A BIOLOGICAL STUDY OF EAST COAST TUNAS AND BILLFISHES, WITH PARTICULAR EMPHASIS ON YELLOWFIN TUNA (*Thunnus albacares*)

Review of Results and Recommendations for Research

Working Paper No. 11/89

BUREAU OF RURAL RESOURCES

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FISHING INDUSTRY RESEARCH TRUST ACCOUNT

FINAL REPORT

PROJECT: F86/127

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TABLE OF CONTENTS

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SUMMARY

(1) The East Coast Tunas and Billfishes Research Program was funded by the Fishing Industry Research Trust Account (FIRTA, F86/127) from July 1986 to June 1988.

(2) The objectives of the program were to identify the stock(s) exploited by the east coast tuna and billfish fisheries, examine the structure of those stocks and collect background fisheries and biological information on the species. Particular emphasis was placed on research into the biology of yellowfin tuna, *Thunnus albacares*, a species of considerable economic importance to commercial longline fishers.

(3) Tag-recapture, electrophoresis and morphometric studies indicated little likelihood of mixing of post-recruit yellowfin tuna of eastern Australian waters with those of distant Pacific regions although no information is available on movements of yellowfin tuna from other Pacific regions into our area. Isolation by distance is likely to determine interaction between the east coast yellowfin tuna fishery and those of other Pacific regions; adjoining yellowfin tuna fisheries will have the greatest and most immediate effect where size classes are similar to those taken by east coast yellowfin tuna fisheries.

(4) Tag-recapture studies showed that yellowfin tuna mix throughout coastal waters[1] of New South Wales and southern Queensland. Recaptures of yellowfin tuna, tagged in coastal waters, were rarely reported by fishers operating in waters beyond the continental shelf. Analyses of electrophoresis and morphometric studies suggested a degree of variability and possible sub-structuring of the yellowfin tuna population within the south-eastern Australian Fishing Zone (AFZ).

(5) Tag-recapture analyses showed considerable interaction among domestic yellowfin tuna fisheries (recreational, commercial longline and pole-and-line). Interaction between domestic east coast yellowfin tuna fisheries and the Japanese yellowfin tuna longline fishery[2] appeared to be low, however, movement of yellowfin tuna from the Japanese yellowfin tuna fishery to the domestic east coast yellowfin tuna fisheries was not investigated. The relationship of yellowfin tuna of the north-western Coral Sea and those of the east coast could not be assessed by the present program.

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[1] The term 'coastal waters' here refers to waters over the continental shelf and slope; waters beyond the continental slope are referred to as 'offshore waters'.

[2] The term 'Japanese yellowfin tuna longline fishery' refers to Japanese fishing activities off the east coast of Australia, within the AFZ, where yellowfin tuna are taken. The more general term 'Japanese longline fishery' refers to those east coast activities where various species of tuna, including yellowfin tuna, and billfish are taken.

(6) Yellowfin tuna are believed to spawn throughout the tropical western Pacific and the present study confirmed that yellowfin tuna spawn in the north-western and central-western Coral Sea during the summer. Although spawning frequency of yellowfin tuna was high in the 'handline' area (in waters adjacent to the Great Barrier Reef off north Queensland), yellowfin tuna are believed to spawn throughout the Coral Sea. Spawning was not evident in yellowfin tuna taken south of 25°S.

Results showed that bigeye tuna, *T. obesus*, spawn in the north-western Coral Sea. Like yellowfin tuna, bigeye tuna probably spawn in other areas of the Coral Sea during the summer.

(7) Estimates of yellowfin tuna length at age by modal analysis, counts of vertebral annuli and tag-recapture were comparable. Preliminary estimates of age suggested that growth rates of east coast yellowfin tuna were similar to those published for yellowfin tuna of other Pacific regions.

(8) Catch statistics were compiled for the developing longline fishery in New South Wales. The fishery was dependent on one or two size modes of yellowfin tuna each year. In some years the small size mode (15-25 kg) did not appear in the catch at the commencement of the fishing season, and poor catch rates were reported in subsequent months.

(9) Analysis of Japanese catch and effort data showed high inter-annual variability in reported catch rates of yellowfin tuna, bigeye tuna, striped marlin (*Tetrapturus audax*) and broadbill swordfish (*Xiphias gladius*). Reported catches and catch rates of black marlin (*Makaira indica*) fell during 1962-87 whereas catches of other species showed no clear trends over the same period.

(10) Bibliographies were compiled of Japanese and English literature relevant to biological and fisheries research conducted on species constituting the east coast tuna and billfish fisheries. Three relevant Japanese research papers were translated.

(11) Recommendations include monitoring of catch levels and size and age composition of the catch for *all* east coast tuna and billfish fisheries. Such monitoring programs are essential for detailed stock assessment and management of the fisheries, and will provide a foundation for future biological research.

(12) Priority areas for research include identification of the spawning population(s) supplying recruits to the east coast yellowfin tuna fisheries, and further investigation of sub-structuring in the yellowfin tuna stock in the AFZ. These questions, however, are large, and difficult and expensive to resolve; and the costs are probably not warranted at this stage in the development of the fisheries. Tagging programs in the western Pacific, such

as that recently initiated by the South Pacific Commission, should be supported as they may provide further information regarding interaction between the east coast yellowfin tuna fisheries and those of adjacent regions, as well as contributing to our understanding of interaction between fisheries using different gear types.

(13) Management of the east coast tuna and billfish fisheries must take into account the high variability in catches and the potential for fisheries interaction through competition for a common resource. Regulations for conservation of black marlin must be considered. Support should be given to international initiatives in this regard because the black marlin population is distributed widely across the Pacific, including waters of the AFZ.

RECOMMENDATIONS FOR FUTURE MONITORING AND RESEARCH

At this stage in our scientific knowledge of the fisheries emphasis must be placed on developing programs for routine collection of data on the species constituting the east coast tuna and billfish fisheries. Information that needs to be consolidated for stock assessment includes catch, catch composition and effort of all fishing methods, and the size and age structure of the stocks. In particular, assessment of the status of yellowfin tuna will require complementary information regarding the source(s) of recruits to the east coast yellowfin tuna fisheries and the relationships between elements of the east coast yellowfin tuna population and those of nearby regions. Detailed recommendations are as follows.

(1)That catch, effort and catch composition be monitored for *all* east coast tuna and billfish fisheries.

- Complete coverage of all commercial tuna and billfish fisheries (currently including domestic and foreign longline, foreign handline, pole-and-line and purse seine) must be pursued.

- No information is available on catch and effort for the recreational tuna and billfish fisheries, which is of particular concern given the importance of the recreational fisheries suggested by tag-recapture studies. A program to monitor catch and effort in the recreational tuna and billfish fisheries must be established as a priority.

(2)That size and age monitoring programs be established for all east coast tuna and billfish fisheries.

- Long time-series of age and size (length and weight) data will be essential for future evaluation of year-class strength and for assessment of the state of the stocks.

- Hard parts that should be collected for the ageing of yellowfin tuna include caudal centra and, for the purpose of cross-referencing and possible x-ray analysis, otoliths.

(3)That the relationship, if any, between spawning by yellowfin tuna in the Coral Sea and other areas and recruitment to the east coast yellowfin tuna fisheries be investigated.

- Yellowfin tuna and bigeye tuna were shown to spawn in the Coral Sea

during October-February. However, the relative contribution of spawning activity in various areas of the Coral Sea to the east coast yellowfin tuna fisheries was not addressed by the present study.

- Suitable techniques for identifying the population(s) supplying recruits to the east coast are not yet available, however, recent developments in 'DNA finger-printing' show promise.

(4)That the sub-structuring, if any, of the yellowfin tuna stock(s) fished in the eastern AFZ be further investigated.

- Further research, using tag-recapture, electrophoresis and analyses of morphometrics, may provide data on the underlying biological structure of the stock(s).

(5)That the level of interaction amongst the various tuna and billfish fisheries existing within the eastern AFZ be monitored.

- Tagging programs, including those which involve recreational fishers, should be encouraged as they may provide information on the level of interaction between the various tuna and billfish fisheries.

- Future tag-recapture projects must cultivate the cooperation of foreign fishing operations.

(6)That the biological status of black marlin be assessed.

- Catches of black marlin are relatively small and incidental to most commercial operations because they are not the target of commercial fisheries. Consequently, commercial catch data are inadequate for detailed stock assessment.

IMPLICATIONS FOR MANAGEMENT

(1) Yellowfin tuna of the south-eastern AFZ (i.e. south of 24°S) should be managed as one stock, until further evidence of sub-structuring is forthcoming.

- Interaction between east coast yellowfin tuna fisheries and those of adjacent Pacific regions is predicted to be low. The magnitude of interaction between east coast yellowfin tuna fisheries and yellowfin tuna fisheries of other Pacific regions will depend on proximity, fishing method, and intensity of fishing activity.

(2) Management of the east coast tuna and billfish fisheries should take into account the variability in abundance of commercially important species.

