good catches in 1969-70, 1978-79 and 1990-91. The information on the short-and long-term fluctuation in the catches of elvers is useful for their effective harvest in Taiwan.

Perspectives of the lobster and abalone fisheries on the northwest coast of Mexico and its management, exploited under a limited access system

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The abalone and lobster fisheries are the base of origin and development of many fishing towns along the west coast of Baja California Peninsula. With regard to Mexican exports of fishing products, abalone is in third place and lobster in fourth, with a value estimated at 50 and 20 US$ millions, respectively. Objectives of this work are to evaluate the efficiency of fishing policies on two benthic resources, being exploited under a system of reserved species for Fishing Cooperatives, and to find other alternatives to improve management strategies with a systemic-ecological approach. Management controls actually include minimum legal size, close seasons, fishing zones, limited entry through transferable concessions and licences, restrictions on effort and fishing gears, annual catch quota for abalone and non-possesion of egg-bearing lobster. Despite some similarities in habitat and fishing regime, each fishery has developed in different ways. While lobsters have developed into a relatively stabilized fishery with an oscillatory pattern, ranging from 1,000 to 2,200 t and an annual average of 1,300 t; the abalone shows the typical trajectory of an overexploited fishery, reaching its maximum catch (6,000 t) in 1955/56, followed by a stabilized period (1956-1974) with an average of 3,000 t, after which it suffered a drastic decline, to a minimum historic level of 450 t. Subsequently, an enforcement control plan was implemented by the Federal Government and Fishing Cooperatives, which in combination with a major change of fishing regime since 1981/82 and favourable environment conditions after 1984, helped the catches to recover to 1,100 tons until 1991/92, although during the last three years a significant decrease happened again.

The oscillatory pattern of lobster catches during the last four decades is not explained by effort changes, but are better related to environment factors, such as the regional marine thermal regime. Declining abalone catches, after its stabilized period, are reflecting drastic decreases in abundance and overfishing as a consequence of cumulative effects derived from wrong policies (trespass of legal sizes, high extraction of young abalone, very short close season) before 1981/82, combined with bad environmental conditions related to climate anomalies during El Niño events.

It is concluded that factors related to fishing regime partially explain the changes on abundance, mainly overfishing in the abalone case, but the hypothesis of climatic-oceanographic effects could explain not only part of abundance decline but also the regular fluctuations, principally in the lobster catches. It is convenient to improve management tools by means of more detailed data on reproductive biology and new information on population dynamics, bioeconomic modelation, the key factors of recruitment and its mechanisms, on the benthic community context.

Estuarine rehabilitation studies in New South Wales, Australia: from intensive to extensive

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The Kooragang Wetland Rehabilitation Project (KWRP), is one of the most intensive rehabilitation projects in Australia. Directed by a small steering committee, the KWRP integrates various research, education and recreation projects within the estuarine habitats of the lower Hunter River. Field studies on fish and decapod crustaceans beg in the Austral spring of 1993 and were soon complemen by investigations of birds, mosquitoes and saltmarsh/mangrove hydrology. These studies are being conducted by New South Wales Fisheries, National Parks and Wildlife Service and the University of Newcastle.

The research aims to mitigate impact begun in the middle of last century when farmers reduced the estuarine habitat at Kooragang Island by land clearing and construction of culverts across tidal creeks to facilitate movement of stock around the island. The culverts severely reduced tidal flow, an undesirable impact as tidal behaviour is believed to have a direct relationship with the recruitment of juvenile fish and prawns to estuarine nursery areas. Sampling of juvenile fish and crustaceans in the tidal creeks has been initiated to assess the effect of replacing culverts with bridges. In addition, predictions of tidal heights under the changed conditions have been prepared.

One of the main objectives for the research at the KWRP is to extend the techniques learned to other degraded estuarine wetlands in NSW. A project to identify these sites began in September, 1994. The first stage involved assessment of 1:25,000 topographic maps for structu which reduce tidal flow (culverts, fords, weirs, dams, bridges, causeways and floodgates). Additional input was sought from commercial fishers and oyster farmers. Field investigations were carried out to determine which structures had an impact on estuarine habitat and to gain an impression of rehabilitation potential. Qualitative assessments of water quality and vegetation were also made.

Six hundred and ninety waterbodies were identified along the 1,900 km coastline of NSW. Of these, 127 waterbodies are considered "substantial" in character due to their size and permanence of which 115 (91%) are presumed degraded in some fashion. The other 563 waterbodies are small and/or ephemeral systems, 175 of which (31%) were degraded in one form or another.

The investigations identified over 4,229 structures in the tidal zone of NSW, 1388 of which have rehabilitation potential: 26 bridges, 185 culverts, 46 causeways, 5 fords, 91 weirs and 1,035 floodgates. Many of these structures have potential for rehabilitation and investigations are continuing to set up a ranking system by which sites with greatest need can be identified.

What are the roles of science, economics, sociology and politics in fisheries management?

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Fisheries management has historically focussed on the biological aspects of the fisheries, concerned primarily with the protection and conservation of fish stocks. However, fisheries management has now progressed to another level of complication, requiring greater consideration of a variety of elements such as advances in fishing technology, stricter controls on catches, requirement for access rights and the effects of fishing on the sea bed and on biodiversity. This, in turn, has led to the need for a clearer definition of the role of the fisheries manager, and the roles of science, economics, sociology and politics in fisheries management.

The directions for fisheries management are set through the political process so as to establish (i) the legislative framework within which the common property fisheries resource will be managed, (ii) the philosophical approach to resource sharing amongst the interested groups, and (iii) the funding arrangements for fisheries management, with special emphasis on the nature of the costs to be paid by industry and those which will be provided by government from the public purse. The objectives set down in the government legislation describe, in broad terms, the outcomes to be achieved.

The fisheries manager is the focal point and the driving force of successful fisheries management. However, a process has to be established to bring together the array of disciplines needed to provide the specialist advice and assist in the task of corporate decision-making. In Australia, this has been achieved through the establishment of management advisory committees, which include members from the fishing industry, for the purpose of examining the data available and developing management plans for recommendation to the relevant authority.

The requirements for information about a fisheries resource can be defined in quite simple terms, although the gathering that information is often difficult, time-consuming and costly. The resource must be maintained at or above a level such that average recruitment does not fall as a result of the reduced abundance resulting from fishing; the effect of environmental variability on the level of recruitment needs to be understood and considered in the context of resource abundance; the size at which fish are allowed to be caught needs to take into account the combination of growth and mortality; and the effect of the fishing gear on the abundance of both the target and non target species as well as on the sea bed needs to be understood.

The specialists have an essential role in the provision of information through the advisory committee process. However, they also have a role in assisting the advisory committees to understand elements of the decision-making process, such as fisheries modelling, the need for environmental policies, the use of the precautionary principle, and maximising economic efficiency in the exploitation of fisheries resources.

Use of artificial stimuli for fish harvesting and controlling purposes

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The present range of fishing gears and methods used for harvesting fish can be classified into four categories depending on the techniques for controlling target fish behaviour to assist the capture process. Stimuli resulting in the contrasting reactions of attraction and repulsion elicit directional locomotive responses, while barriers and traps are used to prevent escapement by restricting locomotion and/or confining fish into a limited space. several artificial stimuli are known to increase the catchability of fishing gears, either directly or indirectly. The use of light stimuli is a good example, with reactions differing in size and species, depending on light quality, intensity and some temporal and spatial effects. Light fishing is emphasised to be effective for attracting fish and squid in purse seine, lift net, jigging and angling operations. The repulsion of fish by sweeping lights has been used in some artisanal freshwater fisheries. The use of other lights such as strobe or intermittent lights, acoustics, chemicals, electricity, air bubble curtains and artificial reefs (FADs) will be highlighted, with particular reference to Japanese experiences, both practical and experimental.

Using remote sensing to locate aquatic habitat

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Increasingly, emphasis is being placed on watershed and basin-wide inventory and management. Traditional methods for identifying the location of different types of habitat and the distribution of aquatic species within a basin rely on intensive sampling with aggregation of information. The process is often time-consuming and costly, and can cover only a limited portion of a basin.

Remote sensing, using satellite and aerial photography, offers an alternative method for locating potential aquatic habitat. A Digital Terrain Model (DTM) provides a surface profile of the landscape and can locate stream channels. The DTM also provides information on valley confinement, gradient, and drainage area. Basic channel configurations, particularly those related to erosional and depositional patterns, can be approximated with the DTM. The availability of habitat types and substrates can be approximated from this information, which can, in turn be used to identify potential habitat for selected aquatic species.

For flat terrain, larger aquatic habitat may be identified directly or through identification of riparian vegetation. This is done using colour, infrared or microwave imagery from satellites or aerial photography. The vegetation, particularly riparian vegetation, may also be used to approximate the quality of the aquatic habitat. Information from both the DTM and vegetation models may be used in a Geographic Information System (GIS) with information from other sources to improve the analysis.

As part of the watershed analysis, the DTM was used to locate potential habitat for resident and anadromous salmonids. The DTM proved quite successful in locating potential habitat. Preliminary analysis of imagery to identify riparian communities has been promising, but additional work is needed to improve accuracy of community identification. Using GIS, other factors, such as potential erosion areas and road networks, which influence the availability and quality of aquatic habitat, may be used in the analysis.

Your work is of value, prove it or perish

D. Baker

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Fisheries scientists and managers "know" that their work is critical and beneficial to the natural resource, but to outsiders evidence of this value may not be obvious. Ongoing financial pressures mean that both public and industry funding is becoming increasingly outcome-driven. The performance of fisheries, fisheries management and fisheries research must increasingly be benchmarked with readily understood performance indicators if they are to retain the support of policy makers and the public. Few such quantitative measures are used in the fisheries arena. As a result the work may be overlooked and undervalued in the eyes of society. Benefits of a well devised set of indicators produced periodically would be provision of evidence of:

- effectiveness and/or efficiency of resource use
- need for increased/decreased expenditure resources
- allocation of resources
- trends in service provision
- resource sustainability

Performance indicators must be targeted to the needs of all clients of the service provided, be they industry, recreational fishers, tourists, the general public or politicians. These indicators can take the form of:

- scientific and environmental data (e.g. abundance and health indices, creel surveys, water quality)
- the application of the accounting concept of stocks and flows to these data
- economic measures (e.g. industry performance, labour and capital costs, pollution costs, management costs, tourism impacts)
- social indicators (e.g. public perceptions, values and behaviour)

To be an effective tool, a suite of indicators must be established, indicative of the interests of all clients. The use of multiple indicators will also reduce the risk of a single incorrect measurement providing a false impression. Information would be compiled and reported on an appropriate periodic basis. Variations in the data between periods or from targets should be explained to increase comprehension by laypersons. The use of complementary indicators can assist this (e.g. a decline in angler satisfaction accompanied by lower stock levels).

The greatest potential in the use of performance indicators is on a site-specific and/or project basis. It is at this fine scale that the policy decisions of management are put into practice. Fine scale parameters can then be summed to present a regional or higher level view.

This paper reviews those indicators currently used in the fisheries arena along with those that could be adopted. It will illustrate how this approach can be applied and what the benefits and disbenefits to fisheries scientists and managers could be. This approach is then applied in a local case study on the River Murray freshwater fishery in South Australia, Australia.

Co-management – fact or fiction?

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Objective:

Victoria is pursuing a more co-operative approach to management of commercial and recreational fisheries through the establishment of a co-management framework. The objective is to involve key stake holders in a partnership with the Victorian Fisheries Branch to better manage the State's fisheries resources.

Statement of Findings:

Management of Victoria's fisheries to date has tended to be adversarial with commercial fishing industry complaints that management decisions are imposed following token consultative mechanisms. A similar cry is heard from the recreational fishing sector. Conservation groups do not believe that the Victorian Fisheries Branch gives enough weight to the needs of the aquatic ecosystem and the conservation of marine habitats and fish resources.

Fisheries agencies throughout Australia are committed to the pursuit of fisheries management in accordance with the principles of Ecological Sustainable Development. An ecosystem-based management approach is espoused as part of this approach. This represents a fundamental change to the nature of fisheries management which can only be successful with the understanding and support of key stakeholders.

Co-management provides a framework for better educating stakeholders in ecological based concepts for fisheries management and involving them in the consequent decision making that will be required to achie ecologically sustainable utilisation of fish resources.

Co-management involves stakeholders in taking responsibility for decisions through reaching consensus with other stakeholders having an interest in the future of fisheries. This is a real challenge for co-management participants who must take on the role of "Resource Manager" and be able to explain and defend consensus decisions to their own constituents.

A move to co-management involves creating a climate of trust between a fisheries agency and key stakeholders and developing a co-management framework with transparent decision making based upon equal understanding of the issues.

The delineation of responsibilities between co-management committees and government (through its fisheries agency) is important. Conservation of the resource and protection of the interests of the wider community, as the resource owner, must remain the paramount consideration of government. Co-management committees need to focus on the regulation of fishing activities including resource allocation, harvesting limits and regulatory regimes. Some level of delegation to co-management committees is possible for these areas.

Cost recovery should not be linked to participation on co-management committees. The concept of "the more you pay the more say you have" must be refuted. Stakeholders deserve to participate in resource management decisions regardless of their capacity to pay.

Conclusions:

ESD based fisheries management has the best opportunity of success through working in a co-management framework with key stakeholders.

Key stakeholders involve fisheries agencies, commercial fishers, recreational fishers and conservation groups. Other potential key stakeholders are indigenous people and the aquaculture and processing sectors.

Co-management involves participants taking on the role of "Resource Manager" and operating on a consensus basis.

Education and support to co-management participants is vital so that there are common understandings on the issues involved in moving towards ESD based fisheries management.

The big challenge of co-management is to ensure that stakeholder participation does not result in "client capture" of the process and outcomes. Any linkage between cost recovery and participation on co-management committees need to be vigorously opposed.

"All quiet on the western front" – the application of war and peace strategies in fisheries management

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'Nothing was of any avail; each measure or step he took was looked upon as the evil invention of a lot of idle civil servants, who were having their salaries paid by the people whom they then proceeded to persecute.' Strindberg, 1849–1912

This paper seeks to show the effectiveness of the application of classical and modern military strategy to real-life fisheries management situations; and to develop a consultative framework for the peaceful resolution of fisheries management issues.

Even one hundred years ago Strindberg recognised the difficulty in implementing new management arrangements for fisheries where the local fishers did not support change. Fisheries managers are finding that their 'prime directive' – to ensure that there is sustainable use of aquatic biological resources – is being overridden by the actions of lobbyists, axe grinders, schemers, politicians, etc. etc. With limited tools in their tool boxes (predominantly based on the application of the 'rational decision-making' paradigm), the fisheries manager's management solutions are increasingly failing to deal adequately with the complexities of the problems they encounter. Attempts to balance biological, economic, social, political and other imperatives fail and they find that their decisions are subject to a barrage of assaults each seeking to weaken the impact of the decision on the disaffected individual or group concerned.

This paper demonstrates that the modern fisheries manager can learn much from classical and modern military strategic thought. A series of case studies is presented on current fisheries management issues in Australia. The approaches taken by the various combatants are then related to the 2,000 year-old writings of the Chinese warrior-philosopher Sun Tzu which highlight the effectiveness of strategic assessments; doing battle; planning a siege; formation; force; emptiness and fullness; armed struggle; adaptations; manoeuvring armies; terrain; nine grounds; fire attack; and the use of spies. Along the way comparisons are also made with more recent military strategic thought.

The problems facing fisheries managers are categorised into simple problems, compound problems, complex problems and meta-problems, and then how each problem should be approached, is demonstrated.

Noting the turbulence encountered by fisheries managers in seeking to effect management changes, contingency theory and crisis management techniques are used to demonstrate how uncertainty can be managed in fisheries management situations.

A different 'spin' in respect of developing a mechanism to resolve the consultation nightmare. This paper looks at the bureaucratic means of avoiding consultation, followed by an outline of a series of consultative strategies, against which the current Management Advisory Committee approach seems cumbersome and dysfunctional.

The view is held that, while there are no easy solutions to the problems fisheries managers face, there is a range of strategies for dealing with these problems which at the end of the day are the solutions which were being sought.

By the end of the paper the reader will have rediscovered the guile of classical military strategy and its uses in dealing with conflict in fisheries management, and will have a clear understanding of how to deal with the different types of problems encountered and an ability to recognise and deal with uncertainty and crises.

Most importantly, there will be a clear understanding of the vast array of tools available for developing a consensus amongst groups being dealt with and for recognising and avoiding the bureaucratic non-participation approaches to consultation.

Use of ecological and genetic data as a basis for multi-jurisdictional fisheries management

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Population levels of western Atlantic American shad, *Alosa sapidissima,* have been depleted since the 1970s when recreational and commercial fishing moratoria were imposed within the tributaries of several U.S. states. Since that time, fishing effort has been redirected toward migrating or overwintering shad from the coastal mid-Atlantic causing political and social concern for the potential effects of ocean harvesting on shad from Chesapeake Bay tributaries and other managed stocks.

American shad populations in virtually all Chesapeake Bay tributaries and in most other east coast drainages are presently in a state of serious decline. Along the Atlantic coast, declines have been linked to overharvest by natal and ocean-intercept fisheries, water quality degradation, and

loss of essential spawning and nursery habitat due to blockage by dams and other impediments. A more recent hypothesis for the decline is that colder than normal winter and spring water temperatures since 1990 may have disrupted spring migration patterns or displaced stocks to areas of high predation and/or poor food availability. Other studies suggest various relationships between spawning stock size, year class strength, and recruitment success. Accurate assessment of the effects of riverine and coastal-intercept fisheries is heavily dependent on determining the relationships among environment, stock size and recruitment success.

Several means have been investigated to discern the composition of the coastal harvest. Physical tagging provides only limited information on the origin of coastally harvested shad because of the moratoria on directed fisheries in rivers. An alternate means is genetic mixed-stock analysis. This strategy works because for many anadromous species, including American shad, high fidelity for the natal river results in segregation of genotypes among rivers over time. As a result, different rivers are characterized by distinctly different and stable assemblages of genotypes. Both genetic and tagging estimates for the origin of U.S. east coast shad concur, indicating the presence of shad from southern stocks (e.g. Santee River) and from northern stocks (e.g. St. Lawrence River) off the coasts of Virginia and Maryland. Data indicate that harvests south of the Chesapeake Bay mouth are composed primarily of lower Bay and southern stocks while harvests along the Delmarva peninsula contain northern and southern stocks and, periodically, significant quantities of Susquehanna shad. Beyond these general patterns, the coastal harvest is composed each year of different quantities of various stocks rendering it impossible to accurately predict the composition of future shad takes.

Using the available ecological and genetic data, management scenarios are limited to three possible options. The first requires no action other than to terminate the coastal intercept fisheries. As a less drastic measure, F_{max} is calculated for each stock. Coastal quotas are then instituted, based on harvest rates (identified by the genetic mixed-stock analysis) for the most depressed stocks. A final option is to implement a genetic monitoring programme during each coastal fishery to track total harvest composition. Coastal harvest would then be closed when the target level set for any component stock is reached.

Conflicts in fisheries: an integrative approach, with management options

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Fisheries have become infamous for feuds over fish, fishing rights and allocation of those rights. As fish resources deteriorate, conflicts over access rights grow ever more bitter. This is especially the case where the sustainability of the resource and therefore livelihoods become threatened. Arguably, the worst-case scenario occurs in the developing world where there are few, if any, alternatives to fishing and where the conflict is often between the traditional small-scale sector and a more powerful large-scale sector. The work reported in this paper investigates the fishery of San Miguel Bay, the Philippines, and develops an integrative approach to the analysis and management of fisheries with such conflict.

The initial premise of the work is that fisheries involve people and that people tend to behave in a manner that is optimal for them. By allowing that people will optimise, various outcomes can be expected regarding rule obedience. Indeed, where there is conflict in a fishery, rule breaking will inevitably occur. Management strategies must therefore explicitly consider the likelihood that rules will not be followed. The second premise is that the natural resource must be managed sustainably. The third premise is that factors such as economics and politics exert a strong influence in fisheries and on fisheries management.

The objective of this work is to bring these three premises together using decision analysis to design management strategies that will reduce conflict and enable sustainable exploitation. This versatile method allows each premise to be explicitly considered in relation to an array of adaptive management strategies, developed through analysis of the fishery using ecosystem modelling (ECOPATH II), semi-quantitative multi-species fishery modelling and economic analysis.

The results confirm that the San Miguel Bay fishery suffe from ecosystem overfishing, that the small and large-sca.. sectors have differential effects on the ecology of the stocks and that the exclusion of some of the small-meshed gears from both the large and small-scale sectors would reduce growth and recruitment overfishing. Previous work has shown that the most capital intensive part of the large-scale sector has already quit the fishery due to lack of profits. Moreover, fishers in the small-scale sector are having to find more of their income from activities outside fishing. Adaptive management strategies, aimed at testing hypotheses about the resource and reducing conflict, included a total ban on all trawl fisheries (large-scale) and a ban on all small-meshed gears. Decision analysis shows that a total ban on trawl fisheries is not acceptable. However, the analysis also indicates that a combination of measures can be developed whereby fishing mortality on juveniles could be reduced, the catch of the small-scale sector might be increased and greater equity in distribution of benefits from the fishery would be achieved.

The key conclusion is that for practicable sustainable management and conflict resolution to occur, methods such as decision analysis that explicitly consider the behaviour fishers, economic and political factors and the ecology or the resource must be used.

Fishcount '95: an innovative design for collection of recreational fisheries data

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Apart from studies to collect base-line participation rates, conventional population survey methods have had limited application in recreational fisheries research. Where detailed catch and effort data are required, on-site creel surveys are usually the preferred method – especially in terms of species identification and reporting bias. However creel surveys are an inherently expensive method with which to collect total catch and effort data at the State or national level and these costs are clearly prohibitive.

After several years of development and field testing, an innovative research method is being employed in the Northern Territory, covering the entire recreational fishery.

Using a unique combination of research methods, the survey provides exceptional cost-effectiveness for a broad range of recreational fishery data. Participation rates, targeting, catch, effort and an array of socio-economic data are collected with the capacity for extensive disaggregation for variables such as species, seasons and geographic regions. Using stratified sampling of the general population (telephone interviews for resident households, face-to-face for tourist accommodation sites), the method comprises three stages: (i) an initial 'screening' interview to identify angler households; (ii) a subsequent four month *longitudinal* survey for anglers, where fishing activity and related expenditure are collected through regular diary contact calls; and (iii) awareness and attitudinal questioning for various fisheries-related issues. Commenced in October 1994, the survey will continue for more than a year, using a monthly 'wave' sampling system to cover seasonality. At the time of writing, eleven 'waves' of enumeration have been successfully completed, with response rates consistently around the 90% level.

Clearly, a most important contributor to this outcome has been the primary design philosophy of absolute minimisation of respondent burden (a problem with logbooks generally), and especially in the diary phase of the study. For example, anglers need only diarise those details of their fishing activity that they would be unlikely to otherwise recall. Similarly, the four month diary period represents a practical maximum in terms of respondent fatigue. Yet, simplicity for the respondent naturally translates to substantial responsibilities on the part of the interviewer and these have been addressed through careful staff recruitment, training and management. Additionally, a rigorous approach to other design aspects has resulted in a range of quality control and validation measures to address various response biases and other sources of non-sample error (e.g. *prestige* bias, species misreporting etc.).

The results of the survey will provide a detailed understanding of the recreational fishery in the Northern Territory, and for the first time, on a *total fishery* basis. This will allow informed decision-making by fisheries managers, the identification of research priorities and monitoring of the recreational sector. Because of the survey's cost-effectiveness in the Territory, it also has widespread potential for use by fisheries organisations elsewhere and overseas, where larger populations exist and there are, therefore, greater economies of scale in sampling.

Environmental impact assessment and other regulatory mechanisms: approaches to fisheries protection and mitigation in Senegal and Indonesia

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Two recent studies, one in Senegal and the other in Indonesia, provide valuable lessons for protecting fisheries resources. Lessons learned are diverse and show that varied approaches need to be utilized. As is typical in many Western settings, fisheries personnel had little to do with basic fisheries protection and resources utilizing systems at village country levels were necessary.

In Senegal, under the Environmental Assessment and Comprehensive Research and Monitoring Plan for the Southern Zone Water Management Programme (SZWMP) for the U.S. Agency for International Development, major issues were raised with respect to the loss of fisheries habitats because of the building of dikes throughout the Casamance River system (southern Senegal). The SZWMP is designed to relieve some of the food deficit in Senegal, by a series of construction and training interventions in the Casamance River system. It includes: the addition of fresh water retention and salt water detention dikes, a series of field berms and development of private initiatives as well as village participation in the activities.

The author worked with the Government of Senegal and the Senegalese Institute for Agricultural Research (ISRA) to develop a model programme for the study of tropical river systems. Impacts of the programmes with respect to socio-economics (e.g. villagers' responsibilities for fishing, handling of aquaculture facilities, value to particular groups for feeding, maintenance, etc.), changes in water quality (particularly with respect to the rainy season) and loss of particular species of fish associated with specific habitats were examined. Results showed the loss of fisheries utilizing valley habitats (probably during the rainy season) and the need for fish aquaculture programmes (and appropriate methodologies for implementation).

In Indonesia under an Environmental planning project for the Republic of Indonesia Environmental Impact Management Agency (BAPEDAL) the author is working to develop appropriate water quality standards throughout Indonesia for protection of environmental resources. Comprehensive assistance in identifying needs for environmental laws, implementation of the environmental testing laboratories through regional BAPEDAL groups, the need for laboratory facilities, standard operating procedures for environmental testing, laboratory certification programmes, QA/QC programmes, information management systems and training programmes all were necessary to begin to put in place protection mechanisms for fisheries.

Incorporating risk in a bio-economic analysis of the orange roughy fishery

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The objective in this paper is to describe a modelling technique that incorporates risk analysis into a bio-economic model. The technique was used to analyse potential harvesting strategies for orange roughy (*Hoplostethus atlanticus*) caught in the south east fishery.

The south east fishery is a multi-species fishery managed by the Australian Fisheries Management Authority (AFMA). Since 1992, sixteen species (or species groups) in the south east fishery have been managed by specifying a Total Allowable Catch (TAC), allocated to operators as an Individual Transferable Quota (ITQ). For orange roughy, AFMA sets the TAC with the objective of maintaining the stock at approximately 30 per cent of pre-fishery biomass with a greater than 50 per cent probability.

The model is used to compare the payoffs and risks associated with alternative TAC levels under two stock assumptions. First, that orange roughy comprised two separate genetic stocks and second, that they comprise a single genetic stock. Profit estimates enable alternative strategies to be evaluated against the fisheries management objectives of sustainability and efficiency.

The model was used to estimate the total catch in each year that would maximise the present value of gross margins over a period 1995 to 2004, while maintaining the biomass of orange roughy at or above the biological reference points of 0.20, 0.30, 0.40 of pre-fishery biomass respectively. In addition, four harvesting strategies proposed by AFMA were simulated and the payoffs and risks associated with each of these were determined.

From the harvesting strategies generated under varying levels of reference points, except in the case of the southern zone, the 0.30% reference point results in the least deviation from being at or above 30 per cent of the pre-fishery biomass with a greater than 50 per cent probability by 2004. The main features of the results show a high level of catch in 1995, and then sharp declines and steady rebuilding to 2004. This reflects the effect that discounting has on fishery behaviour, while still retaining characteristics of stock rebuilding.

From the four predetermined AFMA strategies, under the separate stock assumption, except for one, all have a biomass that is greater than 30 per cent of pre-fishery biomass with a greater than 50 per cent probability by 2004, suggesting that the AFMA strategies were conservative under this stock assumption. Under the single stock assumption, this is true for only two of the AFMA scenarios.

The incorporation of risk in the analysis gives managers a set of outcomes with their associated probabilities. In the scenarios where the strategies have been generated subject to meeting specific reference points, the results give managers some indication of what reference point is appropriate for managing the fishery.

Bio-socio-economic approach in the assessment and management of the purse-seine fishery in the south-west coast of Sri Lanka

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The small pelagic resources in the coastal waters of Sri-Lanka are mostly exploited by the small-meshed gill net fisheries . However, the rapid development of a purse seine fishery in the mid 1980s along the south-west coast led to several fishing conflicts . A study was therefore carried out from October '91 to February '93 with a bio-socio-economic approach, particularly to understand the effects on income distribution and the socio-economic impact of alternative management measures .

An awareness programme was initially carried out for the fishing communities in the study area to explain the objectives of the project. Bio-economic data were collected from the major fish landing sites by making fortnightly visits. The socio-economic data were collected through a frame survey followed by a systematic survey of the randomly selected households. All the data collected were processed through the computer programmes developed for this purpose. Analyses of biological parameters were carried out by using the fishery software packages ELEFAN and LFSA.

The purse seine fishery is a seasonal operation carried out within the depth range of 36 – 62 m by the 3.5 t crafts using nets of 200 m long and 50 m deep with 16 – 23 mm mesh size. In October 1991 there were 69 purse seiners in operation in the study area. The total production from the purse seine fishery was estimated at 615 t in 1992. The average catch per fishing operation during this period was 101.8 kg. *Amblygaster sirm* (pilchard) represent 48% of the purse seine catch followed by 28% squids. The size range of *A. sirm* was 5.0 – 24.0 cm with 87% of the catch consisting of fish larger than 15.2 cm.

The average monthly income and expenditure from this fishery was SLRs. 81653/= and SLRs. 13060/= respectively. The owner, skipper and the crew members each received an income of SLRs. 36045/=, SLRs. 5194/= and SLRs. 3463/= respectively. The socio-economic data revealed that more than 60% of the households engaged in purse seine fishing get income from other fishery and non-fishery activities.

Though the Thompson and Bell prediction analysis sho that the present fishing effort could be increased to produce more fish and attain an MSY of about 1000t and an MEY of SRLs. 40 million, it is not advisable , as it would reduce the catch per unit of effort, thereby making the operations less profitable and may also affect recruitment and yield for other fishing methods.

As the conflict was not due to a fish resources problem but may be due to social reasons it needs to be solved by measures equitable to all and sundry in the fishing community. Therefore several alternative management recommendations are suggested in the paper.

Geographical Fisheries System (GFS): visualising fisheries data

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As part of a research project on a prawn (shrimp) trawl fishery in the Turtle Group region of north-east Queensland (Australia), an interactive, animated computer model for visualising fisheries data has been developed. The Geographical Fisheries System (GFS) is designed to assist fisheries management decision-making by providing users with a better understanding of the fishery. GFS has detailed on-line help, full colour graphics and is an easy to use Windows application. Users can interact with animated analyses by clicking objects to display more detailed information. GFS includes the following features:

- The facility to track the movement of objects (e.g. tagged prawns) through time on a map
- Thematic mapping functions such as displays of prawn densities at different sites through time
- The facility to modify trawl closure lines and view differences between closure options
- Data can be imported from a range of sources for thematic or tagging analyses
- Maps can be imported from MapInfo.

The "Turtle Group Release" of GFS is supplied with the following interactive, animated sample analyses based on data collected in the Turtle Group region in 1993 and 1994:

- Tiger prawn movement from tagging studies
- Commercial prawn densities and species and size composition
- Juvenile prawn densities and species composition.

The following maps are also provided with GFS:

- A basic world map
- A basic map of Australia with a detailed section of coastline and coastal waters in the Turtle Group region.

The PrawnEd educational module is also supplied with GFS. This is an intuitive, "point and click" application intended to provide a general audience with basic information about prawns and the fishery in the Turtle Group region. PrawnEd contains:

- General information about commercial prawns in the Turtle Group region
- Meteorological information from the Turtle Group region
- Prawn distributions in Australian waters
- Summarised prawn size information for the Turtle Group region
- Prawn life history information
  atch and effort information for the prawn fishery in the Turtle Group region.

A Web version of PrawnEd is also available on the Internet at http://ensis.nth.dpi.qld.gov.au or http://131.242.111.20.

The socio-economic effects of longlining versus trawling, and of exploiting bycatch, on the South African economy and grassroots fishing communities

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Longlining as a generally accepted manner of fishing has not yet been introduced in South Africa. A relatively large portion of bycatch from trawling is still being discarded for economic and other reasons. Large industrial fishing companies have over the years invested heavily in boats, equipment and processing facilities on land. The socio-economic well being of fishing communities at grass roots level seems to have been neglected during the decades of exploitation of the resource.

A research project involving these matters is being conducted over a period of three years. There are two major task groups involved namely, the socio-economic team and the marine biological team, working in conjunction. This presentation deals with the first of the two.

A computer model has been developed through which the economic desirability of the two methods of fishing can be compared. Socio-economic matters stemming from the two methods of fishing and of dealing with bycatch have been identified, such as the influence on the fisher communities, on quality and marketing of the catch, concentration of economic power in the industry, wastage of the resource, influence on job creation and several others. An international comparison of these matters is also in progress.

The preliminary results indicate in favour of longlining, and of decreasing the extent of wastage of bycatch, both being of economic and socio-economic importance. A mutual opinion between the two task groups is in the process of being formulated.

The socioeconomic effect and implications of fishermen's community trusts in South Africa

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Various incidents, which gained extensive media coverage, of protest and even violent action associated with the existence of Fishermen's Community Trusts, gave rise to an in-depth academic investigation of the matter. The Trusts caused rifts in certain communities. Mass action over matters concerning Fishermen's Community Trusts resulted in a number of incidents of violence where the police had to be called upon to restore order. The Offices of the Chief Directorate of Sea Fisheries were occupied on more than one occasion and two incidents of physical assault were reported by the media.

In certain circles, decisions of the Quota Board have been regarded as politically motivated and the awarding of quotas has been strongly condemned. There are those who believe that quotas should be granted primarily to those who "wet their hands in the sea".

Against this background a task group was appointed to investigate the matter and to make recommendations for dealing with it in a manner acceptable to all parties concerned.

The research came up with definite conclusions and recommendations on the following aspects:

1. The operation of fishermen's community trusts with regard to election, constitution, administration, financial management, malpractices, project management and acceptability of the concept. Many shortcomings in the existing procedures were uncovered and commented upon.
2. The reasons for conflict in fishermen's communities, such as inadequate infrastructure, complexity of urban communities, politics, quality of trustees, communication, and many more were identified.
3. Who are the real fishermen who should benefit from the Trust? Those that actually go to sea, those working in processing plants on land, dependents or those creating the infrastructure in the community such as religious and social workers, teachers, health service workers and other community services?
4. Socio-economic benefit and desirability of such Trusts. Responses to questions as to whether the Fishermen's Community Trusts are of any socio-economic benefit to society at large, communities and whether they should be maintained, were varied. The research recommendations are quite specific that there are definite benefits to be derived and that the system should be continued, albeit in a different format.
5. The manner by which benefits should be made available to communities. The most popular manner of distribution of benefits is through direct cash handouts to the beneficiaries. The research, however, pointed out that the negative consequences of handouts greatly outnumber the positive effects and recommended against them.

6. Alternative dispensation which could replace the current system, namely the introduction of a Mother Trust to oversee the operations of the individual Trusts. The appointment of the Trustees, functions, funding, operations and responsibilities of the Mother Trust are specifically outlined.

International application of the findings and recommendations are to be found in any fishing community, especially in developing countries, where the social and economic development of the grassroots fishermen is lacking. The recommendations of the research are in the process of being evaluated and at various stages of being implemented in South Africa.

The effect of netting strategy on shark attack risk: is it predictable?

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Since 1952, set gillnets with a 50.8 cm mesh size have been used off the coast of KwaZulu-Natal (KZN), South Africa, to reduce the frequency and risk of shark attack. OLRAC was contracted by the Sharks Board to study the relationship between shark attack risk and netting strategy and to quantify the additional risk associated with the deployment of fewer nets.

OLRAC's objective was to produce a "simple" quantitative decision-making tool which would enable the Board to evaluate a variety of netting options. The nets reduce the risk of shark attack in three ways; (a) by reducing the population size of dangerous sharks – the so-called "fishing effect", (b) by reducing the residence time of sharks in the vicinity of swimming beaches by virtue of their ability to entangle sharks – the "capture effect", and (c) by presenting a physical obstacle to sharks, thereby reducing the possibility of them approaching bathers – the "barrier effect". Circumstantial evidence for the existence of a barrier effect is the 65:35 ratio of sharks caught on the offshore *versus* the inshore side of the nets. OLRAC studied the possible scale of the barrier effect by means of a vector-based spatial computer model which simulates the pattern of movement of sharks in and around the net installation, the response of sharks to encountering a net and the probability of entanglement versus avoidance behaviour. Although very little is known of these processes, it was possible to explore a range of shark convection models, with a view to determining whether there were any persistent results which arose regardless of the detailed assumptions used in the model. The model is able to produce the resultant inshore versus offshore catch rate for comparison with observations. Shark movement is assumed to be governed by a random component and a fixed directional component. Different combinations of random and fixed movement were explored in order to see whether any robust results emerged about the relative importance and scale of the barrier effect versus the capture effect.

The model was modified to use detailed spatial information on four net installations along the KZN coastline. The results show that the nets only result in a reduction in risk of attack in certain regions of parameter space. Some of the results are indicative of a barrier effect of the order of 50-80% (i.e. a reduction in risk due solely to this factor); others suggest that the capture effect is large and outweighs the barrier effect. It is evident that strong onshore convection can, within the framework of the spatial model, lead to the entrapment of sharks in the swim area in between the high water mark and the nets, leading to an increase in risk of shark attack. Furthermore, risk decreases substantially as the probability of entrapment increases. An encouraging feature of these results is the fact that the percentage of sharks captured inshore of the nets is close to the empirical figure of 35%.

The relevance of this work for the potential to reduce netting effort may depend very heavily upon the extent to which the fishing effect of the nets has already reduced local shark populations.

Ownership and management of traditional trochus fisheries at West Gela, Solomon Islands.

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The objective of the present study was to examine a number of factors which affect trochus (*Trochus niloticus*) management in a maritime subsistence community at West Gela in the Solomon Islands.

These include:

1 The rules of inheritance and ownership which regulate who claims/is allocated responsibility for managing stocks on various reefs.
2 Traditional Ecological Knowledge (TEK) regarding trochus emergence patterns, abundance and factors contributing to mortality;
3 Social and economic pressures on members of the community which affect compliance to fishing prohibitions;
4 The relative importance of trochus as a cash earner in the local economy.

The above parameters are examined in the light of stock abundance data obtained using the Petersen mar[k]-recapture technique, which has been successfully trialed [on] trochus stocks at Aitutaki.

At West Gela, sedentary reef resources are owned and managed according to rules of Customary Marine Tenure (CMT). As with many other ownership systems in Melanesia, reefs, including offshore ones, are regarded as an extension of the land and subject to the same rules of ownership and inheritance. The traditional trochus harvesting system used at West Gela is one of serial prohibitions on harvesting, usually lasting from three months to one year, terminated by a community harvest which usually lasts from one to six days. This system lends itself perfectly to accurate stock assessment using the Petersen mark-recapture technique.

A case study of a land dispute, in conjunction with other data on land and reef tenure, demonstrates that, due to the dominant virilocal marriage pattern (which results in most women moving away from the land and reef that their children will inherit) and formalised (but often undocumented and/or poorly remembered) mechanisms of land transfer ("Huihui"), disputes regularly arise over rightful ownership of resources. However, most disputes do not arise until a significant amount of money comes into play, such as in the case of a major development. In other

words, violations of CMT are common, but are tolerated if there is little at stake.

TEK pertaining to trochus is restricted to the following assertions: 1. Emergence is highest between two and four nights after full moon; and 2. If prohibitions are left for too long, too many shells are lost to hermit crab predation or boring polychaetes. These assertions are still under investigation. However, data on harvesting patterns indicate that harvests are not necessarily timed to coincide with the perceived emergence peak after full moon.

Financial pressures often motivate violations of fishing prohibitions, sometimes by members of the ownership group. Trochus typically ranks between 2nd and 4th in importance as a cash earner in most villages. Other important cash earners include an artisanal reef fishery, aquarium fish and garden produce. Size-frequency and stock density data indicate that trochus on many reefs are overfished compared with fisheries on the Great Barrier Reef and in other parts of the Pacific.

The relative importance of the various parameters detailed above is analysed for each village and for the area as a whole.

Industry must be part of the fisheries management system

M.R. France

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Is it a Freudian slip or did the organisers of this Congress who were responsible for the selection of this theme intentionally leave out INDUSTRY when deciding the various roles in fisheries management?

This is no surprise to me after spending a lifetime in the fish business to encounter another occasion when the so-called strategic thinkers, (e.g. scientists, bureaucrats, conference organisers and politicians) seem to overlook the vital role the industry plays in management until they are reminded. Then the reply is usually a paternalistic "of course we haven't forgotten you".

I am going to speak about the role of industry in fisheries management and hopefully impress on this audience the importance of always including industry whenever fisheries management matters are discussed. You might be surprised at the pleasing results.

I have been involved in most facets of fisheries in Australia and overseas, including having spent many years at sea. Any profits that I have made have been reinvested in the fishing industry. To me and most people referred to as INDUSTRY we seek a return on our investment of money and time. We believe we are entitled to earn a profit – albeit that seems to be a dirty word in many quarters.

Because of their heavy financial investment in the fishing industry, fishers are the original conservationists. They are not short sighted rapists and pillagers. They are very much interested in tomorrow.

Good fishers by nature are fiercely competitive and independent and therefore do not easily respect excessive constraint. But they will accept regulatory control if they have been part of the consultative process.

Fishers are surprisingly innovative and can often circumvent surveillance and enforcement regulations that are dreamt up by theorists. The way to discourage such practices is to make fishers part of the decision-making process.

Fishers usually know more about the resource than many scientists and the industry definitely benefits when fishers and biologists work together.

When the fishing industry unites it can apply enormous pressure on the management and political system.

The often quoted and seriously misguided philosophy that fisheries are a common property resource is the root cause of many of the problems. Who is accountable?? If fishers had clearly defined property rights many of the past problems would not exist. It is only when the fishing industry is given the trust and responsibility it deserves that it will protect its investment, take tough decisions and achieve the best outcome.

The Northern Prawn Fishery (NPF) is one interesting case study of all the things we should and should not do. During the early years the Government virtually ignored the industry and established management regimes that resulted in the usual over-capitalisation and effort blowout. The industry was fragmented and suffered huge financial losses. The industry got together and, working with government and scientists, overcame many of the problems and restructured the fishery into one of the pacesetters in fisheries management in Australia and around the world.

Examination of the initiatives taken to provide for a sustainable Northern Prawn Fishery and a glimpse into potential problems in the future demonstrate the essential element of industry in the management decision-making process.

We should learn from past experience when planning for the future, but I often wonder if we do.

The use of DNA markers in the determination of stock structure of the four-wing flyingfish, *Hirundichthys affinis*, and its implications for fisheries management in the central western Atlantic

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The four-wing flyingfish, *Hirundichthys affinis*, is a commercially important species in the eastern Caribbean Islands, in the southern Netherlands Antilles and in Brazil, although it remains unmanaged. An important prerequisite for determining whether management should be international, regional or island-specific is a knowledge of the stock structure of the resource. Previous tagging studies on *H. affinis*, in the central western Atlantic have indicated that flyingfish move freely between the eastern Caribbean Islands, although they do not appear to travel as far as the southern Netherlands Antilles, but were inconclusive for flyingfish tagged off Brazil since recapture rates were low and the average time at large was only three days. However, tagging studies do not indicate whether individuals found in

the same area interbreed and therefore whether or not they belong to genetically discrete stocks.

In this study, 60 spawning flyingfish were sampled from the populations in each of Dominica, Barbados and Tobago (in the eastern Caribbean), from Curaçao (in the southern Netherlands Antilles) and from Caiçara in Rio Grande do Norte, Brazil from April to August 1995. These were analysed using Restriction Fragment Length Polymorphisms (RFLPs) of the hypervariable mitochondrial D-loop region using the Restriction Fragment Analysis Programme (REAP) in an attempt to determine the genetic variation within and between samples. Ten restriction enzymes were screened for usefulness and of these, five were used on the D-loop region amplified from liver DNA samples. Nucleotide diversity was very low among individuals within populations. However, nucleotide sequence divergence revealed significant genetic distance. Genetic distance between the sampled populations in the eastern Caribbean was considerably smaller than the genetic distance between the sampled populations in the eastern Caribbean, southern Netherlands Antilles and Brazil, indicating that *H. affinis* from the central western Atlantic comprises three distinct unit stocks. This implies that flyingfish management will need to be regional in the eastern Caribbean since the separate island states appear to be sharing a common stock and regional in the southern Netherlands Antilles, while flyingfish management in Brazil could be nation-specific.

The joining of provincial government, sportfishing industry and fishery management to help conserve istiophorid stocks

D.L. Hammond

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The South Carolina Governor's Cup Billfishing Series is a cooperative effort by provincial government, industry developers and fishery managers to enhance the state's offshore sportfishing industry while conserving fishery resources. The goals of the programme are:

1. to foster coastal economic development through the promotion of the offshore sportfishing industry
2. to conserve the billfish (Istiophoridae) and other oceanic pelagic gamefish stocks and aid fisheries management through the promotion of tag and release fishing
3. to generate financial support from the private sector for marine fisheries conservation work

The idea for this programme was conceived by former state governor Carrol Campbell. He assembled a panel of top businessmen with interests in offshore sportfishing to work with the South Carolina Department of Natural Resources and the South Carolina Department of Parks, Recreation and Tourism to develop and implement such a programme. The programme utilised the prestige and influence of the Governor's Office to elicit financial support from private industry and to encourage sportfishers to practise conservation by tagging and releasing billfish and other oceanic pelagic gamefish.

The Governor's Cup is an umbrella event of sportfishing competitions, linking six independent billfish tournaments into one overall programme. Participating boats earn points for each billfish tagged and released and for one billfish brought to the dock in each event to determine the overall winners. The Series provides the individual events with extensive national and regional advertising which they could not afford and provides incentives for more boats to participate in their event. In return, the tournaments have to adopt strict conservation standards and operational guidelines set by the Series and to contribute money to a special marine fisheries conservation fund pro rated on the number of boats in their event.

Completing its eighth year, the programme has been a big success. Participation in Series tournaments has reached a near maximum level and charter boats are reporting a significant increase in the number of bookings annually to fish specifically for billfish. The increased charter business together with a dramatic increase in the number of private boats fishing for and catching billfish off South Carolina has served to stimulate the coastal economy.

The programme's effectiveness can best be seen in the conservation of billfish. Prior to the inception of the programme in 1988, South Carolina sportfishers released less than ten percent of the billfish caught with few being tagged. In 1995, slightly over 95 percent of all billfish caught were released alive with virtually all being tagged for science. As a result of this tagging, recaptures have been reported from three foreign countries including the first Atlantic trans-equatorial recovery.

During its eight years of operation, over $US380,000 have been raised through grants and private donations. These funds provide full financial support for the programme's operation as well as supporting other marine conservation efforts such as artificial reef construction and applied research.

This programme has successfully blended the influence of provincial politics with industry development to enhance the coastal economy. It has provided incentives for fishers to reduce the kill of billfish associated with competition fishing, setting an example which non-competitive sportfishers have also embraced.

The EchoListener: a low cost and high resolution acoustic data logger for fishers, marine scientists and hydrographers

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The SonarData EchoListener is a digitising data logger for logging and displaying high resolution digital echogram data. The echogram data are suitable for various analyses including bottom detection for hydrographic surveying, echo integration for fish biomass estimation and pulse shape analysis for acoustic bottom classification.

Hydroacoustic echo integration, for example, is a major field technique for assessing the distribution and biomass of fisheries resources over a large range of spatial and temporal scales. However, the requirement for expensive and complex equipment has meant that such survey techniques have only been available to well funded organisations with good technical support. The EchoListener was specifically developed by SonarData Tasmania P/L as a low cost, portable system which is attached to an existing commercial or scientific echosounder. EchoListeners fitted to fishing boats have been used to record high quality echograms for the estimation of the biomass of spawning blue grenadier

(*Macruronus novaezelandiae*) in deep water off the coast of Tasmania. The EchoListener is ideal for upgrading existing scientific echosounders that currently log only processed data such as echo integration results or seabed depths together with a grey scale chart recording.

The EchoListener is a passive device that "listens" at the transducer of the host echosounder, detecting both the transmit pulse and the scattered signal. The EchoListener compensates the scattered echo for variations in the transmit power of the echosounder, thus enabling quantitative data to be logged from commercial "fishing" echosounders as well as scientific echosounders.

The EchoListener consists of an analog electronics unit that contains only a single circuit board and software for logging and replaying digital echograms on a personal computer. The analog unit comprises filtering and envelope detection electronics and a 12 or 14 bit Analog to Digital Converter (ADC). The unit can digitise the detected-envelope from echosounders operating in the frequency range 12 to 120 kHz. The unit detects the transmit pulse of the echosounder and measures the peak voltage. It then digitises the detected elope at a sampling rate determined by the echosounder frequency and choice of ADC. The raw data are averaged into 500 bins per ping over a specified depth (time) range to form the digital echogram. The raw digitised data can also be recorded for later analysis. The detected-envelope voltage is measured with an instantaneous dynamic range of either 36 dB or 42 dB depending on the choice of ADC. Gain and filter bandwidth are controlled from the logging computer and amplifier saturation is automatically detected.

Echograms are displayed in real time on a computer screen using 12 colours to represent 3 dB steps above a nominated threshold in scattered signal strength. Calibration of the EchoListener using the suspended calibration sphere technique is simplified through the use of a digital oscilloscope display for determining the peak on-axis gain. Echogram data from the EchoListener are compatible with the data formats used by leading scientific echosounders, enabling EchoListener data to be processed using existing commercial packages.

The EchoListener represents the application of relatively simple analog electronics and software powered by an xpensive personal computer to log acoustic data of a quality and resolution previously offered only by expensive scientific echosounders. The EchoListener can put simple but powerful acoustic techniques in the hands of scientists, hydrographers or fishers who have previously been denied access to acoustic tools by the extremely high price of scientific echosounders.

Can the recreational fishing community be used to collect information suitable for fisheries management decision making?

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Fisheries management agencies often use catch and effort information collected by the fisheries to formulate management policies. This information is not only a cost effective means of monitoring trends in catch characteristics of fisheries, but also a means of involving fishers in fisheries management. The "REEF FISH" database consists of over 2,400 individual fishing trips to the Great Barrier Reef. It provides a history of fishing activities and catch characteristics of reef fishing clubs in the Great Barrier Reef region. Competition records supplied from amateur angling clubs operating from their own, or charter vessels, form the basis of the REEF FISH database. These records date from 1957 and provide information from 41,884 angler days fishing effort. The objectives of this study were: i) to characterise fishing activities of suppliers of information to REEF FISH; and ii) to identify regional trends in catch rates, average fish weights and catch composition.

All of the major suppliers of information to REEF FISH operate their fishing competitions to strict sets of rules that regulate the fishing activities and gears used by participants. A survey of two amateur angling clubs in the Townsville region found that approximately 75.4% of the total catch by number was retained by anglers for consumption and recorded in competition records. A further 13.7% of the total catch was released alive and 8.2% was used for bait. The remaining fish were retained for biological samples.

Catch statistics obtained from the REEF FISH database show a clear latitudinal gradient in average catch rates with Cairns, Townsville, Mackay and Rockhampton regions recording catch rates of 2.9, 7.4, 11.3, and 15.6 fish per angler day respectively. Average size of fish decreased over the same range from 2.7 to 1.1 kg cleaned weight. From 1961 to 1986, catch rates of coral trout (*Plectropomus* spp.) and sweetlip emperor (*Lethrinus miniatus*) remained consistent in the Townsville region. Average fish weight over the same period, however, decreased significantly. Lutjanids (mainly *Lutjanus sebae, L. malabaricus* and *L. erythropterus*) became increasingly important components in the catch from 1989 onwards in the Townsville region. Lutjanids, captured in deep inter-reefal waters, now contribute over 50% of the annual catch recorded by clubs that provide information in the Townsville region. This increase was attributed to a change in species targeting by anglers, possibly in response to the decreasing size of *P. leopardus* and *L. miniatus* captured during shallow reef-based fishing activities.

Analysis of the REEF FISH database produced definite regional trends in fishing activities and catch characteristics. The relationships between the catch characteristics recorded by fishing clubs and actual fish stocks have not been identified. The REEF FISH database does, however, provide an accurate history of the fishing activities and fish catch of fishing clubs involved in the database programme which is invaluable in developing sound management for the fishery. The time series of information also provides a standard by which fisheries managers can evaluate what effects, if any, new fisheries management strategies may have on the fishery.

Post-apartheid fisheries management policy in South Africa: the need for a change in management philosophy

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Recent political changes in South Africa provide the opportunity to explore alternative forms of fisheries management policy, including individual transferable quotas, co-management and community-based

management systems. The choice of the management system depends on the objectives and is subject to physical and technical constraints, although the overall goal is based on the concept of sustainable development.

A pilot project was designed to consider the potential role that co-management (or even community-based management) could play in the management of a particular fishery. The aim of the project was not to implement any particular policy, but rather to develop the methodology and tools to consider what baseline information is required, based on information from successful experiences with co-management in other countries (where agreements were implemented between government agencies and user groups and joint management structures were set in place).

In the example considered (a commercial linefish community) the catch composition suggests that physical constraints do not easily allow for any form of community-based management, as the main economically important species are shared by other fishing communities and by recreational fishers. Effective management would require that shared resources be regulated through a single authority, able to follow a consistent overall plan and to control all the user groups. This authority should possess a competent administrative facility, an advanced scientific capability and, most essentially, a powerful regulatory capacity. Considering the opposing interests of the user groups (commercial, semi-commercial, recreational) it seems essential for the senior authority to retain decision-making powers necessary to resolve conflict.

These characteristics describe the present comprehensive management system administered by a central government department. There are however feelings of mistrust amongst fishermen as some feel their concerns were not included in the formation of regulations. It may be argued that management under the previous government was focused on a privileged minority. The aims of the new government are to increase participation, to set up democratic structures in the fisheries and allow for greater access to fishing opportunities by those who have been disadvantaged in the past. Given the strong propensity for controversy and confrontation there is a need for the establishment of a co-management process between government and user groups in an effort to foster cooperation, understanding and mutual advice. Some elements are present in the form of advisory channels of communication, but this falls short of co-management. Potentially there is room for delegation of some part of the management responsibility to user groups, providing that responsibilities are carried out competently and are adequately monitored.

The transferring of a part of the management responsibility to user groups or communities requires that they have suitable management capacity which would require future investment in resources essential to undertake such tasks. Initially there is the necessity to invest in information sharing and education of users as to the status of the stocks. There is a need for a change in management philosophy – a move towards an investment in human resources and capacity-building in communities disadvantaged by the legacies of the previous government system.

Sustainably managing sustainable management

G. Kailis

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Management of fisheries needs to be done on a basis that ensures the management process itself is sustainable and able to cope with changing environmental and social/economic conditions. Generally while we talk about management of fish resources we in fact have limited ability to influence the resource except by managing those who fish it. In most cases there are practical limits in our ability to control fishing activity and compliance with conservation measures requires the support of a significant majority of fishers.

As we need to manage fishers good scientific research/stock modelling is not sufficient in itself. It is dangerous to presume that once we have the 'answers' then contrary to all human experience it will be easy to alter human behaviour. The introduction of management regimes th are inimical to those who are subject to them or which ar introduced in such a way that the necessary atmosphere of cooperation is poisoned, can lead to the failure of attempts to manage fishers, and indirectly the resource, to the detriment of the community.

In the future, conflicts between competing users will intensify as multiple use of the same resource expands. The management process will become even more important and any failure to integrate users with different needs, such as recreational and indigenous fishers, will lead to conflict and an increased likelihood of stock collapse. As all professional fishery managers know, it is far better to take action before conflict arises and stocks start failing.

In discussing these issues, specific examples will be given, drawing on our Company and my personal experience in Australia's leading fisheries: rock lobster, prawns and pearls, as well as my involvement on industry, state and federal research and advisory committees. A number of current issues will be addressed including:

- introduction and content of management plans
- recreational-commercial interaction
- aquaculture/wild fishery interaction
- secure access to marine resources
- native title and indigenous fishing
- appropriate consultative mechanisms

The principal conclusions that will be drawn from these examples are that:

- *ad hoc* consultation is not enough for sustainable management and consultative mechanisms and customs need to be developed
- getting different users talking about research is a good starting point for the development of co-operation
- research needs to be formulated with the active involvement of users in order for it to be meaningful and not just address 'yesterday's problem'
- security of access is necessary to develop responsible use of resources but it needs to clearly be linked to obligations by users to the resource and community.

Review of the effectiveness of a total closure in the Gulf St Vincent prawn fishery

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Excessive fishing effort on the western king prawn *Penaeus latisulcatus* stocks in Gulf St Vincent in the late 1970s early 1980s resulted in a significant stock decline. In the mid 1980s, management practices were introduced with the objective of rehabilitating stocks. Restrictive fishing practices were established including seasonal and area closures to protect key spawning populations and to protect concentrations of smaller prawns by allowing them to grow to a larger and more valuable size. A conservative size criterion was implemented, with the fleet moving away from sub-optimal sized prawns. One option for rehabilitation was to completely close the fishery for a period to provide timum protection. However, it was also recognised that the participants in the fishery and associated industries would be adversely affected by a complete closure and therefore management and harvesting strategies were implemented that resulted in the fishers foregoing significant catch while still allowing controlled fishing to take place to provide some financial turnover.

In association with restrictive fishing practices during the mid 1980s, an economic review of the fishery in 1986 indicated that there was still excessive fishing effort in the fishery and a recommendation for fleet reduction was made. In 1987, five vessels were removed from the fishery utilising a buy-back scheme requiring the remaining participants in the fishery (11 vessels) to service the debt incurred. This was on the premise that some financial gain would be made by those remaining fishers as a result of the removal of vessels.

Monitoring the effectiveness of the management strategies was made by fishery independent surveys utilising the commercial fleet. These surveys indicated an increasing trend in the levels of recruitment onto the fishing grounds tween 1984 and 1991. These were encouraging signs ndicating rehabilitation in the fishery. This could not however, be fully quantified due to lack of comparable data from the pre-impact years and therefore, restrictive harvesting practices and continued protection of key spawning populations and small prawns were maintained. This resulted in a continuation of lower catch levels.

Political and economic factors associated with the buy-back resulted in another review of the fishery in 1991 and a total closure was implemented for two years from November 1991 as a result.

Monitoring of the stock through fishery independent surveys was continued during the closure period, although they were at times restricted due to limited commercial vessel availability. In addition, information was gathered on postlarval settlement and juvenile prawn densities in nursery areas. These measures (postlarval settlement and recruitment indices) can be used to review the effectiveness of a complete closure of the fishery.

Comparing indices before closure (1990/91), during (1992/93) and after closure (1994/95) showed no significant increase in postlarval settlement levels or recruitment to the fishing grounds during the closure period. The economic, social and biological implications of such a drastic management option without any significant measure of improvement need to be evaluated.

Policy, compliance, and ecology: a case study of New England fishers

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The purpose of this study is to examine how both ecology and socio-economics impact on the effectiveness of marine policy. The transition from a non-regulated to a regulated commercial fishery of the New England conch is the focus of investigation. The New England conch fishery can be used as a sample fishery which reflects many of the issues regarding regulation and compliance of fishers in other commercial fisheries.

Conch became a viable commercial fishery in New England as a result of depletion of other conch sources such as the Caribbean and Asia. Ethnic markets in the United States and export to Japan contribute to much of its commercial popularity and the fishery moved from being a predominantly bycatch activity to a multi-million dollar one.

However, fishers are now reporting drastic decreases in their catch. Furthermore, controversies have developed regarding other commercial species such as lobster, sea bass and scup, which also involve the use of fixed gear. In 1992, after a series of regulations impacting on multi-species pot licensing practices in Massachusetts (USA), the Department of Marine Fisheries announced specific regulations for the management of the conch fishery.

The work presented here is part of a longitudinal study that has followed ecological and socio-economic trends related to the fishing and marketing of New England conch both prior to and after the 1992 regulations. In-depth interviews with fishers, fish dealers and managers were conducted, as well as first-hand observations of fishing operations and marketing practices. Fishers' attitudes toward regulations, compliance and depletion of fish stocks were examined.

Fishers and dealers all reported that they were aware of the size limits for conch and all fishers stated that they were aware of the gear limitations. However, measurement techniques for size varied as did actual compliance. Motivations to comply were based on economic and/or ecological considerations. Many fishers also reported reduction in size of catch. Gear restrictions were also controversial. Most fishers felt frustrated that their problems were not being taken seriously and controversies among fishers, as well as with managers, were reported. Licensing practices also were questioned. In addition, almost all of the fishers cited enforcement problems.

This work is significant because conch fishing practices and regulations impact on other fisheries, including high profile ones such as the lobster fishery. Inter-state relations along the coastal United States are also affected. The conch fishery provides important lessons for seafood marketing and handling practices as well as for the effectiveness of communication between fishers and managers.

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Fisheries and the conservation of biodiversity: the case of the Mediterranean monk seal *Monachus monachus* in Greece

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The Mediterranean monk seal, *Monachus monachus,* is presently considered to be the most endangered seal species in the world. Despite efforts undertaken at both national and international levels to increase the survival chances of the species, its total population size at present does not exceed several hundred and seems to be declining (International Union for Conservation of Nature – IUCN 1993) in response to a number of threats. A significant portion of the remaining monk seal population is to be found in the coastal areas of Greece.

The interaction of monk seals with fisheries and their deliberate killing by fishers has been identified as one of the most important threats directly impacting the survival of the species. Over 65% of monk seal deaths registered in Greece from 1988-1993 have been definitely attributed to deliberate killing by fishermen (IUCN, Elliniki Etaireia 1994).

Interactions between monk seals and fisheries fall under two broad categories; biological and operational interactions (Harwood 1987). Biological interactions arise from the fact that seals and fisheries share a common resource. No evidence exists to prove that monk seals may be adversely affecting the potential harvest of the fishers through preying on fish in the wild; the converse relationship may however well apply. A high level of fishing effort, coupled with the use of illegal, destructive fishing techniques (eg. dynamite) is depleting fish resources and threatening monk seal survival. A coastal fisheries survey being carried out by WWF Greece and the National Centre for Marine Research on the island of Zakynthos, within an important and extensively researched monk seal habitat, is aimed at quantitatively assessing the state of fish resources in the area and developing, on the basis of this information, fisheries management proposals in collaboration with the local fiseries cooperative.

Operational interactions arise when monk seals remove fish from fishing gear. In addition to the financial loss caused by removal of the catch, a series of further losses associated with damage to fishing gear, recorded from the Ionian Sea tend to vary both temporally and spatially, reaching average yearly values of as high as 18.1% (Karavellas 1995). In their interaction with fishing gear, monk seals run the risk of accidental entanglement and are further under the risk of being deliberately killed, although protected by national and international legislation.

The survival of this endangered species is clearly dependent on overcoming the antagonism presently felt by fishers towards monk seals and stopping any further deliberate killing. Conservation efforts aimed in this direction by WWF Greece and other non-governmental organizations in Greece, have provided promising results, but are largely applied on a local, project base level. A binding national strategy is urgently required, within which fisheries/monk seal interactions will be addressed as a major component. Such a strategy should aim for the development of a long-term, feasible and pragmatic compensation mechanism which can be implemented in the field, serving to counterbalance losses incurred by fishers and change present attitudes.

Need for further study on environmental control of cyclic reproduction of tropical freshwater fishes

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Fish is an important protein source. Overfishing therefore has considerable impact on protein availability and represents not only a problem in marine fisheries, but also increasingly in tropical freshwater habitats, in inland fisheries of South America, Africa, and Asia. In inland fisheries two possible ways of solving the problem of overfishing seem to be feasible: 1. making regulations in order to decrease overfishing and 2. installation of aquaculture facilities in order to produce fish protein independent of natural resources. In both cases knowledge about the reproductive biology of tropical freshwater fishes, especially of economically important species, is needed. Such knowledge, however, is extremely scarce. One important aspect of the reproductive biology of tropical freshwater fishes concerns cyclic reproduction and its control by environmental cues.

It has been possible to show experimentally that high water conditions (increasing water level, decreasing conductivity, imitation of rain) provoke gonad development and lead to mature gonads after some weeks, whereas low water conditions (increase of conductivity) lead to gonad involution. There is a sex-related difference as far as reaction time is concerned: males show a quicker maturation and delayed involution of gonads compared to females.

Such cyclic reproduction has been demonstrated experimentally in several groups of fishes: in some species of the neotropical knife fishes (Gymnotiformes), in several species of the African mormyriform fishes, in one African schilbeid catfish (*Eutropiellus vandenweyeri*), and in one South East Asian silurid catfish (*Kryptopterus bicirrhis*).

These experimental results clearly show that cyclic reproduction, controlled by the physico-chemical parameters cited above, is a phenomenon widely encountered in tropical freshwater habitats. It is worth mentioning here that these cues are quite different from those (photoperiod/temperature) that regulate the cyclic reproduction of fishes of the temperate zones. During these investigations only a small portion of all the known tropical freshwater fishes have been studied. Field studies, however, indicate that cyclic reproduction is found in many more tropical species, especially in larger, economically important species. The cues, that control this cyclic reproduction, in general are not known.

Future experimental investigations concerning cyclic reproduction therefore are being conducted with the following objectives:

1. The knifefish *Eigenmannia lineata* and the mormyrid fish *Pollimyrus isidori* will be further taken as model systems to complete these studies on the cyclic reproduction of these fishes.
2. Representatives of those tropical fishes in which field studies have revealed cyclic reproduction will be studied.
3. Small species (that are useful for experimental studies) of economical importance will be studied.

The control of cyclic reproduction of tropical freshwater fishes by environmental factors represents only one aspect of the reproductive biology of these fishes; however, it is a

very important aspect. The study of the ecophysiological parameters of the reproduction of tropical fishes has often been neglected, though their knowledge is very important in the context of

1. regulations in order to solve overfishing problems
2. developing aquaculture facilities
3. anthropogenic influences (e.g. the construction of hydroelectric power plants) that have impact on fish population dynamics.

Good management and/or good luck? Timely introduction of input controls in the Northern Territory mud crab fishery

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The history of fisheries management is littered with the remains of once productive fisheries. Usually, this is a direct result of overfishing, although causes such as aberrant environmental conditions or habitat destruction may also be involved. A typical fishery scenario is that management controls are not introduced until fishing effort, having increased alarmingly, is at an unsustainable level and endangering the resource. By this stage, there is often a cast of thousands, financial commitments of the same magnitude, and introduction of controls causes major problems for managers and fishers alike. These potential problems were recognised by the Northern Territory (NT) Department of Primary Industry and Fisheries when implementing the Mud Crab Fishery management regime. By introducing strict effort controls at an early stage in the fishery's development, many difficulties commonly encountered in a developing fishery were avoided.

The NT mud crab (*Scylla serrata*) resource is utilised by traditional, recreational and commercial fishers. Management controls were introduced in 1985 and incorporated a minimum legal size (130mm width), possession limits, pot limits, gear restrictions and area closures to commercial fishing. The commercial fishery was limited to 49 licences, each entitled to use a maximum of 60 pots. These controls were introduced prior to the considerable development which occurred in the fishery.

Development of the NT Mud Crab Fishery occurred as latent effort, present since controls were introduced, became fully utilised. Fishing effort increased from around 100,000 potdays in 1983 to over 600,000 potdays in 1995. This was due to increases in the number of licences utilised, the months worked by each licencee and the days worked per month. Importantly, there has been little "technology creep" in the fishery. The vessels and gear used remained relatively unchanged over the last twelve years and unlike many other fisheries, modern technology such as Geographic Information Systems (GPS) and sounders have been of no advantage in this fishery and are not used. Overall, utilised effort has risen from 10% to 70% of potential effort.

Increased effort levels were reflected in a rise in annual catches from about 25 t in 1983 to over 250 t in 1995. Catch per unit of effort has remained reasonably steady at around 0.33 kg/potday throughout this period, and indications are that stocks are coping with current fishing pressure. Up until now, it seems the input controls have prevented overexploitation of the resource. With such safeguards in place, research into other management controls was undertaken, especially the level of protection offered by the minimum size.

There is no doubt that it was good management to introduce strict input controls early in the fishery's development but with so little known about the fishery at that stage, it was probably good luck that those controls proved adequate for so long. It is difficult to foretell how the fishery may change in the future, but with continued sound research, dynamic management and a bit of good luck, the viability of the NT Mud Crab Fishery should be ensured.

Fisheries management science: integrating the roles of science, economics, sociology and politics in effective fisheries management

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The past four decades have seen considerable innovation and development in the management and regulation of fisheries worldwide. During this period, fisheries management has evolved as an entity in its own right and has shifted from a role of development and expansion to a role of increasingly complicated restriction during a period of high exploitation and continued improvement in fishing technology. However, recent fishery failures, combined with changing views on government regulation, point to the critical and urgent need for a new approach. Shortcomings of current fisheries management systems include the inability to make analytical decisions that account for multiple objectives and the inherent variability of fisheries systems. Future management must focus on integrating biological, economic, social and political considerations, rather than solely on fish populations. This requires development of both a conceptual framework and an appropriate methodology for interdisciplinary decision-making in fisheries management.

Integration of the traditional fields of fisheries science and fisheries management with the scientific problem-solving approaches of management science to form "Fisheries Management Science" is proposed. Fisheries Management Science provides a framework for structured decision-making, employing the techniques of operations research/management science. This includes defining the context and methodologies for setting multiple objectives and constraints, modelling alternative management scenarios and the assessment and management of risk.

