Molluscan Fisheries and Aquaculture
World Congress of Malacology
Perth 2004

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2003/300 Molluscan Fisheries and Aquaculture, World Congress of Malacology, Perth 2004

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NON TECHNICAL SUMMARY:

The World Congress of Malacology was held at The University of Western Australia from 11 to 16 July 2004. Overall the congress was a huge success with over 300 delegates and 25 accompanying people from over 40 countries.

The FRDC sponsored symposium on Molluscan Fisheries and Aquaculture was one of the strengths of the congress. The original plan was to have the entire symposium on Tuesday with about 15 participants. However, there were so many papers that the sessions were resumed on Thursday and went until lunch time. In all there were 38 papers presented: 27 were oral and there were 11 posters. Registrants for this symposium came from all Australian States. Additionally, presenters came from the following countries: China, Denmark, France, Korea, Japan, Portugal, United Kingdom and United States. Dr Sandra Shumway of the University of Connecticut and editor of the *Journal of Shellfish Research* was the plenary speaker for the session.

The plan is to publish selected papers in the *Journal of Shellfish Research.* A total of 13 papers were submitted for consideration for publication (list attached). These have been reviewed and revised, and were sent to the *Journal of Shellfish Research.* Publication is expected in the first half of 2006.

Full abstracts and details of the congress are on the web at: http://www.mollusckey.com/perth

KEYWORDS: **Molluscs, aquaculture, fisheries.**

ACKNOWLEDGEMENTS:

In addition to funding from the Fisheries Research and Development Corporation, this project received funding from the Development and Better Industries Fund administered by the WA Department of Fisheries. The *Journal of Shellfish Research* generously discounted the normal page rates for publication. Salary for time for participation, office costs, etc for Dr Wells were met by the western Australian Museum and those of Drs Maguire and Joll were met by the WA Department of Fisheries.

BACKGROUND:

The World Congress of Malacology was held in Perth, Western Australia, in July 2004. As part of the conference, a major symposium was held on Molluscan Fisheries and Aquaculture. This provided an outstanding opportunity for mollusc researchers to exchange ideas about fisheries and aquaculture across species boundaries, and to present the latest research in this field on a worldwide basis, with Australian research being showcased. Invited papers were published as a refereed proceedings in the *Journal of Shellfish Research.*

NEED:

There is a wide diversity of wild caught fisheries and aquacultural activities dealing with molluscs, including (but not limited to) wild caught scallops, squid, octopus, abalone, and aquaculture industries for pearl and edible oysters, abalone, mussels, etc. Researchers tend to talk to other researchers in their individual industries. The World Congress presents an outstanding opportunity for workers working on molluscan fisheries and aquaculture to interact closely with each other and also with other researchers from throughout the world who work on numerous aspects of molluscan biology. For example, a symposium is planned larval development of molluscs, which has implications for researchers on molluscan aquaculture. Attendance of scientists working on other aspects of molluscs will provide a fertile ground for input from high quality researchers into molluscan fisheries and aquaculture.

OBJECTIVES:

1. To bring together 15 leading fisheries and aquacultural scientists working on molluscs to present papers reporting the latest research in their fields.

2. To encourage participation of other scientists who will not be funded.

3. To provide opportunities for discussions of the latest research in the various fields of molluscan fisheries and aquaculture, and to provide opportunities for full discussions of ideas across fields.

4. To publish selected papers in a format which can be widely distributed.

5. To improve research strategies and applied outcomes for molluscan fisheries

and aquaculture industries.

METHODS:

The World Congress of Malacology, Perth 2004, was organised by a committee headed by Dr Fred E Wells of the Western Australian Museum. The symposium on molluscan fisheries and aquaculture was organised by Dr Wells and Dr Lindsay Joll and Dr Greg Maguire of the WA Department of Fisheries.

The original application sought funds to provide approximately 15 researchers with $ 1000 each for domestic participants and $ 2000 each for international participants towards conference registration, accommodation and meals. Participants covered their remaining expenses. Participants were chosen to represent a variety of fields such as molluscan trawl fisheries (scallops, etc), dive fisheries (abalone, etc), and aquaculture fisheries (pearls, abalone, etc).

This provided a core of outstanding researchers for the symposium, which in turn attracted the participation of other researchers from within Australia and overseas who were not funded.

$ 10,000 will be used to assist in publication costs.

Institutional support was in the form of salaries and on costs for the time spent preparing papers and talks, reviewing of manuscripts, editing the resulting volume, and travel expenses not covered by FRDC.

The proposal represented an extremely cost effective mechanism to stimulate high quality research on Australian molluscan fisheries and aquaculture.

RESULTS/DISCUSSION:

The initial application to FRDC was to provide assistance to allow 15 scientists to participate in the conference. As funding was only half of the requested amount, the number of scientists was expected to be proportionally smaller. However, in the end 33 people from 9 countries presented in the symposium on Molluscan Fisheries and Aquaculture. Registrants for this symposium came from all Australian States. Additionally, presenters came from the following countries: China, Denmark, France, Korea, Japan, Portugal, United Kingdom and United States. Dr Sandra Shumway of the University of Connecticut and editor of the *Journal of Shellfish Research* was the plenary speaker for the session.

A total of 38 papers were presented, 27 as verbal papers and 11 as posters. The papers covered a wide range of taxonomic groups, including 16 on gastropods, 20 on bivalves, one on cephalopods and one on molluscs in general. There were 18 papers on aquaculture, 18 on wild caught fisheries, and two that covered both. With the commercial importance of abalone in southern Australia and the growing interest in their aquaculture in both temperate and tropical areas, there was a substantial interest in abalone research. There was also an emphasis on pearl oysters.

The wide range of topics covered was a strength of the symposium as it provided researchers with a variety of opportunities to discuss their work with people who work on other aspects of molluscs, both from the viewpoint of fisheries and aquaculture and other aspects of molluscan biology.

BENEFITS AND ADOPTION:
The symposium provided an opportunity for interaction between researchers and industry participants and a stimulus for further research into molluscan wild caught fisheries and aquaculture.

FURTHER DEVELOPMENT:
As the process was successful, it is planned to investigate possibilities for holding further such symposia when opportunities arise in Australia.

PLANNED OUTCOMES:
Full abstracts and details of the congress are on the web at: http://www.mollusckey.com/perth

It is expected that thirteen papers will be published in the *Journal of Shellfish Research* in early to mid 2006.

CONCLUSION:
The World Congress of Malacology, Perth, Western Australia 2004 was an outstanding success, with 302 participants from 42 countries. The symposium on Molluscan Fisheries and Aquaculture was one of the strongest parts of the Congress, with 33 researchers presenting a total of 38 papers and posters. Thirteen of these papers have now been reviewed and are expected to be published in the *Journal of Shellfish Research.*

REFERENCES:
None

APPENDIX 1: INTELLECTUAL PROPERTY:
Abstracts of papers presented were published in the conference abstract book and are on the worldwide web. Published papers will appear in the *Journal of Shellfish Research.* Normal copyright laws apply to the *JSR,* but the papers are freely available for use by other researchers and industry.

APPENDIX 2: STAFF
No staff were hired for this project.

APPENDIX 3: ABSTRACTS OF PAPERS PRESENTED

Principles of particle processing mechanisms in bivalves

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Despite the observed diversity of particle processing systems in Bivalves, unifying principles have emerged from new observational techniques and intensive study over the past fifteen years. The close-range mechanism of particle capture, while still in some dispute regarding physical interaction, involves compound latero-frontal cirri in the homorhabdic systems studied to date. Subsequent transport of all particles in this system is counter-current to the ventral gill extremity via muco-ciliary transport, in acidic (viscous) mucopolysaccharides. Transfer to the labial palps is via a mucus bridge, and ingestion volume regulation occurs on the labial palps, where pseudofeces are formed and rejected onto specialized pallial ciliated tracts, consisting of composite cilia and underlying acidic mucopolysaccharides, to the edge of the inhalent siphon.

