



Biology, fisheries and status of longtail tuna (*Thunnus tonggol*), with special reference to recreational fisheries in Australian waters

FRDC Project 2008/058

Final Report

30 July 2010

- Shane Griffiths • Julian Pepperell • Mark Tonks • William Sawynok
- Len Olyott • Sharon Tickell • Mitchell Zischke • John Burgess
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- Kane Moyle



Australian Government
Fisheries Research and
Development Corporation



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

Title: Biology, fisheries and status of longtail tuna (*Thunnus tonggol*), with special reference to recreational fisheries in Australian waters

ISBN: 9781921605741 (pbk.)

Subjects: Tuna fishing—Australia, Fisheries—Australia, Fishery management—Australia.

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Dewey Number: 639.27783

Cover designed by Shane Griffiths, CSIRO Marine and Atmospheric Research, cover photography by Dan Bergamo, Kurt Edwards and Mark Bargaquast.

Published by CSIRO Marine and Atmospheric Research

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[Cite as: Griffiths, S., Pepperell, J., Tonks, M., Sawynok, W., Olyott, L., Tickell, S., Zischke, M., Lynne, J., Burgess, J., Jones, E., Joyner, D., Makepeace, C., and Moyle, K. (2010) Biology, fisheries and status of longtail tuna (*Thunnus tonggol*), with special reference to recreational fisheries in Australian waters. FRDC Final Report 2008/058. 101 pp.]

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1. Non-technical Summary

2008/058	Biology, fisheries and status of longtail tuna (<i>Thunnus tonggol</i>), with special reference to recreational fisheries in Australian waters
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OBJECTIVES:

- 1) Collate available information on the biology, ecology, movements and commercial, recreational and artisanal catches of longtail tuna, particularly in Australia
- 2) Identify key knowledge gaps in relation to biology and catch data, especially in an Australian context, and recommend future data requirements to support management of longtail tuna in Australia
- 3) Develop and recommend methods for cost-effective collection of long-term recreational catch and effort data for longtail tuna in Australia

OUTCOMES ACHIEVED

Available information and knowledge gaps on the biology, ecology and fisheries for longtail tuna, *Thunnus tonggol* (Bleeker 1851), were identified in order to assess the status of this 'recreational-only' species in Australia.

Specialist sport fishers who catch longtail tuna can be considered a 'hard-to-reach' population, which cannot be cost-effectively sampled using traditional recreational fishing survey methods (e.g. creel or telephone surveys). We compared online diaries and 'time-location sampling' (TLS) with a traditional access point survey as potential cost-effective methods for obtaining representative data from these specialised fishers across Australia.

The online diary method was inexpensive but unsuitable for collecting representative data due to avidity, volunteerism, and differential recruitment bias. Access point surveys collected high resolution data on catch, effort and size composition of fish caught. However, the method was expensive, longtail tuna were recorded in only 0.3% of trips surveyed, and the results only represented the trailer boat catch. In contrast, TLS incorporating a 12-month recall survey was a cost-effective method for obtaining catch and effort estimates from boat-based and land-based fishers who represented a range of avidity levels and comprised fishing club and non-club members. It is recommended that multiple surveys using TLS be used to recruit a representative sample of fishers to a diary survey to reduce recall bias. Multiple surveys may also be used to estimate

population size using a capture–recapture methodology, although the specific approach used would require testing and validation before widespread implementation.

Recreational catch and effort survey data and biological information from the literature were brought together in dynamic pool models to assess the longtail tuna stock and to examine the effects of introducing size limits as a management strategy. The preliminary assessment suggests the stock is currently fished at biologically sustainable levels. However, any increase in fishing mortality may result in recruitment overfishing due to the slow growth rate of the species. Imposing a minimum legal length of 80 cm, 90 cm or 100 cm total length was shown to be ineffective for reducing fishing mortality. There was large uncertainty in the assessment due to several key knowledge gaps that require urgent attention including: i) potential stock linkages with southeastern Asia where annual commercial catches exceed 100,000 t, ii) age-at-maturity, iii) post-capture mortality in recreational and commercial fisheries, and iv) a time series of representative annual catch and effort for the recreational sector.

NON-TECHNICAL SUMMARY

Longtail tuna (*Thunnus tonggol*) is a commercially-important species throughout the Indo-Pacific. The species is heavily exploited in rapidly expanding multi-species purse seine, gillnet and troll fisheries in many underdeveloped countries, such as Indonesia, Taiwan, Thailand and Iran. Global catches of longtail tuna increased substantially to around 100,000 t yr⁻¹ in 1985 and continued to increase to 248,000 t in 2007. In contrast, longtail tuna has been only lightly exploited by commercial fisheries in Australia with annual reported landings averaging only 34 t since 1974.

In 2006 the Commonwealth government declared longtail tuna a ‘recreational-only’ species, in recognition of its importance as a sport fish to the recreational fishing sector. It is only recently that formal management arrangements have come into place for longtail tuna, to ensure there will be no future large-scale targeting by commercial fisheries, but also to allow an incidental catch in multi-species commercial fisheries (e.g. gillnet fisheries that target sharks and mackerels). Despite the importance of longtail tuna to recreational fisheries in Australia and commercial and artisanal fisheries throughout the Indo-Pacific, very little is known of the species’ basic biology, stock structure and catch by recreational and commercial fisheries. Such information is fundamental for assessing whether Australia’s new management measure is appropriate to ensure the long-term sustainability of the species. This project aimed to collate existing information on key biological parameters and evaluate cost-effective methods for collecting recreational catch data. Together, information from these two processes can provide a basis for providing a preliminary assessment of the status of longtail tuna in Australian waters guide fishery managers as to the most appropriate means to manage this recreational-only species.

The first two objectives of the project involved i) undertaking a review of the global literature and summarising known information on the biology, ecology, movement, and fisheries of longtail tuna, and ii) identifying major data deficiencies in Australia, particularly in relation to recreational fisheries. The review highlighted that, despite

commercial catches rapidly increasing in countries neighbouring Australia over the past 20 years, few studies had collected basic quantitative information on the stock structure, growth and reproductive dynamics of longtail tuna. A number of studies in southeast Asia used modal progressions of length-frequency distributions to estimate the age and growth of longtail tuna, which suggested they are a fast-growing and short-lived species that are capable of withstanding high fishing pressure. However, a study published during the course of the current project demonstrated that longtail tuna are slow-growing and live in excess of 18 years. Because of their slow growth rate and restricted neritic distribution, longtail tuna may be particularly vulnerable to overfishing, even under seemingly modest fishing pressure by coastal fisheries.

A review of existing data sources and literature revealed that in spite of longtail tuna being important to recreational fisheries in Australia, little is known about the extent of catches and size composition of longtail tuna taken by the recreational sector. A few exceptions were some fishing club records and tagging data. Unfortunately, these data cannot be considered representative of the entire recreational fishery, and on their own, are not suitable to inform stock assessment. This led into the final objective of the project, to develop potential cost-effective methods for surveying specialised recreational fishers and to test these methods for obtaining representative recreational catch and effort of fishers in Australia's longtail tuna recreational fishery. Two innovative methods—online diaries and time-location sampling (TLS)—were tested in the national survey and the results compared with a traditional access point survey. The online diary system and educational website was developed (www.longtailtuna.com.au) where fishers could volunteer to submit data for individual fishing trips where they caught, targeted, or fished in such a manner as to be able to catch longtail tuna. The study objectives and incentives for participation were advertised nationally on radio and in newspapers, fishing magazines and on internet fishing forums.

Collectively, 211 days of sampling was conducted using online diaries, TLS and access point surveys, intercepting 4600 individuals, of which, 3526 (76.7%) were fishers. Recreational fishers who targeted or fished in a manner as to allow longtail tuna to be caught (i.e. 'sport fishers'), comprised around 34% of all fishers sampled. These sport fishers were generally males aged 25-29 years and 84.3% of survey respondents were not members of a fishing club. Most sport fishers did not specifically target longtail tuna, but fished with specialised techniques and methods (e.g. trolling, casting lures, and live bait) to target a suite of sympatric inshore pelagic sport fish, such as spotted and narrow-barred Spanish mackerel. Interestingly, only 24% of surveyed sport fishers were aware that longtail tuna was a 'recreational-only' species. Catch and effort data were obtained from 1182 sport fishers, who undertook 4596 fishing trips and expended 25,138 hours of effort. On average, sport fishers expended 52 hours per year, and individual fishing trips lasted 5.4 hours. Surveyed fishers caught (retained + released) a total of 892 longtail tuna that ranged between 30 cm to 150 cm total length (TL), with the average length being 95 cm TL (or about 8.85 kg). Although the total population size of sport fishers who target or incidentally catch longtail tuna is unknown, our results show that the minimum annual catch from our sample from the sport fishing population is approximately 80 t.

The online diary method was the least expensive and yielded high resolution data for 178 fishing trips from 156 fishers. However, this method suffered from severe avidity,

volunteerism, and differential recruitment bias since the vast majority of respondents were land-based fishers who fished for 10-30 days per year, having an average catch rate of 0.143 (\pm SD 0.366) fish hr⁻¹. The access point survey was the most expensive survey method and accounted for only 7 longtail tuna captures from 2341 fishers intercepted over 41 days of sampling, which resulted in a low catch rate of only 0.006 (\pm 0.067) fish hr⁻¹. In contrast, TLS using a 12-month recall survey accounted for 750 longtail tuna captures from 1029 fishers intercepted at tackle stores at 17 locations around Australia. The average catch rate of longtail tuna by TLS respondents was 0.090 (\pm SD 0.315) fish hr⁻¹. TLS appeared to sample a more representative portion of the sport fishing community, from a range of avidity levels, as well as both fishing club and non-club members. By combining TLS with a diary survey, which was supported by 81% of TLS respondents, high resolution data for individual fishing trips may be collected at relatively low cost. Using this approach, recall bias may be reduced to produce more reliable estimates of catch and effort. None of the three methods trialled was able to directly estimate the population size of the recreational fishery from a single survey, and thus the total recreational catch of longtail tuna. However, repeated TLS surveys may be used to estimate population size using capture-recapture methods, which are widely used in epidemiology and social sciences. Therefore, TLS is the recommended method for a long-term recreational fishing monitoring program for longtail tuna in Australia.

Biological and commercial catch data mined from the literature, unpublished data sources, and recreational catch data collected from the survey methods trialled in the present study were brought together in a preliminary stock assessment using dynamic pool models. The assessment suggests that the stock is currently being fished at biologically sustainable levels, although any increase in fishing mortality may result in recruitment overfishing owing to the slow growth of the species. However, there was significant uncertainty in a number of areas in the assessment, particularly the lack of quantitative information relating to age-at-maturity. A sensitivity analysis showed that if the actual age at maturity was 3 or 4 years, rather than the assumed 2 years, the longtail tuna stock is probably currently being recruitment overfished.

Several management scenarios were explored to reduce fishing mortality, such as imposing minimum legal lengths of 80 cm, 90 cm and 100 cm TL. Unfortunately, these measures were not useful in reducing fishing mortality since the greatest impact on the population is likely to occur on immature fish before they reach Australian waters from a hypothesised nursery habitat in southeastern Asia. Juvenile fish are relatively rare in Australian waters, but comprise the majority of the commercial catch in southeastern Asia, which exceeds 100,000 t annually. Therefore, if longtail tuna in Australia comprise a single stock throughout the Indo-Pacific, there is a need to establish bilateral management strategies that will ensure the long-term sustainability of the entire stock.

In light of the results from the stock assessment and the literature review, a number of important recommendations are made:

- Urgent research is required to determine the stock structure of longtail tuna throughout its Indo-Pacific distribution. Two separate studies are recommended; i) a genetic study to determine the connectivity of longtail tuna throughout its distribution, and ii) a tagging study using electronic satellite tags to better

understand the movement dynamics, possible spawning locations of fish found in Australian waters, and post-release mortality from commercial and recreational fisheries.

- A quantitative biological study is required to determine maturity-at-age and fecundity-at-age relationships, and age and growth of longtail tuna younger than 2 years of age in Australian waters to reduce the current uncertainty in stock assessment results.
- A long-term monitoring program using time-location sampling incorporating a diary survey is required to collect a time series of catch and effort information that is representative of the recreational sector that will allow more sophisticated models to be used to assess the status of the population in future. Ideally, separate surveys for the boat-based and land-based components of the fishery should be conducted annually. However, given the high cost of surveys, catch and effort estimates obtained every 2–3 years may still be useful to assess the status of the longtail tuna population.

Keywords: Longtail tuna, northern bluefin tuna, resource allocation, recreational fishing survey design, avidity bias, fishing club, catch rate, online diary, internet, website, Time-Location Sampling, epidemiology, specialised fishery, hard-to-reach population.

2. ACKNOWLEDGEMENTS

This study was funded by the Fisheries Research and Development Corporation, CSIRO Marine and Atmospheric Research within the Wealth from Oceans Flagship, and from cash contributions by several recreational fishing bodies including Recfish Australia, Recfishing Research, the Australian National Sport Fishing Association, the Amateur Fisherman's Association of the Northern Territory, the Australian Fishing Trade Association, Sunfish Queensland, and the NSW Recreational Fishing Trust. The access point survey component of this work comprised part of a PhD research project by Mitchell Zischke funded by a University of Queensland Postgraduate Award.

We are grateful to Diana Reale for designing and building the longtail tuna website; Ken Pollock from Murdoch University for providing advice on survey design; Bryony Bennett, Meg Rive and Glen Paul from CSIRO and Tim Simpson from Bluewater Boats and Sportfishing magazine for assistance with communications and media releases; Ben Collins at ABC Radio Kimberly, Michael Mihajlov and Kurt Edwards from the Australian Land-based Angler Association for promoting the project; and Lea Crosswell for designing t-shirts used for incentives. We thank Elizabetta Morello from CSIRO for critically reviewing a draft of this report. Dan Bergamo, Kurt Edwards and Mark Bargaquast are thanked for providing the images for the front cover of this report.

We thank Industry and Investment NSW for use of their gamefish tagging program data and commercial catch data, and Fisheries Western Australia, Department of Regional Development, Primary Industries, Fisheries and Resources, Northern Territory, and Department of Employment, Economic Development & Innovation, Queensland for use of commercial catch statistics.

We are particularly grateful for the support of tackle store owners and managers who granted permission for surveys to be undertaken outside their stores, including Glenn at BCF Cannon Hill, Ben at the Tackle Shop Carseldine, Daryl at BCF Loganholme, Joe and Dean at Broome Bluewater Tackle World, Hal at Scarborough Bluewater Tackle World, Doug Burt at Doug Burt's Tackle World, Alan Griffiths at The Tackleshop Shellharbour, Geoff Murray at Gove Tackle and Outdoor, Managers at BCF Lawnton, The Tackle Warehouse, Budd's Bait and Tackle, BCF Darwin and Got One Darwin, Robert at Erskine's Tackle World, Peter at Tackle World Cairns.

The surveys undertaken in this project would not have been possible without the support and generosity of many people who volunteered their time to undertake surveys in the time-location sampling component of the project including Quinton Dell from CSIRO, Kevin Charteris of Bundaberg Sportfishing Club, Allan Petersen, Owen Li from James Cook University, Chris Hill at Tackleworld Kawana, Chris Lacey at Davo's Compleat Angler, Jenny Gates at Tackleworld Exmouth, Judy Lynne from Sunfish, and Cathy Bassett from Darwin Flyrodders.

Finally, we would like to thank all of the fishers who voluntarily provided their valuable fishing information to the project through online reporting, time-location sampling, and access point surveys.

3. BACKGROUND

Longtail tuna, *Thunnus tonggol* (Bleeker 1851), is the second smallest of eight *Thunnus* species and grows to a maximum size of 142 cm total length (TL) and 35.9 kg (Froese and Pauly, 2010). It is an economically important pelagic species inhabiting tropical and subtropical provinces of the Indo-Pacific region between 47° N and 33° S (Froese and Pauly, 2010). Their distribution is unique compared to other *Thunnus* species in that they nearly exclusively occupy neritic areas close to landmasses and are rarely found offshore (Yesaki, 1993). In Australia, longtail tuna are often incorrectly referred to as “northern bluefin tuna”, the common name for *Thunnus orientalis*, which grows to 684 kg and 4.58 m (Collette and Nauen, 1983).

As a result of their coastal distribution, longtail tuna are heavily exploited by small-scale commercial and artisanal fisheries in at least 17 countries throughout the Indo-Pacific. They are mostly targeted by purse seine, gillnet and trolling and comprise a significant portion of multi-species fisheries for small neritic tunas including mackerel tuna (*Euthynnus affinis*) and frigate tunas (*Auxis thazard* and *A. rochei*) (Yesaki, 1993). Thailand, Taiwan, Malaysia and Iran contribute most to reported landings that exceed 100,000 t per year (F.A.O., 2009). Since longtail tuna comprise important artisanal and subsistence fisheries in many countries, reported landings are likely to be significantly underestimated.

In Australia, longtail tuna are abundant in tropical and subtropical coastal waters but have been only lightly exploited by commercial fisheries with annual reported landings averaging around 20 t and not exceeding 138 t since the early 1980s (F.A.O., 2009). However, catches by Taiwanese gillnet fishers in the Arafura Sea between 1974–1986 demonstrated the potential for a longtail tuna fishery after landing up to 5500 t per year, primarily as an incidental catch when targeting sharks and narrow-barred Spanish mackerel (Stevens and Davenport, 1991).

Presently in Australia, longtail tuna are an important sport fish due to their size, fighting ability and because they can be targeted from small vessels in sheltered inshore waters and even from the shore. All 17 IGFA world gamefishing line class records for longtail tuna, including the all-tackle world record, have come from Australian waters, primarily along the east coast (I.G.F.A., 2008). The species has grown in popularity, where in recent years several annual catch and release tournaments have been established to solely target longtail tuna, particularly by saltwater fly fishers.

As a reflection of the importance of longtail tuna to recreational fisheries in Australia, the species was declared a ‘recreational-only’ species by the Commonwealth government in December 2006, with a quota of 70 t per year allocated to Commonwealth commercial fisheries. It is unknown what effect this management arrangement will have on the long-term sustainability of the longtail tuna stock(s) in Australia or its associated fisheries. Therefore, a comprehensive review of existing literature and data and a recreational catch survey was initiated to begin to help inform fisheries managers as to the importance of this species to recreational and commercial fisheries, the current gaps in knowledge of the species, and recommend possible management options.

4. NEED

In 2006 the Minister for Fisheries, Forestry and Conservation declared longtail tuna a 'recreational-only' species, in recognition of the importance of this inshore species as a recreationally-important sport fish. It is only recently that formal management arrangements have come into place for longtail tuna, to ensure there will be no future large-scale targeting of longtail tuna by commercial fisheries, but also to allow an incidental catch in multi-species commercial fisheries (e.g. shark and mackerel gillnet fisheries) that may have difficulty in eliminating longtail tuna captures due to the regions fished and the selectivity of the fishing gears.

Despite the new protection afforded to longtail tuna as a recreational-only species, very little is known of the species' basic biology, stock structure and catch by recreational and commercial fisheries to assess whether the new management measure promotes adequate sharing of the resource, or is appropriate to ensure the long-term sustainability of the species. It is important that the recreational sector demonstrates stewardship for this species, for which they are probably the primary extractive user group in Australia. Collection of information to underpin sustainable management is critical to work towards addressing these fundamental issues for longtail tuna.

5. Objectives

- 1) Collate available information on the biology, ecology, movements and commercial, recreational and artisanal catches of longtail tuna, particularly in Australia
- 2) Identify key knowledge gaps in relation to biology and catch data, especially in an Australian context, and recommend future data requirements to support management of longtail tuna in Australia
- 3) Develop and recommend methods for cost-effective collection of long-term recreational catch and effort data for longtail tuna in Australia

6. Literature Review

6.1 Distribution

Longtail tuna are distributed throughout the Indo-West Pacific region between 47° N and 33° S (Froese and Pauly, 2010). From northern Australia, Papua New Guinea and Indonesia and northwest through Malaysia and Thailand, the species has a continuous distribution to the northeast to southern Japan and to the northwest to Iran and the Red Sea (Figure 6.1). In Australia, longtail tuna are common around the northern half of the continent from Fremantle in Western Australia to Moreton Bay in Queensland. However, during the summer months on the east coast when the warm waters of the East Australian Current (EAC) are at their most southerly extent, longtail tuna can be found as far south as Twofold Bay, New South Wales (Serventy, 1942a). No definite seasonal movement has been documented along the West Australian coast (Serventy, 1956).

The distribution of longtail tuna is unique compared to other species in the *Thunnus* genus in that they nearly exclusively occupy neritic areas close to landmasses and are rarely found offshore (Yesaki, 1993). They also tend to avoid areas near the mouths of large estuaries with low salinity or high turbidity (Collette and Nauen, 1983).

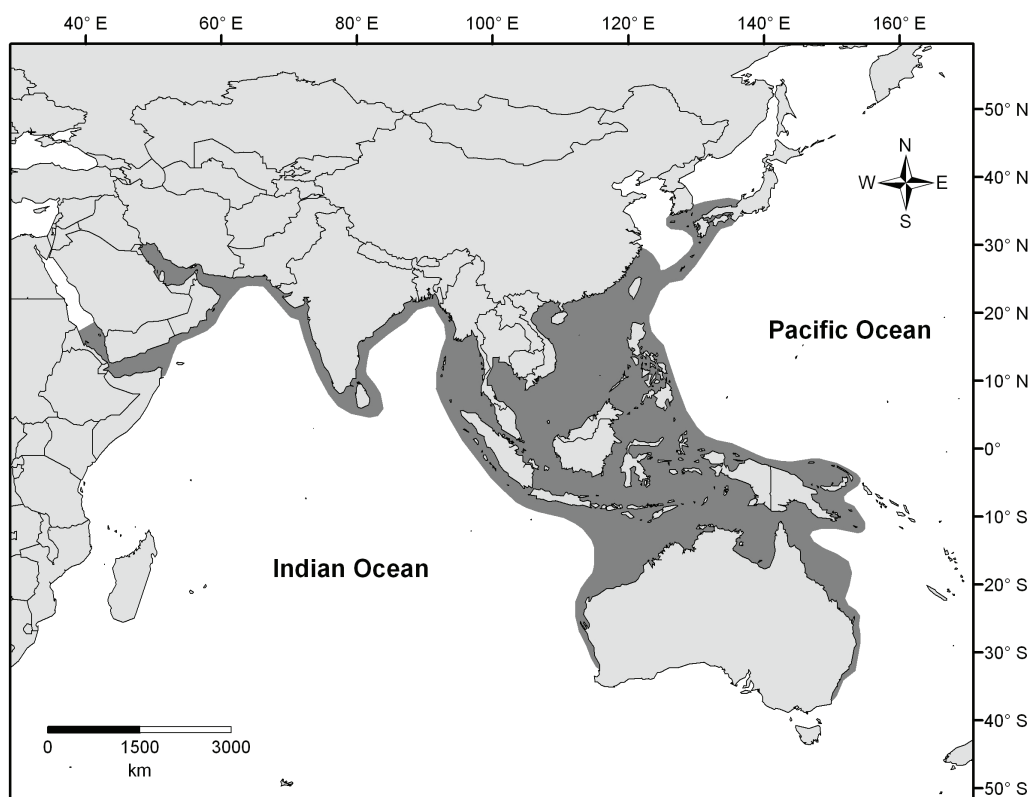


Figure 6.1: Map showing the worldwide distribution of longtail tuna, *Thunnus tonggol*.

6.2 Stock structure

There has been debate regarding the stock structure of longtail tuna throughout the Indo-Pacific region. Abdulhaleem (1989) found significant differences in the number of gill rakers in fish between Oman and India and suggests that this may be indicative of at least two separate stocks in the Indian Ocean. Serventy (1956) also suggested that separate stocks, and possibly even two sub-species, may exist in Australian waters based on the distinct difference in the size distributions of fish off the eastern, northern and western coasts of Australia. Wilson (1981) tested this hypothesis by using morphometrics and allozyme electrophoresis and found no differences between samples collected from Papua New Guinea, Gulf of Carpentaria, Moreton Bay (Qld) and Shark Bay (W.A.). However, he warned that his results need to be viewed with caution owing to small sample sizes from the latter three locations.

It is clear from length-frequency data reported in studies throughout the distribution of longtail tuna, that there is an obvious increase in fish size with increasing latitude. This appears to be most apparent in Australian waters, where several studies (Serventy, 1942a;1956; Wilson, 1981; Stevens and Davenport, 1991) have shown fish to be smallest in the Arafura Sea in northern Australia and gradually increasing in size with increasing latitude southward along both the east and west coasts. Very few small fish less than 40 cm fork length (FL) have been recorded from Australian waters, while fish of this size are abundant in southeast Asia and support large commercial fisheries. This suggests that there may be a southward ontogenetic migration from a more northern nursery ground, such as Thailand and Malaysia (see Yesaki, 1993). As a result, longtail tuna may exist as a single stock throughout southeastern Asia and Australia. However, considering the significant geographic barriers evident throughout the neritic distribution of the species, the possibility of separate stocks of longtail tuna being present throughout its geographical range cannot be discounted. In the absence of tagging data and reliable genetic analyses (i.e. using DNA), the extent of mixing of fish between countries or water masses remains unknown.

