NORTHERN MACKEREL (SCOMBRIDAE: *SCOMBEROMORUS*): CURRENT AND FUTURE RESEARCH NEEDS

T.M. Ward and P.J. Rogers

August 2003

South Australian Research and Development Institute, Aquatic Sciences

PO Box 120
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FRDC Project No. 2002/096

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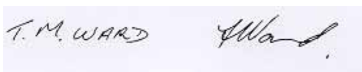

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LIST OF ABBREVIATIONS

Scientific

CPUE: Catch Per Unit Effort

DEPM: Daily Egg Production Method

FL: Fork Length

TL: Total Length

SST: Sea Surface Temperature

Other

AFMA: Australian Fisheries Management Authority

AFZ: Australian Fishing Zone

CFISH: Commercial Fisheries Information System

CRC: Cooperative Research Centre

CSIRO: Commonwealth Scientific and Industrial Research Organization

DBIRD: Department of Business, Industry and Resource Development

ESD: Ecologically Sustainable Development

EPBC: Environmental Protection and Biodiversity Conservation Act

FTO: Fishing Tour Operator

FWA: Fisheries WA

GBR: Great Barrier Reef

GBRMPA: Great Barrier Reef Marine Park Authority

GPS: Global Position System

IMP: Interim Management Plan

LTMP: Long Term Management Program

MSE: Management Strategy Evaluation

NPF: Northern Prawn Fishery

OCS: Offshore Constitutional Settlement

PI: Principal Investigator

QFS: Queensland Fisheries Service

QFS RFISH: Queensland Fisheries Service Recreational Fisheries

QDPI: Queensland Department of Primary Industries

RFISH: Recreational Fisheries Information System

TSPZ: Torres Strait Protection Zone

EXECUTIVE SUMMARY

1. FRDC-funded research on northern mackerels over the last 10 years has been well focused and coordinated, and has delivered significant benefits to industry by enhancing the value of the catch and contributing significantly to the refinement of management arrangements for Spanish mackerel throughout northern Australia and for spotted and school mackerel in Qld.

2. The fisheries biology and stock structure of Spanish mackerel are relatively well known, and age-structured stock assessment models have been developed and applied. The main information needs are for better data on abundance and exploitation rates, which are being addressed in the current GENETAG project (2002/011). Additional large-scale, field-based projects are not required for Spanish mackerel until the GENETAG project is completed. The immediate priorities are to support the existing national age-determination working group to assess the costs and benefits of various approaches to age-determination for stock assessment, to facilitate adoption of appropriate age-determination methods in each jurisdiction, and to produce a document synthesising existing age and growth data.

3. FRDC-funded research on spotted and school mackerel has contributed significantly to the management of the Qld fisheries. The absence of significant fisheries in other jurisdictions means that additional research on spotted and school mackerel is not a high priority from a national perspective.

4. There is a pressing need for information on the stock structure and fisheries biology of grey mackerel in the Gulf of Carpentaria, NT and WA. Additional information is also needed for the Qld east coast. Previous studies on Spanish mackerel provide a blueprint for the type of project that is needed. The project should be cost-effective and involve extensive collaboration among researchers from WA, NT and Qld with strong track records for conducting research on northern mackerels. The current project on blue mackerel (FRDC Project 2002/061) provides an example of how this collaboration could be structured. The aims of the project should be to determine the stock structure, develop a validated age-determination protocol, describe the fisheries biology and establish a framework for future monitoring and assessment of the fisheries for grey mackerel throughout northern Australia.

NON-TECHNICAL SUMMARY

NORTHERN MACKEREL (SCOMBRIDAE: *SCOMBEROMORUS*): CURRENT AND FUTURE RESEARCH NEEDS.

FRDC PROJECT NO: 2002/096

PRINCIPAL INVESTIGATOR: Dr T.M. Ward

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Spanish Mackerel (*S. commerson*)

Previous research on northern mackerel has focused mainly on Spanish mackerel, which has attracted 73% ($1.59M) of FRDC funding over the last 10 years. FRDC Project 98/159 provides information on the stock structure and movements of Spanish mackerel and indicates the spatial scales at which the fisheries should be managed. Previous and current FRDC Projects (e.g. T94/015, 99/151, 2001/019) have provided biological information that has contributed to stock assessment and refinement of management arrangements in the NT, Qld and WA.

An age-structured model for Spanish mackerel was developed as an output of stock assessment workshops in the NT, and was adapted for the Qld east coast by Welch *et al.* (2002). As with the NT assessments, limitations in catch and age data, and high levels of uncertainty for estimates of natural mortality and biomass, limited the reliability of the assessment, which also identified the need for additional age data from the recreational sector. The model was also incorporated into the Management Strategy Evaluation (MSE) that was used to assist the refinement of the management arrangements for the east coast fishery, and which identified the pressing need for better estimates of abundance (Hoyle 2002).

Data on the age and growth of Spanish mackerel are available for most jurisdictions, and monitoring programs have been established to some degree. However, the time series and spatial representativeness of data are generally poor. In several cases, otoliths have been collected but not analysed. Maintaining or enhancing monitoring programs and analysing existing otolith collections are priorities. The optimal age-determination protocol for Spanish mackerel remains the subject of some debate. During the review, several researchers expressed concerns about the use of annuli counts to estimate age, and identified the need to investigate the use of age proxies, such as otolith weight and fish size, more thoroughly. The precision of age estimates required for stock assessment, including the costs and benefits of various approaches, need to be assessed formally. The potential for synthesizing data obtained using several methods to calculate probabilistic estimates of age should also be assessed.

The strong collaboration among researchers throughout Australia established through previous projects needs to be maintained to ensure appropriate techniques for age-determination are adopted nationally. In late 2002, researchers from the CRC Reef initiated the establishment of a national Spanish mackerel age-determination working group for this purpose. The efforts and activities of this group should be supported. Meetings could be conducted cost-effectively by scheduling them to coincide with meetings for other current projects (e.g. GENETAG). As well as ensuring that appropriate methods are adopted, the working group should produce a document that synthesises age and growth data for Spanish mackerel in northern Australia.

The GENETAG project may provide a useful method for estimating the exploitation rate of Spanish mackerel, and has the potential to enhance stock assessment and management of other large pelagic fishes. Until the GENETAG project is completed, there is not a pressing need for additional large-scale, field-based projects on Spanish mackerel. The main priorities are to ensure that the age-determination working group assesses the costs and benefits of various approaches to age-determination for stock assessment, produces a document synthesising existing age and growth data and facilitates the adoption of appropriate age-determination methods in each jurisdiction.

Spotted Mackerel (*S. munroi*) and School Mackerel (*S. queenslandicus*)

The main fisheries for spotted and school mackerel are off the Qld east coast. FRDC contributed $579,140 to two projects (92/144, 92/144.02) that provided valuable information for these fisheries. The final report and six scientific papers contain information that have and will be used to refine management arrangements. For example, results from the study provided the scientific basis for discussions at the Qld Spotted Mackerel Workshop, which resulted in the establishment of new management arrangements in December 2002. This project also highlighted the value of using several methods concurrently to investigate stock structure.

Species-specific stock assessments have not been completed for spotted or school mackerel in Qld. CRC Reef and QFS are currently undertaking a joint assessment of spotted mackerel, and an assessment of school mackerel is planned. Presumably these assessments will adapt the model used for the Spanish mackerel assessment, identify potential biological performance indicators and management options, and determine the research needs for these species. A MSE similar to that conducted for Spanish mackerel may be valuable. As less data are available for spotted and school mackerel than for Spanish mackerel, the assessments are unlikely to be particularly informative about stock status.

The assessments will almost certainly identify the need for ongoing collection of age structure data. Over the past 2 years, QFS has sampled otoliths from spotted mackerel catches. Whilst sampling to date has been sporadic, this initiative is a good step towards the establishment of a more comprehensive program. A program for monitoring the age structure of school mackerel is also needed. As the east coast supports several stocks of school mackerel, the spatial framework for this program will need to be designed carefully.

As is the case for Spanish mackerel, the methods used for age determination of spotted and school mackerel may need to be re-evaluated. This re-evaluation should include assessment of the precision of age estimates needed for stock assessment. The costs and benefits of using age proxies, such as fish size and otolith weight, should also be assessed using unbiased statistical approaches. The potential for synthesising morphometric data, daily ring data, annuli counts and measures of otolith weight to provide probabilistic estimates of age also needs to be investigated.

Grey Mackerel (*S. semifasciatus*)

The national annual catch of grey mackerel is approximately 500-1000 tonnes. Catches off the east coast have declined recently, but catches are significant and/or increasing in the Gulf of Carpentaria, NT and WA. Information on stock structure and biology is needed for these areas. Studies of the stock structure and fisheries biology of Spanish mackerel provide a blueprint for the type of project that is needed. A previous proposal for research on grey mackerel in WA (2002/010) should be expanded to include all waters west of Torres Strait. The project should be cost-effective and involve researchers from WA, NT and Qld with strong track records for research on northern mackerels. The current project on blue mackerel (2002/061) provides an example of how this collaboration could be structured. The project should investigate stock structure, obtain baseline biological data, develop a validated age-determination protocol and establish a framework for ongoing monitoring and assessment of the fisheries.

Future Research Priorities

Maintaining the high level of collaboration among researchers developed through previous projects is a high priority. The age-determination working group provides an effective forum for maintaining this collaboration and could be run cost-effectively by scheduled meetings to coincide with those for other projects (e.g. GENETAG). The primary goal of the working group is to ensure that appropriate techniques for age-determination are used in each jurisdiction. However, the working group should also: (i) produce a document that synthesises existing data on the age and growth of Spanish mackerel; (ii) identify approaches to age determination that are cost effective and will satisfy stock assessments needs; and (ii) develop a national research proposal on the stock structure and fisheries biology of grey mackerel in northern Australia.

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We sincerely thank the large number of people who assisted us to complete the project.

Fisheries scientists, including Rik Buckworth (DBIRD), Drs Daniel Gaughan, Michael Mackie and Steve Newman (Fisheries WA), Drs Andrew Tobin and Gavin Begg (CRC Reef), Dr Jenny Ovenden, Geoff McPherson, Ian Halliday, Micheal O'Neill and Simon Hoyle (QDPI), and Dr Bob Lester (UQ), sent us copies of their papers and reports on northern mackerel and provided valuable comments on drafts of the review.

Fisheries and data managers, including Stephanie Slade and Mark Doohan (QFS), Krisy Saville (WA Fisheries), Ray Clarke (DBIRD), Thim Skousen, Bruce Wallner and Ryan Murphy (AFMA) provided catch and effort data as well as documents and descriptions of the management arrangements for the northern mackerel fisheries in their jurisdiction. We used the information they provided as the basis for many of the conclusions that we have drawn in this report.

Numerous fishers and industry representatives in the NT, Qld and WA provided information on the degree to which results of research have benefited and been communicated to stakeholders.

Dr Patrick Hone and Jane Harris (FRDC) provided information needed for this review, including copies of FRDC reports and proposals, and commented on drafts of the report.

This report was formally reviewed by Dr Adrian Linnane and Mr Craig Noell and approved for release by Professor Anthony Cheshire (SARDI Aquatic Sciences).

CHAPTER 1. INTRODUCTION

1.1 BACKGROUND AND NEED

On 6 March 2002, the Principal Investigator (PI) for this project (2002/096) received a letter from FRDC indicating that over the preceding 10 years the FRDC Board had invested significantly in research and development of Spanish mackerel (*Scomberomorus commerson*), grey mackerel (*Scomberomorus semifasciatus*), spotted mackerel (*Scomberomorus munroi*) and small or school mackerel (*Scomberomorus queenslandicus*), which are collectively termed "northern mackerel" in this report. The letter requested the PI to undertake an independent review of previous research and assess the current and future research needs of the fisheries for these species (Appendix 1) and indicated the following terms of reference for the review:

1) Document past (at least 10 years) and current research projects funded by all agencies and identify the outcomes and consequent uptake of results by stakeholders (impacts).
2) Provide comment on the degree to which the research and development has met management needs and has been used to improve the management arrangements.
3) Undertake a benefit-cost analysis of the previous research and development.
4) Evaluate fishery(s) strategic research plans with respect to whether domestic management needs, industry development, environmental assessment and domestic fishery assessment needs are adequately addressed.
5) Identify significant gaps in current and proposed future research plans and projects, including reference to needs arising from strategic assessment of the fishery under the EPBC and demands arising increased recreational catch.

In response to this request, the PI submitted a project proposal comprising three phases (Appendix 1) that was approved by the FRDC Board in April 2002. The proposal indicated that Phase 1 would involve: (i) undertaking an electronic literature search and developing a bibliographic database for northern mackerel; (ii) conducting telephone discussions and email exchanges with industry representatives, fisheries researchers and resource managers and obtaining fisheries statistics, research reports and management plans in order to develop an overview of previous and current research in each jurisdiction; (iii) assessing the degree to which research has met management needs and been incorporated into current management arrangements; (iv) conducting a preliminary assessment of research costs and benefits to industry; (v) identifying gaps in current and proposed research plans including reference to needs arising from strategic assessment under the EPBC Act and demands arising from increases in the recreational catch; and (vi) identifying perceived current and future research needs.

Phase 2 would involve the PI travelling to Perth, Broome, Darwin, Canberra, Thursday Island, Cairns, Townsville, and Brisbane to: (i) conduct meetings with representatives of fishing industry councils, conservation and resource management agencies/groups in each jurisdiction (ii) discuss the range of views presented to the PI regarding the degree to which research has met management needs and been incorporated into management arrangements; (iii) provide stakeholders with opportunity to comment on methods used to conduct the preliminary cost benefit analysis; and (iv) receive feedback on the PI's initial assessment of the current and future research needs for the fisheries.

Phase 3 would involve: (i) developing a draft report; (ii) circulating the draft to stakeholders for comment; (iii) submitting a draft report to FRDC for comment and/or formal review; and (iv) finalising the report.

1.2 OBJECTIVES

The report reviews previous research on northern mackerel and assesses current and future research needs for these fisheries. It has five objectives:

1. To provide an overview of the fisheries and current management strategies in each state;
2. To assess the degree to which past and current research has met management needs;
3. To summarise and identify gaps in past and current research on northern mackerel;
4. To assess the costs and benefits of research on northern mackerel to the fishing industry;
5. To identify current and future research priorities for northern mackerel.

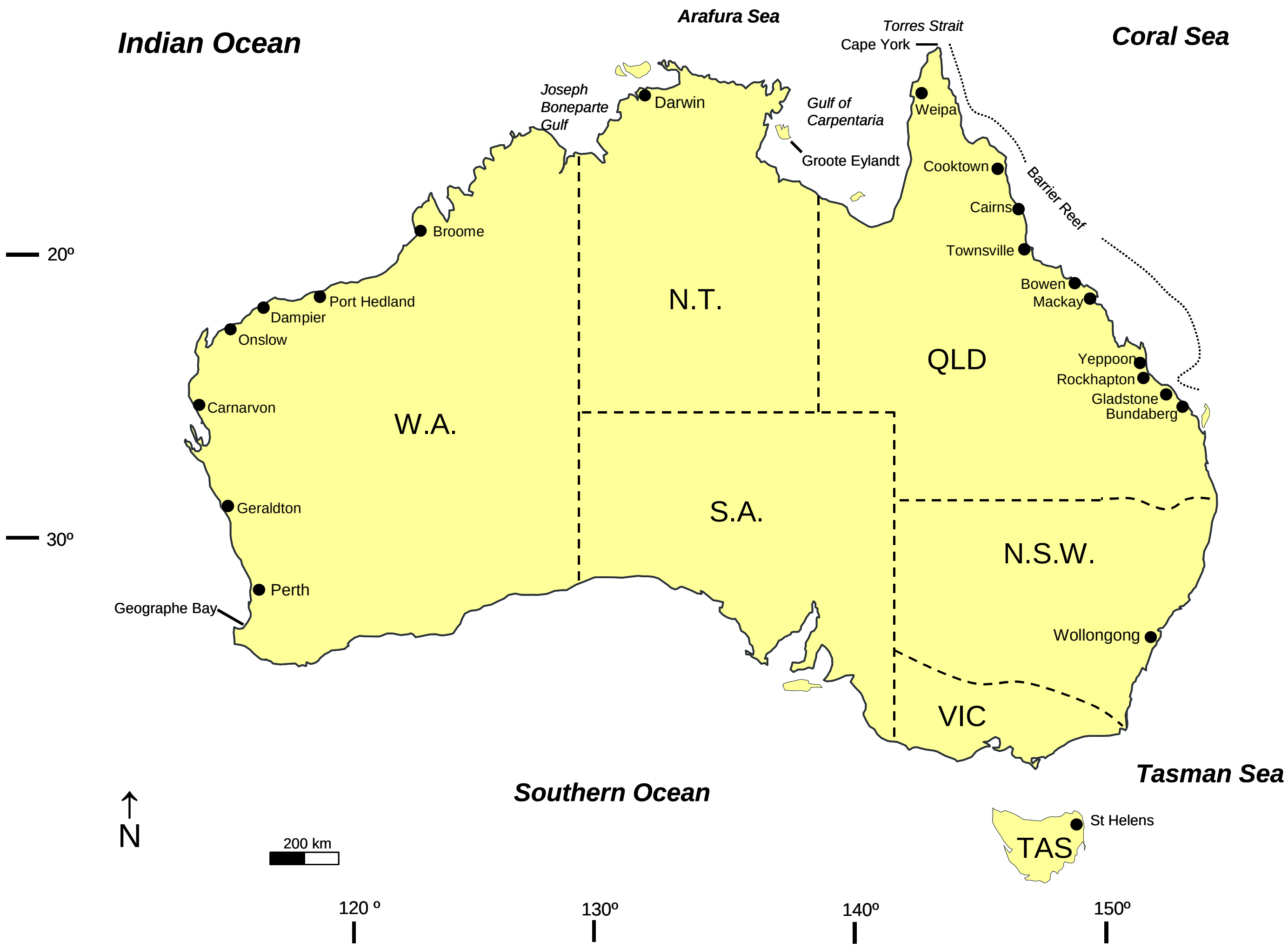
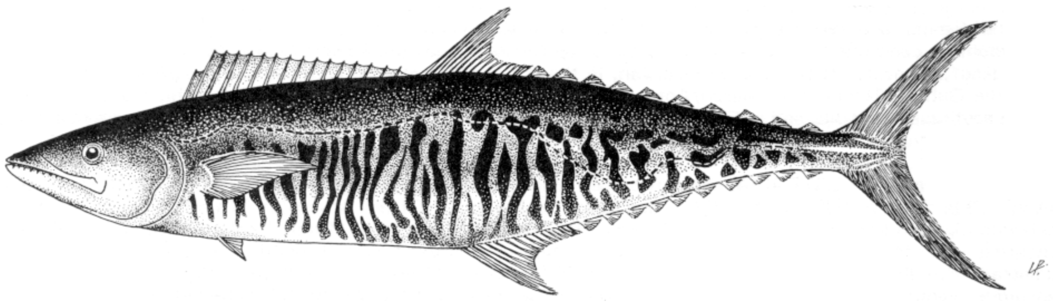


Figure 1. Map of Australia showing the locations mentioned in the text.

CHAPTER 2. SPANISH MACKEREL *SCOMBEROMORUS COMMERSON*



Picture courtesy of the United Nations Development Programme Food and Agriculture Organization of the United Nations (FAO Species Catalogue Vol 2, Scombrids of the World).

Family: Scombridae

Genus: *Scomberomorus*

Other common names: Narrow-barred Spanish mackerel, Spaniard.

Diagnostic features:

Colour: Silvery grey to blue with darker transverse, wavy vertical bars ($\leq$ 20 in juveniles, 40-50 in adults) that break into spots toward the caudal fin.

Fin ray and spine counts: First dorsal = 15-18 spines (usually 16-17); Second dorsal = 15-20 rays (usually 17-18) and 8-10 finlets; Anal fin = 16-21 rays (usually 18-19), and 7-12 finlets (usually 9-10); Pectoral fin = 21-24 rays.

Lateral line bent downward below second dorsal fin.

Vertebral count: 43-46.

Size: Maximum length of approximately 240 cm FL, commonly 90 to 100 cm FL. Commonly caught between 4 and 15 kg. Can reach 70 kg.

References: Collette and Nauen (1983); Kailola *et al.* (1993); www.fishbase.com.

2.1 INTRODUCTION

This chapter: (1) summarises and identifies gaps in past and current research on Spanish mackerel *Scomberomorus commerson*; (2) provides an overview of the fisheries and current management strategies in each state; (3) assesses the degree to which past and current research has met management needs; and (4) identifies current and future research needs for Spanish mackerel in northern Australia. Information presented in this chapter is incorporated into the strategic research plan for northern mackerels (Chapter 7).

2.2 INFORMATION AVAILABLE AND GAPS IN KNOWLEDGE

2.2.1 Critical Scientific Documents and Relevant Reviews

Spanish mackerel is the most extensively studied of Australia's northern mackerels. A brief overview of the biology and fisheries is provided by Kailola *et al.* (1993). Tobin (2002) and Williams (2002) reviewed the biology, ecology and fisheries for this species in Qld waters. Stock assessments for the Qld east coast fishery were provided by O'Neill and McPherson (2000) and Welch *et al.* (2002). Hoyle (2002) conducted a Management Strategy Evaluation (MSE) for this fishery.

The draft Torres Spanish Mackerel Handbook 2001 reviews the fishery, research and management issues and strategies for that region. Williams and O'Brien (1998) and Haywood and Die (1997) provided stock assessments for the Torres Strait fishery.

Comprehensive reviews of Spanish mackerel are not available for the NT, however several FRDC-funded projects and stock assessment reports have been completed (Buckworth 1998, Clarke and Buckworth 2000, Buckworth and Clarke 2001).

Donohue *et al.* (1982) reported on the distribution, biology and catch data for Spanish mackerel in WA. The draft report for FRDC Project 99/151 provides a comprehensive summary of the fisheries biology and fishery in that state. The State of the Fisheries Report 2001/2002 for WA provides catch statistics for the fisheries (Penn 2002).

