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Bridging the gap: a workshop linking student research with fisheries stakeholders.

AJ Williams[1,2], DJ Welch[1,2], G Muldoon[1,2], R Marriott[1,2], JP Kritzer[1,2], S Adam[1,2]

[1]CRC Reef Research Centre
[2]James Cook University

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CRC REEF RESEARCH CENTRE TECHNICAL REPORT No 48

CRC Reef Research Centre Ltd is a joint venture between: Association of Marine Park Tourism Operators, Australian Institute of Marine Science, Great Barrier Reef Marine Park Authority, Great Barrier Reef Research Foundation, James Cook University, Queensland Department of Primary industries, Queensland Seafood Industry Association and Sunfish Queensland Inc

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- Association of Marine Park Tourism Operators
- Australian Institute of Marine Science
- Great Barrier Reef Marine Park Authority
- Great Barrier Reef Research Foundation
- James Cook University
- Queensland Department of Primary Industries
- Queensland Seafood Industry Association
- SUNFISH Queensland Inc.

CRC Reef Research Centre Ltd
PO Box 772
Townsville QLD 4810 Australia
Phone: 07 4729 8400
Fax: 07 4729 8499
Email: info@crcreef.com
Web: www.reef.crc.org.au

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FOREWORD

The CRC Reef Research Centre values and encourages the links between researchers and the users of the researchers' results. In the case of research relating to natural resource management, there are several classes of 'users'. Firstly, the government regulators seek information on the state of the resources for which they are responsible, and information on the likely changes that will occur under various management regimes. Secondly, private companies using natural resources seek information to maximise the return on their investment of time and capital. A third class of 'user' includes researchers working on related topics that can benefit from sharing results. In the case of publicly owned resources, such as fisheries, there is also a fourth group of 'users', the public who want to see that the public resource is conserved and used wisely. CRC Reef encourages the release of its research results to all these users in easily accessible forms.

The management of tropical finfish fisheries is a difficult, often controversial, task and the life histories and behaviours of the species are complicated. Some are quite long lived, some have very patchy recruitment, and some are very migratory. The industry members also are capable of rapid change as markets and opportunities shift. In the case of live fish export, the fishery expanded rapidly as local fishers took advantage of the price benefits for exporting fish to market alive.

In convening this fisheries stakeholders workshop, the CRC Reef students have made a valuable contribution to building links with all user groups having an interest in line fishing in the Great Barrier Reef World Heritage Area. The workshop was well attended by a diversity of users and participation level was outstanding.

The workshop and report have contributed significantly to the goals of CRC Reef and reflect the benefits of engagement with stakeholders which has been a hallmark of CRC Reef's Effects of Line Fishing (ELF) Project. I am pleased to acknowledge Dr Bruce Mapstone's leadership of the ELF Project and CRC Reef's Program on Sustainable Industries. I commend the students for their outstanding contributions and thank the workshop participants for their time and encouragement.

Prof Russell Reichelt

CEO, CRC Reef Research Centre

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ACKNOWLEDGEMENTS

The aim of these proceedings was to document our research results and the issues raised by stakeholder representatives at the workshop because we believe that this will be beneficial for the sustainable management of the GBR Reef Line Fishery. Clearly, this would not have been possible without the enthusiastic participation of all stakeholder representatives at the workshop, for which we are grateful. We would also like to thank CRC Reef for their financial support, which was essential for funding both the workshop and the production of these proceedings.

In particular, we thank Prof. Mike Kingsford and Sue Helmke who refereed these proceedings. Their constructive comments helped improve the quality of this document. We also acknowledge editing/written contributions by Bruce Mapstone, Russell Reichelt and Louise Goggin; recording of discussion sessions by Annabel Jones and Belinda Sweeney; and additional advice and support from Vicki Hall and Vicki Harriott.

EXECUTIVE SUMMARY

Managing fisheries is a complex and difficult process involving, in one way or another, regulators, fishers and other community interests, including researchers. Management decisions inevitably involve compromise among these groups and are based on social, economic, equity and political judgments as well as on information from relevant research. The role of researchers in the management process is to gather and synthesise data and disseminate and explain the information inferred from those data. Filling this role effectively means researchers must be engaged actively with the other stakeholders in the management process, understand their issues and be adept at conveying technical information in accessible ways. It also means maintaining impartiality to the outcomes of the process, advocating only for the correct use of research information on the way. Impartiality doesn't just happen – it has to be managed, with vigilance and caution. Engaging with non-researchers requires practice, humility and enthusiasm.

Conventional post-graduate education in natural resource science, especially the biological sciences, typically does not entail much engagement with stakeholders in management processes, and rarely offers real-life opportunities for students to learn how to be one of those stakeholders. Perhaps the most effective way to develop engagement skills is to 'learn by doing', but post-graduate students usually have their hands full doing their research. The culture of post-graduate training encouraged by the Cooperative Research Centres Program departs from academic convention by actively encouraging and valuing engagement between students and stakeholders who might use, be interested in, or be influenced by research. CRC Reef is at the forefront of implementing this culture.

Some students like this direction; others don't. The group of students who convened this workshop clearly do, and have embraced the spirit of CRCs with enthusiasm and proficiency. When the idea first arose, it was suggested as an option, not a requirement, and it was entirely up to the students whether they pursued the suggestion. The idea was that the students would work as a team to conceive, convene and run a workshop with a wide range of stakeholders in order to discuss the students' research with those stakeholders. The process meant the group of post-graduate students would have to work together, organise their collaboration, find funding for the workshop, organise the venue and logistics, invite relevant stakeholders, and devise an appropriate format for the workshop to maximise both transfer of information and discussion among the participants.

Perusal of these proceedings should indicate that this group of students managed all of these things to bring together a forum of diverse stakeholders (no small feat in itself) and carry the process through to completion (this document). You will read about a range of issues that are important to researching and managing the Queensland reef line fishery, and fisheries generally. From Jake Kritzer, Ross Marriott and Bob Mosse you will learn that some of the reef fish species that are impacted incidentally by fishing, live for very long times (several decades) and are likely to be particularly vulnerable to over-harvest. Samantha Adams discusses how varied the reproductive biology of reef fish can be, even among closely related species, and how important is knowledge of those reproductive strategies when devising management strategies. Ashley Williams raises some important issues that arise when harvested fish stocks have different growth and reproductive characteristics in different places, meaning that one management strategy might not be appropriate in all places where the fish are harvested. Dave Welch provides some insight to difficulties in collecting representative samples from fish populations and the potential to be misled if we fail to take account of sampling biases in research. Jim Higgs discusses the importance of taking into account the motivational and social drivers behind recreational fishing in seeking to devise future management strategies. Finally, Geoffrey Muldoon tackles the controversial topic of the growth in the trade in live reef fish for export markets. He explores the potential for this new marketing strategy to both add value to the commercial fishery but also to raise the spectre of over-capitalisation as additional effort is attracted to the fishery by the high prices paid for live fish.

What this document does not convey is the success of the day of discussions. These students took a bold step in keeping each of their presentations to 15-20 minutes in a 45-minute slot, leaving considerable time for discussion of their research. They adopted this strategy to maximise opportunities for exploration of the research by the assembled stakeholders, thereby exposing themselves to more scrutiny than is usual at international conferences where 'question time' is limited to around five minutes, at best. The approach involved several risks: workshop participants might be reticent to participate in discussion, leaving awkward silences after each presentation; discussion might raise a variety of controversial issues on which different stakeholders would disagree aggressively; the students might be attacked by members of the diverse audience who did not like their message. It is to the great credit of the organisers that none of these scenarios played out. Each student presented their material with such clarity and relevance to issues of the day that participation was complete: every participant joined in the discussions. Moreover, the students demonstrated tremendous finesse and professionalism in facilitating the discussions of their material such that salient issues received lively debate without ever becoming diverted into unproductive arguments.

This workshop was an outstanding success by any standards. Feedback from all participants during and following the meeting was tremendously positive. The students subsequently were asked to present their material to ReefMAC, the major Management Advisory Committee for management of the Queensland coral reef fin fish fishery. There too, they performed outstandingly and their research has had significant impact on the management planning for the Queensland reef line fishery.

What follows in this document is written for a broad audience similar to that at the workshop. The material is simply written to convey the salient points from research that represents over 25-person years of hard work in a short, professional document that should appeal to all who have an interest in understanding the biological issues in managing the harvest of coral reef fish. As with the rest of this process, these proceedings are the product of the students' hard work and determination to complete what they started.

The stakeholder workshop run by these eight students of the CRC Reef Effects of Line Fishing Project has demonstrated the CRC Reef philosophy of post-graduate training at its very best. The students involved demonstrated their generic liaison and extension skills and, I believe, learned a great deal in the process. The stakeholders at the workshop saw a group of outstanding researchers who have significant and important contributions to make to managing fisheries in

Queensland, and are willing and able to do so. They have set an excellent example of how researchers should engage with the issues of the day that call for their research. Many of these students have now completed their post-graduate research training and have been snapped up by employers in Australia and internationally, but other students follow. We look forward to the next CRC Reef student stakeholder workshop where these new researchers can demonstrate the contributions they have to offer.

Bruce Mapstone,
Program Leader, Sustainable Industries Program, CRC Reef Research Centre.

AUTHOR BIOGRAPHIES

Name: **Geoffrey Muldoon**

Affiliation(s): School of Tropical Environmental Studies and Geography, James Cook University & CRC Reef Research Centre

Research Focus: My current research focuses on the impact of innovation induced value-adding of a target species on the structure and behaviour of fishing fleets. Specifically, I'm researching the fleet response to the emerging live fish trade on the GBR with an emphasis on the management of effort and excess capacity. My research interests can be broadly couched as integrating socio-economic analysis with natural sciences and fishery management.

Email Address: geoffrey.muldoon@jcu.edu.au

Name: **Jim Higgs**

Affiliation(s): Queensland Fisheries Service

Research Focus: I am currently manager of the program responsible for the collection of fisheries dependent information for the Queensland commercial and recreational fisheries. My past research has focussed primarily on recreational fishing surveys and analysis of historical fishing club records within the GBR region. My current research interests include forecasting recreational fishing demand, based on state-wide participation rates and population growth, to help produce the most appropriate management strategies to deal with the changing face of the Queensland recreational fishery.

Email Address: jim.higgs@dpi.qld.gov.au

Name: **David Welch**

Affiliation(s): School of Marine Biology and Aquaculture, James Cook University & CRC Reef Research Centre

Research Focus: My research has focused on biases in fish sampling methodologies and the potential implications of these for fisheries management. Past research experience and research interests lie in population parameter estimation for tropical reef fish, effects of fishing on tropical species, fisheries monitoring, genetic stock structure in beche-de-mer, and fisheries stock assessment. Currently I am involved in research that investigates fish stock structure and connectivity between populations using micro-elemental analysis of otoliths.

Email Address: david.welch@jcu.edu.au

Name: **Ashley Williams**

Affiliation(s): School of Marine Biology and Aquaculture, James Cook University & CRC Reef Research Centre.

Research Focus: I am currently researching the population biology of the red throat emperor on the Great Barrier Reef for my doctorate degree. In particular I am interested in understanding the spatial and temporal patterns in the dynamics of reef fish populations such as rates of growth and mortality. More generally I have a keen interest in studying the biology and ecology of reef fish populations with an aim to expand current knowledge and improve tropical fisheries management.

Email Address: ashley.williams@jcu.edu.au

Name: **Jacob Kritzer**

Affiliation(s): Department of Biological Sciences
University of Windsor
Windsor, Ontario, Canada

Research Focus: My research interests lie in the spatial ecology of marine organisms, as well as the implications of spatial structure and patterns for conservation and fisheries management. Currently, I study dispersal and recruitment of fish larvae in the western Caribbean off the coast of Central America. In Australia, my research focused on spatial variation in adult demography and its implications for population dynamics.

Email Address: kritzer@uwindsor.ca

Name: **Ross Marriott**

Affiliation(s): School of Marine Biology and Aquaculture, James Cook University & CRC Reef Research Centre.

Research Focus: My research interest is the population biology of reef fish and their resilience to harvest. At present I am researching the population biology of red bass and will investigate how certain aspects such as fish growth and population age structure vary in populations exposed to different levels of fishing pressure.

Email Address: Ross.Marriott@jcu.edu.au

Name: **Jacobus Mosse**

Affiliation(s): School of Marine Biology and Aquaculture, James Cook University & CRC Reef Research Centre

Research Focus: Bob's research has been focused on aspects of the biology of the bommie cod, a bycatch species in the GBR Reef Line Fishery. In particular Bob has investigated age, growth, mortality and reproduction of the bommie cod and the implications of increased harvest of this species. Bob is currently back in his home country of Indonesia where he will be applying his knowledge to local fisheries.

Email Address: No current e-mail address

Name: **Samantha Adams**

Affiliation(s): School of Marine Biology and Aquaculture, James Cook University & CRC Reef Research Centre

Research Focus: I have two main areas of research focus, these are (1) The reproductive ecology and demography of fishes, and (2) Effects of marine protected areas and fishing on the reproductive demography of harvested stocks.

Email Address: samantha.adams@jcu.edu.au

INTRODUCTION AND OBJECTIVES

It is perhaps not unusual within a fisheries research environment to find an accumulation of distinctive research projects being carried out by postgraduate students that focus on a single fishery. Likewise, it's not uncommon for these research projects to rely heavily on resource users for assistance in collecting data. What is rare is to find such a cohort of students coming together to collectively present their findings to both inform and reward the assistance and participation of a broad range of stakeholders.

The Effects of Line Fishing (ELF) project began in 1995 and took on its first postgraduate student in 1996. Over the ensuing 5 years the project recruited a further nine (9) postgraduates whose research spanned social, biological and economic disciplines. In late 2000, the idea was floated to bring these students together to present their research findings to the diverse range of stakeholders with an interest in the reef-line fishery (RLF) in a day-long workshop. The decision was made to structure the workshop to provide for an open forum discussion of each research project. Each student made a 15-minute presentation during which his or her findings were presented so as to be relevant to invited stakeholders. Each presentation was followed by a moderated discussion of that research during which participants exchanged views and ideas on the implications of the research findings for users, managers and other stakeholders.

Therefore, the overall objective of the workshop was to:

Facilitate the effective transfer of information on current research on the Great Barrier Reef reef-line fishery, to all stakeholders, in an environment conducive to a meaningful exchange of ideas.

A NOTE ON SCIENTIFIC AND TECHNICAL ASPECTS OF PROCEEDINGS

The CRC Reef student stakeholder workshop was intended to involve a wide array of people, and these proceedings are likewise intended to be accessible to a broad audience. Therefore, the content and structure of the following papers does not follow the format of most scientific publications. We aim to avoid burdening or even discouraging non-scientist readers with excessive technical detail, so most of the papers simply describe and discuss research results without explanation of methodology.

Still, we recognise that many readers are likely to be interested in the process by which these research results were attained. We encourage those readers to pursue sources cited throughout these proceedings for the information of interest. PhD or MSc theses and papers in peer-reviewed journals will provide background on sampling design and methodology, validation of age determination methods, and other technical and analytical aspects. Moreover, we encourage readers to contact authors directly for further information. The team that organised the workshop and authored this volume includes researchers at different stages in their studies. While some have reached a stage where their research is appearing in scientific journals, others have only reached the stage of thesis production. Still others have not yet reached the dedicated writing stage, and for these individuals the only source of additional information will be direct contact with the researcher. However, we encourage readers to contact any researcher directly, regardless of the stage of their studies. Our objective in running the workshop was to open a dialogue between early career researchers and a wide array of stakeholders. We did not intend for that dialogue to end when the workshop ended, nor to be limited only to workshop attendees.

Finally, although we have strived to make these papers accessible to a broad readership, some use of specialist terminology was inevitable. We encourage readers to refer to introductory texts on ichthyology, ecology, conservation biology, fisheries management, and economics to clarify any terms or concepts discussed in this volume.

1. THE GREAT BARRIER REEF LIVE FISH TRADE: FISHER RESPONSE TO THE VALUE-ADDING OF EXISTING TARGET SPECIES.

Geoffrey Muldoon

Introduction

Fisheries management typically focuses on fisheries that are over-exploited or have exhibited signs of over-fishing, with the aim of reducing existing effort levels. Often however, a new fishery emerges that either exploits a previously unfished stock (Perez and Pezzuto 1998), makes better use of by-catch species (Meyers 1994), or adds value to existing target species by developing new products to supply an existing or new market (McElroy 1993, Drouin 1999). Such emerging fisheries may have to contend with large influxes of effort, particularly where the prospect of greater returns is compounded by the opportunity for unrestricted entry to that fishery. Even in limited-licence fisheries, such as the reef-line fishery (RLF), unrestricted entry may be possible up to a point, where large numbers of licences are unutilised when these profit incentives arise. This can lead to over-capitalisation and excessive effort being employed (Lawson 1984, Hartwick and Olewiler 1986).

One example of how adding value to an existing target species can present new market opportunities is the live reef fish trade, which has emerged within the Great Barrier Reef (GBR) reef-line fishery (RLF). Innovation in the handling and storage of live fish has led to considerable enhancement of the value of existing target species, with little change in fishing technique. Of particular interest is how this influences fisher behaviour and affects fishing mortality (Holland and Sutinen 1999, Hilborn 1985, Seijo 1998).

This paper draws on data collected from a number of fishing operations within the RLF as part of my doctoral thesis. The data were obtained from personal interviews with owners and collated on the basis of operation type (supplying either live or frozen markets). Information was collected on fishing history, operational characteristics, costs, revenues and management opinions. Changes in the structure and operational behaviour of the reef-line fishing fleet in response to the emerging live fish trade are discussed. Special emphasis is placed on how market conditions (beach price) have impacted vessel productivity and subsequently influenced the adoption of and therefore investment in, new technology. Finally, I discuss fisheries management issues raised by the Live Reef Fish Fishery (LRFF) pertaining to the RLF

The history and development of the Live Reef Food Fish trade.

Hong Kong is the centre of the global live reef fish trade and the sole overseas market for Australian live reef fish. Major source countries include the Philippines, Indonesia, and Australia with small quantities being exported from Vietnam, Thailand and several Indo-west Pacific countries[1]. The most highly valued species are the humphead (Maori) wrasse (*Chelinus undulatus)*, barramundi cod (*Cromileptes altivelis),* common coral trout (*Plectropomus leopardus)* and large cods (*Epinephelus fuscoguttatus* and *E. polyphekadion)*. The demand for live fish coincides closely with events on the Chinese lunar calendar, peaking during traditional Chinese festivals, particularly Chinese New Year in February and the Mid-Autumn festival in September (Lau and Parry-Jones 1999). These festive periods correspond with higher beach prices in Hong Kong, which in turn flow through to Australia (Figure 1.1).

Recorded imports of live reef fish into Hong Kong between 1997 and 2000 range from 21 700 to 17 100 tonnes (Lau and Parry-Jones 1999, McGilvray and Chan 2001). However, these estimates likely under-report imports as a result of there being no requirement for the approximately 100 Hong Kong registered live transport vessels (LTVs) to declare imports entering Hong Kong by sea. Allowing for fish bought in via LTVs, imports of live reef fish into Hong Kong were estimated to be 32 000 tonnes in 1997 by Lau and Parry-Jones (1999) and 30 000-35 000 tonnes in 1999 by McGilvray

[1] See McGilvray and Chan (2001) for a detailed profile of source country imports.

and Chan (2001), suggesting officially declared imports under-report actual quantities by roughly one-third to one-half [2].

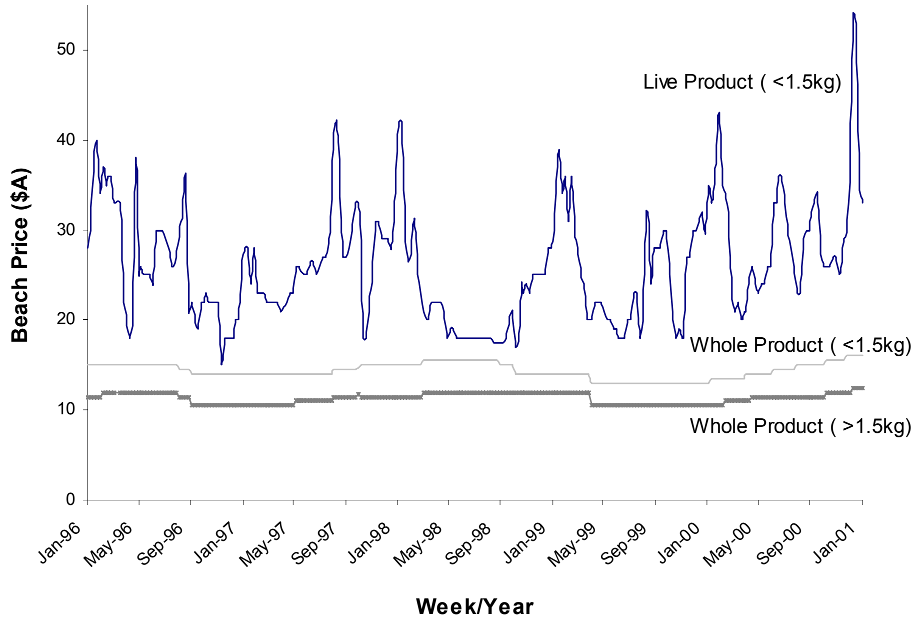

Figure 1.1: A comparison of wholesale beach prices for live and frozen coral trout (*Plectropomus leopardus)* from January 1996 to December 2000. Note the annual peaks in prices during February and September *Source: Wholesale Fish Buyers*

The composition and volume of these imports has changed in recent years. According to Bentley (1999), total exports of reef fishes from South-east Asia declined by more than 20% during 1996. Exports from the major source countries of Indonesia, Malaysia and the Philippines reflect this trend. Since 1996, total exports from these countries have continued to decline falling by 37% between 1997 and 2000. These trends are further emphasised by falling supplies of high value species, suggesting widespread overexploitation of stocks important to the LRFF trade (International Marinelife Alliance (IMA), unpublished data). In contrast, total imports of coral trout species from Indonesia, Malaysia, the Philippines and Australia[3] increased by almost

[2] These estimates are based on monthly import data obtained from surveys of live reef fish traders and records on imports by sea from the Hong Kong Agriculture, Fisheries and Conservation department.

[3] Exports from these countries represent 95% of all coral trout species imported into Hong Kong.

98% between 1997 and 2000. Much of this increased demand for coral trout has been met by Australian exports which have contributed 520 tonnes (~ 52%) of this increase over this time. Much of this increase is attributed to greater demand from China (Bentley 1999), the re-export destination for much of the fish entering Hong Kong since the early 1990's. Re-exports into China have increased from nil in 1990 to nearly 60% in 2000 (Johannes and Reipen 1995, Lau and Parry-Jones 1999, Chan 2000).
The GBR LRFF is an extension of the RLF with the first export of live fish from Australia occurring in 1993. Fishers operating within the RLF are licensed to remove fish from all areas within the GBR marine park open to fishing. There are no restrictions on the form in which fish may be processed and stored (ie live or frozen/chilled) and the same management measures apply with respect to minimum fish sizes and gear restrictions regardless of product form. Operations are endorsed to support between 1 and 7 dories. Nearly all live product landed by the commercial sector in the GBR is exported to Hong Kong live fish markets. Because the use of LTVs within the GBR marine park is restricted, all live export shipments from Australia are transported as airfreight in specially constructed transport bins. Coral trout is the predominant species targeted in the LRFF making up the vast majority of all live reef fish exports. Small quantities of barramundi cod, maori wrasse and the large cods are also exported.

Price, investment and targeting behaviour of fishers in the LRFF.

The higher price paid for live, as compared to frozen or chilled, fish in the reef line fishery provides considerable incentive for commercial fishers to retain reef fish alive. Since January 1996, the wholesale beach price for live coral trout has consistently exceeded the beach price for frozen coral trout, by between 40% and 300% (Figure 1.1).

The dominant view in fisheries economics is that catch will be supplied so long as expected trip revenues exceed expected trip costs (Doll 1988, Sampson 1992). Fishing decisions and behaviour will thus be primarily influenced by changes in trip costs and revenues. While trip costs may differ depending on operational activities, annual costs such as insurance, vessel maintenance and licence fees are independent of the number and type of fishing trip. As such, profitability comparisons between live and frozen operations need only consider *variable costs* (eg. fuel, provisions, fishers wages, bait and tackle, fish handling and storage) directly associated with the fishing trip.