6.3 Reproduction

Sex ratio

Longtail tuna is a gonochoristic species and there is no evidence of sexual dimorphism in external morphology. In the few studies that have examined sex ratio (Klinmuang, 1978; Wilson, 1981; Yesaki, 1982; Griffiths et al., 2010), there has been no evidence of departure from the expected male:female ratio of 1:1. A bias toward males has been noted in the sex ratio of the larger size classes of several *Thunnus* species (Hurley et al., 1981; Wild et al., 1995; Schaefer, 1998; Gunn et al., 2008). Griffiths et al. (2010) found a (2:1) bias towards males for large fish (>100 cm FL) along the east coast of Australia, but speculated that this may be due to inadequate sampling of larger fish, rather than a true departure from the 1:1 sex ratio.

Length at maturity

Length-at-maturity has been determined in only a few studies, although most have reported the length at first maturity rather than the length at which 50% of the population is sexually mature (L_{50}), which is a more reliable estimate of maturity. Nonetheless, there seems to be a large difference between the length at first maturity of females between regions in the northern and southern hemisphere. In the waters off Thailand, Yesaki (1982) used macroscopic staging of gonads of nearly 800 fish to determine that the length at first maturity was 43 cm FL. In contrast, Cheunpan (1984) sampled 939 fish from the Gulf of Thailand and used a gonadosomatic index (GSI) to estimate L_{50} as being 40 cm FL.

In the waters of Australia and Papua New Guinea, macroscopic inspection of gonads by Wilson (1981) led to the conclusion that fish first matured at 51 cm FL and 60 cm FL in each respective region. In a recent study of the reproductive biology of longtail tuna in northern and eastern Australia using histological analysis, Griffiths (unpublished data) found that the smallest mature female was 57.8 cm FL. However, L_{50} could not be determined due to the capture of only one fish less than 55 cm FL. An attempt was made to estimate L_{50} using a less reliable method of determining the most abrupt increase in GSI values with increasing length, which suggested a L_{50} of 72 cm FL for males and 65 cm FL for females.

Spawning locations

The actual spawning location of longtail tuna is unknown throughout most of its worldwide distribution. However, based on the capture of ripe females and the presence of larvae, possible spawning grounds have been proposed for the outer neritic zone in the Gulf of Thailand (Yesaki, 1982), the western Sea of Japan and the East China Sea (Itoh et al., 1999). Furthermore, the presence of large numbers of juveniles <10 cm TL in these regions (Yesaki, 1982;1989b; Itoh et al., 1996) indicate they are nursery habitats and that spawning probably takes place nearby.

In Australia and Oceania, Wilson (1981) hypothesised that spawning may take place in the vicinity of Aru Island, Gulf of Papua, based on the presence of smaller size classes of fish in this region, compared to the east coast of Australia (see 'Stock structure'), and elevated water temperatures in northern waters (24–28°C) that are conducive for spawning among *Thunnus* species (Schaefer, 2001). However, this spawning hypothesis is questionable since no ripe females were captured during six years of monthly sampling. Furthermore, the smallest fish recorded in his study was 46 cm FL, which may be 1–2 years of age (see 'Age, growth and longevity'). The fact that longtail tuna <40 cm FL are relatively rare in Australian waters, suggests they probably spawn elsewhere.

A more recent reproductive study of longtail tuna provided evidence of possible spawning locations of longtail tuna in Australian waters (Griffiths, S.P. unpublished data). In this study, monthly sampling was undertaken over a 15-month period across a large region incorporating the Arafura Sea, Gulf of Carpentaria and the eastern Australian coast to central New South Wales. Histology revealed eight specimens

(57.8–82.5 cm FL) had spent ovaries (Stage VI) in waters offshore of the Edward and Holroyd rivers in the eastern Gulf of Carpentaria, confirming that spawning occurred nearby. A small number of ripe females (late Stage V) were also captured along the east coast of Australia, indicating that spawning may also take place in this region, although a specific spawning location could not be found.

Although Griffiths (unpublished data) confirmed that spawning occurs in northern Australia, the capture of only a small number of ripe or spent fish from a sample of nearly 497 mature fish from coastal waters suggests that the majority of longtail tuna probably spawn elsewhere. It is possible they may move to offshore waters to spawn, which has been suggested to occur in Malaysia (Yesaki, 1989a; Itoh et al., 1999). Alternatively, fish may move from Australian waters altogether. In the nearby waters of Papua New Guinea, Wilson (1981) found no ripe or well developed gonads in female longtail tuna during six years of sampling, again suggesting they probably spawn elsewhere. There is compelling evidence for a spawning location outside Australia, the main reason being that juveniles (<50 cm FL) are rarely encountered in Australian waters, whereas commercial fisheries in Malaysia and Thailand are primarily sustained by small juveniles (20–50 cm FL) (Yesaki, 1989a).

Spawning period

Several studies have investigated the timing of spawning of longtail tuna in a number of countries, primarily using a GSI or macroscopic staging of gonads. The common trend in these studies is that spawning occurs over a period of several months during the warmest period of the year in a particular region. However, there is an apparent difference in the frequency of spawning period between the northern and southern hemisphere.

Yesaki (1982) used macroscopic staging of gonads to determine that mature fish were most abundant in the outer neritic region in the waters off the west coast of Thailand during the beginning and end of the monsoonal period between January–April and August–September. Similarly, Cheunpan (1984) suggested the presence of two spawning peaks occurring slightly later in the year between March–May and July–December in the Gulf of Thailand.

In the southern hemisphere, there appears to be only one spawning peak in the waters of Australia and Papua New Guinea primarily during the austral spring and summer, although the spawning period slightly differed among studies. Serventy (1956) used macroscopic staging of gonads to suggest a spawning period of September–October in southeastern Australia. Wilson (1981) used macroscopic staging of gonads and a GSI and found that longtail tuna had a protracted reproductive period in Papua New Guinea between October–April. Similarly in northern and eastern Australia, a recent study (Griffiths et al., 2007) used a GSI to determine that longtail tuna have an extended spawning season between October–February.

Fecundity

Only three studies have investigated the fecundity of longtail tuna (Klinmuang, 1978; Wilson, 1981; Griffiths, S.P. unpublished data), although none of these studies estimated the frequency of spawning. Wilson (1981) estimated the fecundity of fish from Papua New Guinea. However, he was unable to capture ripe females and therefore, his batch fecundity estimates are probably underestimates. Nonetheless, he estimated that females between 75–98 cm FL produce between 768,000 and 1,900,000 oocytes per spawning.

In northern and eastern Australian waters, Griffiths (unpublished data) estimated the fecundity of 15 females with ripe gonads (Stage V). He found the total number of oocytes produced by individual fish (68.5–106.3 cm FL) ranged between 383,347 and 3,468,350, with the average batch fecundity being 1,352,760 (\pm SD 47,642) oocytes. This study also determined that there was a strong positive relationship between fecundity and fork length.

In the western Gulf of Thailand and off the east coast of Malaysia, Klinmuang (1978) examined the ovaries of four fish between 44–49 cm FL and estimated fecundity to be between 1.2–1.9 million oocytes.

6.4 Age, growth and longevity

Longtail tuna grow to a maximum weight of 35.9 kg and a total length of 142 cm (Froese and Pauly, 2010). A number of growth studies have been undertaken on longtail tuna although the vast majority have been conducted in countries where commercial longtail tuna fisheries are significant (e.g. Thailand, India, Malaysia, and Oman). Modal length progression of cohorts over time has been the primary method used to estimate growth (Table 6.1). Length-frequency analysis can be an unreliable method of determining growth, due to the influence of size selectivity of the sampling gears and frequency of sample collection, and is therefore not discussed here.

Three studies aged longtail tuna using a more accurate method of quantifying growth increments in otoliths. These were undertaken in the East China Sea (Itoh et al., 1999), the waters between northern Australia and Papua New Guinea (Wilson, 1981), and northern and eastern Australia (Griffiths et al., 2010). The former two studies estimated age by counting presumed daily increments and suggest that longtail tuna are fast-growing and short-lived. In contrast, Griffiths et al., (2010) counted both annual and daily growth increments and suggested that longtail tuna is slow-growing and long-lived.

Itoh et al. (1999) aged 33 small fish between 13–49 cm FL, and estimated L_{∞} and maximum age as 55 cm FL and 434 days, respectively, but this probably indicates inadequate sampling of the adult population. In contrast, Wilson (1981) aged 26 fish from a larger size range (45.3–110.9 cm FL), estimated an L_{∞} of 131.8 cm FL and found that the oldest fish was only 1700 days (4.7 years) old at 110.9 cm FL. In a similar region, Griffiths et al. (2010) was able to validate growth increments in otoliths using daily ageing and edge type analysis and estimated that longtail tuna can live for at least

18 years. This study obtained a similar estimate of L_{∞} (135.4 cm FL) as Wilson (1981), although the estimate of K (0.223 yr^{-1}) was nearly half that of Wilson (1981) suggesting the species has a slow growth rate.

Estimated length-at-age appears to vary markedly between studies using different estimation techniques and among regions. This is probably a result of very different maximum sizes of fish present in each study region or differences in the size selectivity of the sampling methods (i.e. gillnets). These factors would therefore affect estimates of L_{∞} and the instantaneous growth rate (K). A comparison of the growth curves and growth model parameter estimates in each study from various regions is provided in Figure 6.2 and Table 6.1, respectively.

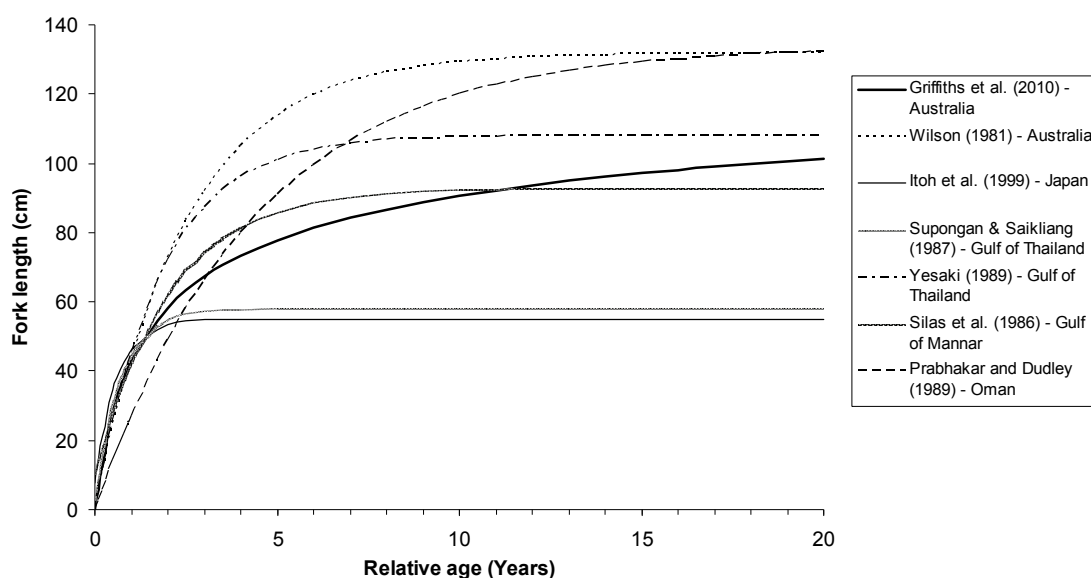


Figure 6.2: Length-at-age curves derived from ageing studies of longtail tuna (sexes combined) from various areas throughout the Indo-Pacific region. All curves follow the von Bertalanffy growth model except for Griffiths et al. (2010), which is a Schnute-Richards growth model.

Table 6.1: Summary of von Bertalanffy growth parameters, longevity and length-at-age (in cm) for longtail tuna estimated in studies around the world that have employed various analysis methods. Note that studies using length-frequency (LF) analysis estimate only relative age. ELEFAN represents Electronic Length Frequency Analysis.

Area	Author	Ageing method	Analysis type	von Bertalanffy growth parameters			Length-at-age					Longevity (Years)
				L_{∞}	K (yr^{-1})	t_0 (yr^{-1})	1	3	5			
Australia	Serventy (1956)	LF	Modal lengths	-	-	-	38	62	-	-	-	-
Australia	Griffiths et al. (2010)	Otoliths	Annual increments	135.4	0.233	-0.02	27	66	91	18.7	-	-
Papua New Guinea	Wilson (1981)	LF	Modal lengths	122.9	0.410	-0.032	42	87	107	-	-	-
Papua New Guinea	Wilson (1981)	Otoliths	Daily increments	131.8	0.395	-0.035	44	92	114	4.7	-	-
Japan	Itoh et al. (1999)	Otoliths	Daily increments	55.0	1.700	-0.089	46	-	-	-	1.2	-
Thailand	Chiampreecha (1978)	LF	Modal lengths	-	-	-	27	45	-	-	-	-
Thailand	Klimuang (1978)	LF	Modal lengths	-	-	-	31	-	-	-	-	-
Thailand	Yesaki (1982)	LF	Modal lengths	-	-	-	30	-	-	-	-	-
Thailand	Supongpan and Saikiang (1987)	LF	Modal lengths	58.2	1.44	-0.027	45	57	-	-	-	-
Thailand	Yesaki (1989b)	LF	Modal lengths	108.0	0.550	--	46	87	101	-	-	-
Malaysia	Chiampreecha (1978)	LF	Modal lengths	-	-	-	30	-	-	-	-	-
India	Silas et al. (1986)	LF	ELEFAN	93.0	0.490	-0.240	42	74	86	-	-	-
Oman	Prabhakar and Dudley (1989)	LF	ELEFAN	133.6	0.228	-	30	68	-	-	-	-

6.5 Feeding ecology

Few studies have quantitatively investigated the feeding ecology of longtail tuna. These studies were undertaken in Papua New Guinea, Malaysia, Australia, and India and show longtail tuna to be an opportunistic coastal epipelagic predator that mainly feed on small pelagic fishes, cephalopods, and a range of crustaceans. Yesaki (1987) observed two major feeding modes in longtail tuna. He noted that fish smaller than 70 cm form ripples on the surface when feeding in large schools on schooling small pelagic fishes, but they rarely leap from the water. In contrast, fish larger than 70 cm TL are less commonly observed as surface aggregations and feed as 'packs' of 15–20 fish, which attack their prey in arrow formation with fish being equidistant to each other. In these cases, some fish have been observed leaping from the water.

In the Gulf of Papua, Wilson (1981) examined the stomach contents of 26 troll-caught fish <70 cm FL and found them to feed mainly on small pelagic fish from the families Engraulidae and Scombridae, crustacean (Alima, Decapoda and Penaeidae) and miscellaneous cephalopods. In contrast, in the Gulf of Mannar, India, Silas (1967) reported that in the 40 fish caught by trolling, squids (Ommastrephidae) were the most important prey item, followed by crustaceans (stomatopods, mysids and megalopa) and a range of pelagic and demersal fishes representing families such as Engraulidae, Clupeidae, Syngnathidae, Lutjanidae and Scombridae.

Perhaps the most comprehensive study of the feeding ecology of longtail tuna, was the examination of stomach contents in 497 fish from northern and eastern Australia collected monthly over a period of 15 months (Griffiths et al., 2007). This study described the spatial and temporal variation in diet composition, estimated daily ration for three size classes of fish, and estimated the annual consumption of individual prey taxa, particularly *Penaeus* prawns targeted in the study region by Australia's valuable Northern Prawn Fishery (NPF). The study recorded 101 prey taxa, with most common taxa (in terms of biomass) being: small pelagic fishes (Engraulidae, Clupeidae, Scombridae, Belonidae and Hemiramphidae), demersal fishes (Carangidae, Leiognathidae and Sillaginidae), cephalopods (Teuthoidea and *Sepia* spp.) and crustaceans (Portunidae, Penaeidae and Squillidae). They showed feeding intensity to have an inverse relationship with reproductive activity, indicating a possible energy investment for gonad development. Daily ration, averaged across all fish sizes, was estimated to be 2.36 % body weight per day. Total prey consumption in the Gulf of Carpentaria was estimated to be 148,178 t yr⁻¹, which included around 600 t yr⁻¹ of commercially-important *Penaeus* prawns. This was equivalent to 11% of the annual commercial catch in the NPF in 2005. The study demonstrated the important ecological role longtail tuna play in Australian neritic ecosystems.

Although not comprehensive, Serventy (1942a;1956) provides several interesting anecdotal accounts of the stomach contents of a small number of longtail tuna from various regions within the entire distribution of the species in Australia, extending from Port Hacking, NSW to Shark Bay, Western Australia. Serventy (1956) described the diet of 25 large fish (mean length 93.5 cm TL) captured with a beach seine in Port Hacking and found 234 pilchards (*Sardinops neopilchardus*), 2 blue mackerel (*Scomber australasicus*), 2 scad (*Trachurus declivis*), 1 leatherjacket, and 1 squid. The diet of a 50

1b (26.7 kg) specimen taken from Port Stephens, NSW, consisted of “the post-larvae of a species of shore crab and a little boxfish, the young of *Ostracion diaphanum*” and “a lot of small leatherjackets...”

In Queensland waters, Serventy (1942a) found longtail tuna to consume longtom (*Tylosurus terebra*), garfish (Hemiramphidae), and squid (Sepioteuthis). He found that the diet of longtail tuna was more diverse in northern Australian waters containing “...flying fish, anchovies and other small clupeoids...with leatherjackets common. Crustacea figure predominately and cephalopods also rate high” (Serventy, 1956).

In Western Australian waters around Dirk Hartog and Bernier Islands, longtail tuna were found to primarily consume anchovy (*Engraulis australis*) and herring (*Harengula punctata*) (Serventy, 1942). Serventy (1956) also recorded leatherjackets, garfish, northern mackerel (*Rastrelliger kanagurta*), mullet (*Mugil compressa*), flying fish, silver biddy (*Gerres ovatus*), and various plectognaths. Interestingly, Serventy (1956) also reported that “Crustacea, particularly stomatopod larvae and prawns, are commonly eaten. Cephalopods are also frequently found...”. A detailed account was given by Serventy (1956) of the diet of a 26 lb (11.8 kg) specimen taken from Shark Bay, W.A. consisting of: 1 garfish (28 cm TL), 3 *Gerres ovatus* (12.6, 11.2 and 8.0 cm), 2 squid (5.6 and 12.5 cm), 8 stinkfish (*Calliurichthys* sp., 9.7–14.3 mm), 1 flathead (*Suggrundus parilis*) (10 cm), 18 anchovies (Engraulidae, 3.7–8.4 cm), 5 gobies (Gobiidae sp. A and sp. B, 3.5–5.7 cm), 1 parrotfish (*Coris auricularis*, 12.5 cm), 1 herring (*Clupalosa lippa*, 8.8 cm) and 1 clingfish (*Lepadichthys sandracatus*, 2.9 cm).

6.6 Movement

Very little information is available on the movements of longtail tuna anywhere throughout its global distribution. The low commercial value of longtail tuna in Australia is the primary reason for the lack of a dedicated tagging program, and as a result, little is known of their movements in Australian waters. However, two sources of information exist for movements of longtail tuna that are relevant to Australian waters. The first is a tagging study initiated by the Papua New Guinea Department of Agriculture, Stock and Fisheries (Wilson, 1981). The second is Industry and Investment NSW’s Gamefish Tagging Program (GTP), which relies on recreational fishers to voluntarily tag gamefish species.

Wilson (1981) recaptured 25 of 414 fish tagged over a two-year period (1974–1975) in the Gulf of Papua, PNG. All recaptures were made within the Gulf and showed limited movements over the 76–103 days that fish were at liberty.

The GTP has recapture information for 55 of the 1240 longtail tuna tagged since 1974. The movement data reveals that the species can move large distances in short periods (Figure 6.3). For example, the fish moving the longest distance was tagged in Moreton Bay and was recaptured approximately 600 km to the south only 24 days later. The tagging data reveals that there may be a seasonal movement of fish with most fish that moved south into NSW waters were recaptured between March and May.

Interestingly, the data also reveals that movement of fish tagged at some locations, particularly Moreton Bay and Hervey Bay, can be very limited. For example, of the 36 fish recaptured after being tagged in Moreton Bay, only 4 fish were recaptured outside of the bay, despite being at liberty for up to 3833 days. This may either reflect permanent residency within the bay or that the region is an annual visiting site during their reputed southward movements during summer and autumn (see Serventy, 1956).

A small number of longtail tuna have been tagged in other tagging programs. A total of 40 longtail tuna were tagged as part of the SUNTAG tagging program, but no recaptures have been recorded (Infotish Services, unpublished data). Opportunistic tagging of 75 small longtail tuna (52–58 cm FL) was undertaken by the Secretariat of the Pacific Community (SPC) on 17/3/1991 in coastal waters off Indonesia (02.29°S, 131.01°E), but no recaptures have been reported (Kaltongga, 1998).

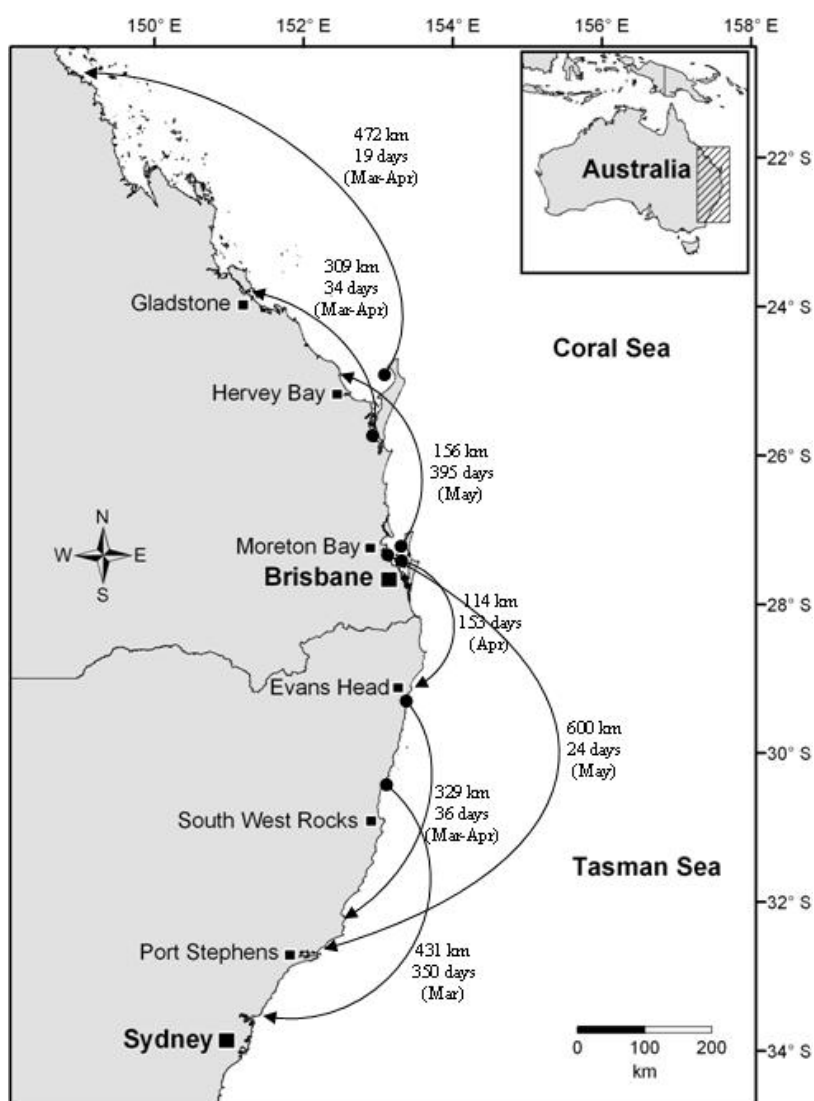


Figure 6.3: Release and recapture locations of seven tagged longtail tuna that showed the largest movements among 55 recaptured fish from Industry and Investment NSW's Gamefish Tagging Program. Number of days and time of year that each tagged fish was at liberty is shown adjacent to their movement path.

Release information from the GTP tagging data can be used to glean information on fish movement by examining the number of tagged fish over an annual period, assuming that tagging effort remains constant between years. These tagging data reveal that longtail tuna are present year-round in northern Australia but their abundance dramatically increases during the ‘dry’ season from April to August (Figure 6.4). On the east coast, NSW commercial catches suggest that longtail tuna are most abundant from July–September with a smaller peak from January to April (Figure 6.5). These peaks may indicate a summer southward movement followed by a winter northward movement as has been suggested by Serventy (1956).