- Analyses of landings of the domestic longline fishery in New South Wales indicate temporal variation in the size structure of the yellowfin tuna catch, which may reflect yearly fluctuations in the strengths of age classes.

- Long-term catch and effort reports for the Japanese longline fishery suggest considerable variation in catch rates of most species between years.

(3) Fisheries interaction will be a prime consideration in managing the east coast tuna and billfish fisheries in the short term.

- Analysis of tag-recapture results suggest considerable interaction between yellowfin tuna fisheries within the south-eastern AFZ.

(4) Measures aimed at ensuring the conservation of black marlin should be considered.

- Further analysis and validation of reported catches is required.

- The Japanese have agreed to return all live black marlin (and Indo-Pacific blue marlin, *M. mazara* Jordan and Snyder) caught in the AFZ; recreational fishers tag and return most black marlin caught.

- International management may be necessary because the decline in reported catches of black marlin might be the result of fishing pressure throughout the western Pacific.

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INTRODUCTION

Although the fisheries biology of tuna and billfish species of the Pacific region had been studied in detail, little information was available to Australian scientists on the fisheries biology of tunas and billfishes of eastern Australian waters before 1986. Concern over the rapid expansion of domestic fishing effort, and the need to integrate management and development of the several fisheries harvesting the species precipitated a meeting of government, commercial and recreational fisheries representatives in 1985. Uncertainties about the identity and condition of the stocks resulted in a meeting of scientists which formulated a proposal for a research project. At the end of 1985 the proposal was endorsed by State and Federal Governments, and commercial and recreational fishing representatives.

The resulting research program, 'A Biological Study of East Coast Tunas and Billfishes with Particular Emphasis on Yellowfin Tuna, (*Thunnus albacares*)' was undertaken from July, 1986 to June, 1988. The program was funded by the Fishing Industry Research Trust Account (FIRTA), with additional contributions from participating organisations in the form of staff, and laboratory and administrative support.

The present report covers results of most work carried out under the program except for those results from the assessment of size data collected by the East Coast Longline Logbook; assessment was hampered by delays in establishment of the logbook. An evaluation of size data collection will be circulated as a separate report. The program also fostered exchange of information and cooperation between tuna biologists of Australia and those of other Pacific regions, such as the South Pacific Commission (SPC).

The original design proposed that data be collected over 3 years. However, after the first year of research the Fishing Industry Research Committee (FIRC) decided that the program should be reduced to 2 years.

Much of the research was preliminary because of the scarcity of fisheries information on the species comprising the east coast tuna and billfish fisheries. The program design, which formed the basis of the proposal, was quite broad, largely as a result of the many facets of the biology of east coast tunas and billfishes which were poorly understood at the time. Results in many areas were precursory because of the breadth of questions addressed and the shortened duration of the program.

The present report comprises three parts:

- a brief description of the east coast tuna and billfish fisheries;
- details of project objectives;

- a review of results.

Detailed reports were produced for each component of the program (listed in Appendix 2). Individual reports and papers include complete examinations of results in specific areas, and the reader is referred to the individual reports for full details of each segment. Bibliographies of Japanese and English literature relevant to the fisheries biology of tunas and billfishes off the east coast of Australia are also included as individual reports. Copies of specific reports may be obtained from originating institutions through the contact officers listed in Appendix 1.

The review considers major findings, pertinent to management of the east coast tuna and billfish fisheries, and future biological research, in relation to relevant biological research from other areas of the Pacific. In many instances the review goes beyond the FIRTA program's objectives and findings in seeking to provide a synthesis of our current knowledge of the biology of species constituting the fisheries.

Yellowfin tuna are currently the most important commercial species taken by the domestic and Japanese longline fisheries operating off the east coast of Australia[3]. The program concentrated on aspects of yellowfin tuna biology and many recommendations relate specifically to knowledge of this species. Results for other species important to the commercial and recreational fisheries, such as bigeye tuna and black marlin, are not generally considered in the review because low catch rates of these species limited data collection. Specific information on other species may be found in the individual reports.

[3]Geographic regions referred to in the paper are shown in Figure 1.

THE FISHERIES

Japanese longliners have fished for tunas and billfishes off the east coast of Australia for more than 30 years. Originating in the early 1900s, a recreational fishery, based on marlin and later other billfish and tunas, grew steadily during the 1970s and 1980s. A domestic longline fishery, targeting yellowfin tuna, developed during the 1980s and now exports much of the catch to the lucrative, fresh-chilled-sashimi markets of Japan.

The position of Australian east coast waters relative to other Pacific regions is illustrated in Figure 1. Current tuna and billfish fishing activity off the east coast of Australia may be separated into six fisheries based on fishing method and areas of operation (Figure 2). The term 'east coast tuna and billfish fisheries' encompasses the fisheries described below which exist off the east coast of mainland Australia (north of 37°30'S), within the AFZ.

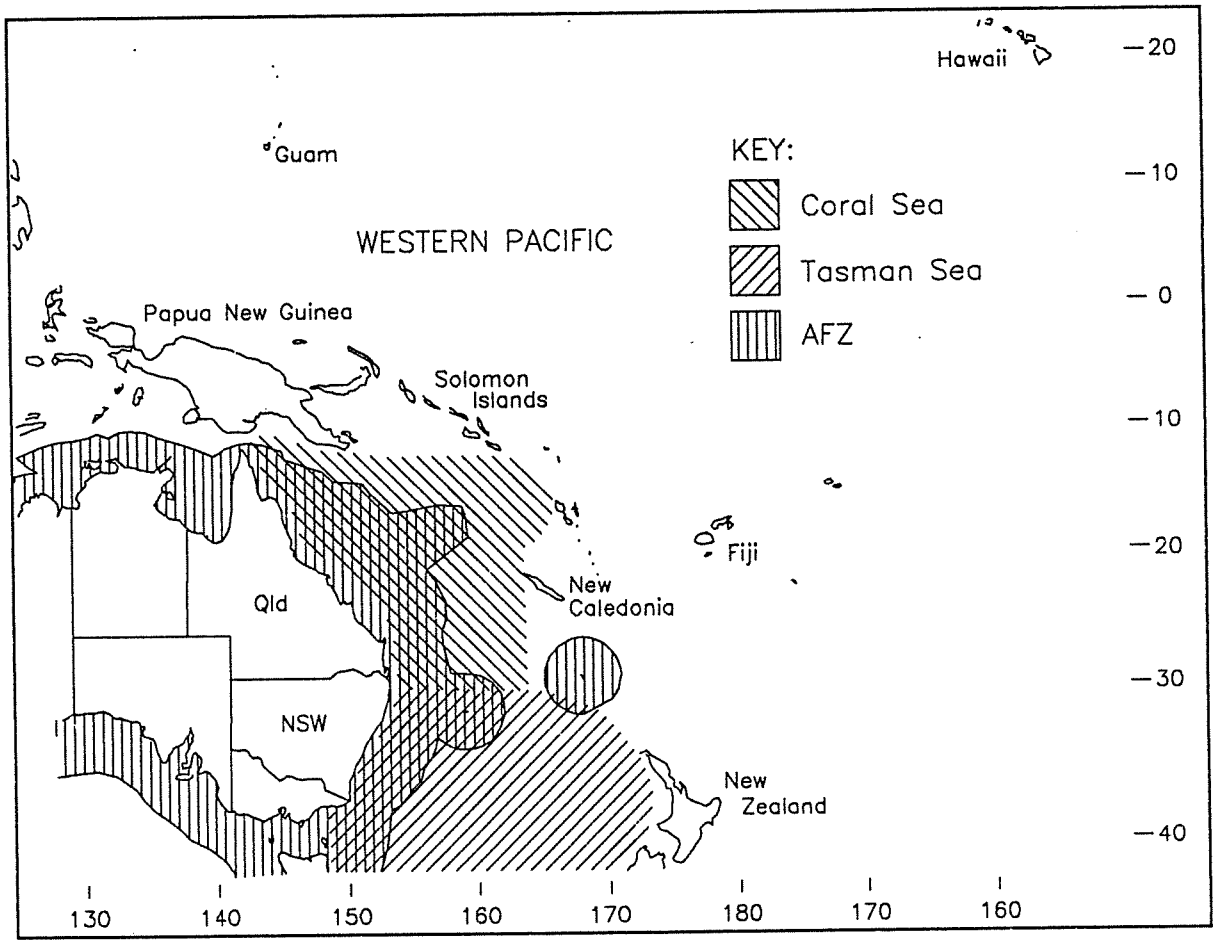

Figure 1. Pacific regions referred to in the current paper. The terms 'eastern AFZ' and 'east coast' are used synonymously and coincide with the intersection of the AFZ, Coral Sea and northern Tasman Sea.

