UTILISING EXISTING R&D TO DEVELOP AND DOCUMENT SUSTAINABILITY FACTSHEETS ON KEY SPECIES

Bob Kearney, Paris Goodsell

Australian Government

Fisheries Research and Development Corporation

FINAL REPORT
FRDC PROJECT NO. 2009/071

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Final Report — **FRDC Project No. 2009/071**

ISBN: 978-0-9804231-6-7

Prof. RE Kearney[1], Dr PJ Goodsell[2]

[1]Emeritus Professor of Fisheries
University of Canberra ACT
bob.kearney@canberra.edu.au

[2]Sydney Fish Market
Pyrmont NSW
parisg@sydneyfishmarket.com.au

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The Fisheries Research and Development Corporation plans, invests in and manages fisheries research and development throughout Australia. It is a statutory authority within the portfolio of the federal Minister for Agriculture, Fisheries and Forestry, jointly funded by the Australian Government and the fishing industry.

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PRINCIPAL INVESTIGATOR: Prof. RE Kearney

ADDRESS: Sydney Fish Market
Pyrmont NSW 2000
Tel: +61 2 9004 1113 Fax: +61 2 9004 1179
bob.kearney@canberra.edu.au

OBJECTIVES:

1. To review and analyse the necessary and appropriate scientific material to document the sustainability status of key seafood species

2. To synthesise the information into a format that is both accessible to, and understandable by, the general public

3. To establish a robust methodology for producing a series of 'factsheets' for public distribution and use by the media

OUTCOMES ACHIEVED TO DATE

The fishing industry has come under much scrutiny in recent years with concerns about overfishing and the sustainability of seafood. Fisheries management in Australia complies with a world class standard for sustainability yet fisheries management agencies and the fishing industry have not provided adequate evidence of this to the public to influence common perceptions. This project produced a series of factsheets that review and evaluate the historical and current status and management of stocks of selected and popular seafood species sold in NSW through Sydney Fish Market Pty Ltd. Using the available scientific data, the factsheets provide a comprehensive guide to the sustainability of the species; outlining historical fishing practices and management and the current management and conservation strategies to address instances of historical overfishing and sustainably manage the species. Areas that remain of concern are identified. The factsheets were developed using methods designed to ensure they represent a coherent and consistent review and evaluation.

We conclude that in general, whilst numerous mistakes have been made in previous management (or lack thereof), the great majority of current management strategies are well on track to ensure the sustainability and/or recovery of the species studied.

The factsheets represent a consistent and well researched presentation of the strategies in place to ensure that the selected species are being harvested sustainably or on the road to recovery. They balance the information about the sustainability of seafood currently available/presented to the public which has to date been dominated by an exaggeration of overexploitation and misrepresentation of the true sustainability of Australian fisheries. Preliminary presentation of the results to the industry has indicated considerable support and acknowledgement of the value of the factsheets.

Many species of fish are harvested in the commercial fisheries of Australia and there is no doubt the total biomass of the stocks of most of them has been reduced as a result of fishing, often considerably. The long-term record of the resilience of many marine species to fishing is, however remarkable[1,2]. There is no global record of a species of marine fish that has been driven to extinction from fishing[3]. Indeed it is difficult to find even a single species of marine fish in Australia that is in danger of extinction as a result of fishing. There are many examples around the world, however, of successful fisheries management which has facilitated controls on fishing effort that have effectively conserved the viability of the species and the restoration of overfished stocks to levels more aligned with economic efficient and sustainable use of resources (ESD)[4]. Unfortunately, Australia's compliance with the legal obligation and indeed aspiration of fisheries management to conform to world standards for sustainability is not a common perception of the Australian public.

This project aimed to: i) review and evaluate the appropriate scientific material to document the sustainability status of common seafood species, ii) synthesise the information into a series of factsheets that accessible to and understandable by the general public and iii) establish a robust methodology for producing these sheets which will be publicly distributed and used for media. To understand the difficulty of evaluating the sustainability status of common fish species marketed in NSW and to provide a transparent review, the species covered in the factsheet series were deliberately chosen to include species classified as 'overfished' (e.g. orange roughy, yellowtail kingfish and mulloway).

Australia has progressively adopted a more ecosystem-based approach to fisheries management so that addressing any impacts of commercial fishing, beyond those on the target species, feature prominently in fisheries management plans. Generally, where there are threats from fishing to the structure or function of marine systems in Australia, these are managed. Acknowledging uncertainties in available data, a precautionary approach is taken, such that management strategies are adaptive allowing controlled levels of fishing with routine monitoring. Performance indicators are set that, if reached, result in modification of fishing activity to ensure that sustainable levels of fishing are maintained.

The individual factsheets convey a consistent and comprehensive message in a non technical format. A brief overview of the relevant biology of each species needed for effective management is given, such as their distribution, habitat, diet, reproductive capacity, growth, age at maturity and longevity (natural mortality).

The fisheries that harvest the majority of the supply of the selected species to Sydney Fish Market Pty Ltd are the main focus of the factsheets and a brief overview is given for other fisheries for the same species in Australia and New Zealand where appropriate. Trends in harvest levels throughout the history of the fishery are described followed by an evaluation of the management strategies that have been introduced to control levels of fishing at sustainable levels and where necessary, recover previously overfished populations. The most current, available, formal assessments of the stocks of the selected species are reviewed. Conservation issues for each species are discussed in terms of risk to the target population from fishing, bycatch issues, risks to the marine environment from commercial fishing and any external non-fishing related threats to the target species. There are limited data for the recreational sector and issues arising from this are discussed for popular recreational species. The information presented in the series of factsheets is based on the scientific and fisheries management data available at the time of publication.

Individual sheets provide a concise summary to inform the consumer of the status and management of the selected species. The factsheets as a series reflect the general efficacy of current fisheries management in Australia.

Sustainability is about the long-term. Fish stocks in many areas have, without human intervention, fluctuated widely over geological time scales. The extent to which fishing impacts marine populations and ecosystem balance and the degree to which this is a long-term problem is poorly understood and somewhat contentious. Fish populations do fluctuate naturally and fishing can trigger similar changes that are not necessarily of concern for the viability of the species. The project acknowledges these issues but full accommodation of their impacts is well beyond the scope of this brief study. Whilst the series of factsheets goes a long way towards providing the information necessary for informing the public that fisheries management in Australia is rigorous, assessed and of a world-class standard, a great deal of follow-up public relations is necessary. Fisheries management is inherently complex and further elucidation of the principles underpinning sustainable resource use (for example, that the term 'over-fished' in Australia almost exclusively describes stocks that have been assessed to be below the level that will produce the maximum sustainable yield rather than an indicator of long-term environmental disaster) is clearly necessary.

KEYWORDS: sustainability, fishing, seafood, fisheries management, environmental assessment, extinction, risk, marine

Acknowledgements

The authors thank FRDC and Sydney Fish Market Pty Ltd for financial support for the project. Drs John Stewart and Kevin Rowling, I&I NSW and numerous staff of AFMA provided valuable data and, assistance. Staff at SFM, in particular Grahame Turk, Bryan Skepper, Gus Dannoun and Louise Shaw were most helpful. Thanks also to Drs James Scandol, Zetafish Pty Ltd and Ian Knuckey, Fishwell Consulting Pty Ltd for review of earlier drafts.

Background

Consumers are becoming more and more aware of environmental sustainability issues when choosing produce. Considering the growing level of 'hype' surrounding the sustainability of seafood in particular, there is a need for credible, accessible and understandable information about Australian seafood, its management and sustainability.

A number of key recreational and commercial stakeholders of the fishing industry were consulted about the value of preparing a series of factsheets outlining the sustainability status of selected species and associated information on the management of the fisheries which target them. All have indicated strong support for undertaking this activity. For example, President of Recfish Australia (2009), Frank Prokop, supported the project, particularly the inclusion of basic information on the sustainability status of important recreational fish species. Jeff Moore, Executive Officer of the Great Australian Bight Fishery was also very supportive. Mr. Moore, like other members of the fishing industry, saw the project as a vital step towards supporting the credentials of the fishing industry and the sustainability of fishing.

In early 2008, OceanWatch Australia Ltd and Sydney Fish Market Pty Ltd did a scoping project to establish what basic information was necessary and available to develop similar sustainability factsheets. OceanWatch Australia Ltd developed sustainability statements about five fish species(5), four of which had been classified 'overfished' to some extent(6,7). The background information in the Scoping Report drew attention to the key issue that "*despite significantly improved fisheries management arrangements, the consumer generally was not aware of such changes*"(5). Not only are consumers not aware of the current status of fisheries management arrangements in Australia but they continue to be mislead by ill-informed, selectively negative inferences from overseas examples that are simply not relevant to the sustainability of Australia's fisheries.

Need

The last three Annual Operating Plans for FRDC identified the following key priorities under the Strategic Challenge 5: Community and consumer support:"*i) to educate the community about fisheries and aquaculture management and its contribution to Australia and ii) to communicate the benefits of government and industry investment in R&D*"(8).

Fishing industries have also identified that development of public communication packages based on easily understandable information about the sustainability of fish and fisheries is a high priority. Currently, fishing industries have very little information available in a format that can be used to promote and defend the status of the industry with regard to its long-term sustainability (and that of the targeted species) and to demonstrate the effectiveness of fisheries management in Australia.

After identifying the need for the development of basic information on key species in a usable format, OceanWatch Australia Ltd published a scoping project with the current principal author (investigator), RE Kearney(5). This provided a template for the information and outputs required for the current FRDC project.

Objectives

1. To review and analyse the necessary and appropriate scientific material to document the sustainability status of key seafood species
2. To synthesise the information into a format that is both accessible to, and understandable by, the general public
3. To establish a robust methodology for producing a series of 'factsheets' for public distribution and use by the media

Methods

Robust methods were developed to obtain the information necessary to make the factsheets as informative and as concise as possible. Data was sourced from grey reference material, appropriate industry and fisheries management bodies and personnel and the scientific literature. Research proceeded in a stepwise manner sourcing information about the relevant biological characteristics, the historical and current nature of the fishery and its past and present management strategies and finally conservation issues associated with the fishery for each species

First, the correct standard fish name, taxonomic name, recent synonyms and CAAB code were verified. Information about the biology of the species (e.g. distribution, habitat, diet, growth, reproductive capacity, spawning characteristics, average age, longevity, size, mortality) was sourced from what were assessed to be the most accurate and up to date publications.

Information about the main fishery in Australian waters was then sourced, including the location, the type of gear used, by which authority it was managed and historical and current catch levels. The management strategies , past and present were sourced including past mismanagement, controls on fishing effort and research programs. Fishery-related data and information about the status of the stocks was sourced from appropriate management strategies and latest available external assessments supported where possible by peer-reviewed, scientific publications. Classifications of stocks were sourced from the latest BRS Fishery Status Reports or the state - level equivalent.

Conservation issues were the final target for review. This was done for three main areas; impacts on the targeted population (e.g. genetic diversity, size and age distribution, recruitment issues), bycatch issues including strategies to reduce bycatch and impacts on the associated environment (e.g. pollution, loss of habitat). Data for each of these was sourced from external environmental assessments as well as peer-reviewed, scientific publications where applicable. Recovery plans for overfished species were reviewed as well as identification of any external threats from non-fishing related activities.

The factsheets as presented here remain in a somewhat scientific format and are as such intended to be fully-comprehensive reference documents. We acknowledge a good deal of follow-up public relations is necessary. Follow-up, effective and constant communication between the marketing department, management of Sydney Fish Market Pty Ltd and the authors (investigators) will hopefully continue, subject to funding, to ensure the factsheets are accessible, relevant and understandable for industry partners and the general public. We intend to make the totally comprehensive factsheets presented here available to the public on the web as supporting documents to the concise public communication packages to be developed.

Results & Discussion

The attached factsheets review the sustainability status and management of selected key species of seafood sold through Sydney Fish Market Pty Ltd; orange roughy, yellowfin bream, tiger flathead, yellowfin tuna, blue swimmer crab, eastern sea garfish, snapper, yellowtail kingfish, mulloway and Gould's squid.

Benefits and Adoption

The factsheets contained in the current report will be available to industry (in particular councils and major markets/cooperatives) from the FRDC website and through seafood marketing campaigns launched by Sydney Fish Market Pty Ltd As part of the dissemination of information to the broader community, FRDC will provide the factsheets as story options for radio and TV programs such as Escape with ET (series 12, Channel 10). In addition, SFM will continue to work with the authors (investigators) to develop punchy marketing statements and media releases that will be developed on a case by case basis for species considered 'newsworthy'.

Further Development

Areas to further develop and disseminate this research are discussed in the non-technical executive summary (page 6). In particular, the authors would like, subject to funding, to work closely with the marketing team at Sydney Fish Market Pty Ltd to create short, punchy and easily accessible guides to be circulated widely to the public in marketing campaigns. The factsheets provided here will form supportive, fully comprehensive documentation.

Planned Outcomes

These factsheets now provide the Australian fishing and seafood industry with usable and scientifically defensible information in an easy-to-understand format. This will increase the community's knowledge of the sustainability of Australia's fisheries and the effectiveness of the work being done by fishers, industry, management and the scientific community to ensure the long-term supply of fresh, wild caught seafood. The series of factsheets represent a vital output to help turn around the mis-information and incorrect perception that the Australian fishing industry is not environmentally responsible.

Conclusions

The factsheets have been completed as attached. All reviewers to date have been most positive. The factsheets form the basis of an increasing public relations strategy by the Sydney Fish Market Pty Ltd and others with an interest in the sustainability of seafood.

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Orange roughy

Hoplostethus atlanticus

Orange roughy fillets with their firm, white, lightly flavoured flesh are a popular choice for seafood consumers (whole fish are seldom sold at the retail level). The current catch of orange roughy from Australian waters is tightly managed and restricted to about 500 tonnes per annum[1]. Most orange roughy sold in Australia is imported from New Zealand; about 1 000 tonnes of processed orange roughy at a wholesale value of over eight million dollars was imported in 2008[2]. Overfishing of several localised orange roughy stocks occurred in Australia and New Zealand, particularly in the 1980s and 1990s when the biology of the species was not adequately understood and the fisheries were not appropriately managed. Current science-based management strategies in each country have, however, greatly reduced catches and in combination with better fishing practices have improved sustainability and allowed for the recovery of previously overfished populations. Australian consumers can enjoy orange roughy knowing that the remaining local fishery is very conservatively managed and the bulk of the orange roughy sold in Australia comes from the much larger, well-managed and sustainable New Zealand fishery. This guide to the sustainability of orange roughy and the management of the fisheries in which they are targeted is based on the scientific and fishery-related data available at the time of publication. The bulk of the funding for the preparation of this series of guides was provided by the Fisheries Research and Development Corporation. The series of guides has been jointly sponsored by Sydney Fish Market Pty Ltd (SFM), which is Australia's largest and best known market for seafood, so individual guides are focused on the sustainability of seafood sold through SFM. Support from OceanWatch Australia Ltd for parts of the research done in this factsheet is acknowledged.

Biology

Orange roughy are deepwater fish found in temperate regions of the Pacific (off western and southern Australia and around New Zealand), Atlantic and Indian oceans. In Australia, orange roughy have been reported at depths between 500 and 1800 m from the central coast of New South Wales, around Tasmania and across to southern Western Australia[3,4]. A robust and deep-bodied fish, orange roughy in the commercial catch are commonly between 35 and 40 cm in length (0.8 - 1.5 kg)[5] with a maximum of 60 cm (> 5 kg)[6]. It is commonly accepted that the species is very long-lived, perhaps up to 150 years[4,6], although the validity of different ageing techniques continues to be disputed[7]. Growth appears to be slow and maturity may be delayed until between 20 and 40 years[4]. Orange roughy are opportunistic feeders, consuming a variety of other fish, crustaceans and squid[4].

Like many deepwater species, orange roughy aggregate to reproduce and even to feed, typically near topographic features on the seafloor, such as seamounts, ridges and plateaus. Individuals may travel up to 200 km to join aggregations[8] which usually extend 5 to 10 m above the sea bed but can extend up to 100 m[4]. Male and female orange roughy release their eggs and sperm into the water column at roughly the same time during a single brief spawning period. The timing of spawning in Australian waters varies depending on location but occurs predominantly between June and August[3,6,pers. comm. I. Knuckey, Fishwell Consulting]. Orange roughy have relatively low reproductive capacity and not all fish spawn each year. Female orange roughy produce less eggs than most marine fish; carrying between 10 000 and 72 000 eggs each[9,10]. When fertilised the large eggs are nourished by buoyant oil sacs and float up to about 200 m before hatching several days later[11]. Little is known of the behaviour of juveniles as they are rarely caught with the adult population. Individuals are recruited into the fishery at between 24 to 42 years of age (i.e. when they are mature)[6]. Like most deep sea fish, natural mortality is low, estimated to be about 5 % of the population per year[12].

Fishery & management

The major global fisheries for orange roughy are in waters off New Zealand and Australia and the fish sold through Sydney Fish Market Pty Ltd are from these commercially fished populations.

Australia

Orange roughy are fished commercially in Australia at depths between 700 and 1200 m(12) all year with peak catches from June to August when the fish are aggregated. The species was originally targeted by the trawl sector (formally the South East Trawl Fishery) of the Southern and Eastern Scalefish and Shark Fishery (SESSF) managed by the Commonwealth. The first substantial catches of orange roughy were taken off Tasmania in 1981. Historically, major fishing areas included the Cascade Plateau, St Helens Hill and the South Tasman Rise. The South Tasman Rise fishery straddles the Australian Fishing Zone and the High Seas and is fished by both Australian and New Zealand vessels, so the fishery there is now co-managed with New Zealand under a Memorandum of Understanding (MOU)(13). Smaller quantities of orange roughy were taken in the Western Deepwater Trawl Fishery (WDTF) and the Great Australian Bight Trawl Fishery (GABTF) managed by the Commonwealth of Australia(4,14). These are the only areas across the entire distribution of orange roughy in Australian waters where the species has been or still is targeted by commercial fisheries (Figure 1).

Fishing effort for orange roughy in Australian waters peaked in 1990 with landings of approximately 50 000 tonnes(15) (including mortality from burst nets, illegal and unreported fishing, dumping of fish and loss of gear containing fish, total fishing induced mortality on orange roughy was likely well in excess of this figure). The development of the orange roughy fishery in Australia was extremely poorly managed with excessive fishing effort, wastage and low fish prices the norm for almost two decades. The original management strategy (by the Australian Fishing Management Authority; AFMA) was to maintain the spawning biomass at the internationally agreed sustainable level of above 30 % of the pre-fishery biomass(16). Total Allowable Catches (TACs) which would supposedly serve this objective were set but in the early years of management, the science underlying the TACs was imprecise and unreliable. For example, early estimates of factors that influence the productivity of orange roughy (such as growth, age, recruitment and mortality) were biased by pre-existing knowledge of other fish species for which there were better data. The result was over-optimistic estimations of the state of orange roughy stocks and sustainable harvests such that the controls applied under the management regime of the time were not adequate to restrain catches to sustainable levels. Furthermore , when tighter management was mandated the rate and levels at which catches were reduced was far too slow and meagre to prevent overfishing in several areas. As a result stocks in these areas were reduced to below those that would produce maximum/optimum sustainable yields.

The structure of orange roughy stocks in Australia remains poorly defined (i.e. whether stocks fished in different areas are in fact different populations and therefore require different management strategies)(17-19). Nonetheless, stocks in the SESSF are managed in 11 separate zones, including the eastern, southern, western, Cascade Plateau and the South Tasman Rise(20). Classifying fisheries by separate zones has the unfortunate tendency for localised depletion in one area to be misconstrued to support incorrect claims that the species is 'overfished' across its entire distribution. The reality is that there has been little targeted fishing of the total Australian distribution of orange roughy outside the relatively small areas of the main seamounts east and south of Tasmania(20) (Figure 1). The current separation of stocks for management purposes and the associated individual management plans (and continued investigation of alternative stock-structures) is a most precautionary approach to sustainable management of the fisheries. As discussed below, it guarantees the conservation of the species from fishing[21].

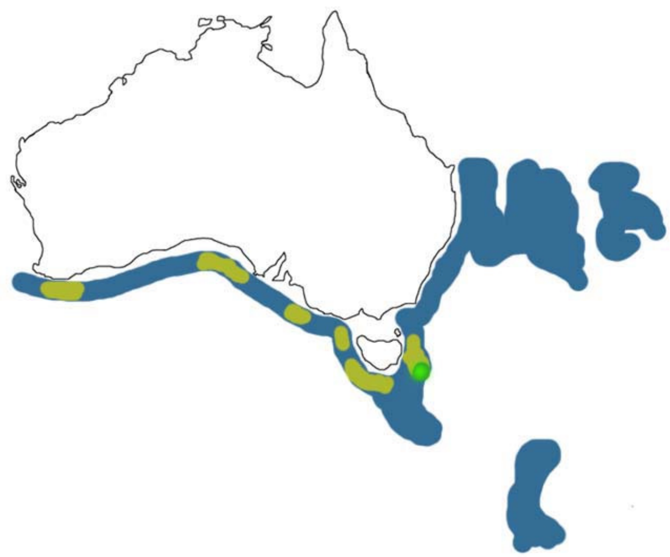

Figure 1. Estimated current distribution of orange roughy (blue) and areas in which fishing for the species used to occur (yellow). Fishing for orange roughy is now only allowed in the Cascade Plateau (green) in Australian waters[22-24].

As for most deepwater fish, it is difficult to obtain accurate and precise estimates of pre-fishery and current biomass that are necessary to properly assess the status of orange roughy stocks in Australia. The species has been the subject of a great deal of research and estimates have been made using trawl surveys, egg and larval surveys, acoustic surveys and Catch Per Unit Effort (CPUE) data. Current assessments combine all relevant methods but a level of uncertainty remains in the available data and hence, estimates of biomass remain imprecise and variable. Current estimates of the pre-fishery biomass in each management zone include: between 95 000 and 110 000 tonnes in the eastern zone (St Helens Hill)[25,26], between 56 000 and 148 000 tonnes in the southern zone[14,27], about 19 000 tonnes in the western zone[27] and between 10 000 and 59 000 tonnes on Cascade Plateau[15,27,28]. Discrepancies among reported estimates of current and pre-fishery biomass also exist. For example, Bax 1997[29] suggested an estimate of 160 000 to 172 000 tonnes for the southern and eastern zones combined; the higher figure being well below the sum of the higher estimates for each of these zones given above. In addition, data on reported catch differ among sources and inconsistencies between these data and estimates of biomass mean that the status of the stocks, determined by various methods, are still to be reconciled.