A case study, based on the Bay of Fundy herring fishery, illustrates both the conceptual and practical aspects of the new approach – including development of a co-management structure characterized by industry involvement, interdisciplinary management teams, modelling of spatial/temporal elements of the fishery designed for in-season management, explicit consideration of risk and decision performance monitoring.

Biological advice on fishery management in the North Atlantic 1970-1995: structure, principles and results

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Biological advice on fishery management in the North Atlantic is provided through international scientific cooperation within the International Council for the Exploration of the Sea (ICES), within the Northwest Atlantic Fisheries Organization (NAFO) (prior to 1979 International Commission for Northwest Atlantic Fisheries [ICNAF]), and after 1979 nationally by coastal states for stocks within the Extended Fishing Zones (Canada and US).

The scientific assessment strategies have been similar throughout this area – the analytical assessment being the target – but this has only been achieved in a few cases. There have been attempts to introduce less data-demanding assessment strategies, e.g. dynamic pool models, but these have never become widely used.

The Total Allowable Catch (TAC) system has been used widely in the area and the biological advisory machine has been geared to generate input to this system. Therefore, the discussions during the period have focused on

- Management objectives
- Biological reference points
- Minimum biological acceptable limits (safe biological limits)

and calculation of TAC under various options, e.g. status quo fishing, 30% reduction of current fishing (as a step towards F_{max}), F_{max} and $F_{0.1}$.

The paper investigates the assessment of groundfish throughout the North Atlantic exemplified by cod and the development of the assessment technique and form of management advice. Furthermore, it attempts to evaluate the present status and discuss changes required for hopefully better results in the future.

New technology for fisheries management – implementing a satellite-based vessel monitoring system

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Objective: To describe AFMA's experiences in implementing a satellite-based vessel monitoring system with the aim of making fisheries management measures more effective and efficient. The future development and use of this technology, as well as key success factors, are proposed.

Statement of findings: The fishing industry has been very successful in applying new technology to the process of harvesting fish, effectively increasing applied effort. Use of these same technologies is now being adapted to fisheries management. Management organisations such as AFMA are now using the Global Positioning System (GPS) and satellite communications systems such as Inmarsat to monitor the activity of fishing vessels and to collect catch and effort data.

AFMA has implemented a Vessel Monitoring System (VMS) for both compliance and data collection purposes. In the Orange Roughy (*Hoplostethus atlanticus*) deep sea trawl fishery the VMS is being used to monitor the positions of vessels and determine probable fishing activity. This has proven to be a valuable tool in detecting and investigating possible breaches of fishing permit conditions. While no specific legal actions have yet been brought as a result of the VMS it is highly valued by compliance officers and the level of compliance with a zone-based quota system has improved markedly since the introduction of the VMS in January 1994. It is proposed to extend the system to include data collection on a real time basis. It is expected that this will achieve compliance and research/efficiency advantages.

AFMA already has some experience with VMS data collection. Japanese tuna long-line vessels fishing inside the Australian Fishing Zone are reporting their catch to bc AFMA and the Japanese Fisheries Agency on a daily bas... This results in a reduction in errors in data transmission and entry, lower costs and more rapid availability of data for scientific and management assessment.

Conclusions: The future will see an expanding use of this technology across fisheries world-wide. Fisheries management organisations will continue to use it for both compliance and data collection functions but additional data types, greater ease of use and administration and more innovative developments within these functions will evolve.

The fishing industry will reap the rewards of a more controlled management regimes through sustainability of the resource. Ancillary benefits relating to sea safety and the pervasive availability of a reliable communications medium on more fishing vessels will also be realised. This will also lead new applications such as at-sea marketing of the catch.

Moves are being made within the United Nations to require greater use of VMS and the concept of flag state responsibility with monitoring even on the high seas is not far from reality. To achieve this and to create a manageable system world-wide, it will be necessary to achieve a hi level of compatibility and standardisation. Ease of use for fishing operators must be considered through standardised data reporting requirements. The logistic effort in putting equipment and software on vessels must be simplified through standard equipment types and programming interfaces. The fishing industry, scientists, management organisations and equipment and service providers must all play a part and co-operate. The technology is here now and its future as a tool in improving and assuring the integrity of fisheries management regimes will be achieved if the will to do so exists.

An empirical evaluation of important sources of price risk for Tasmanian southern rock lobster

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Fishing firms face many sources of risk. These impact upon business performance to varying degrees and in a variety of ways. One of the most important economic variables to affect profitability is beach price. When much of the catch is exported, beach prices received by fishing firms are subject to exchange-rate risk, as well as changes in foreign demand that are induced by cultural events, season and income shifts.

The approach adopted involves evaluating price risk by examining the significance of regression coefficients for an inverse demand function for Tasmanian lobster. These fficients may be used to enumerate elasticities of beach price with respect to exchange-rate and income measures. The results confirm that movements in Japanese income and the Australian dollar/Japanese yen exchange rate have recently accounted for much of the price risk faced by Tasmanian lobster fishing firms.

Cooperative tagging programmes: scientists and anglers working together

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Several cooperative tagging projects have been conducted in conjunction with the Queensland branch of the Australian National Sportfishing Association (ANSA). The ...us of these projects has been elucidation of species movement patterns and validation of growth estimates. The major advantage for scientists of using a cooperative tagging programme is that it can result in the tagging of more fish over a wider geographic area. The three cooperative tagging projects discussed in this poster have all met with success, but they have also identified problems with utilizing cooperative tagging. From personal experiences variable tagging quality can potentially lead to violation of several of the assumptions of tagging projects. An underlying problem of cooperative tagging is that the "quality" of tagging can vary between taggers. Other problems can include non-reporting of recaptures from the commercial fishing sector due to direct identification of the project with the recreational sector, major components of the population being missed due to an uneven distribution of tagging effort, and measurement errors at recapture that can potentially lead to inaccurate growth estimates. Minimizing or eliminating the problems inherent in cooperative tagging is a challenge for both scientists and the anglers involved in tagging. This poster highlights approaches to meeting the challenge.

Monitoring fisheries effort and catch using a geographical information system and a global positioning system

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A major pre-requisite for effective fisheries management is a comprehensive and integrated information system enabling monitoring and control of stocks and activities in the short term, as well as providing support for planning and marine environment modelling in the long term. Since the underlying problems facing marine resource exploitation are frequently associated with differentiation in the spatial domain, then Geographical Information Systems (GIS) provide an important computer-based tool for initiating their management. It is sought to demonstrate a total fisheries effort and catch monitoring programme, which makes use of GIS linked to a ship-based Global Positioning System (GPS) having an integrated programmable data logger. Various maritime nations are increasingly requiring certain of their fisheries vessels, or vessels fishing in their waters, to be equipped with GPS, mostly as a means of monitoring fishery activity. The likelihood of having to do this in the future has increased following the United Nations Conference on the Law of the Sea (UNCLOS) agreement on migratory and straddling stocks. As part of fisheries management policy, fishing vessels could utilise their GPS to routinely collect data on fishery activity relating to trawl set and haul location, temporal information, gear type, depth and catch weights. Since most of these data are conventionally collected, then this would involve little extra crewing responsibility.

The design of the GIS data model proposed ensures that dynamic data relating to fisheries activities, such as trip lengths, haul times and fish catches, are associated initially with time and location in space, and then with static spatial criteria, i.e. zones of interest such as coastlines, statistical divisions and ports of origin. The spatio-temporal semantics underlying the design of the information system enable it to respond to information needs from various perspectives. Equally important aspects of the GIS are the visualisation and information retrieval capabilities. Thus data routinely collected via GPS loggers can be displayed in "map" forms for visualisation and thus monitoring of fishery activities. Quantities caught per species, as well as total fishing effort, can be quantified for unit areas of sea, including official statistical divisions. Summation for any mapped parameters can be made for areas over particular time periods enabling long-term temporal comparisons of stocks and activities. Data capture would relate to the spatio-temporal scale of trawling activities, but screen visualisation, mapping output and analytical functions can be accommodated at almost any scale. Initially GIS functionality will be in 2-D or 2.5-D. However, given that suitable depth criteria were established and data was forthcoming, then the GIS would be extendable to 3-D, an essential pre-requisite for fisheries modelling. The real importance of the GIS is that it is extensible, enabling effort and catch to be matched to any other spatially related data covering the relevant sea area, e.g. to bottom sediment type, water qualitative parameters, plankton counts, plus indices of past effort and catches. GIS will then have supplied the capability for spatial analyses and modelling, and eventually for complete spatial

management including informed decision making and prescriptive planning.

Differential immunomodulatory effect of nickel compounds in *Oreochromis mossambicus* (Peters)

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Heavy metals are considered to be an important aquatic pollutant of concern because of their prevalence in polluted aquatic environments and their toxic potential to a variety of organisms including man. Numerous investigations in recent times have been directed towards analysing the immunotoxic potential of heavy metals to aquatic species, particularly fishes, because of the possible aetiological link between the metal-induced immunosuppression and disease incidence among fishes in both capture and culture fisheries. The heavy metal, nickel, is used in a variety of industries including nickel- processing and electroplating industries which constitute the major source of nickel pollution. Not much is known about the immunotoxicity of nickel in fishes. Hence, the present study aims at investigating the possible immunomodulatory effect of organic and inorganic forms of nickel in *Oreochromis mossambicus* (Peters) in terms of humoral immune response and lymphoid cells and organs.

Sublethal doses of nickel acetate or nickel sulphate were administered intraperitoneally into fish, and their immunomodulatory effects studied. In another set of experiments, fish were exposed to sublethal concentrations of the metal for 96 hours. After immunizing the metal-treated fish with bovine serum albumin (BSA), serum anti BSA antibody titres were quantified by passive haemagglutination assay. Effect of the metal on lymphoid organs and cells was studied by gravimetry and total/differential counting respectively on samples collected from metal-administered fish. Both forms of nickel suppressed the immune response, the organic form (nickel acetate) being more immunosuppressive than the inorganic form (nickel sulphate). Immunosuppression was observed irrespective of the route of administration of the nickel compounds. Similarly administration of nickel compounds prior to or after immunization resulted in suppression of antibody response though to different degrees. Significant reduction in spleen weight, splenocyte count, peripheral blood leukocyte and lymphocyte was observed in the metal-administered fish with the organic form of metal being more effective than the inorganic form.

From the results obtained, it is evident that i) nickel is immunosuppressive even at very low doses and ii) the organic form (nickel acetate) is more immunosuppressive than the inorganic form (nickel sulphate). The implication of the finding is that the immunocompromised fish population in water polluted with nickel (and/or perhaps other heavy metals) is under constant threat of imminent microbial infection and disease-outbreak. This kind of pollutant-induced immunosuppression leading to disease incidence in aquaculture is perhaps the main reason for the high losses of revenue due to disease in global aquaculture production. The recommendation is to study the possible differential effects of other heavy metal pollutants and to explore the possibility of converting toxic forms of metal into less or non-toxic forms at effluent-treatment level in industries which use heavy metals. This conversion would greatly contribute towards minimising the degree of aquatic pollution due to industrial discharges and surface runoff.

The role of science, economics, sociology and politics in the sustainable management of the fishery at the Victoria Reservoir, Sri Lanka

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The existing fishery at Victoria, Sri Lanka's largest and deepest hydro-power reservoir, has the potential for further development by the introduction of appropriate measures. To achieve this objective, certain scientific, economic, sociological and political factors have to be considered.

Scientifically, care has to be taken in the selection of the most suitable fish species to colonize the reservoir and to determine their ecological requirements for successful establishment. Of the three cichlid species, *O. mossambicus* is the most promising. Its intrinsic breeding potential and the fact that it is primarily detritivorous help it to thrive well under the existing conditions in this reservoir. *O. niloticus*, which has the best consumer acceptance due to its larger size and palatability, comes next. However, this species is more selective in its requirements and the larger individuals are confined to the main inflow area of the reservoir. The common carp *Cyprinus carpio* is also a favourable species breeding in the inflows and could also be established with success. For sustainable management it is important to ensure scientific stocking taking into account the biological and ecological requirements of the different fish species. In the past, stocking this reservoir was both an ecologically and economically wasteful procedure, since it was done very haphazardly.

For economic success, the financial requirements of the fisherfolk are important. For their active participation, introduction of Loan and Saving Scheme Facilities is essential.

At present, there has been a progressive reduction in the number of those who are attracted to this profession. Of the 125 registered fishers only 10 percent are engaged in full time fishing while 50 percent are engaged in part time fishing and supplement their income by engaging in other occupations.

These fisherfolk are a socially neglected and discriminated against community. By the formation of a distinctive organization these fisherfolk should be given social recognition and encouragement.

Politics has played a vital role and has had both positive and negative impacts on this fishery. Initially, since the government of Sri Lanka had made a substantial allocation from its annual budget for the development of inland fisheries, fishing crafts and gear were provided on a 90 percent subsidy. In July 1990, the government of Sri Lanka arbitrarily declared the cessation of state patronage for inland fisheries and withdrew its support. This decision resulted in many unwarranted anthropogenic activities and the subsequent decline of the fishery in this reservoir.

There is plenty of scope for the development of this enterprise if appropriate measures are adopted in the future

taking into consideration the scientific, economic, sociological and political factors involved.

Setting objectives: lessons learned from Pacific northwest, United States of America

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The Yakima Fisheries Project (YFP) plans illustrate how adaptive management can integrate objective setting, decision making, benefit and risk assessment, and monitoring around the sometimes seemingly different goals of science, socio-economics and politics. The objective of the YFP describes how natural production of salmon and steelhead *Oncorhynchus* spp. can be supplemented. Adaptive management is a method of planning, scheduling and controlling the implementation of a course of action. Project objectives, that is, statements of planned accomplishments, include goals for genetics, natural production, experimentation and harvest.

The genetics, production, experimentation and harvest objectives describe desired results that need to be achieved in a specific time. Understanding the characteristics of objectives in a long-range plan is essential to effective environmental management. Fisheries objectives must be suitable, that is, they must support the basic purpose of the project. The objectives must be measurable over time, feasible and clearly stated. Objectives that are set too low or too high are not motivating. When objectives are too low or too high, environmental managers can not generate the resources and other support needed to implement the selected course of action. Objectives that are not clear will be resisted and ignored.

The YFP includes a project management plan. This adaptive plan is a network of vertically-integrated learning processes carried out through experimental policy decisions aimed at achieving a set of human/ecological objectives. The plan is directed by the assertion that all human interactions with nature should be experimental. Thus, the plan is a framework for hypothesis-testing through the implementation of closely monitored experimental strategies. By following a variable nonlinear process, rather that a fixed linear path, the adaptive plan enables concurrent co-learning generated and communicated from a variety of explanations to be transferred quickly into capabilities, through feedback loops. The learning process in adaptive environmental planning does not require waiting for agreement on a unified design or system-wide resolution of uncertainties before strategies are selected, implemented, or adapted. Although the adaptive planning is human and ecosystemic in scope, the experimentation and evaluation processes are non-generalized and highly selective.

Database management: the application of Lotus Macro for on-farm economic analysis of rice-fish data

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The study focused on the development of a simple Lotus Macro run database spreadsheet for non-programmer field researchers cum extension workers involved in field monitoring, tabulation, computation and analysis of rice-fish intergrated farming systems' data.

The designed rice-fish database spreadsheet features direct data entries from the Field Input Sheets (FIS) or monitoring forms to the Computer Output Sheet (COS) to generate data on labour and material costs and gross product value. These data when extracted from the COS and file combine later in the Computer Analysis Sheet (CAS) can do a number of economic and statistical calculations (e.g. cost and return, partial budgetting, measures of dispersion, etc.) and graphics.

The Lotus Macro programme is suited for the researchers with no programming background. Once learned, the user can save a lot of time and effort in doing repetitive computational tasks, thus providing timely information for decision on appropriate farming systems options.

The stakeholder satisfaction triangle: a model for successful management

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Fisheries management decisions often follow a tortuous path paved with argument, accusation, procedural redundancy and legal action. The results are delay, wasted funds and declining fisheries. The fundamental problem is that each decision is treated in isolation, concluding that positional bargaining is the best method to "get our way" and ending with a win-lose result. As facilitators of this contest, public officials are often frustrated and ineffective.

A different approach, based on the "stakeholder satisfaction triangle", can foster management success. The triangle recognizes three important sides to consensual decisions: process, content and relationship. *Process* involves the explicit development and implementation of a procedure for reaching a decision. *Content* involves the development and analysis of factual information to guide the decision. *Relationship* involves building trust and understanding with important stakeholders, transcending individual decisions. Emphasizing any side of the stakeholder satisfaction triangle while ignoring the others can lead to management failure, while balancing all three sides generally promotes success. A series of case studies illustrates these points.

The development of fish consumption advisories has been a continual problem in the midwestern and northeastern parts of the United States because of emphasis on process issues. Concerns about processes for fish sampling, laboratory handling and health interpretations have led to advisories that are relatively useless – they vary across jurisdictions, are overly general or too specific and poorly distributed. Consumers either ignore them or quit fishing, and special interests challenge agencies on process issues.

The chemical control of sea lampreys in the Great Lakes has emphasized content in the development of specific poisons and criteria for treating streams. Technicians failed to consider the increasing concerns of stakeholders about broadcast chemicals and about non-target effects. Similarly, salmon harvest regulations for Lake Ontario were based almost entirely on technical analysis, while many stakeholders had ethical and aesthetic concerns about harvest techniques and distributions. In both cases, decisions have been mired in political and legal sloughs that halted effective management.

Broader consideration of both process and content, along with major attention to relationship, however, can encourage consensual and timely decisions. The salmon fishery in the Bighorn River (Montana) was nearly closed in the mid 1970s because of stakeholder conflicts. By emphasizing public involvement over the next several years, managers and stakeholders reached a consensus to improve habitat rather than squabble over quotas. Lake Winnebago (Wisconsin) contains fishery and water quality issues that had people fighting for decades. But, in 1986, fisheries managers began working with a broad group of stakeholders on a long-term management approach based on building strong relationships; the outcome has been a comprehensive plan with full local support and voluntary action on nearly two-thirds of the plan's 120 recommendations. On the Susquehanna River (Pennsylvania), a series of power dams had blocked anadromous fish migrations for more than a century. An effective liaison among public agencies, power utility companies and conservation and civic groups, however, has led to construction of the world's largest fish-lift and an ongoing commitment to restore anadromous fisheries throughout the basin.

A comparison of the benefits and costs of quota versus effort-based fisheries management

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Prior to 1970, the regulatory approach for the management of Canadas East Coast fisheries was effort – based management. Since then, quotas have become the backbone of fisheries management, with fishing effort regulations providing support as required. In Canada, as elsewhere, the failures of fisheries management are being partially blamed on the inherent deficiencies of quota-based regulations and some have called for further consideration of effort – based controls, which have in some fisheries been referred to as successful. The elements of both quota and effort-based management systems are defined and examined as to how they are implemented in three fisheries off Nova Scotia, these being offshore scallops (single-species, quota based), inshore lobster (single-species, effort based) and groundfish (multispecies, quota based). For each fishery, the costs of the regulations are evaluated in relation to the benefits, these being measured with reference to the attainment of some conservation objective. It is shown that the apparent successes in effort-based regulations are more related to the biology of the species being exploited, rather than being due to inherent value in the regulation itself. While the costs of regulations are quite different among these fisheries, these are mostly due to the diversity in the harvesting fleets. Effort-based regulations are not a panacea for fisheries management and have their own problems. It is concluded that it is more appropriate to use a mixture of effort and quota-based regulations and to pursue the development of institutional structures that encourage the involvement of the industry in the setting and enforcement of fisheries regulations which are suited to their particular circumstances.

Strategic planning in fisheries management – a blueprint for sustainable harvesting

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Fisheries management requires the activities of numerous government , non-government and industry organizations working together to achieve a defined set of objectives. Experience has shown that the participants in a fishery often have different, and competing, objectives which can compromise fisheries management efforts. This not only occurs within national fisheries, but also between countries harvesting common, international resources. It is the authors' thesis that this conflict between resource user groups is a fundamental problem with fisheries management efforts worldwide. It has led to decisi making that is dominated by short term considerations of resource sharing and has created an atmosphere of uncertainty about long term resource utilization and sustainability. This has in turn prevented rational decisions on fleet and processing capital investment. It is contended that fisheries management must occur within the context of a long-term strategic plan which clearly states the long-term intent of management, the obligations of those governed by the plan, as well as the legal and cost-sharing arrangements. It removes any ambiguity about the responsibilities of the user groups and what are the rules of governance and therefore prevents 'end-runs' around the system. Drafting of this strategic plan requires a great deal of consensus building and represents the essential first step in the co-management of a fishery. A fisheries strategic plan is under development for the groundfish fishery off Nova Scotia and serves as an example for plans that could be developed at a larger scale. The first component of this plan outlines the conservation principles that govern all user groups. This includes objectives and strategies relating to the management of not only the individual stocks, but also constraints imposed by the ecosystem. This component serves as a common link to the subplans developed by the individual user groups. What defines a user group is clearly outlined. This includes association accreditation, formation

of legal governing entities and so on. Each of these user groups is required to develop a subplan which outlines their objectives/mission statement, the means whereby they will regulate fishing activity, and the monitoring plus research requirements. It is the responsibility of each user group to define a decision-making organization to develop these subplans. This could involve user boards with the legal authority to manage the fishery. Associated with these decision-making organizations are technical advisory groups commissioned to provide the decision-makers with management options, using a well-defined peer review process. These groups involve not only government experts but also those representing the industry. Finally, the financial arrangements associated with the strategic plan are outlined, including who pays for what and how these funds are managed. Elements of this plan have been implemented. In other areas, consensus building is proving very difficult. The reasons for this inevitably relate to security of access and resource sharing. It is argued that a property-rights system within the confines of an overall strategic plan can resolve many, if not all, of these disputes.

Integrated fisheries management: structured solutions to managing political, economic and scientific chaos in degraded wild stock fisheries

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Fishers, fisheries managers and communities worldwide face the reality of degraded wild fish stocks armed with many tools but little understanding of how to put together the best combination of tools to produce the best results. A chaotic mix of political, financial, economic and scientific problems increasingly impinge upon stocks for which few punters would back any bet other than continued decline. Past management in many such fisheries chronicles a legacy of reliance on *ad hoc* flavour-of-the-month saviours (remember ITQs, hatchery-based enhancement and modern renditions to the tune of cooperative management and ITQs). Stakeholders faced with an ever leaner economic future can no longer afford to wait for a management team to randomly compose a Shakespearean plan for their fisheries.

This paper seeks to replace the myth of fisheries management as either art or science with the model of management as a Plan relying on explicit selection of management options possessing quantitative benefits/disbenefits to stakeholders. Such a model closely parallels the Integrated Pest Management system applied successfully and now almost universally in agriculture. The success of this thesis in fisheries rests in part upon review evidence indicating that the challenges facing most fisheries are similar, but with specific factors varying in degree of importance. A second key premise is that the options available to managers are also similar across fisheries. Therefore, by analysing the benefits/disbenefits of options prior to implementation, research direction is automatically set, resource constraints (financial and otherwise) are explicitly defined and selection outcomes can be made clear to all interested parties.

An example of the use of such a general model aimed at native fish enhancement is applied to the Murray-Darling Basin of Australia.

Hierarchical categories follow the format:

- identification of existing and potential stakeholder goals and objectives, (e.g. definition of players, their relative value, their willingness to pay for fishery benefits)
- identification of available policy and administrative tools (e.g. access arrangements, harvest control mechanisms)
- selection of:
  - social enhancement options (e.g. empowerment of key community groups, network development arrangements, strategies for managing the politics of the fishery, education)
  - habitat enhancement options (e.g. water quality, habitat improvement directions)
  - stock enhancement options (e.g. hatcheries, genetic engineering, spawning stock protection, refuge implementation)
  - future threat aversion options (e.g. exotic species protection and control, prediction of future conflicts)

Thus, the full range of options available to meet the current and future demands on a specific fishery can at least be explicitly placed before managers and stakeholders. In each case, the relevance of each option can be assessed and the evaluation of benefits/disbenefits taken to the level deemed necessary. For example, some key options may warrant detailed research and/or quantification while others only require qualitative assessment.

The resulting ranking of options with indicators of both benefits and disbenefits can then provide a clear basis on which all interested parties can reach consensus on what would usually be a multi-option strategy for future management. In these days of user pays, ranking of options by efficiency relative to goals and cost allows simple selection of the opportunities which the fishery can afford and justify. Outcomes relevant to specific sectors can then be benchmarked using performance indicators already identified during the selection phase – thereby enabling tuning of the strategy with time and uncertainty. Finally, with stakeholder-relevant outcomes and an agreed plan, responsibility and accountability can be delegated back to the relevant sector rather than remaining with central government.

Exploration of a multi-disciplinary taxonomy of fisheries

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This poster describes an attempt to devise a multi-variate, multi-disciplinary taxonomy of world fisheries that could be used to diagnose problems and prescribe categories of management and possible remedies that would enhance sustainable exploitation. The scheme might also be used in a triage of fisheries to determine where restricted management resources might be focused to most effect.

Fisheries attributes are grouped in each of ecological, economic, operational, social and policy areas. Multivariate methods including Principal Components Analysis are used

to ordinate and classify fisheries from commercial, subsistence, artisanal, industrial and recreational sectors.

Problems of defining fisheries for the scheme are grouped into conceptual problems and measurement problems. The two principal conceptual problems are first, in determining the most useful boundary of fisheries ordinated by the scheme on a local, stock or species scale. Secondly, how to deal with multi-species, multi-gear and multi-sector fisheries. These problems may be resolved to some extent by carefully defining the focus and scope of the ordination and classification desired.

Measurement problems group into availability and relevance categories. The principal concern is with the availability of reliable data on catch, gear, fleet composition, and economic and social factors, which vary greatly among fisheries. Extracting useful data for an interdisciplinary overview like this often entails delving into very detailed studies in a range of disciplines, each of which has evolved its own ground rules, jargon and unstated assumptions.

Analyses are presented and compared for some Canadian, European, African, Asian and Australian fisheries.

Advances in Bayesian stock assessment and decision analysis – application to orange roughy off Tasmania

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Orange roughy (*Hoplostethus atlanticus*) is the most valuable species in Australias south east fishery, being worth A$33.8 million in 1993. It is therefore of considerable importance to management to be able to assess the current status of this population and to determine the likely impact of alternative future management actions.

The assessments of this stock are complicated by a number of factors. Foremost among these are uncertainty about the form of the stock-recruitment relationship, the extent of inter-annual fluctuations in recruitment, the value of the rate of natural mortality and whether commercial catch-rate data provide a relative index of abundance. There is also considerable stock-structure uncertainty. These factors have important implications for the assessment of the current status of the population and its likely level of long-term sustainable yield. The data collected from this fishery are currently not particularly informative, because fishery independent relative abundance indices are available only from 1990 and absolute abundance estimates in 1992, and because there is little information about the age composition of the annual catches.

The method applied to assess this stock (stochastic stock reduction analysis) is based on an age- and sex-structured population dynamics model that incorporates the effects of fluctuations in births explicitly. The values for most of the parameters of the model are set using the results of analyses of existing data. However, there are several parameters, such as the virgin biomass and the annual number of births, which are poorly determined by the available data. A Bayesian estimation approach is therefore used to take account of the uncertainty in the model parameters by specifying prior distributions for these parameters and applying Bayes rule to synthesize the information in the priors and the data. The resultant posterior distribution for these parameters is used as input to analyses to determine the risk associated with various alternative management actions. The sensitivity of the results to alternative, yet plausible, choices for the prior distributions and the data used in the analyses is examined.

The population is assessed to be currently between 35 and 40% of its virgin size. The results are not particularly sensitive to alternative choices for the priors and for different sets of abundance indices. The relative credibility of two alternative stock-structure hypotheses (discrete stocks in the southern and eastern sectors versus a single stock assumption) is evaluated using the Bayes factor approach.

Counting migrating juvenile and adult salmonids (*Oncorhynchus* and *Salmo* spp.) in rivers, using split-beam hydroacoustics and target tracking

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Split-beam hydroacoustic techniques were used to monitor juvenile and adult salmonids (*Oncorhynchus* and *Salmo* spp.) in nine rivers at six dams in North America and Europe from 1992-1995. Escapement and entrainment, fish size, spatial and temporal distributions, diel distributions, three-dimensional trajectory path and fish speed were estimated. Fixed-location hydroacoustic techniques were combined with split-beam target tracking. Fish were tracked in three dimensions in real-time as they passed through the acoustic beam, using split-beam phase information. Acoustic sampling was complicated by low signal-to-noise ratios, high water velocities, and interference from the bottom, surface, and structures. High sensitivity, low side lobe transducers with elliptically-shaped beams aided aiming near these boundaries. Sampling was physically and acoustically challenging and required sophisticated equipment and careful deployment, calibration and testing.

For counting upstream migrating adult salmonids in open rivers, narrow beam width transducers were aim horizontally, monitoring the fish in side-aspect. Short pulse lengths and rapid transmission rates were used. In virtually all cases, anadromous salmonids were strongly shore- and bottom-oriented, where water velocities were slowest. This was probably an effort to conserve energy. Typically 10-25% of the fish monitored were moving downstream, identifying a potential source of bias in escapement estimates for techniques not able to conclusively identify direction of movement.

Downstream migrating salmon and steelhead trout smolts were monitored at hydropower dams using split-beam techniques. Results were used to design and/or evaluate the effectiveness of different techniques for diverting smolts from potentially injurious turbine units. In virtually all cases, smolts have been found to be more surface-oriented during daytime than at night, making surface bypass techniques more effective during the day. Passage rates were highest during nighttime hours.

At Rocky Reach and Rock Island dams, (Columbia River, Washington State) horizontally scanning split-beam hydroacoustics were used to monitor downstream migrating smolts in the reservoir immediately upstream of the dam, determining the movement patterns of the juvenile salmonids as they migrated through the reservoir. Three-

dimensional target tracking and remote multiplexing and transducer aiming was employed. The trajectory profiles, target strength distributions, velocity profiles and spatial distributions of the outmigrating juveniles were estimated for each of the six different aiming configurations utilizing six different elliptical split-beam transducers. The results showed that the fish migrated primarily downstream along the east side of the reservoir and were concentrated in the upper water column. The results were used to determine the optimal location for a surface collection/bypass system. This system was used to collect and bypass smolts past the dam, as a safer alternative than being entrained into the turbine intakes. At Wanapum Dam, vertically-oriented elliptical-beam transducers were used to evaluate the effectiveness of a prototype surface collector for bypassing smolts. Smolt passage through turbine units and the collector's baffle opening was monitored. Effectiveness (relative to one turbine unit) was estimated at 35%.

Potential improvements in monitoring capabilities include the addition of FM Slide/Chirp to increase the signal-to-noise ratio, minimizing bias and variability around estimates.

Structural adjustment and fisheries in Australia: sustainability and economic efficiency. Policy considerations for a national fisheries adjustment programme

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Many fisheries around Australia are experiencing acute structural dysfunctions as conflicts arise about Optimal Sustainable Yield, between resource users and the State. An integrated fishery-wide approach is required involving sustainability on four broad fronts:

(i) Ecological (at a species and ecosystem level)
(ii) Socio-economic (at an individual as well as an aggregate level)
(iii) Community (at a human systems level)
(iv) Institutional (financial, administrative and organisational level).

The task of establishing fishery resources on a robust sustainable footing is a national issue which requires the coordination of fishery-wide issues that transcend State borders. Buttressing this national task must be a National Structural Adjustment Mechanism which would bind the many structural issues, which are currently delaying sustainable development, into a coordinated national action plan.

Best practice results will be used to broadcast the benefits of a national approach to sustainable development and more clearly delineate areas where harvesting programmes are not functioning efficiently.

A framework for a national programme would embrace the following critical areas:

(i) Management and Cross Jurisdictional Arrangements
(ii) Priority Fisheries
(iii) Labour and Capital Adjustment
(iv) Regional Development
(v) Legislative Framework
(vi) Fisher Participation and the role of other User Groups
(vii) Timetable for Implementation.

An important background to the formulation of policy and functional guidelines for such an adjustment scheme involve the following:

- Review national and international experience in fisheries adjustment and structural outcomes.
- Review of current legislative support for structural adjustment in both fishing industry and other industries.
- Review other non-fishery institutional support mechanisms such as general industry structural adjustment exit programmes and labour market programmes.

The paper will draw together critical issues gleaned from national and international experience and develop policy principles and objectives of a National Fisheries Adjustment Scheme. These principles and objectives will include the following :

- Review management data requirements and establish a standardised framework for collection and analysis
- Link sustainability indicators with structural fundamentals
- Devise national reporting mechanisms which will alert managers to possible structural dysfunctions
- Develop retraining and mobility programmes which will ameliorate exit difficulties
- Devise administrative guidelines for the role of the finance sector in the development of adjustment packages
- Highlight the roles of the Commonwealth and the States in adjusting species-wide fisheries and other jurisdiction complexities.

As an aid to policy deliberations a regional Case Study has been used to highlight the economic and social impacts of fishing (both recreational and commercial) with particular attention to a fishery undergoing structural change. The Portland region of Victoria was investigated with an emphasis on the Southern Rock Lobster Fishery.

Selecting an appropriate fishery adjustment programme must take into account the particular situation of specific fisheries with respect to the fish type, the structure and sustainability status of the fishery, and the region in which it is located. These factors will be considered in comparing the benefits and costs associated with specific fishery adjustment programmes.

Effective consultation and its impact on the management of eastern Australian gemfish

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Objectives:

1. To show the benefits of effective consultation by describing and contrasting the consultation and decision making processes used by two agencies, the Australian Fisheries Service (AFS) and the Australian Fisheries Management Authority (AFMA), which were sequentially

responsible for the management of the eastern Australian gemfish (*Rexea solandri*).

2. To examine the application of the consultation/decision - making process used by AFMA to other fisheries management issues.

The AFS sought management advice on the gemfish fishery from the South East Trawl Management Advisory Committee (SETMAC). However, there was no direct link between gemfish fishers and SETMAC, and consequently the AFS did not understand the views and needs of the fishers concerned. In addition, SETMAC was not well constructed or briefed by AFS to handle such issues. The outcomes of this process were:

- a lack of communication of key issues in the fishery at all levels, resulting in inappropriate action
- the total allowable catch (TAC) being overrun by 250% in 1992
- confrontations between fishers and fisheries officers.

At the time of AFMA's inception in 1992 the eastern gemfish stock was known to be seriously depleted and a rebuilding strategy was vital. SETMAC, which was now operating under substantially revised policy guidelines, established a working group to develop management arrangements specifically for the fishery. The working group was comprised of three industry members with a direct association with the eastern gemfish fishery, as well as scientific, State fisheries and AFMA interests. Although required to report to SETMAC and AFMA, the working group was given substantive responsibility for recommending the management direction for the fishery. The outcomes from the working group have been:

- formulation of a management strategy which simultaneously sought to minimise the fishing mortality whilst having a minimal impact on the fishing for associated species. The main elements of this strategy were
  - per vessel trip limits implemented to enable the landing of incidental bycatch
  - cooperation of fishers not to fish on the gemfish grounds during the spawning migration
- an industry/government funded study to address industry concerns in relation to the scientific assessment of the resource
- an investigation into the socio-economic impacts of proposed closures for the fishery.

Since the formation of the working group recorded catch has fallen from 650t (1992), to 260t (1993), to134t (1994) and to 90t (provisional for 1995).

Despite these initial successes, the changing circumstances in the fishery require the group to annually review the management arrangements and re-evaluate its role.

Key Conclusions:

1. A more effective consultative process has resulted in the reduction of the recorded catch of eastern gemfish and will provide the fishery with a better chance of long-term recovery.

2. The consultation/decision making process used by AFMA may be useful in other situations to resolve specific fisheries management issues.

3. The process described has the following attributes:
   - involvement of all key stakeholders, particularly those directly affected by management decisions
   - a devolution of management responsibility to fishers and other interests
   - all participants acknowledging the views and needs of others
   - making industry aware of, and educating them about, fishery science and management
   - developing acceptable solutions from a basis of understanding, within recognised constraints.

Cost-effective recovery of endangered Snake River salmon

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The high price tag – approximately a half billion dollars annually for an extended period – for the recovery of Snake River chinook (*Oncorhynchus tshawytscha*) and sockeye salmon (*O. nerka*) has created opposition to otherwise broadly supported environmental policies. The objective of this research was to develop a procedure for identifying which recovery strategies could achieve the biologi recovery goals with the least economic sacrifice.

The research drew on two complex biological simulation models. The Columbia River Salmon Passage (CRiSP) model developed by the Center for Quantitative Studies at the University of Washington traced salmon smolts from spawning habitat or hatchery to the ocean. Model outputs from CRiSP were inputs to the Salmon Life Cycle Model developed by researchers at the U.S. Forest Service and Resources for the Future. A range of potential recovery actions was translated into parameter changes for simulation modeling and combined to form recovery scenarios; these actions included many of those recommended by the Snake River Salmon Recovery Team (SRT) which had been convened by the U.S. National Marine Fisheries Service (NMFS). Using the gross population targets for each of the chinook salmon stocks identified by the SRT as recovery criteria, Monte Carlo simulation was conducted. The proportion of model games achieving population targets was interpreted as the probability of recovery under each scenario. The costs of the recovery actions were taken from a long-term planning project undertaken by the U.S. Corps of Engineers : associated agencies called the System Operation Review; original analysis by Daniel Huppert and David Fluharty of the University of Washington, and other sources produced by the NMFS-convened Economic Technical Committee, coordinated by Huppert and Fluharty. The combination of the simulation model outcomes and the cost of recovery actions then traced a cost-effectiveness frontier showing the relationship between the cost of various recovery scenarios and their associated probability of meeting recovery goals.

Cost-effectiveness analysis identifies costly and problematic recovery options. However, it cannot identify the best approaches and cannot exclude specific approaches. Social equity considerations, such as the need for all parties sharing blame for species decline to also participate in recovery, have been omitted. Also, estimates of expected probabilities of recovery display neither the variability around the expected values nor the divisiveness among scientists about biological mechanisms in the models. For example, the most expensive options are to re-engineer dams to reduce mortality of downstream migrating smolts and to alter the flow of water around and through dams so that less hydroelectricity is available during times of peak demand. So little is known about sources of mortality under the various flow and passage options that scientists and

political interest groups take strong, often conflicting positions based on intuitive conclusions. This analytical exercise reflects the debates between scientists and interest groups and reinforces the need for better economic and biological research upon which to base species recovery.

Fisheries management: developing an environmentally driven predictive capability (EDPC) for the South African squid fishery

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All fisheries are influenced to some extent by perturbations in the environment. Many of these perturbations can be ted to El Nino-Southern Oscillation events (ENSO). In South Africa, the first fishery to be impacted by such perturbations is the hand-jigged, labour intensive, chokka fishery of the Eastern Cape. In this fishery, environmental perturbations cause immediate, often large, fluctuations in catches, the proportional range and frequency of which are greater than that experienced in other fisheries. For example, in 1988-89, some 10,000 tons of chokka were caught, fetching R 100 million. However, in 1992 catches dropped to a quarter of this. Needless to say, poor catches such as the above negatively impact not only on the industry but also, and to a greater extent, on the lives of the 4000 informally employed fishermen and their families. In this paper, an overview is given of a methodology and model currently being developed by the Sea Fisheries Research Institute, to lessen the impact of environmental perturbations. Referred to as an Environmentally Driven Predictive Capability (EDPC), it is aimed at providing long-range forecasts (1 year) of monthly chokka catches. The model, when complete, will not only be used to adjust effort control by fisheries managers but also used by the South African squid fishing forum to forewarn the industrial sector d fishing community of poor seasons so that appropriate cial and economic strategies can be implemented well in advance to lessen the impact.

To realise the EDPC, a multi-disciplinary research approach is necessary. Five programs (modules) were initiated, the first in 1991. Three of these address understanding and modelling the oceanography, the atmospheric driving forces, and the regional long-range forecast of synoptic pressure fields using Global Circulation Models (GCM's). The fourth module which seeks a relationship between the oceanography and behaviour of spawning chokka, and hence catches, involves acoustic telemetry experiments, diving-camera studies and CPUE studies on spawning aggregations of chokka. The newest thrust, and perhaps the most relevant, is module (5) which is the extension and implementation of the EDPC into the fishing industry and community. Its aim is first to understand, in a quantitative manner, the impact that chokka catch fluctuations have on the industrialised sector of the fishery, as well as the fishing community, and having established this, methods must be found to lessen the impacts of poor fishing seasons. Despite steady progress being made in each module, it is clear that we are still some years from the completed EDPC product. The realisation of the EDPC is ultimately going to depend on (1) the ability of GCM's to reliably forecast extra-tropical climate variability, and (2) determining a satisfactory quantitative relationship between squid catches, water temperatures and benthic turbidity. The usefulness of the EDPC will depend on the forecast range.

Fisheries management in the Great Barrier Reef Marine Park

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Fishing, both commercial and recreational, is the largest extractive activity in the Great Barrier Reef Marine Park. The principal conservation agency for the Marine Park, the Great Barrier Reef Marine Park Authority (GBRMPA) does not directly manage fisheries in the Marine Park, but does have control over fishing by virtue of the use of a zoning system which specifies which fishing activities can occur in particular areas. Through the use of this zoning system to protect habitats and fish communities from fishing and by working with the fisheries management agencies to ensure that fishing in the open access areas is ecologically sustainable, the GBRMPA attempts to minimise the impacts of fishing on the Marine Park and and the GBR World Heritage Area.

The success of the management plan for the Great Barrier Reef is difficult to assess as still little is known about the major natural communities in the Marine Park and the ecological impacts of fishing. In many locations in the Marine Park, research has found higher numbers of larger fish on reefs protected from fishing in comparison with adjacent fished reefs and in many senses these act as effective harvest refugia. However, these results are not always conclusive and depend on the level of fishing effort, the possibility of illegal fishing and the resilience of the fish species in question. The GBRMPA has proceeded to overcome the paucity of knowledge about the impacts of fishing and the efficacy of the management plan by funding large scale manipulative research into the impacts of the two major fishing activities in the GBR Marine Park; (i) prawn trawling in the GBR Lagoon and interreefal communities and; (ii) reef based fishing by commercial and recreational fishers. Once completed, the two projects will give a much greater understanding of the direct impacts on the target species, the indirect impacts of fishing on associated communities, the dynamics of recovery once fishing ceases and a much better idea of the effectiveness of the current Marine Park management plan and other proposed conservation management strategies. Using the results of this research and through the implementation and/or refinement of other management policy in conjunction with the other fisheries management agencies, the GBRMPA is attempting to ensure that fishing is ecologically sustainable in the GBR Marine Park.

The Australian orange roughy fishery: a process for better resource management

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The management of new or developing fisheries is often extremely difficult. Industry is optimistic due to high catch

rates. Scientists do not have a time-series of fishery data on which to base assessments and, in most cases, the responses of the population to exploitation are not yet apparent. Resource managers are receiving conflicting advice.

The Australian orange roughy fishery is an important case study. The processes established provide a framework for avoiding many of these problems. The fishery developed rapidly in the late 1980s, from less than 200 t in 1985 to about 28,000 t in 1989. Industry's expectations were high: catch rates of 100 t per two minute bottom time were recorded, large marks were seen on echo sounders. Parallels were drawn with a larger orange roughy fishery in New Zealand.

There were two significant contributions to the assessment and management of this fishery. First, in 1987, the research effort in southern Australia was apportioned amongst research institutions according to the expertise of the particular institution, rather than the previous open competition for funds. Secondly, in 1989 at industry's instigation, an industry/technical liaison committee was established. This committee developed a stock protection strategy, determined research needs, and evaluated and funded research, through a voluntary industry levy. By all measures this committee was successful. There was not always agreement and debate was often heated. However, there was common ownership and mutual respect. A Total Allowable Catch (TAC) was applied to the fishery in 1990 when the total catch was in excess of 40,000 t. As a result of the close working relationships between industry and scientists, the overall reduction in catch from the peak in 1990 to current landings of less than 10,000 t proceeded in a relatively ordered manner.

There are two broad principles which can be drawn from this fishery. First, industry must be organised to address concerns in its ranks before negotiations. Second, scientists must interact with industry both formally and informally. Common ownership of problems, solutions and outcomes is a critical component of successful fishery management.

Fuzzy control theory applied to American lobster management

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This work describes some results of a collaborative project to investigate quota-based management for an offshore fishery for the American lobster in the Northwest Atlantic region. It demonstrates the application of an integrated software platform for the design and implementation of an adaptive control system which allows for combination of fuzzy logic and neural networks in a single framework. Although control engineering has already been applied to fishery regulation problems, it is generally recognized that many complex systems cannot be satisfactorily controlled using conventional control theory, primarily because the precise structure of the system is not known.

However, this lack may be balanced by considerable scientific background which is difficult to quantify and utilize. Fuzzy control theory allows linguistic and inexact data to be manipulated as useful tools in complex systems. In this application a neural network was utilized as a predictive tool to forecast lobster stock abundance two years ahead based on a time series of trawl survey data. The results of the neural net forecast, as well as other more qualitative data, were then combined in a fuzzy rule-based expert system to provide a final quota estimate which is then adjusted annually in a like manner. Simulation studies with this adaptive management system indicate that it is robust and provides more accurate and precise predictions than those obtained by traditional time series methodologies.

This fuzzy rule-based approach is believed to be very useful in fisheries management. The range of the applicability is large because a large class of nonlinear functions can be described. Furthermore, this approach remains simple because it is composed of simple local models along with procedures to go smoothly from one domain to another. Finally, fuzzy rule-based models are capable of accounting for empirically observed data.

Squid fishers and scientists – creating a symbiotic environment

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Prior to 1984, all commercial squid catches in South Africa were trawled, mostly as a bycatch of the hake and sole fishery. Since that time, a commercial jig fishery has developed along the inshore areas of the south eastern Cape, which now catches over 90% of the total catch. The first 10 years of the fishery show two distinct stages, an early 'gold rush' phase (1984-1986) and a stabilization phase (1987-1994). The initial increase in fishing effort included increased numbers of vessels, larger vessels, lights, blast freezing facilities aboard vessels and better fishing methods. After licensing was introduced in 1986, the industry entered a stabilizing period. The stabilizing effect included permits, the use of better fish finding equipment, greater experience of the fishers and skippers in finding squid schools, the erection of local packing factories and better offloading facilities, including offloading vessels. Initially (1985-1988) competition between the various processing plants buy squid was intense and price wars became commonplace. The relationship between the fishers, local government bodies and the scientists at the Sea Fisheries Research Institute was strained to say the least. The formation of the South African Squid Management Industrial Association (SASMIA) in 1989 has done much to settle the young industry and enhance cooperation between the industry and research. A thorough knowledge of the fishery was shown early on to be essential for understanding the feasibility and impact of regulations on the fishery and to avoid misinterpretation of baseline data. Research utilising commercial vessels now includes environmental monitoring, extensive diving operations to study spawning behaviour, recording substrate type and the influence of fishing on spawning concentrations, detailed recording of catch per unit of effort (cpue) data, recording shoal behaviour using colour video echo-sounders and tagging operations. It is recommended that more emphasis be placed on collaboration between fishers and researchers in data collection. This will improve both the quality and quantity of baseline data and make use of the expertise of the fishers who, after all, spend their lives in the field.

Sportfish tagging data and its role in a recreational fishing database in Queensland

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Objective: To outline the data collected through the Sportfish Tagging programme which will be included in a recreational fishing database in Queensland.

Background: While much data are available on commercial fishing and effort, very few data in a readily accessible form are available on recreational fishing. To support sound management decisions an extensive database on recreational fishing is required and is currently being developed. Wherever possible this should include existing data that are readily available.

As part of that, development data from the Sportfish Tagging programme will be integrated into the database.

Recreational tagging data have been collected in the Sportfish Tagging database for ten years and currently (as at August 1995) contains 110,000 tagged fish records and 9,000 recapture details.

Data Collection: Sportfish Tagging is a somewhat unique programme in that it is a joint one between the Qld Department of Primary Industries (QDPI) and the Australian National Sportfishing Association Qld Inc (ANSA Qld) and has been managed by ANSA Qld since 1987.

Over the past ten years the programme has moved from general tagging of recreational species to specific target species that are being researched where there is a tagging component required to address the objectives of the research. In the future the focus for the programme will be on projects aimed at addressing specific issues.

Findings: Data collected in the programme have been used to support research on:

- Flathead in South Queensland
- Snapper in South Queensland
- Small mackerel species along the Queensland coast
- Ageing of Fingermark Sea Perch and Mangrove Jack in North Queensland
- Barramundi movements in the Fitzroy River in relation to the Barrage
- Swallowtail Dart in South Qld

These data have provided information mainly on growth, movement and stock distribution.

There is also significant supplementary information that can be derived from the data:

- indicator of changes in fishing effort through changes in the tag return rate
- size/frequency of fish caught in various locations
- effect of imposition/changes to minimum/maximum sizes on recreational catches
- dispersal of juvenile fish from nursery areas (particularly barramundi)
- compliance with minimum legal sizes through the rate of kept/released recaptured fish

The development of tagging skills among ANSA taggers has led to experienced taggers being involved in double tagging of fish to assess tag shedding rates and in tetracycline injection to assist with ageing by otolith analysis.

Key Conclusions: Considerable useful data can be readily incorporated into the recreational fishing database.

The volume of data that can be collected for the available funding has been significantly increased as most of the work has been carried out on a voluntary basis.

Involvement in research data collection has led to a greater understanding between anglers and researchers and a greater acceptance of research findings.

Tag and release by ANSA taggers has lead to a more rapid acceptance of catch and release among recreational anglers and a reduction in their impact on fish stocks.

A well administered programme with significant voluntary resources provides an opportunity for further data to be collected, particularly catch/effort.

Converting research results into improved management using Bayesian statistics: the example of Pacific salmon gauntlet fisheries

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Converting the results of scientific research into improved management can be a difficult process. Often the confidence that researchers have in their conclusions is marginal. These types of studies often languish under the perspective "we have an interesting result but we need more data before we can make strongly worded recommendations". Given the tightening research and management budgets faced by resource agencies, such indecision about the applicability of scientific results is becoming no longer viable. Fisheries managers require quantitative methods to be developed, applied and tested which allow variable quality scientific results to be embedded within management procedures.

One such method already exists and is already in use by corporate decision makers. Bayesian statistics provides a quantitative procedure for combining prior information about a process with data to generate post observation (posterior) statistical inferences. We suggest that in some circumstances Bayesian statistics provides an excellent mechanism for absorbing scientific results. The fishery we use to illustrate this process is the gauntlet-style fishery on sockeye salmon (*Oncorhynchus nerka*) returning to the Fraser River in British Columbia, Canada.

Salmon runs are distributed as a normal distribution in space and time, with a run peak (the mean) and a spread (standard deviation) of around seven days. Around 70% of a run passes a single point in space within ±7 days of the run peak. Managers of Fraser River sockeye salmon need to know the total number of fish within a run so that complex allocations between native, commercial and sport fisheries can be specified whilst allowing adequate escapement for future production. These fisheries are distributed unevenly in space and time and can result in a harvest of up to 70% of a several million fish salmon run. Using estimates of fishery harvest rates and the results of systematic test fishing programmes it is possible to estimate the run sizes using a variety of statistical methods. Two complications increase the variability of these run size estimates: the inter-year anomaly of the time of the run peak (± 7 days) and the

percentage of fish which divert around the north of Vancouver Island (via Johnstone Strait) as opposed to passing through Juan de Fuca Strait.

Using a variety of research methods scientists have and continue to develop methods which allow pre-season estimates of salmon run sizes, run timing anomaly and run diversion. None of these deductive or inductive methods are completely reliable but they do present a source of information that can be quantitatively integrated into assessment procedures. Such information can be interpreted as informative prior probability distributions within a Bayesian inference scheme. Should these prior models misrepresent any particular salmon run, the assessment will be initially biased towards the prior estimate, but ultimately corrected as in-season data dominate the inference. Managers can reflect the credibility of prior information, i.e. the research results, by using low variance distributions for reliable results and vice versa. The ability of managers to remain "in control" of the assessment procedure is an important component of this strategy for transforming science into management.

Quantification of objectives, strategies and performance criteria for fishery management plans – an Australian perspective

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During the 1990s, Australia has been moving towards the development of formal management plans for a number of its fisheries. For federally-managed fisheries there are several such plans in place and a larger number in various stages of development. This paper reviews the objectives of these plans, the strategies which are used to achieve the objectives, and the performance criteria which have been developed to assess whether the strategies are meeting the objectives. The particular focus is on quantification in framing objectives and performance criteria.

Management objectives in Australian fisheries tend to fall into three broad areas: 1) conservation and ecologically sustainable development; 2) economically efficient exploitation; and 3) efficient and cost effective management. The need to rebuild depleted stocks is referred to in some plans. Management strategies generally deal with broad areas such as research, monitoring and enforcement, and in some instances refer explicitly to the use of particular input or output control measures.

The development of management plans has gone a long way towards making management objectives more explicit (and in recognizing multiple objectives), but in general the quantification of objectives and performance criteria has not proceeded very far. Exceptions include the use of quantitative biological targets and thresholds. These are often expressed as percentages of spawning biomass at the onset of significant commercial fishing ($\%B_0$). Examples include the southern shark fishery, where a target of 40% B_0 is identified, and a time frame of 10-15 years for stock recovery is mentioned. Another example is the orange roughy (*Hoplostethus atlanticus*), where there is also recognition of uncertainty in judging stock status with respect to such targets. Management objectives for this fishery state that there should be less than a 50% probability that current biomass is below 30% of pristine levels. For this fishery there is a Total Allowable Catch (TAC) reduction strategy in place to meet this particular objective.

Further progress can be expected in setting quantifiable targets and performance criteria for fishery management plans in Australia. However the next logical step is to develop a full "management procedure" for an Australian fishery. This approach has been developed by the International Whaling Commission (IWC) for whale management, and has been applied to several fisheries in South Africa. A management procedure can be thought of as an agreed combination of data, models and a decision rule which is used to manage a fishery over a specified period of time. The management procedure is developed by specifying quantifiable performance measures which relate to management objectives, and then testing the performance of a range of management procedures via simulation. The process of developing and choosing a management procedure requires close collaboration between scientists, industry, managers and other stakeholders in the fishery.

Can fishery catch data supplement research cruise data? A geographic comparison of research and commercial catch data

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Over 350 vessels operate annually in the U.S. west coast groundfish fishery; the 1991 reported catch was more than 278,000t. Logbooks maintained by the fleet provide a detailed set of catch and effort data with broad temporal and spatial coverage. An elaborate coastwide monitoring system also provides records of the actual weights of fish sold. Although large amounts of site-specific information are compiled in these programmes, much of the data is not used for fishery management, primarily because of the large volume of data, and concerns about potential data biases.

A Geographic Information System (GIS) was developed to compare ten years of data (1980-89) from the Oregon commercial trawl fishery with data from U.S. National Marine Fisheries Service (NMFS) triennial trawl research cruises conducted at the same time in the same area. The objectives were to map fishery and research catch locations for five fish species (sablefish, Dover sole, English sole, yellowtail rockfish and shortspine thornyhead), and compare catch distribution patterns, catch rates and biomass estimates. Isopleths were computed and plotted representing the 50th, 75th and 90th percentile levels of catch per unit of effort for each species, year and data type. Logbook and research catch locations were compared by overlaying maps and evaluating the geographic co-occurrence of the polygons defined by isopleths. Catch per unit of effort (cpue) and biomass estimates produced by the two data types were also statistically compared.

For both logbook and research data sets, locations of high catch rates varied little between years. Mean cpue per stratum of depth and latitude for each of the five species showed a high degree of correspondence between commercial and research catches. Linear correlation

analysis comparing logbook and research cpue yielded statistically significant results in all but one case. Commercial and research biomass estimates were similar for species that were broadly distributed and well sampled by trawl nets. Both research and logbook estimates of biomass for schooling yellowtail rockfish were highly variable, suggesting that neither logbook nor NMFS surveys adequately assess pelagic rockfishes. Biomass estimates derived from logbook data for the summer season were similar to estimates derived for an entire year, but displayed consistently narrower 95% confidence intervals. This implies that in addition to the obvious logistical advantages to surveying in the summer, researchers are maximizing the statistical reliability of the triennial trawl cruise data by sampling in the summer.

Results indicate that commercial fishery logbooks provide data about fish distribution and abundance that are comparable to research surveys. It is suggested that logbooks provide an additional tool that can be used to improve the design of scientific research studies and to improve estimates of the distribution and abundance of [illegible]ected species.

Cooperative and non-cooperative exploitation of the Arcto-Norwegian cod stock

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A two-agent model for the exploitaton of the Arcto-Norwegian cod stock is developed to investigate the economic benefits that can be realised from the resource, and the effect of exploitation on stock sustainability under cooperation and non-cooperation. The two agents are identified in this study as a trawl fishery versus a coastal fishery. Unlike in Munro (1979), where conflicts in the management strategies of agents arise from differences in the perceptions of the discount factor, fishing effort costs and consumer preferences, here conflicts arise mainly from the differences in fishing gear and grounds, and the age up of cod targeted by the two agents. In addition, conflicts may arise in the model as a result of differences in fishing effort costs. Using a game theory framework, it is shown that given available data, the optimum is obtained under cooperation with side payments and no predetermined harvest shares, in which case the trawl fishery buys out the coastal fishery. However, given the current socio-cultural dynamics of the Barents Sea cod fisheries, it is concluded that the most likely outcome is cooperation without side payments, where the preferences of the trawl fishery are given higher weight.

Louisiana striped mullet: integration of science, fishery and management

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Louisiana's striped mullet, *Mugil cephalus,* fishery is a relatively young industry in comparison with the other areas of the United States, particularly Florida. The Louisiana fishery, primarily a gill net fishery, is a roe-based industry which has increased from near zero in the early 1970s to over five million kg in the 1990s. Biological studies have been conducted over the past ten years to ascertain how knowledge of the life history of striped mullet can be useful to the fishery and provide guidance for a sustained harvest. Public concerns regarding saltwater finfish resources, as well as other considerations, led the 1995 Louisiana Legislature to severely restrict harvest by gill nets. This law forbids mullet harvest outside the roe season, threatening the very existence of this expanding industry. The allocation of harvest to this season was not due to concerns of researchers or management personnel, but rather to the realization that there would be restrictions on the use of gill nets in Louisiana, and harvesters were asked to select a short mullet season in which they could best operate. The potential for simple gear regulations providing biological safety for the fishery was not addressed.

Examination of the reproductive biology of striped mullet showed that Gonadosomatic Index (GSI) increased with size to around 330 mm FL, so that the fishery was "better off" harvesting larger females with average GSI of 20 to 22%. The roe fishery season extends from October through mid-January when ovaries enlarge to an acceptable market size (100-200g). The data suggest that the fishery should wait until November for maximum roe per mullet harvest. The success of the roe fishery for striped mullet results from the species being an isochronal spawner, i.e. virtually all oocytes of striped mullet maturing together, the ovary enlarges to the point where the gonads are economically feasible to harvest.

Size-at-age data (1986-1990) showed that three year old mullet varied between 200 and 400 mm FL, centred near the GSI asymptote, and contributed significantly to spawning. This age class was prevalent in the commercial catch, but age structure of selected gillnet samples showed that the dominant year classes of the Louisiana catch were 4 and 5 year olds. These data support the recommendation to the fishery that for each cohort two year old and most three year old mullet be allowed to spawn before recruitment into the fishery. Whether this can be sustained with expanded harvest to produce a "self-managing" fishery has yet to be determined.

A fishery is the intersection of a resource and human users of that resource. The biology of the resource only examines one side of this interaction and the sociology and economics of the fishery can be as important in the functioning of a fishery as is the biology. Only through the cooperation of researchers and management agencies with the harvesters and processors and through the education and interest of the general public in the continuation of the industry can any fishery truly become a stable environment.

When science isn't enough: improving survival of discarded Pacific halibut

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Groundfish fisheries in waters off Alaska are managed, in part, with limits on the bycatch mortality of Pacific halibut (*Hippoglossus stenolepis*); halibut must be discarded to the sea with minimum injury except during open periods with legal gear. Data collected by on-board observers are used to calculate bycatch mortality. Groundfish fisheries often close before they attain the harvest quotas when they reach the bycatch mortality limits. The bycatch causes loss to the directed fishery for halibut because halibut catch limits are reduced by the amount of bycatch mortality, about 20% of the Total Allowable Catch. Both fisheries would benefit from reductions in bycatch mortality. Efforts to reduce mortality fall into two categories: reducing the amount of bycatch through avoiding halibut or more selective fishing; and increasing the survival of halibut discarded as bycatch.

In 1993, management agencies and industry jointly conducted research aboard a factory trawler in the eastern Bering Sea and northern Gulf of Alaska to test methods of decreasing mortality rates of discarded halibut. The experiment consisted of three treatments: 1) Sorting on deck, followed by sorting in the factory; 2) sorting only in the factory quickly after dumping the catch; and 3) sorting in the factory after a 45 minute delay to simulate slow discard procedures on some vessels. On-deck sorting decreased discard mortality rates by 14% over rapid sorting in the factory and 24% over factory sorting with delay. However, halibut sorted during the first 20 minutes out of water, in the factory or on deck, showed no difference in survival, demonstrating that time out of water is a critical factor. Overall, discard mortality rates of halibut bycatch could be lowered by an estimated 15-25% if on-deck sorting were applied to factory trawlers in appropriate fisheries. Maximum reductions in discard mortality rates result if sorting on deck and sorting in the factory can co-occur, but a single observer cannot monitor both sortings. Thus, data quality diminishes. Lower reductions result if factory-sorting follows deck-sorting, so that a single observer can completely monitor the catch, because of longer time out of water.

A proposal to require factory trawlers to sort and discard halibut on deck, facilitated by a sorting grid over the hold, received widespread support from management agencies and industry at the conceptual stage. As details of the proposal came forward, opposition developed and the proposal died. On-deck sorting conflicted with another management programme designed to reduce bycatch rates, although that programme had demonstrated little success to date. Additional observer duties needed for on-deck sorting conflicted with existing duties, and managers cited safety concerns for observers working on deck. Non-trawl industry groups withheld support, possibly because of potential reallocation to non-trawl gears of target species that could not be caught by the factory trawlers closed down by bycatch limits. Concern about cheating on unobserved hauls and disagreement on interpretation of data further reduced support. The potential for bycatch mortality reduction from on-deck sorting could not compete with the existing policies and politics of bycatch management.

The roles of science, economics, sociology and politics in fisheries management – the South African experience

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Activities within a fishery are biological, technical and economic. Biological activities pertain to the dynamics of fish stocks, such as the relationship between stock size and growth, factors affecting natural mortality and the extent and nature of species interdependency. Technical activities refer to the physical harvest process, i.e. the relationship between catch and the amount of equipment, gear, labour, vessel etc used. Economic activities include processes which determine prices, costs and income levels. All three sets of activities are interdependent and the purpose of this paper is to illustrate this interdependence through the use of two examples: fisheries management and economic sector analysis.

Indeed, the student of fish population dynamics and the research economist have much in common. Both must generate and test their hypotheses in the absence of controlled experiments. They must use data originating in events having nothing to do with research (eg market transactions, migratory patterns). Furthermore, these data must display enough variation to permit the testing of cause and effect hypotheses; otherwise, how can yield-effort and landings-price relationships be estimated? Thus it is often necessary to use data generated over long periods of time. In some cases, time series data are available (e.g. landings) while, in others, they are not (e.g. information on the tastes and preferences of both fish and humans). Beyond this a clear interpretation of existing data is often lacking, with the meaning of "effort" figures being a typical example.

For most countries, statistics specify foreign trade with a satisfactory level of detail, while the statistics for domestic production and inventories do not. The reason is that it is difficult to establish a solid basis for collection of data on domestic consumption of fresh fish. Domestic consumption often has to be estimated, but it must be done on a continuous basis in order to create a sufficiently long time series for statistical analysis. However, very few countries provide such estimates.

Data collection is not costless, however. Furthermore, there are political considerations involved. Biological data shared among nations are not always unbiased, especially where such data emanate from the catch figures of harvesting nations. Sharing of economic data is even more difficult. What incentives do competing countries have to exchange information on their markets? One solution to this may lie in international organizations which operate in an environment which is relatively free of political allegiances.

Thus there are two missions. One is to bring biological and social sciences together; the other is to foster cooperation among scientists across political boundaries. Fishery managers and policy makers have demonstrated some understanding of the role that can be played by both biological and social scientist. Despite the refinements of bio-economic models, interaction between the two disciplines generally takes place on an *ad hoc* basis.

Effect of feedback on commercial fisher data collection in remote area fisheries

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Fisheries management, when based on data analyses rather than on intuitive views of the fishery, relies on the data being a true reflection of activities in the fishery. The Queensland part of the Gulf of Carpentaria inshore fishery in north eastern Australia illustrates how cooperation between the fishers and researchers provides useful and reliable data for fishery management planning in remote area fisheries.

This foreshore and river fishery of the eastern Gulf lies between 11°00'S and 18°00'S and 142°30'E and 138°00'E, has a area of approximately one million km² and is managed from Brisbane, 2,000 km to the south. Day-to-day management relies on two officers based in the southern Gulf at Karumba, nearly 800 km from the fishery's northern boundary. Human population is sparse with four main villages adjacent to the 1,500 km coastline. There are about forty rivers in this raised seabed landscape of extensive flood plains. Highly variable summer monsoon rains of about 750 mm fall mainly between November and March. Existing management philosophy is input and location limiting and commercial fisher driven.

Some 280 fishers operate from about 100 commercial fishing units and target, with set gillnets, a suite of mostly fast-growing, long-lived, protandrous, diadromous, environmentally sensitive species such as barramundi (Centropomidae), and blue and king threadfin salmon (Polynemidae). The catch is processed to fillet form at the grounds, stored in freezers and marketed throughout Australia. Lifestyle components are important to this fishery.

All species catch fell from about 1,600t in 1981 to 1,200t in 1994 with a marked decline from 1986. Recorded fishing effort also fell sharply after 1986, with days fished declining from about 24,000 in 1981 to 12,000 days in 1994. Fishing unit numbers fell from 160 to 100.

Judging harvest performance (species catch weight, effort, location and catch per unit of effort (CPUE) and resource monitoring (time series analysis for life history sensitive parameters) form the bases for the data collection programmes used: compulsory logbooks and voluntary biological sampling.

The logbook programme commenced in 1981 and has had four phases. Each new phase required more detailed fishing activity information to be provided. The current phase, commencing in 1993, collects daily data on fishing location (mainly six nautical mile grids), effort (net descriptions), species catch weight and processed form (filleted etc). Numbers of fish caught (by species) are voluntarily recorded.

Volunteers providing biological samples freeze fish frames of selected species, record associated capture information and deliver them to concentration points for collection.

The Gulf inshore fishery features strong liaison and cooperation between the researchers and commercial fishers. The commercial fishers have a strong commitment to ensure fishery productivity is increased for profitability as well as intergenerational transfer reasons. Enthusiastic discussion at biannual fisher forums of their data has built trust in the programme with the results and implications presented in a management context.

Reporting back has encouraged fishers to voluntarily provide more information and to improve the quality of the data provided. Also, fishers are aware that recommendations to modify management arrangements are based on the results of analyses of the data they provide.

A change in management plan development has recently evolved in Queensland. The emphasis is now on plan development by stakeholder consensus. While the commercial sector activity is well documented, the scale and level of catch from the recreational and indigenous fishers are not known with any degree of confidence. Establishing the resource demands of the various user groups will be made easier through interrogative processes similar to those now in use in the commercial sector – but that is in the future.

Fisheries access rights: dishing out what remains of the South African fish pie

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Presently, South Africa is undergoing major social and political changes that are affecting virtually every aspect of life. In addition to the democratization of its people, these changes have created opportunities for re-developing past policies, including those for fisheries. For the past two years a fisheries policy development process has been underway, which has resulted in a draft policy being submitted to the South African Parliament in June 1996. This process has created enormous expectations, especially amongst the previously marginalized fishers of South Africa.

South Africa has rich marine fish resources in its EEZ, with an annual harvest of almost 700,000 million t, worth US$300 million, and providing direct employment of 27,000 people. This paper briefly highlights both the varied nature of the resources and the different methods of harvesting. South African fishing rights have traditionally been primarily vested in a few large companies. While this is, in part, due to the offshore and industrial nature of some harvesting, it was also influenced by past political policies. Consequently there are three major areas of concern:

(i) Correcting past wrongs in resource allocation;
(ii) Finding "new" resources that will increase the pie (including improved usage of existing resources) so that access can be broadened; and
(iii) Adopting the best fishery concepts, i.e. learning lessons from others.

Central to the entire policy development process has been the issue of access rights. A task team was appointed to review the options and procedures for broadening access. This involved grouping fisheries according to their fishery types, including the mobility of stocks, distance offshore, types of control and characteristics of present and anticipated users. All fisheries were grouped into four major types and different levels of access proposed for each.

Following the development and general acceptance of the basic access philosophy, the process of delivery and implementation remains a major challenge, especially to provide immediate relief to previously marginalized subsistence fishers. This aspect necessitated consideration of re-allocating resources from present participants to the disadvantaged fishers. Various options have been proposed including transfer of rights from dormant participants, progressive change in TAC allocations and the re-allocation of potentially recovering stocks. An important consideration in this process of re-allocation will be the registration of subsistence fishers according to defined guidelines.

Has it been successful? Certainly, some notable achievements have been made, especially in communication amongst fishery participants. But, the policy development process has yet to be finalized and huge challenges remain. Whether good science and optimal harvesting strategies will prevail remains uncertain.