Not unexpectedly, the higher prices received for live fish result in increased profits for those operations marketing their product live. Figure 1.2 contrasts average profitability between live and frozen operations expressed as net revenues (i.e. gross revenues from fish sales minus variable trip costs). All figures are standardised to dory days to enable direct comparison of operations of different sizes (i.e. number of dories)[4]. Although fishing costs were between 20% and 30% more for live operations, their net revenues were higher for all years. The years 1997 and 1998 were characterised by poor catch rates for coral trout and consistently lower live prices, due to the Asian economic downturn, contributing to comparatively lower returns for live operations. In contrast, net revenue for live operations was significantly greater than for frozen operations in 1998/99. Although data are not yet available for the financial year 1999/00, consistently higher prices for live coral trout during 2000 (Figure 1.1) would suggest the disparity in net revenue (profit) between live and frozen operations may be ever greater in this financial year.

[4] Dory days are the number of annual operation days fished multiplied by the number of dories supported by that primary vessel. Profit per dory day is simply the operations revenue per trip from fish sales, minus variable trip costs divided by the number of dories supported by the primary vessel.

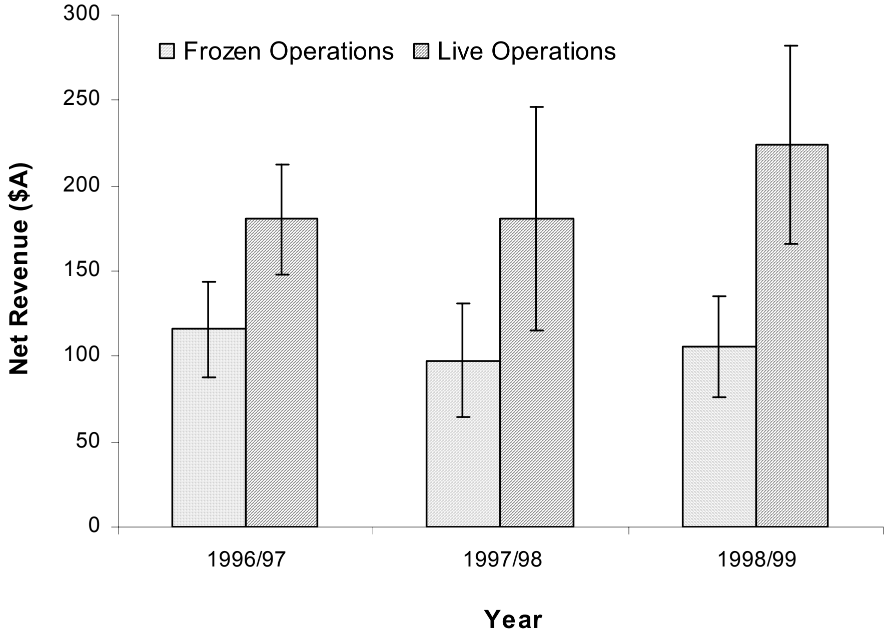

Figure 1.2: Average net revenue per dory day for live and frozen operation for the financial year's 1996/97 to 1998/99. Net revenue is total revenue from fish sales less annual and variable fishing costs. Error bars are 95% confidence levels. *Source: Muldoon (unpublished. data).*

The range of species targeted and the capture methods employed are comparable whether catching fish for the live or frozen markets. The compatibility of fishing methods remove the need for acquiring new fishing gear or fishing skills, providing an additional incentive for fishers to configure their vessel to catch and store live product[5]. Of the 50 operations included in this research, 33 converted to live between 1994 and 1999, with the majority (15) of conversions occurring during 1997. Only 6 further conversions were completed in 1998 and 1999, which was attributed to the downturn in the Asian economy and poor catch rates. A further 8 operations converted to live during 2000 in the wake of an improving Asian economy

The entry of fishing firms into the live market need not require substantial financial outlay. Costs of upgrading are dictated by the decision to either purchase a new vessel or convert an existing vessel, and the complexity of the live storage facility chosen. The cost of converting to a live operation varied widely among the vessels

[5] All vessels that are set up to store live product retain freezer space to enable the storage of frozen product. Some may have the capability to store their catch fresh on ice as well as in frozen or live form.

surveyed, ranging from $5 000 for installation of simple above deck tanks to in excess of $100 000 for new vessel purchases including structural modifications to the vessels below deck, freezer and/or storage capacity. For those operators who upgraded their existing vessel, the average cost of entry into the LRFF was $24 440. For those whose entry into live fishing involved replacing an old vessel or purchasing a new vessel, the average total cost was $281 845 excluding the cost of acquiring a licence (Table 1.1).

Fishers have been shown to respond to expectations of greater financial returns (Opaluch and Bockstael 1984, Bjorndal and Conrad 1987, Holland and Sutinen 1999). Given the fluctuating beach price for live fish in Australia (Figure 1.1), this research examined how fishers, who had invested in live technology, responded to these seasonal changes in the price of live product. Fishers were asked to indicate the months in which they targeted live coral trout between July 1997 and December 1999. The number of vessels allocating effort toward the capture of live coral trout corresponds reasonably well with the seasonal pricing pattern, suggesting fishing operations make short-run price dependent decisions on whether or not to target trout for the live market (Figure 1.3).

Table 1.1. Average total upgrade costs for both existing and new operations (new operations include purpose built live vessels and vessels requiring additional upgrade/conversion work).

	Existing			**New**		
	Boat Costs ($)	Upgrade Costs ($)	Total Costs ($)	Boat Costs ($)	Upgrade Costs ($)	Total Costs ($)
Average	–	24 440	24 440	232 370	49 475	281 845
Minimum	–	5 000	5 000	100 000	0	0
Maximum	–	70 000	70 000	650 000	150 000	730 000

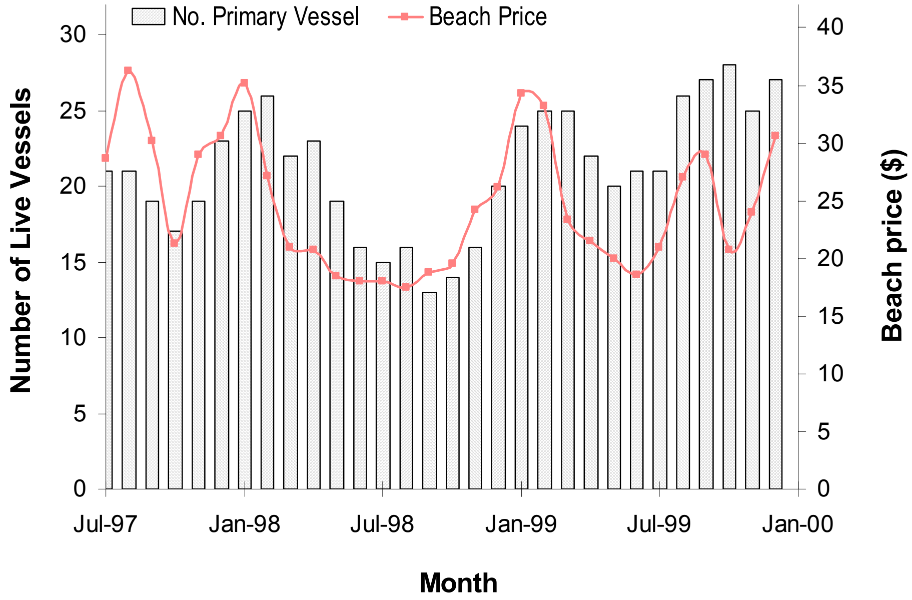

Figure 1.3. Number of live vessels and wholesale beach price of live coral trout between July 1997 and January 2000. Bars represent the number of operators (n = 33) targeting live trout, while the solid line is the beach price. *Source: Muldoon (unpublished data).*

The correlation between price and targeting of coral trout for either the live or frozen market is more pronounced prior to July 1999, after which there is less fluctuation in the switching behaviour of operations. For the larger operations, this may reflect either the higher average prices received or a greater understanding of the cost and revenue differences for the two types of fishing. In contrast, a large number of smaller operators continue to enter and exit the fishery on the basis of prices (M. Elmer, Queensland Fisheries Service, personal communication).

Latent Effort

Since the mid-1990's, substantial increases in fishery-wide effort have been observed within the RLF (Table 1.2). Much of the increase has been attributed to the economic incentives presented by the emergence of the LRFF. These opportunities for total effort increases are being compounded by the presence of latent effort in the fishery.

Latent effort is the difference between actual fishing effort applied and the potential effort, if all licence holders were to fish to their capacity. The characteristics of latent effort within a fishery may change over time because of technological advances that improve effective fishing effort or through incentives to reactivate unutilised or under-utilised capacity (Maurstad 2000, Thunberg 2000). The presence of excess capacity within the GBR line fishery can be traced to the multiple endorsement nature of fishing licences (Taylor-Moore 1998). Increased participation leading to effort increases in the fishery may emanate from:

(i) vessels that are operating below full capacity becoming more active;
(ii) multi-endorsed vessels utilising a previously dormant line fishing endorsement; and
(iii) previously inactive licences being reactivated by those not currently participating in any fishery.

Although pinpointing the actual sources of latent effort remains problematic, fishery wide effort patterns suggest that only a small percentage of the total fleet is fishing at or near its capacity. Of the more than 1 800 registered line fishing endorsements, less than 30% annually report catches of reef species within the GBR. Furthermore, the major proportion of commercial reef fish catches is taken by a relatively small number of licence holders with 15-20% of the fleet accounting for approximately 65-85% of the catch of coral trout and 70% of other reef species (Mapstone et al. 1996).

There has been a substantial increase in the total number of days fishers recorded catches of live product, from less than 100 days in 1993 to nearly 7 400 days in 1999. However, the contribution to overall effort increases in the fishery attributable to increased targeting of product for live markets is ambiguous (Table 1.2).

Table 1.2. Summary of operation days and total days fished on which coral trout in any form was targeted by the commercial sector of the GBR reef-line fishery and operations days on which catches of live coral trout were recorded from 1994 to 1999. *Source: Mapstone (unpublished data).*

Year	No. of Vessels	Operation Days Effort	Total Days Effort	Live Operation Days Effort
1994	352	17 207	62 537	355
1995	385	17 531	61 585	1 131
1996	488	21 831	74 640	3 140
1997	549	23 514	80 152	4 920
1998	521	22 821	77 161	5 154
1999	n.a	n.a	n.a	7 397

From 1995 to 1996, effort in terms of total live operation days increased by 180% (or 2 010 days) to 3 140 days. In contrast, total operation days fished on which coral trout in any form was targeted increased 25% (or 4 300 days) to 21 831 days. Thus the increase in live effort made up only 50% of the increase in total days fished. This is despite the number of live days fished as a proportion of total days fished, on which coral trout were targeted increasing from 6.4 % to 14.4 %. In the following year, total live days effort increased by 57% (or 1 780 days) to 4 920 days while total operation days fished on which coral trout was targeted increased 8% (or 1 685 days) to 23 514 days. Live effort actually exceeded the increase in total days fished and the proportion of total operation days on which live trout catch was reported increased from 14.4 % to 21% (Figure 1.4).

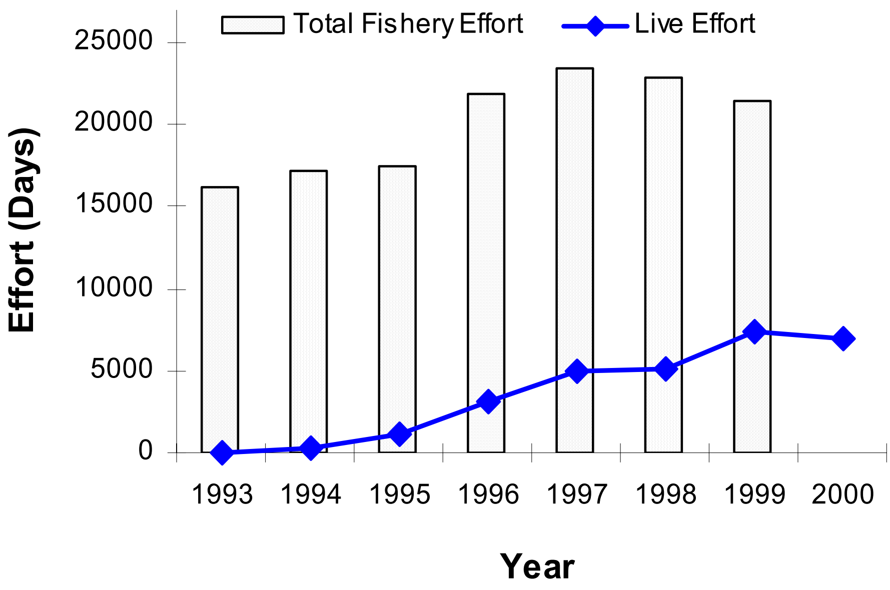

Figure 1.4. Total fishing effort and live fishing effort within the GBR reef-line fishery (excluding Eastern Torres Strait) for days on which catch of coral trout was recorded for the period 1993 to 1999. *Source: Queensland Fisheries Service; Mapstone (unpublished data, 2000).*

The difficulty faced in contrasting live and total effort stems in part from inadequate and erroneous reporting in the QFS logbooks (M. Elmer, Queensland Fisheries Service, personal communication.) and also in differentiating between the potential sources of total effort increases. Prior to 1997 there was no requirement for operators to discriminate between live and fresh/frozen product in their compulsory logbooks, likely resulting in under-reporting of live effort days (Mapstone et al. 2001). In terms of the sources of effort increases, the difficulty arises in distinguishing between effort increases emanating from existing fishing operations who, when switching to fishing for live product, increase their annual effort input, or from the entry of new operations fishing to supply either the live or fresh and frozen markets.

This section has highlighted a discernible trend of increasing effort directed at the capture and marketing of live reef fish species over the last 6 years. Predicting future trends requires an understanding of the role played by Australia in supplying the lucrative Hong Kong market relative to other sources of live reef fish.

Exports and the global importance of the Australian LRFF

Virtually all live product landed by the commercial sector in the GBR is exported, via wholesalers, to the Hong Kong live fish market. Annual exports of live reef fish have increased from 101 tonnes in 1995 to 785 tonnes in 2000 (Table 1.3). Coral trout is the predominant export species comprising approximately 90-95% of all live fish exports. Annual coral trout exports have increased from 97 tonnes in 1995 to 721 tonnes in 2000 (Australian Quarantine Inspection Service unpublished data; IMA, unpublished data). Contiguous declines in annual exports in 1997 and 1998 were due to the combined effects of a depressed Asian market and declining catch rates in the wake of a large-scale cyclone disturbance (C. Davies, personal communication). The effect of the recovery of the Asian economy, in concert with improved catch rates (anecdotal evidence from fishers), is reflected in an increase in coral trout exports in 1999 and 2000 of 150% and 50% respectively.

Table 1.3. Annual exports (kg) of selected live reef fish species from commercial catches within the Great Barrier Reef World Heritage Area from 1995 to 2000. *Sources: Australian Quarantine Inspection Service (AQIS), IMA.*

	Species Exported (kg)					
Year	**Coral Trout**	**Barramundi Cod**	**Maori Wrasse**	**Cod (other)**	**Mixed Species**	**Totals**
1995	97 735	650	70	1 060	2 165	101 680
1996	431 935	1 185	555	4 540	10 605	448 820
1997	345 030	715	545	4 345	2 425	353 060
1998	198 095	555	3 725	2 230	10 405	215 010
1999	493 300	1 250	6 865	10 580	27 530	539 525
2000	721 021	3 560	5 170	11 160	44 590	785 501

As noted above, total imports of coral trout species into Hong Kong have been increasing in recent years. Since 1998, total imports of coral trout have increased by 1006 tonnes or 88%. A considerable proportion of this increased demand is being sourced from the GBR with Australian exports making up 523 tonnes or nearly 52% of this increase. By 2000, Australia supplied nearly 35% of all imports of live coral trout into Hong Kong, a marked increase on the 17% of all imports it supplied in 1998 (Figure 1.5). The growth in demand for coral trout, emanating mainly from China, is likely to continue as consumers become increasingly wealthy. This has implications for sustainability of stocks of target species in the GBR RLF, which may be vulnerable to large increases in effort.

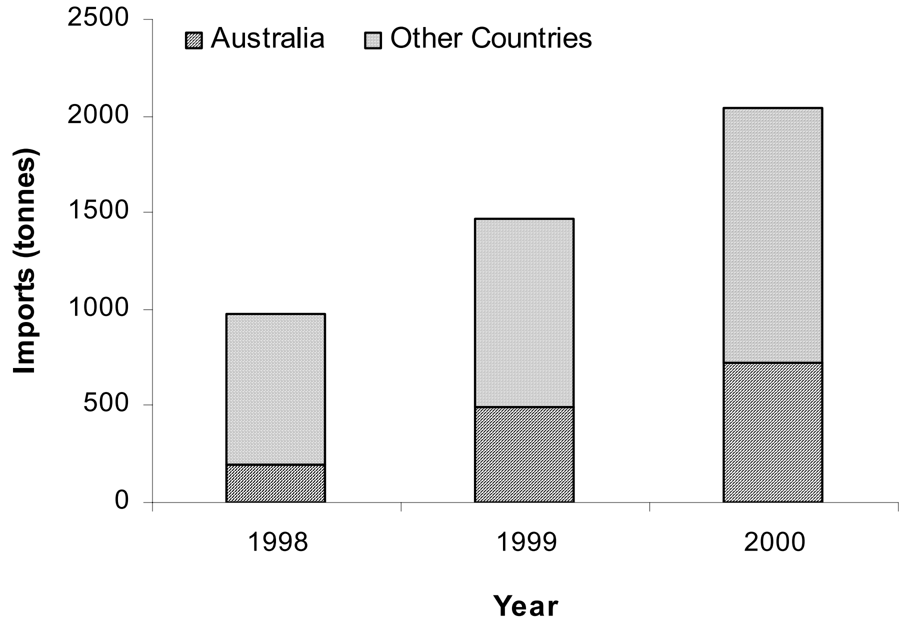

Figure 1.5. Total imports of coral trout into Hong Kong for the years 1998 to 2000. Other countries consist of Indonesia, Malaysia and the Philippines. *Source: Hong Kong Census and Statistics Department, International Marinelife Alliance and Australian Quarantine Inspection Service.*

Management Considerations and implications for the reef-line fishery

In the quest to supply this lucrative market, the fishery resources of many Southeast Asian countries have been heavily over-fished. Unsustainable fishing practices[6] have seen fish stocks dramatically depleted and habitat devastated (Bentley 1999, Johannes and Reipen 1995, Barber and Pratt 1997, Sadovy and Pet 1998). The demand for live fish is likely to continue growing, on the back of an expanding Chinese market. Further, trends over the past three years indicate that while demand for the high priced species[7] declines or remains steady, demand for live coral trout is increasing significantly (McGilvray and Chan 2001). The continued popularity of coral trout in Hong Kong and the over-exploitation of reef fish stocks in other major source countries suggest Australian exports from the GBR will play an increasingly important role in supplying this increasing demand.

The higher prices fishers receive from marketing their fish live has been shown to increase the profitability of their operations. Yet, while the value-adding of existing target species is a positive development, both positive and negative implications of the switch to live fishing emerge.

Mapstone et al. (2001) investigated the hypothesis that live fishing practices led to lower catch rates through increased handling time of catch. They speculated that lower catch rates may be offset by increased prices for live product to the extent that total revenue increases, benefiting both the fish stock and operators. However, their research concluded that 'live' and 'frozen' operations exhibited similar per vessel catch rates, emphasising the positive income effect from targeting live fish. Any long-term benefits will be contingent on the level of any new effort attracted to the fishery by the potential for increased profits. If too many new vessels enter the fishery, the excess effort may undermine gains from changing fishing practices.

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[6] The use of cyanide and dynamite, and targeting of spawning aggregations have been acknowledged as destructive fishing techniques occurring throughout south-east Asia that have ecological and economic implications.

[7] Humphead (Maori) wrasse and barramundi cod.

Evidence suggests the prospect of over-capitalisation in the RLF is a tangible one, and is being exacerbated by the presence of excess fishing capacity in the fishery. Despite it being a limited licence fishery, licensing arrangements have meant that a large proportion of potential effort is not being applied. This is compounded by uncertainty as to what constitutes a sustainable harvest in the RLF. The implications of mobilisation of this latent effort for the sustainability of the GBR reef fish stocks are not well understood. As Mapstone et al. (1996) point out, "the current dearth of conclusive data about the effects of line fishing on target species, non-harvested species, and current and future fishing is cause for considerable concern". This uncertainty reinforces the urgent need to manage for this excess capacity in the wake of economic incentives to enter this fishery.

The likely increase in demand for coral trout from Australia may precipitate structural and behavioural adjustments in the RLF. In particular this may lead to a concentration of effort among fewer operators, much in the way Individual Transferable Quotas are seen to transform market power (McCay 1996, Palsson and Helgason 1996, Copes 1997). At the other end of the spectrum is the possibility that smaller operations will represent the next wave of effort influx into the fishery. Both outcomes point to a need for stakeholders to work together in managing the difficult issue of effort reductions

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DISCUSSION MINUTES

Question (Rosemary Lea): You made the point that Australia now supplies 46% of Hong Kong's demand for coral trout. Why has the proportion of coral trout supplied by Australia increased so much? Is it because other countries have over-fished their stocks? Would it be fair to suggest that demand for coral trout will increase over the next few years?

Response (GM): Well there are two parts to your question, and I'll answer each separately. On the subject of why has Australia become a key exporter of the common coral trout, *Plectropomus leopardus*. It's no secret that destructive fishing practices such as cyanide fishing and dynamite fishing are widespread in many SE Asian countries. These countries have historically been the major exporters of coral trout but destructive fishing may be taking its toll in terms of their capability to maintain supply. Following on from this many countries that supply coral trout have a problem with high post-harvest mortality rates due to a combination of cyanide use and poor holding conditions. Another factor contributing to Australia's emergence as a key supplier is that it can offer a stable supply of a high quality product. Because all exports are transported by air the shipment can be in Hong Kong less than 12 hours after leaving Australia and with almost zero mortality. Lastly, political instability in some of the traditional supply sources in SE Asia and the Indo-west Pacific has effected their ability to maintain a constant supply.

On the second part of your question; yes it would be fair to expect an increase in demand for coral trout over the next few years. Coral trout is a high value species in the live fish trade and also one of the most preferred because of its colour. At present, 60% of imports into Hong Kong are re-exported to China but this percentage has increased from 30% five years ago. As China continues to open up and become more affluent, demand will undoubtedly rise. Also if China is successful in becoming a member of the World Trade Organisation we can expect an increased flow of coral trout directly into China

Question (Bob Grimley): With the shift from marketing product in frozen and filleted form to marketing product alive, have we seen the total take of coral trout stay the same or increase?

Response (GM): Many of the vessels that were already participating in the line fishery have simply switched from targeting fish for the frozen and fresh market to targeting fish for the live market. Even so the information from the QFS would suggest that total catches, of coral trout, have increased since the advent of the live trade.

Response (Mark Elmer): There has been a decline in the catch of fish destined for the frozen and fresh markets and an increase in the catch of fish destined for the live market. The increase in catch for the live market is greater than the decline in catch for the frozen market so overall total catch has increased. This is reflected in the 1996 – 97 logbook data and the fact that boat numbers for the fishery have gone up.

Response (Bruce Mapstone): I'd estimate that the catch of coral trout has increased by 10%

Response (Mark Elmer): The problem in estimating the change in catch of coral trout is the historical inaccuracies in logbook data filled out by fishers. In the early days of the fishery, reporting of live catch was not compulsory. A lot of the live catch was reported as whole so the live catch was greatly understated. It was only from 1998 onwards that logbooks were modified and it became compulsory to record live catch. The figures that are available on live catch can be adjusted by looking at export figures from AQIS.

Response (Bruce Mapstone): It may be that the early catch statistics are not completely accurate but there is no doubting that the trends tell a story. There has been an increase in exports of live product, which has corresponded with an increase in total catch of coral trout.