The two heterorhabdic systems (filibranch and pseudolamellibranch) show some similarities and some marked differences. The capture mechanism is not firmly understood, but since neither system possesses compound latero-frontal cirri (oyster lfc's are composite), and since the principal filaments only move particles hydro-dynamically toward the dorsal (initial acceptance) tract, the mechanism is assumed to be hydro-dynamic, accompanied by relatively low-viscosity mucus. Material initially rejected on the gill is transported ventrally on the ordinary filament plicae, and in the filibranch system such material is voided via valve clapping without reaching the labial palps. In the pseudolamellibranch system, ventrally-directed material in acidic mucopolysaccharide mucus may be rejected directly onto the mantle rejection tracts in the event of gut satiation, or it may continue toward the labial palps for further decision. Pseudofeces from the labial palps are deposited on the mantle rejection tracts, and voided from the inhalent aperture.

The sites and mechanisms of qualitative selection are the objects of renewed interest. In the heterorhabdic systems, both the gills and the labial palps are involved in this process. The filibranch principal filaments studied to date are large enough to allow entry of a very wide particle size range, so there is no size constraint on site of particle selection. In the pseudolamellibranch system, however, the principal filaments are too small to allow entry of particles > 70 :m; qualitative selection of larger diatoms etc. therefore takes place on the palps. Unambiguous identification of quality cues is difficult and ongoing; the outer casing and associated organic molecules of diatoms have recently been identified as such.

Throughout the particle processing systems, common underlying mechanisms are apparent: the types of mucus used in transport on different types of surfaces, the types of cilia used for specific tasks, and the general architecture of the pallial organs in relation to the type of task performed (open vs. enclosed, raised vs level).

Optimal conditions for artificial fertilization, embryonic development, and larval growth of the purple clam *Saxidomus purpuratus* in the southern coast of Korea

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Laboratory experiments were conducted to obtain the basic information on culture conditions for the larvae of the purple clam *Saxidomus purpuratus*, one of important clam resources in the southern coast of Korea. This study was focused on (1) the success in fertilization and development from artificial fertilization according to the different months of a year, (2) the viability of sperms after exposure to seawater, (3) and the effects of temperature, salinity, and food organism on the survival and growth of larvae.

High fertilization rate of gametes obtained from dissecting gonads was obtained at all months if clams were kept in room temperature. But high successful development occurred only during May-July. Developmental success seemed to be related to the egg quality at the fertilization time. Developmental times for 2-cell, 4-cell, 8-cell, blastula, trochophore, and veliger at 20℃ were 1.5, 2, 4, 18, 24, and 32 hours, respectively. Sperms could survive for up to 8 hours; however, actively swimming sperms could be found within 1 hour after exposure to seawater. Thus sperm should be used for fertilization as soon as possible when they were exposed to seawater.

At high temperature (35℃), all the larvae died within 48 hours. Larval survival decreased when salinity was either lower than 20 psu or higher than 40 psu, and it was nearly 0% when salinity was 10 psu. Optimal temperature and salinity ranges of larvae of *S. purpuratus* were 20-25℃ and 20-40 psu, respectively. Larvae grew from 111.5 to 235.3 μm during 21 days. Larvae grew faster when mixed algal diets were supplied than single kind of algal diets: the fastest growth was observed when larvae were fed on the mixture of *Isochrysis galbana* and *Nannochloris oculata*.

Reproduction of *Adelomelon brasiliana*, a commercial volutid from Argentina (Caenogastropoda)

Cledón, Maximiliano

Adelomelon brasiliana (Caenogastropoda; Volutidae) inhabits shallow waters between 5 and 20 metres depth on sandy bottoms of the south-western Atlantic Ocean. The commercial importance of *A. brasiliana* emerged during the 80's and early 90's. In Argentina *A. brasiliana* is a very abundant species being captured by bottom trawling near the coast. The reproductive season of a studied population near Mar del Plata (38°20'S) extends from September to April (austral spring and summer), showing synchronization with water temperature (oocytes growth with low temperatures and spawn with high temperatures). Yolk content of the oocytes increases until they reach 200 mm in diameter before spawning. In autumn, a resting phase begins, in which no new oocytes develop and the non-spawned ones undergo reabsorption. Gonadic development begins during the early winter and new previtellogenic oocytes can be observed under the epitelium. The shell size at sexual maturity is about 100 mm, while the 50% of the population is mature approximately

at 115 mm shell length, when they are 8 years old. The maximum age registered was 20 years. TBT pollution in the studied area is very low and does not affect the reproductive cycle of the population. TBT in sediment ranges from 1,4 ng*g-1 in the areas near the port to 0,2 ng*g-1 in the less affected areas. A one year TBT and imposex monitoring *A. brasiliana* in the most polluted area showed high constant TBT and DBT concentrations in hepatopancreas 90 and 38 ng*g-1 wet mass respectively, while in muscle the concentrations of TBT were around 35 ng*g-1 and DBT decreased from 17 to 9 ng*g-1 its purification capacity. % of imposex decreased from 100 to 60.

Identifying pearl oyster spawning patterns from spat surveys and dispersion modelling on Australia's North West Shelf

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Pearl oyster spat (*Pinctada maxima*) surveyed in the 80-Mile Beach section of the North West Shelf have been used in conjunction with outputs from a particle dispersion model to identify likely spawning grounds. The dispersion model consisted of a sophisticated three-dimensional circulation model for the region in which large numbers of individual particles were tracked over the period 1994 to 1999. From the settlement areas defined by the spat data, larvae were tracked back in time over their estimated pelagic phase of 24 to 31 days within the main spawning period of mid October to late December. Results demonstrate how large tidal currents in the region move larvae back and forth across the shelf. However, it is the lower frequency currents which mainly determine their net transport. While some model larvae travelled up to 100 km, most were transported less than 30 km. The implied spawning population tended to be concentrated northeast of the settlement sites and in slightly shallower water. This distribution is consistent with the observed distribution of Mother-of-Pearl.

Long term trends in the world abalone market and the influence of this on the economic viability of abalone aquaculture

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Continued increases in the production of farmed abalone, combined with an unfortunate proliferation of the illegal wild catch, have resulted in the current world supply of abalone nearing the historical abalone abundance of the mid 1970's. Sparked by the rising middle class in China, a global shift in both abalone availability and distribution has occurred. Although, over the past few years, farmed abalone production in China has increased almost exponentially, this has, surprisingly, not had a major effect on the international market price, primarily because almost all of the Chinese production is locally consumed. By contrast, however, the illegal trade in abalone has seriously undermined the legal industry. For abalone farmers, the

factors that are most important in affecting economic viability are those such as local production costs and international currency fluctuations. These, and other factors, will be discussed using examples from both high-cost, and low-cost, production locations.

The roles of bacteria, micro and macro algae as a feed for juvenile abalone in aquaculture

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Abalone aquaculture in Australia is dependent on cultured algae to induce larval settlement and as a food source for the early life stages of abalone until formulated food is introduced into the growout system.

In the natural environment, abalone larvae settle on coralline red algae, however, propagation of coralline red algae is not practical at commercial scale. Abalone farms in Japan successfully settle abalone larvae on the green alga *Ulvella lens* but *U. lens* had never been tested with Australian abalone species. We demonstrated earlier that *U. lens* is suitable to enhance settlement of both cultured southern Australian abalone species and most abalone farms in Australia are now growing *U. lens* for that purpose. *U. lens* is easy to culture, no specific facilities are needed and the alga can be grown on PVC settlement plates in commercial nursery tanks. However, *U. lens* has limited value as a feed for growing post-larvae. Instead, cultured diatoms can be added after larvae successfully settle and start feeding. However, juveniles abalone (>5mm in shell length) can consume *U. lens* and grow rapidly on this alga. Diatom cultures and biofilms developing on settlement plates are not axenic and the role of bacteria in early post-larvae feeding is poorly understood. Bacteria have been isolated from these diatom cultures and identified and strains and we are now tested in isolation and combination with respective diatom species. It has been suggested that bacteria may perform metabolic activities in the undeveloped gut of young post-larvae. At later stages of the nursery phase it becomes increasingly hard to maintain adequate feed on the plates and this is still regarded as a significant bottleneck for the industry. Recent investigations have indicated that sporelings of macroalgae like *Ulva* sp. may provide a suitable food source for juveniles (>3 mm in shell length).