2.2.2 Distribution

Spanish mackerel occurs throughout continental shelf waters of the Indo-West Pacific, between the west coast of Africa and Fiji and throughout Indian and south-east Asian waters as far north as China and Japan (Collette and Russo 1984). In Australia, it has been caught from Geographe Bay in southern WA, throughout tropical and subtropical waters of WA, NT, Qld and NSW to

St Helens in Tasmania (Kailola *et al*. 1993) (Fig. 1). Catch and tag-return data have been used to infer that the range of Spanish mackerel extends southward during summer and that this may be associated with a seasonal migration. A thorough quantitative analysis of all the catch and tagging data currently available is needed.

2.2.3 Stock Structure

Compared to most fish populations, broad-scale stock structure of Spanish mackerel in northern Australia is well understood. FRDC project 98/159 examined the genetic composition, otolith microchemistry, and parasite fauna of samples collected from sites located throughout northern Australia. Collectively, the findings of this study suggest the existence of at least two distinct stocks, each comprised of sub-units that are spatially confined and undergo limited intermixing.

The genetic analysis suggested that a distinct stock occurs from south-eastern Torres Strait to northern NSW and that a second stock occurs from the Gulf of Carpentaria to Shark Bay in northern WA (Fig. 1). Fish within the Torres Strait stock have some similarities to both stocks, but are genetically more similar to the east coast stock than the northern stock (Ovenden and Street, in prep). These results support the findings of Shaklee *et al.* (1990), who also suggested the existence of eastern coast and northern stocks that should be managed separately.

The genetic study also tested for temporal stability in the allozyme composition of mackerels over a period of 15-20 years by comparing the allele composition of samples collected in the 1980s by Shaklee (unpublished data) with those obtained during the course of FRDC Project 98/159. The results of this comparison suggested a shift away from genetic (Hardy-Weinberg) equilibrium over 15-20 years and significant short and long-term instability in allele frequencies in at least two loci at four out of five locations. The authors suggested that these finding could be linked to localised gene flow and widespread changes in the number of spawning individuals and number of individuals successfully recruiting into the next generation.

The findings of the otolith microchemistry study enhanced the results of the genetic analyses and suggested that Spanish mackerel across northern Australia are comprised of sub-units that do not inter-mix extensively and essentially form a “metapopulation or a metastock” (Buckworth 2002, FRDC [GENETAG] Proposal 2002/001). At least seven distinct assemblages of adult Spanish mackerel were identified in northern Australia, including Great Barrier Reef, Torres Strait, Groote Eylandt, Darwin, Central Kimberley, Onslow, Exmouth, Shark Bay and Abrolhos Islands. The finding that sub-units are spatially confined provided additional evidence that both stocks are susceptible to localised depletion and has been used to emphasise the need for finer scale spatial management within the two major stocks (Newman *et al.* in review).

The use of gill and stomach parasites as biological tags generated results that further elucidated the stock structure and movements of Spanish mackerel in northern Australia. The analysis of long-term parasites (trypanorhynchs and anisakids) confirmed the existence of several sub-units with limited mixing. Short-term parasites (gill copepods and monogeneans) suggested male and female fish have different migration patterns, and that males may intermingle with adjacent stocks during feeding (Lester *et al.* 2001). The synthesis of information from short and long-term parasites suggested that stock boundaries and interactions of Spanish mackerel in northern Australia vary over time (FRDC Milestone report December 2000) and was used to emphasise the need for (i) ongoing monitoring of stock boundaries/overlaps and population dynamics and (ii) an integrated approach to management by WA and the NT.

2.2.4 Patterns of Migration

Despite insights obtained from FRDC Project 98/159, the migration patterns of Spanish mackerel within the northern and western population sub-units are not understood clearly. Information available suggests that movements at a range of spatial and temporal scales may be linked with seasonal and spatial variations in sea surface temperatures (SST) and currents (e.g. McPherson 1981, 1982, 1992; Donohue *et al.* 1982). A review of stock definition research in Qld waters that will be incorporated into the final report for FRDC Project 98/159 includes a summary of tagging studies conducted since 1976 and provides a qualitative movement model for the east coast (Geoff McPherson, QFS, personal communication).

To develop this model, McPherson used tag-recapture data, trends in catches and biological knowledge of similar species to infer that: (i) spawning occurs on the inshore reefs in the northern Great Barrier Reef during October to November; (ii) after spawning, older fish migrate southwards into northern NSW and southern Qld, whereas younger fish disperse but remain in tropical regions; (iii) older fish migrate northwards from sub-tropical and temperate areas into warmer tropical waters during winter in preparation for spawning; (iv) this migration may occur at a rate corresponding to the northward movement of 22-24^{0}C SST isotherm (McPherson 1981, 1992). Interpretation of recapture data presented by McPherson (1981, 1982) was impeded by lack of information on the spatial and temporal patterns of fishing activities that provided recaptures. Quantitative analysis of existing tag-recapture data would be useful, but McPherson's qualitative model is probably adequate for most management purposes.

Exploratory fishing conducted during 1981 provided insights into the distribution patterns and relationships with SST of Spanish mackerel in WA (Donohue *et al.* 1982). Results were interpreted to suggest that Spanish mackerel follow the 22-24^{0}C SST isotherm south during summer and north during winter. However, the results of FRDC Project 98/159 tend to suggest that in northern areas Spanish mackerel may not undertake long annual migrations but may exhibit a high degree of fidelity to specific locations (e.g. Lester *et al.* 2001, Newman *et al*. in review).

Catch and tag recapture data suggest that Spanish mackerel in the NT may undergo complex but poorly understood migrations that may be linked to seasonal changes in SST and salinity in inshore waters or to variations in the availability of prey (Rik Buckworth, DBIRD personal communication). Large mackerel are not amenable to conventional tagging studies (e.g. Mackie *et al.* 2003). The innovative genetically based tagging techniques currently being developed (FRDC Project 2002/011) may be useful for investigating the movement patterns of large Spanish mackerel (and other large pelagic fishes).

2.2.5 Ecological Interactions

Spanish mackerel is ecologically similar to other members of the genus *Scomberomorus*. It occupies a wide range of habitats including shelf and inshore waters, and is often found near coral reefs and drop-offs, headlands and estuaries. It appears to be an opportunistic predator that feeds on a wide range of small pelagic fishes including herrings, sardines and anchovies as well as squids, penaeid prawns and small reef fishes (McPherson, 1987). However, only one study has been conducted on the diet of Spanish mackerel in Australian waters, based on 59 fish from the Cairns area (McPherson 1987). Minimal information is available on: spatial or temporal variations in feeding patterns; interactions between baitfish migrations and movements of Spanish mackerel; ecological interactions with other pelagic species; and the influence of environmental factors on movement patterns, feeding or reproduction. Such knowledge would be useful given the trend towards ecosystem approaches to resource management, but is not currently a critical requirement for management of the Spanish mackerel fishery.

2.2.6 Reproductive Biology

Reproductive data are available for Spanish mackerel between Cooktown and Townsville, and between Mornington Island and Torres Strait (McPherson 1993). FRDC Project 2001/019 has and will provide additional information for other parts of Qld (e.g. Mackay, Rockhampton, Bundaberg and Brisbane). FRDC Project 99/151 involved macroscopic and microscopic analysis of gonad samples obtained from commercial and recreational samples in WA, and concluded that macroscopic staging of gonads was an efficient method for assessing the reproductive status of individuals and for ongoing monitoring of stocks (Mackie *et al.* 2003). Few data have been published on the reproductive biology of Spanish mackerel in the NT.

Off the east coast of Qld and in Torres Strait the minimum length at sexual maturity is 79 cm FL (McPherson, 1993). In the NT, females reach reproductive maturity at approximately 95 cm FL and 2 years of age (Buckworth and Clarke 2001). In WA, 50% of individuals are sexually mature at <2 year of age, at 90 and 70 cm TL for females and males, respectively (Mackie *et al.* 2003).

Off Townsville, the spawning season extends from October to early December, whereas in Torres Strait, Spanish mackerel spawn between August and March (McPherson 1981; O'Brien 1994). The spawning season in the Gulf of Carpentaria is poorly understood, however fish in spawning condition have been collected from the north-eastern gulf during July and October (McPherson 1997). The spawning season of Spanish mackerel in WA extends from October to January in the Kimberly and Pilbara regions and no spawning fish have been sampled in the west coast region (Mackie *et al.* 2003). Currently, no information has been published on the spawning season of Spanish mackerel in the NT.

Important spawning areas off Queensland include those reefs northeast of Townsville and between Townsville and Bowen (latitude 19°S) (Fig 1) (McPherson 1993). In WA, the major spawning areas are located along reefs in the northern Kimberley region (Fig. 2), with the southern most extent of spawning at approximately 22°S (Mackie *et al.* 2003). The location of spawning areas in Torres Strait or the NT is not well known.

Spanish mackerel is a batch spawning fish with the number of oocytes per batch ranging between 380,000 and 1,400,000 (Mackie *et al.* 2003). In WA, spawning fraction varies between regions with lowest being recorded in the Pilbara region (4-28%), which indicates that spawning occurs every 3.6-25 days. The highest spawning fractions (33-56%) were recorded in the Kimberley region, which suggests that spawning occurs every 1.8-3 days (Mackie *et al.* 2003).

Spawning frequencies have only been estimated during October in eastern Gulf of Carpentaria and Torres Strait and during October and November off the east Queensland coast. Off the east coast, females have been estimated to spawn every 3.7-5.9 days and in the Gulf of Carpentaria this ranged from 1.9-3.1 days (McPherson 1993). Spawning frequency for the east coast may have been underestimated, however, as gonad tissue was collected outside the main spawning season (McPherson 1993).

2.2.7 Early Life History

The pelagic eggs of Spanish mackerel are spherical and range between 1.05 and 1.38 mm in diameter with an oil-droplet of 0.3-0.39 mm in diameter (Munro 1942). Spanish mackerel eggs cannot be easily distinguished from the eggs of other northern mackerels, which currently prevents the application of egg-based stock assessment methods, such as the Daily Egg Production Method (DEPM). Information on the effect of temperature on rates of egg development would also be required for application of the DEPM.

Larvae hatch approximately 25 hours after fertilisation, are readily identifiable and commonly found in lagoons off Townsville between November and January (Munro 1942; Jenkins *et al*. 1985). Larvae and small juveniles collected in light traps off Cape Cleveland and Cape Bowling Green between 1988 and 1990 ranged in sizes between 12 and 41 mm TL (Thorrold 1993). Larvae mainly feed on the larval stages of other fishes (Jenkins *et al.* 1984). The season of high larval abundances coincides with periods of high food availability and high water temperatures that are conducive to rapid growth (Jenkins *et al*. 1984; 1985). No information has been published on the seasonal and spatial distribution of Spanish mackerel larvae in any other regions of Australia. The effects of environmental conditions on the recruitment patterns of Spanish mackerel are unknown.

Off the east coast of Qld, small juveniles inhabit shallow creeks, estuaries and inter-tidal flats for the first six months of life and migrate to offshore waters in May-June (McPherson 1981; 1987). Large juveniles up to 40 cm FL are taken in prawn trawls in water depths of 6-12 m (McPherson 1981). Nursery areas have not been formally identified outside Qld. Little information is available on the transition period between spawning and movement to juvenile nursery areas. The mechanisms for, and timing of, these movements are poorly understood. Additional information on juvenile distribution and abundance would provide insights into recruitment patterns and may provide a mechanism for forecasting year class strength.

2.2.8 Age and Growth

Unvalidated daily growth increments in sagittae have been used to determine the age of small numbers of juvenile Spanish mackerel from Queensland and Western Australia (McPherson 1992; Mackie *et al*. 2003). In WA, juveniles grow rapidly at rates of 3-4 $mm.day^{-1}$. Growth rates decrease significantly after the first year (Mackie *et al*. 2003).

The otolith of one juvenile (62 cm FL) from Qld contained 380 “daily” growth increments and a complete opaque band at the outer margin (McPherson 1992). This observation suggests that the first annual increment may be deposited after approximately 1 year. Daily growth increments in the otoliths of other juvenile scombrids have been validated directly (Peters and Schmidt 1997).

Whole and sectioned sagittae have been used for age determination of adult Spanish mackerel (e.g. McPherson 1992; Buckworth 1998; Mackie *et al.* 2003). However, the presence of sub-annual rings and opaque material complicates the interpretation of whole otoliths (Buckworth 1998). Marginal increment analysis has been used as an indirect validation technique in northern Qld and WA, however the reliability of this method is reduced in areas where samples are only available on a seasonal basis (McPherson 1992; Mackie *et al*. 2003). Assessments based on unvalidated analyses of otolith structure should be interpreted with caution. A project undertaken in WA (FRDC Project 99/151) involved injection of tagged fish with calcein in order to validate annual deposition of otolith increments. That study found Spanish mackerel had a low tolerance to capture, with high mortality rates of tagged fish resulting from shark predation and provided no validation of annuli deposition (Mackie *et al.* 2003).

A study of age and growth of adult Spanish mackerel was conducted in Qld between 1977 and 1979 (McPherson 1992). Otoliths were obtained from 1634 fish (45-155 cm FL) sampled from commercial trolling vessels off Bramble Cay and from reefs between Lizard Island and Townsville. Juvenile and large fish were poorly represented in samples. Results suggested that Spanish mackerel from commercial catch in northern Qld reach ages of 14 years (155 cm FL and 35 kg) for females and 10 years (124 cm FL and 19 kg) for males. Growth rates were high especially during the first 1 to 3 years. Von Bertalanffy (*VB*) growth parameters for Spanish mackerel in Qld waters were: K = $0.25yr^{-1}$, L_∞ = 127.5 cm FL and t_0 = -1.72 for males and K= $0.17.yr^{-1}$, L_∞ = 155 cm FL and t_0 = -2.22 for females (McPherson 1992). The largest fish recorded in Qld waters was 240 cm FL and weighed 70 kg (McPherson 1992). FRDC Project 2001/019 has and will provide valuable additional data on the age composition and growth rates of fish taken by commercial and recreational fishers off the east coast of Qld (see Welch *et al.*

2002). Currently, no data have been published on the age structure of Spanish mackerel in the eastern regions of the Gulf of Carpentaria.

In the Torres Strait, Spanish mackerel taken in the troll fishery mainly range between 90 cm and 110 cm FL and rarely exceed 130 cm FL. Fish from this area appear to be larger at a given age than those taken the off east coast of Qld, suggesting higher growth rates. No significant difference was observed in patterns of length at age between sexes for Spanish mackerel caught in the Torres Strait. Fish grow to approximately 60 cm FL in the first year, with individuals between 80 cm and 120 cm FL being typically 2 to 5 years old. QDPI is currently reanalysing otoliths collected between 1978 and 2000 from spawning aggregations in Torres Strait.

In the NT, Spanish mackerel have been recorded to weights of up to 60 kg (Rick Buckworth, NT Department of Business, Industry and Resource Development, personal communication). The largest fish recorded by fisheries researchers was 174 FL cm and 45 kg (Buckworth and Clarke 2001). Fish taken mostly ranged between 90 cm and 100 cm FL and 3 to 6 years of age. The oldest specimen aged from the NT commercial catch was 12 years of age (Buckworth 1998). Growth rates in the NT are high, and comparable to those in Torres Strait. The *VB* parameters for both sexes combined are K= 0.24yr^{-1}, L_∞ = 121.79 cm, t_0 = -3.25 (Buckworth 1998).

In WA, Spanish mackerel grow to 240 cm FL and weights of approximately 70 kg. As part of FRDC project 99/151, a total of 2211 sagittae obtained from commercial and recreational catches in the Pilbara, west coast and Kimberly regions (Fig. 2) were sectioned and analysed (Mackie 2003). These analyses suggested a maximum age of 22 years for males and 17 years for females (Mackie *et al.* 2003). *VB* growth parameters for Spanish mackerel in WA were: K = 0.85 yr^{-1}, L_∞ = 106.7 cm and t_0 = -0.21 for males and K = 0.64yr^{-1}, L_∞ =121.9 cm and t_0 = -0.26 for females in the Kimberly; K = 0.69 yr^{-1}, L_∞ = 115.5 cm and t_0 = - 0.29 for males and K = 0.63 yr^{-1}, L_∞ = 125.9 cm and t_0 = -0.29 for females in the Pilbara; and K= 0.76 yr^{-1}, L_∞ = 114.0 cm and t_0 = -0.21 for males and K = 0.66 yr^{-1}, L_∞ =120.5 cm and t_0 = -0.23 for females on the west coast (Mackie *et al.* 2003).

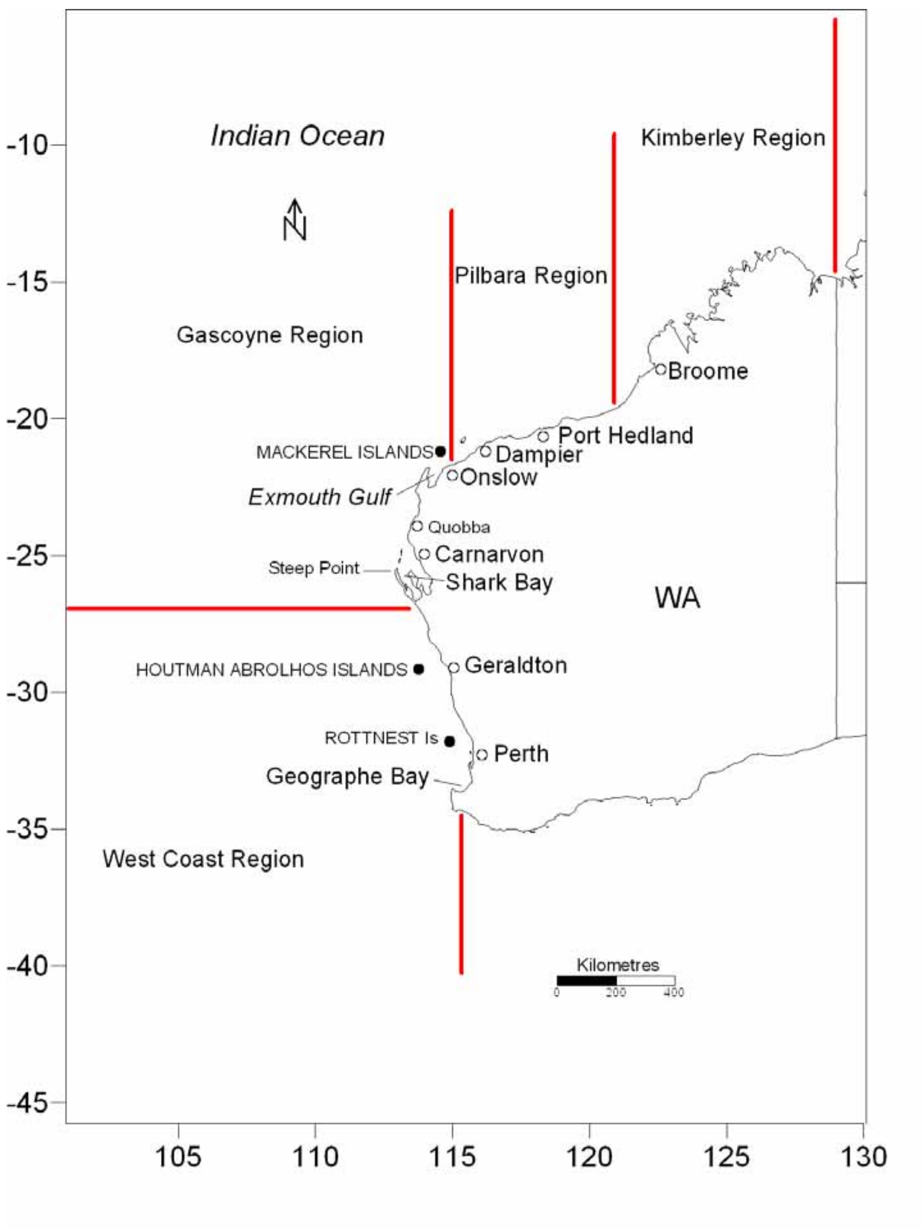


Figure 2. Regions important to the Western Australian Spanish mackerel fishery.

2.2.9 Mortality

There are few published estimates of natural or fishing mortality in Qld or Torres Strait. The MSE by Hoyle (2002) provided a maximum likelihood estimate of natural mortality of 0.418, with 95% profile likelihood interval of 0.267 to 0.813. The draft final report for FRDC Project 2001/019 also provides regional estimates of mortality for the commercial and recreational sectors off the Qld east coast.

FRDC Project 1999/151 suggested that total mortality (Z) rates were 0.45 and 0.43 $yr^{-1}$for females and males, respectively in the Kimberley, 0.26 and 0.16 yr^{-1},respectively in the Pilbara, and 0.27 and 0.16 yr^{-1} in the west coast region (Mackie *et al.* 2003). In WA, fishing mortality (F) estimated from $Z - M$ (natural mortality), ranged between 0 and 0.13yr^{-1} (Mackie *et al.* 2003). This study recommended that further studies of mortality be undertaken in WA and cited the methods being developed in the GENETAG Project 2002/011 as being potentially the most suitable.

In the NT, the total mortality rate (Z) has been estimated to exceed 0.75 yr^{-1} for individuals aged 6 years or older. As natural mortality is thought to be approximately 0.40 yr^{-1}, the fishery may have had a significant impact on large, old fish (0.35 yr^{-1}) (Buckworth and Clarke 2001).

2.2.10 Stock Assessment

An age-structured model for Spanish mackerel was developed in the NT as an output of FRDC-funded workshops in 1992, 1996 and 1997 and was recently adapted for the Qld east coast (O'Neill and McPherson 2000; Welch *et al.* 2002). As was the case in the NT, limitations in the catch and age data, and high levels of uncertainty associated with estimates of parameters such as natural mortality and unfished biomass, limited the reliability of the assessment. The model did, however, identify the need for ongoing collection of age data from representative samples of the catch, especially by the recreational sector.

The model was further developed for use in the MSE for the east coast fishery by Hoyle (2002). The MSE identified the need for additional information on age structure, recreational catches and fishing mortality rates. It also demonstrated that although age data is useful for monitoring variations in year class strength, which is critical for stock assessment, it has limited power to detect changes in abundance.