Comment (Steve Hall): Your discussion has raised an important aspect of the live fish trade and it's immediate future. You're saying that at an individual level, the live fish trade has the capacity to increase net revenue for live operators. This is resulting in more people being attracted to the fishery. This additional effort is coming from either existing fishers converting their vessels so as to market live product or new vessels entering the fishery for the first time. The latter category is evidence of the existence of 'latent effort' in the fishery. The extent of latent effort in the fishery is substantial. If it continues to be activated, the biological and economic sustainability of the fishery may be compromised. The fishery may not handle the increase in effort so it is urgent that the latent effort be managed for now.

Question (John Robinson): What about preferred size of fish for the live market?. Have fishers changed there targeting behaviour towards smaller fish?.

Response (GM): The preferred size of fish for the live market in Hong Kong is about 30cm which is smaller than the legal size limit in Australia. Fishers do prefer catching fish closer to the legal size limit because they receive a higher price from wholesalers who in turn get a better price from importers in Hong Kong.

Question (Rosemary Lea): When comparing live boats against frozen boats, how do the catch rates compare?

Response (GM): One of the commercial fishers in the audience may be better placed to answer that question.

Response (Terry Must): At one stage I had two boats running, one doing frozen and the other live. The frozen boat might bring in on average 1 tonne of coral trout per week for a two-week trip. The live boat probably brought in about ½ tonne for a weeklong trip.

Comment (Bruce Mapstone): Results from a recent FRDC report on live fishing show little difference in catch per unit effort between live and dead boats. Over the years handling has improved greatly and there's not too much extra time taken to release the fish alive.

Question (Leanne Fernandes): During your talk you mentioned a southerly shift of effort. Why are fishers shifting south (southern regions) where travel distances to fishing grounds are greater and therefore fuel usage and fuel costs are higher.

Response (GM): The fishers themselves aren't shifting south. The point I was making is that in Queensland the live fish trade started in the Cairns region, but over time there has been an increase in live effort coming from the southern regions. In the early days of the live fish trade, effort was concentrated around Cairns. At the time fishers were only able to keep fish alive onboard for up to five days. For boats operating out of Mackay or Gladstone, who travel for 16-20 hours to get to the fishing grounds a five day trip wasn't efficient. Improvements in animal husbandry have meant fish can be kept alive for up to 10 days making trips more cost efficient. So what I was saying is that fishers already in this region have subsequently changed to live fishing and now we see a greater proportion of overall live effort coming from the southern regions. Also in 1997 catch rates dropped in southern areas due to a large cyclone event. What we saw were some southern boats moving north in search of better catch rates. The following year they returned to their home ports that could have added to this pattern.

Question (Rosemary Lea): Where has your data originated?

Response (GM): From several sources. Some of the data have come from structured interviews with fishers, some from aggregated data supplied by the ELF project, from wholesalers and from governmental organisation in both Australia and Hong Kong.

Comment (Mark Elmer): Total export figures are very close to the mark and fairly accurately represent the trends in volume of live fish exported from Australia

Question (Bryony Barnett): It's surprising to see how the live industry in Australia is reliant on one particular species. To what extent does this dependency on one species affect the Australian market?

Response (GM): At present, there are no visible effects. The demand for coral trout remains strong and fishers are quite happily supplying this demand. The costs of transporting fish to Hong Kong generally preclude large quantities of species other than coral trout being exported. This is mostly because the prices paid for other species such as the cods aren't high enough to offer any sizable profits. I was recently informed by the Chairman of the Hong Kong Seafood Traders that demand and prices for the large cods (Flowery and Camouflage cod's) are increasing. Example of changing preferences.

Response (Howard Choat): In other countries supplying the live trade, epinephelines play a large part in those countries exports. If these cods continue to become more in demand, they may reduce some of the demand for coral trout which may remove some of the pressure off Australian coral trout stocks.

Question (Chris Roberts): Is there an opportunity for indigenous people on the Cape to get into the industry? What is the furthest point north that an operation can participate in the live trade.

Response (GM): I'd have to say yes but obviously there would be a fairly substantial financial outlay required in order to buy a boat and a licence. In terms of how far north a boat could operate, Cooktown is currently the northern-most port where live catch can be unloaded. Given that operators can keep fish alive for up to 10 days, I'd say probably 5 days north of Cooktown would be the northern most limit but it would depend where you started the trip from.

Question (Rosemary Lea): How do small operations differ from the large ones?

Response (GM): We actually have a small operator here. His operation consists of a single speedboat, no dories. He probably travels further to the reef from Bowen than most large operations.

Response (Dennis Rodgers): The operation is commercially viable but you only fish when the prices are high and because of the size of your vessel, you're restricted by the weather.

Question (Leanne Fernandes): What about by-catch. Are there any differences between live and frozen operators in terms of by-catch?

Response (Bruce Mapstone): There tends to be less by-catch with live operators. In a recent FRDC funded ELF project on the live trade we placed observers on live vessels and conducted confidential interviews. Results showed by-catch to be about half that of frozen operators. Also more of these were released. Also if a dory-man began fishing a particular hang but was catching fish other than trout he'd be more likely to move to a new site in search of coral trout.

Response (Robin Stewart): There is a big difference in the amount of by-catch between when you're targeting fish for the frozen or live market. When we are freezing and filleting the catch, by-catch is much higher than when we are keeping the catch alive. When fishing for live, much less red throat emperor and small snappers were caught or kept.

Response (Terry Must): There's less caught but also more thrown back. Crew doesn't want to have to process fish and some skippers won't pay fishers for lower value species. Also some operators are storing some of their catch on ice for the fresh market. There are restrictions on how much ice you can carry and trips are shorter so you don't want to waste space on other species.

Comment (Jake Kritzer): A post release mortality study looking at survival rates in small snappers showed survivorship of released fish to be quite high.

Question (Ann Ferguson): Is there a risk of over-capitalisation, particularly with the level of latent effort in the fishery? How confident are you that catch rate is sustainable?

Response (GM): Certainly there is a big risk of over-capitalisation. Not so much over-capitalisation of individual operations, but for the fishery as a whole. This is the latent effort issue, which is hopefully being addressed through the draft management plan proposals. On the issue of what is a sustainable catch, I'd defer to Bruce Mapstone.

Response (Bruce Mapstone): No-one can really answer that but work is being done. There is a long-term goal for sustainability for the line fishing industry. Dealing with latent effort is the most pressing issue now and it will be a huge job. There is a lot of work to be done in this area in order to ensure the fishery is managed more sustainably. Fishing mortality at the moment is 0.3 – 0.4.

2. RECREATIONAL FISHING IN THE GREAT BARRIER REEF REGION.

Jim Higgs

Introduction

As with most recreational fisheries around the world, the managers of the Queensland Great Barrier Reef (GBR) recreational line fisheries have been operating in an information poor environment. In the 1980's there was only one estimate of the magnitude of the recreational fish catch (6,570 to 8,770 tonnes) for the reef line fisheries (Driml et al. 1982), and a forecast that this catch would reach 12,000 tonnes by 1990 (Craik 1989). The second GBR wide recreational fishing survey indicated that the catch for 1990 was in fact between 3500 to 4300 tonnes (Blamey and Hundloe 1993).

In response to the inclusion of the principles of Ecological Sustainable Development (ESD) into the Fisheries Act (1994)[8] the Recreational Fishing Information Coordination Committee (RFICC) was established in 1995 and tasked with establishing the most appropriate means of monitoring the activities of the Queensland recreational fishery (QFMA 1995). Based on consultation with a range of fisheries research and management agencies including the CRC Reef Research Centre, RFICC suggested that the centrepiece of the monitoring program should be a statewide multistage telephone survey to determine community participation rates (QFMA 1999). Volunteers identified during the telephone survey were then asked to maintain a diary of their fishing activities to provide data for estimating the catch characteristics of the Queensland recreational fishery (Higgs 2001, Higgs 1999). It was further recommended that the recreational fishing survey (RFISH) occur on a biennial basis to allow for trends in the recreational fishery to be monitored in line with the commercial fisheries logbook program.

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[8] Direct regulation of the fishery and fishing activity is administered under the *Fisheries Act* (1994) by the Queensland Fisheries Service (QFS). The Act also sets out the legal requirements for the development, implementations and repeal of fisheries management plans by the QFS.

Information collected as part of the RFISH program is to be incorporated into the management planning process to ensure that the catches of the recreational sector are factored into the development of fisheries management plans. This will strengthen management efforts to meet the sustainability goals for Queensland fish stocks for present and future generations.

Results

From information collated from RFISH telephone surveys conducted during 1996 and 1998, the number of Queensland residents, aged 5 years and above, who had fished in the 12 months prior to the telephone surveys was estimated at 882,000 and 848,000 respectively.

Of these totals, an estimated 229,000 (26.0%) anglers in 1996 and 215,000 (25.4%) in 1998 resided in the Rockhampton, Mackay, Northern (Townsville) and Far Northern Statistical Divisions (SDs) that are adjacent to the GBR Marine Park. A similar minor decrease in the numbers of fishers in these Statistical Divisions aged 15 years and above was also recorded (177,000 (20.1%) in 1996 to 164,000 (19.3%) in 1998 (QFMA 1999). Of these anglers aged 15 years and above, those who had fished from a boat, or from a boat and shore, and assumed to be able to access species within the tropical coral reef line fisheries plan accounted for just over 72% in both survey years.

Of those anglers who indicated they had fished for saltwater species in either 1996 or 1998, only 35% and 36.6% respectively indicated that they had targeted a particular species of fish in the 12 months prior to the telephone surveys. Mackerel species (5.3% and 5.1%), coral trout (2.6% and 2.6%), mangrove jack (1.7% and 2.3%), reef fish species (unspecified) (1.6% and 1.7%), emperor/red emperor (1.1% and 1.6%) and sweetlip/red throat (1.2% and 1.4%) were the top coral reef target species identified by anglers during the telephone surveys (Roy Morgan Research 1998).

In 1996, the proportion of anglers from the Far Northern (60.2%), Mackay (56.3%) and the Northern (55.1%) SDs who went recreational fishing for “food” was significantly higher than the State average (49.1%) (Roy Morgan Research, 1996). In

1998, only anglers in the Far Northern (53.1%) and Mackay (50.4%) SDs were significantly more likely to fish for food than the statewide average (42.1%) (Roy Morgan Research, 1998). Overall, there was a significant decline in the percentage of anglers that had fished for food between the two surveys.

When comparing those anglers who had indicated they fished for food, on the basis of age, considerable differences were evident. From the 1996 survey, 60+ year old anglers (57.1%) were more likely to fish for food, and the 20-29 year old anglers (44.9%) less likely to fish for food than the statewide average of 49.1% (Roy Morgan Research 1996). In 1998 anglers aged 50-59 and 60+ years old were again significantly more likely to go fishing for "food" while anglers aged 15-19 (34.5%) were significantly less likely than the state average (42.1%) to indicate that obtaining food was a reason for fishing (Roy Morgan Research 1998).

Harvest estimates from the 1996 and 1998 diary programs indicated that the recreational catch was in the vicinity of 46 and 48 million fish (fish, crabs, squids, freshwater crayfish and their like - excluding prawns) respectively (Higgs 2001). Coral trout catches remained consistent between the surveys at around 552,000 and 589,000 fish, respectively, or approximately 1.2% of the total statewide recreational catch. Of these catch totals for coral trout only 306,000 (0.7%) and 329,000 (0.7%) were actually harvested, with the remainder released as undersized.

During 1999, a large number of anglers participated in a diary program to collect data for estimating catches of coral trout. Catch data from this diary survey were compared against targeting data collated from the 1998 telephone surveys. Regional catches of coral trout were found to be reflective of the percentage of total numbers of anglers that indicated they had targeted coral trout in the 12 months prior to the diary survey (Figure 2.1). Further, both these surveys highlighted the importance of coral trout to the northern coastal regions of Queensland.

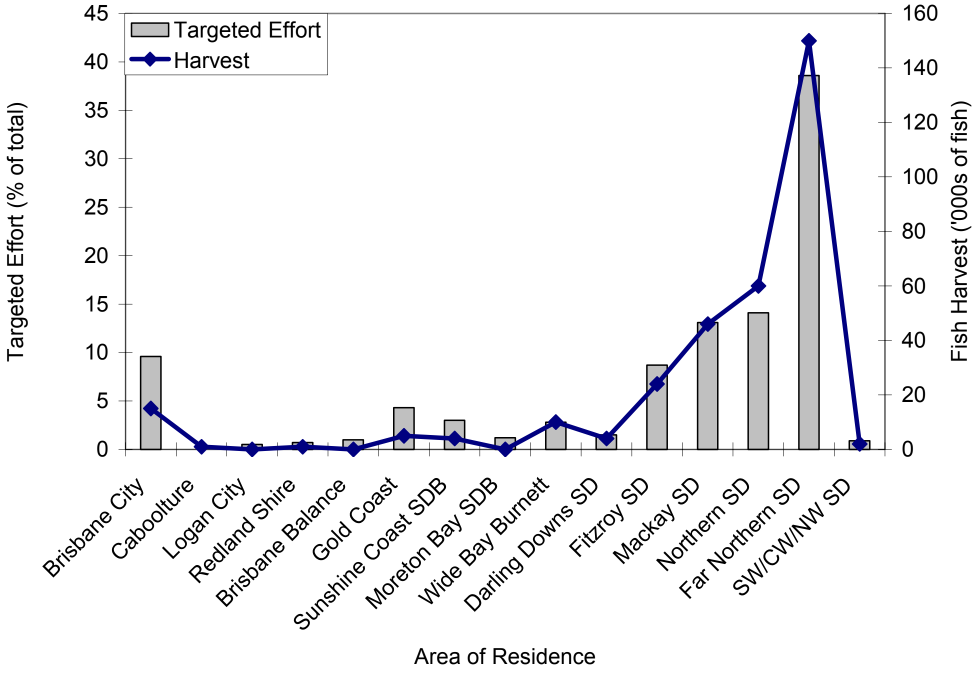

Figure 2.1. A comparison of the regional summary of the coral trout catches reported in the 1999 diary program and the percentage of total survey participants who indicated they had targeted coral trout during the 1998 RFISH telephone surveys.

Conclusion

Fisheries managers within Queensland now have access to one of the most comprehensive recreational fisheries data sources available in Australia from which to obtain information for developing fisheries management plans. Information collated as part of the statewide recreational fishing surveys is gaining greater credence as more data is collected. As the credibility of the data improves, its use in the negotiation stages of fisheries management plan development will become more accepted by stakeholder groups. The information currently collected highlights the importance of the recreational sector in harvesting a number of species within Queensland.

Information from these recent statewide surveys indicates that the harvest of coral reef species such as coral trout is considerably lower than those estimates from the GBR wide surveys conducted in 1980 and 1990. There are a number of possible explanations for these differences. An obvious explanation is the differences between the survey methods adopted during the earlier GBR wide surveys and those employed during the recent RFISH statewide surveys. Concerns over the lack of useful comparisons of results that could be made across the surveys, because of the different methodologies employed, was one of the primary reasons behind the decision to conduct the new statewide surveys on a biennial basis (QFMA 1995).

Another possible explanation for the difference in the catches between the earlier and later surveys is that there has been a major change in the motivations and attitudes of recreational anglers accessing the GBR line fisheries. Unlike many states within Australia, prior to 22 May 1990 anglers were able to sell part of their catch under Section 35 of the *Fishing Industry Organisation and Marketing Act 1982.* Although there were relatively small amounts of fish product sold under Section 35, a substantial amount of black marketing of product was thought to occur, with some sections of the fishery assuming the existence of Section 35 inferred a right to all unlicensed fishers to sell product. With the abolishment of this Section, the commercial incentive to harvest sufficient numbers of coral reef species to offset costs of the trip to reef locations was removed, potentially reducing the recreational harvest from the GBR proper.

Although because of methodological differences the recent statewide surveys are not directly comparable with earlier GBR wide surveys, it is interesting to note the importance of consumptive motivations reported by respondents to recreational fishing surveys conducted in 1980 and 1990. Blamey and Hundloe (1993) found that 76% of their respondents indicated that "fishing for food" was an "important" or "very important" reason for fishing. It was, however, ranked less important than reasons for fishing including to: "Relax and unwind"; "outdoor family enjoyment"; "enjoy natural surroundings"; and, "thrill of contest/catching fish". Unfortunately no attitudinal component was included in the earliest GBR recreational fishing surveys, but an estimate of the proportion of anglers that sold their catch was provided. Hundloe et al. (1980) reported that 23% of respondents that had fished in the Capricornia Section of the GBR Marine Park had sold fish in the 12 months prior to the survey. Of these fishers, approximately half had sold fish to friends, with only one third sold legitimately through the Queensland Fish Board. The remaining fish were sold to fish shops, restaurants or did not have a nominated buyer.

The presence of regional and age specific differences in angling motivations indicates the necessity to include this type of information in any ongoing angler surveys to enable the development and selection of management regimes that will deliver the management responses with the least impact on the angling population. The ability to predict the motivational characteristics of the angling population is essential in the development of ongoing management regimes that will continue to deliver the desired outcomes as the Queensland recreational fishery enters the 21^{st} century.

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DISCUSSION MINUTES

Question (Mick Bishop): Effort creep is important in the commercial fishery. Is this important in the recreational fishery?

Response (JH): Better equipment does not necessarily relate to more catch for recreational fishers. Looks like effort in the recreational sector will actually decrease, but better technology may mean the catch remains the same. However motivation for going fishing is not always around catching lots of fish.

Question (John Evetts): Can the survey results be split up into coastal fishing and reef fishing? What percentage fish on reefs?

Response (JH): The survey results can not be split into coastal and reef fishing from phone surveys, however logbook surveys do have that information. From this information not many fish on reefs.

Question (Vern Veitch): Queensland transport has information on the size of recreational boats. Not many large boats are being sold currently. Is there any estimate of a break down of size range between vessel owners?

Response (JH): Previously when recreational fishers could sell their catch, this may have influenced the size of boats that people had. This is now not allowed and probably influenced the size of boats being used in the recreational fishery to smaller boats.

This will probably be more so in the future as people do not have time to go fishing. This may also increase demand for charter fishing trips as people opt to not have their own boat as they don't use them often, and instead go out with a charter operator. (JH)

Question (Helene Marsh): Indigenous fishers have different motivations for fishing, and studies in Torres Strait show this. There is now many more Torres Strait Islanders living in cities such as Brisbane, and this should be an important consideration for management as these demographics may influence fishing activities in these areas.

Response (JH): Recreational fishing phone surveys do get some of this information, but it is an important consideration for management.

Question (Geoff Muldoon): Cairns areas have a large percentage of people targeting coral trout.

Response (JH): This is probably due to reefs being close by that are easily assessable by recreational fishers. This information can help by indicating where management considerations are needed.

Question (unknown): Does boat ramp survey information match with the phone surveys?

Response (JH): Even though there has been a number of boat ramp surveys completed they are not directly comparable as they are not carried out on a regional basis, thus making comparisons difficult.

Question (unknown): What sort of dropout rate is there on the surveys?

Response (JH): There is around a 40% dropout rate on the diary program. There is no correlation in the fishing activities between those that drop out and those that stay in. That is, the keen fishers are not staying in the program longer than the occasional fisher.

There is a greater need to investigate the motivations of Queensland anglers and to determine if there are significant regional differences in fishing motivations and attitudes. For example, the next survey may well show a decreased number of young males going recreational fishing as a direct result of increased competition for recreation time by other activities such as computer games etc.

3. BIAS IN FISH SAMPLES TAKEN BY LINE FISHING ON THE GREAT BARRIER REEF.

David J. Welch

Introduction

Fish sampling

We sample fish populations in the hope of obtaining a "snapshot" that represents the larger stock. With that snapshot, we can then estimate a number of different population characteristics. These include abundance, mean sizes and ages, rates of growth and mortality, patterns of movement, spawning frequency, and age and size at maturity or sex change. For fished populations, this information is crucial as it is the type of information that ultimately determines the management strategies for the fishery.

How we sample a fish population depends largely on the species in question. Often, the best method is the harvest gears commonly used by that fishery. On the Great Barrier Reef (GBR), hook and line is used extensively by both recreational and commercial fishers targeting demersal reef fish. It can be relatively simple and cost-effective to obtain samples of GBR reef fish species directly from line fishers. Also, structured research sampling using hook and line can provide scientists with a relatively cheap source of samples because many samples can be collected over large areas and depth ranges in a short period of time. Hook and line therefore represents a potentially useful method for both fishery-dependent and fishery-independent sampling.

Sampling bias

We know from experience that all fish sampling gears are biased to some extent (Miranda et al. 1987, Hovgard and Riget 1992, Pope et al. 1975). That is, they do not give us a sample of fish that is representative of the overall population. This bias is usually size-dependent, meaning that fish of a certain size are more likely to be caught than fish of a different size. For example, larger fish have been observed to chase smaller fish away from baited hooks in some species (Bertrand 1988, Lokkeborg and Bjordal 1992), and I have observed this behaviour among coral trout on the GBR. Clearly, this behaviour will make certain fish more likely to be caught and will therefore affect the sample that is collected. Other factors that may influence the sample collected are fish mouth size and gape relative to hook size (Ralston 1982, Cortez-Zaragoza et al. 1989, Lokkeborg and Bjordal 1992).

Samples affected by gear selectivity or fish behaviour will produce inaccurate, or biased, estimates of fish size. Since there is generally a relationship between size and age in fish, estimates of age would also be biased. It is therefore likely that estimates of survivorship, growth and average maximum size will also be biased. This type of information is important for stock assessments because it determines the natural resilience and productivity of a stock. This then indicates how much yield can be sustainably removed from a fish stock, and how quickly the stock will recover from fishing. It is therefore critical that we are able to determine the extent and implications of bias in the sampling methods we use in order to minimise the uncertainty inherent in fisheries management.

Study objectives

The objectives of this study were twofold:

i) to determine the relative bias in line caught samples of common coral trout, *Plectropomus leopardus* using several different population indices, and

ii) to see if the bias was consistent over different areas and different management zones of the GBR.

The common coral trout was chosen for this study because it is the species most heavily targeted by line fishers on the GBR, accounting for up to 35% of the total commercial catch (Mapstone et al. 1996).

One way to estimate the relative bias of line fishing is to compare the age and size information obtained from line fishing with those obtained from similar areas at a similar time by another potentially less biased fishing gear. One sampling gear that is potentially less biased is spear fishing. I confirmed this in a pilot study that compared speared samples with underwater visual surveys conducted at the same time and place and found the samples to be similar (Welch 1998). Subsequently, I collected common coral trout samples during structured spear fishing surveys on reefs from the Lizard Island, Townsville, Mackay and Swains regions of the GBR. These reefs constitute the reef clusters that form part of the Effects of Line Fishing (ELF) Project and included reefs both open and closed to fishing. These same reefs were sampled at a similar time by structured line fishing to compare the two methods. To estimate the relative bias of line fishing I examined the differences in estimates of average size and age, size and age distribution, growth and survivorship between line- and spear-caught samples.

Results

The average size estimated from the line-caught sample (40.5cm) was 21% larger than that estimated from the spear-caught sample (33.6cm) (Figure 3.1). The average age estimated from the line-caught sample (5.0 years) was 43% older than that estimated from the spear-caught sample (3.5 years) (Figure 3.1).

SPEAR
Average size = 33.6cm
Average age = 3.5 years

LINE
Average size = 40.5cm
Average age = 5.0 years

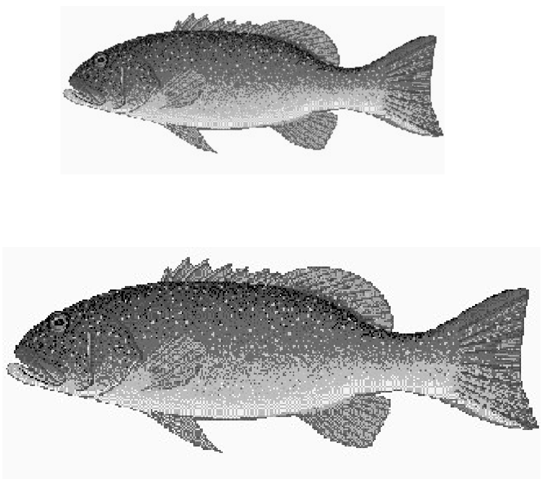

Figure 3.1. Relative difference in average size and age between line-caught and spear-caught samples of common coral trout.