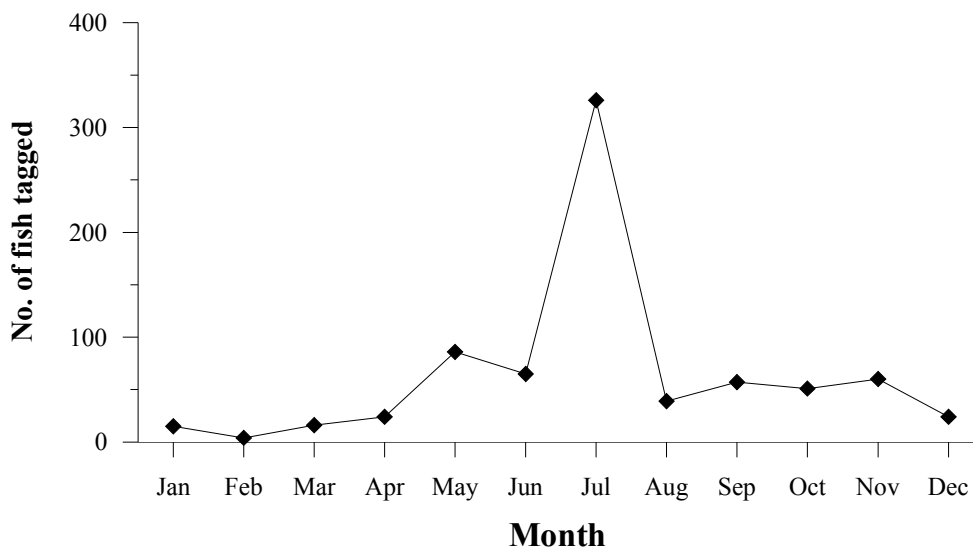


Figure 6.4: Total number of longtail tuna tagged during each calendar month (pooled for 1984–2003) in the Gulf of Carpentaria by recreational fishers for Industry and Investment NSW’s Gamefish Tagging Program.

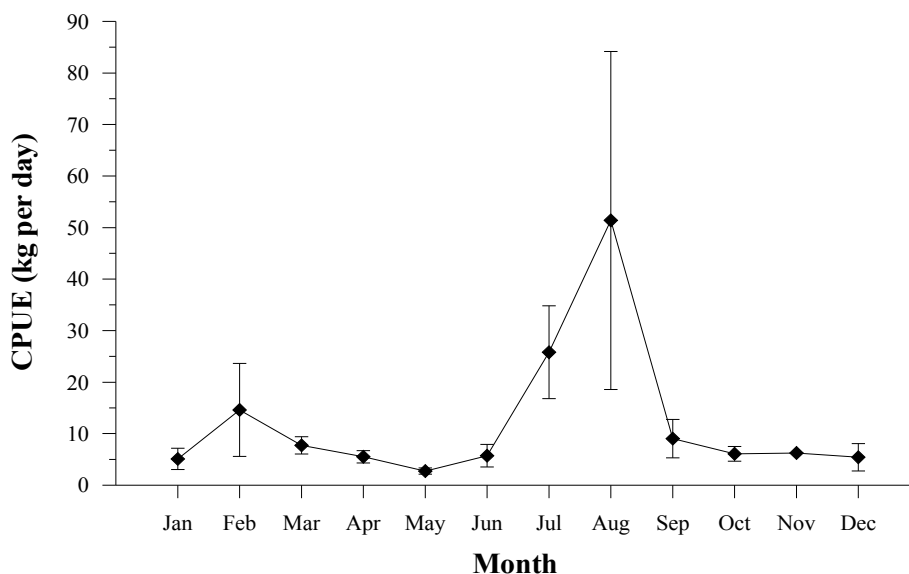


Figure 6.5: Mean monthly CPUE (± SE) of longtail tuna by NSW commercial fishers pooled for all methods and years for 1985–2007.

6.7 Fisheries

6.7.1 Commercial fisheries

Global catches

Longtail tuna is an important resource that is heavily exploited in mainly underdeveloped countries bordering the central, southwest and western Pacific Ocean and the eastern and western Indian Ocean. Although longtail tuna can be found in a range of water temperatures between 16°C and 30°C (Itoh et al., 1996), the optimal water temperature range for the species has been suggested to be 24–25.6°C (Mohri et al., 2005; Mohri et al., 2008). Two major fisheries exist for longtail tuna, which also interact with fisheries for other smaller neritic tunas, such as mackerel tuna (*Euthynnus affinis*) and frigate tunas (*Auxis thazard* and *A. rochei*). The first is in the South China Sea where longtail are targeted by purse seine, gillnet and trolling in Malaysia, Thailand, Taiwan and Indonesia. The second major fishery for longtail exists in a number of countries bordering the North Arabian Sea, including Oman, Iran, Pakistan and the United Arab Emirates, where fish are mainly targeted by gillnet and, to a lesser extent, by trolling (Yesaki, 1989a). Reasonable catches have also been made in the waters around southern Japan, although the catch of longtail appears to be incidental when targeting by juvenile Pacific bluefin tuna (*Thunnus orientalis*) (Nakamura, 1969; Itoh et al., 1996).

Indonesia and the United Arab Emirates were the first countries in FAO records to report the commercial capture of longtail tuna, with the total reported catch being less than 1000 t in 1950. Since 1985, 17 countries have reported annual landings of longtail tuna, taking a combined catch of over 100,000 t per year, which has continued to increase to in excess of 200,000 t per year after 2003 and reaching 248,000 t in 2007 (Figure 6.6). Annual reported catches have been variable for most countries, although over the past decade Thailand, Indonesia, Malaysia and Iran have contributed most to the global catch (Figure 6.6) with the majority of fish being less than 50 cm FL (Kamarruddin and Raja Bidin, 1991; Raja Hassan and Rumpet, 1993; Chullasorn, 1996). It is important to note that there is significant underreporting of longtail tuna catches in underdeveloped countries, especially where the species is targeted in artisanal fisheries. Therefore, the catch statistics presented here are likely to be significant underestimates.

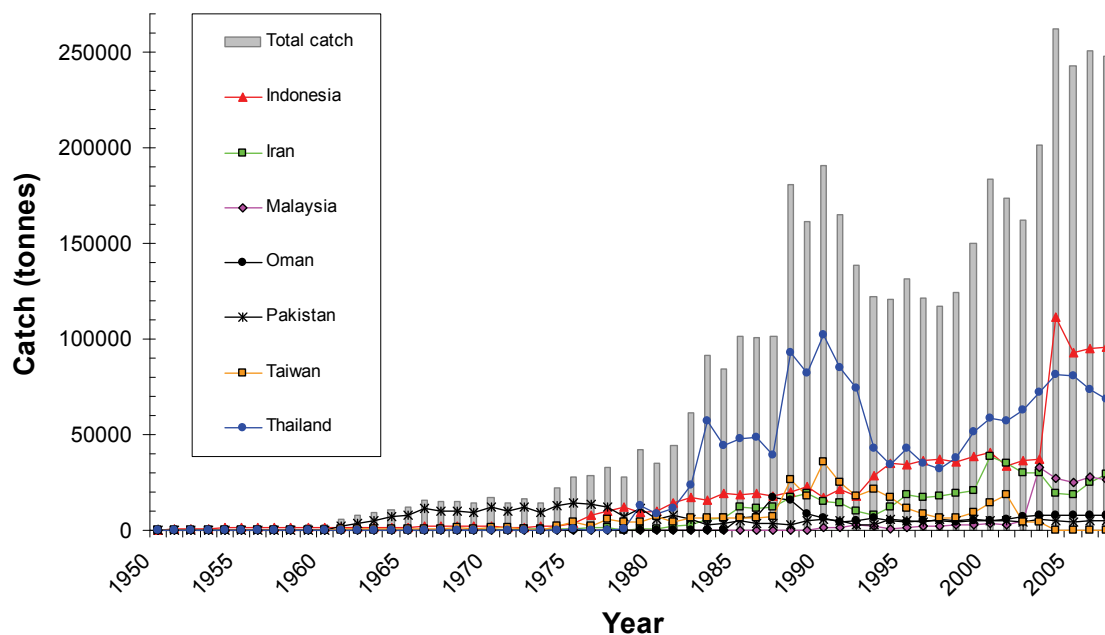


Figure 6.6: Annual global catches of longtail tuna pooled for all countries and gears for the years 1950–2007 (F.A.O., 2009). Catch trends from countries having the highest catches are shown.

Australian catches

In Australia, longtail tuna have been fished since at least 1897 (Serventy, 1956). Annual combined catches for Australian fisheries between 1950–2007 have ranged between 0–138 t, but have averaged about 34 t since 1974 (F.A.O., 2009). Longtail tuna have not been a primary target species of any state or Commonwealth fishery but they are occasionally caught in the Western Tuna and Billfish Fishery (WTBF) and the Eastern Tuna and Billfish Fishery (ETBF) by rod and line (Australian Fisheries Management Authority, unpublished logbook data). In the WTBF, annual catches varied considerably between 1–32 t. The peak in catches occurred in 1998 (32 t) but has steadily declined to 7 t in 2008 (Figure 6.7). In the ETBF, catches have been far more sporadic being less than 1 t in most years, apart from 2000 (3 t), 2001 (24 t) and 2008 (2 t) (Figure 6.7).

Lower catches in Australia compared to other countries that commercially target longtail tuna certainly does not indicate that populations are smaller in Australia. Catches by Taiwanese gillnet fishers operating under a bilateral agreement in the Australian Fishing Zone (AFZ) off northern Australia between 1974–1986 ranged between 200–2000 t per year whilst primarily targeting sharks and narrow-barred Spanish mackerel (Stevens and Davenport, 1991). Longtail tuna are currently captured in reasonable numbers in northern Australia, such as the Queensland offshore gillnet fishery (N9). However, in this fishery they are generally a discarded bycatch due to their relatively low market value and a bycatch limit of 10 fish per trip stipulated under the Offshore Constitutional Settlement agreement between state and Commonwealth fisheries in Australia.

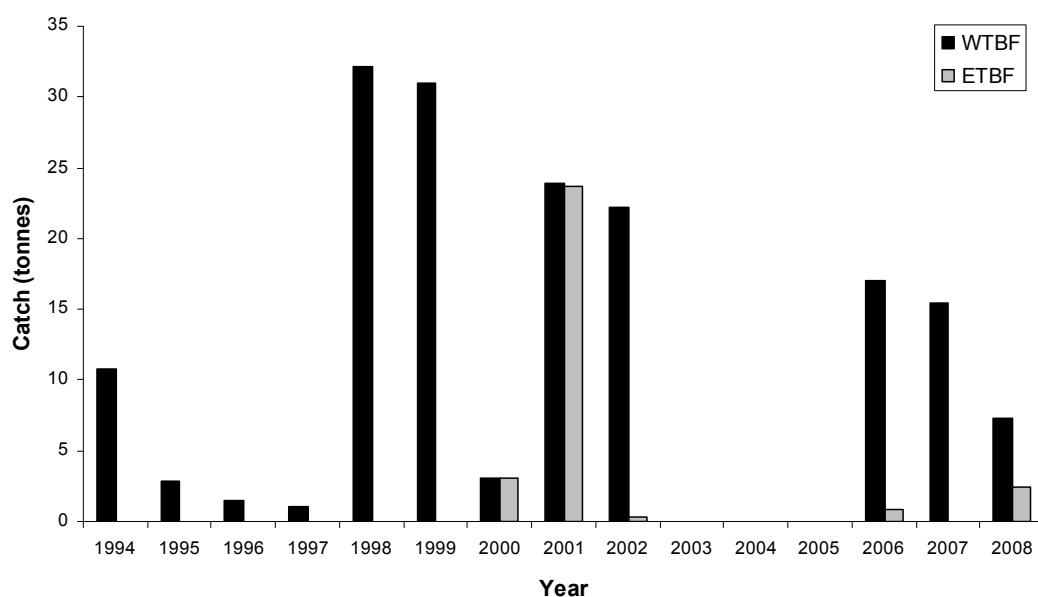


Figure 6.7: Annual catches (landed and discarded) of longtail tuna reported in logbooks for the Commonwealth-managed Western Tuna and Billfish Fishery (WTBF) and the Eastern Tuna and Billfish Fishery (ETBF) for 1994–2008. Note that data were not available for 2003–2005.

State catches

Annual reported commercial catches of longtail tuna were available from Qld, NSW, and WA. Tuna catches from NT are reported as “Tuna, General”, which may comprise a number of species, although the majority of the catch is likely to be longtail tuna. The combined catch of longtail tuna by state fisheries for 1994–2008 ranged between 1–35 t. Peaks in catches occurred in 1991 (25 t), 1995 (20 t) and 2004 (35 t), with Western Australia contributing nearly 32 t to the 36 t total catch in 2004 (Figure 6.8).

There were no obvious trends in the annual catches of any individual states, with catches varying markedly over the periods for which data were available in each state. This variation may be attributed to a range of factors including changes in local availability, shifts in effort, changes in gear restrictions and market drivers. The annual catch was generally less than 10 t in each state fishery. In NSW, catches ranged between 0 t and 10 t with the most consistent catches of 2–7 t for the years 1997–2001 (Figure 6.8). After this time catches have remained below 1 t. Despite longtail tuna being abundant in Qld waters, annual catches were by far the lowest in this state ranging between 0.1 t and 4.2 t. However, catches have noticeably increased from 0.6 t to 4.2 t over the period 2002–2005 (Figure 6.8). Catch data from WA were only available from 1999 to 2005, but showed a dramatic increase from 0.1 t to 32 t (Figure 6.8). If it can be assumed the “Tuna, general” catch category in the NT commercial catch data is primarily longtail tuna, catches in this state are the most consistent of all states, averaging around 6 t since 1985 (Figure 6.8).

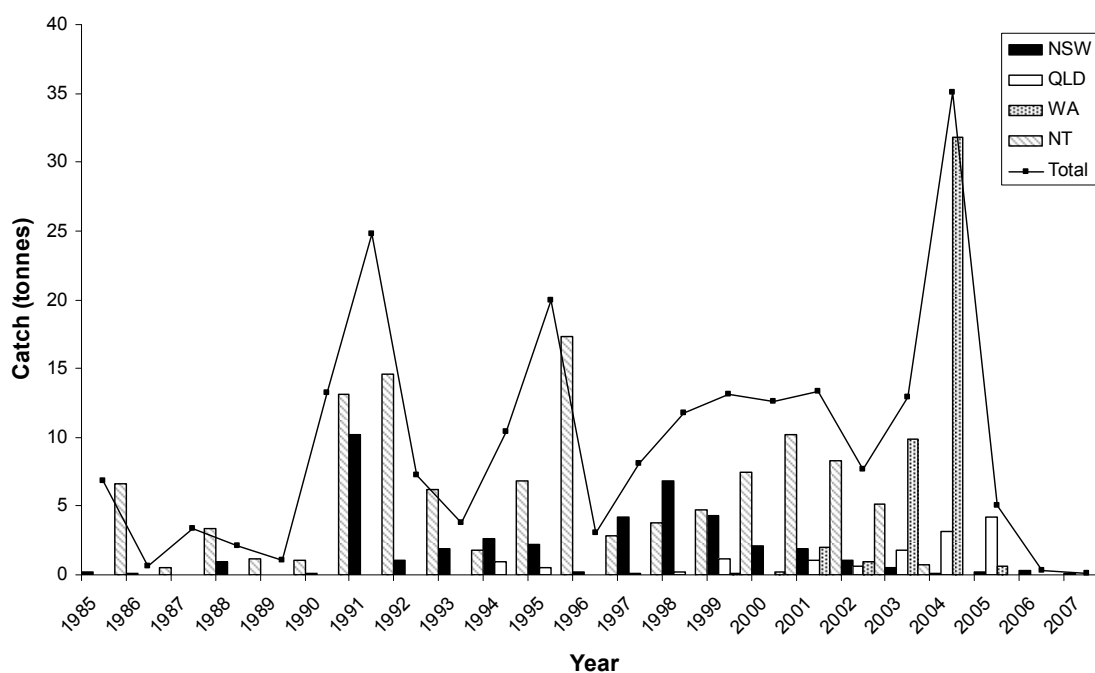


Figure 6.8: Annual catches of longtail tuna reported in logbooks for 1985–2007 in state-managed fisheries in New South Wales (NSW), Queensland (QLD), Western Australia (WA) and Northern Territory (NT), and the Commonwealth-managed Western Tuna and Billfish Fishery (WTBF) and the Eastern Tuna and Billfish Fishery (ETBF). Note that years for which data were available differ between states.

6.7.2 Recreational fisheries

In Australia, longtail tuna are valuable to recreational fisheries as they are highly regarded for their relatively large size and fighting ability, and because they can be targeted from small boats in relatively sheltered inshore waters. They are a particularly important target species for saltwater fly fishers in northern Australia and southeastern Queensland, and in recent years catch and release competitions have been established to target longtail tuna.

Very few sources of data exist for the recreational catch of longtail tuna. Several comprehensive surveys of the recreational catch of boat-based anglers have been undertaken around Australia (e.g. Steffe et al., 1996; Sumner et al., 2002; Lowry and Murphy, 2003) none of which have recorded longtail tuna. However, longtail tuna may have been recorded in these surveys but reported in broader taxonomic categories such as “tunas”. The only quantitative survey of recreational anglers that explicitly includes longtail tuna was for the land-based gamefish fishery along eastern Australia (Griffiths, S.P. unpublished data). A total of 66 longtail tuna were recorded in angler diaries and on-site roving creel surveys in 2006–2008. Catch rates were found to be very low, with an angler catching one longtail tuna for every 62.5 hours of effort expended ($0.016 \text{ fish hr}^{-1}$).

7. NATIONAL LONGTAIL TUNA RECREATIONAL CATCH SURVEY

7.1 Introduction

Longtail tuna (*Thunnus tonggol*) is a recreationally important pelagic sport fish in the northern half of Australia from Perth, W.A. to Eden, N.S.W. The species' importance to recreational fishers in Australia was formally recognised in 2006 by their declaration as a 'recreational-only' species by the Commonwealth Government. In spite of their apparent importance to the recreational sector, very little is known about the extent of targeting, demographic profiles of fishers targeting the species, spatial distribution of the fishery, catch rates, size composition and ultimately, the total recreational catch of longtail tuna. In order for fishery managers to ensure the longtail tuna population remains biologically sustainable in the long-term, detailed catch information is required to support management strategies.

There are very few recreational-only species in Australia, and the data requirements to support the ongoing management of these species are poorly known. Therefore, the aim of the present research was to attempt to develop methods to obtain representative data from fishers within the longtail tuna recreational fishery and obtain first order estimates of the catch. The importance for the recreational sector to demonstrate stewardship for this species was taken into account, and therefore a concerted effort was made to develop cost-effective methods that may be used in a long-term monitoring program, with a view to the program possibly being managed by recreational fishing organisations.

Specialist recreational fishers who target sport and game fish such as longtail tuna represent a very small minority of the general recreational fishing community. However, these fishers are likely to account for the vast majority of the total recreational catch of longtail tuna. Therefore, it is essential that these fishers be adequately sampled in surveys for estimating the total recreational catch. Unfortunately, in the absence of a complete sampling frame (e.g. a list of licence fishers) and the rarity of these fishers within the general fishing community, it is too costly to employ traditional survey designs such as general population telephone surveys to specifically intercept longtail tuna fishers within the overall community (Essig and Holliday, 1991; Teisl and Boyle, 1997; Henry and Lyle, 2003). Irrespective of expense, such surveys rarely yield a random sample from a population due to non-coverage of households and persons without landline telephones, non-response and non-contact issues (Pollock et al., 1994; Lyle et al., 2002), and an increasing refusal rate due to telemarketing saturation (N.R.C., 2006).

Given the difficulties in cost-effectively accessing a representative sample of fishers who target or incidentally catch longtail tuna, we sought to test two innovative sampling methods—online diaries and 'time-location sampling'—and compare these with a traditional access point survey to form the basis of a long-term recreational fishing monitoring program for longtail tuna in Australia.

7.2 Methods

7.2.1 Online diary

In recent years there has been development of online tools for inexpensive monitoring of recreational fishing catch and effort data across large spatial scales. In Australia, an online recreational fishing logbook system (OLFISH Web Data Logger – <http://www.olfish-data-logger.com>) has been used to collect recreational catch and effort data. Online systems have the flexibility to record detailed information on various aspects of recreational fishing, which can allow the collection of higher resolution data compared to other methods such as phone surveys where recall bias can be a problem, and where interview times are minimised to ensure each respondent completes the entire survey.

Although simple to administer and inexpensive, the major disadvantage of passive online reporting methods is that participation is voluntary and data is self-reported. These issues may introduce several types of biases, particularly avidity, volunteerism, prestige and rounding bias. Furthermore, fishers require access to a computer and the internet, so this may introduce other biases. However, with increasing use of computers and the internet in the wider community, online reporting may be an inexpensive and rapid means to collect a large amount of data across large spatial scales.

Online diaries can cost-effectively gather catch and effort data from recreational fishers who target longtail tuna in Australia. Unfortunately, this method cannot provide a direct estimate of population size in order to expand sample estimates to estimate the total catch of particular species. This is because the population from which the volunteers are derived, is unknown. However, it is important to acknowledge that this method may be used to provide an index of catch per unit effort (CPUE) to monitor longtail tuna populations in the long-term if identified biases can be taken into account and corrected.

To test online diaries as a sampling method, a website was established (www.longtailtuna.com.au) where fishers could directly enter their data for individual sport fishing trips undertaken in discrete geographic regions for the previous twelve months. Fishers had the option of i) remaining anonymous or ii) registering with their email address and offered the incentive of obtaining a single entry in a monthly draw for limited edition longtail tuna t-shirts for each fishing trip they reported. The website was extensively promoted nationally through various media channels including radio interviews, magazine, newspaper and website articles, and posts on popular internet fishing forums (Appendix 3).

Online diary database and website structure

The website was written in C#, using the ASP.NET MVC Libraries, and information entered on the website was automatically entered into a MySQL database hosted on an IIS 6.0 Web Server owned by CSIRO. The underlying database design is shown in Figure 7.1.

Fishers were asked to report information on individual fishing trips including fishing location, effort, numbers and sizes of longtail tuna caught and/or released (Figure 7.2). The website also served as an educational tool, where up-to-date information on longtail tuna was made available, including global commercial catches, age and growth, reproduction, feeding ecology, habitat preferences, and movement (Figure 7.3).

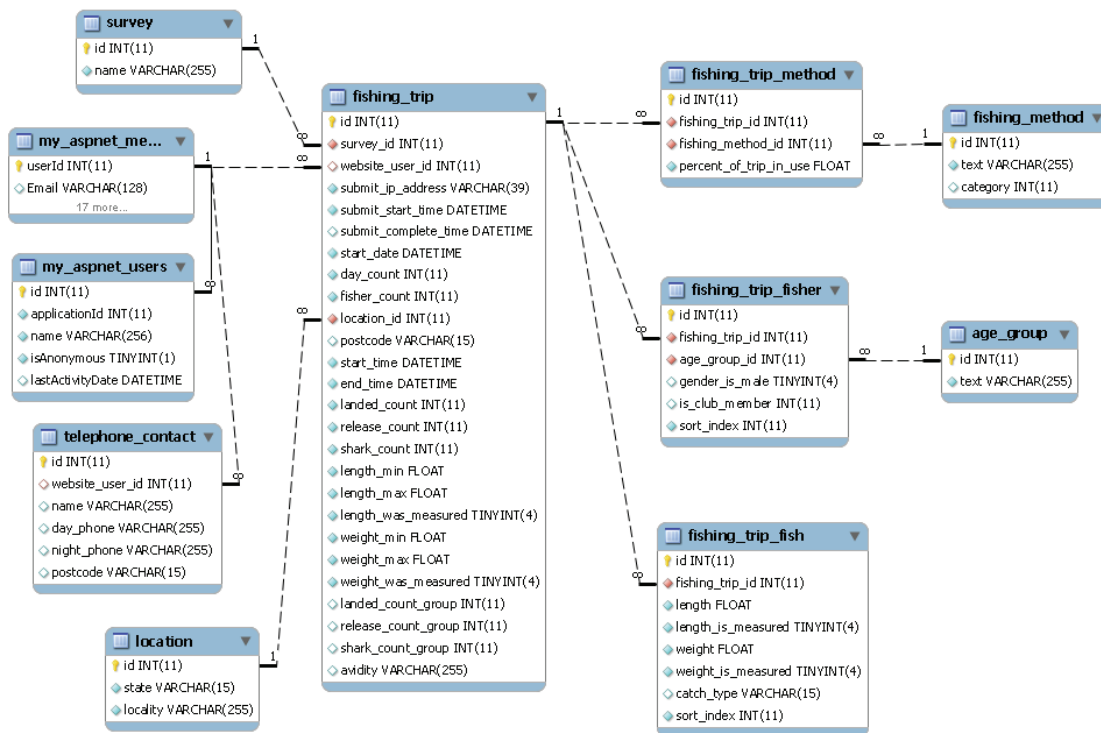


Figure 7.1: The MySQL database structure and relationships between data tables for the longtail tuna website, where fishers could enter information for individual fishing trips.

Step 1 - Enter Your Fishing Trip Details

Trip Details
All fields except postcode are required

Start date: What date did your trip begin on?

Number of days: How many days did your trip last for?

Start time: The time of day you started fishing or searching for Longtail Tuna

End time: The time of day you stopped fishing for Longtail Tuna

Number of fishers: How many people participated in this trip?

State: Please select an option

Location: Please select a state

Postcode of fishing location: Additional information used for economic surveys.