Japanese Longline Fishery

Substantial Japanese longline activity occurs in waters of the eastern AFZ and beyond. Japanese activity is now not permitted in the eastern AFZ between 34°S and 39°S, and in various other areas - generally beyond 50 nautical miles of the coast. Longlines usually consist of 2250-3250 hooks, shot and retrieved daily. Southern bluefin tuna (*T. maccoyii* or SBT) was an important commercial species to the Japanese longline fishery before a dramatic decline in SBT catch rates during the mid-1980s and exclusion of Japanese longliners from the area between 34°S and 39°S. Currently species of commercial importance to the Japanese longline fishery are yellowfin tuna, bigeye tuna and broadbill swordfish. Several species of billfish (mainly black marlin and striped marlin) are a significant component of the incidental catch. The catch is sold at frozen-sashimi markets of Japan. Recently, several Japanese-style longliners operated by Australians have commenced fishing in offshore areas.

Handline Fishery

Japanese longline vessels may participate in a handline fishery (using handlines and pole-and-line) for surface-schooling yellowfin tuna and bigeye tuna in the north-western Coral Sea during full moons of October-December. Between six and twenty vessels participate in the fishery in any one year. A few domestic longline vessels also operate in the area at the same time as the Japanese.

Domestic Longline Fishery

Commercial longlining by Australians is centred on coastal waters (generally within 60 nautical miles of the coast) of New South Wales and southern Queensland, between 24°S and 37°S. Vessels normally return to port each day, although, more recently 2- or 3-day expeditions have become common. Between 200 and 500 hooks are shot. High quality catches of yellowfin tuna, bigeye tuna and striped marlin are flown to the fresh-chilled-sashimi markets of Japan. Other commercially important species include broadbill swordfish and albacore (*T. alalunga*), which are sold on the domestic market.

Low levels of domestic longlining also occur in waters adjacent to Cairns during the summer, and in the vicinity of Lord Howe Island. In the present paper activities off Cairns and Lord Howe Island are not included in references to the domestic longline fishery. Domestic longlining activities off Cairns are included under the general heading of 'handline fishery'.

Domestic Purse-seine Fishery

Skipjack tuna (*Katsuwonus pelamis*) are caught by purse-seine by several vessels operating in coastal waters of southern New South Wales during summer months. The tuna are sold to a local cannery. Exploratory purse-seining for skipjack tuna was, at the time of writing, being undertaken by one vessel in the Coral Sea.

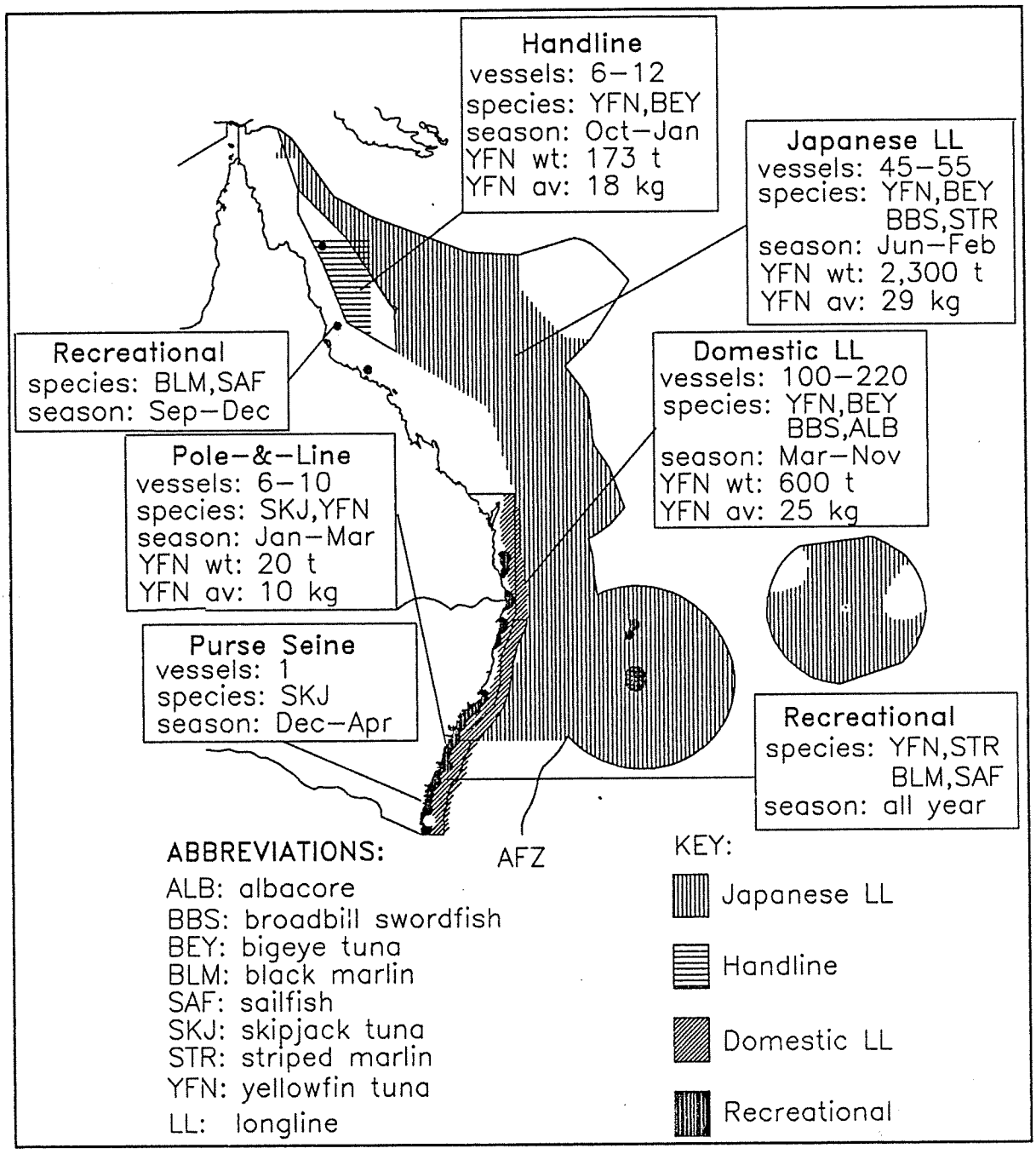

Figure 2. Summary of fisheries constituting the east coast tuna and billfish fisheries. Estimates of yellowfin catch levels and average size are for recent years.

Pole-and-line Fishery

Commercial pole-and-line fishing for skipjack tuna and yellowfin tuna is undertaken by several vessels operating off the south coast of New South Wales during January-March. The tuna are canned locally.

Recreational Fishery

Recreational fishing[4] for various species of tuna, including yellowfin tuna, skipjack tuna, longtail tuna (*T. tonggol*) and bigeye tuna is common throughout coastal waters of New South Wales and southern Queensland, and around Lord Howe Island. SBT are also taken by recreational fishers off the south coast of New South Wales. Fishing for billfish, mainly black marlin, striped marlin, sailfish (*Istiophorus platypterus*), spearfish (*Tetrapturus angustirostris*) and Indo-Pacific blue marlin occurs off north Queensland, Moreton Island, Lord Howe Island and along the coast of New South Wales.

[4]Recreational fishing for tunas and billfishes is commonly called 'sport and game fishing'.

PROGRAM OBJECTIVES

The program was designed to assemble biological and fisheries information required for effective management and development of the east coast tuna and billfish fisheries. Practically no biological research had been conducted in eastern Australian waters on the species constituting the fisheries, so the program aimed to address the question of stock identity of yellowfin tuna, and initiate the collection of basic fisheries information on species of commercial importance. The original objectives of the program were:

> *'(1) to develop an understanding of stock structure in the eastern AFZ and relationships with stocks in the broader south-western Pacific so that the respective consequences of fishing activities on these species within the AFZ and in the broader adjacent region can be determined;*
>
> *(2) to assemble background biological data on these species in the eastern AFZ to assist examination and interpretation of stock structure and to facilitate management and development of the fisheries on them.'*
>
> (FIRTA Application for Grant, 3 March 1986)

The majority of the program's resources were allocated to a tag-recapture study initiated off the coasts of north Queensland and New South Wales in order to address the first objective. Electrophoretic and morphometric studies were intended to complement the tag-recapture study in determining stock structures, and to characterise the stock(s). Parasites have been used as markers for tracing the movements of fish, and the potential for use of certain parasites of yellowfin tuna as population markers was considered recently by Brill *et al.*, 1987. The program intended to compile a species list of parasites so as to provide a foundation for future research into parasites as population markers or indicators of movement.

Collection of fisheries and biological data was a secondary though significant aim of the program. The program sought to develop sample collection and treatment procedures, and to initiate routine data collection programs. Fisheries and biological information gathered by the program included investigations of reproductive biology, development of age determination techniques, and feeding ecology, and analyses of the size structure of the catches.

Bibliographies of English and Japanese literature, relevant to the biology of the east coast tuna and billfish fisheries, were required for dissemination and consolidation of results of past research. Such bibliographies were intended for scientists involved in the current program as well as for future researchers.