Tropical abalone aquaculture genetics: how gene discovery and analysis informs hatchery practices

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In the face of a growing demand worldwide for ‘cocktail’-sized abalone, we are using our studies of the biology of the tropical species *Haliotis asinina* to develop a suite of hatchery practices. Here we highlight our analysis of genes involved in a number of commercially-important traits, specifically larval settlement, reproduction, growth and shell production.

Analysis of neutral gene markers – mitochondrial and microsatellite loci – has identified distinct *H. asinina* stocks in the Indo-Pacific and has shed light on fertilization dynamics in the hatchery. These data in turn have contributed to the implementation of a set of hatchery practices designed to maximize genetic diversity of reared offspring.

We are studying regulatory genes that control a wide range of developmental and physiological processes (e.g. *Hox*, *Sox* and *POU* transcription factor genes). Our goal is to understand their roles in constructing the abalone body plan and in controlling the apparent antagonism that exists between growth and reproduction. The differential expression of these genes during reproduction and growth suggests they play a key role in regulating the abalone's physiology and thus may be appropriate as future targets of selection and genetic enhancement programs. We have used these genes to determine if castrating factors released by a parasitic digenean trematode can be used to promote high growth in aquaculture.

High-throughput gene expression analyses are being applied towards identifying the optimal larval age to induce settlement, thermal tolerance, growth and shell production. This approach has lead to the discovery of gene batteries consisting of hundreds of genes who each contribute to the trait of interest.

Importantly, the conservation of haliotid genomes suggests that genetic insights into *H. asinina* development, physiology and structure will be directly applicable to other commercially-important abalone species.

Studies of bivalve pump dynamics using new techniques

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Debate regarding mechanisms of pumping and its control in bivalve molluscs continues. One view contends that pumping activity is autonomously regulated, proceeding at a constant rate approximately equal to maximum theoretical values. The second view supports physiological regulation and implies an adjustment of filtration rate according to environmental cues in order to meet nutritional needs. Arguments have assumed that all bivalves have similar feeding strategies. Further, models of bivalve pumps have been based predominantly on experiments with the mussel, *Mytilus edulis*, and may not adequately explain pumping by bivalves with different gill types.

We are examining individual components of feeding activity (pallial cavity pressure, valve gape, and inhalant and exhalant flow velocities) using a low-pressure/valve-gape system and particle image velocimetry. These components are being investigated in three different species of bivalve molluscs, each with a unique gill morphology: oysters, *Crassostrea virginica*; mussels, *Mytilus edulis*; and scallop, *Placopecten magellanicus*. While current models of bivalve pump characteristics will be used to establish starting points, we suspect the relationships among the various components of feeding activity will be species specific. These experiments will

provide data on pumping activity and behavior of three bivalve species and insight into if and how bivalves control pumping performance.

A broodstock conditioning trial with greenlip abalone (*Haliotis laevigata*) in Western Australia

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Managing the broodstock conditioning process is very important to the successful establishment of an abalone industry that can reliably produce juveniles from captive stock. The ability to have ripe individuals year-around or at predictable times in the year allows the culturist to schedule the hatchery process to occur at the most favourable time of the year for growth and survival to conduct selective breeding.

Four conditioning periods of 6, 8, 10 and 12 week intervals were tested, using a constant conditioning temperature and ambient temperature as a control. Broodstock were collected from the wild and range from 87.5 to 142.1mm in shell length and 108.2 to 482.8g in whole weights. Greenlip abalone were spawned all year round and large numbers of "out of season" spawnings were recorded particularly with conditioned stock. Over the whole trial period, greater egg production from prescheduled spawnings occurred in the conditioned group with an average of 1.7 x 10^6 eggs per tub of 5 female abalone, compared to abalone held in the control tubs that only produced an average of 0.4 x 10^6 eggs per tub. The group that was spawned every 8 weeks produced the largest average number of eggs per holding tub. There was very little difference between conditioning periods in terms of number of successful spawnings per spawning round. The egg production for all planned spawnings was highest before the "natural spawning season" for greenlip abalone. In comparison, the highest numbers of unplanned spawnings occurred around the natural spawning period for both the conditioned and control groups. Handling of broodstock abalone prior to spawning reduced the number of eggs produced per tub of abalone but did not affect the number of successful spawnings per spawning round. Histological examination showed that using the visual gonad index is not a good indication of maturation of the abalone but it confirmed that abalone can be conditioned out of season.

Effects of clam dredging on consolidated grounds and subsequent recovery of benthic habitat off the Portuguese southern coast

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Several studies showed that bottom mobile fishing gears have a deleterious effect on the environment. The ecological effects of clam dredging can be short-termed or lead to long-term changes in community structure, depending on several factors, such as depth, sediment type and hydrodynamics. Sometimes it is difficult to distinguish between fishery driven changes in community structure and those caused by natural phenomena. Therefore, it is of utmost importance to evaluate the ecological relevance of fishing disturbance *versus* natural perturbation.

In this context a study was undertaken aiming (1) to analyse the immediate environmental effects of Portuguese clam-dredge fishery on benthic communities, (2) to monitor its subsequent recovery and (3) to evaluate the changes in community structure due to natural perturbation. Hence, a summer to fall sampling program was undertaken during 2003. Two 2500 m^2 areas each, at 20 metres depth, were subjected to different stress levels, considering sporadic fishery (experimental area) and no fishery (control area). In the experimental area, fishing stress was simulated following usual commercial fishing procedures, thus dredging an area for an hour using two clam-dredges simultaneously. In each area, benthic macrofauna and meiofauna samples were collected by divers periodically (before dredging, immediately after and on the ensuing 24h, 48h, 120h and 13, 35 and 90 days). All sampling was performed with adequately replicated corer collection, using 64cm^2 corers for macrofauna and 20 cm^2 for meiofauna, buried 15cm and 10cm, respectively. Oceanographic parameters were also registered during the sampling period.

Considerably minor dredge fishery driven effects and fast recovery of the benthic communities are highlighted in opposition to some degree of natural variation. The present poster summarily describes the preliminary results of the Project DREDGIMPACT (POCTI/ MGS/ 42319/ 2001), which is funded by the “Fundação para a Ciência e Tecnologia” (FCT).

Which are the benefits of using more selective and efficient bivalve dredges?

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Clam and razor clam mechanical dredges are extensively used along the Portuguese coast. These fishing gears are composed by a rigid iron structure with a toothed lower bar that can penetrate into the sediment up to 50 cm, depending on target species and sediment type. These dredges dig bivalves out of the sediment, impacting the benthic habitat, both in terms of its physical structure (smoothing sedimentary bedforms, reducing bottom roughness and re-suspending the sediment) and its biological communities (destruction of the benthos and loss of biodiversity).

Apart from landings, dredging also causes other kind of mortality, either directly or indirectly. In the case of the infauna, if individuals are retained for a long time in the net bag, the stress to which they are submitted increases. As a consequence, the undamaged individuals that escape through the net bag do not bury themselves immediately, being more vulnerable to predation. Furthermore, low selective fishing gears lead to large amounts of by-catch. It is known that for some species survival of undamaged discarded individuals is directly related to the time of aerial exposure on deck. Individuals returned to the seabed, will provide potential food for scavengers and predators. Therefore, their survival depends on the time needed to rebury (in the case of infauna) or to restart their normal activity (in the case of epifauna).

Since the Portuguese bivalve fishery is managed by daily quotas per boat, the higher the catching efficiency of the fishing gear the lower the fishing area needed to achieve the quota. Taking into consideration all the above considerations, a new bivalve dredge was developed, which is more selective and efficient than the traditional ones. In this presentation we will show how gear modifications became effective in reducing the environmental impact of dredging.

Influence of conditioning diet and spawning frequency on variation in egg diameter for greenlip abalone, *Haliotis laevigata*.

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Abalone larvae are lecithotrophic and thus rely heavily on yolk reserves provided by the egg to fuel development. Previous work indicated that smaller eggs hatched better and contained more total lipid. Both egg provisioning and egg diameter are therefore important factors governing the development and survival of larvae. The diet of female broodstock and the conditioning regime are likely to contribute to the quality of abalone eggs.