Your fishing experience:
In the last 12 months, how many days did you fish in a manner where it was possible to catch a longtail tuna?
 Please select an option

Step 2 - Enter information about the people on the fishing trip

Person	Age Group (Required)	Gender	Holds Fishing Club Membership?
YOU:	-- Please select an option --	-- Please select an option --	-- Please select an option --
Other Fisher 1:	-- Please select an option --	-- Please select an option --	-- Please select an option --
Other Fisher 2:	-- Please select an option --	-- Please select an option --	-- Please select an option --

Step 3 - Enter information about the fishing methods you used on this fishing trip

You must enter a percentage of time for at least one method. If you used more than one method, then please enter the percentage of time each one was used; these may add up to more than 100% if multiple methods were used at the same time.

Fishing method:	Percentage of trip that this method was used:
Boat-based - dead-bait	<input type="text"/> %
Boat-based - fly fishing	<input type="text"/> %
Boat-based - live bait	<input type="text"/> %
Boat-based - lure casting	<input type="text"/> %
Boat-based - trolling (bait)	<input type="text"/> %
Boat-based - trolling (lure)	<input type="text"/> %
Land-based - dead bait	<input type="text"/> %
Land-based - fly fishing	<input type="text"/> %
Land-based - live bait	<input type="text"/> %
Land-based - lure casting	<input type="text"/> %
Spearfishing	<input type="text"/> %
Other	<input type="text"/> %

Step 4 - Enter information about your Longtail Tuna catch.

	Number of Longtail Tuna caught and kept:	Number caught and then released alive:	Number taken by sharks before capture:
Your personal catch (required):	<input type="text"/>	<input type="text"/>	<input type="text"/>
The combined catch for everyone on your trip (optional):	<input type="text"/>	<input type="text"/>	<input type="text"/>

Step 5 - Enter weights and lengths for the fish that you caught personally

Either provide a length and weight range for all your fish

Or enter the length and weight of each individual fish

Individual Fish	Total Length (cm)	Weight (kg)
0	<input type="text"/> Measured	<input type="text"/> Measured
	<input type="text"/> Estimated	<input type="text"/> Estimated
3 Kept Fish	<input type="text"/> Measured	<input type="text"/> Measured
	<input type="text"/> Estimated	<input type="text"/> Estimated
0	<input type="text"/> Measured	<input type="text"/> Measured
	<input type="text"/> Estimated	<input type="text"/> Estimated

Congratulations!

You have successfully completed your trip details for the trip to [Norfolk Island, NSW](#). Your data is safely stored and completely confidential.

- [Report another trip](#)
- [View your previously reported trips](#)
- [Get up-to-date Research Results](#)
- [Make a comment or suggestion about this website](#)
- [Tell us your observations about longtail Tuna](#)

Figure 7.2: Online diary forms used in the national longtail tuna survey.

NATIONAL longtail tuna SURVEY

Welcome | [Home](#) | [Report Your Fishing Trip](#) | [View Your Saved Trip Reports](#) | [Learn about Longtail Tuna](#) | [How your data will be used](#) | [Links](#)

At a glance

- Second smallest species of the 'true' tunas (i.e. the *Thunnus* genus) growing to a maximum total length of 142 cm and weight of 35.6 kg
- Longtail tuna is unique compared to other tunas, they have a narrow coastal distribution in tropical and temperate waters of the Indo-Pacific region
- The only species of the 'true' tunas (the *Thunnus* genus) that lack a swim bladder
- Often incorrectly called "Northern bluefin tuna", which is the official common name for *Thunnus thynnus*, confined to the Atlantic Ocean that grows to 684 kg

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- > [Sustainable management](#)
- > [Identification](#)
- > [Fisheries](#)
- > [Determining age](#)
- > [How old is your tuna?](#)
- > [Reproduction](#)
- > [Diet and prey](#)
- > [Tracking movements](#)
- > [Recreational Only species](#)

Map source: [www.fishbase.org](#)

Photo: [Tim Simpson](#)

Every month registered fishers reporting their catch will go into a draw to win an exclusive longtail tuna t-shirt!

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Correctly identifying a longtail tuna

Longtail tuna are among the easiest of the tunas to identify. The key diagnostic features are:

1. Do not use yellow colouration of fins as an identification since this occurs in most tunas
2. Maximum size 130 cm fork length, or 142 cm total length
3. Long slender tail, body deepest near middle of first dorsal fin base
4. Colouration dark blue to black on upper 1/3 of the body and silvery white on the lower 2/3, with colourless elongate oval spots arranged in horizontal rows, particularly evident when fresh
5. Second dorsal fin <20% of fork length and higher than first dorsal
6. Pectoral fins short, 22-31% of fork length in fish <60 cm and 16-22% in larger individuals
7. Swimbladder absent or rudimentary
8. Ventral surface of liver not striated

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Longtail tuna fisheries

- Primarily caught in small coastal fisheries in at least 17 countries
- Targeted by purse-seine, gillnet and trolling
- 247,991 t catch in 2007, but reported landings are likely to be gross underestimates
- Catches in Australia average 34 t since 1977. Despite common belief, longtail tuna have never supported significant commercial fisheries

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Data source: [FAO](#)

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How old is the longtail tuna I caught?

Without inspecting a fish's otoliths, determining an accurate age of a fish based on its length or weight is difficult. In the same way the age of a human can vary at a particular height, a fish's age can vary too. However, if a large number of fish are aged across the entire size range of the population, a growth model can be fit to the data to produce the average age at a particular length. Below is the best available growth curve for longtail tuna in Australian waters based on age estimates from 461 fish ranging from 25 cm FL (0.2 kg) to 125 cm FL (28.9 kg).

Further reading:

Griffiths, S.P., Fry, G.C., Manson, F.J. and Lou, D.C. (2009). Age and growth of longtail tuna, *Thunnus tonggol*, in tropical and temperate waters of the central Indo-Pacific region. *ICES Journal of Marine Science* 67(1): 125-134.

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What do longtail tuna eat, when do they eat, and how much?

Similar to most tunas, longtail tuna are an opportunistic predator, consuming a wide variety of prey items including various fish, squid, and small crustaceans. Their preferred prey is small pelagic fish, such as anchovies and sardines. However, the diet of longtail changes as they grow, with the diet of small fish that primarily consume anchovies gradually being replaced with larger and faster-swimming prey such as blue mackerel, scads, garfish, and even flyingfish. A CSIRO study of 497 fish caught during the day and night over 2 years in northern and eastern Australia showed around 90% of fish fed during the day. Interestingly, fish increased their feeding rate leading up to spawning, probably to boost their energy stores for their 5-7 month spawning season. Longtail tuna consume around 2% of their body weight in prey each day, but this decreases as the fish grow. Longtail tuna were estimated to consume around 1.48,000 tonnes of prey each year in the Gulf of Carpentaria, of which, 600 tonnes comprised commercially important prawns.

Further reading:

Griffiths, S.P., Fry, G.C., Manson, F.J. and Pillans, R. (2007) Feeding dynamics, consumption rates and daily ration of longtail tuna (*Thunnus tonggol*) in Australian waters, with emphasis on the consumption of commercially important prawns. *Marine and Freshwater Research* 58, 376-397

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Longtail tuna now a "recreational only" species in Australia

- Longtail tuna is managed by the Australian Fisheries Management Authority (AFMA)
- Minister for Agriculture, Fisheries and Forestry declared longtail tuna a "recreational only" species in December 2006
- 70 t annual commercial bycatch limit (35 t on the east and west coasts) imposed by AFMA for Commonwealth Fisheries
- No recreational catch estimates – annual catch by land-based gamefishing anglers preliminary estimated at ~60 t on east coast for 2005
- Recreational fishers need to abide by size and bag limits imposed by state fisheries agencies

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Photos: left: Shane Griffiths, right: Goshie.

Every month registered fishers reporting their catch will go into a draw to win an exclusive longtail tuna t-shirt!

Figure 7.3: An example of the information pages on the national longtail tuna website.

7.2.2 Time-location sampling

Sport fishers can be considered to comprise a ‘hard-to-reach’ population, since they are generally a minority group within a much larger population of recreational fishers. Many rare, hidden or hard-to-reach populations tend to gather or congregate at certain types of locations at particular times. For example, epidemiologist and social scientists have found that hidden populations of illicit drug users tend to congregate at ‘shooting galleries’ or in other areas where drug or needle transactions take place, and often in the evenings. Venue-based or targeted sampling (Watters and Biernacki, 1989), often referred to as “time-location sampling” (TLS), capitalises on these types of predictable behaviours of the target population, whereby a researcher identifies aggregation sites in a geographic region of interest prior to a survey as a sampling ‘universe’ and a subset of the sites is chosen as a probability sample (Muhib et al., 2001; Stueve et al., 2001). The researcher then interviews individuals entering or leaving an aggregation location over a pre-defined period (e.g. a randomly chosen 3 hour interval on a randomly chosen day).

TLS is a similar concept to access point surveys used in traditional recreational fishing surveys. However, the problem with access point surveys at boat ramps for example, is that the sample is only representative of fishers who fish from vessels that can be launched from a trailer. Land-based fishers and fishers owning larger vessels berthed in marinas, moorings or private property are missed using boat ramp access point surveys. This may cause a significant bias in total catch and effort estimates for the overall fishery if the characteristics of the missed groups differ to those of individuals intercepted at boat ramps. In contrast, TLS may be used to obtain a representative sample from the recreational fishing community if a location can be found where a representative cross-section of fishers congregate. One such approach is to conduct a survey of customers at fishing tackle stores, since most fishers, regardless of ability, fishing experience, avidity or mode of fishing, need to purchase fishing tackle at some point. A similar approach was used by Pepperell (1994) to sample game fishers on the east coast of Australia.

It is possible that tackle store customer surveys may under-represent certain anglers since there is an apparently increasing number of highly specialised and avid anglers who purchase their tackle through websites or overseas. This can be due to a lack of supply of specialised equipment in Australia and/or favourable foreign currency exchange rates. Nonetheless, these fishers are likely to enter tackle stores at some point to purchase minor items, or to simply view and handle particular products before purchasing the products online or by mail order. Therefore, if sufficient sampling is undertaken across a range of stores in a particular region, it would be theoretically possible to attain a representative sample of the target fishers.

In the present study, TLS was undertaken at a range of tackle stores around Australia to interview a sample of sport fishers as they exited the stores. Sampling was undertaken during a 3-hour period on Saturday mornings, or on Thursday nights in locations where stores were open for late night trade. These times were generally regarded by the store owners to have the highest concentration of customers. Sampling ‘high traffic’ times was preferred as we were primarily testing the efficacy of using TLS for intercepting the hard-to-reach proportion of the recreational fishing community who catch longtail tuna. If a larger budget were available for future surveys, it is recommended that a

random stratified survey design, covering all time and space strata, be implemented in order to gain a better representation of tackle store customers.

During each 3-hour survey, as far as possible, each person exiting the store was intercepted. It was explained that the CSIRO was leading a national collaborative survey on sport fishing, particularly for longtail tuna. This approach was taken as we were also interested in better understanding the proportion of tackle store customers who were sport or game fishers (but did not catch or target longtail tuna) and the proportion of these fishers who were fishing club members. This was important to determine because if the vast majority of fishers were members of fishing clubs, then more cost-effective methods that be employed in future studies by simply surveying members of fishing clubs for which list frames and a population size is known. We also found that explaining the survey was about sport fishing in general was important to prevent some respondents from opting out of the survey once they heard the survey focused on longtail tuna. Our initial experience was that many sport fishers would state that they did not catch longtail tuna, but later in the interview they actually recalled incidentally catching longtail tuna while fishing for other species, such as spotted mackerel.

When an intercepted subject expressed interest in participating in the survey, they were asked if they had fished for any species of marine pelagic sport fish in the past 12 months. Customers who were ineligible or refused to participate were recorded as belonging to one of ten refusal/ineligible categories (Appendix 4). Eligible subjects were then asked if they would like to participate in an interview that would take approximately 90 seconds. Undertaking short interviews was important to minimise refusals. Initial surveys indicated that busy customers became disinterested during longer interviews and survey staff felt that respondents were likely to provide responses that lacked candour in an attempt to expedite the interview. Subjects agreeing to participate in the interview were asked to report information on the general location of their fishing activities (e.g. Exmouth, Gulf of Carpentaria), fishing effort, and number of longtail tuna caught and/or released over the previous 12 months, even if zero (Appendix 4). The TLS survey had many of the same questions as the online survey, although not all of the online survey questions could be asked in the TLS survey due to time constraints.

7.2.3 Access point survey

An access point survey is an on-site method that involves intercepting fishers at points where they terminate a fishing trip, such as boat launching ramps, marinas, and in the case of land-based fishers, piers and rocky headlands. Fishers are intercepted as they leave the fishery after they have completed their trip. This type of method has the advantage of being able to collect high quality species-specific information on numbers and size composition of fish caught because the catch can be viewed (with the fisher's permission) by scientific survey staff. Furthermore, recall bias for effort is minimised because the fisher is intercepted immediately at the end of the trip rather than days or months later, which can be the case for some diary or recall surveys. However, access point surveys have the disadvantage of being labour-intensive and very expensive due to the enormous sampling effort required to comprehensively sample all access points across large spatial and temporal scales. They also have the disadvantage of generally

only being representative of the day-time catch, due to safety concerns for staff undertaking night-time surveys. In the case of sport fishing however, this is probably not a significant issue since this group generally targets fish only during daylight hours when pelagic fish are most active.

Although this project aimed to undertake a national survey of recreational longtail tuna catches, resource constraints prohibited the implementation of a large-scale access point survey around Australia. Instead, we used access point survey data that was part of a larger concurrent survey on sport fishing undertaken by Mitchell Zischke from the CSIRO and the University of Queensland. The survey was undertaken at four high-use public boat ramps within the Tweed Heads–Maroochydore reporting zone using in the TLS and online diary surveys and were used to compare the efficacy of this method for accessing sport fishers who may catch longtail tuna. It is acknowledged that this type of survey design would not account for land-based fishers who catch longtail tuna.

Stratified random sampling was used, with each survey day regarded as the primary sampling unit. The survey design was stratified by boat ramp location (Mooloolaba, Scarborough, Manly and Tweed Heads), day type (weekdays and weekends/public holidays), and month of the year during the survey period (January–May). Replication of survey days were weighted so that 60% of sampling occurred on weekends or public holidays (with 40% on week days) to weight in favour of the increased fishing participation at these times.

Prior to beginning the survey, observations of boat traffic at each boat ramp were made on each day type for the entire summer daylight period (approximately 0400–1700hrs) to determine peak boat retrieval times throughout the day. Survey times were then selected to align with these peak times, so that 65% of daylight hours were surveyed, which approximately corresponds with 85–90% of the total daylight boat traffic. Survey shift times were adjusted each month to correspond with seasonal changes in daylight duration.

On each survey day, recreational fishers were intercepted as they retrieved their boats and asked to participate in a short survey on recreational fishing. Once fishers accepted they were asked questions relating to their species-specific catch and effort for longtail tuna, and other profile information such as whether or not they were a member of a fishing club. Fishers were also asked if their catch of longtail tuna could be inspected to validate species identification and record the size of each fish retained. Fishers were also asked to estimate total length of longtail tuna that were released.

7.2.4 Estimating survey costs

Comparing the cost and efficacy of different recreational fishing surveys is complex, not only due to difficulties in predicting or quantifying the sampling power required to obtain representative data from the target fishery, but also because each survey method has different biases, some of which are difficult to detect or quantify such as non-response and prestige bias. For the purposes of this study, we calculated the cost of conducting a single annual national survey using each survey type having sufficient sampling power required to intercept a reasonable number of longtail tuna fishers based on our survey results.

It should be noted that a single survey is likely to only provide a reliable estimate of the catch from the sampled population, which may provide an index of catch-per-unit-effort (CPUE) that can be used as a proxy of fish abundance in some types of stock assessments. Therefore, a single survey is unlikely to provide a total catch estimate for the entire participating sport fishing population across Australia. If a total catch estimate is required, further method development is required in order to access longtail tuna fishers, who are rare in the wider community. One possible approach is to use capture-recapture methods to estimate population size (see Larson et al., 1994; Dávid and Snijders, 2002; Tate and Hudgens, 2007), although this requires surveys to be undertaken on multiple occasions, and therefore greatly increases survey costs.

In the costing scenarios for undertaking a national longtail tuna survey, labour costs were based on the daily wage of a CSIRO CSOF 5.1 for the Principal Scientist and statistician, and a CSOF 3.1 for field and technical staff. Overhead costs for salary and operating are not included since this can differ significantly between research organisations and even for different project components within an organisation (e.g. salary vs. operating expenses). However, as a general guide overhead rates can range between 50% and 120%. The estimated costs should be considered minimum estimates that do not include additional salary, travel and operating costs in the case of poor weather and other unforeseen circumstances that may result in additional sampling being required. Such contingencies would almost certainly add to overall costs.

7.3 Results

The three sampling methods used to collect recreational fishing information with regards to longtail tuna collected different types of data. Therefore, for ease of interpretation, two separate sections are presented to describe the results from i) the innovative methods being trialled (time-location sampling and online diary), and ii) the traditional access point survey. An overall comparison of the results and costs of the methods is made at the conclusion of the results section.

7.3.1 Innovative survey methods

Time-location sampling

A total of 26 days of sampling was undertaken between 17 December 2009 and 8 May 2010 in regions around Australia where longtail tuna may be caught by recreational fishers (Figure 7.4; Table 7.1). A total of 1536 individuals (1227 males; 309 females) were intercepted using time-location sampling as they exited fishing tackle stores. An additional 141 individuals (123 males; 19 females) could not be intercepted due to field staff already conducting interviews with other individuals.

Of the individuals intercepted, 1266 were ineligible to participate in the survey (i.e. were not sport fishers), 125 refused to participate, and 270 (17.6%; 255 males and 15 females) were eligible for the survey as they had fished for sport or game fish in the past 12 months. Of these eligible fishers, none refused to participate in an interview.

Although not quantitatively recorded, it was estimated by survey staff that about 10–20% of interviewed fishers specifically targeted longtail tuna. The vast majority of fishers viewed longtail tuna as an important bycatch species when fishing for species such as spotted and narrow-barred Spanish mackerel. In far northern Australia, namely Broome, Darwin and Gove, many sport fishers regarded longtail tuna as a ‘pest’ species and avoided areas of high concentrations because they were often reported to take baits or lures intended for billfish or mackerel.

An alarming result was that only 24.4% of sport fishers interviewed were aware that longtail tuna was a ‘recreational-only’ species. This is a statistic of concern considering the Federal fisheries minister declared longtail tuna a recreational-only species in December 2006. The percentage of interviewed fishers having knowledge of longtail tuna being a recreational-only species was 22.3% for non-club members and 32.2% for club members. This indicates that information for longtail tuna’s recreational-only status has been, and is being, poorly disseminated throughout both the general public and fishing clubs.

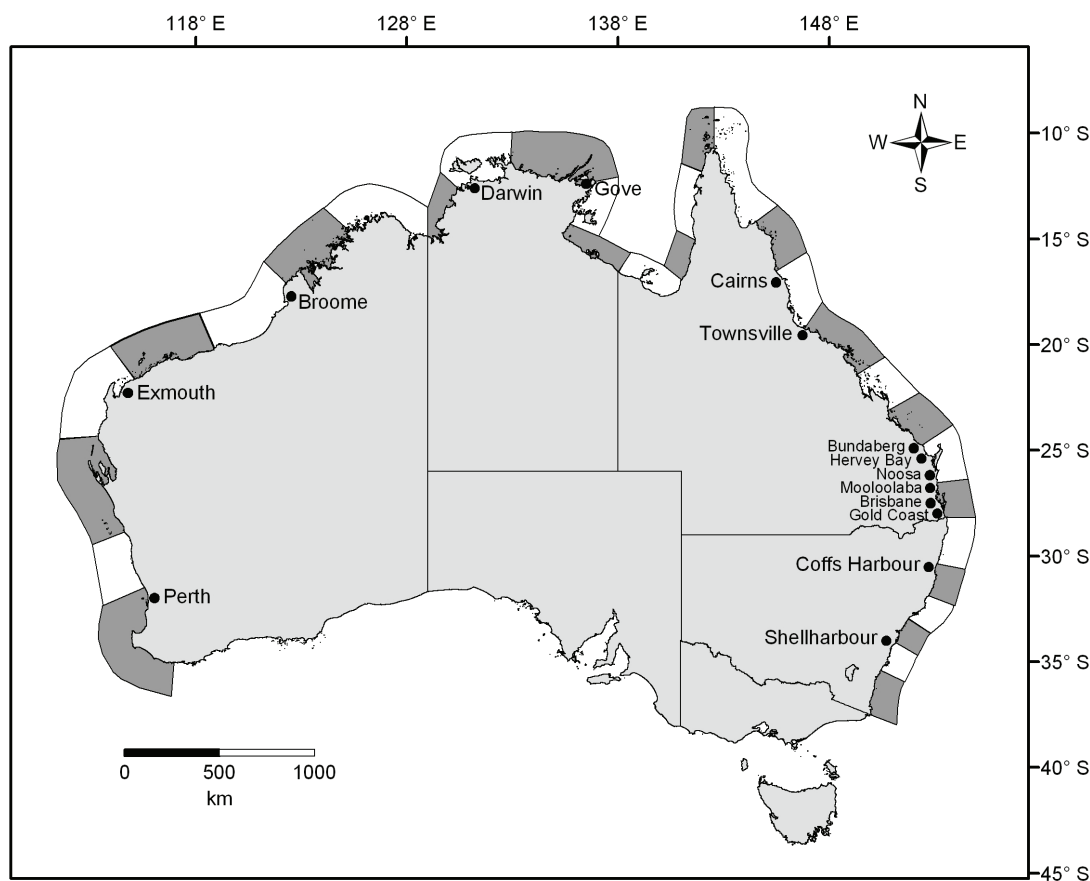


Figure 7.4: Map showing reporting zones (in alternating shading) for online diaries and locations where time-location sampling was undertaken between 17 December 2009 and 15 May 2010.

Table 7.1: Number of survey days undertaken in each region and state between 17 December 2009 and 15 May 2010 using time-location sampling (TLS). The online diary method is not included due to sampling days being dependent upon fishers voluntarily reporting data.

State	Region	No. of days sampled
NSW	Shellharbour	1
	Coffs Harbour	1
QLD	Gold Coast	1
	North Brisbane	2
	South Brisbane	8
	Mooloolaba	1
	Noosa	1
	Hervey Bay	1
	Bundaberg	1
	Townsville	1
Cairns	2	
NT	Gove	1
	Darwin	2
WA	Broome	1
	Exmouth	1
	Perth	1
Total		26

Of the 1266 ineligible individuals, most males either did not sport fish (64.1%) or did not sport fish in the previous 12 months. In contrast, most females either did not fish (55.2%) or did not sport fish (37.5%) (Figure 7.5).

Of the 125 individuals (109 males and 16 females) who refused to participate, most males and females gave the reason of being ‘too busy’ or ‘not interested’, while a few males refused participation on the basis of language difficulties. Only one individual refused to participate for political reasons, which was related to the establishment of the Great Barrier Reef Marine Protected Areas. Three individuals refused because they primarily fished commercially, or they had been interviewed on a previous occasion (Figure 7.6).

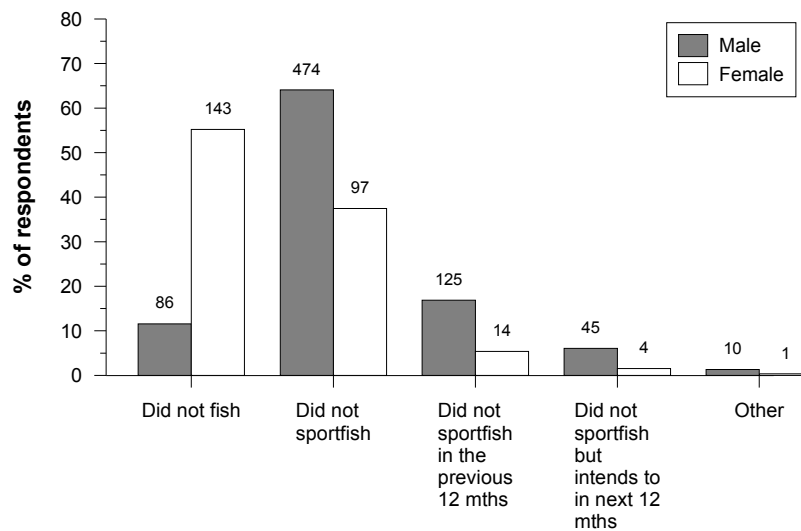


Figure 7.5: Percentage of males and females intercepted during time-location sampling who were classified as ineligible to participate in the national longtail tuna survey. Numbers above bars denote number of individuals.