"As nets belong to fishers, fisheries belong to them" (Jaal jar jala taar)

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(In this paper, the author uses his personal experiences, obtained in his own country, Bangladesh, to draw general conclusions which may have relevance to similar situations elsewhere.)

Firstly, access rights are the essential ingredient of peaceful management, possession, production and enjoyment of water bodies. In the past, the fishing profession was socially neglected by the so-called aristocratic class of society, with the result that traditional fishers were undisputed occupants and users of the inland water bodies. But now this has been reversed. Controversy and conflict occur over access rights between the traditional and non-traditional fishers and the wealthy class of society,

In south Asian countries like Bangladesh, traditional fishers are socially identified and neglected for their profession and have suffered extremely from poverty, exploitation and illiteracy. Directly or indirectly, the big people or non-professionals are holding the rights and enjoyment of the water bodies for want of proper management policy.

Priority over access rights in the inland and coastal water bodies should be given to the traditional fishers, together with necessary inputs and financial assistance for conservation and catch.

In culture fisheries and in deep-sea fishing, industrial groups can be recognised, irrespective of fishers and non-fishers maintaining the interest of traditional fishers as far as equity and fairness.

For recreational purposes, limited numbers of water bodies may be chosen for project implementation by the government and private initiatives while guaranteeing access rights to the common people only for recreational catch.

Secondly, with regard to input controls, there is instinctive tendency among fishers to maximise the catch, providing a threat to sustainable development with depletion of stock and production. It is therefore essential for conservation legislation in the respective countries to be implemented properly. Production, application and marketing of destructive fishing gears should be prohibited by enacting appropriate laws and ensuring compliance with these laws. Fishers need to be made conscious of this necessity and the benefits to be obtained from compliance with the conservation laws by way of training, motivation and demonstration.

To prevent overexploitation and to ensure sustainability, numbers of fishing trawlers, gears and fishers need to be controlled, and their catches in marine and inland water bodies limited according to area and productivity.

The use of insecticides for agriculture, construction of unplanned roads and barrages, industrial effluent and water polluting activities which have adverse effects, should be controlled by coordination between the relevant agencies of the respective countries and international concerns.

Output controls are an unavoidable and essential factor for ensuring sustainability and production of fish. To that effect, peak periods for catching should be specified after

considering the local strategies of inland and marine water bodies of the respective countries.

In inland capture fisheries of Bangladesh, fishers are allowed to catch for only 5-6 months in a year, but when they become unemployed outside the peak season, they violate the conservation laws by indiscriminate fishing to meet their need for survival. It is therefore necessary to provide income-generating alternatives in the non-peak season, particularly in the underdeveloped countries where such circumstances exist.

Quotas for catch need to be set with reference to sustainability, overexploitation, fishing for juveniles and depletion of stock and species. But in deciding quotas, questions of viable catch, investment and employment of the fishers need to be considered carefully.

In Bangladesh, fishers and their organisations have been demanding perpetual rights and enjoyment over the inland water bodies without any resource rent. The Government of Bangladesh has recently declared the open fisheries free from rent for non-mechanised boat owners. In this respect, considering the better results of production-oriented management, nominal resource-rent should be levied but in case of additional investment being needed for resource management, rent may be levied in order to cover that investment.

Jurisdiction and boundaries of inland and marine water bodies have become matters of conflict. The existence of inland fisheries is under threat due to natural siltation in the flood plain areas and encroachment by the agriculturist. In marine fisheries there is conflict between fishers due to encroachment into each other's territorial jurisdiction.

To put an end to this, catches in the marine fisheries are to be restricted to within the respective territorial jurisdiction demarcating the boundaries according to international marine laws, where it should be ensured by coordination and cooperation among the respective governments and fishers' organisations. The boundaries of the inland water bodies need to be demarcated and development in the form of project implementation should be ensured in the light of biological management.

Management of offshore marine resources in the new South Africa

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Situated in a major upwelling region, South Africa is richly endowed with marine resources. Deep-sea fisheries contribute by far the most in terms of value (more than 90% of the 1992 total of around $340 million). These comprise demersal trawl and longlining ($174 million), pelagic purse-seining ($74 million) and squid jigging ($30 million) sectors.

In the past, the political system resulted in access rights in terms of quotas or being concentrated in the hands of relatively few companies which had large capital resources. Little or no recognition was given to other groups with legitimate aspirations to utilize resources. These problems are now being addressed. A Fisheries Policy Development Committee (FPDC) has been appointed and aims to restructure the fishing industry in terms of the government's Reconstruction and Development Programme (RDP) which, it is hoped, will create jobs and real growth, while at the same time ensuring sustainable utilization of resources and full development of underutilised resources. Its main task is to develop a broad framework for policy development. Allowing greater equity of access to marine resources vested in the State is widely seen as an important principle, but how it should be addressed it not a simple matter. Proposals have been put forward by many interest groups.

The rational management of deep-sea resources is complicated by several factors in the current situation. An important one is that the new policy is not yet in place. Dealing with the many recent applications for exploratory fishing and new developments, for example, present problems when the future access rights policy has not been spelt out. Another is that none of the major resources can accommodate large increases in the total catch to satisfy the needs of the many aspiring entrants. In the case of the demersal fishing industry the management strategy has been conservative and aimed at rebuilding depleted stocks of the most important species, hake. The development of a longlining sector is seen by many as a way of incorporating a large number of small entrepreneurs, but this clashes with existing trawling interests, who provide many jobs. Also, the fishing expertise often does not lie with the small fishers the government would most like to help, so they also need training if they are to benefit directly. The impact of longlining on the hake stock is currently under investigation. In the case of the pelagic purse-seine fishery, targeting for anchovy and sardine, access is equally difficult for the dispossessed, because of the high levels of capital investment required. The management strategy for these resources is currently under review, as the pilchard stock appears to be increasing and anchovy declining, but both are close to being maximally exploited. It seems inevitable, though, that some form of access will have to be agreed on. The lucrative Eastern Cape-centred squid fishery is also beset with controversy. It was largely developed by small entrepreneurs in the 1980s and has up to now been managed by means of effort limitation with a strong emphasis on research and self-management. Impoverished fishers in the region are also demanding access.

The establishment of democratic structures for the management of resources is a further major objective of the FPDC. Conventional approaches to stock assessment will obviously have to continue, but social and economic considerations also need to be taken into account. More appropriate approaches to local management need to be developed where local users take on responsibilities in protecting their own resource assets.

A burning issue is whether marine resources should be managed centrally or regionally. A powerful lobby is pushing for provincial jurisdiction over marine resources. This issue has been addressed by the FPDC. Some local control over shore and coastal resources may be advisable, but not for deep-sea resources.

The role of protected marine areas in fishery management: Florida Keys national marine sanctuary

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Designating certain marine areas as "protected" – usually by officially naming them "sanctuaries" or "reserves" -is a revolutionary resource-management tool used in mitigating habitat degradation and overfishing. In reserves, access to critical habitats is restricted in an effort to conserve biodiversity and environmental quality, and to sustain resource usage. Despite widespread interest, this new concept is relatively untested. Few quantitative paradigms or management models are available for implementing or developing strategic plans for reserves (e.g. their overall design, including number of reserves and their total areal extent, and proximity to physical factors for each reserve). The Florida Keys National Marine Sanctuary (FKNMS) is a national treasure with rich subtropical multi-species reef fisheries, a multi-billion dollar tourist economy and unique aesthetic qualities. The increase in the protection of this valuable habitat and its resources brought about by its status as a sanctuary, underscores the need for an adaptive management strategy that defines the structure and function of reserves within the FKNMS. A systems approach using a nexus of advanced visualization, data assimilation and quantitative analysis techniques has been employed to develop: (1) a model that links relatively sparse survey estimates of reef fish densities to key physical factors, and (2) a multi-species assessment index that can be used in making management decisions concerning the FKNMS and that can help define the evolving role of marine protected areas in fishery management.

Critical tests of variation indicate mtDNA characters are powerful for mixed stock analysis

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The geographical and temporal stability of mitochondrial (mt)DNA variation in American shad, *Alosa sapidissima*, was investigated as a means of estimating the contribution of broadly distributed river populations to mixed ocean fisheries. Because of the increase in coastal intercept fisheries, a method for partitioning mixture composition is desperately needed for effective interjurisdictional management of shad and other migratory fish species along the North American east coast.

The efficiency of sampling strata for capturing informative genetic variation to be used in Mixed Stock Analyses (MSA) was also examined. Because shad are harvested primarily from the open ocean rather than from rivers of origin, there is a growing potential for disputes over stock ownership among multiple jurisdictions. Genetic stock identification may be a potent method for monitoring ocean harvest pressure on individual river stocks.

MtDNA variation was examined for 1888 individuals, representing 17 putative stocks, over a two year period. Fourteen restriction endonucleases were used to uncover 62 polymorphic cleavage sites for each individual; a strategy that coarsely sequenced ~ 3.5% of the genome and yielded 127 unique baseline haplotypes. It was discovered that standard restriction fragment and site analysis of mtDNA furnished sufficient information about variation in American shad to support MSA, provided that adequate sample sizes were collected from all relevant contributing stocks. It was also discovered that a diminishing-returns relationship operated when additional restriction enzymes were added beyond the best six, although absolute resolution continued to increase.

Temporal variance between years was investigated to establish whether river populations were stable over time. MtDNA genotype arrays did not exhibit appreciable temporal flux, unless some major perturbation affected a population, such as extremely reduced effective population sizes or recent stock transfer across watershed boundaries. Yearly variation contributed an insignificant portion of the total genetic variation. As a result, samples from successive years could confidently be pooled to enhance sample sizes and improve the accuracy of MSA.

Two standard quadratic programming approaches were used for estimating the contributing stock composition from an open ocean mixture. Both methods provided maximum likelihood estimates of harvest composition, one of which (GIRLSEM) assumed baseline frequencies were known without error and one of which (SHADRACQ) assumed they were estimates. Both techniques provided similar estimates of shad admixture proportions using mtDNA data arrays. In spite of the inability to assign individuals to a particular natal river with great confidence, MSA (with either of these procedures) permitted the production of accurate population estimates. These data document the utility such an approach for interjurisdictional management of American shad and possibly other migratory species.

Development of the stout whiting fishery in southeast Queensland

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The stout whiting, *Sillago robusta*, is one of the most abundant fish species in coastal waters off southern Queensland. In the past, they have been taken both by prawn trawlers, as marketable bycatch, and fish trawlers targeting the species. However, during the past ten years the fishery for this resource has been sporadic, with annual landings in Queensland varying between zero and 2,700 t, depending on market demand. Stout whiting are a high volume, low priced marine commodity. They are caught, packed and frozen aboard ship and exported to southeast Asia for value-adding before being on-sold into the Japanese and Taiwanese retail markets.

The targeting of stout whiting for the Japanese kisu market began in the very early 1980s. By mid-1984, seven prawn trawlers were supplying wholesalers with whiting. Access to the fishery remained effectively unlimited in the 1980s and by 1990 eleven vessels were targeting stout whiting. Annual landings increased from 200 t in 1986 to 1700 t in 1990. In February 1991, the Queensland Fish Management Authority, taking a conservative approach, gazetted the stout whiting fishery as a limited entry, developmental fishery and restricted the number of endorsements to six. The Authority also instituted a pilot study to examine and document the fishery's history, catch and effort status, bycatch considerations and the basic biological parameters of the target species. Indicative data on age composition of the fished stock were obtained from the pilot study, but the Authority recognised the need for additional data on age structure, distribution and catchability to follow changes in age composition and stock abundance during the development phase. In 1992, further research was commenced. The specific objective of the project was to describe basic biological parameters necessary for effective management of a trawl fishery for stout whiting.

The developmental fishery has been monitored for the past four years. In 1991–1992 there were marketing problems associated with the fishery, but by late 1993–94 the market was able to accommodate all available product. This boom period was assisted by a marked improvement in gear technology. Catch per unit effort (cpue), estimated from areas consistently fished during all years, declined in 1994. A length-cohort analysis of samples taken from commercial landings between 1991 and 1994 indicates a trend towards growth overfishing in this fishery. Both management and commercial participants have shown a willingness to consider scientific advice on input and output reductions in order to ensure the ecological sustainability of this fishery. Several fishers are also examining market diversification and on-board value-adding to improve profit margins and reduce total catch. As there is little undiscovered fishable area left from which new stock could be taken, further monitoring of this fishery in conjunction with a flexible management strategy will be paramount to its sustainable development.

Management considerations for the dusky flathead fishery in Moreton Bay, Queensland, Australia

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Many inshore stocks of fish adjacent to major cities, such as the dusky flathead in Moreton Bay, are subject to both recreational and commercial exploitation. Dusky flathead (*Platycephalus fuscus*) are carnivorous fish endemic to the east coast of Australia. They inhabit shallow estuarine bays and inlets and are found over all substrate types. The only direct management strategies at present affecting fisheries for dusky flathead are gear restrictions and a minimum legal length of 30 cm.

In Moreton Bay, the species is taken commercially by tunnel, seine and mesh net. The average annual commercial catch is about 40t, most of which is taken in winter. Dusky flathead comprise an important part of the inshore multi-species net fishery. The recreational catch of dusky flathead in Moreton Bay probably exceeds the commercial catch. The recreational fishery peaks in spring at the estuarine entrances and sandy beaches adjacent to oceanic influence. As this is also the peak spawning period for dusky flathead, a spawning closure for this species would affect the recreational fishery far more than the commercial fishery.

The length at which 50% of female dusky flathead are capable of spawning is about 45 cm. Male flathead do not grow longer than about 50 cm and mature at a smaller length than females. No evidence of protandrous hermaphroditism in the species has been found.

Given that the exploitation rates and stock – recruitment relationships for the species are unknown, conservative management measures are recommended. The minimum legal length for dusky flathead should be increased at least to 35 cm and possibly to 40 cm. The increase from 30 to 35 cm would result in a 30% reduction by number in recreational catches and 18% reduction in commercial catches. The impact of increasing the minimum legal length to 40 cm needs to be closely investigated as about 25% of both the commercial and recreational catch is between 35 and 40 cm. A minimum legal length equivalent to the 45 cm total length at first maturity is not considered the best management option as all fishing would then be primarily focused on females.

Recreational daily bag limits and a maximum legal length to protect larger spawning females are further options. In a roving creel survey of 1,600 anglers the largest catch taken by an angler was six flathead. Proposed daily bag limits of ten flathead per person would not appreciably reduce the recreational catch. Maximum legal lengths would have a greater impact on the recreational sector where 9% of the catch by number exceeds 65 cm. In contrast, only 1% of the commercial flathead catch is greater than 65 cm.

Brown shrimp (*Penaeus aztecus*) fisheries resources in the Mexican waters of the Gulf of Mexico

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Brown shrimp (*Penaeus aztecus*) comprise around 90% of catches from coastal lagoons and offshore in Northeastern Mexico. Annual average catches registered in Tamaulipas State are 10,382 t, fresh weight, from which 5,454 t (53%) are obtained by the offshore fleet. This species is caught offshore all year, with a maximal abundance from March to November. In the lagoons, catches amount to around 4,880 t (47%). Juvenile brown shrimp is exploited there during a short period comprising from March to August, with maximal abundance between May and July. This is the result of migrations between the lagoons and the sea. Recruitment to the lagoon and offshore fisheries occurs from May to July. The massive exploitation of the juveniles led to the establishment of a closed season to protect the early growth and migration of the species. The closed season was established for the first time in 1993, lasting 45 days in June and July, and from May 15th to July 30th in 1994 and 1995. From 1993 onwards the closed season became one additional variable to account for in the fishery. Although it resulted in increasing catches, it also resulted in a more intensive exploitation during 45 days after the start of the fishing season. In the lagoons the closed season

resulted in the protection of around 40% (1,800 t) of the prejuvenile population and favoured its development and migration to the sea, compensating somehow for the so far uncontrolled artisanal fishery within the lagoons.

After the closed season was established, the yields in the offshore fishery per fishing trip rose to 2,371 kg/trip in 1993 and 1,824 kg/trip in 1994 from the historic average of the last 18 years in the zone (1,518 kg/trip). Catches during August, immediately after the end of the closed season, were higher (2,500 t in average) than from the same month during the 18 years (624 t).

Appropriate spatial scales for marine fishery reserves for management of coral trout, *Plectropomus leopardus*, on the Great Barrier Reef

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The concept of Marine Fishery Reserves, or permanent spatial closures, has received substantial attention as a potential management tool for exploited stocks of demersal reef fish. A fundamental assumption underlying the use of spatial closures is that there is limited exchange of adults among separate management units. The aim of this study was to test this assumption for the common coral trout, *Plectropomus leopardus*. *P. leopardus* is a medium size serranid which is highly valued by fishers on the Great Barrier Reef (GBR). The Great Barrier Reef Marine Park is managed by a zoning system which allows fishing in some zones while excluding it from others, effectively implementing a spatial closure management strategy on the fishery. The spatial scale of the zones vary, from a section of a reef to groups of several reefs. The objectives of this study were to determine: i) the extent of movement of post-settlement *P. leopardus* within and among individual coral reefs, and ii) whether there was a temporal pattern of movement associated with the spawning activity of *P. leopardus*.

A total of 4,627 *P. leopardus* were tagged with t-bar anchor tags and released on five reefs in the central GBR from five tag-release occasions over 22 months. 443 individuals were recaptured; 300 by commercial and recreational fishers and 143 from four research tag-recovery cruises. 99% of the research returns were recaptured on the reef of release. One inter-reef movement was recorded between two adjacent reefs (from a reef open to fishing to a reef closed to fishing). The research returns indicated that the extent of inter-reef movement was negligible. In contrast, there was considerable movement within individual reefs. On average 35% of the *P. leopardus* returned from the research tag-recovery cruises had moved out of the 1.5-2.5 km section of reef perimeter in which they had been released. The extent of movement varied among reefs, and appeared to be related to movement to or from spawning aggregations.

In contrast to the negligible level of movement among reefs from the research returns, 36% of public returns were nominally returned from reefs other than the one on which they were released. The majority of movements among reefs from public returns were from the reef closed to fishing to the next adjacent reef (which was open to fishing). This disparity in the extent of movement of *P. leopardus* between the public and research returns appears to have been the result of infringement and misreporting of location of capture. The majority of public returns which were nominally recaptured on a different reef to that of their release were returned by one fisher. The available anecdotal evidence suggests that these fish were actually recaptured on the reef on which they were released.

These results indicate that the level of movement of *P. leopardus* among individual reefs is negligible. The extent of movement of *P. leopardus* within individual reefs, however, was found to be high. This suggests that partial reef partial reef closures may not effectively protect populations of more mobile reef fish, such as *P. leopardus*, and that the minimum spatial scale for Marine Fishery Reserve design should be an individual reef.

International bio-political fisheries management: sashimi on the cutting edge

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Any attempt to present the issues of the management of highly migratory species of fishes in one presentation of limited time must make significant compromises in coverage of the problems. There is one issue that drives all other considerations and that is "allocation", which is the division of the availablefish among all parties that desire a share of the fishery resource.The allocation conflict is a result of two basic facts: the fisheries are generally open access and they take place in international waters.

Atlantic bluefin tuna will be used as an example and the historical, cultural, economic and political dimensions of the fishery briefly covered. At that point the allocation issue will be presented from the perspectives of policy development, management procedures and practices, implementation, enforcement and dispute resolution. In each case it will be shown how a lack of information about the basic biology of the fishes limits the resolution of the allocation issue. The paper will conclude with a vision the future management of highly migratory fishes.

South African east coast trawling – what's the (by)catch?

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Fishing by demersal trawlers is often indiscriminate, resulting in a bycatch of non-target species, many of which are discarded owing to low marketability. This is not only wasteful, but may also impact negatively on other fisheries, for example by removal of juveniles of target species. Hook and line fishers on the east coast of South Africa frequently hold prawn trawlers responsible for declining catch rates of their target species. The objective of this study was therefore to investigate the perceived user conflict between penaeid prawn trawlers and boat-based hook and line fishers on the east coast of South Africa. The research approach involved onboard sampling of trawlers from 1989 to 1992, in order to determine the composition and quantity of bycatch. Further, an analysis of a national database of reported recreational

and commercial hook and line catches from small fishing boats (skiboats) was made.

Trawler bycatch was dominated by small, shoaling demersal species, commonly associated with soft substrata. Three families (Sciaenidae, Engraulidae and Trichiuridae) comprised 80 percent of teleost bycatch by number. Skiboat catches were dominated by reef fish (Sparidae and Serranidae), pelagics (Scombridae) and Sciaenidae. Only one species, the sciaenid *Argyrosomus thorpei,* was common in both trawl and skiboat catches. This species occurred in the trawls mainly in January and February and ageing studies showed that most individuals were young-of-the-year. Yield per recruit analyses showed that if trawlers did not catch *A. thorpei,* relative yield to the skiboat fishery for this species would improve over a range of mortality values. Examination of trawl logbooks showed that catches of the trawler's target species (penaeid prawns) were low in January and February and that trawling was generally unprofitable in these months.

The conclusions were that direct overlap of trawl and skiboat catches was limited to one species only. Closure of trawl fishery during January and February would minimise the user conflict and have potential benefits for both fisheries. Skiboaters would benefit from potentially improved yield and trawl operators would benefit by optimising their catch per unit of effort. However, continued monitoring of trawler bycatch is recommended to determine the long term ecological impacts of trawling.

The division of access in a fully exploited fishery: restructuring the Tasmanian rock lobster fishery

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One of the key issues that must be addressed by managers, Governments and industry when faced with managing a declining fishery is determining how access to the resource should be allocated and fishing effort reduced. Any measures implemented to reduce catch or effort will inevitably lead to some operators getting reduced access to the fishery. There are many examples of fisheries worldwide that have addressed this problem, some successfully, some not.

The Tasmanian rock lobster fishery targets the southern rock lobster, *Jasus edwardsii,* in coastal waters, generally within 15 nautical miles from the coast. Currently the fishery has 335 commercial operators competing for a share of a catch which was in excess of 1,700 t per annum for the twelve years prior to 1993. Modelling by fisheries scientists in 1993 suggests that the estimated sustainable catch level necessary to maintain the biomass at its present level is 1,640 t. Recent trends in catch rates suggest that this figure could be lower, perhaps 1,500 t. The fishery is currently managed via the use of size limits and input controls that include: fishing seasons; a limit on the number of licences and pots; and limits on the setting and hauling of pots. The Tasmanian rock lobster fishery provides a case study of a fishery where catch and fishing effort must be reduced in conjunction with restructuring the fishing fleet.

Reducing the level of exploitation and improving the economic viability of the fishery have been the primary concerns in developing appropriate management options for the future. The level of exploitation has been addressed in the short term by reducing the length of the fishing season. However, changes in fishing patterns demonstrate that short season closures soon become ineffective as fishing effort increases. The use of short season closures further erodes the economic viability of the fishery as operators counter the effects of a reduced season by fishing harder and smarter, further overcapitalising the fishery.

One of the key issues that must be addressed when managing a fishery with declining catch and rising effort is in determining how access to the resource should be allocated and fishing effort reduced in the longer term. A joint Industry and Government working group identified two management options for addressing growth and perhaps recruitment overfishing and economic viability in the fishery. These options were pot reductions or individual transferable quotas. The past two years has seen considerable debate over which option has the greater merit. It is clear that there are advantages and disadvantages associated with each option and that the choice of future strategy requires a careful risk assessment in a climate of great uncertainty.

Towards management of Lake Tanganyika's fisheries

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Lake Tanganyika, extending over 32,000 km^2, is shared by four nations; Burundi (8%), Tanzania (41%), Zaire (45%) and Zambia (6%). Its fish species and fisheries resources have unique characteristics not found elsewhere. Fisheries target the abundant pelagic resources, composed of two freshwater clupeids and their four endemic Nile perch-like predators.

This unique pelagic ecosystem with its characteristic fluctuations in fish catches and continuing changes in species composition has been the subject of development programmes and studies undertaken under FAO auspices in the 1960s and 1970s which concluded that simultaneous lakewide research was needed to understand the observed phenomena. To this end, the four riparian states requested, in 1977, funding for a regional fisheries research project. Eventually, the Finnish International Development Agency (FINNIDA) honoured this request and a regional research project entitled 'Research for the Management of the Fisheries on Lake Tanganyika' (LTR) became operational in January 1992. It is executed by FAO in close cooperation with the University of Kuopio.

LTR aims to determine, through implementation of a modern scientific research programme, the biological basis for fish production and thus to allow for the formulation of a coherent lake-wide fisheries management policy. As the details of LTR scientific programme are the subject of another presentation, the current paper highlights the process of establishing a coherent fisheries management plan for Lake Tanganyika.

Over the years, the four riparian states have introduced their own regulations aimed at controlling either the quantitative or qualitative dimensions of fishing effort. These regulations, however, have never been introduced in the 'lake-wide' context and, due to poor design and very

limited enforcement capabilities, their effectiveness has been quite insignificant.

While biological parameters are still being collected and/or analysed, a number of steps was already being undertaken by LTR. Emphasis was given to assembling the existing data and information. This was followed by facilitating contacts by assembling relevant participants for meetings and workshops. These participants were from Government and private sectors, representatives of artisanal and industrial fishers and others. Through these actions, consensus on a number of issues was reached and it was agreed that several actions could be initiated immediately. These included: (1) the Lake's stocks and fisheries should be managed as one entity; (2) a draft text of harmonized fisheries legislation be prepared; (3) each state should ensure the optimal utilization of fishery resources in its area of jurisdiction and give neighbouring states access to the surplus of the allowable catch, once determined; (4) involve lakeside communities and fishers; (5) monitor economic information to assess the fisheries social and economic benefits; and (6) initiate actions required to establish the Lake Tanganyika Fisheries Commission. These and other actions are required to formulate and implement management policies.

Controlling illegal fishing in closed areas: the case of mackerel off Norway

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In the North Sea mackerel fishery the stock is in Norwegian waters from late autumn until January when the fish migrate back to the west of the British Isles to spawn. Whilst the fish are in the Norwegian sector, the Norwegian fleet has first access. Only later are European Union (EU) boats allowed in. Some EU boats cross illegally into the Norwegian sector to catch mackerel. If they are caught by the Coast Guard, the ships are taken to port and very large fines imposed.

An EU skipper has to take a decision about whether he is going to cross or not into the Norwegian sector. If he crosses he can expect a catch of mackerel with a certain probability, which may depend on the area. He also knows he can expect to be detected by the Coast Guard. If detected he is fined a large amount. What the skipper has to weigh is the gain to be had from taking a catch against the cost of having to pay a fine if he is caught.

The Coast Guard has to decide how big the fine needs to be to "persuade" the fisher that he should stay out of the Norwegian zone. The fine's effect will be influenced by how likely it is that the fisher will be detected. The Coast Guard could decide to increase the detection rate and lower the fines or lower the detection rates and increase the fines. It would be cheaper to do the latter. The Coast Guard needs to know what size fine is required to deter the fisher, assuming a given probability of detection.

Dynamic programming is used to model a voyage which includes some time trespassing in the Norwegian zone. At each decision point, the skipper would go into the zone with a given probability or stay out. Choices are made to maximise the amount of money gained at the end of the trip (the state variable). This is calculated from the value of the catch minus any fines that have been incurred.

To illustrate the approach, hypothetical values of the probability of a catch, of being detected, of intruding into the closed zone, and of fine size, are used in the model to show how catch probability, fine size and detection rate interact to make zone invasion unprofitable. New knowledge needs to be obtained on the likelihood of making a catch inside and outside the Norwegian zone. To estimate this, information is required on: (1) the sizes of the areas that might contain mackerel in EU waters and in Norwegian waters; (2) the relationship between area size and fish abundance; and (3) the probability of making a catch given that the fish are present at a certain abundance. Data on (1) and (2) could be obtained from satellite studies and from information on board fishing ships. Data on (3), the probability of making a catch, would come from the observations on board ship.

Resource allocation in the South Australian marine inshore fishery

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In many fisheries around the world, the longest running and most heated debates between recreational and commercial fishers are concerned with the question of who takes the largest share of a resource and how that resource should be allocated. One of the fundamental reasons for the longevity of these debates is the lack of statistically sound quantitative information which captures the spatial variability in resource partitioning. Recent techniques, such as the "bus-route" creel survey method developed by Robson and Jones (1989), have enabled these assessments to be made reliably. This method was used to conduct a 12-month survey of the marine recreational boat fishery in Gulf St Vincent, South Australia. Spatial and temporal stratification were used to allow comparisons to be made of the distribution, seasonality and length frequency of catches between the commercial and recreational sectors. Creel sampling routes were closely matched to the statistical fishing blocks used for recording commercial catch and fishing effort. Five of the most important target species in the commercial fish were also the top five contributors to the recreational harvest (in terms of numbers). For many of these species, total annual recreational catches were significant, amounting to, for example, 42.3% and 19% of the overall catch of King George whiting (*Sillaginodes punctata*) and southern calamary (*Sepioteuthis australis*) respectively. The relative contribution of the recreational catch varied greatly by season and region. The recreational allocation of King George whiting rose to a high of 65% of the total in Adelaide metropolitan waters, while elsewhere it was less than 10%. For southern calamary, these proportions ranged from a maximum of 44% to a minimum of 2.2%. Therefore, some resource partitioning occurs on a spatial basis but there are large areas of overlap which can lead to potential conflict between commercial and recreational fishers. Importantly, this study has produced the type of data required to enable reasoned and informed debate on resource allocation between competing sectors.

Design of experimental manipulations of line fishing and area closures on the Great Barrier Reef

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Fishing remains the major extractive industry in the Great Barrier Reef (GBR) Region. Diverse commercial and recreational fisheries are widespread, and constitute multi-million dollar industries in the region. Biological information about species targeted by fishing is necessary but not sufficient to successfully manage the fisheries and ecosystem. Controlled experimental manipulations of fishing pressure and management options have been recommended previously as the most effective mechanisms for assessing empirically the responses of targeted stocks, other reef organisms, and fishing practice to changes in fishing pressure. Such information is not currently available for the GBR reef line fisheries, but will be critical to future decisions about management of GBR recreational and commercial fisheries. We used computer simulations to model the population dynamics of the main target species of recreational and commercial reef-line fisheries (*Plectropomus leopardus*), and fishing and closure strategies to assess the potential for such experiments to produce unequivocal results. We have now implemented a large scale experiment that is affordable, feasible and has a high probability of producing clear signals about the relationships between catch rate, fishing dynamics and stock density, and provides direct tests of the effectiveness of area closures as a fishery/stock management strategy on the Great Barrier Reef.

Our computer simulations considered 18 variables that were most likely to produce nuisance perversities in the experimental data. We set the variations in variable values beyond the extremes seen in existing field data. The results indicate that large scale experiments utilising whole coral reefs as units of experimental manipulation can be designed such that the resulting field data will have good statistical power (>0.8) to detect moderate effects of fishing on catch rates and stock density and to measure responses of fished stocks to protection from further fishing. Under the 'best case scenario many alternative designs would be feasible, but under the most extreme perversities in our simulations only experiments involving 24 reefs or more would be likely to produce useful results.

The experimental work must be supported operationally by the commercial and recreational fishing communities and supported administratively and legally by the relevant management agencies. This support has been obtained through an extensive consultation and liaison programme, which included input from all sectors on reef-selection, refinement of experimental design, and experimental implementation.

The experimental design involves 4 clusters of 6 reefs each, spread over 7° of latitude between Cape Flattery in the north and the Swain Reefs in the south of the GBR. Two treatment regimes and one control regime are applied within each cluster. The controls incorporate 2 reefs per cluster that have been closed to fishing historically and remain closed during the experiment, and which provide our best estimates of background environmental changes that are not related to fishing. The two treatment regimes consist of (i) hard fishing over one year on two reefs per cluster that have been closed to fishing, and which are re-closed after the fishing manipulation and (ii) increased fishing pressure on 2 reefs per cluster that have been open to fishing historically, but are closed for 5 years after manipulation.

Franchising fisheries resources, an alternative model for defining access rights in Western Australian fisheries

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The limited entry management system first developed in the 1960s and now extended to cover all major Western Australian (WA) commercial fisheries, has a conceptual basis which closely parallels the successful franchising model being used extensively in the wider business community. Access rights, generated by the WA fisheries management system, have now assumed a capitalised value of about $A2 billion, relative to annual production valued in excess of $400 million to fishers. The fisheries covered under these access arrangements include Australia's most valuable fishery, the western rock lobster fishery ($300 million annual production), prawn fisheries ($50 million annual production), scallop fisheries ($20 million annual production) and more than twenty smaller fisheries, mainly for the less valuable finfish species.

The common element in these access arrangements is the use of a sophisticated system of "individually transferable effort" (ITE) management which both controls exploitation rates, allows industry restructuring and indirectly limits overcapitalisation, a common problem with limited entry systems. The increasing values attached to these access rights are attributable to the success of this system in both maintaining and optimising the value of the catch.

Despite the regular debate on the question of "ownership" of the resource and its impact on investment, the historically beneficial partnership between commercial fishers and the State has been widely recognised by financial institutions and is reflected in the significant "good will" values being paid on licence transfer. While the legal framework supporting the WA limited entry fisheries continues to be developed, it has yet to clearly define the nature of these commercial access rights relative to the expectations of other stake holders and the wider community. This paper proposes that the contractual relationships between franchisees, master franchisors and their shareholders in the wider business community, which replicates the relationship between commercial fishers and the Government representing other community stakeholders, could be used as the basis for future legislation to manage fisheries.

WA commercial fishers, like other franchisees, are provided with a defined operating territory which limits competition between fishing units, and gear/vessel limits which balance capital inputs with potential turnover (catch), while allowing each fisher to operate as an independent entrepreneur. Similarly, Government as a master franchisor, has responsibility for keeping the number and distribution of a variety of franchisees in balance with the stock's capacity to reproduce, requires franchisees to provide information for strategic planning

while charging fees for both services provided and a return to shareholders (the community).

The use of the franchise model for fisheries legislation is therefore proposed as a commercially tested basis for establishing clearly defined reciprocal rights, obligations and franchise fee structures for resource users, while allowing Government conservation obligations and resource allocation issues to be dealt with in a commercially rational contract framework.

Optimal allocation of fisheries quotas under a transferable quota management system

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Individual Transferable Quota (ITQ) management of fisheries is gaining rapid acceptance as the management policy of choice in many fisheries worldwide, often replacing management by input controls . In almost all instances, this change in policy involves making decisions regarding initial allocation of fisheries quotas among both traditional users of the resource and the wider community. However, despite the experience that initial allocation decisions are the source of significant discontent in introducing transferable quota management, there is an almost complete absence of a theoretical framework for fisheries quota allocation which addresses the key issues of economic efficiency, resource rent allocation and public policy objectives.

This paper draws upon game and auction theory and the extensive practical experience of resource allocation gained in other industries (such as the communications, airlines and financial industries) to examine the relative efficiency of presently-used and alternative fisheries quota allocation systems. The role of secondary markets in correcting inefficiencies in initial quota allocation is also examined.

It is shown that presently-used methods of fisheries quota allocation are invariably economically inefficient in addressing public policy issues and, moreover, that these inefficiencies are not entirely corrected even by efficient secondary markets. A fisheries quota allocation system, based on modern auction theory, is described which is better able to address the common policy issues of transferable quota management than the allocation systems presently used. This quota allocation system is shown to be more economically efficient than present systems and is similar to those which have evolved over the past two or three decades in other major industries.

The Victorian recreational fishing peak-body

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The Victorian Recreational Fishing Peak-Body is a registered company established to represent the interests of the recreational fishing community in Victoria to both government and the public. It was formed at the initiative of the Minister for Natural Resources, Geoff Coleman, on 7 February 1995.

The Peak-Body is registered under the Corporations Law as a company limited by guarantee and not having a share capital. The governing "Body" of 43 members comprises two members nominated by the 19 major recreational fishing organisation in Victoria, who are affiliated with the Peak-Body, plus five non-Club members. These five members represent those recreational fishers who do not belong to a club; they also represent the five areas of the State – Port Phillip, North West, North East, South West and Gippsland.

Each year, the members elect nine directors (including the chairman) who comprise the "Board". There is also a fulltime executive officer who is also company secretary. There is provision for appointing associate members to the Peak-Body.

The Mission Statement of the organisation is "To advance the interests of the recreational fishing community for the benefit of everyone involved".

The Board has established a number of committees for 1996/97, each chaired by a member of the Board:

- Policy/Finance/Administration Committee
- Marketing and Communications Committee
- Port Phillip and Western Port Vision Committee
- North East Vision Committee
- North West Vision Committee
- South West Vision Committee
- Gippsland Vision Committee

The Peak-Body supports a framework that provides a holistic and sustainable approach to the management of aquatic resources.

The government, through the Minister for Natural Resources, Geoff Coleman, has now recognized the organisation as the Peak-Body that represents the interests of the recreational fishing community in Victoria, independent of government. This means that the Peak-Body will be a key source of policy advice and will consult with the government on matters of importance to the recreational fishing community. Recreational fishers now have the opportunity to play a major role in the management of recreational fishing resources in the State of Victoria.

Already the results have been impressive, the Peak-Body has been involved in extensive negotiations with government and other stakeholders on the introduction of a new Fisheries Bill 1995. Major initiatives included in the bill are the setting up of a Co-Management Council that will bring together commercial, recreational, conservation and traditional users of the resource. This Council will provide the Minister with policy advice on fish resource issues. Also the government has announced a ban on scallop dredging after the Peak-Body made a number of submissions to government.

Property rights in fishery resources

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One of the major issues of the 1990s has been the push for "property rights". What is being sought is difficult to define as in many ways practically all commercial fishing entitlements possess many of the characteristics of property. Usually they can be traded for value, bequeathed and used as security for finance. The additional factor that seems to be sought is that of permanency i.e. that once granted the

right will exist in perpetuity and may not be redistributed without compensation.

At the same time as the commercial debate has been raging about "who owns the fish?", the decision of the High Court of Australia in the *Mabo Case* and the subsequent enactment of the *Native Title Act 1993* has opened the door to native title claims in maritime areas and already several applications covering parts of established fisheries have been lodged.

Australia is a Federal nation with the responsibility for fisheries management shared between the Commonwealth, six States and one Territory.

Notwithstanding that jurisdictional boundaries between the Commonwealth and States may be altered by agreement, there have been several different approaches adopted in the legislation of each government as to the granting of access rights and the security to be given to such rights.

Some of the provisions of each government have already been tested in Federal and State Courts while at the same time the National Native Title Tribunal has sought to define the nature and extent of maritime native title claims.

Australia offers an interesting case study of different approaches to property rights from which experience other nations may be able to draw conclusions as to the approach best suited to their conditions.

Objectives are to:

Examine the nature of fisheries resources and the various types of rights that may be applicable to such resources.

Examine the different legislative approaches to access rights and why different jurisdictions have adopted such approaches.

Evaluate the success of such approaches.

Examine various State and Federal court decisions relating to access rights.

Examine the impact of native title on the different approaches.

While in the short and medium term management and industry have common goals as regards security of access, in the longer term the goals will diverge. Secure long term access will fundamentally alter the traditional nature of fisheries resources and have the potential to restrict innovative and dynamic management or to make such management expensive. Secure long term access rights may affect the recreational sector and cause antagonism between sectors. Secure long term access is a transfer of resources from the community to industry with little apparent benefit to the community. The granting of secure long term access rights are likely to be permissible acts under the *Native Title Act 1993*. However to the extent that those rights may extinguish native title, compensation may be payable. Although such compensation would be directly payable by government, the question of recoupment from rights holders has yet to be resolved.

It is concluded that secure long term access rights may have long term management implications which need to be balanced against the short term benefits in granting such rights. Communities should be wary of granting such rights without adequate return. Offshore native title rights are unlikely to have a major impact on commercial fishing interests.

Enforcing quotas in Alaska

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The National Marine Fisheries Service of the United States implemented the world's largest Individual Fishery Quota (IFQ) system in the Gulf of Alaska and the Bering Sea in 1995. The programme is designed to manage the Pacific halibut and sablefish longline fisheries. It involves more than 6000 persons holding more than 10,000 IFQ permits. The fleet of vessels eligible to fish these IFQs is approximately 16,000. This programme was designed for safety and market reasons. Previously, halibut was commercially taken during three 24-hour openings a year and the sablefish yearly total allowable catch was taken in less than two weeks.

The National Marine Fishery Service's Alaska Enforcement Division is tasked with the mission to monitor and enforce the programme. In response to the programme requiring more enforcement to assure managers of compliance, the Alaska Enforcement Division has doubled its number of enforcement personnel and the number of offices throughout Alaska.

The benefits of recreational fisheries: cases from Kenya, South Africa and British Columbia

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Properly managed recreational fisheries may produce two important benefits. First, recreational fisheries are among the few fishery sectors that produce a positive economic rent. Secondly, sport fisheries may be more easily managed to conserve top predators in marine ecosystems than traditional commercial food fisheries. Both sectors may co-exist in harmony and co-manage the fish stocks if the necessary agreements and consultative councils are put in place.

This paper estimates the economic benefits of sport fisheries in three widely dispersed areas of the globe: British Columbia, Canada, Kenya, and South Africa. Direct economic benefits derive from payment of licence fees, charter and hire of fishing vessels, purchase or hire of gear and bait. Indirect benefits come from hotel or fishing lodges, purchase of meals and souvenirs and travel to the fishing site. Capital costs are hard to estimate as many facilities have multiple use.

The paper compares and contrasts the economic benefits and the impact on conservation of major sport fishery stocks. In British Columbia these are chinook, coho and steelhead salmon, halibut and lingcod. In Kenya, the principal species are marlin, sailfish and yellowfin tuna. In South Africa, recreational species include snoek, yellowtail, steenbras and kob, with tuna, broadbill swordfish, marlin and sailfish offshore.

In the Skeena River in British Columbia, the sport fishery is included as a stakeholder alongside major commercial harvestors in a co-management scheme. In the Indian Ocean, data gathered in the sport-fishery helps to assess and monitor the status of yellowfin tuna stocks and many billfish are tagged and released. In South Africa, recreational fishing has great potential in the fledgling tourist industry but access rights are currently an issue. Where depleted stocks are threatened, catch and release, sometimes with tagging, are options easily accepted by many sport fishers.

Marine harvest refugia as a tool for inshore fish population enhancement

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Classical fisheries management has usually revolved around stock assessment and (hopefully) the estimation of optimum sustainable yields based on the scientific analysis of population structure and population dynamics, this being followed by the application of restrictive measures designed to limit catch and/or fishing effort. These practical and traditional fisheries management measures have usually included size limits, catch quotas, gear restrictions, limits on numbers of fishers or vessels, and/or seasonal or other temporary closures of specific areas to fishing.

While this population dynamics-based approach and the application of these conventional management measures have in some cases been arguably successful, particularly in the management of some single-species/single-gear fisheries (and mainly in cool to cold temperate waters), they have not generally been applied very successfully to managing inshore demersal and reef fisheries in tropical to warm temperate waters, where these types of fisheries are often of a multi-species/multi-gear nature. Here there has often been overexploitation of stocks, and sometimes the collapse of populations of individual species or whole fisheries, due to a lack of appropriate and effective management measures.

In the light of this scenario, the potential applicability in such cases of an alternative management strategy, namely the use of "Marine Harvest Refugia" or fisheries replenishment areas for stock enhancement, is considered.

First, some of the biological and population characteristics of typical inshore demersal and reef fish species are considered, the vulnerability of stocks of such species to fishing pressures are illustrated, and then some examples from Australia and elsewhere which indicate the potential usefulness of marine harvest refugia in enhancing inshore demersal and reef fish populations in adjacent fished areas are discussed. Finally, some of the relative advantages and disadvantages of this management strategy, compared with more conventional fisheries management measures, are outlined.

It is concluded that the only long-term solution to the problem of sustainable fisheries management may lie in the total protection from consumptive exploitation of relatively large areas of the inshore marine environment and its living resources in such marine harvest refugia. Their establishment, coupled with the use where necessary of more conventional but less holistic fisheries management measures in surrounding exploited areas, should help to replenish the fishable stocks in these latter areas through protection of adult spawning stocks and of juvenile fish in their nursery habitats. Apart from providing continuous recruitment of potentially harvestable resources to these surrounding fished areas, such marine harvest refugia would also be available for a wide variety of other generally non-consumptive (e.g. recreational, educational, scientific and aesthetic) uses, with existing conflicts between resource production potential and these more passive uses being greatly reduced.

Concepts and practice of individual transferable quotas for the management of fisheries – an overview

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This paper describes the implementation and key features of management by Individual Transferable Quota (ITQ). The sustainable part of the stock by species by area is determined by stock assessment. Total Allowable Catch (TACs) are set annually by fish stock by area. Allowance is made for traditional and/or recreational fishing. Fully tradable quotas are allocated. Government monitors catch against quota so "traditional" input controls can be eliminated. Quota holders catch up to their yearly quota, removing the "race for fish".

Governments traditionally encouraged commercial fishing. Improved catching and processing meant sustainability was threatened. Overfishing led to the imposition of input controls which were expensive and impossible to police. Fishing effort and cost of fishing activity increased; yields based on catch per units of effort declined; industry became overcapitalised/uncompetitive; and over-regulation led to cost inefficiencies.The first step to output controls placed limits on fish extracted. Problems were the "race for fish" and policing difficulties. A second step involved non-transferable allocations to individuals which restricted rational economic behaviour and efficiencies. Under ITQs the conservation of threatened stocks is facilitated by a direct limit on the output from the fishery; encouragement to "farm" rather than "hunt"; reduced need for the "race for fish", thus reducing capitalisation; and instilling attitudes compliance with industry. ITQs encourage economic/efficient behaviour by reducing costs to fishers; allowing fishers to adjust level of activity; and encouraging inefficient operators to exit. They provide a means of assessing fishery value and assets for raising capital for fishing ventures. ITQs reduce State involvement in setting rules or making allocations, and for costly policing.

Many benefits of ITQs are immediate, but some require time. Implementation requires increased sophistication of Government managers and industry in information systems and reporting; higher level of analysis of fisheries sustainablity; and redirection of enforcement. ITQs pose some financial risk for Government and industry. Countries introducing quotas without tradability have failed. Tradability allows people to enter and leave the industry and allows industry rationalisation driven by the market. ITQs can deal with yearly variability in stocks by under- and over-fishing rights, seasonal adjustments and trade-off between species. Consideration is needed on whether quotas are expressed in tonnage or proportional terms. New Zealand started with tonnages and effectively changed to proportional quotas. In New Zealand some stressed inshore fisheries which were near commercial collapse in the 1980s, such as rock lobster, show healthy recovery. The

commercial fishing industry has prospered with quota assets on balance sheets and shares fisheries management with Government. Indigenous Maori people are involved in fishing at a traditional level and as part of the commercial industry. Government has ceased intervening directly in the management of individual fishing operations.

The New Zealand experience confirms ITQs benefit the economy. The fishing industry has enhanced its status within New Zealand and international market places and fish stocks have been protected and enhanced. Arguments for introducing a quota management system using ITQs are compelling. Failures of traditional fishery management will continue unless world fisheries move to quota management systems.

A novel approach for rebuilding fish stock and ecological balance to help small scale and traditional fisheries

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Large scale introduction of modern fishing fleets along the coastal zones of the developing countries like India has certainly hindered the activities of the small scale fisheries if not ended them in some of the coastal districts of the country. Bottom trawling for shrimps in the 1960s and purse seining for pelagic resources of oil sardine and Indian mackerel in the mid 1970s were introduced along the coastal zone with encouragement and financial assistance in the form of subsidies by the State Government without any measures for controlling the fishing effort. Indiscriminate exploitation of juvenile and potential spawners by these gears has resulted in the depletion of certain fish stocks and also damaged the bottom fauna. The stock of catfish (*Tachysurus* sp.) appears to be badly affected in inshore waters due to heavy fishing of brood fish and large scale destruction of eggs. Further, the discharge of sewage, industrial effluents, inflow agricultural pesticides and erosion due to reclamation of mangrove areas, had caused environmental degradation of coastal waters. This is a serious matter since these coastal zones invariably remained as an important area for breeding of many fish species.

In order to protect these grounds for resource generation and development of small scale fisheries to provide traditional fishers with sustained employment, a coastal belt up to about 10 nautical miles (n.m) should be demarcated for the exclusive use of the fishers community of that region by using the energy efficient traditional fishing methods such as long-lining, hand-lines, traps, gillnets, cast nets, etc. No mechanised fishing activity should be encouraged, including the use of outboard motors on canoes, since the fibre glass-reinforced canoes fitted with powerful outboard engines have caused similar damage to that by the mechanised boats by operating a type of mini-purse seine gear for catching the spawners during the rainy season. There should be restrictions on fishing methods employed as the modern trawling and purse seining methods are too efficient and harvest the fish resources and the bottom fauna very easily and too quickly. The trawlers should be encouraged to go into deeper waters beyond this zone to reduce the fishing effort and given proper training and provided with assistance by the respective governments to procure electronic appliances such as GPS- Navigator for navigation and fish finders for locating the fishing grounds, which are essential for the success of deep sea fishing.

Demarcation of the 10 n.m coastal zone could be done by the erection of Fish Aggregating Devices (FADs) which could be looked after by the local fisher community. The FADs are used not only as an obstruction against trawlers operating gear in these waters but also as a place for recruitment of fish resources around these devices. Further, these areas also form good fishing grounds for the local small scale fishers to operate their traditional gears.

The paper deals with this NOVEL approach that can be adopted successfully for resource generation and the development of small scale fisheries by arranging programmes on resource awareness among fishers, training local communities in FAD construction, erection and maintenance, design and development of energy efficient fishing gears and methods and use of sail technology for energy conservation. The social benefits envisaged are sustained fishing activities from generation to generation, increased business activities in villages, more employment of fishers in marketing and higher standards of living due to sustained income generation.

Risk and uncertainty – implications for the sustainable management of bycatch mortality of Hector's dolphin

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Hector's dolphins are found only in New Zealand waters. Between 1984 and 1988 some 230 Hector's dolphins were killed in gillnets in the waters around Banks Peninsula (South Island, New Zealand). This level of human impact was not sustainable. Population models for Hector's dolphin indicate a maximum population growth rate of the order of 2-4%. For the Banks Peninsula population during 1984-88, even these maximum rates of population growth were exceeded by gillnet mortality. US regulations for marine mammal bycatch were far exceeded. Risk analyses indicate a very high risk of population decline. It has been difficult to convince managers to act on the basis of these analyses. Political pressures have tended to outweigh biological considerations in the management of this bycatch problem.

Octopus fishing at Eaglehawk Bay: a case study of conflict and resource management

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Eaglehawk Bay in Tasmania is a unique, tranquil location within the quiet waters of Norfolk Bay, just tens of metres from the ocean waters of Pirates Bay, on the other side of a narrow isthmus. One might think this an unlikely place for conflict. But large numbers of octopus, often weighing some 8 kg, enter Eaglehawk Bay when the tide is right and they are at the centre of flourishing conflict.

The conflict evident in the Bay is typical of the problems encountered so often in more substantial fisheries and the

lessons learned in this microcosm may have broader application to the bigger problems.

Until recently octopus was not particularly popular in Australia, but it is traditionally very popular in some European countries, particularly Greece. The Greek community in Tasmania long ago noticed the Eaglehawk Bay phenomenon, and there has been a recreational fishery in Eaglehawk Bay for at least 32 years, which involves at least 100 participants.

In recent years a small commercial fishery has developed, with its catch being either pickled or smoked. Total catch has shown some signs of decline. Commercials and recreationals both use nets which have the effect of stopping the fish but not entangling them. Fishing by both recreationals and the two commercial licence holders is confined to an area about 400m by 400m.

The area suitable for fishing is restricted by the depth of the water and its clarity. But a new road has been constructed, with run-off diverted to the Bay, and this is blamed for much of the increased turbidity of the water. A nearby oyster farm is also blamed. Whatever the cause, this turbidity has the effect of further restricting the area suitable for fishing, and thus increasing the potential for conflict.

Finally, in addition to these changes there has been significant residential development along the shoreline, so there are more people likely to be disturbed by the lights and noise of fishing activity, which can occur each night.

Conflict arises primarily between the commercial and recreational fishers, but the local residents and several Government agencies are also involved in the debate. The main charges by the commercials are that recreationals are selling their catch, reducing the amount that can be taken commercially and cutting into the legitimate market. The recreationals argue that commercials overfish and cut off access by setting nets which are too long and block off the whole Bay. In addition, both sides blame the other for starting various confrontational incidents. All attempts to resolve conflict have so far failed.

Managing this fishery needs to take account of sustaining the octopus resource, as well as an equitable sharing of the resource between commercial and recreational use. But in the long term it is desirable that the arrangements are accepted by both groups.

A draft management plan, with provisions including gear and bag limits, has been prepared but not yet agreed to by the parties. It is clear that research is required on the biology of the resource, and that methods of monitoring and fixing environmental problems associated with development need to be assessed.

An initiative likely to be in place by the time of this Congress is the formation of a community fishcare / landcare group with some responsibility for looking after Eaglehawk Bay. Representation would come from commercials, recreationals (who have formed an Australian Greek Fishing Club), local residents, local fish farms, and relevant State Government departments. A major priority would be research – which could draw on considerable volunteer assistance – to provide facts to underpin resource management, and to moderate some of the high emotions now prevalent. Government representation would serve both to facilitate productive cooperation and to remind all parties that Government still has a responsibility to act, if necessary on its own account, to protect the resource and its habitat.

This approach could work when others have failed.

Management of New Zealand's snapper fishery: allocation of a limited resource between commercial and non-commercial users

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In 1986, a Quota Management System (QMS) of Individual Transferable Quotas (ITQs) was introduced into most of the fisheries in New Zealand. At this time the inshore fisheries appeared to be overexploited, in particular the stocks of snapper (*Pagrus auratus*) appeared to be at very low levels of biomass. The landings of snapper in New Zealand had declined from a peak catch in 1978 of nearly 18,000t to only 9,000t in 1985. With the introduction of the QMS, Total Allowable Commercial Catches (TACCs) for snapper were set at levels below the current catch levels to allow rebuilding

The snapper fishery is the most valuable coastal finfish fishery in New Zealand, earning over NZ$60 million in exports in 1993. Most of this catch comes from the Hauraki Gulf. The snapper fishery in the Hauraki Gulf is also the most important recreational fishery in New Zealand.

In 1995, the results of a large scale tagging programme on nortern snapper stocks became available. The assessment of the Hauraki Gulf stock suggests that the population is at half B_{msy}, the level of stock supporting maximum theoretical yield.

The Fisheries Act 1983 requires that an allowance be made for non-commercial users, before the TACC is set for the commercial sector. This is interpreted as a priority right, requiring both access to fishing grounds and a free share of the harvest. In the period from 1985 to 1994, the recreational catch in the snapper fishery increased by 75%. This is likely to have resulted from increased use of boats, more efficient fishing gear and increased effort. The recreational catch is managed by input controls on fishing gear, a daily bag limit and a minimum size limit. However, no upper limit is set to the total catch. The non-commerc catch in 1986 (when the QMS began) was estimated to be 1,600t per year (about 25% of the total yield); the latest survey in 1993-94 resulted in an estimate of 2,800t (36% of the annual yield).

In this study the effect of a range of management measures was modelled to determine the long-term allocation between the different sector groups when the stocks were rebuilt. Stronger recreational controls and reduced TACC limits which would result in rebuilding of the stock to B_{msy} in 10-15 years were investigated.

Projections of the model show that reductions in commercial TACC to allow for rebuilding would result in an increased non-commercial yield. The non-commercial catch increased despite the imposition of stronger input controls. Modelling results indicate that when the stock level is at B_{msy}, the noncommercial share could be up to 60% of the total yield.

The possibility of increasing the Maximum Sustainable Yield (MSY) from the fishery was also studied. A reduction in prerecruit mortality in the commercial fishery would increase the recruitment entering the exploited stock. Input controls which could reduce prerecruit mortality include closure of areas where small fish are abundant and

increased mesh sizes for trawl and Danish seine vessels. Increased yield-per-recruit also offers an opportunity for increased MSY. This could result from increased minimum sizes for longline and recreational fishers.

The current situation highlights the problem of allocation in fisheries where recreational fishers are important. Quota holders in the commercial fishery were given an expectation that a share of the resource was allocated to them under the policy of the QMS. However, current legislation allows for non-commercial users to be given priority over the commercial sector. As no overall limit is defined for non-commercial use, their total catch will inevitably increase.

Problems associated with the assessment of offshore multi-user fisheries

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Snapper (*Pagrus auratus*) are fished by three fishing sectors in Queensland:- commercial line fishers, recreational line fishers and charter boat fishers. Apart from a recreational bag limit, current management measures ensure that no particular sector has a competitive advantage since each has identical restrictions on fishing gear. Catch and effort information is available for the commercial sector *via* compulsory daily logs; however there is virtually no recreational catch and effort information. Due to the recreational importance of snapper, a study was undertaken to document the commercial and recreational catch and effort and to estimate the size and age structure of the catch of each sector. During the course of the study a number of problems were encountered which highlight the difficulties associated with assessing recreational fisheries even when identical fishing methods are employed between sectors.

It was possible to sample the lengths of 10% of the monthly commercial catch from a thirty nautical mile square grid with less than three person days effort because fewer than ten fishers were involved. At the same time compulsory catch and effort information was available for 90% of the commercial fleet. However to sample the recreational catch from the same grid required the sampling of over thirty different access ramps and hundreds of survey interviews. Associated with the increased time commitment in sampling was a reduction in the accuracy of catch estimates in particular due to the greater variance in catches between recreational fishers compared with commercial operators and charter operators. Differences in the size and age structure of the catch between sectors meant that both had to be sampled and extrapolating catch characteristics across all sectors was likely to bias estimates. This was despite the fact that virtually identical gear was used by each sector.

Bag limit restrictions further complicated the collection of biological samples, such as otoliths from recreationally caught fish, and it was common to see fewer than twenty snapper during an eight hour recreational survey shift. Recreational anglers were also often reluctant to wait at boat ramps whilst researchers removed biological samples from fish. By comparison hundreds of snapper could readily be sampled for otoliths in a few hours at a processors' premises.

In Queensland, as in other parts of the world, there has been a move in recent years to limit commercial effort in nearshore fisheries in the face of increased recreational fishery participation and a call by vocal recreational lobby groups for a greater share of the catch. At the same time there has been considerable debate over the economic value of recreational *versus* commercial fisheries and this is likely to continue. However, as fisheries move away from those where the bulk of the catch is taken by a relatively small number of commercial fishers to those where the majority of the catch is taken by a large diverse pool of recreational fishers there will inevitably be an increased cost associated with the assessment and management of those fisheries.

The allocation of marine inshore and estuarine fish resources in Australia: the need for a precautionary decision making paradigm?

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The key issue facing marine inshore and estuarine finfish resources fisheries in Australia is the complexity of resource allocation. Failure of management planning to produce equitable, efficient and socially and ecologically acceptable outcomes has forced a fundamental rethink of fisheries management throughout Australia. There is now a need for a new fisheries resources allocation paradigm based on the precautionary principle.

The array of social, economic, political and ecological problems facing key Australian marine inshore and estuarine cross-boundary fisheries such as salmon (*Arripis* spp), snapper (*Chrysophrys auratus*), tailor (*Pomatomus saltatrix*), barramundi (*Lates calcarifer*) and whiting (*Sillago* spp) are, *inter alia:*

- fisheries habitat degradation through improper farming practices, impacts of fishing and exotic diseases/species on benthic flora, sediment loads and pollution, manipulation of streams, loss of riverine vegetation
- fisheries habitat loss through coastal development
- marine park planning redistributing access from fishers to other marine based uses such as tourism
- overfishing by fishers
- insufficiently selective fishing gear
- overcapitalisation and excessive fleet sizes
- lack of fisheries management planning
- unreliable data bases
- paucity of fisheries information
- bycatch/non-target overfishing
- redistribution of fisher access (time, spatial and quantity)
- managing growth of open access recreational fisheries
- cross-boundary management of migratory species
- implementing ecological sustainable development

Resource allocation in these fisheries highlights the multi- and interdisciplinary approaches needed under the new ecologically sustainable development-based precautionary principle and consultation methodologies of this new fisheries management paradigm.

Resource allocation must be seen in the context of the current main objectives of fisheries management planning in Australia: fair access to stocks, optimal community

benefits, cost recovery and ecologically sustainable use of fisheries resources.

The precautionary approach to fisheries resource allocation involves decision making based upon limited but best available information, multiple reference points (social, biological, economic and ecological), extensive and empowered consultation and risk management leading to planned rather than unplanned shifts in the use of fisheries resources. The outcomes of these shifts are a redistribution of: wealth and political power; ownership of fisheries resources; fish stocks between harvest users; fisheries habitat between fish and other users; regional economic development; and access to fishing areas. Unplanned shifts lead to inevitable undesirable outcomes such as overfishing by one sector and social dislocation imposed on another.

Key principles of the precautionary resource allocation paradigm that should apply to these inshore coastal fisheries are:

- net economic benefits based on the economic value of the fisheries resources
- social justice for affected parties
- equal opportunity for consultation
- equal opportunity for access to fisheries resources by all users
- decision rules based on multiple reference points
- use of best available information
- objectives are specific and outcomes are measurable
- risk management
- intra- and inter-generational equity

An analysis of the principles, processes, methods and outcomes of previous allocation decisions in these fisheries, such as recreational-only fishing areas, bag limits, introduction of individual transferable quotas, indigenous commercial fishing access, adjustment of specific commercial fisheries and beach access rights, show that the application of these precautionary allocation principles may lead to more planned, sustainable and socially acceptable distributions of fisheries resources.

Allocation issues between recreational and commercial fishers: the Australian experience

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In common with many western nations, Australia's recreational fishing effort continues to rise. Although catch data are limited and individual recreational catches are being increasingly controlled by management measures such as bag limits and gear restrictions, there is little doubt that recreational fishers are cumulatively taking a larger portion of resources shared with commercial fishers.

Commercial catch levels are now constrained by a variety of input and/or output management controls. The past decade has seen a decline in commercial fishing effort in inland and estuarine waters, largely in response to recreational fishing demand. Commercial effort reduction has been achieved *via* licence buy-back (e.g. Northern Territory barramundi fishery), a freeze on new licences followed by natural attrition (e.g. NSW inland fishery) and various spatial and/or temporal closures to fishing (Australia-wide). In marine waters, exclusion zones (for certain types of commercial fishing) have so far been the major management tool used. Many such restrictions were prompted by political lobbying by the recreational sector, rather than socio-economic analysis of the trade-offs involved. Such analysis has been greatly hampered by sparse recreational catch and effort data and the difficulties in attributing absolute values to recreational fisheries.

As more commercial fisheries become subject to output controls such as quotas aimed at holding the overall catch at a sustainable level, a major management problem is determining what proportion of a shared fishery should be 'set aside' for angling. Where a stock is overexploited, this problem is exacerbated. Recreational catch estimates must be included in stock assessment and allocation processes.

Although fishers from both sectors mostly acknowledge the need for whole-stock, all-method management and share many environmental concerns, there is still considerable conflict between sectors; as exemplified by recent (June 1995) heated debate over billfish bycatch by tuna longliners. Recreational fishers are swift to blame commercial fishing for any perceived reduction in fish availability, despite known fluctuations in stock abundance and studies showing that the recreational catch is greater in some shared fisheries. Popular angling magazines and fishing tackle manufacturers/importers still promote anti-commercial fishing dogma. Also, the granting of so-called "property rights" to commercial fishers is an emotive issue to anglers. Who pays for management is another.

Communication between the two sectors is limited, but improving. Some fisheries agencies have established advisory committees embracing both sectors (and other stake holders) and are compiling recreational catch data. However, allocation criteria have yet to be developed and management still largely relies on mutually exclusive policies for each sector.

Research-directed management or management-directed research? The Torres Strait prawn fishery

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Current management of this international multispecies penaeid fishery allows for cross-border fishing and the use of transferable effort quotas *in lieu* of the total allowable catches agreed to by Australia and Papua New Guinea. Although the management of this limited entry fishery is complex because of its strategic location and because of the legislated dedication of marine resources to the indigenous peoples of the area, the management is further complicated by its relationship to adjacent penaeid fisheries. Vessels entitled to fish in this fishery are also entitled to fish in one or more other fisheries which share target species but have other management structures. Changes in management measures such as seasonal closures in these other linked fisheries therefore affects the distribution of fishing effort in this fishery. Considerable research effort has been applied to giving management measures a firm biological basis.

Models have been developed representing the recruitment, growth and migration of the major penaeid species. Fishing effort and its response to seasonal and spatial closures have also been modelled. Recruitment patterns proved to be

complex in nature. Like many penaeid fisheries, the major species breed at most times of the year but migration pathways appear to change for some periods. As a result, recruiting prawns in this fishery have a wide range of sizes and values which makes the application of simple seasonal closures to prevent growth overfishing difficult. Spatial models have also been investigated but benefits from these closures can be reduced by non-compliance. A combination of seasonal and spatial closures is now used to manage the fishery. "Pulse fishing", the application of intense fishing effort immediately following a seasonal closure, especially by vessels normally fishing in adjacent fisheries, remains a controversial effect of these closures. Without this increase in fishing effort annual catches would fall but with them questions of resource allocation and optimising catch rates arise.

Monitoring continues via logbook records and commercial catch sampling. The management arrangements for the fishery are reviewed periodically by a committee of industry, management and research representatives. The viability of fishers in this export-orientated fishery is dependent on prices and access to adjacent fisheries for part the year. Current management appears to have capped effort within sustainable limits given today's efficiencies. It is likely that future management will require the use of models linked to models of adjacent fisheries.

An economic assessment of reallocating salmon and herring stocks from the commercial sector to the recreational sector in Western Australia

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Competing demands by various user groups for coastal and hery resources in Australia are becoming a major issue in fisheries management. Increasing pressures on fish and their habitats have led to conflict over the extent of access that should be allocated to each interest group. For example, the growing number of anglers has raised concerns about overfishing in some fisheries, and managers are faced with the option of reducing either angler catch, commercial catch, or both. In other fisheries, there are sufficient quantities of the resource for both users but conflict still exists because one group may be prejudiced towards another group's use of the resource or to its social behaviour. Similar dilemmas arise when fisheries become subject to growing pressures from tourism, aquaculture and mining interests.

This study focuses on the Australian salmon (*Arripis truttaceus*) and Australian herring (*A. georgianus*) fisheries of Western Australia which are fished jointly by commercial and recreational fishers. Conflict over resource sharing is a major issue in these fisheries and in response the government has considered a range of policies for partially reallocating fish stocks to the recreational sector. The main purpose of this project was to quantify the economic gains and losses from a shift in allocation. A related objective was to define the strengths and limitations of survey techniques designed to elicit recreational benefits with a view to making some statement about their suitability for inclusion in future resource allocation studies.

The survey obtained comparable estimates of recreational benefits using the contingent valuation and travel cost methods. On average, anglers spent $21 per day or $902 per year on fishing, which represents a minimum value for recreational fishing. In addition to expenditures, anglers obtained between $15 and $33 per day consumer surplus from their fishing experience. The aggregate value of these benefits amounted to between $A1.5 and 3.4 million, a measure of the net welfare generated by recreational fishing in southern Western Australia. It is difficult to determine how sensitive these benefits are to changes in the availability of salmon or herring, but it was estimated that anglers would be willing to pay, on average, $5.55 for one extra salmon on a day's fishing. This far exceeds the net commercial value of salmon. The results for herring are less conclusive as the survey was unable to obtain a reliable marginal value for this species.

Some difficulties with using open-ended contingent valuation to elicit the marginal value of recreational catch were identified. The main difficulty arose because respondents tended to base their valuations on an *ex ante* appraisal of all future fishing experiences rather than confine their valuations to an *ex post* assessment of a specific fishing trip, known to researcher and respondent, which had measurable quality characteristics. Consequently, future work in this field needs to model quality attributes of the fishing experience as an expectation function for each individual, rather than to assume an exogenous level of quality across all participants.

Fisheries of Cambodia: the Tonle Sap Great Lake and River ecosystem under threat

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The Tonle Sap Great Lake and River, situated in the heart of Cambodia, is a tributary of the Mekong river and represents about 10.7% of its entire catchment area. Annual monsoon-driven flooding of the Mekong River causes the Tonle Sap river flow to change direction for about 3 months resulting in the expansion of the Great Lake from about 2,500km^2 in the dry season to about 16,000km^2 depending on the height of the floods. Many fish species utilize the inundated forest and wetland areas around the lake and river for spawning, nurseries and feeding, giving rise to an enormous productivity. When the floods recede, fisheries using a variety of filtering devices start capturing the fish migrating back to the lake, river and eventually to the Mekong proper. Relationships exist between the level of the Mekong River flood, the size of the flooded area and the quantity of fish produced.

A significant lowering of the level of the Mekong River floods through increased water usage, e.g. by hydroelectric power generating dams and irrigation schemes, could lead to a great decline in fish production and might even stop the turning around of the Tonle Sap River flow.

The richness of these fisheries was recognised as early as 1864 and state-controlled mechanisms for extraction of resource rent were put into place. So called fishing lots (areas with exclusive exploitation rights) are auctioned once every two years and despite heavy exploitation (as there are no incentives to preserve the stocks in the long term) are still lucrative. Apart from the dams, the main threats to the resources come from the open access nature of the remainder of the fisheries, the (licensed) middle- and (unlicensed) small-scale fisheries, and from the destruction of the flood forest around the Great Lake (which has decreased by one third since 1973/6).