In this study we examine the effect of four broodstock diets (three formulated diets differing in fatty acid composition and a red seaweed control) and conditioning regime on egg diameter variability within a batch spawned from one female and between batches. Abalone broodstock were spawned at the beginning of the experiment and again after 16 and 32 weeks using commercial hatchery practices. Eggs obtained from individual females were measured prior to fertilisation. Cytoplasm diameter, vitelline layer and jelly coat thickness were compared between eggs spawned from individual females and between females. The variability of egg diameter within batches spawned from the same female over two spawning rounds and within diet treatments were determined.

Egg diameter variability appears to be driven primarily by the individual female rather than by diet treatments or spawning frequency. Batches spawned from the same female abalone became more variable over time with a shift in size frequency distribution. In addition the relationships between broodstock parameters (weight and shell lengths) and batch size (number of eggs spawned by one female) as well as egg diameter were explored. We found a significant correlation between batch size and egg diameter. No relationship between batch size or egg diameter and broodstock parameters was found. Results indicate that the variability of egg

diameter within a batch changes from female to female and highlights the importance of selecting successful broodstock for conditioning at commercial hatcheries.

Growth in recovering beds of Tasmanian commercial scallops (*Pecten fumatus*)

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The Bass Strait scallop fishery collapsed so that a stratified random dredge survey in 2000 found only one very small concentration of commercial scallops (*Pecten fumatus*) across the traditional scallop grounds in Commonwealth waters to the northeast of Flinders Island Tasmania. Annual surveys since then have followed the recovery of various scallop beds. It has been possible to follow the fate of known age cohorts of scallops across an array of different density beds in different geographical areas. The growth of the animals in these beds has been formally described and compared. Variation with respect to depth and latitude is described. Video footage of different scallop beds is used to illustrate the range of habitats. In general, it takes approximately 3+ years for Tasmanian scallops to grow to 90 mm shell length in the Bass Strait region.

The Roe's abalone fishery near the Perth metropolitan area, Western Australia

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The recreational Roe's abalone fishery is concentrated on easily accessible reefs that adjoin metropolitan Perth. There is a restricted recreational fishing season of 1.5 hours a morning, for six consecutive Sundays in November and December each year. The reefs near Perth are also the focus of the commercial Roe's abalone fishery in Western Australia. The recreational catch and effort for each 10 nautical mile section of the Perth fishery are estimated from creel surveys with instantaneous counts and interviews with fishers, aerial surveys, and mean weight measures, from 1997 to 2000. The majority of the recreational and commercial catches were taken from small areas of the fishery, with approximately 88% of the recreational catch coming from two 10 nm sections, and 98% of the commercial catch coming from these two and one additional 10 nm section. The total catch of between 66 and 81 tonnes for the four years is approximately evenly divided between the recreational and commercial sectors with notable variation in the spatial distribution of the catch between sectors. The recreational catch and effort estimates for 1999 and 2000 were corroborated by an independent telephone survey.

Towards methods for estimating incidental mortality from the recreational Roe's abalone fishery near Perth, Western Australia

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Recreational fishing for Roe's abalone is carried out while wading or snorkeling in high density (30-90 legal size animals per m^2) populations on reef platforms and sub-tidal reefs using a screwdriver or similar implement to lever abalone from the reef. This fishing technique coupled with the high stock density results in two presently unquantified sources of incidental mortality. Firstly, some fishers 'high-grade' their catch, selecting the largest from many, and discard the rest; secondly, inexpert use of the lever commonly results in injury to the foot of the abalone. Two methods were used to estimate incidental mortality from three discreet areas (600, 713, and 825 m^2) of reef. Method 1 calculated the proportion of total catch represented by shells found with soft tissue immediately after fishing. It assumed exact catch was known from each area. Method 2 used an estimate of dead shells after each day of fishing (n=4) and an estimate of dead shells found after four days of non-fishing in order to estimate the incidental fishing mortality. Method 1 estimates were 7%, 20% and 21% of the recreational catch from the same reef area, and Method 2 estimates were 4%, 40% and 52%. Based on the known catch and area from one site (Beaumaris: 3,535 abalone from 825 m^2), and an estimated legal-sized density (40 animals per m^2) from field surveys, these mortality estimates suggest an incidental fishing mortality in the range of 0.4% to 5.6% of total legal sized stock, suggesting only a minimal impact on stock sustainability but still an unnecessary mortality that should be addressed through an education program. Further trials are required to assess the assumptions of the methodology so they can be scaled to assess incidental mortality over the whole fishery.

Growth, mortality, and recruitment in wild stocks of the silver-lipped pearl oyster *Pinctada maxima*, in Western Australia.

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Growth, mortality and recruitment experiments were undertaken on wild stocks of the silver-lipped pearl oyster *Pinctada maxima* at sites spanning the geographic range of the commercial fishery. Three mark-recapture studies yielded 2717 individual growth increments (initial size: 10 – 217 mm DVM; time at liberty: 346-745 days), which were combined with data from cohort analysis of younger age classes, and growth

estimated using maximum likelihood methods. Natural mortality was determined from tag and recapture studies at fixed sites, and by measuring *in situ* length-frequency structure of stocks and applying length converted catch-curve analysis. Settled *P. maxima* spat on adult shell were quantified (119 000 shell produced 1317 spat in 2003) to obtain an annual recruitment index. Growth parameters (L_∞, K) from the von Bertalanffy growth equation were estimated to be 210 mm DVM (± 16 mm SD) and 0.74 at the Lacepede Islands, 199 mm DVM (± 6 mm SD) and 0.79 on 80 Mile Beach, and 194 mm (± 1 mm SD), 0.72 in Exmouth Gulf. Estimates of natural mortality (M) by tagging were very low (0.02-0.03), but catch-curve analyses yielded M estimates from 0.10 in deeper (30-34m) populations, to 0.18 in shallow (9-12m) populations. *Pinctada maxima* spat were easily separated into 0+ and 1+ age classes, and showed clear temporal trends in abundance. The annual recruitment index over 7 years (1992-1995; 2001-2003) varied from 5.1 to 8 spat per 1000 shell for the 0+ age class, and 3.5 to 6.2 spat per 1000 shell for the 1+ age class. More work is required on spatial and habitat effects on spat settlement before the potential of the 0+ and 1+ recruitment indices as predictors of future stock abundances can be fully explored.

In pursuit of cost-effective enhancement of mollusc fisheries, using blacklip abalone *Haliotis rubra* as a case study

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The components of responsible marine stock enhancement are briefly reviewed. The basis of economic success of fisheries enhancement boils down to answering two interrelated questions. The first question is, “what is the margin by which revenue per unit of additional sustainable production is likely to exceed that of the cost?” Such costs include those of producing and deploying the seed plus harvesting and post-harvesting costs through to the point of sale. The second question is, “what probable scale of additional production is needed to make the whole exercise worth pursuing in the first place?”

While the questions themselves are straight forward, providing answers, particularly determining the most cost-effective size and age of seed and how best to produce and deploy them, is likely to be time-consuming, complex and expensive, requiring both innovative biotechnology and a comprehensive knowledge of the natural biology of the species. Elements of biology that must be considered include age and size specific growth and mortality rates of wild stocks from settlement to market size and factors that control them and the production capacity of particular areas and sub-populations. For reef species such as abalone, this also entails an understanding of key inter-relationships with other community species especially those that compete directly with them for space, shelter and food. Urchins are primary competitors of abalone but other surface grazing and seaweed-eating molluscs may also be important. Continuing endeavours to develop cost-effective enhancement of the NSW blacklip abalone fishery, are used as a case study.

Embryonic and larval development of the tropical black-lip rock oyster *Saccostrea echinata*

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The tropical black-lip rock oyster *Saccostrea echinata* has high potential for aquaculture in tropical Australia and the Indo-West Pacific region. Despite several studies conducted with this species, it has not received the same level of research interest regarding its mariculture potential as temperate rock oysters. There is a paucity of information on the basic biology of *S. echinata*, and little is known of embryonic and larval development in this species.