	Eastern		Southern		Western		Cascade Plateau	
Year	Catch	TAC	Catch	TAC	Catch	TAC	Catch	TAC
1997	2 063	2 000	454	1 000	352	1 500	1 178	1 000
1998	1 968	2 000	251	1 000	361	1 500	1 560	1 600
1999	1 952	2 000	177	700	246	1 500	1 689	1 600
2000	1 996	2 000	311	700	192	1 250	1 639	1 600
2001	1 823	1 800	357	560	247	1 000	1 467	1 600
2002	1 584	1 500	167	420	294	500	1 592	1 600
2003	772	820	210	340	243	450	1 638	1 600
2004	768	720	80	100	321	450	1 520	1 600
2005	754	720	99	100	281	450	1 275	1 300
2006	614	720	<1	10	159	250	728	700
2007	113	27	22	40	31	61	215	483
2008	< 1	25	-	25	5	50	242	600
2009	194	25	10	35	16	60	467	500
Biomass	11 509 -16 785		6 871		1 478		20 000 - 38 000	
Management	13 - 24 % of pre-fishery biomass TAC is bycatch only Closed		18 % of pre-fishery biomass TAC is bycatch only Closed		TAC is bycatch only Closed		62 - 82 % of pre-fishery biomass TAC keeps stock > 60 %	

Table. Catch data (pers. comm. T. Skousen, AFMA) and Total Allowable Catches (TACs) of orange roughy (tonnes), biomass estimates from the latest available assessment of the stocks and current management plans[6,28].

Some stock and fishery assessments indicate high probabilities that the current biomass of orange roughy is below 30 % of the pre-fishery biomass in most management zones, except the Cascade Plateau. As a result these areas have been classified as 'overfished'[6]. It therefore appears that the management strategy used for controlled reduction of the biomass to above 30 % of pre-fishery biomass did not adequately constrain catches in most of the managed zones. Recent estimates of biomass of orange roughy (from acoustic surveys) are between 20 000 and 38 000 tonnes on the Cascade Plateau[6] (perhaps as high as 80 % of mean estimates of pre-fishery biomass, discussed below) and about 20 000 tonnes (10 % of unfished) in the other management areas combined[27]. This represents serious overfishing in most fished areas but also indicates that a substantial biomass of orange roughy, made up of an estimated 30 million mature individuals, remain in the SESSF (assuming an average 1.5 kg fish). It is equally important to acknowledge that the severe cuts in fishing in recent years have resulted in the assessment that orange roughy is currently 'not subject to overfishing' in any of the management zones nor in the remaining area in which it is fished.

Given the status of orange roughy as 'Conservation Dependant' (see below), management of the fishery is done under the Orange Roughy Conservation Programme (ORCP)[30]. Currently, targeted fishing for orange roughy is only permitted on the Cascade Plateau where stocks are 'not overfished' and are 'not subject to overfishing'[6]. Independent assessments of the stocks have been done annually for several years using increasingly more reliable estimates of the longevity, growth and reproductive capacity of orange roughy in each management zone. Subsequently, TACs have been adjusted based on these assessments. Current TACs appear to adequately constrain the harvest to a much smaller proportion of the biomass, i.e. sustainable catches are estimated to be only a few percent of the pre-fishery biomass[32 cited in 31]. The TAC for the only permitted commercial fishery, on the Cascade Plateau, was reduced from 700 tonnes in 2008 to 500 tonnes in 2009[33] and maintained for 2010/11[34]. According to the latest assessment (updated in 2009 amid concerns that the biomass had been overestimated in the 2006 assessment), fishing at this restricted level will maintain the stock in 2011 at an estimated 63 % of the pre-fishery biomass[35]. This is in accordance with the very conservative target of keeping the stock on the Cascade Plateau ≥ 60 % of the pre-fishery biomass as required by the ORCP.

New Zealand

Most (approximately 90 %) of the orange roughy sold in Australia is caught in New Zealand. Recent imports of fillets (frozen and fresh) of orange roughy from New Zealand averaged about 1 200 per annum[2] (i.e. a landed catch of about 3 000 tonnes). In contrast, the total catch from Australian waters in 2008/09 was only 492 tonnes[1], much of which was exported. Orange roughy consumed in Australia is therefore many times more likely to have been caught in waters off New Zealand than off Australia. The status of orange roughy stocks in New Zealand waters is therefore particularly relevant to Australian consumers.

New Zealand has received international acclaim for the research into and management of its orange roughy fisheries[36]. This reputation has been hard-earned; the industry-levied contribution alone to research and management of orange roughy stocks has exceeded $NZ 100 million since 1990[37]. The management strategy for orange roughy in New Zealand is similar to that for Australia, i.e. optimum sustainable harvest to be achieved by maintaining the biomass at or above 30 % of the pre-fishery biomass[36,38]. And, as in Australia, the management of orange roughy in New Zealand has not been without uncertainty and mistakes. These, again, have been due largely to earlier disbelief of the estimates of the longevity of the species and to the particular difficulty in obtaining an adequate understanding of the biology and behaviour of orange roughy and reliable estimates of the pre-fishery and current biomass of this deepwater fish.

New Zealand has eight orange roughy management areas, including an area that supports the biggest and oldest fishery for orange roughy in the world; the deep sea Chatham Rise ridge off the north-east coast. The first commercial catches were taken here in 1979 and annual landings peaked at about 32 000 tonnes in 1988/89[39] then started to decline. Total catch remained between 20 000 and 30 000 tonnes into the early 1990s, declining further to about 10 000 tonnes in the mid 1990s[39](Figure 2). The Chatham Rise fishery has been intensively assessed since its development and has a relatively reliable and long time-series of data from annual trawl surveys, commercial catch records and scientific observation on board commercial and research vessels[reviewed in 31, 40]. Similar to the Australian experience, as the biology of the species became better understood, it was apparent that the initial Total Allowable Commercial Catches (TACCs) were set too high and by 1997, stocks were estimated to be below 20 % of the pre-fishery biomass, i.e. 'overfished'[40].

The Chatham Rise fishery was thought to contain several stocks of orange roughy with the bulk of the catch taken from the stock in the south-east region of the management zone (once separated into south and east stocks but now considered a single south-east stock)[41]. The latest assessment of the stocks of orange roughy in 2009 (from 2008 data) reported the biomass in the south-east Chatham Rise to be between 13 and 30 % of the pre-fishery biomass, i.e. between 60 000 and 103 000 tonnes, with another 63 750 tonnes in the other management areas[39,41]. This is almost three times the biomass recorded in Australian waters and includes an estimated 100 million mature fish. The TACC for orange roughy in the entire Chatham Rise zone has been set at just above 10 000 tonnes for the last several years[39] but it has been suggested that orange roughy stocks in the south-east Chatham Rise may continue to decline at this level of catch[39,42].

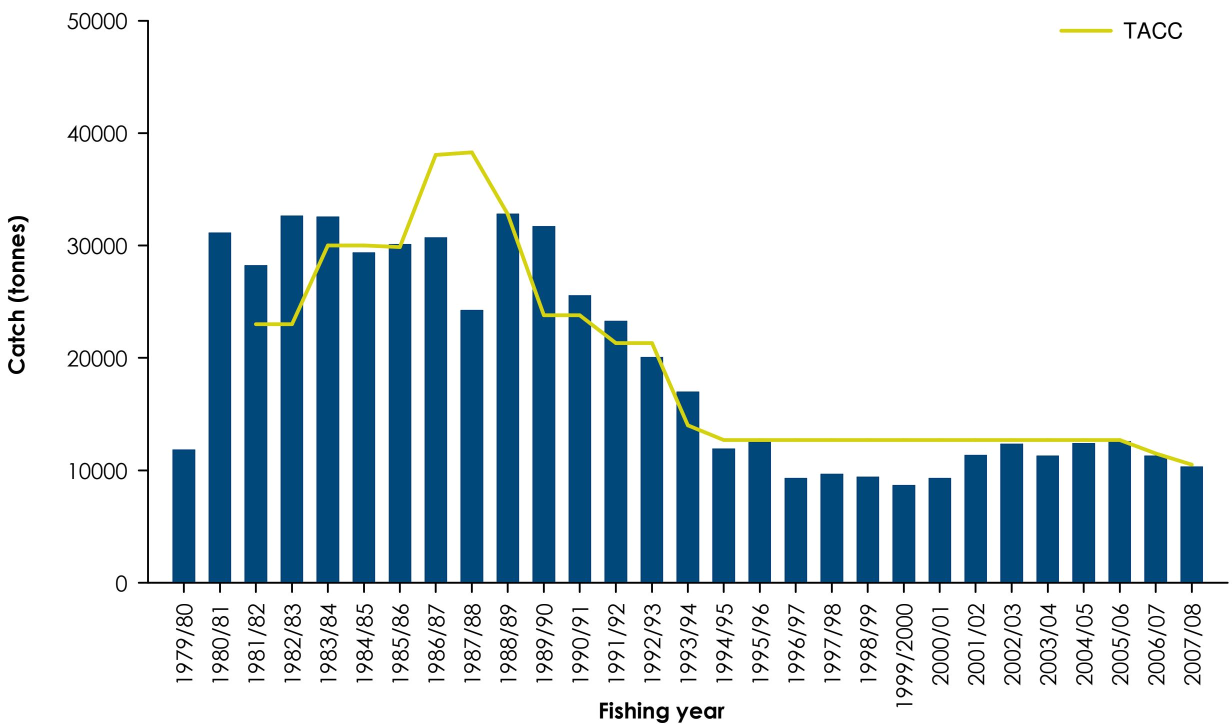

Figure 2. Reported commercial and Total Allowable Commercial Catch (TACC) of orange roughy on the south and east Chatham Rise, New Zealand[39].

The fishing mortality considered sustainable for stocks of orange roughy in the Chatham Rise is estimated to be 4.5 % of the best estimate of current biomass[39]. Considering uncertainties in the data for this estimate, the sustainable yield was last estimated to be between 4 000 and 5 000 tonnes per annum[41,43]. Following advice from updated assessments and reviews of the stocks in this management zone, a new strategy to sustainably fish the stocks was developed in 2008. This will progressively reduce fishing effort to the estimated sustainable level by 2010 (i.e. thereby lessening the economic cost to the fishery of a singular dramatic reduction) [41]. Accordingly, the TACC for the south-east Chatham Rise stock was reduced from over 7 000 tonnes to over 6 000 tonnes for 2008/09[39] and again to the estimated sustainable level of 5 000 for 2009/10[41].

Conservation

Orange roughy is listed as Conservation Dependant

As for many harvested species, the Australian orange roughy fishery developed rapidly. Management was, as discussed earlier, too late and not sufficiently restrictive to prevent the biomass of orange roughy in several areas being reduced to below target levels. During the ‘fish-down’ phase of a fishery the biomass is reduced to a target level (in this case 30 %) that is assumed to produce the optimum surplus production from the population and enables the maximum sustainable yield. Even when ‘fish-down’ is exactly as prescribed by best resource use practices the resultant decrease in biomass and subsequent catch-rates can be misinterpreted as unsustainable population decline and even potential extinction risk.

In 2006, the Commonwealth Threatened Species Scientific Committee (TSSC) [44] recommended that orange roughy be listed as 'endangered' (EPBC Act 1999)[45] because it had undergone a substantial reduction in abundance as indexed by catch rates and biomass estimates from certain fished areas (the only areas for which data were available). Criteria in the EPBC Act against which the TSSC was required at the time to assess the extinction risk of a species were, however, based on terrestrial management paradigms and concepts. These criteria did not accommodate the contrasting biology and environmental conditions that characterise marine organisms or the basic concepts of fisheries management which must accommodate a reduction in the biomass of exploited populations in order to achieve the maximum or optimum sustainable yields[32]. Furthermore, the EPBC Act requires that the status of a species be assessed over the whole area of its distribution, but the data available to the TSSC in 2006 was disproportionately biased towards those areas which had been heavily exploited. As a result evidence of localised depletion provided disproportionate representation of overexploitation of the species across its entire Australian distribution.

Marine fish tend to occur in patches over a wide distribution and consequently a substantial decline in one fished stock (or population) does not necessarily imply extinction risk for the species as a whole. The International Union for the Conservation of Nature (IUCN) recognised that sole use of a substantial reduction in abundance is an exaggeration of the extinction risk for many marine organisms and subsequently developed new criteria[46,47]. Following suit, the Commonwealth department responsible for the environment recognised the limitations of the original criteria in the EPBC Act 1999 and mandated for the TSSC in so far as they relate to marine species that were the subject of well managed fisheries, i.e. in which population levels in certain areas could undergo major reductions as part of deliberate and approved management strategies. As a result a new category of classification, 'Conservation Dependent', was developed which acknowledges that approved fisheries management is adequate to stop the decline and support the recovery of fish species. In 2006, orange roughy was listed by the Commonwealth of Australia as Conservation Dependent.

In response, the ORCP[30] was established as the main management strategy to protect orange roughy from overfishing, ensure the recovery of overfished stocks and the long-term survival of the species, i.e. that orange roughy do not become Vulnerable, Endangered or Critically Endangered. The commercial fishery can now only target orange roughy on the Cascade Plateau (classified 'not overfished'). TACs for this zone are reviewed annually and set to maintain biomass at or above 60 % of the estimated pre-fishery biomass. This very conservative level is applied so the population is demonstrably protected and of such a size as to ensure that fishing in this zone does not negatively impact the recovery of populations in other zones. The current, sustainable TAC for the Cascade Plateau is 500 tonnes for 2010/11[34]. The only targeted fishing for orange roughy permitted in the Southern, Eastern and Western Zones (classified as 'overfished') is that required for research. TACs in these zones are restricted to unavoidable bycatch and allowances for research are between 25 and 60 tonnes for 2010/11. Importantly, catches in these zones have been below these levels in each year since the establishment of the ORCP in 2007. Additionally, trawling is not permitted below 700 m in the SESSF (excluding Cascade Plateau), within 12 zones of the Great Australian Bight Fishery, The South Tasman Rise (declared a deepwater marine reserve) and the spawning area at St Helens Hill seamount off Tasmania[48]. A research program is also being done to better estimate the biomass of orange roughy in the eastern zone using advanced surveying methods[49].

Recruitment is a critical issue for the sustainability of any fish species, but particularly for orange roughy as it is sporadic and possibly infrequent[31]. The recovery of overfished populations of orange roughy may therefore be relatively slow, even if there is no fishing[21]. A biologically reasonable average time-frame for recovery to target levels (i.e. those assessed to be sustainable) is estimated to be between 40 to 45 years[27]. An absence of rapid recovery does not, however, necessarily equate to extinction risk; indeed where targeted fishing has ceased, orange roughy stocks have not continued to decline[27]. Furthermore, as the Australian fishery has been in operation for a total of only 30 years, which is less than the time it can take for recruitment to the fishery (between 24 and 42 years[6]), there should still be recruits which were produced from spawning that occurred prior to any fishery induced reductions in biomass that are still to arrive in the fishery.

Bycatch

Removal of substantial numbers of one species of fish may cause changes in the composition and abundance of associated species. The few studies that have been done from trawl surveys in New Zealand have suggested however, that no significant changes have occurred in species composition of fish assemblages impacted by deepwater trawling[50-52 cited in 12]. Bycatch associated with orange roughy consists mainly of oreo dories (smooth, black and spiky) and coral (species of hard and soft corals). A particular danger with deepwater bycatch is that there is almost always 100 % mortality from barotrauma (being brought relatively quickly to the surface from great depth). Landings of bycatch species when trawling for orange roughy are, however, small[53] and as mentioned previously, only a small percent of the seabed in Australia and New Zealand is currently trawled (see also below). Furthermore, a study in the South Tasman Rise reported that the landing of these taxa has been consistently reduced since 1997[53]. Bycatch action plans have been developed by AFMA (and the individual fisheries) to ensure that relevant information is collected on the potential impact of the fishery on by-catch species and that bycatch is kept below a level that might threaten such species[54].

Environment

Deep seamounts have fauna including corals, sponges and sea urchins which are often distinct from that on the adjacent sea-bed. Removal and/or damage of these taxa by bottom trawling for orange roughy could obviously impact these assemblages, at least in the area trawled[12]. For example, photographs taken in New Zealand show lower abundances of coral and invertebrates and larger areas of relatively bare ground on heavily fished versus less fished areas[12,55,56]. Such impacts should not, however, be assumed to be widespread or to have excessive negative impacts on broader ecosystems or biodiversity. Advances in technology (e.g. GPS) and fishing knowledge mean that trawling for orange roughy (and indeed most trawling in the SESSF) is increasingly concentrated in small areas on established grounds[57]. Major impacts associated with trawl gear therefore tend to be localised. In Australia, the ORCP restricts trawling in known aggregation areas over seamounts to minimise the potential for negative impacts to these habitats[30]. Between 90 to 95 % of the area available for fishing, or previously fished, is now closed to fishing[58,59]. In New Zealand, most of the trawling for orange roughy is done on relatively flat ground (< 400 m features) rather than on seamounts proper (> 1 000 m)[38] reducing the impact on seamount fauna. Furthermore, in New Zealand only about 10 % of the seabed within the depth range in which orange roughy is targeted (750 m – 1 500 m) has been contacted by trawl gear in the life of the fishery[43] and over 30 % of the seabed of New Zealand waters has been permanently closed to deepwater trawling. These closed areas include relatively pristine areas that have never been trawled[38].

The sustainability of orange roughy in Australia and New Zealand

The methods by which stocks of orange roughy are assessed in Australia (including how the data are estimated) were internationally reviewed and found to be consistent with world best practice[21]. Past mismanagement has caused stocks to be depleted in many of the localised and relatively small areas that were historically fished for orange roughy in Australian waters. Severe cuts in fishing effort in recent years, however mean that the species is currently 'not subject to overfishing' in any of the management zones of Australia[6]. The current science-based management system that limits entry and quotas, strictly monitors and controls catch to conserve productivity of the species are all in keeping with the FAO guidelines on the precautionary approach to sustainable fisheries management[21,60]. Similarly, whilst many of the stocks of orange roughy in New Zealand waters have been substantially reduced, current management strategies are well-recognised internationally and appear to have affected sustainability and facilitated eventual recovery of New Zealand stocks. Any threat to the survival of the species in Australia and New Zealand that may have been posed by uncontrolled expansion in the fisheries has been removed by strict controls on effort and the promotion of recovery strategies for previously overfished stocks.

The logical conclusion for consumers of orange roughy in Australia and New Zealand is that the limited quantities that are marketed locally are sustainably caught. Previously overfished areas have been closed to fishing and the remaining fisheries have been rigorously and repeated assessed to be sustainable given the scientific data available. Suitably, precautionary and science-based management strategies are well on track to ensure the recovery of previously overfished populations. Current levels of targeted catch and the limited remaining by-catch of orange roughy pose no known threat to the long-term survival of the fisheries or the species.

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Yellowfin bream

Ancanthopagrus australis

Yellowfin bream are deep bodied fish with flavoursome, moist flesh; a favourite for seafood consumers, particularly cooked whole. Despite continued fishing of this species and degradation of water quality and habitat in the many estuaries of NSW, eastern Victoria and south-east Queensland with which they are associated, the species seems very resilient and stocks have remained remarkably stable. Fishing at current levels is clearly not a threat to the sustainability of the species. The management strategies for the commercial fishery which targets yellowfin bream in NSW was externally assessed to be adequate to provide for the ecological sustainability of the species and appropriate to minimise environmental risks associated with the fishery. The recreational catch of yellowfin bream now substantially exceeds the commercial catch but no assessments of the environmental impact of the recreational fishery are available. The combined impact of the commercial and recreational catch was, however considered sustainable. This guide to the sustainability of yellowfin bream and the management of the fisheries in which they are targeted is based on the scientific and fishery-related data available at the time of publication. The bulk of the funding for the preparation of this series of guides was provided by the Fisheries Research and Development Corporation. The series of guides has been jointly sponsored by Sydney Fish Market Pty Ltd (SFM), which is Australia's largest and best known market for seafood, so individual guides are focused on the sustainability of seafood sold through SFM. Support from OceanWatch Australia Ltd for parts of the research done in this factsheet is acknowledged.

Biology

Yellowfin bream are endemic to eastern Australia and found in estuarine and coastal waters to depths of about 35 m from Townsville, Queensland to the Gippsland region in eastern Victoria[(1)]. In NSW estuaries, bream are associated with many types of habitat including seagrass beds, mangroves, rocky reefs and even relatively bare substrata. They can be found up to the limit of brackish water in coastal rivers. Juveniles are particularly concentrated in small creeks and sheltered waters. Adults are also found along surf beaches, around rocky headlands[(2)] and associated with near-shore reefs. Yellowfin bream eat a variety of prey including prawns, molluscs, worms, crustaceans and small fish[(2)] and are also noted scavengers. Individuals grow to a maximum of about 56 cm in length (4.5 kg)[(3)] but are mostly harvested at 25 to 35 cm (0.2 - 1.2 kg)[(4)].

Some adults annually migrate from estuaries to spawn in the surf zone at the entrance of estuaries, predominantly during Austral winter but the timing of spawning varies annually and throughout the distribution of the species[(2)]. Estimates of the reproductive capacity of yellowfin bream remain limited but females of the closely related black bream (*Acanthopagrus butcheri*) release between 300 000 and 3 million eggs per year[(2)]. The planktonic larvae of yellowfin bream enter estuaries on flood tides and then settle out of the plankton. Small juveniles subsequently live in sheltered, shallow water, particularly associated with seagrass and mangrove habitats. Larger juveniles occur in most areas of estuaries in slightly deeper waters and are also associated with coastal reefs[(5)]. Growth rates of yellowfin bream are thought to be rapid as juveniles[(3)], ranging between 0.02 mm to 0.39 mm per day[(6)] and up to 0.67 mm per day under the right conditions[(7)]. Growth is slow after maturity (about 1 cm a year)[(3)]. Maturity is thought to be reached from 22 to 31 cm[(3)] and the maximum confirmed age is 12 years[(8)] but greater longevity is thought to be achieved in at least some areas. Natural mortality is estimated to range between 14 and 21 % of the population per year[(3)].