The need for catch and effort data for proper interpretation of tag-recapture data and biological research was apparent from the start of the program. The program initiated collection of catch statistics from the domestic longline fishery

in New South Wales in lieu of the east coast longline logbook, which was to have been implemented by the Australian Fisheries Service (AFS). Japanese data represented the only widespread, long-term information on the east coast tuna and billfish fisheries. Descriptions of trends in catch and effort in the domestic longline fishery in New South Wales and the Japanese longline fishery provide important pointers to changes in the fisheries, as well as being essential for considering the impact of specific management measures.

REVIEW OF RESULTS

INTERACTION

Summary

Tagged yellowfin tuna displayed low rates of movement in eastern Australian waters. The majority of recaptures of tagged yellowfin tuna were made over a period of 2 years within 200 nautical miles of the sites of release. A preliminary assessment of the factors influencing interaction suggests low levels of interaction between the east coast yellowfin tuna fishery and fisheries of adjacent regions. Tag-recapture results showed that yellowfin tuna mixed throughout coastal waters of south-eastern Australia. Although detailed analysis of tag-recapture results was not possible without comprehensive catch and effort data series for the fisheries, tag-recapture results indicated interaction between the various domestic fisheries of the eastern AFZ. Interaction between domestic yellowfin tuna fisheries and the Japanese longline fishery appeared to be low.

Introduction

Following the rapid expansion of the domestic longline fishery during the 1980s, scientists, fisheries managers and members of the industry saw an urgent need to examine the relationship and extent of mixing between yellowfin tuna taken by the fishery and those exploited by other western Pacific yellowfin tuna fisheries. Long-range migrations by tagged yellowfin tuna were highlighted in the literature (see review by Cole 1980) suggesting that there could be broad mixing of yellowfin tuna throughout the western Pacific. Presumably assessment of the 'status' or well-being of the stock would need to take into account overall fishing pressure in the western Pacific, especially the intensive purse-seine operations in equatorial waters. If this were the case, then management measures aimed at controlling fishing pressure on the yellowfin tuna stock might have negligible effect if instituted solely in the AFZ. Instead effective management would require a multi-national approach.

On the other hand, some Australian fishers believed that yellowfin tuna caught in coastal waters of south-eastern Australia were different in appearance to those taken from waters beyond the continental shelf. They believed that the yellowfin tuna of coastal waters formed localised populations. If this were the case, then management of the east coast yellowfin tuna fishery might be dealt with independently of fishing activities in the broader western Pacific. Further support to this view was given by Hilborn and Sibert (1988), who questioned the accepted conclusion that yellowfin tuna migration rates were significant over large distances. Instead, they claimed that the majority of yellowfin tuna in the Pacific were restricted to local areas (e.g. the large Exclusive Economic Zones of some Pacific nations) during their juvenile and adult stages.

The main objective of this element of the research program was to address the question of whether yellowfin tuna of eastern Australian waters belong to discrete local populations or are essentially part of a larger, western Pacific population. The identification of sub-populations (should they exist) within the yellowfin tuna population(s) was addressed by the study.

The program initiated a tag-recapture study to assess movement of yellowfin tuna in eastern Australian waters. The program also examined genetic (electrophoretic and morphometric) attributes of the yellowfin tuna fisheries in order to characterise the populations and allow comparison with attributes of yellowfin from other Pacific regions.

Tag-recapture Studies

In all, 460 fish (360 yellowfin tuna) were caught (by pole-and-line), tagged and released in the north-western Coral Sea handline fishery in December 1986 (Table 1). Ninety-seven and 944 yellowfin tuna were caught by longline and pole-and-line, respectively, off the coast of New South Wales during February-March 1987. Despite comprehensive planning, the study did not tag as many yellowfin tuna as planned. Tagging charters coincided with exceptionally poor catch rates compared with those of previous years in the domestic pole-and-line and longline fisheries in New South Wales. Tagging in the north-western Coral Sea was hampered by the late arrival of the charter vessel and difficulties in locating surface concentrations of yellowfin tuna.

Table 1. Summary of tagging and reported recaptures of yellowfin tuna. Results of the Australian Gamefish Tagging Program and the FIRTA-funded tag-recapture study are combined (source: J.G. Pepperell and J.H. Diplock, unpublished[5])

	FISHERY:				
	Recreational	Pole-&-line	Domestic longline	Handline	TOTAL
Total No. tagged	3611	944	97	360	5012
Total No. recaptured	64	26	0	1	91

[5]All reports and papers produced by the program, including unpublished papers and papers proposed for publication, are listed in Appendix 2.

In the 2 years after tagging, 26 of the yellowfin tuna tagged during pole-and-line charters off New South Wales were recaptured[6]. The Australian Game Fish Tagging Program, coordinated by the New South Wales Fisheries Research Institute (FRI), contributed results amounting to 3611 tagged yellowfin tuna (most tagged during 1984-87) of which recaptures of 64 were reported. Overall, 2-3% of yellowfin tuna tagged by the two programs were recaptured. Recaptures of fish tagged by the current program are expected to continue for the next 2 or 3 years.

The maximum straight-line distance between release and recapture of tagged yellowfin tuna was 569 nautical miles over 9 months. Ninety per cent of all recaptures were made within 200 nautical miles of release. Yellowfin tuna tagged in coastal waters were rarely recaptured in offshore waters. Analyses of recapture data show that tagged yellowfin tuna dispersed throughout coastal waters of New South Wales and southern Queensland. Movements were correlated with sea surface temperatures of 21-22°C.

Although yellowfin tuna were shown to mix throughout coastal waters, tag-recapture results indicated that yellowfin tuna tagged in coastal waters were rarely recaptured by the Japanese longline fishery, which operates in offshore areas. The Japanese longline catch of yellowfin tuna near the main centres of tagging was at similar levels to that estimated for domestic yellowfin tuna fisheries during 1987, yet fewer than 5% of the tagged yellowfin tuna recaptured were reported from the Japanese longline fishery.

One interpretation of the low number of recaptures reported by the Japanese is that low rates of movement maintain a 'local' population of yellowfin tuna in coastal waters of south-eastern Australia. However, several factors may have acted to reduce the numbers of tagged yellowfin tuna available to the Japanese longline fishery compared with the numbers available to domestic fisheries. Firstly, all yellowfin tuna were tagged during domestic fishing operations, the majority by recreational fishers and during pole-and-line charters. Recreational and pole-and-line fishing are surface fisheries which exploit a different component, in terms of size composition and behaviour, of the yellowfin tuna stock than that exploited by longline. Secondly, most of the tagged yellowfin tuna were released in coastal waters of New South Wales and southern Queensland, whereas the Japanese longline fishery operates in more offshore waters, to the north of centres of tagging. The size of the tagged population would be reduced through mortality and, perhaps, tag-shedding, while tagged yellowfin tuna grew to the size at which they would be vulnerable to Japanese longlining and dispersed from areas of release. Finally, Australian fishers had a high awareness of the tag-recapture programs. Hence the non-reporting of recaptures of tagged fish by Australians may have been lower than that by the Japanese. In summary, the low number of recaptures reported from the Japanese longline fishery may have been due to the affects of growth and

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[6]Recognising that all recaptures of tagged fish are not necessarily reported, the term 'recaptures' is used here to refer to recaptures of tagged fish *reported* by fishers.

mortality of tagged yellowfin, and differences in reporting rates between domestic and Japanese fishers rather than being indicative of sub-structuring of the yellowfin tuna population.

All four recaptures (one yellowfin tuna and three bigeye tuna) among the 460 fish tagged and released in the north-western Coral Sea were recaptured in the handline fishery close to the point of release, almost exactly 12 months later.

No yellowfin tuna tagged and released in the north-western Coral Sea were recaptured in southern waters. However, relatively few tagged yellowfin tuna were released in the north-western Coral Sea, and the effects of dispersal and mortality over time would reduce the numbers of tagged yellowfin tuna available to fisheries to the south.

No yellowfin tuna tagged and released in southern waters were recaptured in the north-western Coral Sea. Dispersal and mortality over time would have acted to reduce the size of the tagged population available to the north-western Coral Sea handline fishery. Furthermore, fishing activity in the north-western Coral Sea was at relatively low levels of intensity, reducing the likelihood of recapturing yellowfin tuna which had been tagged in southern waters were they to have reached the area.

Consequently, conclusions regarding the relationship between yellowfin tuna of the northern Coral Sea and those of more southern waters should not be drawn from the tag-recapture results.

The yellowfin tuna tag-recapture study indicated considerable interaction among domestic yellowfin tuna fisheries (Table 2). The longline and recreational fisheries recaptured similar numbers of the pole-and-line releases (54% and 46% of recaptures, respectively). Only one of the yellowfin tuna tagged during New South Wales pole-and-line charters was reported by a Japanese longliner.