The paper presents an overview of the fisheries operating in this area and, based on a recently set up catch/effort data collection system, provides estimates of their 1995 catch by species, which is in the order of 80,000 t excluding the small-scale fisheries, or at least 107 kg/ha, if an average lake size of 7,500km^2 is used. Catch per ha is comparable to or higher than in similar wetland areas in South and South-East Asia. Estimates of present catch levels are of the same magnitude as rough estimates made in the past, although the abundance of a number of species is strongly reduced and it is generally believed that catch levels have declined. Nevertheless, fish prices are still low and therefore fish is the single most important source of animal protein in the diet of the Cambodian people.

Management should focus on the preservation of this ecosystem from threats posed by the proposed dam building programme in neighbouring countries and Cambodia itself, as well as on the continuing destruction of the flood forest and illegal/unsuitable fishing practices.

Sustainable management of northern Australian fisheries resources – access and catch sharing with traditional Indonesian fishers

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Australia's northern (EEZ) Exclusive Economic Zone contains national territorial waters and fisheries resources that abut the Indonesian EEZ for a length of about 2,700 km. Some seagoing Indonesian ethnic groups have fished selected resources in these Australian waters for more than 300 years. Since 1974, Australia has acknowledged these traditional fishing activities and has permitted access to Indonesian fishers, using "traditional" methods, within a restricted area of the Timor Sea under a memorandum of understanding (MOU) with the government of Indonesia. However, increasing fishing pressure by these traditional fishers as well as illegal fishers, operating outside the terms of the MOU, led to concerns about the impacts upon the fisheries resources. These concerns prompted a review of Indonesian fishing in northern Australian waters, including trends in Indonesian fishing activities, estimates of Indonesian catches and the impact of these catches on the stocks. From this information, sustainable management policies to bring about controlled, equitable access to Australian fisheries resources are suggested.

Indonesian fishers visiting Australia come from four main ethnic groups and originate from six principal geographic areas of the Indonesian archipelago. Most fish legally within the MOU area using approved sail-powered *perahus*. A smaller proportion enter Australian waters illegally to fish mainly for shark. Based upon examinations of confiscated catches and surveillance data, annual catches of principal species groups were estimated. The current total annual catch by Indonesian fishers in Australian waters is about 600–800t of shark, 340–500t of sea cucumber or trepang, 50–75t of demersal reef fish and 15–25t of trochus shell. About 70–90% of this catch is legally taken within the MOU area.

At present there is little conflict with Australian fishers for these species and the shark catch is below estimates of sustainable yield. However, trochus, clams, trepang and possibly some species of fish are heavily exploited at reefs within the MOU area. There are indications that the exploitation level is unsustainable and requires management intervention, although currently there is no way to limit traditional Indonesian fishing effort within the MOU area.

Ideally, management should adopt an integrated ecosystem approach encompassing stocks throughout their geographic range; by removing or expanding the MOU boundaries; improving the information base for management; managing cooperatively with Indonesia; and determining appropriate levels of fishing effort and how it should be allocated. In future, sustainable use of fisheries resources within Australian waters will require limitation of Indonesian fishing effort. Policy options to limit this effort could include the allocation of access rights and should promote the interests of artisanal fishers who have a traditional interest in Australian fisheries resources. To these ends, the definition of 'artisanal' should imply that fishers use simple methods and equipment and that fishing is their livelihood through subsistence, barter or trade. The definition of 'traditional' should imply that fishers have a history of fishing for a living spanning generational time scales. In addition, access rights should be non-transferable, be granted to an individual rather than attached to a perahu, and require compliance with other rules. These rules would likely include observance of protected area or protected species legislation, bans on some gear (e.g. SCUBA), requirements to register with local Indonesian port authorities, and carrying identifying marks visible from surveillance aircraft.

Computer simulation of fisheries closures

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Management to ensure the optimum long-term value from fisheries often involves the use of seasonal and spatial closures. A wide range of biological, economic and industry-related factors determines the effectiveness of these closures. There is considerable reluctance to close a fishery until potential benefits can be demonstrated. Predicting the benefits of a seasonal and/or spatial closure can be a complex modelling process. These models must incorporate approximations of the key processes involved and allow for uncertainty in parameter estimates. These uncertainties arise through variation in biological processes such as annual recruitment, through our imprecise

knowledge of important parameters such as natural mortality rates and through our inability to predict the response of components of the model, such as fishing effort patterns, to the proposed management measure.

One approach to providing insight into the potential benefits of fishery closures is simulation modelling. Such a computer model, Simsys, has been used for several years to address these needs for several multi-species penaeid trawl fisheries in Queensland and elsewhere. Presented in the familiar Microsoft Windows format, this programme allows the user to build a database of characteristics for the species and the fishery. Facilities exist for estimating recruitment patterns from length-frequency data and incorporating these into the model. Fishing effort and its response to closures are modelled in a variety of ways. Uncertainty in parameter estimates can be included in the analysis and the effect of this uncertainty is monitored for a wide range of predictions including yield, catch rate and catch value. A migration model also allows investigation of spatial closures. Abundant graphs and interactive forms facilitate understanding of the assumed processes and help to formulate parameter estimates.

ing this computer model on tropical penaeid fisheries it has been found that the value of a seasonal closure is highly dependent on the pattern of prawn recruitment (timing and size structure) and on the response of fishing effort to the closure (especially the redistribution of fishing effort from the closure period). For the penaeid fisheries examined, the model predicts that short seasonal closures can increase catch values by 10% or more, but only if prawn recruitment is simple (discrete and unimodal) and if there is a compensatory increase in fishing effort in the months following the closure period. For these fisheries, properly located spatial closures, though decreasing total yields, can increase catch values by 10%, if migration rates (residence times) have low variances. Further studies have revealed how the level of non-compliance (fishing in closed areas) changes the size of optimum spatial closures and erodes their benefits. These simulations have also been used to clarify problems in resource allocation.

Institutional reforms: realigning the roles and responsibilities of ..shers and the government

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Self-management has become a popular addition to the lexicon of public resource managers, particularly among fishery managers. But can all management decisions in the fishery be devolved to the fishers themselves? Does self-management necessarily mean the substitution of private decisions for public decisions or can a larger degree of self-direction be accommodated within traditional models of public administration?

In Canada's Pacific fishery, the agency responsible for fisheries management, the Department of Fisheries and Oceans (DFO), has launched an initiative aimed at divorcing the distributional (licensing and allocation) function from the operational side of fisheries management. This is not a self-management initiative in the usual sense. Decisions about who will be given access to the resource and what their allocation should be will remain the responsibility of government.

There are many arguments supporting the splitting of these decisions from the other aspects of fisheries management. The Economic Council of Canada, in a study of fisheries policy, concluded "fishery officials should be as insulated as much as possible from decisions about who is to participate, so as to depersonalize and depoliticize the choice of gear and fishermen."

Licensing and allocation decisions involve social consequences that extend well beyond the community of fishers. In other words, fishers' private interests do not necessarily equate to the public interest. For example, licensing and allocation decisions can affect processing employment and the viability of coastal communities. While some may argue that access and allocations should be left to the marketplace, where individuals could "vote with their dollars" for access to the resource, it is unlikely that the general public would accept such an unfettered approach to the distribution of fishing privileges. The public could also be concerned about the possibility of excessive concentration of licences in a few hands, particularly the domination of the fishery by corporations able to outbid individuals. For these reasons, the government has decided that in assigning fishing privileges and setting allocations, government rather than industry or the market should be the decision-maker. While fishers will not be given a direct *role*, they will be given a direct *voice* in decision-making.

This paper provides a detailed description of the proposal to establish an arm's length, quasi-judicial Board to make licensing and allocation decisions and apply sanctions in Canada's Pacific commercial fisheries.

Fisheries co-management: a comparative analysis

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This paper examines more than thirty fisheries co-management case-studies on small-scale, semi-industrial and industrial fisheries in developing as well as developed countries, all over the world. The theoretical basis for the case study analysis comes from common property, institutional and organization theory. The Institutional Analysis and Development framework developed by researchers at the Workshop in Political Theory and Policy Analysis at Indiana University, USA has been adapted and used to analyse fisheries co-management institutions.

The paper analyses the organisation of the fisheries management systems, in particular the influence of user-participation in the decision-making process. Decision-making arrangements refer to rights and rules, in particular who allocates/makes them (representation), what they contain (relevance) and whether they can be enforced (enforceability). The paper investigates how co-management arrangements are functioning and evaluates how these arrangements contribute to efficiency, equity, stewardship and resilience in the fisheries co-management process under various conditions and institutional arrangements.

The analysis shows that co-management covers a broad variety of collaborative arrangements between government and users, ranging from consultative cooperative to delegated local management. Key contextual variables and decision-making arrangements which determine the type of co-management arrangement are identified. Based on the case studies, a typology of the different co-management arrangements is then developed which includes identification of the types of management tasks which could be delegated under each of these. Finally, the paper concludes with some general lessons for success or failure in fisheries co-management.

How can aquaculture help sustain world fisheries?

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The Earth is three-quarters water, and has a probable inexhaustible seafood resource for human needs. In recent years, however, fisheries landings have levelled off or declined, reaching a peak in 1989 at 89.7 million t. This is an indication that capture fisheries have almost reached their maximum sustainable yield. With the increasing human population coupled with an increasing demand for animal protein of aquatic source, aquaculture has been increasingly seen as the answer to this gap.

While aquaculture may be seen as the answer to the shortcomings of marine fisheries, the prospects are not all that bright. As the aquaculture industry grows, so will conflicts over the use of water and land between the users, particularly along the coasts. In recent years, aquaculture has been facing three very difficult dilemmas.

First, aquaculture destroys a lot of marsh lands and mangroves, which are the nursery grounds for juvenile fish, prawns and other organisms. As a result, fingerlings and juveniles of many species are reduced greatly in number. On the other hand, considerable catches of broodstocks of fish and prawns for artificial propagation reduce the natural resource.

Second, pollution caused by industry wastewaters and outlet waters brought about by urban life has seriously affected the quality of coastal waters and thus, the fisheries resource. As the population expands, land, air and water pollution will become more severe.

Third, mass mortality caused by disease outbreaks has been recently experienced in cultured prawns. Consequently, the prawn culture industry has suffered and is still trying to recover from the deleterious effects.

There are many ways to overcome these dilemmas in aquaculture, for example, to improve the technology for increasing productivity or unit production, to produce friendly feeds for the reduction of both production costs and environmental pollution, to apply biotechnology for the improvement of species traits and disease resistance, to utilize automation technology for manpower reduction and savings, among others.

The most important strategy may just perhaps be waiting – the vast ocean. By means of artificial propagation and aquaculture technology, millions of seeds of many species can be released to enhance stocks. Artificial reefs can be constructed to make more habitats for aquatic animals. Such stock enhancement, which is also known as marine ranching, can help restock the natural resource, but it requires a preliminary pollution-free environment. This is also a complex activity. Fortunately, knowledge of stock enhancement has been accumulating, with this activity being conducted in Taiwan since the early 1960s, including the identification of suitable species, mass production of seeds, appropriate release sites, regulations of fishing season and fishing methods, tracking research and result assessment. Of course, the fisher's or aquafarmer's enthusiasm and concern for resource protection and the governments policies on resource management are the basis for the sustainable utilization of fisheries resources and for the success of stock enhancement.

In addition, to utilize processing technology, to increase added values, to produce friendly feeds, to establish quality control, and to adopt effective policies and marketing systems are also important in fisheries. More important is getting the government's attention for resource management, information communication and personnel training. Once we have the appropriate personnel who devote themselves to society, then aquaculture can help to sustain world fisheries.

Evaluation of the relative importance of hatchery-reared and wild fish in the restoration of Lake Superior lake trout

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Stocking hatchery-reared fish is one tool used to restore wild stocks that have been severely depleted. This paper evaluates the success of such a programme for lake trout in Lake Superior, North America. This stocking programme represents a major long-term investment: stocking began in 1952, and more than 90 million lake trout have been stocked.

Historically lake trout were a dominant predator and supported a large commercial fishery on the Laurentian Great Lakes. In Lake Superior they provided an annual yield in excess of 1.8 million kg during the 1930s. Their stocks collapsed during the 1940s and 1950s due to a combination of parasitism by the exotic sea lamprey and intense commercial fishing with gill nets. Although mortality of lake trout caused by sea lamprey is still significant, sea lamprey abundance is limited through regular chemical treatments that kill their larvae in streams. While both commercial and recreational fisheries exist, fishing is severely constrained by regulations. In concert with controls on sea lamprey and fishing, large numbers of juvenile hatchery-reared lake trout have been released into the Great Lakes. In spite of these restoration efforts, only in Lake Superior have self-sustaining lake trout populations recovered. Remnant stocks of wild fish persisted to a greater extent in Lake Superior than in the other Great Lakes, and one hypothesis is that the recovery of lake trout in Lake Superior is primarily due to these remnant wild stocks and not to the stocking programme. The objective was to determine the relative importance of wild and hatchery-reared spawners in achieving the stock recoveries in Lake Superior. This objective was pursued by estimating the contribution of wild and stocked adult lake trout to lake trout recruitment during the recovery period using Ricker stock-recruitment models.

The stock-recruitment models described total number of observed recruits as the sum of recruits from the two parental stocks. Data were from lake trout catches in gill-net assessment fisheries prosecuted each spring during 1959-1993 in United States waters of Lake Superior. Hatchery-reared fish could be distinguished from wild fish (i.e., those produced in the lake), because they were consistently fin clipped. Estimates of the recruits produced per hatchery-reared parent, for low stock sizes, were significantly above zero. In contrast, estimated recruits per wild parent were near zero, except in the eastern portion of the lake. During the initial recovery, adult lake trout abundance did not appear to have reached levels that inhibited recruitment: parameters describing density-

dependence in the stock-recruitment relationships were near zero.

It was concluded that stocked lake trout played an essential role in population recoveries in Lake Superior. Results are encouraging because they indicate that pre-existing wild populations are not a necessary condition for re-establishing a self-sustaining stock of lake trout in the Great Lakes. Restoration of lake trout may have been more successful in Lake Superior than in other Great Lakes because fish were stocked nearer to spawning grounds.

An Italian enhancement programme for slipper lobster, *Scyllarides latus*

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The Mediterranean slipper lobster, *Scyllarides latus*, has provided a small but quite common resource for Italian artisanal fishers until 20-25 years ago; now, it is a rare occurrence, probably because its behaviour results in intense fishing pressure from SCUBA divers (even though fishing is illegal for recreational divers).

With this in mind, an enhancement programme has been envisaged, that will utilize protected areas (marine sanctuaries and parks) as centres of spreading and recolonization. The original project considered restocking with juveniles from both the fishery and aquaculture and adult potential brooders from surrounding areas; the latter were to be positioned one-by-one by divers.

An intense search, with fishers interviews and underwater inspections, has confirmed the extremely weak status of Mediterranean slipper lobsters almost everywhere except S-E Sicily (Capo Passero).

Up to now, a few hundred adults have been tagged (with "spaghetti" and PITs) and released, already resulting in one resights. Both kinds of tag appear to be compatible with moulting and are retained through ecdysis: consequently, long-term checking could allow measurement of growth and understanding seasonal migrations and homing.

However, juveniles are not yet available: in fact, newly-hatched larvae survive only a few weeks (at least at this stage of the experiments), *ad hoc* post-larval collectors have failed until now to catch nistos at sea, and natural settlement and nursery grounds are still unknown (no *S. latus* under 100 g has ever been collected).

Since very little information exists on the physiology and ecology of the Mediterranean slipper lobster, a series of indoor experiments has been conducted: they focussed on reproductive behaviour, embryo and larval stages, shelter preferences, reaction to predators and feeding habits. Among the results, it appears (from repeated and documented studies) that the animals do copulate, spawn and breed in aquaria, and that eggs hatch into viable phyllosomas (but fertilisation of the berried mass is often incomplete); adults adapt to the experimental environment and, while they prefer live mussels, they can also be fed commercial pellets; moulting (and thus growth) is not hampered by the artificial conditions.

Lastly, morphometry has shown that meristic characters are highly variable; a genetic comparison of animals from different sources (in Italy and abroad) is still under way.

In conclusion, experimental restocking of slipper lobster in Italy is presently carried out with multiple approaches and might become feasible. However, further researches and a thorough cost-benefit analysis are required before deciding on its implementation.

A responsible approach to marine stock enhancement

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Declining marine fish populations worldwide have rekindled an interest in marine fish enhancement. Recent technological advances in fish tagging and marine fish culture provide a basis for successful hatchery-based marine enhancement. The objective of this paper is to demonstrate the need for a careful approach in the implementation of marine stock enhancement programmes and to outline the tactics that are gaining support as a responsible approach for replenishing depleted fisheries. To ensure success and avoid repeating mistakes, a responsible approach must be taken to developing, evaluating, and managing marine stock enhancement programmes. A reponsible-approach concept with several key components is described. Each component is considered essential to control and optimize enhancement. The components include the need to (1) prioritize and select target species for enhancement; (2) develop a species management plan that identifies harvest opportunity, stock rebuilding goals, and genetic objectives; (3) define quantitative measures of success; (4) use genetic resource management to avoid deleterious genetic effects; (5) use disease and health management; (6) consider ecological, biological, and life-history patterns when forming enhancement objectives and tactics; (7) identify released hatchery fish and assess stocking effects; (8) use an empirical process for defining optimum release strategies; (9) identify economic and policy guidelines; and (10) use adaptive management. Developing case studies with Atlantic cod, *Gadus morhua*, red drum, *Sciaenops ocellatus*, striped mullet, *Mugil cephalus*, and white seabass, *Atractoscion nobilis* are used to verify that the responsible approach to marine stock enhancement is practical and successful at increasing fish abundance and fishery yields.

Can cryopreservation of sperm gametes help sustain aquaculture diversity?

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There have been several research development, extension and practical applications of sperm cryopreservation of aquacultured finfish and shellfish in Asia. This paper aims to provide a preliminary general understanding by summarising these efforts.

Already, there exist about 50 publications in Asia on the cryopreservation of fish sperm. In Japan, the sperm of three major categories, including marine fishes, salmonids and

other freshwater fishes, were cryopreserved with the best cryoprotectants and protocols suitable for each category.

In Taiwan, the sperm cryopreservation of 16 finfish and three shellfish was studied, with post-thawing fertility ranging from 64.0 to 93.4% in commercially-important finfish and 37.7 to 94.8% in shellfish. There is still a need for more similar studies in less commercially valued and endangered species.

In India, significant successes have been achieved in the cryogenic preservation of sperm of certain marine fishes such as *Liza parsia, Sillago sihama, Mugil cephalus* and *Gerres oyena* ranging from 30 days to 240 days with moderate percentages of motile spermatozoa.

In Thailand, the sperm cryopreservation of the endangered Mekong giant catfish, *Pangasius gigas,* had been reported and was used to produce the hybrid between *P. hypophthalmus* and *Clarias macrocephalus.*

Thus there are huge possibilities for (1) providing cryopreserved sperm for hatchery work, such as in grouper; (2) the hybridization of seasonally-distinguished, location-distant species such as *Tilapia* and grey mullet; (3) the protection of endangered species such as the sweet fish, *Plecoglossus altivelis* and the Mekong giant catfish; (4) the increase of market value of aquaculture species, for example, the desired characteristics of colour as in the hybrid between female red sea bream, *Pagrus major,* and the male crimson sea bream, *Evynnis japonica.* All these contribute to extend aquaculture diversity. For the long term sustainability of aquaculture diversity and practical cryopreservation of sperm gametes, considerable interest and efforts are, however, absolutely needed to provide a pool of genetic materials to enhance breeding in captivity and ensure desirable characteristics in aquatic animals.

Preliminary trials on larval rearing of the Australian eel tail catfish, *Neosilurus ater* (Perugia)

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Three studies have been conducted to evaluate the effect of starvation, the use of wild and naturally occurring zooplankton, Tetramin and finely ground barramundi pellets for larval rearing of *Neosilurus ater.* In the first study, the larvae were reared in a clear-water recirculating system while in the second and third studies, the larvae were reared in the green-water recirculating system.

In the first study, there were two treatments, namely control (no feeding) and feeding with wild zooplankton. In the second study, the two treatments were either feeding on natural zooplankton only or feeding with zooplankton plus Tetramin. In the third study, the treatments were either feeding on natural zooplankton only or feeding with zooplankton plus finely ground barramundi pellets. There were three, two and three replicates per treatment for the first, second and third studies, respectively.

The results of the studies have shown that starved fish began to die from the second day of larval rearing i.e. 7 days post-hatching at 28°C, and that larvae that were fed wild zooplankton showed some growth but poor survival. This was attributed to the lack of zooplankton prey of suitable size.

In the second study, the water temperature ranged from 26.0 – 30.3°C and the variation between treatment tanks was small. The dissolved oxygen and the pH values ranged from 4.3 – 7.7 mg/L and 8.4 – 9.9, respectively, and the variations between treatment tanks were also small. The total ammonia-nitrogen ranged from 0 – 0.1 mg/L in all tanks during the study indicating that the green-water system was effective in maintaining low ammonia-nitrogen levels. The size of fish after ten days of larval rearing in the group that received only zooplankton were 10.60±0.33 mm in Total Length (TL) and 0.0090±0.0010 g in Body Weight (BW) while that in the group which received zooplankton plus Tetramin were 12.49±0.51 mm TL and 0.0150±0.0030 g BW. The larvae that received natural zooplankton plus Tetramin grew significantly faster than the larvae which received only natural zooplankton ($P<0.05$) indicating that the larvae were able to digest and assimilate the nutrients in Tetramin.

In the third study, the water temperature ranged from 27.5 – 31.3°C and the variation between treatment tanks was negligible. The dissolved oxygen and the pH values ranged from 3.1 – 8.2 mg/L and 7.7 – 8.4, respectively, and the variations between treatment tanks were also small. The total ammonia-nitrogen in most tanks during the study ranged from 0 – 1.0 mg/L. At the end of the fifteen day tri the larvae that received only natural zooplankton were 18.36±2.95 mm TL and 0.0530±0.0270g BW while the larvae that received natural zooplankton plus finely ground barramundi pellets were 19.52±2.91 mm TL and 0.0610±0.0310 g BW. Even though the larvae that received natural zooplankton plus finely ground barramundi pellets were larger than the larvae that received only zooplankton, the sizes of fish from both treatments were not significantly different ($P>0.05$).

Larval rearing of the Australian eel tail catfish under hatchery conditions has been demonstrated. Starved larvae begin to die 7 days post-hatching at 28°C and both Tetramin and finely ground barramundi pellets can be used for enhancing larval rearing in the green-water system.

Ecological consideration for the planning, implementation and practice of pond mariculture

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Aquaculture, to be sustainable, must not only be economical but also ecologically-sound. An ecologically-sound aquaculture development will bring long-term benefits toward the successful conduct of aquaculture operations.

Just like any industry involving the exploitation and utilization of natural resources, the aquaculture industry can bring about adverse impacts on the ecosystem, especially when aquafarmers seek maximal short-term profit. These impacts, however, can be minimized by being aware of the importance of a sustainable benefit and by careful planning, implementation and practice of the industry.

For pond mariculture, site selection should consider that the biota, such as the number of species, biodiversity, habitat and productivity, and hydrological regimes such as flow pattern and salinity gradients of the surrounding environment, will not be significantly altered by the water usage and manipulation of the planned farm. Impact from implementation through operation should be thoroughly assessed and stated in the site evaluation study. Remedies

and measures to minimize the expected changes should be incorporated into the planning and detailed design. These include setting up buffer zones, spreading out water intakes and discharges, integration of culture systems and activities to conserve nutrients, and discharge disposal. During implementation, all options, such as construction time (season) and dredging, filling, and contour sequences, should be considered to prevent washout and erosion. Water and nutrient conservation are the main ways to reduce the environmental impact during operations. These can be achieved by using ecologically-sound culture systems, environmentally-friendly feeds, effective and efficient feeding management, and discharge and pond cleaning management.

Transient gear shellfish aquaculture, an innovative, socially acceptable complement to the wild stock capture fishery

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Shellfisheries in Narragansett Bay, Rhode Island, have declined in the last decade in response to decreasing abundance of wild stock available for harvest and decreasing price for product harvested due to a loss of market share. Traditional shellfishers have vigorously resisted efforts to introduce aquaculture, in that it is perceived as a threat to the open access fishery.

Transient gear shellfish aquaculture involves the use of portable cages, similar to traditional lobster and fish pots, to grow shellfish from seed to market size. The transient gear shellfish aquaculturist must tend the cages weekly, removing biofouling from the cage and growing bags, sorting the shellfish and continuing to place shellfish in bags of ever-larger mesh as they grow. The cages are mobile and can be moved to different areas in the estuary for nursery, grow-out, over-wintering, etc.

Conventional shellfish aquaculture technology involves the privatization of bottom or water-column through direct ownership or lease. Traditional wild stock shellfishers lose access to the common property resource when privatization occurs, hence their resistance to conventional shellfish aquaculture.

The successful introduction of an innovative aquaculture method to wild stock shellfishers requires both research and extension education. The ongoing research programme involves a comparison of shellfish growth rates in various areas of the Narragansett Bay estuary, relating growth to seston flux and other environmental parameters. The extension education programme involves the offering of a workshop series to fishers that includes lectures on biology, permitting, business and field experience on the methods involved with transient gear shellfish aquaculture. As a result of these programmes, shellfishers, who once opposed aquaculture, are now considering shellfish aquaculture as a complement to their traditional fishery.

Bio-preservation of fish by-products for aquaculture feed in tropical Africa

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Vast quantities of fish by-products (pelagic fish, waste fish, fish wastes) are generated from fishing operations and are often processed into fish meal for use in aquaculture feeds. Fish meal production is impracticable in tropical Africa because of capital and energy requirements. Periodic scarcity and high prices of imported fish meal have however justified the development of low-cost, low-technology processes for utilizing fish by-products as feed resources. Bio-preservation (biological fermentation using lactic acid bacteria) represents one of such processes. Studies were therefore conducted on the preparation, storage properties, nutritional and economic value of bio-preserved fish products.

Fermented silage was prepared from a mixture of minced tilapias (stunted/undersized specimens), 15% w/w molasses (carbohydrate substrate) and 5% w/w *Lactobacillus plantarum* (inoculum); incubated anaerobically for 30 days at 30°C. After 7 days, a desirable and stable pH <4.5 was attained, the non-protein nitrogen (NPN) content increased while the proximate composition of the liquid silage varied slightly from that of minced tilapias after 30 days. Further storage for 180 days increased the NPN content and there was 8-11% loss of tryptophan. Free fatty acid content increased during storage. Addition of sodium chloride (5% w/w) to minced tilapia, or preheating minced tilapias at 90°C for 30 minutes prior to fermentation, inhibited protease activity thereby preventing proteolysis, and decreased the formation of total volatile bases. Addition of potato extracts (5% v/w) had no significant ($P>0.05$) effect on protein solubilization and protease activity. Addition of formalin (5% v/w) proved effective as an antioxidant as thiobarbituric acid value remained low after 30 days fermentation.

Dried silage meals were prepared from 1:1 (w/w) blends of wet silage with soybean meal, poultry by-product meal, hydrolysed feather meal or meat-bone meal; and evaluated as protein source in dry pelleted diets for juvenile catfish, *Clarias gariepinus*, fed at 4% body weight/day for 70 days. Significant differences ($P<0.05$) occurred in mean weight gain, specific growth rate and protein productive value, but feed conversion and protein efficiency ratios were similar ($P>0.05$). Protein digestibility was reduced ($P<0.05$) in catfish fed diets containing fish silage:feather meal blend while energy digestibility was lower ($P<0.05$) in catfish fed diets containing fish silage:soybean meal blend. Carcass composition of catfish was not affected by silage blend used and histological examination of exocrine pancreas, liver and intestine tissues did not show any lesions suggestive of nutritional imbalance. Hematocrit and haemoglobin content as well as the mean cell haemoglobin concentration values showed no differences ($P>0.05$) among the diet treatments. Results indicated that the dried fish silage blends were suitable as protein supplement in dry catfish diets without affecting feed efficiency, fish growth or health.

The bio-preservation process can be used economically where small quantities of fish by-products do not justify investment in a fish meal plant, and is particularly appropriate for remote artisanal fisheries landing sites. Dried silage production is more profitable than fish meal manufacture in terms of technology and costs; moreover, it is nutritionally adequate, physically acceptable, practically

applicable and economically feasible for aquaculture production in tropical Africa.

Clam and scallop fisheries and culture in Baja California Sur, Mexico

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Clams have been important to the people living on both the Baja Californian Pacific and Gulf of California coasts . This edible resource was widely used as food by native Californians. Species consumed then continue to be actively exploited. Along the Pacific coast, three clam, two scallop, one ark and one pen species have dominated commercial interest. On the Gulf coast, four clam, one scallop and two pen species are exploited. Landing statistics for the early fisheries are vague. Only since the 1970s have landings been separated by species. At the end of the 1980s, annual landings averaged about 35,000 t, but by 1991 to 1994 they had declined to about 5,400 t. The State of B.C.S. is the production leader with more than 75% of the Mexican production. On the Pacific coast the pismo clam, *Tivela stultorum,* found in sandy exposed beaches, the arkshell, *Anadara tuberculata,* in mangroves and *Chione* spp. have significant annual production. Along the Gulf of California coast, the clams, *Megapitaria* spp., and the pen, *Pinna rugosa,* are most productive. The Pacific calico scallop, *Argopecten circularis,* is the most important commercial species on both coasts. Between 1986 and 1991, there were large catches.

After 1991, catches declined steadily through 1993. There was overexploitation, forcing the adoption of management measures. The Government established regulations for exploitation and scallop culture development. The spawning time for populations of clams was determined in the three principal bays. In 1994, CICIMAR and the Fisheries Department initiated research on the feasibility of increasing the biomass of this overexploited resource. They created a reseeding programme with its main objective to develop artisanal fishing. The use of onion bags to collect spat in Bahia Concepcion (1988 to 1994) demonstrated that settlement was cumulative from January to March. In 1994, deploying ten collectors one to two weeks before the peak of late umbonate larvae gave a mean settlement value of 152 spat/coll. At Punta Coloradito, there were two peaks; in January and early March. Late umbonate larvae (120 μm) were periodically detected in the plankton. Commercial collectors were deployed from 12 to 22 February at El Indio. There were 2,160 collectors giving a mean value of 223 spat/coll (10-32 mm). About 443,000 spat were then released. At El Remate, collectors were deployed from 4 to 20 April with similar results. On 15 June, about 933,000 juvenile scallops were placed in an enclosure at a density of 330 scallops/m^2. They were held until 10 August and then released. Mass mortality of the scallops was observed in September with more than 80% mortality, increasing to 99% in October. The cause of this mass mortality is being investigated but is not yet known.

The myth of sustainability in managed wild fisheries: the economic case for aquaculture subsidies

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The objective of this study is to recast the role of aquaculture as an alternative tool of policy to supplement traditional fisheries management techniques. Another goal is to devise a methodology to assess the feasibility of promoting aquaculture development with subsidies when the market fails to provide the socially optimum level.

Ocean fisheries are increasingly being depleted, despite regulatory policy, yet the demand for ocean resources growing. Traditional policy focuses on the supply-side because it restricts fishing inputs (effort and technology) and outputs (harvest). It is demonstrated that such policy cannot ensure sustainability when worldwide demand accelerates.

Rather than focus on aquaculture's passive role as an enhancer of wild fish supply, cultured fish are examined as a market substitute for wild fish, and biological and market interactions modelled. The bio-economic model demonstrates that aquaculture is an appropriate demand-side approach to sustaining the wild fishery against increasing demand, without some of the problems of traditional policy.

The model identifies three sources of social net benefits from aquaculture: (1) direct wild fishery, (2) indirect recreational use, and (3) indirect passive use. Indirect benefits are positive (+), but wild fishery benefits are ambiguous (±), depending upon economic parameters and harvest relative to biological Maximum Sustainable Yield (MSY). The model is applied empirically to the Gulf of Mexico red drum fishery to compute parameters and wild fishery social net benefits for given aquaculture scales.

The economic approach suggests that substitution is the appropriate vehicle to mitigate long term fish scarcity because it is unlikely that new fish stocks will be discovered, and technological progress in wild fisheries leads to depletion. It is important that markets work and that fish prices fully reflect scarcity cost in order to signal the optimal provision of substitutes, such as aquaculture output.

The key finding is that markets fail in both aquaculture and the wild fishery so as to impede the optimal substitution of aquaculture by private investors. First, investors cannot easily factor public good benefits of Research and Development (R&D) into their decisions, and there are problems of risk pooling and scale economies. Second, the price of wild fish lies below its true scarcity cost. Thus, price cannot properly signal aquaculture as a scarcity-mitigating response because the substitution ratio of wild fish price to aquaculture cost is below the social optimum. Traditional policy, which seeks to raise the ratio's numerator, falls short because Individual Transferable Quotas (ITQs) do not internalize externalities of wild harvest on recreational and passive uses.

Market failure can be overcome if aquaculture cost in the substitution ratio's denominator could be lowered to signal more profitable aquaculture production. Production and/or R&D subsidies are classic policy solutions to lowering costs.

The study concludes that aquaculture subsidization is justified when the net benefits of aquaculture exceed the social cost of the subsidy. Social cost is the highest valued bundle of public goods sacrificed to fund the subsidy, and should include externalities which adversely impact the wild fishery (pollution, habitat, genetics, etc.).

Can aquaculture help restore and sustain production of giant clams?

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Stocks of the larger species of giant clams have been depleted in many developing countries in the Indo-Pacific to supply the market for adductor muscle in Taiwan. Now that these stocks can no longer support fishing, smaller species of giant clams are being exploited for sale to the aquarium trade. Although technically feasible, aquaculture has not yet been able to restore the production of the larger species of giant clams for the adductor muscle market: villagers have been unwilling to husband the clams for the long periods (at least 7 years) needed for the clams to reach minimum acceptable size, and there are major difficulties in the storage and transport of product from remote locations. The objective of giant clam research at the ICLARM Coastal Aquaculture Centre (CAC) in the Solomon Islands has been to identify viable farming methods for small giant clams, and develop techniques for re-establishing the larger species in the wild. To date, large-scale grow-out trials have demonstrated that giant clams can be farmed profitably for the aquarium trade by coastal villagers. For example, 20 mm "seed" of *Tridacna derasa* can be grown to a mean size of 88.4 mm ± 8.7 SD in eight months with a mean survival rate of 93% ± 11.2 SD, and *T. squamosa* attains 65.2 mm ± 8.3 SD in the same period with a mean survival of 66.6% ± 15% SD. The village farming techniques developed by ICLARM have also paved the way for cost-effective restoration of giant clams in the wild. Village farmers maintain a proportion of their "seed" clams in protective cages until clams are large enough to escape predation. The clams are then placed on nearby reefs and monitored regularly. ICLARM is currently coordinating the reseeding of clams at 25 villages throughout the Solomon Islands. The important question that needs to be answered to ensure the success of programmes to re-establish giant clams is: how should the clams be distributed to maximize their survival and spawning success?

The fisheries-aquaculture relationship in New Zealand: is it competitive or complementary?

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The thirty year history of aquaculture in New Zealand has been one of competition for resources. The three established export-producing aquaculture industries (Pacific oysters, mussels and salmon) have had to compete with numerous alternative users for their most essential resource, namely the water. Recreational, navigational, traditional and aesthetic interests have posed major constraints on the development of aquaculture but direct competition has also occurred with the existing wild fisheries. Pacific oyster farming has alienated intertidal areas for set netting. Greenshell mussel farming is incompatible with line, trawl and dredge fishing. Sea-run salmon farming has found itself in competition with both the recreational fishers on the river banks and the commercial trawlers off the river mouths. Continuing expansion of mussel farming into more open waters, together with new ventures, such as cage farming of finfish, will lead to further competition with wild fisheries. Proposals for rock lobster farming by on-growing juveniles have already raised the spectre of competition with the lobster fishery for the puerulus stage.

Fishery-aquaculture competition has also occurred at the product end of the industry. The rapid rise in production of farmed greenshell mussels was matched by the complete demise of the wild dredge fishery, whose product could not compete against the smaller, succulent, fast-grown, farmed product.

The alternative to competition has to be collaboration; the outstanding example from New Zealand being the enhancement of the Tasman Bay scallop fishery. This highly successful fusion of fishery and aquaculture techniques has perhaps provided the model by which to enhance other fish and shellfish resources. The application of aquaculture techniques for settling larvae of the dredge oyster is currently being tried as a means of rejuvenating the wild fishery in Foveaux Strait. At the same time hatchery production of seed is being developed for establishing dredge oyster farming and as a means of expanding, by enhancement, the small wild dredge fishery in Tasman Bay/Golden Bay.

Marine farming in New Zealand was developed by individuals and specialist aquaculture companies. It was not until the mid 1980s that traditional fishing companies got involved, and took advantage of the complementary attributes of marine farming and fishing. Fishing companies are now involved in the oyster, mussel and salmon farming industries, as well as the developing aquaculture of abalone (paua), and are showing interest in such species as rock lobster, snapper and surf clams. The complementary interests of fishing and aquaculture are exemplified by the scallop enhancement company's funding of research into snapper rearing, aimed at producing juveniles either for enhancement of wild stocks or for sea cage farming.

Any expansion of New Zealand's aquaculture will of necessity remain low volume, high quality, export-oriented. The market promotion necessary for these quality products fully complements the value-added promotion of New Zealand's wild fishery exports.

Review of epizootics in cultured fish in Taiwan

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Common epizootics and their etiological agents of the major cultured marine, brackish and fresh water fish species were reviewed.

White spot syndrome associate baculovirus (WSBV) and monodon baculovirus (MBV) were the primary etiological agents related to mass reduction of captive tiger prawn production in the recent year, but bacteria of *Vibrio* spp, gill parasites and undefined stressors always aggravated the

epizootics. Yeast of *Debaryomyces hansenii* induced milk disease of *Macrobrachium rosenbergii,* during the cold water season, caused more than 50% mortality.

Heavy loss of grouper and other captive marine species was mainly caused by infection of *Cryptocaryon irritans, Epistylis* sp and *Trichodina* sp on the gill during the cold water season. Leech was also a common parasite on the body surface of cultured marine species, evident impacting was not recognised. Lymphocystis in grouper caused by Icosahedral cytoplasmic DNA virus was the only other viral infection of fish in Taiwan. However, histopathological change similar to that induced by virus had been recognized in the red snapper (*Luijanus argentimaculatus*) but the suspected pathogen could not be isolated.

Epizootics in milkfish and other brackish water species were exclusively caused by *V. anguillarum, V. parahaemolyticus* and *V. alginolyticus.* The infection occurred every winter causing heavy loss. The stress of low temperatures certainly caused the onset of the eipzootics.

Edwardsiella tarda caused two types of infection in cultured Japanese eel (*Anguilla japonicum*): liver type and kidney type; but isolates of the two types of clinical signs did not biochemically differ. Motile aeromonasis and *Cytophaga columnaris* induced gill and tail rot are next to edwardsiellosis in impact. *Dactylogyrus* and *Pseudodactylogyrus* on gill and *Pleistophora anguillarum* in muscle are the most common parasites of the captive eel but both were controlled either by chemotherapeutics or by improved cultured techniques. Saprolegniasis in the elver stage used to be a serious problem but is now completely controlled by indoor rearing management. Branchiomycosis was also recognized in sporadic cases. Culture of *A. rostrata* and *A. anguilla* had been tried for decades. Most failures were related to heavy parasite infection of the gill. Today great improvement has been reached in indoor culture systems.

Two species of *Lernea* and *Argulus japonicum* are common parasites of cyprinid fish including big head, grass carp and silver carp. Rickettsia infection in Tilapia was first recognized in 1993. This also was the first report in the world of this organism as fish pathogen. The main problem of rainbow trout is gill rot caused by filamental bacteria and *Ichthiophthirius.* Chemotherapeutics gained small effective results.

Superintensive culture of bullfrog and tigrinaris frog in Taiwan contributed to several millenary tons production yearly. High mortality of both species was caused by streptococcicosis and flavobacteriosis; all other pathogen is not known or of little impact.

Infectious diseases including fibroma, fibrosarcoma and papiloma were only sporadically recognized but increased during the recent year. The exact etiological agent or factor has not yet been identified.

Progress towards development of culture methods for glass eels of the Australian short-finned eel, *Anguilla australis*

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World aquaculture production of eels, *Anguilla* spp., exceeds 86,000 t per annum (approximately 85% of the total harvest), with a nett value of more than US$900 million. The vast majority of this production is based on the supply of wild juvenile (glass) eel seedstock, primarily from selected European and Asian species. Annual production from the Australian industry is in excess of 600 t per annum, the majority of which is wild caught or "extensively farmed" in unmanaged waters. The objective of the present stu funded by the Fisheries Research and Development Corporation, is to develop more intensive culture technology for glass eels of the Australian short-finned eel, *A. australis,* for the purpose of enhancing production over existing practices.

Glass eels (0.1-0.2g mean weight) were obtained from selected south-eastern Australian estuaries, including the Snowy, Barwon and Tarwin Rivers in Victoria and the Tamar River in Tasmania and were successfully transferred from estuarine waters to freshwater hatchery conditions without the need for prolonged acclimation. Protozoan diseases encountered during experiments (*Ichthyobodo* and *Trichodina* infestations) were successfully treated using standard therapeutic methods. Preliminary observations indicated that the newly caught glass eels need to undergo a weaning phase before they will feed on an artificial diet. Initial weaning diets of either *Artemia* or freshly minced fish were found to be suitable for such a purpose, with active feeding commencing within several days of capture.

Experiments were conducted under semi-intensive conditions in fibreglass tanks supplied with filtere recirculated water at constant temperature. The growth an survival of glass eels weaned onto two different artificial diets (trout starter diet or commercial eel diet in the form of a moist dough) were compared over two periods of different duration (5 days: 20% change of fish mince to artificial diet every day and 15 days: 20% change every 3 days) against non-weaned eels fed on minced fish only. Results indicated that the slower weaning period gave faster growth rates than the shorter, 5 day weaning period and that both growth and survival were significantly greater when eels were weaned onto a commercial eel diet than onto the trout starter diet (both weaning periods). A comparison of growth in weight under similar conditions showed that glass eels reared at 25°C grew faster (13.5% per week) than those reared at 20°C (4.1% per week), whereas at 15°C eel weight decreased (-0.9% per week). Growth in weight of pigmented elvers reared at low density in fertilised earthen culture ponds under ambient summer/autumn conditions in western Victoria ranged from 8.8% to 12.5% (mean 10.9%) per week. Survival in these ponds after 10 weeks ranged from 61 to 93%.

Other experiments are in progress or proposed, including tank trials investigating grading effect on growth depensation, weanability of glass eels compared with larger elvers, optimal stocking density and feed rates and pond

trials investigating effects of supplementary feeding and the use of managed wetlands for enhanced growout under ambient conditions. From a technical perspective, glass eels of *A. australis* appear to be a suitable candidate for intensive/semi-intensive aquaculture under a range of conditions, although the economic feasibility of such a development is yet to be determined.

Hormone induced spawning of the threatened Macquarie perch (*Macquaria australasica*): an Australian native freshwater fish

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Macquarie perch, *Macquaria australasica* (Percichthyidae), were once widespread throughout the cooler upper reaches of the southern tributaries of the Murray-Darling River tem. However, the distribution and abundance of the species has declined since European settlement, with remaining populations being relatively small and fragmented. The national conservation status of the species is currently classified as indeterminate. Reasons for this decline are unclear but are thought to include habitat loss and modification, fishing pressure and competition with introduced fish species. A Macquarie perch stock enhancement programme utilising hatchery progeny for restocking purposes has been initiated within Victoria as part of an integrated management strategy. The aim of the present study is to develop hormone-induced spawning techniques for such a programme to enable reliable, large-scale hatchery production of juvenile Macquarie perch.

A range of commercial hormone treatments at varying rates were trialed on wild, sexually mature broodfish collected from a viable, natural population of Macquarie perch in Lake Dartmouth and its major tributary the Mitta Mitta River, in north-eastern Victoria, during the annual spawning season (October-December). All females were injected intraperitoneally, held in tanks at constant 200C temperature, and hand stripped of eggs after a 40-45 hr ency period. Running ripe males were not injected, but otherwise held under similar conditions and hand stripped of sperm immediately prior to fertilisation. A dry fertilisation method was employed and fertilised eggs were incubated in flowing water at constant 20°C temperature.

Established techniques have relied on the use of Human Chorionic Gonadotrophin (HCG) to induce spawning. However, initial experiments showed that the proportion of females induced to ovulate and spawn and the viability of eggs (24 hours post fertilisation) were both greater for fish injected with salmon Gonadotrophin Releasing Hormone analogue (*sGnRHa*) and Ovaprim (*sGnRHa* and *Domperidone*) (Syndel, Canada) than for fish injected with HCG. Subsequent experiments indicated that 20-40 µg/kg *sGnRHa* resulted in a higher proportion of ovulation and 24hr viability than did dosages of either 10 or 100 µg/kg *sGnRHa*. Ovaprim applied at 0.5ml/kg resulted in a higher rate of ovulation and egg viabilities than for dosages at 1.0 ml/kg.

The use of new generation hormone treatments has enhanced the reliability and overall production of Macquarie perch under hatchery conditions *per se*. However, over the past five years there has been an overall decline in the number of Macquarie perch larvae per unit weight of females injected each year. There has also been a steady decline in the performance of some hormone treatments (proportion of females to ovulate and 24hr egg viability) for the same period. Indeed the size of female Macquarie perch taken from Lake Dartmouth for spawning purposes has declined steadily each year from a mean weight of 1.16 kg in 1990 to a mean weight of approximately 980g in 1995. Lake Dartmouth contains the largest remaining natural population of Macquarie perch within the Murray-Darling Basin. However, since filling for the first time in 1991, the lake level has fluctuated markedly due to irrigation demands, and the natural productivity of the lake appears to have declined accordingly. Notwithstanding the effectiveness of the induced spawning methods, the declining productivity of the lake, together with the impacts of fluctuating lake levels on spawning habitat in the immediate upstream reaches of the Mitta Mitta River, raise some concerns over the longer term conservation status of the species.

Evaluation of two electronic juvenile fish counters

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Aquaculture operations which involve large scale hatchery production of seedstock, necessitate routine enumeration of larvae and fry in order to enable optimal stocking densities and associated feeding regimes and to periodically assess productivity at critical developmental and production stages. An efficient and reliable method to accurately enumerate various juvenile stages is therefore critical to the success of such culture systems. Within Australia, hand counting, volumetric methods and weight sampling are often used to estimate numbers of juvenile finfish. However, recent technological advances have led to the introduction of a range of electronic counters specifically designed for aquaculture applications.

In the present study, two electronic counters were evaluated for accuracy against hand counts, effects on fish survival and ease of use. The Jensorter counter, Model FC (Jensorter Inc. USA) is designed to count newly hatched larvae, with a body diameter of 0.8-2.0 mm, using an eight channel infra red detection system mounted beneath a water-filled hopper. The manufacturer claims a counting capacity of one million fish per hour and an accuracy of up to 98%. The TPS Fish Counter (Impex Agency, Denmark) is designed for counting juvenile fish weighing 0.5-6.0 g. Fish are counted when they pass from a holding tank through a chute containing two photoelectric counting heads. A capacity of up to 35,000 fish per hour is reported by the manufacturer.

Jensorter trials were conducted on larvae of three Australian native species (size range 7.8-9.6 mm mean total length). TPS trials were conducted on fry of four Australian native species (size range 0.59-1.06g mean weight) and two salmonid species (size range 0.46-2.3g mean weight). Counting accuracy was determined by repeatedly (5 times) hand counting, then machine counting a single group of fish for each species. The effects of counting on fish survival were determined by hand and machine counting five groups of fish which were then placed in separate tanks and monitored for 48 hours.

For the Jensorter trials, both machine and hand counts varied by up to 3% for all species. In most of the TPS counter trials there was no significant difference between hand counts and machine counts, which mostly varied by

less than 1%. There was no significant difference in survival between the two counting methods in most of the trials for each counter, with survival greater than 99% after 48 hours in all Jensorter trials and ranging from 84.1% to 100% in all the TPS trials. Counting capacity of both machines varied considerably and depended on the species being counted and operator experience. The Jensorter counter with a single person operator had a capacity ranging from 17,600 to 100,000 larvae per hour, compared with approximately 5,000 larvae per hour per person by hand counting. The TPS counter with a single person operator had a capacity of from 10,300 to 23,000 fry per hour, compared with approximately 4,000-6,000 fry per hour per person by hand counting.

Having obtained a high degree of accuracy and high post counting survival rates, both counters are now routinely used for native fish aquaculture operations at the Victorian Fisheries Research Institute, Snobs Creek Hatchery, including enumeration of post-hatch larvae (Jensorter) and pond-reared fry (TPS). The initial cost of these electronic counters is more than offset by savings in time, labour and an improved confidence in production figures.

Indian aquaculture: where does it stand?

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This paper reviews the development of aquaculture in India. It assesses the aquatic resources, the production systems existing and identifies areas where a quantum leap is possible. With the stagnation of production from the marine sector, the Government has launched a number of innovative schemes and provided strong research support to boost aquaculture. The entry of industrial houses and the rapid, increase in area covered have added to production.

India is one of the very few countries with a rare blend of immense water resources and mega-diversity in aquatic species. The country's total fish production is 4.6 million t per year. Roughly 40 percent is from the inland sector. With the production from the marine system appearing to plateau the targeted production of about 10 million t annually would have to rely heavily on aquaculture.

The country has drawn up a National Fisheries Policy, elaborate guidelines for brackishwater farming and is actively sorting out environmental issues that have cropped up in the exploitation of coastal ecosystems.

India is poised for a significant increase in production, based on a judicious management of its resources in consonance with principles of eco-sustainability. The paper brings out the strengths and weaknesess of Indian aquaculture and outlines a blueprint for sustainable development.

With vast resources in the form of a long coastline (~8000 km); brackishwater (1.2 million ha); ponds and tanks (2.2 million ha); reservoirs (1.9 million ha); rivers (29,000 km); derelict waters/swamp (1.2 million ha); and a wide biodiversity with 2200 species of which 15% are important from the point of aquaculture, the country is poised for a quantum leap in production.

Bringing 10% of the available brackishwater area under shrimp farming with an average production of 5 t/ha/yr can generate US$3 billion annually. The picture is similar with the different sectors of freshwater resources. Major developmental schemes with emphasis on non-traditional species are underway. Seven National Institutes for fisheries and a number of State Agricultural Universities including Colleges of Fisheries along with significant funding from the Government agencies like the Department of Biotechnology are providing critical support to aquaculture. Major initiatives have demonstrated high production in shrimp and carp farming. The entry of major industrial houses into shrimp aquaculture is ample proof of its vibrance.

Production of critical inputs like seed and feed need stepping up. Besides import of feed, a number of feed manufacturing units have been set up. Seed production is being boosted through new hatcheries. Diversification of aquaculture is receiving priority. Emerging culture technologies are those of shrimps (other than tiger and white shrimp), holothurians, sea bass and freshwater prawns. Strong support is provided for research on feed, breeding, spawning agents, bio-active substances, cryopreservation, vaccines, diagnostics and transgenics.

Intensive production of Japanese flounder with a closed recirculating culture system

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1. Objective. This study was designed to evaluate the growth of fish and the water quality in a closed seawater recirculating culture of Japanese flounder (*Paralichthys divaceus*) under intensive culture condition.

2. Culture system. The experimental culture system consisted of a fish tank of 6m in diameter, two aerobic submerged filters with a net filter medium of about 600 m^2 in surface area, heating-cooling unit, a circulation pump, UV sterilizer of 540 W, and blowers. Total water volume in the system was 22 m^3.

3. Culture condition. Two thousand juvenile fish of 3.[illegible] initial body weight were cultured for 330 days. Fish were fed on a commercial pellet diet for flounder, to satiation twice a day on Monday to Friday, and once a day at weekend. Temperature was set at 20 or 25°C. Natural seawater collected from the coastal zone near Onjuku in Chiba Prefecture was used as culture water.

4. Results.

(1) Survival rate through the culture was 88%. Average final body weight of fish was 480 g and total biomass in the system reached 844 kg. Culture density per square meter of bottom area of the fish tank was about 30 kg at the end. Food conversion efficiency (weight gain/food intake) was 99.5%.

(2) Six and 9m^3 of culture water were exchanged with fresh seawater at the 193rd and 242nd day, respectively. Therefore, total water volume used was 37 m^3.

(3) Ammonia and nitrite were controlled under 1 mg-N/L during the first 100 days; however, both values varied between 1 and 8 mg-N/L thereafter. Although nitrate increased continuously to a maximum of 380 mg-N/L at the 191st day, it decreased remarkably from the 220th to the 265th day.

(4) It is estimated that 44L of seawater and 1,000 to 1,100 yen of operation costs (seedling, food and electricity) were required to produce 1 kg of Japanese flounder (*Paralichthys divaceus*).

5. Conclusion. In this study, although some problems in water quality occurred during the culture, it is clear that Japanese flounder can be produced successfully with a very small volume of seawater and without any serious impact on the natural environment by using a closed recirculating culture system.

Demand for recreational fishing and stock enhancement program in the northeast region of Taiwan

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The demand for recreational fishing is increasing in many countries. Thus, there is increasing pressure by not only commercial fishers but also sport fishers on world fish stocks. Assessing the demand for recreational fishing on fisheries resources is one of the most difficult tasks confronting fisheries management. Thus, this paper aims to analyse the demand for recreational fishing off the northeast coast of Taiwan and to discuss some implications for stock enhancement programmes which have been undertaken by fishery agencies to improve sustainability of fishing stocks in the region.

Survey data from coastal sport fishers and charter boat fishers in the northeast region were used in conducting the empirical demand model estimation. The analysis incorporated socio-economic and fishing success variables in the travel cost demand model to determine their influence on fishers' decisions about recreational fishing trips. Catch per trip has a significant effect on the number of fishing trips taken. It suggests that catch rate should be an important determinant of the demand for recreational fishing. Fishers are responsive to changes in fishing success. Catch rate is therefore critical to good management of recreational fisheries. The improvement of catch rate can be accomplished by stock enhancement programmes. However, in Taiwan and many other countries, the objective of stock enhancement programmes has been to rebuild fishing stocks for commercial fisheries. There is a need to establish cooperation between biologists and economists for the ultimate success of the stock enhancement programmes. The biologists must develop the necessary aquaculture technologies for improving commercial and recreational fishery resources, while economists should assess the benefits of such technologies and enhancement activities.

Survey of leptocephalus of Japanese eel in the Western Pacific Ocean

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The Japanese eel, *Anguilla japonica*, is widely distributed in the northwestern Pacific Ocean, south of the Philippines, through Taiwan, China, Korea and north to Japan; and the spawning ground is estimated to be in the area west of the Mariana Islands. On the other hand, it is also one of the most important species of fish culture in Taiwan. However, since the artificial propagation techniques of eel have not been established yet, all elvers needed for cultivation are collected from estuaries during their upstream migration. But still the supply of elvers from the Taiwan estuaries was far below the demand for aquaculture, therefore a lot of elvers were imported to Taiwan.

To increase the production of elvers, hormone-induced maturation eels have been released by the Taiwan Fisheries Research Institute (TFRI) since 1976 and also the eels were tagged since 1987 to study their migration route, growth and other biological characteristics. In 1976-1993, 13 eel-releasing activities had been conducted but the recovery rate was quite low. Until recently, it was reported that only one tagged eel had been recaptured not far away from the release site after 19 days liberation in the 1987's activity.

Since the results from the tagging experiment were not satisfactory, other ways of approach were considered in addition to the continuous releasing and tagging activity. Consequently, consecutive cruises to survey the spawning ground of the Japanese eel are planned by TFRI since 1995. Our first year's primitive results herein are summarised as follows:

- The study was taken from August 14 to August 23, 1995. The ORI, IKPT and Vongo net were used to collect the leptocephalus. In the 50 stations, 50, 36 and 15 casts of ORI, IKPT and Vongo net were made respectively.

Totally, 27 leptocephali were collected, in which 4 were identified to be Japanese eel (*Anguilla japonica*), 20 A sp., 1 Nettastomadidae, 1 Xenocongridae, and *Ariosoma* sp.

The four leptocephali of Japanese eel were collected at 13°00'N 130°30'E 131°30'E; 14°00'N 137°30'E; and 14°30'N 140°30'E, the number of their myomere was counted at 112, 114, 115 and 117 while their length was measured to be 27.0, 28.85, 31.45 and 56.35 mm respectively.

A pilot evaluation of aquaculture integration with irrigated farming systems

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The production of silver perch *Bidyanus bidyanus* under semi-intensive cage culture conditions was evaluated as part of an integrated agriculture/aquaculture research project in the Goulburn-Murray Irrigation District (GMID) of Victoria. The study, funded by the Rural Industries Research

and Development Corporation, aimed to demonstrate the integration of aquaculture into existing irrigated farming systems to enhance farm productivity, water use efficiency and overall sustainability. The strategy was to adapt and develop appropriate husbandry and general production methodologies to enable viable, cost-effective commercial fish production in such systems.

Silver perch were grown in three experimental systems, *viz.* channel cages (floating cages in an irrigation supply channel), reservoir cages (floating cages in an on-farm storage) and groundwater tanks (floating cages in circular, prefabricated, above-ground PVC lined tanks). Cages were of 1.0m^3 volume, constructed of polyurethane mesh (144mm^2), and were anchored to floating walkways in the channel and reservoir systems and to the sides of the tanks in the groundwater system. A fourth "control" system, an industry standard, consisted of purpose-built, earthen fish ponds at a local commercial fish farm, subject to ambient environmental conditions.

All cages were stocked with hatchery-bred, "advanced young-of-the-year" silver perch (18.8 g mean weight; 109.4 mm mean total length) in November, 1994. Primary experimental fish husbandry variables for each experimental culture system included high and low stocking and high and low feeding rates. Fish were hand-fed once daily with commercially available feed and all feed rations were adjusted according to increments based on monthly weight measurements which were determined from random subsamples collected at the commencement of the trials and at monthly intervals. All live fish were counted at the completion of the trials to estimate survival. Key water quality parameters were monitored on a weekly basis in each system.

Survival of fish exceeded 90% at both the channel and reservoir cage sites, with the lowest survival (45.5%) recorded at the groundwater site due to poor water quality within the tanks. No significant differences in growth rate were found either between treatments within each site or between treatments between sites. However, growth was significantly greater in the channel and reservoir cages than for the other sites. The final mean size of the fish was less than 90g in all cases, which is inadequate for commercial purposes. However, the maximum final weight of fish from the channel and reservoir cages exceeded 200g, suggesting that greater overall production of silver perch is possible in at least these systems. Taste panel analysis of the organoleptic properties of the cultured fish indicated that site significantly affected the sensory attributes of the fish in some cases, but that in general the produce was very acceptable to the palate.

In these trials, optimal temperatures (20-25°C) existed for no more than half (three months) of the total trial period. However in the latter part of the season, when water temperatures began to decline, growth rates were maintained in all systems, even at temperatures less than 20°C. This suggests that other parameters such as feed type and other water quality factors are also equally important determinants to growth and that under more optimal conditions growth rates may be significantly enhanced and viable integrated production of silver perch achieved in the GMID.

Coastal planning and aquaculture: regional marine farming development plans

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Marine aquaculture in Tasmania began to reach a critical stage in the early 1990s with industry demand for expansion outstripping supply of readily available areas of suitable water. A relatively new feature of this situation was that applications for new aquaculture sites began to meet with occasionally vigorous opposition from conservation and community groups. It became clear that existing legislation was inadequate to properly manage industry growth as well as account for other coastal zone uses and users. No over-arching framework for coastal planning that adequately encompassed aquaculture existed. A 'first come, first served' legislative framework with limited supporting poli development was in place, but it had struggled to keep pac with industry development in the previous decade.

To encourage sustainable growth of the aquaculture industry the Tasmanian Government has enacted a new legislative package concurrent with the development of regional aquaculture planning documents covering management and expansion of the industry. In these plans, areas of water are set aside for marine farming – called zones – which are similar in legal status and planning focus to those on land (e.g. residential or urban industrial zones). Included in the plans are management strategies for each zone with particular emphasis on assessment and monitoring of the environment. It has become clear that preparation of these documents has encompassed a comprehensive coastal planning exercise with increases in available area of 200-300% achieved with full community consultation. In this paper the background to aquaculture management in Tasmania, the new legislative framework and results of regional aquaculture planning in Tasmania are outlined.

Estimation of *invivo* digestibility of diets fed to barramundi (*Lates calcarifer*)

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Accurate measures of digestibility of dietary ingredients are necessary when formulating aquaculture diets. A growing interest in farming *Lates calcarifer* in Australia prompted a series of experiments to develop a suitable method of measuring digestibility of dietary components, especially protein, by this species.

In the first experiment 3 diets containing 514,458 and 406g crude protein(CP)/kg DM (dry matter) and 1 g/kg DM of the digesta marker titanium dioxide were each fed to 5 juvenile fish in ten 25L tanks connected to a common recirculating freshwater sysyem. In a second series of experiments 10 diets containing from 530 to 650g CP/kg DM and the titanium dioxide marker were each fed, during 3 experimental periods, to 10 juvenile fish in 2 tanks. Faeces that accumulated on the bottom of the tanks during 24h periods after feeding were collected, freeze dried and analysed. Digestibility coefficients for DM, energy, fat and

protein, calculated on the assumption that all faeces that were voided were collected, were very high (>90%), indicating that faeces recovery was not complete. Digestibility coefficients calculated from concentrations of titanium dioxide in the diet and in faeces were highly inaccurate, for example calculated DM digestibility for one diet in experiment 2 varied from –20% to 69%.

To determine why the above technique was inaccurate, faecal samples, some of which contained titanium dioxide, were obtained from the terminal large intestine of anaesthetized fish by manual expression (stripping). These were freeze dried and then 3g samples were suspended in 150 ml water to mimic the collection conditions in the experimental tanks. After standing for 6 or 24h the supernatant was separated from the faeces that had precipitated to the bottom of the beakers and both fractions were freeze dried. Analyses showed that significant proportions of faecal DM and protein either dissolved or stayed in suspension in the supernatant fraction. A large proportion of the faecal protein was insoluble in tungstic acid (true protein) and this fraction was mainly (77%) in the precipitate while the soluble protein was mainly (79%) in the supernatant fraction. The titanium concentration in the sediment was about 50% of that in the original faecal sample. These results clearly showed why digestibility estimates obtained by analysing samples of voided faeces were incorrect.

In a third experiment six 500g fish were placed in each of ten 250L tanks that were connected to a recirculating freshwater system. The fish in 5 tanks were fed a diet based on fishmeal while the fish in the other 5 tanks were fed a diet based on meat and bone meal. Each diet contained the digesta markers chromic oxide, ytterbium acetate and titanium dioxide at 5, 0.1 and 1g/kg, respectively. After the fish had adapted to the diets, faeces samples were obtained from them, after anaesthesia, by stripping (5 tanks) or by gently sucking through a glass tube inserted into the rectum (5 tanks).

Estimates of DM and protein digestibility calculated from analyses of faeces samples obtained by suction were about 5% lower than values calculated from analyses done on faeces obtained by stripping. The suction technique possibly removed some of the intestinal lining or the faeces sucked from the rectum were not completely digested. The most reliable estimates of digestibility were obtained when faecal samples were obtained by stripping and faecal output was calculated by reference to the markers ytterbium acetate or titanium dioxide; the average standard errors for the estimates of DM and protein digestibility were 2.25% and 1.11%, respectively.

Immunoindicators of environmental stress and disease outbreak in aquaculture

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Fish are protected from microbial diseases by a complex immune system which is fairly similar to that of higher vertebrates, including man. The homeostatic system of fish is constantly challenged by environmental stressors which are chemical (e.g. heavy metals, pesticides, etc) or non-chemical (e.g. temperature, pH, overcrowding, etc) in nature. The primary response of fish to stressors involves release of corticosteroids. Cortisol is the main corticosteroid produced in interrenal cells in fish. Elevation of cortisol results in immunosuppression and the immunosuppressed fish population is under constant threat of microbial infection and disease outbreak. Some of these stressors like heavy metals can also directly interfere with immunocompetent cells and molecules resulting in immunosuppression. The objective of the study was i) to understand the effect of various aquatic pollutants such as heavy metals and pesticides on immunity in the tilapia, *Oreochromis mossambicus* (Peters) with reference to antibody response and leukocyte/lymphocyte count, and ii) to develop a model for using the possible immunomodulatory effect of these pollutants as an indicator of environmental pollution/stress for predicting imminent microbial infection and consequent disease outbreak in fish populations in an aquaculture system.

When groups of *O. mossambicus* were exposed to very small concentrations (0.1-10% LD/Lc_{50}) of heavy metals such as chromium, mercury, nickel, lead, or aluminium, pesticides such as monocrotophos, endosulfan or quinolphos and effluents from tannery or dyeing industry there was significant reduction in the magnitude of humoral immune response and the number of leukocytes/lymphocytes. In field tests, when fish were maintained in cages in polluted waterbodies, the magnitude of immune response was suppressed.

There is a broad spectrum of immunological assays which can be used for indicating environmental stress in fish populations. If these immunological tests indicate that the immune system is compromised, microbial disease outbreak may be predicted and steps can be taken to save the fish. These tests range from simple non-specific assays such as enumeration of leukocytes, gravimetry of lymphoid tissues and macrophage function tests, to complex sensitive specific immune response tests such as passive haemagglutination, immunoelectrophoresis and Enzyme Linked Immunosorbent Assay (ELISA). The levels of testing include uncontrolled or controlled field tests and *in vivo* or *in vitro* laboratory tests. These immunoindicators are sensitive, relevant and reproducible and hence are useful for monitoring the environmental stress and taking necessary prophylactic measures to save the fish in intensive and extensive aquaculture systems.

Intensive fishculture and its impact on the environment: the role of natural zeolites in the reduction of the ammonium content in the effluents

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Good management of intensive fishculture involves the reduction of the impact of pollutants in rivers collecting the effluents and on the whole freshwater system in the coastal zone.

Among aquaculture waste water pollutants, ammonium is of the upmost importance.

Reduction of the ammonium content in aquaculture wastes can be achieved by using different filtering materials. Among these materials, zeolite-bearing rocks are well known for their ammonium binding capacity and for their low cost.

Zeolite is a framework of aluminosilicate. Its structure contains channels filled with water and exchangeable cations. The negative charges of the framework are balanced by alkalies and alcaline earths located in the channels. This structure allows zeolites to exchange cations with a capacity ranging from 2.16 mEq/g to 4.73 mEq/g.

A model Italian trout farm, producing 100 t/year of fish, wastes 4.2 to 12.4 t of NH_4^+–N per year. Taking into account that in Italy the average production is 40,000 t/year of trout the mean NH_4^+–N output per year can be estimated to be between 1680 and 4800 t.

Through filtration on a large scale using natural granular zeolite containing phillipsite (3-8 mm diameter) it is possible to reduce the ammonium content of the effluents by up to 67% of the initial value. This reduction is, however, only possible if the ammonium level of the influent into the filtering system is sufficiently high to enable the zeolite to carry out its ammonium capturing selectivity: the latter in spite of the presence of high concentrations of interfering cations, and in particular potassium, sodium, calcium and magnesium. Studies have established that the lowest ammonium level for efficient filtration is 0.35ppm, which corresponds, for the above mentioned model trout farm, to a waterflow of 500 L/sec in the lowest ammonium output forecast.

The use of zeolite filters can therefore reduce the impact of intensive troutculture in Italy on the Adriatic sea coastal zone (Central Mediterranean Sea) by 550-1580 t/year of NH_4^+–N.

Ammonium captation involves a cation release from the zeolites that is related to the natural content of exchangeable cations in the framework. For Italian phillipsite the exchange involves an annual release of 910-2590 t K and of 380-1080 t Na.

Exhausted material can be regenerated using NaCl 1M solutions and then re-used, or simply disposed of in soils requiring nitrogen. However, regeneration involves advanced technology and high costs, therefore only large scale plants could use this system. Small scale plants and rearing farms located near expanses of arable land could then consider it cheaper to dispose of the exhausted zeolites in the soil, where they can act as nitrogen fertilizers.

Therefore, the use of rocks containing zeolites can be recommended for the development of sustainable aquaculture.

Feasibility of abalone stock enhancement and rehabilitation by larval reseeding: new developments in South Australia

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Wild abalone stocks are fully exploited worldwide and in many places have declined through overfishing, disease or habitat degradation. Stock enhancement and rehabilitation using small juvenile abalone have been attempted in many countries and have been found to have a number of biological, economic and logistical shortcomings. Larval reseeding has been attempted elsewhere on an *ad hoc* basis but has not been thoroughly assessed as a method of stock enhancement.

Here is reported the progress of a project which began in July 1994 to assess the feasibility of releasing hatchery-produced abalone larvae into natural habitats in South Australia. The project's key objectives are to develop suitable transportation and deployment technology, to determine settlement success and to quantify the subsequent survival of the resultant juvenile abalone. These biological measures of success will then be used to evaluate the cost-benefits of abalone larval reseeding. A further year's data will be available by the time of the World Fisheries Congress.

The larvae of two commercially fished species, *Haliotis laevigata* and *H. rubra,* were released at the "competent to settle" stage (about 5 days old) at a total of eight sites. A simple small-boat based delivery system, using drums of suspended larvae and compressed air as the propellant, was devised and the larvae were released by divers on to suitable habitat within pre-chosen sites. Monitoring of sites was done one week, one month and six months after seeding at some sites, and 12 months after seeding at all sites. Abundance of abalone was compared with unseeded control sites also selected *a priori.*

Larval abalone were collected from commercial hatcheries, transported to the reseeding sites on damp 100 micron mesh and then resuspended in sea water. They were sampled by divers during delivery to assess mortality after transportation, resuspension and pumping and to assess larval suspension homogeniety.