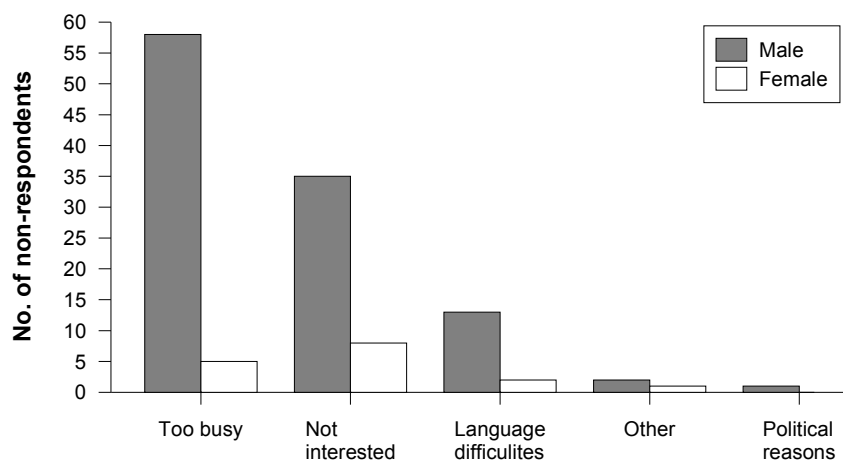


Figure 7.6: Number of males and females providing specific reasons why they refused to participate in the national longtail tuna survey after being intercepted during time-location sampling. (It should be noted the vast majority of refusals were polite).

Online diary

During the period 17 December 2009 to 8 May 2010, a total of 107 individuals registered on the website to use the online diary, of which 49 submitted data for at least one fishing trip within one of the reporting zones (Figure 7.4). We assumed the remaining 58 registered usernames each belonged to different individuals who were part of the recreational fishery for longtail tuna but had not fished for longtail tuna in the previous 12 months, but intended to fish in the next 12 months. A further 49 fishing trips were reported anonymously. Although it is not possible to determine how many individuals contributed this information, since they did not register, for the purposes of this study it has been assumed each trip has been submitted by a different individual. Therefore, a total number of 156 individuals were assumed to have contributed information through the online diary.

7.3.2 Fisher profiles

Age composition of fishers

Due to interview time restrictions in TLS and access point surveys, age composition of fishers was only collected for online diary respondents. Age class of fishers ranged from 10–14 years to 60–64 years, although the vast majority of fishers were aged 25–29 years (Figure 7.7). All fishers were male apart from four females in age class 25–29 years and two in age class 40–44 years.

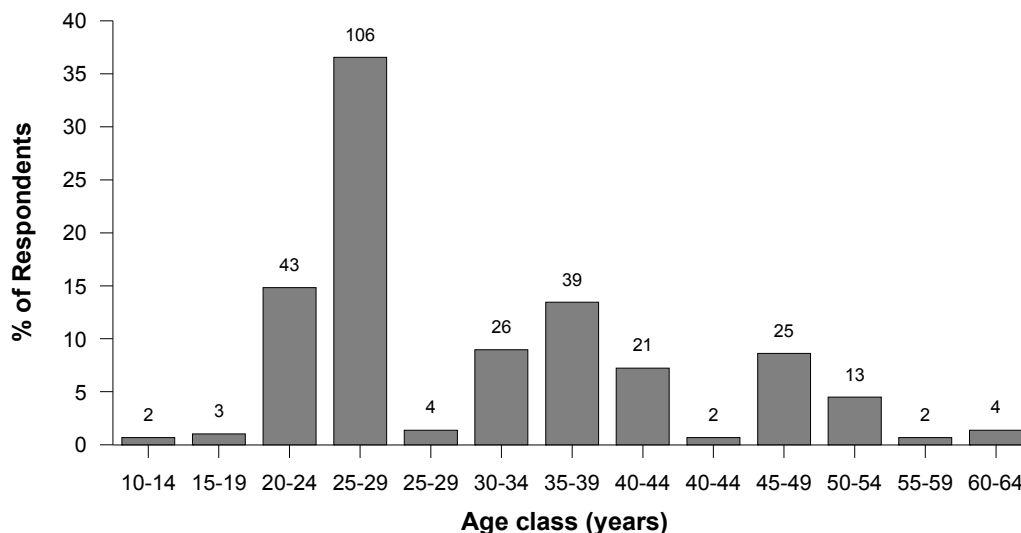


Figure 7.7: Age-frequency distribution of sport fishers who submitted fishing trip data on the longtail tuna website. In each report, the respondent provided the age class of each member in their fishing party. Numbers above bars denote number of respondents.

7.3.3 Fishing methods

The TLS survey showed that the most popular method for targeting longtail tuna from boats was trolling lures (37.3%), casting lures (25.6%), followed by live bait (12.8%) and dead bait (8.4%) (Figure 7.8). Despite longtail tuna apparently being a primary target species for many saltwater fly fishers, this method was only used by 1.4% of respondents.

In contrast to TLS, the most popular methods used to target longtail tuna by respondents using the online diary was land-based lure casting (36.0%) and land-based live bait (33.7%) (Figure 7.8). It is important to note that most fishers in both TLS and online diaries cited using two or more methods to target longtail tuna. For land-based fishers, this usually involved casting lures and live bait, whereas for boat-based fishers, trolling lures, trolling bait and casting lures were often used together during an individual fishing trip.

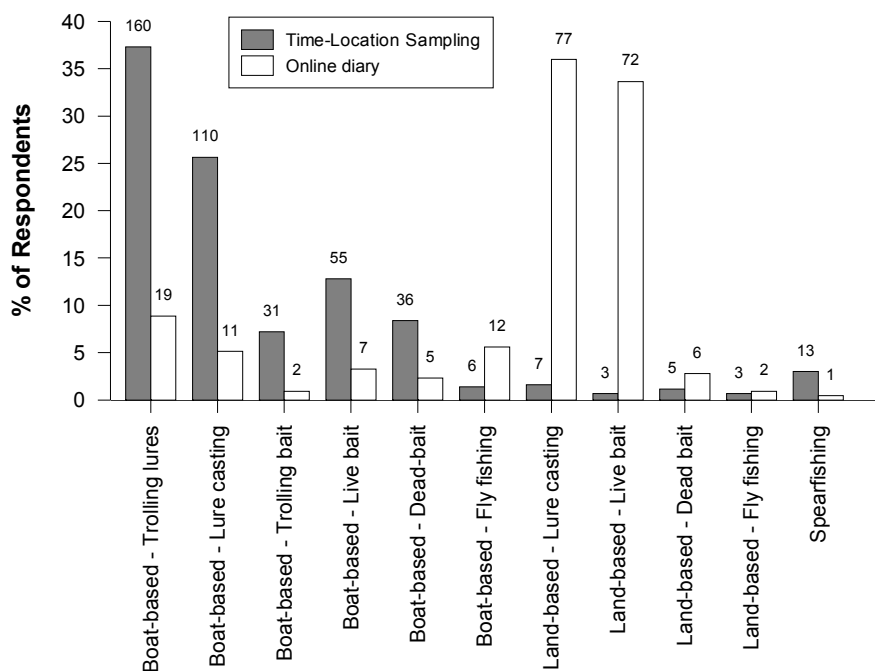


Figure 7.8: Percentage of respondents utilising particular fishing methods for catching longtail tuna in Australia, as determined by time-location sampling of tackle store customers and online diaries. Numbers above bars denote number of respondents.

Fisher avidity and fishing club membership

Of the 270 eligible fishers in TLS, 59 (21.9%) were members of a fishing club, whereas of the 71 fishers entering fishing trip details through the online diary, only 9 (12.7%) were members of a fishing club. Interestingly, 95.8% of sport fishers surveyed by TLS fished from a boat, compared to only 28.1% of respondents who completed online diaries.

There was a marked difference in the avidity between fishing club members and non-fishing club members sampled using TLS and the online diary method (Figure 7.9). In TLS, 64.8% and 25.3% of fishers fished for 0–10 days and 11–30 days in the past 12 months, respectively. A higher percentage of non-club members fished for 0–10 days (67.7%) compared to club members (54.2%) (Figure 7.9).

In contrast, 35.3% and 43.4% of respondents using the online diary fished for 0–10 days and 11–30 days in the past 12 months, respectively. Most non-club members (46.1%) fished for 11–30 days, while the majority (64.2%) of club members fished for 31–100 days (Figure 7.9). However, the percentage of non-club and club fishers who fished more than 100 days per year was equally low for both survey methods.

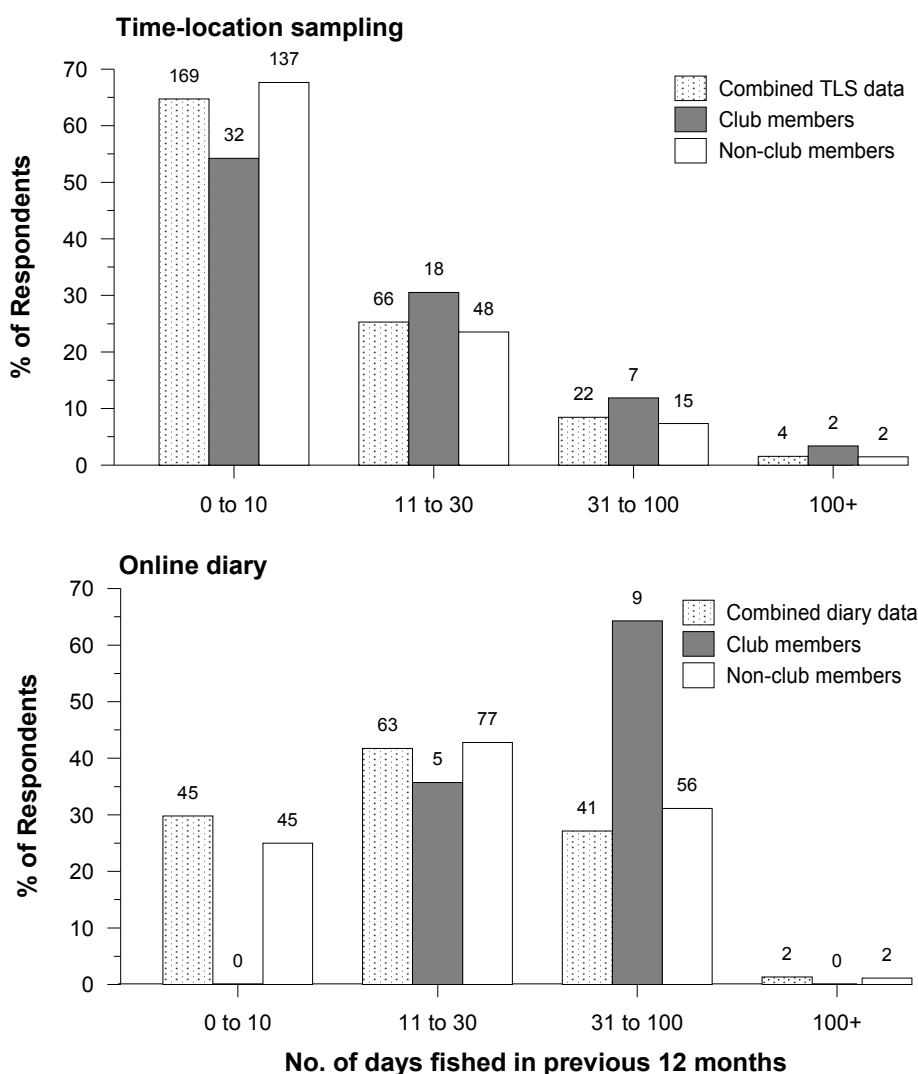


Figure 7.9: Self-reported avidity of fishing club members and non-fishing club members (and both groups combined) surveyed in time-location sampling and online diaries, quantified as number of days fished for sport fish in the 12 months previous to being interviewed. Numbers above bars denote number of respondents.

7.3.4 Effort, catch and size distribution

Number of fishing trips by reporting zone

Respondents in TLS and online diaries targeted longtail tuna from 26 regions spanning the entire Australian distribution of longtail tuna and encompassing the states of New South Wales, Queensland, Northern Territory and Western Australia. In the TLS survey, the highest number of trips was recorded in Tweed Heads–Maroochydhore (primarily Moreton Bay) (82), followed by Townsville–Port Douglas (29) Port Hedland–Exmouth (primarily Exmouth Gulf) (29), Cobourg Peninsula–Dundee Beach (20), and Broome–Port Hedland (17) (Figure 7.10). An interesting result was that TLS respondents often reported fishing in regions outside of the region where the surveys were undertaken. For example, several fishers in the Brisbane and Perth metropolitan areas reported that the majority of their fishing for longtail tuna took place in Hervey Bay, Qld and Iluka, NSW.

In contrast, the highest number of trips reported in online diaries were undertaken in Newcastle–Port Macquarie (147), followed by Woolgoolga–Tweed Heads (28), and Cronulla–Newcastle (23) (Figure 7.10). The marked difference in zones where trips were reported between TLS and online diaries was primarily due to the large number of land-based fishers using the online diary to submit trip information for a small number of reporting zones where there are suitable locations for targeting longtail tuna from the land, such as Forster, Iluka and Port Stephens (Figure 7.10).

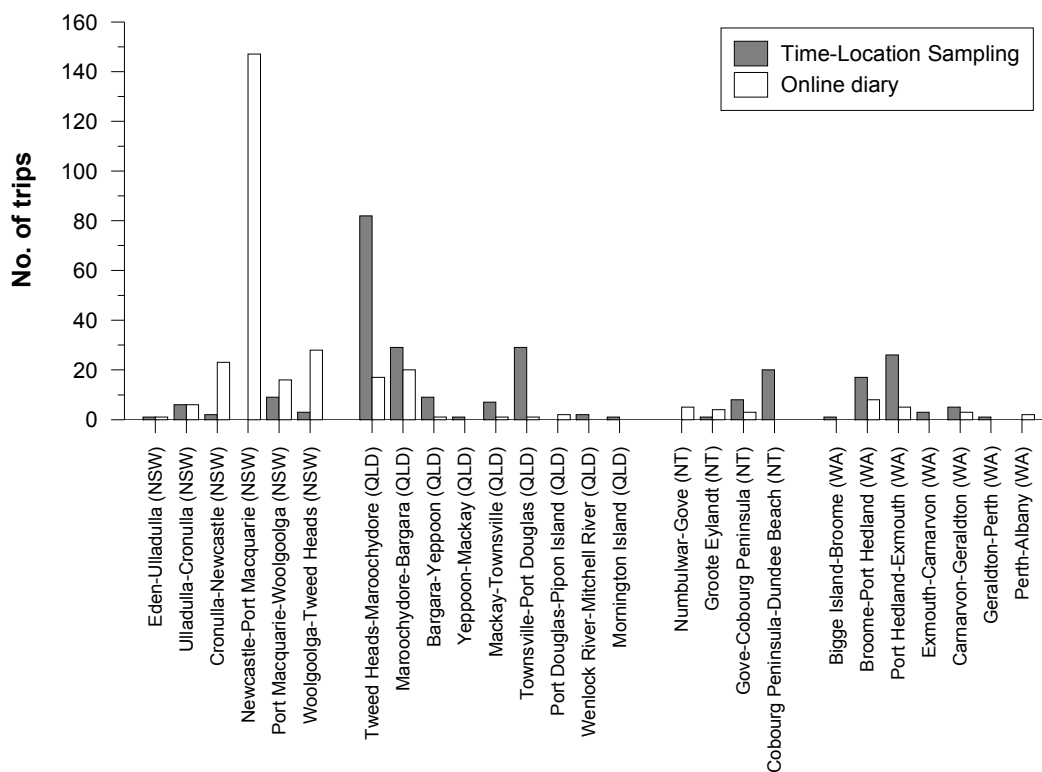


Figure 7.10: Number of trips in each reporting zone (grouped by state) where longtail tuna were targeted by respondents in time-location sampling and the online diary system.

Annual fisher effort by reporting zone

The mean annual number of hours fished per fisher in TLS was 83.2 (\pm SD 158.9) hr yr⁻¹, with the mean individual trip length being 4.8 (\pm SD 0.2) hours. The reporting zones (see Figure 7.4) with the highest mean annual effort per fisher were Mackay–Townsville (232.3 \pm 255.7 hr yr⁻¹), Port–Headland (143.6 \pm 306.1 hr yr⁻¹) and Gove–Cobourg Peninsula (100.4 \pm 108.1 hr yr⁻¹) (Figure 7.11).

In contrast, the mean annual number of hours fished per fisher in the online diary was 20.5 (\pm 29.6) hr yr⁻¹, with the mean individual trip length being 7.6 (\pm SD 0.3) hours. The reporting zones with the highest mean annual effort per fisher were Newcastle–Port Macquarie (17.93 \pm 297.0 hr yr⁻¹) and Cronulla–Newcastle (16.0 \pm 23.1 hr yr⁻¹) (Figure 7.11).

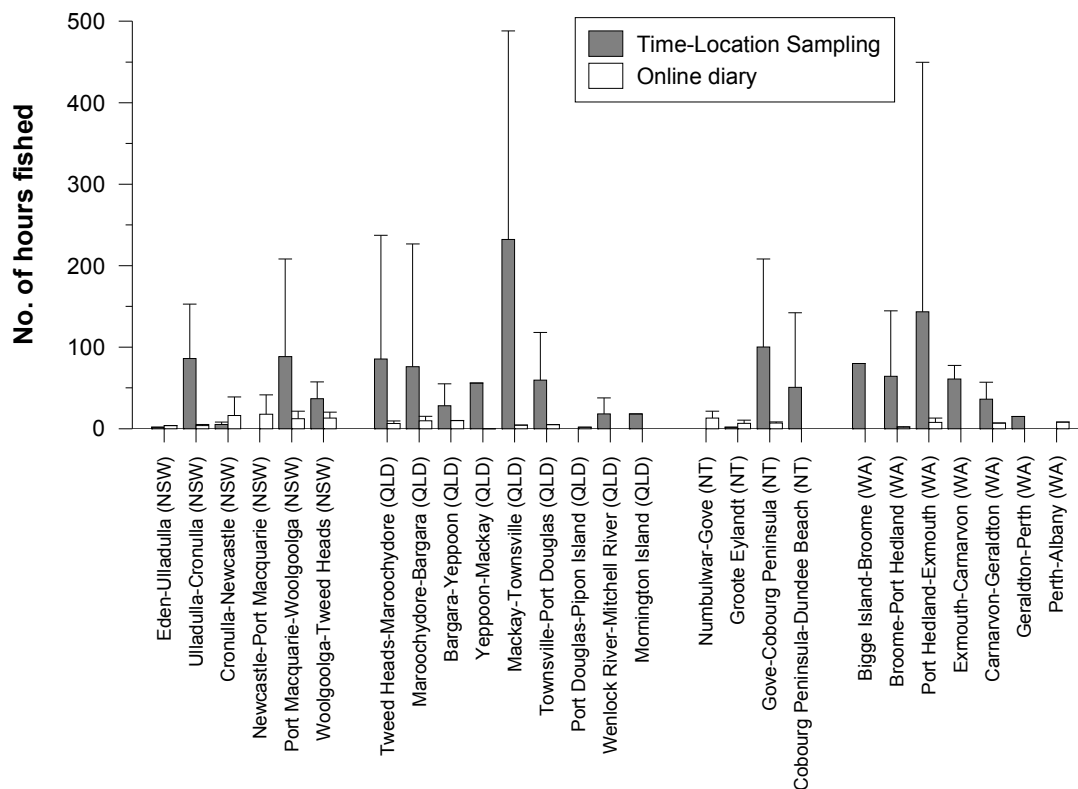


Figure 7.11: Mean (\pm SD) number of fishing hours directed at longtail tuna in each reporting zone (grouped by state) by respondents in time-location sampling and the online diary system.

Annual fisher catches by reporting zone

The mean annual number of longtail tuna caught per fisher was 2.86 (\pm 8.3) fish yr⁻¹ (which includes fishers who caught no longtail tuna). The highest mean annual number of fish caught per fisher in TLS were recorded at Port Headland–Exmouth (10.2 \pm 21.5 fish yr⁻¹), Groote Eylandt (7.0 \pm 0 fish yr⁻¹), Gove–Cobourg Peninsula (6.9 \pm 8.9 hr yr⁻¹), and Carnarvon–Geraldton (4.6 \pm 4.9 fish yr⁻¹) (Figure 7.12).

For the online diary method, the mean annual number of longtail tuna caught per fisher was 1.59 (\pm 3.6) fish yr⁻¹. The reporting zones with the highest mean annual effort per fisher were Numbulwar–Gove (15.5 \pm 2.1 fish yr⁻¹), Maroochydore–Bargara (3.6 \pm 5.6 fish yr⁻¹), and Gove–Cobourg Peninsula (2.7 \pm 1.2 fish yr⁻¹) (Figure 7.12).

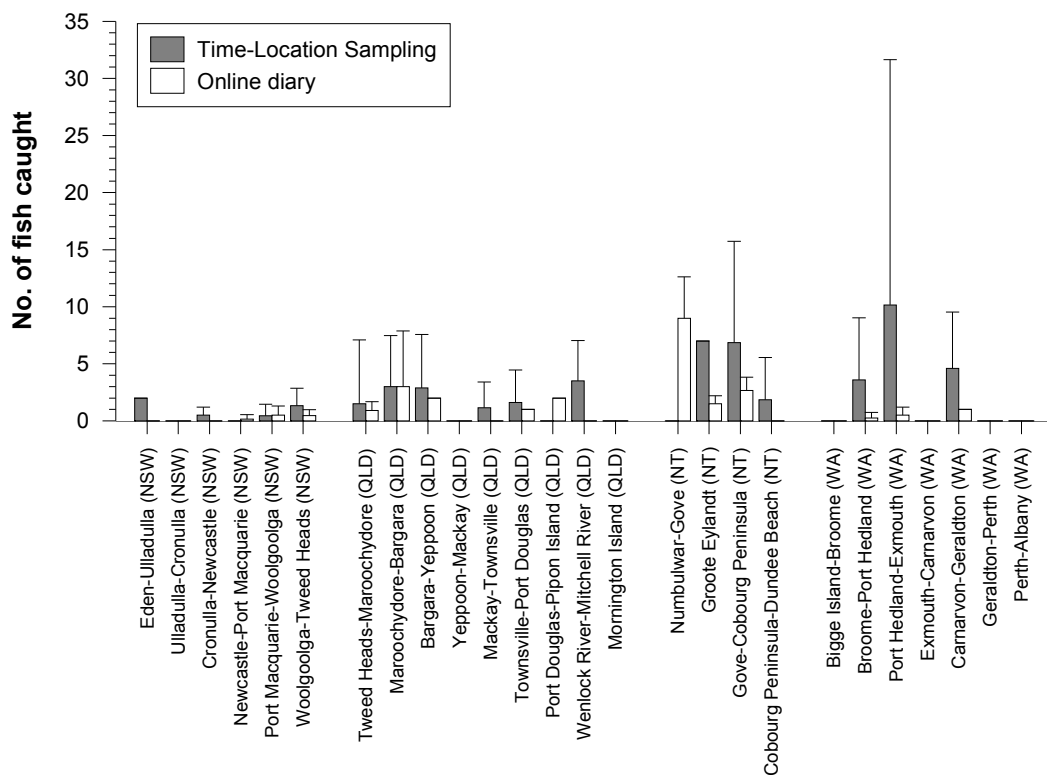


Figure 7.12: Mean (\pm SD) catch (retained + released) of longtail tuna in each reporting zone (grouped by state) by respondents in time-location sampling and the online diary system.

Catch rates by reporting zone

The mean catch rate combined for all reporting regions for TLS was 0.09 (\pm 0.32) fish hr^{-1} , compared with 0.14 (\pm SD 0.37) fish hr^{-1} for online diaries. The large variance around the mean catch rate estimates for TLS was due to 67% of respondents not catching a longtail tuna during the 12-month recall period (Figure 7.13). In contrast, 46% of respondents using the online diary did not catch a longtail tuna during the study period. Considering that the vast majority of online diarists fished from the land where longtail tuna are often considered a ‘rare event’ capture, it appears likely that some fishers may have only recorded data for trips when a longtail tuna was captured. It is unknown whether this represents non-reporting bias or prestige bias, or whether these are in fact accurate results. Fishers from TLS and the online diary that did catch a longtail tuna, generally caught less than six during the 12-month recall period, whereas only 11 respondents caught more than 10 fish (Figure 7.13).

The highest mean catch rates were recorded at Groote Eylandt (3.5 fish hr^{-1}) and Eden–Ulladulla (1.0 fish hr^{-1}) (Figure 7.14), although these zones were each represented by only one respondent in TLS. The highest catch rates recorded in zones where data were available for more than two respondents in TLS were at Wenlock River Mouth–Mitchell River (0.22 \pm 0.05 fish hr^{-1}), Carnarvon–Geraldton (0.20 \pm 0.22 fish yr^{-1}) and Cobourg Peninsula–Dundee Beach (0.18 \pm 0.34 hr yr^{-1}). In contrast, the highest catch rates in the online diary were recorded at Numbulwar–Gove (1.1 \pm 0.6 fish hr^{-1}), Port Douglas–Pipon Island (1.0 \pm 0.1) fish yr^{-1}) Maroochydore–Bargara (0.42 \pm 0.8 fish hr^{-1}), and Gove–Cobourg Peninsula (0.41 \pm 0.2 hr yr^{-1}) (Figure 7.14).

Lengths of fish reported in online diaries to have been caught or released ranged from 34 to 150 cm TL, with the majority of fish being between 85 and 120 cm TL (Figure 7.15). Lengths of fish caught by respondents in TLS were not recorded.