Fishery & management

Commercially, in NSW yellowfin bream are a target of the Estuary General Fishery (EGF) managed by the NSW Government. The species is caught year-round with greatest catches coming from the Clarence River, Port Stephens, Tuggerah Lakes and historically Botany Bay and Lake Macquarie before these waters were closed to commercial fishing in 2002. Bream are caught primarily using mesh and haul nets but also in fish traps, particularly on near-shore reefs and close to rocky structures in estuaries. Peak catches occur in Austral autumn and winter(2). Yellowfin bream are also harvested in smaller amounts in the Ocean Haul, Ocean Trawl and Ocean Trap and Line Fisheries of NSW. In Queensland, bream are targeted by the Queensland East Coast Inshore Fin Fish Fishery (ECIFFF) but yellowfin are not distinguished from black bream. Commercial landings were 152 tonnes and 258 tonnes in 2002 and 2007 respectively, with catches fluctuating around 200 tonnes in the intermediate years(9) and the fishery was assessed to be sustainable in 2009(10) by the government department responsible for the environment. The Victorian Commercial Bay and Inlet Fisheries mainly target black bream which is considered fully fished at current levels of effort(11). Black bream are often difficult to distinguish from yellowfin bream in estuarine catches and this difficulty is confounded because some hybridisation occurs between the two species, especially in Victoria. Yellowfin bream can migrate large distances and it is likely a single stock exists across its distribution in eastern Australia(2).

The Estuarine General Fishery (EGF) of NSW

The EGF is an artisanal style fishery with small vessels (3 - 6 m in length), yet is of considerable economic value; annual total catches of all species, including yellowfin bream, are around 5 000 tonnes worth about $19 million at the first point of sale in 2002(12). It is an important regional industry and source of highly prized local seafood for many Australians. Reported commercial landings of yellowfin bream have been relatively stable since the 1950s(5).

The number of licensed commercial fishers was reduced from 944 in 2001(13) to 722 in 2002 as a result of the creation of recreational fishing havens and the associated buyout of commercial fishers in that year. Commercial catches did increase in the early 1990s, possibly due to increased fishing effort, but declined again during the late 1990s. This was at least partly because pound nets (permanent net traps also known as figure 6 nets) were banned in Port Stephens and adjoining coastal waters(5), but declines in environmental conditions(12) and increased recreational catches were also probable causes. In the new millennium, commercial landings have remained relatively stable at about 350 tonnes(5,14). The age and length compositions of catches have also remained relatively stable with a possible indication of a marginal decline in the proportion of larger fish(5).

Catch levels are notoriously imprecise indices of abundance and their use to establish the status of the stocks of yellowfin bream is much less than ideal. Alternative estimates of biomass or even relative abundance are, however, lacking for this species and are certainly not available for each and every estuary or habitat type occupied by the species. Available information on their biology (age, growth and reproduction) comes from studies done mainly in Queensland and may not therefore be accurate for fish in NSW. Nonetheless, noting the wide distribution of the species, its occupation of varied habitats, mobility and multiple spawning sites and the remarkable stability of total catches over many years(5), there is little concern for the resilience of this species.

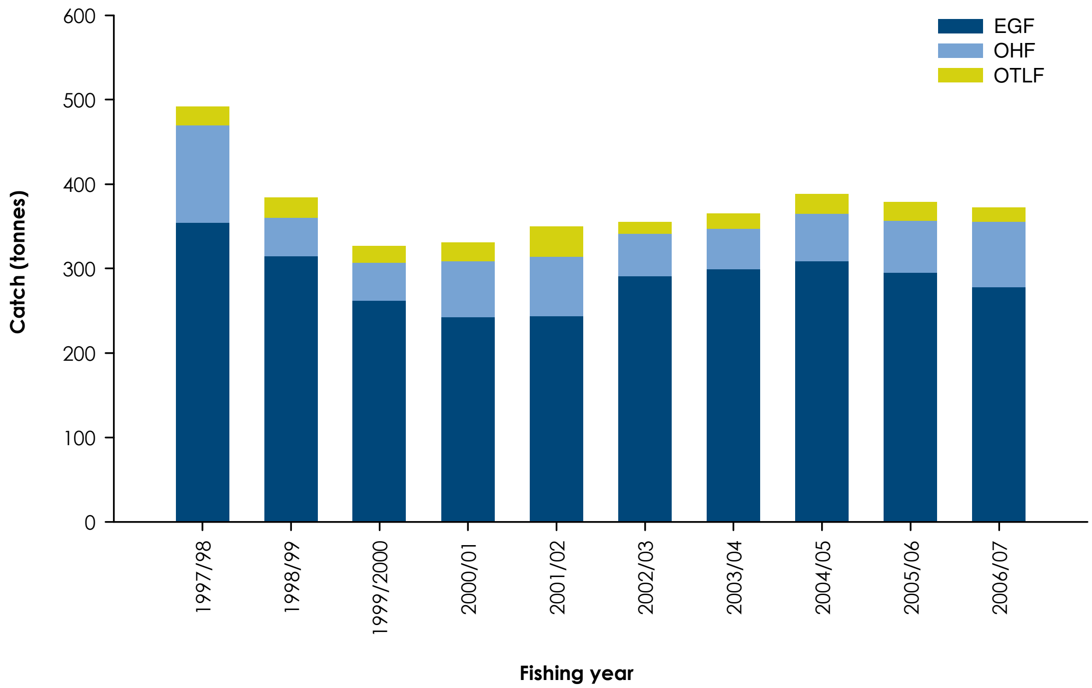

Figure. Commercial catch of yellowfin bream in the fisheries of NSW in which the species is mainly caught; EGF (Estuary General Fishery), OH (Ocean Haul Fishery), OTLF (Ocean Trap and Line Fishery)[14].

Yellowfin bream are extremely popular with recreational fishers. The species is caught using rod and handline, often around easily accessed structures such as jetties and pylons and on ocean beaches. The catch from this sector in NSW has been greater than that of the commercial sector for some time[2,5]; the more recent estimate of the recreational catch across NSW (about 1 000 tonnes per annum)[5] is two to three times the reported commercial catch. In many areas, particularly in selected estuaries, the recreational catch is many times greater than the commercial catch.

The species is considered by NSW DPI to be sustainably fished[13] at a 'fully fished' level (the classification that fisheries are producing maximum sustainable yields) in the combined commercial and recreational fisheries[5]. The primary goal of the EGF to maintain the stocks of targeted species at sustainable, fully fished levels, is pursued by input controls including, restrictions on the number of licenses, size and engine capacity of boats, gear restrictions and temporal and spatial closures. Limit reference points are set as performance indicators for the fishery and if these are triggered fishing effort is curtailed and recovery plans are developed if necessary for overfished species[12]. The size limit for yellowfin bream has been maintained at 25 cm total length since the 1960s[5]. This limit is suitably precautionary to ensure that many individuals have had the opportunity to spawn at least once before legal harvest (maturity is estimated at a minimum of 22 cm)[8]. Most of the fish caught commercially are above this limit and the size distribution of the commercial harvest has been stable since the 1950s[13]. The maximum yield is thought to occur at 27 cm[3]. There are also strict regulations on the mesh size (> 80 mm) and dimensions of nets (maximum headline length of 500 m is now in place in all areas) to help reduce incidental catch and to facilitate the release of juveniles in the best possible condition. The maximum allowable dimensions of traps, 2 × 1.5 × 1 m with a mesh size > 50 mm, are designed to achieve the same goals. Time restrictions for the setting of mesh nets are also applicable and these vary in different estuaries[12-13]. To prevent unwarranted increases in fishing effort, new entrants to the EGF must replace previously active fishing effort, boats and nets must be registered and licenses for each are only given in replacement of existing vessels and equipment that are no longer serviceable[13]. Statistics from 1999/00 showed many of the registered fishers did not actively fish and potential reactivation of at least some of this latent effort was acknowledged as a potential risk[13]. Nonetheless, at the latest assessment of the EGF, levels of total fishing effort for yellowfin bream were not considered to be excessive[13]. Nonetheless, the recreational sector requires careful monitoring, because landings from this sector are much larger than the commercial catch and additionally many bream are captured and released (an estimated 63 %)[15] and are not represented in the estimates of landings. Whilst studies have shown the survival rates of line-caught yellowfin bream are between 72 and 100 %[16], the impact of being caught still needs to be included in assessments.

Scientific assessments of stock levels and research to understand the ecology of targeted species and bycatch and the impacts of fishing on the ecology of estuaries are periodically carried out (e.g. Environmental Impact Statements; EISs). In the latest assessment, the levels of spawning and available stock were considered adequate to sustain the population at current levels of fishing[13]. Such assessments appear to be needed more regularly given the last EIS was almost a decade ago[13] and whilst catches of yellowfin bream have been stable for decades and the fishing effort considered moderate, the increasing impact of non-fishing activities such as coastal development on the ecology of NSW estuaries[12,13] is an acknowledged and growing concern.

Conservation

Bycatch

Mortality rates of bycatch from fishing for yellowfin bream in haul nets in the EGF was assessed to be negligible, mainly because the catch must be sorted in water or released immediately[13] and the species is relatively hardy. Tagging studies from fish caught in nets showed that yellowfin bream have a good survival rate[17 cited in 13]. Individuals released after incidental capture in fish and crab traps are also generally in good condition[13]. Over half (63 %) of the recreational catch of yellowfin bream in Australian waters is released mainly because the fish are too small[15]. Whilst the mortality level of these released fish is unknown, one estimate was roughly 15 % dying soon after release[18].

The impact of the fishery on the biodiversity of NSW estuaries was assessed to be minimal. Major factors leading to this conclusion were the current management of commercial fishing, the overall distribution of fauna and habitats and the available data on fishing effort and catch of yellowfin bream[13]. The most recent Environmental Impact Statement (EIS) concluded that the current management strategy of the EGF, which includes routine monitoring of fishing activity and sets reference points so that harmful practices can be detected and modified if necessary, was adequate to maintain the sustainable use of its resources[12].

Environment

Much remains unknown about the extent and type of impacts on diversity and habitat of NSW estuaries from fishing and other activities. Whilst it is probable that commercial fishing in the EGF does have some impact, wide-scale and severe impacts from the fishery were considered to be minimal[13]. The risk of long-term changes in the structure of estuarine species as a result of fishing was deemed small (with a possible exception of pelicans that may have come to rely on discards from fishing)[13]. Fishing effort in the EGF is dispersed, so in general, whilst there may be some localised effects of fishing, wide scale or major impacts seem unlikely. Risk of introducing exotic species by fishing is negligible and the translocation of species introduced from other sources is small and controlled (for example, the use of haul nets has been banned in affected estuaries to reduce the spread of the marine weed, *Caulerpa taxifolia* caught in fishing gear)[19]. The impacts of hauling on different types of seagrass can vary seasonally, among estuaries and by type of seagrass, but they are generally minor and/or beds recover rapidly[20]. The long-term consequences of hauling on seagrass distribution or the seabed are usually minor[21], particularly when compared to other non-fishing impacts, such as pollution, siltation, displacement by introduced species and other forms of habitat degradation.

External threats

The main concern for the fishery was the impacts of external factors such as land-based catchment uses, contamination and habitat degradation[13]. For example, substantial loss of seagrass habitat in NSW (which is considered important for juvenile yellowfin bream) has been attributed to physical disturbance through siltation, eutrophication and toxicants[22] and there is little evidence of large-scale recovery[23]. Other anthropogenic impacts such as excess nutrients, reduced flows from freshwater streams and exotic species are all major factors contributing to environmental degradation in estuaries[24]. On the other hand, water quality is usually relatively quick to recover from natural disturbances (e.g. floods) and even from relatively short-term pollution events (such as rain induced acid-sulphate soil run-off) and adult yellowfin bream have been known to relatively quickly recolonise affected areas, immigrating from other estuaries and coastal areas, to levels which could support sustainable fishing[25], albeit at reduced levels.

The sustainability of yellowfin bream in New South Wales

Industry & Investment NSW (I&I NSW) is committed to a strategic research plan including stock assessments, quantification and reduction of bycatch, understanding the importance of habitat and ecological dynamics on fish populations and the impacts of fishing on these processes[12]. The current strategy is to continue to use age-based assessments of the yellowfin bream stock obtained from sampling the commercial catch. Because relying on these data is not an ideal way to assess stocks collection of fishery independent data through scientific sampling is being done to provide a more rigorous assessment for yellowfin bream[26]. Unfortunately, the major negative impacts on yellowfin bream and their ecosystems, primarily habitat contamination and destruction, are not the subject of similar research and management action.

Despite current levels of uncertainty about the exact status of the stock and impacts of non-fishing activities, consumers of yellowfin bream can comfortably do so knowing that commercial and recreational fishing effort poses no threat to the survival of the species. Considering progressive environmental declines in estuarine habitats and water quality, populations of yellowfin bream (and indeed other estuarine species) appear remarkably resilient.

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Tiger flathead

Platycephalus richardsoni (synonym: *Neoplatycephalus richardsoni*)[1]

Tiger flathead are flat bodied, greenish-grey fish with orange-red spots prominent on the dorsal surface. The species is noted for its tender flesh and light but distinct flavour. Tiger flathead were historically overfished but reductions in fishing effort since the middle of the last century have maintained steady catch levels. The current management of tiger flathead was most recently determined against global standards to be precautionary with effort and subsequent catches constrained within limits that are considered sustainable. Consumers can enjoy tiger flathead knowing that the supply in Australia is effectively managed. This guide to the sustainability of tiger flathead and the management of the fisheries in which they are targeted is based on the scientific and fishery-related data available at the time of publication. The bulk of the funding for the preparation of this series of guides was provided by the Fisheries Research and Development Corporation. The series of guides has been jointly sponsored by Sydney Fish Market Pty Ltd (SFM), which is Australia's largest and best known market for seafood, so individual guides are focused on the sustainability of seafood sold through SFM.

Biology

Tiger flathead are endemic to Australia and are found continuously around the east coast south from Coffs Harbour NSW, to Portland Victoria, including Bass Strait[2]. They occur at depths between 200 to 400 m[3]. Juveniles live in shallower waters and move into deeper waters as they reach maturity[2]. The species has often not been distinguished from the toothy flathead which is now recognised as different species (*P. aurimaculatus*); toothy flathead are similar but can be differentiated by their different coloured spots, different caudal fin and the absence of a swim bladder[3]. Tiger flathead are relatively inactive, resting on the sea floor during the day in sandy or muddy habitats. At night they may move up the water column to feed on small fish (e.g. silversides and cardinalfish), crustaceans and even other flathead[2].

Tiger flathead spawn between October and May and the exact timing varies throughout their range[2]. Females can release between 1.5 million to 2.5 million eggs per spawn[2]. The eggs and larvae are pelagic and probably distributed widely by water movement along the east coast of Australia[4]. Juveniles feed predominantly on crustaceans including krill[2]. Tiger flathead reach maturity around 4 to 5 years (males grow slightly slower than females[4] reaching maturity at 30 cm for males compared with 36 cm for females) and can live for up to 12 years[2]. The disparity in age at maturity produces different sex ratios in the commercial catch with females dominating the catch of larger fish[4]. Tiger flathead are most frequently caught at around 55 cm (1.3 kg) but can grow up to 70 cm (3 kg)[3]. The species appears to be short-lived with a high rate of natural mortality (above 70 % per annum)[5].

Fishery & management

Tiger flathead is a target species of the trawl sector of the Southern and Eastern Scalefish and Shark Fishery (SESSF) managed by the Commonwealth. Most of the catch is taken off New South Wales, Victoria and in Bass Strait by otter trawl all year round and by Danish seine from October to March[2]. Tiger flathead were commercially targeted from the early 1900s in waters between Crowdy Head and Gabo Island, NSW expanding into Bass Strait in the 1930s[2]. A peak catch of over 6 000 tonnes was recorded in 1929 when tiger flathead made up the majority of the trawl catch of the SESSF[2]. Catches subsequently began to decline and despite expectations that the fishery would recover during World War II (when little trawling was done), in the post-war years catches continued to decline to around 1 000 tonnes. This led to concerns that the species had indeed been overfished, had not sufficiently recovered during the war down-time and was therefore still likely being overfished[5]. It should be noted however, that these assessed declines were based on data recorded only in areas where trawling for flathead was done. They may have reflected localised depletion at key fishing sites more than the overall status of the species. Catch levels, in trawled areas, started to increase from the 1970s with the increase in the number of smaller board-trawlers off the south east coast of Australia and probable expansion in the fished areas. Catches have remained relatively stable at around 3 000 tonnes since 2000[6]. The reported catch in 2008, was just over 3 000 tonnes[7]. The recreational sector was estimated in 2008 to harvest between 20 and 60 tonnes of tiger flathead annually in NSW[8].

There seem to be adequately long-term and detailed data on the biology and catch statistics of tiger flathead[e.g. 4,5] to assess the stock and manage the fishery effectively (albeit uncertainties still exist in the data[7]). Tiger flathead are managed as a single stock, although there are differences in growth rates and spawning periods throughout their distribution[2,9]. Commercial catches of flathead in the SESSF have been managed since 1992 by setting Total Allowable Catches (TACs)[6]. The TAC is set for total flathead catch and while tiger flathead make up the majority of this catch (> 95 %)[10], four other species are also included in the annual TAC (blue-spotted, southern blue-spotted, southern sand and toothy flathead)[7]. Commercial catches of flathead have fluctuated under the set TAC (around 3 000 tonnes) since 2004[6].

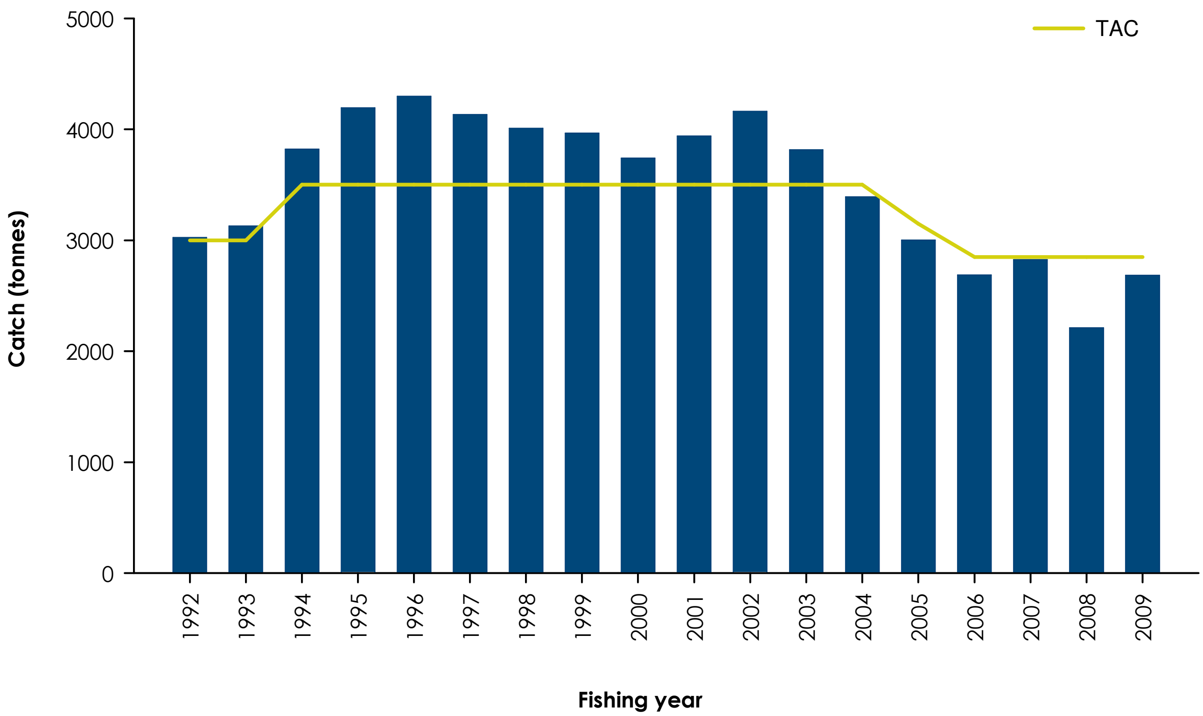

Figure. Annual commercial catch and Total Allowable Catch (TAC) of flathead in the Southern and Eastern Scalefish and Shark Fishery managed by the Commonwealth of Australia[11,pers. comm. T. Skousen, AFMA].

Stock assessments for flathead have been done and revised since the early 1980s and flathead have been classified as 'not overfished' in each year since 1992 (note that in 2005 the species was classified as 'subject to overfishing')[10] . The formal assessment in 2006, estimated the biomass of flathead to be at the recommended level of above 40 % of the pre-fishery biomass under the most likely modelling scenarios[9]. It has been suggested that harvesting more than 3000 tonnes annually was excessive and that the sustainable yield was more likely to be between 2 000 and 2 500 tonnes per annum[6]. Nonetheless, the TAC has been set at 2 850 tonnes for the last three years which reportedly would maintain stocks at or above 40 % of the pre-fishery biomass[7]. The TAC for 2009/10 was reduced to 2 750 tonnes[12]. Flathead is currently classified as 'not overfished' nor 'subject to overfishing' in the SESSF[7]. The current harvest of tiger flathead is very close to one of the more recent estimates of maximum sustainable yield[8], however, the estimated biomass appears to be above that which would necessitate immediate downward alteration of the TAC . Regular resource assessments will be required to support fine-tuning of optimum TACs.

Conservation

Bycatch

Considering tiger flathead are targeted by bottom trawling, detailed assessment of the bycatch is necessary. Incidental catch in and physical damage by trawl nets are recognised as potential impacts on sea-bed ecosystems. Commonly recorded bycatch species in trawl nets targeting tiger flathead include eastern school whiting, redfish, jackass morwong and john dory[2]. A bycatch action plan for the SESSF has been developed to monitor and assess species that may be at high risk from the fishery and aims to ensure that bycatch is kept below a level that might threaten bycatch species and juveniles of the target species[13]. The impact of fishing for tiger flathead specifically has not been assessed. Research has shown that increasing mesh size (from the 90 mm introduced in the early 1950s) may reduce bycatch but this would also result in decreases in the catch of tiger flathead [14]. Escape panels in the codends of trawl nets are required in this fishery and this is thought to be a better strategy than regulating mesh size to reduce bycatch in the trawl sector of the SESSF[12].

Several areas have been closed to trawling as a result of the declaration of marine parks in NSW but more comprehensive investigation of the efficacy of area management in this trawl fishery is necessary. Because of the complexity of the assemblages, including flathead, taken in the whole of the trawl fishery off south eastern Australia, the total impact of this fishery requires further investigation and concerted monitoring.

Sustainability of tiger flathead in NSW

Whilst tiger flathead have been historically overfished, reductions in targeted fishing effort in the middle of the last century and restrictions placed on the amount allowed to be caught for the last several decades have maintained steady catch levels in recent years. Recovery of the stocks was not initially as pronounced nor rapid as expected from early years of overfishing but the latest assessment estimated the biomass of tiger flathead to be well above that which is globally considered sustainable for a commercially fished species. There is some concern that current levels of fishing may be just above that which is considered to be the maximum sustainable, but not of a level that represents a threat to the survival of the species or is even likely to cause unexpected declines in catches. Careful assessment of the stocks is continuous and management is currently responsive to scientific advice so consumers should have no hesitation to enjoy the tiger flathead that are made available in Australia.