Domestic longliners and domestic pole-and-line vessels took 34% and 25% of the yellowfin tuna tagged and released by recreational fishers (recreational fishers took 37% of these recaptures). Japanese longliners reported 4% of the recaptures of these yellowfin tuna (three yellowfin tuna, two of which were released near Lord Howe Island).

Interaction between the domestic yellowfin tuna fisheries and the Japanese longline fishery appeared to be low: the Japanese caught fewer than 5% of the recaptures from recreational and pole-and-line releases (two of the four recaptures were tagged in waters adjacent to Lord Howe Island). Domestic longliners caught 57% of the recaptures of yellowfin tuna tagged by recreational fishers. Recreational fishers took 39% of these yellowfin tuna.

Table 2. Summary of tagging and reported recaptures of yellowfin tuna relative to fishing method. Recaptures are presented as percentages of total recaptures according fishing method (source: J.G. Pepperell and J.H. Diplock, unpublished[5]). See Table 1 for numbers of yellowfin tuna tagged and recaptured

RECAPT. METHOD	TAGGING METHOD: Recreational	Pole-&-line	Domestic longline	Handline	TOTAL
Recreational	37	44	0	0	39
Pole-&-line	25	0	0	0	18
Domestic longline	34	52	0	0	37
Handline	0	0	0	100	1
Japanese longline	4	2	0	0	4

In contrast to yellowfin tuna, black marlin were highly mobile (Pepperell 1989). Some tagged black marlin were recaptured more than 600 nautical miles from the point of release in the first year. Black marlin cannot be considered a 'migratory' species because movement did not appear to be in any consistent direction(s). However, recaptures of adult black marlin were frequently made in close proximity to the point of release after almost exactly 1, 2, 3 or 4 years, suggesting annual homing behaviour or, less likely, localisation of some elements of the population. Analysis of size frequency distributions from the recreational fisheries suggested that juvenile black marlin may move south along the east coast, from north Queensland to central New South Wales, in 'waves' of similarly sized individuals.

Electrophoresis

The electrophoresis study by Smith *et al.* (1988) distinguished four loci exhibiting polymorphic enzymes suitable for yellowfin tuna population analyses. Two loci were particularly robust, as they remained usable after yellowfin tuna had been caught by purse-seine, frozen in brine storage for several months, and thawed before sample collection. Preliminary results suggested that yellowfin tuna from eastern Australian waters belong to a sub-population separate from those yellowfin tuna sampled from other areas of the Pacific Ocean (Caroline Islands, Hawaii) as well as the Indian Ocean (Seychelles Islands).

On a finer scale, genetic relationships between yellowfin tuna taken from several areas within the eastern AFZ were suggested by the electrophoresis analyses (Figure 3). However, we must stress that such relationships are tentative and will need to be verified with further electrophoretic work on much larger sample sizes.

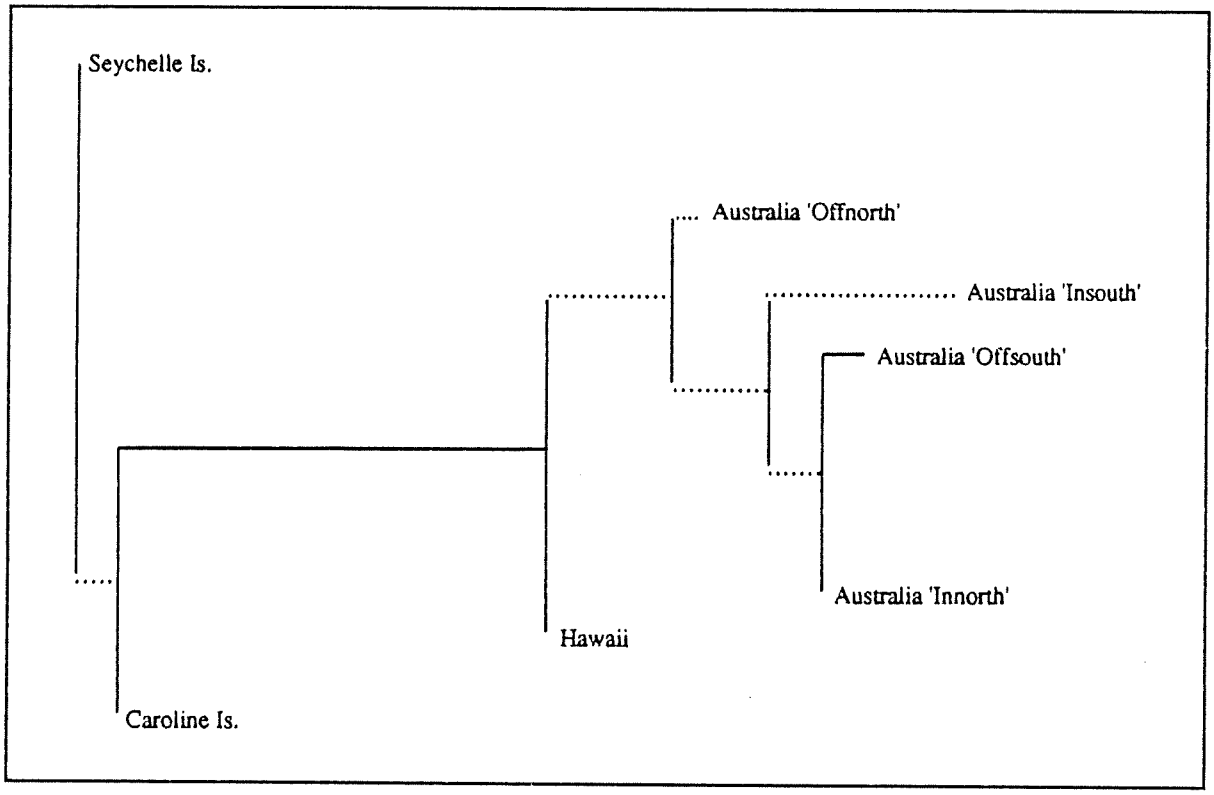

Figure 3. Dendrogram showing electrophoresis relationships between yellowfin tuna from various regions (Smith *et al.* 1988). Sub-structuring of Australian yellowfin tuna may be a sampling artefact and is tentative.

Morphometrics

The program participated in a wider study of the meristics and morphometrics of yellowfin tuna, conducted by K.M. Schaefer, Inter-American Tropical Tuna Commission. Schaefer's study indicated significant differences in the meristics (gill raker counts) and morphometrics of yellowfin from five Pacific sites (Australia, Japan, Hawaii, Ecuador, Mexico). The yellowfin tuna from Australia were most similar to those from Japan.

Preliminary morphometric analyses of the relative lengths of the anal and second dorsal fins of east coast yellowfin tuna (J.H. Diplock and D.D. Reid, unpublished[5]) revealed evidence of two morphological types of yellowfin tuna. Yellowfin tuna with relatively short second dorsal and anal fins were common

in catches in coastal waters, and yellowfin tuna with longer fins tended to be more frequent in catches further offshore. There was, however, substantial overlap in the distribution of the two types.

The morphometrics and electrophoresis studies produced results indicating gross differences in the genetic make-up of yellowfin tuna across the Pacific Ocean. Consequently both methods should be considered further for examination of stock structure on a finer scale, within the AFZ. However, it must be noted that, because of the timing of east coast fishing activities, there may be difficulties in collecting the necessary quantities of samples or measurements from several geographical areas simultaneously.

Parasites

Several new species were recognised and descriptions are currently being published (see Bruce and Lester, in press). This work is preliminary, being essential for any future studies which might investigate the use of parasites as population markers.

Interaction with Fisheries Beyond the AFZ

Interaction between east coast tuna and billfish fisheries and those of adjacent regions will depend on distance between the fisheries, natural mortality, fishing mortality and movement of fish. Fishing operations may interact if they are separated by relatively small distances, and if appreciable movement in relation to growth and mortality occurs between the populations that they exploit.

With respect to distance between fisheries, the Japanese longline fishery extends from within the AFZ to New Caledonia and beyond. Other fisheries are substantial distances from the AFZ relative to distances moved by yellowfin tuna, estimated from tag-recapture studies in eastern Australian waters. The closest fisheries include pole-and-line and artisanal operations in waters adjacent to New Caledonia and the Solomon Sea, and pole-and-line and purse-seine operations in waters to the north of Papua New Guinea, respectively 500, 1000, and 1500 nautical miles from the nearest major centre of east coast domestic longline activity (Mooloolabah, southern Queensland). Developments in purse-seine activity north-east of Papua New Guinea and in the northern Coral Sea should be monitored closely for interaction.

Analyses by the current program suggest that growth rates of eastern Australian yellowfin tuna (K, 0.30-0.49; L_∞, 161-197 cm length to caudal fork)[7] were comparable to those estimated for yellowfin in other Pacific regions (J.H. Diplock and D. Watkins, unpublished[5]).

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[7]K is the instantaneous growth rate derived from the von Bertalanffy growth equation and L_∞ is the maximum length predicted by the same equation.