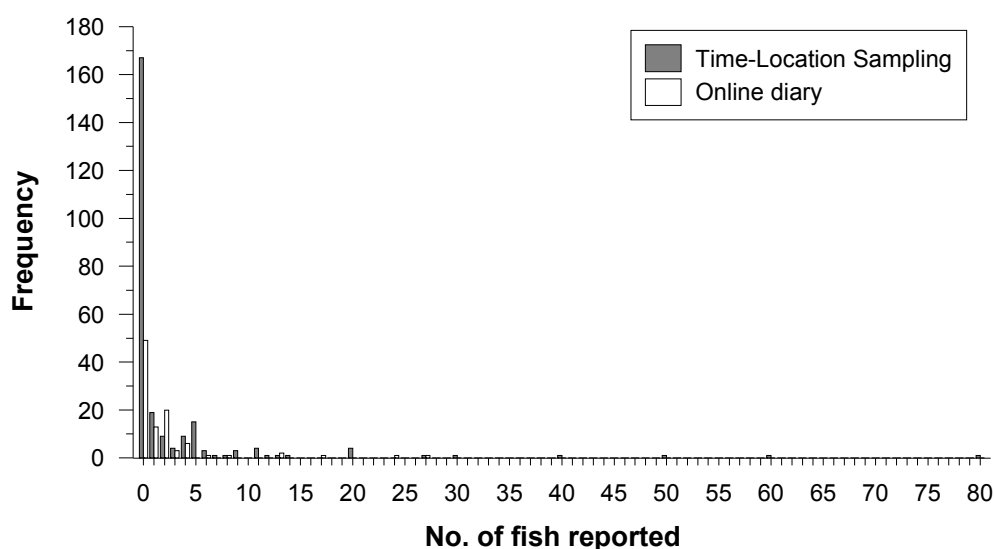


Figure 7.13: Frequency distribution of the number of longtail tuna reported by each respondent in time-location sampling and the online diary system. Note that respondents of the online diary were expected to report data for individual trips, so the catches were summed for each respondent over the sampling period.

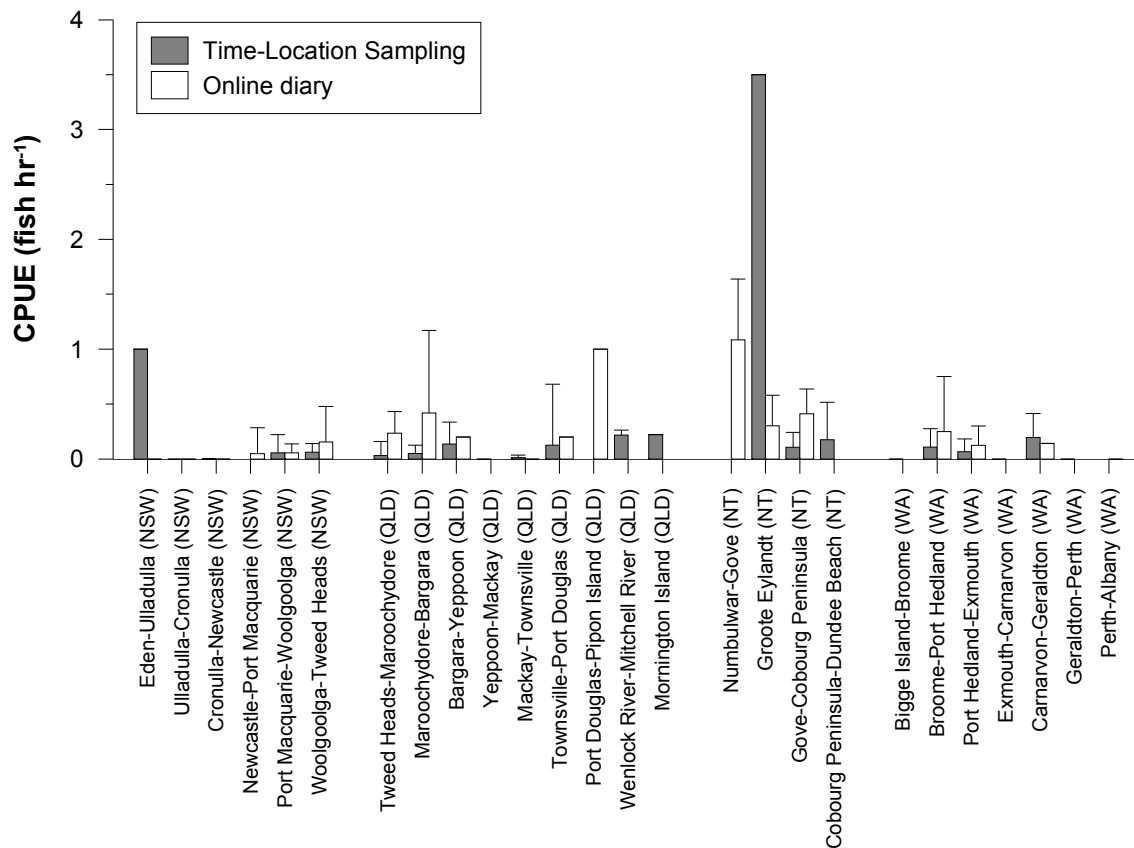


Figure 7.14: Mean (± SD) catch per unit of effort for longtail tuna in each reporting zone (grouped by state) reported by respondents in time-location sampling and the online diary system.

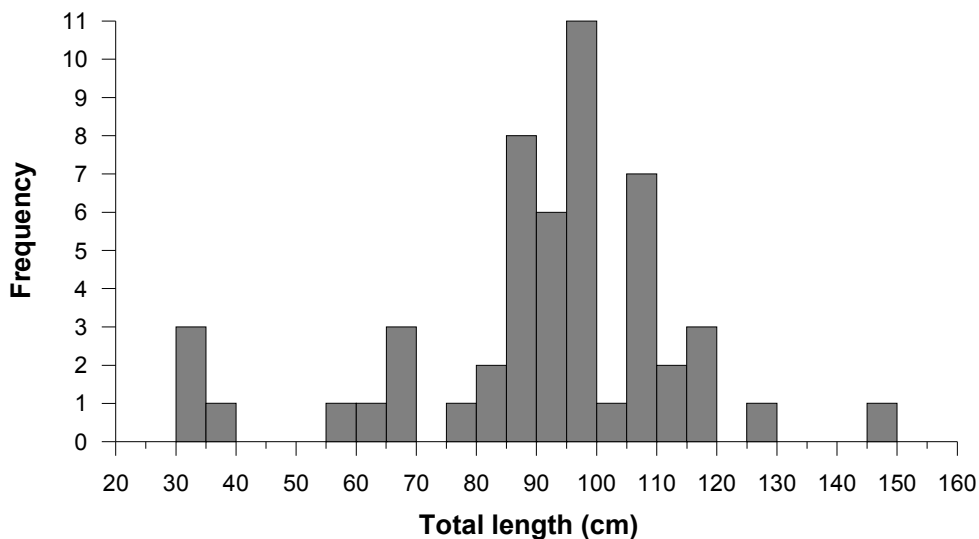


Figure 7.15: Length-frequency distribution (in 5 cm increments) for longtail tuna reported in online diaries to have been retained or released.

Fisher preferences for future survey design

Of the 270 sport fishers interviewed in TLS, 254 (or 94.1%) had access to the internet. Of these fishers, when asked whether they would participate in a future diary survey 205 fishers (80.7%) and 186 fishers (73.2%) said they would report their fishing trip details using an online diary system and conventional paper fishing diary, respectively.

Of the respondents agreeing to complete a paper diary, 66% and 26% fished for 0–10 days and 11–30 days in the past 12 months, respectively. The 76 respondents who declined to participate in a diary survey had similar avidity levels to fishers agreeing to participate with 61% and 24% of respondents fishing for 0–10 days and 11–30 days, respectively. Although the sample size is small, within the category of avid anglers (31–100 days) 16.5% declined to participate in a diary survey, compared to 6.8% who agreed to participate (Figure 7.16).

Of the respondents who declined to participate in a diary program, most stated they were too busy (32.5%) or rarely fish for longtail tuna (25.3%), while 10.8% of respondents felt that completing a diary required too much effort and 9.6% felt a diary would invade their privacy (Figure 7.17).

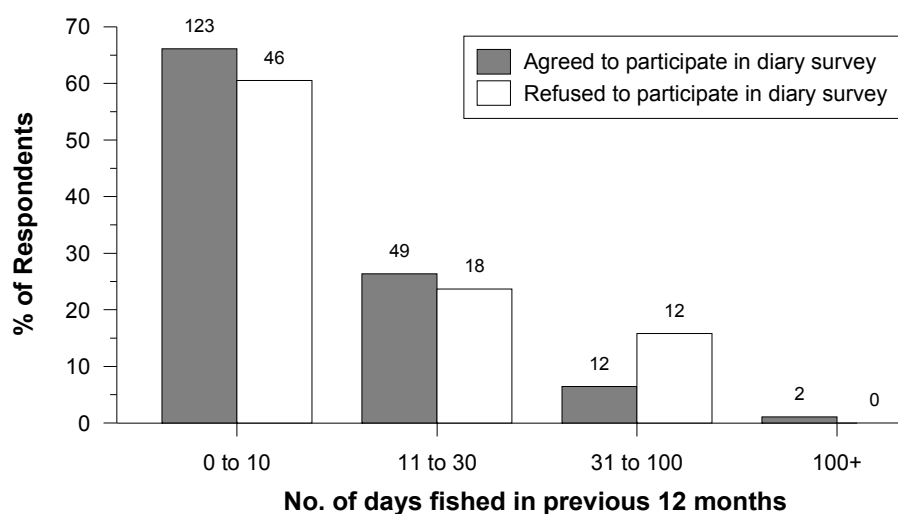


Figure 7.16: Percentage of respondents in four avidity categories (i.e. number of days fished per year) who agreed or refused to complete a fishing diary over a 6–12 month period in a future survey on longtail tuna in Australia. Numbers above bars denote number of respondents.

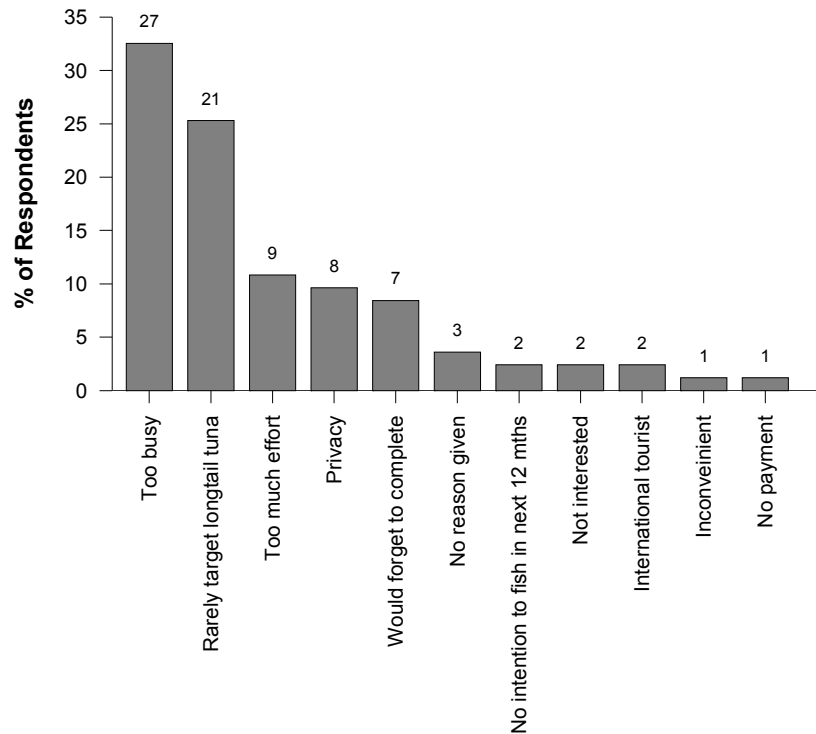


Figure 7.17: Percentage of respondents giving specific reasons why they would refuse to complete a fishing diary in a future survey of longtail tuna in Australia. Numbers above bars denote number of respondents.

7.3.5 Access point survey

A total of 333 hours over 41 days was spent undertaking access point surveys at Mooloolaba (12 days) Scarborough (11), Manly (9) and Tweed Heads (9) between 3 January 2010 and 9 May 2010. Overall, 1339 vessels were intercepted at boat ramps. Although interviews were conducted with one nominated person from each boat, these interviews represented the activities of 2908 individuals (2419 males and 489 females). Only 13 individuals refused to participate in surveys.

Overall, 2341 (80.5%) individuals from 981 (73.3%) vessels were fishers, and of these, 765 (32.7%) individuals from 326 (33.2%) vessels were sport fishers who expended a total of 1344 hours of effort fishing in such a manner as to allow longtail tuna to be caught. The average trip length of sport fishers was 3.8 (\pm SD 2.1) hours. Of the sport fishers intercepted, 117 (15.3%) were members of a fishing club. Only 7 longtail tuna were recorded (5 kept, 2 released)—all from Mooloolaba—and ranged in size from 80 cm to 87 cm FL. The mean catch rate of longtail tuna by those who fished in such a manner that could have caught this species, combined for the four survey sites, was 0.006 (\pm SD 0.067) fish hr^{-1} . This low catch rate highlights the difficulty of intercepting specialist longtail tuna fishers, since the catch rate is diluted by many zero catches from fishers targeting other species, such as billfish in offshore waters.

7.3.6 Comparison of survey costs and efficacy

Collectively, online diaries, TLS and the access point survey used in the present study accounted for 211 days of sampling. Catch and effort data were obtained from 1182 sport fishers who undertook 4596 fishing trips and expended 25,138 hours of effort fishing such a manner as to allow longtail tuna to be caught. This yielded a total catch (retained + released) of 892 longtail tuna that ranged in length between 30 cm to 150 cm TL, with the average length being 95 cm TL, or about 8.85 kg. Although the total population size of sport fishers who target or incidentally catch longtail tuna is unknown, our results show that the minimum annual catch from our relatively small sample of the sport fishing population is approximately 80 t.

A summary of the estimated costs for undertaking a single national recreational catch survey for longtail tuna using each survey type is shown in Table 7.2. The online diary method was estimated to be the most inexpensive sampling method for undertaking large-scale sampling of individual fishing trips, primarily due to low labour, travel and operating costs. This method sampled the highest number of fishing days and yielded the highest proportion of sport fishers. However, this method surveyed the lowest number of individuals, fishing trips and hours fished, but had the highest catch rates (0.143 ± 0.366 fish hr⁻¹) (Table 7.3).

The access point survey method was estimated to be the most expensive method for a national survey (Table 7.2). This method intercepted the highest number of individuals and sport fishers, although it surveyed only a small number of fishing trips, and the shortest average fishing trips (Table 7.3). Most importantly, only 7 longtail tuna were sampled, which resulted in this method yielding the lowest catch rate (0.006 fish hr⁻¹).

Time-location sampling using a recall survey is a reasonably low-cost sampling method that can rapidly collect data for a large number of fishing trips across large spatial scales (Table 7.2). TLS was conducted for the shortest period, yet it sampled the largest number of fishing trips and hours fished by sport fishers, and recorded the largest number of longtail tuna captures (Table 7.3). A national survey using TLS in combination with a diary survey to increase resolution of the data and to reduce recall bias would approximately triple the cost of a TLS recall survey. TLS would also be a highly effective method of screening and recruiting longtail tuna fishers for a longitudinal study, or longer follow-up interviews.

Table 7.2: Estimated costs for undertaking an annual national survey of the recreational catch and effort of longtail tuna. A brief explanation of the time and tasks required for each survey are provided. Daily wages of a Principal Scientist (PS) and a statistician (ST) are represented by a level CSOF 5.1 in the CSIRO salary scale, while field and technical staff (TS) represent a CSOF 3.1.

Survey component	Online diary	Time-location sampling (recall)	Time-location sampling (diary)	Access point survey
Survey design – Exploratory analyses to investigate survey design and sampling power; 3 days for PS	\$915	\$915	\$915	\$915
Website design – Construction of website interface; 3 days for TS	\$589	-	-	-
Website server hosting – \$50 per month for 12 months	\$600	-	-	-
Website database design and testing – 14 days for a TS	\$2750	-	-	-
Scoping of sampling ‘universe’ – determining the most appropriate sampling locations – 5 days for TS	-	\$982	\$982	\$982
Sampling required to intercept ~1000 sport fishers for TLS – 110 days for TS and 1728 days for APS to sample 1 weekday and 1 weekend each month in 36 reporting zones	-	\$21,604	\$21,604	\$339,373
Travel – flights to survey locations @ \$500 per flight for 2 x TS staff for TLS and 4 staff for APS	-	\$55,000	\$55,000	\$432,000
Accommodation and meals – 1 night per TS at each survey location @ \$200	-	\$22,000	\$22,000	\$172,800
Diary respondent contact calls – 1 call per month for 1000 respondents ~285 days of a TS	-	-	\$55,973	-
Diary production costs	-	-	\$400	-
Website maintenance – address general technical interface and database issues; 5 days of a TS	\$982	-	-	-
Data entry – ~30 days of survey data can be entered per TS work day; 33 days for ~1000 surveys in TLS, 702 days for ~21073 surveys in APS	-	\$6481	\$6481	\$137,870
Data entry – ~30 days of survey data can be entered per TS work day; assume 1000 respondents each undertake 30 trips = 1000 days of a TS	-	-	\$196396	-
Data analysis – 10 days of a ST to complete statistical analyses	\$3049	\$3049	\$3049	\$3049
Total survey cost	\$8,885	\$110,031	\$362,800	\$1,086,989

Table 7.3: Comparison of sampling effort, fisher profiles, and catch and effort between time-location sampling, online diary and access point survey methods used in the present study.

Survey component	Online diary	Time-location sampling	Access point survey	Overall
Total number of sampling days to complete survey	144	26	41	211
Total number of hours required to complete survey	3456	78	328	3862
Total number of individuals intercepted	156	1536	2908	4600
Number (and %) of intercepted individuals who were fishers	156 (100)	1029 (67.0)	2341 (80.5)	3526 (76.7)
Number (and %) of intercepted individuals who were sport fishers	156 (100)	270 (17.6)	756 (26.3)	1182 (33.5)
Number (and %) of sport fishers who were fishing club members	9 (12.7)	59 (21.9)	117 (15.3)	185 (15.7)
Total fishing trips undertaken by respondents	178	4092	326	4596
Total number of hours fished by respondents	1323	22471	1344	25138
Mean (\pm SD) annual number of hours fished per year	20.5 (29.6)	83.2 (158.9)	-	51.9 (94.3)
Mean (\pm SD) fishing trip length (in hours)	7.6 (0.3)	4.8 (0.2)	3.8 (2.1)	5.4 (0.8)
Total number of longtail tuna caught (retained + released)	135	750	7	892
Mean (\pm SD) catch rate of longtail tuna (fish hr ⁻¹)	0.143 (0.366)	0.090 (0.315)	0.006 (0.067)	0.080 (0.703)

7.4 Discussion

The national recreational fishing survey for longtail tuna was the first attempt to obtain baseline information on the recreational catch and effort directed towards Australia's newest 'recreational-only' species. By using two potentially cost-effective and innovative sampling approaches—time-location sampling and online diaries—information on fisher profiles, catch, effort and size composition of retained and released fish was able to be collected cost-effectively across all regions in Australia where longtail tuna are caught by recreational fishers. The use of a traditional access point survey enabled the performance of the two new methods to be assessed for obtaining representative catch and effort data on longtail tuna in a cost-effective manner in a long-term monitoring program. Such a program is required to collect meaningful catch and effort data for stock assessment and to demonstrate stewardship for the species by the recreational fishing sector.

Fisher profiles

Recreational fishers who target or incidentally catch longtail tuna were generally males aged 25–29 years, and 84.3% of respondents were not members of a fishing club. These fishers generally targeted longtail tuna using specialised equipment and techniques such as trolling lures, casting lures at feeding tuna schools, and using live bait. Fishers used sport fishing techniques for an average of about 52 hours per year, where individual fishing trips lasted for an average of 5.4 hours.

The recreational fishery for longtail tuna was characterised by low catch rates, where fishers, on average, caught 0.08 fish hr⁻¹, or in other terms, one fish for every 11 hours of sport fishing effort. Generally, most fishers caught less than 1 fish over the 12-month study period. This catch rate is about an order of magnitude higher than the tournament catch rates for other 'rare event' game fish, such as black marlin and striped marlin, which were 0.0084–0.0425 fish hr⁻¹ based on a 10 hr fishing day (Lowry and Murphy, 2003). Similarly, the catch rates of relatively small coastal pelagic sport fish caught by trailer boat sport fishers in New South Wales (based on a 10 hour fishing day) were lower than for longtail tuna, such as yellowtail kingfish (0.008–0.018 fish hr⁻¹), yellowfin tuna (0.001–0.004 fish hr⁻¹) and Australian bonito (0.005–0.013 fish hr⁻¹) (Lowry et al., 2006). The higher catch rates of longtail tuna may be explained by the effectiveness of time-location sampling for surveying the proportion of the population that may catch longtail tuna. The access point survey undertaken in the present study recorded low catch rates for longtail tuna (0.006 fish hr⁻¹), which were similar as catch rates recorded by Lowry et al. (2006) for other sport fish. This is likely to be a result of many zero catches by fishers who do not target sport fish, which was estimated to be 74% of recreational fishers surveyed by time-location sampling (see 'Results').

On face value, these low catch rates suggest low abundance of longtail tuna near metropolitan areas where most fishers were sampled, such as the suburbs around Moreton Bay. However, many fishers stated longtail tuna are a bycatch species when targeting other pelagic species such as spotted mackerel and narrow-barred Spanish mackerel. Interestingly, in northern regions such as Broome, Gove and Darwin, sport fishers often stated that they actively avoided areas where longtail tuna were

particularly abundant because they compromise baits and lures being used for billfish and Spanish mackerel.

Comparison of survey methods

Comparing the cost and efficacy of different recreational fishing surveys is complex, not only due to difficulties in predicting or quantifying the sampling power required to obtain representative data from the target fishery, but also because each survey method has different advantages and disadvantages, some of which are difficult to detect or quantify such as non-response and prestige bias. As a result, we provided approximate minimum costs for undertaking a national recreational fishing survey for longtail tuna based on the data collected using the methods trialled in the present study alone.

The online diary method was estimated to be the most inexpensive sampling method for undertaking large-scale sampling of individual fishing trips, primarily due to relatively low labour, travel and operating costs. This method avoids unnecessary sampling of individuals who may not fish, based on the simple assumption that only fishers who fish in a manner allowing longtail tuna to be caught are eligible to submit data. However, the catch rates were at least twice as high as any other method. The vast majority of respondents fished for 11–30 days per year, while the majority of TLS respondents fished less than 10 days per year. This result may be explained by 73% of website respondents being land-based fishers; a group that only comprised 4% of respondents in TLS. This is probably a result of the passive nature of the online diary method, whereby fishers need to be sufficiently motivated to contribute data, and therefore the method suffered from volunteerism bias.

Land-based game fishers are generally a very motivated and avid group of fishers, since they are restricted in the areas they can fish for tuna. It is generally recognised among this group that a large amount of effort needs to be expended in order to have a chance of interacting with a longtail tuna in the relatively shallow waters close to the shore. It is clear that the online diaries were overrepresented by land-based fishers, since it is generally well known that this group is a minority within the recreational fishing sector (as shown in the TLS survey). Land-based gamefishers in sub-tropical and temperate regions of Australia do not have a large variety of species to target, and so longtail tuna are one of the primary targets, due to their relatively high abundance in comparison to their other target species such as yellowfin tuna and black marlin. Consequently, this group of fishers are strong advocates for ensuring the sustainability of longtail tuna, since the capture of a longtail tuna by members of this group is generally regarded as a prestigious event. Because this group of fishers appear to be socially connected through personal contacts and internet forums, the media releases for this project probably reached a large proportion of them rapidly. This type of recruitment pattern is generally indicative of ‘differential recruitment bias’ (Magnani et al., 2005; Heckathorn, 2007), which describes the disproportionate representation of sub-components within a sample of a population.

The apparent differences in attitudes of sub-components of the recreational longtail tuna fishery resulted in an elevated potential to incur avidity, prestige and volunteerism biases using the online diary method. Because there is no list frame of fishers who could potentially submit data, there is no way of knowing if a representative sample of fishers

has been collected, or understanding other types of biases such as non-response (Fisher, 1996). Because of these risks, this method is not recommended as a sampling method for a long-term monitoring program.

Access point surveys were estimated to be the most expensive method for a national longtail tuna survey. However, this method has the distinct advantage of allowing collection of high quality species-specific catch, effort and size distribution data, which are least affected by recall and many other types of biases. In particular, this method excludes the land-based component of the longtail tuna fishery, which, although apparently small, appears to expend a high level of effort and probably contributes to a reasonable proportion of the total recreational catch in some areas. If the land-based fishery was to be included in the national survey, a separate on-site survey method would be required, such as a roving creel survey, which would probably be a similar cost as the access point survey for boat-based fishers.