The size distributions of the line and spear fishing samples show that the most striking difference between the two methods is the proportion of small fish. Line fishing caught very few fish smaller than 31cm, whereas a large proportion of fish sampled by spear fishing were less than 31cm (Figure 3.2). Further, it is likely that spear fishing underestimates the number of smaller fish (< 200 mm FL) due to the increased difficulty in both sighting and capturing these individuals (Welch 1998). There is also evidence that line fishing may have sampled the larger fish more representatively. This potential bias of spear fishing might be due to the fact that sampling by spear was restricted to depths of 10m or less whereas line sampling was able to sample a much greater depth range. Larger fish of a population are often found in deeper water (Ayling 1983, Morales-Nin and Ralston 1990, Wigley and Serchuk 1992), and anecdotal evidence from the GBR suggests that this is also the case for common coral trout.

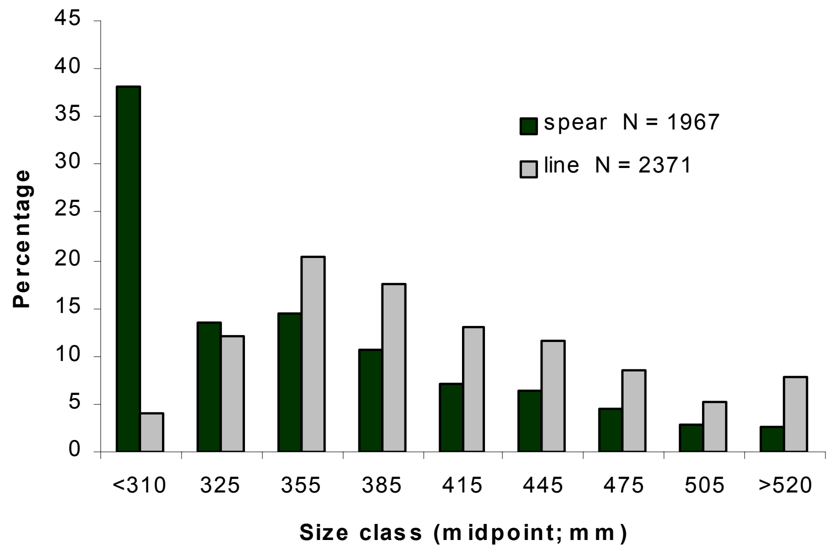

Figure 3.2. Size frequency distributions for the spear- and line-caught samples pooled across management zones and regions. Line fishing under-sampled smaller (<310mm) fish, but spear fishing might have under-sampled the largest fish.

A comparison of the age distributions between methods showed that line fishing caught very few fish younger than 3 years old, while a large proportion of the spear catch was comprised of these young fish (Figure 3.3). Line fishing also appeared to sample the older fish (>5 years) more effectively possibly due to the biases in the spear method as mentioned earlier. The differences in average size and age and size and age distributions between methods (Figures 3.1-3.3) were consistent among the different regions and management zones of the GBR sampled in this study

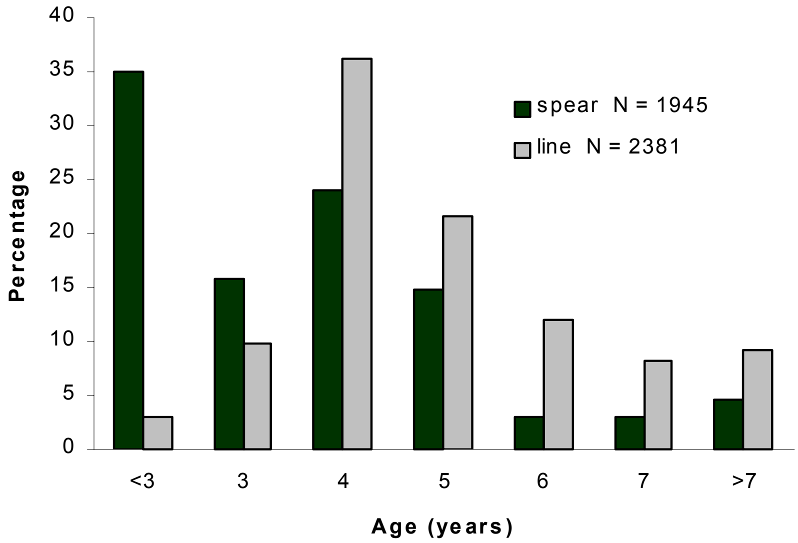

Figure 3.3: Age frequency distributions for the spear and line samples pooled across management zones and regions. Line fishing under-sampled the younger (<3 years old) fish but spear fishing may have under-sampled the older (>5 years old) fish.

Estimates of growth were then calculated using the size and age data collected by each method. Not surprisingly, the growth trajectories estimated for each method were quite different (Figure 3.4). At early ages, predicted growth patterns were fairly similar. However, the methods differed in estimating where the growth curve begins to flatten. The point at which this flattening occurs is an indication of the average maximum size attained by fish in the population. The line fishing sample estimates this length to be larger than the spear fishing sample. This difference becomes much more exaggerated if we consider growth in terms of weight or biomass rather than length (Figure 3.5).

Estimates of survivorship were also calculated for each sample as the proportion of fish that survive from one age class to the next (Welch 2001). The survivorship estimate derived from the spear-caught sample was 63%, while the estimate derived from the line-caught sample was 55%. This difference means that we would estimate that 8% more of the population will survive to the following year using the spear-caught sample, than if we had used the line-caught sample. This difference becomes especially significant when compounded over time. The differences in growth and survivorship between methods were also found to be consistent among the regions and management zones.

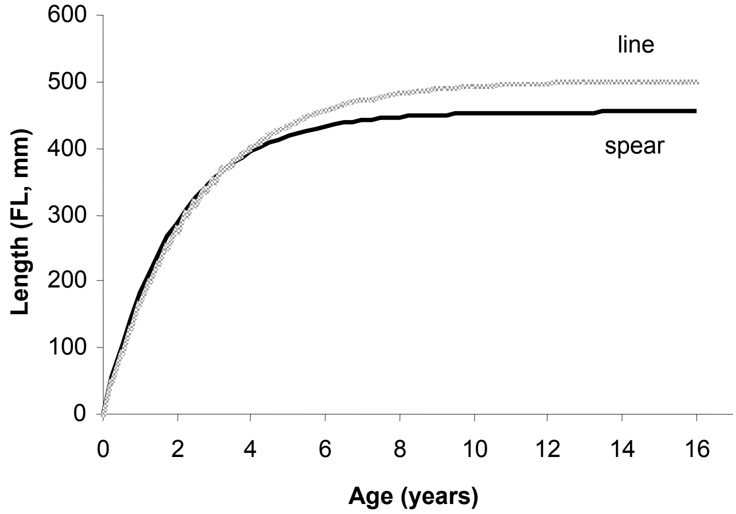

Figure 3.4. The growth curves derived from the spear and line size and age data showing that the line-caught sample estimates a larger average maximum size.

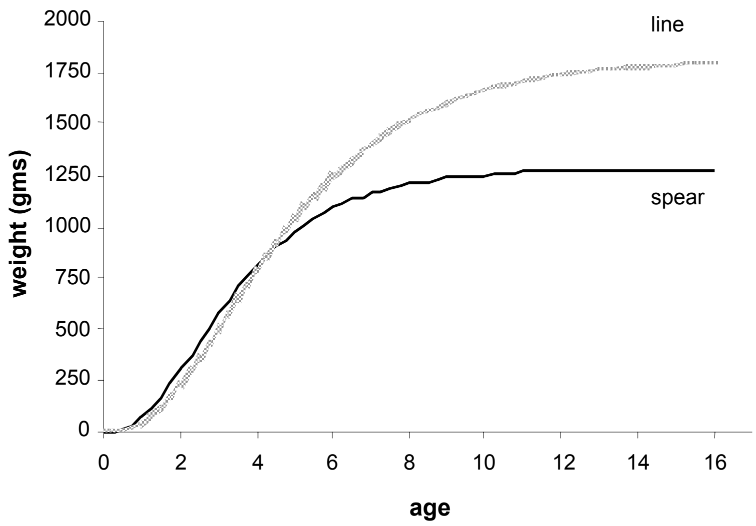

Figure 3.5. The growth curves derived from the spear and line size and age data this time expressed in terms of weight[9]. This better demonstrates the greater growth potential estimated by the line-caught sample.

In summary, line fishing tends to under-sample smaller, younger fish resulting in over-estimation of average size and age. Line fishing is also more likely to over-estimate the growth potential (an index of productivity) of a fish stock, but under-estimate survival rates. Importantly, these observations were consistent among different regions and management zones of the GBR.

Management implications

With large hook sizes and large bait sizes line fishing generally catches larger fish (see Lokkeborg and Bjordal 1992). What is clearly demonstrated in this study is the extent that line fishing under-samples small, young fish. The spear fishing samples show that these fish make up a large proportion of the population. These are also the fish that are critical for estimating age and size at maturity. From a management perspective, it is important that minimum legal sizes allow some fish the opportunity to reproduce at least once before they recruit to the fishery. Only by effectively sampling the smaller, younger fish can we obtain reliable information about when fish are likely to reach maturity. Furthermore, being able to sample smaller, younger fish may also be useful in assessing reproductive responses of a population to fishing pressure. Line-caught samples are less likely to provide accurate information without supplementing the sample with fish caught by another gear. For example, alternative sampling methods (eg. spear fishing or fence netting, Ferreira and Russ 1994, Choat and Axe 1996), or variations in the line gear (eg. smaller hook and bait sizes), may better capture smaller individuals. Underwater visual surveys (UVS) are a quicker alternative sampling method, however they are prone to underestimating numbers of smaller fish (Ayling 1983) and are only useful for estimating size and relative numbers since length is a poor indicator of age (Ferreira and Russ 1994).

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[9] Weight was estimated using the formula of Ferreira and Russ (1994) that describes the relationship between total weight and fork length in *P. leopardus*.

Age structures provide important information about fish stocks. They may reflect different biological characteristics of a population that might indicate discrete stocks (eg. Smith et al. 1998), reflect fishing effects as fishing most often impacts on older fish in a population (Russ 1991), or provide information about recruitment history (Jones 1991, Doherty and Fowler 1994). These types of information are all extremely useful for managers so it is important that samples replicate age structures as completely and accurately as possible. For example, because line fishing under-samples the youngest age classes, weak or strong year classes will not be identified in line-caught samples before they become vulnerable to the fishery. Knowledge of these weak or strong year classes can be useful for predicting poor or good fishing years in advance and modifying harvest strategies appropriately (Russ et al. 1996).

Line-caught samples also potentially overestimate the growth potential of a stock and underestimate rates of survival. Greater potential for growth implies that more biomass can be taken from the stock because the stock is better equipped to rebuild. Similarly, lower survival rates (higher natural mortality rates) suggest that the stock is less vulnerable to fishing. Any increase in mortality due to fishing is proportionally small when natural mortality is high compared to a population with lower natural mortality. Using overestimated mortality rates in a management context would therefore mean that the level of fishing effort predicted to maximise yield is likely to also be overestimated (Welch 2001). The result may be that the stock is fished at an unsustainable rate. The estimates based on line-caught samples would provide the least conservative estimate of fishing effort needed to maximise yield.

This study found that the bias present in the line samples was consistent across regions and management zones of the GBR. This is an important result in that line-caught samples can be readily evaluated relative to spear-based data, regardless of where the line samples were collected (ie. no zone or region-specific bias). These consistent patterns also indicate that line fishing alone is useful for relative comparisons of population characteristics. For stock assessments and predictive modelling, however, data derived from line-caught samples should be treated with extreme caution.

This study highlights a consideration frequently neglected when sampling fish populations: the effects of the gear used to collect the sample. Researchers and managers both need to be aware of the potential biases associated with sampling gears so that the data can be interpreted and applied in the most appropriate manner.

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DISCUSSION MINUTES

Question (Vern Veitch): With the spear fishing sampling, was it geared to sample the whole size range of the population?

Response (DW): Yes. The spear fishing method used was specifically designed to minimise the selection of particular sized fish and aimed to, as representatively as possible, sample the whole size range.

Question (Mark Elmer): Is the take home message that there is bias in line fishing assessing and monitoring?

Response (DW): Yes it is. Relative comparisons of different populations on the GBR are likely to be valid from line samples, however for use in stock assessments data are biased and should be treated with caution. The line fishing gear used mimicked standard gear for the reef line fishery. That is, relatively large hook sizes and relatively large bait sizes were used which tends to effectively target larger fish. Commercial fishers use this gear so they are not catching small fish that have to be returned. There is room for research on gear selection and another way to better understand hook and line selection would be to compare the catch from a range of different hook sizes.

Question (Mark Elmer): Recreational fishers release 60% of fish caught. What do we know of the survival of coral trout after release?

Response (DW): There have been limited studies on post-release survivorship of fish and this was not within the scope of this study.

Comment (Bruce Mapstone): Hook size was standardised over the catch surveys which influences selectivity of fish caught. In the commercial fishery, hook size may be selected to ensure undersized fish are not taken. 100% selection to hook and line gear used in the GBR line fishery occurs at about 39cm. For recreational fishers where different gears are used, size selectivity will be much different.

Question (Leanne Fernandes): Did you do a pilot study to compare your 10 metre depth limit with 20 metres? For instance, if your dives were to 20m does this change the samples?

Response (DW): There is catch data from the line catch surveys that can be broken into samples from <12 metres depth and from >12 metres for comparison. I haven't done that comparison but it is a valid point as there is ample anecdotal evidence (and some empirical) of large fish generally inhabiting deeper water. The 10m limit for spear fishing was a logistic and safety issue.

Comment (Leanne Fernandes): Spearing may actually be underestimating size, as it didn't seem to get as many of the larger fish. Visual surveys indicate spear is underestimating small fish, while catch surveys indicate that spear is underestimating larger fish.

Response (DW): Visual surveys and spear samples were quite similar. Spear sampling may actually be under-sampling very small fish such as those under 20cm. If spear does under-sample the larger fish as it appears to do, then the bias at each end of the size range will probably cancel each other out to some extent.

Comment (Leanne Fernandes): This may suggest that visual samples may be better than spearing if otoliths and gonads are not required.

Response (DW): I didn't go into visual surveys specifically here but rather used it to test a method I felt pretty certain was a less biased method than line fishing. If you don't require samples UVS is better because it is non-destructive.

Question (Bryony Barnett): Spear fishing is managed differently to line fishing eg. yellow zones no spear fishing, but allows line fishing. How does this study reflect on this?

Response (John Robinson and DW): Data was structured for research. It was done on SCUBA, and included undersized fish. Therefore it does not reflect in any way normal spearfishing activity.

Question (Vern Veitch): Can the information from your studies be used to modify the computer model (ELFSim) for future management? Can this information be used to make sure information used in the model(s) is reflective of actual stocks rather than that which is caught?

Response (DW): This data has already been used to tune the ELFSim model. The main use of information from this study to date has been to develop a gear selection model for hook and line fishing on the GBR.

Question (Geoff Muldoon): The growth rate from the line sample indicates there is more potential for fishing mortality, however survivorship is lower in the line data. If there is a high mortality rate already can you fish harder, faster?

Response (DW and Jake Kritzer): An increase in fishing mortality will be proportionally less to a population with high natural mortality than to one of lower natural mortality. The line data in this case would therefore predict the least conservative estimates of fishing effort. The old rule of thumb is fish at twice the mortality rate.

Comment (John Evetts): In charter fishing we now see a lot more undersized coral trout caught. In recent years we have been using smaller hooks (5/0).

Comment (Robin Stewart): In commercial fishing we haven't noticed any difference in numbers of undersize fish. Commercial fishers use larger hooks (7/0 – 9/0) and this may influence numbers of under sized fish caught. Differences in numbers of undersize fish may only be important if differences in hook size are, say, 9/0 to 5/0.

Comment (Terry Must): Differences are seen in different areas, some areas we see lots of undersized fish. If we find ourselves in these areas we move.

Comment (Ray Gleeson): We see around 50% undersized fish captured.

Question (Annabel Jones): Do you have any comment on the ability of spear to select specific fish? Can spear-fishers tell if a fish is under-size?

Response (DW): While the spear study was artificial in the design, that is there was a requirement to catch undersized fish, from my own experience spear-fishers can very effectively select their targets. An issue for me was to get spear-fishers to change their habits and to target undersize fish. In practice I think recreational spear-fishers tend to err on the side of caution and select not to target fish that may be undersized.

Response (John Robinson): Especially in more recent times, spear-fishers have a good reputation for being very responsible in their catch and therefore the total numbers of fish speared is much reduced. The real power with spear is you can target what you don't want to catch. Most commonly the fish you see and want to catch, you probably won't.

Response (Mark Elmer): I think spear fishing may be a more ecological way to fish by reducing by-catch. Spear fishers are generally enthusiasts. They have a good track record of responsible fishing practices.

Response (DW): In the early days of recreational spear fishing some individuals gave the sport a poor reputation. Things have changed dramatically and today they are generally very responsible.

4. REGIONAL VARIATION IN THE DEMOGRAPHICS OF THE RED-THROAT EMPEROR AND THE IMPLICATIONS FOR MANAGEMENT.

Ashley J. Williams

Introduction

Fishes of the family Lethrinidae, more commonly known as "emperors" are abundant on coral reefs of the Indo-Pacific region and are important target species of many commercial, recreational and artisanal fisheries (Carpenter and Allen 1989). The red-throat emperor, *Lethrinus miniatus*, is a relatively long-lived member of the Lethrinidae family, usually inhabiting coral reefs and surrounding shoal areas of the western Pacific and eastern Indian Oceans (Carpenter and Allen 1989). The red-throat emperor is the second most important demersal species in the Great Barrier Reef (GBR) reef line fishery, accounting for up to 1000t of the combined annual commercial and recreational catch (Mapstone et al. 1996, Higgs 2001).

The commercial importance of red-throat emperor has prompted a number of studies on the species over recent decades (Walker 1975, Loubens 1980, Church 1995, Brown and Sumpton 1998, Williams et al. 2003). Estimates of population characteristics of red-throat emperor, such as growth and survival rates, have differed widely among these studies. These discrepancies may be due to a number of factors including the geographic locations of the studies, methods of collection, and techniques used for estimating age and growth rates. This paper uses data collected as part of my doctoral research to describe the population characteristics of red-throat emperor across the spatial extent of the GBR, focusing on regional differences in these characteristics. The population characteristics used to examine variation across the regions of the GBR include average age, growth, survival rates, and reproductive traits. Where differences do exist, the implications for the management of this species are discussed.

Current biological knowledge and management of red-throat emperor

The red-throat emperor is one of the most abundant predators in the Lethrinidae family, and is commonly found on mid and outer shelf reefs between Cairns and the Capricorn Bunker group. They live to approximately 20 years of age and grow to about 60 cm fork length. Recently we have confirmed that they change sex from females to males at some stage during their life and it is thought that the process of sex change is quite rapid (Bean et al. 2003). Unfortunately the juvenile habitat of red-throat emperor has yet to be located and as such we have no information on the early life history of this species. The location of the juvenile habitat remains a high priority for future research.

The current management strategy for red-throat emperor includes a minimum size limit of 35 cm for all line fishers and a possession limit of 10 fish per person for recreational and charter fishers. These restrictions are currently uniform throughout the entire GBRWHA, the implication being that red-throat emperor can be managed as a single uniform population.

Regional variation in spawning season and reproductive potential

Monthly samples were collected from commercial fishing vessels operating in four regions of the GBR (Townsville, Bowen, Mackay, Swain reefs) to look at regional variation in the spawning season and reproductive potential of red-throat emperor.

The size or weight of female ovaries is often used as an indicator of the spawning season for a species. The time of year when female ovaries are at their largest gives an approximate indication of the spawning season. The size of female ovaries obviously depends on the size of the fish, so a relative measure of gonad weight is needed. The gonosomatic index (GSI) takes into account this size variation of the fish and is simply the weight of the gonad divided by the weight of the fish, expressed as a percentage. The average GSI for female red-throat emperor during the spawning season is usually greater than 1% (Figure 4.1). This means that the ovary makes up more than 1% of the total fish's body weight.

Based on monthly measurements of GSI for 2 consecutive years, the spawning season for red-throat emperor on the GBR was found to be between July and October (Figure 4.1). This period of spawning activity was found to be very similar across all four regions of the GBR. That is, red-throat emperor appear to be spawning at the same time in all regions of the GBR. This contrasts with other reef species such as the coral trout, which has been suggested to spawn earlier at lower latitudes.

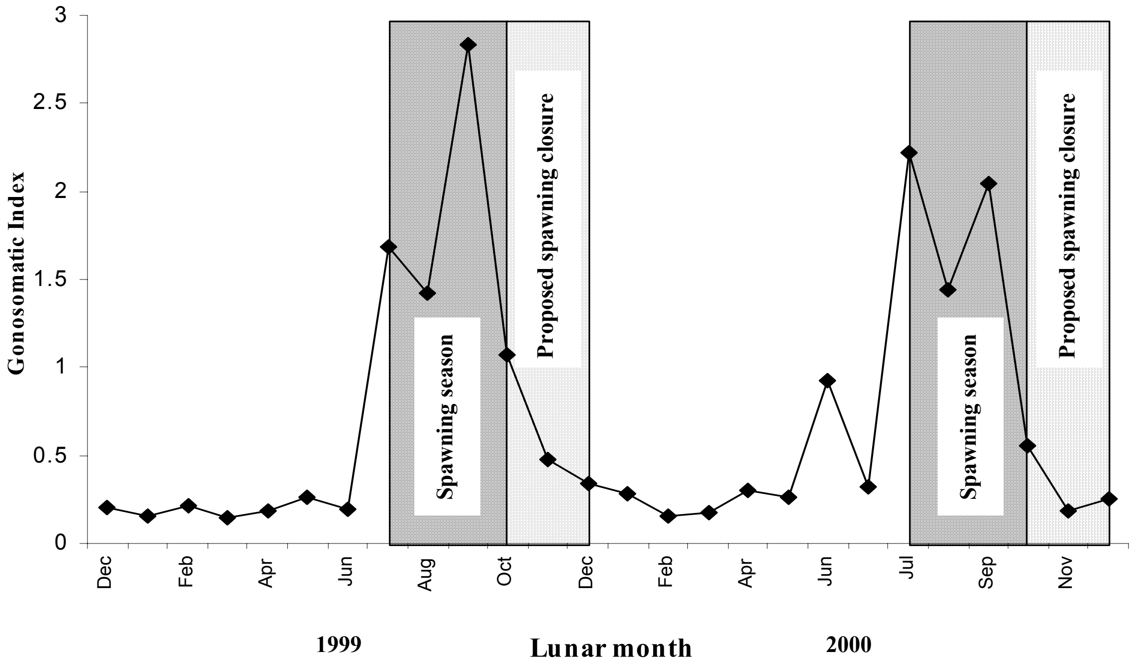

Figure 4.1. Monthly gonosomatic indices (GSI) for female red-throat emperor for two consecutive years. The spawning season (period with highest GSI values) and period of proposed spawning closure are also shown.

Although the spawning season of red-throat emperor is similar throughout the GBR, there appears to be differences in the spawning potential in different regions of the GBR. In the more northern regions of the GBR (Townsville, Bowen) a greater proportion of females are in spawning condition (ripe females) during the spawning season than in the more southern regions (Mackay, Swains) (Figure 4.2). This suggests that the spawning potential for red-throat emperor may be much greater in northern GBR regions where densities of red throat emperor are lower (Williams and

Russ 1994), implying these populations are capable of producing proportionally more larvae than are populations in the southern GBR regions.