Preliminary assessment suggests low levels of interaction between east coast yellowfin tuna fisheries and other western Pacific yellowfin tuna fisheries. Yellowfin tuna of eastern Australian waters appear to be relatively fast growing and, at present, exposed to low levels of exploitation in the eastern AFZ and adjacent regions; intense purse-seine operations are currently a considerable distance from the main centres of domestic activity. The impact of fishing operations on recruits and the population(s) supplying recruits to the east coast fisheries cannot be addressed until those populations are identified.

REPRODUCTION AND RECRUITMENT

Summary

Yellowfin tuna spawn in the north-western and central-western Coral Sea. Spawning frequency of yellowfin tuna was especially high in samples from the handline fishery in the north-western Coral Sea, although yellowfin tuna may spawn throughout the Coral Sea as far south as 30°S in summer. Samples from the north-western Coral Sea indicated that bigeye tuna spawned in the area during the period of the handline fishery. The limited number of bigeye tuna samples precluded conclusions regarding reproductive activity in other Coral Sea areas and at other times.

Yellowfin Tuna

Spawning and reproductive development of yellowfin tuna and bigeye tuna in the north-western and central-western Coral Sea are examined in the reports by McPherson (1988b, 1988c).

Yellowfin tuna spawned in the north-western and central-western Coral Sea. Spawning was detected in ovary samples taken from handline- and longline-caught yellowfin tuna during October-February, although the frequency of spawning was calculated to be much higher in samples from the handline fishery. There was significant variation in the spawning frequency of yellowfin tuna throughout the duration of the handline fishery. When spawning was first detected in the handline catch, spawning frequency was once every 1.82 days. Spawning frequency was almost daily (i.e. once every 1.18 days) at the conclusion of the handline period. Spawning frequency, calculated from all samples, appeared to be independent of size. The length at which 50% of female yellowfin tuna were mature ('length at first maturity' or LFM) was 101 cm length to caudal fork (LCF) in samples collected from the handline fishery.

Spawning was evident in longline-caught samples of yellowfin tuna from several areas of the Coral Sea as far south as 24°S during summer months, although spawning frequency was estimated to be lower than in the handline area of the north-western Coral Sea. Spawning was not detected in samples from Japanese longline, domestic longline, or recreational fisheries off the coast of New South Wales (J.H. Diplock, unpublished[5]), where most of the domestic

catch is taken. Although sample collection was limited by timing and by areas of the fishing activity, surveys of scombrid larval distribution (e.g. Nishikawa *et al.* 1985), and the suggestion that yellowfin tuna spawning depended on a surface water temperature of 26°C (Hisada 1973), indicate that spawning is likely throughout the Coral Sea, possibly, as far south as 30°S in the late summer.

There was no significant difference between the ratios of males to females in either the domestic longline or pole-and-line or Japanese longline fisheries. However, female yellowfin tuna were significantly less common in the larger size classes, with no females larger than 70 kg total weight recorded during the study. The average sizes of yellowfin tuna taken in the handline fishery were about the same as the estimated size at maturity (101 cm LCF) in that area.

Bigeye Tuna

Bigeye tuna had similar reproductive characteristics to yellowfin tuna, although fewer samples were available for the study of bigeye tuna reproduction. Bigeye tuna in spawning condition were detected in the handline fishery. Female bigeye tuna from the handline fishery attained maturity at 100-125 cm LCF. Spawning frequency of bigeye tuna during the handline fishery was estimated to be every 2 days. The limited number of bigeye tuna samples precluded conclusions regarding reproductive activity in other Coral Sea areas and at other times.

Aggregations in the Handline Area

Based on information from the handline fishery operated by the Japanese in the north-western Coral Sea, yellowfin tuna and bigeye tuna may form aggregations in the area during the full moons of October-December. One hypothesis to explain the formation of aggregations in the handline area is that they are formed in response to high concentrations of a single prey species (*Diaphus* sp., Myctophidae) and/or certain oceanographic events (McPherson 1988a).

Recruitment

Although investigation of recruitment to the east coast tuna and billfish fisheries was not an objective of the current study, information gathered by the program provides an insight into mechanisms which may determine recruitment to the fisheries. Using catch data J.H. Diplock and D. Watkins (unpublished[5]) suggested that, in any one year, the domestic longline yellowfin tuna fishery was dependent on one or two size modes (presumably corresponding to specific age groups or 'cohorts') of yellowfin tuna. In 1986 and 1987, for example, the domestic longliners did not make contact with any new size classes, and catch rates were consequently low. The erratic annual appearance of size modes of small yellowfin tuna in the catch may result from intermittent recruitment to the fishery.

Despite description of yellowfin tuna and bigeye tuna spawning activity in the Coral Sea there is considerable uncertainty regarding sources of recruits for the east coast yellowfin tuna fisheries. Tag-recapture, electrophoresis and morphometric analyses suggest that it is unlikely that juvenile or adult yellowfin tuna are recruited to the east coast yellowfin tuna fisheries from distant Pacific regions, so it is likely that they come from nearby regions. One hypothesis for recruitment to the yellowfin tuna stocks of eastern Australia is that larvae hatch in the Coral Sea. Some might be transported southwards by the East Australian Current, eventually arriving as juveniles in coastal waters of southern Queensland and New South Wales; other larvae might remain in the Coral Sea, growing to maturity to spawn and complete the life cycle.

The origin(s) of spawners in the Coral Sea remains open to speculation. The Coral Sea spawners might be an isolated sub-population, or they might include adults moving from adjacent areas, including, perhaps, the Tasman Sea.

AGE DETERMINATION

The principal objective of the age determination in the program was to develop reliable techniques for the ageing of yellowfin tuna. A description and appraisal of the ageing techniques for yellowfin tuna is presented in the report by J.H. Diplock and D. Watkins (unpublished[5]). The program investigated age determination of yellowfin tuna through counts of growth rings apparent on hard parts (vertebrae, otoliths and dorsal fin spines).

- Growth rings (annuli) on vertebrae were demonstrated to be laid down annually, as validated by modal weight progressions which matched growth predicted by counts of vertebral annuli.

- Inner growth rings of fin spines were found to be resorbed in older yellowfin tuna.

- Counts of daily rings on otoliths corroborated the age estimates determined from vertebrae. However, the difficulties of collecting otoliths and reading daily increments currently preclude their use for routine monitoring.

Estimates of growth parameters based on hard parts were compared with growth estimates derived by other means, such as modal progressions and tag-recapture (Table 3). Results show a range in estimates for the various parameters.

The estimates of various growth parameters for yellowfin tuna of the east coast were, however, comparable to estimates for yellowfin tuna from other Pacific regions, e.g. Yang *et al.* (1969, cited in Cole 1980) by scale reading of longline-caught fish from the western Pacific; Yabuta and Yukinawa (1959, cited in Cole 1980) by analysis of modal progressions of longline-caught fish from the

western Pacific; and Moore (1951, cited in Cole 1980) by modal progressions of longline caught fish from the central Pacific. East coast yellowfin tuna appear to have relatively high rates of growth, much higher than southern bluefin tuna (K, 0.128; Kirkwood 1983, from tag-recapture and modal progressions), though lower than short-lived species such as skipjack tuna (K, 0.9451; Josse *et al.* 1979, from tag-recapture in the western Pacific).

Table 3. Summary of von Bertalanffy growth parameter estimates for yellowfin tuna (source: Diplock and Watkins, unpublished[5]). Growth parameter estimates published by several other workers (cited by Cole 1980) are also shown

METHOD	PARAMETER: t_0	L_∞	K
Caudal centra	-0.0869	196.86	0.3027
Modal progressions	-	174.95	0.4883
Tag-recapture	-	160.87	0.4849
Yang *et al.* (1969)	0.27	195	0.36
Moore (1951)	0.22	192	0.44
Yabuta and Yukinawa (1959)	0.66	150	0.66

CATCH ANALYSIS

Summary

Catch and effort data were compiled for the domestic longline and pole-and-line fisheries in New South Wales. Catch rates of yellowfin tuna in the New South Wales domestic longline fishery tended to decrease after initially high catches in 1984/85. Catch and catch rates of most species, reported by the Japanese, were quite variable from year to year, and showed no apparent trends. Yellowfin tuna catch rates reported by Japanese longliners declined during 1985 and 1986, returning to previous levels in 1987. The fluctuations in catch rates for both longline fisheries were well-within the ranges observed in catch rates of the Japanese longline fishery during the previous 25 years.

Reported catches and catch rates of black marlin by Japanese longliners declined

substantially during 1962-80. The decline in reported catches of black marlin should be viewed with concern by those responsible for managing fisheries that may take black marlin, while the possibility exists that it is due to a reduction in the black marlin population.

Data

Catch and effort data from logbooks and radio reports were available for the Japanese longline fishery through the Australian Fishing Zone Information System (AFZIS) from the inception of the Zone in 1979 to the present. Longline data (number of fish and hooks) published by the Japanese were also available for the period 1962-80 at a resolution of 5-degree squares. The two data sets are not strictly comparable in terms of area.