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Yellowfin tuna

Thunnus albacares

Yellowfin tuna are prized around the world for a wide variety of culinary uses, ranging from sashimi to canned products. They are also a popular target for recreational fishing. Australia exports the bulk of its catch of yellowfin tuna with most (over $7 million in the 2007/08 financial year[1]) destined for Japan as whole fish. On the other hand Australia imports considerable quantities of canned yellowfin tuna . Domestic concerns were raised about growing fishing effort and as a result effort is now regulated by input controls (e.g. Total Allowable Effort; TAE). In recent years, domestic fishing effort on yellowfin tuna has declined.

In the greater western Pacific Ocean, which includes Australia's major yellowfin tuna fishing grounds, the current estimate of the biomass is above the target level for sustainability. Recent catches in the whole of the western and central Pacific Ocean have been smaller than the estimated maximum sustainable yield and the species is not considered to be 'overfished' or 'subject to overfishing'[2], in fact it is technically 'underfished'.

This guide to the sustainability of yellowfin tuna and the management of the fisheries in which they are targeted is based on the scientific and fishery-related data available at the time of publication. The bulk of the funding for the preparation of this series of guides was provided by the Fisheries Research and Development Corporation. The series of guides has been jointly sponsored by Sydney Fish Market Pty Ltd (SFM), which is Australia's largest and best known market for seafood, so individual guides are focused on the sustainability of seafood sold through SFM.

Biology

Yellowfin tuna are found worldwide in tropical and subtropical open seas (except the Mediterranean Sea) at surface and mid-water levels[3]. Their distribution is limited by water temperatures, oxygen and salinity concentrations such that they are rarely found deeper than 250 m[4]. Individuals school with fish of similar size, other species of tuna and in the Eastern Pacific Ocean are often associated with dolphins, a practice not common in the western Pacific Ocean[4]. Yellowfin tuna are fast swimming and travel vast distances migrating through the fishing zones of many different countries and also into the high seas beyond jurisdiction of any country. They prey in surface waters feeding on whatever is available including other fish (e.g. pilchard, anchovy, mackerel and other tunas including yellowfin tuna), cephalopods and crustaceans[4]. Yellowfin tuna grow rapidly, for example, females average 55 cm (5 kg) at age 1 and 155 cm (55 kg) at age 5[4]. The average size of yellowfin tuna caught varies according to the type of fishing and the area fished but average about 30 kg in the current Australian fishery (by longline)[1]. The species can reach over 2 m and weigh up to 176 kg[3]. Estimates of age and length at maturity vary from 1.5 to 3 years (40 - 120 cm)[1,5] probably depending on the availability of food and variations in water temperatures. Estimates of the average life-span of yellowfin tuna range from 4 to 9 years[1,2,5].

Generally yellowfin tuna spawn throughout the year, although spawning may peak at certain times of the year[6] or be restricted to certain times[7] in different locations. In the equatorial region of the Pacific Ocean (where temperatures remain at around 26°C), they spawn every few days during the spawning period[7]. Yellowfin tuna have a large reproductive capacity; females can release from 200 000 to over 1 million eggs in a spawning period[4]. Larvae float in the surface waters drifting in the currents[4] and occur continuously across the open waters of the equatorial Pacific with hotspots of greater density[6].

Recruitment occurs when age class 1 fish appear in the catch which is almost continuously[2]. Estimates of recruitment were high in the early years of the fishery (1950 - 1960), remaining stable throughout the 1970s and 1980s[8], then slightly increasing until the 1990s after which it has been declining[2]. Like most fish, estimates of natural mortality vary with size but commonly used minimum composite rates for yellowfin tuna range between 60 to 80 % per annum[2].

Fishery & management

Australia

Yellowfin tuna are targeted in waters off eastern Australia year-round in the Eastern Tuna & Billfish Fishery (ETBF) managed by the Commonwealth, with smaller quantities landed in the Western Tuna & Billfish Fishery (WTBF). The ETBF extends to the limit of the Australian Fishing Zone (AFZ) from Cape York, Queensland to the Victorian/South Australian border including waters around Tasmania. The fish are caught mainly by pelagic longline (baited hooks suspended from multiple branch lines attached to a longline deployed behind the boat) with less than 5 % of the annual catch from minor line methods (handline, troll, rod and reel)[9]. The fishery expanded rapidly in the 1950s and catches in the ETBF have been well over 1 000 tonnes since 1987 and peaked at 3 148 tonnes in 2003[1]. In addition, Japanese fleets fished for tuna in the Australian Fishing zone from the 1950s to the late 1990s with annual catches from 1 000 to over 3 000 tonnes[1,9]. Total catches of yellowfin tuna in the ETBF over the last three years have ranged between 1 390 tonnes and 1 650 tonnes[pers. comm. J. Fielding, AFMA]. Recreational fishing for tuna may be substantial but data are extremely limited[9].

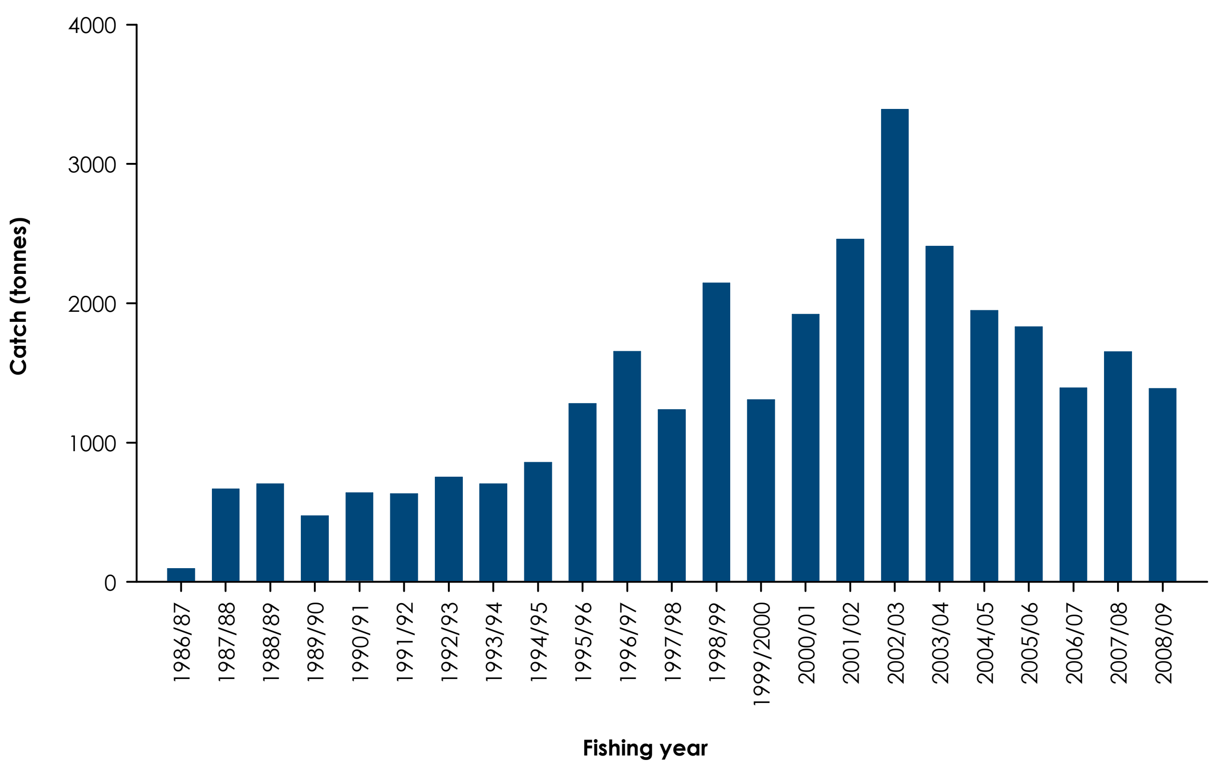

Figure 1. Reported commercial catch of yellowfin tuna in the Eastern Tuna and Billfish Fishery managed by the commonwealth of Australia[10,pers. comm. J. Fielding, AFMA].

Management strategies for the ETBF are determined in consultation with the Eastern Tuna Management Advisory Committee (ETMAC), the Eastern Tuna Resource Assessment Group (ETRAG) and must be consistent with strategies implemented by the Western and Central Pacific Fisheries Commission (WCPFC), the body responsible for assessing tuna in this region. Fishing effort was historically controlled by restricting entry (i.e. limits on the number of fishing permits, vessels and trip times[9]) but concerns were raised that localised depletion was occurring. Subsequently, fishing effort was restricted via input controls (i.e. Total Allowable Effort; TAE) set at 12 million hooks[11]. This level remains above the recommendation of the Management Advisory Committee that the TAE be set to about 8 million longline hooks[12]. Careful monitoring of the fishery in the next few years should provide better information to set a sustainable level. A minor-line TAE has been set at the recommended 16 lines[11,12].

The current total biomass of yellowfin tuna for the region of the western and central Pacific Ocean in which the ETBF operates was estimated to be between 75 and 80 % of the pre-fishery biomass[2]. This is higher than the averaged figure for the whole of the western Pacific Ocean of a little more than 60 %[2]. Considering target levels for sustainability are generally around 20 to 40 % of the pre-fishery biomass and recruitment of yellowfin tuna is likely to be locally sourced within the Australian region[2], the current estimate in the region where Australia fishes for yellowfin tuna is well above the target level for maximum sustainable yield.

Western and central Pacific Ocean

Because yellowfin travel large distances and fishing effort in one area can affect abundance in another, a great deal of international cooperation will be required if populations are to be optimally managed. Different stocks are thought to exist around the world and these are separately managed by Regional Management Fisheries Organisations (RFMOs) responsible for the research, assessment and implementation of conservation strategies. Yellowfin tuna in the Indian and Atlantic Oceans are monitored by the International Commission for the Conservation of Atlantic Tuna (ICCAT) and the Indian Ocean Tuna Commission (IOTC) respectively. The Inter-American Tropical Tuna Commission (IATTC) manages the stock of yellowfin tuna in the eastern region of the Pacific Ocean and the Western and Central Pacific Fisheries Commission (WCPFC) manages the western stock (limited mixing may occur between the two Pacific regions)[2].

The yellowfin tuna caught in the Australian fishery forms part of the huge stocks in the western and central Pacific Ocean (WCPO); the area bounded to the east by 150°W and to the west by the continent of Asia, the eastern shore of Indonesia, the Malaysian Peninsula and the eastern shore of Australia (Figure 1). This is presumed the largest stock of yellowfin tuna in the world[6] and supports the largest yellowfin tuna fishery landing almost 55 % of the world catch[8] (the Eastern Tuna & Billfish Fishery operates off the east coast of Australia and is contained within the Western and Central Pacific Ocean; figure 2). The total catch of yellowfin tuna in the WCPFC has remained fairly stable since 2000 between 370 000 and just over 500 000[2,8] with the record catch (539 000) in 2008[15]. The majority of the catch in the WCPO is taken by purse-seine and the multi-gear domestic fisheries of Indonesia and the Philippines[5].

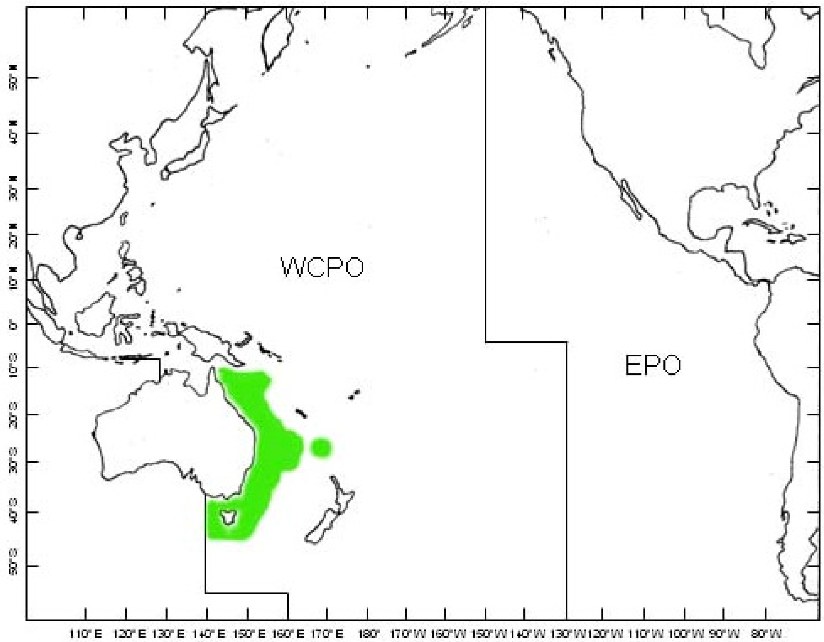

Figure 2. Area of the Eastern Tuna and Billfish Fishery (ETBF) in which Australia fishes for yellowfin tuna within the Western and Central Pacific Ocean (WCPO).

Because of the highly migratory nature of the species the sustainability status of yellowfin tuna in Australia is based on assessments for the whole stock of the WCPO(16) by The Secretariat of the Pacific Community (SPC), which is the scientific body responsible for assessing the stock of yellowfin tuna in the WCPO. The SPC assessments inform the management decisions by the WCPFC. The objective of the WCPFC is to maintain stocks of yellowfin tuna at levels capable of producing the maximum sustainable yield (MSY)(17). Assessments of the stock have been done annually since 1999 to estimate recruitment, biomass and fishing mortality. These estimates are done for separate regions within the WCPO as well as for the whole area. Estimates of biomass in the whole of the WCPO from the 2007 assessment show declines in the 1970s, stability through the 80s, then declining again until about 2005 when biomass began to increase(8). The biomass of yellowfin tuna in the entire WCPO was estimated in 2007 to be approximately 50 % of the pre-fishery biomass(5,8) and hence classified as 'not overfished'. The biomass was estimated to be 17 % greater than would support the MSY (consistent with the previous assessments of 2005 and 2006). The assessment indicated that catches at the time were 5 % below the MSY and the stock is classified as not 'subject to overfishing'(1,8).

The more recent assessment in 2009 was somewhat more positive using more accurate and up to date estimates of population dynamics and catch levels(2). The total biomass of yellowfin tuna for the total WCPO was estimated to be about 60 % of the pre-fishery biomass(2). The total sustainable yield was estimated to be between 550 000 and 630 000 tonnes which is substantially higher than the average total catch that has been over the last few years(2). Subsequently the stock of yellowfin tuna as a whole was not considered to be in an overfished state, not subject to over fishing and capable of supporting sustainable yields at greater than current levels of catch. It was noted, however, that the sustainable yield estimate may be optimistic as recruitment in recent years has been substantially lower (about 80 % of previous estimates between 2000 to 2005) than that used to calculate the MSY(2).

Conservation

Bycatch

The main impact on the environment of the ETBF was assessed to be the take of bycatch as minimal disturbance of habitat occurs[16]. Fish, sharks, seabirds, turtles and marine mammals have been recorded as bycatch in the ETBF[16]. A number of strategies are mandated in the fishery to limit the impact of bycatch in the ETBF, including restricted access zones during certain times of the year to limit bycatch of southern bluefin tuna, the banning of finning of sharks at sea[12] and the use of synthetic leaders on longlines instead of wire to reduce shark mortality[1]. The incidental catch of seabirds (albatross, shearwaters, petrels) by longline fishing was listed as a key threatening process in 1995[18]. A threat abatement plan and a bycatch reduction plan for the ETBF were developed to limit the bycatch of marine birds[19,20]. Under these plans, operators are required to deploy bird-scaring 'tori' lines, weigh the line so it sinks quickly, use thawed baits and retain offal during the setting and hauling of the line[1]. As at 2008, the fishery had not exceeded the agreed seabird bycatch of 0.05 birds per 1 000 hooks[12] set under the threat abatement plan[20]. The EBTF also interacts with a small number of 'Protected Species' as listed under the EPBC Act[21] such as certain species of turtles, sharks, whales and albatross. Risks to these species need greater assessment, but line cutters and de-hookers have been issued to all operators as a preliminary measure to reduce fatal bycatch of turtles and sharks[16]. The number of recorded 'interactions' with protected species was 33 in 2007, 8 were fatalities. Following an assessment of the risk from fishing of the sustainability of bycatch species by CSIRO, 5 species were classified as high risk of potential overfishing as bycatch: longfin mako, crocodile shark, pelagic thresher, ocean sunfish and southern ocean sunfish.

The limited data available from on-board observers in the WCPO, shows that over 100 000 tonnes of finfish and shark, 90 seabirds, 313 mammals and 1834 turtles were caught as bycatch in the yellowfin tuna fishery of the WCPO in 2004[8]. Mortality of finfish is unknown but mortality of birds was estimated to be 100 %, of sharks 28 %, of mammals close to 0 % and of turtles 54 %[8]. Considering that all turtles incidentally caught in the WCPO are threatened or endangered and many seabirds are also listed as threatened or endangered, mitigation measures are a priority of the WCPFC. As is the case for Australian tuna fisheries, fishers in the WCPO are required to use bird-scaring devices, weighted lines, manage offal discharge and carry line-cutters and de-hookers for safely releasing turtles[8]. More and better data are needed to assess whether bycatch levels are having a significant adverse impact on populations of non-target species in the WCPO. The latest management plan of the WCPFC was to increase coverage of the observer program to 20 % in 2009 and 100 % in 2010[8].

The sustainability of yellowfin tuna in the western and central Pacific Ocean

Whilst the overall management arrangements of the ETBF met of the requirements of the Australian government for sustainable fisheries[16], unjustified concern were still expressed about the status of yellowfin tuna. The most recent assessment of yellowfin tuna in the whole of the WCPO was estimated to be about 60 % of the pre-fishery biomass and specifically 75 to 80 % in the region from which Australia fishes for tuna in the ETBF[2]. At these biomass levels the species is clearly under-fished in the total western Pacific and particularly off eastern Australia.

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Blue swimmer crab

Portunas pelagicus

Blue swimmer crab, distinguished by their colourful bodies and long, meaty pincers, are highly regarded by seafood consumers for their sweet taste. Current catches in the fisheries which supply the majority of crab to Sydney Fish Market Pty Ltd (i.e. the Blue Crab Fishery of South Australia) are relatively stable and considered to be sustainable(1). Moreover, increased research and better assessments of the stocks of blue swimmer crab are planned to underpin the future management of the species. This guide to the sustainability of blue swimmer crab and the management of the fisheries in which they are targeted is based on the scientific and fishery-related data available at the time of publication. The bulk of the funding for the preparation of this series of guides was provided by the Fisheries Research and Development Corporation. The series of guides has been jointly sponsored by Sydney Fish Market Pty Ltd (SFM), which is Australia's largest and best known market for seafood, so individual guides are focused on the sustainability of seafood sold through SFM.

Biology

Blue swimmer crab are found throughout the Indo-Pacific region off the coasts of Japan, the Philippines and throughout southeast Asia to Indonesia, Australia and east to the Fiji Islands(2). In Australia, the species is widely distributed from Cape Naturaliste, Western Australia around the north of the country to Eden, New South Wales(3). Although primarily a tropical species, they are also relatively abundant at the limit of their temperature range in South Australia where they have adapted to grow and reproduce in the warmer months and remain relatively inactive in the cooler seasons(4). Adult crab are predominantly found in coastal waters, bays and estuaries(5) in sandy or muddy habitats often near reefs, mangroves, seagrass and algal beds to depths of 60 m(2,6). As the name suggests, they are active swimmers but when inactive they bury in the sediment exposing only their antennae, eyes and access to their gills(3). Juveniles are most common in intertidal, shallower areas(2). Blue swimmer crab feed on a variety of sessile and slow moving animals such as molluscs, crustaceans and worms but also scavenge dead fish and invertebrates(2,5).

Maturity is reached at about one year but the size at which blue swimmer crab mature varies around Australia; in New South Wales maturity occurs between 4 and 6 cm carapace length (CL)(3,5), in South Australia individuals reach maturity at between 7 and 9 cm CL(1) and in Western Australia it occurs mostly below 10 cm CL(7). Spawning can occur all year round in tropical waters but in South Australia, blue swimmer crab spawn mainly in late spring to late summer(8). Female blue swimmer crab can produce up to two million eggs per spawn and they can, but don't always, spawn a few times during a season which lasts for a few months(4,6). The eggs develop internally, are fertilised and extruded from the abdominal flap(4) where they are attached to hatch a couple of weeks later. The planktonic larvae can drift far out to sea before settling back to shallow coastal waters(3,5). Juveniles actively settle to intertidal seagrass beds but in the absence of such habitat settle to shallow rocky areas or unvegetated soft substrata rather than to deeper, subtidal seagrass beds(8). Blue swimmer crab grow to a maximum of about 22 cm across the shell (> 1 kg)(3,6) but the maximum size does vary throughout their distribution. Individuals moult several times in their lifetime and can live for up to 3 years(5).

Fishery & management

Blue swimmer crab sold at Sydney Fish Market Pty Ltd come primarily from South Australia with secondary supply from Western Australia and a small amount from New South Wales(pers. comm. G. Dannoun, SFM). Consequently, the sustainability of the blue swimmer crab fishery of South Australia is important to seafood consumers across southern Australia.

New South Wales

Blue swimmer crab are targeted in the Estuary General Fishery (EGF) in New South Wales using pots and hoop nets and are taken in mesh nets as a secondary species(9). They are also taken as bycatch in prawn trawl fisheries. Catches of blue swimmer crab increased substantially from < 50 to > 200 tonnes per year between 1990 and 1992, largely due to increased fishing effort arising from expansion in the market for the species and associated increases in its value. The commercial catch has remained fairly stable since 1992(9) and has been about 150 tonnes per year in the last few years(5). The status of the species is assessed using commercial catch data, which is recognised as less than ideal. Blue swimmer crab are currently classified as 'fully fished' indicating stable catch rates and size distributions(5). In NSW, blue swimmer crab mature at approximately 4 cm (carapace width), hence the minimum legal width is set at a larger size, in this case 6 cm, to provide most individuals with the opportunity to spawn at least once before being targeted by the fishery. Blue swimmer crab are also an important species for the recreational sector, with an estimated annual harvest of between 150 and 310 tonnes(10); between one and two times the current commercial catch. The same size limits apply to the recreational sector as well as a bag limit of 20(5).