This paper presents a description of embryonic and larval development of *S. echinata*, using digital photomicroscopy and video clip images. Growth rates of larvae under hatchery conditions, and morphology of the larval shell (size, prodissoconch development), are described. The development of embryos and larvae is compared to those of other oyster species. *S. echinata* has the fastest development to the trochophore and veliger stages so far recorded for Ostreid larvae. Trochophore larvae develop 5.5 hours after fertilisation while D-stage veligers first appear 12.5 hours after fertilisation.

This study is part of my PhD thesis on the topic “Aquaculture potential of the tropical black-lip oyster *S. echinata*”.

Diseases of pearl oysters and other molluscs: A Western Australian perspective

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Mollusc culture, particularly the cultivation of pearl oysters, is an important component of the aquaculture industry in Western Australia. As a result there has been a long-term investment in surveys of commercial mollusc species for potential diseases of concern. A number of these potential pathogens within wild-stock shellfish have the potential to affect mollusc populations including haplosporidians, *Bonamia* sp. and rickettsia-like organisms. Others may pose risks if translocated in association with aquaculture activities. The microsporidan *Steinhausia multilovum*, which is found in ova of *Mytilus galloprovincialis,* poses intriguing questions about the origin and dispersal of its host.

Seed production techniques of abalone *Haliotis discus hannai* based on larval and post-larval ecology

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The culture techniques of abalone have been developed in the last 30 years and have made great advances. However, many abalone hatcheries around the world still suffer from low and inconsistent survival in the first few months post-settlement. This is due to low and variable settlement rates, and difficulty in keeping adequate quantity and quality of initial foods, which are usually benthic diatoms. The tolerance of newly metamorphosed post-larval abalone to starvation is extremely low and limited food over several days has a harmful effect on the survival of post-larvae. Post-larval growth and survival rates are considerably affected by diet and the ability of individuals to utilize available food. Hatcheries in northern Japan, which produce juvenile *Haliotis discus hannai* by the pre-grazed plate method, are going relatively well in comparison with hatcheries in many other countries. Survival rates from larva to 12 months, in the hatcheries in northern Japan, are usually from 10 to 30 %. Recent progress in understanding larval and post-larval ecology can explain scientifically the role of the pre-grazed plates for abalone. In this paper, we summarize key findings on larval and post-larval ecology of *H. discus hannai*, and evaluate the present seed production techniques in abalone hatcheries.

Effects of algal concentration and temperature on the feeding rates at three life stages (Larva, spat, adult) of the Purple Clam, *Saxidomus purpuratus*

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The purple clam, *Saxidomus purpuratus* is a local species inhabiting relatively restricted areas around Korea, Japan, and China. Recently, the commercial yield from the traditional exploitation of natural fisheries by divers has been declining due to over-harvesting. Much attention has been concentrated to the aquaculture and restocking of this species. The purpose of this study was established to know the feeding rates and to determine optimal ration level for each life stage of *S. purpuratus*. Experiments were carried out to know the clearance rate (CR) and ingestion rate (IR) as functions of algal concentration and temperature of each stage using *Isochrysis galbana*.

At all three stages, algal concentration strongly affected CR. With increasing algal concentration CR increased rapidly, but after a certain threshold level it decreased gradually. IR was also affected by algal concentration. In the experiments with larvae and spats, the changing pattern of IR could be divided into two phases: (1) as algal concentration increased with low level, IR increased rapidly, (2) but, as algal concentration increased further, IR did not increase any more. However, in the experiments with adults, IR increased continuously. For rearing larvae and spats with

better nutritional conditions, algal concentration should not be less than 1.6×10^4 cells/ml for larvae and 7.0×10^5 cells/ml for spats. As for temperature, maximum IR in spats of *S. purpuratus* increased when temperature increased from 5 to 25℃, but it was lowest at 30℃. Between 15 and 25℃ the IR was most stable. At this temperature range, the Q_{10} was 1.6. To acquire fast growth of spats in inland culture during winter, it is necessary to maintain water temperature over 15℃.

Performance of triploid Pacific oysters (*Crassostrea gigas*), produced from diploid or tetraploid broodstock, in cool and warm temperate growout sites in Australia

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Relative growth rates of triploid and diploid oysters could be influenced by method of triploid induction and by water temperate and food availability during growout on inshore leases. Triploid Pacific oysters and Sydney rock oysters (*Saccostrea glomerata*) oysters (3N), produced from diploid (2N) oysters by blocking the second polar body of eggs (2N eggs) after addition of sperm (1N), grew much faster than diploid oysters in warm temperate sites in Japan and New South Wales, Australia that were considered to have favourable natural food densities. However, the growth advantage for similar triploid Pacific oysters was both delayed and lower at three cool temperate sites in Tasmania, Australia two of which had favourable natural food densities. At two warm temperate sites in South Australia, where natural food densities can be limiting, large growth rate advantages were still not evident for triploid Pacific oysters.

Blocking of polar body 1 in triploid females with unusually high levels of gonad development produced tetraploid (4N) offspring after addition of sperm (1N) from diploid males. Crossing tetraploid males with diploid females produced predominantly triploid Pacific oyster offspring. In New South Wales this led to a huge size advantage over diploid oysters during Growout whereas, in Tasmania, growth rates at the only site used varied for individual pair crosses and only one of four triploid lines grew rapidly.

Investigating the life history and aquaculture potential of the marine mollusc *Dicathais orbita*

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Dicathais orbita is a large predatory gastropod (Family Muricidae), which is native and common to southern Australian waters. This gastropod is at present harvested along the New South Wales and Victorian coasts by a relatively small recreational fishery and used as food and bait. *D. orbita* is not only edible, but also contains active ingredients that have been shown to display potential medicinal properties. In light of these health benefits there is strong potential for this species to be utilised on a commercial basis. However, it is questionable if wild stocks could sustain a higher level of commercial demand, hence it is suggested that this demand be fulfilled by culturing these animals in an aquaculture system. To date, there have been no documented attempts to aquaculture *D. orbita*, and information on their life history, reproduction, development and conditions needed for optimal growth, is scarce. It is therefore, the aim of this research to assess the feasibility of culturing an ecologically and economically sustainable supply of this species through aquaculture. Specifically, this project will investigate the reproductive biology, larval settlement and metamorphosis of *D. orbita* with the ultimate aim of establishing a self replenishing population in aquaria. Once this population has been established it will be used to define growth rates and to determine an effective means of aging and sexing the animals. Experiments will be established to investigate the effect of abiotic factors such as temperature on gonad ripening with the ultimate aim of determining a method of inducing maturation. In addition, feeding trails will be conducted to investigate the effect of natural and artificial diets on the growth, survival and tissue quality of the animals.

Spatial and seasonal variation in reproductive characteristics and spawning of southern calamary: spreading the mortality risk

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Southern calamary in Tasmania form spawning aggregations in Great Oyster Bay on the central east coast of Tasmania during spring/summer, which are targeted by commercial fishers. However, it is not known if similar aggregations occur further south in Tasmania or at other times of the year, especially since this species lives for less than a year. Therefore, the aim of this study was to describe and identify differences in reproductive ecology of southern calamary on the east and south-eastern coast of Tasmania. This was achieved by sampling adults and surveying egg masses during 2001 at inshore sites in both regions. Inshore populations of southern calamary in both regions showed a consistent seasonal trend of large gono-somatic index, reproductive output and body size, and greatest abundance during spring, and lowest in autumn. The number of egg masses found was higher on the east coast, where mature animals formed large spawning aggregations during the spring and summer. Such aggregations however were not observed during

winter or autumn. Along the south-east coast spawning activity was sporadic, resulting in isolated, low density, egg patches deposited over broader spatial areas during spring, summer, and winter. There was no evidence of areas of seagrass or macroalgae with large depositions of egg masses at any time in the south-east. It appears by adopting different spawning behaviours in different locations and seasons that southern calamary may spread the mortality risks in both space and time. The biological significance of this is unclear, particularly with respect to understanding the mechanisms that drive the development of spawning aggregations. Both spatial and seasonal spawning patterns appear to be the result of very specific use of inshore sites at certain times of the year. Consequently, any management concerns about fishers targeting spawning aggregations in the south-east may be unfounded.