The use of mesh tents to retain reseeded larvae within selected microhabitat was tested and an artificial substratum was tested as a tool for monitoring settlement success of reseeded larvae. Several different densities of reseeded larvae were also tested to determine optimal rates.

Results to date show that the larvae survive transportation, resuspension and pumping through the delivery system, though homogeneity of the suspension of negatively buoyant larvae was variable. Settlement and growth of larvae were found on natural and conditioned artificial substrata both one week and one month after seeding and increased numbers of juvenile abalone were found at seeded sites six months and one year after reseeding.

Artificial substrata trials were successful, with the artificial substrata being both more uniform and easier to handle than natural substrata. Mesh tents were not shown to be successful and were abandoned.

The continuing research will include further reseeding and ongoing monitoring to assess the significance of stock enhancement achieved as well as improved damp larval holding techniques and a benefit-cost analysis of larval reseeding as a method of stock enhancement.

Conservation of genetic resources for aquaculture

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Most of the ancient and recent history of aquaculture has run its course without the characterization and purposeful management of fish genetic resources. Apart from some salmonids, catfishes and cyprinids, notably the common carp, there are no well-documented breeding histories for farmed fish and very few current scientifically-based breeding programmes, especially in warmwater aquaculture. Does this really matter? Is the conservation of fish genetic resources important for breeding programmes? Could not aquaculture continue its worldwide expansion based upon farming whatever 'seed' is available, as it has done in the past? Could not modern technologies targeted on fish breeding (e.g. cryopreservation of gametes; sex reversal; polyploidy; transgenics) make it unnecessary to conserve genetic resources for the domestication of aquatic organisms and the evolution of breeding programmes? This paper concludes that the effective conservation of fish genes and genotypes is of great importance to keep options open for the sustainable development of aquaculture and for the generation of a wide diversity of aquatic produce.

Strategic planning to tide over the present crisis and sustain the brackish water aquaculture industry in India

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The objective of the study is to develop a strategic planning model to tide over the present crisis faced by the brackish water aquaculture industry in India, due to quality and socio-economic problems and to sustain the industry.

India is leaping towards the "blue revolution". The stagnant or dwindling natural resource reduces the rate of progress towards the target but efforts are on at a national level to promote aquaculture as an alternative resource. Aquaculture has been a small-scale activity in India from time immemorial, especially in the State of Kerala and West Bengal. India, with a coastline of 8,025 km, continental shelf area of 51,200 km^2, Exclusive Economic Zone of 2.02 million km^2, inland water bodies of 5.48 million ha and a network of 164,000 km of rivers and canals, is the seventh largest fish producer in the world. Harvest of important fishery resources including shrimp from the inshore waters of India has been stagnating over the past few years indicating that the resources are overexploited and hence the focus is now on aquaculture development.

Of the total brackish water area of 1.2 million ha available in the country, only 100,700 ha are presently under shrimp farming. The traditional practice of paddy-cum shrimp farming is being carried out mainly in West Bengal, Kerala, Karnataka and Goa in about 50,000 ha. Productivity from these farms is very low and ranges from 200 to 500 kg per ha against 5,000 to 10,000 kg in scientific farming. In the case of semi-intensive aquaculture farms, the average production is 4 tonnes of shrimps per ha. During 1994-95 total loss of shrimps was also noticed in many parts of Andhra Pradesh and Tamil Nadu due to mass mortality. This was mainly due to stress and microbial attack on the stock.

Social objections in some states have culminated in a Supreme Court interim order banning agricultural lands and salt farms from being converted into commercial aquaculture farms and withdrawal of ground water for aquaculture purposes in the disputed State of Andhra Pradesh, Tamil Nadu and Pondicherry.

The paper identifies Strategic Planning as a useful tool towards improving the situation and increasing productivity in brackish water aquaculture systems in India. A model has been developed which consists of:

- a Strategic Planning Group (SPG) which works as a team to achieve the target envisaged
- analysis of the current situation as visualized by various interested parties. Here the mandate of the institution is clarified and an environmental scan of internal and external factors is carried out (Strength, Weaknesses, Opportunities and Threats of the brackish water aquaculture systems in India).

A better situation is visualised for the future of the brackish water aquaculture systems.

After identifying the current view situation and better view situation the next step in the model was to develop specific strategies that would contribute to the journey from current view situation to better view situation.

The model then envisages formulation of plans and several small projects in detail to achieve the mission of sustaining brackish water aquaculture in India.

Influence of channel catfish, *Ictalurus punctatus*, size-class distribution on protein utilization

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Most channel catfish pond-feeding trials have been conducted over a 5 to 6-month period, stocked with similar-sized fingerlings and fed to satiation. These experimental conditions do not reflect conditions in southeastern United States commercial ponds. Farmers usually practice annual multiple-harvesting of each pond, removing only the food-sized fish portion of the total population. Fingerlings are re-stocked following harvests, resulting in mixed-size fish populations. If large fish inhibit feeding activity of small fish, as suspected, then protein level in the feed may be more important to small fish in mixed-size populations than in same-size populations. Thus, the objective of this study was to evaluate the influence of size-class distribution protein utilization.

Channel catfish were stocked at 12,500/ha into 18 approximately 0.05ha ponds on 28 June 1994. The study was conducted using both large (avg. 392.1g) and small fish (avg. 24.1g). Fish were either stocked with fish only of the same size or in a 50:50 ratio with fish of the other size. All fish were fed to satiation one time daily with either 28% or 32% protein floating catfish commercial feed. All ponds were harvested after 125 days. Statistical analyses were conducted separately for large and small fish. There was no significant interaction between the two stocking treatments

or the two feeds. There were no significant differences in average harvest weight, average weight gain, survival, feed conversion, or proximate analyses of whole fish or fillets for fish fed either feed or stocked with only fish of the same size *versus* mixed-size ponds. However, there were significant differences in dressout characteristics between fish stocked with only fish of the same size versus mixed-size ponds. Large fish stocked with small fish had higher percentage fillet, carcass and fat dressout (32.2, 51.5, and 2.3, respectively) than large fish stocked alone (29.7, 48.3, and 1.6, respectively). Small fish stocked alone had higher percentage carcass dressout (50.3) than small fish stocked with large fish (47.6). Additionally, small fish stocked in mixed-size ponds displayed significantly less average weight gain (147.5g) than small fish stocked alone (264.3g).

Assessment of stock enhancement of barramundi *Lates calcarifer* in a coastal river system in far northern Queensland, Australia

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The Queensland Department of Primary Industries has cultured barramundi for stocking since 1986. Initially, fingerlings were stocked into freshwater impoundments where this species does not breed naturally. However, with increasing public demand for enhancement of existing stocks, research has turned to the efficacy and cost-benefits of stocking barramundi in coastal rivers.

Specific objectives of the research are:

1 Development of a stocking strategy for coastal rivers;
2 Assessment of the contribution that stocked fish make to the fishery; and
3 Assessment of the cost-benefits of stock enhancement.

To discriminate hatchery-reared fish from wild barramundi, coded wire tags, implanted in the cheek muscle, are being used to mark stocked barramundi. Tagging rates range from 250-350 fish per hour with tagging mortality (to 48h) less than 1%, and tag retention (to 48h) greater than 96%.

This research, which commenced in the 1992-93 breeding season, is being undertaken in the Johnstone River catchment, near Innisfail in far northern Queensland.

Development stocking strategy: The initial experiment is examining the effects of fish habitat and fish size at release on survival of stocked barramundi. Fingerlings are released at 3 sites representing 3 different aquatic habitats; lower estuarine / mangrove, lower freshwater / tidal and upper freshwater / stream. In addition, fingerlings from 2 size classes (small: 30-40 mm TL, and large: 50-60 mm TL) are released at each site.

Recaptures indicate that fish from both size classes, and fish released at all 3 sites have survived. Stocked barramundi have moved long distances throughout the catchment; in one case a fish moved at least 44 km from the release site (upper freshwater site) into tidal waters.

Assessment of the contribution that stocked fish make to the fishery: It is expected that the first year class of stocked fish will enter the fishery (minimum legal size ≥58 cm) in early 1996 at age 3+. Sampling of barramundi in the Johnstone River catchment indicates that stocked fish represent about 17% of the population. A long-term programme of assessing catch and effort in both the commercial and recreational fisheries is being undertaken to assess whether measurable increases in catch per unit of effort have resulted from the enhancement of barramundi in this catchment.

Assessment of cost-benefits of stock enhancement: Using the value of each fish harvested ($25-$50), the commercial:recreational harvest ratio (3:1), and the cost of the 47,000 fish stocked to date (about $12,000), the break-even point for this programme is reached when 390 fish are harvested. This represents less than 1% of the fish that have been stocked into the catchment to date. Results indicate that this harvest can easily be achieved, and that stocking barramundi in coastal rivers provides important economic benefits for local communities.

Towards sustainability – the aquaculture industry

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The topic of this paper offers solutions through integrated strategic management to the problematic areas impeding the sustainable development of the aquaculture industry in Australia. The main solutions are:

- community participation in vertically integrated planning and decision making at the local level and at the regional level; and
- "one stop shop" process for a reformed Approval process in relation to lease applications. This process works within an ecologically sustainable framework.

The paper suggests that the options provided by the essential elements in integrated resource management, provide the solution to enhance the industry's ability to reach its potential in an Environmentally Sustainable Development (ESD) context, especially in New South Wales.

These elements are essentially the characteristics of 'a mechanism for change', known as an *Industry Management Practice, whose central characteristic for managing t' change is the Community Impact Agreement.* The approac_ is considered to have universal application, and can be applied to other forms of major developments, although it has not been tested.

The strategic management elements for the sustainable development of the aquaculture industry are:

- a systems approach.;
- a balanced approach;
- an integrated approach;
- a stakeholder approach;
- a partnership approach.

The *Community Impact Agreement* (CIA) provides a mechanism for addressing all these approaches. The approaches are embodied in an *Industry Management Practice* (IMP) using the CIA to implement options to resolve the current day impediments preventing the sustainable development of the Aquaculture Industry

The IMP is especially suited to being incorporated into the strategic planning and development of the national aquaculture industry, applied on a regional basis. It also provides a mechanism to simplify the Approval process into a "one stop shop". In achieving this goal the IMP provides the link between aquaculture and integrated coastal zone management. It demonstrates that aquaculture, or any new

development (with coastal and catchment management impacts), managed within an ESD framework can be an essential component in effective coastal zone management.

Effects of growth and starvation on the concentration of free histidine in the muscle of milkfish (*Chanos chanos*)

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A previous report by the authors revealed that histidine was the most prominent free amino acid (FAA) in milkfish muscle, accounting for about 63% of the total FAA. Compared with other fish and shellfish, milkfish has a similar FAA pattern to migratory fish such as mackerel, tuna and skipjack, which also possess a very high level of histidine. The living environment, swimming activity and feeding diet for pond-reared milkfish are apparently different from those of migratory marine fish. The reason why milkfish has a similar FAA profile to that of migratory fish is an interesting subject for study. The objective of this study was to investigate the change of histidine concentration in milkfish muscle during the periods of growth and starvation.

Milkfish increased their body weight from 1.4g to over 580g during the growth period of eight months. The level of histidine in larval fish was 7.2 µmole/g wet weight, accounting for 19% of the total FAA. After the first month of growth, the histidine level was increased to as much as 37.4 µmole/g, which amounted to 49% of the total FAA. Further increase was observed during the elongated growth. There was no significant correlation between the total FAA amount and fish body weight (36 fish), while the histidine concentration correlated well with fish size (r=0.80). Histidine has been reported to serve as a pH buffer in migratory red-fleshed fish muscle when fish move vigorously, resulting in accumulation of acidic end products during the period of anaerobic metabolism. Milkfish is a very active fish and its high level of histidine in the muscle may play a role in buffering capacity. Larger fish may need more histidine for pH buffer function as the movement activity increased with fish size.

Milkfish (n=60) decreased their body weight from 47 to 28g over the 60 day period of starvation. Starvation resulted in a reduction of muscle lipid and protein. The control group of fish without starvation showed no significant changes in both concentrations of the total FAA and histidine in the muscle after 60 days of growth. However, both concentrations were gradually decreased in fasting fish during the period of starvation. The reduction of the total FAA was found to be directly associated with the decrease in histidine. There was no significant change in histidine level during the first 25 days of starvation. Histidine decreased significantly after fish were starved for 40 days, and the concentration in fasting fish was decreased by 46% as compared with that of the pre-starved fish. The results suggest free histidine may serve as an energy source for milkfish during prolonged starvation.

Improved dietary phosphorus utilization by striped bass fed phytase

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Phosphorus (P) in addition to being an essential mineral for fish has been determined to be one of the most limiting nutrients for plant growth. As such, its presence in the environment, particularly in waterways, increases eutrophication. Aquaculturally reared finfish or other intensive fish containment systems typically utilize diets having large amounts of protein and therefore, P, in order to meet dietary amino acid requirements. When diets contain feedstuffs of plant origin such as wheat corn and soybean products, most of the P is in unavailable phytate form. Therefore phytate P is excreted unutilized into the water, degraded by microorganisms and made available for undesirable plant growth. Significantly improved utilization of phytate P could be accomplished by adding a phosphatase i.e. phytase capable of acting in the acid stomach of a teleost such as the striped bass (*Morone saxatilis*). The objective of these experiments was to determine the feasibility of adding a commercial phytase product to striped bass diets to improve dietary phosphorus utilization. A commercial phytase (EC 3.1.3.8) produced from a molecularly modified strain of *Aspergillus ficuum* was sprayed onto diets after extrusion pelleting. In three experiments with fingerling striped bass, levels up to 4,800U phytase/kg diet were tested in diets containing high levels of phytate P. It was determined that diets containing 0.19% available P and 0.5% total P produced P deficiency in bass but not with the addition of 2,400U phytase per kg. Therefore it was concluded that adding phytase at 2,400U/kg diet enabled striped bass to utilize enough dietary P to meet their requirement for scale and bone calcification.

Status and prospects of small abalone culture in Taiwan

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The small abalone (*Haliotis diversicolor*) is one of six *Haliotis* species that inhabit the waters of Taiwan. Commercial culture of *H. diversicolor* emerged in Taiwan in the late 1970s. Total volume of its culture production reached 2600 t in 1994, worth approximately US$ 70 million. Exports to Hong Kong, Mainland China, and Japan shared about 30% of the total production.

The artificial propagation of *H. diversicolor* was first successfully completed in 1979 in Taiwan. Spawning season spans October to February. Hatchery and nursery rearing lasts for about two and a half months to get seedlings at a size of 0.4–0.5 cm in shell length. The grow-out system has been developed into three types:

1 the system of intertidal ponds
2 the system of terrestrial ponds with imbricating concrete plates
3 the system of terrestrial ponds with multi-stacked baskets

Throughout the grow-out phase, *H. diversicolor* are fed with *Gracilaria*, supplemented with *Ulva* and Sargassum weed and the food conversion factor is 16 to 1. On average *H. diversicolor* should reach the market size of 5-6 cm in another 10 months.

Production of *H. diversicolor* in Taiwan may reach over 5000 t in recent years if the international markets can be well expanded. However, development of suitable formulated diets and improvement of strains through selective breedings shall be stressed to ensure the momentum of further development.

World inland fisheries and aquaculture – changing attitudes to management

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The world is in a state of accelerating change brought about by the exponentially increasing human population. The pressure of humanity on natural resources is severe and conflicting demands for food, employment and recreation are leading to a crisis in management of natural resources. In particular there is an intense competition for water which, through its use for irrigation, is fundamental to increases in food production. Production figures from the world's inland waters show a static and, in some cases, declining inland fisheries sector. Much of the change in inland capture fisheries has been traced to environmental impacts and to the results of overfishing. It is also evident that in some areas there has been a marked change in use of the resource.

There is considerable divergence between the recreational and aesthetic destination of inland aquatic resources in the temperate zones and the emphasis on food production in the tropics. Both systems, however, rely increasingly on stocking and enhancement to maintain preferred species in the face of environmental change and heavy fishing. In extreme cases such fisheries are being converted into culture-based systems. The shift away from commercial fisheries in most temperate and in some tropical fisheries in favour of recreational uses frequently masks intense fisheries for domestic consumption. When the catches from such sources are taken into account and added to the not inconsiderable catches from inland fisheries which are too small and too diffuse to be recorded, it may be concluded that the real production from natural inland waters is far greater that indicated by the statistics.

By contrast aquaculture is expanding worldwide and is becoming accepted in areas outside its traditional confines in Asia and Europe. The majority of aquaculture remains firmly based in low cost inland farming systems particularly for carps and tilapias, whereas the highly visible, marine, high cost shrimp and salmon cultures represent only a small proportion (about 9%) of total production by weight, although their total contribution by value is much higher (about 30%). The growing success of aquaculture in new areas derives from its development as a source of income rather than for subsistence, and its incorporation into local agriculture practice as a means of diversification of income and diet. As a result, more flexible integrated culture systems which include fish are being adopted in many regions but a considerable potential for further expansion remains.

The steady increase in aquaculture and culture-based fisheries is indicative of the more general tendency to increasing control over water and the maximization of use of this resource for the production of a variety of crops as well as to fulfil other human needs. However, the same intensification will introduce competition for land, water, feed and financial resources between the various production sectors which may prevent aquaculture reaching its full potential.

Improved grow-out diets for farmed barramundi *Lates calcarifer* (Bloch)

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Production of farmed barramundi in Australia has increased rapidly from 2 t in 1986 to 450 t in 1994/95 worth $A5 4 million. A major impediment to continued expansion barramundi farming is the high cost of feeding since food comprises 40-50% of on-farm costs. In Australia, all farmed barramundi are fed on artificial diets which are expensive ($A1200-$A1500/t). Feed costs are high since diets currently contain large amounts of fishmeal and because a lack of information on the fish's nutrient requirements hinders the development of cost-effective feeding strategies. Research to define the requirements of the fish for key nutrients, and to assess the suitability of terrestrial protein sources as cheaper alternatives to fishmeal, is being undertaken as a priority for improving farm profitability.

In this paper are reported two growth experiments that were carried out to study responses of barramundi to changes in dietary protein (P) to digestible energy (DE) content when fish were kept at various water temperatures (WT) representative of the range experienced on commercial farms in Australia. In each experiment, three diets were formulated to provide P content varying serially from 350 to 450 g/kg. In Experiment 1, all diets were isoenergetic (15 kJ/g) such that the P:DE ratio varied serially from 24 to 30 g/kJ. These three diets were factorially arranged with four WT spaced equally from 20 to 29°C, and for eight weeks fish were fed twice daily according to a restricted scale that allowed an intake equivalent to about 90-95% of satiety at each WT. In Experiment 2, DE content of the three base diets varied serially from 14 to 18 kJ/g such that the P:DE ratio remained constant at 25 g/kJ; by varying the relative inclusions of fish oil and soybean oil, two series of diets were prepared which provided total n-3 to n-6 fatty acids at ratios of either 1.1:1 or 1.5:1. These six diets were factorially arranged with two WT (20 or 29°C) and fish were fed to satiety twice daily for either 10 or 8 weeks respectively. In both experiments, treatments were applied to 24 tanks (800 L) each containing 25 (Expt 1) and 30 (Expt 2) fish of initial mean weight (±SD) of 158±3.5 g and 59±1.8 g respectively. Tanks were arranged as four independent freshwater recirculation systems in an air-conditioned aquarium facility where photoperiod was controlled to a 12:12 cycle. Fish were weighed fortnightly. Measurements of daily food intake (DFI), growth rate (GR) and food conversion rate (FCR) were analysed by ANOVA in accordance with the balanced factorial design of each experiment.

It was found that WT had a marked effect on all production traits with responses improving with increasing WT. Varying dietary P:DE (Expt 1) had little effect on GR at WT ≤23°C but

at ≥26°C, GR improved with increasing P:DE; FCR improved (P<0.05) with each increase in P:DE. Increasing dietary DE (Expt 2) reduced DFI at high but not at low WT; GR and FCR improved directly with increasing DE irrespective of WT. Altering the dietary n-3 to n-6 fatty acid ratio had little effect on production responses.

It was concluded that the optimum dietary P:DE specification for juvenile barramundi decreases with WT from 28-30 g/kJ at ≥26°C to no more than 24 g/kJ at ≤23°C. At low WT, fish performance improved with increasing dietary DE content up to 18 kJ/g but at high WT, fish voluntarily limited intake of high DE diets apparently so as not to exceed an energy consumption threshold.

Nutritional requirements of domestic striped bass broodstock

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Striped bass, *Morone saxatilis,* have received considerable attention in the United States from economic, research, management and culture perspectives. The species currently faces severe pressures including: overharvest, pollution, and loss of spawning habitat, and considerable efforts to culture juvenile striped bass have been exerted to enhance and/or restore declining populations. In addition, significant efforts are underway to domesticate the species for aquaculture food fish production as it is the fastest growing segment of the commercial finfish industry in the United States. Specifically, a report will be given on the captive striped bass domestication research programme, located at the University of Maryland, Department of Animal Sciences' Crane Aquaculture Facility (CAF). The breeding and domestication programme at the CAF was initiated in 1983 by spawning wild striped bass from the Chesapeake Bay (Maryland, U.S.A.). Striped bass families 1, 2, or 3 generations removed from the wild founders have been produced, reared under intensive culture conditions to maturity, and are being maintained at the research facility.

is is the largest captive stock of striped bass with the longest history of domestication available for research, and there are records on the growth performance of mature, individually tagged broodfish. Unfortunately, the nutritional requirements for striped bass in general and for the broodfish specifically are largely unknown, in spite of the significant culture and management effort to date. Knowledge of diet and nutrition that influence viability and hatchability of striped bass eggs, as well as the survival and growth of subsequent larvae can provide insight into the requirements that influence production in cultured species and/or recruitment success in wild populations. Experiements have been conducted to define the dietary requirements of the striped bass. To date dietary requirements have been determined for phosphorus in growing striped bass and calcium to be 0.47 and approximately 0.30% respectively. Vitamin D_3 levels in the diet supported normal growth and maintenance at 200 IU (5μg) D_3/kg diet for as long as 26 weeks. Using the "Ideal protein" method, the essential amino acid requirements for reproduction in the female striped bass are estimated to be 1.5 arginine, 0.7 histidine, 1.1 isoluence, 2.0 leucine, 2.3 lysine, 1.0 methionine + cysteine (TSAA), 1.0 phenylalanine, 1.1 threonine, 0.3 tryptophan and 1.3 valine (g/100g diet containing 320 Kcal of digestible energy) respectively.

Processes of membrane digestion in reared fish species

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Modern research studies of food assimilation processes have achieved considerable success which is closely connected with Uglov's discovery (at the end of the 1950s) of a membrane digestion mechanism ensuring breaking up 80 – 90% of molecules' biopolimer chemical bonds. Now membrane digestion is identified in animals of different taxonomic groups including fish. In the normal course of hydrolysis proteins, fats and carbohydrates are simultaneously digested and definitely influenced by each other. For the first time reciprocity effects at the substrate level of membrane digestion have been determined in carp, which is a traditional object of aquaculture. It has been shown that the same substance can be an activator to another one. However it is interesting to note that the effects of trisubstrate digestion are not the sum of bisubstrate ones, moreover they can have a contrary trend.

It should be noted that during research of trisubstrate interactions, only an activating effect has been discovered. Now, in view of the need to create complete feed for aquaculture diet, effect on the activity of the digestive hydrolaz is being intensively studied. Membrane digestion process adaptation of growing fish to various feed and fodder additions has been observed in the course of these studies. Specifically the substitution of a diet consisting only of natural food by a compound feed diet has considerably influenced the digestive function of reconstruction of carp intestine. Moreover this change of diet resulted in forming at the functional level a period of habit that was expressed in a reduced level of digestive enzyme activity. Essential change in the activity of the enzymes fulfilling membrane digestion during introduction of various vitamin – mineral premixes and biostimulators into feed composition has been found.

It should be noted that a key problem of modern biology is the study of hydrobiont adaptation to constantly-changing environment. For the first time complex research on circadian rhythmic activity of carp digestive enzymes, fulfilling break up of carbohydrate and protein components of feeds and parameters, characterising nutrition in ponds, has been determined and the 24 hour presence of rhythm, both during consumption and hydrolysis of food components, has been found. In the course of studies of the temperature effects on the morphofunctional characteristics of carp intestine, it has been discovered that no adaptive changes in the activity and properties of intestinal enzymes during fish acclimatization to various temperatures, took place. Homeostatic effect is obtained at the higher systematic level due to the mass regulation of the mucous membrane of the intestine; when the temperature of the medium decreases, enzyme activity decreases too, but mucuous mass increases. Such reaction permits the membrane digestion process to be maintained at a relatively constant level during changes of medium temperature.

All the basic data obtained permit more profound study of the problem of consumption and hydrolytic assimilation of food components in growing fish species and assist towards understanding the adaptive reconstruction mechanism of the digestive system during constant changes of their medium.

Limits to exploitation of capture fisheries

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The conference theme to which this paper is addressed poses the question: "What is the scope for development of wild stock fisheries?". As can be seen from the program, this question has a wide variety of answers and many facets of fisheries science are involved. There are three issues which are likely to be of important in the future development of capture fisheries. They are:

(i) better management;
(ii) the development and sustainable exploitation of new fisheries; and
(iii) the enhancement of capture fisheries.

In this paper, some of the issues involved in these three areas are explored.

Better management

An obvious way in which yield can be increased from capture fisheries is by better management, and many of the presentations in this symposium are addressed to this issue. It is reasonable to enquire to what extent yields can be increased in this way?

If yields from capture fisheries are to be increased on a sustainable basis, then the successful application of new management techniques is going to be required. A key area which has often been overlooked in the examination of fisheries management is the enforceability of regulations. A system needs to have:

(i) regulations to meet sustainability criteria;
(ii) regulations of the sort that they can be enforced with reasonable levels of cost; and
(iii) information obtained from the fisheries that is sufficient to meet the requirements for regulation.

An important issue which has been recently addressed at a global level concerns the enormous level of discards that are involved in commercial fisheries. Mechanisms of management which can improve on this are obviously attractive.

New fisheries

Clearly, one way in which capture fishery yields can be increased is by the sustainable management of new fish stocks. Here there is a plethora of underlying theories which can provide insights into the potential yield that these fisheries can provide. These are explored in the context of some new fisheries. However, a central problem for which little theoretical understanding exists is the limit to which aquatic ecosystems can sustain fisheries. This issue is explored.

Enhancement fisheries

Enhancement fisheries for good reason have been primarily in freshwater and the potential for marine enhancement is largely unexplored. In freshwater, the scope for increase in yields is significant. An example from analysis of river fisheries indicates the scale of increased yields where enhancement fisheries are practised.

There is relatively little understanding of the problems of these fisheries even in simple systems where enhancement occurs only by the introduction of young fish. Some recent developments which examine management options for increasing yields by enhancement are explored.

Research is needed in all these areas if capture fisheries are to increase sustainably; this is the challenge for the future.

Quantitative assessment and forecasting of Australia's orange roughy stocks

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Commercial fishing for orange roughy, *Hoplostethus atlanticus,* in Australian waters commenced in 1982. Catches were low until a non-spawning aggregation off western Tasmania was found and fished from 1986 to 1988. Catches increased dramatically in 1989 and 1990 with the discovery of non-spawning aggregations off southern Tasmania and a major spawning aggregation off eastern Tasmania. The aggregating behaviour of orange roughy and their longevity (maximum age over 100 years and age at maturity 20 to 30 years) makes them susceptible to being fished at a level greater than the stock productivity can support. The longevity also renders precise ageing impossible for much of the recruited stock.

The susceptibility of the orange roughy to fishing and a rapid increase in catching capacity of the southeast Australian fleet, required an equally rapid approach to providing scientific stock assessment advice. Stock reduction analysis provided estimates of pre-fishery and current biomass from catch data, biological data and relative and absolute biomass survey estimates. Two stock hypotheses were considered: a single unit stock, or separate stocks off eastern and southern Tasmania, with fishing directed on spawning and non-spawning aggregations respectively. Biomass estimates for the eastern fishery were derived from the spawning aggregation with egg production methods and annual acoustic surveys. Surprisingly (for an aggregated stock), catch per unit of effort indices of relative abundance matched the fishery independent abundance indices for the spawning aggregation. Biomass estimates for the southern fishery were therefore derived from catch per unit of effort and two absolute acoustic biomass estimates.

Early biomass estimates and assessment results indicated that Australia's orange roughy resource was not as productive as had been first hoped. The stock reduction methods were further developed to include probabilistic forecast scenarios. Alternative harvest strategies (developed by fishers and fishery managers) were evaluated against the objective of maintaining or returning the fishery to sustainable levels over a ten-year time frame. Following an international review of the scientific advice, one of these strategies was chosen and implemented.

A comparison between diamond and square mesh codend selectivity in the northern prawn fishery of Australia

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The ability of two sizes of square mesh codend to reduce catches of small unwanted fish and maintain catches of prawns was studied in Australia's Northern Prawn Fishery. This study involved the collaboration of biologists and fisheries technologists from the CSIRO, Australian Maritime College and Northern Territory Department of Primary Industry and Fisheries. Comparisons were made between catches from a standard 45mm diamond mesh codend (currently used in Australia's Northern Prawn Fishery) and both 38mm and 45mm square mesh codends. The mesh opening of diamond codends tends to close under the weight of the retained catch, whereas square codends are hung so that the mesh openings remain fully square and open under the accumulating weight of the catch. Codend covers with 16mm mesh were used to catch animals that escaped through the codends.

Both of the square mesh codends retained less bycatch than the diamond mesh codend – the 45mm square mesh catching 22% less and the 38mm square codend 3% less small fish bycatch than the diamond mesh codend.

Knowledge of the quantities of both the retained and escaped animals, their length frequencies and body shapes allowed detailed comparisons of the catching ability of each codend type. From these data, selectivity curves were produced for 10 common fish bycatch species of different body shapes and for the main commercially important prawn species. They showed that all codend types lost prawns and that the 11% extra loss of prawns from the 45mm square mesh codend consisted of sub-adult animals. The selective catching ability of each codend differed between species and was determined mainly by the body shape and size of each species. More of the cylindrical shaped fish such as *Saurida micropectoralis, Pomadasys maculatum* and *Apogon poecilopterus* were retained in catches using the diamond mesh codend than the square mesh codends. Laterally compressed fish such as *Leiognathus splendens* and *Caranx bucculentus* showed fewer differences in selectivity between diamond and square mesh codends.

Square mesh codends have the advantage of providing a high degree of control over the sizes of small fish and prawns allowed to escape, although they can have the disadvantage that specific sized fish can gill in the meshes and so clog the codend. However, they remain an important bycatch reduction device for the future of Australia's prawn trawling industry where there is mounting pressure to minimise catches of unwanted species.

Assessment of an environmentally friendly, semi-pelagic fish trawl

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Minimising catches of non-target animals in a trawl fishery reduces the impact on a marine community and may help to sustain the fishery resource in the long term. Hence the desirability for trawls that minimise impacts on non-target species while maintaining catches of target species. This study resulted from a need to further develop easily handled, semi- pelagic style trawls for Australia's Northern Fish Trawl Fishery. In November 1993 we compared catches from three differently rigged versions of a demersal wing trawl: one was fished in a standard demersal configuration with its footrope on the sea bed; and two were fished semi-pelagically, with their footropes raised to either 0.4 – 0.5 m or 0.8 – 0.9 m above the sea bed.

Catches of the main target species *Lutjanus malabaricus* and *Lutjanus erythropterus* by the three trawl types were not significantly different. However, the mean catches of both these species and of other commercially important snappers, were highest in the semi-pelagic trawl raised 0.4–0.5 m above the sea bed. This increase could be due to the larger spread of the trawl rig or because this version of the trawl fished higher in the water column.

Of the 107 species of fishes analysed, 61 were caught in greater abundance in the demersal trawl. More of seven species were caught in the semi-pelagic trawl with the footrope 0.4–0.5 m above the substrate; no species were caught in higher numbers with the footrope set at 0.8–0.9 m. Epibenthic byproduct species (squid and *Thenus orientalis*), fish bycatch, sponges and other epibenthic invertebrates were also caught in lower numbers in the semi-pelagic trawls. The semi-pelagic trawls caught less (in both numbers and biomass) of the unwanted species which are normally discarded. Semi-pelagic fish trawls of the types tested are suitable for Australia's Northern Fish Trawl Fishery and probably other demersal trawl fisheries that would benefit from the conservation of non-target epibenthic communities.

An assessment of eight bycatch reduction devices in Australia's northern prawn fishery

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The effects of demersal trawling on marine communities in Australia has become an issue of major concern to the fishing industry, fisheries managers, conservation agencies and the Australian public. This concern stems mainly from the non-selective nature of trawling as a harvesting method and the consequent impact on the large number of species not targeted. One of the main aims of a study recently funded by the fishing industry and the Australian Government (through the Fisheries Research and

Development Corporation) was to develop and test Bycatch Reduction Devices (BRDs) in Australia's large Northern Prawn Fishery (NPF). Effective BRDs can transform demersal trawling into a more selective harvesting method, resulting in a decreased impact on non-target species.

The collaborative efforts of biologists and fisheries technologists from the CSIRO, Australian Maritime College (AMC) and Northern Territory Department of Primary Industry and Fisheries, resulted in the building and testing of eight BRDs thought to have potential for use in Australia's NPF. BRD performance was first examined in a flume tank at the AMC and then fine tuned using full scale trawls in clear waters off Tasmania. Biological trials were then carried out in NPF waters off Weipa in the Gulf of Carpentaria. BRDs were tested in dual rigged, 14 fathom Florida Flyer prawn trawls. Pairs of BRDs were used in a rotating sequence against each other and a standard trawl (one with no BRD), resulting in 120 paired comparisons and about 30 trawls for each device. The BRDs tested included: two inclined grids – Nordmore grid and Supershooter – used mainly to exclude large animals such as turtles and stingrays from entering the codend; four versions of a Square Mesh Window, each rigged with a different device to stimulate fish to swim up through open meshes of the window rather than fall back into the codend; Fisheyes which are a frame used to support an elliptical escape opening for fishes; and a Radial Escape Section – a circumference of large meshes for fish to escape. All devices were placed ahead of the codend bag by at least 50 meshes.

Several of the BRDs significantly reduced bycatch while maintaining catches of commercially valuable prawns. Both inclined grids totally eliminated catches of turtles and reduced catches of other large animals such as sharks and stingrays. The Fisheye, Square Mesh Windows, Radial Escape Section and Nordmore Grid reduced significant quantities of unwanted fish bycatch, while the Fisheye, Square Mesh Windows, Radial Escape Section and Supershooter showed no loss in catches of prawns. The performance of these BRDs will be improved with further research and increased industry involvement. Each differs in its ability to exclude certain types of bycatch and their use will depend on regional characteristics of the bycatch or the management requirements in different fishing areas. The study provides new evidence of effective devices for reducing bycatch in Australia's prawn trawl fisheries. Their use by the prawning industry will improve fishing procedures and address several key issues relating to the concern over trawling impact on marine communities.

Recent advancements in environmentally friendly trawl gear research in Australia

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The impact of prawn trawling on non-target species (bycatch) has become an issue of great concern to the fishing industry, fisheries managers, conservation agencies and the Australian public. This concern stems from a recognition of the importance of ecologically sustainable fishing practices and the maintenance of marine biodiversity, as well as Australia's commitments to international agreements. As part of the response to this concern, the fishing industry and the Australian Government (through the Fisheries Research and Development Corporation) funded a three-year project to study the use of a variety of environmentally friendly fishing gears in Australia's northern trawl fisheries. The collaborative project brought together biologists and fisheries technologists from the CSIRO, Australian Maritime College (AMC) and Northern Territory Department of Primary Industry and Fisheries. New or imported fishing gears were designed and/or built at the AMC, tested in their flume tank and then tested at sea in Tasmania before being compared with standard fishing gears in northern Australian waters. The project has:

(i) designed, tested and reported on an easy-to-use semi-pelagic fish trawl which greatly reduces catches of benthos and other bycatch while maintaining catches of target fish species,
(ii) tested and reported on the ability of a suite of devices to reduce bycatch while maintaining catches prawns,
(iii) measured the damage to and survival of fish escapees from square mesh codends,
(iv) made detailed studies of the ecology of some important fish bycatch species,
(v) monitored and improved the use of vital research tools such as underwater video and Scanmar acoustic net monitoring devices,
(vi) tested the most promising bycatch reduction devices under commercial fishing conditions and
(vii) begun the process of integrating this technology into the fishing industry.

Recent advances in research into environmentally friendly fishing gears in Australia can be the springboard for the development of Australia's trawl fisheries into a more efficient, acceptable and sustainable long term industry.

Catch and abundance in areas with different exploitation rates in the Sicilian Channel

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The objective of this paper is to compare the species composition of catches in fishing areas characterized by different exploitation rates. In addition, differences in both abundance and population structure of *Merluccius merluccius, Mullus barbatus, Parapenaeus longirostris* and *Raja clavata* are studied.

The data used in the study were collected during seasonal trawl surveys which the Istituto di Tecnologia della Pesca e del Pescato has routinely carried out since 1985 with the primary aim of assessing the demersal resources in the Sicilian Channel. Particularly, two series of eight seasonal surveys were carried out over the periods May 1985 – February 1987 and May 1990 – February 1992 respectively, while a third series of six-monthly surveys initiated in May 1994, is going to conclude in November 1995. Moreover, eight seasonal surveys aimed at the collection of catch and effort data were carried out in the ports whose trawling fleets operated in the study area at the same time as the first

series of trawl surveys. Through interviews with fishers at the landing places, it was possible to identify the fishing areas of the different fleets, as well as the exploitation rate in each area expressed as fishing days per quarter. For the purposes of this study, two main areas were identified, characterized by a very high and a low exploitation rate respectively. Data from trawl surveys were therefore used to compare abundance and mean length of all the species caught in the two areas, while the four species mentioned above were chosen for more detailed analysis.

Relationships between different life history stages of the western rock lobster, *Panulirus cygnus*, and implications for management

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Management of fisheries is enhanced by an ability to forecast sustainable catch levels and set apppropriate catch controls. For fisheries such as the Western Australian rock lobster fishery, where recruitment varies significantly between years and regions of the fishery, an ability to forecast catches has proved a major benefit to the management process.

This fishery supports one of the world's largest rock lobster fisheries with an average annual catch of over 10,500t valued at about A$300 million in the 1994/95 season. This fishery has an extensive history of research and management (and enforcement of regulations), being one of the first limited entry fisheries when management controls were introduced in 1963. It continues to operate sucessfully under a system of individually transferable fishing effort quotas.

The database of life history and other relevant information includes: (a) spawning stock estimates; (b) indices of abundance of puerulus settlement at ten locations throughout the fishery; (c) indices of abundance of juveniles (under legal size); (d) total catch and fishing effort; (e) environmental factors affecting the level of puerulus settlement such as strength of the Leeuwin Current and strength of westerly winds; (f) environmental effects on catchability e.g. water temperature and swell; (g) vessel characteristics and gear and equipment information affecting fishing power; and (h) value of catch and licences.

These data bases are used for regional predictions of catches up to four years ahead based on puerulus and juvenile abundance as well as the level of fishing effort. Predictions are regularly utilised in the decision making process of the management of the rock lobster fishery and allow management measures to be undertaken before a year-class reaches legal size. The trend in the abundance of the spawning stock and the effect of spawning stock and environmental factors in explaining the variations in puerulus settlement are also considered in setting effort levels for the fishery. The increasing efficiency of vessels is also taken into account in determining effort.

In recent years management measures have been introduced in response to concerns about the declining trend in spawning stock below 20% of the estimated virgin biomass. These measures include a variable pot usage (currently reduced by 18%), increase in minimum size from 76 to 77 mm for part of the season, introduction of a maximum size and return to the sea of setose (mature) females. This case study illustrates the array of data inputs which are relevant to the stock assessment process and highlights the value of long time series of data in refining the management process.

Distribution, abundance, reproductive biology, age and growth of *Loligo chinensis* and *Loligo duvauceli* in the western gulf of Thailand

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Loligo chinensis and *L. duvauceli* are highly abundant and commercially important marine resources of Thailand. Surveys on distribution, abundance and reproductive biology were made by research vessel trawl, with a cod end of 4 cm and cover net of 2.5 and 1 cm in mesh size. It was operated in day time, at 23 stations of a fixed grid with depth ranges from 10 to over 50 metres in the western Gulf of Thailand. Specimens from the cover net of 1 cm mesh size, are treated as juveniles. Size caught of adult *L. chinensis* ranged from 6 to 42 cm ML and were distributed abundantly in areas IV and V at depths of more than 30 metres. *L. duvauceli* were randomly distributed in shallow water to depths over 50 metres and size caught ranged from 6 to 30 cm ML. Juvenile squid are found throughout the year. Juveniles of *L. chinensis* were highly abundant in January, March to June, at depths of 30 to 50 metres. Juveniles of *L. duvauceli* were also found in abundance in the same periods at depths of 20 to 40 metres.

Mature females of *L. chinensis* and *L. duvauceli* are found throughout the year, showing continuous spawning and corresponding to the mature males. The combined data on abundance of spawners, percentage of maturity, population fecundity index and sex ratios, are used to determine the spawning periods. The spawning peaks occur over two periods annually. The most productive spawning peak is around February to May. *L. chinensis* spawns at depth of about 40 metres, south of Chuang Island, off Prachuab-Kirikhan Province and Chumporn Province. The spawning ground of *L. duvauceli* is close to the shoreline, from Prachuab-Kirikhan Province down to Chumporn Province, and around Samui and Pha-ngan Islands. The abundance of juveniles of both species also coincides with the spawning periods. The juveniles, adults and spawners are found within the same areas as well as the fishing grounds.

Two methods were applied to estimate age and growth, one from length frequency analysis based on the von Bertalanffy growth model and the other from daily increments of statoliths. The data were obtained from the research vessel, commercial trawlers, and squid light-fishing. The FiSAT, FAO-ICLARM package of microcomputer programme as stock assessment tools were used for the analysis of length frequency data. The growth parameters L_∞ (cm), K (yr^{-1}) and t_0 (yr) of *L. chinensis* are 42.04, 0.1340, 2.62 for males and 36.77, 0.1355, 2.70 for females, respectively. The L_∞ (cm), K (yr^{-1}) and t_0 (yr) of *L. duvauceli* are 32.65, 0.1256, 3.04 for males and 30.56, 0.0901, 2.52 for females, respectively. The results show that squid grow very fast and are short-lived species. They attain mature sizes in a few

months, about four months for *L. chinensis* and about three months for *L. duvauceli*. The expected life spans might be about one year.

Documenting fisheries habitat resources – mapping mangroves with remote sensing in Queensland, north-east Australia

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The contribution of mangroves to fisheries productivity has long been recognised. The Queensland Department of Primary Industries is undertaking assessment and monitoring of these complex and diverse intertidal plant communities. The general nature of mangrove communities (e.g. tides and relative isolation) makes the collection of field data challenging, as does the Queensland coastline which extends for 5,700 km. Remotely sensed imagery, such as Landsat data and colour aerial photography, offers a cost effective way to complement the field data. Gathered integrated information is stored in a Geographic Information System (GIS), a useful tool for enabling better management decisions, and for modelling complex coastal systems.

Landsat Thematic Mapper (TM) bands 1 to 5 and 7 are digitally classified over the intertidal zone using unsupervised techniques. The results are validated in terms of dominant genera of a community and its relative density against 1:50,000 colour aerial photography and field data. Field data are collected by a combination of helicopter, boat and 4WD vehicle. Validated classes are vectorised and then polygons created for GIS input. Hardcopy maps at 1:100,000 are produced with the coloured classes displayed on a black and white background of Landsat TM band 3 (visible red light). The mangrove communities (with densities) identified are *Rhizophora* (closed), *Ceriops* (closed and open), *Avicennia* (closed and open), *Rhizophora/Ceriops* (closed), *Avicennia/Ceriops* (closed and open), landward rim (closed), mixed (closed) and saltpan.

Areas in Queensland recently mapped using this technique are Cape York Peninsula, south-eastern Gulf of Carpentaria, the Burdekin Delta region, Repulse Bay, the Gladstone region and Moreton Bay. Like mangrove species diversity, the number of mangrove community types present decreases with increasing latitude. Cape York Peninsula (11°S) has eleven mappable community types whereas Moreton Bay (27°S) has only four.

This method for mapping mangrove communities has been used consistently and successfully across tropical and subtropical areas. Queensland displays a large variation of mangrove communities and all areas mapped using this method have had accuracies greater than 80%. The speed of the digital classification of the imagery and the coverage between field data collection points make this method cost effective. Use of helicopters for gathering field information is most effective for remote areas. Despite the increasing utilisation of digital data, hardcopy products are important, particularly during discussion and negotiation of additional habitat management measures with client groups. The mapping scale of 1:100,000 is a balance between feasible collection of data for an enormous coastline and production of useful information for local management of the resource.

The value of research to age abalone, and how to time-stamp them

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The high price of abalone results in enormous pressure to exploit it, and equally, enormous future value in managing populations sustainably. Basic information for the secure management of a population includes the stock size, the rate of recruitment to the adult population and how recruitment changes with stock size. As there appear to be many independent local abalone populations with varying characteristics, obtaining all the information required is extremely challenging. To build models to understand and predict stock dynamics, key parameters are growth rate how individuals vary in growth and the natural mortality rate. Once individuals can be aged, various methods can be applied to provide data on recruitment, individual growth and even mortality, at far less cost in time and money than current methods. It would also allow monitoring of the age distribution of catches, which fishery simulations suggest can be used to provide early warning of stock collapse.

In contrast to scalefish, very few abalone species can be aged at present, as most do not have clearly defined external annual growth checks. The most promising method is to use the number of white and dark aragonite nacre layers under the spire, which are formed parallel to the plane of the shell. The white layers are formed by thin tablets of aragonite, laid down like bricks, while the dark layers consist of crystals perpendicular to the shell surface, embedded in protein. To determine whether individuals deposit layers on a regular periodic schedule, a method to label the nacre being deposited (time-stamping) has been developed, so that labelled animals can be released and subsequently recaptured; and the number of layers deposited during release can be determined.

To 'time-stamp' abalone shells, abalone are immersed in seawater baths containing manganese solutions. The manganese ion appears to be incorporated into the shell as a replacement for calcium, as mineralised manganese layers in shell sections can be detected using cathodoluminescence microscopy. Manganese bound in the calcite and aragonite layers of the shell emits red-orange and green-yellow light, respectively, under a beam of electrons. Electron microprobe analysis of shell sections confirmed that these marks were activated by elevated concentrations of $MnCO_3$ in the shell layers. The length of the cathodoluminescent marks and the concentrations of manganese recorded in different areas of the shell suggest that the rate of shell deposition is highest at the shell edge. The labelling method provides a means to investigate the process and timing of nacre layer deposition.

Bycatch reduction in Northwest Atlantic bottom trawl fisheries: myth or reality?

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Bycatch reduction in the Northwest Atlantic bottom trawl fisherieshas been achieved using a wide range of measures from closed areas and seasons to technical limitations on the towed gear that affect the selectivity of the gear.

Selection processes in bottom trawls are divided between size and species differentiation of the animals that encounter the trawl. Size selection has been demonstrated to occur in the extension and codend sections of the trawl, with probability of retention determined primarily by mesh size and shape. Species selection based on size also occurs in the extension and codend using mesh size and shape, separating larger retained animals from smaller escapees, or using a grate device to separate larger escapees from smaller animals that are retained in a small mesh codend. Separating species of similar sizes is achieved by making modifications to the trawl that take advantage of different behavioral responses to trawl stimulus in the net mouth or body.

In the Northwest Atlantic, researchers and fishers have made significant progress in the search for size and species selectivity. Single species models for size selection as a function of mesh size and shape are now available for the major groundfish species. The implementation of these models in a multi-species fishery is more problematic. However, this has not deterred the management agencies from universally adopting minimum mesh size regulations. Successful results of experiments and fisher acceptance of a Nordmore grate-like device have resulted in regulations requiring a sorting grid in the Gulf of Maine shrimp fishery. Northern shrimp, the target species, are separated from juvenile and adult groundfish. The small mesh trawl fisheries of southern New England are more problematic. Various sweep designs have been evaluated for their ability to separate non-target flatfish from hake, the target species, with limited success. Ongoing experiments on commercial fishing vessels with large-mesh, colored panels in the lower belly of the net mouth are proving to be more successful at consistently separating the non-target flatfish species, without negatively affecting the catch of hake, the target species.

Can biological research influence management decisions in a trawl fishery for tropical prawns? The Australian northern prawn fishery

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The Australian Northern Prawn fishery is the largest and most valuable (A$ 100-200 million per year) of all Australian Commonwealth fisheries. Prawn trawling developed in the 1960s partially as a result of research surveys which identified productive grounds in the Gulf of Carpentaria. Because of the early involvement of scientists and government in the development of the fishery, biological research has always been seen as a key to the sustainable development of this fishery.

Over the last 25 years a large and diverse range of research projects have endeavoured to provide biological knowledge that could help the management of the fishery. During that time the fishery, the fishing fleets, prawn catches and prawn stocks have seen dramatic increases and decreases. The role of scientists and the delivery of research results have also changed: researchers are now accepted as partners in the management of the fishery.

We have looked at the breadth of biological research conducted in the Northern Prawn Fishery and evaluated the impacts of research projects in the management of this fishery. The analysis reveals that the initial basic biological research was of strategic importance to today's more applied research on the biological implications of management strategies. This research identified the key nursery habitats for tiger and banana prawns, and resulted in the establishment of shallow water fishing closures of seagrass beds. The identification of the links between rainfall and banana prawn recruitment, and the development of a banana prawn catch predictive model have guided the present management objective of short-term yield maximisation for this species. The recognition of the possibility of biological over-fishing of tiger prawns contributed to the decisions to reduce the fleet (from ~300 to 125 boats) through an industry-funded buy-back scheme.

Our experience in the Northern Prawn Fishery shows that the presence of a strong partnership between government, industry and scientists is essential to ensure that biological research contributes to the good management of a prawn trawl fishery. It also reveals that, ultimately, the key to the impact of biological research resides as much on the mechanisms for providing advice as it resides on the quality of the research itself.

Genetic origins of rainbow trout and chinook salmon transferred to New Zealand from California at the turn of the century

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The genetic origins of the successful transfer of rainbow trout (*Oncorhynchus mykiss*) and anadromous chinook salmon (*O. tshawytscha*) from California to New Zealand rivers at the turn of the century have been speculated on for the past 50 years. According to records of the US Fisheries Commission (1887-1910), salmon eggs taken from the upper Sacramento River at Baird Station were shipped to locations around the world (Europe, Japan, Asia, Australia, Latin America). The early chinook salmon sent to New Zealand have produced the only self-sustaining, anadromous runs in areas outside the natural geographic range of this species.

The ancestry of the early transfers of rainbow trout to New Zealand has been confused by a lack of historic records and the intermingling over time of stocks from various geographic areas, both in New Zealand and California. It is speculated that the original trout sent to New Zealand contained both coastal and inland (redband) stocks. The distribution of these genetically separable groups in New Zealand waters remains unknown.

The authors compared genetic diversity among contemporary New Zealand salmonid stocks and Californian populations from putative parental populations. Genetic data were drawn from studies of diversity for mitochondrial DNA control region sequence and nuclear microsatellite loci extracted from fin clips and amplified by the polymerase chain reaction (PCR). Patterns of genetic distance based on three microsatellite loci and parsimony analysis of mtDNA sequence were used to show the degree of genetic relatedness remaining among populations.

These studies help clarify the origins of early fish transfers to New Zealand, and illustrate the degree of divergence that can be demonstrated by molecular markers for fish populations separated for less than 100 years.

Development and validation of a fish index of biotic integrity as part of an evaluation of aquatic ecosystem condition

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Current monitoring and assessment programmes for inland fish populations frequently lack sufficient data within a suitable framework for quantitative analysis of the relationship between community status and available habitat. For the purpose of preparing ecosystem-based fish management plans, comprehensive and objective data, collected by way of standardised methodology on an appropriate spatial and temporal scale, are required which characterise the status of fish species and communities. Such data should also be "manager friendly" and be able to be readily correlated with data which measure aquatic habitat condition, particularly in relation to habitat loss, modification and general suitability. Indices of Biotic Integrity (IBIs) have been proposed as a means of monitoring and assessing status of fish and aquatic resources from relevant, measurable, key indicator attributes, as derived from a representative sample.

In the present study, a fish IBI is being developed and validated as part of an overall study into the condition of aquatic ecosystems in three major anabranches of the Murray River in north-western Victoria, *viz.* the Lindsay River, Wallpolla Creek and Gunbower Creek. Integrated fish and habitat surveys were undertaken in each anabranch at three fixed representative sites on a quarterly basis for 12 months. Fish survey methods were designed to be both comprehensive and to minimise operator bias and gear selectivity and included the use of boat electrofishing, fyke nets, drum nets and mesh nets in a range of sizes. Key fish parameters measured included species diversity, biomass, catch per unit of effort, trophic composition, assemblage naturalness (ratio of endemic to exotic species) and incidence of deformities, hybrids, parasites etc. Raw data were subsequently transformed into standardised indices by rating each parameter on the basis of fixed score criteria. IBI ratings were thus compiled for each survey/site and compared between anabranches over time.

Validation of the index is being achieved by multivariate analysis, including multi-dimensional scaling, of the raw fish data to identify existence of relevant and discrete patterns over time and space within the surveyed anabranches. Furthermore, such analysis is being used to establish correlations between theoretically related fish and habitat data over a similar spatial and temporal scale. Preliminary IBI values for the study sites and associated analysis have identified significant differences between anabranches for key fish parameters, with the relatively natural Lindsay and Wallpolla systems having similar, highly rated community structures, which in turn are significantly different from the lower rated, highly modified Gunbower system. The latter is regulated for irrigation purposes and is subject to widespread impacts from agricultural development. Inclusion of the habitat data into the analysis indicated a significant correlation between the fish communities and habitat condition. Indeed, analysis of the habitat data in isolation has revealed the same associations and relative condition ratings forming between anabranches. No seasonal variation is apparent within the anabranches at this stage.

In general the IBI methodology has the potential to detect differences in the status of resident fish communities over a relatively broad spatial scale and as such can be used to indicate habitat and general aquatic ecosystem conditions or river "health". The ease of use and practical application of the IBI suggest that fisheries management plans cou use IBI values as an objective and quantitative unit of measure when monitoring and assessing fisheries status, aquatic habitat/ecosystem condition and the impacts of threatening processes and for effective evaluation of management actions designed to protect and restore fish and aquatic resources.

Headline height modifications to improve prawn trawl performance

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The headline height of prawn trawls is not necessarily related to the vertical distribution of prawns, but is designed to maintain trawl geometry. This is because the headline attached to the aft trailing edge of the otterboard. The use o. larger trawls and otter boards in the Northern Prawn Fishery (NPF) since 1987, has resulted in an increase in trawl headline height which may have increased the amount of fish bycatch taken by NPF vessels. This is the first in a series of studies assessing the effect of reducing prawn trawl headline height on prawn catches and bycatch and is a collaborative study between the Australian Maritime College, the Northern Territory Department of Primary Industry and Fisheries, and the CSIRO Division of Fisheries. To this end, a multi-level beam trawl (MBT) was used to establish the vertical distribution of prawns and finfish entering a prawn trawl by separating the catch into three equally spaced horizontal compartments. A panel of netting – known as a leadahead panel – extended horizontally out from the top of the beam trawl to prevent animals escaping upwards. Fifty tows of 30 minutes duration were made with this device in the eastern Gulf of Carpentaria during November of 1993.

The codend on the lowest compartment caught the highest numbers of prawns and fish. This suggests that either their usual habitat is close to the seabed (already known for prawns), that escape response of most fish and prawns is close to the seabed, or a combination of these behaviours. The top compartment caught less fish and prawns than the

lowest but more than the middle compartment, suggesting that the leadahead panel blocked and guided many animals into the trawl that otherwise would have escaped over the top.

Further assessment of prawn and fish behaviour is required with the leadahead panel attached to the lowest compartments. Gear redesigned with a headline height and leadahead configuration suited to the target species may help reduce the amount of bycatch. A reduction in headline height will also provide increased fuel efficiency and/or gains in swept area.

Evidence for genetic differentiation among striped bass populations in eastern North America

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Three PCR-RFLP assays have been developed that detect genetic variation in striped bass (*Morone saxatilis*) nuclear DNA. These assays are simple to perform, require little DNA and provide independent measures of genetic variation in striped bass. They are especially important since previous studies have found little genetic variation among striped bass. Control experiments using genetic crosses demonstrated that each assay measured genetic variation at a single locus that appeared to be inherited in a Mendelian fashion. Using these assays analysed genetic variation among striped bass populations found in various rivers along the east coast of North America. Results suggest that genetic differentiation has occurred among several geographically distinct populations of striped bass. However, the most surprising result occurred among fish sampled in the Santee-Cooper River system in South Carolina during the spawning season. Two branches of the same river contain genetically distinct populations despite the fact that there are no apparent physical barriers to migration. Therefore, it appears that the striped bass in this stem exhibit fidelity to specific spawning grounds within e system. In summary, these results demonstrate that striped bass are not as monomorphic as some previous studies have suggested. Furthermore, they suggest that most geographically distinct striped bass populations may be genetically differentiated. Therefore, striped bass stocking programmes should be re-evaluated to take into account the presence of discrete genetic stocks.

Age, growth and reproduction of cobia, *Rachycentron canadum*, from the northern Gulf of Mexico

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The cobia, *Rachycentron canadum*, is a migratory, coastal pelagic fish which has a wide geographic distribution throughout most of the warm oceans of the world, except for the Pacific coast of North America. The cobia is a highly prized species in the Gulf of Mexico recreational fishery. This study was undertaken to determine the age, growth, timing of reproductive development and gonadal maturation of cobia in the Gulf's northern region, in response to the need for scientific information on the life history and population dynamics of this valuable species. From 1987 to 1995, cobia (n=1,322) were sampled dockside and at sport fishing tournaments. Specimens ranged 840-1,854 mm fork length (FL) and 4-62 kg total weight (TW).

Ages were estimated by analysing thin-sectioned otoliths (sagittae). Marginal increment analysis indicated that annulus formation occurred between April and July and peaked in May. The relationship between fish length and otolith radius was best described by the regression equation $FL=2.0643OR^{0.8579}$, $r^2=0.73$ for males and $FL=0.837876OR^{0.7365}$, $r^2=0.73$ for females. Length variation within age groups was large. The oldest female (1,854 mm FL) and the oldest male (1,250 mm FL) were 9 years. The von Bertalanffy growth equations, derived from back-calculated mean fork lengths-at-age, were as follows: males, $Lt=109.7(1-e^{-0.592(t+0.133)})$ and females $L_t=134.1(1-e^{-0.436(t+0.054)})$. Growth (length) was rapid until age 4, and then slowed gradually. The relationship between fork length and total weight, for combined sexes, was $TW=0.167X10^{-5}FL^{3.412}$, $r^2=0.962$.

Based on a combination of GSI (gonado-somatic index), oocyte size-frequency and histological assessments, females were found to be ripe from May-September, which coincided with the spring-autumn interval of occurrence in the northern Gulf for this migratory species. Nonsynchronous oocyte maturation, characterized by the presence of at least two distinct size groups of oocytes in the same ovaries that had undergone vitellogenesis as well as postovulatory follicles and atretic eggs, strongly suggested that cobia are multiple spawners, releasing more than one batch of oocytes per spawning season. Batch fecundity was estimated to range from $2.6x10^6$ to $1.91x10^8$ oocytes (mean=$4.8x10^7$), depending on the size of the fish/ovaries, and was based on the advanced mode of developing oocytes since none of the specimens examined showed histological evidence of recently hydrated oocytes. Histological examination indicated males matured at age 1 and females at age 2.

In conclusion, cobia from the northern Gulf were found to be rapid growers with a relatively short life-span (9 years). Females grew larger and matured later than males. Analysis of gonadal development and maturation established that spawning occurred from spring through autumn and provided evidence of multiple spawning. Spawning season was initiated with the arrival of cobia which migrated from the wintering grounds located in the southern Gulf of Mexico and South Atlantic Ocean. Peak fishing effort for cobia in the northern Gulf was coincident with the spawning season and younger, mature fish (ages 2-4), primarily females, dominated the catch. The study provided valuable scientific data on cobia to marine fisheries managers responsible for assessing pelagic fishery stocks in the Gulf of Mexico.

Depletion experiments and estimation of abundance in reef fish stocks of Solomon Islands and Fiji

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In the assessment of reef fish stocks, new methods based on Underwater Visual Census (UVC) are an alternative to more traditional catch per unit of effort (cpue) methods. The accuracy of biomass and density estimates obtained by UVC, however, are critical to the application of these new methods.

Two depletion experiments were conducted in Fiji and Solomon Islands to compare abundance estimates derived from depletion models with those derived from UVC and to determine if UVC could detect the removal of biomass caused by intensive fishing. The study focused on those species of fish that are caught by spear-fishers and that tend to be associated with individual reefs. The depletion experiments included two parts: UVC surveys and a controlled fishing experiment. In the UVC surveys, point counts were used to assess the initial abundance of six families of fish before the fishing experiment and the final abundance after three days fishing. The fishing experiment was organised as a fishing competition among spearfishers. The range of depths covered by the UVC surveys were the same in the two countries but the design of the spear guns used was different. A total of 136 species from 26 families was recorded during the fishing in Fiji and Solomon Islands. In Fiji, cpue of individual fishers decreased as the depletion experiment progressed and allowed the estimation of initial biomass using the depletion model. Cpue did not change in Solomon Islands.

UVC detected changes in abundance, biomass and average fish size in both locations; however, the nature of this change was different in the two countries. In Solomon Islands, the decrease in biomass was 25% and average fish length increased by about 20%. In Fiji, fishing reduced the biomass by more than 50% and decreased the average fish length by 25%. It seems that this was the result of the different fish sizes removed from the populations in the two countries. Fish caught by Solomon Islanders were smaller than those caught by Fijians. In Fiji, fishers targeted larger, less abundant fish hence more likely to be depleted. The UVC method can detect changes in abundance of reef fish stock caused by fishing. It is therefore proposed that UVC provides appropriate information for the development of assessment models for reef fish fisheries.

A cross-check of catch data collected by a traditional fishing community

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To assess the impact of fishing activities on populations of vulnerable animals such as dugongs and turtles, it is important to know the size of the catch for each species. Because fishing takes place from small isolated island communities, it is difficult and expensive to acquire accurate information on the catch of these animals. These difficulties and costs are reduced by research strategies that place greater reliance on the information provided directly by the fishing communities. However, the information from the fishing communities is rarely cross-checked against other independent methods to examine its quality.

The catch of dugong and turtles was recorded by schools in traditional fishing communities on 14 small islands in Torres Strait, Australia, for 3 years starting February 1990. Independent roving fishery observers also collected information on the catch from the same islands for one year, between June 1991 and May 1992. This allowed a cross-check of the catches of these animals.

The two monitoring methods gave results that were in close agreement for the catch of dugong. They indicated that slightly more than 1,000 dugongs were caught in a year. This catch was higher than previous estimates and coincided with an increase in the size of the dugong population as indicated by aerial counting surveys conducted four years apart. The increase in the size of the dugong population could only be explained as the result of a movement of animals into Torres Strait. The timing of the movement could be investigated using the records of the community schools. Catches started to increase in April 1991 and were highest between December 1991 and March 1992. There were significantly higher ratios of female to male, and pregnant female to female, in the catch in 1991, the year of the movement, compared to 1990 and 1992. This change is consistent with an increased availability of animals, as females, a especially pregnant females, are preferentially caught.

The two monitoring methods did not agree closely for turtles. The sampling survey estimated significantly more turtles (mean 2,410, SE 350) were caught than had been recorded by the schools (1,559 turtles). This was most pronounced in two zones where the survey found significant numbers of smaller turtles were caught and missed by the schools. No reliable information could be collected on the sexes of turtles. However, the school records clearly identified a seasonal variation in the catch of turtles related to the nesting season.

The size of the animals, their importance in the communities and the manner by which they were landed were identified as contributing to the different successes obtained for the two methods. Because the communities have a clear stake in the results, information collected from fishing communities forms a good basis for management. The success of community programmes to collect catch information are crucially dependent on the support of the community, and the public relations skills and personalities of a few individuals – factors that must be considered when collecting such information over the longer term.

Estimating fisheries impacts using commercial fisheries data: simulation models and time series analysis of Hawaii's tuna fisheries

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Commercial fisheries data are often used to evaluate fisheries impacts on fish populations. However, fisheries data usually do not provide enough information for reliable estimation of the population parameters required to evaluate fisheries impacts using traditional stock assessment methods. Hawaii's tuna fisheries exploit both bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*T. albacares*) which are widely distributed and closely related to the stocks of these species across the Pacific Ocean. Migration patterns of these species between the Hawaii Exclusive Economic ne (EEZ) and other Pacific regions are poorly understood, and so are other population parameters, such as natural mortality and catchability. Hawaii commercial fisheries data only provide time series of total catch and indices of catch per unit of effort (cpue).

This study examines a tool that can be used to estimate fisheries impacts on local fishery performance when only commercial limited fisheries data are available. Simulations were first used to model relationships between total catch and cpue in Hawaii and patterns of these relationships under different scenarios of key parameters: migration rates, fishing mortality, and catchability. Time series of total catch and cpue produced by the models were then analysed using time series transfer function models. The transfer function models were also applied to real commercial fisheries data from Hawaii's tuna fisheries. Finally, comparisons of the results from the simulation models and the real fisheries data were used to estimate the power of the transfer function models to detect local fishery impacts.

In this study, the simulation models were run at monthly time steps for thirty years. The simulation models include ›chastic processes in migration rates, fishing mortality, ...id catchability, and each scenario was simulated 1000 times. The transfer function model is a technique in time series analysis that is used to examine the effects of the input variable (e.g. catch) on the output variable (e.g. cpue) after the serial dependencies and seasonal trends in both series are removed. Total catches of both tuna species from 1962 to 1994 were estimated from all fishing gears within the Hawaii EEZ, including longline, troll and handline. Cpue of both tuna species were, however, separately estimated from each gear and from each island.

Preliminary results indicated that total catches by Hawaii's fisheries had low probabilities of affecting local cpue for both tuna species. Further analysis will focus on time series of catch and cpue estimated from the same fisheries but at finer spatial and temporal scales, as it is expected that fisheries would have higher probabilities of affecting local cpue at finer scales.

Effects of cathepsin B on the disintegration of minced mackerel

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In order to investigate the effect of endogenous cathepsin B on the disintegration (Modori in Japanese) of minced fish, the crude cathepsins B + L activity of mackerel meat before deboning, after leaching, and after grinding with 2.5% NaCl were measured using Z-Phe-Arg-MCA as substrate, and were 6.02, 5.23 and 4.07 units/g respectively. Around 82% of cathepsins B+L still remained in leached surimi. When the cathepsin B was purified and stored at -40C, there was 80% activity retained even after eight weeks' storage. These data suggested that cathepsins B+L were very hard to remove through the washing process and very stable (at least cathepsin B) during frozen storage. As compared with the SDS-PAGE electrograms of surimi incubated with E-64, a specific inhibitor for cathepsins B+L, degradation on myosin was observed on those incubated with cathepsins B+L, or B only at 40 and 55C under pH 5.5~7.5. The gel strength of kamaboko made from the surimi with cathepsin B decreased significantly from 649 (pH 7.0) and 611 g.cm (pH6.5) to 315 and 383 g.cm after 2 hours' incubation at 55C under pH 7.0 and 6.5 respectively. These phenomena strongly suggested the contribution of cathepsins B+L or B to the disintegration of minced fish products.

Development and validation of an index to evaluate the condition of aquatic habitat

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Widespread loss and degradation of aquatic habitat has led to a general decline in freshwater fish abundance and distribution throughout Australia. However, due to a lack of reliable data on the condition of aquatic habitat, overall impacts on freshwater communities are difficult to measure. Indeed few tools are available to monitor and assess the condition of aquatic habitat on a sufficiently objective and quantitative basis. Such tools are an essential requirement of effective fisheries management within an ecosystem framework.

In the present study a stream condition index (SCI) was developed and validated to assess aquatic habitat in relation to the status of freshwater fish communities. The index was based on *in situ* measurement of key environmental parameters, including channel form and dimensions, water quality, instream and riparian characteristics. Development of the index involved consolidation of available quantitative data on fish habitat preferences and, additionally, a body of related, qualitative, anecdotal information that was structured within a quantitative framework by way of an "expert panel" approach.

A pilot application of the SCI was undertaken within three major anabranches of the Murray River in north-western Victoria, *viz.* the Lindsay River, Walpolla Creek and Gunbower Creek, all of which represent varying degrees of flow regulation and general habitat modification. Integrated

fish and habitat surveys were undertaken at three sites on each waterway on a quarterly basis over a 12 month period. SCI scores were compared with key attributes of surveyed fish communities as a basis for preliminary index validation.