Monitoring the abundance of Spanish mackerel has been problematic in all jurisdictions. Despite widespread recognition of its inadequacies for schooling fishes, CPUE is still used as a surrogate index of abundance in most areas. Results of the recent FRDC-funded study in WA (Project 1999/151) suggest that egg-based biomass estimation methods may not be appropriate for Spanish mackerel. Biomass dynamics modelling estimated the biomass for the west coast region of WA at 1,111 tonnes in 1979, 494 tonnes in 1992 and 926 tonnes (95% CI = 471 to 14,175 tonnes) in 2002. However, high levels of uncertainty were associated with all of these estimates, and there were insufficient data to run the biomass dynamics model for Pilbara and Kimberly regions (Mackie *et al.* 2003). The current GENETAG project may provide a valuable mechanism for determining exploitation rates and monitoring the biomass of Spanish mackerel (and other large pelagic fishes).

2.3 FISHERIES, RESEARCH AND MANAGEMENT

2.3.1 Qld

Background

Spanish mackerel has been taken commercially from Qld waters for 60 to 70 years. It is the second most important species in the Qld commercial line fishery (Williams 2002). This fishery extends from the Gulf of Carpentaria to Cape York and down the east coast and is comprised of three components: (1) the Coral Reef line fishery which operates in the Great Barrier reef system, (2) the Gulf of Carpentaria fishery, and (3) the Rocky Reef fishery which is a small component that operates in southern Qld. The recreational sector caught approximately 390 t of Spanish mackerel in 1999 (Williams 2002).

Most catches are taken by trolling or drifting baits over areas of deep water adjacent to reefs (Cameron and Begg 2002). Small quantities of Spanish mackerel are taken as bycatch in the gillnet fishery for school and spotted mackerel. The fishery is fully developed with recent stock assessments suggesting that the biomass has declined by up to 56% since 1950 (Welch *et al.* 2002).

Monitoring

Since 1988, comprehensive catch and effort information has been collected for the Qld east coast and Gulf of Carpentaria through the Commercial Fisheries Information System (CFISH) logbooks. Some historical catch data from the Queensland Fish Board are also available. The Coral Reef line and Rocky Reef fisheries also report the size and species composition of their catch through the compulsory (CFISH) program. This data provides the basis for assessing the status of Spanish mackerel stocks in Qld waters, and assumes that all mackerel species are identified accurately. This factor has been identified as a major concern by fisheries managers, researchers and licence holders.

QFS introduced an age monitoring program for Spanish mackerel in 2001, as part of its Long Term Monitoring Program. Samples are now collected annually from the east coast of Qld and Torres Strait.

Information on historical catch patterns for the recreational fishery is not available prior to 1994. However, information on the total recreational catch is available from the RFISH program.

The charter fishery began collecting catch information in voluntary logbooks in 1993. These became compulsory in 1996.

Fishery

The commercial troll fishery targets relatively small fish ranging between 4 and 5 kilograms and mostly operates off north-east Qld in the Gulf of Carpentaria (Kailola *et al*. 1993; Tobin 2002). The total catch between 1970 and 1999 ranged between 440 and 1,047 tonnes per year. Mean CPUE between 1989 and 1998 was 59 kg per boat day (O'Neill and McPherson 2000).

Spanish mackerel are taken along most of the east coast of Qld, and significant fleets operate off Cairns, Yeppoon, Mackay, Bundaberg, Hervey Bay and Moreton Bay (Fig. 3). The most important fishing region is around Rib Reef, east and south-east of Cardwell (Fig. 3). Most fishing is conducted around the dark moons in November and December (Ludescher 1997). The catch of Spanish mackerel by line increased from 446 tonnes in 1988 to 770 tonnes in 1999, but decreased to 572 tonnes in 2000. CPUE remained relatively stable during this period ranging between 52 kg per boat day and 67 kg per boat day between 1988 and 1999 and was 56 kg per boat day in 2000 (Williams 2002).

The Gulf of Carpentaria fishery for Spanish mackerel is relatively new compared to the east coast fishery and is confined mainly to the area between Weipa and Cape York. The number of mackerel fishers increased to between 40 and 50 vessels during the 1990's, but stabilised at 24 vessels during 2000 (Tobin, 2002). Catches and effort peaked at 216 tonnes in 1996/7 and 1527 days fished in 1995. In 2000, 123 tonnes of Spanish mackerel were taken in the Gulf of Carpentaria Fishery, and effort stabilised at 652 days fished. CPUE increased from 145 kg per boat day in 1999 to 189 kg per boat day in 2000 (Williams 2002). Significant quantities of Spanish mackerel are also taken as bycatch by the grey mackerel and tropical shark net fisheries in the Gulf of Carpentaria, with catches increasing from 3 tonnes in 1990 to approximately 33 tonnes during 2000 (Williams 2002).

The Qld Coral Reef Line Fishery is a multi-species fishery that mostly operates in the vicinity of the Great Barrier Reef and extends from Gladstone to the Torres Strait. Spanish mackerel is caught over the length of the reef system by commercial, recreational and indigenous fishers. Spanish mackerel catches comprise about 20% of the catch of the commercial sector, and catches ranged from 430 to 709 tonnes between 1988 and 2000. Spanish mackerel comprise approximately 46% of the recreational catch, and approximately 180 tonnes were taken by this sector in 1999 (Williams 2002).

The Qld Rocky Reef Fishery is also a multi-species reef fishery that targets demersal and pelagic species. Operators mostly fish between Gladstone (24.5 ^{o}S) and the NSW border and are reliant on bands of rocky reefs that run parallel to shore at depths of up to 150m. Spanish mackerel is one of the two key species (the other being snapper, *Pagrus auratus*), with commercial catches ranging between 16 and 51 tonnes per year between 1988 and 2000. Spanish mackerel comprises over 50% of the recreational catch from these reefs. Approximately 210 tonnes was taken in 1999, which was approximately 54% of the total Qld recreational harvest for this species (Williams 2002).

Surveys of the Qld east coast in 1997 and 1999 suggest that approximately 52,000 Spanish mackerel were caught per year by recreational fishers, which equates to approximately 365 tonnes (Williams 2002). However, the confidence intervals for these estimates were wide due to the small number of samples and high variability in catches. The accuracy of species identifications was also a concern, particularly in 1997. In the Coral Reef Line Fishery, 170 and 180 tonnes were taken in 1997 and 1999, respectively. Similarly in the Qld Rocky Reef Fishery, 210 tonnes were taken per year by recreational fishers during 1997 and 1999.The National Recreational Survey estimated that in Qld during 2000/2001 approximately 339,445 mackerel of all *Scomberomorus* species were taken (Henry and Lyle 2003). This comprised 72% of the estimated national recreational catch during the survey period. This survey estimated that in Qld the indigenous harvest was 2,382 individuals of all *Scomberomorus* species.

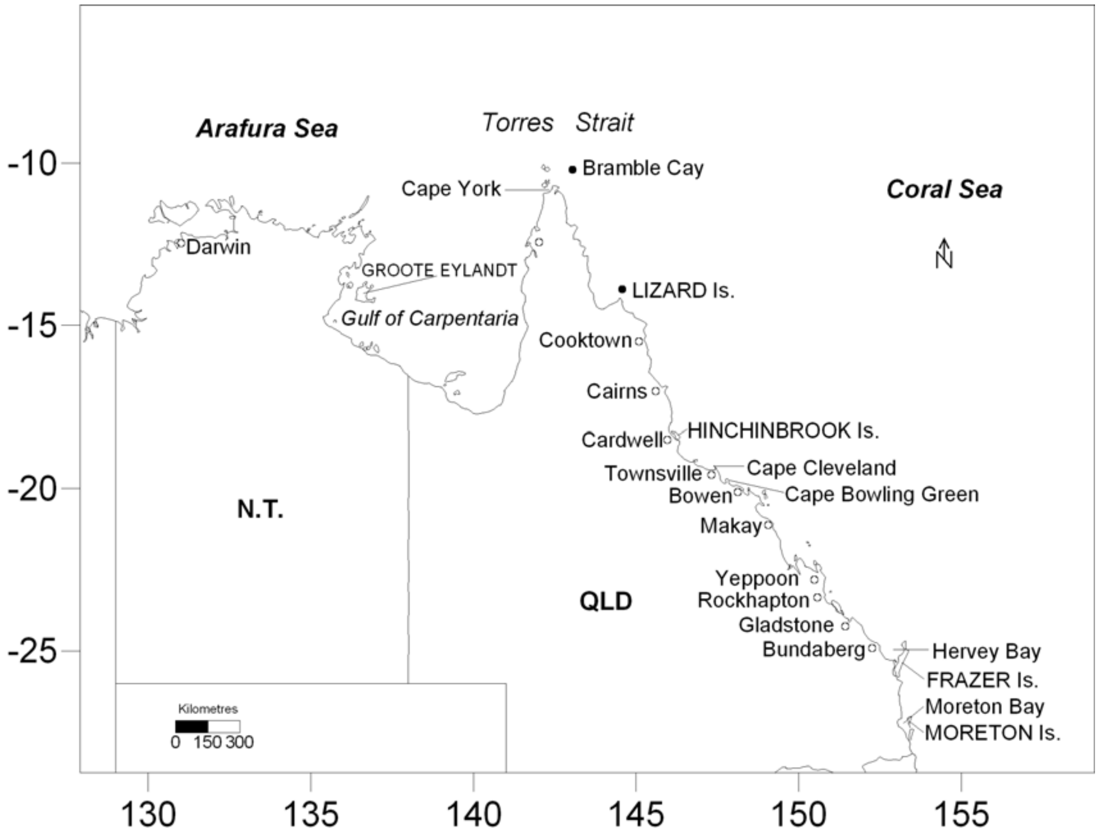


Figure 3. Locations and regions important to the northern mackerel fisheries in the Northern Territory and Queensland.

Management

The Rocky Reef Line, Coral Reef Line and Gulf of Carpentaria fisheries all have commercial, recreational, charter and indigenous sectors that are managed by the QFS (Tobin 2002; Williams 2002). The Coral Reef Fishery operates within the jurisdiction of the World Heritage listed Great Barrier Reef Marine Park and is managed by the Great Barrier Reef Marine Park Authority (GBRMPA). The GBRMPA has implemented management measures in the form of protected areas and closures to troll and line fishing.

There is a minimum legal size of 75 cm TL in the commercial and recreational troll and line fisheries. Gillnets cannot be used to specifically target Spanish mackerel and each commercial trolling vessel can only use three troll lines and six hooks. The recreational bag limit is currently 10 fish per person. Major changes to management arrangements are currently being developed for the fishery.

Extent to which research outcomes have been incorporated into management arrangements

The minimum legal size off the east coast is based on the study of reproductive biology conducted by McPherson (1993), and has recently been assessed as being appropriate based on the implications for yield per recruit and egg production analyses (Hoyle 2002).

Recent management decisions have been made largely on the basis of concerns about declining commercial catches and anecdotal reports of localised depletion in key fishing areas rather than biological (e.g. age structure) data from the fishery. However, commercial catch data show no evidence of localised depletion and suggest current catches are at historically high levels (Hoyle 2002). The reliability of catch data is not well understood.

Until recently, information on the age, growth and reproductive biology of Spanish mackerel off the east coast was based mainly on samples collected between 1977 and 1983 (e.g. McPherson 1992). Information on the age structure and reproductive biology of Spanish mackerel of the east coast of Qld obtained by the CRC Reef (FRDC Project 2001/019) were incorporated into the preliminary assessment of the fishery (Welch *et al*. 2002) and MSE completed in 2002 (Hoyle 2002).

The review of management arrangements for the Qld east coast Spanish mackerel fishery being undertaken by QFS has primarily been based on information arising from a preliminary assessment and MSE completed in 2002 (Stephanie Slade, QFS, personal communication).

These documents recommend limiting participation in the commercial sector and applying a flexible quota for those vessels remaining in the fishery. The MSE recommends setting the total allowable catch (TAC) for the commercial fishery at the average of the 1992/93 to 2000/01 commercial catch and reviewing this level annually. Without annual assessment and review, the MSE recommends setting the TAC at 70% of this average catch level. The MSE also models the effect of reducing recreational possession limits on the total recreational catch, and highlights the need for better data for future stock assessments. These data that are needed include results from the current GENETAG project, biological information and more detailed catch and effort information. While some of this information may be collected through the commercial fisheries logbook program, additional research projects may be required.

In the *Draft Fisheries (Coral Reef Fin Fish) Management Plan 2002*, QFS adopted an approach of proposing recreational possession limits at a point at which 90% of recreational angler trips would not be affected. This method has been used in proposing an amendment to the current recreational possession limit of 10 Spanish mackerel. In applying this approach, data from the Recreational Fishing (RFISH) Surveys and the National Recreational and Indigenous Fishing Survey (NRIFS) were incorporated into the review of management arrangements. The QFS will continue to conduct recreational fishing surveys and will endeavour to improve the information gained via these surveys (Stephanie Slade, QFS, personal communication).

Gulf of Carpentaria

Late in 2002, QFS released a policy regarding the reduction of latent effort in the Gulf of Carpentaria line fishery. The policy allows QFS to refuse to renew the Gulf line fishery access on licenses that have not been used to a commercial level. This policy was released in recognition of the excess capacity in the Gulf of Carpentaria and the risk that latent effort poses to Spanish mackerel stocks in the Gulf (Stephanie Slade, QFS, personal communication).

2.3.2 Torres Strait Fishery

Background

In Torres Strait, the commercial fishery for Spanish mackerel began in the 1950’s and is currently worth $1.2 million annually (Williams and O’Brien 1998; Torres Strait Protected Zone Joint Authority, 2001). Although current local Islander participation in the fishery is relatively low and dependent on the availability of freezers on the islands, it provides an important source of income for a small proportion of the population. The Torres Strait Spanish mackerel fishery is located in the eastern portion of the archipelago and is a relatively small fishery compared to those in the Gulf of Carpentaria and off the east coast of Qld. Spanish mackerel was taken as bycatch by Taiwanese gillnet vessels in waters adjacent to Torres Strait during the early 1980's and may have decreased catch rates during that period (McPherson 1985; Buckworth 1991).

Monitoring

AFMA Fisheries logbooks were introduced in 1986. Gross under-reporting of catches, incomplete logbook recording by fishers and problems with the AFMA Torres Strait Mackerel database has lead to difficulties monitoring the fishery (Haywood and Die 1997; Williams and O'Brien 1998). These data have been deemed to be unsuitable for stock assessment purposes. In 2000, AFMA transferred the Torres Strait data into its corporate logbook database and implemented improved quality assessment on the data being received. However, there are still significant problems with incomplete and unreturned logbooks. Since late 2002 there has been a considerable improvement in rates of completion following initiatives by AFMA to follow up on non-returns and to educate fishers to record entries accurately.

Queensland implemented a Long Term Monitoring Program (LTMP) in Torres Strait in 2000 to collect ongoing length and age data from spawning aggregations. It is intended that future Qld assessment will involve use of the AFMA database, historical length, age and tagging (limited) data, stock definition information (from FRDC Project 98/159). The CRC Reef will commence an assessment of the Torres Strait fishery as part of the CRC Torres Strait Program.

Fishery

Spanish mackerel is the main target species in Torres Strait, although small quantities of other northern mackerel species are also taken. The fishery mainly targets spawning aggregations and there is a strong seasonal trend in catches with the peak occurring between September and November (Torres Spanish Mackerel Handbook 2001). Between 12 and 15 fishers take the majority of catch. Between 1988 and 1996, commercial catches ranged between approximately 40 and 120 tonnes (filleted weight) per year (Haywood and Die 1997; Williams and O'Brien 1998). The Torres Spanish Mackerel Handbook 2001, stated that between 1994 and 2000 catches varied between 145 tonnes and 185 tonnes of fillets. The seasonally adjusted CPUE remained relatively stable between 1988 and 1996, and ranged between 14 and 24 kg per day. Approximately 10 tonnes are taken annually by local indigenous fishers.

Management

The Torres Strait mackerel fishery is managed by AFMA and since 1985 has been managed in accordance with Articles 22 and 25 of the Torres Strait Treaty. Management arrangements limit participation by non-traditional inhabitants. These include boat replacement policies, prevention of licence splitting, limits on the number of tender vessels (dories). Currently, there is no limit on participation by non-traditional inhabitants (Torres Spanish Mackerel Handbook 2001).

Management boundaries for the Torres Strait mackerel fishery include Australian waters within Torres Strait Protected Zone (TSPZ) (Fig. 3) and areas outside but near the Protected Zone defined in the Torres Strait Fisheries Regulations (Williams and O'Brien 1998). In 2000, 250 vessels were licensed to fish for mackerel in Australian waters of TSPZ and 150 of these were held by islanders. There are 12 vessels that specifically target Spanish mackerel in Torres Strait. Vessels operating in the mackerel fishery are not allowed to purchase product from tender vessels that are not part of their licence package within 10 nautical miles of a community in the TSPZ without permission from the chairperson (Torres Spanish Mackerel Handbook, 2001).

As the Spanish mackerel fishery is managed as an Article 22 Fishery under the Torres Strait Treaty, PNG is entitled to catch sharing arrangements specified in Article 23. In Australian territorial seas north of the fisheries jurisdiction line (FJL), PNG is entitled to 50% of the catch and in Australian waters south of the FJL PNG is entitled to 25% of the catch. To give effect to this entitlement Australia has arrangements with PNG for 2003 where up to 16 PNG mackerel vessels would be endorsed to fish in Australian waters. However, to date no PNG operators have taken up the opportunities to fish for mackerel in Australian waters. Australia is currently working to develop mechanisms to compensate for additional PNG fishing effort, should it eventuate, through reductions in fishing effort by Australian operators. (Jim Prescott, AFMA, personal communication).

There is a minimum size limit of 45 cm FL (Torres Spanish Mackerel Handbook 2001). (Fisheries Management Notice 67 increased this to 75 cm FL, Jim Prescott, AFMA, personal communication). Use of gillnets to take Spanish mackerel in Torres Strait is illegal. Spanish mackerel can only be taken by trolling, handlining and droplining and cannot be taken from vessels greater than 20 m in length (Torres Strait Protected Zone Joint Authority Annual Report 1999-2000; Torres Spanish Mackerel Handbook 2001). Development of a gillnet fishery in the Gulf of Carpentaria that could take Spanish mackerel may have implications for stocks in the Torres Strait (Torres Mackerel Handbook 2001).

Extent to which research outcomes have been incorporated into management arrangements

Management arrangements for the Torres Spanish mackerel fishery have been based mostly on issues surrounding indigenous fishing rights that limit non-traditional participation. The minimum legal size was until recently based on the size at which Spanish mackerel suffer low rates of post-release mortality, rather than the minimum size at sexual maturity. Management restrictions are also partially based on impacts of PNG licensed Taiwanese gillnetting fleets during the early 1980's.

There is a clear need for ongoing monitoring of the age structure of catches from this region. No formal stock assessment of Torres Strait stocks has been completed although QDPI undertook comprehensive biological sampling between 1978 and 1983, which included collection of length data and otoliths (Williams and O'Brien 1998). QDPI is reanalysing age structure information collected between 1978 and 2000 (Torres Mackerel Handbook 2001). The Reef CRC will commence an assessment of the status of the Torres Strait fishery as part of the CRC Torres Strait Program.

2.3.3 NT

Background

The NT Spanish mackerel troll fishery was relatively small until the mid 1970's and the major issue of concern was significant landings of small Spanish mackerel by Taiwanese gillnet vessels between 1974 and 1986 (Buckworth and Clarke 2001). Data collected by Australian Fishing Zone observers suggest that catches of >1000 tonnes per annum were taken in the late 1970s (Buckworth 1998). Declines in catch rates and mean size over this period suggest that the stock was significantly reduced.

Commercial operators are currently permitted to fish NT waters, seaward of the coasts and river mouths to the outer edge of the Australian Fishing Zone (AFZ) and between the WA and Qld borders (Buckworth and Clarke 2001). There are no seasonal closures and the target level for the annual commercial catch is set at 450 tonnes (Buckworth 2001).

In 1992, a licence reduction plan was implemented to reduce effort in the NT Spanish mackerel fishery. Between 1993 and November 2000, the number of licences dropped from 28 to 19, with 9 fully transferable and 10 having transferability restrictions. Each licence holder is allowed to operate one mother ship and two dories. During 2000, the NT Troll Line Association suggested that the current management plan should be extended for another 5 years.

Monitoring

CPUE data is only available for the NT from 1983 onwards. Logbooks were introduced in 1991 to collect data on size, composition of catch and fishing effort. During 1991, a research program was established to facilitate collection of size, sex and age information from the fishery (Buckworth and Clarke 2001). Catch and effort information for recreational and indigenous sectors was recorded in the National recreational fishing survey (Buckworth and Clarke 2001). Fishing tour operators began collecting catch and effort data for Spanish mackerel in 1994. Possible improvements to the monitoring program could include the Fishing Tour Operators (FTOs) and recreational fishers identifying their catch to species level and becoming involved in collection of biological samples in remote areas that are difficult for research staff to access.

Fishery

Commercial catches of Spanish mackerel in NT were relatively low throughout the mid to late 1980's and ranged from 54 tonnes in 1986 to 124 tonnes in 1989. Commercial catches in troll fishery increased steadily during the 1990s and reached 320 tonnes in 1999 (Clarke and Buckworth 2000; Buckworth and Clarke 2001). CPUE in the troll fishery ranged from 93 to 248 kg per day during the 1980's and reached 454 kg per day in 1999. Small quantities of Spanish mackerel are also taken by the Western Tuna, NT Shark, Northern Prawn and Northern Fish Trawl Fisheries as bycatch (Buckworth and Clarke 2001).

Between 1994 and 1999, Spanish mackerel catches by FTOs increased from 741 to 1,665 individuals per year. The number of fish released over this period increased from 465 to 1,116 per year (Buckworth and Clarke 2001). Recreational fishers in the NT were estimated to catch 25,099 (SE = ±807) and retain 24,522 (SE = ±1,796) Spanish mackerel in 1995 (Buckworth and Clarke 2001). The 2000/2001 National Recreational Survey estimated that in the NT approximately 21,292 mackerel (all *Scomberomorus* spp.) were taken (Henry and Lyle 2003). This comprised 4.5% of the national recreational catch.