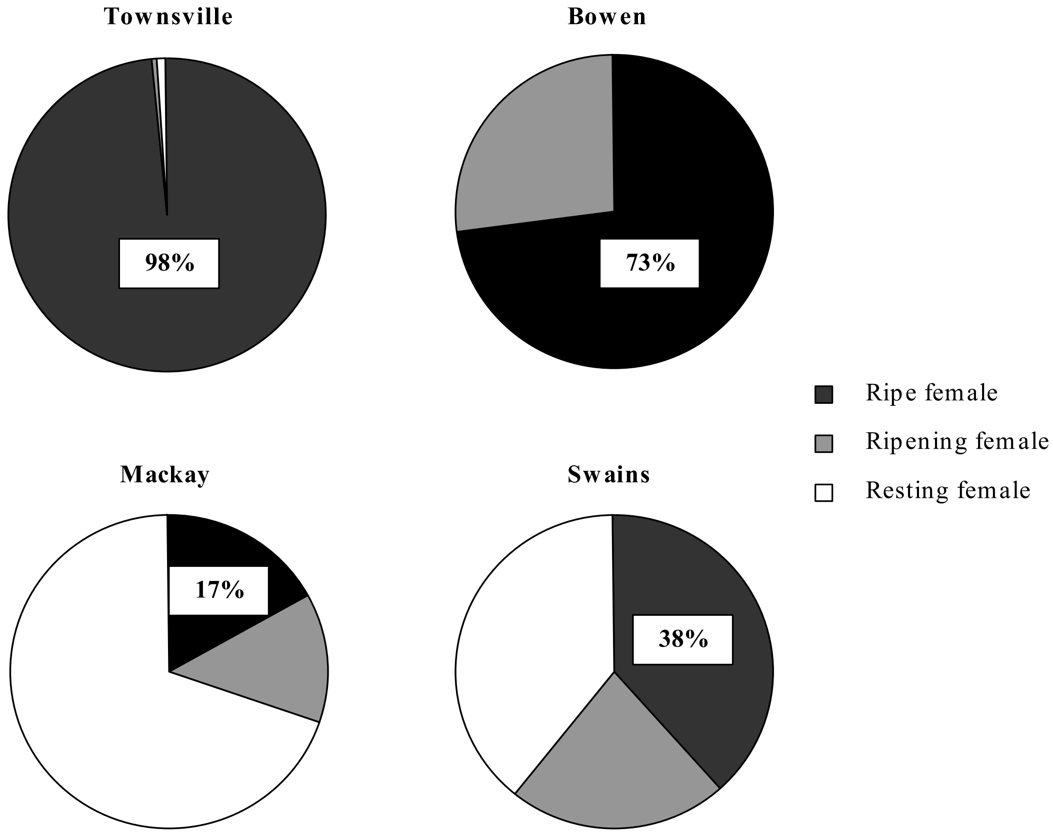

Figure 4.2. Proportion of females at different reproductive stages in 4 regions of the GBR during the spawning season in years 1999 and 2000. The proportion of ripe females is shown for each region as a percentage.

Regional variation in age, growth and survival rates

Samples were collected from the Effects of Line Fishing catch surveys in three regions of the GBR (Townsville, Mackay, Storm Cay) to look at regional variation in age, growth and survival rates of red-throat emperor.

The average age and survival rates of red-throat emperor for the three regions are shown in Table 4.1. The average age of fish in the Townsville region is higher than for fish in the two southern regions. This is due to the higher survival rate of fish in the Townsville region compared with the 2 southern regions. Survival rate is a measure of the proportion of fish in an age-class surviving into the next year. Red-throat emperor in the Townsville region have a 66% chance of surviving to their next year whereas in the two southern regions they only have a 50 to 55% chance of surviving to their next year.

Table 4.1. Average age and survival rate of red-throat emperor in three regions of the Great Barrier Reef.

Region	Average age (years)	Survival rate (% per year)	Age range used to estimate survival (years)
Townsville	7.7	66	6-16
Mackay	5.7	50	6-12
Storm Cay	6.5	55	6-10

The growth pattern for red-throat emperor in terms of how length increases with age appears relatively similar among each of the three regions (Figure 4.3a). Generally, in all regions, red-throat emperor do not increase significantly in length once they have reached about eight years of age. Average maximum lengths for this species are also relatively similar among regions with the largest difference being 19 mm between the Townsville and Mackay regions.

However, when growth is examined in terms of how the weight of fish increases with age, large differences in growth among regions become apparent (Figure 4.3b). The average maximum weight differs significantly among all regions with the largest difference being over 600 grams between the Townsville and Mackay regions. This difference is considerable given the consistency in length among regions and equates to fish of similar lengths being nearly 50% heavier in the Mackay region than the Townsville region. These differences are visible with fish being ‘fatter’ and ‘healthier’ for a given length in the southern regions.

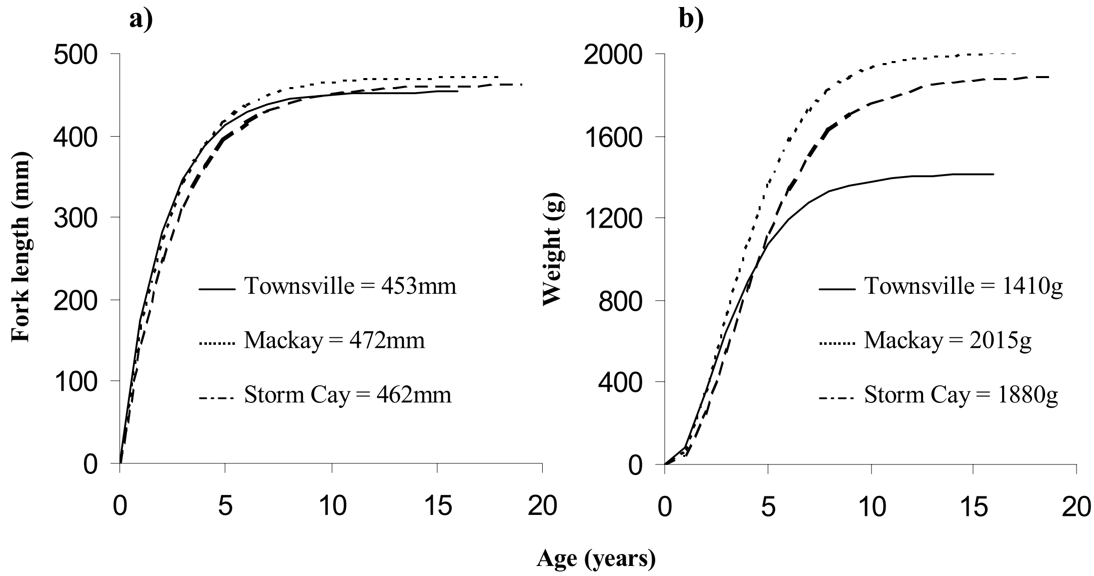

Figure 4.3. Growth in a) length and b) weight of red-throat emperor in three regions of the GBR. The average maximum lengths and weights are shown for each region.

Summary

Although the spawning season appears to be similar throughout the GBR, the other results presented above suggest that populations of red-throat emperor on the GBR, are diverse with respect to population characteristics. Populations in the northern regions (Townsville, Bowen) are characterised by a much higher spawning potential, higher survival rate, older average age and a smaller maximum size, particularly with respect to weight, than populations in the southern regions of the GBR (Mackay, Storm Cay, Swains).

Some genetic research suggests that populations of red-throat emperor in these regions of the GBR are genetically similar. Therefore the differences in population characteristics discussed above may be a result of regional differences in environmental conditions such as variations in water temperature and food availability, or perhaps regional differences in historic fishing pressure. Regardless of what is actually causing the differences, there are some important implications of these results for management.

Management implications

Spawning closures

There is currently a proposal for a closure of the GBR line fishery for nine-day periods around the new moon in October and November in northern regions and in November and December in southern regions (QFMA 1999). These proposed closures are intended to protect the spawning activity of reef fish, particularly spawning aggregations (QFMA 1999). However these proposed spawning closures do not coincide with the spawning season of red-throat emperor (Figure 4.1). We can therefore assume that the spawning stock of red-throat emperor will gain little, if any, protection of spawning activity from the proposed closures.

The proposed spawning closures are based on the spawning activity of coral trout, as they are the main target species of the GBR line fishery. At the time these closures were proposed, a paucity of information existed on the spawning activity of other targeted reef fish. The results of this research reflect the importance of gathering as much information as possible on the spawning activity of other target and non-target species before implementing spawning closures. Without such information, the intended objectives of proposed spawning closures might not be achieved for these other reef fish species.

Spatially explicit management

Populations in the northern regions may be more vulnerable to fishing pressure. This is because they have higher survival rates and, on average, reach an older age than populations in southern regions. Typically fishing will remove proportionally more older fish from a population with high survival rates and long life spans compared with populations with low survival rates and shorter life spans, such as those in the southern regions. These older fish also often contribute substantially to the spawning stock biomass of the population.

The smaller maximum weight and the greater proportion of spawning fish in northern regions suggests that northern populations put more energy into reproduction and less energy into growth than southern populations. In contrast, fish in the southern regions are growing heavier and may be compensating for the lower proportion of spawning fish by having larger ovaries and consequently higher fecundity. To further compensate for the lower proportion of spawning fish it may be possible that northern populations are contributing, to some degree, to the replenishment of southern populations through the supply of larvae.

As mentioned above the current management strategy for red-throat emperor is uniform throughout the GBR, and implicitly assumes red-throat emperor comprise a single homogeneous population or stock. The results from this research indicate that there are consistent differences between populations in different regions. Therefore it may be worth considering tailoring management strategies on a regional scale, to enable managers to take into account the regional differences in populations. Such strategies may include different minimum or maximum size limits for different regions of the GBR, or perhaps regional controls on fishing effort. Although the importance of information on the stock structure of exploited species for management is well recognised, there are limited cases, particularly within Australia, where stock structure information is used in fisheries management. However, regionally tailored management strategies have been successful in the Blacklip abalone fishery where they have been successfully implemented on a small spatial scale (Kailola et al. 1993). Therefore, if necessary, it may be possible to apply a similar approach to fisheries management on the GBR.

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DISCUSSION MINUTES

Question (Mick Bishop): The key issue with spawning protection is the degree to which they aggregate. Are there any comments on how they aggregate?

Response (AW): There is some anecdotal evidence from fishers that red-throat emperor form spawning aggregations, but there is no confirmed evidence of this.

Question (Mick Bishop): Are there any differences between regions in the age/size at which red-throat emperor change sex?

Response (AW): There are some data on sex change available for red-throat emperor but differences in the age/size at sex change among regions has not yet been looked at. This information will be available in the near future.

Question (Howard Choat): Are there any differences in abundance between regions on the GBR?

Response (AW): There are differences in abundances of red-throat emperor between regions. Abundances are generally higher in the southern regions than in the northern regions. North of Cairns there are very few red-throat emperor caught.

Question (Vern Veitch): Red emperor come into inshore waters as juveniles, can we speculate that red-throat emperor also come into inshore areas as juveniles?

Response (AW): There has been quite a lot of work done, including in inshore areas, to find the juveniles of sweetlips. The juvenile stages of nearly all sweetlips have been found but not for red-throat emperor.

Comment (Andrew Tobin): With the amount of inshore work that has been done, juvenile red-throat emperor would have been found by now if they were there.

Comment (Chris Evetts): It is well known by many commercial and charter operators that certain reefs or areas of reef have an abundance of smaller red-throat emperors. These areas are generally avoided by fishers as there are too many small fish and not enough larger fish. Perhaps it is worth investigating these areas for the smaller juvenile red-throat emperor.

Question (Jim Higgs): After Cyclone Justin in 1997 there were record numbers of large red-throat emperor caught. Did this occur only north of Townsville? And if so are the differences we see in the size and age of red-throat emperor between different regions a result of this.

Response (Bruce Mapstone): The influx of larger red-throat emperor was wide spread over most of the GBR. In 1997 red-throat emperor were caught much further north than usual, as far north as Portland Roads, and were larger and in better condition than usual.

Comment (Terry Must): After the cyclone the abundance of red-throat emperor was much greater than normal as well. Larger numbers of red-throat emperor continued to be caught by commercial fishers for a long time after the cyclone.

Response (AW): The figures on size and age of red-throat emperor, which I presented today, are from data collected from the 1995 Effects of Line Fishing catch surveys and therefore could not be influenced by the 1997 cyclone event.

Question (Mick Bishop): Are red-throat emperor under the legal size of 35cm fish capable of spawning?

Response (AW): Yes. They mature somewhere below 35cm but we are not certain exactly at what size they mature as we have yet to locate the juveniles.

Comment (Terry Must): Red-throat emperor which are just over the legal size are not usually kept by commercial fishers as the fillet size is too small. Therefore a review of legal size limits, based on size at maturity, would have a minimal effect on commercial fishers.

Question (Leanne Fernandes): Why does a higher survivorship mean a population is more vulnerable to fishing?

Response (AW): Higher survival rate means a lower mortality rate. A population with a lower natural mortality rate will feel the effects of added fishing mortality proportionally more than a population that already has a higher natural mortality.

Question (Vern Veitch): Red Throat Emperor is a relatively heavily targeted recreational fish, particularly in the Townsville region but we are not seeing any real effect on the stock at this stage. The population seems pretty resilient. If in Townsville we are seeing an older average age does this indicate good management?

Response (Mark Elmer): Management should be conservative and should not 'chance your arm' on these stocks by assuming management strategies for this species are OK.

Comment (Bruce Mapstone): The effects of Cyclone Justin saw a lot of big red-throat emperor turning up on the reef from somewhere else. This indicates that this species is quite mobile and fishers may not be fishing a static stock. Perhaps there may be a refuge of red-throat emperor somewhere, which is not being harvested.

Comment (Mark Elmer): There was some concern on stocks of RTE within ReefMac and other management agencies prior to 1997. The natural event of Cyclone Justin and its effects on red-throat emperor stocks steered us away from our concern.

Question (unknown): Were catches of red-throat emperor going down prior to 1997?

Response (Terry Must): Catches of red-throat emperor were fairly steady up to Cyclone Justin, however coral trout catches were fairly high and therefore fishers were not concentrating on red-throat emperor. After the cyclone the catches of coral trout went right down and catches of red-throat emperor were well up indicating there is large numbers of red-throat emperor that are not usually fished.

Response (Chris Evetts): Some charter operators have found reef catches of RTE are down about 50% compared to 30 years ago. They are fishing much harder now to get the same catch of red-throat emperor.

Response (Bruce Mapstone): There is some anecdotal evidence that suggests that catches of red-throat emperor are currently down.

Question (John Robinson): Are there any other major fisheries for red-throat emperor?

Response (AW): They catch a lot of red-throat emperor around the Abrolhos Islands in Western Australia. There is also a fishery for red-throat emperor in New Caledonia and Norfolk Island.

Question (John Robinson): The lower survival rates and higher growth rates for red-throat emperor in southern regions compared with northern regions are also seen in coral trout. Is this a trend for other species?

Response (Jake Kritzer): There are some non-target species that initially grow very fast and have low mortality rates. In these populations we see individuals reaching a much older age.

Question (Vern Veitch): For good management of this species it is important to get more information on all stages of the life cycle. Are big red-throat emperor in much deeper water than most people are fishing?

Response (Dave Williams): There are much higher catch rates of red-throat emperor in waters around 100m deep than on the reef itself. Studies indicate that some species move into deeper cooler water, and Cyclone Justin may have caused enough cooling of the water to bring these fish into shallower reef waters.

Comment (Howard Choat): We will probably find that there are large populations of red-throat emperor in deeper water, greater than 100m, and I suspect the juveniles are there as well. The distribution of red-throat emperor is likely to extend further north at these depths than the distribution we see on the reef.

Question (Helene Marsh): The closure periods for red-throat emperor and coral trout would differ given the different spawning times of each species. How hard would it be to have staggered closures to encompass spawning of different species?

Response (Terry Must): There would need to be moon closures over more months of the year. This would result in a 4-month period of total closure.

Comment (Bob Grimley): It would be a nightmare from an enforcement point of view.

Comment (Rosemary Lea): It depends on whether it is a total area closure or a species closure. If species are easily identifiable it may be easier and more effective to have species closures rather than area closures.

Question (Mark Elmer): There would be difficulties associated with enforcing species closures? The proposed spawning closure is centred on coral trout.

Response (John Evetts): The charter industry is dead against closures. If there were a decent management plan closures would not be an issue. Reducing effort should be a greater priority than spawning closures.

Comment (Bob Grimley): The challenge for managers now is to come up with a strategy that can be effectively enforced while also ensuring protection of fish at this critical time during spawning.

5. BIOLOGY AND MANAGEMENT OF SMALL SNAPPERS ON THE GREAT BARRIER REEF.

Jacob P. Kritzer

Introduction

Fishes of the family Lutjanidae, commonly known as 'snappers', represent a diverse and abundant group of predators on tropical reefs worldwide. Species within the family on the Great Barrier Reef (GBR) vary widely in body size and ecology, with the large deepwater 'reds' such as the red emperor *Lutjanus sebae* being prized targets of commercial and recreational fishers alike. However, several smaller shallow-dwelling species, often referred to as 'seaperches' in Queensland, also play a role in the GBR line fishery but are infrequently discussed in the context of conservation and fisheries management.

I have recently completed a doctoral thesis (Kritzer 2001), part of which focused on the biology and ecology of one of these small snappers, the stripey bass *L. carponotatus*. My thesis, other studies on stripey bass and several studies on other small snappers suggest that this group of fishes have much in common in terms of their biology and role in the GBR line fishery. Therefore, rather than simply focus on one species, this paper will address biological and management issues common to the suite of small snappers on the GBR. In addition to stripey bass, species covered include hussar *L. adetii*, black-spot snapper *L. fulviflamma*, moses perch *L. russelli*, five-line snapper *L. quinquelineatus*, and brown-stripe snapper *L. vitta*. Other small reef-dwelling snappers such as *L. decussatus*, *L. kasmira* and *L. lutjanus* are likely similar in terms of biological traits, but they are excluded due to a lack of readily available information.

In this paper, I first describe available data on catch of these species to illustrate their role in the fishery and I discuss how this role might change. Then, I summarise biological information on these species that is most relevant to management. Next, I evaluate current and proposed management regulations in light of the species' biology. Finally, I suggest additional considerations that will need to be borne in mind if the harvest of these fishes changes in the future.

Small snappers in the GBR line fishery

Table 5.1 summarises available information on catch of small snappers by commercial, charter boat and recreational fishers (information on catch of indigenous fishers is not readily available). For all species, these figures are probably underestimates for two reasons. Firstly, many small snappers will be recorded as part of the 'mixed reef' catch by commercial fishers. For example, recorded catch of stripey bass increased tenfold from 1992 to 1994, but changes in effort and total catch were nowhere near as drastic (Mapstone et al. 1996). The pattern is likely due to changes in reporting behaviour of fishers. The second source of underestimation is the use fish as bait. Higgs (1993) estimated that recreational fishers use between 0% and 66% of small snappers caught as bait (Table 5.1). Other sectors are also likely to use some fish as bait and therefore to not record those fish as retained catch. Unpublished data from the ELF project suggest that up to 34% of small snappers caught by charter fishers are released (Table 5.1), but this is not likely to represent a third source of unreported mortality. Small snappers seem to be quite hardy fish typically caught from shallow depths for which post-release survivorship has been estimated to be as high as 98% (Diggles and Ernst 1997).

While the data likely underestimate catch of these species, the degree of underestimation is probably not severe. The reasons for this are that the mixed reef catch, of which small snappers are only one component, is but a small proportion of the total catch (Mapstone et al. 1996) and all fishers seem to rely only partially on harvested fish as bait (personal observations). Therefore, it appears that small snappers generally make up a very small proportion of the overall catch of the reef line fishery. With the exception of hussars, these fishes seem to comprise less than 2% of the catch of the three main sectors whether measured in terms of numbers or weight of fish. Even hussars, which appear to be caught with much greater regularity, particularly from southern regions of the GBR, comprise less than 10% of the catch of any sector.

Table 5.1. Information on catch of small snappers on the Great Barrier Reef. Sources: commercial - Mapstone *et al*. 1996; charter - ELF unpublished data; recreational - Higgs 1993.

	commercial		charter		recreational	
species	avg. catch per year in kilograms	avg. % total catch in weight	% total catch in numbers of fish	% catch of each species released	% total catch in numbers of fish	% catch of each species used as bait
hussar	15,347 (1988-95)	0.53%	9.1%	7.9%	5.6%	34%
moses perch	7,022 (1990-95)	0.25%	0.2%	34%	1.8%	5.3%
stripey bass	1,258 (1992-95)	0.04%	1.4%	32%	0.4%	0%
brown-stripe snapper	n.a.	n.a.	0.009%	0%	0.3%	66%
black-spot snapper	97 (1988-95)	0.002%	n.a.	n.a.	n.a.	n.a.
five-line snapper	n.a.	n.a.	n.a.	n.a.	0.4%	50%

Despite the presently low catch levels, future changes in the harvest of small snappers are not entirely unlikely. The GBR line fishery is different from many tropical reef fisheries in that small snappers are not heavily exploited (see Polovina and Ralston 1987), but fishing pressure could increase due to one or both of two possible scenarios. Firstly, attention might shift to currently non-targeted species if more valuable species become severely depleted. Secondly, consumer preferences can change demand for various species, which in turn will influence fishing behaviour. For example, Figure 5.1 contains an article describing increasing demand for small snappers and other plate-size tropical fishes among Western Australian consumers that is linked to increasing popularity of Asian cuisine and not overfishing of other stocks. Also, increasing prices for preferred species can guide consumers toward good tasting but lower priced species. The live reef fish component of the GBR line fishery has had the effect of increasing prices for premium frozen or chilled product as local supply declines due to overseas export (G. Muldoon, CRC Reef, personal communication). Therefore, in light of the potential for future increases in catches of small snappers, now, while catch levels are low, is the opportune time to consider their biological characteristics and associated management implications.

Biological characteristics of small snappers

Distribution, densities and movements

Four studies have examined densities of the Lutjanidae as a family on broad spatial scales (Newman and Williams 1996, Newman et al. 1997, Sweatman et al. 1997, Mapstone et al. 1998). Two of these (Newman and Williams 1996, Newman et al. 1997) also report patterns for individual species in addition to family-level patterns. The species-specific trends show that small snappers are the most abundant species in the family, and therefore that patterns for the family as a whole are driven largely by patterns within the small snapper complex.

A different kettle of fish

The popularity of Asian cuisines is raising the profile of tropical varieties.

epicure

North-west snapper, barramundi, red emperor, coral trout, salmon, tuna and more recently swordfish are the Australian fish of choice. But lately some of the lesser-known species that grace our waters have been making their way on to the fishmonger's icy shelves.

Red mullet, threadfin bream, flag fish, spangled emperor, moses perch and spotted cod are some of the names you may have seen recently but shied away from because you didn't know what they tasted like or how to best cook them.

Kailis Bros director Theodore Kailis says demand for these species has increased as people have shown interest in Asian cuisines.

All of these species are tropical fish which are found in waters north of Carnarvon and throughout the southern Asian region, and therefore they are traditionally used in the dishes of Indonesia, Thailand, and Vietnam.

Theodore says that in general they are all great served as whole fish cooked in a wok Asian-style or grilled Mediterranean-style.

"Eating fish off the bone maximises the flavour," he says.

"It's like eating a T-bone steak, you get more flavour from cooking with the bones."

Some of these fish, such as the red mullet and flag fish, do tend to have a fairly strong flavour and firm white flesh that holds together well, so you could cook them just about any way you like — poached, steamed, baked, pan-fried or barbecued.

These species also represent good value for money, with an average price around the $6kg mark.

Red mullet and flag fish can be as cheap as $4.99kg.

"You get three to four fish per kilo, and if your serves are around 300g per person that works out at about $2 a serve," says Theodore.

You'll find these species on the Kailis Bros cafe menu when supplies are good. Red mullet is currently on the menu served Mediterranean style, char-grilled and brushed with olive oil, wild oregano and lemon juice. Or you can recreate this dish at home.

Lynda Rovis-Hermann

Figure 5.1. Reprinted with permission from the Perth Weekly.

These density and distribution studies collectively suggest that, of the three main groups of large predators on the GBR (families Lutjanidae, Lethrinidae and Serranidae), snappers are the most abundant. Densities of snappers vary between regions of the GBR to some extent (Sweatman et al. 1997, Mapstone et al. 1998), but more pronounced differences are apparent among continental shelf positions. All four studies report a drastic drop in snapper numbers at outer shelf positions. However, there are discrepancies as to whether the group is more abundant on inshore (Sweatman et al. 1997) or mid-shelf (Newman and Williams 1996) reefs. For at least one species, stripey bass, their preference for inshore reefs is quite clear (Newman and Williams 1996).