Inter-annual and spatial variation in spawning periodicity in blacklip abalone: A case study from South-East Tasmania.

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Spawning periodicity in blacklip abalone *Haliotis rubra* was investigated at three sites in South East Tasmania. Gonad Indices and qualitative staging of gonad sections for 10 females were obtained monthly at George III Rock Reef between January 1988 and January 1992, and monthly from Port Arthur and Shag Rock Bay between January 1991 and February 1992. Oocyte stage frequency and Oocyte size frequency data were obtained from George III Rock samples for 12 months in 1991. These data are used to examine temporal and spatial patterns in spawning activity, and variation within and among individuals.

Inter-annual spawning patterns were complex and unpredictable with asynchrony among and within individuals in a given month. Evidence of significant spawning events were rare and were not strongly seasonal, although spawning activity was largely absent in December and January of all years at George III Rock. During 1991, monthly patterns of GI and gonad stage at Shag Rock Bay, Port Arthur and George III Rock contrasted strongly. Evidence of spawning was apparent in histological samples of at least some individuals in every month sampled, and pre-vitellogenic oocytes were always abundant with minor seasonal variation.

The implications of multiple asynchronous spawning events for blacklip abalone ecology and fisheries management are discussed.

Spatial scales of managing abalone in Tasmania, interactions of fishery dynamics and biology – the ideal and the practical

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The scale of management for the Tasmanian abalone fishery has become an increasingly important issue for this fishery. The pressure for increased spatial resolution in management stems from a combination of fishery dynamics and the biology of the target abalone species.

A better understanding of growth, size/age of maturity and early life history is critical for decision making and management of the fishery with very real implications for long term sustainable management. Such information at a finer scale has been required.

Over the last decade the catch has become increasingly concentrated in the east with catch and effort declining in the west and north.

This issue has been addressed by 'zoning' the fishery and the TAC into sub-units with specific portions of the TAC to come from the zones. A number of block 'caps' have now also been implemented to cap the catch in certain key fishing blocks at predetermined levels.

Research suggests that abalone may not travel very far, and may be reef specific to island reefs. The distance for larval advection also is small. For these reasons catch restrictions would be ideally set on a reef by reef basis.

Abalone in Tasmania have markedly variable growth and maturity parameters across their distribution. This variability has important implications for the other major management 'lever' for this fishery – size limits. In response the size limits in the fishery have become more sophisticated and complex, moving from a single size limit to 6.

Increasing the complexity of management drastically increases enforcement issues in the fishery, with increasingly more complex and restrictive operational requirements increasing the operational and logistics issues for fishers.

Balancing these competing objectives of management, the ideal with the practical and achievable remains an issue for managing this valuable fishery.

Developing extensive cultivation systems for the restoration of *Margaritifera margaritifera* in Northern Ireland

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The freshwater pearl mussel was once common in the river catchments of Northern Ireland. Populations of these mussels, in common with other populations throughout Europe, have been decimated as a resulted of pearl fishing, pollution and declines in stocks of their glochidial hosts. Small populations (~1000 individuals) now occur in only 3 rivers in Northern Ireland: the Swanlinbar, Owenkillew and Ballinderry. Recent information suggests that there has been no recruitment to these populations in the last 10 years. In most other catchments mussels are either extinct or in very low numbers (groups of <10 individuals). The population on the Ballinderry River, which once extended for most of the 40km length of the river, has declined to about 2000 individuals restricted to a 6km stretch.

Measures to conserve and restore mussel populations include: 1) protected areas; 2) transfers of mussels from rivers with healthy populations; 3) intensive cultivation for restocking and 4) extensive cultivation by releasing large numbers of host fish infected with glochidia. The Ballinderry River is undergoing designation as Special Area of Conservation; measures 2 and 3 are not options in Northern Ireland because of the dearth of large populations or on the grounds of cost and the 4th measure has yet to be rigorously tested. This is the basis of the present study.

A small pilot facility, which mimics a stretch of river, has been established at the Ballinderry Fish Hatchery. For the last 4 years batches of brown trout infected with *Margaritifera* glochidia have been released into the system. Sediments have been monitored annually and juveniles from 3 year groups have been identified to date which demonstrates the potential for extensive cultivation systems in mussel restoration programmes. Current plans are to scale up the facility and continue to monitor juvenile settlement and survival.

Lipid and fatty acid compositions of pearl oyster *Pinctada fucata martensii*

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The lipid and fatty acid compositions of pearl oyster *Pinctada fucata martensii* under four different areas in Japan were analyzed to clarify their physiology and to utilize as marine products. All specimens were collected at the aquaculture field in the northern Pacific Ocean and the Japan Sea.

Its lipid content in spawning season (1.0-2.0%) was higher than that in the growing season (0.4-0.7%). Phospholipids (PL, phosphatidylethanolamine; 24.2-30.8% of the total lipids and phosphatidylcholine; 8.7-13.8%) were the major components in its polar lipids, with significant levels of ceramide aminoethylphosphonate (6.3-11.9%),

and medium levels of triacylglycerols (TAG, 7.4-27.3%) was found in its neutral lipids.

The major fatty acids in TAG were 14:0, 16:0, 16:1 n-7, 18:0, 18:1 n-7, 18:1 n-9, 20:4 n-6, 20:5 n-3 (EPA), and 22:6 n-3 (DHA), while those in PL were 18:0, 20:4 n-6, 20:5 n-3, 22:2 n-7, 15, 22:2 n-9, 15, 22:3 n-6, and DHA. Although the shorter chain and lower unsaturated fatty acids were mainly contained in the depot lipids TAG, the levels of the longer chain and higher unsaturated fatty acids increased in the tissue PL. This finding suggests that *P. fucata* might be a typical bivalve species, which contains high levels of non-methylene interrupted fatty acids, and accumulates polyunsaturated fatty acids in its tissue lipids.

A review of abalone fisheries in Australia

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Abalone fisheries exist in the five southern States of Australia, and target mainly three haliotid species (*Haliotis rubra, H. laevigata,* and *H. roei*) with a very small fishery for *H. scalaris.* Each State manages its own fishery, using licence limitation, quotas, and size limits within zones, and fishery catch and effort data collected at various scales. Fisher-independent surveys are also undertaken to provide data on abundance of the spawning stock and recruitment. Stock assessment models, simulating exploited stocks, and employing biological data, such as growth, mortality and recruitment, provide stock assessment advice in the form of alternative catch scenarios and projections of stock biomass for some years into the future. These are employed in New South Wales and Victoria, and are being introduced in other States. These models incorporate, in a precautionary approach, indicators of the fishery as reference points for management. Problems in the management of abalone fisheries include: the cost of independent surveys, inherent ambiguities in most indicators, the spatial heterogeneity of many biological parameters, and the large number of small ecologically independent stocks. In New South Wales, some declines in northern populations of *H. rubra* have occurred due to *Perkinsus* disease, and also near population centres. In Victoria, Tasmania and South Australia the fisheries target *H. rubra* and *H. laevigata.* Minor declines have occurred, in some cases with evidence of serial depletion, but the fisheries are mainly stable. In Western Australia a third species, *Haliotis roei*, is also taken. In WA there have been slight declines in the catch of *H. laevigata,* and greater reliance on stunted stocks. Since the previous review in 1992, greater realization of the fine-scale metapopulation structure of abalone has led to finer-scale management, by applying differential size limits, rotational harvests and localised quotas.

Molluscs in the new millennium

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Molluscs have, for centuries, been an integral part of art, scientific discovery and coastal development. From the earliest depictions of the Birth of Aphrodite from a scallop shell, to the most recent attempts to develop molecular markers for shellfish disease, molluscs have been a common thread throughout human history. They have fascinated collectors, served as currency and provided a source of food for many. They have been the basis for extraordinary art, natural history studies, scientific research programs, commercial and subsistence fisheries and aquaculture ventures, and now international trade.