For habitat data pooled over all sites for the survey period, SCI scores were significantly correlated with fish abundance, total biomass and community naturalness (ratio of endemic to exotic species). The SCI scores also highlighted significant differences between the three systems over the survey period, with the highly regulated Gunbower system being shown to be more degraded than either the Lindsay or the Walpolla. These results suggest that the index provides a quantitative measure of the condition of aquatic habitat from a fisheries perspective, although further validation is required. The preliminary analysis is based on a simple correlative model which defines fish assemblage attributes as a linear, unidirectional function of the SCI. Ongoing analyses are attempting to validate the method based on a multi-dimensional scaling approach to establishing a statistical correlation between key fish and habitat parameters using the raw data. Further sampling within both the anabranches and additional lowland river sites is proposed over a total three year period, for the purpose of ongoing development and testing of the method.

The SCI is designed to be a rapid, versatile and reliable method to monitor and assess the status of aquatic habitat over a wide variety of stream types. Such an index has great potential to assist in the management of freshwater fish and aquatic resources by providing objective, quantitative data which can be incorporated into fisheries management plans as a means to evaluate threatening processes, rates of change and the efficacy of ecosystem-based, Integrated Catchment Management actions.

A framework for solving bycatch problems: examples from New South Wales, Australia, the eastern Pacific and the north-west Atlantic

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A framework for solving bycatch problems is described that involves combining the respective expertises of scientists and fishers. The first prerequisite for any attempt to ameliorate bycatch problems involves identifying and quantifying bycatches using large-scale observer programmes. These programmes involve scientists collecting information at sea from normal commercial fishing operations and so determining potential problems without relying on anecdotal information or data from research vessels. Once the species-specific distributions and abundances of bycatches are determined, modifications to fishing methods are tested in experiments using commercial fishing vessels. The fishers' roles in this framework are: (i) to be seen as the driving force in addressing any conflicts that may come from their bycatches; (ii) to provide scientists with their unique practical knowledge of the relevant fishing technology; and (iii) to implement solutions into normal fishing operations quickly and, in many cases, voluntarily. The scientists' role is to organise, analyse and disseminate the work, provide information on possible solutions through their access to the international literature and to ensure the scientific rigour of the experiments. Finally, both scientists and fishers are responsible for communicating the solutions (and their adoption) to the public and other interest groups. The success of this approach is described using examples from the prawn trawl fisheries of New South Wales, Australia, the tuna purse-seine fisheries of the eastern Pacific and the shrimp and fish trawl fisheries off the northeastern United States.

Natural stable isotope abundance used for assessment of anadromous and amphidromous migrations in fish ecology: implications for fisheries management and habitat protection

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Fishes of the genus *Coregonus* (Coregoninae, Salmoniformes) numerically dominate coastal and freshwaters of the Alaskan Arctic coastline. In addition to being obligate freshwater spawners, they undergo feeding migrations into coastal waters during the summer. The migration passages used by these fishes have been subjected to physical alterations as a result of industrial development. Considerable effort has been made to ascertain whether structures such as causeways located in migration routes have had a detrimental effect on these species. No detrimental effects have been detected using conventional research tools. Because stable isotope ratios are conserved during feeding processes, they make effective tracers of food sources enabling one to distinguish between use of food sources when natural gradients exist. Natural stable isotope abundance is being developed as a new technique to assess change in the migrational behavior not otherwise detectable.

A large $^{13}C/^{12}C$ gradient was found to exist between obligate freshwater and marine biota along the Alaska Arctic Coast Plain. Comparisons of riverine and lacustrine migrational and non-migrational coregonine populations were used to assess natural stable isotope methods in migrational ecology studies.

Broad whitefish (*C. nasus*), an important commercial and subsistence fisheries species, had $^{13}C/^{12}C$ distributions consistent with shifts in feeding habitat as a function of age. Adult broad whitefish sampled at a riverine location (~30 km upstream from the sea) were dichotomous in $^{13}C/^{12}C$ suggesting exclusive freshwater or marine feeding. Furthermore, the 3:1 ratio of freshwater to marine feeding is consistent with adult migration intervals of several years. Juvenile fishes tended toward intermediate $^{13}C/^{12}C$ suggesting frequent migrations. Least ciscos (*C. sardinella*), a secondary harvested species, and humpback whitefish (*C. pidschian*), a non-targeted species, also from the riverine site had $^{13}C/^{12}C$ distributions similar to broad whitefish.

A lacustrine least cisco population (with ~100 km tortuous pathway to the sea) existing as sympatric growth forms (determined by length at age) is hypothesized to differ in migrational behaviour. Ratios of $^{13}C/^{12}C$ were consistent with the reduced-growth-rate form feeding exclusively in fresh water and thus non-migratory. The normal-growth-rate form had $^{13}C/^{12}C$ similar to the riverine population.

The range in $^{13}C/^{12}C$ of coregonine fishes suggest great diversity of feeding sites. This evidence demonstrates the need for habitat protection beyond migrational access. Differences in growth rate (and metabolism) between migrating and non-migrating North Slope coregonines suggest physiological adaptations related to habitat variations. This has significant implications if industrial developments restrict migration pathways. Because $^{13}C/^{12}C$ reflects migrational ecology, this parameter should be used to assess the effects of industrial development to ensure that fish populations continue to utilize habitats to which they are adapted. Furthermore, these results have implications for fisheries management since migrational behaviour shifts induced by anthropogenic selection are discernable by changes in $^{13}C/^{12}C$ over time.

The key criteria to sustaining the wild stock Murray cod fishery in Lake Mulwala

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Murray cod (*Maccullochella peeli*) is the largest freshwater angling species in Australia, having been reported to over 190 kg in weight. Situated on the Murray River, Lake Mulwala is one of the country's premier cod fisheries and is maintained entirely by wild stocks. In order to manage this fishery, there is a need to determine the resource, the development pressure and to understand the ecological requirements of the species. As the ecological requirements of this species have not been well understood, the first step has been to determine the habitat preferences, movement and recruitment within the lake and inflowing rivers.

Results have indicated a close inter-relationship between lake fish and the inflowing rivers. Radio tracking has shown spawning fish to move out of the lake and up into the rivers to spawn, then return to their original positions in the lake. Distances travelled have been recorded up to 100 km, with the greatest distances recorded during years of high flows. Cod larvae were found to drift downstream from the rivers to the lake where they would settle out in the still water. Lake Mulwala is a relatively shallow lake, with abundant wood debris, which was determined to be the preferred habitat for both large and small Murray cod. The lake provides an abundant food supply for juvenile fish and therefore appears to fill the role of a suitable nursery ground for this species. Population structure within the lake is much younger than in the rivers, thus supporting this proposition. During the past three years there has been good survival and recruitment of Murray cod within the lake, whereas significant survival of young-of-the-year fish has only occurred in the river during years of high flows, despite spawning occurring.

There would appear to be an important relationship between the rivers and the lake in maintaining this fishery and the two should be managed together in order to maximise production. Large wood debris must be maintained in the rivers both as habitat and spawning sites. Water levels should be maintained in the lake during rearing times. A fish lift has been installed to assist upstream fish passage over the lake wall, and consideration must be given to the safe downstream migration of fish. Flooding appears important in the survival of recruits in the rivers, whilst the lake forms a nursery area for larvae drifting from upstream. An assessment is still to be made of the pressure on this fishery and monitoring of the stocks and recruitment should be established in order to maintain this wild stock fishery in an ecologically sustainable manner now that these mechanisms are understood.

Molecular genetic markers in discriminating stocks of Australian penaeid prawns

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The catch of wild penaeid prawns in Australia is worth more than $A250 million per year. In the battle to maintain a sustainable harvest in these fisheries, managers require basic information on the identification and definition of the fundamental units of management, the stocks. Without an understanding of the number and extent of discrete stocks in a fishery and the degree of migration between those stocks, it is extremely difficult to accurately estimate stock size, stock-recruitment relationships or the effects of management decisions. Genetic markers are powerful tools for detecting population subdivision and gene flow. However, particularly in the marine realm, they are also conservative in detecting the levels of subdivision and migration in which managers are interested. It is therefore critical to use the most powerful genetic techniques available in order to provide fisheries managers with appropriate data on population structure. This is particularly so in penaeid prawns where previous analyses have revealed very little useful genetic variation.

Both mitochondrial DNA (mtDNA) and nuclear DNA (nDNA) markers are being used to examine stock structure throughout the Australian (and South-east Asian) distributions of three commercially-important species of penaeid prawn: *Penaeus merguiensis*, the white banana prawn (6 Australian sampling sites and 5 SE Asian sites); *P. esculentus*, the brown tiger prawn (9 Australian sites); and *P. plebejus*, the eastern king prawn (10 Australian sites). The segments of the mitochondrial genome that are being targeted are portions of the large subunit ribosomal RNA (16s rRNA) gene and the Cytochrome Oxidase subunit I (COI) gene. These regions are being examined using a combination of PCR (Polymerase Chain Reaction) amplification with penaeid-specific primers, DNA sequencing of a small number of individuals and routine screening of larger samples using diagnostic restriction fragment analysis. In addition to allozymes, nDNA variation is being examined using microsatellite markers. Twelve microsatellite loci have been cloned and sequenced, and flanking PCR primers were designed for nine of these loci to enable rapid amplification of these polymorphic markers.

DNA results from a small number of individuals taken from the extremes of the species Australian distributions have revealed a wealth of genetic variation. Mitochondrial DNA haplotype diversities are relatively high: *P. merguiensis* (H = 0.72), *P. esculentus* (H = 0.78) and *P. plebejus* (H = 0.84). Compared with allozyme heterozygosity in penaeids (mean 0.02), preliminary estimates of microsatellite heterozygosity are extremely high (mean 0.78). The higher levels of diversity detected using DNA techniques permits much more powerful tests of population subdivision than were possible using results from allozymes alone. Using mtDNA from only 5-10 individuals per site, eastern Australian stocks were easily discriminated from western Australian stocks in both *P. merguiensis* and *P. esculentus*. Previously, this had

not been possible using allozymes alone. Although high levels of mtDNA variation were found in *P. plebejus*, no significant population structuring has yet been detected in similarly small samples from the east coast. Additional individuals of the three species from all sampling sites are currently being analysed for both mtDNA and nDNA variation to address the questions of more fine-scale population structure.

The direct analysis of mtDNA and nDNA in penaeid prawns has revealed a wealth of genetic variation previously hidden. These techniques are currently proving extremely valuable in determining the stock structure of wild prawn fisheries and are likely to be similarly useful in prawn aquaculture.

The management implication for the Indian Albacore stock when production model analyses result in discrepancies in estimated parameters

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Several algorithms to fit production models have frequently been used in evaluating the status of the Indian albacore stock. Those algorithms include generalised production models with different shape parameters (Fox's model and Schaefer model), a surplus production model incorporating covariates (ASPIC), and an age-structured production model (ASPM). Note that resultant discrepancies occurred from evaluation of fitting real catch and effort data to those models, and that the stock status is still uncertain. This paper aims at how to address a substantial implication for management purposes using those different results obtained from production models analysis of catch and effort data from 1968 to 1993.

Parameters of MSY, f_{opt} (or F_{MSY}), biomass ratio (B/BMSY), fishing mortality ratio (F/F_{MSY}), stock depletion percentage (B/K) and replacement yield (RY) were estimated from models under various assumptions, and were mainly derived to address the implications for managing Indian albacore stock. MSYs were estimated to be from 14,800 to 21,800 t by the generalised production models, and from 14,550 to 18,380 t and 24,200 t by ASPIC and ASPM respectively; f_{opt} was from 50 to 150 million hooks by generalised production models; F_{MSY} were 0.254/year and 0.145/year for ASPIC. Those results obviously show that the stock has been overexploited since 1984 when the nominal catch was over 27,000 t and effective fishing effort approached 145 million hooks. However, the values of B/B_{MSY}, F/F_{MSY}, B/K and RY estimated by ASPM show that the stock is still between under- and full-exploitation.

Consequently, resultant discrepancies of production model analyses on alternative error assumptions could mislead management implications when MSY and f_{opt} (or F_{MSY}) are used alone to indicate the stock status. Therefore MSY and f_{opt} (or F_{MSY}) should incorporate information on biomass ratio, fishing mortality ratio and RY, and then a substantially concrete and optimal management policy can reasonably be made, when production models are used to assess fish stock.

Structure of seagrasses and their carrying capacity for juvenile penaeid prawns: studies of the effects of prawn density and predation

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The inshore distribution of seagrasses defines the extent of the tiger prawn fishery in tropical Australia, which catches about 4,000t each year (value ~ $A100 million). The critical nursery habitats for tiger prawns (*Penaeus esculentus* and *P. semisulcatus*) are intertidal and shallow subtidal seagrasses. Field data show, however, that in some regions, juvenile tiger prawns are more abundant on seagrass beds with high biomass and greater structure, than in low biomass beds. The aims of this study were to investigate the carrying capacity of seagrasses for juvenile tiger prawns: specifical' how growth and survival are influenced by the density o prawns; and how the structure of seagrass influences predation rates by fish on juvenile tiger prawns.

Small juvenile *P. semisulcatus* were stocked at densities of 4, 16 and 32 prawns m^{-2} in small enclosures (c 1m^2base and 1 m high) and the survival and growth (measured as carapace length – CL) of prawns was studied over 16 days, in the absence of predators. The lowest density used in these experiments compares with field densities of 2-4 prawns m^{-2} at times of peak recruitment. The highest growth rate (mean±1SE) of 1.29±0.11 mm CL wk^{-1} was recorded at a density of 4 prawns m^{-2} growth. Growth rates declined to 1.01±0.18 mm CL wk^{-1} at 16 prawns m^{-2} and 0.72±0.01 mm CL wk^{-1} at 32 prawns m^{-2}. Mortality rates were lowest in the low density treatment (2.5% wk^{-1}) and increased to 13.5 and 15.8% wk^{-1} at the higher densities. These results suggest that in the absence of predators, seagrass beds are able to sustain higher densities of prawns than are usually found under natural conditions.

Predation rates of juvenile penaeids by fish were compared on two intertidal seagrass beds in the pre-wet (October ar November) and late wet seasons (March and April). On seagrass bed (Sg1) had a 10x higher biomass of seagrass (c 100 g m^{-2}) than the other (Sg2, c 10 g m^{-2}). Although the gut contents of 4,135 fish were examined, only 896 penaeid prawns were found from 37 fish species. In general, tiger prawns (*P. semisulcatus* and *P. esculentus*) made up only a minor proportion of the gut contents by weight and accounted for 25% of the dry weight of penaeids in only 15 species of fish. Clear differences were not found between the numbers of *P. semisulcatus* in guts between Sg1 (129) and Sg2 (92) in the pre-wet season, despite the large difference in biomass and structure of these seagrass beds. Only relatively few prawns were found in guts in the late-wet season. Results suggest that predation on tiger prawns appears to be low and relatively unaffected by the structure of the habitat. This conclusion and the results from the enclosures suggest that recruitment to the seagrasses is the main factor limiting the size of prawn populations in these habitats.

Selectivity of deep water prawn Danish seine assessed by experimental net with infrared underwater video

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Species and size selectivity in the Danish seine fishery for deep water prawn, *Haliporoides sibogae*, in the East China Sea was assessed. The study aimed at improvement of fishing gear for exclusion of both undersized prawns and bycatch finfishes for the purpose of management of prawn resources and conservation of the fishing ground. Reduction of the time for sorting catch and clearing enmeshed finfish was also considered to encourage fishers to adopt selective fishing gear because of the higher quality prawns and rationalized work on board.

The present trials were conducted in the commercial fishing ground of 400m depth to clarify the capture process and to induce selectivity of the fishing gear currently used. The experimental net was equipped with a newly developed underwater video camera with an infrared lamp of which wave lengths are beyond 720nm in order to observe behaviour of deep organisms without disturbance by visible light. The net was also fitted with pocket nets which covered 1.4% to 6.2% of meshes of the net panels and a cover net over the codend in order to assess exclusion occurring at different portions of the net.

A majority of prawns swam freely in the net during drag. When the tailpiece of a prawn encountered the net webbing, the abdomen was bent to rush backwards and then stretched when bumped on to the net. This was repeated several times until either exclusion through a mesh or the encounter stimuli ceased. This was the only behaviour which resulted in exclusion of prawns, while finfishes swam through meshes occasionally. This reaction was not induced by touching other prawn body components such as antennae and chelate legs on to webbing. The analysis of the organisms retained by the pocket and cover nets revealed that more prawns were excluded through the meshes of the wing portion adjacent to the main body of the net, compared with exclusion through the codend, while a majority of finfishes were excluded by the codend. Selectivity of either the whole net or the codend for prawns and finfishes was represented by logistic curves of different slopes.

Selection of prawns was considered to be governed by the geometrical relationship between the sections of bent abdomens of prawns and the mesh opening, as well as different probabilities of encountering of prawns with net panels. A large number of prawns excluded by the latter part of wings were, therefore, attributable to the greater number of encounters by prawns. This suggests that mesh sizes of wings and hanging ratios over the net are important factors to be taken into fishing management in addition to ordinary regulations for codend mesh sizes. The selectivity curves for prawns and finfishes suggest that improved size selectivity for prawns by using enlarged meshes must also contribute to species selectivity against bycatch finfishes in the case of the fishery studied. It is advisable that studies on size and species selectivity which have been relatively separated over recent years, must be confirmed.

Multi-species separation in the Japanese coastal trawl fishery

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Historically, most of the trawl catch such as fish, shellfish and shrimps has been utilised for human consumption. However, recent shortages of labour in the coastal fishery have resulted in poor on-deck sorting and increased levels of discards including hatchery released juveniles of commercial food fishes. As an integral part of the management of coastal resources, fishers from the port of Chosi, Chiba prefecture, have taken voluntary action to seek a technological solution to this problem. The first stage was to investigate the catch composition and quantify levels of non-target species, sizes and shapes. Results of this research indicated that species separation was required and a Soft BRD (Bycatch Reduction Device) type separator device with square meshes was designed and tested using twin codends on commercial fishing grounds. Separation efficiency of fish and shrimps varied with mesh size and towing condition with increases in marine debris reducing separator efficiency significantly. Underwater video observation indicated that species size and shape selection was a function of the mechanical properties of the BRD and that marine debris clogged up the BRD. The key to developing an effective practical separator device lies in understanding and taking advantage of behavioural differences between species during the capture process.

Assessment of the potential of glass eel resources in south-eastern Australia for commercial aquaculture

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Juvenile (glass) eels, for use as commercial aquaculture seedstock, are currently at a premium within a world market, with prices recently exceeding $A10,000/kg for some Asian species. To date, Australian glass eel stocks have been relatively unexploited for commercial purposes, although there is a well established commercial eel fishery based on wild and "extensively farmed" stocks, with annual production in excess of 600 t. In the present study funded by the Fisheries Research and Development Corporation, surveys were undertaken in south-eastern Australian estuaries during 1994 and 1995 to assess the potential for harvesting naturally migrating glass eels of the Australian short-finned eel, *Anguilla australis*, to be used as commercial aquaculture seedstock. The surveys aimed to characterise the environmental influences associated with eel recruitment patterns, including the migration into and within estuaries by glass eels. Predictive modelling of such events, based on these and other environmental factors, may provide the basis for cost-effective and sustainable harvesting of a potentially valuable glass eel resource.

Sampling was undertaken during late winter/spring, on flood tides between sunset and sunrise. Sixteen rivers in Victoria and two in Tasmania were sampled during 1994 using 2.0mm mesh, double-winged fyke nets which could be set at any level in the water column. In 1995, three rivers were sampled in southern NSW, five in Victoria and five in Tasmania using glass eel nets and stow nets (20m length x 6m depth x 2.0 mm mesh set with anchors).

In 1994, mean catch per unit of effort (cpue) was greatest in the Snowy River in Victoria (58 glass eels/net/hour) and the Tamar River in Tasmania (56 glass eels/net/hour) using glass eel nets. The greatest mean cpue in 1995 was recorded using stow nets on two occasions in each of the Tarwin River (1375 and 1281 glass eels/net/hour respectively) and the Snowy River (mean cpue = 344 and 669 respectively) in Victoria and the Tamar River (mean cpue = 214 and 225 respectively) in Tasmania. In general, CPUE in 1995 in glass eel nets was similar to that recorded in 1994. The catch rates using stow nets were significantly greater than those made by glass eel nets in both 1994 and 1995, suggesting that the stow net may be more appropriate for commercial fishing in some estuaries. In general, glass eel migrations appear to be influenced strongly by temperature and salinity, although lunar and tidal phases are also relevant. The invasion of glass eels into estuaries occurs over an extended period (May-October) in south-eastern Australia, although the best catches during the survey period occurred during August in eastern Victoria and late September in northern Tasmania. In general however such movements appear to be more protracted in some rivers than initially thought, with major invasions assisted by spring tides during new and full moon periods particularly, probably occurring through the estuary mouth over a period of several weeks.

The results from the 1995 surveys provide encouraging evidence to suggest that, at least in some rivers in south-eastern Australia, under specific environmental conditions, short-finned glass eel recruitment occurs to such a degree that the commercial harvest of glass eels may be a viable option. Further surveys are scheduled for 1996.

Spiny lobster fisheries and management concerns in Sultanate of Oman

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In Oman, the spiny lobster, *Panulirus homarus,* is one of the major shellfish species traditionally fished by tangle nets and traps.The annual production during 1994 fishery season was estimated to be about 623 t, with a value of about six million U.S.dollars. This paper reports the history of the fishery in general, size distribution, variations in sexual maturity and egg production levels in the population sampled in three sites; Shuwamiyah, Sadh and Mugsyl along the Dhofar coast in Sultanate of Oman. Size at morphological maturity was determined based on the external sexual characters: development of ovigerous setae and presence of spermatophore. Size at functional reproductive maturity was determined by the ovigerous condition. The female lobster population in the sampling sites shows variation in size at sexual maturity resulting in different levels of egg production contributed by various size classes. The variation in reproductive activity was explained by the levels of fishery exploitation, coastal geomorphology and the strength of coastal upwelling in the study region. The present minimum capture size regulation of 80 mm carapace length (CL) and its biological rationale were reviewed using the results of the present study.

Developing a strategy for measuring the relative abundance of pueruli of the spiny lobster *Jasus verreauxi*

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Attracting devices ("collectors") have been used to collect information on the relative abundance of the puerulus larvae of shallow water spiny lobsters. This information has been used to predict the level of the commercial catch in future years and in calculating stock-recuitment relationships. A knowledge about the impact of factors th may affect catches on collectors is needed to develop a sampling strategy that will minimise such effects so that any observed differences in mean estimates of relative abundance can be attributed to changes in the abundance of the organism rather than to "noise" in the sampling methodology. Three experiments based upon fully orthogonal or nested, multi-factorial designs, were done in the field to test hypotheses concerning the effects of collector design, collector position, lunar month and phase, location and soak-time on catches of pueruli of the spiny lobster *Jasus verreauxi*.

In the first experiment, the effects due to two designs of collectors (seaweed and crevice types) and two positions (surface and bottom) were compared. Pueruli were only caught on seaweed type collectors, with significantly greater catches on collectors near the surface.

In the second experiment, seaweed type collectors were set at locations that were exposed to, or sheltered from oceanic swell. At each site (within a location), collectors were positioned proximal to reef in waters of less than 5 m depth (near), or away from reef over bare sand in waters of arour 10 m depth (away). Exposure to oceanic swell did no significantly affect catches, but fewer pueruli were caught on collectors set near to reef than on those away from reef.

The third experiment investigated the effects on catches of lunar month and phase, location and soak-time. At each location, four replicate collectors were sampled at soak-times of 1,2,3 or 4 weeks during each lunar phase over 3 months. There was a significant higher order interaction indicating that catch depended upon the lunar month and phase, soak-time and location. Comparisons of means among treatments within the interaction term showed that on most occasions when there was a significant difference between lunar phases, mean catches were greater at new moon or first quarter than at other phases. Similarly, on most occasions when there were significant differences between soak-times within a particular lunar month, phase and location, mean catches were greater from collectors soaked for 4 weeks than from those soaked for 1,2, or 3 weeks. Cost-benefit analyses used on a subset of data from this experiment and with time as the limiting cost showed that 3 collectors was the optimum for each site.

It was concluded from the results that seaweed type collectors are best suited for catching pueruli of *J. verreauxi* and that these should be set near the surface in waters of 10 m depth and over bare sand. Further, 3 collectors set at

each site within a location are best sampled every 4 weeks around the first quarter of the lunar month.

Danube delta fisheries in transition from economic exploitation to sustainable use

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Within the Danube Delta, the Danube Delta Biosphere Reserve (DDBR), covering 580,000 ha, was established to protect the largest wetland zone in Europe. The main objective of the DDBR is to preserve biodiversity through regulating the exploitation of the available resources within the sustainable limits of its ecosystem. This requires a change from economic management of the fishery to that of sustainable use of the fishery resource.

In the past, the Danube Delta fisheries have had different management systems. In the 1920s, the income from the catch was distributed as follows: 1/3 of the value for state tax; 1/3 of the value for the owner of the fishing gear and 1/3 of the value for the fisher. Commercialisation through auction was first introduced during 1895-1910 after which a system of fixed price was introduced (1910-1928). However this failed and the previous auction system was re-introduced in 1928 and continued until 1947. From 1953 till 1990, fisheries and the commercialisation of fishing in the Socialist Republic of Romania were regulated by state-owned companies. After political reforms in 1989, privately owned fishing companies were able to operate alongside of the state companies within the Danube Delta.

In recent times fishing effort has increased greatly as a result of fishing by the new companies and increased fishing effort by the state companies. At present the danger of overexploitation of the fish resources is close to causing the collapse of the fisheries. The Danube Delta Institute (DDI) is undertaking a research programme to establish Maximum Allowable Catch by Virtual Population Analysis in which total catches and effort are used, but there are uncertainties because of poaching, black markets and incomplete records of fishing data. To improve fish stock assessment that will provide a sound basis for sustainable management of the fisheries and for meeting the objectives of the DDBR, many problems with fishing rights, fishing licences and fisheries law have to be solved.

DDI and DDBR have been trying since 1993 to promote a management plan based on a fisheries licensing system that regulates fishing quota, fishing effort and individual fishers to certain areas. These options require new legislation and infrastructure supporting facilities. The Danube Delta fisheries are in a transitional period from past to new management . If this is protracted, capture fisheries will collapse. If the scientists, managers, politicians and fishers accept the critical situation of the Danube Delta fisheries, there will be hope for man and nature to coexist.

Hydroacoustic methods and results of krill stock surveys for three consecutive years in east Antarctica

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Antarctic krill (*Euphausia superba*) have been fished commercially since the early 1970s. Catches reached their peak in the 1981/82 season when over half a million tonnes were caught. In 1994/95 the krill catch was 117,000 t, mostly taken in the South Atlantic by Japanese and Ukrainian vessels. The krill fishery, like all other fisheries in the Antarctic region, is managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). Management measures adopted by CCAMLR take an "ecosystem approach" to allow for the needs of dependent and related species. Precautionary catch limits have been placed on the krill fishery in the South Atlantic, FAO Area 48 (1.5 million t) and in the South West Indian Ocean, FAO Division 58.4.2 (390,000 t).

Krill have been caught consistently in the South Indian Ocean (FAO Area 58) since the commencement of commercial krill fishing activities. The peak catch in Area 58 occurred in 1980/81 when 155,000 t were taken, mostly in the Western Indian Ocean. Recent catches in the Indian Ocean have been small (<6,000 t) taken by a single Japanese vessel operating off the Wilkes Land region of Antarctica, Division 58.4.1. This region is currently not covered by a precautionary catch limit, although the stock of krill in Division 58.4.1 will be assessed during the summer of 1995/96 by Australian scientists with the aim of presenting CCAMLR with the data necessary to set a catch limit.

Three consecutive acoustic surveys for the estimation of krill abundance and distribution were conducted in the Prydz Bay region in East Antarctica. The surveys were in January/February 1991, February/March 1992 and January/February 1993. They consisted of a number of regularly spaced north-south transects within the area bounded by 60°–81°E and 63°–69.5°S. They were conducted from RV *Aurora Australis* using a calibrated Simrad EK500 echo sounder operating at a frequency of 120 kHz.

The results indicate the highly variable nature of these estimates, which has wide implications for monitoring regimes looking at distribution and abundance estimates for fisheries impact management. In general the shelf break was not a region of comparatively high abundance, though some association of krill with the shelf break was evident in the western part of the survey area. To enable an assessment of the diversity of scattering species and the patterns of species zonation, trawls were aimed at acoustically identified targets and at regularly spaced sites. Inter-annual survey to survey variations in the mean surface density of krill were large. Though in general the surface densities estimates for this region are large compared with estimates for FAO Statistical Areas 48.1,48.2 and 48.3, they are small compared with estimates for January 1985 from the Australian SIBEX-II data. The Australian SIBEX-II estimates fall in the middle of the range of densities estimated from seven surveys between 1981 and 1985. The distribution of Sa values for the lower biomass years 1992 and 1993 were similar but distinctly different from the higher biomass year of 1991. The difference is characterised by the high percentage of lower Sa values (60% < 10

m2/nm2) for 1992 and 1993 compared with the even spatial distribution of medium Sa values (10 to 200 m2/nm2) 1991. The biomass distribution and density patterns are described for distributed scattering layers and aggregated targets.

Research for management of the ornate rock lobster fishery in Torres Strait

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Ornate rock lobsters (*Panulirus ornatus*) have been fished by the traditional inhabitants of Torres Strait long before commercial fishing began in the late 1960s. The fishery is now a major source of income for Torres Strait Islanders and management aims to balance the needs of traditional and commercial users across complex boundaries, under an international treaty with Papua New Guinea (PNG). The lobsters do not enter pots, so they are speared by divers fishing from small dinghies. Several hundred dinghies are operated by Islanders and there are also several dozen small commercial freezer boats, each with 1-6 dinghies. The annual catch of the fishery ranged from 68 to 124 t of tails in the 1970s, 124-350 t in the 1980s, and has averaged ~185 t in the 1990s. Effort in the fishery has increased substantially over this period and catch rates have decreased ~3-fold – hence, there is a continuing need for research and stock assessment to provide advice for management.

The first research provided information on the life history of the lobster, particularly the existence of an annual migration out of Torres Strait to breeding grounds in the Gulf of Papua, PNG. This breeding population forms the basis of a traditionally important artisanal fishery that lasts for only a few months each summer because the lobsters are in very poor condition and virtually all of them die after breeding. Larvae spawned during the breeding season develop for about six months in the Coral Sea and then settle into nursery grounds in Torres Strait. There, they grow very quickly, recruiting into the fishery about one year later and are fished until they are ~2.7 years old when they then emigrate. Prawn trawlers previously targeted the migrating lobsters and catches of up to ~200 t were recorded. This activity was banned in 1984, to preserve the PNG traditional fishery, the breeding stock and future recruitment.

Research has become more directed at stock assessment for management, beginning in 1989 by visually censusing the absolute abundance of lobsters, sampling catch and effort of Islander fishers and estimating the potential yield of the fishery. Since 1989, smaller annual surveys of the relative abundance of the stock and monitoring of catches have enabled a simple model of the fishery that, for a given level of fishing mortality, estimates the potential yield and proportion of the population that escapes fishing to emigrate and breed. This model has provided annual assessments of the status of the stock and potential yield, one year in advance – information valuable for managers considering development options and negotiating catch sharing agreements and access rights.

In future, stock assessment will continue and other research will address the extent of deepwater breeding populations; alternative fishing methods for capturing a value-added live product; and ecological linkages required as a basis for ecosystem management strategies.

A new family of empirical models for the potential yield of lake fisheries

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A new family of approximate models for the estimation of the potential sustainable yield of lake fisheries is based on the projection from a well-estimated fishery in a baseline lake to a data-sparse fishery in a target lake. Areal fish yields are scaled by the ratio of the logarithm of average annual primary production.

The model has been applied to fisheries for introduced species in the African lakes such as Nile perch and freshwater sardines. In cases where baseline and target fisheries are for different taxa in analogous lacustrine niches, such as the silvery pelagic zooplanktivores that are generally either cyprinids or clupeid species in African lakes, potential yields are scaled by the ratio of the auximetric growth parameter, ø.

The principal uncertainties in applying the new model are evaluated. Estimation errors are accommodated using Monte Carol bootstrapping from the error distributions of the input parameters. The principal process error is embedded in the assumed correlation of primary production and fish yield. The relationship of ø with productive capacity is explored. The new family of models may be made more precise by incorporating further determinants of productive capacity. Extension to multispecies systems would be beneficial and might be achieved through the ECOPATH mass-balance model.

Performance of transect and point count underwater visual census methods for reef fish assessments

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Underwater visual census methods are widely used to estimate the abundance of reef fishes throughout the tropical Pacific. Though cheap and effective, these methods vary considerably in their application, prompting moves to standardise them across the South Pacific. Different methods vary in their advantages and biases but it is difficult to assess their performance under field conditions because actual fish densities are not known. Computer simulation offers a means of studying the relative performance of these methods under the wide range of conditions encountered in field studies.

Performance is one measure of a method's suitability for a field study. Performance was measured as the reduction in the mean squared error of density estimates with sampling time. Sampling times were based on averages from field reports. The effect of density, distribution patterns, net movement and sample size on the performance of transect and point count methods, were examined.

The two methods are compared on the basis of statistical and logistical measures related to efficiency. Trade-offs between the methods are examined with regard to bias and

results are summarised to compare the advantages and disadvantages of the two methods.

Development of improved techniques for the transport of live finfish

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Since 1993, there has been rapid development in the sale of live finfish in Australia, to both domestic and export markets. Live finfish bring premium prices, so the development of this market has allowed value-adding to wild-caught and farmed finfish and the development of markets for traditionally under-utilised species. The overall project objective is to develop cost-effective techniques for transporting live Australian tropical and temperate finfish..

This project is divided into three major areas of research:

1. Capture and maintenance prior to transport
2. Transportation
3. Post-transport maintenance.

The investigation covers the effects that modifications to existing capture techniques, such as gill-netting, line fishing and trapping, have on survival and stress in the captured fish. The relationship between capture conditions, barotrauma and survival and the efficacy of swim bladder puncture as a technique for treating barotrauma are also being examined. Mortality in captured coral trout (*Plectropomus* spp.) is related to the level of barotrauma: coral trout with extreme barotrauma exhibit mortality rates about twice as high as those with slight barotrauma. Puncturing the swim bladder of fish affected with barotrauma improves survival by about 10-20%.

Wild-caught fish are often stored in 'coffs'. The effects that different coff materials have on fish condition and survival have been examined and an improved coff designed, based on aquaculture cage construction that retains the fish in premium condition.

Transporting live finfish results in rapid and severe water quality degradation in the transport water. Typically, fish are subjected to low dissolved oxygen, high carbon dioxide, low pH and high ammonia levels. Most water quality changes occur in the first hour after the fish are packed and subsequent water quality changes occur relatively slowly.

Reducing the temperature of the transport medium reduces the metabolic rate of the fish. The optimum transport temperature and the rate at which this temperature is achieved during pre-packing cooling affect survival of the transported fish. Both factors vary between fish species.

Transportation of live finfish results in severe physiological stress, leading in many cases to death. A number of physiological variables have been examined to determine the effects of confinement and adverse water quality on finfish. The zero mortality observed in fish confined within standard fish transport containers, but with a flow-through water supply system, indicates that confinement *per se* has little or no short-term effect on transported finfish.

Improving survival in live fish transport applications involves alleviating the water quality degradation that causes mortality. Some systems currently being trialed are:

- circulation of oxygen-enriched air to each box
- removal of carbon dioxide
- redesigned packaging to facilitate the provision of gas recirculation.

The parasite fauna of transported fish as has the bacterial flora with particular respect to potential human health pathogens have been examined. Results for barramundi indicate that the parasite fauna does not dramatically increase following transport and maintenance in tanks following transport. Similarly, no bacterial proliferation that may pose a threat to human health was found in barramundi following transport.

Trawl industry considers new AusTED design

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Prawn trawling is a non-selective method of fishing that in recent times has generated concerns from many sectors of the Australian community. These concerns have resulted in devices that make trawl nets more selective for their target species. These devices are collectively known as Trawl Efficiency Devices or Turtle Excluder Devices (TEDs). A project started in Australia in 1992 aimed to develop a TED suitable for Australian prawn trawl fisheries. The result was the AusTED, a trawl efficiency device incorporating a unique flexible wire grid and one or two bycatch escape windows. AusTEDs were trialed aboard commercial trawlers in four different fishing grounds in northern Australia. Catch reductions varied, with minimal prawn loss (0 to 5%) and significant bycatch reductions (about 30%). All large animals (>25 cm diam.) were excluded from nets fitted with the AusTED.

Trialing the AusTED aboard commercial trawlers was beneficial as problems associated with particular fisheries or vessels were identified. Using commercial trawlers increased the profile of TEDs with trawl operators. This exposure and consequent communication between researchers and industry has reduced the resistance of individuals to trialing TEDs. Industry recognition and modification of TEDs are important in maintaining the viability of the industry under increasing pressure from conservation groups and government to reduce the catch of non-target animals.

Population size-structure and recruitment of freshwater fish species in the Murray-Darling River system, Australia

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Poor recruitment is considered to be the major cause of declining populations of native fish in the Murray-Darling River system. In contrast, the abundance of alien species has increased, with carp, *Cyprinus carpio,* now the dominant species in southern parts of the system. Fish habitats within this river system display a large degree of heterogeneity, so that the population dynamics of individual species might be expected to vary between regions. However, due to the large size of this river system (1,073,000 km^2, or 14% of Australia), the full extent of regional variation is difficult to assess. The objectives of this study were to determine the population size-structure of native and alien species within the Murray-Darling River system, to estimate growth rates and levels of recruitment and to evaluate variation in recruitment among different catchments.

Fish were collected biannually from permanent lakes and rivers, and ephemeral creeks and floodplain habitats, associated with the Paroo, Darling, Murrumbidgee and Murray rivers during wet and dry seasons over three years. Multiple mesh-size gillnets and fyke nets were used to sample large juvenile and adult fish, while light traps and plankton nets were used to catch larvae and early juveniles.Three species of commercial or recreational importance – golden perch (*Macquaria ambigua*), bony herring (*Nematalosa erebi*) and carp (*Cyprinus carpio*), and another three non-target species – spangled perch (*Leiopotherapon unicolor*), gudgeons (*Hypseleotris* spp.) and Australian smelt (*Retropinna semoni*) were caught in sufficient numbers to analyse population structure. Length-frequency data for bony herring were adjusted for size-selectivity of gillnets to increase the reliability of population size structure estimates.

Length-frequency distributions were analysed using the MULTIFAN programme to estimate growth and recruitment rates. This programme uses non linear modelling techniques and a robust maximum likelihood procedure that allows objective discrimination of best fit parameter estimates. Site-specific age-length keys were constructed for golden perch and bony herring using ages estimated from otoliths. Considerable variation in age-length relationships were found among sites and among individual river systems. These keys were subsequently used to validate growth estimates derived using MULTIFAN.

Recruitment of golden perch and bony herring occurred following flooding at sites in the Paroo and Darling catchments. Few adults of these species were caught in the Murrumbidgee and Murray rivers and no recruitment was detected. In contrast to native species, carp recruited to all four catchments during the study. These results indicate that recruitment of native species is restricted to a narrower range of environmental conditions than recruitment of carp.

Gauntlet fisheries for large, long-lived sharks: approaches to research and management

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Large, long-lived sharks present a unique challenge to both the researcher and to the fisheries manager. The difficulties of sustainability of shark populations in general to directed fishing, due mostly to their low reproductive rate, have been well documented. Large, long-lived species are an extreme case of this with biological characteristics such as a long period to reproductive maturity, long life span, slow growth, population segregation and long distance migrations, adding to the difficulties for sustainable fishing. This paper examines some of the approaches that can be taken to both research and management of these populations where a gauntlet fishery exists (e.g. gillne drawing on the Western Australian dusky whaler fishery (*Carcharhinus obscurus*) as an example.

To provide useful information for fisheries management, researchers must collect relevant biological (e.g. age and growth, reproduction, natural mortality, movements, size selectivity of gear) and fishery data. The large size of mature individuals and the large distances that they move may make data collection difficult. To overcome these data shortcomings a modelling approach can be used to evaluate approaches to management.

Analysis of the dusky whaler fishery in Western Australia indicates that where a gauntlet fishery exists, the highest yield per recruit is attained if sub-adult ages are fished. However, with price decreasing with increasing size, the greatest economic return per recruit is achieved by aiming the gauntlet at the smallest juveniles. Analysis of the young per recruit indicates that best results are achieved when the gauntlet is aimed at either the smallest juveniles or adults. Age-structured population modelling of the dusky whaler population allows for the projection of future stock levels given specific harvest strategies. In the case where th gauntlet is aimed at the smallest juveniles, the long perio from recruitment to maturity means that the effects of fishing are not observed until 15 to 20 years later. Tagging of mostly 0+ individuals in the Western Australian dusky whaler fishery has been undertaken to provide estimates of the exploitation rate achieved by the fishery.

The biological characteristics of large, long-lived sharks mean that a precautionary approach to management should be taken whenever possible as the recovery time for a stock is extremely long. The Western Australian approach has been to set target breeding stock levels for the stock at 40% of virgin biomass using the model output, while also using modelling to review parameter inputs and sensitivities as more data are collected. Adding to the biological difficulties are factors such as: (1) the high value of fins from adults which encourages "poaching" of breeding stock; (2) mercury levels in the flesh increasing with age (above recommended health limits in older individuals); (3) stock movements that may cross jurisdictional boundaries; and (4) the perception that large sharks are "man-eaters" and are unworthy of conservation.

Usefulness of mesh size management in pelagic trawl fisheries

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Minimum mesh size regulations have traditionally been applied in many fisheries to limit the retention and discarding of small fish by fishing gear and to increase long-term yields. However, research conducted during recent years indicates that conventional codend mesh size management may be ineffective for pelagic trawl fisheries. The objective of this paper is to illustrate the inadequacies of minimum cod-end mesh size regulations in certain pelagic trawl fisheries.

Evidence is presented illustrating that size selection in lagic trawl codends diminishes as catch volume ıcreases, regardless of codend mesh size or mesh type. This reduced selectivity is due to increased mesh blocking with increasing catch volume. Underwater observations demonstrate that as catch starts to accumulate in the codend, exhausted fish quickly begin lining (or are pressed against) the codend walls. This mechanism of mesh blockage can take place several metres ahead of the eventual catch bulge, effectively preventing fish from reaching open and unobstructed meshes. Clearly, passive sieving of fish in the codend will not guarantee effective size-sorting. The blocking problems observed for codend meshes may be substantially reduced or eliminated by using special sorting devices in front of the codend, such as rigid sorting grids that permit adequate escapement of undersized fish before they reach the codend. Preliminary trials with rigid sorting grids in pelagic herring trawls have been promising.

The survival of escaping fish is also an important consideration. Selection is based on the fundamental assumption that escaping fish survive, but recent experiments show that small pelagic fish (such as herring .d vendace) managing to escape through cod-end meshes may be extremely vulnerable to the capture and escape process (i.e. mortality can be high). Most of the injuries and exhaustion experienced by small pelagic fish take place inside the codend and the rear funneling part of the trawl. The mesh size in the codends did not have a significant effect on mortality rates. Mortality of escapees was strongly dependent on fish size; the smallest escapees suffered the highest mortality.

Clearly, the usefulness of conventional minimum cod-end mesh size management in pelagic fisheries is questionable. Alternative methods for protecting young fish should be evaluated, such as sorting systems that provide conditions which stimulate undersized fish to try to escape and better facilitate escapement without causing damage to escapees.

Intrinsic quality and fisheries management: bioeconomic analysis of the Pacific whiting fishery

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Fisheries management often overlooks physiological changes caused by maturation, spawning, migration and feeding. For many marine species, such changes impact condition factors, proximal content and organoleptic properties. In turn, these intrinsic factors affect harvest yields, processor recovery rates and market value of harvested and processed products.

The Pacific whiting (*Merluccius productus*) fishery serves as a case study to illustrate the importance of intrinsic quality. Pacific whiting is the largest groundfish stock located off the west coast of North America south of Alaska. Contemporary management develops allocation formulas and annual harvest guidelines. Although a licence programme limits entry, industry capacity generates "Olympic" fisheries in which harvest is captured within weeks or months depending on the fishing sector. These early season and compressed fisheries raise concerns that quality and yield of processed products including surimi, fillets, headed and gutted and meal, are compromised due to the low intrinsic quality of the raw product.

A bio-economic programming model is developed to evaluate how alternative seasonal and allocation strategies impact management goals of conservation, efficiency and utilization. An age-structured biological submodel incorporates selectivities, fishing and natural mortality, migration, seasonal growth rates and stochastic recruitment. An intrinsic quality submodel includes information on recovery rates, qualities of processed products, and dynamic changes in protein, moisture, fat and condition indices. A market submodel shows the economic value of marginal improvements in surimi quality. An economic submodel summarizes information on the onshore and offshore industries including capacity constraints, sector costs, output prices and product recoveries.

The model selects monthly harvest rates and allocations which maximize Net Present Value (NPV) subject to resource conservation. The optimal solutions are compared with baseline models which represents contemporary management strategies. Assuming fixed allocation of 50% between onshore and offshore fleets, the baseline model generates US$120-150 million in NPV under early season fisheries. When seasonality information is included and allocation becomes a choice variable, the model selects late season strategies and generates between $200-285 million in NPV. Harvestable biomass increases between 5 and 10% leading to gains in NPV of $10-25 million. Protein content increases from 15% to 17%, moisture decreases from 84% to 81% and fat increases from 2% to 3%. These changes in proximal content and condition indices improve relative recovery rates from 6%, 12% and 20% respectively for meal, fillets and surimi, and generates an additional $50-70 million in NPV. Changes in proximal content also increase surimi

quality by improving gel strengths by 10-20%. Surimi prices consequently increase by $.08-$.16 per kg, which generates additional NPV of $20-50 million. Although the model allocates proportionally higher percentages to the offshore sector, total NPV increases only marginally.

Results show that stock size is conserved and that an additional 1.5 million fish are available annually to the ecosystem through natural mortality. Overall findings demonstrate that goals of conservation, efficiency and utilization are complementary. The results, however, suggest difficulties in micromanaging intrinsic quality and potential benefits of rights-based management approaches.

Study on the early life of skipjack tuna, *Katsuwonus pelamis*, in the tropical western Pacific

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In the life history of skipjack tuna, the ecology of juvenile and young stages is almost unknown compared with the adult stage. Because they have a relatively high capability for swimming, it is difficult to collect samples with the usual gear. Accumulating biological data on juvenile and young is necessary for the assessment of recruitment of adult skipjack in the western Pacific. Since 1992, the early life history of skipjack has been studied in the tropical western Pacific.

New collecting gear for juvenile and young skipjack has been developed through cooperation between TNFRI and Nichimo Co. Ltd. This was a large-opening and high-speed midwater trawl net of 71.6m in total length. The estimated net opening was 20m (width) by 18m (height). Maximum towing speed of the net was designed to be 5 knots. The stretched mesh size was 1000mm at the mouth, and diminished successively to 60mm at the codend. The inner net of 8mm mesh size was put inside the codend to collect samples. The midwater trawl survey was carried out from late October to early December in 1992 to 1994. The survey area was offshore of the Palaun and Micronesian islands in the tropical western Pacific. Midwater trawl sampling was conducted four times a day during daytime as well as at night. Each tow had a standard duration of one hour. The net was towed at different depth strata at each station. Ten strata were taken from surface to 200m depth. Towing speed was maintained at 4 to 5 knots.

Over 3,200 specimens of skipjack and 1,000 tunas, *Thunnus* spp. were collected by 327 tows of the midwater trawl net over three years. 324 specimens of skipjack were caught from 44 stations (1992), 1232 specimens from 62 stations (1993) and 1662 specimens from 57 stations (1994). The average catch per tow of skipjack increased remarkably – 3.0 (1992) to 10.2 (1993) and 17.0 (1994). The ratio of tows with skipjack to total tows also increased 40.7% (1992) to 51.2% (1993) and 58.2% (1994). The specimens consisted of various sizes of skipjack, from early juveniles to middle young stages. Standard body length of skipjack ranged from 15mm to 160mm (1992), 8mm to 149mm (1993) and 7mm to 172mm (1994). Specimens of early juvenile stage were more abundant, whereas young specimens collected were few. The catch of skipjack was greater at night than in daytime. Young skipjack were caught only at night. Skipjack distributed vertically from the surface to 200m depth. The most abundant depth was 100m-120m. *Thunnus* spp. were in shallower depths than skipjack. The difference in vertical distribution between skipjack and *Thunnus* spp. is similar to that of their larval stage. The vertical distribution of skipjack and *Thunnus* spp. tended to change with their life stage and was related to the development of their swimming ability.

Development of a multi-species, ecosystem model for managing fisheries resources in the Greater Prince William Sound

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The implementation of an ecosystem research programme in 1994 has allowed for the assessment of dominant marine plankton and nekton populations in Prince William Soun (PSW) Alaska. Three dimensional visualization shows the population distribution of walleye pollock, Pacific herring and macrozooplankton to be temporally and spatially dynamic. The variability observed in the distribution of these species suggests that stock assessment without knowledge of the population distribution is invalid.

Remote sensing with quasi-continuous samplers (optics and acoustics) is the only method that has the sampling power to determine the distribution of highly dynamic populations. New hardware, such as digital echosounders, and software for data analysis and visualization have reduced costs and advanced the resolution of processing information. However, the most costly aspect and weakest quantitative step of stock assessment continues to be the dependence on subsampling targets with discrete samplers (nets, traps etc.) to classify targets. Multi-frequency, time- and frequency-domain filters promise better signal classification tools in the future but until proven, subsampling with nets will remain a prerequisite for data interpretation.

In PWS, pink salmon (ca. 90% originate at hatcheries), Pacific herring and walleye pollock support the domina commercial fisheries. Exploitation rates are set independently of each other. Pacific herring and walleye pollock are year round occupants of the Sound and are competitors and predators with each other and the outmigrating salmon fry. In 1993, 1994 and 1995, the herring biomass was estimated to be 19,13 and 13 thousand t respectively. These biomass estimates of herring are believed to be historical lows. Since 1992, the marine survival of pink salmon fry has become erratic with several major failures reported by PWS hatcheries. In 1995, the walleye pollock biomass was estimated to be 38,000t.

Subsequent to the *Exxon Valdez* oil spill, there are major ongoing efforts to restore the herring population and improve the survival rates of pink salmon fry from hatcheries in PWS. One possible strategy of restoration is to design exploitation rates on the three dominant species to favor a particular outcome. In this case, a higher exploitation rate on pollock may enhance survival rates of both herring and pink salmon which are targets of restoration. The capability to track these populations with accurate assessments is an advantage of adopting a multi-species approach. However, the disadvantage is that there are no models that can accurately predict outcomes. A first generation model is presented that simulates several possible exploitation scenarios given present biomass conditions.

It is time for fisheries science to implement the large scale use of remote sampling to improve the accuracy of stock assessments. Improvements in measurement data are a prerequisite to the development of numerical models and monitoring programmes that can make better predictions. Sustainable development of fishery resources depends upon improving an ability to predict population changes.

Stock assessment of southern rock lobster (*Jasus edwardsii*) at Apollo Bay, Victoria, Australia

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This project has studied the suitability of using the Change-In-Ratio (CIR) and Leslie methods, tagging and SCUBA surveys to determine the stock size of southern rock lobster (*Jasus edwardsii*). The first part of the project has involved llecting empirical data from Apollo Bay to use in these methods and to investigate their assumptions.

Surveys in shallow areas using SCUBA divers to count lobsters produced density estimates that were imprecise due to the patchy distribution of lobsters and lobster habitat. Subjective assessment of the amount of suitable habitat within quadrats was made in later dives and could be used to increase survey precision by allocating searching effort to quadrats where lobsters are more likely to be found.

Because there is a minimum legal length for *J. edwardsii*, legal-size lobsters are removed from the population during the fishing season. The CIR method uses the change in the proportion of legal-size to undersize lobsters from a known removal of legal-size lobsters to calculate abundance. The proportion of legal-size lobsters in the catch was obtained from observations onboard a commercial lobster fishing boat. The number of legal-size lobsters removed was obtained from these onboard observations and from interviews, tag-recapture and catch per unit of effort (cpue) data. Tagging showed that the sampled population can be assumed to be closed to immigration and emigration. There as moulting of undersize lobsters to legal-size during ampling, violating an assumption of the CIR method. Moult probabilities will be estimated and incorporated into the CIR calculations to eliminate this bias. A preliminary CIR analysis (without allowing for moulting) resulted in a density estimate much lower than that obtained from the SCUBA surveys; however, the SCUBA surveys may have selectively targeted areas of high lobster density.

Monthly cpue data from commercial fishers' log-books (modified to account for discarded legal-size female lobsters that were still carrying eggs at the start of the season) were used in Leslie depletion analyses. Because there is a drop in catchability (primarily of females) late in the season, due to the mature female moulting and reproductive period, data from this time were not included. The Leslie analyses suggest a lower drop in stock size than the annual cpue trend indicates and catchability estimates show a decreasing trend over time even though fishing power is assumed to have increased due to the introduction of colour echo sounders and GPS (Global Positioning System). A higher level of trap saturation or inter-fisher competition early in the fishing season in later years when fishing power would be highest could have produced smaller than expected decreases in CPUE through the season, resulting in underestimates of catchability and overestimates of stock size for more recent years. Improvements to this method may come from using auxiliary information on pot competition and soak-time, sex-ratio, moult-timing, water temperature and weather patterns in an analysis where catchability is not assumed constant through the season.

Estimation and prediction of growth heterogeneity in the context of fish stock assessment problems

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For an adequate fish stock assessment the problem of accuracy of estimation of size distribution of individuals in the population is a basic one. For commercial species, fishery mortality is defined by minimum legal length or size-specific selectivity of fishing. Therefore, the accuracy of prediction for catch depends directly on the precision of modelling of the population length heterogeneity.

Heterogeneity of length in the population is caused by a number of factors, just some aspects of which are considered here. Heterogeneity of growth can be caused by variation in environment or genetic differences and obviously, that type of heterogeneity of growth in a population has a "systematic character" and can not be adequately described in terms of precision of measurement.

Individual histories of growth are considered as realisations of a random process that has one dimensional distribution F(x,t) of length x in a cohort in time t. However, different random processes can have the same one dimensional distribution. Sequentially, different models of individual growth can give us the same model (distribution of length) for population. This means that in most cases population growth data do not provide enough information for testing hypotheses about individual growth. This paper emphasises the study of growth at the population level. All our assumptions relate to properties of F(x,t). Any additional hypotheses about individual growth are acceptable, and the only minimum requirement is: it should not be in contradiction with the properties of F(x,t). Similarly, in the case of a (more conventional) deterministic growth model, the growth function is also not a representation of individual growth, but a model of the growth of the biomass.

For modelling of growth using ageing or tagging data special conditional and unconditional density distribution functions are used. Deterministic growth functions with random growth parameters are used for building the models. The general properties of growth models in the form of density distribution functions are described. Using examples with the Weibull, Gamma and Log-Normal distributed von Bertalanffy growth rate K the sensitivity of the stochastic parameterisations is shown with respect to growth heterogeneity in the population.

For numerical demonstrations ageing data for gummy shark vertebrae ring growth (from T. Walker, VFRI) and tagging data for a *Haliotis tubra* Abalone (H.rubra) (from H.Gorfine, VFRI) were used. Examples of these data are used to explicitly show size of error which is caused by using expected values of growth parameters for estimation and comparison of biomass growth for populations with high growth heterogeneity.

New simple, informative indices for comparison of population in growth and the management of fish stocks are proposed. The prime outcome of this study is; development and testing of new mathematical tools for significant improvement of accuracy in assessment and prediction of fish stock for populations with high level of growth heterogeneity.

How far do prawns and fish move into mangroves? Distribution of juvenile banana prawns, *Penaeus merguiensis*, and fish in a tropical mangrove forest in northern Australia

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It is accepted that mangroves are important nursery areas for prawns and fish, including some of major commercial importance. However, in many countries, mangroves are still being destroyed for woodchip production, aquaculture, housing and tourism. Banana prawns, *Penaeus merguiensis*, contribute to many important commercial fisheries throughout the Indo-West Pacific and their juvenile stages are found mainly associated with the mangrove-lined areas of rivers and creeks. In the Gulf of Carpentaria, northern Australia, the size of the commercial catch of adult banana prawns in offshore waters is correlated with the length of mangrove-lined rivers adjacent to the fishing grounds. However, there are some deviations from this relationship which may be related to differences in the type of mangrove habitat. In fact, very little is known about how these mobile animals use the mangrove forests. In this study, the aim was to find out how far prawns and fish moved into mangrove forests and whether they preferred particular mangrove types.

The distribution of juvenile banana prawns and fish in a broad riverine mangrove forest adjacent to a small creek in northern Australia was recorded in November 1992 and in March 1993. Four discrete areas of the forest were enclosed with a 100 m long, 2 mm-mesh stake net: two at the creek mangrove fringe and at two further distances into the mangroves. The mean distance of each sampling site inland from the creek mangrove fringe ranged from 13 to 59 m and the area of the sites ranged from 480 to 640 m^2. Two mangrove communities, one dominated by the structurally complex *Rhizophora stylosa*, the other by the more open *Ceriops tagal*, were sampled.

A large size range of juvenile prawns and small fish moved at least 43 m into the mangroves at high tide, and the density of prawns near the creek mangrove fringe was inversely related to the maximum tide height. The highest density of juvenile *P. merguiensis* recorded in the mangroves in November was 18.3 prawns 100 m^{-2} and in March was 334.5 prawns 100 m^{-2}. The mean fish density over all samples was 83.0 fish 100 m^{-2} and the mean fish biomass was 3.9g m^{-2}; 55 species of fish were caught during the sampling. *Penaeus merguiensis* showed no apparent preference for either of the two mangrove communities sampled; however, more fish (101 fish m^{-2}) and more fish species (26) were caught at the creek mangrove fringe site than at the other more inland sites; the lowest number of fish (27 fish m^{-2}) and species (13) were caught at the inland site (*Ceriops*). On average, fish caught at the fringe site were also longer and heavier than fish caught at other sites. By morning, well into the mangrove forest, prawns and small fish are probably less vulnerable to predation by larger fish. Although the type of mangrove does not seem to influence the prawn's distribution, small prawns and fish are clearly using large areas of the mangrove forest.

Assessment of stocks of sea mullet (*Mugil cephalus*) in New South Wales and Queensland waters

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The sea mullet (*Mugil cephalus*) is a very important fis species in Australia and worldwide. In Australia the commercial catch averaged approximately 6000 t per annum during the past 10 years. Most of this catch was from the east coast with ~3000 t (50%) from New South Wales and 2500 t (42%) from Queensland. In these States the sea mullet catch is the largest amongst finfish species. Another ~500 t (8%) of the catch was from Western Australia and less than 1% from the rest of Australia.

A preliminary assessment of catch statistics from New South Wales indicates that while the estuary catches have remained stable at approximately 2000 t, the ocean beach component of the catch has increased substantially from approximately 500 to more than 1000 t in the past 10 years. The ocean beach component of the fishery targets the pre-spawning sea mullet which travel in ocean waters during autumn and winter. The increase in catch of these pre-spawning sea mullet is driven largely by the developing overseas markets for sea mullet roe.

In January 1995, a two year research project on sea mullet in New South Wales and Queensland commenced. This is a joint project involving the New South Wales Fisheri Research Institute and the Queensland Southern Fisheries Centre. Also the project has federal funding from the Fisheries Research and Development Corporation. The main justifications for the project are that (1) the sea mullet is commercially important, and (2) there is a need to examine the possible impact of the increases in ocean beach catches on the stock. The project aims to collect information for stock assessment, to compare the value of different components of the fishery and to calculate the social and biological impact of alternative management regimes. To achieve these objectives the project is to estimate the value of various components of the fishery and collect biological information on the growth and reproduction of sea mullet, the age structure and sex ratio of commercial catches, and trends in the catch and fishing effort.

Important sources of catch and effort information include departmental, fishers' cooperative, and buyers/processors records. Departmental records in New South Wales contain data on total catches for at least the last 40 years and have the potential to provide useable effort data, particularly for the last 10 years.

Otolith sections are being used to age sea mullet. Many show clear growth rings and appear to be more reliable than scales, even though scales have been used in most

previous studies on sea mullet. Also, early results indicate that otolith weight has the potential for estimation of age.

A tagging study has revealed northern and southern movements of sea mullet on the coast of New South Wales. In a previous tagging study by the Commonwealth Scientific and Industrial Research Organisation, only northern movements of sea mullet were recorded on the coast of New South Wales. The movements recorded in this study have implications for stock identity and management of the fishery.

This project is providing information for stock assessment and comparison of alternative fishery management regimes for sea mullet in New South Wales and Queensland.

Squid stocks in south-east Australian waters

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Catches of arrow squid, *Nototodarus gouldi* (Cephalopoda: Ommastrephidae), achieved record levels in south-east Australia and New Zealand in the 1994/95 season. Australian industry interest in the resource reached a peak, with increased effort from trawlers and jiggers. In Portland, Victoria, fifteen jig vessels operated during summer, with rates of up to 9t per vessel-night and an estimated season's catch of 1,100t. In south-east Australian waters, the 1993 recorded annual catch of squid (estimated to be about half the actual catch) was 400 t from jigging and 500t as trawl bycatch. Domestic catches to date have been considerably below the 1980 foreign catch of 8,839t, suggesting under-utilisation of the squid resource in south-east Australia. Foreign nationals are requesting access to squid in Australias Exclusive Economic Zone, highlighting the issue of fishing rights to an under-utilised resource.

As controls are tightened on the sixteen quota species in the South East Fishery, non-quota species such as squid are attracting increasing attention. In addition, fishers have redirected their effort from collapsed fisheries such as scallops in Port Phillip Bay, Victoria, to jigging for squid. This raises the question of the scope for development of the wild stock squid fishery. The current trend of rapid increase in squid catch is occurring in the absence of any knowledge of the potential yield from the resource, although the quota is nominally set at 10,000t.

Squid are caught by many sectors, including trawlers, seiners, jiggers, gillnetters and longliners. Squid are a pivot in the food chain, being food for species such as southern bluefin tuna, sharks, seals and seabirds, and predators of myctophids and krill. These complex interactions in the shelf ecosystem need research to assess the implications for other fisheries of increasing the squid harvest.

Marketing and processsing aspects of the squid fishery were previously an impediment to developing the resource. Recent value-adding and new post-harvest technology have quadrupled the return to fishers. Australia imports about 5,000t of squid annually, mostly *Nototodarus gouldi* from New Zealand. Import replacement is an issue for developing the domestic squid fishery. Fishing for *Nototodarus gouldi* in New Zealand may have implications for management in Australia as it is unknown whether the same stock is shared by the two countries.

Issues of developing and sustaining the fishery are raised by the under-utilised state of the squid resource in south-east Australia. There is little knowledge about the ecosystem being harvested and its trophic linkages. Fishing effort has shifted rapidly to squid from quota species and overfished resources. The state of the squid resource requires rapid evaluation and management for its sustainable exploitation.

A bioeconomic analysis of seasonal closures in Australia's multispecies northern prawn fishery

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In Australia's Northern Prawn Fishery, seasonal closures are used to manage the size composition of the commercial catch. While primarily aimed at short-term economic benefits of improved yield per recruit, they are also used to help reduce the risk of recruitment overfishing. Until recent years, seasonal closures took the form of a single closed season in late summer to protect juvenile banana prawns *Penaeus merguiensis* during months of peak recruitment. However, with the growing commercial importance of tiger prawns, *P. esculentus* and *P. semisulcatus,* and concern for their recruitment overfishing, a second mid-year closure was introduced to further protect sub-adult tiger prawns until their main spawning season, which begins in August. In this paper, we use a simulation model of the Northern Prawn Fishery to assess the biological and economic effectiveness of seasonal closures, specifically in yield, income, net operating income and spawning stock indices. Because there is no reliable spawning stock-recruitment relationship, recruitment was assumed to be constant; thus analysis was effectively per recruit. Our base model, with closures between 1 December and 1 April and between 25 June and 1 August, closely resembles the current seasonal closure regime in the fishery. Using this model, net operating income was found to increase by 3.7% with a single closed season between 28 November and 14 April, but tiger prawn spawning indices reduced by an average of 5.6%. A single closed season between 13 December and 8 May retained the same protection on sub-adult tiger prawns as the base model, but increased the net income by 2.3%. Net operating income was relatively insensitive to closure dates; any opening date between 17 March and 2 June would result in net operating income within 5% of the maximum.

Applying bioenergetic models to fisheries management: a simulation of prawn consumption by juvenile barramundi

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Background: An understanding of trophic interactions can suggest options for fisheries management in cases where both predator and prey species are commercially important or where the predators compete for prey with human fisheries. Studies of predatory impact involve assessments of the densities, diets and consumption rates of predatory species. While information on densities and diets can be

obtained by field sampling, accurate estimates of meal size and feeding frequency are harder to acquire. Attempts to deal with this problem include making an assumption that fish predators eat a constant percentage of their body weight per day, or extrapolating consumption rates from the laboratory to the field. An alternative approach is to use bioenergetic models to estimate consumption rates under field conditions. Advantages of this method include gains in accuracy which accrue when observed growth trends are used to constrain consumption estimates, and the possibility of modelling dynamic changes in consumption in response to variations in prey availability and abiotic conditions. Recent years have seen several applications of bioenergetic models to fisheries problems, but these have been confined largely to freshwater systems of North America.

Objective of the present study: To simulate seasonal trends in the consumption of penaeid prawns and other prey by a "typical" barramundi growing through the first year of life in the Gulf of Carpentaria. Surveys indicate that the barramundi (*Lates calcarifer*) is one of the main fish predators of commercially important prawns in northern Australian estuaries, but there have been few studies of the impact of fish predation on juvenile prawns in estuarine environments.

Findings: (i) The specific consumption rate of barramundi decreased sharply in early life but stabilised at c. 3% body weight / day after 6 months. The stabilised rate agreed with a constant value of 3% assumed in previous studies, but such an assumption is likely to significantly underestimate the consumption rates of young fish below c. 250 g weight or 280 mm total length.

(ii) Absolute consumption of penaeids and other prey rose linearly through the first half of the year. Consumption then dropped to c. 80% of the June peak in July-October (this drop coinciding with a seasonal depression in water temperature), with a partial recovery to c. 90% in November-December.

(iii) Barramundi fed at 40-50% of their maximum possible rate for most of the year, with an increase to 68-77% in March-May. This rise, and an associated acceleration in growth rate, probably reflect a higher availability of preferred prey at this time.

Key conclusions: Previously assumed mean consumption rates are supported. Predation by young barramundi on penaeids is likely to be particularly intense in late summer and autumn, when juvenile banana and tiger prawns emigrate from protective nursery habitats. Further modelling of the impact of predation on prawn populations by different age classes of barramundi is continuing.

Comparison of molecular genetic techniques for assessing the global population structure of yellowfin tuna

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Yellowfin tuna (*Thunnus albacares*) forms the basis of important fisheries in the tropical and subtropical regions of the Pacific, Atlantic and Indian Oceans. The total catch per annum exceeds one million tonnes. The principal objective of the research was to determine the genetic population structure of this valuable species with the aim of assisting sustainable management.

Samples were taken throughout its range, from the Atlantic (one region), Indian Ocean (two regions) and Pacific Ocean (six regions). Samples ranged in size from about 20 to more than 150 individuals: the average was around 90. These samples were analysed for variation at polymorphic allozyme and microsatellite loci, representing nuclear DNA variation, and for mitochondrial DNA variation. The results of these three different genetic approaches were used to assess population relationships and also compared to determine their relative abilities to discriminate populations of a migratory, globally-distributed, pelagic species.

The data are consistent with a minimum of four different stocks – Western/Central Pacific Ocean, East Pacific Ocean, Indian Ocean, and Atlantic Ocean.

Fishing characteristics of tuna longlines – from theory to practice

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Longlining is a fishing technique used to catch non-surface pelagic species, most commonly tunas. While all tuna species have a widespread distribution, fishers usually rely on a number of techniques to target the preferred habitats of each of the target species. These techniques include the use of sophisticated electronic equipment to locate the desired water masses, together with the ability to set the longline at the assumed depth of the targeted species. Previous studies have found that the various tuna species have definite temperature preferences and that they carry out both horizontal and vertical migrations to stay within their preferred temperature ranges. A fisher's skill is therefore based on having an understanding of these preferred temperatures together with a knowledge of the depths at which they occur and an ability to set the longline accordingly. Fishing depths of longlines can be calculated theoretically based on the catenary configuration they assume under the action of gravity alone. However, in a buoyant medium such as water and under the influence of ocean currents the ultimate configuration of a longline often uncertain. The problem of understanding the fishing depths of longlines is furthermore being made more difficult with the introduction of new lightweight monofilament gear. These new gears are less likely to obey the principles under which the traditional gears were operated.

In order to compare the present understanding of the deployment of longline gear and the targeting of tuna species and with the actual operational characteristics of such gear, small hook monitors, which can measure depth, time and temperature, were attached to the hooks of longlines. A variety of vessels and locations were used, ranging from Australian domestic longliners targeting yellowfin and bigeye tunas in the Coral Sea to Japanese longliners fishing for southern bluefin tunas off Tasmania. Results show that in most instances, depending on the type of line and deployment techniques, the hooks were fishing deeper than expected. The depth of individual hooks was also found to vary considerably with time. In many instances the hooks fished the maximum depth for only a relatively short time and then gradually rose through the water column, effectively taking them out of the targeted fishing depths. Fishing depth, water temperature and capture species were found to be correlated. However, fishers' understanding of the optimum depths at which the various tuna species occur was often found to be incorrect.