Two studies at Lizard Island have examined movements of stripey bass and black-spot snapper (Davies 1995, Hilomen 1997). Both found these to be relatively site-attached fishes, with movements rarely exceeding 250 m. Furthermore, fish are unlikely to move across areas of open sand, suggesting that movement between reefs is even more infrequent than extensive movement within reefs. In contrast, Sheaves (1995) found that moses perch move to coral reefs from estuaries around age two when they begin to reproduce. This one-time migration appears to be unique among small snappers and raises additional management issues relevant to this species that will not be addressed in this paper.

Demography and reproduction

Table 5.2 summarises available information on the longevity, survivorship, maturation and body size of small snappers. These species are, for the most part, long-lived fishes, with lifespans generally approaching or exceeding those exhibited by other predators that can be more than twice as large. Only brown-stripe snapper do not appear to live close to two decades or more. As a consequence of their long lifespans, annual survivorship of small snappers is generally high (around 80%). Over most of their long lives, most snapper species experience little growth (Figure 5.2). Growth is highly asymptotic, meaning that after an early three to five year period of rapid growth, maximum body size is attained and little further growth occurs over the remainder of the fish's life (this is known as a 'flat-topped' growth pattern). The early cessation of growth seems to coincide with the onset of sexual maturity. Around 50% of small snappers first begin to mature quite early in life

(Table 5.2), with all individuals reproductively active by the time final body size is attained at age four or five.

Spawning seasons have been estimated for three species on the GBR - stripey bass (Kritzer 2001), black-spot snapper (Hilomen 1997) and moses perch (Sheaves 1995) – as well as for brown-stripe snapper on the North West Shelf of Australia (Davis and West 1993). All appear to spawn primarily in late spring and early summer (October through December), with some spawning activity also occurring in early spring (September) and early autumn (March). Although anecdotal information exists, there is no published information on whether small snappers aggregate to spawn.

Current and proposed management regulations

Size and possession limits

A minimum legal size of 250 mm total length currently exists for hussar, moses perch and stripey bass, and this size limit is proposed to remain intact after revision of the fishery management plan (QFMA 1999). The stated objective of minimum legal sizes is to allow at least 50% of fish to spawn at least once (QFMA 1999). Given that the largest estimate of average size at maturity for any small snapper is 220 mm fork length (Table 5.2), this size limit is likely meeting the stated objective.

Currently, no possession limits exist for any species of small snapper. However, for recreational and charter boats, possession limits of five fish per person per day are proposed for nearly all species (QFMA 1999). Exceptions include a group of fishes perceived to be highly abundant and for which a limit of ten fish is proposed (QFMA 1999). Hussar and stripey bass are both included in this group. The validity of any specific possession limit can only be evaluated by comparing absolute abundance data with catch and effort data, which is currently not possible for small snappers. However, the higher densities of small snappers compared with other species harvested in the fishery suggest that the higher relative possession limit for hussar and stripey bass is justified to some extent.

Table 5.2. Demographic parameters of small snappers on the Great Barrier Reef.Sources: 1) Davis and West 1993; 2) Davies 1995; 3) Sheaves 1995; 4) Newman et al. 1996; 5) Hilomen 1997; 6) Newman et al. 2000a; 7) Kritzer 2001; 8) Kritzer 2002.

species	max. age (years)	annual survivorship	avg. age at maturity (years)	avg. size at maturity (mm fork length)	max. reported size (mm fork length)	avg. max. size (i.e. L_∞) (mm fork length)	Sources
hussar	24	79%	n.a.	n.a.	301	265	4
moses perch	17	78%[a]	2[b]	220[b]	445	330[b]	3
stripey bass	20	81%[c]	2	190	385	280[c]	2, 6, 7, 8
brown-stripe snapper	12	71%	1-2[d]	160[d]	274	245	1, 6
black-spot snapper	17	79%	2-3	205	270	246	5
five-line snapper	31	86%	n.a.	n.a.	233	207	4

[a] Not reported, so estimated from the maximum age using the equation of Hoenig 1983.

[b] Parameters not reported and were estimated visually from Fig. 4b in Sheaves 1995.

[c] Estimates are available from several locations. Presented are approximate average values.

[d] Parameters from the North West Shelf of Australia used due to lack of data for the GBR.

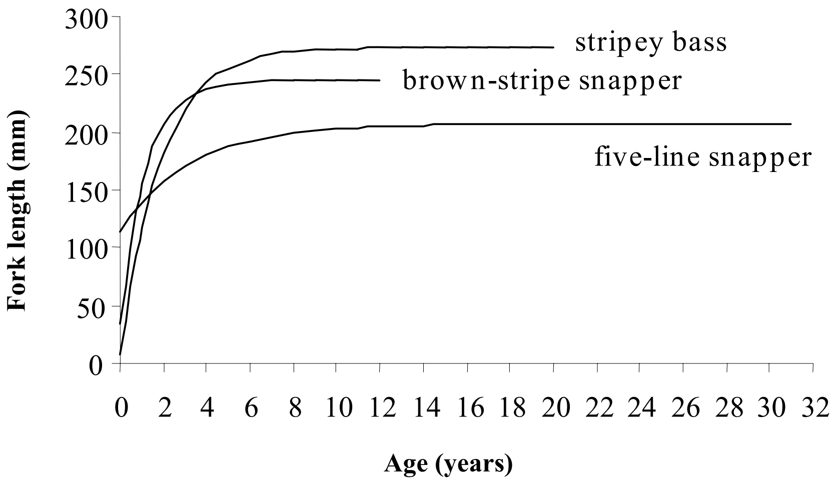

Figure 5.2. Sample growth curves for small snappers on the GBR. The growth curves illustrate the broad range of maximum ages, narrower range of maximum sizes, and common pattern of highly asymptotic or 'flat-topped' growth. Sources: Newman et al. 1996 (five-line snapper); Newman et al. 2000a (brown-stripe snapper); Kritzer 2001, 2002 (stripey bass).

A potential problem with the proposed size and possession limits is that the regulations differ for different species in the small snapper complex. Species apart from hussar, stripey bass and moses perch will have no minimum legal size, and species apart from hussar and stripey bass will have a possession limit of only five fish. Small snapper species are quite similar in appearance and are known by a variety of common names, some of which are used for multiple species, which may prove problematic. For example, a fisher who identifies a brown-stripe snapper as a 'hussar' is quite likely using what he or she perceives to be a legitimate name. However, if that fisher were to retain ten brown-stripe snapper, he or she would unintentionally be in violation of Queensland Fishery Service (QFS) regulations. Because biological characteristics, including sizes at maturity and densities, are similar among species it might be worthwhile applying common size and possession limits to the group as a whole.

Spawning closures

Closures of the GBR line fishery are proposed for nine-day periods around the new moon in October and November in northern regions and in November and December in southern regions (QFMA 1999). These proposed closures are aimed at protecting spawning activity and especially spawning aggregations of coral trout and other finfish species (QFMA 1999). The information on spawning seasons of small snappers suggest that the majority of these species' spawning activity takes place during the proposed closure months, although there is no information on lunar spawning cycles. However, there is a paucity of information on the existence or prevalence of spawning aggregations of small snappers and most coral reef fish species, as well as the relative vulnerability of aggregating and non-aggregating species on the GBR, so the efficacy of the proposed closures is difficult to assess.

Additional management considerations

Simple fisheries models will often predict that older age classes have little value in terms of production of biomass, and therefore reproductive output and fishery yield, when growth of a species is highly asymptotic. For instance, Newman et al. (2000b) estimated the age at first capture at which yield is optimised for small-mouthed nannygai *L. erythropterus*, a long-lived species with a flat-topped growth curve like the small snappers. They found that, although the fish could live up to 34 years of age, yield was maximised by catching fish from as young as age four. This result is due to the limited gains in body size beyond the point at which growth levels off failing to offset losses of individuals to mortality. In other words, the trade-off between growth and mortality is too heavily weighted toward mortality, suggesting older fish hold little value to the population or the fishery.

Models such as that employed by Newman et al. (2000b) make one critical assumption: that recruitment, or influx of new fish to the reef-dwelling population, is fairly constant from year to year. However, some biologists hypothesise that long lifespans evolve in species that are faced with very unpredictable and irregular levels of recruitment. Such species rely on some fishes surviving to old ages to persist through periods of poor recruitment and replenish the population when conditions again become favourable. This process has been dubbed the 'storage effect' because reproductive potential is stored through time in older age classes (Warner and

Chesson 1985). Insufficient data exist by which to assess whether the storage effect is operating among snappers of the GBR. If it is operating, management will need to ensure that fishing does not push the average age too low, move the age structure too much toward young age classes, or drastically reduce the average reproductive lifespan of fish.

Summary

Small snappers are an abundant group of fishes, but are currently only a minor component of the GBR line fishery. However, this could change if demand and/or fishers' behaviour changes. Proposed size and possession limits seem justified in light of the species' biology, but compliance might be simplified by applying common regulations to all species. Small snapper spawning seasons coincide with proposed spawning closures, but there is little information on aggregating behaviour. If fishing pressure on these species increases, research will need to identify whether the storage effect is important for these species' population dynamics. If it is, management might need to take steps beyond the currently proposed regulations to preserve an intact natural age structure. The most effective way of achieving this might be through a strategically designed network of marine protected areas such as those being developed through the GBRMPA Representative Areas Program.

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Question (Chris Roberts): Is there any evidence of age- or size-specific changes in relative fecundity or other aspects of reproduction among these small snappers?

Response (JK): I only have information on stripeys. The data suggest that spawning season ovary weight is a linear function of body weight within a given region, but this does not mean that relative ovary weight is consistent across body sizes because the negative regression constant is a greater proportion of the weight of smaller fish. Also, there is evidence of spatial variation in the body weight-ovary weight relationship. Fish at the Lizard Island group on average have heavier ovaries at a given body size than fish at the Palm Island group.

There might be age- or size-specific differences in duration of the spawning season, but I have not yet looked for that[10].

Question (Bruce Mapstone): Is there an increase of parasite load in older fish?

Response (JK): I find very few parasites in the viscera (i.e. internal organs) of stripeys, unlike other species I've seen such as small cods. As I just mentioned, the data I've analysed to date do not suggest changes in reproduction with age or size after maturity. It might be the case that mortality through predation takes effect before senescence (i.e. deterioration due to old age).

Question (Vern Veitch): Are small snappers a target fish?

Question (Rosemary Lea): For live boats shortage of space for fillet product may mean these species are not kept in preference for higher price product such as coral trout. Is this the case?

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[10] see Addendum for more information on this topic.

Response (Robin Stewart): There has always been a demand for smaller snappers due to the high price of coral trout. They are also favored by some fishers despite their low price.

Comment (Vern Veitch): Recreational fishers will probably not keep more small fish, unless there is significant depletion of more favoured species.

Question (Mark Elmer): Over-fishing of other species should cause the domestic market to be starved of fish. Has there been a displacement of demand for different species locally since the catch of coral trout is mostly onto planes overseas?

Comment (Commercial operator): If the domestic market were to respond to reduced supply due to increased export, the only evidence that the operator would see is an increase in local price of various species. This has not happened.

Comment (Rosemary Lea): The colour of these snappers (Gold) is also a point which the Asian market deems desirable.

Comment (Mick Bishop): For export a major consideration is whether it is viable to export them, for snapper this would not be the case at the moment.

Comment (Vern Veitch): It isn't preferable to fillet these smaller fish in commercial quantities.

Question (Leanne Fernandes): Is it likely that the storage effect is important for species on the GBR? If it is an issue for current fisheries management, is it possible to model it with ELFSim?

Response (JK and Bruce Mapstone): We don't yet have long term recruitment data for the GBR to answer that question. Data for a number of marine animals in other parts of the world suggest recruitment often follows long-term cycles, so it is a realistic possibility. We have not modelled this explicitly in ELFSim.

Comment (Dave Williams): Two species I have studied became locally extinct because of persistent recruitment failure.

Comment (Howard Choat): Recruitment is highly variable in long lived reef species in particular. The persistence of older fish may allow the population to ride out poor recruitment periods.

Comment (JK): If fish on the GBR have to contend with these sorts of periodic recruitment failures, long lived species can hang in there and persist if the natural age structure is not truncated too much by fishing.

Question (Mick Bishop): Will the limit of 2 hooks per line proposed in the Draft Management Plan affect catch of hussar since they are a schooling species?

Response (Terry Must): We don't really keep hussars, but further south they do catch some of them and hussars may be kept. Mixed B is mainly Moses perch and bastard lipper. Whatever is kept is very dependent on the fisher.

Response (Robin Stewart): That shouldn't be a big problem since we don't catch many anyway – maybe 1% of the total catch.

Comment (Mark Elmer): It would be preferable to look at catch in numbers of fish rather than the percentage of catch. The data shown could actually mean a large catch when looking at total weights.

Response (JK): Catch is much less than coral trout, however snappers are much more abundant than coral trout. The take home message is that catch of snappers is small.

Question (Ann Ferguson and Rosemary Lea): What steps can be taken to help the resource deal with potential increases in harvest if species are reliant upon the storage effect? Would bag limits or maximum sizes help?

Response (JK): Maximum size limits would not be appropriate for these species because growth is highly asymptotic. This means that many age classes accumulate within a narrow size range and there's no guarantee that older fish would be protected. Also, these species only seem to recruit to the fishery at sizes near the asymptote so a maximum size would essentially eliminate harvest.

Bag limits would help reduce overall fishing pressure, but again would not protect specific ages. The best option is likely to be preserving an intact natural age structure in certain areas through a carefully planned system of marine reserves. The GBRMPA Representative Areas Program can hopefully help accomplish this.

Question (Anne Ferguson): What are we going to do about increased demand for this species? Where is the future for this species?

Response (Mick Bishop): It's a tradition in fisheries management to deal with problems only when in trouble. We should look at prevention rather than cure. For the reef line fishery the GBRMPA has concentrated on coral trout. There is a danger that less targeted species can become threatened so snappers should be considered. Size of maturity is a good thing to see.

Response (JK): Historically, fisheries management worldwide has involved dealing with problems that already exist. Scientists and managers try to assess the status of a stock and understand the natural biology of the harvested animals after fishing has been operating for some time.

This is a perfect opportunity to avoid this problem. Australia is an anomaly among countries with tropical reef fisheries because small snappers are not a large part of the catch. However, the history of many fisheries is one of changes through time in target species, so small snappers might be more heavily exploited in the future. If that happens, we can be in a good position then by learning about their biology and thinking about the implications now.

Some fisheries scientists in the U.S.A. have been encouraging the use of regular recruitment surveys to forecast the future status of stocks rather than always trying to hindcast their status based on catch records. What you would do with that sort of information is a complex question, but it could be a powerful tool.

Question (Bryony Barnett): Is management faced with a situation of different life history strategies for different species and, if so, how are we to respond to this diversity of strategies?

Response (Mark Elmer): Ultimately, management actions will be guided by the precautionary principle, but the issues of biodiversity and fishery management are the responsibility of separate agencies.

Question (unknown): What is the likelihood that fishing pressure on these small snappers will actually increase in the future and what would cause the shift in effort?

Response (commercial operator): If there were more pressure put on small snappers it would be a consequence of a decline in other more valuable species.

Comment (Vern Veitch): Recreational fishers likewise won't keep more small fish unless there is depletion of other species.

Comment (JK): That might not necessarily be true: there is increasing popularity of plate size fish in Western Australia due to increasing interest in Asian cuisine, which often involves whole fish grilled, fried or baked.

Comment (Geoffrey Muldoon): Demand doesn't always originate with the consumers. QSIA, for example, could initiate a marketing program to increase demand for a wider array of species. This could increase their value and fishers could therefore achieve similar levels of profit while putting less pressure on stocks that are currently heavily exploited.

Addendum

Since the workshop presentation and discussion, I have looked at differences in the extent of the spawning season between sizes classes of stripey bass (Figure 5.3).

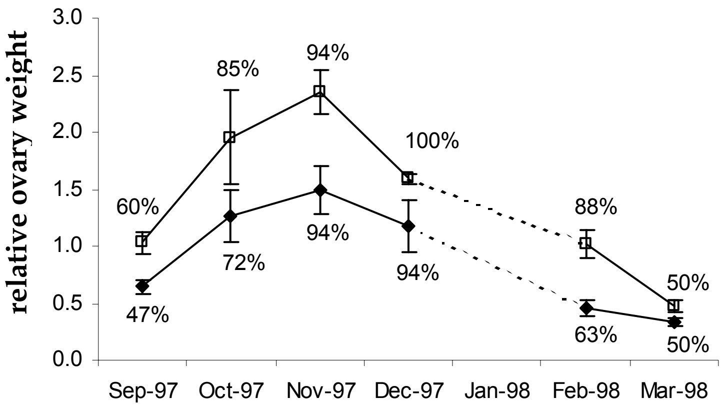

Figure 5.3. Ovary weight as a percentage of body weight for female stripeys during spawning months for fish ≤230 mm fork length (◆) and fish >230 mm fork length (☐).Also indicated is the percentage of fish in each size class during each month with ripe (i.e. ready to spawn) ovaries.

These data suggest that the ovaries of larger fish make up on average a greater percentage of body weight than those of smaller fish. The patterns seems to be due in part to a greater proportion of larger fish being in ripe spawning condition early and late in the protracted spawning season.

6. AGE, GROWTH AND SEX STRUCTURE OF RED BASS POPULATIONS ON THE GREAT BARRIER REEF.

Ross Marriott

Introduction

My research concerns the population biology characteristics of red bass, *Lutjanus bohar* on the Great Barrier Reef. The red bass is a large predatory reef fish that is abundant in the mid- to outer-shelf reefs of the Great Barrier Reef World Heritage Area (GBRWHA). It also has a widespread distribution throughout the Indo-West Pacific and is one of the most recognised species for causing ciguatera fish poisoning.

Little is known about the population biology of red bass. There is currently no information on the growth or reproduction of red bass within the GBRWHA. Although the red bass is a non-target bycatch species of the commercial reef line fishery, there has been a recent trend for commercial fishers to retain smaller red bass for sale because these are considered to be safe to eat and unlikely to cause ciguatera. Therefore it is important to research this species to determine the potential effects this shift in effort may have on populations of red bass. My research is focused on the age, growth, and reproduction of red bass. This information will provide the basis for informed management of this species.

Results

Preliminary results of age and growth characteristics have been obtained by sampling red bass populations from study reefs of the CRC Reef Effects of Line Fishing (ELF) project[11]. Once lengths were measured (fork length: mm) and ages estimated (years) for all red bass sampled, it was possible to fit a trend to the resulting length-at-age data (Figure 6.1).

[11] Data presented here are pooled across all reefs sampled.

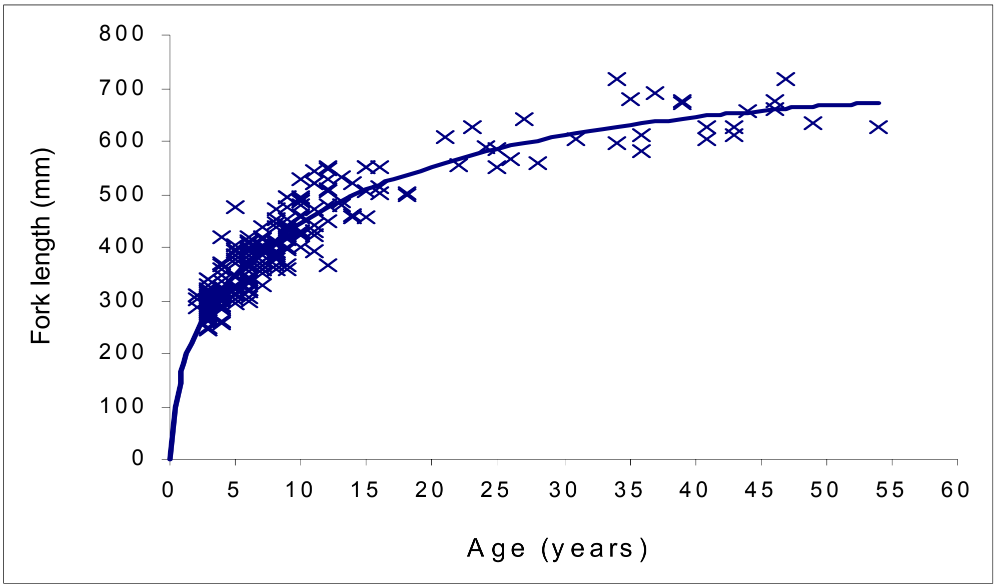

Figure 6.1. Predicted relationship between age and length for *L. bohar*

This relationship of fish length with estimated age predicts the general trend of growth for red bass populations on the Great Barrier Reef. This growth trend is exceptional for a tropical reef fish, with respect to estimated longevity and general shape of the curve.

Firstly, this species appears to be quite long-lived, since the maximum age estimated in these preliminary results is older than fifty years. Secondly, the shape of this growth trend indicates that the growth rate of red bass on the GBR is relatively slow throughout life. The very gradual "leveling off" of this curve towards a maximum length of approximately 700 to 800 mm (fork length) over many years suggests that it takes a long period of time for red bass to achieve this maximum size.

This growth trend also does not completely "level off" or "asymptote" at a maximum size with increasing fish age, like the growth trends reported for many other tropical reef fish species (eg. see growth trends reported by Kritzer, Williams, and Mosse et al. in this proceedings). This might be because the largest, oldest red bass have not been sampled from the population, or because growth in length continues in older-aged red bass, throughout life.

Discussion

These preliminary results suggest that the red bass is a very long-lived, slow growing reef fish. The highest age estimated for red bass in this study is much higher than that reported for other closely related species from the GBRWHA. Table 6.1 presents the maximum age reported for red bass in this study, along with maximum age estimates reported for other tropical snappers (lutjanids) in scientific literature.

Table 6.1. Maximum ages reported for some lutjanids from the GBRWHA.

Common name	**Taxonomic name**	**Maximum age**
Red Bass	*Lutjanus bohar*	54
Small Mouth Nannygai	*Lutjanus erythropterus*	32[a]
Five-lined Bass	*Lutjanus quinquelineatus*	31[b]
Common Hussar	*Lutjanus adetii*	24[b]
Red Emperor	*Lutjanus sebae*	22[a]
Large mouth Nannygai	*Lutjanus malabaricus*	20[a]

Source: [a]Newman et al. 2000, [b]Newman et al. 1996.

The oldest age that I have estimated for red bass (54 years) is much higher than those maximum ages reported for the other lutjanids listed in Table 6.1. The second oldest maximum age reported amongst these lutjanids was 22 years younger than this maximum age for red bass. I predict that even older-aged individuals are likely to reside in the red bass populations of the GBRWHA, because anecdotal evidence suggests that the sample used for this study has not included the largest, oldest red bass from this region.

From these preliminary results it is possible to make some tentative predictions about the potential effects of fishing on red bass populations. Firstly, the long-lived, slow-growing life history of red bass suggests that it would have a low resilience to harvest. This is because it is generally acknowledged that a slow-growing species is less resilient to harvest than a faster-growing species. A slower-growing species takes longer to achieve maturity and spawn, and therefore is less efficient at replenishing

its population numbers in response to fishing. At present data is not available on the length of time it takes red bass on the GBR to achieve maturity, however, I can make some predictions based on research conducted in other countries.
Previous studies have reported the size of red bass at first maturity to be 44 cm (standard length) and 45 cm (fork length) for populations in East Africa (Talbot 1960) and Papua New Guinea (Wright et al. 1986), respectively. If the size of red bass at first maturity is similar for populations in the GBRWHA then I would predict from the relationship established between fish age and length (Figure 6.1) that red bass on the GBR could mature at 10 to 15 years of age. If this were so then the red bass would be considered to mature relatively late in life.

Therefore the slow growth, long life span and possible late maturity characteristics of this species suggest that red bass populations would have a low resilience to commercial harvest in the GBRWHA. Populations would be potentially vulnerable to overfishing, particularly if the younger, smaller individuals are targeted. The targeting of smaller, younger individuals could result in the removal of a significant number of juveniles from the population, thereby reducing the potential for these individuals to mature and contribute to the replenishment of population numbers in the future. Although there is anecdotal evidence that red bass stocks are currently not harvested to any significant extent on the Great Barrier Reef, it is possible that these harvest trends could change in future.