The program collected data for the domestic longline and pole-and-line fisheries in New South Wales (numbers and weight of fish and number of vessels), including a breakdown according to destination of product (domestic or export) with information on size and price for several species. Effort was estimated as number of boat-days per port.

No data were available on recreational catch and effort or for the Queensland tuna and billfish fisheries. Monitoring the entire catch of the east coast tuna and billfish fisheries must be given priority. Future analyses will be assisted by data sets with comparable units of catch and effort, and information on gear and targeting. Information on targeting practices is essential for proper interpretation of catch and effort data in multi-species fisheries, and comparisons of Japanese and domestic catch rates may be unreliable without knowledge of size composition of the catches, targeting and gear.

Domestic Longline and Pole-and-line Fisheries

A logbook system was to have been developed by the AFS to monitor the domestic longline fishery and to complement the logbook data for the Japanese longline fishery. The program aimed to use length and weight data collected in the logbook as an efficient means of monitoring fluctuations in catch composition and size distribution of the target species. Although a logbook was designed and copies were distributed to some fishers, the AFS was unable to satisfactorily implement the logbook system during the present program. The program monitored the catch landed in New South Wales in the interim.

Data on the domestic catch landed in New South Wales (species, quantity, weights) were collected through regular surveys of fishermens' cooperatives, fish markets, export agencies and other commercial outlets. Effort data were compiled in terms of landings (number of days), allowing estimation of catch per unit effort in terms of numbers and weight (kg) of fish per day's landing at each port. Details of size and price were collected for individual fish on most surveys.

Yellowfin tuna were the most commercially important species taken by the domestic longline fishery in New South Wales. Other species of economic importance included bigeye tuna, broadbill swordfish, albacore and striped marlin.

The domestic longline fishery was highly seasonal, with fishing activity tending to follow water masses of distinct temperatures (often 19-22°C). Domestic longliners tended to concentrate activity in continental-shelf waters off the New South Wales north coast during mid- and late-winter, moving further south following the warming influence of the East Australian Current as summer progressed.

The fishery generally exploited yellowfin tuna of what are believed to be 2-7 years old. Size frequency distributions indicated that the fishery exploited what may have been 'pulses' of recruits that appeared to move along the coast with warm water masses.

The domestic pole-and-line fishery, which accounted for fewer than 2% of the domestic commercial catch, exploited yellowfin tuna of 1 and 2 years old. The results of the tag-recapture study suggest that at least some juvenile yellowfin tuna are vulnerable to the pole-and-line fishery before entering the domestic longline and recreational fisheries.

Quantitative information on the recreational catch was not readily available, although tagging studies indicated that recreational fishers reported almost 40% of all yellowfin tuna recaptures. The proportion recaptured by recreational fishers is probably overestimated because most tagged yellowfin tuna were tagged by recreational fishers and, hence, the likelihood of recapture by recreational fishing would be high.

Japanese Longline Fishery

Japanese data were analysed for 1962-80 (Japanese 5-degree-square data set) and 1980-88 (AFZIS data set) for waters east of 140°E corresponding to the AFZ (P.J. Ward and A.E. Caton, unpublished[5]). Interpretation of trends is limited because of discontinuity in the data sets, and absence of data on variations in targeting and size composition of the catch. Although the study was descriptive the work provides fisheries managers and fishers with a historical perspective on the fisheries.

Japanese fishing effort in eastern waters fluctuated between 5 and 28 million hooks a year. Effort tended to fall during 1966-77 but then, in later years, recovered to levels similar to those of the early 1970s. Access restrictions, catch rates (within the eastern AFZ and in relation to other Pacific regions), price and operating costs have influenced fishing patterns.

A major finding of the study is the high inter-annual variation in catch rates reported for many species of commercial importance, including yellowfin tuna,

bigeye tuna, striped marlin, black marlin and blue marlin. The variability cannot solely be accounted for by variations in effort. For instance, 1984 saw a catch of 35 000 yellowfin tuna which doubled to 70 000 in the following year despite

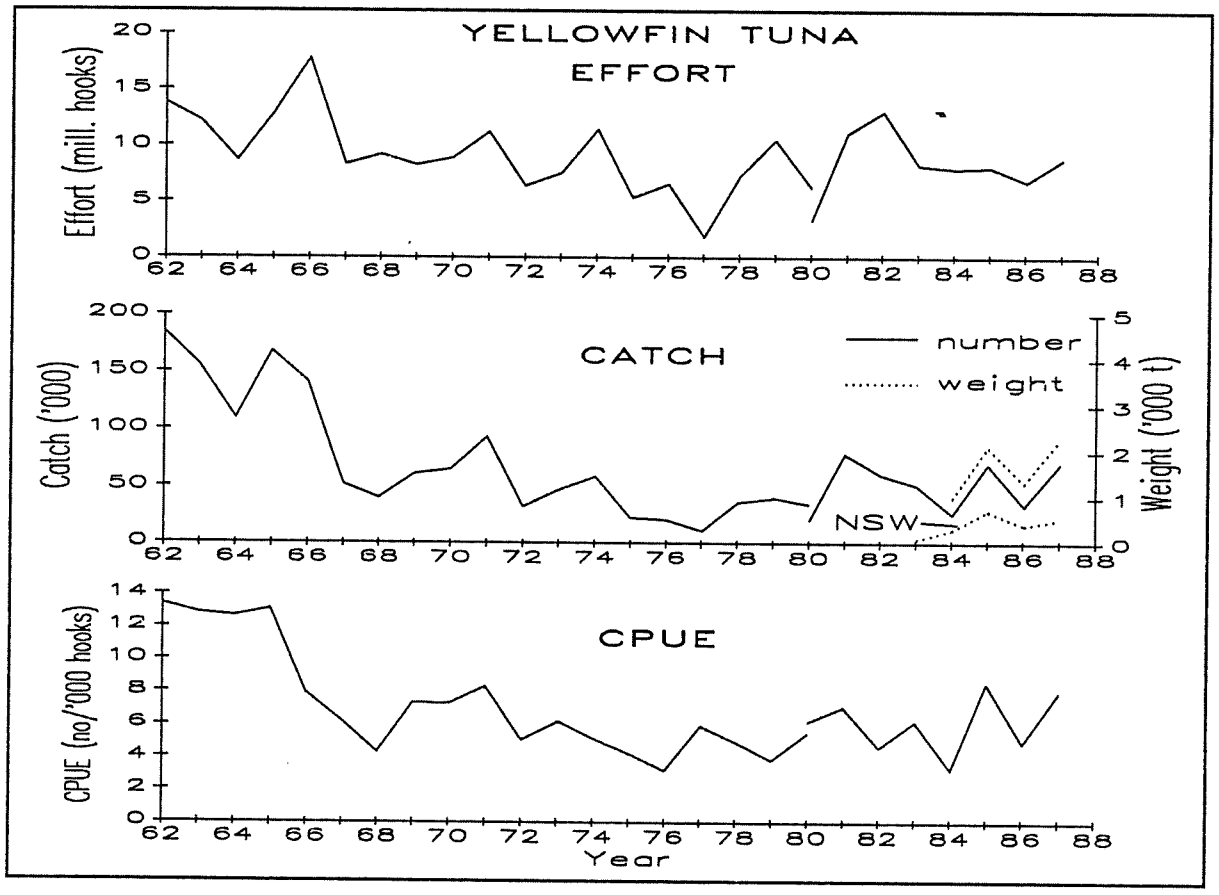

Figure 4. Trends in the annual Japanese longline catch of yellowfin tuna and fishing effort. Catches and catch rates are presented as numbers of fish (the weight of Japanese and NSW domestic catches are also indicated).

effort being constant during the period (Figure 4). The east coast tuna and billfish fisheries are at the limits of the distribution of several of the component species, e.g. major yellowfin tuna fisheries are concentrated between 10°N and 10°S, and yellowfin tuna are rarely found south of 40°S (Cole 1980), perhaps explaining the variability in catch rates. Fisheries managers and fishers must keep the high variability in mind when interpreting short-term trends in the domestic catch.

The variability in catch rates tended to mask any long-term trends, if they exist, in catch and catch rates. In general, catches and catch rates reported were particularly high for all species during 1962-64 and especially low in 1976-77, following low levels of effort. Regardless of the annual variability in catch and effort, the data indicated no obvious trends in catch and catch rates of most species during the 25 years for which data were available.

Despite the level of variability in the data, both catches and catch rates of black marlin tended to fall throughout the period of investigation (Figure 5). Various explanations may be put forward to explain the decline:

- modifications to fishing gear or technique (e.g. targeting of other species);
- mis-reporting of black marlin catches;
- release of live black marlin[8];
- introduction of restrictions on access to areas of the AFZ;
- a decline in the abundance of black marlin in adjacent regions as a result of over-fishing in those regions;
- trends in abundance associated with long-term changes in oceanographic conditions which affect survival of black marlin or vulnerability to longline gear.