This survey estimated that the indigenous harvest was 1,416 individuals (all *Scomberomorus* spp.).

Management

The Spanish mackerel fishery is managed as a multi-species mackerel troll fishery. The number of licences is currently 19, under the Spanish Mackerel Fisheries Management Plan that was introduced in 1993. This plan involves a licence reduction scheme, which means that new licences can only be secured if two other licences are passed in. The target yield for the fishery has been set at 450 tonnes per annum and currently there are no minimum or maximum size limits (Review of Spanish Mackerel Fishery Management Plan, Nov 2000; Buckworth and Clarke 2001). This target acknowledges yield estimates provided by Stevens and Davenport (1991). Further yield estimates by Walters and Buckworth (1997) confirmed that the values derived in 1991 should continue until the fishing mortality rate could be more accurately defined (Ray Clarke, NT Department of Business, Industry and Resource Development, personal communication).

Maximum bycatch levels in the shark fishery during 2000 were legislated to be 300 kg (whole weight) of Spanish mackerel trunks and an additional 100 kg trunks, for each tonne over 3 tonnes of grey mackerel. Western Tuna and Northern Prawn fisheries are permitted to retain 10 fish of a range of species, including *Scomberomorus* species (Review of Spanish Mackerel Fishery Management Plan, Nov 2000; Buckworth and Clarke 2001).

There is currently no upper threshold on number of FTO licences that can be issued in the NT. Participants are permitted to take five Spanish mackerel per person per day. No fish caught during tours can be sold. FTOs are required to record the number of Spanish mackerel taken and released per day (Buckworth and Clarke 2001).

There is a bag limit of five Spanish mackerel per person per day for recreational fishers. No size limits apply to recreational fishers (Buckworth and Clarke 2001).

Indigenous fishers can catch Spanish mackerel using traditional or recreational equipment. Commercial equipment is not permitted. No bag limits apply to indigenous fishers and fish cannot be sold.

The Spanish Mackerel Fisheries Management Plan also establishes catch shares by individual industry sectors (principally recreational and commercial stakeholders) as a benchmark for future management. Any change in the catch share by any particular sector will be addressed though tailored management responses for that sector. This will also serve as a benchmark against which future management arrangements will be gauged (Ray Clarke, NT Department of Business, Industry and Resource Development, personal communication).

Extent to which research outcomes have been incorporated into management arrangements

The impact of the Taiwanese gillnet fishery in the 1980's (Stevens and Davenport 1991) provided the impetus behind major management decisions in the early 1990's, including the introduction of a target yield and an upper limit on licences (Buckworth and Clarke 2001). The maximum sustainable yield for the fishery was estimated to be 200 tonnes using age-structured population model that used CPUE as index of abundance. However, the target yield for the fishery has been set at 450 tonnes per annum based on the equilibrium catch of Taiwanese-operated gillnet fishery (Buckworth and Clarke 2001).

There are few published studies of the age structure or reproductive biology of the commercial catch on which to base management decisions, with the exception of Buckworth (1998). This last major study of the age structure of commercial catch was based on samples collected between 1991-93. There is a clear need for updated stock assessment information, especially the establishment of program for monitoring the age structure of the catch. The current GENETAG project is designed to provide managers with estimates of harvest rates for the commercial fishery and further tagging information.

The initial outcomes of the stock discrimination research suggest that *S. commerson* form a mosaic of small sub-stocks across the north of Australia and that it is unlikely that there are extensive movements. The revised fishery management plan will provide for the declaration of management areas within the confines of the broader Spanish mackerel. This approach seeks to provide for spatial management of Spanish mackerel on a stock basis and has been agreed as a direct result of the stock discrimination research program (Ray Clarke, DBIRD, personal communication).

2.3.4 WA

Background

The commercial mackerel fishery in WA extends roughly, from Geraldton to the NT border. The fishery is currently open to all WA licensed vessels, although in reality this is limited to approximately 91 vessels that operate north of Shark Bay. Only about twelve fishers target *S. commerson* full time during the six or so months when this species is abundant off the coast.

Many other fishers catch *S. commerson* opportunistically whilst targeting other species (Kristy Saville, Fisheries WA, personal communication).

Spanish mackerel is the major target species in the WA northern mackerel troll fishery and comprises approximately 80% of the mackerel catch from the Northwest Shelf (Mackie *et al.* 2003). Fishing techniques include trolling rigged baits or lures on heavy handlines and game rods. In most regions the catch is either filleted on board or trunked and sold on the Perth domestic market. In the Carnarvon, Port Hedland and Quobba regions, fish are kept whole in brine and sold on export markets (Mackie *et al.* 2003).

The WA Spanish mackerel fishery is divided into three main management sectors, which include the Gascoyne (between 112 to 113^{o}E and north of 27^{o}S), Pilbara (between 114 and 121^{o}E) and Kimberley (between 121^{o}E and the NT border) regions (Mackie 2001) (Fig. 2). During 1999, 75 licensed vessels were operating in WA mackerel fishery. Concerns about the sustainability of the Spanish mackerel fishery in WA during the late 1990's lead to preparation of an Interim Management Plan for protection of the resource.

Spanish mackerel is an important and prestigious recreational sport-fish in WA. The majority of the recreational Spanish mackerel catch is taken between Perth and Dampier. However, recreational fishers target Spanish mackerel along the entire north coast. It is the focus of annual sport-fishing competitions conducted by the Perth Game Fishing Club (Mitchell 2002). Popular fishing locations include the Mackerel Island group off Onslow. Spanish mackerel is also taken from the cliffs and limestone platforms near Quobba and Steep Point using lures or baits suspended under balloons (Mackie *et al.* 2003).

The 2000/2001 National Recreational Survey estimated that in WA approximately 85,208 mackerel (all *Scomberomorus* spp.) were caught (Henry and Lyle 2003). This comprised 18% of the national recreational catch for this period.

This survey estimated that the indigenous harvest was only 424 fish (all *Scomberomorus* spp.).

Monitoring

Catch and effort information have been collected for the WA Spanish mackerel fishery since 1980 and stored in the CAES Database. Researchers at WA Fisheries recently identified the need for improvements to the database/logbook system including better spatial resolution in catch/effort data and identification of individual species (FRDC roject 2002/010). Other factors that influence the accuracy of the database information include the changing nature of the fishery. For example, the time spent catching mackerel while fishing for other species and the effects of increasing technology (GPS and plotters) and fisher skill over time are difficult to quantify. Additionally, many catch returns do not specify which mackerel species were taken and combine all *Scomberomorus* species (Mackie *et al*. 2003).

Fishery

Catches in the troll fishery on the NorthWest shelf typically peak during mid-winter (July and August) (Kailola *et al.* 1993). Annual catches in the Kimberley ranged from 48 to 173 tonnes between 1990 and 1997, with a mean of approximately 100 tonnes. Five of the main mackerel vessels fished a total of 437 days. Annual catches in the Pilbara ranged from 68 to 127 tonnes, with a mean of 95 tonnes. Eight vessels fished a total of 516 days. In the Gascoyne region, annual catches ranged between 21 and 80 tonnes, with a mean of approximately 57 tonnes during the same period. Seven vessels fished 271 days (Mackie 2001). Mean CPUE for mackerel vessels operating in Kimberley, Pilbara and Gascoyne sectors between 1978 and 2000 was 300.2, 208.5 and 91.9 kg (whole weight) per day, respectively. For all other vessels (that catch more than 1,000 kg in the Kimberley and Pilbara and 500 kg in the Gascoyne) mean CPUE was 251.8, 120.7 and 67.8 kg (whole weight) per day in the Kimberley, Pilbara and Gascoyne sectors, respectively between 1978 and 2000 (Mackie 2001).

Fisheries WA conducted recreational fishing surveys between 1996 and 2000 in three main regions. These surveys found the recreational component of the Spanish mackerel catch was significant. The regions that were surveyed included the Augusta to Kalbarri, Shark Bay to Exmouth and Pilbara regions and did not include the charter fishers or data from boats launched from beaches (Mackie *et al.* 2003). In the Augusta to Kalbarri region, approximately 13 tonnes were taken in 1996/67. During 1998/99 approximately 47 tonnes were caught between Shark Bay and Exmouth. During 1999/00, approximately 21 tonnes of Spanish mackerel were caught in the Pilbara region. The total recreational catch over this period was 81 tonnes (Mackie *et al.* 2003).

Management

The minimum size limit for the recreational and commercial sectors is 90 cm TL (www.fish.wa.gov.au) and a bag limit of four Spanish mackerel per day applies to the recreational sector.

Following extensive consultation, recommendations of the Mackerel Independent Advisory Panel (MIAP) and advice from the Department of Fisheries, the Minister for Agriculture, Forestry and Fisheries has approved the formalisation of a number of management arrangements for the Western Australian mackerel fishery. The *Mackerel Fishery (Interim) Management Plan 2004* (the Plan) for the Western Australian commercial mackerel fishery is due to commence on 1 January, 2004 (Kristy Saville, Fisheries WA, personal communication).

Applicants that satisfy the approved entry criteria will be granted access to the commercial fishery. The Plan will be based on output management with a Total Allowable Commercial Catch (TACC) estimated separately for the three zones of the fishery (Kimberley, Pilbara and Gascoyne/West Coast).

Each zone of the fishery will be unitised, the value of which will be proportional to the annual quota apportioned to each zone. The number of units apportioned to each permit will be determined from their historic catch as a proportion of total catch in each zone. However, a minimum of 5% of unit holdings will be required (in a zone) before a fisher can actually operate in the fishery (Kristy Saville, Fisheries WA, personal communication).

Extent to which research outcomes have been incorporated into management arrangements

The reasons for the Minister's decision to implement the interim management plan for the commercial mackerel fishery were the recommendations from FRDC Projects 99/151 and 98/159 including:

- commercial catches have been at historically high levels in Western Australia but have been decreasing in the Kimberley;
- there are no significant levels of mixing of Spanish mackerel across long lengths of coastline (eg. from Exmouth to Broome). However, despite limited alongshore mixing of juveniles and adults, genetic relationships are thought to span broader regions. Hence the effects of fishing in one zone are likely to have flow-on effects in other zones;
- it would be inappropriate to manage the fishery by size limit alone, as mortality of released fish is likely to be high, as is mortality due to sharks, both of which may add substantially to fishing pressure;
- this species schools in large numbers, in well-known locations, and hence can be captured in large quantities. Catch rates of schooling pelagic species can remain high until stock sizes have decreased significantly.

- long-term commercial mackerel fishers had raised concerns about the mackerel stocks; and
- it was also the view of the majority of the commercial and recreational fishers consulted during the process that the fishery should be managed (Kristy Saville, Fisheries WA, personal communication).

This information was crucial in the approval of a management plan and continues to be crucial in the development of the management plan. Data from FRDC project 99/151 provided the basis for recommending possible management approaches. The project provided detailed information on the biology of *S. commerson* and the associated WA troll-based mackerel fishery, which is used to ensure the sustainability of this fishery. FRDC project 99/151 was complemented by FRDC Project 98/159 on the stock structure of *S. commerson* in WA, NT and QLD waters (Kristy Saville, Fisheries WA, personal communication).

2.4 CURRENT AND FUTURE RESEARCH NEEDS FOR SPANISH MACKEREL

FRDC Project 98/159 has and will provide improved understanding of the stock structure of Spanish mackerel throughout northern Australia. The eastern and northern stocks are clearly comprised of spatially discrete sub-units. These sub-units should provide the basis for large-scale management arrangements and emphasise the need for ongoing collaboration between researchers and managers in WA and the NT. The excellent national collaborations that were established through previous and current projects should be maintained in order to establish integrated research and management arrangements among the key states.

Considerable data are available on the biology of Spanish mackerel in north-eastern Qld. Current FRDC studies in WA and Qld will provide additional biological data needed to refine current management arrangements in these states. Additional biological information is required in some areas, including the NT, where collection of comprehensive biological information has been impeded by the seasonality of the fishery. There is a clear need to collate existing information from throughout northern Australia. A document that synthesizes information on the age and growth of Spanish mackerel in the northern Australia is also needed.

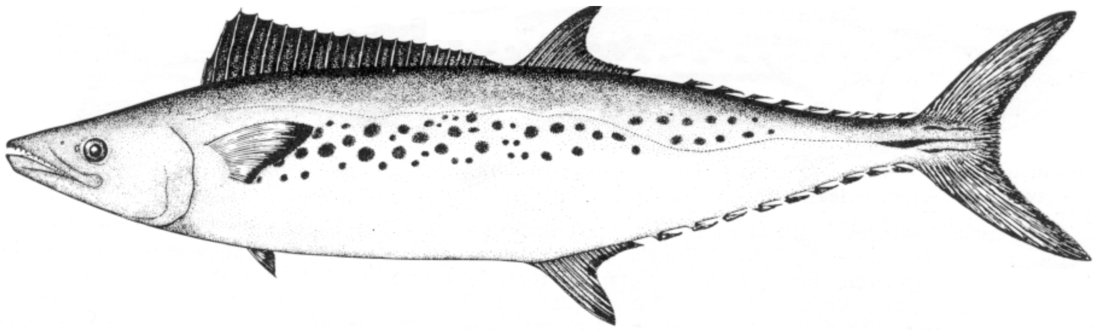
Studies of age and growth have been conducted in all jurisdictions. However, no long-term series of annual age structure data is available for any area. For example, the recent assessment of Spanish mackerel of the east coast (Welch *et al.* 2002), where the largest fishery is located, was based on age data for 1977/78, 1978/79 and 2001 only. Additional otoliths appear to have been collected and archived (but not read) in several areas. Analysing these otoliths is a high priority.

Programs for monitoring the age structure of catches have been conducted and/or established recently in several areas. For example, an ongoing program for monitoring the age structure of Spanish mackerel on the east coast spawning grounds was established by QFS in 1999. Continuing these monitoring programs is critical, as age structure data is needed for reliable stock assessment. However, previous studies have shown that age determination of Spanish mackerel is not straightforward (e.g. Buckworth 1998). The precision of information required for stock assessment should be assessed formally, to ensure that cost-effective methods that provide the level of information required for reliable stock assessment are established. The costs and benefits of using annuli counts or age proxies, such as fish size and otolith weight, also need to be assessed in this context. Assessments of the suitability of otolith weight should not assume that annuli counts are 100% reliable (as has been done in several previous studies) as this approach biases the analyses. Innovative approaches to age estimation may need to be developed, such as synthesising several types of data (e.g. morphometrics, daily rings, annuli counts, otolith weight, etc.) to provide probabilistic (rather than absolute) estimates of age.

There is a clear need for ongoing collaboration among researchers on the technical issues associated with otolith analysis. CRC Reef addressed this need in late 2002 by initiating the establishment of the national Spanish mackerel age-determination working group. The efforts and activities of this group should be supported by management agencies in each jurisdiction and by FRDC. Meetings could be conducted cost-effectively by scheduling them to coincide with meetings for other current projects (e.g. GENETAG). As well as ensuring that appropriate and consistent methods are adopted for age-determination, the working group should produce a document that synthesises age and growth data for Spanish mackerel in northern Australia.

The need to develop more effective methods for estimating the abundance of Spanish mackerel is pressing. CPUE data is still used as an index of abundance in most assessments, despite widespread acknowledgments of the risks associated with this approach. Results of the WA study suggest that egg-based methods and biomass dynamic modelling may not be appropriate for Spanish mackerel. The GENETAG project may provide a mechanism for determining exploitation rates and thus monitoring biomass. Until the GENETAG study is completed, additional large-scale research projects are not required for Spanish mackerel. The main priorities are to ensure that the age-determination working group facilitates the adoption of consistent and appropriate methods in each jurisdiction and produces a document that synthesises existing information on age and growth.

CHAPTER 3. SPOTTED MACKEREL *SCOMBEROMORUS MUNROI*



Picture courtesy of the United Nations Development Programme Food and Agriculture Organization of the United Nations. (FAO Species Catalogue Vol. 2, Scombrids of the World).

Family: Scombridae

Genus: *Scomberomorus*

Other common names: Spotty.

Diagnostic features:

Colour: Poorly defined rows of small round spots down mid-sides (smaller than diameter of eye). First dorsal is blackish blue.

Fin ray and spine counts: First dorsal = 20-22 spines; Second dorsal = 17-20 rays, followed by 9-10 finlets; Anal fin = 17-19 rays, followed by 8-10 finlets; Pectoral fin = 21-23 rays.

Vertebral count: 50-52.

Size: Maximum length of approximately 100 cm FL, commonly 70-85 cm FL. Commonly caught between 3 and 4.5 kg. Can reach 8 kg.

References: Collette and Nauen (1983); Allen and Swainston (1988); Kailola *et al.* (1993); www.fishbase.com.

3.1 INTRODUCTION

This chapter: (1) summarises and identifies gaps in past and current research on spotted mackerel *Scomberomorus munroi*; (2) provides an overview of the fisheries and current management strategies in each state; (3) assesses the degree to which past and current research has met management needs; and (4) identifies current and future research needs for spotted mackerel in northern Australia. Information presented in this chapter is incorporated into the strategic research plan for northern mackerels (Chapter 7).

3.2 INFORMATION AVAILABLE AND GAPS IN KNOWLEDGE

3.2.1 Critical Documents and Relevant Reviews

No formal stock assessments have been undertaken for spotted mackerel in any state or territory. However, Cameron and Begg (2002) provide critical information on the fisheries biology of spotted mackerel in Qld. These authors also summarise information on the commercial and recreational fisheries for spotted mackerel in Qld and provide recommendations for future management of the fishery. Associated papers provide specific information on the age and growth, reproductive biology, stock structure, movements and feeding ecology of spotted mackerel in Qld (Begg *et al.* 1997; Begg and Hopper 1997; Begg 1998; Begg *et al.*1998a, b; Begg and Sellin 1998).

The proceedings of the spotted mackerel workshop held in Qld on the 6-7 March 2002 provides a summary of research and management of the fishery off the east coast and identifies issues for future research and management (QFS Spotted Mackerel Workshop Proceedings 2002).

3.2.2 Distribution

Spotted mackerel inhabits tropical and subtropical waters between Rottnest Island in WA and Wollongong in NSW (Collette and Nauen 1983; Kailola *et al.* 1993). It is found mostly in offshore waters and deep bays, but is rarely encountered in depths greater than 100 metres. Spotted mackerel occurs in similar areas to school mackerel; large feeding and spawning aggregations of both species are commonly encountered around Hervey Bay and Moreton Bay in southern Queensland (Begg and Hopper 1997).

3.2.3 Stock Structure

There is minimal genetic differentiation among spotted mackerel along the east coast of Qld and researchers have concluded that this region supports a single stock (Begg *et al.* 1997; Begg *et al.* 1998a; Begg *et al.* 1998b). Elemental analysis of otoliths from the same fish examined in the genetic study support these conclusions (Begg *et al.* 1998b; Cameron and Begg 2002), as did tagging and growth data (Cameron and Begg 2002). However, significant genetic variation was detected between samples collected from the Arafura Sea and off the east coast of Qld, suggesting that northern and eastern Australia may support separate populations (Begg *et al.* 1998a). Few data are available on the stock structure of spotted mackerel in the NT and WA.

3.2.4 Patterns of Migration

Spotted mackerel undergo large-scale northward migrations along the Qld east coast during winter (August/September) and return to southern waters in December (Begg *et al.* 1997). Approximately 39% of individuals recaptured in a recent tagging study moved up to 100 km from their release site, which supports conclusions that the east coast supports a single stock (Begg *et al.* 1998a; Cameron and Begg 2002). Few data are available on the movement patterns of spotted mackerel north of Cairns, or in Torres Strait, the Gulf of Carpentaria, Arafura Sea or WA. Commercial fishery data provide poor spatial resolution and the accuracy of species identification is questionable.

3.2.5 Ecological Interactions

Spotted mackerel appear to feed only on small pelagic fishes, including herring, sardines and anchovies, and, unlike Spanish or school mackerel, do not feed on benthic or epibenthic invertebrates (Begg and Hopper 1997). However, this feeding study was undertaken between Cairns and Moreton Bay only, and no information is available on feeding patterns in Torres St, the Gulf of Carpentaria, NT or WA. There are also few data available on interactions of spotted mackerel with other large pelagic fishes (e.g. tunas and other mackerels) or prey species (e.g. clupeoids), with the exception of the study of feeding and niche interaction with school mackerel between Cairns and Moreton Bay (Begg and Hopper 1997).

The influence of environmental/ecological factors on seasonal migrations along the east coast of Qld is poorly understood. However migration patterns and reproductive indices suggest that, like Spanish mackerel, spotted mackerel may follow warm isotherms north during winter (to spawn) and south during early summer (McPherson 1981, 1982).

3.2.6 Reproductive Biology

In Qld, spotted mackerel forms spawning aggregations in coastal bays off Mackay and south of Townsville between August and November, with a peak in spawning activity occurring during September (Begg 1998; Cameron and Begg 2002). Male and female spotted mackerel reach maturity at 2 years of age at lengths of 50 and 61 cm FL, respectively (Cameron and Begg 2002). Currently, no information is available on the location or seasonality of spawning in other states or regions. Batch fecundity has been estimated to be 250,000 oocytes at 50 cm FL, however spawning frequency is unknown (Cameron and Begg 2002).

3.2.7 Early Life History

There are currently no published descriptions of the developmental stages of eggs or larvae of spotted mackerel. Larvae and small juveniles ranging between 12 and 41 mm TL were collected in light traps off Cape Cleveland and Cape Bowling Green, which are adjacent to a major spawning area (Thorrold 1993).