By helping to gain a greater understanding of the fishing characteristics of longline gear and the vertical distribution of tuna species, the results indicate that by altering the deployment of longlines the catch of targeted tuna species can be optimised. At the same time, this knowledge also enables fishers to specifically avoid particular depth and temperature regimes in order to minimise the bycatch of unwanted species, such as billfish species, important to the recreational fisheries.

The falling velocity of cuttlefish eggs in water

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Basket traps are used to capture mature cuttlefish (*Sepia esculenta*) in south west Japan. The cuttlefish lay their eggs on structures on the seabed and consequently by the end of the fishing season the basket traps and/or attached tree ' ranches are covered with many cuttlefish eggs. The eggs, nich are usually scraped off the traps by the fishers, are thrown back into the water over the fishing ground.

This research was aimed at clarifying the relationship between the falling velocity of the eggs and the weight and size of the sand/shell particles that adhere to them. Because comparatively fast water currents occur over the fishing ground it is important to know how quickly the eggs will reach the bottom because if they fall too slowly they may be swept off the fishing ground and lost to the fishery.

The test eggs were collected from the basket traps between 31 January 1995 (early in the fishing season) and 23 June 1995 (the end of the fishing season). Two experiments were made. These aimed at determining the terminal velocity of the eggs with and without attached eggs and to measure the size of the sediment particles adhering to the eggs.

The long and short axes of the eggs were measured and the eggs were weighed in water. The rate of falling in water was recorded by videotaping the test eggs falling in a cylindrical water tank marked at 5 cm intervals, then calculating the time required (1/30 sec) to pass every vertical mark. The sediment as analysed by both the pipette and wet sieving methods.

Some of the results are as follows:

1. The long and short axes of the eggs measured 15.8 and 9.7 mm respectively when sand was attached and 12.3 and 7.1 mm respectively when no sand was present.
2. The median/mean diameter of the sand covering the cuttlefish eggs was 1.85 mm (skewness 1.5) with shell particles, and 2.4 mm (skewness 0.81) without shell particles.
3. Terminal velocities of the eggs were approximately 14.1 cm/s with sand attached and 7.3 cm/s without sand.

From these data it was estimated that the eggs would take about ten minutes to reach the seabed. If, after settlement, the eggs remain and develop on the fishing ground then the scraping action of the fishers plays an important role in sustaining the cuttlefish fishery.

The pot fishery for cuttlefish (*Sepia esculenta*) in Nagasaki, Japan

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The pot fishery for cuttlefish has operated extensively in Nagasaki, located in south-western Japan. The main fishing ground is in the inland sea, in Shimabara Bay and Omura Bay. Cylindrical pots with one entrance at the side are widely used to capture *Sepia esculenta*. The pots are constructed from framework with a cover net with 48 mm mesh (two bars). The fishing period is mainly from March to May. The contribution of this species to the total catch is over 90%.

The amount of catch is closely related to the lunar cycle with a maximum at neap tide, or ebb, and minimum at spring tide. The tidal current at the fishing ground is one of the most important factors to control the entry behaviour of individuals into the pot. The peak catch appears after three days. It can be assumed that there is an optimum length of set days to increase the catch.

It was found that the pot fishing method employed for cuttlefish is very appropriate. This report provides an example of how the potting method for cuttlefish has been optimised for effective utilization of this species in the inland sea ecological system.

Utilization of *Leiognathus equulus*, a low-value fish species, in fishball processing

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Low-value fish make up to a sizeable proportion of the total catch landed in Malaysia. One of these species is ponyfish. Three species of ponyfish are usually caught, mainly off the northern coasts of peninsular Malaysia. These are *Leiognathus bindus, L. splendens* and *L. equulus*. The usual practice is to render these species into animal feed or as fertilizer, although occasionally, the fish is processed into salted-dried fish. The highbone content of ponyfish limits its usage as fresh fish. Of the three species, *L. equulus,* the common ponyfish, is the largest in terms of size and is the most commonly caught. The aim of the present study is to increase utilization of *L. equulus* by its incorporation into the formulation of an existing fish product , fishballs, and to examine its effect on quality and acceptability. *L. equulus* was substitued for *Nemipterus tolu* in the fishball formulations. The ratios of *N. tolu : L. equulus* used were 100:0; 95:5; 90:10; 85:15; 80:20 and 75:25. All formulations contained 5% potato starch, 3% salt, 0.2% sodium tripolyphosphate, 0.2% monosodium glutamate and 25% ice. Sensory evaluation was carried out on colour, flavour, texture and overall acceptability with 20 experienced panelists using a Hedonic scale of 1 to 9, 9 for'like extremely' and 1 for 'dislike extremely'. Results were analysed using analyses of variance. Gel strength and

springiness were measured using an Instron UTM (Model 1140) and the folding test respectively.

Results from sensory evaluation showed that fishballs containing *L. equulus* were acceptable up to a substitution level of 15%. At 20% substitution and above, there were significant differences in texture and overall acceptability. Gel firmness and springiness values were also significantly different at 20% substitution and above. Springiness, as measured by the folding test, also declined. Samples containing 20% of *L. equulus* had a folding test grade of A, which meant that there were slight tears in any one of five samples tested when folded into quarters. This grade is short of good commercial grade products, which should have a folding score of AA. This would denote that the gel strength of *L. equulus* is considerably weaker than that of *N. tolu,* which is the commonly-used species in fishball production, mainly due to its good gel strength and whiteness of flesh. Although the use of *L. equulus* is limited by its weak gel strength, nevertheless, it can by incorporated up to a level of 15% without significantly affecting product quality. Incorporation of *L. equulus* would reduce costs as it is a cheaper species compared to *N. tolu.* No significant differences in moisture , protein, fat and ash contents were observed among all formulations used. The recovery rate of flesh from *L. equulus* is lower than that of *N. tolu,* at 24.9%.

Fisheries management and sustainability: a new perspective of an old problem?

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Numerous prescriptions for improved management of fisheries have been given since the diagnosis (and prognosis) established by Graham (1936). The overall results have been very disappointing and the situation in world fisheries calls for urgent change in both government's and fishery sector's attitude and policies, in fishery research priorities and agendas, in institutional and legal frameworks (e.g. promoting or establishing use rights), in the level of participation and accountability of the fishery sector in decision-making, in the level of commitment to long-term conservation and to more precautionary approaches to fisheries development.

The paper nests its approach to responsible fisheries management in the context of sustainable development and in line with the spirit of United Nations Conservation and Environment Department (UNCED). It briefly addresses the macro-economics and environmental questions of fisheries, with the issues of property, access rights, discount rates, uncertainty, economic incentives and disincentives, technology transfer, human capital and investment policies, institutional arrangements, environmental degradation and conservation. Based on a broad-brushed diagnosis of the present situation of the world fisheries, and recognizing their diversity, the paper identifies the approaches available for more responsible fisheries management and development and the conditions for their improved implementation.

These approaches include harmonization between fisheries and environment management objectives, improved control on reduction of fleet sizes, more explicit allocation of resources, rights, responsibilities, better accountability, reduction of waste and threat to the resources and environment, generalization of the precautionary approach, better cooperation on transboundary resources, improvement of information on and increased transparency in fishing operations, more active fisher participation, better account of other competitive uses of the aquatic resources and environment and innovation in ecosystems rehabilitation and enhancement.

How to achieve sustainable fisheries development in a developing country – a look at some of the possible solutions: the case of Mexico

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The central question this paper tackles deals with the special problems of how to achieve sustainable fisheries development in a developing country. That is, how to implement a complex concept – developed for the most part in developed countries – in a setting in which the overall lack of financing, organisation, research, information flow, legal framework and enforcement is the rule.

We analyse the case of Mexico as an example. Mexico is a developing country with more resources than most such countries but with acute social problems and over-population pressures; it is also under extreme international pressure regarding the environment from neighbouring countries. The most important steps the country has taken and some of the results are described below.

First, fisheries at the federal government level was made part of a new, large secretariat that also includes natural resources and the environment. This forces the environmental variable into fisheries thinking and changes the perception that fisheries has no social interaction of consequence for sustainability. Together with these changes, the agency in charge of research (INP, National Fisheries Institute) was restructured and promoted, legally and financially, to a level comparable to that of the fisheries management branch but with the specific charge of an advisory body, whose best-science based advice is always (by design) taken into account. Also, enforcement is now a separate agency independent from both research and management, and in charge of all environment and natural resources' law enforcement. This promotes confidence both in research and in the management agencies.

These changes, together with a long-standing policy of the Mexican Government in support and international promotion of responsible fishing, the precautionary approach, regulations regarding high-seas fishing, and keen attention to aspects of adaptive management, have led to the development (with major input from INP) of a fisheries plan for the years 1995-2000. The plan focuses on efficiency, diversification, integral views and quality rather than in increasing production alone. One of its cornerstones is a specific mandate to strengthen applied fisheries research, both within the government and elsewhere in the country.

Now given these changes, the key issues are:

- How to reach a balance between development and conservation
- How to reach a workable definition of sustainable development in fisheries
- How much and what kind of fisheries research is appropriate to reach this goal
- How to take legal and management measures in the face of incomplete information – a situation so prevalent in developing countries
- How to make the society aware of these problems and how to manage so that all users have an input into management decisions

To look at these questions and to assess how these policy changes are shaping fisheries management, several fisheries in Mexico are reviewed. Particular emphasis is given to the most important fishery in Mexico, the shrimp fishery where the start and the closure of the seasons have been reached, under the guidance of the INP, by means of user consensus the last two years, producing a favourable balance for the resource and increased earnings for both artisanal and industrial fishermen. Other fisheries are also analysed, ranging from the almost complete open-access (tuna fishery) to the almost private property case (sea-urchin concessions) and the very difficult to regulate (because of social pressure) coastal shark fishery.

Quantifying hook-release mortality in marine recreational fisheries: working toward more effective fishery management

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Hook-release mortality research on marine species is providing fishery managers with better data on this highly variable component of overall fishing mortality. Research documenting release mortality rates from <5% to 70% in laboratory and field studies was reviewed during a May 1995 conference in the USA. Results of over 24 research projects also provided evidence that marine fish release mortality rates often can be relatively low (<20%) with variation largely attributed to the hooking site in fish, associated bleeding, water temperature/DO, capture depth, fish size, hook size/type and salinity (in estuaries). Continuing research in the USA on *Paralichthys dentatus* (summer flounder/fluke) and *Cynoscion regalis* (weakfish/gray trout), as well as USA/AUS work on *Pomatomus saltatrix* (bluefish/tailor), all supporting significant recreational fisheries, adds further support to the conference's findings.

Tank and field fishing experiments determined that significant flounder hook-release mortalities happened only in deeply-hooked fish, i.e. hook embedded in posterior mouth-tongue-oesophagus or gill tissue, such mortalities primarily occurring within 1-24 hours after release. Hook site and resulting bleeding rate were the only significant variables versus fish length (166-467 mm TL), hook type and removing/leaving hooks in place. Field experiments documented 10-25% of captured flounder were "deeply-hooked", producing overall release mortalities of 6-17%. Possible relationships between water temperatures of 22-24°C and higher release mortality versus mortality at 15-17°C (tank trials) were neither statistically confirmed nor supported by field results.

Size limits on weakfish in the USA do not include data on angling release mortality in sub-legal fish (304-406 mm TL). Weakfish (300-453 mm TL) captured by anglers from fishing piers and held 72 hours in aerated tanks exhibited a mean release mortality of 2.6% with no significant difference between fish taken on natural versus artificial baits.

Bluefish/tailor research documents release mortality in hooked fish of about 3% (shore fishing-AUS) and 5-7% (charter fishing-USA). In Western Australia controlled field experiments indicated 1-10% hook-release mortality (2 hour tank observations) depending primarily upon fish size (1+,2+,3+ cohorts) and hook type, with older fish exhibiting highest mortality. Higher mortality may be associated with more severe injuries in fish having greater rates of hook ingestion and damaged gills. Mortality was significantly greater in fish taken with large "gang hooks" fitted with a trailing treble hook. Highest mortalities (10-18%) occurred in fish with deep wounds to the throat and gills versus jaw/eye injuries, similar to the USA findings.

'No-take' marine reserve networks support fisheries

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'No-take' marine reserves offer a new and additional form of fisheries management. Such reserves avoid detailed arguments about 'allocation' and 'proof of damage', and allow non-specific but strong support for stocks, habitats and ecosystems. The first 'no-take marine reserve in New Zealand was established in 1977. A further ten have been added in the past five years, and at least 25 more proposals are under active public consideration. A representative network is now the official aim.

To date, the promotion and use of marine reserves has come mainly from marine scientists, divers, conservationists, teachers, tourists, and the general public. Most fisheries scientists and managers have remained skeptical or uninterested. This could change rapidly, due political pressure or professional recognition of the opportunities. All major political parties in New Zealand now propose "more marine reserves" and most are suggesting "10% by the year 2000". Despite the application of many stock-specific management techniques, it is officially recognised that many N.Z. fisheries have serious problems, and new ideas are needed.

Data-based, stock-specific fisheries management, focused on the interests of existing user groups, is a political and practical necessity. However, the history of resource management and recent events in fisheries indicate that this approach is not sufficient. Concentrating on the effects of existing activities distracts attention from the intrinsic properties of the ecosystems, and prevents consideration of other values or different uses. Furthermore the standard approach inevitably suffers from 'infinite regression', with more-and-more data being required to predict increasingly precise questions.

Well-understood business systems have many types of insurance, that operate in different ways. Insurance assumes uncertainty, ignores detailed causation, and concentrates c preventing damage without specific prediction. Its succes depends on the perception of risks, not on knowledge of causes. The multiplicity of fishery regulations obscures (i) their focus on stock-specific dynamics – a very narrow base; (ii) the need to demonstrate damage to stocks – which prevents proactive management; and (iii) the assumption of fishing rights – which precludes natural baselines and promotes 'brinkmanship' (e.g. maximum sustainable yields).

Until recently, non-involvement in fishing meant non-interest, except in the price of food fish. However, as has already happened in forestry and mining, the environmental views of the general public are becoming significant. 'No-take' marine reserves appeal to the lay public as a form of insurance, not because they doubt the skill of fisheries scientists and managers but because they believe their aims are too narrow. Such ideas are reinforced by the discovery that fisheries management is not always successful even in sustaining fisheries.

If fishery scientists and managers upgraded their status to 'public guardians of all marine life' (which they earlier held by default), they could escape from the problems of extreme specialisation, promote 'no-take' marine reserves as sensible form of insurance, and earn the active support of an increasingly-concerned general public.

Sustainable coastal area development: a framework for sustainable fisheries

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In the Philippines, more than half the population is concentrated in the coastal area. Coastal communities and fishers belong to the lowest income groups in spite of its 4% contribution to the country's GNP. Policy environment promotes overexploitation of resources and marginalization of fishing communities. Such policies have led to the degradation of coastal and marine habitats.

Several studies made by the Tambuyog Development Center (TDC) since 1991 revealed major realizations and insights. Coastal communities and fishers are caught in a vicious cycle of poverty and resource degradation. The marginalization of these communities is brought about by iniquitous power and property relations and reinforced by policies that threaten traditional forms of controlling and managing coastal resources. Marginalized coastal communities, having the biggest stake in coastal resources, are potentially the best resource managers. Property rights assignment is a key issue in the management of coastal and marine resources and conservation of biodiversity.

With this in mind, TDC developed the Sustainable Coastal Area Development (SCAD) Programme which envisions organized and self-reliant communities that control and manage coastal resources for a sustainable national development.

The programme hopes to facilitate the establishment of community structures and organizations of men and women that shall pursue area-based, sustainable development to address the lack of access and control of the community over their resources (both land and water) and the benefits that come from them. It also hopes to mitigate poverty through cooperation, self-help and shared responsibility.

Lastly, it hopes to lessen conflict between and among resource users and facilitate the community's active participation in the decision- and policy-making processes and development efforts in the community.

Tambuyog has identified five principles of SCAD-Community-Based Coastal Resources Management (CBCRM). These are empowerment, equity, sustainability, system-orientation and gender-fairness. The bundle of rights as components of CBCRM include use rights, exchange rights, distribution entitlements and management and authority schemes. Scoial technologies so far developed within the programme are formal and informal structures – Community Organizations, Resource Management Cooperatives and Resource Users' Forum. This highlights Tambuyog's framework for sustainable fisheries as implemented in three coastal communities in the Philippines.

Management regimes for the main Greenland fishery resources

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The most important fisheries in Greenland waters are offshore shrimp fisheries and deepwater fisheries for redfish and Greenland halibut conducted by a modern stern trawler fleet equipped with production facilities onboard. Also an inshore fishery for Greenland halibut comprises a significant economical component of fisheries in Greenland. The basis for scientific advice on the resources is achieved by the Greenland Institute of Natural Resources, and management advice is conducted through the international bodies ICES and NAFO. For the shrimp fishery, the largest fishery in the world on cold-water shrimps, annual TACs are distributed as a percentage-of-the-total-TAC-quotas amongst the shipowners who have a license to fish and allocated on management areas. The quotas are transferable, thereby reducing the role of the authorities in the further regulation of numbers of ships etc. The TACs for offshore fisheries for redfish and Greenland halibut are allocated yearly on management areas to fully licenced shipowners as quotas in tons, which are not transferable. All fisheries are mesh size regulated and further limited by boxes to protect juveniles. The inshore fishery for Greenland halibut is only regulated by means of gear limitations for certain areas, mostly restricted to use of longlines. The harvesting strategy for all fisheries on Greenland halibut is moving towards use of longlines, considered the most responsible way of harvesting.

Conservation when fisheries collapse: the Canadian Atlantic experience

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Atlantic Canadian groundfish fisheries used to be an important industry, with landings around 600,000 t/yr, and providing income to more than 60,000 persons annually. From a peak of 760,000t in 1986, landings constantly decreased and, among the twenty-one major stocks, eleven had to be closed to direct fishery. Recognizing that the "classical" management system was unsuccessful, the Canadian Government created, in 1994, an independent advisory body, the "Fisheries Resource Conservation Council" (FRCC), which is composed of academic researchers, fishery stakeholders, provincial delegates and representatives from the Department of Fisheries and Oceans. The objective of the FRCC is to recommend conservation actions to rebuild the stocks and thereafter to maintain them at their "optimal" level. It has also to advise on research priorities. Its first drastic action was to recommend fishing closures.

FRCC was created in a difficult context. The fisheries crisis in Atlantic Canada appears along with changes in ecological structures: changes in hydroclimate (temperature below

normal over the past ten years), global decrease of every groundfish species in some sectors, explosive increase in seal populations, possible upward trends in crustacean biomasses. The socio-economical structure is also modified, as several communities were relying on the sea for their subsistence: in Newfoundland, the Province's GIP and unemployment rate appear to be related to groundfish values and landings. A way of life, shaped by hundreds years of fishing activities, is disappearing as well as ancestral knowledge. The Council also faces ambiguous concepts. "Conservation" may signify preservation of the ecosystem (structure and function) or the maintenance of a resource level allowing an "optimal" exploitation rate (the goal of the fisheries management system). As well, "ecological" management may signify exploiting the resource so as not to modify the ecological system or using ecological knowledge to optimize the exploitation and the management. The expected effect of closures implies reversibility of the system (releasing the pressure meaning a return to the "previous" state). However, the whole fishery's system is changing and it is difficult to imagine what it will look like in the future (biological structure ? socio-economical structure ?).

It is admitted now that studying the fishery through the sole relationship fish-fisher is insufficient to understand the trajectory of the system: neither the stocks (and the related economy) nor the ecosystem have been conserved. The crisis necessitates an approach based on a global understanding of the system, human activity being an integral part of it. In this context, the FRCC intends to develop an "ecosystemic" approach in fisheries. Fostering close partnership between stakeholders, management and science, recommending global studies in fisheries science, and encouraging stakeholders' participation in the process through public audiences are first steps. The FRCC is still evolving: designed as a "Council for the fish", it may face the question of broadening its actions. Only the future will tell if this new structure is an effective "part of the solution".

Fishing in Darwin's paradise: can the Galapagos Islands survive commercial export fisheries

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The Galapagos Islands are renowned as a hotbed of biological diversity and the birthplace of evolutionary science. Yet current pressure to develop commercial export fisheries is threatening the ecological integrity of the Islands and may undermine sustainable local fisheries. In 1986, the coastal and pelagic waters surrounding the archipelago were designated the Galapagos Marine Resources Reserve and 306 teleost fishes (17% endemic) and 27 elasmobranchs have been described to date. These marine populations have supported artisanal fisheries since the Islands were settled in the last century. Nature-oriented tourism, including the recent growth in dive tourism, has provided Galapagos and Ecuador with a sustainable, non-extractive source of income since the 1960s.

Open access and the "get-rich-quick" mentality of the export fisheries are drawing fishers from the overfished coasts of mainland Ecuador to the Islands. More than 1,000 fishers are now operating in Galapagos waters compared with a few hundred fishers in the early 1990s. This rapid expansion is making it increasingly difficult to monitor and control the fisheries. Sea cucumbers, sharks, lobsters, sea urchins, sea horses and other species have been targeted for the export trade. When an "experimental" sea cucumber fishery for export to Asia was opened in 1994, a three-month quota of 550,000 sea cucumbers was established. Despite the quota, more than 6 million had been collected by the time the fishery was finally closed after only two months. The subsequent protest and seizure of the Charles Darwin Research Station by angry fishers made international headlines. Yet illegal sea cucumber fishing is still rampant. Although attempts to legalize a shark fishery were recently rejected by Ecuador, illegal shark fishing and export of fins continue. Experience from other parts of the world indicates that export fisheries for sharks and sea cucumbers are notoriously unsustainable. In addition to the overexploitation of marine resources, there is concern that overfishing may upset the delicate balance between terrestrial and marine fauna in this insular system.

Sustainable use of the living marine resources of the Galapagos Islands is possible, but responsible management will require: (1) investment in fisheries research to establish a biological basis for management; (2) fisheries linked to local markets and the tourism industry; (3) prohibition of large-scale export fisheries; (4) access limitation to thwart overcapitalization and discourage immigration to the Islands; and (5) investment in enforcement policies and infrastructure. The Galapagos are at a crossroads. Ecuador must choose between a potentially sustainable future of artisanal fisheries and nature tourism or an uncertain future dependent on unsustainable export fisheries. An ecological masterpiece hangs in the balance.

Role of economic performance indicators in ensuring fish resource use management objectives

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Objective: In this paper, the nature, purpose and requirements of appropriate economic performance indicators for fisheries management are examined.

Findings: Poorly defined property rights over fish resources result in market failure leading to degradation of the marine environment and inefficient harvesting. To counter market failure the Commonwealth and State governments manage fish resources within Australia's extended economic zone on behalf of the Australian community. Institutional changes in the management of Australian fisheries are giving increased sovereignty over fish resources to user groups. The introduction of user pays management systems is resulting in commercial operators demanding greater fisheries management performance accountability. Adequate fish resource use management is further complicated by the large numbers of different user groups of the resource. These user groups, including recreational users, consumers and environmentalists, are also requiring increased accountability and increased participation in fish resource use decisions. These institutional changes have removed decision makers away from direct parliamentary responsibility and weakened the traditional lines of ministerial accountability.

Fisheries management performance indicators are needed to set standards and ensure accountability and control over performance outcomes. While the private sector can rely on

market forces to ensure performance discipline, this is not possible for public fishery management agencies which need to meet a number of, often, contradictory performance objectives. Achievement of performance control requires monitoring of: (a) the social resource use performance objectives, set by government and society at large — that is, finding out what is wanted; (b) the use of performance indicators by the fisheries agencies to monitor their 'production' of fisheries management services; and (c) performance feedback to resource owners and their agents and to the consumers of fisheries management services, to ensure management outcomes meet required social resource use objectives.

Key conclusions: The type of performance indicators used will affect the type, accuracy, availability and timeliness of the information supplied in performance management and will affect the incentives faced by fisheries managers. While fisheries management agencies are making increasing use of biological and economic performance indicators, it is observed that these indicators are, on their own, inadequate to ensure management objectives are met. Further, if performance indicators are to be used for performance management control as well as a means of performance review, they need to be integrated into the management information systems. This requires identification of the timing of performance indicators, review and appropriate sequencing in reviewing performance, to identify causes of possible performance failure. In applying performance indicators, issues of timeliness, accuracy and detail of information supplied need to be traded off against cost. This means that readily obtainable performance indicators need to be integrated with occasional, more detailed, costly and time encroaching base line studies.

Evolution of a fishery assessment process

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Australias fisheries are generally characterised by high diversity and relatively low value by world standards. A good example is the South East Fishery, Australias most important trawl fishery for scalefish, which supplies the bulk of fresh fish for domestic consumption in New South Wales, Victoria and Tasmania. The fishery is managed by the Australian Fisheries Management Authority, a statutory body of the Australian Commonwealth Government. The fishery includes more than 90 commercial species. Output controls, in the form of total allowable catches and individual transferable quotas apply to 16 species or species groups. These impose significant assessment requirements, yet the total value of the fishery was estimated at less than $A60m in 1994 with orange roughy accounting for over $25m and only a handful of species exceeding $2m. In addition, the scope of fishery assessment is expanding to encompass the management objectives of ecologically sustainable development.

This presentation examines how fishery assessment has evolved in the South East Fishery to meet these challenges and contrasts the approach with those taken in other countries such as New Zealand, Canada and the United States. Themes investigated include:

- the development of a standardised format for documentation and reporting
- the tailoring of assessment methods to individual species according to biological and socio-economic criteria with corresponding identification of data requirements
- the almost complete reliance on fishery dependent data leading to development of an integrated scientific monitoring programme
- a cooperative approach involving many different individuals and institutions
- the move towards a broader perspective involving a variety of stakeholders, the effects of fishing on the environment and socio-economic considerations.

While this approach is very different from that in some other countries, it is necessitated by limited resources, and is evolving in ways that should improve its effectiveness in the future. Although there are still problems to be overcome, eventually assessments in the South East Fishery could provide a useful model for other fisheries elsewhere with large assessment demands and limited resources to devote to them.

The impact of urban drain management on fisheries habitat in north Queensland, Australia

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The city of Cairns, North Queensland, has been constructed on sand dunes and swamp land. Cairns waterways form part of the Trinity Inlet catchment area which opens to the Coral Sea and the Great Barrier Reef.

Vast wetland areas of the Cairns coastal plain have been altered and filled since World War II to prevent flooding and to reduce the possibility of malarial outbreaks. Remaining waterways, both tidal and freshwater, still function as valuable fisheries habitat serving to support regional fishing industries.

The Cairns urban drainage system now consists of either natural channels (mud or gravelly substrate) or concrete-lined drains. Waterways on the urban periphery have been left relatively untouched and are still mangrove-lined within tidal limits. Towards the city centre, channels are predominantly concrete-lined which, whilst improving hydraulic efficiency, offer little shelter for resident fish species.

Other natural channels left within the built up areas are now largely lined exotic with vegetation. These waterways are also regularly cleared of sediment and vegetation to prevent flooding. This clearing, combined with the perceived diminishment of fish habitat from concrete channelling, has raised concerns that valuable fish habitat is being destroyed and regional fisheries productivity lost.

In response to these concerns Cairns City Council, in collaboration with Trinity Inlet Management Programme, have commissioned the Department of Primary Industries, Northern Fisheries Centre to formulate a Cairns Urban Drain Plan. The Plan will recommend maintenance techniques that safeguard the fisheries values of these waterways whilst ensuring the drainage function of the waterways is not compromised.

The project is recording fisheries species present in the drains and assessing the extent and nature of drain vegetation. Substrates, drain lining material and previous clearance techniques are being noted. Water quality

readings are also being taken. These data will provide a habitat profile for each of these waterways.

The role of riparian vegetation in the filtration of stormwater is also being investigated. Project objectives include the provision of guidelines for clearing techniques appropriate to the role these waterways play for both juvenile and mature commercial fish species.

So far, 27 species of fish (including prawns and crabs) have been positively identified and 7 species of mangrove recorded and mapped as part of the vegetation survey. Fisheries species present include *Lates calcarifer* (barramundi), *Lutjanus argentimaculatus* (mangrove jack), *Pomadasys hasta* (grunter), *Scylla serrata* (mud crab) and *Metapenaeus endeavouri* (endeavour prawn).

The data collected through this study are being presented in a GIS (Geographic Information System) format for the information of coastal fisheries managers, drainage engineers and town planners. It is hoped that the findings and recommendations of this project will feed into the general issue of floodplain management for sustainable fisheries productivity.

Effects of bottom sediment type, salinity and temperature on the dynamics of 0⁻ fry population of European sea bass, *Dicentrarchus labrax* (Linnaeus, 1758), used as seed for aquaculture

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The aim of this study is to examine the effects of population distribution and parameters of the European sea bass, *Dicentrarchus labrax* fry during its first appearance in the coastal areas of Western Greece. Sampling of fry was carried out on a monthly basis for two successive year periods using beach seines. The sampling stations were located in areas with silt-mud or mud bottoms or covered with *Zostera* algal beds, sheltered from islands or in small coastal lagoons. Standard population dynamics and ecological analysis methodologies were used in order to correlate the basic population parameters (growth, mortality, yield and distribution) with coastal characteristics (bottom sediment type), temperature and salinity. The findings of the study support that coasts near human activities (urban areas and harbours) with mud bottoms are mostly preferred by the fry during the first months of its life history resulting in high growth rates. This preference should be associated with the benthic organisms that are supported by the mud sediment along with the eutrophication produced from human activities. Additionally, high growth rates can be observed in individuals that have entered small coastal lagoons. Increased mortality rates are observed in areas with silt-mud bottoms rich in food (near river deltas) or in areas with bottoms covered by algal beds, while low mortality is observed in sheltered coastal lagoons and areas with silt-mud bottoms. Best yields were observed in areas rich in food (urban areas and near river deltas) or in the coastal lagoons, while lowest yields were observed in areas with algal beds and pure silt-mud bottoms. Increase of temperature (within the range of 20-24°C) shows an overall increase in growth rates, natural mortality rates and yield per recruit, while biomass per recruit decreases and total mortality seems unaffected. Increase of salinity (within the range of 18-30° ‰) causes an overall increase in mortality rates and yield per recruit; it does not appear to affect the growth rates significantly and causes biomass per recruit to decrease.

The development of techniques for estimating the recreational harvest of marine fish species in New Zealand

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A technique developed in New Zealand for estimating marine recreational harvest is described. Such estimates are required to ensure that fishery resources are used sustainably, that harvest is allocated equitably between commercial and recreational sectors, and that individual fishers have access to a fair share of the recreational harvest. Prior to 1991, recreational harvest was, for most species, an unknown quantity in stock assessments in New Zealand.

Estimates of marine recreational harvest were produced from a combined household telephone survey and diary scheme conducted in the South, Central and North regions of New Zealand during 1991/92, 1992/93 and 1993/94. A total of 35,115 randomly selected households was telephoned. From the 5,773 households found to contain marine recreational fishers, 4,579 fishers agreed to provide quarterly records of their fishing activities for one year. Quarterly response rates for diarists varied from 76 to 92%. Harvest estimates were derived from the number of fish recorded by diarists, an adjustment factor based on response categories, and estimates of average fish weight. Estimates of recreational harvest with acceptable precision were derived for 20 significant recreational species.

Diary schemes have generally been regarded in the past as a cheap but questionable means of estimating recreational catch and effort. The unreliability of previous diary schemes stemmed mostly from biased distribution of diaries in the fishing population, and from poor and biased response rates. The combined household telephone – diary scheme was designed to alleviate these problems and to estimate recreational harvests for widely distributed species caught using several fishing methods. As a test of the reliability of the technique, however, field studies were devised to provide independent estimates of harvest with which diary estimates could be compared.

The recreational harvest of snapper was estimated for line fishers using trailer boats within the Hauraki Gulf during four months in 1994. This area is the most intensively fished in the country and ~80% of fish caught are snapper, a species for which a good estimate of recreational harvest was urgently required. The independent harvest estimate was derived from a combination of aerial counts to estimate fishing effort, and on-site interviews to estimate average harvest rates for completed fishing trips. Aerial counts of recreational trailer boats were undertaken on randomly selected days, randomly located within time strata. On all such days, interviews were conducted at randomly selected access points to determine the number of fish caught and the duration of fishing. A total of 82 flights was made, during

which 17,669 trailer boats were counted. Interviews were conducted for 8,642 trailer boats, accounting for 28,337 snapper, about one third of which were measured.

The estimate of snapper harvest by trailer boat fishers in the Hauraki Gulf during the four month period using aerial counts and interviews was 378,000 to 402,000 snapper with a relative standard error of ~10%. Using diaries from trailer boat fishers fishing the same area in the same time period led to an estimate of snapper harvest of 420,000 snapper with a relative standard error of ~13%. It is surmised that these estimates of snapper harvest from trailer boats in the Hauraki Gulf are comparable.

Fish ageing: validation by radiometric analysis for oreo dories (Family Oreosomatidae)

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Accurate estimation of fish age is essential for fisheries management and yet it still remains one of the fundamental problems in fisheries biology. Counting annuli alone is not sufficient to provide age estimates and therefore alternative methods are needed to validate ages. Recent work in Australia has compared ages obtained from sectioned otoliths with those from radiometric analysis of ^{210}Pb and ^{226}Ra levels in otoliths for several species of deep-sea fish. For these deep-sea fish most of the usual methods of validation (e.g. tagging, tetracycline marking) are not possible because the fish cannot survive the pressure changes involved in collecting and returning them to their deep-sea habitat.

The radiometric technique offers an alternative method of validating ages. It is based on the fact that radioisotopes decay at known rates and therefore provide natural "clocks" by which age can be determined. Natural levels of the radioisotopes ^{210}Pb (22.3 year half-life) and ^{226}Ra (1,602 year half-life) can be used for ageing fish. These isotopes occur naturally in seawater and are incorporated unequally (i.e. in disequilibrium) into the otoliths of fish. ^{226}Ra is taken up as a chemical analogue of calcium and thereafter decays into ^{210}Pb. It is the increasing level of ^{210}Pb relative to ^{226}Ra that provides a measure of time elapsed since incorporation, and hence fish age.

The radiometric technique has proven very useful for deep-sea fish species. The results of recent studies on 3 oreo dory species, spiky dory, *Neocyttus rhomboidalis*, smooth dory, *Pseudocyttus maculatus*, and black dory, *Allocyttus* niger, have confirmed ages estimates from sectioned otoliths and have revealed that these species are long-lived; at least two of the species are in excess of 100 years old. The similarity in age estimates from the two methods for oreo species further supports the value of radiometric analysis for age estimation and validation.

Legal regimes for fisheries management

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Fisheries resource managers, public sector regulators of fisheries and fisheries research scientists should use their experience and skills to make a greater input to the legal regulatory regime. Fisheries resources are regulated by complex legal regimes at international and national levels. In the case of Australia, fisheries resources are managed in accordance with a complicated and subtle set of arrangements involving international law, the Commonwealth legislation, legislation of the States and in some respects the responsibilities of local government. The legal regime for controlling fisheries resources at these levels comprises a set of rules and principles governing the development of fisheries resources by the private sector in accordance with a regulatory structure created by the legislation indicating how those responsible for controlling fisheries resources in the public interest should discharge their responsibilities. It is thus a fusion of private sector and public sector interests and processes.

Ecologically sustainable development of fisheries resources is increasingly the outcome specified for these regulatory systems and this is achieved by a number of mechanisms including traditional regulation, management plans, systems of allocation and quotas. The rights conferred upon private sector fisheries managers are valuable assets with potentially substantial commercial value. The stability of these interests in legal terms affects directly the commercial value of these interests. Stability is assessed in accordance with the capacity of public sector regulators to revoke, amend or modify existing rights. It is therefore critical for managers, regulators and scientists to understand the intricacies and the subtleties of the interplay between the nature and stability of the private interests created by this system on the one hand and the powers conferred upon public regulators and the way in which these powers must be exercised in individual cases on the other hand.

The development of fisheries resources either at the coastal margin or in the marine area has, in addition to conservation implications, actual or potential major environmental impacts. Control of environmental degradation of the coastal margin and of the marine environment forms an important part of these international and national legal regimes. This aspect cannot be ignored. Although managers, regulators and scientists may be unversed in the law, they need to know at the very least when a legal issue might arise. It is important that scientists and managers cooperate with lawyers to be part of a collaborative approach to the regulatory regime.

Co-operative management – a fisheries ecosystem approach to jurisdiction

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The objective is to create an efficient and effective administrative and legal environment for fisheries management for stocks straddling jurisdictions that would foster sustainability of the resources and efficiency within the fishing industry using those resources.

The management of fisheries resources around Australia is subject to a series of Agreements between the Commonwealth, States and Northern Territory, known as the Offshore Constitutional Settlement (OCS).

Prior to the first OCS Arrangements, made in 1986, fisheries within three nautical miles of the baselines were managed by States or the Northern Territory and fisheries between three and 200 nautical miles by the Commonwealth. Until the most recent round of Agreements, OCS Arrangements were made on an *ad hoc* basis to meet the resource management, economic and political objectives of governments.

On 3 February 1995, new Arrangements took effect between Western Australia and both the Commonwealth and the Northern Territory. New Arrangements involving Queensland followed on 8 February 1995. These 1995 Arrangements resulted from a totally new approach to cooperative fisheries management in Australia.

For two years preceding the signing of these Arrangements, Australia's Commonwealth, State and Territory Fisheries Ministers sought to develop new Arrangements based on the principles of fisheries ecosystem management. Previous Arrangements had been based on target species and fishing methods, without recognition that bycatch was part of the fishery ecosystem and, therefore, a management issue.

No longer were individual fisheries to be "traded" on the basis of short term management objectives. Jurisdiction was considered in terms of creating an administrative and legal environment for fisheries management that would foster sustainability of the resources and efficiency within the fishing industry.

This environment was created through providing for different levels of jurisdiction within the Arrangements:

(i) single jurisdiction from low water mark to the extent of the Australian fishing zone
(ii) Joint Authority management, usually under State law – or
(iii) jurisdiction of a limited number of specific fisheries remaining split at three nautical miles or covering the area of a specific fishery

The cooperative approach that led to the making of these Arrangements was significant. However, of most significance was the recognition by governments that ongoing cooperation in the areas of management, research, enforcement and monitoring would be essential to the success of the OCS Arrangements. This recognition was borne out in the countersigning by Ministers of Memoranda of Understanding between the Commonwealth and each State or Territory and between adjoining States or Territory.

Possibly for the first time in Australia, governments had entered into formal agreements to cooperate in the development of complementary and cooperative fisheries management, research strategies and programs; exchange of research data and developments; and monitoring and enforcement programs which covered all fish resources off northern Australia.

Also for the first time, bycatch levels were developed. The Memoranda of Understanding defined specific trip or possession limits for bycatch species to be enforced by each government. Legislation for bycatch levels has been or is in the process of being prepared by each party to the Arrangements.

Fish do not recognise jurisdictional boundaries, industry does not appreciate administrative inefficiencies and scientists and managers struggle to do their best with inadequate information. The management of sustainable fisheries requires cooperation, full information flow, involvement of all stakeholders (regardless of place of residence) and relevant supporting organisational structures. The new approach to OCS has set an environment within which this can occur.

Sustainability and living marine resource management in the United States of America

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The management of Living Marine Resources (LMRs) in the United States of America is conducted under three principal laws: the Marine Mammal Protection Act (MMPA), the Magnuson Fishery Conservation and Management Act (MFCMA) and the Marine Protection, Research and Sanctuaries Act (MPRSA). Management failures are protected under the Endangered Species Act (ESA). Of course, there are also other domestic environmental laws that affect the LMR's ecosystem and numerous international LMR conservation agreements to which the U.S. is a party. Each of the three principal LMR management laws and the ESA is comprised of a set of principles and processes. To some degree, each set is different. Can they, at least in theory, lead to sustainable use and do they in practice? The main objective of this paper is to compare two of them, the MMPA and the MFCMA.

The MMPA was established to restore overexploited marine mammal populations and to maintain them at optimum sustainable levels. The principal policy reason articulated for this was a recognition of the marine mammals' essential role in the ecosystem and, of course, population sustainability was to be the objective. The law affords protection to marine mammals through the risk averse policy of establishing a moratorium on taking with only a few exceptions. Taking is essentially defined as anything that could not be deemed unharmful including indirect effects through ecological processes, another risk averse process. Each of the moratorium exceptions, at least in the beginning, requires obtaining a permit through a public process whereby the permit requestor has the burden to show a lack of harm to the marine mammal population from which the take would occur. The law established an oversight body, the Marine Mammal Commission (MMC), to keep tabs on the federal agencies entrusted to carry out the law's many provisions.

The MFCMA was established to manage fisheries within 200 nm of the U.S. coastline and to achieve an optimum yield from each fishery. A fishery is left unmanaged unless a

fishery management plan is developed for it, a risk prone policy. The process for developing these plans and, indeed the implementing regulations, can best be described as nearly user self-regulation. Optimum yield, the management objective, is defined as maximum sustainable yield as modified by relevant social, economic and ecological factors so sustainability is not the principal concern of management but simply a starting reference point. There are seven national standards by which the plan's features and regulations are to be judged, many of which are risk prone.

Towards sustainable management of NSW riverine fish: developing knowledge on diversity, distribution and biotic integrity

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An understanding of the processes which nurture fish is essential for their sustainable management. Because of exploitation or ecological change, riverine fish and fisheries face a wide range of threats. The basic nature of many of these threats is reasonably well documented, but sustainable fisheries management of any particular river or region requires data on its fish stocks, an understanding of the ecosystem that supports them, and knowledge of the factors causing ecological change in those particular rivers. Knowledge of the fish, ecosystems and ecological change in the rivers of New South Wales, south-eastern Australia, was patchy and uncertain until recently, but a new commitment to sustainability has prompted actions to rectify these deficiencies on several fronts. One of these was a large-scale fisheries project, the NSW Rivers Survey.

The NSW Rivers Survey set out to provide a reliable assessment of the fish of the State's rivers and an indication of the health of their environment. It addressed issues including the status of native fish, the distribution of alien species especially carp, the effects of river regulation, and the need for better tools for river-health assessment and monitoring. The project was a stratified, replicated, modified-random survey of fish communities in 80 river reaches throughout NSW. Four drainage regions were identified, each with four classes of river reaches (montane, slopes, regulated lowland and unregulated lowland). Replicate river reaches were each sampled four times over two years, using electrofishing plus passive fishing methods. Finally, relative population-density data were converted to absolute estimates using a calibration experiment.

Results of the survey reinforced community concern over the health of NSW rivers and the status of their fish stocks. Diversity and abundance were low in many rivers especially those of the the Murray drainage, which are the most highly regulated. Some of the randomly selected reaches were too degraded to justify sampling. Carp were very widespread, and dominated the fauna in a number of areas. The 'threatened species' status of 17% of the fauna was confirmed.

Data from the rivers survey have provided a sound baseline for future studies. More immediately, they provide the basis for development of the Index of Biotic Integrity (IBI) as a tool for assessing and monitoring the condition of rivers. A provisional structure for application of the IBI has been developed for the four drainage regions of NSW, and the power and suitability of the IBI is now being independently tested.

Fisheries enforcement: our last fisheries management frontier!

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As is emphasised in the themes of this Congress, fisheries management is usually seen as a blending of science, economics, sociology and politics through skilful management policy which achieves a divinely successful fishery. Despite the fact that illegal fishing activity is a fact of life in essentially all world fisheries, that compliance officers are the most visible public component of fisheries management agencies, and that enforcement personnel usually average about one third of staff within such agencies, it is argued that enforcement is more often an afterthought of management rather than an integral part of the process from inception to delivery. For example, enforcement workers are not listed among those who will benefit from this Congress, despite the fact that they will have to deal almost universally with the products of all six Congress themes. The objective of this contribution is to review the meagre literature available concerning the enforcement process and to make recommendations for increasing enforcement benefits to sustainable fisheries management.

Existing literature concerning the enforcement process coupled with survey results and specific contact with agencies indicates:

- an almost complete absence of research undertaken on the enforcement process with a view to assisting its improvement, despite a massive research effort concerning biological aspects of fisheries and improving bases in economic, sociological and political arenas.
- virtually no quantification of the economic benefits of enforcement activity to specific fisheries or under different management regimes.
- extensive data concerned with the impact of various harvest controls on fish stocks, but virtually none aimed at the efficiency of different harvest controls to police or on their impact on target illegal activities.
- evidence that in Australian State-level fisheries agencies, at least 50% of fisheries regulations are not effectively enforced due to under-resourcing of compliance units; a trend which qualitiative evidence confirms as similar elsewhere.

It is recommended:

- that specific research be undertaken aimed at optimizing enforcement efficiency and effectiveness in diverse fisheries worldwide
- that political and social scientists broaden their work to include impacts of fisheries policy on compliance providers as well as improving their policing impact on the desired end targets
- that legislation be enacted with an initial focus on minimizing compliance demands, rather than as an afterthought

- that a major theme of the Third World Fisheries Congress be "Defining Worlds Best Practice for Fisheries Enforcement".

It is concluded that the Enforcement arena is currently the most neglected component of sustainable fisheries management and therefore an area where increased focus and assistance from the other sectors of management should yield considerable benefits to world fisheries.

Conservation technology research in Japanese coastal fisheries

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In 1993, the coastal fishery caught 1.9 x 10^6 t of fish, employed around 275,000 fishers and generated $US 7.4 x 10^9. Japanese consumption of fish products is approximately 68 kg per person per year and comprises 40% of the total animal protein intake, demonstrating the importance of fish protein in its food culture. At the same time the fisheries may be characterized as having: (1) declines in coastal stocks and supplemented by artificially cultured juveniles, (2) few young entrants (3.8% < 25 years old) with the work of sorting and gear handling being done by older fishers (33.9% > 60 years old), (3) increased labour costs, and (4) potential impacts on fish and fishing grounds from transportation, land reclamation, aquaculture and leisure industries.

To combat the changing nature of coastal fisheries in Japan requires the setting of strategic goals in capture fisheries in the following areas: (1) identification of capture technologies, fishing strategies and fishing tactics that minimize biological and economic waste, (2) identification of capture technologies that minimize damage to the marine environment, (3) identification of the impacts of other industries on the condition of fishing grounds and fish behaviour, and (4) improvement in automation of coastal fishing systems for the purpose of reducing fishing costs and improving safety and working conditions.

Results of the first stage of this strategy have been to set up a network of researchers, research facilities, fishers and industry working cooperatively. Investigation of sources of biological waste by fishers has led to: (1) the development of selective devices (BRD) by fishers to reduce the capture of juvenile flatfish and sea bream in coastal trawlers, (2) sorting techniques to reduce discard mortality of released fish, and (3) laboratory research to investigate fish stress and mortality during fishing operations. Investigation of the impacts of other industries on fishing grounds have focused on noise levels generated by high speed ferry boats and aircraft. Research into ways of reducing fishing gear interactions with the seabed by coastal trawls has resulted in the development of flexible canvas kites to reduce the weight of gear in contact with the sea bed. Automation of the coastal set nets has included the development of automatic detection and entrapment of fish entering fishing gears and machinery capable of reducing the number of persons required to operate the gear.

Longlining or trawling – managing change in the demersal fisheries of a new South Africa

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This paper describes recent changes to management of demersal fisheries in South Africa. April 1994 heralded dramatic political change and in the fisheries context, this resulted in increased demands for access, forcing both the established industry and resource managers to reconsider their management strategies. The implications of these changes are illustrated using the largest commercial fishery in the country.

The South African demersal fishery targets on two hake species, *Merluccius paradoxus* and *M. capensis*. Following the declaration of the 200 mile EEZ in 1977, foreign fishing fleets targeting on hake were excluded from the fishery ar in 1978 a TAC (Total Allowable Catch) was introduced fo the first time. Based on surplus production modelling, a $B_{0.2}$ strategy was applied that resulted in a gradual increase in the TAC from 120,000 t in 1978 to 151,000 t in 1994. This apparent rebuilding of the hake stocks and the conservative $f_{0.2}$ strategy led to increased demand for access to a fishery that was dominated by a few large trawling companies. Pressure to gain access took on new perspectives after political change. Localised fishing communities were allocated small amounts of hake in the form of community trusts. As most communities did not have the capital to invest in trawlers they were still dependent upon the larger trawling companies to catch and process their allocations. Demands for access gained momentum and longlining was suggested as the means by which access to the hake fishery could be gained. As opposed to the capital-intensive trawling, longlining was mooted as a more selective, less capital-intensive and biologically preferable fishing technique. A comprehensive research programme, aimed at investigating the viability of longlining as opposed to trawling, was initiated and included both scientific and socio-economic studies.

The first phase of the research aimed at comparing the selectivity patterns of the two gear types so that the potential yields of the two fisheries could be compared. Longlining was found to be highly selective for adult hake and differed significantly from the less selective bottom-trawl fishery. Longline caught a higher proportion of female hake than did trawls and depending upon the depth fished, could target on different hake species. Longlining was found to be biologically acceptable and based on yield-per-recruit analysis, it was shown that longlining could sustain the hake stocks at a higher level than trawling, assuming similar catch levels. There is however still much uncertainty related to the long-term impact of longlining on recruitment and a cautious strategy has been adopted. Phase two of the research programme is a closely monitored two year "experimental fishery" in which no permanent rights are given. If proven successful however, longlining could have a significant effect on the future management of the South African demersal fishery. The introduction of a new fishery would result in an increased number of smaller entrants that would place significantly higher demands on monitoring and control and will present industry and resource managers with a new set of challenges.

Giving an old fishery a new lease of life

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The Trepang Fishery was probably the first export industry in Australia and pre-dates European settlement. The Macassans made annual visits in their prau to the Top End of the Northern Territory (NT) as early as the 1600s. In the early 1900's the South Australian Government (then responsible for the administration of the Territory) started to heavily tax the Macassan fishermen and by 1908 they were almost taxed out of existence.

Limited trepang fishing continued until about 1945 with a few Europeans relying heavily on Japanese and aboriginal divers to catch and process the product. From 1945 until 1992 there was no commercial harvesting of trepang in NT waters. In 1989, renewed interest in the Fishery resulted in a market research report and the undertaking of a resource survey of elville Island, Gove Harbour and Croker Island, NT.

In 1991 the NT Department of Primary Industry and Fisheries (DPIF) was approached for assistance in obtaining export approval for trepang through the Wildlife Protection (Regulation of Exports and Imports) Act, administered by the then Australian National Parks and Wildlife Service, (ANPWS) in Canberra, a Federal organisation. This Act is intended to protect Australia's native flora and fauna from unchecked exploitation and prohibits the export of any species unless an approved management programme is in place or the species is contained on a Schedule in the Act.

The most commercially important species of trepang (*Holothuroidea scabra*) was not on a Schedule, so a Management Programme was prepared by DPIF. A policy decision was made that only the six existing licences would be permitted in the Fishery and these would be non-transferable and regionalised in an attempt to spread effort and encourage the search for new grounds.

Only 5 t, dry weight, of trepang is consumed annually in Australia with the major markets occurring overseas, ¬articularly Asia. The six licensees could legally fish in NT aters and sell their product in Australia but the critical factor in trying to encourage the development of this Fishery was to obtain export approval.

It was a classical "Catch 22" situation, where no fishery would develop without export approval and export approval would not be given without greater knowledge of the resource, particularly its distribution. Increased resource knowledge was unlikely to be obtained unless a small commercial fishery was established. After extensive negotiations with ANPWS and some frustrating delays, at the end of 1991, the Federal Minister for Arts, Sport, the Environment and Territories, approved the export of certain species of trepang from Northern Territory from 10 March 1992, subject to conditions.

Since 1992 catches in the Fishery have varied between 42 and 108 t (live weight) with a corresponding value between $180,000 and $326,000. This figure is expected to increase due to a world-wide shortage of product resulting from overexploitation of stocks in many parts of the world. With conservative management in the NT it is expected that sustainable utilisation of the trepang resource will provide employment opportunities in both the aboriginal and non-aboriginal population for generations to come.

Genetics and morphology distinguish three species of mud crab, genus *Scylla*

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Mud crabs of the genus *Scylla,* are associated with mangrove areas throughout the Indo-Pacific countries. They are the basis of substantial fishery and aquaculture operations. A proportion of the catch has a low flesh content and these crabs are widely used in small, but highly profitable fattening operations. Small juvenile crabs are stocked into fish ponds for growout to market size. Because of the high value of mud crabs, rising demand in international trade and the availability of existing pond infrastructure in some Asian countries, there has been considerable research emphasis on many aspects of mud crab biology. Although a number of species of *Scylla* have been described, there is still much confusion over whether there are one or more valid species. The likelihood that there are a number of genetically distinct species is one of the major difficulties facing the effective management of the wild fishery and development of aquaculture.

Mud crab specimens (n=265) were obtained from 29 locations throughout the Indo-west Pacific; west to the east African coast, north to Okinawa, south to Australia and east to Fiji. The objectives of this study were two fold: one to test for genetically distinct species within *Scylla;* and two, having identified these, to stabilise the nomenclature by comparing with type specimens where extant, or erecting neotypes where necessary.

Of the 36 loci examined using allozyme electrophoresis, fixed genetic differences indicative of species level differences between morphs were observed at 10 loci. Only 14 loci had no apparent genetic variation between the morphs. At 16 loci polymorphism was observed within one or more morphs. These results, while clearly showing that there were three distinct "biological" species of mud crabs with fixed differences between them, were unusual. It is usual for different species to exhibit at least one unique allele and often more. For the mud crabs, two species were clearly defined by fixed differences at eight loci. However, the third species had a genetic makeup with no unique alleles but rather an original combination of alleles present in one or the other two species. No hybrids were observed. Examination of the mitochondrial DNA was used to substantiate or refute this interpretation of speciation.

DNA sequencing of the mitochondrial genes for Cytochrome Oxidase I (COI) and 16S rRNA produced comparable results. Between species variability was approximately ten times greater than within species variability for COI at 13.20%. Between species variability for the 16s gene was about 15 times greater at 7.26% than that observed within species. Mean within species gene variability for the COI gene was 1.29%, considerably higher than the 0.48% found for the 16s gene sequence.

The "biological" species defined by the genetic studies were used as a base to investigate their comparative morphology so as to provide characters that could be used to identify clearly the different species. We are now conducting an ACIAR funded international aquaculture project which will examine the habitat preferences of the three species so that production techniques can be modified to suit there

respective requirements. In addition, much will be learned of the biological and ecological requirements for survival and growth through laboratory experiments of the larval stages of each species.

Key conditions for community-based fisheries management: a case study on self-imposed management in Alfonsino fishing ground off Katsuura, Japan

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The objective of this paper is to attempt to elucidate and analyse key conditions for Community-Based Fisheries Management (CBFM) of unrestricted fisheries in Japan. It examines empirical evidence about the natural outcome for socio-economic rationality of the self-imposed management of 'common property' with reference to the Alfonsino (*Beryx splendens*) fishing ground off Katsuura by the Chiba Prefecture Small-type Coastal Fishing Vessel Fishery Cooperative (STCC). It shows that the management of the Alfonsino fishing ground off Katsuura is a case of fishery management where the order of fishing operations was established with two local communities (Amatsu and Kominato) playing the central role, while protection of the fishing ground was made possible as a result of the settlement of several disputes over fishing ground in which the STCC was directly and/or indirectly involved.

Although it is difficult to generalize, this observation indicates that exclusive use of fishing grounds exists as a necessary condition to establish CBFM in an unrestricted fishery and that adjustments of fishery operations and other matters are also necessary, based on the establishment of an organization of fishing ground users. However, one should not overlook the fact that, in the background of self-imposed management, there existed among fishermen a communal solidarity and social milieu to protect the fishing ground from which they derive their means of livelihood under the cooperation of members of the Alfonsino Group of STCC. Moreover, it is important to point out the serious attitude, as well as the professionalism, of the fishers towards their fishery. This has become the key motive force for forming a gentleman's order among the fishermen in the unrestricted Alfonsino fishery off Katsuura fishing ground, and the greatest key to facilitate the present self-imposed fishing ground management.

An evaluation of fishers' perceptions, and management, of the South African marine linefishery

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A programme to evaluate participation in, and management of, the South African marine linefishery was initiated in 1994. The programme was divided into four regional projects, encompassing the Kwazulu-Natal, eastern, southwestern and western Cape coasts. Two of the objectives were to determine fishers' (boat and shore-base commercial, recreational and artisanal/subsistence) perceptions of management regulations and the extent to which their activities are controlled by the current legislation. Methods used were random shore and harbour patrols, during which individual fishers were interviewed using detailed questionnaires.

Initial estimates indicate that there are approximately 800,000 recreational shore anglers, 80,000 recreational boat anglers, 25,000 commercial boat fishers and 12,000 drift net and beach-seine fishers active in the fishery for linefish. Numbers of subsistence fishers are difficult to define but they exist in the net fishery and amongst recreational fishers, 16% of whom illegally sell their catches. Of 2,516 fishers interviewed, 54% were white, 25% Indian, 19% coloured and 2% black, most falling into the 20-40 year age category and only 1% being female.

8% and 80% of those interviewed attributed a general decline in catches to overfishing by all and competing sectors respectively. In descending order of usefulness, fishers rated size limits, closed areas, bag limits and closed seasons as effective ways to conserve fish stocks. However 51% admitted to disobeying these regulations and when tested a mere 4% knew the bag, size and seasonal restrictions on their three most frequently targeted species. Catch inspection rates varied from 9 inspections per fishers per year in Kwazulu-Natal to once every 25 years in the southwestern Cape.

It is argued that a large increase in effort can be expected as the black community, who were historically excluded from the linefishery for economic, political, social and cultural reasons, enter the fishery. This will occur with increasing or decreasing affluence as more persons will be able to afford to enter the recreational fishery or be forced to become subsistence fishers. It is concluded that the ineffectiveness of current management measures is due to ignorance of the regulations by fishers and the inability of the inspectorate to enforce them. In anticipation of a large increase in effort, a revision of current management measures should include the registration of recreational, artisanal and commercial fishers and the expansion of the fisheries inspectorate to include both educational and law enforcement sections.

The costs of fisheries management information and fisheries research

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The costs of collecting information and conducting research for fisheries are infrequently assessed in relation to the value of the resource. At an extreme, doing little or no data collection or research is inexpensive but provides no sound basis for changing management practices. A modicum of activity provides some insight into local problems as well as participation in the professional network of managers and researchers. The greater the investment the smaller may be the risk of management error, but the costs may not be commensurate with the increased value of the catch.

The issue of costs of management and research is particularly relevant to current enthusiasms for ecosystem management. Present understanding of marine ecosystems is far from sufficient for management purposes. Existing models do not provide a sound basis for management. Models such as ECOPATH describe stationary states rather than the dynamics of marine ecosystems and even for that limited purpose suffer from lack of data on which to estimate parameters.

For groundfish fisheries of temperate latitudes the more direct approach of Multi-Species Virtual Population Analysis (MSVPA) requires information on catch and diet of major species in a fish community. To be of greatest value MSVPA should be augmented by a fleet interaction model that describes the way in which the fishing fleet collectively reacts to changes in relative abundance. These information requirements are alone fairly daunting even under ideal conditions. Statistics of catch do not include discards and are frequently perjuries in any case. Moreover, obtaining proprietary information about industrial fishing tactics is much easier said than done. For tropical groundfish fisheries, the data requirements for these methodologies are enormous. The only reasonable approach is adaptive management as practised for the fishery of the northwest shelf of Australia.

For intense gauntlet fisheries for anadromous species such as Pacific salmon, information requirements include daily estimates of catch and escapement for several hundreds of different races, each returning to a different stream of origin. Vulnerability of anadromous species to changes in their freshwater environment adds a further burden of management and research costs.

For these and other fisheries a substantial back-up of basic and applied research is essential if stocks are to be maintained. Equally important is a strong enforcement arm to ensure compliance with regulations.

In these circumstances, costs associated with management can become greater than the economic return, particularly when the resource has been depleted. Subsidization of fisheries and implementation of social programmes to maintain coastal communities and fishing as a livelihood may have the dual result of increasing costs of management while further depressing the resource and its economic return. Subsidies provided in one country may depress the resource and increase the costs of management of another.

To improve the ratio of economic return to management and research costs no measure is more effective than reduction of fishing effort. To date that has only rarely been accomplished but the institution of various schemes of right based fishing are promising.

The biology of yearling groundfish on Georges Bank: a spatially explicit dynamic model and its policy implications

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The extreme variability in the survival of early life stage gadoid fishes is widely considered to be the primary determinant of the strength of the adult population as well as the strength of any accompanying fishery. Subject to severe mortality during the pelagic larval and juvenile stages, the survival of demersal juveniles very likely depends on the substrate on which the fish settle, as particular substrates provide varying degrees of suitable habitat. Here suitable habitat suggests a benthic community rich enough to support the food requirements of the yearling groundfish, while simultaneously providing adequate cover from rampant predation.

Cod eggs and larvae are distributed across Georges Bank by a vigorous clock-wise current gyre, leading to their eventual settlement as transition juveniles to a wide variety of habitats. The bottom topography of Georges Bank is a mixture of sand, clay and glacial outwash in the form of pebbles, cobbles and larger boulders, each of which provides varying degrees of suitable habitat. Mobile fishing gear, primarily otter trawls used by the groundfish and scallop fisheries on the Bank, drag extensive sections of the bottom annually, devastating the benthic community and reducing the available habitat.

Synthesizing knowledge of benthic succession, juvenile recruitment, and fishing behaviour, a spatially explicit dynamic model of yearling cod survival is presented for Georges Bank. The multi-generation model is run over a ten year period at a monthly time interval. Juvenile survivorship curves are derived for size-dependent cohorts of 4-7 cm, 7-10 cm and 10- 13 cm on three different substrates--gravel, clay and sand. Experiments are conducted to simulate 1) the relative importance of catch *versus* habitat destruction on the cod population, 2) the ratio of the rate of benthic habitat recovery to the rate at which habitats are dragged which is necessary to maintain the fishery, and 3) to explore the significance of marine refugia in the recruitment process. Data for the model are collected from public records, and scientific and government publications.

Fisheries resources assessment of coastal rivers in the Wide Bay-Burnett region of Queensland, Australia – a base-line for fisheries management

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A series of research projects was initiated in 1991 to identify and catalogue the fisheries resources within the major catchments of the Wide Bay-Burnett region of Queensland. To date, research has focused on the following systems; Elliott, Burnett (in progress), Baffle and Calliope. The estuarine and riverine fauna and flora associated with these sub-tropical river systems have been characterised and the degree of human impact assessed. This work has identified estuarine and riverine fauna habitat preferences and pinpointed locations of high fisheries productivity so that these areas can be given protection as Fisheries Habitat Areas.

The documented fisheries resource information from these concurrent projects includes: fish and crustacean diversity, seasonal occurrence, juvenile recruitment, abundance, and reproductive condition. Water parameters, aquatic and riparian vegetation diversity and estimates, sediment types, waterway profiles and map references are also listed.

The relatively undisturbed coastal river systems contain in excess of 94 estuarine fish and crustacean species and 29 riverine species. As these surveys have used standardised sampling strategies and techniques, the results can be used to compare relatively undisturbed and unregulated rivers, with substantially modified river systems. This diagnostic comparison process benefits future development strategies and planning processes.

Fisheries in Queensland are almost solely based (95%) on estuaries and associated wetlands. Within the systems studied, fishes of economic interest to both recreational and commercial fishers were well represented as juveniles and adults. A number of management measures for fish stocks are in place (e.g. closed seasons, bag limits, size limits) and these, in conjunction with habitat protection measures, should ensure long term sustainable catches within these systems.

The data and results of this base line research have been widely utilised in regional development strategies whilst also complementing geographic information systems. In conjunction with integrated catchment management practices, these projects develop inter-agency and public awareness of fisheries habitat requirements.

Managing Namibia's fisheries sector: optimal resource use and national development objectives

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The objective of this presentation is to examine management approaches to sustainable development of marine fisheries in the context of broader development objectives of developing countries.

It is generally accepted that, if a common pool fishery has commercial potential, is not subject to effective regulation and is competitively exploited, then there will be inevitable eventual market failure as each fishing enterprise imposes negative production externalities on the others.

There are two accepted ways of dealing with this problem in large marine fisheries. These are establishing property rights to fish stocks, the most notable form being individual transferable quotas (ITQs), and the regulation and imposition of taxes by public authorities.

It is also now widely recognised that, in certain instances, self-management and regulation of relatively small and contained common pool resources have worked well over decades and even centuries.

The reason why ITQs have shown promise is because the number of companies in the fisheries tends to reduce to a point where those remaining in the industry operate as a sole appropriator, cooperating rather than competing. A sole exploiter must contend explicitly with the user costs which become endogenous.

If government has equity objectives in the use of the resource for development, as Namibia does, then accommodating a consolidation leading to private monopoly behaviour becomes problematic.

On the other hand, problems arise in the exercise of direct controls. Costs of policing are often excessively high; efforts to negate the effects of restrictions often defeat their purpose; quota allocations frequently generate rent seeking behaviour.

Since independence Namibia has succeeded in gaining control over its depleted fisheries. It has begun the process of rebuilding its stocks and the biomasses of most commercial species are recovering well. The Namibian Government is now earning significant net revenue from its fisheries and is managing to recover a significant portion of the resource rent for purposes of development. However, resource rent not recovered by Government, functions as a subsidy and needs to be more explicitly recognised as such, making more transparent its use and justification.

While Namibia's system of regulation is essentially a restrictive one, it is a relatively transparent system of resource management, and institutions have been creat which are encouraging greater industry participation in monitoring and managing the resource. Namibia appears to be developing a reasonably cost-effective system which could evolve into co-management leading to efficient and sustainable use of its fisheries resources.

The self-management cooperative arrangements of some relatively small common pool resources, whereby a group of resource appropriators act as one coordinated entity employing peer monitoring, function in essentially the same way as a relatively small number of companies in a large fishery acting together as a monopoly. In both cases, through negotiation, the externalities that arise in a competitive situation are diminished.

Creating institutions which encourage intra-industry negotiation and co-management with government offer greatest possibilities for making costs endogenous, meeting government's development objectives and generating the sustainable use of fisheries resources for developing countries.

To manage fisheries sustainably, new philosophies are required

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Fish populations are in trouble worldwide, and the examples of sustainably managed populations are few. It is maintained that two important factors contribute to our inability to manage fish sustainably: 1) A tendency by managers to rely on unproven "techno-wizardry" to mitigate damage from management activities; and 2) A serious disconnect between science and management policy. Until we implement new management philosophies, little progress towards sustainable management will occur. Management activities (e.g. logging, dam construction, cattle grazing, fishing) have resulted in many adverse impacts to fish and their habitats. Despite many studies describing adverse effects, activities continue based on optimistic assumptions that technology exists to mitigate these impacts. For example, published accounts have described the unrealistic assumption that hatcheries would offset the many impacts to fish from dam construction (lost habitat, altered flows, no access to spawning grounds, juvenile entrainment). Coincident with dams and hatcheries has been a serious decline in the number of native fish species, and an unprecedented number of listings of threatened and endangered species. Nevertheless, management agencies continue harmful practices based on optimistic assumptions that mitigative procedures will be effective despite evidence that some activities cause irreversible damage. Secondly, the collapsed New England marine fisheries and cattle-caused degraded aquatic ecosystems provide classic examples of managers not heeding scientists' advice. Fishing off the northeastern coasts of Canada and the United States continued at unsustainable levels despite advice from scientists to reduce fishing quotas. Moreover, hundreds of studies have described damage to fish and their habitats from cattle grazing, yet little interaction occurs between scientists and managers. To retain objectivity, scientists are often reluctant or discouraged by their agencies to make specific management recommendations that are critical of past actices. Similarly, managers are often reluctant to ask scientists for advice, and seldom are scientists' recommendations implemented into management changes. Even so, despite widespread acknowledgement that rangelands are in poor condition, cattle grazing continues in the hope that mitigative attempts such as fences to exclude cattle will provide adequate restoration for the entire ecosystem. Management agencies and environmental laws continue to give those conducting the management activity the benefit of the doubt while the burden of proof is placed on those protecting the resource to prove that the activity is causing damage. To manage fisheries sustainably, new management philosophies need to be implemented that place the burden of proof on those conducting the activity to prove beyond a reasonable doubt that the proposed activity will not adversely impact fish and their habitats. The numbers of threatened and endangered fish species and damaged habitat are unacceptable, and to sustainably manage fisheries requires a strategy that places species and habitat protection foremost, and discontinues untested mitigative procedures. Moreover, within management agencies (e.g. U.S. Forest Service, National Marine Fisheries Service, USDI Fish and Wildlife Service), scientists and managers need to increase dialogue, without fear of scientists losing their objectivity, with the overall goal of sustainable management.

100 years of fishing Pacific halibut: why do we still have a fishery?

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Pacific halibut fishing began in 1888 and continues to the present. The lowest total removal (commercial and sport catch, plus bycatch mortality) under full exploitation has been 14,000 metre tons (t) in 1974 and the highest removal was 42,000t in 1988. The present total removal is 35,000t. This three-fold fluctuation in removals has both natural and man-made causes. While the maximum difference in yield is rather large, the stock has never been at risk of collapsing. It is important to fisheries scientists and managers, particularly at a time when so many major stocks have collapsed, to be appraised of the harvesting strategy and decision-making that has yielded such long term success.

To manage any fishery successfully four requirements are necessary: (1) All removals of fish from the stock must be accounted for; (2) Good science must produce a measure of abundance that is directly proportional to actual stock abundance; (3) A sound management strategy must determine an exploitation rate to produce the highest yield allowable subject to maintaining a low risk of overfishing; and (4) Political and social pressure to increase catches beyond those recommended by good science must be ignored.