Although no evidence is available to refute any of the above explanations, the decline in reported catches of black marlin should be viewed with concern by those responsible for managing the fisheries while the possibility exists that it is due to a reduction in the size of the black marlin population.

No obvious temporal trends were detected in reported catch rates of yellowfin tuna, the mainstay of the domestic longline fishery (Figure 4). Examination of catch data for the domestic longline fishery in New South Wales indicates that catch rates of yellowfin tuna tended to decreased after 1985, recovering slightly in 1987/88. Yellowfin tuna catch rates reported by Japanese longliners declined from 1985 to 1986, returning to previous levels in 1987. The fluctuations in catch rates for both fisheries are well within the ranges observed in catch rates of the Japanese longline fishery during the previous 20 years.

On average, the Japanese longline fishery tended to take larger yellowfin tuna than the domestic fisheries (P.J. Ward and A.E. Caton, unpublished[5]). The average size (33 kg dressed weight) was above the size at first maturity estimated for yellowfin tuna in the north-western Coral Sea. The average size taken by the fishery varied between about 30 and 35 kg during 1984-88.

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[8]Japanese longline fishers agreed to return all live black marlin and blue marlin caught in the AFZ as from November 1986.

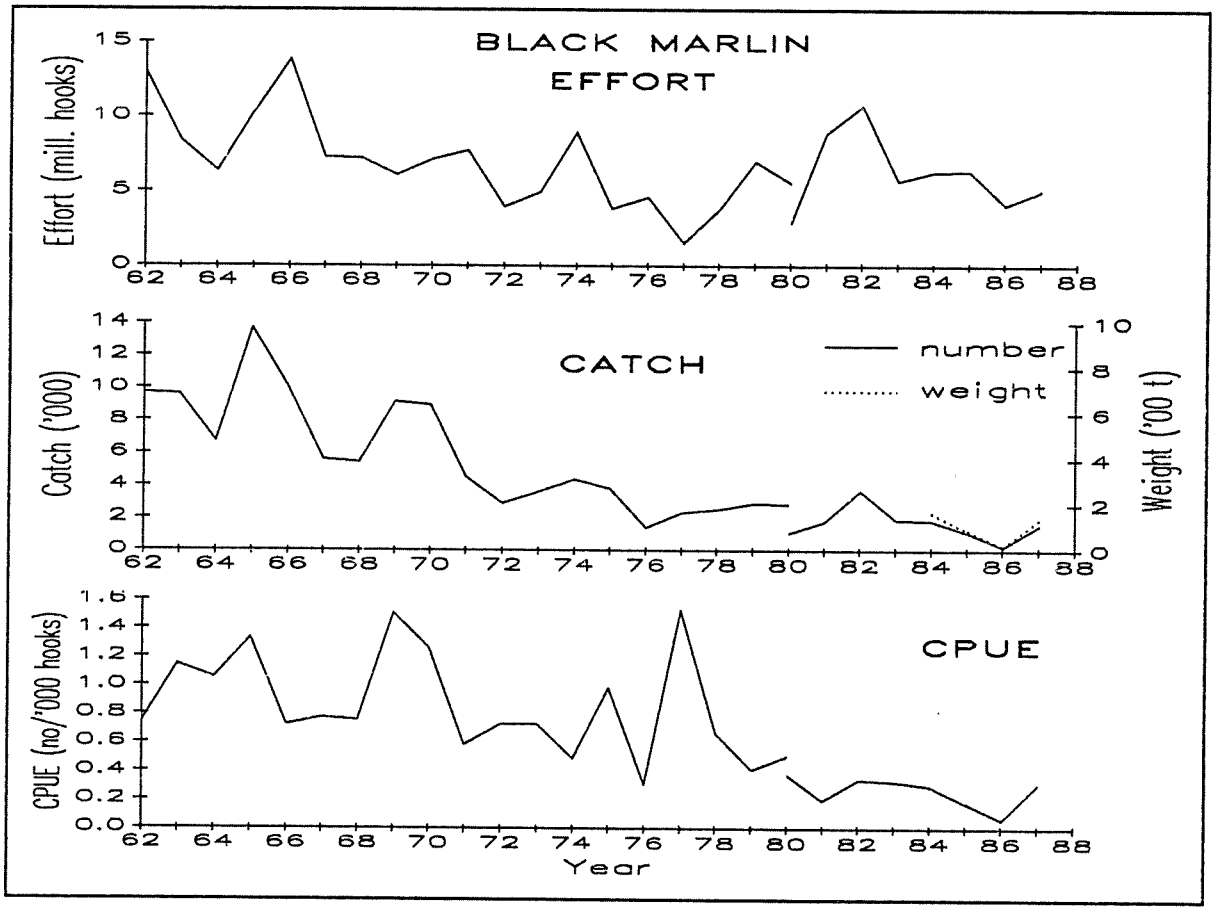

Figure 5. Trends in the annual Japanese longline catch of black marlin and fishing effort. Catches and catch rates are shown as numbers of fish (catch weight is shown for 1984-87). Refer to text for an explanation of trends.

BAITFISH

The study of baitfish resources collected preliminary data on the taxonomy and seasonal patterns in distribution of common baitfish species off north Queensland. The study was conducted by the Australian Institute of Marine Science (AIMS) as part of a wider research program (see Williams 1989).

LITERATURE

The program compiled bibliographies of literature related to the biology of the tunas and billfishes taken by the east coast fisheries. The *Bibliography of Japanese Literature on the tunas (excluding southern bluefin tuna) and billfishes of the Coral and Tasman Seas* comprises 82 annotated citations. English translations of three significant articles written in Japanese were also produced by the project. More than 230 citations, many of which are annotated, are presented in *An annotated*

bibliography of tuna and billfish stocks occurring in eastern Australian waters. The bibliographies will be a valuable source of literature for future research and will be maintained by the Bureau of Rural Resources (BRR).

ACKNOWLEDGMENTS

The review was drawn from the collective wisdom of many fisheries scientists. The scientists particularly helpful in compiling and reviewing this paper included Albert Caton, Bob Kearney, Meryl Williams, Geoff McPherson, Julian Pepperell, and John Diplock. Not to be overlooked are those researchers, and their assistants who contributed to the program, without whose dedication and cooperation such a diverse research program would not have been possible. Researchers and their assistants are acknowledged in individual reports produced as part of the program, however, the technical support provided by Dianna Watkins, Craig George, Robyn Pethebridge, Kerrie Deguara and officers of the AFZ Observer Program (Bill Anderson, Mike Baron, Russell Naumann, David Strong) deserve special commendation.

The review was compiled by Peter Ward, Bureau of Rural Resources.

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[9]Denotes reports and papers produced by the present program.

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APPENDIX 1: PARTICIPATING INSTITUTIONS

The bulk of biological research associated with the program was undertaken by the New South Wales Fisheries Research Institute and Queensland Northern Fisheries Research Centre. The Fisheries Research Institute also monitored the domestic longline and pole-and-line catch in New South Wales. The University of New South Wales' Centre for Marine Science analysed electrophoresis samples. CSIRO Division of Fisheries Research and the Bureau of Rural Resources compiled the bibliographies and the Bureau also analysed Japanese catch and effort data. The Australian Institute of Marine Science and University of Queensland both conducted research associated with the present program as parts of wider studies. The Australian Fisheries Service was responsible for the east coast longline logbook.

The Bureau of Rural Resources coordinated the program and compiled this summary.

Institutions and contact officers who may be approached for copies of specific reports produced as part of the program are listed below.

INSTITUTION	CONTACT OFFICER	PHONE NUMBER
Fisheries Research Institute, NSW Department of Agriculture (FRI)	The Librarian	02 5278411
Northern Fisheries Research Centre, Queensland Department of Primary Industry (NFRC)	Geoff McPherson	070 515588
Centre for Marine Science, University of New South Wales	Pat Dixon	02 6972112
CSIRO Division of Fisheries Research	The Librarian	002 206222
Fisheries Resources Branch, Bureau of Rural Resources, Department of Primary Industries and Energy (BRR)	Sally Wells	062 725534
Australian Institute of Marine Science (AIMS)	David Williams	077 789282
Queensland Museum	Neil Bruce	07 8407715
Australian Fisheries Service, Department of Primary Industries and Energy (AFS)	Peter Neave	062 725286

APPENDIX 2: REPORTS AND PAPERS ASSOCIATED WITH THE PROGRAM

The following list includes publications, reports and papers proposed for publication, and (unpublished) internal papers produced in association with the program.

Bruce, N.L. & Lester, R.G. (in press) *Hysterothylacium, Iheringascaris* and *Maricostula* new genus, nematodes (Ascaridoidea) from Australian pelagic marine species. *Journal of Natural History.*

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Diplock, J.H. (in review) Feeding ecology of yellowfin tuna in the eastern Australian Fishing Zone. Paper submitted for publication in *Australian Fisheries.*

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