However, I must emphasise caution in the consideration of these early predictions because they are based on limited data. For instance, there is no information available on the harvest of this species, trends of relative abundance, or, maturity and reproduction characteristics for red bass populations in the GBRWHA. Information on these attributes would be required to make more informed predictions.

Future research directions

These results on red bass growth characteristics are preliminary in the sense that additional size and age data are currently being collected and that regional variability in growth has not been examined (see Williams in these proceedings for further discussion). Additional length-at-age data is required for those red bass that were either too small or too large to be sampled by the line fishing method of the ELF research surveys. I will also investigate the regional variation in age and growth characteristics for red bass in the GBRWHA by comparing growth trends and age structures for populations sampled in different study regions or “reef clusters” of the ELF experiment.

I will compare growth trends and age structures of red bass populations sampled from the GBRWHA with red bass sampled from the Seychelles. The red bass is one of the main target species of the artisanal fishery of the Seychelles Republic, where incidents of ciguatera fish poisoning are rarely encountered. The results of this study will provide fishery managers with important information that will be used to ensure the sustainable harvest of red bass in the Seychelles. This research will also indicate how age-growth characteristics may vary for red bass populations that are exposed to different fishing pressures and different environmental conditions.

In addition, I will investigate the size and age when red bass first mature, the timing and duration of the red bass spawning season, sex-specific growth, and quantify the accuracy, precision and bias of all age estimate results that will be used to determine if the red bass requires special management consideration in the GBRWHA at present. This information can also be used to develop management strategies for the sustainable harvest of red bass on the GBR, and this may be particularly important if red bass are increasingly targeted by fishers in the future.

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Comment (Mark Elmer): Firstly, there has never been a "ciguatera list" of those species which are considered to be toxic on the Great Barrier Reef, although there was a brochure produced by Queensland Health on this subject. Secondly, it would be difficult to justify developing specific management strategies for this species given the potential management considerations raised in the presentation. The cost to manage the harvest of this species would be likely to exceed financial profits. It is also difficult to understand why this species is harvested given its potential for causing ciguatera. Fish suppliers would be liable for selling ciguatoxic fish such as red bass.

Response (RM): That is a good point. Ciguatera is very difficult to predict because toxicity varies not only with the size of fish but also on a spatial scale and over time. We also currently have a poor understanding about the factors that cause ciguatera fish poisoning and therefore it is difficult to explain these trends in ciguatera toxicity. In some countries, such as in the Seychelles, ciguatera fish poisoning does not occur and red bass is one of the major target species for the commercial line fishery.

However, it is important to continue research on the biological characteristics of this species for its management on the Great Barrier Reef. Red bass is a component of the by-catch for the commercial reef line fishery and is one of the main competitors with coral trout for a baited hook. At this stage we do not fully understand the extent of its commercial harvest. However, we also do not understand the impact that commercial fishing will have on red bass stocks, even if the majority of red bass are not retained for sale by commercial fishers.

Response (Terry Must): Buyers (e.g. restaurants) will not buy large fish due to the risk of ciguatera.

Comment (Jake Kritzer): This presents an interesting situation for the management of red bass, in that for most species fishers are targeting the older and larger individuals, whereas for red bass the larger fish are avoided. This will present unique management and research challenges because we have a situation where the threat is to the younger, smaller and more abundant component of the breeding population rather than the older, larger and less abundant component that is affected in most fisheries.

Comment (David Williams): There is evidence from previous research conducted by Dr. Richard Lewis that red bass are no more likely to cause ciguatera than the common coral trout on the Great Barrier Reef.

Comment (Mark Elmer): Due to the ciguatoxic risk associated with this species, it remains a high-risk species to market.

Comment (David Welch): Remember, that despite the ciguatera issue, an important message here is that the life history characteristics of this fish, with respect to its long life, relatively slow growth rate and perhaps late maturation make it a potentially vulnerable species to any increase in fishing, should its marketability/public perception change.

Question (Anne Ferguson): If this species was protected from fishing due to its possible risk of over-exploitation would this effect commercial fishers?

Response (Robin Stewart): Due to the very low numbers of red bass kept by commercial fishers it would have very little effect on commercial fishers if management strategies for this species meant they were totally protected.

Response (Terry Must): If commercial fishers wouldn't eat it themselves, they wouldn't sell it. The only way it would be sold is as fillets in frozen cartons.

Closing comment (Bruce Mapstone): To summarise the last two discussion sessions it has become apparent that red bass and some of the lesser snappers comprise a smaller component of the catch for the commercial reef line fishery and therefore present a lower priority for present fisheries management. However, it is important to note that market trends can shift and there may be an increased demand for these species in the future. The recent trends observed in the market for live reef fish have provided a good indication of how this market demand can change. It is therefore an advantage to have such information and be forewarned of potential management implications, rather than having to implement management strategies without such prior knowledge if stocks become threatened in the future.

7. BOMMIE COD, (*CEPHALOPHOLIS CYANOSTIGMA*): A BIG SURPRISE FROM A LITTLE FISH.

Jacobus W. Moss, Samantha Adams and David J. Welch.

Introduction

Epinepheline serranids are important targets of tropical and subtropical fisheries worldwide (Sadovy 1996). However, research has largely been done on the larger, commercially important members of this group such as the larger groupers (Williams and Russ 1994). Very little research has been done on the smaller serranids such as the wire netting and bommie cods. These smaller cods are predominantly treated as by-catch within the Great Barrier Reef (GBR) Line Fishery. However, in regions such as South East Asia, these smaller cods are heavily fished. This is due to cultural preferences for smaller fish, as well as the depletion of larger serranids in these areas. The potential exists for increased targeting of these small serranids in the GBR Line Fishery given that the live fish component of this fishery is largely driven by market forces in the South East Asia region (Geoffrey Muldoon, personal communication). This highlights the importance of obtaining information on such species on the Great Barrier Reef, prior to increases in fishing pressure.

Little is known about the post-release mortality of small cods (but see Diggles and Ernst 1997) and some fishers commonly use cods as bait to catch large blue-spot coral trout (*Plectropomus laevis*) or common coral trout (*P. leopardus*). Thus, there is potential for fishing to have an indirect effect on these populations, despite the fact they are not targeted specifically. Therefore, this study focused on the biology of the bommie cod (*Cephalopholis cyanostigma*). The bommie cod is a common by-catch species of the GBR Line Fishery. At present, it is unknown how long the bommie cod live or how fast they grow. Previous work has found the bommie cod to be a protogynous hermaphrodite, whereby individuals function first as female and later in life become male after undergoing sex change (Mackie 1993). Protogyny is a common sexual pattern in the serranids and is thought to make these species more vulnerable to fishing than those species that do not change sex (Punt et al. 1993, Vincent and Sadovy 1998). This is because males have a tendency to be larger and therefore disproportionately removed by fishing, leaving too few males in the population to effectively fertilise eggs.

The objectives of this study were two fold: (1) to examine aspects of the biology of the species that can give some indication of its relative vulnerability to fishing pressure compared to other members of the Serranidae, and (2) to investigate differences in the average size of bommie cod populations between open and closed reefs along the GBR to assess the efficacy of spatial closures in protecting natural population structure. The latter objective would also provide a preliminary view of whether historical fishing pressure has impacted on the average size of bommie cod. To address these objectives this study examined:

(i) The average life span of bommie cod (i.e., longevity),
(ii) The relationship between size and age to estimate growth,
(iii) The sex-specific size structure, and,
(iv) The difference in average size between open and closed reefs.

Results and Discussion

Growth and Longevity

Bommie cod were found to live for an exceptionally long time despite their small size (Figure 7.1). The maximum age of bommie cod was found to be about 40 years old (Figure 7.1). This was an unexpected result, particularly considering the larger serranids like the coral trout only live for approximately 16 years (Welch 2001). In general, there appears to be a trend for smaller cods to live longer. The reason for the exceptionally long life in these species remains uncertain. One theory is that they have a very cryptic life-style, in that fish primarily hide within the reef architecture, and that this allows them to escape predation. The relationship between maximum age and size in the serranids contrasts sharply with conventional theory based on land animals, with larger animals generally living longer. Furthermore, older individuals, although few in number, are hypothesised to be important to reproduction of the population through years when recruitment of young individuals to the population is low (Warner and Chesson 1985). Variable recruitment is a common factor in reef fish populations (Mapstone and Fowler 1988, Doherty and Fowler 1994), and thus the maintenance of older fish is important.

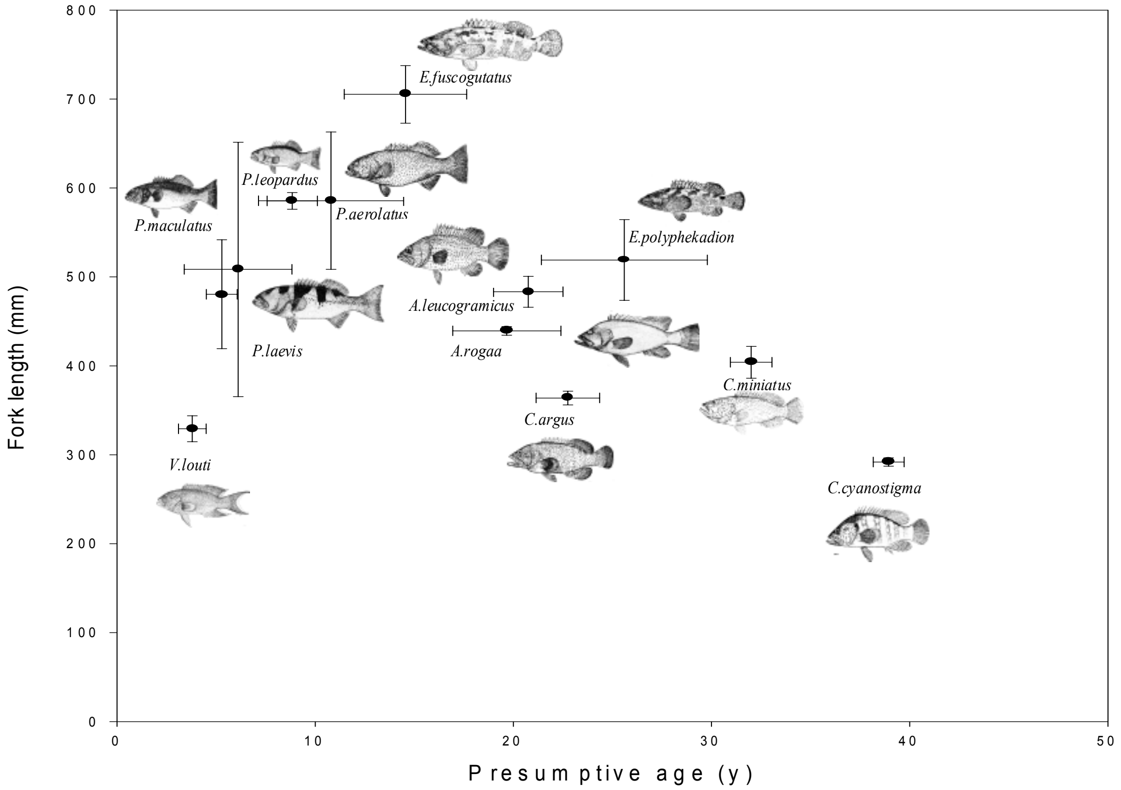

Figure 7.1. Relationship between maximum age and maximum fork length (each ±95% confidence interval) of twelve serranid species from the Great Barrier Reef.

As well as being a long-lived fish, the bommie cod also exhibits very slow growth throughout its life. Bommie cod reach an average maximum size of approximately 260 mm and it takes approximately 10 years to attain this size (Figure 7.2). These characteristics alone make the bommie cod vulnerable to fishing should they be targeted by the line fishery because biomass removed by fishing will be very slow to recover. If fishing pressure were high enough it would easily outweigh the ability of the species to replenish biomass. This would result in a decline in bommie cod populations and yield to the fishery.

The reproductive biology of bommie cod.

This study found no immature females, likely because the size at sexual maturity was less than size at vulnerability to the sampling gear. Therefore, the size at 100% maturity is less than 140 mm FL, and most individuals caught in the GBR Line Fishery are likely to be mature. Bommie cod were found to be protogynous, which concurs with the results from Mackie (1993). The Palm Island populations of bommie cod existed in a female biased sex ratio and males tended to be larger than females (Figures 7.2, 7.3), which is typical for a protogynous species. These populations therefore may be at risk of disproportionate removal of males due to fishing selecting for the larger individuals. However, individuals can change sex over a wide range of body sizes, from as small as 160 mm FL and up to at least 260 mm FL (Figure 7.3). This suggests that sex change in adult females may be sufficiently flexible to replace males lost due to fishing. Bommie cod populations may therefore be at less risk of sperm limitation due to disproportionate male removal than in populations where sex change is less flexible (Vincent and Sadovy 1998).

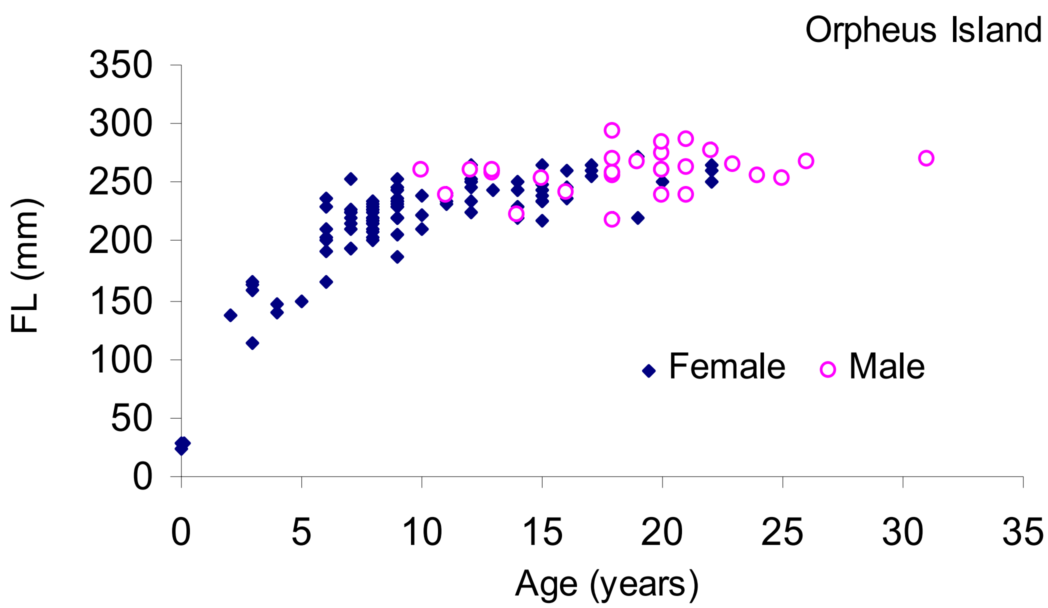

Figure 7.2. Size at age of female and male bommie cod at Orpheus Island, central Great Barrier Reef. The data illustrate a minimum age at sex change of approximately 10 years, and a lack of growth spurt following sex change.

The relationship between size and age can vary substantially between the sexes in a protogynous species. For any given age, males are often significantly larger than females (e.g. McErlean and Smith 1964, Choat et al. 1996). Large size in males is favoured in many protogynous species as this allows them to hold spawning territories and reproduce with many females over a short time. The common relationship between sex and size-at-age has been explained by two conflicting hypotheses. Some biologists propose that the larger size-at-age of males is the result of a growth spurt following sex change (transitional growth spurt hypothesis, Moe 1969, Hoffman et al. 1985, Ross 1987, Warner 1988). An equally plausible (conflicting) hypothesis, is that the differences in size-at-age observed between the sexes are a consequence of variable juvenile and female growth trajectories, with fish that grew fast early in life more likely to become male later in life (Francis and Barlow 1993, Adams and Williams 2001). In either case, variation in the relationship between the sexes in size-at-age can cause problems for fisheries models that pool size-at-age data for both sexes. For example, yield per recruit modelling that pools the sexes can lead to overestimation of optimal fishing mortality, as the few fast growing males cause an overestimate of the population growth rate (Punt et al. 1993).

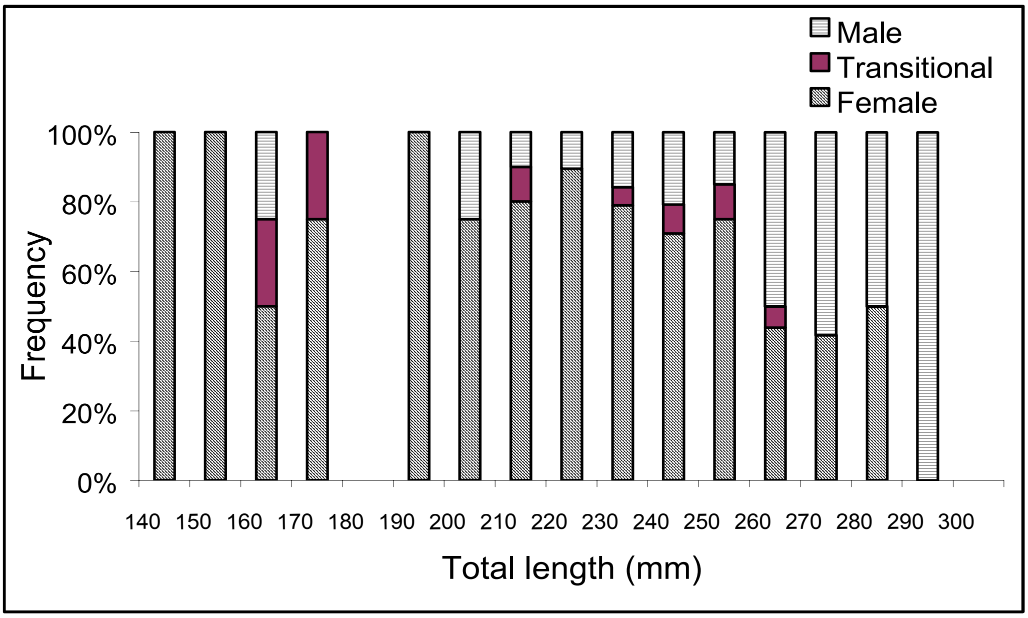

Figure. 7.3. Size frequency of female, transitional and male bommie cod (*Cephalopholis cyanostigma*) sampled from Palm Island group, central Great Barrier Reef.

Unlike other protogynous species, the relationship between size and age for bommie cod appears to be similar between the sexes with no growth spurt apparent (Figure 7.2). Bommie cod exist in small social groups consisting of one male and two or three females (Mackie 1993). Social conditions have been found to have a significant influence on fish demography, particularly those that exist in groups (Shapiro 1981, Warner 1988). Therefore, combining a number of different social groups characterised by different growth schedules may have masked any sex-specific differences in growth within specific groups. However, irrespective of the factors driving the similar size-at-age relationship between the sexes, pooling males and females for size based fisheries analysis, such as yield per recruit, is likely to be appropriate for this species.

The effects of management zoning on the average size of bommie cod

Line fishing generally selects for the larger individuals (Jennings and Lock 1996 Welch 2001). If this were the case, it would be expected that the average size of bommie cod on reefs open to fishing (blue zones) would be smaller than on closed (green) reefs. However, patterns in the average size of bommie cod between open and closed reefs was highly variable among regions (Figure 7.4). Overall, there were very minor differences in the mean size of bommie cod on open and closed reefs within each region. In the Lizard Island region, bommie cod were slightly larger on closed reefs (≈2%). In contrast the opposite pattern was apparent in the Townsville region where the mean size was approximately 5% larger on open reefs. There were no significant differences in the average size of bommie cod between management zones in the Mackay and Storm Cay regions.

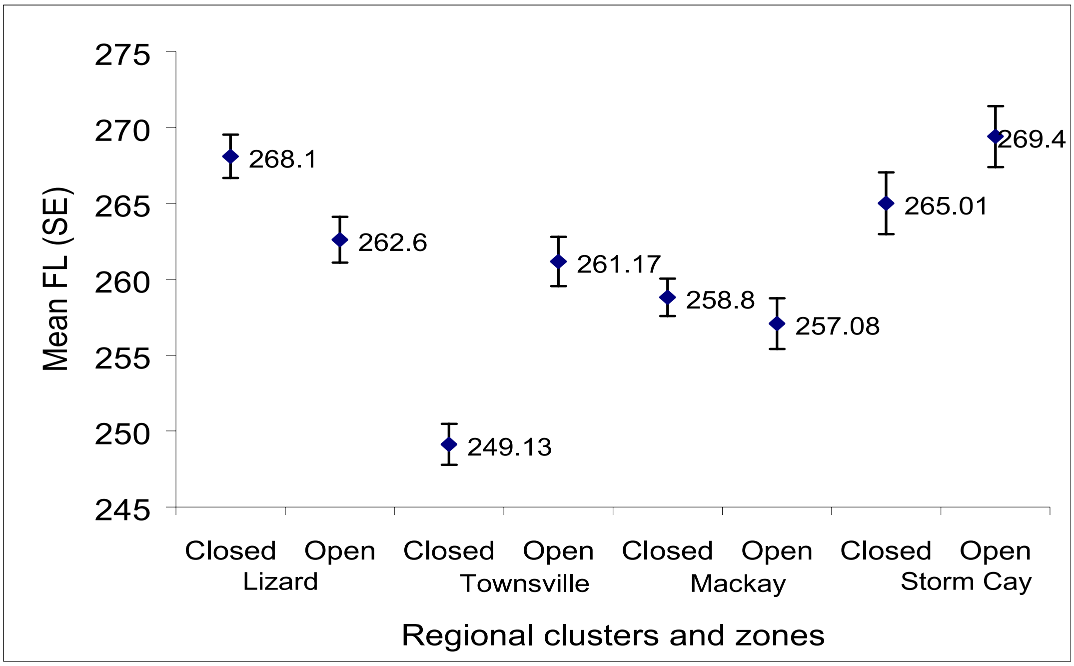

Figure 7.4. Plots of mean fork length (mm) of bommie cod on closed reef and reefs open to fishing within four regions of the Great Barrier Reef.

There are a number of possible explanations as to why bommie cod populations showed neither pronounced nor consistent response to management zones. It could be that the indirect effect of fishing via post release mortality is minimal on bommie cod (c.f. Diggles and Ernst 1997), explaining the lack of predicted differences between open and closed reefs across regions. If this is the case, the minor differences in mean body size that were observed within each region but were not consistently aligned with management zones could be due to local environmental heterogeneity among reefs. Variability in growth among neighbouring populations has been reported for several reef fishes on the GBR (Hart and Russ 1996, Newman et al. 1996, Williams 1997, Kritzer in press) and could be driving the observed differences in body size among bommie cod populations.

Conclusion

The most surprising result of this study is the maximum age attained by the bommie cod, with the oldest individual having reached 45 years. This is especially surprising given that the average maximum size of around 260mm is relatively small. The sex-specific size structure of the bommie cod populations presented here supports the protogynous life history reported by Mackie (1993). These data also indicate high variability in the size at which sex change occurs. This plasticity in sex change is a characteristic that likely makes the bommie cod robust to selective removal of larger males by fishing. Although current levels of bommie cod harvest in the GBR Reef Line Fishery are very low, the old age attained and the slow rate at which they grow to maximum size make them especially vulnerable to fishing pressure should targeting increase. Given the popularity of small cods in the southeast Asian live fish trade, it is possible that targeting of bommie cod on the GBR will increase in the future. Managers will need to monitor the fishery to ensure that any increases in fishing pressure result in sustainable catches of bommie cod and other small serranids.

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DISCUSSION MINUTES

Question (Jim Higgs): Did you look at average age or size compared to densities of coral trout, considering that coral trout are likely to be a major predator of bommie cod?

Response (JM): No, I did not look at the densities of coral trout and their possible affect on the average size or age of bommie cod.

Question (Richard Quincey): Was sample size on reefs big enough to see a difference between open and closed reefs in average size? Or possibly also size at sex change?