Poorly documented bycatch removals in the 1960s by the non-domestic trawl fleets caused the International Pacific Halibut Commission to underestimate the size of the bycatch removal. This occurred at a time when recruitment was at a low point in its cycle. These two conditions, particularly the failure to account for the total removals, caused a precipitous decline in the stocks to the lowest recorded level. Once full reporting was initiated by the United States, the Commission was able to set yields low enough to rebuild the stock to an all time high in the late 1980s.

Past management strategies were based on annual observations of density (catch per unit of effort or cpue). As the field of population dynamics advanced, improvements were made to the analysis of the halibut fishery. At the present time an age structured model which includes cpue is used to annually estimate exploitable biomass (ages 8-20). Current research attempts to incorporate cyclic trends in growth (and selectivity) and the adult bycatch age structure into the model. Continued improvement to the stock assessment model should further reduce variability and bias of the biomass estimates.

At present a constant exploitation rate strategy is applied to the exploitable biomass. Exploitation rate is initially derived from analytic of considerations and then subjected to simulation studies which incorporate fluctuations in recruitment and environmental factors. The risk of reducing the spawning stock below historic lows is investigated and adjustment to the exploitation rate is made to reduce the risk to acceptable levels. The proportionality between biomass estimates and true biomass is accounted for by the exploitation rate.

Historically, the Commissions management strategy has been very conservative. This has been possible because the

scientific staff is not subjected to political pressure and has the support of a conservation-minded halibut fishing industry. The Commission has a close working relationship with fishers and the processing sector. However, only statistically defensible information from fishers is used in setting harvest levels. Fisher's opinions often do not correspond to their actual experience, and the harvest strategy does not (and should not) acknowledge the harvesters social structure. The Commission manages halibut stocks, while the United States and Canadian governments manage harvesters. The insulation of stock assessment and harvest quota setting from fisheries allocation considerations and their political consequences has been a major reason for the success of the Commission.

Recently, the open access fishery has ended and both United States and Canada have adopted individual transferable quota systems for Pacific halibut. These systems have stabilized the fishery and further reduced the risk of overfishing. Continued increase in knowledge and its incorporation into the management strategy, adherence of the fundamental tenet of "always choosing the conservative option when decisions are made," and the continued insulation of fishery science and the harvest level process from socio-political pressure, will ensure the maintenance of the halibut fishery into the future.

Australian Fisheries Management Authority organisational structures and management philosophy

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Objective: To describe the new organisational structure developed to implement the Australian Government's policy announced in 1989 to establish a statutory authority, the Australian Fisheries Management Authority, to effect the Government's responsibilities in a flexible, open and less bureaucratic way, and to allow greater community and industry participation in determining the most appropriate management programmes for Commonwealth fisheries.

Statement of findings: Prior to 1992, responsibility for Commonwealth fisheries management resided with a division known as the Australian Fisheries Service within the Federal Department of Primary Industries and Energy. In the late 1980s and early 1990s, the Australian Government recognised that, despite its best endeavours, the Australian Fisheries Service was not able to effectively manage Commonwealth fisheries. It therefore established the Australian Fisheries Management Authority to address the following pressing issues:

- resource overfishing;
- industry, which was paying for a portion of management costs, did not consider that management services were being provided in a cost-effective manner;
- industry frequently did not accept stock assessments;
- industry did not trust management and *vice versa*, with the result that user groups in general had little effective say in the development of management arrangements and the setting of management objectives;
- management/user group conflicts;
- the Commonwealth Minister responsible for fisheries needed to be removed from many no-win decisions. (Up until 1992, the fisheries portfolio seldom provided political benefits to the party in power in Australia).

In summary, the Australian Government decided that major and fundamental changes in fisheries policy were needed to correct the situation, and in 1989, the Government published a Policy Statement entitled "New Directions for Commonwealth Fisheries Management in the 1990s". Subsequently, in 1991, a package of new Commonwealth fisheries legislation was passed by the Australian Parliament which established the administrative and operational structure for the implementation of the Commonwealth's fisheries management objectives.In particular, the legislation established the Australian Fisheries Management Authority, or AFMA as it has become known, to manage Commonwealth fisheries.

The paper assesses the success of the AFMA model and the accompanying Management Advisory Committee (MAC) framework, together with the management philosophy pursued by AFMA in its dealings with major user groups including recreational and environmental interests.

Key findings: The AFMA experience is that partnership with industry do work, and that industry involvement is in many ways a big part of the solution to issues such as resource overfishing, expansion of fishing fleets, overcapacity, allocation of the resource, compliance, reliable stock assessment and adjustment schemes. Specifically, industry advice and input to fisheries management issues on an equal partner basis generally costs very little, yet it is seen as crucial to the determination of practical and sensible outcomes. Similarly, confidence, trust and respect are the underlying and key principles in achieving effective and lasting solutions.

AFMA recognised at a very early stage in its evolution as a fisheries management agency that a fundamental change in the culture of staff and in the delivery of services was essential to cost-effective fisheries management and administration and has successfully established this culture through workplace enterprise agreements. It has developed effective management information systems for both administrative and fisheries management purposes, and has been able to successfuly address major policy issues such as cost recovery and access rights.

Australian fisheries resources – the status of Commonwealth-managed fisheries

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The underlying aim of fisheries management is to conserve the resources within sustainable limits while maintaining an economically viable industry. Assessment of the status of a resource relies on information derived from both scientific research and regular monitoring of fisheries. An important step in improving the quality of stock assessments is to publicize existing assessments and identify where improvements are needed. The Bureau of Resource Sciences, (BRS) produces annual Fishery Status Reports on Australias Commonwealth-managed fisheries resources. These reports reflect current knowledge of the biology and population dynamics of the fish stocks. The reports also highlight uncertainties in the state of knowledge of the resources and indicate what information and research are needed to improve the quality of future stock assessments.

Although the Australian Fishing Zone is the world's third largest, Australia's waters are generally low in nutrients and annual fisheries production ranks only about fiftieth in terms of tonnes of fish landed. Many of the fisheries, however, target high-priced species such as prawns, lobsters, abalone and tuna. Management of these resources is a complex jurisdictional mix of Commonwealth and State responsibility. In simple terms, State waters extend to 3 nautical miles from the coast. Commonwealth responsibility for fisheries management is for those fisheries outside State waters, those fisheries which extend across waters of several States and those fisheries that target highly migratory species. In many cases the resources are managed through cooperative arrangements between the Commonwealth and the States. Commonwealth fisheries were valued at about $A300 million in 1993-94.

Increasing demands on Australia's fisheries resources and changing management strategies are placing greater emphasis on the need for high quality stock assessment advice. Many of Australia's fisheries have a larger catching capacity than is needed to take the catch efficiently. Several fisheries are now fully exploited or over exploited and strict management controls have been introduced in some cases. Previous Fishery Status Reports have indicated that approximately half of the species or species groups reported upon were overfished or fully exploited. Southern bluefin tuna, for example, has been regarded as overfished for a number of years and despite strict management measures parental biomass remains at a low level. By contrast, although there has also been some concern over the resource status of the Northern Prawn Fishery, the thrust of management measures has been to reduce economic inefficiency by halving the size of the fishing fleet.

This paper presents the findings of the latest BRS Fishery Status Reports.

Comparing the introductions of trawl excluders and bycatch excluders in Australia and the U.S.

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Turtle excluder devices (TEDs) are now being trialed on a voluntary basis in many Australian prawn (=shrimp) trawl fisheries to reduce sea turtle captures. Analysis of TED introductions into shrimp trawl fisheries of the USA provided major insights into why conflict occurred between shrimpers, conservationists, and government agencies. A conflict over the introduction and subsequent regulation of TEDs occurred because the "problem" and the "solution" were perceived differently by the various interest groups. Attempts to negotiate and mediate the conflict broke down, resulting in litigation against the USA Government by conservationists and shrimpers. Litigation was not an efficient resolution to the sea turtle-TED-trawl conflict but it appears that litigation is the way the conflict will be addressed in the USA. We review the developments of TEDs in two major Australian trawl fisheries. In view of the different nature of Australian trawl fisheries and our insights from the conflicts concerning sea turtles and TEDs in the USA, it is likely that TEDs will be introduced to Australian fishers with a good level of acceptance.

Modern fisheries research vessels

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Critical to the development and management of a sustainable fishery is the ability of scientists to evaluate and predict fisheries stocks. Since 1882, the National Marine Fisheries Service (NMFS), and its predecessor organizations, have used research vessels to acquire both fishery stock assessment data and oceanographic data to aid in fishery management. The ageing of the present fleet, most of which were built in the 1960s, together with advancements in fisheries research technologies, have prompted NMFS to investigate new developments in modern fishery research vessel designs. NMFS conducted a thorough examination, beginning in 1993, of recently developed fisheries research vessels in other countries. The uniqueness of scientific research in fisheries demands that fisheries research vessels be designed to support the mission of collecting both stock assessment data and environmental data simultaneously. Recent assessments of the requirements found by NMFS for a modern fisheries research platform are: acoustic quietness to reduce fish avoidance, new hydroacoustic tracking technology, trawling capabilities and state of the art computer systems. Combined with these, research platforms must have the ability to stay on station for long periods of time through the use of dynamic thrusters, and provide stability for sensitive instrumentation in various sea states. In addition, modern research vessels must be built to accommodate future advancements in stock assessment techniques, such as 360° sonar. Recent technological design advancements in ocean going research platforms could greatly enhance the quality of scientific data needed to support management decisions. Fisheries research is integral to building and maintaining sustainable fisheries and any future research platforms should be built to accommodate the best technology, present and future.

Sustainable development and fisheries management in Islamic Republic of Iran

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In this paper are presented the characteristics of the fishing industry in I.R. Iran and its role in the national and coastal fishery economies, and also the programmes and measures being taken toward the sustainable use of fishery resources. During the last few years, especially after the completion of the country's first 5-Year development plan, and following on with the second 5-Year plan, valuable steps have been taken towards the sustainable use of fisheries resources which could be useful for other developing countries.

Total fish production in I.R. Iran reached 350,000 t during 1994. This is 20,000 t less than the previous year, due partly to a planned decrease in harvesting of demersal resources (with a continuous decrease in the number of trawlers) and partly to natural fluctuations of small pelagic resources. Out

of 350,000 t of fish, more than 300,000 t were landed from the Caspian Sea, Persian Gulf and Sea of Oman, and about 45,000 t from inland waters (cultured).

The plan is that, during the second 5-Year socio-economic development plan, the total production of inland water and marine fisheries should reach about 680,000 t representing an increase in the *per capita* fish consumption from 3.9 kg (at present) to 6.5 kg. The main proposed policies and measures for development are:

1 Considerable increase in fish culture production in accordance with the vast potential existing in the country especially regarding commercially important species such as shrimp and tunas.

2 Increase in the utilization of underexploited resources such as kilka (clupeids) in the Caspian Sea and sardines in the Persian Gulf and the Sea of Oman.

3 Decrease in the yield of overexploited resources such as demersal species and reconstruction of these resources.

4 Ban on harmful fishing methods such as gill netting for bonyfishes in the Caspian Sea and trawling in southern waters (Persian Gulf & Sea of Oman.)

5 Improvement in handling and quality control in order to decrease fish wastes and increase the fish *per capita* consumption.

The Iranian fisheries company (Shilat), which is the representative of the government and acts as the custodian (administrator) of the fishing sector, has from the beginning of the first 5-Year development plan started to decrease its role as an incumbent by continuous vesting of its monopoly, of fish distribution activities and also the ownership of some fishing industries. To continue this process, it intends to extend fisheries management measures to all fishing processes, from production to consumption, within a uniform framework. This includes:–

- resource management (marine and inland water)
- fishing management (subsistence, small-scale and industrial fishing)
- culture management (pond and reservoir culture)
- port management (landing facilities, gear and fishing equipments)
- fishing industry management (production industries, equipment and byproduct industries)
- market management (fresh fish, fisheries products)

Shilat believes that management measures should be applied to all targeted aspects on a regular and organized basis; neglecting one aspect will jeopardise the achievement of positive results from others measures taken. The first requirement is for legal and regulatory measures and the second, for capabilities in data gathering and information systems. These are being taken seriously by the relevant departments. All these programmes will be piloted by adequate research and studies for which the government has allocated a considerable budget during the second 5-Year programme (1995–1999).

Shilat has taken the necessary steps towards the implementation of management measures regarding resources, fishing activities, aquaculture, marketing and fishing ports, and in administering the fishing industry towards wise utilization and sustainable development of resources, believes that the main criterion for the fulfilment of these objectives the implementation of fisheries management in all its aspects, so as to prolong the continuous and long term economic utilization of the fisheries resources into the future.

Central Ageing Facility

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Age-structured stock assessment methods are the primary basis for providing management advice in many world fisheries. Knowledge of the age structure of exploited fish populations is crucial to understanding their dynamics and the impacts of exploitation. The age structure of the catch is a key input to the stock assessment process. Age composition data also provide fundamental insights into fish biology and stock productivity and allow the estimation of the basic parameters for describing growth, mortality rates and recruitment. There has been much written on methodological issues regarding the selection of appropriate ageing methods. Others have highlighted the need for greater rigour in the validation of ageing methods. The importance of obtaining accurate ages is self-evident, and the implications of incorrect ageing data have been reported. However, little has been written about the process of taking validated or accepted methods and applying them in a consistent manner to new samples to ensure that the resulting age estimates are also valid.

This ongoing process of assessing age structures is termed "production" ageing. There are requirements of a production ageing process which are very different from those of a study aimed at validating an ageing method for a particular species, describing the growth of a species or stock, or of a study which applies an ageing method in a short-term study.

A specialist ageing unit, the Central Ageing Facility (CAF), was established at the Victorian Fisheries Research Institute in 1991. The main aim was to undertake production fish ageing for Australia's key fisheries. In addition to this role, the CAF's auxiliary function is to provide age determination for clients, advice on ageing techniques and training for national and international scientists. This paper describes the role of the CAF and the use of an integrated image analysis system for accurate onscreen digitising, data capture and automated file handling. It also addresses the issues of quality assurance that are unique to the process of "production" age estimation. Quality assurance is a crucial element in the ongoing process of stock assessment.

The CAF ageing protocols and system were designed for handling large sample sizes of otoliths (teleosts) and the vertebrae (elasmobranchs) for "production" age determination. Typically, in a twelve month period about twenty thousand otoliths are received from which up to twenty thousand individual readings are made. For the majority of the samples received by the CAF, thin sections are cut which are then mounted on slides. With a high throughput, it was necessary to design a system that reduced user strain and minimised possible error sources. Modern image analysis software provided the tool to build an integrated package that is user-friendly, efficient, very flexible and operates in the Microsoft (MS) windows environment.

Managing fisheries sustainably: the Australian solution

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The objective of this paper is to show that Australia has developed a series of initiatives to achieve sustainable management of its fisheries. Ecologically sustainable development is the fundamental principle to natural resource management in Australia. A series of government initiatives are in place, or are planned, to guide the sustainable use and management of Australia's marine resources. The Commonwealth Coastal Policy, adopted by the Australian Government in May 1995, provides a clear statement of the Australian Government's position on coastal management matters by adoption of common objectives and guiding principles and through implementation of the following initiatives to improve management of the coastal zone, including Australia's fisheries: 1. promotion of an integrated strategic planning approach, 2. increasing the capacity and knowledge of coastal managers, and 3. promotion of community participation in coastal management.

Achieving ecological sustainable development (ESD) in Australia's fisheries will ensure the protection of the fisheries ecosystems, maintenance of biodiversity, and that the resources will be available for rational exploitation by future generations. To achieve ESD of the fisheries in Australia's Exclusive Economic Zone is a major challenge, but the rewards will be vast and could reach an additional $5-10 billion per year within 25 years.

The solutions require an increased knowledge of the resources, developments in aquaculture, development of alternative methods to address the environmental effects of fishing, and improved handling and marketing techniques. These are in addition to actions to achieve maintenance of marine and coastal habitats, control of marine and estuarine water quality, long term research and monitoring of the marine environment, and strategic, integrated planning and management of Australia's marine and coastal environments.

The Australian federal system of government introduces a range of jurisdictional complexities to the implementation of a multiple use framework for resource management. Successful resolution of the key policy issues can only be achieved by involvement of the Australian community. Australia is confident of a successful outcome using this approach.

New approaches to fisheries management in Lake Kariba (Southern Africa)

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The fishery on Lake Kariba comprises commercial and artisanal components, each with their own set of management regulations and specific problems in enforcing those regulations.

The commercial fishery is based on an exotic freshwater sardine which was introduced in Lake Kariba to fill a planktivorous niche, following the impoundment of the River Zambesi to form a lake for hydropower generation. This fishery today constitutes the main supply of fish for Zimbabwe. It is also an important supply of fish for Zambia, the other country that shares the lake with Zimbabwe. However, due to political differences between the two countries prior to Zimbabwe's independence, this fishery has, until recently, been managed separately by the two countries. The problems of managing a common resource separately were noted by both countries and currently efforts are underway to promote a joint management policy. A donor-funded regional project is currently working to achieve this goal.

The yield of the commercial fishery is very dependent on nutrient inflow through rainfall. The fish stock is very resilient and fast growing and research suggests that it is not in danger of recruitment overfishing. As a result, economic factors are more important than biological factors in determining the level of fishing effort. Management is solely by control of fishing effort as a 'total allowable catch' (TAC) policy is not appropriate for very rapidly growing species where it is not possible to predict stock size and hence yield for the following year.

Zambia and Zimbabwe have, on the basis of an economic evaluation of the fishery and also on the evaluation of data on the effects of increasing effort on catch per unit of effort (cpue), decided on an approximate fishing level which will result in a near maximum yield and at the same time maintain income per boat at profitable levels. The two countries have therefore agreed to co-ordinate the limitation of effort through an international protocol which will serve as the basis for management of this fishery.

The artisanal fishery is 'open access' in nature and therefore very difficult to manage from a central institution. Management systems are currently based on rules and regulations which are costly and difficult to enforce. It has been realised that to sustain this fishery it is necessary to change the emphasis towards community-based management. Sociological studies, extension programmes to establish fishers' management associations, training fishers in management matters and introduction of exclusive fishing zones are programmes currently underway to encourage fishers to manage their own resources with limited support and assistance from government institutions.

This paper also discusses problems of conflict with other sectors that utilize the waters of Lake Kariba and suggestions are made on how to resolve these.

Freshwater fisheries management conflicts in Cuban reservoirs

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The popularity of largemouth bass (*Micropterus salmoides*) as a sport fish in the United States has led to numerous

introductions of this species to other countries throughout the world. Largemouth bass were first introduced from the Florida Everglades to the Antilles, including several rivers in Cuba, in the 1920s. The reservoir populations that resulted from these introductions produced tremendous sport fisheries that became famous for the production of trophy-sized bass. In recent years, biologists and anglers have noted a decline in the quality of largemouth bass fisheries in central Cuban reservoirs. The present study was initiated in 1993, at the request of scientists and government officials in Cuba, to assess the condition of these very valuable fisheries and to identify potential causes for their decline.

Largemouth bass populations were surveyed on four Cuban reservoirs in August 1993 and February 1994 using a variety of recreational gear. All fish were weighed and measured and stomach contents were collected by gastric lavage. Populations were evaluated for size structure (relative stock densities) and average condition (relative weight) of fish in critical size groups. A subsample of fish was sacrificed for liver enzyme electrophoresis to evaluate genetic composition (subspecific status) of the populations.

Initial findings indicate that management problems may be related to overharvest by commercial and subsistence fisheries which increased as the Cuban economy worsened after the collapse of the Soviet Union. A secondary cause may be competitive interactions of largemouth bass with another recently introduced exotic species, the blue tilapia (*Tilapia aurea*). All fish were found to be pure Florida largemouth bass (*M. s. floridanus*) and may represent one of the few remaining pure stocks of this subspecies. Further sampling to clarify the ecology of these fish communities and to develop improved management strategies for these fisheries is planned.

The Cuban government has taken the first steps towards recovery and conservation of largemouth bass populations on two reservoirs (Lake Hanabanilla and Lake Granizo) where popular trophy sport fisheries once existed. Commercial and subsistence fishing with gill nets has been banned in all but limited areas of these reservoirs. Sport fishing will be catch-and-release only. A user fee will be levied on all foreign sport fishers and proceeds will be used to support monitoring and management of fish populations on these reservoirs.

Future management problems to be addressed include the potential effects of rapidly spreading exotic plants (*Hydrilla verticillata*) and the equitable allocation of fisheries resources between tourist enterprises and local residents. Eventual removal of the United States economic embargo will undoubtedly result in increased tourism pressure on sport fisheries. Resource allocation problems and potential contributions to local economies from tourism need to be resolved before increased demand complicates the situation.

The role of local fisher communities in the sustainable management of the Great Lake fisheries: a case study in Kompong Khleang community, Sot Nikum district, Siem Reap province, Cambodia

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The objective of this paper is: (1) to identify the structure of the fisher communities and their practices; (2) to identify the current management system and its consequences; (3) to explore the feedback from the local communities, and (4) to suggest a plan of action for sustainable management of the Great Lake fisheries and their environment.

The Great Lake, occupying nearly 6% of the country's tot. area is the single most important fish treasury of Cambodia. Nearly 2.7 million people (27% of the total population of the country) reside in six provinces around the lake, of which about 650,000 people live in floating fishing villages. The fisher communities rely exclusively on natural fishing and related activities. The fisheries are divided into fishing lots for large scale fishing and regulated areas for middle scale and subsistence fishing. The fishing lots are auctioned every two years for exploitation. In actual practice, one or two leaseholders get the right to exploit the same fishing lots for many consecutive lease terms while many thousands of fishers are restricted from access to good fishing grounds and continue to overexploit the already reduced fisheries. The situation has resulted in illegal fishing and poaching by the fishers. In addition, the inundated forest that serves as a critical ecological input to the productivity of the fishery is being cut for wood and cleared for agricultural purposes.

Recognizing the decline in the natural fish and wildlife and fearing a drastic change in the fishery environment, the local authorities and fisher communities have shown keen interest in restructuring the current management syster and the government considers that there is an imperativ need in changing the management policy. As an outcome of participatory rural appraisal technique, the local fisher communities have requested more access to fishing grounds especially to fishing lot exploitation and proposed that they pay the bidding fee to the government collectively and follow fishing regulations for environmentally sound fisheries resource management. The paper concludes that the local authorities and fisher communities can become potential partners in fisheries co-management through empowering them and giving them more responsibilities in the use and management of the resource, with the possibility of integrating rural development programmes in resource management practices.

Effect of size and density on the rates of ammonia excretion in freshwater prawn *Caridina weberi*

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Three size groups of *Caridina weberi*, namely size group A (75.6 + 4.5mg), B (148.6 + 2.6mg) and C (502.3 + 5.6mg) reared in different densities such as 1,2,4,8 & 16 prawns per aquaria, were chosen for the present investigation. Experiments were carried out at 30+1°C.

The rates of ammonia excretion decreased with increasing biomass irrespective of the density of the prawn/aquarium. For instance, in one animal density of size group C the rate of NH_3 excretion decreased from 49.2 + 0.63 to 15.3 + 0.51mg/g/h. An increase of more than six fold in body weight results in the decrease of at least 60% in the rate of ammonia excretion.

There is a positive correlation between the time of experimentation and the rates of ammonia excretion. The first hour of exposure always showed higher rate of ammonia excretion.

Increasing the density of prawns resulted in slow reduction of the rate of ammonia excretion. A density of 16 times increase resulted in the reduction of ammonia excretion to the extent of 75%.

The variation in the rate of ammonia excretion might be due to the influence of condition factor and the possibility of a switching over from ammoniotelism to ureatelism, although the influence of high density stress can not be ruled out.

Acute toxicity of mercuric chloride on respiratory metabolism and tissue pathology of the freshwater prawn, *Caridina weberi* (de man)

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Experiments were carried out on three size groups (A = 50.9 + 3.9mg; B = 90.1 + 6.5mg; C = 156.2 + 8.6mg) of *Caridina weberi* to study the influence of four sublethal concentrations of mercuric chloride on the rate of O_2 consumption and the tissue pathology of gills and hepatopancreas. The rate of O_2 consumption decreased with increasing biomass irrespective of the different concentrations of mercuric chloride. The rate of O_2 consumption measured at varying partial pressures of oxygen (PO_2) showed a linear relationship with increasing PO_2 in all three size groups of prawns tested. The slope values obtained for the three size groups of prawns exposed to four sublethal concentrations of mercuric chloride ranged from 0.0024 to 0.0077.

The time required to reach asphyxiation in *C. weberi* decreased with increasing biomass irrespective of the concentration of mercuric chloride. For instance, the asphyxiation time in size group A decreased from 5.25 to 3.25 hr. Contrary to asphyxiation time, the oxygen concentration at the asphyxial time for each size group of prawns increased with increasing concentration of mercuric chloride. For instance, the asphyxial O_2 level increased from 1.359 to 1.868 mg O_2/L in size group A.

Histopathological studies on gills and hepatopancreas of *C. weberi* showed shrinkage of gill stem, depletion of gill epithelium, hyperplasia, vacuolisation, dilation of tubules, reduction in the height of lobular epithelium and tubular hypertrophy.

The variations in the rate of O_2 consumption and asphyxiation at varying concentration of exposed mercuric chloride might be due to mucous accumulation on the surface of the gills and other histological changes in the liver.

Changes to fish communities in Port Phillip Bay, Victoria, Australia, over two decades: 1970–1991

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Changes to the structure of fish communities in Port Phillip Bay between 1970 and 1991 were analysed by trawling at 14 stations sampled regularly between 1970 and 1975 and again in 1990/91. Differences between fish communities at each station were compared using Bray-Curtis dissimilarity indices, multi-dimensional scaling, and analysis of variance for the most abundant species. Depth-related spatial differences in fish communities were observed and correlated with the shallow, intermediate and deep regions found in other studies of fish communities in Port Phillip Bay.

There were significant temporal differences between fish communities sampled in 1970-71, 1972-75 and 1990/91. Differences in catches between both sampling periods in the 1970s appear to be the result of different vessels being used for trawling during the two periods. While a third vessel was used during 1990/91, differences in catches between 1972-75 and 1990/91 appear to represent real temporal changes rather than differences in trawl efficiency.

Between 1972-75 and 1990/91 there were significant decreases in the catches of most species, but a few species increased in significant abundance. Changes to fish communities were attributed to the effects of exploitation, habitat loss, reduced competition and the establishment of additional exotic species during the past two decades. Heavily-fished species such as sand flathead, yank flathead, toothy flathead and common gurnard perch appear to have declined due to high levels of exploitation. Significant declines in the abundance of King George whiting, cobbler, greenback flounder, six-spined leatherjacket, mosaic leatherjacket and long-finned pike appear to be largely due to habitat changes and particularly to a poorly-documented but substantial decline in seagrass abundance in the Geelong Arm. The increased abundances of eastern shovelnose stingaree and sparsely spotted stingaree were probably caused by reductions in populations of their major competitors. The oriental goby has been introduced into Port Phillip Bay since the 1970s. Populations of little rock whiting in the Geelong Arm and globefish populations in deep regions of Port Phillip Bay appear to have increased

due to habitat changes resulting from the recent establishment of additional exotic invertebrates.

The probable interactions observed in this study between commercial and non-commercial species illustrate the importance of considering ecosystems as a whole when assessing the sustainability of fisheries. The inclusion of commercial and non-commercial species in fisheries monitoring programmes provides data which may indicate not only the magnitude of changes in species abundance, but the possible causes of these changes.

Responses of an overexploited Caribbean trap fishery to the introduction of a larger mesh size

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Trap fisheries on coral reefs are important in the Caribbean, but yields are depressed because of overexploitation and habitat degradation. A minimum mesh size regulation is a possible management tool for these fisheries, but effects of increasing mesh size on catch rate are not easy to predict and have not been quantified.

This study is the first attempt in the Caribbean to document the effects of introducing a larger mesh size (1.5" compared with 1" and 1.25") into an active, small-scale, overexploited trap fishery. Catch rates and catch composition (by species and fish size) were examined for all traps in the fishery and for 1.25" and 1.5" mesh separately, 10 months before (in 1990, when < 6% of traps were 1.5"), immediately after (in 1991, when 68% of traps were 1.5"), and three years after (in 1994, when 42% of traps were 1.5") the introduction of the larger mesh size in the Discovery Bay trap fishery in Jamaica.

Mean catch by weight for the entire fishery showed an initial but insignificant decline of 6.5% from 0.77 to 0.72 kg/trap/haul between 1990 and 1991. By 1994, mean catch had increased significantly (48.1%) to 1.14 kg/trap/haul. This may indicate either that larger mesh traps have a higher catch than smaller mesh traps, or that population biomass has increased, perhaps in response to the reduction in number of small mesh traps in the fishery. Both factors appear to be contributing to the higher catches. Mean catch for 1.25" traps increased from 0.60 to 1.03 kg/trap/haul between 1991 and 1994, and that for 1.5" traps from 0.83 to 1.24 kg/trap/haul, strongly suggesting an increase in population biomass. Mean catch per haul for the 1.5" traps was higher than for the 1.25" traps in both years, probably resulting from the fact that they are soaked for longer (5.2 days) than the 1.25" traps (3.0 days). However, the catch rate (as catch per week) was higher for the 1.25" traps than 1.5" traps (e.g. 2.77 kg/trap/week compared with 1.81 kg/trap/week in 1994).

Mean size of trapped fish increased significantly (38%) with the introduction of the larger mesh, from 0.13 kg in 1990 to 0.18 kg in 1991, reflecting the tendency of larger mesh traps to catch bigger fish. Mean size of fish taken by 1.25" traps did not change (0.13, 0.15 and 0.14 kg in 1990, 1991 and 1994 respectively), whilst mean size of fish in 1.5" traps declined significantly from 0.25 to 0.20 kg between 1991 and 1994. This clearly suggests that mean size of fish in the multi-species population has not increased and hence that the increase in population biomass detected reflects an increase in population numbers. A decrease in mean fish size with increasing fish numbers is expected in a growing population.

Species composition (by weight) of the catch has changed significantly between 1990 and 1994 towards larger and more valuable species, suggesting further benefits to fishers arising from the introduction of larger mesh traps.

This study has demonstrated the effectiveness of an increase in mesh size in a trap fishery. But it has also shown that, as smaller mesh gear is phased out, the remaining small mesh traps become more effective and therefore more popular. This will make it more difficult to prevent the use of small mesh traps and achieve the full benefits of the larger mesh gear.

The headaches and benefits of compiling an historical summary of industry based fisheries statistics

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Historical catch statistics summaries are an important tool for assessing the status of commercial fisheries. They are required by researchers assessing the status of fisheries stocks and by resource managers developing and implementing management plans for these fisheries. The objective of this project was to assemble a database of annual catch statistics data for the fiscal years (July to June) from 1940/41 to 1991/92 using all of the available official catch return data for New South Wales so that a global overview of fisheries production could be produced. A secondary objective was to identify mechanisms for improving the quality of fisheries statistics in New South Wales. The findings and conclusions from this project provide valuable lessons that are generally applicable to most agencies that collect industry-based statistics for the research and management of regional fisheries.

It was a complex and difficult task requiring significar. resources to assemble adequate historical catch statistics summaries for New South Wales from the available records. The information from four different secondary and tertiary summary sources had to be compiled then checked for integrity and consistency.

The final report provides a brief summary of gross trends in fishing effort and a detailed summary of commercial fisheries production during the study period. Production trends were elucidated for 83 species and species groups at 37 ports of landing in the ocean sector, at 31 estuaries in the estuarine sector and 15 catchment areas in the freshwater inland sector. The HCATCH database now provides a valuable resource of historic annual production information for these 83 species at 286 regional locations.

The report provides a good overview of historical fisheries production in New South Wales, but there are some limitations on the usefulness of this information for finer scale assessments. These limitations stem primarily from inadequacies in the data collection system. During most of the study period, fishing effort data requested by the monthly catch return system were inadequate for catch per unit of effort analysis. Some taxonomic groups containing multiple species were listed on the return forms, making it impossible to follow the production of some individual

species. Daily logbook systems are now being developed to collect detailed catch and effort information for the major fisheries. Because monthly catch returns supplied by the fishers were the only official source of catch statistics for most of the fisheries, it was not possible to validate the catch information and assess the rate of misreporting. Consideration is being given to a system for registering all primary fish receivers and collecting landings and price information from this secondary source for quota monitoring and validation of logbooks.

A primary conclusion from this project is that fisheries agencies should regularly review and update the data requirements and associated data collection systems for their managed fisheries. Resources invested in this process will reduce future resource requirements for summarising and applying this information.

Traditional fishers and the 'new fisheries management policy', Bangladesh, 1986–96

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A long-term historical study has been undertaken of the rights of traditional fishers in colonial Bengal and its successor states of Bangladesh and West Bengal. This has been focused on the changes in state policy towards fisheries management in the region in the colonial and post-colonial periods. In contemporary Bangladesh the implementation and operations of the "New Fisheries Management Policy' (NFMP) since its introduction in 1986, have been analysed.

Colonial policy until 1947 kept the control of most fisheries ('jalmohal') in Bengal in the hands of landowners ('zamindars'), who treated them as a source of rental income from leaseholders ('ijaradars'). Leasing was generally short-term and neither zamindars nor ijaradars took any interest in protecting fish stocks. Fishers were sometimes able to take leases but the majority remained throughout the period of British rule, a dependent stratum with practically no rights in water or to fish. With independence, Pakistan abolished zamindari rights and the government took control of fisheries. Seeing fisheries more as a revenue-raising device than a resource to be nurtured and protected, the government leased out through an open auction system which favoured rich and powerful interests. Organised fisher representations produced only cosmetic change: in the late 1960s fisher cooperatives were given preference in auctions if they offered the highest bid and after liberation in 1971 cooperatives were given the exclusive right to bid in the first round – but this led to non-fisher interests entering the system under the guise of the cooperatives so that, in effect, the old system continued.

In the 1980s fishers campaigned against their lack of control over fisheries and the exploitative practices of leaseholders and moneylenders, and they demanded an end to the leasing system through tender. In response, in 1986, the Government introduced the NFMP. This new policy aimed to license the jalmohal to fishers for an annual fee, to increase production (rather than government revenues) through new management techniques and to ensure sustainable fish stocks by giving fishers long-term security. This policy has not been fully implemented: only 300 out of 10,000 jalmohals having been transferred to genuine fishers or fishers' associations. At present, therefore, two policies exist side by side. The main policy continues to be open auction leases where wealthier non-fishers dominate while the NFMP operates in a much more limited area.

In its three goals of greater equity, productivity and sustainability the NFMP has had limited success. It has been responsible for a small shift towards greater equity but there is a need for concerted efforts to transfer more fisheries permanently to fisher control. Licence fees need to be reduced and more effective credit made available to fishers. Productivity and sustainability, moreover, depend on greater fisher control. Those outcomes require the restoration of natural ecosystems linking natural waterways and jalmohals to encourage fish migration and biodiversity and for this it is essential to draw on the accumulated knowledge of traditional fishers and farmers: there is a need to return to an approach that sees agriculture and fishing as complementary, not competing, activities in rural Bangladesh.

Management of Australia's northern prawn fishery: a delicate balancing act

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The Northern Prawn Fishery, one of Australia's largest fisheries, is regarded as one of the pace setters in fisheries management in Australia and around the world. This has been achieved by a means of a delicately balanced cooperative management plan worked out by industry, State and Commonwealth fisheries managers and research scientists.

The Northern Prawn Fishery, or the NPF as it is commonly known, covers an area of more than one million km² of ocean out to the extremity of the Australian Fisheries Zone between Cape York in Queensland and Cape Londonderry in Western Australia.

During its history the fishery has experienced many ups and downs. First there was the banana prawn gold rush in the 1970s when there were record catches and a rapid increase in the size and number of trawlers to a peak of 312. This was followed by a downturn in catches, prawn prices and profitability which led to a drastic restructuring of the fleet in the early 1990s when trawler numbers were reduced to 130 by means of a buy back that cost industry in excess of $A30 million and by compulsory reduction of fishing units.

Only nine species of prawns are harvested commercially in the NPF. They are white banana (*Penaeus merguiensis*), Indian banana (*P. indicus*), brown tiger (*P. esculentus*), grooved tiger (*P. semisulcatus*), giant tiger (*P. monodon*), blue endeavour (*Metapenaeus endeavouri*), red endeavour (*M. ensis*), western king (*P. latisulcatus*) and red spot king prawns (*P. longistylus*).

The development of the NPF has not been without criticism and conflict. Trawler owners were accused of "plundering" the resource, companies described as being "monopolistic" and "pack rapists" and government managers "irresponsible". The NPF is not the only fishery in the world managed by input controls to suffer from overcapitalisation and excess fishing effort but it is an all too rare example of how these problems can be overcome.

Today the NPF is fully developed, efficiently managed and profitable. Jurisdiction has passed from joint management

by Commonwealth, State and Territory agencies to the Commonwealth's Australian Fisheries Management Authority. The fishery has a long term annual production of between 8,000 and 10,000 t and potential yearly export earnings of between $A100 and $200 million shared by a fleet of 126 modern trawlers that stay at sea for months, and process and pack their catches on board. The fleet is owned by a mix of independent single boat operators, small fleet owners and large corporate owners of 10 to 15 vessels each. However, NPF industry and fisheries managers are not complacent. They are continually working on new management options to control the inevitable increasing effort likely to flow from the introduction of more sophisticated catching technology which could threaten prawn stocks and erode industry profitability. It is an ongoing challenge to sustain the biological and economic viability of the fishery in the face of constant changes in environmental factors, fishing effort, currency fluctuations and market trends.

Spatiality, stock assessment and property rights in Indo-Pacific fisheries

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Many Indo-Pacific fish stocks are relatively small by global standards, spatially intricate and difficult to assess. Genetically, areas of stock in a fishery may be relatively uniform but still respond variously to the impact of fishing. Many fish stocks have complex spatio-temporal structures. The terminology of concentration profiles, chaos theory and population genetics is being applied. The spatio-temporal distribution of fished stocks has been described in terms of nuggets, fractals and meta-populations within populations.

In the Indo-Pacific region the spatial distribution of the stock and the relationship between areas of stock are often crucial indeterminates in stock assessments. Whether measured directly through survey or indirectly through commercial catch rate data, all aggregated indices of abundance implicitly have assumptions about spatial structure. Spatial misaggregation of abundance indices is most likely to obscure trends in population abundance, but can also 'create' trends which do not exist. The likely impact of an undescribed spatially structured biomass on any assessment is extremely difficult to gauge without knowing the spatial structure of the stock. But this makes the estimation of confidence regions around stock assessments problematic because by definition you cannot know the unknown. More often than not estimated confidence regions only reflect statistical variability within measurements. They cannot reflect the major uncertainties associated with a stock assessment and consequently give fish stock managers mistaken confidence in stock assessments.

Early workers in the field of stock assessment emphasised the need to spatially structure data used to estimate indices of stock abundance. But subsequently this priority seems to have been overlooked. Relatively little of our exploding computer power has been directed into spatially structuring data collection and analysis. Our massive computer power has been directed at handling larger and larger aggregations of data, and performing countless iterations so that increasingly vague confidence regions can be charted.

Why has no recognised field of fish cartography emerged? Where are the fish mappers and maps we need? Geographic Information Systems and Global Positioning Systems offer all the necessary basic tools.

One partial explanation for this lack of information is the jealousy with which fishers guard their positional information. Fishers' personal logbooks are variously; handed down father to son, sold with the boat, stored, sunk or stolen. But as commercially important data they are valued by the fishing industry because they contain the 'right spots'. Fishers have most of the information stock assessors want, and are willing to co-operate with science in the interest of long term sustainable productivity. But no person can be expected to surrender such valuable information willingly and truthfully without the belief that its contribution is in their own long term interest. This reluctance to provide accurate spatial catch information can be addressed through developing a management framework which guarantees long term access rights to identified shares of the fished renewable resource.

Decline of world fisheries

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Overfishing, habitat destruction, bycatch and poor management have resulted in dramatic declines of some wild marine animal populations and economic hardship within fishing communities. Military technologies developed during the second world war were adapted to fishing on the high seas in the 1960s and 70s. This increased capability caused tremendous increases in world catches for decades, but the worldwide catch of wild fish has been stagnant or declining for several years now, with severe depletion in some regions. This poster is an overview of the resulting problems and possible solutions resulting from decades of extracting fish faster than many populations could replace themselves. The United Nations Food and Agriculture Organization recently determined that most of the world's major fisheries are fully exploited or depleted. Between 1970 and 1990, the world's industrial fishing fleet grew at twice the rate of the global catch. This was mad possible through subsidies: to catch $70 billion worth of fish in one year, governments pay the fishing industry $54 billion. Meanwhile, the catch of wild marine fish continues to decline and the world's population is increasing by about 100 million a year, putting further pressure on an important but diminishing source of protein. With the decline of so many species, aquaculture has been on the rise to make up for the shortfall, its ouput doubling in the past decade. However, aquaculture has not reduced the pressure on wild populations and in fact threatens marine fish by destroying natural habitat, polluting coastal waters and removing newly hatched fish from the wild, a practice that leads these species even further into decline. Much of the world's mangroves has been removed to make way for aquaculture, often only to have the more expensive artificially-raised fish exported to richer countries, leaving subsistence communities to struggle for their own needs amidst declining resources. Worldwide, about 200 million people depend on fishing for their livelihoods. Although debates over the conservation of natural resources are often cast as a conflict between jobs and the environment, the restoration of fish populations would in fact boost employment. In the U.S. alone, if depleted species were allowed to rebuild to their long-term potential their sustainable use would add about $8 billion to the U.S. gross domestic product—and

provide some 300,000 jobs. If fish populations were restored and properly managed, about 20 million t could be added to the world's annual catch. But reinstatement of ecological balance, fiscal profitability and economic security will require a substantial reduction in the capacity of the commercial fishing industry so that wild populations can recover. The necessary reductions in fishing power need not come at the expense of jobs. Governments could increase employment and reduce the pressure on fish populations by directing subsidies away from highly mechanized ships. The United Nations has made historic progress toward conservation through a proposed treaty dealing with high-seas fishing. Such measures, together with regional and local efforts to protect the marine environment, should help guide the world toward a more sustainable future for life in the oceans.

Alaska's sockeye salmon fishery management: can we learn from success?

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Alaska's sockeye salmon (*Oncorhynchus nerka*) production is entering a second decade of historically high return. Despite nearly universal declines in fisheries globally, this fishery provides an example of how a once depleted resource can recover and sustain high harvest levels. This fishery has some distinguishing features: 1) area managers reside in the local fishing communities and have emergency closure authority with law enforcement status; 2) allocation disputes are settled through local advisory committees reporting to a state-wide politically appointed Board, traditionally composed of a variety of individuals with experience in the fishing industry; 3) new regulations may be proposed by individuals, groups and government entities which are evaluated with equal status regardless of the originator; 4) management of most stocks is by a single jurisdictional authority (the State of Alaska); and 5) enhancement practices are primarily supported by private non-profit commercial fishing organizations through voluntary harvest assessment taxes and terminal cost recovery fisheries. In addition, hydroelectric power development has been restricted to non-salmon systems or those with minimal resources, while a low population density with modest industrial development has helped to maintain habitat quality. Also a limited entry system developed by limiting licences in 1973 when fisheries were depleted, has created a transferable permit system whereby individual permits have increased in value and have provided a long term investment in the sustainability of these fisheries. A "conservation ethic" has developed in many coastal communities because of the communal "memory" of this overfishing legacy.

The state has had a history of fishery depletion through overharvest, despite conservative constant harvest rate guidelines (50%) developed in 1920 under the White Act. An uncommon feature of the modern major sockeye salmon fisheries is harvest regulations based on in-season "spawner escapement" goals, as opposed to harvest quotas or constant harvest rates. A number of critics see an overwhelming case for superiority of the *constant harvest rate* policies for salmon, and have suggested Alaska change policies. They argue that under some utility functions, a constant harvest rate policy has a higher expected utility because it is more risk adverse (an economic argument), and without sufficient variation in escapement, the underlying stock-recruitment relationship can not be determined by a stock-recruit analysis (a fisheries argument). The case for the constant harvest rate policy is examined from a point of view different from the traditional approach of computer simulation of the Ricker model. A body of limnological evidence is drawn on that is usually ignored in these discussions, and Karluk Lake on Kodiak Island is provided as a case study of how traditional analysis and conservative harvest rates resulted in declining yield. The practical consequences to actual management if a constant harvest rate policy for sockeye salmon were implemented in Alaska (socio-political argument), are also considered. For example, escapement data collected independent of the fishery and reported daily provide the public with an immediate feedback on the performance of the harvest regulating agency in meeting stated conservation objectives. This results in a public and a political demand for meeting a conservation objective rather than meeting an economic objective such as a catch quota. This also provides political support for funding more precise management through better stock assessment programmes and improved evaluation of escapement goals.

The Natal Parks Board and small-scale fisheries along the coast of KwaZulu-Natal

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The Natal Parks Board in conjunction with the KwaZulu Department of Nature Conservation is responsible for ensuring the wise use of the living marine resources of KwaZulu-Natal. With the recent political changes in South Africa, there is a growing need for formerly disadvantaged people to have greater access to these marine resources. As in the rest of Africa, population growth rates are extremely high (in excess of 2.8% per annum). The Conservation Authorities have taken cognisance of this and are developing small scale fisheries.

The following examples will be illustrated:

1. *Fish harvesting in Kosi Bay estuary system:* Here traditional fish traps have been operating in the estuarine lake prior to colonisation by Europeans which took place in this area around the 1850s. The Kosi lakes now fall within a protected area. Local people who traditionally operated the fish traps have been catered for, and other small scale fisheries (gill netting) have been initiated.

2. *Fish netting at St Lucia:* There is no record of traditional fishing in the St Lucia estuary, parts of which have been a game reserve for 100 years. Over the years, a substantial recreational fishery has developed. Recently the neighbourhood tribal communities have been given access to the fish stocks through limited legal gill netting. Effort levels have been set after an intensive research program which took into account the fish catches by the other users, i.e. recreational fishers, and by the considerable natural populations of pelicans and crocodiles.

3. *Mussel harvesting south of Mapelane:* There have been conflicts between recreational harvesting of mussels and the subsistence gathering from the same stocks. A programme has been initiated to establish a small-scale sustainable mussel fishery. Here representatives from the

local community are being involved in experimental work to ascertain the best method and levels of harvesting. In the process the community is being taught responsible stewardship of the resource. Each of the above fisheries will be described in the paper. The common threads are:

(a) a move away from centralised fishery control where the needs of small communities are not adequately met. The local people are now being involved in the decision making,
(b) different user groups have very different needs – such as the times, methods and quantities for harvesting. These are taken into account where possible,
(c) reduction of conflict between user groups, and
(d) an objective of sustainable yields.

It's about time: rethinking fisheries management

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The recent decades' stock decline in ocean fisheries is just one of many signs of the lack of societal will in resource management contexts. Although there has been adequate theory and somewhat adequate information from fisheries activities, the continuous sequence of surprises and stock failures provides the impetus to revise not only the basic theory of resource management, but also the philosophies under which conventional fisheries management is practiced.

The issues are not simple nor well resolved via the present trend of giving the responsibilities of resource allocation back to the fishing industries, particularly the often "empty cup" that once sustained smaller local to regional fisheries. What clearly appears not to be very effective is pitting government science against industry lawyers. The uncertainties of context-free fisheries stock assessments become the bases of legal contentions. Gross perturbations of ecosystem structures due to fishing have often been denied. The "innocent until proven guilty" legal philosophy has resulted in the systematic decimation of most of the natural resources in the developed world. Habitat degradations define the principal issues of anadromous and estuarine species. Of course, in less sophisticated settings usually associated with developing nations, the general absence of information along with the underlying ignorance of coastal subsistence fishers can only lead to despair for natural losses, and dwindling environmental quality.

Another important issue is that of maintaining biodiversity in natural populations. For most exploited fisheries it is not known what levels of diversity reside within the exploited populations. Significant efforts to measure and understand these have simply not been funded within recent decades. We have no idea of losses during the recent "swarming" of fisheries over the global oceans. A related problem is the "inconvenience" of complex stock structures which have in most cases been assumed away through the years, as data from ever broader ranging fisheries are merged to produce biomass estimates from which most fisheries have been managed. There is at hand a crisis period in which it needs to be specified what array of information other than catch per unit of effort (cpue), yield per recruit, VPA and poorly fitted stock recruitment data, needs to be integrated into assessments and management processes.

To date, few or no fisheries management plans include environmental contexts. Physical variations that affect given resources are well defined from basic psychological ecology. Interdependences of ecosystem components can be resolved from food web structure studies. Only within the last decade and a half has it been possible to discuss openly the consequences of fishery independent causalities such as climate-driven oceanographic processes that affect fluctuations of the major pelagic fish stocks. It is the rare resource management success story that proves able to cope with dwindling or highly variable resource bases that does not include understanding of natural environmental patterns and the responses of living resources to variations

Last, but certainly not least, there is the issue of where to best apply meaningful resource management regulations. The limited success of direct manipulation of fishing effort in many cases can be attributed to other, often unregulated sectors of the industry. In recent years the focus amongst environmental activist groups on market places has been much more effective than conventional negotiated effort limitations, treaties etc. Perhaps there is a lesson to be learned.

Conservation and management of chondrichthyans

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Chondrichthyans are taken in directed fisheries and as bycatches worldwide. In this contribution different groups of species are examined, which either inhabit freshwater or are taken by inshore line fisheries, littoral and continental slope trawling, and oceanic fisheries, and different strategies proposed to manage chondrichthyans and cohabitants of such communities.

The diversity of chondrichthyan fishes (900-1200 spp., 55 living families and 171 genera) is matched by diverse habitat choice. Most species are marine, but a few are found in fresh water. Because of their generally low economic importance in most commercial fisheries, there have been few attempts to manage chondrichthyans and even those have been criticized as 'too little too late'. Depletion of stocks has been noted in numerous studies in the developed world and underdeveloped areas are subject to similar, but unrecorded, declines. Chondrichthyans are particularly vulnerable to human impacts because of their life history traits of low growth rate, low fecundity and late maturity.

All freshwater and estuarine species are highly vulnerable to environmental degradation, such as loss of habitat from river modification and estuarine silting; and pollution. Species loss will be experienced because of human overpopulation and inability to control land use in most parts of the world.

Inshore marine species of continental shelves are threatened by their proximity to the coast where human influences are highest, but large marine reserves are likely to protect at least the less mobile species. Such reserves already exist in many parts of the world but more are needed.

Continental shelf species inhabiting waters of 50-200 m are affected by most fishing activities including trawling and line fishing. There are numerous examples of population declines but only recently have a limited number of attempts been made to assess the so-called bycatch or trash fish in fisheries. The use of observers to monitor catches

would help assessment of impacts. Promulgation of large refugia where fishing is banned may assist conservation of entire marine communities.

The slope and open ocean fauna needs protection by means of refugia, preferably in areas of known fisheries wealth and species diversity. Traditionally these areas are overlooked in management plans but increasingly need attention, given the advances in fishing technology.

Ultimately, political will is vital for management and the importance is stressed of attempting to conserve communities rather than relying on single species models in fishery management. The technology for monitoring fishing locality is available using satellites, so it should be relatively easy and cheap to police fishing in reserve areas even on the open seas, but whether fishing nations would be willing to embrace management of slope and open ocean fishing is questionable. Finally, the development is recommended of a substitute source of collagen fibres to replace their source from shark fins to reduce fishing pressure on sharks.

ustainability indicators for fisheries development

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The United Nations Conference on Environment and Development (UNCED) in Brazil provided a broad framework for global sustainable development. Agenda 21, Chapter 40 of the declaration arising from the conference calls for the development of indicators for sustainable development. More recently, the completion of the Uruguay round and formulation of the World Trade Organisation has placed further emphasis on the need for an accreditation process in which sustainability indicators will play a major role.

In a fishery context, sustainability indicators are part of a larger process that evaluates whether fishing (both commercial and recreational) is sustainable in terms of economic and social development while conserving the ecosystems for the benefit of future generations.

In developing sustainability indicators for fisheries velopment, one has to establish at what level the development is to be evaluated. For example, this could be the total fishery of a country, fishing on a particular mix of species within a clearly defined ecosystem, or fishing on a single species taken by a particular fishing method (e.g. trawling). For any particular level, indicators need to be developed which measure economic and social development, as well as the conservation of the resource. The latter includes both the species being harvested and the environment on which these depend. These indicators are then compared with reference criteria (e.g. a biological reference point in the case of a harvested species) and an evaluation of current status and progress is made.

Traditionally, fisheries assessments have concentrated on the sustainability of the main harvested species, based on yield indicators and maximum sustainable yield reference points. This limited approach, however, is now being replaced by a broader ecosystem management approach which recognises the interactions between fishing, resource sustainability as well as economic and social development.

This presentation focuses on the development of a simple 'Report Card system for assessing whether fishing is sustainable in a given fishery. The report card is based on a list of simple questions derived from a range of resource, economic and social indicators. When carried out annually, these cards provide a simple check on progress towards sustainable development.

A new paradigm for managing marine fisheries in the next millennium

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The objective of this paper is to suggest a new paradigm for managing worldwide marine fisheries to replace the failed model of the past. The need for fundamental reform of marine fishery management has become abundantly clear over the past decade. Fisheries that have sustained coastal communities for generations have suffered catastrophic declines. In some areas, excessive fishing has driven staple species such as Atlantic cod commercially extinct. Increasingly volatile "fish wars," such as the 1995 dispute between Canada and Spain, have erupted over what remains. Governments pay more than $50 billion each year in fisheries subsidies. Gone forever are the historical estimates that marine catches could top 500 million metric tons per year. According to the FAO, we have exceeded the limit of the seas.

The essential question is thus not whether the past model of marine fishery management has failed, but why? What lessons can we draw for the future? Throughout modern history, governments have largely managed worldwide marine fisheries for the growth and development of their associated commercial fishing industries. Decision makers have paid scant attention to the sustainability of those fisheries, much less the health of their associated ecosystems or the needs of artisanal fishers exploiting the same species. In virtually every case, the short-term socio-economic needs of a region's fishing industry have rendered long-term sustainability of catches a futile management goal. In many parts of the world, subsidized fleets have become grossly overcapitalized. Unsustainable fishing has literally become an industrial addiction.

This predicament cannot be attributed to a lack of scientific information. Fisheries scientists have for years provided more-or-less accurate models of fish population dynamics and educated estimates of fishery production. But all too often, fishery managers more concerned with political than scientific realities have been compelled to ignore the implications of the "best available science." Politicians, often at the highest levels, have frequently intervened in decisions about specific fisheries. Society has simply lacked the political will to forestall the fishing industry's tendency to use up its capital and thereby destroy itself.

Powerful socioeconomic and political forces that are firmly entrenched in our management infrastructure drive unsustainable fishing. As a result, governments have typically avoided any actions that carry a price unacceptable to industry. Reversing this situation will require harnessing public support for a new paradigm of management. The foundation of this new model must be greater public involvement and accountability in the fishery management process. If we are to save world fisheries, we must somehow bring to bear the same worldwide public concern that banned the trade in elephant ivory and outlawed commercial whaling. We must create incentives for sustainable fishing. Only concerted public interest has the power to stop overfishing and to shift the paradigm of

fishery management from development and exploitation to conservation and sustainability. It will not be easy; fish neither sing like whales nor look like pandas. However, the stakes are high: the health of world fisheries, their associated marine ecosystems, and the millions of people that depend on them for food and employment.

Great Lakes fisheries futures: using an ecosystem approach to balancing the demands of a binational resource

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The fishery resources of the Great Lakes have changed dramatically over the past century as a result of an increasing human population and extensive land and water use changes in the Great Lakes basin. The indigenous ichthyofauna of these lakes consisted primarily of a coregonid complex, lake trout, burbot and Atlantic salmon. Historically, these fish populations comprised an important subsistence fishery for Native Americans and early settlers. As the human population increased in the basin, however, subsistence fisheries changed to commercial. Concurrent with this increase in exploitation were significant changes in the land and water use patterns in the Great Lakes region. These changes, including deforestation, wetland draining, mining, an increase in agricultural activities, and the development of the Great Lakes shipping industry, reflected the industrialization and urbanization of the watershed and have greatly impacted the water quality of the lakes and their tributaries. The combined effects of increased exploitation, and land and water use changes, resulted in a collapse of the historic fisheries, eutrophication of the lakes, contamination of their biota and spread of exotics into the basin.

Fisheries management agencies responded to these changes using a traditional production paradigm which seeks to maintain maximum yield of certain fishes for harvest. This type of approach focuses on single species management with little consideration for the ecosystem in which the species resides. However, fisheries managers are becoming increasingly aware that fish communities and fisheries are integral components of complex aquatic ecosystems. Therefore, effective management of production and yield of Great Lakes fisheries depends on understanding and rehabilitating the biological, chemical, physical and social components of the ecosystem. The ultimate success of Great Lakes fisheries management activities is closely tied to an ability to manage the ecosystem as a whole for the long term optimal production of target fisheries.

In the Great Lakes, the complexity of the ecosystem is further exacerbated by an equally complex governance system which includes two nations, eight states, one province, and a multitude of local and municipal governance structures. Therefore, Great Lakes fishery managers are struggling to balance a wide variety of demands on the Great Lakes ecosystem which impact their fishery resources. As fish production is directly related to the quantity and quality of the surrounding watershed and airshed, which are not based on geopolitical boundaries, fisheries professionals need to shift from the traditional production view to a more holistic ecosystem view. This shift would allow managers to not only focus on single species management, but also to focus on the conservation of all species and the maintenance of ecosystem processes. Additionally, using an ecosystem framework, jurisdictional boundaries would become secondary to the system boundaries, allowing management practices to be developed in a holistic rather than a jurisdictional basis. This management approach recognizes that successful fisheries management relies on an understanding of the relationships between the biological and sociological capabilities of the ecosystem.

Use of a marine GIS to examine variability in squid fisheries over the Patagonian Shelf in relation to remotely-sensed oceanographic variables

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The fisheries over the Patagonian Shelf exploit two species of squid, *Illex argentinus* and *Loligo gahi*. Both species have a life span of approximately one year, but their life cycles take place over very different spatial scales. Several stocks of *I. argentinus* are recognised of which the most important to the fishery is the southern, winter spawning stock. This stock is thought to spawn off the continental shelf near to the confluence of the Falkland (Malvinas) Current and the Brazil Current, from where it migrates to the Falkland Islands (Malvinas) to feed and mature during the austral summer and autumn. It is at this time that it is exploited by the fishery, prior to the return migration to the spawning grounds. In contrast, *L. gahi* probably spawns inshore in the Falkland Islands (Malvinas) and two or three seasonal broods undergo ontogenetic migrations into deeper water where they are exploited at an intermediate age. In both species annual catch is poorly correlated wit. the estimated size of the spawning stock of the parent cohort, highlighting the likely importance of oceanographic variables in influencing recruitment strength.

The advent of remote sensing techniques has enabled large scale physical oceanographic processes over the Patagonian Shelf to be examined. Historical data from polar orbiting satellites, together with data from the British Antarctic Survey's satellite receiving station on the Antarctic Peninsula, now enables sea surface temperature (SST) to be measured and fluctuations in the position of ocean fronts and water masses to be determined. In order to relate some of the large scale datasets derived from remote sensing, and to examine levels of temporal and spatial variability, a marine Geographic Information System (GIS) has been developed. The GIS now allows the association of data that were previously difficult to relate. The Falkland (Malvinas) Current/Brazil Current system has strong northerly and southerly components and marked gradients in sea surface temperature. Variability in this system has been examined for the period 1985 – 1994. The system is strongly seasonal and exhibits a southward displacement in summer and a northward displacement in winter. It also shows evidence of interannual variability, with high mean temperatures in some years. There are also strong indications of interannual

variability in the displacement of the Falkland (Malvinas) Current/Brazil Current confluence close to where the southern stock of *I. argentinus* is thought to spawn.

Use of the GIS has also allowed both the *I. argentinus* and *L. gahi* fisheries to be mapped. The two fisheries are pursued in different areas of the shelf. The *I. argentinus* fishery develops mainly to the northwest of the Falkland Islands (Malvinas), whereas the *L. gahi* fishery develops mainly to the south and east. The distributions of the fisheries differ somewhat in different seasons, but are strongly related to particular bathymetric contours. For both species, interannual variability in catch and catch per unit of effort have been examined. The problems associated with a simplistic correlation to large scale oceanography have been investigated and temporal and spatial problems have been examined.

International environmental instruments and their impact on the fishing industry

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Since the declaration of 200 nautical mile Exclusive Economic Zones, there has been a significant rise in the fishing pressure on fish stocks under national jurisdiction, and on the High Seas in particular. These developments have led international governmental and non-governmental organisations to call for domestic and international action to promote more rational conservation and sustainable utilisation of the fisheries resources of the oceans. These "green" concerns relate to target stocks issues, such as species selectivity (bycatch), and the impact of fishing gear on the marine environment.

In response to these concerns, a number of international instruments have been developed with the specific purpose of regulating how fishing is carried out. In addition to attempts to directly intervene in fishing, a host of other international instruments which have been developed to address wider conservation and environmental issues, have the potential to be applied to fisheries.

These instruments may be divided into two groups in terms of their legal effect. In the first group are those instruments which qualify as treaties or conventions in international law and are therefore binding on the parties to them. In the second category are those instruments which may be described as "soft law", that is to say that they are not legally binding but have political and moral force. They reflect international public opinion and may indicate future trends in the development of binding legal rules.

These international environmental instruments have significant implications for the fishing industry world-wide in terms of their operations and for fisheries administration by government. Based on the authors' commissioned research for the Australian Fisheries Research and Development Corporation it is concluded that the fishing industry will be subject to an increasing number of policies that conserve marine areas by restricting vessel access. Similarly protection and restoration of endangered fish species will lead to area, fishing method, and bycatch-reducing restrictions on fishers. These will usually be implemented through national legislation. In fisheries management, international obligations will lead to greater detail in management planning and acceptance of the precautionary principle. There will also be a shifting in the burden of proof required for new fishing ventures, with industry being required to prove that their fishing is not deleterious to the marine environment.

The fishing industry response to international environmental instruments is seen in the development of the Code of Conduct for Responsible Fishing developed by the FAO. However at a national level the industry must decide to adopt a code of conduct suited to national requirements. This would usually include a bycatch response strategy, with the development of appropriate bycatch exclusion devices, and may extend to policies on eco-labelling of products to capture any market advantage from conforming to environmental standards. The fishing industry will face compliance problems within industry for any measures adopted and must support their representative organisations to meet the environmental challenge and to communicate with government agencies and non-government organisations. The fishing industry cannot ignore international environmental instruments and their impact on fishing.

Community-based management for a sustainable seahorse fishery

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Seahorses are heavily exploited for Chinese medicines and aphrodisiacs, and also for aquarium fishes and curios. At least 25 countries are now involved in supplying the increased demand for seahorses engendered by China's rapid economic growth. The vast scale of this trade threatens seahorse populations globally. Declines in seahorse catch are particularly worrying for artisanal fishers in the Philippines, who may derive more than half their annual incomes from these fishes. This project recognizes that seahorse conservation can be approached through wise management of the seahorse fishery, but only if the community can be convinced of its necessity and involved in its implementation. The establishment of such co-operation has been sought.

The work is based in Handumon village, Jandayan Island off the island of Bohol in the central Philippines. This is an influential centre in the Filipino seahorse fishery, and changes here affect activity in other areas. About one quarter of the families in the village catch seahorses, but seahorse numbers have declined substantially in recent years. A seahorse management project was launched late in 1994, with community involvement as a priority. Neither promises nor bribes were offered. The project is guided by two biologists and one community organizer, all Filipinos, with direction from the senior author.

A strong conservation programme is now in place, less than one year after the project began. The village has established a no-exploitation reserve (directed towards seahorses but encompassing all fishes) which they patrol. Seahorse fishers bring their daily catches for examination, enabling recording of biological parameters, gathering socio-economic data, and assessment of catch per unit of effort.

From these daily meetings arose an agreement for a conservation gain without economic loss: pregnant males are now held in cages in the sea until they give birth, allowing the young to escape to the sea before the empty male is sold. Seahorse collectors also assist with underwater studies of seahorses and some fishers donate part of their seahorse catch (at economic cost to themselves) to restock the reserve and other depleted areas.

The work in the village becomes increasingly holistic and now includes educational programmes on ecological issues, a high school scholarship in exchange for weekly participation in marine conservation work, tree planting on World Environment Day, and planning for solid waste disposal.

The considerable effort involved in community liaison has produced strong support from the village and municipality and allowed a remarkable collaboration with the seahorse fishers. Nearby villages are also adopting aspects of the project. Results in terms of seahorse conservation should be emerging by the time of the Congress, but attitudes towards conservation and management in general are clearly already changing. In the Philippines at least, fishing communities can be more than willing participants in resource management.

Can shark stocks be harvested sustainably – a question revisited

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Sharks are characterised as long-lived, slow-growing and producing few offspring, and shark populations are assumed to have a close stock-recruitment relationship. Even though sharks constitute less than 0.5% of world fish production, experience with shark fisheries and the peculiarities of shark biology have led to doubts about whether sharks can be harvested sustainably.

The view that shark stocks have low productive capacity was formed over 40 years ago largely from research on *Galeorhinus galeus*. A short-term demand for shark liver oil during World War II stimulated rapid growth of the Californian and southern Australian fisheries for *G. galeus*, but the stocks soon collapsed off California and gradually declined to 10-25% of initial biomass off Australia. *G. galeus* is particularly long-lived (it holds the world record of >42 years for a tagged fish at liberty), takes a long time to reach sexual maturity (8-10 years) and breeds only once every 3 years. Early research on *Squalus acanthias* in North America and the East Atlantic revealed similar biological characteristics and fishery trends.

More recent studies show that some sharks, such as *Mustelus antarcticus* taken off southern Australia, are more productive than *G. galeus* and *S. acanthias* and can be harvested sustainably. *M. antarcticus* has a longevity of about 16 years, breeds every 1 or 2 years, produces up to 41 offspring per pregnancy and begins breeding as early as age 3 years. Other harvested species, such as *Rhizoprionodon terraenovae* in the Gulf of Mexico and eastern USA, and *Carcharhinus sorrah* off northern Australia, are even shorter lived and breed earlier.

With careful management sharks can provide for particularly stable fisheries. Young sharks are born well formed, meaning that survival and recruitment are less likely to fluctuate in response to environmental variation than do survival rates of the eggs and larvae of invertebrates and scalefish. Modelling southern Australian shark stocks provides evidence that natural mortality of a cohort declines with increasing age for the first years of life and that only a small proportion of a shark population breeds at any given time. This suggests that there might be advantages in harvesting sharks at young ages when natural mortality is high and in protecting the older sharks with low rates of natural mortality for breeding purposes. This can be achieved by adoption of legal maximum lengths or mesh-sizes of gillnets small enough to enmesh young sharks but deflect older sharks.

Adequate stock assessment and management of shark fisheries require monitoring of catch, catch composition and fishing effort; developing models which incorporate the peculiarities of shark reproduction, survival, complex movement and distribution patterns and selectivity characteristics of gillnets and longlines used predominantly in shark fisheries; and determining appropriate biological reference points for sharks which will vary between species.

Sharks can be harvested sustainably, although harvest levels from any particular stock will be limited by its reproductive capacity. However, sustainability will be achieved only if there is a vast improvement in the information base and a strengthened will around the world to control shark catches.

Management arrangements for developing fisheries: the precautionary principle and use of adaptive management strategies

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A majority of fisheries in Australian waters are considered to be either fully- or overexploited. This overexploitation is often a consequence of allowing too many participants access to the resources during the development phase or during periods of increased exploitation of a fishery.

The 'precautionary principle' has been used to effect government policy to restrict access to developing fisheries and the use of some fishing gear. A definition of the precautionary principle as it relates to the management of marine resources is provided and its use in formulating an adaptive management strategy explained.

Case studies are presented on two developing bivalve fisheries, a crab fishery and one involving new fishing technology. Appropriate harvest levels were set for the bivalve fisheries after consultation with identified stakeholders, and a mix of input and output controls used to achieve management objectives. The use of twelve-month licences and individual contracts strengthened the level of compliance with licence conditions, and the level of responsibility by fishers in changing harvest patterns and size limits to provide for the testing of adaptive management strategies. Contracts gave fishers a greater degree of ownership of the resource even though the licence period was restricted to twelve months. There is an expectation that some level of access will be maintained to a developing fishery, if licence conditions are not breached, and contracts are fulfilled.

Management arrangements for the bivalve fisheries contrast with the strategy used to determine access and catch for the king crab fishery. Fishers were encouraged to target crabs with no emphasis given to the precautionary principle. Management authorities were slow to react and access arrangements were virtually unrestricted. The problem was further exacerbated by the erroneous assumption that increased fishing effort maximises economic performance in a developing fishery.

Management success can be measured in the short term by performance measures against the stated objectives of the management strategy, but long term sustainability is very difficult to quantify and measure. Setting conservative objectives based on the precautionary principle is both biologically and politically defensible when determining exploitation levels for developing fisheries. Continued analysis of data to provide for some form of risk assessment is essential from day one.

Experience shows that developing fisheries are quickly subjected to unsustainable levels of fishing effort, with the erosion of community benefits, if an early management objective is to allow open access. The rapidly increasing value of the fishery tends to block the initiatives by government and some industry participants to constrain fishing effort. Information on the fishery biology and fleet dynamics is more important than the secondary consideration of operator earnings in providing for a sustainable outcome and economic efficiency.