Western Australia

Blue swimmer crab are targeted in a number of commercial fisheries of WA operating in estuaries and coastal embayments; chiefly Shark Bay, Cockburn Sound and the Peel-Harvey estuary. The majority of the current commercial catch comes from Shark Bay following the ban on commercial fishing for blue swimmer crab in Cockburn Sound at the end of 2006(7). The total catch of blue swimmer crab in 2007/08 in WA was > 800 tonnes, more than 500 tonnes of which came from Shark Bay(7). Recreational fishing for blue swimmer crab is popular and estimated to be over 70 % of the total catch(7). The minimum size limits (for the commercial and recreational sectors) are set to be well above the size at which blue swimmer crab mature in WA; currently varying between 127 and 130 mm CL for different regions of the state(7). Spatial closures and gear restrictions, including limits on the number of traps that can be used in the fishery and a total ban on taking females with eggs are also used to help keep the fisheries for blue swimmer crab in WA sustainable(7,11).

Commercial catches of blue swimmer crab in Cockburn Sound have historically fluctuated but from 2003/04, commercial catches started to decline rapidly. The catch of 159 tonnes in 2003/04 dropped to 84 tonnes the following year and only about 40 tonnes were landed in 2005/06(12). Coupled with scientific evidence of low recruitment, thought to be the result of a combination of environmental variation, especially in temperature (chief among other factors) and possible overfishing, the inlet was closed to commercial and recreational (in some areas) fishing for blue swimmer crab as a precautionary measure(7). The recovery of the stock in this area has been slow despite the cessation of fishing and the potential resilience of the species considering its capacity for reproduction, fast growth and early maturity(13). This slow recovery suggests that environmental variation, rather than fishing, was the primary driver of the original population decline. The stock has however, increased and the inlet was re-opened to fishing in late 2009 with an increase in the minimum size limit (from 130 - 140 mm) and a 20 % reduction in the number of pots allowed in the commercial sector(14). The closure of this fishery, the subsequent recovery of the stock and continued control of fishing effort is a good example of precautionary (the cause of the decline remains uncertain) and successful fishery management in Western Australia.

Targeted, commercial fishing for blue swimmer crab in Shark Bay began in 1998 and catches increased rapidly from 132 tonnes in 1998/99 to 478 tonnes in 2001/02 in line with increased effort[15]. Catches in more recent years have stabilised at about 500 tonnes[7]. The efficacy of the management strategy for this fishery is measured against several performance indicators and objectives. Current estimates of the adult biomass of crab in Shark Bay are derived from catch per unit effort data (CPUE), again recognised to be less than ideal. Nonetheless, CPUE is above the minimum estimated to be consistent with adequate recruitment[11]. As such the Shark Bay fishery for blue swimmer crab is considered to be suitably precautionary to maintain the sustainability of the fishery and the species and to have negligible impact on the environment[11].

South Australia

The Blue Crab Fishery (BCF) has been managed by the South Australian Government since 1996. There are two main fishing zones based on the assumption of separate stocks of crab; the Spencer Gulf and Gulf St. Vincent[16]. As discussed above, growth and recruitment of blue swimmer crab are greatly influenced by temperature and as such, the ecology of the species varies not only between gulfs in South Australia but also from other regions in Australia[8]. Two types of commercial operators participate in the fishery: pot fishers, who fish exclusively for crab using pots, and scale-fish fishers who use hoop or drop nets to catch crab but also target several fish species[1].

Blue swimmer crab were initially caught as bycatch in other fisheries of South Australia until the sale of crab taken in these fisheries was prohibited in 1986[1]. Trial fisheries specifically targeting blue swimmer crab were started in the early 1980s in Eyre Peninsula (West Coast), Spencer Gulf and Gulf St. Vincent. The West Coast region had only four license holders but collapsed in 1986, probably due to environmental variability rather than overfishing of the species[4]. Small commercial landings of blue swimmer crab (recent catches average only < 50 tonnes)[8] are currently taken from this area but are included as the harvest of the Marine and Scalefish Fishery of South Australia rather than as part of the BCF[1].

Since the first recorded, targeted catch in 1983/84, the harvest of blue swimmer crab in the BCF increased dramatically until concerns over the sustainability of the species were raised. Catch peaked at 650 tonnes in 1995/96, when Total Allowable Catches (TACs) were introduced for the commercial catch and set at 520 tonnes for 1996/97[1]. The catch was subsequently reduced to fluctuate around 400 tonnes between 1996/97 and 1998/99 with a transfer of effort from the scale-fish sector to the pot sector[17]. Levels of harvest have been steadily increasing above 600 tonnes since 2003/04; the commercial catch in 2007/08, the most recent for which data are available, was 618 tonnes[17].

The management of the blue swimmer crab fishery in SA is advised by the Blue Crab Fisheries Management Committee (BCFMC). The TAC is based on estimates of fishing mortality, exploitation rates, recruitment, sex ratio and the stock biomass and has been set at about 630 tonnes since 2000/01[1]. Various input controls are also in place including spatial closures (5 marine reserves within or near the fishery zones)[4] and temporal closures (between November and January during the peak spawning period)[8] and output controls including minimum legal width (11 cm CL)[4] and total ban on harvesting females with external eggs[18]. The TAC has never been taken in any year but recent catches have come close[1]. As a result the limit reference point of the TAC (no more than 80 % of the TAC be caught in any year)[4] has been exceeded since 2005/06 with over 90 % of the TAC landed[1,4]. In the latest assessment, the proportion of undersize and female individuals in the catch in Spencer Gulf also exceeded target reference points. Performance indicators were all below target reference points in Gulf St Vincent[1], but catches and catch rates have remained high. Appreciating the pressing need to revise the status of the fishery, or at least several of the performance indicators for the fishery (presumably because some have been met or exceeded), a new management plan is currently being developed for the commercial fishery[17].

There seems sufficient biological data to effectively manage the fishery but the impact of the development of the fishery on the status of the stock is poorly described[8,19]. Fishery independent surveys have been done annually since 2002 to estimate the biomass of blue swimmer crab and to collect other biological information used to assess the stocks. The most recent survey showed an increase in the abundance of crab in Spencer Gulf since 2002 and in Gulf St Vincent in 2005/06 after 3 previous years of decline[1]. There is no detailed environmental assessment of the Blue Crab Fishery to date[20]. The most recent stock assessment (done in 2005/06) did, however, consider blue swimmer crab to be being harvested sustainably in South Australia[1].

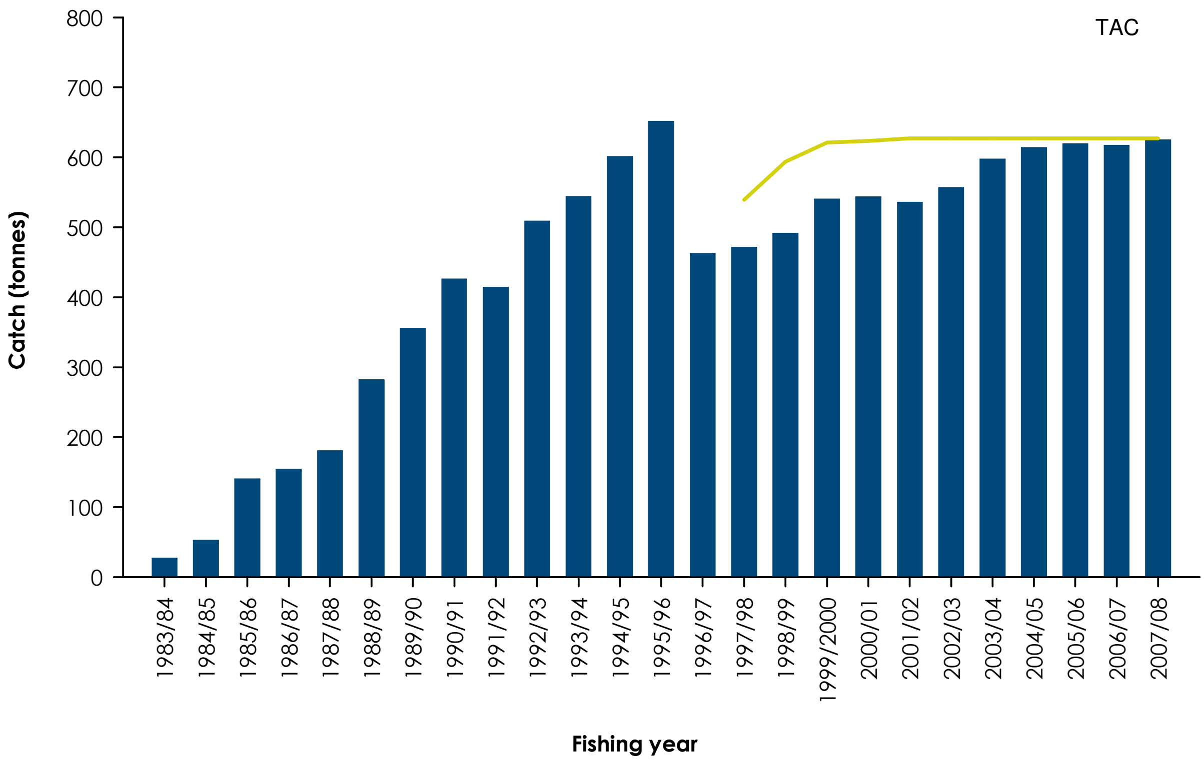

Figure. Commercial catch and Total Allowable Catch (TAC) of blue swimmer crab in the Blue Crab Fishery of South Australia[4,17].

The species is also an important part of the recreational fishing sector which uses drop or hoop nets and raking and dabbing in near-shore shallows to harvest crab. Although detailed assessment of this sector has not been done the recreational catch was estimated to be over 380 tonnes[10] which is more than half of the commercial catch. A proportion of this estimate is probably discarded because the cab were undersize or the bag limit exceeded, so the recreational harvest was estimated to be about 30 % of the total catch[1]. Recreational fishers are limited to 40 crab per day per person with a boat limit of

120; a maximum of 3 drop nets and 10 hoop nets is applied[4]. Recreational fishing methods at current levels of effort are not considered a threat to the species or the environment[4].

Conservation

Bycatch

The main species caught incidentally in the pot fishery component of the Blue Crab Fishery of South Australia are rock crab, spider crab and leatherjacket and most are returned alive (although data on the subsequent survival of discarded bycatch are limited)[1]. A substantial number of juvenile blue swimmer crab are also caught as bycatch in the prawn trawl fisheries and net fisheries but again most are returned alive[4,21] especially if individuals can be removed from nets with minimal force[22]. Landing of bycatch is currently prohibited in the pot fishery and in addition, pots have been modified to exclude finfish and current mesh size restrictions (75 mm) reduce the incidental catch of undersize crab[4].

Environment

Pot and net fishing for blue swimmer crab in the BCF is considered to be of minimal risk to the benthic environment. The technique itself causes little damage to the surrounding habitat and the fishery is focused in a relatively small area in each of the gulfs of South Australia[4].

External threats

Contamination and degradation of water quality and habitat from anthropogenic activities may be a threat to populations of blue swimmer crab. Seagrass meadows are an important nursery ground and habitat for blue swimmer crab and impacts upon these habitats from land-based activities may be a substantial risk, at least for local stocks. Substantial loss of seagrass has occurred in the gulfs of South Australia, for example over 4000 ha was lost from the Adelaide metropolitan coastline (Gulf St Vincent) between 1949 and 1996[23]. Although natural causes for this cannot be ruled out (e.g. high temperatures during unusually low tides may have caused dramatic and rapid dieback of seagrass in Spencer Gulf[24]), the slow decline of seagrass beds is primarily attributed to reduced water quality from industrial, agricultural and urban outfalls and coastal development[25,26]. Direct causes of loss of seagrass beds are hard to establish, particularly because studies are usually limited to after losses have occurred. Some recovery of seagrass meadows after either natural or anthropogenic disturbance has been recorded but changes in composition may occur[24] and recovery is generally slow[27]. Blue swimmer crab may also be directly affected by contaminant loads from agricultural and industrial runoff[e.g. 28]. Considering the number and size of industrial activities on the coastline of each gulf in South Australia and the semi-enclosed nature of the gulfs, the potential for large concentrations of contaminants is high[29].

The sustainability of blue swimmer crab in Australia

Blue swimmer crab are harvested in many states of Australia and although the status of stocks is mainly assessed using commercial catch data (which is not ideal), catches in recent years in most states have been controlled and are stable and considered sustainable[5,11]. Most of the blue swimmer crab sold through Sydney Fish Market Pty Ltd come from South Australian waters. Concerns over the sustainability of the fishery there had been raised, but TACs were subsequently set to reduce the catch and current levels of harvest are considered sustainable[1]. Furthermore, the biomass of blue swimmer crab in South Australian waters seems to be on the increase in the last few years[1]. More detailed assessments of the stocks are required but at current levels of catch, the commercial fisheries of blue swimmer crab pose no known threat to populations in Australian waters. Furthermore, recent responsible management has demonstrated that the species can recover from population declines. Recoveries have occurred even in cases where the cause of the decline was uncertain.

There have been few if any detailed assessments of the full environmental impacts of the commercial fisheries for blue swimmer crab, but considering the mode and level of fishing, significant negative impacts are unlikely. Unfortunately, degradation of water quality and seagrass habitats appears to be a serious threat, at least for local stocks of blue swimmer crab, and abatement measures have proven elusive.

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Eastern sea garfish

Hyporhamphus australis

Eastern sea garfish are pale greenish blue, slender bodied fish with the lower jaw much longer than the upper[(1)], producing a prominent bill or beak. Although garfish fillets are slender they are sweet and flavoursome. Commercial catches of eastern sea garfish declined substantially over the years leading to the species being classified as overfished in 2002. Although fishing may not be the sole, or even the primary, cause of the decline in estimated abundance, the precautionary approach to greatly reduce fishing effort and catches by a variety of input controls has coincided with a halt in the apparent decline in catches. The substantially reduced current catch level appears to be sustainable and the status of the stock is improving. This guide to the sustainability of eastern sea garfish and the management of the fisheries in which they are targeted is based on the scientific and fishery-related data available at the time of publication. The bulk of the funding for the preparation of this series of guides was provided by the Fisheries Research and Development Corporation. The series of guides has been jointly sponsored by Sydney Fish Market Pty Ltd (SFM), which is Australia's largest and best known market for seafood, so individual guides are focused on the sustainability of seafood sold through SFM. Support from OceanWatch Australia Ltd for parts of the research done in this factsheet is acknowledged.

Biology

Eastern sea garfish are surface dwelling fish endemic to eastern Australia[(2)]. They occur in the surface few metres (< 20 m) of inshore coastal waters, embayments and sometimes in estuaries from Moreton Bay, QLD through to Eden, NSW and in near-shore waters of Lord Howe and Norfolk Islands[(3)]. Large aggregations have also been observed in offshore waters[(pers. comm. D. Brown, fisherman, NSW)].The distribution of the closely related southern sea garfish (found in coastal embayments, gulfs and estuaries in Victoria, eastern Tasmania, South Australia and southern Western Australia) overlaps with that of eastern sea garfish and hybrids of the two species have been reported[(4)]. Eastern sea garfish are omnivorous, consuming aquatic plants, algae and crustaceans[(2,5)] supplemented by diatoms, insect larvae, and worms[(3)]. Individuals grow to 45 cm (0.4 kg) but are commonly caught around 30 cm (0.1 kg) or less[(4)].

The species spawns many times throughout the spawning season which varies throughout its distribution; from late November to December on the south coast of NSW and from June to September in the northern part of their distribution[(6)]. Generally females have relatively small batches of between 100 to 3500 eggs[(6)]. The eggs are large (2.5 mm diameter) and covered with long, adhesive filaments which attach to seagrasses and macroalgae[(1)]. A relationship between the number of eggs produced and the size of females is to be expected and has been suggested but the strength of the relationship could be also influenced by a number of factors including environmental conditions[(6)]. Eastern sea garfish grow quickly with a maximum age of four years or slightly more[(7)]. Females grow faster and reach bigger sizes than males[(1)] and although males may reach sexual maturity at much smaller sizes than females, 100 % of the population is estimated to reach maturity at about one year[(6)]. The American Fisheries Society (AFS) has, based on growth rate and fecundity[(2)], classified eastern sea garfish as 'highly resilient' with a minimum population doubling time of less than 15 months.

The eastern sea garfish population is likely to be one stock that probably migrates with the seasonal distribution of warmer water from the Eastern Australian Current (EAC), i.e. moving northwards in Austral autumn to winter[(6)]. This may also mean that individuals within the population spawn in numerous locations over the seven month total spawning period.

Fishery & management

Eastern sea garfish are most commonly targeted in the Ocean Haul Fishery (OHF) which is managed by the NSW Government[1,4]. The fishery largely follows the spawning aggregations and is therefore locally seasonal with a greater commercial catch landed in summer on the south coast and in autumn and winter on the north coast of NSW[6]. Smaller catches are also taken from the NSW Estuary General Fishery (EGF) and in Queensland waters (mainly in Moreton Bay)[3]. They are caught using nets which are buoyant and designed to fish the surface waters to selectively catch garfish (different types of nets are used in different fisheries). From the beginning of the fishery, in the 1950s to the late 1970s, catches of eastern sea garfish were stable averaging about 40 tonnes. Development of the export market for garfish and changes in fishing practices contributed to a steady increase in catch to peak at 280 tonnes in 1992/93. Since then commercial catches have declined rather dramatically to levels more in keeping with those up to about 1980[1]. The smallest annual catch, 21 tonnes, was recorded in 2002/03[1]. Catches have been relatively constant at about 50 tonnes for the last 5 or so years[1]. The estimated recreational catch in NSW is not substantial (less than 10 tonnes annually)[1] and a bag limit of 20 individuals currently exists[1].

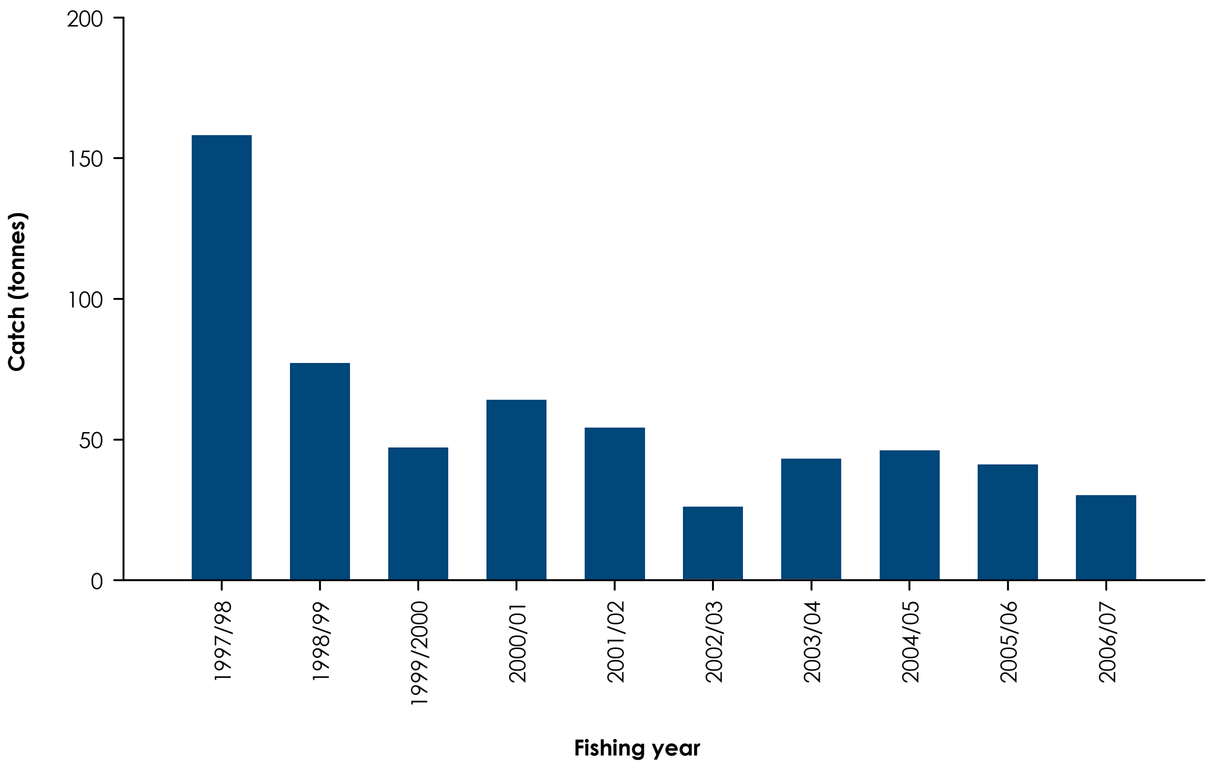

Figure. Annual commercial catch (tonnes) of eastern sea garfish in the Ocean Haul Fishery of NSW[8].

The fishery has been managed through a mixture of predominantly input controls which have been modified through the history of the fishery. For example, in response to suggestions that spawning may not be effectively protected by the December-only closure[6], seasonal closures have been progressively extended and expanded. Currently, commercial fishing for eastern sea garfish is restricted on all weekends throughout the year[9]. Fishing effort is also constrained by zoning rules which prevent fishers from operating in multiple zones[10]. The protection of selected spawning sites from all human activity, including but not restricted to fishing, is not currently part of the management strategy but may need to be considered in the future. Other input controls include gear restrictions; the permissible minimum mesh size of a garfish haul net is 28 mm and the total net length is set at 300 m[9]. Whilst there is no minimum legal length for eastern sea garfish in NSW waters, the length distribution of commercial catches indicates that the current techniques already target fish bigger than the size at first maturity[11]. It is unlikely that size limits for this species would be a better management strategy than gear restrictions because garfish are extremely flighty, fragile fish that do not often survive capture and release[11].

Although catch data have indicated good recruitment of eastern sea garfish to the fishery in the last few years, the majority of fish have not persisted beyond the first year. Such a selective diminution of older fish is often associated with excessive fishing pressure very soon after recruitment to the fishery. The fact that more large fish are not making their way through the fishery is not consistent with the dramatic reduction in fishing effort and continued improved recruitment in recent years. This suggests that the decline in eastern sea garfish stock is not directly related to fishing, but more likely to a non-fishery factor, such as habitat loss or a new pathogen. No matter what the cause, the failure of larger fish to properly recover would be even more worrying if recruitment had not been continuing to improve.

The recent increase in the allowable mesh-size of nets used in this fishery (from 25 mm to 28 mm) may prove beneficial to the size, and presumably age, composition of the stock[1]. Further investigation of the impact of individual management actions in the commercial fishery on the observed changes in apparent abundance and size composition of the stocks would be beneficial for future management.

As at 2002, eastern sea garfish were classified as 'overfished' based on indications that "current fishing levels may not be sustainable, an/or yields may be higher in the long-term if the fishing level is reduced in the short-term"[9]. This assessment is a precautionary measure based on commercial catch data alone (which is recognised as less than ideal). More recent stock assessments using detailed information on the biology of the species, estimated the biomass to be between 10 and 25 % of the pre-fishery biomass and the fishing mortality to be over 3 times that of natural mortality[5]. The stock was again classified as 'overfished' in 2008[1].