3.2.8 Age and Growth

Validation of the age determination method used for adult spotted mackerel has been problematic. Marginal increment analysis is only useful for fish up to 2 years of age and the use of biochemical markers in tagged fish has been unsuccessful due to low recapture rates (Begg and Sellin 1998). Data available suggest that spotted mackerel grow quickly during the first 1-2 years, reaching up to 100 cm FL and 8 kg (Collette and Russo 1984; Cameron and Begg 2002). Spotted mackerel reach up to 7 years of age off the east coast of Qld, and growth patterns are sex-specific with females reaching greater ages and sizes than males (Cameron and Begg 2002; QFS Spotted Mackerel Workshop Proceedings 2002). *VB* growth equation parameters for spotted mackerel in Qld are K= 0.410 yr^{-1}, L_∞ = 86.0cm and t_0 = -1.78 for females and K= 0.313 yr^{-1}, L_∞ = 72.9 cm and t_0 = -3.13 for males (Cameron and Begg 2002). No age and growth data available for Torres Strait, the NT or WA. Information on the age structure of spotted mackerel in key spawning areas would provide useful insights into the status of the stock.

3.2.9 Mortality

In Qld, instantaneous mortality rates were estimated for each gear type (Cameron and Begg 2002). Females were most susceptible to the line fishery (F = 1.037) and the two mesh sizes used in the ring net fishery (10 cm net, F = 1.839; 12.5 cm, F = 1.282). Annual mortality rates for all fishing gear types were also relatively high (0.689). There are no mortality estimates for the region north of Cairns or for other states where spotted mackerel are taken in the Spanish mackerel troll fisheries

3.2.10 Stock Assessment

No formal stock assessments have been completed for spotted mackerel. No biological indicators have been developed for the Qld fishery. Cameron and Begg (2002) identified serious concerns about the sustainability of the resource and made several recommendations for future management. The key issues of concern were that: (1) historical spotted mackerel catches off the east coast of Qld appeared to have peaked and were showing serious signs of decline; (2) most fishing effort was centred on feeding and spawning aggregations off Hervey Bay and Bowen; (3) signs of localised stock depletion were observed in Qld bays; (4) there had been shifts in effort away from Spanish mackerel and towards spotted mackerel in some regions; (5) levels of bycatch/discard mortality in gill net and trawl fisheries were poorly understood. A current CRC reef project is conducting a stock assessment on spotted mackerel (Dr Gavin Begg, CRC Reef, personal communication).

3.3 FISHERIES, RESEARCH AND MANAGEMENT

3.3.1 Qld

Background

In Qld, spotted mackerel has been targeted by commercial fishers for over 30 years (Dr Gavin Begg, CRC Reef, personal communication). The main fishing areas are between Bowen and Moreton Bay, with fishers in the Hervey Bay/Fraser Island regions taking most of the catch (Williams 2002). Fishers target predictable seasonal aggregations associated with northward spawning and feeding migrations. Most spotted mackerel are taken using encircling ringnets with smaller quantities also taken by gillnets and trolling (Cameron and Begg 2002).

Spotted mackerel are highly prized by recreational fishers in Qld and the recreational harvest comprises approximately half of the total annual catch. Historically, there has been considerable conflict between the recreational and commercial sectors regarding overfishing and gillnet “dropout”. However an observational study undertaken in Hervey Bay and Moreton Bay during 1995-96 suggested that gillnet dropout is not a significant management issue (Cameron and Begg 2002).

Monitoring

The commercial fishery is monitored using compulsory fishery logbooks (CFISH) introduced in 1988. Data are recorded daily, and include location, catch by species, weight, gear type and measures of fishing effort. This data is the primary source of information for stock assessment and management.

Recreational telephone surveys in 1994-95, 1997 and 1999 showed that recreational fishers could not accurately identify smaller northern mackerel species. Information on “other” mackerels was thus pooled and the proportion of spotted mackerel was estimated (Williams 2002).

The current logbook programs need to be improved. One of the key issues is the correct identification and recording of the spotted mackerel catch.

There is also minimal information on the proportion of spotted mackerel taken as bycatch in any state where fisheries exist. Annual catch and effort surveys should include all relevant sectors and enable researchers and managers to accurately quantify the proportion of the spotted mackerel catch taken by recreational, charter and indigenous fisheries in Qld.

Age structure data from the commercial fishery in southern Qld are now being collected as part of the Long Term Monitoring Program.

Fishery

Fishing is confined mainly to northern regions during winter and Moreton Bay and the Hervey Bay/Fraser Island region during summer. Each vessel only fishes 8-10 days per season, as schools move into the coastal bays.

In Hervey and Moreton Bays, the number of commercial vessels recording catches of spotted mackerel increased from 16 vessels in 1988 to 132 vessels in 2000. Catches increased rapidly during this period from 7.85 to 406 tonnes per year, with a mean annual catch between 1988 and 2000 of 118 tonnes. CPUE increased from 55 to 185 kg per day during this period (Cameron and Begg 2002; Williams 2002).

In 1994 and 1995, approximately 19,000 recreational boats targeted other northern mackerel for 120,000 boat days and a total catch of 370,000 individuals. Spotted mackerel were estimated to comprise approximately 70 tonnes of this harvest. In 1997, 155,000 spotted mackerel with a total weight of approximately 148 tonnes were taken (Williams 2002). A similar survey in 1999 found that 130,000 spotted mackerel for a total weight of 150 tonnes were caught by recreational fishers (Williams 2002).

Management

Significant increases in commercial and recreational catches since the mid 1990's have resulted in pressure from all stakeholders to implement catch quotas and seasonal closures to protect spawning stocks from over-exploitation. The spotted mackerel workshop in March 2002 was a positive step and involved discussion of a range of potential input and output controls, including limited entry, total allowable catches (TAC), individual transferable quotas, zoning of fishing areas, boat-day limits, gear and vessel restrictions and seasonal/area closures. Possible input controls discussed for the recreational fishery included line strength, hook size and material restrictions.

New management arrangements for spotted mackerel were introduced in December 2002, including a minimum legal size of 60 cm TL (increased from 50 cm TL); a recreational possession (bag) limit of 5 (decreased from 30); an annual quota of 140 tonnes, with a commercial possession (bag) limit of 150; an incidental catch limit of 15 (catches under 15 spotted mackerel in any 24 hour are not counted against the annual quota; and a prohibition on the use of nets to target spotted mackerel (i.e. no ringnetting). Over the next 12 months the QFS, in consultation with industry, will determine if further management arrangements are required. Issues to be considered will include new limited entry criteria, regional quotas and/or individual transferable quotas (Mark Doohan, QFS, personal communication).

Extent to which research outcomes have been incorporated into management arrangements

The finding by Cameron and Begg (2002) that the east coast supports a single stock emphasises the vulnerability of the Qld fishery to overfishing and the need to protect spawning aggregations. The report by Cameron and Begg (2002) also raised serious concerns about the sustainability of the resource and made several recommendations for future management. Information provided in this report and in Begg *et al.* (1997), Begg and Hopper (1997), Begg (1998), Begg *et al.* (1998a, b) and Begg and Sellin (1998) provided the scientific basis for the Qld spotted mackerel workshop in March 2002. This workshop provided a mechanism for researchers (i) to advise fisheries managers of biological issues relevant to the management of the fishery, and (ii) to work with stakeholders to carry out a preliminary risk assessment. The new management arrangements for the fishery listed in the section above were introduced as a result of the 2002 workshop.

3.3.2 Other States

Background

Spotted mackerel is only a minor bycatch species in the troll fisheries for Spanish mackerel in Northern NSW, Torres Strait, the NT and WA. It is also a minor bycatch component in several other trawl, line and net fisheries across northern Australia.

Monitoring

Monitoring systems used to collect data on the spotted mackerel catch in other states consist of non-specific mackerel catch and effort recording via recording of commercial fishery logbooks. Outside Qld, spotted mackerel are not separated from other northern mackerels on catch returns. Catches in states other than Qld are thus only discussed in terms of the proportions of "other" mackerel catches.

Fisheries

In the NT between 1991 and 1999 commercial catches of other northern mackerel ranged between 120 and 534 kg per year (Clarke and Buckworth 2000). In WA, the other northern mackerel harvest between 1980 and 2000 was approximately 63 tonnes per annum, with a peak of 175.2 tonnes in 1990 (Cameron and Begg 2002; www.fish.wa.gov.au). During 1999, 115 tonnes of other northern mackerels were taken in WA with school, shark and spotted mackerel consisting of only 7% of the catch and the remainder comprised of grey mackerel. Spotted mackerel have been estimated to comprise <1% of the commercial troll catch in Western Australia (Mackie *et al.* 2003)

Management

In Torres Strait, spotted mackerel is only a minor component of the Spanish mackerel fishery. No size or bag limits apply to the recreational or indigenous sectors (Torres Spanish Mackerel Handbook 2001).

Spotted mackerel can be taken as bycatch in the NT Shark, Western Tuna and Northern Prawn Fisheries. The Western Tuna and Northern Prawn Fisheries are allowed to take 10 fish, including spotted mackerel. The quantity of spotted mackerel retained in the Northern Prawn Fishery (NPF) is determined by the NPF Management Plan (Buckworth and Clarke 2001). In the NT, there are no recreational size limits for spotted mackerel. The species falls under general limits for unmanaged species in the NT that state "a person may not possess a combination of fish and fillets exceeding the equivalent of 30 whole fish, other than in his or her place of permanent residence" (NT Fisheries Website 2002). Indigenous fishers are permitted to catch spotted mackerel using traditional and recreational equipment and no bag limits apply.

Commercial fishers in WA are not required to identify and separate lesser mackerels to species level in logbooks. Spotted mackerel are classified as "unspecified" mackerels for management purposes (Cameron and Begg 2002). The recreational size limit for spotted mackerel is 50 cm TL (www.fish.wa.gov.au). There is currently a total mixed bag limit of 8 in total and four of each species of northern mackerel in WA.

Extent to which research outcomes have been incorporated into management arrangements

There has been no research on spotted mackerel outside Qld on which to base management decisions. Management decisions are currently based on ad-hoc/precautionary approaches. This will continue until (1) biological monitoring systems are implemented and (2) fishery logbooks are updated to provide species-specific data for spotted mackerel.

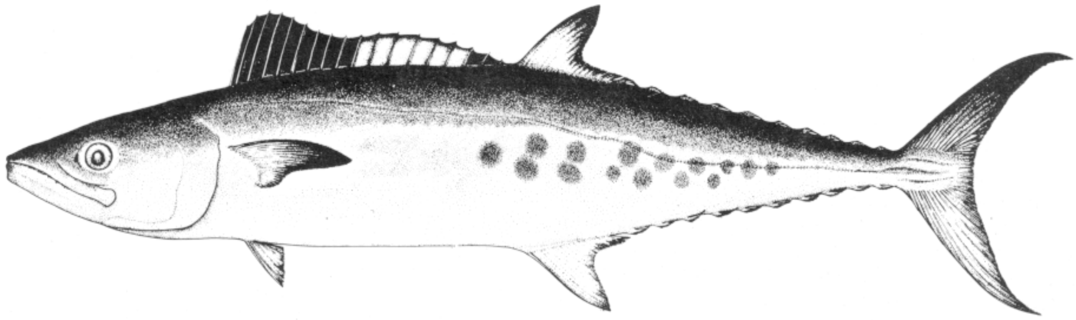
3.4 CURRENT AND FUTURE RESEARCH NEEDS FOR SPOTTED MACKEREL

Considerable biological data are available for spotted mackerel off the east coast of Qld, where the major fishery is located and the need is greatest. The recent Spotted Mackerel Workshop in Qld identified future research needs for the fishery (QFS Spotted Mackerel Workshop Proceedings 2002). The QFS East Coast Inshore Finfish Management Advisory Committee also listed the following as research priorities relevant for spotted mackerel: investigate and define location and timing of spawning, nursery grounds and preferred habitat; and design and undertake access point and on-site surveys to assess the recreational harvest and effort (Mark Doohan, QFS, personal communication). Research on spotted mackerel is clearly a state, rather than a national, priority.

Monitoring the age structure of spawning aggregations will be important. However, methods used for age determination may need to be re-evaluated. As is the case for Spanish mackerel, the precision of age estimates needed for stock assessment should be assessed formally, and the value of age proxies, such as fish size and otolith weight should re-evaluated (using unbiased methods) in the context of this assessment. The potential for synthesising morphometric data, daily rings counts, annuli counts and otolith weight measures to provide probabilistic estimates of age need to be investigated in detail.

Formal stock assessment of the Qld spotted mackerel fishery is currently being undertaken by CRC Reef (Dr Gavin Begg, CRC Reef, personal communication). Presumably, this will involve adapting the age-structured model used for the assessment of Qld Spanish mackerel by Welch *et al*. (2002). Ideally, the assessment would identify research needs for spotted mackerel, identify potential biological performance indicators and future management options. A MSE similar to that conducted for Spanish mackerel would also be valuable. However, as less data are available for spotted mackerel than Spanish mackerel, the assessment may not be particularly informative about stock status. A method for estimating exploitation rates or fishing mortality is needed for school mackerel – as it is for Spanish mackerel. However, the cost of genetic mark-recapture studies being evaluated in the GENETAG project on Spanish mackerel may be prohibitive for the relatively low value spotted mackerel fishery, at least in the foreseeable future.

CHAPTER 4. SCHOOL MACKEREL *SCOMBEROMORUS QUEENSLANDICUS*



Picture courtesy of the United Nations Development Programme Food and Agriculture Organization of the United Nations. FAO Species Catalogue Vol. 2, Scombrids of the World).

Family: Scombridae
Genus: *Scomberomorus*
Other common names: Doggy, Blotched or Queensland mackerel

Diagnostic features:
Colour: Sides with three indefinite rows of indistinct blotches. The membrane of first dorsal fin is black with a large area of white between the sixth and last dorsal spine. The lateral line is gradually curved down toward the caudal peduncle.
Fin-ray and spine counts: First dorsal = 16-18 spines (usually 17); Second dorsal = 17-19 rays, followed by 9-11 finlets; Anal fin = 16-20 rays, followed by 9-11 finlets; Pectoral fin = 21-23 rays.
Vertebral count: 48-49 (usually 48).
Size: School mackerel reach lengths of 100 cm FL, and weights of up to 12.3 kg.

Reference: Collette and Nauen (1983); Allen and Swainston (1988); Kailola *et al.* (1993); www.fishbase.com)

4.1 INTRODUCTION

This chapter: (1) summarises and identifies gaps in past and current research on school mackerel *Scomberomorus queenslandicus*; (2) provides an overview of the fisheries and current management strategies in each state; (3) assesses the degree to which past and current research has met management needs; and (4) identifies current and future research needs for school mackerel in northern Australia. Information presented in this chapter is incorporated into the strategic research plan for northern mackerels (Chapter 7).

4.2 INFORMATION AVAILABLE AND GAPS IN KNOWLEDGE

4.2.1 Critical Documents and Relevant Reviews

Several scientific papers have been published on aspects of the fisheries biology of school mackerel off the east of Qld, including the patterns of age and growth, stock structure, reproductive biology and feeding interactions with other *Scomberomorus* species (Begg and Hopper 1997; Begg *et al.* 1998a, b; Begg and Sellin 1998; Begg 1998). This information and a summary of the commercial and recreational fisheries for school mackerel are provided in the final report for FRDC Projects 92/144 and 92/144.02 (Cameron and Begg 2002). A short review of the Qld fishery, biological and ecological data and marketing of school mackerel is provided in Williams (2002).

4.2.2 Distribution

School mackerel are endemic to inshore waters of northern Australian and southern Papua New Guinea and occur from Shark Bay to Sydney (Collette and Nauen 1983; Williams 2002). This species is commonly found in relatively shallow, turbid coastal waters where they aggregate to spawn and feed (Collette and Nauen 1983; Kailola *et al.* 1993). These aggregations are commonly encountered in Hervey Bay and Moreton Bay, and are often associated with schools of spotted mackerel.

4.2.3 Stock Structure

The stock structure of school mackerel appears to be more complex than that of other *Scomberomorus* species in northern Australia. Genetic data and elemental compositions of otoliths suggest that at least two separate stocks exist off the east coast (Begg *et al.* 1998a, b; Begg 1998). In addition, significant genetic variation has been observed between samples collected from the Arafura Sea and the east coast of Qld (Begg *et al.* 1998a). No stock structure information is available for school mackerel populations between Joseph Boneparte Gulf and Shark Bay. Tag-recapture studies off Qld suggest that movement between regions may be limited, and that separate genetic groups may be associated with individual coastal embayments and spawning areas (Begg *et al.* 1997; Begg *et al.* 1998a).

4.2.3 Patterns of Migration

School mackerel recaptured off the Qld coast moved only short distances from the location of capture and release, and may not undertake the migrations observed in other *Scomberomorus* species (Begg *et al.* 1997; Cameron and Begg 2002). No data are available on the movement patterns of school mackerel in other parts of its range.

4.2.4 Ecological Interactions

School mackerel feed on a wide range of benthic and pelagic prey, including small pelagic fishes, such as clupeoids and engrualids, small crustaceans and cephalopods (Begg and Hopper 1997). The two main feeding periods off the east coast of Qld are late autumn and early winter (Begg and Hopper 1997). School mackerel utilises similar habitats to spotted mackerel off Qld (Begg and Hopper 1997). No information is available on the feeding patterns or diet of school mackerel in Torres Strait, the NT or WA.

4.2.5 Reproductive Biology

The reproductive biology of school mackerel has been studied between Cairns and Moreton Bay only (Cameron and Begg 2002). In this area, school mackerel spawn in coastal bays and estuaries from October to January (Begg 1998). The spawning season is protracted and spawning occurs concurrently at locations along the coast (Begg 1998). Both sexes reach sexual maturity at approximately 2 years of age. The length range at which 50% of individuals are sexually mature is 40-45 cm FL for females and 35-40 cm FL for males (Cameron and Begg 2002). Females dominate larger size classes off east Queensland and represent all fish over 73 cm FL (Begg 1998). Batch fecundity has been estimated to be approximately 262,000 eggs per batch for individuals of 50 cm TL (Cameron and Begg 2002).

4.2.6 Early Life History

Limited information is available on the early life history of school mackerel. Larvae have been collected from coastal lagoons near Townsville (Munroe 1943; Jenkins *et al*. 1984a; 1985) School mackerel eggs have not been formally described. No information is available on the nursery areas for larvae or early juveniles in any other state or region.

4.2.7 Age and Growth

The patterns of age and growth of school mackerel have been studied between Cairns and Moreton Bay only. In these waters, fish between 40 and 60 cm FL were between 1 and 3 years of age (Begg and Sellin 1998). Females live for up to 7 years and reach a maximum size of approximately 78 cm FL. Males live for approximately 10 years and reach 69cm FL (Begg and Sellin 1998; Cameron and Begg 2002). *VB* growth equation parameters for Qld combined were; K=0.585 yr^{-1}, L_∞=65.1cm and t_0=-1.4 for females and K=0.704 yr^{-1}, L_∞=62.8 cm and t_0 =-1.3 for males. As is the case for spotted mackerel, marginal increment analysis is only useful for validating the timing of annuli deposition for fish up to two years old. The use of tetracycline as a biochemical marker was also unsuccessful due to the short period between release and recapture of tagged fish (Begg and Sellin 1998).

4.2.8 Mortality

Instantaneous mortality rates for school mackerel are available for the Qld east coast line and net fisheries. Mean instantaneous mortality rates ranged from 0.60 to 1.38 and approximately 40% of the stock survives annually (Cameron and Begg 2002). The instantaneous mortality rates (Z) for males and females taken in Qld Line fisheries were 0.743 and 0.869, respectively. For the 10.0 cm nets, Z =1.38 and Z =1.34, respectively for males and females and for 12.5 cm nets, Z =0.9 and Z =0.60, respectively for males and females. The instantaneous mortality rates for all Qld fisheries, regions and gear types combined were 0.961 and 0.877 for males and females, respectively (Cameron and Begg 2002). No information is available on the mortality rates for school mackerel in the Torres Strait, the NT or WA.

4.2.9 Stock Assessment

As is the case for grey and spotted mackerel, formal stock assessment procedures have not been conducted for school mackerel in any state or territory Increasing annual catches and signs of localised depletion in Qld suggest that such assessments are overdue. Cameron and Begg (2002) and Williams (2002) identified the urgent need for single species stock assessment of school mackerel (and other northern mackerels) in Qld. The localised nature of spawning aggregations and presence of several stocks of school mackerel off the east coast of Qld, suggest that these assessments should be done on a regional basis.

4.3 FISHERIES, RESEARCH AND MANAGEMENT

4.3.1 Overview

School mackerel forms predictable seasonal aggregations in inshore waters that are easily targeted and accessed by members of all sectors in relatively small and inexpensive vessels (Williams 2002). School mackerel is taken by commercial and recreational fishers throughout northern Australia. Most of the catch is taken in Qld coastal waters by commercial fishers using bottom set or drifting gillnets. Small quantities are taken as bycatch in the Spanish mackerel troll and line fishery, and trawl fisheries in the NT, Torres Strait and WA.

4.3.2 Qld

Background

In Qld, school mackerel is mostly captured south of Rockhampton. The Hervey Bay-Fraser Island and Moreton Bay regions yield the majority of the catch. Most of the catch is taken by net with the remainder taken by trolling and handlining (Williams 2002). The mean annual catch of school mackerel in Qld between 1988 and 2000 was approximately 31 tonnes (Cameron and Begg 2002).

Monitoring

Qld commercial fishers are required to complete compulsory logbooks (CFISH) detailing the composition and weight of catch, and the number of days fished. (Williams 2002). Catch and effort for school mackerel by recreational fishers has been estimated from tri-annual phone surveys (RFISH), however difficulties associated with the accurate identification of other mackerel species limits the reliability of the estimates.

Fishery

Since the mid 1990's, there have been substantial increases in catches of school mackerel by commercial and recreational fishers. The annual commercial catch of school mackerel in east coast waters ranged between 1.99 and 92.96 tonnes in the period between 1988 and 2000. The number of vessels operating in the fishery increased from 26 in 1988 to 114 in 1999. During 2000, 83 vessels operated in fishery for a total of 1003 days fished (Cameron and Begg 2002; Williams 2002). Between 1988 and 2000, CPUE ranged between 21 and 92 kg per day fished (Williams 2002).