Technological advances in instrumentation, development of improved hatchery techniques, more efficient fishing gear, and the advent of computers have, in many respects, advanced our knowledge and understanding of this large and diverse group of animals. Information and recommendations gleaned from these efforts, no matter how interesting or innovative, are only useful if utilized. The questions I pose are: What have we done with this knowledge, how efficiently has it been used, and what are we missing as a result of all this technology? Or, in other words: What do we know, when did we know it, and where do we go from here? A brief overview of past and current molluscan studies will be augmented with personal observations, and suggestions proffered for future initiatives.

Pros and cons of small scale native oyster restoration programmes: experiences gained in Strangford Lough Northern Ireland

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Strangford Lough historically had a productive *Ostrea edulis* fishery supporting up to 20 boats in oyster dredging in the 19th century although by 1903 oyster fishing in the Lough had effectively ceased. Growth trials of oyster spat in the Lough in the 1970's produced favourable results for both *O. edulis* and *Crassostrea gigas* and resulted in the start of commercial cultivation for *C. gigas*. Between 1997-99 an EU funded project led by fishermen was started to re-establish a sustainable native oyster fishery in the Lough. This involved cultch deposition and the addition of seed and brood stock oysters. As a result of these efforts, there has been a dramatic increase in intertidal populations of *O. edulis* in Strangford Lough.

Surveys of oysters were completed for 30 intertidal sites between October 2002 and February 2004. During these surveys hand gathering of oysters was recorded at a number of intertidal sites. In addition Strangford Lough is a candidate Special Area of Conservation (cSAC). The present study was therefore able to undertake an assessment of unregulated harvesting and conservation issues and their likely impact on the restoration project.

Growth and survival of juvenile greenlip abalone (*Haliotis laevigata*) feeding on germlings of the macroalgae *Ulva* sp. in comparison with a current commercial diet consisting of *Ulvella lens* plus the diatom species *Navicula* cf*. jeffreyi*

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Germlings of the green alga *Ulva* sp. were developed as a diet for juvenile *Haliotis laevigata* (≥2.5mm shell length) and compared to a current commercial practise consisting of *Ulvella lens* plus the diatom species *Navicula* cf*. jeffreyi*. The utilisation of macroalgae germlings (juvenile gametophyte and sporophyte) allowed a 3-dimensional growth and subsequently provided greater feed biomass in comparison with the current 2-dimensional commercial feed thus maintaining adequate food during the later nursery phase of the 5-10mm shell length abalone juveniles.

The juvenile abalone showed active feeding on both the *Ulva* germling diet and the current commercial diet with a steady increase in shell length over the 2-month feeding trial. The *Ulva* germling diet resulted in abalone of slightly higher shell length with a greater growth rate than those feeding on the commercial diet. During the first month, the growth rates of 90-110μm day^{-1} produced on the *Ulva* sp. germling diet were superior to those recorded on the *Ulvella lens* plus *Navicula cf. jeffreyi* diet (70-90μm day^{-1}). Importantly the growth of abalone as a function of their weight (g) on the *Ulva* sp. germling diet was also greater than on the *Ulvella lens* plus *Navicula cf. jeffreyi* diet.

Over the first month of the feeding trial the *Ulva* germling abundance decreased after the first week of grazing from 165 to 140 germling.cm^{-2} at the mid point of the trial. *Ulvella lens* showed a similar pattern but not to the extent of the *Ulva* germlings with only approximately a 6% decrease in cover. The diatom cover (*Navicula cf. jeffreyi*) across the entire feeding plate also decreased, however the cover towards the top of the plate actually increased for the first few weeks which may have been due to lower grazing pressure or greater light intensity.

Preliminary study of short-neck clam (*Paphia undulata*) fishery in Sihanoukville, Cambodia

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Targeted fishery for short-neck clam (*Paphia undulata*) in Cambodia is a fairly recent addition after a market in Thailand was identified. There is no scientific information about population dynamics or impacts of this fishery on the benthic community. We studied the clam fishery in Koh Khchorng and Champu Khmoav villages, Sihanoukville municipality, Cambodia. The fishermen use simple motorized canoes.

Fishing grounds are located close to the mangrove edge at a depth of about 2 m. The sediment is sandy mud with high sulphide content. The clam dredges are made of iron grid, about one meter long, 12 cm in diameter, and 1 cm grid size. Each boat can tow up to 4 dredges at one time. The majority of the catch is non-target species and, except for other bivalve species, the by-catch is discarded. One dredge contained 28 specimens of *Paphia undulata* 42-53 mm long, 26-31 mm high and 14-19 mm wide. The same dredge also contained 9 other bivalve species, of which *Placuna placenta* was the most abundant. The total number of species was 26, with a total of more than 200 specimens. A second dredge had 36 *P. undulata*, 8 other bivalve species, and a total of 23 species and about 200 specimens. The fishing season runs from November till May, i.e. the dry season. The fishermen fish for clams about 10 days per month. In Sihanoukville there are 35-40 boats involved in this fishery, and they catch about 1000 t per season.

Growth rate estimation of *Murex trunculus* (Gastropoda: Muricidae): Results of marking / recapture experiments in an earth-pond in the Ria Formosa Lagoon (Algarve - Southern Portugal)

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2. Universidade do Algarve (UAlg), Faculdade de Ciências do Mar e do Ambiente (FCMA), Centro de Ciências do Mar (CCMAR), Campus de Gambelas; P-8000-810 Faro, Portugal

The muricid gastropod *Murex trunculus* is a commercially important species in Portugal, where the growing demand for whelks in the market generates some expectation in relation to its potential as a new species for molluscan aquaculture. The present communication reports preliminary growth rate estimations of *M. trunculus*, obtained through marking/recapture experiments in an earth-pond in the Ria Formosa lagoon.

The specimens were tagged with Dymo® tape, which was adhered to the shell with cyanoacrylate glue and covered with epoxy glue, to minimise the abrasion and settlement of encrusting organisms. Marked individuals were held during 24 hours in laboratory aquariums with running seawater. No adverse effects on the whelks' behaviour or immediate post-marking mortality were detected.

Until now, 642 marked individuals (shell length and total weight range of 20.65-58.36 mm and 0.86-19.89 g, respectively) were released into a fish culture earth pond, previously limited by a plastic net fence (area≈100 m2), which closely resembles the natural environment (water temperature and dissolved oxygen were monitored daily).

Periodic recaptures have been made monthly, both with a locally traditional fishing gear ("wallet-line") and by scuba diving. Shell length, total weight and the position of the tag on the shell were registered both during the marking process and immediately after the recapture operations.

To this point, 153 marked individuals were caught (shell length and total weight range of 36.22-65.97 mm and 4.42-27.35 g, respectively), corresponding to a

recapture rate of 23.8%. Simultaneously, 104 dead individuals were recaptured, corresponding to a mortality rate of 16.2%.

During the study period, the marked and recaptured specimens presented growth rates of 1.17±1.03 mm/month (2.86±2.79% length/month) and 0.89±0.67 g/month (13.35±12.22% weight/month). These growth rates were compared to results obtained with other gastropod species (some of high commercial value), in order to evaluate the potential of *M. trunculus* for molluscan aquaculture.

Progress in a genetic improvement program for Pacific oysters (*Crassostrea gigas*) in Australia

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Pacific oysters were deliberately introduced to Australia in the late 1940s and early 1950s. The intention was to establish a new industry based upon natural spat-fall. However, recruitment proved to be unreliable and in 1979 the first commercial hatchery was established in Tasmania. Now there are four commercial oyster hatcheries in the major Pacific-oyster producing states of Tasmania and South Australia and virtually all Australian production is hatchery based.

In 1996/97 we commenced the first generation of mass selection for growth rate, and in 1997/98 we began family and individual selection for growth rate and some other traits. In 2002/03 we spawned the fifth generation of both our mass selection and family lines. Progeny from all generations have been grown out on one subtidal and two intertidal farms in Tasmania and two intertidal farms in South Australia. Generally, ranked performances were similar across sites, although a few families appeared to have site-specific performance. Small but significant genotype by environment (equating to family by farm) interactions were observed in generations 1, 2 and 4 but not in generation 3. Data from generation 5 are not yet available. Substantial gains in growth rate have been made. Some of these results will be presented and discussed.