Somewhat surprisingly, the access point survey intercepted the highest number of sport fishers, which may be explained by the fact that each sport fishing boat intercepted carried more than one sport fisher. However, access point surveys can only survey individual trips, and therefore, the sampling effort required to represent the annual catch and effort for longtail tuna is high. For example, it took 41 days of sampling to record only 7 longtail tuna captures, which resulted in this method yielding the lowest catch rate of 0.006 fish hr⁻¹. Consequently, the sampling cost to obtain representative data from the entire Australian fishery is too high for this method to be considered a cost-effective option for a long-term monitoring program.

Time-location sampling using a recall survey is a reasonably low-cost sampling method that can rapidly gain access to sport fishers and collect data for a large number of fishing trips by intercepting sport fishers at one of their main aggregation point and by asking respondents to recall their fishing trips undertaken over the previous 12 months. However, travel costs are high for undertaking sampling across large spatial scales. It may be possible for this method to be undertaken using community involvement of recreational fishing groups to significantly reduce labour and travel costs, although this is unlikely to be successful in all reporting regions in the long-term. A significant effort was made in the present study to engage the recreational sector in the current research, since the project directly deals with a 'recreational-only' species for which we suspected there would be substantial support. Unfortunately, significant difficulties were encountered with recruiting volunteers and reliability issues with non-scientific personnel, which indicates that full scientific quality control is required for this method to be implemented successfully.

Effort estimates from recall surveys may be affected by recall bias if the recall period is longer than about two months (Tarrant et al., 1993; Pollock et al., 1994), which was the case in the present study. Effort estimates may also have been affected by longtail tuna often being an incidental catch when fishers target species such as Spanish mackerel. Therefore, recalled effort may be underestimated since fishers may have varying opinions of what constitutes fishing effort that is conducted in a fashion as to make capture of a longtail tuna possible. However, recall bias may not be a significant issue for recording catch when a capture is a memorable event (Pollock et al., 1994). In many interviews, fishers were immediately able to recall the number of longtail tuna caught, particularly when the number of fish caught was less than six. This is because longtail

tuna is not a common capture for most fishers and is a memorable capture. However, this may introduce telescoping and perhaps prestige bias, whereby a fisher recalls memorable events that occurred outside of the 12-month recall period. Therefore, it is important for researchers to provide clear reference dates that define the beginning of the sampling period, such as 'New Years Day' or 'Christmas Day'. Nonetheless, a TLS recall survey is reasonably low cost and is able to sample fishers from a range of avidity levels and across large spatial scales.

The TLS recall survey design could be improved to collect higher resolution data for individual trips and reduce recall bias if used in combination with a diary survey. Our survey specifically asked respondents if they would be willing to complete a diary for a 12-month period if a longer-term survey was undertaken. In general, it appears that a high percentage of sport fishers would be willing to complete a diary. The respondents who refused to complete a diary cited reasons other than being opposed to the sampling methodology. For example, most respondents stated they were too busy to keep a record of their fishing trips. However, these respondents are more likely to participate if the burden of data collection was transferred to the researcher, who could call respondents on a regular basis to recall their fishing trip details. Researchers could ask an approximate date of when the respondent is likely to fish again and call the respondent following the date provided. This is likely to reduce recall bias since the time between the trip being undertaken and the details recorded by the researcher is minimised. Such an approach is currently being used in a state-wide recreational fishing survey in Queensland.

The TLS survey could be used to cost-effectively recruit a representative sample of fishers across Australia to complete a fishing diary over a 12-month period. This approximately triples the survey cost due to additional labour required to manage the survey and to keep in contact with respondents on at least a monthly basis. This approach is likely to reduce recall bias and provide a more reliable catch rate estimate than a TLS recall survey, which makes this method the most cost-effective choice for a long-term monitoring program to collect data for stock assessment.

Estimating the total recreational catch of longtail tuna

Although TLS and access point surveys may be capable of providing a representative sample of the catch and effort of recreational fisheries targeting longtail tuna in Australia, they cannot directly estimate population size in order to expand sample estimates. Consequently, this study was unable to provide estimates of the total catch of longtail tuna in Australia. In most large-scale recreational fishing surveys that aim to estimate the total recreational catch of a species, a large-scale general population telephone survey is undertaken to estimate the proportion of the population who are active recreational fishers (Lyle et al., 2002). Unfortunately, this is not possible for small 'hard-to-reach' sport fishing populations such as recreational longtail tuna fishers, since the high sampling effort required to intercept these relatively rare fishers make the survey cost prohibitive (Teisl and Boyle, 1997).

However, with further development, population estimates may be made using capture-recapture techniques using time-location sampling and even access point surveys. This may be achieved by undertaking multiple surveys at each site, where respondents could

be asked for their name or asked if they had been interviewed previously. By recording the number of respondents that are 'recaptured' in each subsequent survey, it is possible to use capture-recapture models to estimate population size. This approach has been successful for estimating the population size of other 'hard to reach' populations that lack a list frame such as the homeless (Dávid and Snijders, 2002) and HIV-infected injection drug users (Mastro et al., 1994).

Although the total recreational catch could not be estimated using the three methods used in the present study, we can provide an estimate of the minimum number of longtail tuna caught by the relatively small number of recreational fishers surveyed in this study. The total catch (retained + released) in the surveys was 892 longtail tuna, which ranged in length between 30 cm and 150 cm TL, with a mean of 95 cm TL, or about 8.85 kg. This translates into a minimum annual catch by surveyed fishers of approximately 79 t. The total annual recreational catch is likely to be significantly higher than this minimum estimate if greater sampling effort could be expended across all time and effort strata, and an estimate of the population size could be attained. This highlights the need for a more comprehensive national survey in order to obtain a reliable estimate of longtail tuna catch by the recreational sector.

8. PRELIMINARY STOCK ASSESSMENT

8.1 Background

Longtail tuna (*Thunnus tonggol*) is a commercially-important species throughout the Indo-Pacific. The species is heavily exploited in rapidly expanding multi-species purse seine, gillnet and troll fisheries in underdeveloped countries, such as Indonesia, Taiwan, Thailand and Iran. Global reported catches of longtail tuna increased substantially to around 100,000 t yr⁻¹ in 1985 and continued to increase to over 200,000 t yr⁻¹ after 2003 and reached 248,000 t in 2007 (F.A.O., 2009). Over the past decade Thailand, Indonesia, Malaysia and Iran contributed most to the global reported landings.

In contrast, longtail tuna has been only lightly exploited by commercial fisheries in Australia with annual reported landings averaging only 34 t since 1974 (F.A.O., 2009). However, catches of longtail tuna in the Taiwanese gillnet fishery that operated under bilateral agreement in northern Australian waters between 1979 and 1986 reached 2000 t yr⁻¹, which was primarily taken as a bycatch when fishers targeted sharks and narrow-barred Spanish mackerel (*Scomberomorus commerson*) (Stevens and Davenport, 1991). Longtail tuna was recently recognised as being more important as a sport fish in Australia, and as a result, was declared a ‘recreational-only’ species by the Commonwealth government in 2006 (see www.daff.gov.au). However, an annual catch bycatch limit of 70 t is permitted for Australian Commonwealth commercial fisheries, which is approximately double the average annual commercial catch since 1974 (FAO, 2009). The sport fishery for longtail tuna is primarily catch-and-release, although the retention rate is high in some recreational sub-fisheries, such as the land-based fishery.

Despite the importance of longtail tuna to commercial and sport fisheries throughout their worldwide distribution, no stock assessments have been undertaken to determine whether current harvest rates are biologically sustainable. Stevens and Davenport (1991) raised concern over declining catch rates of some species targeted in northern Australia by the Taiwanese gillnet fishery in the early 1980s, although insufficient biological and catch data were available at the time to assess the status of longtail tuna. Although the Australian government has been pro-active by managing longtail tuna as a ‘recreational-only’ species in Australian waters, the efficacy of this management measure is unknown. However, recent completion of biological studies on longtail tuna in Australia (Griffiths et al., 2010) have provided some of the key information required to undertake an assessment of the current and historic status of longtail tuna in Australian waters.

8.2 Objectives

The objectives of this component of the longtail tuna project were to:

- 1) describe the length and age structure of the longtail tuna population exploited by commercial and sport fisheries in Australia,
- 2) estimate the current fishing mortality rate in Australian waters using existing datasets,
- 3) undertake a preliminary stock assessment using dynamic pool models to assess the current status of longtail tuna in Australian waters,
- 4) assess the efficacy of size limits and reduced post-release mortality rates through improved handling practices on the sustainability of longtail tuna in Australian waters.

8.3 Methodology

8.3.1 Defining the stock

Limited data are available on the stock structure of longtail tuna throughout its worldwide distribution. Wilson (1981) suggested that longtail in Australia and Papua New Guinea are a single stock based on a small number of genetic samples analysed using allozyme electrophoresis. In contrast, Serventy (1956) analysed morphometric measurements and suggested that fish from western and eastern Australia comprise two separate stocks, and possibly separate sub-species. Recent tagging data from Industry and Investment NSW's Gamefish Tagging Program suggest that longtail tuna make extensive movements along the east Australian coast and it is likely these fish mix, at least to some degree, with fish from the Gulf of Carpentaria (GoC) in northern Australia (Figure 8.1). Very little is known of the movements of fish in western Australia, or whether fish move from the Australian Economic Exclusion Zone into the waters of neighbouring countries such as Indonesia.

In the absence of reliable evidence relating to stock structure, a precautionary approach was undertaken in this study which assumed that longtail tuna exist as a single stock from the central Arafura Sea and eastward along the eastern coast of Australia (Figure 8.1). This was also the same region used by Griffiths et al. (2010) to define the population boundaries for an age and growth study of longtail tuna in Australian waters.

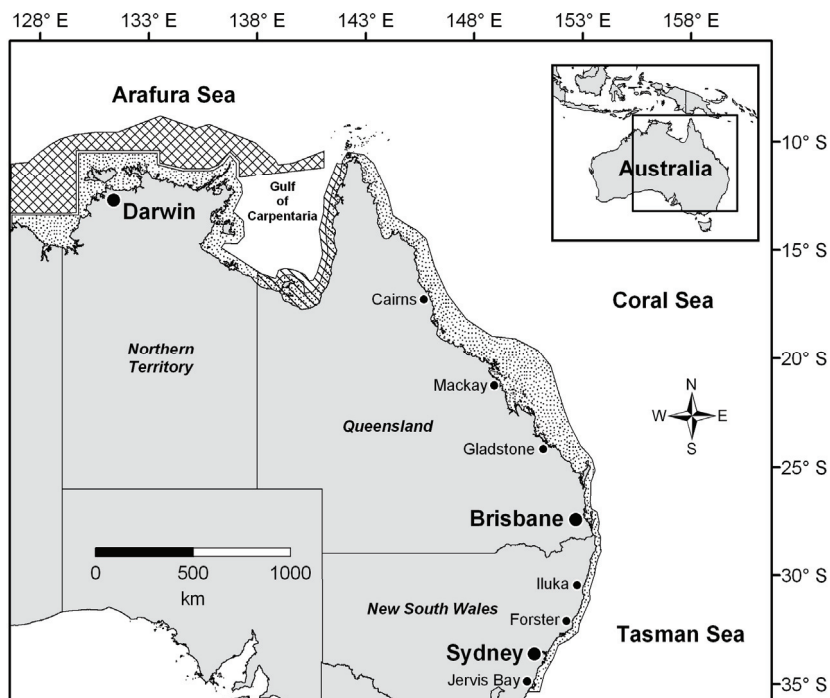


Figure 8.1: Map of the assumed stock region extending throughout the Arafura Sea, Coral Sea and Tasman Sea, Australia. Areas where data were available comprise the Queensland N9 offshore gillnet fishery (diagonal lines), the combined boat-based and land-based sport fishery (dotted area), and the Taiwanese gillnet fishery (cross hatched lines).

8.3.2 Fishery data used to estimate fishing mortality

Longtail tuna are not a target species of any state or Commonwealth commercial fishery in Australia. Consequently, there are currently no available time series data of catch and effort for undertaking detailed stock assessment analyses. However, there are limited sources of age or size composition data that can be used to estimate total mortality (Z) from linear catch curves (and thus F , assuming $F = Z - M$) to provide information for a preliminary assessment of the stock status of longtail tuna in Australia.

The largest data source available for longtail tuna in Australia was collected via logbooks and CSIRO scientific observers for the Taiwanese gillnet fishery between 1979 and 1986 across northern Australia (Stevens and Davenport, 1991). Vessels used gillnets comprised of 145 mm to 190 mm monofilament mesh and having an average length of 16,000 m. Logbook catch data were available for 24,842 gillnet sets, but unfortunately longtail tuna were aggregated with several other species and reported as “Scombridae” or “tuna” in logbooks, so detailed analysis of catch rates was not possible. Detailed information on catch and size composition of longtail tuna (and all other species caught) was recorded by scientific observers for 381 gillnet sets that were primarily made off northern Australia between 1981 and 1985. However, given the high size selectivity of this fishery, this information cannot be used to estimate a historic fishing mortality rate using catch curve analysis. Therefore these data were used in association with other data sources from the GoC and the east Australian coast to describe possible ontogenetic migration and construct selectivity-at-age functions for gillnets.

In recent years, the Queensland (Qld) N9 gillnet fishery and the sport fishery were the only domestic fisheries having any significant interaction with longtail tuna. The N9 gillnet fishery chiefly operates in the GoC and uses similar gear as the Taiwanese gillnet fishery, monofilament gillnets of around 1400 m in length with mesh size of 165 mm to target sharks and grey mackerel (*Scomberomorus semifasciatus*). Longtail tuna comprise a significant bycatch in this fishery, but a trip limit of only 10 fish has generally resulted in fish being discarded. Catch and length-frequency data were used from 268 sets monitored by scientific observers throughout 2005 along the eastern coast of the Gulf of Carpentaria in northern Australia (Figure 8.1).

Data for the sport fishery were collected from boat-based and land-based anglers from coastal regions throughout the study area (Figure 8.1). Catch and length-frequency data representing the boat-based sport fishery were collected from fishing tournaments and independent scientific sampling using typical sport fishing gear in the GoC and along the east coast described by Griffiths et al. (2007). Longtail tuna are a primary target species in the recreational land-based gamefish (LBG) fishery where anglers generally capture large specimens in the region extending from Gladstone, Qld to Jervis Bay, NSW. Catch and size composition from the LBG fishery was collected using on-site roving creel surveys and angler-reported electronic logbooks between 2005 and 2006 (Griffiths, S.P. unpublished data). It is important to note that while the LBG fishery was sampled to Jervis Bay, NSW, catches of longtail tuna were only available as far south as Forster, NSW (Figure 8.1).

8.3.3 Estimates of mortality

Three empirical equations were used to estimate the instantaneous natural mortality rate (M) of longtail tuna. The first model is based on Pauly (1980):

$$\log_e(M) = -0.0152 - 0.279 \log_e(L_\infty) + 0.6543 \log_e(K) + 0.463 \log_e(T), \text{ (Pauly 1980) } \quad (2)$$

where K and L_∞ are von Bertalanffy growth parameters of 0.223 yr^{-1} and 135.4 cm FL , respectively (Griffiths et al., 2010) and T is the annual mean water temperature throughout the study region estimated at 22.9°C (CSIRO unpublished sea surface temperature data).

The second model was that of Jensen (1996):

$$M = 1.60 (K), \quad (3)$$

where K is the von Bertalanffy growth parameter.

The third model was based on Hoenig (1983):

$$M = -\log_e(0.01)/\omega \quad (4)$$

where ω is maximum age (18.7 years; Griffiths et al., 2010), or more specifically, the age at which 1% of the population would survive in the absence of exploitation. Although a reasonably large sample of fish was aged in the vicinity of the maximum

recorded size for this species (Griffiths et al., 2010), the population has undergone various degrees of exploitation by commercial and sport fisheries since at least 1897 (Serventy, 1942b). As a result, it is possible that the assumptions of this method were violated, so results were viewed with caution.

The three models were used to estimate M because this parameter is difficult to measure empirically and the variability in this value needed to be accounted for. However, these three models assume that M remains constant across all age classes, which is often not the case for tunas. Hampton (2000) showed that in skipjack, bigeye and yellowfin tuna natural mortality-at-age tends to be “U-shaped” with rates being around 2–4 times higher during the first year than in subsequent years where M is generally more constant. Therefore, a modified natural mortality-at-age function for bigeye tuna in the Pacific Ocean was used (Langley et al., 2008), since this species has a similar intrinsic growth rate ($K = 0.238 \text{ yr}^{-1}$) as longtail tuna ($K = 0.223 \text{ yr}^{-1}$) and both species have a similar lifespan of about 18 years (Farley et al., 2006; Griffiths et al., 2010). The natural mortality-at-age function was adjusted proportionally so that the mean mortality across all age classes equalled the estimates from each of the three empirical equations.

Length-frequency data were converted to ages using the length-at-age function of Griffiths et al. (2010) in preparation for age-based catch curve analysis (Beverton and Holt, 1957), which was used to estimate the total annual instantaneous mortality rate (Z). Estimates of M were subtracted from Z to derive the current annual instantaneous fishing mortality rate (F_{current}) for the period 2005–2007 using data combined for the N9 gillnet fishery, the boat-based sport fishery in northern and eastern Australia, and the land-based gamefish fishery along eastern Australia.

Because size selectivity patterns differed between commercial and sport fisheries, numbers-at-age caught in each fishery required adjustment prior to construction of catch curves. Total mortality of each length or age class, t , can be expressed in equilibrium state as:

$$Z_t = M_t + S_t^{\text{commercial}} F_t^{\text{commercial}} + S_t^{\text{sport}} F_t^{\text{sport}}$$

where M_t is the natural mortality rate of age class t , S_t and F_t is the selection probability and fishing mortality of age class t , for the commercial and sport fishery, respectively.

Selection probability-at-age in each fishery was estimated using one of two methods described by Sparre and Venema (1992). Selection probabilities in line fisheries (e.g. longline and hook and line) tend to follow a logistic function (Hovgård and Lassen, 2000) because the gear is usually capable of catching fish of any size after recruitment to the fishery. Although the length- and age-frequency distributions differed between sport fisheries in northern and eastern regions, they use similar techniques and gear so these differences were attributed to availability of fish of different size classes in specific regions, rather than differences in gear selectivity. Therefore, data were combined to estimate a selectivity function for the overall sport fishery. This was done by first regressing the natural logarithm of the number of fish in each age class against age, as per standard linear catch curve analysis. The probability of capture was then estimated by backwards extrapolation of the descending limb of the catch curve to include younger age classes that were likely to be underrepresented in the catch. A

logistic function was then fit to the selection probability-at-age data to estimate the age (t) at which 50% of fish were susceptible to capture (T_{50}) and was best described as:

$$S_t = \frac{1}{1 + e^{8.8842 - 2.2394t}}$$

T_{50} was considered to be the age of recruitment to the sport fishery, which was later used in per-recruit analyses.

In contrast to the sport line fishery, selection probability-at-age for gillnet fisheries generally follow a normal distribution and can be expressed as:

$$S_t = \exp\left[-\frac{(t - t_m)^2}{2 \times s^2}\right]$$

Where t_m is the age of fish most susceptible to capture and s is the standard deviation of the normal distribution. The Taiwanese and N9 fisheries used the same gear, although their catch-at-age distributions differed markedly. This probably reflects the presence of smaller fish in northwestern Australia where the Taiwanese fishery operated (see Results and Serventy, 1956), rather than differential gear selectivity. Therefore, these two curves were combined to describe the overall selectivity curve for a 165 mm mesh gillnet as input into the per-recruit models. This was achieved using the methods detailed by Sparre and Venema (1992) where by the ascending limb of the curve catching the smaller-sized fish (Taiwanese gillnet fishery) was combined with the descending limb of the curve catching larger-sized fish (N9 fishery) and the selection probability for fish sizes in the region where the two curves overlap was 1.

Similar to the sport fishery, the numbers of fish in each size class in the commercial fishery were then adjusted given their probability of capture, and then combined with the sport fishery data for catch curve analysis. Total mortality was then estimated from the slope of a linear regression fitted to the declining limb of the age distribution. An estimate of F_{current} was then made by subtracting M from Z .

8.3.4 Per-recruit analyses

Yield-per-recruit (Y/R) and spawning stock biomass-per-recruit (SSB/R) of longtail tuna in northern and eastern Australia was assessed using the model of Quinn and Deriso (1999). This model was used in preference to the widely-used Beverton and Holt (1957) model since the knife-edge selectivity assumption for all age classes was violated due to the sport and commercial fishery having different size selectivity patterns. The Quinn and Deriso (1999) model defines the age-specific annual exploitation rate (μ_t), which can be represented as:

$$\mu_t = \frac{F_t}{F_t + M} \left(1 - e^{-(F_t + M)}\right)$$

Here, the fishing mortality rate-at-age, F_t , is a separable product of age-specific selectivity, which was estimated from selectivity-at-age ogives in each fishery and expressed as:

$$F_t = S_t F$$

However, longtail tuna are caught by commercial and sport fisheries in Australia, each of which has different age selectivity patterns that can be expressed as:

$$F_t = \sum_j S_{t,j} F_j = \sum_j F_{t,j}$$

where $S_{t,j}$ and F_j is the age-specific selectivity probability and fishing mortality in the j th fishery, respectively (Quinn and Deriso, 1999).

There are no available maturity functions or reliable estimates of the length or age at 50% maturity (L_{50} and A_{50}) for longtail tuna. However, histological data from 461 fish collected in Australian waters (Griffiths, S.P. unpublished data) indicates that most fish appear to be mature at 60 cm FL (2 years of age) and all fish are mature by 70 cm FL (~4 years of age). Therefore, a logistic maturity-at-age function was developed where A_{50} and A_{100} were 2 and 4 years, respectively. However, due to uncertainty in A_{50} , a sensitivity analysis was undertaken to explore the effects of using an A_{50} of 3 or 4 years on SSB/R.

Due to uncertainty in natural mortality, Y/R and SSB/R analyses were undertaken using three values of M (0.2, 0.3 and 0.4), which captured the range of values estimated from the three natural mortality equations. The change in Y/R and SSB/R was explored by hypothetically imposing different minimum legal lengths (MLL) (no MLL, 80 cm, 90 cm and 100 cm TL) as a method for managing the commercial and sport fishing harvest. This was undertaken by varying the age at first capture in the Y/R model. Although delaying the age (or increasing length) at first capture in a fishery will theoretically increase yield and the mean size of fish, this will only occur if the gear selectivity is modified to avoid capturing undersized fish or if released undersized fish do not incur significant post-capture mortality (Griffiths et al., 2006).

Tunas can incur significant physical trauma and physiological stress during capture, which can significantly affect the probability of survival of released fish (Skomal, 2007). For species that interact with multiple gear types, such as longtail tuna, the post-capture survival rates from each fishery need to be incorporated into population models in order to understand the full extent of the impact by each fishery (Skomal, 2007). Therefore, separate post-capture mortality estimates were applied to the commercial gillnet fishery and the sport fishery.

Post-release mortality is difficult and expensive to evaluate in large oceanic pelagic fishes, and there is currently no species-specific data available for longtail tuna. Longtail tuna are obligate ram ventilators that need to swim constantly in order for their gills to extract sufficient oxygen from the water to satisfy their body's metabolic demands (Korsmeyer and Dewar, 2001). Therefore, capture by gillnets in northern Australia, where soak times are often long (up to 12 hrs), normally results in all longtail

tuna being dead upon capture. Consequently, post-capture mortality was assumed to be 100% for the N9 fishery.

In contrast, longtail tuna caught by the sport fishery are often released, but the probability of fish surviving release is likely to be dependent upon numerous factors including fight time, tackle used, hook type and hooking location (Skomal, 2007), as well as their vulnerability to predation once released (Kerstetter et al., 2004). There is no quantitative information on post-capture mortality of longtail tuna released by the sport fishery, although there is limited information from studies on other high performance fishes such as tunas and billfishes that are caught by hook and line. These studies suggest a wide range of survival rates between 60% (Yuen et al., 1974) and 100% (Holland et al., 1990). Recently, Graves et al. (2002) and Kerstetter et al. (2003) used pop-up satellite tags to determine that the short-term post-release mortality rate of line-caught blue marlin was 11% and 22%, respectively. Skomal et al. (2002) found that around 28% of juvenile Atlantic bluefin tuna caught by sport fishing anglers off eastern United States incurred potentially lethal injuries due to deep hooking by standard “J” hooks. Therefore, longtail were also assumed to have a post-release mortality of 28% for all age classes less than the age of recruitment into the sport fishery. For these age classes, fishing mortality can therefore be expressed as:

$$F_t = \sum_j S_{t,j} P_{t,j} F_j = \sum_j F_{t,j}$$

where $P_{t,j}$ is proportion of fish incurring post-release mortality (assumed to be 0.28; Skomal et al., 2002) in each age class (t) less than the age at recruitment (i.e. a MLL) to the j th fishery.

The possible effects of reducing post-release mortality on the stock status was also explored through improved fish handling practices by sport fishing anglers via a national awareness campaign, if it was determined that imposing a size limit was ineffective or logistically difficult. Sawynok (2004) estimated that 35% of anglers adopted new release strategies following a recent campaign to promote best handling practices for sport fishing anglers in Australia. Therefore, a fourth management scenario simulating the effect of having no MLL but reducing post-release mortality-at-age by 35% was explored.