The state-wide recreational fishery telephone survey (RFISH) undertaken in 1995 estimated the recreational catch to be approximately 44 tonnes, which was 21 tonnes higher than the commercial catch for the survey year. The 1999 survey found 65,000 school mackerel were caught for total weight of 88 tonnes, which was the same as the catch recorded for the commercial fishery (Williams 2002).

Management

The minimum size limit for school mackerel is 50 cm TL. The recreational bag limit of 30 fish per person applies. There are no catch quotas or seasonal restrictions to protect spawning stocks from overfishing.

Extent to which research outcomes have been incorporated into management arrangements

The minimum size limit is loosely based on the size at which 50% of males and females reach sexual maturity. However, there are few examples of research findings being used as the basis for decision-making on school mackerel.

4.3.3 Other States

Background

School mackerel only constitute a small component of the bycatch of the Torres Strait, NT and WA Spanish mackerel fisheries. The Northern Fish Trawl Fishery, Northern Prawn, NT Shark, and Western Tuna fisheries also take small quantities of school mackerel as bycatch. School mackerel are prized by recreational anglers and are taken opportunistically by clients of fishing tour operators (FTOs) and charter fishers in the NT and WA.

Monitoring

Logbooks have been used to record commercial catches of school mackerel in the NT since 1983. In WA, catch data for small northern mackerel are combined, and no historical records of school mackerel catches are available.

Fishery

School mackerel are only a minor component of the mackerel catch in the NT. No catches of school mackerel were recorded between 1983 and 1990. Between 1990 and 1999 commercial catches ranged from 0.000 and 136 kg for a combined total catch of 440 kg (Buckworth and Clarke 2001). Currently, no catch data are available for the recreational, FTO or indigenous fisheries for school mackerel in Torres Strait, the NT or WA. In 1999, the unspecified mackerel catch in WA was 115.5 tonnes. School mackerel comprise <1% of the commercial troll catch in WA (Mackie *et al.* 2003).

Management

In the NT there are no size limits for school mackerels, which, like grey and spotted mackerel, fall under general personal fish possession limit for unmanaged species. The same restrictions Fisheries for other northern mackerel species apply to the Western Tuna and Northern Prawn Fisheries.

In WA, the size limit for school mackerel is 50 cm TL. A total mixed bag limit of eight with four of each species is in place for other northern mackerels, including grey mackerel.

Extent to which research outcomes have been incorporated into management arrangements

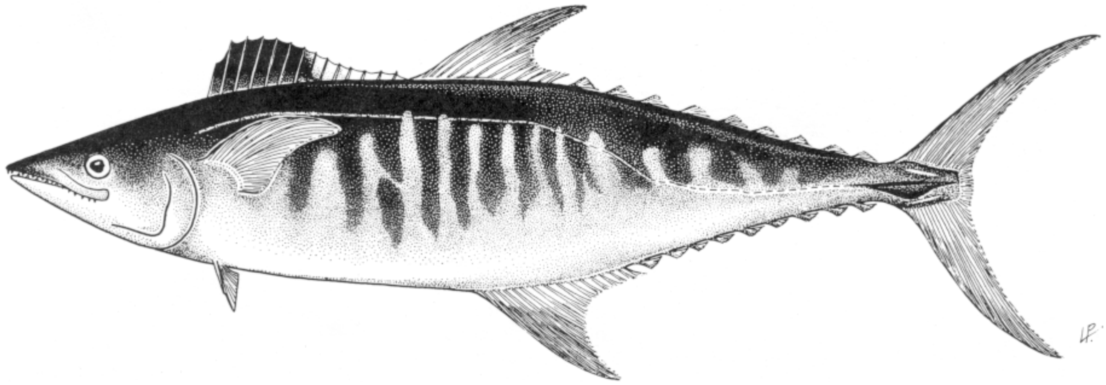
In Torres Strait and the NT no information on the age structure, reproductive biology or stock structure of school mackerel is available on which to base management decisions. Similarly, there are no published biological data for school mackerel in WA. Precautionary management arrangements have been established on the basis of information from Qld.

4.4 CURRENT AND FUTURE RESEARCH NEEDS FOR SCHOOL MACKEREL

The QFS East Coast Inshore Finfish Management Advisory Committee has listed the following as research priorities relevant for school mackerel: investigate and define location and timing of spawning, nursery grounds and preferred habitat; and design and undertake access point and on-site surveys to assess the recreational harvest and effort (Mark Doohan, QFS, personal communication).

Species-specific stock assessments of school mackerel are needed in Qld where there is a significant fishery. There is also a need to establish ongoing programs for monitoring the age structure of catches and spawning aggregations. The limited movements of school mackerel and evidence of existence of more than one stock off the east coast means that monitoring programs will need to be conducted at a regional (cf state) level. Few biological data are available for Torres Strait, the Gulf of Carpentaria, NT or WA. The low catches of school mackerel in these areas indicate that such studies are not a high priority.

CHAPTER 5. GREY MACKEREL *SCOMBEROMORUS SEMIFASCIATUS*



Picture courtesy of the United Nations Development Programme Food and Agriculture Organization of the United Nations. FAO Species Catalogue Vol. 2, Scombrids of the World).

Family: Scombridae

Genus: *Scomberomorus*

Other common names: Broad-barred king mackerel, grey or brownie.

Diagnostic features: Colour: Broad dark bars along the upper side and a white region on the centre of the blackish first dorsal fin.

Fin-ray and spine counts: First dorsal = 13-15 spines; Second dorsal = 19-22 rays (usually 20), followed by 8-10 finlets (usually 9); Anal fin = 19-22 rays (usually 21-22), followed by 7-10 finlets; Pectoral fin = 22 to 25 rays (usually 23-24).

Vertebral count: 44-46 (usually 45).

Size: Commonly 70-85 cm. Can reach approximately 120 cm FL. Commonly caught at 3.5-4.5 kg. Can reach 10 kg.

Reference: Collette and Nauen (1983); Allen and Swainston (1988); Kailola *et al.* (1993); www.fishbase.com.

5.1 INTRODUCTION

This chapter (1) summarises and identifies gaps in past and current research on grey mackerel *Scomberomorus semifasciatus* (2) provides an overview of the fisheries and current management strategies in each state (3) assesses the degree to which past and current research has met management needs and (4) identifies current and future research needs for grey mackerel in northern Australia. Information presented in this chapter is incorporated into the strategic research plan for northern mackerels (Chapter 7).

5.2 INFORMATION AVAILABLE AND GAPS IN KNOWLEDGE

5.2.1 Critical Documents and Relevant Reviews

No single species stock assessments have been completed for grey mackerel for any state or region. Cameron and Begg (2002) investigated aspects of the fisheries biology for this species off the east coast of Qld and in the Gulf of Carpentaria and the NT. The report investigated the age, growth patterns, mortality rates, reproductive biology and stock structure of grey mackerel and summary data from the commercial and recreational fisheries. Williams (2002) summarises biological, fisheries and marketing information and comments on the status of stocks of the east coast of Qld and in the Gulf of Carpentaria.

5.2.2 Distribution

Grey mackerel occurs between Shark Bay in NorthWest WA and northern NSW (Collette and Nauen 1983; Collete and Russo 1984; Kailola *et al*. 1993). It inhabits a diverse array of marine habitats ranging from offshore waters near the edge of the continental shelf to shallow, inshore waters adjacent to rocky reefs, headlands and river mouths and to estuaries characterised by low salinity.

5.2.3 Stock Structure

Minimal genetic variation was detected among grey mackerel samples collected off the east coast of Qld, suggesting the existence of a single east coast stock (Cameron and Begg 2002). There was, however, evidence of significant genetic differences between grey mackerel taken from the Arafura Sea/Gulf of Carpentaria and off the east coast of Qld, suggesting the existence of at least an eastern and northern stock (Cameron and Begg 2002). The level of interaction betweengrey mackerel populations in NT and WA waters is unknown. A recent FRDC proposal (2002/010), aimed to investigate the stock structure of grey mackerel between Joseph Boneparte Gulf and Shark Bay (WA) using otolith microchemistry. More information would be obtained by expanding the study to include NT and Qld waters and by using a combination of genetics, otolith microchemistry and parasitology (see FRDC Project 98/159)

5.2.4 Patterns of Migration

Low genetic differentiation among grey mackerel collected along the east coast of Qld suggests this species may undergo north-south migrations similar to those of spotted and Spanish mackerels (Begg *et al*. 1997; Begg *et al*. 1998a, b; Begg 1998). Elemental analysis of otoliths also suggests that grey mackerel moves between regions along the east coast of Qld (Cameron and Begg 2002). There are currently no tag-recapture data to support these conclusions: Of 313 individuals recently tagged only one was recaptured (Cameron and Begg 2002).

Migratory patterns of grey mackerel in the Torres Strait, Gulf of Carpentaria, NT and WA are unknown. The rapid growth of the fisheries for grey mackerel in these areas suggest there is an urgent need for such data. The lack of success of previous tagging studies and difficulties capturing this species by line suggest that conventional tagging studies may not be appropriate for investigating this issue. A study of the stock structure of grey mackerel in NT, Qld and WA that used a combination of genetics, otolith microchemistry and parasitology would provide useful insights to migratory patterns of this species.

5.2.5 Ecological Interactions

Grey mackerel feed on small pelagic baitfish, such as herring, anchovy and sardine. It has been reported that freshwater input from rivers and estuaries is an important environmental cue for the aggregation of grey mackerel (Williams 2002). There have been no studies of the feeding ecology, interactions with prey species and other pelagic fishes or the influence of environmental factors on behavioural patterns in any state or region.

5.2.6 Reproductive Biology

Grey mackerel spawn between September and January off the east coast of Qld. Males and females reach maturity at approximately 2 years of age and at 67 cm and 81 cm FL, respectively. Grey mackerel produce approximately 250,000 oocytes per batch at 50 cm TL (Cameron and Begg 2002). Few data are available on the reproductive biology of this species in northern Qld, the NT or WA.

5.2.7 Early Life History

The early life history stages of grey mackerel are often associated with estuarine and other semi-protected inshore habitats such as lagoons and coastal embayments (Williams 2002). Larvae and early juveniles have been found at Cape Cleveland and Cape Bowling Green, near Townsville (Jenkins *et al.* 1985; Thorrold 1993). The eggs of grey mackerel have not been described.

5.2.8 Age and Growth

Age determination has focused mainly on adults. Marginal increment analysis has been used to validate the timing of annuli deposition in 1 and 2 year olds (Cameron and Begg 2002). The usefulness of this approach is reduced in older fish due to changes in otolith morphology (Cameron and Begg 2002).

Like other species of *Scomberomorus*, grey mackerel grow rapidly, especially as juveniles and off Qld reach maximum sizes of approximately 99 cm FL at ages of approximately 12 years (Cameron and Begg 2002). Males grow significantly faster than females (Cameron and Begg 2002). *VB* growth equation parameters for grey mackerel of the east coast of Qld were: K=0.301 yr^{-1}, L_∞=92.8 cm and t_0=-3.17 for females and K=0.475 yr^{-1}, L_∞=81.1 cm and t_0=-2.13 for males (Cameron and Begg 2002).

Few data are available on the growth patterns and age structure of commercial and recreational catches in the Torres Strait, Gulf of Carpentaria, the NT or WA. A recent FRDC proposal (2002/010) addressed the need for this information and aimed to validate the timing of annuli deposition using calcein as a biochemical marker.

5.2.9 Mortality

Estimates of instantaneous and annual mortality rates are only available for the east coast of Qld and the Gulf of Carpentaria (Cameron and Begg 2002). In the east coast gillnet fishery, which uses 15.24cm mesh, the instantaneous mortality rate (Z) for males (0.499) was higher than that for females (0.454). However, in the Gulf of Carpentaria fishery, which uses 16.51cm mesh nets, the instantaneous mortality rate was lower for males (0.297) than for females (0.406). These differences may reflect the larger overall size of females in these regions as compared to males. When all gear types (mesh sizes) were combined, the annual mortality rate for males was slightly higher (0.389) than for females (0.382). There are no estimates of mortality or survival for grey mackerel north of Cairns, in Torres Strait, the NT or WA.

5.2.10 Stock Assessment

No formal stock assessments have been conducted for grey mackerel in any state or territory. To date, assessments have been restricted to analysis of catch and effort data. Better assessments of grey mackerel stocks are needed because of: (1) the complexities and lack of knowledge of stock structure across northern Australia; (2) increasing exploitation rates and fishing efficiency; (3) signs of localised stock depletion off the east coast of Qld and increasing commercial catches in the Gulf of Carpentaria; (4) shifts in effort away from Spanish mackerel toward other northern mackerels off the east coast, in the Gulf of Carpentaria and in WA (Cameron and Begg 2002; Williams 2002). Better assessments will require additional biological data from the Gulf of Carpentaria, NT and WA and establishment of an ongoing biological monitoring program off the east coast.

5.3 FISHERIES, RESEARCH AND MANAGEMENT

5.3.1 Overview

Commercial gillnet fisheries for grey mackerel operate off the east coast of Qld, and in the Gulf of Carpentaria, NT and WA. Small quantitiesof grey mackerel are also taken by trolling and line fishing, however this species is more difficult to catch by line than other species of *Scomberomorus*. As a result, most of the commercial grey mackerel catch is taken by netting.

5.3.2 Qld

Background

There has recently been a significant geographical shift in grey mackerel catches. In the late 1980's and early 1990's, the fishery was centred off the east coast but most of the commercial catch is now taken from the Gulf of Carpentaria (Cameron and Begg 2002). This shift in catches and apparent stock depletion off the east coast has lead to recommendations for the implementation of an ongoing program for monitoring biological performance indicators and the establishment of improved arrangements for monitoring Qld's grey mackerel stocks (Williams 2002; Cameron and Begg 2002). However, the banning of gillnetting for Spanish mackerel off the east Queensland coast may also have affected grey mackerel catches during the late 1990's.

Monitoring

Catch and effort information for the Qld east coast and Gulf of Carpentaria commercial net, troll and line fisheries have been collected through Commercial Fisheries Information System (CFISH) logbooks since 1988. Recreational surveys (RFISH) were used to estimate the proportion of grey mackerel in recreational catches in 1997 and 1999.

Fishery

The mean grey mackerel catch for all regions of Qld between 1988 and 2000 was approximately 329 tonnes (Cameron and Begg 2002). Off the east coast of Qld grey mackerel catches steadily declined from 241 tonnes in 1989 to 42 tonnes in 2000. Despite this decline, CPUE remained relatively stable, ranging between 65 and 106 kg per boat day between 1989 and 2000.

In the Gulf of Carpentaria, specialised shark and grey mackerel net fishers and a few inshore barramundi net fishers take most of the grey mackerel catch, with the remainder taken by troll and line fishing (Cameron and Begg 2002). Mesh sizes in bottom-set gillnets range from 162.5 to 245 mm (Mark Doohan, QFS, personal communication). Large meshed gillnets are generally favoured in the Gulf as sharks are also targeted. Between 1989 and 2000, the number of commercial vessels targeting grey mackerel declined from 334 to 129 and the annual commercial catch increased from 6 to 526 tonnes. CPUE increased from 12 kg per boat day in 1989 to 536 kg per boat day in 2000.

A state-wide diary survey in 1995 estimated the annual recreational catch of grey mackerel catch was approximately 12 tonnes. Similar surveys off the east coast estimated that approximately 8000 grey mackerel with a total weight of 18 tonnes were taken in 1997 and 5,000 grey mackerel with a total weight of 19 tonnes were taken in 1999 (Williams 2002).

Management

The minimum size limit for grey mackerel in Qld is 50 cm TL and the recreational bag limit is 10 fish per person. Management arrangements for grey mackerel are still in “developmental” stages despite substantial increases in commercial and recreational catches since 1989. Cameron and Begg (2002) and Williams (2002) suggested that management arrangements for grey mackerels should be reviewed and updated to protect stocks from increasing fishing pressure.

The use of all commercial nets (other than bait nets) is prohibited in the Gulf for around three months a year (October-January) to protect spawning populations of barramundi. This netting closure also coincides with for spawning season for grey mackerel in the Gulf.

A number of new management arrangements have been proposed for grey mackerel in the Gulf. These include a possible increase in the minimum legal size and restrictions on catch and effort through the introduction of new entry criteria for the target fishing of grey mackerel, as well as possession limits for incidental catches.

New management arrangements for the east coast commercial fishery for grey mackerel are also proposed. Management proposals will be developed in association with the proposed fisheries management plan for the east coast inshore fin-fish fishery. Proposed management arrangements for this fishery are to be released for public comment later this year.

The QFS East Coast Inshore Finfish Management Advisory Committee has listed the following research priorities for grey mackerel: enhance fishery dependent and independent monitoring of mackerel components of inshore net fisheries; stock assessments (including stock structure) of grey mackerel in east coast waters; investigate and define location and timing of spawning, nursery grounds and preferred habitat for each small mackerel species; design and undertake access point and on-site surveys to assess the recreational harvest and effort for each small mackerel species.

Extent to which research outcomes have been incorporated into management arrangements

Cameron and Begg (2002) provided baseline biological data to assist the management of grey mackerel. However, there are few clear examples of how research information has been incorporated into management arrangements for grey mackerel. For example, the minimum size limit in Qld (50 cm TL) is well below the minimum size at sexual maturity (males at 67 cm FL, females 81 cm FL) identified by Cameron and Begg (2002).

5.3.3 NT

Background

Grey mackerel is the second most important species in the NT Spanish mackerel troll fishery. Between 1996 and 1998, the catch of grey mackerel ranged between 240 and 284 tonnes per year and exceeded that of Spanish mackerel. The species is also targeted by recreational fishers and is taken as bycatch in the NT Shark, Western Tuna and Northern Prawn Fisheries. Shark netting accounts for a significant proportion of the total grey mackerel catch in the NT, with a total of approximately 1095 tonnes taken between 1995 and 1999 (Buckworth and Clarke 2001). There is currently no species-specific stock assessment or biological monitoring for grey mackerel in NT. Catch and effort data for grey mackerel is included in stock assessments for Spanish mackerel.

Monitoring

Logbooks were introduced in 1991 to obtain fisheries data, including size of fish, composition of the catch and fishing effort in days. Catch and effort information for the recreational and indigenous sectors were recorded in the recently completed National Recreational Fishing Survey (Buckworth and Clarke 2001). Fishing tour operators also collect catch and effort data, but this was not available at the time of this review.

Fishery

Commercial catches of grey mackerel in the net and troll fisheries ranged between 0.02 tonnes in 1983 and 284.9 tonnes in 1997. In 1999, the catch had decreased to 139.8 tonnes (Clarke and Buckworth 2000). The total grey mackerel catch for this period was 1,983.3 tonnes. CPUE for grey mackerel (all commercial fisheries combined) peaked at 563.4 kg per day in 1985 and was 207.4 kg per day in 1999 (Buckworth and Clarke 2001).

Grey mackerel is taken opportunistically by recreational fishers and clients of fishing tour operators (FTOs) targeting Spanish mackerel. Currently, no species-specific catch data for grey mackerel are collected from recreational or indigenous fishers or FTOs. Recreational surveys conducted in 1994/5 estimated that annual harvest of all *Scomberomorus* species combined was approximately 24,522 individuals (Coleman 1998).

Management

No species-specific management arrangements are in place for grey mackerel in the NT. There is currently no minimum legal size for grey mackerel taken by recreational, indigenous or FTOs. Grey mackerel are included in a general personal fish possession limit for unmanaged species that states "a person may not possess a combination of fish and fillets exceeding the equivalent of 30 whole fish, other than in his or her place of permanent residence" (NT Fisheries Website 2002).

There are currently no species-specific bycatch limits for grey mackerel in the Northern Shark Fishery. Participants in the Western Tuna and Northern Prawn (NPF) Fisheries are permitted to retain 10 fish of a range of species including *Scomberomorus* species (Buckworth and Clarke 2001). The quantities of grey mackerel (and other northern mackerel) retained to be sold by the Northern Prawn fleets is determined by the NPF Management Plan (Buckworth and Clarke 2001).

Extent to which research outcomes have been incorporated into management arrangements

Few biological data are available on which to base management of the NT fishery.

5.3.4 WA

Background

Grey mackerel is mostly taken in the west coast region and have recently been targeted using jigging techniques (Mackie 2003). Grey mackerel are becoming an increasingly important component of the Spanish mackerel troll catch in WA. This species is only targeted for periods of one to two months each year and their importance varies between region and year. The grey mackerel catch (~44 tonnes) was worth approximately $448,000 to fishers during 2001 (Mackie 2003).

Monitoring

Monitoring of the commercial troll fishery is undertaken using a commercial logbook system identical to those used in other states for *Scomberomorus* fisheries (www.fish.wa.gov.au). There are problems with regard to the accuracy of species identification of other northern mackerels recorded in logbooks by commercial fishers (Mackie 2003).

Fishery

The seasonality of the grey (and Spanish) mackerel catch has led to the commercial fishery existing as a subgroup within other WA line fisheries such as the snapper line fishery. Grey (and Spanish) mackerel are often taken on the troll while steaming between snapper fishing grounds. Grey mackerel comprise approximately 80% of the commercial catch of other northern mackerel (www.fish.wa.gov.au; Mackie *et al.* 2003). Grey mackerel is preferred to Spanish mackerel on export markets, however the annual catch is highly variable and different fishing methods are required to target this species successfully (Penn 2002). During 1999, the catch of "unspecified" mackerel (other northern mackerel) was 77.6 tonnes in the west coast sector, 27.8 tonnes in the Kimberley and 10.1 tonnes in the Pilbara sector. In 2001, the grey mackerel catch was approximately 45 tonnes (Mackie 2003). No catch data for grey mackerel are available from recreational fishers, fishing tour operators or indigenous fishers in WA.

Management

Grey mackerel is considered to be vulnerable to overfishing in WA (www.fish.wa.gov.au). The current recreational size limit for grey mackerel is 75 cm TL. A total mixed bag limit of eight mackerel, with four of each species is in place for other northern mackerels, including grey mackerel.