Conservation

Species Recovery Program for eastern sea garfish

Regardless of the reason for the decline in commercial catch, a precautionary approach was adopted to reduce fishing pressure under the Eastern Sea Garfish Species Recovery Program[10]. The management controls covered in the Fisheries Management Strategy for the OHF are continued in the recovery program but there are extra management responses designed to affect the recovery of the species. These are primarily concerned with better understanding of the impact of the effort that is currently permitted (including by monitoring age/size composition of the commercial catch) and constraining the fishing effort that will be allowed after the stock recovers[10]. Several areas are closed to commercial garfish fishing under fisheries legislation (see www.dpi.nsw.gov.au/fisheries/closures). Recently two more marine parks that further restrict garfish fishing have been declared; the Ports-Stephens-Great Lakes Marine Park and the Batemans Marine Park[12]. Given the apparent resilience of eastern sea garfish, the stock should recover further under the current fishing regulations if favourable environmental conditions for recruitment continue[5].

The recovery program is currently under review, but it already appears that the species is recovering, albeit only slowly, under the current management arrangements[1]. The species does not appear to be in immediate danger of further declines. In fact, verbal reports(pers. comm. J. Stewart, I&I NSW; Vince Jordan, fisherman, NSW) of the catch rates in 2010, particularly in the northern part of the State, suggest that the status of the stocks is improving.

In 2008, the management strategy for the OHF was externally assessed to be performing satisfactorily against the international standards for ecologically sustainable management of fisheries, including maintaining small levels of bycatch and minimising risk to the survival and conservation status of the targeted species, other species and the relevant ecosystem[13,14].

Bycatch

The OHF generally targets mono-specific aggregations of adult fish including eastern sea garfish and the nets used selectively target only surface species, hence levels of bycatch are usually minimal[15]. At the latest performance report for the fishery in 2004, substantial amounts of pilchard, bonito and leadenall were reported, representing 11 % of the catch from garfish hauling nets. This total was over the set limit of 5 % of the catch being non-target species[16], however opinions vary within the industry about the actual vs. recorded level of bycatch in garfish nets and whether this is a cause for concern.

Environment

Any impacts from the physical effects of hauling are not likely to be dramatic because the gear specifically targets the surface waters over the relatively bare sandy bottoms that exist off coastal beaches[15]. Nonetheless, the use of haul nets has been prohibited over seagrass beds to minimise any physical impact of fishing on these habitats[9]. The environmental impact statement of the OHF reported little risk to coastal habitats and non-target species from the fishery[15] and a formal assessment of any interactions between the fishery and the environment is part of the management strategy[9]. Similarly, the risk of pollution generated by the fishery was likely to be minimal considering the small number of vessels and the open, high energy nature of coastal beaches where fishing occurs[15].

External threats

The available catch data certainly indicate that a decline did occur in relative abundance of eastern sea garfish in NSW but are, however, insufficient to attribute this solely to overfishing. For example, cyclic peaks in the catch of eastern sea garfish have coincided with cycles related to water temperature and air pressure from El Niño events[17]. The possibility that the observed decline in apparent abundance (as estimated by drops in catch data) has been impacted by disease, either directly or indirectly, can also not be ruled out. For example, the Californian herpes virus reduced pilchard populations in the whole of southern Australia's coastal waters by approximately 70 % at about the same time as declines in eastern sea garfish catches in the same general area were observed. This virus, or another pathogen introduced by the same or similar vector could be a cause of the decline in sea garfish populations[18]. It is also possible that eastern sea garfish have become more sought after by predators as a result of the decreased availability of pilchards or that declines in apparent abundance of garfish were, at least in part, associated with the pronounced increases in biomass of Australian salmon (a known predator) over the same time period[17].

There is evidence to suggest that garfish are at least to some extent reliant on seagrasses for food and as nursery habitats[references within 6]. Furthermore, eastern sea garfish spawn in near-shore areas and have eggs that tend to attach to seagrass and macroalgae[3]. These crucial habitat requirements may render garfish particularly vulnerable to anthropogenic reductions of these habitats known to have occurred in many regions throughout NSW(e.g. 19). Garfish are extremely timid and flighty and as they occupy only surface waters they are extremely susceptible to displacement by any watercraft activity, even surf-boards.

The sustainability of eastern sea garfish in NSW

Commercial catch levels of eastern sea garfish declined substantially over the years leading to the species being classified as 'overfished'. Fishing has been assumed to be the cause of the decline, although the destruction of nursery habitat, increased watercraft activity in their primary habitat areas and the possibility that introduced disease(s) have seriously impacted stocks cannot be ruled out. The species recovery program, that has constrained fishing effort and catches by a variety of input controls appears, however to have arrested the decline. The management strategy for the fishery includes research programmes to better estimate actual biomass, investigate potential reasons for declines in catch (including those external to the fishery) and collect biological data to facilitate management and a sustainable future for the species and the fishery. Already the precautionary recovery program for eastern sea garfish appears effective in that the substantially reduced current catch appears to be sustainable and the status of the stock is likely improving.

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Snapper

Pagrus auratus

Snapper have tender flesh with a sweet, mild flavour that is highly regarded by seafood consumers. As a result the species has been subject to heavy fishing pressure by the commercial fishing sector. The recreational sector also targets the species because of its prominence in coastal habitats and its feeding and fighting characteristics. Following concerns that snapper had been overfished in some parts of Australia, more efficient management of most fisheries has seen reduced harvests and recovery or maintenance of stocks at levels considered to yield close to optimum sustainable catches in most areas. Concerns remain over Queensland stocks and to a lesser extent, those in northern New South Wales. Controlled harvests of snapper in New Zealand have resulted in increased stocks and stable catches in recent years. Australian consumers of snapper can be assured the survival of the species is not in danger from fishing and stocks in Australia and New Zealand are closely monitored and progressively managed. Further reductions in catches may, however be necessary to ensure long-term optimum yields. This guide to the sustainability of snapper and the management of the fisheries in which they are targeted is based on the scientific and fishery-related data available at the time of publication. The bulk of the funding for the preparation of this series of guides was provided by the Fisheries Research and Development Corporation. The series of guides has been jointly sponsored by Sydney Fish Market Pty Ltd (SFM), which is Australia's largest and best known market for seafood, so individual guides are focused on the sustainability of seafood sold through SFM.

Biology

This species occurs predominantly in the Indo-Pacific Ocean; off New Zealand, Australia, the Philippines, Indonesia, China, Taiwan and Japan[(1)]. In Australia, the species is distributed south from Townsville, Queensland through Bass Strait to north of Shark Bay, Western Australia[(2)]. Snapper are predominantly found offshore on rocky reefs to depths of up to 200 m but are more commonly caught at about 35 m[(3)]. They also occur in estuaries, bays and inlets associated with muddy, sandy and seagrass habitats, particularly as juveniles and especially in South Australia and Victoria, as large adults. Individuals tend to be relatively sedentary, particularly in preferred locations, but they are capable of substantial migrations[(4)]. Snapper mainly eat crustaceans (crabs, shrimps, etc.) but also include marine worms, starfish, sea urchins, shellfish and other species of fish in their diet[(1)].

Adult snapper aggregate to spawn throughout the Austral spring and summer, generally in waters < 50 m deep[(2)]. Spawning occurs daily during the season with females releasing eggs in numerous batches averaging roughly 100 000 eggs per kg weight of the fish in each batch[(5)]. Once fertilised, the buoyant eggs may drift for a few days before hatching[(2)] and whilst adult stocks on the east coast are somewhat locally resident, drifting of the eggs and larvae in the East Australian Current may facilitate genetic exchange between populations[(6)]. Juveniles develop initially as females and some of the population changes sex before maturity[(7)]. Most juvenile snapper inhabit shallow coastal embayments and sheltered waters often over mud and seagrass. They generally leave these habitats at around 12 months (6 cm in length) to inhabit deeper coastal and offshore waters[(1,2)]. Snapper are generally slow-growing but growth rates can vary, probably dependent on the habitat in which they occur[(2)]. Maturity is reached at about 3 to 4 years of age (20 - 30 cm in length) and this also varies throughout their distribution[(2)]. Individuals have been reported to live for over 40 years in Australia and up to 60 years in New Zealand[(8)]. In NSW, snapper are commonly landed between 30 and 90 cm (0.8 – 8 kg)[(9)] and have been recorded at a maximum length of 130 cm (19 kg). The magnitude of recruitment is variable over time and throughout their distribution and is thought to be influenced, among other factors, by ocean temperature[10,11]. Natural mortality has been estimated to range between 8 and 12 % per year[12].

Fishery & management

Snapper are commercially fished in most states of Australia (Queensland, New South Wales, Victoria, South Australia and Western Australia) using a variety of methods including long-line, hand-line, traps, hauling and mesh net. Separate fisheries are managed by the relevant state government. Tagging and genetic evidence suggests there are several stocks of snapper in Australia[2] but these are not strictly aligned with state management units. The species is caught all year round but peak supply varies across their distribution[2]. Catches in snapper fisheries are influenced by large variation in annual recruitment. Strong recruitment years often support the fishery through numerous years of low recruitment.

Queensland

The commercial catches of snapper in Queensland (Rocky Reef Fin Fishery) fluctuated around the 100 tonne mark from the early years of the fishery (mid 1990s) and increased to between 100 and 200 tonnes in recent years[13,14]. The most recent assessment of the Queensland stock estimated the biomass to be between 15 and 50 % of the pre-fishery stock and current levels of harvest to be at or just over the maximum sustainable (estimated to occur at 35 % of pre-fishery biomass)[13]. The stock is currently considered to be either 'fully-fished' or 'overfished'[14]. An effort to rebuild the stock by reducing the harvest was recommended[13]. Setting a Total Allowable Catch (TAC) of 400 tonnes for the commercial fishery was suggested to be sufficient to rebuild the stock, although uncertainty in the available data to assess the stock was acknowledged[13]. As yet, however, no TAC has been set for snapper in Queensland but new management arrangements based on advice from industry, scientific and conservation groups are currently being considered[14]. Snapper are also a prized recreational fish in Queensland and it is somewhat concerning that whilst an estimated 60 %[13] of the total annual catch of snapper probably comes from the recreational sector, no formal assessments of catch and effort, etc have been done for this sector. Regardless, legal size (min. 38 cm length) and bag limits (5 per person) apply as a precautionary strategy to protect the spawning biomass. The efficacy of these limits is currently being seriously questioned and even the recreational sector itself has suggested more stringent management is urgently needed.

New South Wales

Snapper are commercially targeted in the Ocean Trap and Line Fishery (OTLF) managed by the NSW Government. Landings in 1949/50 of about 300 tonnes increased to fluctuate between 500 and 900 tonnes until 1980 when they began to decline[8]. Catches stabilised at around 300 tonnes in the late 1990s, but decreased again in 2001/02. Since then, catches have been stable at around 200 to 250 tonnes and catch rates appear to be improving[8], most notably on the south coast. The sizes of snapper caught have been relatively stable for over a decade[12] with most individuals retained in NSW fisheries are within 3 cm of the legal limit of 30 cm[8]. The stock is assessed to be 'growth overfished'; the bulk of the catch is made up of fish of a size less than that which would produce the maximum yield-per-recruit and catch rates are less than 30 % of initial levels[8]. Estimates of biomass are not available nor are reliable measures of annual recruitment strength. As a result, the status of snapper stocks in NSW is not known precisely. Analyses show that the stock may be at risk of not sustaining adequate biomass at current levels of fishing and suggest that a further increase of the legal size limit (planned but not in place at the time of publication) would address growth overfishing[12].

The recreational catch of snapper in NSW is substantial; the most recent estimates of the annual recreational harvest are between 180 and 250 tonnes(8,15), i.e. about equal to the commercial catch. The same size limit exists for this sector and a bag limit of 10 per person applies. Noting the large number of juvenile snapper (under the minimum legal size) also caught, but mostly not retained, by recreational fishers in estuaries, bays and inlets, the total recreational fishing mortality probably far exceeds the commercial mortality and more accurate information and monitoring for this sector is needed.

Victoria

Snapper are a key target species of the Commercial Bay and Inlet Fishery (CBIF) in Victoria. Commercial catches have been declining since 1978/79 and from1997 to 2000 have been < 100 tonnes(3). Little catch data or formal assessments for snapper were publicly available but the CBIF fishery as a whole is considered to be sustainable at current levels of effort(16).

Snapper is an important recreational species in Victoria; the state had the largest recreational catches (over 300 tonnes) at the last survey during 2000 -2001(15). As for other states, the recreational fishery for snapper in Victoria is managed via minimum length (28 cm) and bag limits (10 per person per day).

Western Australia

Most of the commercial catch of snapper comes from the Shark Bay Managed Fishery (SBMF) which is part of the General Demersal Scalefish Fishery (GDSF). The species is also taken in other fisheries managed by the Western Australian Government. Commercial catch in the SBMF was about 600 tonnes in the mid 1990s and then peaked at 1 300 tonnes in 1985(17) at which time concerns were raised that the stocks were being overfished. Management strategies were then introduced to limit fishing effort and to control output in the form of minimum legal size limits (41 cm) and a TAC of 550 tonnes per annum(18). Spatial closures also currently exist in the SBMF to protect certain areas in which snapper spawn.

Commercial catches in this fishery were about 450 tonnes between 1999 and 2002 but in 2003, concerns were again raised about the status of the stocks and the TAC was reduced to 338 tonnes(17). In 2004, the government department responsible for the environment considered the stocks had been ‘overfished’ but that the management strategy was sufficient to ensure the recovery of the stocks and that the fishery was being managed in an ecologically sustainable way(17). The TAC was reduced again in 2007 to 250 tonnes(19). The latest assessments of commercially fished stocks in Western Australia considered snapper in the GDSF to be close to 30 % of the pre-fishery biomass and to be recovering adequately at current levels of fishing(19). Concerns about the status of stocks have, however, been raised for some other Western Australian stocks (e.g. in the WCDSF)(17). A seasonal closure for fishing of snapper in Cockburn Sound occurs in a few months of the Austral summer, the timing of which is continually reviewed to ensure it covers the peak period of spawning in the area(19).

The recreational catch of snapper is estimated to only be a small percentage (< 10 %) of the commercial catch in each of the Western Australian fisheries(17,19). This sector is again managed via bag (8 individuals per fisher) and size limits which vary throughout the state depending on the size at maturity in different stocks. In some regions, recreational fishing is subject to the same seasonal closures as for the commercial sector(19).

Because much of this species of snapper sold at Sydney Fish Market Pty Ltd is sourced from fisheries in South Australia and New Zealand(pers. comm. G. Dannoun, SFM), the fisheries and the management and conservation of these stocks are discussed in detail.

South Australia

Snapper is commercially targeted by The Marine Scalefish Fishery (MSF) managed by the South Australian Government. The species is fished predominantly by longline but also by handline. Commercial catches in this fishery peaked in 1971 at over 500 tonnes, then ranged between 200 and 500 tonnes in the 1990s[3]. Catches increased from 2000 suggesting an increase in biomass (possibly the result of a strong recruitment year in 1991). Reported catches in 2004 through to 2006 were about 500 tonnes per annum[20]. In more recent years, concern over stock levels has grown amid worry that longline catches have been excessive. Commercial catches of snapper have increased since 2003/04, reaching over 700 tonnes in 2007/08[21]. The recreational catch of snapper was estimated to average 48 tonnes per year from 1994 through to 1996, representing 17 % of the commercial catch within that period[20]. A survey covering 2000/01, however, estimated the total recreational harvest at over 400 tonnes; almost the same as the commercial catch for that period (550 tonnes)[20]. More recent data on the recreational catch was due in mid 2009[22], yet is still unavailable at this time.

Current management of the snapper stocks in South Australia is done via a range of input and output controls. The use of nets to catch snapper was prohibited in 1993 and only handline and longline commercial fishing is currently permitted using no more than 400 hooks per day. A legal size limit of 38 cm[20] applies. This size limit also applies to the recreational fishery which also has bag and boat limits which vary among different regions in the state[20]. Because of substantial declines in the commercial catch in 1998/99 (40 % that of the previous fishing year), strategies to increase the efficacy of managing the stocks were compared. As a result, rather than further restricting size limits, the introduction of seasonal closures was concluded to be a more economically acceptable approach[23]. Seasonal closures were established in 2000 and then modified in 2003 to a one month period at the start of the summer spawning[23]. This strategy was reviewed in 2006 and was concluded to be successfully reducing fishing effort and catch[24], yet no data were given to indicate a subsequent benefit to the stock. This remains a research priority to be addressed for the snapper fishery in the MSF of South Australia.

Stocks of snapper in the MSF are currently managed by estimating several fishery-related indicators, e.g. commercial catch, Catch Per Unit Effort (CPUE) and targeted effort and several biological indicators, e.g. current biomass, recruitment and exploitation rate. These are then regularly monitored against appropriate limit reference points which have been estimated to protect the sustainability of the species and the fisheries[25]. Stock assessments have been done regularly since 1997 (the most recent using data up to 2006) and, whilst normally done for several geographic regions, the data presented here are state-wide (the South Australian stock is most likely comprised of related sub-populations that form a single fishable stock)[20]. The longline CPUE has increased over recent years and breached the relevant performance indicator at the last assessment. Estimates of recruitment (from 2002 data) also fell short of the reference point for this biological indicator[20]. Nonetheless, the biomass of snapper was estimated to be 6 % above the average of the preceding years and annual harvests were estimated to be < 10 % of the biomass[20]. In 2005, the management strategy of the MSF, as a whole, was assessed by the government department responsible for the environment to be suitably sustainable. It was also found that commercial fishing would not be detrimental to the survival and conservation status of any of the targeted species, nor any of relevant ecosystem[22]. An updated stock report in

2009 found that the 2007/08 commercial catch was at record levels and had breached the total catch performance indicator[21]. The impact of this on stock levels will need to be carefully assessed.

Because of the strong interest in snapper stocks from both commercial and recreational sectors in South Australia, the species will continue to be very closely monitored and management will presumably remain adaptive. Strategies have been planned to develop more accurate and appropriate sustainable yield estimates which will facilitate more precise management of the fishery but, in the interim, consumers can be confident that even under the existing arrangements the management of snapper in South Australia is appropriately cautionary.

New Zealand

Australia imports 60 % of the snapper exported from New Zealand[26] and the majority of the snapper sold at Sydney Fish Market Pty Ltd comes from New Zealand[pers. comm. G. Dannoun, SFM]. The sustainability of the snapper fishery in New Zealand is therefore of particular importance to Australian seafood consumers. In New Zealand, the species is found predominantly around the North Island and particularly in the Bay of Plenty region, most commonly in depths of between 10 and 100 m[26]. The commercial snapper fishery is one of the largest and most valuable in New Zealand[27]. Snapper are caught predominantly by trawl and longline.

Early catches of snapper peaked in 1978 at 18 000 tonnes[27] but following increasing use of longline from 1980, catches declined to almost half that of the peak catch by the mid 1980s (i.e. between 8 500 - 9 000 tonnes). Assessments of some stocks indicated that overfishing was occurring at that time[27] and precautionary Total Allowable Commercial Catches (TACCs) were introduced in 1986 and set at levels that would allow the rebuilding of stocks. Total catches of snapper in New Zealand have remained fairly stable since 1995/96 with annual catches fluctuating around 6 500 tonnes and close to if not slightly over the total TACC set for that year[28]. The largest recreational fishery in New Zealand targets snapper[27] and catches have risen steadily in the main fishing region from 1 600 tonnes in 1985 to over 2 000 tonnes in 2004[27]. Recreational fishing is managed by output controls in the form of bag and size limits which were initially set in 1986/87 and have been subsequently reduced in several regions to effect sustainability[27] (currently 10 fish per person and a minimum size limit of 27 cm for the main fishing region). Uncertainty about the catch by the recreational sector remains a concern for management.

As a result of evidence to suggest that separate stocks of snapper may exist in New Zealand the fishery is managed in 7 zones, each with separate TACCs. These have been individually reduced or increased depending on the levels of catch in each region[27]. Most snapper are caught in the management zone SNA1 in the northern waters of the North Island (harvests in this zone fluctuated between 5 000 and 6 000 tonnes through the 1980s and 1990s)[27]. The initial TACC was set at 4 710 tonnes for 1986/87 but subsequently increased to over 5 000 tonnes and even 6 000 tonnes in the early 1990s. The catch was then reduced by TACCs of about 4 900 tonnes from 1992/93 to 1996/97. The TACC has remained at 4 500 tonnes since then and the annual catch in SNA1 zone has been stable at or slightly above this level[27,28].

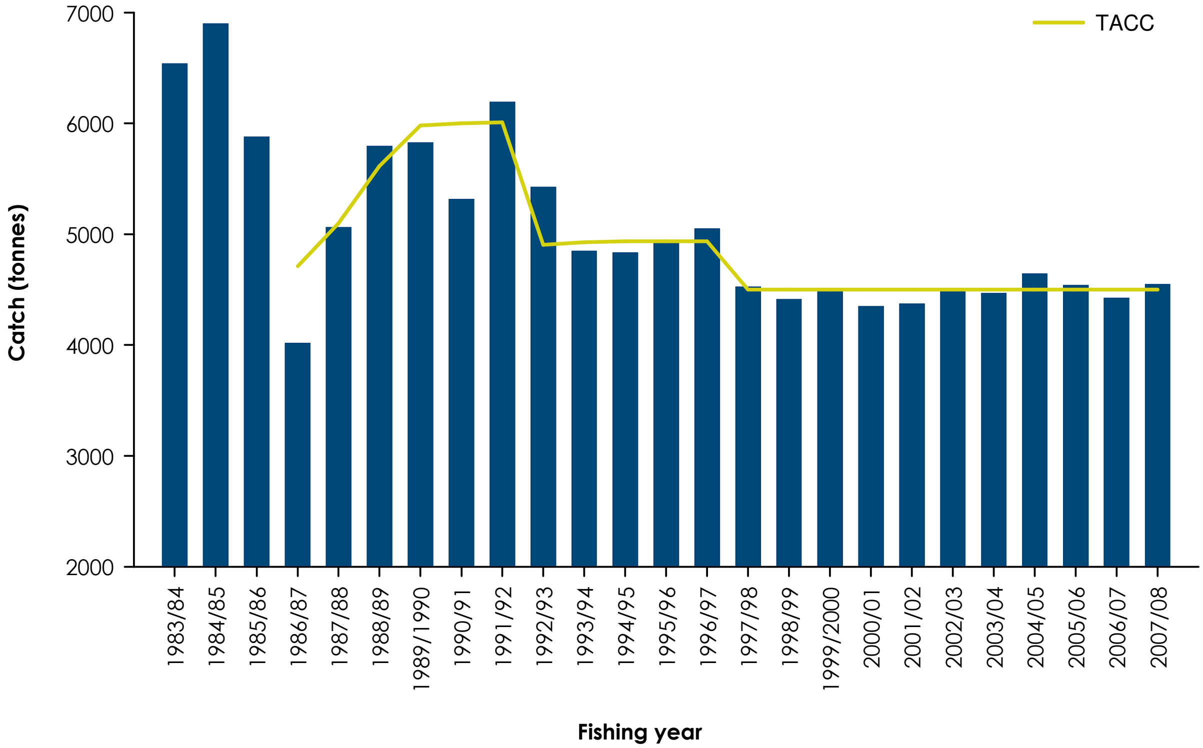

Figure. Reported commercial catch and Total Allowable Commercial Catch (TACC) of snapper in the main fishing region (SNA 1) in New Zealand waters[27].