Commercialization of the improved lines is being undertaken by a new company, Australian Seafood Industries Pty Ltd, in cooperation with the research partners. In 2003/04, ASI spawned generation six. Full scale commercial trials of some chosen lines are underway, and some lines are now being produced commercially with resultant spat sold at a premium price.

Cross fertilization of scallop *Chlamys farreri* with *Patinopecten yessoensis* and the character inheritance of the hybrid

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Intercross and inbreeding of *Chlamys farreri* and *Patinopecten yessoensis* were produced in this study. The result showed that the sperm could incorporate oocyte,

the fertilized eggs of the reciprocal crossing could finish the first and the second meiotic division and release the first and the second polar body, the chromosomes from sperm and oocyte associated together and then the diploid zygotes nucleus formed, it could divided normally, and the hybrid embryo could develop the same as inbred embryo of the maternal scallops. In the process of intercross, the egg could be fertilized normally by heterogenous sperms, the fertilization rate could reach more than 90% without significant difference comparing to contrast.

Hybrids of intercrosses *Chlamys farreri* (♀)×*Patinopecten yessoensis* (♂), *Chlamys farreri*(♂)×*Patinopecten yessoensis* (♀) , and the inbreeding offspring were derived and were breeding in the same sea area. The results indicated that: I. The external shape of hybrid was similar to female parent, the hybrid derived from *Chlamys farreri* (♀)×*Patinopecten yessoensis* (♂) had a survival rate of 95% and the growth rate was improved by 23% , while there was large scale death of *Chlamys farreri* in high water temperature season. II. The survival rate of the hybrid derived from *Chlamys farreri*(♂)×*Patinopecten yessoensis* (♀) was improved by 16%, but there was no significant differences in growth rate comparing with female parents; III. Gonad of the hybrid could develop normally, and mature hybrids were able to spawn naturally. It was concluded that the cross offspring of *Chlamys farreri* and *Patinopecten yessoensis* had a high production trait as well as the strong disease resistance ability.

APPENDIX 4: LIST OF CONFERENCE PAPERS PUBLISHED

Wells, Fred E. & Jernakoff, Peter. 2006. The environmental impact of pearling (*Pinctada maxima*) in Western Australia. *Journal of Shellfish Research* **25**(1): 141-150.

Daume, Sabine. 2006. The roles of bacteria, micro and macro algae in aquaculture - A review. *Journal of Shellfish Research* **25**(1): 151-158.

Gifford, Scott P., MacFarlane Geoff R., O'Connor, Wayne A. & Dunstan, R. Hugh. 2006. Effect of the pollutants lead, zinc, hexadecane and octocosane on total growth and shell growth in the akoya pearl oyster, *Pinctada imbricata Journal of Shellfish Research* **25**(1): 159-166.

Hancock, B.T. & Caputi, N. 2006. The Roe's abalone fishery near the Perth metropolitan area, Western Australia. *Journal of Shellfish Research* **25**(1): 167-178.

Condie, Scott A., Mansbridge, Jim V., Hart, Anthony M. & Andrewartha John R. 2006. Transport and recruitment of silver-lip pearl oyster larvae on Australia's North West Shelf. *Journal of Shellfish Research* **25**(1): 179-186.

Freeman, Kylie, Daume, Sabine, Rowe, Matthew, Parsons, Steve, Lambert, Rick, & Maguire, Greg B. 2006. Effects of season, temperature control, broodstock conditioning period and handling on incidence of controlled and uncontrolled spawning of greenlip abalone (*Haliotis laevigata* Donovan) in Western Australia. *Journal of Shellfish Research* **25**(1): 187-194.

Graham, Fiona, Mackrill, Tahryn, Davidson, Mark & Daume, Sabine. 2006. Influence of conditioning diet and spawning frequency on variation in egg diameter for greenlip abalone, *Haliotis laevigata*. *Journal of Shellfish Research* **25**(1): 195-200.

Hart, Anthony M. & Joll Lindsay M. 2006. Growth, mortality, recruitment and sex-ratio in wild stocks of the silver-lipped pearl oyster *Pinctada maxima* (Jameson)(Mollusca: Pteriidae), in Western Australia. *Journal of Shellfish Research* **25**(1): 201-210.

Heasman, Michael P. 2006. In pursuit of cost-effective enhancement of New South Wales blacklip abalone, *Haliotis rubra* (Leach) fishery. *Journal of Shellfish Research* **25**(1): 211-224.

Jackson, Daniel & Degnan, Bernard M. 2006. EST analysis of genes expressed during development of the tropical abalone *Haliotis asinina. Journal of Shellfish Research* **25**(1): 225-232.

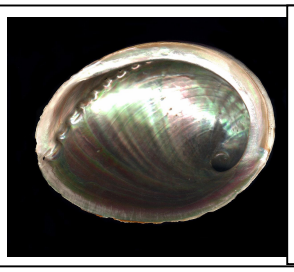
Jones, J. Brian & Creeper, John. 2006. Diseases of pearl oysters and other molluscs: A Western Australian perspective. *Journal of Shellfish Research* **25**(1): 233-238.

Strain, Lachlan, Borowitzka, Michael A., & Daume, Sabine. 2006. Growth and survival of juvenile greenlip abalone (*Haliotis laevigata*) feeding on germlings of the macroalgae *Ulva* sp. *Journal of Shellfish Research* **25**(1): 239-248.

Vasconcelos, P., Gaspar, M.B., Pereira, A.M., & Castro, M. 2006. Growth rate estimation of *Murex* (*Trunculariopsis*) *trunculus* (Gastropoda: Muricidae) based on mark / recapture experiments in the Ria Formosa Lagoon (Algarve - Southern Portugal). *Journal of Shellfish Research* **25**(1): 249-256.

Ward, Robert D. & Thompson, Peter A. Progress in a genetic improvement program for Pacific oysters (*Crassostrea gigas*) in Australia. *Journal of Shellfish Research* **25**(1):

APPENDIX 5: LETTERS OF SUPPORT FROM INDUSTRY ORGANISATIONS



WESTERN AUSTRALIAN ABALONE
AQUACULTURE ASSOCIATION Inc

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Phone: 0892442933 Fax: 0892442934
ABN: 87092057126

30 June 2006

Dr Fred Wells,
Fisheries WA.
Perth.

Dear Fred,

Re: 2004 International Symposium on Molluscan Fisheries and Aquaculture

I have recently seen the publications resulting from the above symposium, that were published in the Journal of Shellfish Research, Volume 25(1). I write, on behalf of members of WAAAA, to congratulate the Organising Committee of the symposium, not only on this excellent publication, but also on the symposium as a whole. Many people involved in the abalone farming and fishing industries attended the symposium and, without exception, were extremely impressed by the quality of the presentations. All learned a great deal from the symposium and, as far as we are concerned, it was a great success.

Regards,

Dr. Peter Cook
Chairman

PEARL PRODUCERS ASSOCIATION

PO Box 55 Mt. Hawthorn 6915. Phone (08) 9492 8888 Fax (08) 9244 2934

Dr Fred E Wells
Principal Management Officer
Fish and Fish Habitat Protection
Western Australian Department of Fisheries
3rd Floor, The Atrium
168 St Georges Terrace
Perth WA 6000

Dear Fred,

Molluscan Fisheries and Aquaculture at the World Congress of Malacology.

I write to congratulate your group for the organisation of the symposium which I attended last year.

The quality of the papers presented and many and varied questions taken during the sessions has proved extremely useful in regard to progress on pearling research and other policy fronts.

As you are aware the pearling industry is developing it's portfolio of environmental credentials in an effort to support marine planning processes to better understand the benign impacts of pearling operations.

Papers presented and subsequent follow-up of research previously unknown to the industry has assisted in our goal of developing these credentials for public consumption. The PPA is currently entering an FRDC project to review the environmental impacts of pearling in the Kimberley and some of these research techniques have been incorporated. The Total Organic Carbon work carried out through University of Newcastle at the Port Stephens Akoya pearling operations has now been adapted for inclusion in our project.

Once again congratulations on the quality of your symposium.

Yours sincerely,

Brett McCallum
Executive Officer