Prior to 2000, commercial mackerel fishers in WA were not required to identify and separate grey mackerel to species level when filling out logbooks. Grey mackerel were classified as "other" mackerels for management purposes. Until the formalised Spanish mackerel management plan is implemented sometime in 2004, the commercial mackerel fishery will be open access for commercial operators (Mackie *et al.* 2003)

Extent to which research outcomes have been incorporated into management arrangements

Management arrangements for grey mackerel, such as the minimum legal size, have been based on information from other states (Qld). FRDC proposal 2002/010 aimed to provide baseline biological data for grey mackerel in WA, improve data recording procedures for the mackerel troll fishery, improve the WA fisheries databases to distinguish between other northern mackerel species and provide fisheries managers with a stock assessment for grey mackerel.

5.4 CURRENT AND FUTURE RESEARCH NEEDS FOR GREY MACKEREL

The total national annual catch of grey mackerel appears to be in the vicinity of approximately 500 to 1000 tonnes. It has been reported that this species is preferred to Spanish mackerel on some export markets. Information on the stock structure and biology of grey mackerel is needed for the Gulf of Carpentaria, NT and WA, where this species comprises a significant proportion of the total northern mackerel. The QFS Gulf of Carpentaria Management Advisory Committee has listed stock assessment of grey mackerel populations in the Gulf as one of its highest research priorities (Mark Dooohan, QFS, personal communication). Similarly, research on grey mackerel is a priority for the NT (Ray Clark, DBIRD, personal communication). Stock assessments of grey mackerel are needed to establish management arrangements that satisfy OCS agreements between the NT and Qld governments.

The high priority that WA Fisheries places on the need for research on grey mackerel was evidenced by the submission of FRDC Proposal 2002/010. In light of the broad need for research on grey mackerel, the previous WA proposal should be expanded to include all waters west of Torres Strait (inclusive). There may also be value in conducting some additional research on the east coast of Qld. Current stock structure (FRDC Project 99/151) and stock assessment studies (FRDC Project 99/151) on Spanish mackerel provide blueprints for the type of project that is needed for grey mackerel. The critical elements of this project should be to determine stock structure and investigate the fisheries biology of grey mackerel, to develop a validated age-determination protocol and to establish an age-structured model. When this is completed it would be useful to conduct a management strategy evaluation similar to that by Hoyle (2002). The reduced recreational importance and commercial value of grey mackerel compared to the Spanish mackerel suggest that this project will need to be conducted cost effectively.

CHAPTER 6. COSTS AND BENEFITS OF PREVIOUS RESEARCH ON NORTHERN MACKEREL

6.1 INTRODUCTION

Since 1992, FRDC has funded six research projects on Spanish mackerel (Table 1) and two projects on other northern mackerels with a combined total cost of $5,472,813 and an FRDC contribution of $1,701,324. Two of the projects on Spanish mackerel have been completed (1992/125.4, T94/015), two are nearing completion (98/159, 99/151) and two are ongoing (2001/019, 2002/011). Both projects on other northern mackerels (92/144 and 92/144.2) have been completed.

Several projects not focused specifically on Spanish mackerel have benefited research and management of this species. These projects include the series of tropical stock assessment workshops conducted in the NT in 1992, 1996, 1997 and 2000 that were funded by FRDC (and its precursor FIRC) and the NT government.

6.2 METHODS

The costs and benefits of FRDC projects on Spanish mackerel were assessed using evaluation guidelines outlined in Lal *et al.* (1994). All assessments are either based on the potential benefits or actual benefits of research to the fishing industry. No formal quantitative analysis was undertaken in these assessments due to the difficulty in measuring and comparing the 'true" value of each project. In most cases the benefits hinge upon the uptake of research findings by fishers and fishery management bodies in each state, both of which are difficult to quantify. The overall success and value of individual FRDC-funded projects on Spanish mackerel and other northern mackerels are assessed separately at the end of the chapter.

6.3 SPANISH MACKEREL

6.3.1 Research Costs

Total

The cost summary for FRDC-funded research on Spanish mackerel is provided in Table 1. Project summaries and further information on the costs and benefits of each project is available in Appendix 2. The total combined cost of the six projects funded since 1992 is approximately $4,070,099. FRDC has contributed $1,586,632 to these projects, which comprises 39% of the total funding (Table 1). The commercial and recreational sectors have contributed $631,299

(15.5%) and $49,200 (1.2%) respectively. The applicants for these projects and other research agencies have contributed $1,595,206 (39.2%) and $207,762 (5.1%), respectively.

Tropical stock assessment workshops

The costs of the tropical stock assessment workshops conducted in the NT in 1992, 1996, 1997 and 2000 are difficult to estimate accurately, because the workshops often focused on several species, unspecified supporting funds were provided by the NT government and the workshops were often conducted as "add-ons" to other activities (such as the 1997 ASFB Conference). Suffice to say that, overall, the cost to FRDC and FIRC was relatively low, i.e. <$20,000.

Completed projects

The total cost of the project "Maximising economic returns to the NT Spanish mackerel fishery (1992/125.24) was low ($29,700). FRDC provided 100% of the funding.

The total cost of project "Age structure of the commercial catch of NT Spanish mackerel" (T94/015) was low ($45,319). FRDC and NTDPIF contributed 41.2% and 58.8% of funds respectively. Industry did not contribute to the project.

Projects nearing completion

The total cost of "Stock Structure of northern and western Australian Spanish mackerel" (98/159) is $1,222,814, of which FRDC is contributing $319,318 (32%), and industry and NT Fisheries are contributing 24.8% and 43.2% respectively.

The total cost of "Stock Assessment of Spanish mackerel (*Scomberomorus commerson*) in WA" (99/151) is $1,076,425, of which FRDC is contributing 49.2%, with contributions from recreational fishers (4.5%), commercial fishers (13.75%), NT Fisheries (1.6%) and WA Fisheries (30.8%)

The total cost of "Exploitation dynamics and biological characteristics of east coast Spanish mackerel harvested by the recreational and commercial sectors" (2001/019) is $440,818 of which FRDC, Reef CRC and QDPI are contributing 37.1%, 25.7% and 37.2%, respectively.

Ongoing projects

The total cost of "Genetic mark-recapture for real-time harvest rate monitoring: pilot studies in northern Australian Spanish mackerel fisheries" is $1,255,003 of which FRDC contributed 36%, industry contributed 14%, and NT Fisheries contributed 49%.

Table 1. Cost summary for all contributors of past and current research projects on Spanish mackerel (in $A).

FRDC Project Number	FRDC	Industry	Applicant	Research Agencies	Recreation Fishers	Project Total
1992/125.24 Maximising economic returns to NT fishery	29,720					29,720
1994/015 Age structure of NT catch	18,662			26,657		45,319
1998/159 Stock structure in northern & western Australia	391,318	303,526	527,970			1,222,814
1999/151 Stock assessment in WA	529,921	148,500	331,557	17,247	49,200	1,076,425
2001/019 Exploitation dynamics and biology on east coast	163,633		113,327	163,858		440,818
2002/011 GENETAG	453,378	179,273	622,352			1,255,003
Contributor Total	**1,586,632**	**631,299**	**1,595,206**	**207,762**	**49,200**	**4,070,099**
%Total Funding	**39.0**	**15.5**	**39.2**	**5.1**	**1.2**	**100.0**

6.3.2 Major Benefits to Industry

Tropical stock assessment workshops

The NT stock assessment workshops for tropical fisheries 1992, 1996, 1997 and 2000 provided outputs that have and will assist stock assessment of northern mackerels throughout Australia. The most notable of these outputs was the age-structured model that has been used in NT Spanish mackerel assessments since 1997 and which was recently adapted for use in the Qld east coast Spanish mackerel fishery (Walters and Buckworth 1997; Buckworth and Clarke 2001; Welch *et al.* 2002; Hoyle 2002).

Completed projects

FRDC Project 1992/125.24 addressed a clear need for improved handling and storage practices to allow NT fishers to access key markets. The project was scientifically successful and clearly identified methods for optimising the quality of Spanish mackerel taken in the NT fishery. Importantly, NT fishing industry representatives consider that the project was instrumental in establishing improved handling techniques in the fishery and enhancing the image of NT mackerel in key markets (e.g. Milton Miller, Chair, NT Troll Fishermen's Association, personal communication). The degree to which these handling practices have been adopted in other states is unclear. In the Western Australian Spanish mackerel troll fishery, handling and storage practices vary between regions and fishers depending on the target market (Mackie *et al.* 2003).

FRDC Project T94/015 improved techniques for age-determination, determined the age structure of catches and provided additional information on growth patterns of Spanish mackerel in the NT. However, the PI considered that the project was only partially successful because of the difficulties that were encountered establishing and validating an age-determination protocol, fitting growth curves and assessing the status of the stock (Rik Buckworth, DBIRD, personal communication).

Projects nearing completion

The final report for FRDC Project 98/159 is nearing completion and several papers resulting from the study have been published or accepted for publication. Draft reports provided to the authors of this review indicate that the project has significantly improved knowledge of the stock structure of Spanish mackerel in northern Australia. The project further developed the approach taken in FRDC Projects 92/144 and 92/144.02 on other northern mackerels and confirms the value of concurrent application of genetic, otolith microchemistry and parasitological approaches to investigate the stock structure of pelagic fish. As such, this project should provide a blueprint for future studies of stock structure of marine fishes, including grey mackerel. In terms of outcomes to assist future management of the fishery, the information indicating the value of managing sub-populations of Spanish mackerel at refined spatial scales and with strong collaboration between managers in the NT and WA is important. The level to which managers implement the findings of the report may well be determined by future economic developments in the fishery.

The draft final report for FRDC Project 99/151 has been submitted. The report provided valuable information on the biology of Spanish mackerel in WA and the mackerel troll fishery that was used in the development of the Interim Management Plan for the WA Mackerel Fishery. Information in the final report to FRDC will be used to finalise the Management Plan.

The draft final report for the project "Exploitation dynamics and biological characteristics of east coast Spanish mackerel harvested by the recreational and commercial sectors" (2001/019) has been submitted. The project provided useful information on the biological characteristics of Spanish mackerel taken in regional commercial and recreational fisheries of the Qld east coast.

Information was used in the stock assessment of the east coast fishery by Welch *et al.* (2002) and the management strategy evaluation by Hoyle (2002). The findings of these studies were used to develop a draft management plan for the fishery.

Ongoing projects

It is not possible to assess the benefits to the GENETAG project other than to say it is progressing well and has the potential to revolutionise stock assessment of large pelagic fishes.

6.4 OTHER NORTHERN MACKERELS

6.4.1 Research Costs

The total cost of "Fisheries biology and interaction in the northern Australian small mackerel fishery" (92/144 and 92/144.02) was $1,135,367, of which FRDC contributed 51%, QDPI contributed 44.6%, the QDPI Director General contributed 2.0% and the applicants contributed 2.4% (Table 2). A project summary and further information on the costs and benefits of each project is available in Appendix 4.

Table 2. Cost summary for all contributors of past and current research projects on other northern mackerels ($AUD).

FRDC project Number	FRDC	Applicants	Research Agencies	Other	Project Total
92/144 Small mackerel	488,606	26,767	506,464	20,000	1,015,070
92/144.02 Extension to small mackerel	90,534	26,767		2,996	120,297
Contributor Total	**579,140**	**26,767**	**506,464**	**22,996**	**1,135,367**
%Total Funding	**51.0**	**2.4**	**44.6**	**2.0**	**100.0**

6.4.2 Major Benefits to Industry

The total cost of "Fisheries biology and interaction in the northern Australian small mackerel fishery" (FRDC Projects 92/144 and 92/144.02) was $1,135,367. All the objectives of the projects were achieved; a Ph.D. thesis and several scientific papers, as well as the final report, have been published. Findings clearly show that these species of other northern mackerel need to be managed separately. The project also dispelled misconceptions regarding high rates of gillnet dropout of spotted mackerel in the commercial fishery. Results of this study provided the scientific basis for establishing new management arrangements for Qld spotted mackerel in December 2002. The project showed the value of using several methods to investigate stock structure and as such was a precursor for FRDC Project 98/159.

6.5 DISCUSSION

The tropical stock assessment workshops that have involved Spanish mackerel, the five completed research projects on northern mackerel and the two studies nearing completion have been successful scientifically. More importantly they have provided significant benefits to industry, both directly and indirectly, by increasing the value of the fisheries, improving knowledge of stock status and assisting the establishment of better management arrangements. The generally collaborative approach taken by the research scientists involved have also ensured, with only one or two exceptions, that findings and developments have been shared effectively among the Australian research community. It is important that future research proposals build on this generally high level of collaboration among jurisdictions.

CHAPTER 7. GENERAL SUMMARY AND DISCUSSION

7.1 FISHERIES AND CURRENT MANAGEMENT STRATEGIES

7.1.1 Spanish mackerel

Significant fisheries for Spanish mackerel have been established in Qld, Torres Strait, the NT and WA. The total national catch is currently around 1,500 tonnes per annum and has a value of approximately ~$18M. There is considerable potential for increasing the value of the fishery by expanding the proportion of the product that is sold on export markets.

Nets cannot be used to target Spanish mackerel in most jurisdictions. Minimum legal sizes are in place in all areas except the NT. Recreational catches are constrained by bag and boat limits. Management plans based on recent research findings have been drafted and/or implemented in Qld, the NT and WA. In WA, the new arrangements place additional limits on participation and control catch through individual transferable quotas. A similar approach seems likely to be adopted in Qld. In the NT, the fishery is managed by input controls, a licence reduction scheme is in place and a target yield has been established for the commercial fishery. Management arrangements for Torres Spanish include a range of effort restrictions, but have focused mainly on issues limiting non-traditional participation.

7.1.2 Spotted and school mackerel

Spotted and school mackerel support significant fisheries off the Qld east coast, but comprise only small components of northern mackerel catches in most parts of Australia. The Qld fisheries have annual catches of approximately 120 and 50 tonnes of spotted and school mackerel respectively, and have a combined value of around $2M annually.

The use of nets to target spotted and school mackerel in Qld has recently been prohibited. Refined management arrangements for spotted mackerel (e.g. reduced minimum legal size, reduced recreational bag limits, and a total annual quota) have been established recently, and the need for additional management arrangements for this species will be assessed over the next twelve months. The main management controls for school mackerel in Qld are the minimum legal size limit and recreational bag limits.

7.1.3 Grey mackerel

Grey mackerel are taken by line throughout Qld, the NT and WA, and by netting in the Gulf of Carpentaria. Catches off the east coast of Qld have declined recently, but catches in the Gulf of

Carpentaria and WA are significant and/or increasing. The total annual catch of grey mackerel is over 500 tonnes, with an estimated annual value of over $6M.

Management of the grey mackerel fisheries is impeded by lack of information on stock structure and fisheries biology. There are minimum legal size limits and recreational bag limits in place for grey mackerel in Qld and WA, but no species-specific management arrangements for this species in the NT.

7.2 DEGREE TO WHICH RESEARCH HAS MET MANAGEMENT NEEDS.

7.2.1 Spanish mackerel

Minimum legal sizes in most jurisdictions have been based mainly on scientific data. However, until recently, most other management arrangements had been developed on the basis of anecdotal information, catch and effort data, and (in Torres Strait and the NT) information on the Taiwanese gillnet catch during the 1980s. This approach was taken mainly because of the lack of scientific data on which to base more formal assessments. In recent years, additional information on stock structure and fisheries biology have been collected and better (but still limited) assessments have been conducted. For example, data collected during the new QFS monitoring program and FRDC Project 2001/019 were incorporated into the recent stock assessment and management strategy evaluation of the Qld east coast fishery. Importantly, the results of these studies provided the basis for refining the management arrangements for the fishery. Similarly, the recent review of management arrangements for the WA fishery was based on information obtained during FRDC Project 1999/151.

7.2.2 School and spotted mackerels

Information in Cameron and Begg (2002) provided the basis for discussions at the 2002 Spotted Mackerel Workshop and assisted the refinement of the management arrangements for the east coast fishery listed above. Information in Cameron and Begg (2002) will also assist future refinement of the management arrangements for the east coast school mackerel fishery.

7.2.3 Grey mackerel

The limited management arrangements for grey mackerel reflect the paucity of information on the stock structure and fisheries biology of grey mackerel for all regions except the east coast of Qld.

7.3 GAPS IN PAST AND CURRENT RESEARCH

7.3.1 Spanish mackerel

The current FRDC-funded stock assessment project has yielded more information on the stock structure of Spanish mackerel than is available for most pelagic fish species worldwide and will identify the spatial resolution at which management in northern Australia should be conducted. The current GENETAG (2002/011) project may also provide additional information on the movement patterns of Spanish mackerel within and among jurisdictions that will assist the establishment of appropriate fisheries management boundaries.

Age structured models that provide a useful framework for conducting stock assessments have been developed and applied in the NT and Qld, however the reliability of assessments using these models have been limited by lack of critical information, especially on the age structure of catches and population size. Although considerable age and growth data have been collected and programs for monitoring the age structure of commercial catches have been established in most jurisdictions, the time series of age data are generally poor, sampling regimes are rarely representative of the spatial extent of the fisheries, and samples from recreational catches are usually collected sporadically. In several cases, significant quantities of otoliths appear to have been collected but not analysed. Enhancing or maintaining existing monitoring programs and/or analysing existing otolith collections is a high priority in all jurisdictions.

The optimal age-determination protocol for Spanish mackerel remains the subject of some debate. During the review, several researchers expressed concerns about the use of annuli counts to estimate age, and identified the need to investigate more thoroughly the use of age proxies, such as otolith weight and fish size. The precision of age estimates required for stock assessment, including the costs and benefits of various approaches, needs to be assessed formally. The potential for synthesizing data obtained using several methods to calculate probabilistic estimates of age should also be examined. Maximum benefits will be obtained if this research is coordinated nationally.

Lack of information on population size is the major impediment to stock assessment of Spanish mackerel in all jurisdictions. As a result, CPUE is still widely used as an index of abundance, despite universal acknowledgement of the weaknesses and risks associated with this approach. The recent FRDC-funded project in WA suggested that egg-based assessment methods, such as the Daily Egg Production Method, may not be suitable for Spanish mackerel. The innovative

GENETAG project may provide a method for estimating exploitation rates and monitoring biomass that will enhance stock assessment of Spanish mackerel, and other large pelagic fishes.

7.3.2 School and spotted mackerels

The final report for two FRDC projects and six scientific papers resulting from Cameron and Begg (2002) provide valuable information on the movements and stock structure, age and growth, and reproductive biology of school and spotted mackerels of the east coast of Qld. However, species-specific stock assessments have not been completed for either spotted or school mackerel. CRC Reef and QFS are currently undertaking a joint stock assessment of spotted mackerel, and a stock assessment of school mackerel is planned.

The introduction of species-specific stock assessments will almost certainly identify the need for ongoing collection of data on the age structure of commercial catches. Over the past 2 years, QFS has sampled otoliths from spotted mackerel catches. Whilst sampling to date has been sporadic, this initiative is a good step towards the establishment of a more comprehensive program. Similarly, a program for monitoring the age structure of school mackerel is needed. As the east coast supports several stocks of school mackerel, the spatial framework for this program will need to be designed carefully.

As is the case for Spanish mackerel, the methods used for age-determination in support of stock assessment may need to be re-evaluated for both spotted and school mackerel. This re-evaluation should include assessment of the precision of age estimates needed for stock assessment. The costs and benefits of using age proxies, such as fish size and otolith weight, should also be assessed using unbiased statistical approaches. As suggested previously, the potential for synthesising morphometric data, daily ring data, annuli counts and measures of otolith weight to provide probabilistic estimates of age also needs to be investigated.

Few data are available on the abundance of spotted or school mackerel in Qld, or elsewhere. Cost-effective, reliable methods of estimating abundance are difficult to develop for schooling pelagic fishes. Commercial fishers routinely locate spotted mackerel schools using planes, and aerial surveys could potentially be used as a fisheries-independent index of abundance for this species. However, this method would require the development of species validation procedures and would be particularly difficult if mixed schools were common during some years. The genetic mark-recapture studies being evaluated in the GENETAG project on Spanish mackerel could also be useful for spotted and school mackerel, however the costs of this approach may be prohibitively high for these relatively low value fisheries (at least in the foreseeable future).

7.3.3 Grey mackerel

Grey mackerel catches have declined off the east coast but have been increasing in the Gulf of Carpentaria and WA, where fishing techniques are being continually refined. The status, structure and the biology of this species in northern Australia are virtually unknown. The recent proposal to investigate the biology of grey mackerel off WA should be expanded into a national study. Current stock structure (FRDC Project 99/151) and fisheries biology (FRDC Project 99/151) studies on Spanish mackerel provide a blueprint of the type of project that is needed for grey mackerel. The relatively low recreational importance and reduced commercial value of grey mackerel compared to Spanish mackerel suggest that this project will need to be cost-effective. The project should involve researchers in WA, NT and Qld with proven track records for investigating the stock structure and fisheries biology of northern mackerels. Activities of the project could be coordinated through the Spanish mackerel age-determination working group.

7.4 COSTS AND BENEFITS OF RESEARCH ON NORTHERN MACKEREL TO THE FISHING INDUSTRY.

During the initial stages of the cost-benefit analysis of northern mackerel research it became apparent that it was unrealistic to attempt to quantify the benefits of each project. This is because the benefits of research are often intangible, and include results like resolving misconceptions and reducing conflict among sectors, as well as increasing the economic value of fisheries and/or assisting the establishment of management arrangements to ensure sustainability. In addition, there is often a considerable lag-time before the benefits of fisheries research are realised. For these reasons we have restricted our analyses to a qualitative assessment of the benefits of individual projects.

The total cost of FRDC Projects on Spanish mackerel over last decade has been approximately $4,070,099 of which FRDC and commercial and recreational fishers contributed $1,586,632 (39.0%), $631,299 (15.5%) and $49,200 (1.2%) respectively. The benefits of the tropical stock assessment workshops, the completed research projects and the studies nearing completion have been significant. For example, the workshops led to the development of an age-structured model that has been used and further developed in the NT and Qld. The recent stock structure project indicated spatial framework in which the fisheries should ideally be managed, as well as confirming the value of concurrently applying several techniques to investigate the stock structure and providing a blueprint for studies of the stock structure of other important pelagic fishes, such as grey mackerel. Results of the current projects in WA and Qld also provided valuable information and have been used to assist the development of interim management plans in these states.