The most recent detailed stock assessment of the main snapper stock (SNA 1) in New Zealand was done in 2000 for two separate regions within the management area; East Northland (EN) and Hauruki Gulf - Bay of Plenty (HG - BoP)[29]. Biomass in the EN area for 1998/99 was estimated to be above 13 000 tonnes and at a level below that expected to produce the maximum sustainable yield (the pre-fishery biomass was estimated to be above 66 000 tonnes). In the HG - BoP area, biomass in 1998/99 was estimated at 50 000 tonnes, an estimate below that expected to produce the maximum sustainable yield (the pre-fishery biomass was estimated at over 270 000 tonnes). Most importantly, stocks in each area were expected with acceptable probability (> 60 %) to exceed levels that would support the maximum sustainable yield by 2020 if harvest levels remained at about 4 500 tonnes[29]. The TACC for SNA 1 has remained at 4 500 tonnes since 1997/98 and catches have rarely exceeded this level in any one year. The TACC considered sustainable for the whole snapper fishery in New Zealand waters was over 6 000 tonnes for 2009/10[26].

Conservation

Bycatch

Over half (66 %) of the recreational catch of snapper in Australian waters is released mainly because the fish are too small[15]. Whilst the mortality level of these released fish is unknown, one estimate had about 30 % dying soon after release[33].

Sea-birds, sharks and marine mammals have been recorded as bycatch in the MSF in South Australia, with 98 % of affected individuals released alive in 2007/08[22]. It is not clear, however, what proportion or species were incidentally caught as a direct result of fishing for snapper. The data and analyses generally available on bycatch for snapper fisheries in Australia and New Zealand are unfortunately limited.

Environment

Limited data and assessments of the potential environmental impact of snapper fisheries in Australian and New Zealand waters are available. The South Australian MSF was however externally assessed to not have a seriously negative impact on the survival and conservation of the associated environment(22).

External threats

The abundance of snapper is likely to be affected by the abundance and quality of coastal and estuarine habitats available for spawning, feeding and/or nursery areas. For example, juvenile snapper are often associated with seagrass, and substantial losses in seagrass habitat have been reported in WA, SA, Victoria and NSW and attributed to physical and chemical disturbance through siltation, eutrophication and toxicants(34-37). The impact of such external threats on snapper populations has not been quantified and it is most unlikely assessments that could be used in the precise management of harvest levels will be available in the foreseeable future.

The sustainability of snapper in Australia and New Zealand

Although subject to heavy levels of fishing, stocks of snapper in Australia and New Zealand appear to now be managed more effectively and in a manner that will ensure their long-term sustainability via controlled harvests. Recovery of previously overfished populations continues along with the maintenance of stocks at levels considered to yield optimum sustainable catches, despite environmental concerns that need to be assessed. Further reductions in catches and increasing size limits (e.g. in NSW) may, however be necessary to ensure long-term optimum yields. More research is also required to assess how best to manage the sustainability of the growing recreational sector which takes a large proportion of the snapper catch in Australian and New Zealand waters. The current management of the recreational sector is likely to be however, a resource allocation issue rather one of concern for the conservation of the species.

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Yellowtail kingfish

Seriola lalandi

The firm flesh of yellowtail kingfish has a distinct, pleasant flavour and is high in Omega 3 fatty acid. Overfishing of yellowtail kingfish in NSW waters occurred more than a decade ago but subsequent management appears to have corrected this. The species is currently classified as 'growth overfished'[1] but the stocks appear to be increasing under existing management arrangements. Trends in the commercial catch and indices of relative abundance of yellowtail kingfish since 2004/05 have been stable[2]. This guide to the sustainability of yellowtail kingfish and the management of the fisheries in which they are targeted is based on the scientific and fishery-related data available at the time of publication. The bulk of the funding for the preparation of this series of guides was provided by the Fisheries Research and Development Corporation. The series of guides has been jointly sponsored by Sydney Fish Market Pty Ltd (SFM), which is Australia's largest and best known market for seafood, so individual guides are focused on the sustainability of seafood sold through SFM. Support from OceanWatch Australia Ltd for parts of the research done in this factsheet is acknowledged.

Biology

Yellowtail kingfish is a highly migratory, pelagic species found in the temperate regions of the Pacific and Indian oceans off South Africa, USA and in Australia from southern Queensland southwards to central Western Australia. The species also occurs off east Tasmania, Lord Howe Island, Norfolk Island and in New Zealand waters[3]. Yellowtail kingfish are found in coastal waters near off-shore islands and reefs and also in bays, inlets and even estuaries, often solitary or in small schools[3,4]. They are found up to depths of 200 m but are commonly caught at depths of about 50 m[5]. They are opportunistic feeders, preying on small fish, squid and crustaceans[3].

Spawning occurs in offshore waters generally in Austral spring-summer[6] but the exact spawning period varies throughout their distribution[3]. Females are thought to release batches of eggs numbering in the millions but their precise capacity for reproduction is not well known[7]. The eggs are released into the open ocean and hatch within 2 to 3 days[3]. Juveniles can enter estuaries (usually in Austral autumn) and rely on nearshore and estuarine areas as nurseries[4]. Individuals grow rapidly and can reach lengths of up to 200 cm (60 kg)[8] and live up to 21 years of age[9]. The minimum legal length (65 cm) is reached at about 2 to 3 years[1]. Although growth-rates are similar between sexes[9], males and females reach maturity at different ages: at about 2 years of age (80 cm) for females and less than 1 year (40 cm) for males[1,6]. Annual natural mortality has been estimated at 12 %[10].

Fishery & management

The bulk of the yellowtail kingfish sold through the Sydney Fish Market Pty Ltd now comes from aquaculture but the main supply of wild yellowtail kingfish is taken from waters off NSW in the Ocean Trap and Line Fishery (OTLF) managed by the NSW Government. Yellowtail kingfish are also taken in much smaller quantities in other fisheries in NSW. As such this review of the sustainability of yellowtail kingfish is focused on the commercial wild fishery in NSW.

Tagging programs have shown that while most individuals remain local (< 50 km), large scale movements occur along the coast of NSW (> 500 km) and between NSW and New Zealand (> 2000 km)[8]. A single stock is assumed across the east coast of Australia[11]. The fish are currently taken using handlines and occasionally with droplines or trawls[12] and are caught primarily from December to May[1]. The commercial catch of yellowtail kingfish fluctuated between 100 and 300 tonnes from the

1950s to the 1980s, then dramatically increasing to peak at about 600 tonnes in the mid 1980s(1). During this period of peak catches, most yellowtail kingfish were taken in traps which are particularly effective for this species and subsequently the species was overfished. Catches declined from the late 1980s to historical levels of about 100 to 300 tonnes by the mid 1990s(1). Recent harvest levels have fluctuated between 100 and 150 tonnes(13).

Yellowtail kingfish are a popular target for recreational fishers. The recreational catch is substantial with anglers reporting particularly good catches in 2008/09 in central NSW(pers. comm. A Steffe, I&I NSW). It is unknown to what extent the recreational sector contributed to the decline of commercial catches from the mid 1980s to the late 1990s. The recreational effort has increased considerably since the 1980s and the current estimated catch is between 120 and 340 tonnes per annum(14) which is of similar magnitude to the commercial catch. A bag limit of 5 individuals applies to the recreational sector in addition to the same minimum size limit as the commercial sector.

Following concerns about overfishing, a minimum legal length was set at 60 cm in 1990(7) and targeted trapping of the species was banned in 1996(13). The minimum legal length was increased in 2007 to 65 cm(13). Commercial fishing effort is also controlled by limiting entry and restrictions on the number of hooks, lines and poles that can be used(15). Since these management strategies have been in place, catches appear to be steadily increasing (although still characteristically variable)(7). Reported commercial catch-per-unit-effort has also increased considerably and relatively consistently since 1996(7). The species is currently classified as 'growth overfished', i.e. the size at which they are caught is smaller than that which would produce maximum yields(7,13). Whilst males mature at a size smaller than the minimum legal limit, it is estimated that the age at maturity of female yellowtail kingfish is approximately 80 cm(6). There appears to have been little change in the size composition of the commercial catch since the 1990s suggesting the minimum legal length had little effect on the size structure of the catch(9). Fishing mortality was estimated to be between 27 and 75 % per annum(9) and it was suggested yellowtail kingfish may be at risk of being recruitment overfished at levels of fishing mortality that occurred in 2004(5). Considering the remaining uncertainty over the status of the stocks and that the age at maturity of female yellowtail kingfish is well above the legal size limit, review of the optimal size of harvested individuals is needed.

The status of the stock of yellowtail kingfish have been assessed using commercial catch data which is not ideal because the collection and reporting methods have varied throughout the history of the fishery(7). Declining catches and inadequate information for accurate stock assessment led to this species being classified as in 'moderately-high' risk of being an unsustainable resource if the fishing practices current at the time of the assessment (2006) continued(7). The management strategy current at that time included collection of the necessary data (e.g. catch, catch rates and length/age composition of the catch,) to better assess the stock and was considered a substantial contribution toward reducing this risk(7).

Performance reports are done regularly to review the effectiveness of the management responses as are assessments of the stock(15). These reports are not always made public. The last assessment was done in 2006(16) and the government department responsible for the environment considered that the management strategy of the OTLF met most of the requirements for ecologically sustainable fisheries as set by the Australian Government(17) at least in the short term. This includes acknowledging that the strategies sufficiently control and monitor fishing effort to not pose any threat to the survival of the target species, allow stocks that have been overfished, including yellowtail kingfish, to recover and were adequately precautionary to affect the sustainability of the fishery as a whole and minimise adverse environmental impacts[16]. A new assessment has been done[pers. comm. K. Rowling, I&I NSW] but was not publicly available at the time of publication.

Exploitation status of the stocks of primary species in the OTLF are updated annually. Although there are areas of concern for this species, current indicators of the status of the stocks from data from the commercial fishery do suggest that the stocks are increasing under existing management arrangements[5]. There is no indication of recruitment problems for kingfish and there is even a suggestion of an increase in the number of medium sized fish in recent years.

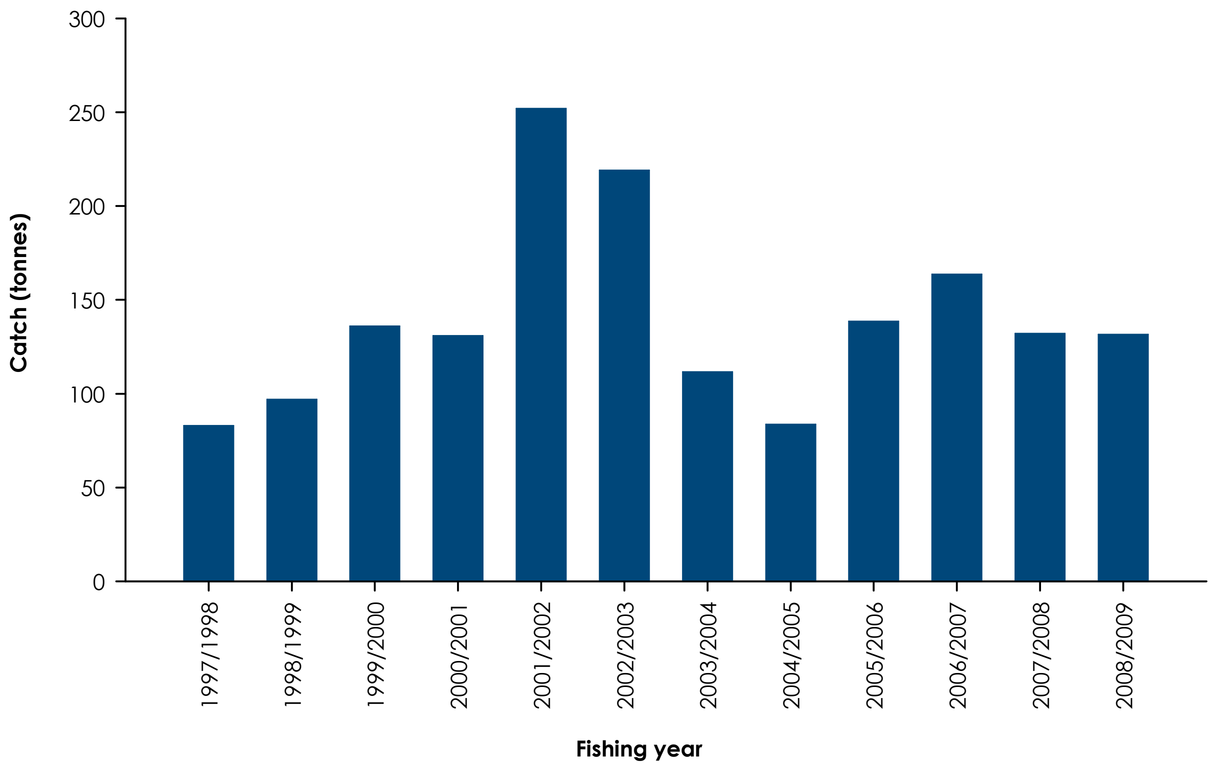

Figure. Commercial catch of yellowtail kingfish in the Ocean Trap and Line fishery managed by the NSW Government[7, pers. comm. J. Stewart, I&I NSW].

Conservation

Target population

The classification of yellowtail kingfish as 'growth overfished' has not led to the development of a recovery program (as required by the Fisheries Management Act[18]). The classification is acknowledged to be an economic rather than biological condition and as such a recovery program may not be the most effective management strategy[7]. Although the appropriate data are being collected to better assess the stock of yellowtail kingfish[15], the risk of overfishing in the short-term would not be mitigated by this process[7]. Nonetheless, I&I NSW is monitoring the characteristics of the stock and will develop an appropriate recovery program if the species continues to be classified as 'growth-overfished'[15].

Bycatch

The impact of incidental catch is poorly understood in the OTLF and addressing this deficiency is acknowledged as a research priority(7). In particular, incidental catch of grey nurse sharks (listed as critically endangered in eastern Australian waters under the EPBC Act(19)) by handlining by both commercial and recreational fishers targeting yellowfin kingfish was considered to be a substantial, but not singular, threat in areas where grey nurse sharks are known to aggregate(7). This threat has been reduced somewhat by the requirement on commercial fishers to use circle hooks on unattended lines to reduce incidental/gut hooking (and investigating their efficacy in reducing hooking for attended lines)(15). The proposed observer program and reporting system for bycatch will not necessarily reduce incidences of hooking but were deemed important to evaluate the impacts of the fishery(7). Furthermore, the risk to grey nurse sharks in each of the established critical habitat sites was assessed(7) to identify potential spatial closures (marine parks) which can help mitigate the threat of incidental bycatch of this threatened species(7). The government department responsible for the environment considered the fishing practices of the OTLF to not adversely affect the survival of threatened species(16).

Discards of undersize kingfish may be substantial and were considered a high risk for the OTLF and a management plan was recommended to investigate and mitigate this concern(7). Adaptive closures to protect juveniles are a problematic possible solution considering yellowtail kingfish are highly mobile and widely-distributed. The recreational sector also releases just over half (55 %) of the catch(14). Survival rates of discarded/released yellowtail kingfish are difficult to estimate.

Environment

Few, if any, studies have been done to assess the effect of fishing methods on the marine habitats potentially affected by the OTLF. Nonetheless, the types of gear used and the general operation of the vessels in the OTLF were considered to pose minimal risk to marine habitats and water quality(7) as they do not make major contact with the bottom and do not represent chemical hazards. The current management strategy has allocated resources to identify habitats potentially at risk and better understand the nature of an extent of any impacts fishing in the OTLF may have on marine habitats(15).

The sustainability of yellowtail kingfish in NSW

Current indicators are that this species is demonstrating a classical recovery after having been overfished to an extent which reduced the economic and social returns from the numerous fisheries but did not seriously threaten the sustainability of the species or, apparently, the level of recruitment to the fisheries. Although there are still areas of concern for the fishery (particularly about growth overfishing), landings and length composition of yellowtail kingfish do appear stable(5). The history of the fishery of yellowtail kingfish provides an example of an effective management response to growth overfishing before the conservation of the species was seriously threatened. The status of the stocks of yellowtail kingfish in NSW appear to be continuing to improve.

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Mulloway

Argyrosomus hololepidotus (synonym: *A. japonicus*)[1]

Mulloway, distinguished by their metallic silver/bronze colour, are an excellent seafood choice with moist flavoursome flesh that forms large, firm flakes when cooked. Commercial catch of mulloway has declined in NSW over the past 15 years leading to concerns over the status of the stock[2]. Current declines are strongly suggestive of overfishing but other causes cannot be ruled out from at least contributing to the declines in relative abundance. Nonetheless, even the current reduced levels of abundance do not represent a threat to the sustainability of the species in NSW. The declines must be corrected, however if the economic and social returns of the fisheries are to be optimised and a commitment to precautionary fisheries conservation and management is to be confirmed. This guide to the sustainability of mulloway and the management of the fisheries in which they are targeted is based on the scientific and fishery-related data available at the time of publication. The bulk of the funding for the preparation of this series of guides was provided by the Fisheries Research and Development Corporation. The series of guides has been jointly sponsored by Sydney Fish Market Pty Ltd (SFM), which is Australia's largest and best known market for seafood, so individual guides are focused on the sustainability of seafood sold through SFM. Support from OceanWatch Australia Ltd for parts of the research done in this factsheet is acknowledged.

Biology

Mulloway are widely distributed through the Pacific and Indian oceans surrounding Australia, Africa, India, Pakistan, China, Korea and Japan. In Australia, mulloway are distributed along the eastern, southern and western seaboards from the Burnett River, QLD to North West Cape, WA[3]. It is a nearshore coastal (< 100 m depth) fish occurring off ocean beaches, on inshore reefs and in the lower reaches of estuaries[4]. Juvenile mulloway can also be found in embayments and well into estuaries[references within 2]. Adult mulloway can be found as solitary fish or in schools[3] but juveniles usually form schools of relatively similar sized individuals. Adults prey on a variety of fish including mullet, leatherjackets, pilchards, whiting, luderick and bream. They also eat crabs, squid, prawns and marine worms[3]. Juveniles feed mainly on shrimp which becomes a less important prey as the fish mature[2]. Mulloway have a prominent swim bladder against which muscles are vibrated making a drumming sound, hence members of this family are known as croakers.

Mulloway in NSW waters reach maturity at an estimated 3 years (51 cm) for males and 5 years (68 cm) for females[5] and are also thought to spawn at a much younger age than elsewhere (e.g. South Africa)[6]. The species shoal to spawn in surf zones and around the mouths of estuaries mainly in Austral spring/summer[3] but the exact timing varies throughout their distribution and is probably related to temperature[2]. Mulloway in NSW waters are thought to spawn predominantly between November and March[2]. Females release between an estimated 90 000 to just over 1 million eggs[7] and larvae are pelagic[8]. Juveniles settle into near-shore areas and estuaries at about 10 cm in length[3] where they usually remain for up to about 3 to 4 years when they move into offshore waters[9]. They are a fast-growing fish and growth varies across the distribution of the species in Australia[3]. Males and females grow at different rates but there is little difference in length/weight relationships between the sexes[2,10]. Mulloway are a very large fish; individuals can grow up to 180 cm (60 kg) and are regularly caught up to 150 cm (35 kg)[4]. Mulloway can live up to 30 years[3].

Fishery & management

Mulloway are caught commercially in all states of Australia except Tasmania near river mouths, in estuaries and in open waters(3). The majority of mulloway that is sold through SFM is grown in aquaculture. The bulk of the supply of wild mulloway comes from NSW waters with very little to no supply from SA or WA waters(pers. comm. G. Dannoun, SFM). As such, the following review is focused on the fishery in NSW.

Mulloway are targeted in waters along the coast of NSW predominantly in the Estuary General Fishery (EGF) and also by the Ocean Trap and Line Fishery (OTLF) and each is managed by the NSW Government. They are caught using gillnets in estuaries and by line and trawl (as an incidental catch) in ocean waters. Large-scale movements (about 400 km) have been observed between estuaries in NSW but some fish are relatively sedentary (particularly as juveniles)(2). There is some evidence to suggest that a single stock exists along the east coast of Australia and in South Australian waters but is a separate stock to that in WA waters(10 cited in 2).

Commercial catches of mulloway fluctuated between 50 and 150 tonnes between 1940 and 1970 until catches peaked at 380 tonnes in 1973/74 corresponding with an increase in trawling and the removal of the minimum legal size limit in 1971(2). Since the mid-1970s, commercial landings have declined consistently and rather dramatically(11) to less than 80 tonnes in recent years(12). The species is managed in each fishery by a number of gear restrictions, spatial and temporal closures(2) and a minimum legal size limit which is currently 45 cm in NSW(11). Commercial catch rates (CPUE) for mulloway in the EGF and OTLF have remained fairly stable at about 4 and 7 kg per day respectively for the last decade or so(2). This stability in catch rates suggest that declines in the commercial catches is related to decreased effort (number of fishers targeting mulloway) in NSW(2). Using catch rate data as an indicator of relative abundance for species such as mulloway that aggregate episodically, is however, far from ideal.

The availability of larger fish (> 60 cm) to the commercial sector also appears to have decreased considerably, particularly in recent years(11). The available size and age data of the commercial catch of mulloway strongly suggests a smaller proportion of larger, older fish in current catches compared to that between 1986 and 1990 and from 1994 to 1999(11). Unfortunately, conclusions from this limited data set are confounded by the relative similarity of size composition data from current catches with that from the earliest period of available data (from 1972 to 1975).

The total recreational catch of mulloway in NSW has undoubtedly increased substantially since the 1960s but there are few data to document such an increase. The recreational catch is currently estimated to be between 100 and 500 tonnes per annum(13) which represents between almost two and ten times that of recent commercial catches. Increased landings by the recreational sector since the 1960s would almost certainly have contributed to the recorded decline in the commercial landings but the extent to which this may have happened is not known. The same size limit applies to both sectors and the recreational sector has a total bag limit of 5 fish with only 2 individuals over 70 cm(11).