Response (JM): For differences between open and closed areas sample sizes were between 300 to 400. This should be enough to detect some differences. Although for some reefs, the sample size was relatively small and the difference in size and age structure between closed and open reefs were highly variable. Unfortunately, this section of the study did not have enough reproductive data to comment on sex change. The difficulty in obtaining proper information on sex change and other reproductive components for the GBR was that samples were limited by hook size. Consequently, this component of the study was lacking small immature females due to sample regime within the ELF project. However, I do have a reliable estimate of female maturity from my Palm Island samples which I sampled monthly using an unbiased sampling technique.

Question (Richard Quincey): Differences between age structure and size structure in Townsville region seemed to be contrary to what you would expect. Could this be due to habitat types?

Response (Bruce Mapstone): Sampling regime was designed to be consistent across reefs. There is some habitat differences between reefs, but sampling regime should have averaged these habitat effects.

Question (Bryony Barnett): Was there any difference in abundance of bommie cod between open and closed reefs?

Response (JM): Yes, there was a difference, there tended to be more bommie cod on closed reefs.

Question (Bryony Barnett): Do these fish move around reefs or between reefs much?

Response (JM): There were 75 bommie cod injected with tetracycline back in 1993 and 5 years later 3 fish were recaptured where they were released. This gives some indication that bommie cod may not move much between reefs.

Question (David Williams): Are there other small long-lived serranids like bommie cod?

Response (JM): So far they haven't been found. There are some examples from overseas that are long lived. Some other Australian species such as coral cod and peacock cod reach about 30 years, but these are also larger than bommie cod. The small size and long life of bommie cod may be because of their cryptic life-style, as they are able to hide and avoid predation.

Question (Anne Ferguson): So bommie cod make up to 12% of commercial catch but have no current value? This should give it a fair priority for the investigation of potential ecological effects of cod removal by the fishery.

Response (Bruce Mapstone): Up to 12% as mentioned in the abstract comes from ELF catch surveys which is slightly different to unstructured fishing which normally occurs in the fishery as determined by observer surveys. This 12% is also by number, not weight, and it is numbers caught, not necessarily kept.

Question (Mick Bishop): I was wondering about post-release mortality, given these fish aren't kept. Does anyone know what depths these fish can come back from?

Comment (Terry Must): They have the potential to be caught up to 50m depth.

Response (Mark Elmer): Discarding has not been a big consideration in management in the past except for trawl discard. This is changing in more recent times. Discard mortality is now seen as a priority for research by FRDC. The issue of discard mortality must be investigated. This is not only an issue for the commercial fishers, but also for the recreational fishery as it is a major by-catch species by recreational fishers as well.

Comment (Vern Veitch): An education program on handling of fish for discard is important to improve survivorship of species such as bommie cod.

Comment (Mark Elmer): The solution to the by-catch issue does not lie in the regulation.

Comment (Bruce Mapstone): In other countries bommie cod are kept and sold live to market, therefore there is the potential for bommie cod to enter Australian fish markets. This information will therefore be important when and if this occurs.

Comment (Leanne Fernandes): The fact that the species is protogynous, with potential for fishing to effect not only maturity but also sex change schedules should be a major consideration for management.

8. REPRODUCTIVE DIFFERENCES BETWEEN CORAL TROUT SPECIES ON THE GREAT BARRIER REEF.

Samantha Adams

Introduction.

Reproductive strategies of teleosts

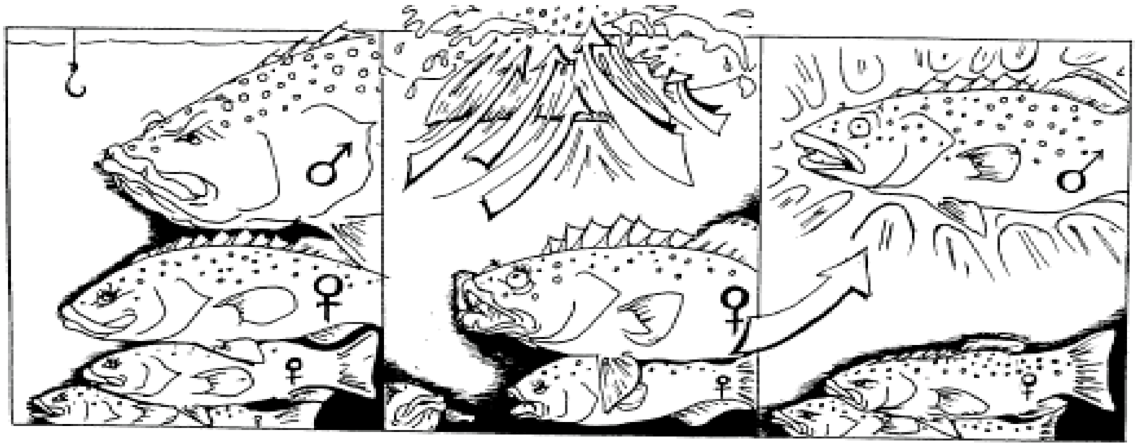
Fish are one of the most important natural resources providing over 10% of the world's animal protein requirements (Anon. 1993). The maintenance of an ecologically and economically sustainable fishery is dependent upon effective strategies for management of harvest. These strategies have primarily been based on traditional theory established for species that have separate sexes throughout life (gonochoristic species) (Beverton and Holt 1957, Adams 1980). An increasing number of fish species however, have been identified as hermaphroditic, whereby individuals can change sex at some point in their adult lives. Although hermaphroditic species only constitute a small proportion of species targeted by fisheries worldwide (Anon. 1993), a large proportion of targeted families in tropical and subtropical regions have hermaphroditic representatives. Protogyny, where individuals reproduce first as a female, and later on in life as male, is the most common form of hermaphroditism amongst marine fishes and is the dominant sexual strategy in coral reef systems (Warner 1984).

Protogynous serranids and fisheries management.

Most hermaphroditic species targeted by fisheries are protogynous, in particular, groupers, cods and coral trout (Serranids, Sub. F. Epinephelinae). A protogynous reproductive strategy has the potential to complicate the management of harvested species (Armsworth 2001). This is because commercial and recreational fisheries that target hermaphroditic stocks are often characterised by selective fishing of the larger, older individuals (Jennings and Lock 1996). In protogynous species, these are most likely to be male (Figure 8.1). There are two predicted alternative out-comes under this form of selective fishing, depending on the mechanisms governing sex change (Figure 8.1). If sex change is under some form of social control, sex change in the larger females to male is predicted to occur to replace the male lost due to fishing

(Figure 8.1a). The operational sex ratio (numbers of mature males to mature females) is therefore maintained but the average size and age of males and females is reduced (Figure 8.1a - Compensated response). Although the sex ratio of the population is maintained, this response could lead to a reduction in population fecundity due to the decreased average female size (Sadovy 1996).

(a) Compensated response



(b) Uncompensated response

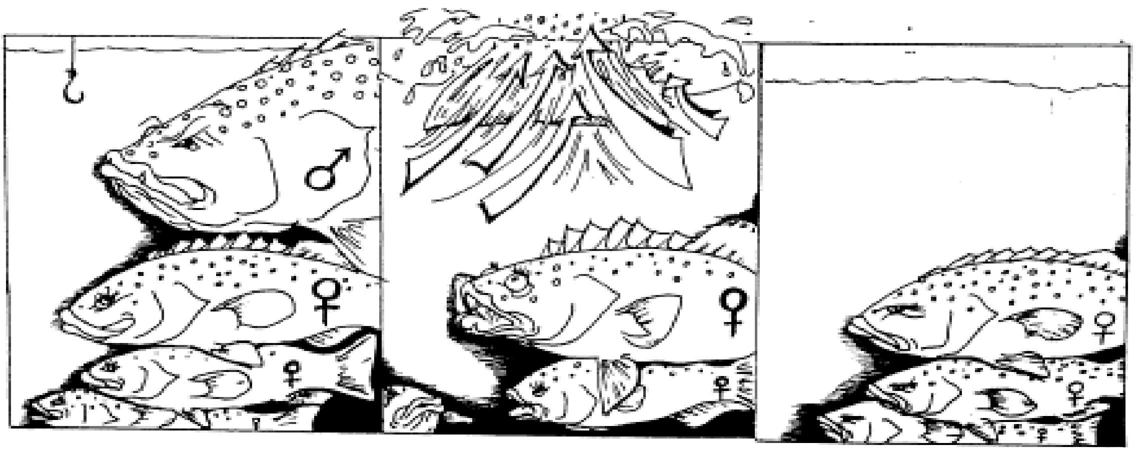


Figure 8.1. Diagram showing the two alternative predicted response of protogynous species following the removal of larger males by fishing: **(a)** Compensated response – where sex change is under social control and **(b)** Uncompensated response – where sex change is under genetic control or males are removed by fishing faster than they can be replaced in the population by compensation. Diagram adapted from Vincent and Sadovy (1998).

If sex change occurs at a fixed size or age, and/or the rate of male removal by fishing is higher than the rate that males can be replaced in the population via the above compensated response (Figure 8.1a), a highly female biased sex ratio is expected to result (Figure 8.1b - uncompensated response). It is the latter response that is thought to make protogynous populations more vulnerable to fishing pressure than species that do not change sex because successive removal of males may leave an insufficient number of males to fertilize eggs (Sperm limitation). There is no direct evidence for either of these responses occurring in protogynous populations, inferences generally relying on indirect evidence via comparison of reproductive parameters for protogynous populations in fished and un-fished areas. Both a reduced average male size as well as a highly female biased sex ratios have been found in heavily fished protogynous populations (e.g. Thompson and Munro 1978, Coleman et al. 1996). The level of female bias in the sex ratio that causes reproduction to cease, however, is unknown.

Reproductive biology and the management of coral trout on the Great Barrier Reef

The genus *Plectropomus* (coral trout) are important components of tropical fisheries worldwide (Bentley 1999). In Australia, the common coral trout (*P. leopardus*) and the blue-spot trout (*P. laevis*) are the major targets of the Great Barrier Reef Line Fishery where the common coral trout is the dominant species of the commercial catch of coral trout. Although generally a minor component of the commercial fishery, the bar-cheek trout (*P. maculatus*) is an important species to the recreational sector due to its inshore distribution. At present these three species are managed with the same regulations (e.g. share the same minimum legal size of 38 cm Total Length (TL)). The general objective of minimum legal sizes is to allow some individuals of each sex to reproduce prior to recruiting to the fishery (at the minimum legal size, Hill 1990). However, differences in the timing of maturity and sex change between these three species are likely to result in differences in the numbers of individuals that have the opportunity to spawn prior to recruiting to the fishery. Furthermore, the population characteristics associated with protogyny in general (females always small, males always large) can complicate the use of minimum legal sizes by allowing females to spawn prior to recruiting to the fishery, but not males (Hill 1990). Therefore the objective of this study was to compare the sizes at first reproduction and sex change among the three coral trout species. These data would help determine the proportion of mature individuals of each sex below the minimum legal size for each species. The opportunity for males and females to spawn prior to recruiting to the fishery at the minimum legal size can then be assessed.

Results

The results showed that the proportion of mature individuals of each sex below the current minimum legal size varied between species (Figure 8.2). Therefore varying numbers of each sex will have the opportunity to spawn prior to recruiting to the fishery at the current minimum legal size.

Proportion of mature females below the minimum legal size (38 cm TL)

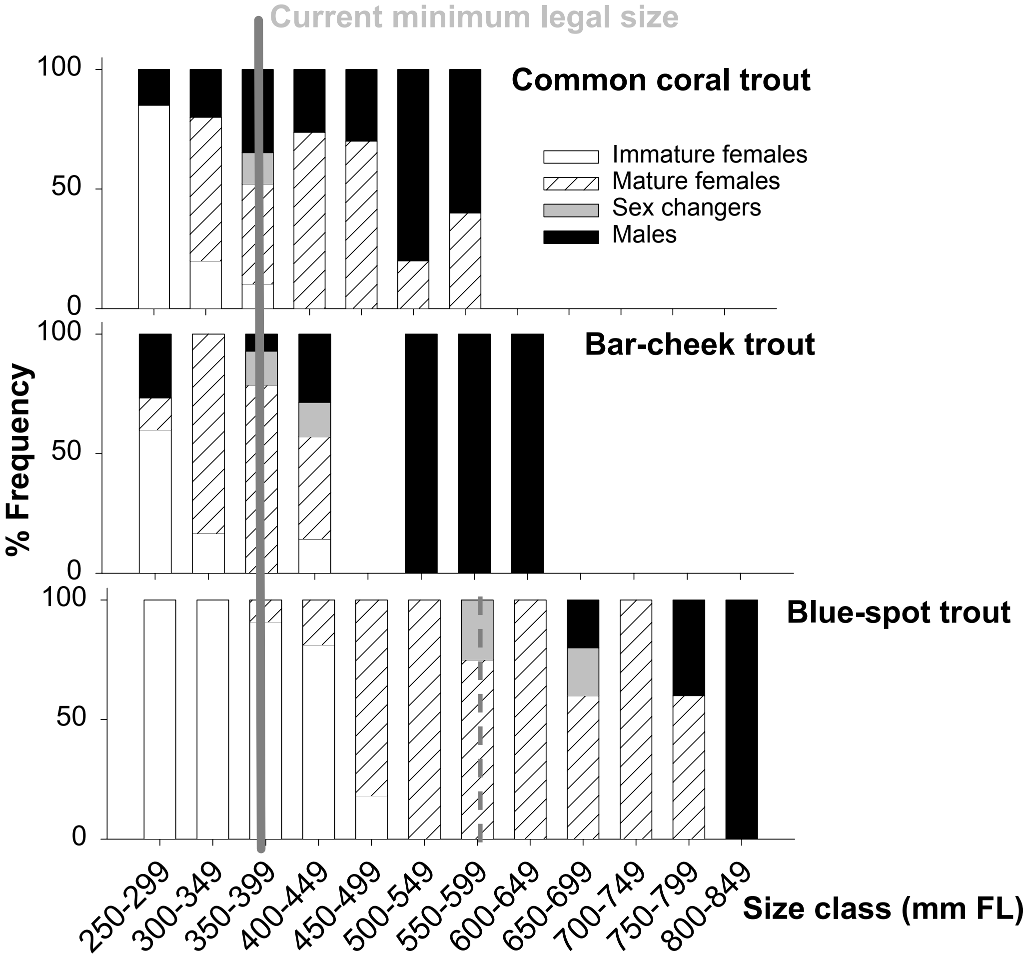
There was substantial variation in the sex structures among the three coral trout species. Nearly all females are mature before the minimum legal size for the common coral trout and all females have reached maturity before the minimum legal size for the bar-cheek trout. This means that all female common and bar cheek trout are likely to spawn at least once, and some possibly twice prior to recruiting to the fishery at the minimum legal size. However, less than 5% of blue spot trout females are likely to spawn prior to recruiting to the fishery at the current minimum legal size.

Proportion of mature males below the current minimum legal size (38 cm TL).

The common coral trout and the bar-cheek trout differ from the blue spot trout by having higher numbers of small males below the minimum legal size (Figure 8.2). Some male common and bar-cheek trout therefore gain some protection from the minimum legal size and are likely to spawn prior to recruiting to the fishery (Figure 8.2). However, the majority of the fished bar-cheek trout populations are male. Furthermore, no males of the blue-spot trout occur below the minimum legal size and therefore will not get an opportunity to spawn prior to recruiting to the fishery (Figure 8.2).

Proposed minimum legal size for blue-spot trout (60 cm TL)

The new proposed minimum legal size for the blue-spot trout is well above the size at which half of the females are mature (Figure 8.2). Females are likely to get an opportunity to spawn twice prior to recruiting to the fishery at 60 cm fork length (FL). However, no males occur below the minimum legal size, and therefore will not



get an opportunity to spawn prior to recruiting to the fishery at the proposed minimum legal size (Figure 8.2).

Figure 8.2. Sex specific size percentage frequency distribution for the common coral trout, bar-cheek trout and the blue-spot trout showing the current minimum legal size at 38cm TL ~ 36 cm FL (solid line) and the new minimum legal size of 60 cmTL~56cm FL (dashed line) for blue-spot proposed by the QFS draft management plan.

Conclusions

The three species of coral trout differed markedly in the timing of maturity and sex change. This means that different proportions of mature individuals of each sex have an opportunity to spawn prior to recruiting to the fishery at the current minimum legal size. Further work that I have done on the common and bar cheek trout has found them to be 'diandric protogynes' meaning that males can be developed from juveniles as well as through sex change in mature females. This explains the small males present in these two species. The presence of small males in these two species means that, if larger males are removed by fishing, smaller males will still be present to fertilize the females eggs before recruiting to the fishery at the current minimum legal size. The common and bar-cheek trout are therefore at a low risk of reproductive failure due to sperm limitation. Furthermore, females in both the bar cheek and common coral trout are likely to be able to spawn twice prior to recruiting to the fishery at the current minimum legal size, which further ensures successful reproduction in these two species.

The blue-spot trout is more vulnerable to detrimental effects to reproduction due to fishing under the current minimum legal size given that very few females (5%) and no males have the opportunity to spawn prior to recruiting to the fishery at the current minimum legal size. All males are large and very few in number, making the blue-spot trout more vulnerable to sperm limitation should fishing effort on large males be high. The new proposed minimum legal size for blue-spot trout is conservative for females, as all females are likely to get an opportunity to spawn prior to recruiting to the fishery. However, the new proposed minimum legal size does not allow males to spawn prior to recruiting to the fishery. The fishable stock under the proposed minimum legal size for the blue-spot trout is predominantly male, placing the species at equal risk of sperm limitation as under the current minimum legal size. The barramundi, a species that changes sex from male to female, posed a similar problem for fisheries managers. In this species, it was the females that were large and few in number, but essential for future reproduction of the stock. In this case, a maximum legal size was used in combination with a minimum legal size, to protect spawning of both sexes in this species and therefore future reproduction of the stock.

This work has highlighted some of the problems associated with managing multi-species fisheries and application of minimum legal sizes to species with alternative reproductive strategies. Further work from my Ph.D. project has found that reefs closed to fishing maintain a significantly larger size of the sexes compared to open reefs, at least in regions where fishing effort has been traditionally highest. Therefore combined use of conservative minimum legal sizes, coupled with areas closed to fishing will aid in ensuring future reproduction in coral trout species on the Great Barrier Reef.

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DISCUSSION MINUTES

Question (Mick Bishop): Are males in the smallest size class of common coral trout mature? Are these born male?

Response (SA): A number of individuals in the common and bar cheek coral trout do appear to be able to develop into males without reproducing as a female. This does not seem to occur in *P. laevis.*

Question (Mark Elmer): How useful are minimum size limits as a management tool?

Response (SA): Seems to be most effective for the common and bar cheek coral trout as both sexes gain some protection and females have an opportunity to spawn twice.

Question (Ashley Williams): Are there any regional differences in sexual structure?

Response (SA): There are no marked differences in the size and age at maturation. Regional differences occur in other aspects of the sexual structure but this becomes less clear when looked at over a number of years, possibly due to recruitment pulses which can alter sex ratios and timing of sex change. The age of sex change is latter in southern regions if examining sex changing individuals only. Additional differences include smaller males in the southern regions.

Question (Mick Bishop): Protection of males is not included in current management strategies, are there any suggestions how this could be better managed?

Response (SA): Possibly by a maximum legal size for the blue spot trout. However, this may be unnecessary as these larger individuals are generally not kept due to the risk of ciguatera poisoning from eating these fish.

Question (Bryony Barnett): Has any work been done on behaviour of sex change of coral trout to see if they can compensate for male removal?

Response (SA): Melita Samoilys has done spawning behaviour showing a dominant male with numbers of females. However, this does not give information on whether females change sex in response to loss of males in their population. The ELF Experiment has shown a decrease in the average female size on green reefs that were open to fishing, suggesting that relatively unfished populations do have some ability to compensate for male removal via earlier sex change.

Question (John Robinson): Is there any evidence of males turning back to females?

Response (SA and Howard Choat): There is no evidence of this in coral trout. There are a very few number of fish that have this ability.

Question (Bruce Mapstone): Could the small males that are seen in the common coral trout be a response to years of fishing?

Response (SA): Possibly but unlikely because the data was from a green reef.

Question (Mark Elmer): Will this data be incorporated into ELFsim?

Response (SA): Although not in the short term, the data will be incorporated into ELF sim in the future.

Question (Bruce Mapstone): What are the long term implications for the stock if fishing leads to smaller males?

Comment (Mick Bishop): Research has highlighted the importance of access to green zones to properly address these sorts of questions.

Comment (Jim Higgs): This is particularly important for the bar cheek trout where males are predominantly large and old.

Question (Ann Ferguson): What is the general 'feel' of fisheries managers of current management in light of the data presented?

Response (Mark Elmer): Minimum legal sizes have worked well for the common coral trout but consideration for alternative measures for the other species is necessary.
Comment (Mick Bishop): Knowledge of the relative abundance's of larger older males is also necessary to determine the necessity of maximum legal sizes, particularly in the blue spot trout where males are few.

Comment (Terry Must): A lot more larger blue spot trout are caught up north, however, ciguatera may be effective in protecting the larger males.

Comment (John Robinson): Most of the data I have seen shows no difference in sex specific parameters between reefs open and closed to fishing. This was clarified as the data from the ELF project shows that green reefs definitely maintain a larger population of males and females.

Comment (Mick Bishop): The likely reason for no difference between green and blue reefs is that green areas are not large enough.

Comment (Bruce Mapstone): In the data analysed to date there are often regional differences in the effectiveness of marine zones. For example, there is minimal difference in the size and age structures of coral trout between blue and green reefs in Lizard Island, however, in the southern regions there are. This is likely to be attributed to regional differences in historical fishing effort, which traditionally has been higher in the south.

PARTICIPANTS AT THE CRC REEF STUDENT-STAKEHOLDER WORKSHOP 14 MARCH, 2001.

From left to right: (Back row) Bruce Mapstone, Vicki Hall, Richard Quincey, Phil Cadwallader, Mick Bishop, Robert Grimley, Jim Higgs,
(Centre row) Terry Must, Bryony Barnett, John Evetts, Mark Elmer, Chris Evetts, Howard Choat, Andrew Tobin, Geoffrey Muldoon, Jake Kritzer, Sam Adams, Ross Marriot, Chris Roberts, David Williams
(Front row) Jacobus Mosse, Ashley Williams, David Welch, John Robinson

List of e-mail addresses of the participants at the CRC Reef Student-Stakeholder workshop March 14, 2001.

Name	Email address	Affiliation
Bryony Barnett	bryony.barnett@crcreef.com	CRC Reef
Mick Bishop	m.bishop@gbrmpa.gov.au	GBRMPA
Belinda Boyce	-	CRC Reef
Phil Cadwallander	p.cadwallander@gbrmpa.gov.au	GBRMPA
Howard Choat	john.choat@jcu.edu.au	JCU
Mark Elmer	elmerm.dpi.qld.gov.au	QFS
Chris Evetts	gbrca@mcs.com.au	Charter Fisher/GBRCA
John Evetts	(fax) 49552629	Charter Fisher
Ann Ferguson	ann.ferguson@jcu.edu.au	WWF
Leanne Fernandes	leanne.fernandes@gbrmpa.gov.au	GBRMPA
Raymond Gleeson	-	Charter Fisher
Robert Grimley	grimler@dpi.qld.gov.au	QFS (QBFP)
Steve Hall	s.hall@aims.gov.au	AIMS
Vicki Hall	vicki.hall@anu.edu.au	CRC Reef
Annabel Jones	Annabel.jones@jcu.edu.au	CRC Reef
Rosemary Lea	lear@dpi.qld.gov.au	QFS
Bruce Mapstone	bruce.mapstone@jcu.edu.au	CRC Reef
Helene Marsh	helene.marsh@jcu.edu.au	JCU
Terry Must	arabon@telstra.easymail.com.au	Commercial Fisher
Richard Quincey	richard.quincey@env.qld.gov.au	QPWS
Russell Reichelt	Russell.reichelt@crcreef.com	CRC Reef
Chris Roberts	chris.roberts@balkanu.com.au	BALKANU
John Robinson	john.robinson@beyond.net.au	Recreational Fisher AUFQ
Doug Rodgers	-	Commercial Fisher
Robin Stewart	-	Commercial Fisher
Andrew Tobin	andrew.tobin@jcu.edu.au	CRC Reef / QDPI
Vern Veitch	-	SUNFISH
Dave Williams	david.williams@crcreef.com	CRC Reef / AIMS