The total cost of the two projects on small northern mackerels was $1,135,367, of which FRDC contributed 51%. The reports and papers showed the value of using several methods to investigate stock structure and the study acted as a precursor for FRDC Project 99/151. The project also dispelled misconceptions regarding high rates of gillnet dropout of spotted mackerel in the commercial fishery and helped reduce conflict between the commercial and recreational sectors. The report and associated papers provided the scientific basis for establishing new management arrangements for Qld spotted mackerel in December 2002. Findings also show that spotted and school mackerel on the east coast should be managed at different spatial scales.

7.5 CURRENT AND FUTURE RESEARCH PRIORITIES FOR NORTHERN MACKEREL.

One of the highest priorities for future research on northern mackerels is to maintain the high levels of collaboration among researchers that were developed through previous and current FRDC Projects (notably Projects 92/144, 98/159 and 2002/011). The establishment of the national Spanish mackerel age-determination working group is a useful step towards maintaining this collaboration. In the short term, the most cost-effective option would be for the working group committee to conduct meetings in conjunction with the workshops for the current GENETAG project (as most of the committee members would also be participants in these workshops). It may be worthwhile for FRDC to consider assisting relevant researchers not directly involved in the GENETAG project to attend these workshops. However, Commonwealth and state research and managements agencies will be the major beneficiaries of this group, and mechanisms need to be established to ensure that agencies support the ongoing activities of the working group. An additional benefit to these agencies would be that the working group could provide a national forum for the peer review of stock assessments conducted by individual agencies.

As well as ensuring the development and application of a standardised age-determination technique and the collation and publication of existing age and growth data, the working group could also oversee the development of a national research proposal for grey mackerel. This proposal should include key researchers from each state, and involve significant technical cooperation for activities such as genetic analysis and age-determination to ensure that the project is cost-effective. The current research project on blue mackerel (FRDC Project 2002/061) provides a good example of how this collaboration and cooperation could work. The critical elements of the grey mackerel project should be to determine stock structure, investigate fisheries biology, develop a validated age-determination protocol and establish an age-structured model (or at least adapt the Spanish mackerel model).

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APPENDIX 1

CONSULTANCY PROPOSAL

Aims: To review previous research on northern mackerel and to assess current and future research needs for these fisheries.

PHASE 1

- Conduct electronic literature search on northern mackerel: ie Spanish, small, grey and spotted mackerel.
- Develop bibliographic database.
- Read and analyse papers and reports.
- Conduct telephone discussions and email exchanges with industry representatives, fisheries researchers and resource managers throughout Australia with following objectives:
  - ✓ to obtain fisheries statistics and "grey literature", especially research reports and management plans;
  - ✓ to obtain an overview of previous and current research for each jurisdiction;
  - ✓ to assess the degree to which research has met management needs and been incorporated into current management arrangements;
  - ✓ to identify perceived current and future research needs; and
  - ✓ to arrange meetings to be conducted in Phase 2.

- Produce draft document identifying outcomes of R & D and subsequent uptake of results by managers.
- Conduct preliminary assessment of costs of research and benefits to industry.
- Identify gaps in current and proposed research plans including reference to needs arising from strategic assessment under the EPBC Act and demands arising from increased recreational catch.

PHASE 2

- Travel to Perth, Broome, Darwin, Canberra, Thursday Island, Cairns, Townsville, and Brisbane to conduct meetings with representatives of fishing industry councils, fisheries management agencies and research organizations in each jurisdiction as well as Northern Fisheries Management Group, GBRMPA, EA, etc.
- Confirm interpretation of information provided by telephone and email.

- Discuss range of views presented regarding the (i) degree to which research has met management needs and been incorporated into current management arrangements and (ii) current and future research needs.
- Receive feedback regarding findings of preliminary cost benefit analysis and methods used to calculate the ratio.

PHASE 3

- Incorporate findings from meetings into report.
- Finalise bibliographic database.
- Produce preliminary draft.
- Send first preliminary draft to stakeholders for comment.
- Incorporate stakeholders comments to produce second preliminary draft.
- Submit second preliminary draft to FRDC for comment.
- Incorporate FRDC comments to produce final draft.
- Submit final draft report to FRDC for formal review.
- Finalise report.

APPENDIX 2

SUMMARY OF THE COSTS AND BENEFITS OF INDIVIDUAL PROJECTS

2.1 PROJECT TITLE: MAXIMISING ECONOMIC RETURNS IN THE NT SPANISH MACKEREL FISHERY.

Status: ***FRDC Project 1992/125.24*** **- Completed**

Key issues: Evaluation of factors affecting the shelf life of chilled Spanish mackerel.

Introduction

The need for this project stemmed from significant demand for Spanish mackerel products on local and overseas markets. The competitive nature of these markets required improvement of post-harvest methods and flesh quality. The main problem addressed by this project was the lack of data on market requirements, handling and storage practices that are required to attain a high quality export product.

Objectives

1. To assess the impact of bleeding, gutting and de-heading on the quality of Spanish mackerel.
2. To determine the impact of spiking and icing on the onset of rigor in Spanish mackerel.
3. To evaluate the effect of ice storage on the shelf life and sensory properties of Spanish mackerel.
4. To assist in the preparation of a Code of Practice for capture, handling and packaging of Spanish mackerel for the domestic market.

Research costs

FRDC contributed all ($29,720) of the total funds required to complete the project.

Benefits evaluation

Attractiveness – benefits relative to costs

- Industry benefited due to the flow-on effect of improved methods for controlling flesh quality, odour and flavour and therefore an increase in the potential value of the export product.

- The project led to development of a Code of Practice for handling, processing and packaging.

Feasibility - likelihood of realising benefits

- There was a high likelihood that the Code of Practice would be adopted by the local Spanish mackerel industry in NT at the completion of the project.

Conclusion

The project lead to tangible benefits for the Spanish mackerel industry, which included improved techniques for post-harvest handling, a better quality product and enhancement of the image of NT Spanish mackerel on local and export markets.

2.2 PROJECT TITLE: AGE STRUCTURE OF COMMERCIAL CATCH OF NT SPANISH MACKEREL

Status: ***FRDC Project T94/015*** **– Completed**.

Key issues: Investigation of the age structure of the NT Spanish mackerel troll fishery to enable development of an age-structured stock assessment model.

Introduction

This project addressed the need for improved stock assessment information, particularly the age structure of the commercial catch. It also identified the need for refinement of age validation, otolith preparation and analysis methods for Spanish mackerel on a national scale.

Objectives

1. To determine age structure of Spanish mackerel catches in the NT troll mackerel fishery for 1991-93 for incorporation into an age-structured population model.
2. To verify the growth relationships currently in use for stock assessment and provide information from which new age-size relationships could be developed.

Research costs

Total funding for the project was $45,319. FRDC contributed $18,662 over 1 year, which comprised 41.2% of total funds. Industry did not contribute to the project. NT Fisheries contributed $26,657, which comprised 58.8 % of the funds required.

Benefits evaluation

Attractiveness - benefits relative to the costs

- This project led to improved validation and age determination protocols for Spanish mackerel.
- More information available for implementation of an age structured stock assessment for management of the fishery in the future.

Feasibility - likelihood of realising benefits

- Target catch currently based on catch of Taiwanese gillnet fishery from 1980-85, therefore all potential benefits have not been realised.

- Outcomes of the project have the potential to contribute to more robust stock assessment of Spanish mackerel in NT.

Conclusion

Project was partially successful as it led to improvement of age determination methods. However, there are still concerns over accuracy and precision of these techniques for Spanish mackerel. The completed project did not result in age-structured model providing outputs that could be used to set the TAC.

2.3 PROJECT TITLE: STOCK STRUCTURE OF NORTHERN AND WESTERN AUSTRALIAN SPANISH MACKEREL

Status: ***FRDC Project 98/159*** **– Final report in preparation**.

Key issues: Determining the spatial scales of northern and WA Spanish mackerel stock structure.

Introduction

Prior to this study the genetic structure of Spanish mackerel populations in northern Australia was unclear. Stock boundaries were not defined, especially at finer spatial scales. This information is needed to determine the appropriate spatial scales for management to ensure the stock(s) are protected from overfishing.

Objectives

1. To establish the degree of complexity of the northern Australian Spanish mackerel stock structure over a wide geographical range.
2. Having demonstrated the structural differences in the northern stock on a large spatial scale, to define the finer spatial scale stock structure differences.
3. Provide advice to fisheries managers on the appropriate geographical scale of assessment and management actions.
4. To include otoliths and genetic material from Kupang in stock structure analysis.
5. To collect and analyse parasite samples from Spanish mackerel.

Research costs

Total funding for the project was $1,222,814. FRDC contributed $391,318 over three years, which comprised 32% of total funds. Mackerel fishers contributed $303,525 for operating costs, which comprised 24.8% of total funds. NT Fisheries contributed $527,970 (43.18%).

Benefits evaluation

Attractiveness - benefits relative to the costs

- High likelihood of providing information on stock structure needed to make management decisions.
- Industry involvement indicates willingness to take financial responsibility for high priority research.

- Industry to benefit from research that will provide improved understanding of effects of intensive fishing pressure in specific areas and contribute to protection of the resource.
- Findings have the potential to increase the efficiency of harvesting strategies.

Feasibility - Likelihood of realising benefits

- The PI is highly experienced in coordinating research on northern mackerels.
- Success of the project was largely dependent on obtaining representative samples over a large spatial area; throughout eastern Qld, Torres Strait, Gulf of Carpentaria, Arafura Sea, Kimberley, Gascoyne and Pilbara regions of WA.
- Sampling regimes for analyses of otolith microchemistry, mtDNA and parasite fauna had to be sufficient to provide the spatial resolution required to determine differences among states and regions.
- There lies a potential risk in using mtDNA as many previous genetic studies of pelagic fishes have produced inconclusive results.
- Likewise there are risks associated with using otolith (isotope ratio) microchemistry as chemical signals in the otoliths may not be strong enough to draw conclusions about movement between regions, especially over the fine temporal scales (months) needed to determine movement patterns and stock overlaps.
- Similarly there are risks associated with using parasite information to infer stock structure boundaries, as this approach is reliant on parasite "type" and residence time on hosts.

In summary, these risks are reduced significantly by using several methodologies, simultaneously.

Conclusion

The project has have been scientifically successful and elucidated the stock structure of northern Spanish mackerel. Simultaneous use of several techniques should be a blueprint for future stock structure studies. Several scientific journal articles have been published and/or submitted for publication, however the level of uptake of this information by managers may depend on the economic development of the fishery.

2.4 PROJECT TITLE: STOCK ASSESSMENT OF SPANISH MACKEREL (*SCOMBEROMORUS COMMERSON*) IN WA.

Status: ***FRDC Project 99/151*- Draft Final Report Submitted.**

Key issues: Research on the biology and exploitation status of Spanish mackerel is needed for development of management strategies for the WA fishery.

Introduction

Spanish mackerel is the second most valuable fin-fish fishery in WA, with the annual catch valued at $5.2M in 1997. An interim management plan is currently in place for WA and managers are awaiting advice from this project for finalisation. The project was established in response to the need for establishment of biological indicators for the fishery, including biomass, exploitation levels and fishing mortality.

Objectives

1. To determine the age, growth and reproductive biology of Spanish mackerel in WA.
2. To determine the most realistic measures of effort for the commercial fleet and identify the historical changes in fishing efficiency.
3. Evaluate a biomass dynamics model(s) for stock assessment of Spanish mackerel in WA.
4. Use yield per recruit and egg per recruit models to determine appropriate levels of fishing mortality for Spanish mackerel; and estimate the current level of fishing mortality.
5. Evaluate the feasibility of future use of the daily egg production method for estimating the spawning biomass of Spanish mackerel in WA.
6. Provide advice to industry and fishery managers on the status of Spanish mackerel stocks and provide views on the effectiveness of different management options.
7. To assess the most cost-effective method of ongoing monitoring of the Spanish mackerel fishery.

Research costs

Total funding for the project was $1,076,425. FRDC contributed $529,921, which comprised 49.2 % of funds. Pilbara recreational fishers contributed $49,200 for operating costs, which comprised 4.5% of total funds. NT Fisheries contributed $17,247 (1.6%). Commercial fishers contributed $148,000 (13.75%). WA Fisheries contributed $331,557 (30.8%).

Benefits evaluation

Attractiveness – benefits relative to the costs

- Introduction of new management strategies.
- Improved mechanisms for monitoring the fishery, which has important implications for all sectors.
- Improvements in analysis of fisher efficiency over time, knowledge of stock structure and seasonal patterns of abundance.
- This project represents a benchmark for determining cost-effective methods for stock monitoring and assessment of *Scomboromorus spp*.

Feasibility - Likelihood of realising benefits

- The PI and his research team are highly experienced in pelagic fisheries research therefore the project has a high probability of successful outcomes.
- Similar stock differentiation methods have been used successfully for *Scomberomorus* species in Qld and NT.
- Pilot studies by the PI and his research team suggested a high probability of success.
- High probability of successful outcome if adequate biological samples could be collected for each component of the study.

Conclusion

The final report provides useful information for management and the results have already been used to refine management arrangements for WA fishery, and establish an interim Management Plan. This final report to FRDC will be used as the basis for finalising the Management Plan for the Western Australian Spanish mackerel fishery.

2.5 PROJECT TITLE: EXPLOITATION DYNAMICS AND BIOLOGICAL CHARACTERISTICS OF EAST COAST SPANISH MACKEREL HARVESTED BY RECREATIONAL AND COMMERCIAL SECTORS.

Status: ***FRDC Project 2001/019*** **- Commenced July 1 2001**

Key issues: Stock assessment of Spanish mackerel in east Qld incorporating all relevant fishing sectors.

Introduction:

The project addresses concerns raised by all sectors and fisheries managers regarding the over-exploitation of the resource in east Qld. The aims of the project are to compare biological characteristics of Spanish mackerel collected in regional commercial and recreational fisheries and obtain fisheries data that will expand on the QDPI long-term monitoring program. The project addresses the need for estimating total fishing mortality for east coast of Qld and will provide managers with additional information necessary for the establishment of new management arrangements.

Objectives

1. Identify and compare biological characteristics (catch at age, catch at length and sex ratios) of fish taken by recreational and commercial sectors in six regions on the Qld east coast.
2. Assess the effectiveness of current minimum legal size and quantify the level of latent effort present in current recreational bag limits.
3. To provide recommendations to fisheries managers.

Research costs

The total budget required to complete the project is $440,818. FRDC is contributing $163,633 over two years, which comprises 37.1% of total funding. Industry is not contributing to the project. Reef CRC and QDPI are contributing $113,327 (25.7%) and $163,858 to salaries (37.2%), respectively.

Benefit evaluation

Attractiveness - benefits relative to costs

- Provide estimates of biological parameters and harvest rates for six distinct fishing regions, thus enhancing current management arrangements.
- The outcomes of the project are likely to lead to improved efficiency in the commercial fishery at no direct cost.
- The project should ensure that the fishery complies with ESD and EPBC guidelines and therefore potentially improve the market value of the product on domestic and international markets.

Feasibility Likelihood of realising benefits

- There is a high probability that the project would achieve its scientific objectives and extend the outcomes to management.
- The PI is an experienced member of an expert research team that has developed solid relationships with the recreational and commercial sectors and is a member of relevant management committees.
- The overall success of the project was largely dependent on the collection of monthly samples from each region, which will require regular communication with fishers.

Conclusion

The draft of the final report was submitted and the information was used in a stock assessment and management strategy evaluation of the east coast fishery (Hoyle 2002; Welch *et al.* 2002). These studies have been used to develop a new management plan for the Qld Spanish mackerel fishery.

2.6 PROJECT TITLE: GENETIC MARK-RECAPTURE FOR REAL-TIME HARVEST RATE MONITORING. PILOT STUDIES IN NORTHERN AUSTRALIAN SPANISH MACKEREL FISHERIES.

Status: ***FRDC project 2002/011*** **- Commenced 1/7/02.**

Key issues: Development and assessment of new methods for stock/harvest monitoring in northern Spanish mackerel fisheries.

Introduction

The project addresses the lack of information on Spanish mackerel stocks needed for implementation of sustainable management measures in northern Australia. Currently there are no indicators of abundance, spawning biomass, recruitment or harvest rates available for Spanish mackerel. The estimation of real-time harvest rates could be used as a management tool to maximise fishing production and ensure sustainable utilisation of the resource.

Objectives

1. To confirm the technical basis of *in-situ* genetic tagging for large pelagic fishes.
2. To provide initial estimates of Spanish mackerel harvest rates in the Darwin area and develop protocols for monitoring of harvest rates in other northern mackerel fisheries using genetic and conventional tagging.
3. To compare genetic and conventional tagging mortality and retention for *Scomberomorus spp*.
4. To provide information on movement rates of *S. commerson* in northern Australia.
5. To develop a general methodology for the use of genetic mark-recapture as the basis of fishery harvest rate monitoring.

Research costs

Total funding required for the project is $1,255,003. FRDC is contributing $453,378 over three-years, which comprises 36% of total funds. The mackerel industry is contributing $179,273 (14%). NT Fisheries is contributing $622,352 (49%).

Benefit evaluation

Attractiveness – benefits relative to the costs

- The major benefit of the project to industry will be the development of reliable methods for measuring harvest levels.
- This will reduce the current reliance on CPUE as an indicator of abundance and facilitate optimal utilisation of the stock.
- The project has the potential to reduce uncertainty in the fishery and increase production without risking the sustainability of the resource.
- Benefits may flow on to lesser mackerel fisheries and lead to improved management arrangements for those fisheries.
- Measure of tag-loss and elucidation of movement patterns represent benefits to stock assessment.

Feasibility - likelihood of realising benefits

- The PI has an excellent track record in pelagic fish research, which suggests the benefits identified should be realised.
- Pilot studies by the current research team found use of micro-satellite DNA (msDNA) and *in-situ* biopsy methods were feasible for Spanish mackerel.
- Costs of genetic technology are declining, thus making this approach more practical as a monitoring tool.
- The biological attributes of this species and the nature of the fishery suggest the probability of success of this project is high.
- The feasibility of obtaining tissue samples from a large proportion of the commercial catch is high.
- Important information from the recreational Suntag program will increase the likelihood of obtaining samples and recaptures.
- Improved harvest rate estimates will increase the confidence of industry in management.
- Possible risks include failure to tag the targeted number of individuals (500 to 3000) annually, difficulties obtaining sufficient recoveries to estimate harvest rates reliably, difficulties retaining cooperation of commercial and recreational fishers, and problems processing all of the genetic material within the time allocated.

Conclusion

The project is currently ongoing. This project remains one of the best options for estimating the abundance of Spanish mackerel and possibly other *Scomberomorus* spp.

2.7 FISHERIES BIOLOGY AND INTERACTION IN THE NORTHERN AUSTRALIAN SMALL MACKEREL FISHERY

Status: ***FRDC project 92/144 and Extension 92/144.02*** – Completed.

Key issues: Investigation of important aspects of biology and fishery dynamics of lesser mackerel needed for stock assessment.

Introduction:

The project addressed important issues regarding lesser mackerel fisheries, which included the increasing conflict caused by overlap and interaction between different fishing sectors and the need for improved biological information to aid management decision-making processes. These issues have become more pressing due to increasing catches by all sectors and the vulnerability of stocks to over-exploitation. Gillnet dropout led to broad ranging concern from the fishing industry, researchers and general public and this project helped to dispel this issue.

Project *92/114* set out to test the following hypotheses:

1. That the Australian Spanish mackerel resource, comprising four main species of the genus *Scomberomorus*, is exploited recreationally and commercially in three distinct areas of tropical Australia, in each of which the population of each species is an autonomous unit stock.
2. That the species composition of the resource s the same in the three areas.
3. That the three unit stocks of each of the three smaller species (school mackerel *S. queenslandicus*, spotted mackerel, *S. munroi* and grey mackerel *S.semifasciatus*, do not differ as to growth rate, reproductive potential or survival rate under average environmental conditions, nor, in consequence, in composition as to sex, age and size.

Objectives of extension *92/114.02 (Extension)*

1. To determine the rate of gillnet dropout in the spotted mackerel ring net fishery.
2. To determine if the rate of gillnet dropout varies with respect to fish length, mesh size, or location.

Research costs *92/114*

The total budget required to complete the project was $1,015,070. FRDC contributed $488,606 to the project over four years, which comprised approximately 48.14% of total funding. QDPI contributed $506,464 to salaries, which comprised 49.9% of total funding. The QDPI Director General contributed $20,000. Industry made no financial contribution.

92/114.02 (Extension)

The total budget required was $120,297. FRDC contributed $90,534 to the project over 1 year, which comprised approximately 75.26% of total funding. QDPI and CSIRO Marine Laboratories contributed 22.25% and 2.5% of total funding, respectively

Benefit evaluation

Attractiveness - benefits relative to costs

- The likelihood of the potential benefits of this project being realised is dependent on uptake of results and recommendations by fisheries managers.
- The multi-species information provided the basis for future single species stock assessments on lesser mackerels.
- Stock structure information should be used to determine management spatial scales.
- The project provides an important review and assessment of catch and effort data for recreational and commercial sectors.
- The extension project should resolve conflicts between the recreational and commercial sectors regarding gillnet dropout.
- For the commercial and recreational sectors, benefits will be proportional to the level of uptake by managers and the degree to which the study ensures the protection of the resource (at no direct financial cost to either sector).

Feasibility Likelihood of realising benefits

- Ultimately the project will be successful if research outputs lead to sound biological-based management strategies.
- Significant hostility between recreational and commercial sectors will only be resolved if management regimes are discussed and evaluated by all sectors. Gillnet dropout project led to resolution of conflict between sectors (net, line and recreational).

Conclusion

The project generated new knowledge on small *Scomberomorus* species and has the potential to generate tangible benefits for all sectors. The flow of benefits to industry is dependent on implementation of new management strategies for the lesser mackerel stocks in east Qld, especially implementation of single species stock assessments.