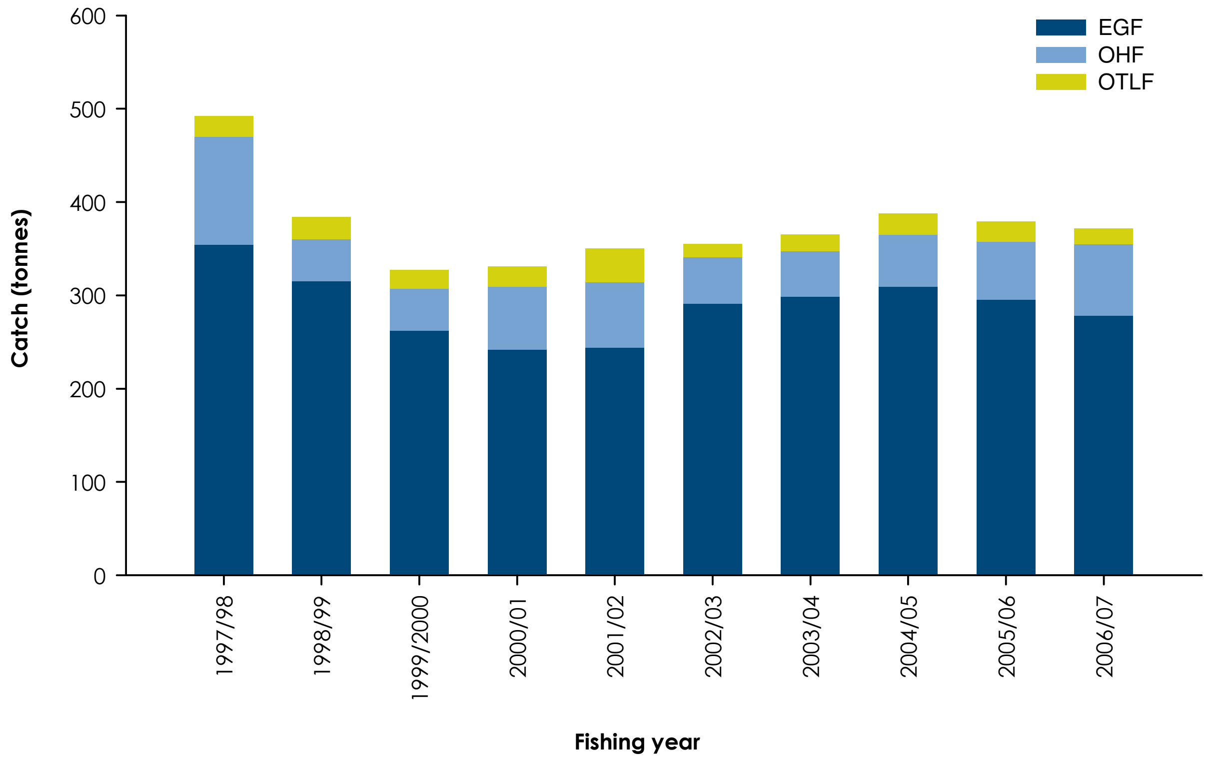

Figure. Total catch of mulloway in the commercial fisheries of NSW that mainly target the species; Estuary General Fishery (EGF), Ocean Haul Fishery (OHF) and Ocean Trap and Line Fishery(OTLF)[14].

I&I NSW considers mulloway in NSW to be substantially growth 'overfished'[11], i.e. that too many small fish are being caught to maintain optimal yield. It is recommended that fish be caught at 80 to 100 cm in length to maintain an optimum yield but the minimum legal size is currently 45 cm[11] which is smaller than the size at which females are mature (> 60 cm)[5]. There are concerns that the species may be in danger of recruitment overfishing, i.e. that recruitment is being measurably suppressed as a result of reduced spawning biomass[11]. Increasing the legal size limit to 70 cm has been suggested to allow for at least one spawn before capture[11] but a reduction in the bag limit to one fish may represent a better management option.

Conservation

Target population

Recognising that there is uncertainty in the limited available data, current indicators of the status of the stock of mulloway in NSW are concerning. There is evidence from other countries that local populations of closely related species (large croakers) have declined dramatically as a result of overfishing and anthropogenic degradation of, or changes to, their habitat[15]. Nonetheless, even the largest species, the giant yellow croaker (*Bahaba taipingensis*) has survived (albeit at tremendously reduced levels) the intense fishing that occurred as well as the extent of coastal development in China and Taiwan[15]. This strongly suggests that the plight of mulloway in NSW is, at least for the immediate future, an economic and social fisheries management issue and not a major concern for the survival of the species. Declines in apparent abundance must, however be addressed as a matter of urgency.

A species recovery program was drafted in 2008[11] but was not publically available at the time of publication. This will introduce new strategies to reduce fishing pressure and attempt to affect the recovery of the species, including research plans to better understand the impact of the current fishing effort and appropriate fishing levels that will be allowed after the stock recovers.

Bycatch

Mulloway are often incidentally caught in estuarine and coastal prawn fisheries in NSW, especially as juveniles[16]. For example, an estimated 48 000 fish were discarded between 1990 and 1992 from prawn trawlers in the 4 major ports of NSW[17]. Under the recovery program a number of strategies are in place to reduce the incidental catch of mulloway. Whilst the impact of incidental catch remains as a research priority[8]), much has already been done to minimise the incidental capture of juvenile mulloway in prawn trawl fisheries particularly with the use of bycatch reduction devices (BRDs) in trawl nets[reviewed in 18]. Generally the total prawn trawling effort has been considerably reduced in recent years, more effective bycatch reduction devices are now being used, closures to certain trawl grounds and areas (prawn trawling is only permitted in three of the many estuaries in NSW) and in certain times when juvenile mulloway are more prevalent exist (i.e. in areas where seasonal or episodic high catch rates of juvenile mulloway may be taken).

The minimum mesh size for nets set overnight in the EGF was increased to 95 mm and the use of circle hooks on lines, escape panels in fish traps and limits on the number of hooks and traps is mandatory the OTLF[pers. comm. F. McKinnon, I&I NSW]. Although the efficacy of these strategies has not been formally assessed, it is unlikely that incidental catch is now primarily responsible for the continuing decline in the commercial and recreational catches of mulloway in NSW. Incidental catch from the recreational sector is potentially of much greater concern with an estimated 50 000 individuals being discarded per year[13]. Survival rates of these discards are uncertain but may be high

Environment

Much remains unknown about the extent and type of impacts on diversity and habitat of NSW estuaries from fishing and other activities. A lack of data and resulting inadequate understanding of the impacts of the OTLF on the associated ecosystem and its processes is acknowledged. Nonetheless, the types of gear used in the OTLF were considered to pose minimal risk to marine habitats and water quality[8]. Similarly, wide-scale and severe impacts on the biodiversity of NSW estuaries from the fishery were considered to be minimal[12]. The adaptive approach of the current management strategy for each fishery, which includes routine monitoring of fishing activity and sets reference points so that harmful practices can be detected and modified if necessary, was considered adequate to maintain the sustainable use of its resources, provide the necessary opportunities to address the lack of available data and react in a precautionary manner[8,19].

External threats

It is not possible to eliminate disease, pollution or habitat destruction as causes of, or at least contributors to, the apparent decline in the commercial fishery for mulloway. There have been no reports of significant new diseases specific to mulloway, however there have been known outbreaks of diseases such as redspot (which affects many species of fish) and the Californian herpes virus which reduced pilchard populations by an estimated 70 %[20]. Degradation of estuarine habitats, excess nutrients, chemical contaminants, reduced flows from freshwater streams and exotic species are all major factors contributing to environmental degradation in estuaries[21] which could have contributed (and likely still do) to the decline in commercial landings of mulloway. The main concern, at least for the

EGF, was assessed to be the impacts of external factors such as land-based catchment uses, contamination and habitat degradation[12]. For example, substantial loss of seagrass habitat in NSW has been attributed to physical disturbance through siltation, eutrophication and toxicants[22] and there is little evidence of large-scale recovery[23]. Mulloway may not, however be as dependant on shallow vegetation in estuaries as nursery habitat as much as other estuarine species in NSW[2].

The sustainability of mulloway in NSW

There are several indicators of recent declines in catches of mulloway and commercial and recreational fishing does appear to be implicated. The extent to which other possible causes including disease, pollution and habitat destruction or alteration may have caused or contributed to declining catches is, however, unknown. Reduced flow of freshwater into key nursery areas, such as the Hawkesbury River, is one environmental variable that may well have impacted recruitment, it would be surprising if it had not. The stock of Mulloway in NSW and the factors which influence their abundance do appear to be in need of additional research and management. Because of the highly mobile nature of the species management of fishing will have the greatest chance of being effective if based on catch reductions and size limits across the whole distribution of the stocks that are harvested in NSW. Furthermore, as catches by the recreational sector now represent between two and ten times that of recent commercial catches, restrictions will need to be addressed primarily in the recreational sector. If recruitment has been impaired because of a fishing-induced decline in the spawning biomass then additional management of the recreational fishery becomes more imperative.

Appropriate management plans will also need to identify other potential cause of declining commercial catches. For example, if the declines in catches are due to pollution, disease and/or reduced freshwater inflows these will need to be addressed at their source, and their amelioration will likely be outside the jurisdiction of fisheries management agencies. Considering the extensive distribution of Mulloway, the survival of the species is unlikely to be seriously threatened by habitat damage, pollution or over-fishing in any one area. There may well be, however localised depletion of populations by fishing or local habitat damage.

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Gould's squid

Nototodarus gouldi

Gould's squid have light brown/pink skin with a purple/blue stripe down the centre of the mantle. They have a light, subtle taste and are firm, yet tender when properly prepared. Squid are distinguished from calamari in that the fins are usually less than half the mantle size whereas the fins of calamari usually run the whole length of the mantle[1]. Gould's squid are fast-growing and short-lived with a great capacity to replenish the population. The species is currently classified as 'not overfished' nor 'subject to overfishing' and levels of effort are small in comparison with many other Australian fisheries and pose no threat to sustainability. The fishery also has no substantial bycatch and has minimal impact on the marine environment but its economy is being threatened by cheaper imports of squid from Asia.

Gould's squid caught between Botany Bay and western Victoria dominates the catch (by weight) of squid and calamari sold through SFM[pers. comm. G. Dannoun, SFM]. This guide to the sustainability of Gould's squid and the management of the fisheries in which they are targeted is based on the scientific and fishery-related data available at the time of publication. The bulk of the funding for the preparation of this series of guides was provided by the Fisheries Research and Development Corporation. The series of guides has been jointly sponsored by Sydney Fish Market Pty Ltd (SFM), which is Australia's largest and best known market for seafood, so individual guides are focused on the sustainability of seafood sold through SFM.

Biology

Gould's squid are oceanic and are found throughout the waters of southern Australia from Brisbane, QLD through to Geraldton, WA including waters around Tasmania and in the northern waters off New Zealand[2]. They are found in estuarine and oceanic waters to depths of about 500 m but are most abundant above the continental shelf from depths of 50 m to 200 m[1]. Gould's squid are a schooling species aggregating near the seabed during the day and dispersing through the water column to the surface at night[2]. They are voracious predators feeding on crustaceans, fish (e.g. pilchards and small barracouta) and small squid mainly at night[3]. The population dynamics (growth, reproduction, maturity, etc) of Gould's squid are very variable in time and space and closely tied to environmental factors[4] which in marine habitats are notoriously variable themselves.

In south-eastern Australia, Gould' squid spawn in most months of the year, with 2-3 peak periods[5]. Whilst there is much variation in the patterns of maturation and spawning in squid, evidence suggests that Gould's squid are multiple spawners, releasing batches of eggs into the water column over a period of time[6,7]. The larvae are pelagic and have a large capacity for dispersal[7]. The species overall is fast-growing although actual rates are variable throughout their distribution, seasonally and annually[7]. Generally females grow more quickly than males[1] reaching a maximum mantle length of 40 cm (1.6 kg) compared to 35 cm (1.2 kg) for males[2]. Male squid generally mature faster than females (22 cm mantle length v. 30 cm respectively), however, the size at maturity varies throughout their distribution[2]. The average size at which squid are caught is 23 cm (0.3 kg)[1]. Gould's squid are short-lived and generally die soon after they spawn at the end of their first year[7].

Fishery & management

The first worthy commercial catches of Gould's squid were taken in Tasmania beginning in the early 1970s and historically the greatest commercial catches came from Victorian, South Australian and Tasmanian waters[2] often by foreign vessels. A single stock of Gould's squid is assumed throughout southern Australia (although there is some genetic evidence to suggest there may be a separate stock on the northern east coast)(7). A specific squid jig fishery began in the mid 1980s(2), developing into the Southern Squid Jig Fishery (SSJF) managed by the Commonwealth. Although the fishery extends to waters of NSW, VIC, TAS and SA(8), current catches in the fishery are mainly taken from waters off Queenscliff and Portland, VIC and south of Kangaroo Island, SA(9). Jigging gear consists of barbless 'cluster' hooks attached to 1 or more lines which are pulled through the water on rotating elliptical shaped spools creating a jigging effect. Jigging is done at night in depths of between 60 and 120 m using lights to attract squid closer to the surface where they are commonly caught(8). Coastal squid jigging (i.e. within the 3 nm limit) is managed by the relevant state government(8). The fishing season can occur all year but is mostly between February and July with highest catches in March and April(9,10); peak catches and targeted fishing varies throughout the distribution of squid in southern Australian waters(2,8). Gould's squid are also caught as a bycatch of the trawl sectors of the Southern and Eastern Scalefish and Shark Fishery (SSESF) also managed by the Commonwealth. Small amounts of Gould's squid are caught (on jigs) by recreational fishers but southern calamari (*Sepioteuthis australis*) seems to be the preferred species of this sector(2). There exists a daily bag limit of 10 individuals of any squid or calamari species in Victoria but not in other states(2). The recreational catch of Gould's squid is considered negligible(10).

Catches of Gould's squid are very variable on spatial and temporal scales reflecting the influence of environmental factors (weather, phases of the Moon, depth, etc.) on the biology and behaviour of this species causing extreme variations in abundance(7,8,11). Prior to the early 1970s, catches of squid were < 100 tonnes a year and mostly as bycatch from the trawl fisheries operating in south-eastern Australia(12). Annual commercial catches of Gould's squid from jigging were no more than 400 tonnes a year up to 1995 when over 1 200 tonnes were landed(8). Annual catches of Gould's squid in the trawl sector of the SSESF have been mostly between 400 to 900 tonnes in the last decade with a peak catch of over 1 800 tonnes in 2001(8). A trend has existed since 1995/96 in the SSJF of larger catches every second year(10).

The fishing effort for squid in 2008 was the lowest since the fishery developed in the early 1990s and the catch was less than 200 tonnes. This is thought to be a result of increasing fuel and running costs of squid jigging combined with consumer preference for southern calamari and the lower market price of Gould's squid which is also suffering competition from cheaper imports(8).

Historically, the status of Gould's squid was listed as 'uncertain' because there was insufficient survey and biological information to estimate their abundance and sustainable yield(2,8). Estimates of the status of the stock were based on commercial catch data which was acknowledged to limit the understanding of the sustainability of the fishery(12). Research priorities were identified and a substantial research program initiated to get a better understanding of the biology of Gould's squid including reproduction, mortality, recruitment biology, stock structure and environmental factors that influence the species and the sustainability of the fishery(7,12). This was an unusual opportunity to get the data necessary for responsible management of a marine species, before it came under threatening fishing pressure. Subsequently, a formal management plan was developed for the SSJF in 2005(13) regulating entry to the fishery and the number of jig machines that can be used (via a Total Allowable Effort; TAE)(8). A trigger catch limit of 6 000 tonnes was implemented for all squid (including the trawl sectors of the SSSF), at which point further catches are prohibited and the impact of this level of harvest must be assessed before fishing can continue(10). The initial TAE was set at 800 jig machines in

2006 and 2007[8], reduced to 640 machines in 2008 and further reduced to 590 in 2009 in line with the number of fishing rights surrendered in the previous year[14].

In 2009, Gould's squid was classified as 'not overfished' and 'not subject to overfishing'[15]. Although there has been no formal stock assessment for this species, the classification was given based on low catch rates and the high reproductive potential of the species. Trigger points have been set on a precautionary basis, but the only fisheries management concern appears to be a very slight risk of limited localised depletion in areas of intense fishing. Analysis of historical catch and fishing effort showed that fishing could cause appreciable depletion of Gould's squid from Cape Otway, VIC to Robe, SA but not to the point where overfishing would occur[8], i.e. even at peak effort the stock was estimated to be at or above 50 % of the pre-fishery level[9]. In all the other regions of the SSJF analyses showed resources of squid were even further underfished[9]. Catch rates are currently small (due more to economic reasons than the availability of squid) and below the catch triggers for the SSJF[9].

Rapid turnover in squid populations means that the fishery effectively exploits a new generation each year and the substantial variability in populations dynamics of squid make for a typically 'boom and bust' fishery[7]. Fishing effort is carefully monitored; fishers are required to record and submit catch and effort data and an on-board observer program currently validates the catch and bycatch data and collects samples to support estimates of population parameters[9]. The management plan and bycatch action plan for the SSJF are reviewed biennially and the whole fishery is externally assessed every five years.

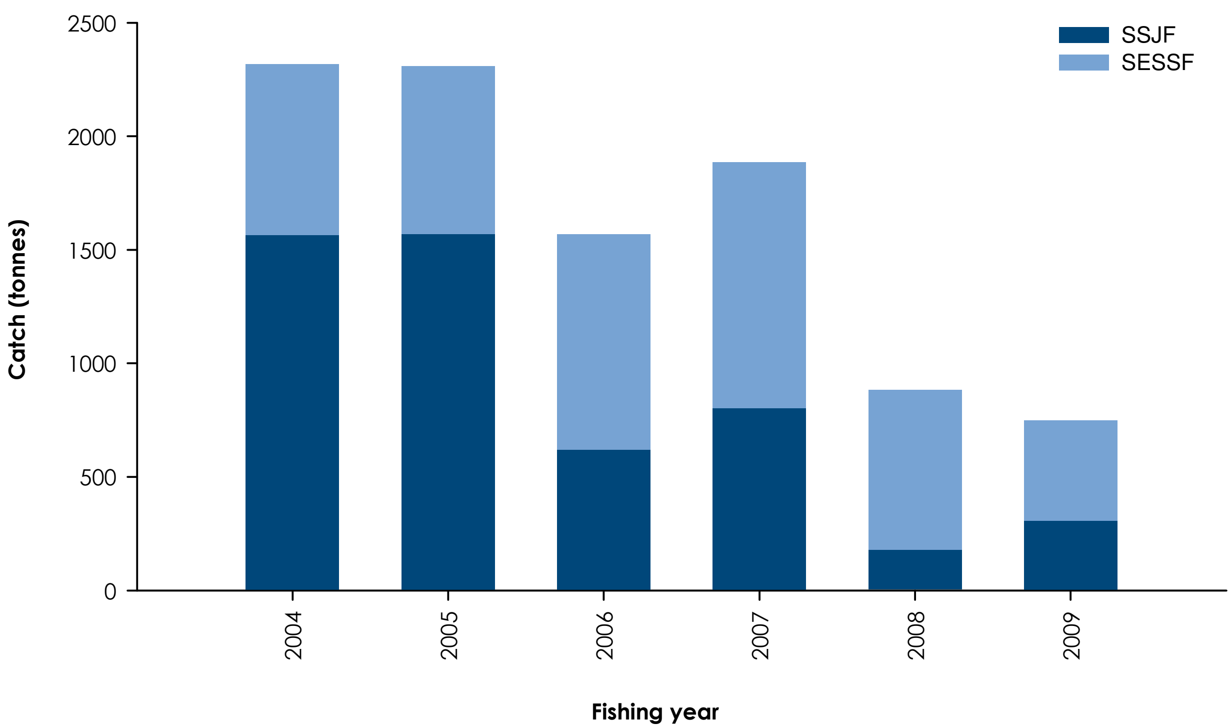

Figure. Recent annual commercial catch of Gould's squid in the Southern Squid Jig Fishery (SSJF) and the trawl sector of the Southern and Eastern Scalefish and Shark Fishery (SESSF)managed by the Commonwealth of Australia[9].

Conservation

Bycatch

The SSJF is a highly selective fishery and very little bycatch of fish or other marine specie has been reported(8). Reports since 2001 show certain species of fish (particularly barracouta and garfish) and blue shark taken as bycatch in small quantities(16). Seals may also be attracted to the schooling squid targeted by the fishery but there have been no reports of incidental catch or entanglement(16). The bycatch action plan for the SSJF(16) has developed various strategies to reduce bycatch and decide levels of sustainable impact. The current plan is a precautionary strategy and in general the bycatch from the SSJF is low(10); the removal of bycatch was < 200 kg in 2004(16). Currently the fishery is limited to a maximum bycatch of 100 kg per trip and a total ban on bycatch of certain species (e.g. tuna, marlins, blue eye trevalla)(17). Other species of squid can also be a by-product of fishing of Gould's squid but this incidental catch is estimated to be < 1 % of the total catch in the fishery(9).

Concerns were raised in the 1980s that increased squid jigging in south eastern Australia may cause an impact of commercial fish stocks that rely on squid for food (including tunas and sharks). One study concluded, however, that Gould's squid was not a consistently major part of the diet of many commercial fish species in the area and commercial fishing of squid was hence unlikely to have any substantial effects on the abundance or distribution of species at higher trophic levels(18).

Environment

Minimal environmental impacts are associated with the SSJF because it is such a specific, pelagic fishery. The ecological risk assessment completed in 2006 did not identify any threats to the marine environment from this fishery(19).

The sustainability of Gould's squid in Australia

The species is fast-growing and short-lived, meaning that rapid stock regeneration can occur if conditions are favourable. This results in large fluctuations in biomass and subsequent catches. Alternatively, this can also result in a danger of the fishery crashing if a year of intense effort coincides with a year of poor recruitment, but even such crashes are unlikely to affect the long-term sustainability of this particularly resilient species.

There is general agreement that Gould's squid is currently 'under fished'(10). Research to reduce the minimal bycatch that exists is being done and bycatch levels are strictly monitored. Whilst no formal assessments of the status of the stock of Gould's squid have been done, reduced catches in recent years due to economic factors, coupled with the ability of squid to rapidly replenish their population mean that the stock is in no danger of overfishing. At the latest assessment , the fishery was considered to be suitably managed with precautionary measures in place to prevent over-fishing and limit unsustainable impacts on the marine environment(10).

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