A number of reference points were used to assess the status of the longtail tuna population in Australia compared to the present fishing mortality rate (F_{current}). The reference points were: F_{MSY} , the fishing mortality rate that produces the maximum yield-per-recruit; $F_{0.1}$, the fishing mortality rate at which the slope of the yield-per-recruit curve is 10% of the slope at the origin; $F_{25\%}$ and $F_{40\%}$, the fishing mortality rate corresponding to the 25% and 40% of the spawning potential ratio (SPR), respectively. The SPR is the SSB/R at a given fishing mortality divided by the SSB/R where $F=0$.

8.4 Results

8.4.1 Age structure exploited by fisheries

Length- and age-frequency distributions differed markedly between fisheries that operated in distinctly different regions throughout the Australian distribution of longtail tuna. The Taiwanese gillnet fishery that operated intensively in the Arafura Sea off northern Australia during the early 1980's captured a restricted size and age range of longtail tuna between 500–600 mm FL and 2+ years, respectively (Figure 8.2). In the northeast of the region within the Gulf of Carpentaria, the domestic N9 gillnet fishery caught slightly larger and older fish between 700–800 mm FL and 3+ years (Figure 8.2). The sport fishing fishery in the Gulf of Carpentaria also mainly caught fish between 700–800 mm FL and 3+ years, although the overall size range of fish caught was slightly narrower than the N9 gillnet fishery. In contrast, the sport fishery on the east Australian coast caught fish from a wide size range from 800–1100 mm FL and ages of 4+ to 8+ years (Figure 8.2).

8.4.2 Age and size selectivity of fisheries

Selectivity analyses indicated that the age (and length) at which 50% of longtail tuna (A_{50}), became susceptible to the Taiwanese, N9 and sport fisheries was 2.3 yrs (569 mm), 3.2 yrs (705 mm) and 3.5 yrs (725 mm), respectively (Figure 8.3). Because the Taiwanese and the N9 fisheries used similar mesh sizes, the apparent difference in selectivity curves reflects the presence of smaller fish in the Arafura Sea, rather than differential gear selectivity. Therefore, these two curves were combined, as previously described, to provide an overall selectivity curve for the commercial fishery (that use 6-inch gillnets) in the per-recruit models.

8.4.3 Mortality estimates

Natural mortality (M) estimates differed depending on the empirical equations used; 0.246 yr^{-1} (Hoenig, 1983), 0.357 yr^{-1} (Jensen, 1996), 0.399 yr^{-1} (Pauly, 1980). Natural mortality-at-age curves were then constructed for input into per-recruit analyses (Figure 8.4). Catch curve analysis incorporating sport and commercial catches for 2004–2006 yielded a total mortality (Z) estimate of 0.566 yr^{-1} (Figure 8.5). By subtracting estimates of M from Z , this translates to an annual fishing mortality (F_{current}) of $0.167\text{--}0.320 \text{ yr}^{-1}$ and an exploitation rate ($E = F/Z$) of $0.295\text{--}0.565$.

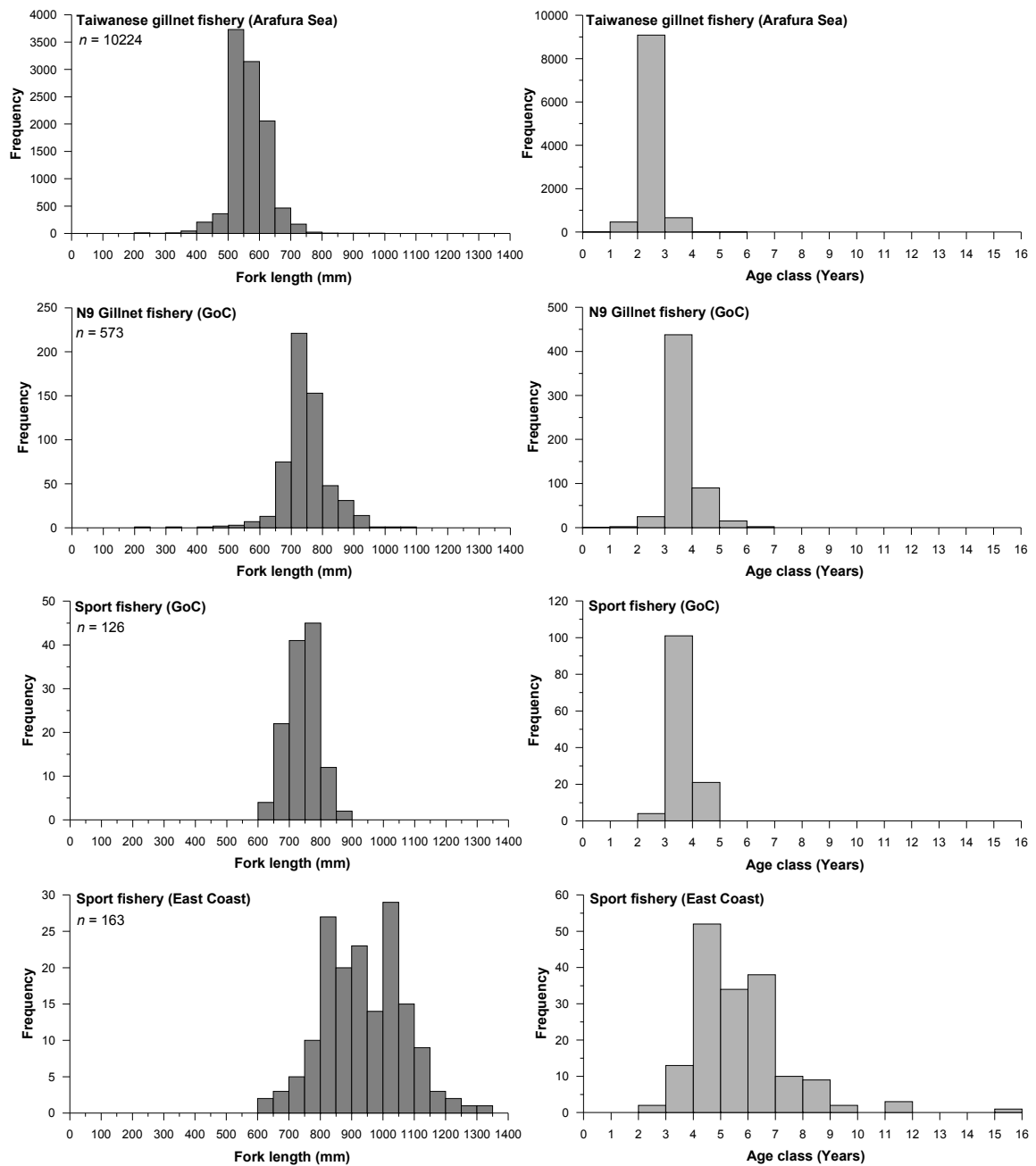


Figure 8.2: Length- and age-frequency distributions of longtail tuna caught in the Taiwanese gillnet fishery in the Arafura Sea (1981–1985), the Queensland N9 offshore gillnet fishery, and the sport fisheries (boat-based and land-based catches combined) in the Gulf of Carpentaria (GoC) and the eastern Australian coast.

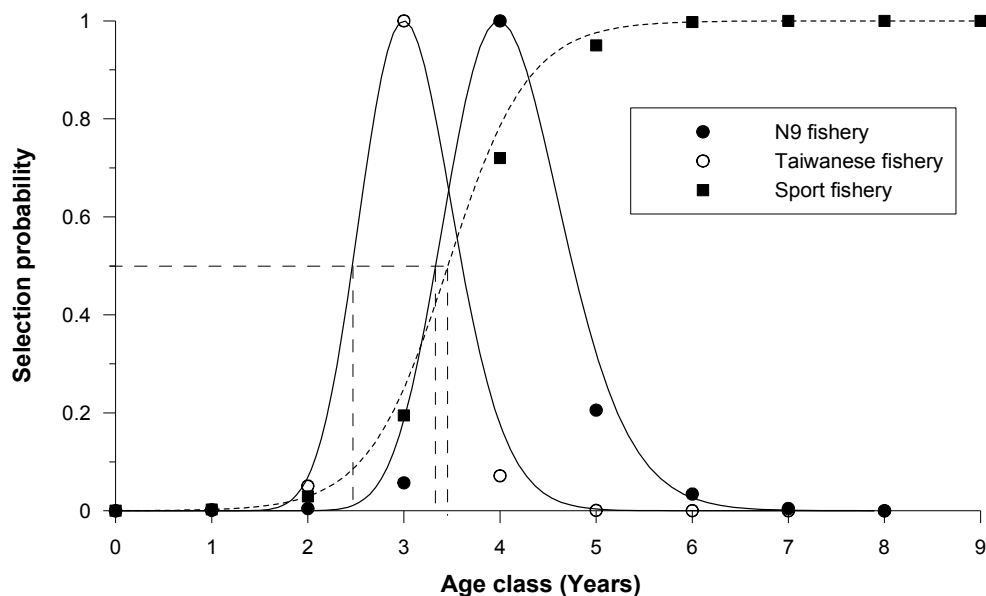


Figure 8.3: Age selectivity curves for longtail tuna caught in the Taiwanese gillnet fishery in the Arafura Sea (1981–1985), the Queensland N9 offshore gillnet fishery, and the sport fishery (combined for boat-based and land-based catches in the Gulf of Carpentaria and eastern Australia). Dotted lines show the age at recruitment to each respective fishery, defined as the age at which 50% of fish are susceptible to capture by the gear used in each fishery.

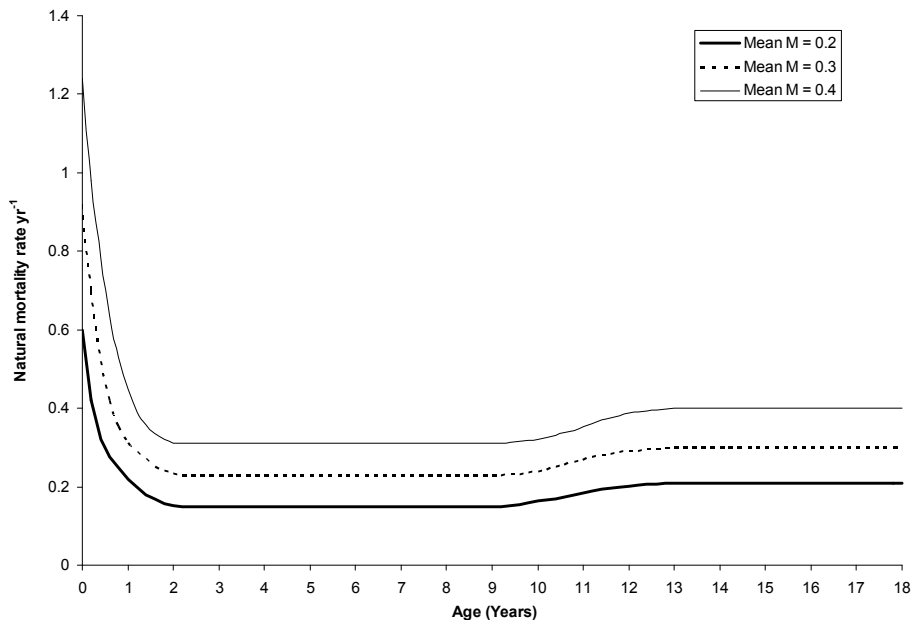


Figure 8.4: Natural mortality-at-age functions used in the yield-per-recruit analyses where the mean natural mortality rates (M) were 0.2, 0.3 and 0.4, respectively.



Figure 8.5: Age-based catch curves used to estimate total mortality (Z) of longtail tuna caught in commercial and sport fisheries for 2004–2006 in northern and eastern Australia. Numbers of fish in each age class from each fishery were corrected using selectivity probabilities-at-age before being combined to produce the overall catch curve for the longtail tuna stock.

8.4.4 Per-recruit analyses

Yield per-recruit was strongly influenced by the value of natural mortality used. However, the effect of increasing MLL was negligible with F_{MSY} varying across the four scenarios by only 41 g, 12 g and 0.1 g per recruit for natural mortality rates of 0.2, 0.3 and 0.4, respectively (Figure 8.6). The status of the longtail tuna population was therefore independent upon the value of M used.

Under all four management scenarios the estimated current fishing mortality, $F_{current}$, did not exceed F_{MSY} for any value of M (Figure 8.6). $F_{current}$ also did not exceed the precautionary $F_{0.1}$ reference point in each management scenario where $M = 0.3$ or 0.4 , but was in the vicinity of this reference point where $M = 0.2$. For all scenarios where $M = 0.3$ or 0.4 , fishing mortality could be increased to 0.5 and 0.7, respectively, before the precautionary $F_{0.1}$ would be exceeded (Figure 8.6).

Spawning stock biomass-per-recruit (SSB/R) was not significantly influenced by different MLLs, varying across the four scenarios and the three values of M by less than 105 g (Figure 8.7). The same pattern was apparent for all four management scenarios in that $F_{current}$ did not exceed the $F_{25\%}$ and $F_{40\%}$ reference points for any value of M . An exception was where $M = 0.2$, which resulted in $F_{40\%}$ being exceeded in all four management scenarios (Figure 8.7). If $F_{40\%}$ was used as a limit reference point, any increase in fishing mortality would not be recommended, except where $M = 0.4$ in which case fishing mortality could be approximately doubled (Figure 8.7).

Given the uncertainty in age-at-maturity (A_{50}) for longtail tuna, a sensitivity analysis was undertaken to assess the effect of increasing A_{50} to 3 and 4 years on $F_{40\%}$ and $F_{25\%}$ and the change in SSB/R at F_{MSY} . Using an A_{50} of 3 and 4 years resulted in a decrease in SSB/R at F_{MSY} by 28% and 41%, respectively (Table 8.1). Varying A_{50} did not affect F_{MSY} . Similar decreases occurred in SSB/R at $F_{40\%}$ and $F_{25\%}$ when increasing A_{50} (Table

8.1). However, the fishing mortality at which these reference points were attained decreased with increasing values of A_{50} . Given the aforementioned stock status described using $A_{50} = 2$ years, if A_{50} was in fact closer to 3 or 4 years, it is likely that the stock is recruitment overfished at any value of M .

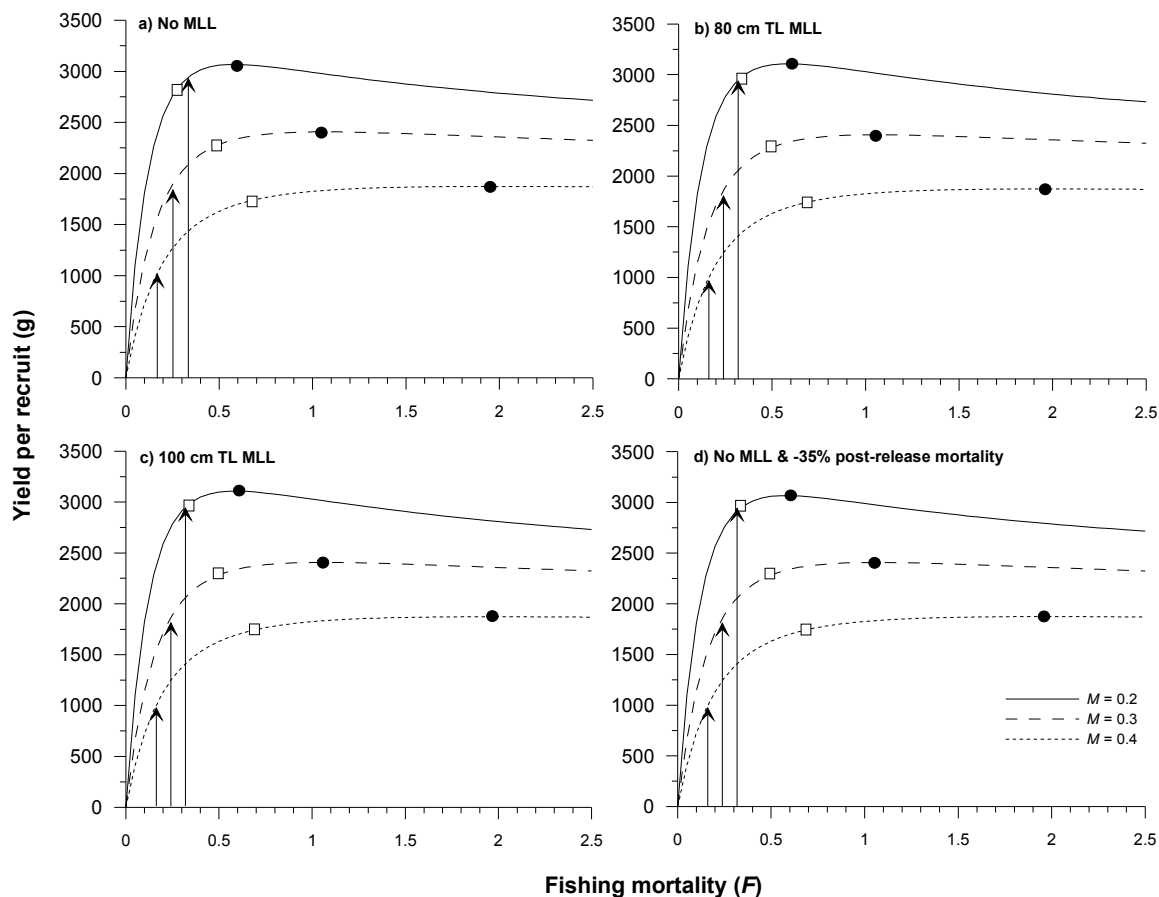


Figure 8.6: Yield per-recruit curves using natural mortality (M) estimates of 0.2, 0.3 and 0.4 simulating five hypothetical management scenarios: a) no minimum legal length (MLL), b) 80 cm TL MLL, c) 100 cm TL MLL, and d) No MLL with a 35% reduction in post-release mortality resulting from a national awareness campaign. Reference points F_{MSY} (solid circles) and $F_{0.1}$ (open squares) are shown in relation to the current fishing mortality rate, $F_{current}$ (solid arrows).

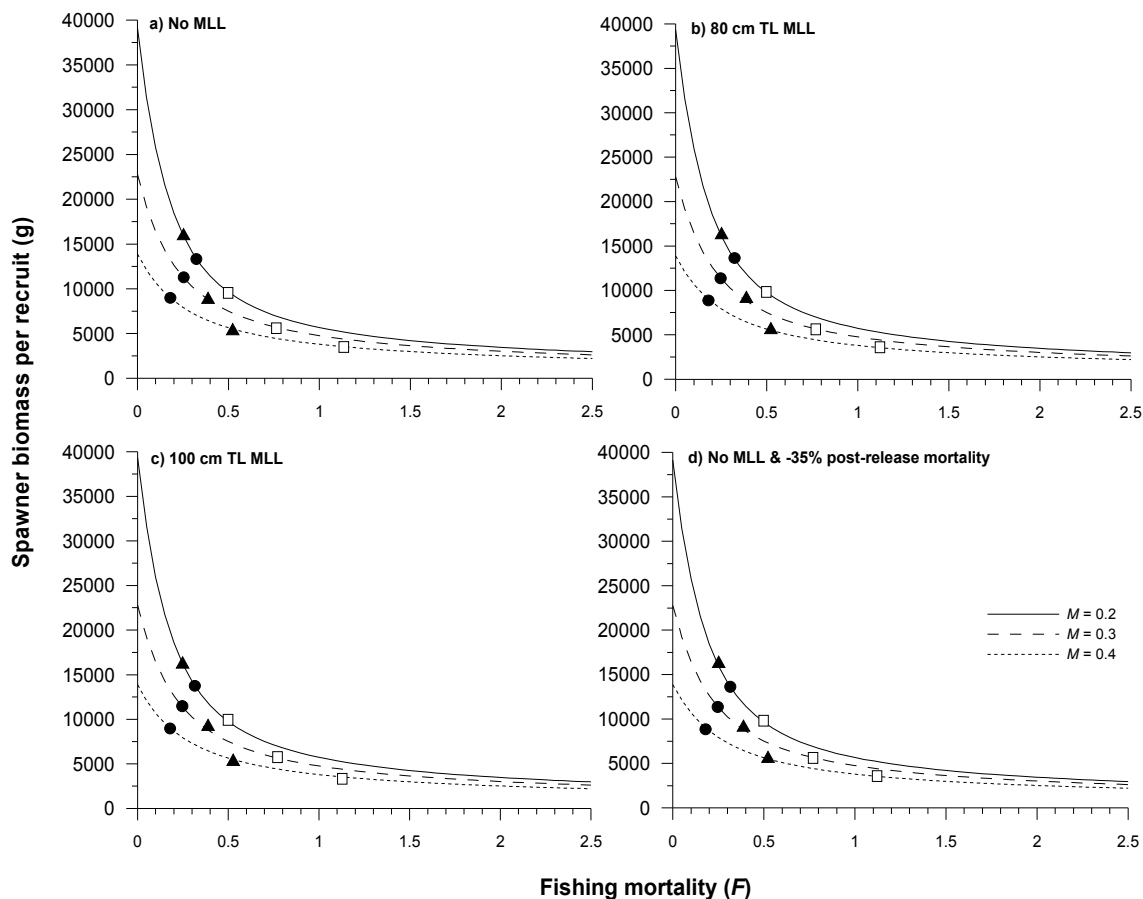


Figure 8.7: Spawner biomass per-recruit curves using natural mortality (M) estimates of 0.2, 0.3 and 0.4 simulating five hypothetical management scenarios: a) no minimum legal length (MLL), b) 80 cm TL MLL, c) 100 cm TL MLL, and d) No MLL with a 35% reduction in post-release mortality resulting from a national awareness campaign. Reference points $F_{40\%}$ (solid triangles) and $F_{25\%}$ (open squares) are shown in relation to the current fishing mortality rate, $F_{current}$ (solid circles).

Table 8.1: Results of a sensitivity analysis exploring the effect of varying age-at-50%-maturity (A_{50}) on the spawning biomass-per-recruit (in grams) at three reference points F_{MSY} , $F_{40\%}$ and $F_{25\%}$.

A_{50} (yrs)	M	F_{MSY}		$F_{25\%}$		$F_{40\%}$	
		SSB/R	F	SSB/R	F	SSB/R	F
2	0.2	8359.7	0.60	9629.8	0.67	16011.1	0.28
	0.3	4606.4	1.05	5758.2	1.10	9367.2	0.37
	0.4	2555.7	1.95	3495.9	1.75	5643.4	0.53
3	0.2	6034.7	0.60	7160.1	0.5	13103.0	0.22
	0.3	3033.8	1.05	3936.7	0.75	7075.3	0.29
	0.4	1628.9	1.95	2274.9	1.05	3979.4	0.41
4	0.2	4915.2	0.60	5877.2	0.34	11206.9	0.2
	0.3	2470.3	1.05	3192.9	0.65	5847.9	0.28
	0.4	1354.1	1.95	1864.8	1.0	3239.9	0.35

8.5 Discussion

The collation of data from contemporary studies and historic data from the Taiwanese gillnet fishery revealed interesting trends regarding the stock structure and possible movements of longtail tuna in Australian waters. It is clear that different ontogenetic stages exist in different regions throughout Australia, which appears to be responsible for differences in length-frequency distributions of longtail tuna caught in different fisheries, rather than differences in size selectivity of the gear used in each fishery. This was demonstrated by the Taiwanese gillnet fishery in the Arafura Sea and N9 gillnet fishery in the Gulf of Carpentaria (GoC) both using 165 mm monofilament mesh but having very different length-frequency distributions. However, the sport fishery in the GoC had the same length composition as the N9 fishery indicating their methods were largely unselective and catching fish from all available size classes. Lastly, the sport fisheries in the GoC and off eastern Australia both utilise the same methods (primarily high-speed spinning with metal lures or using live bait), yet their length compositions did not show any significant overlap, with larger fish being more common along the east coast. This provides strong support to the hypotheses of Serventy (1956) and Wilson (1981) that longtail exist as a single stock in Australian waters and that northwestern Australia is a nursery habitat from which fish radiate eastward and southward. This information therefore provides a strong justification for treating longtail tuna as a single population in the current stock assessment.

The life history of longtail tuna appears to be very different to other similar-sized tropical tunas in that the species is relatively slow-growing and long-lived (Griffiths et al., 2010). Instead, their growth dynamics appear similar to what has been observed for the large *Thunnus* species, such as bigeye tuna (*Thunnus obesus*), which can grow in excess of 200 kg and live for at least 16 years (Farley et al., 2006). Figure 8.8 illustrates the similarity of the growth dynamics of longtail tuna with larger, slower-growing *Thunnus* species, with growth dynamics standardised by the age at which each species attains 80% of L_{∞} .

Longtail tuna do, however, have an apparently high reproductive potential, having a protracted spawning period (Griffiths et al., 2007) and producing over one million eggs per spawning (Griffiths, S.P. unpublished data), although it is unclear at what age fish become sexually mature in Australian waters. From the available evidence fish may mature relatively early in life at less than 60 cm FL and two years of age. However, no reproductive study has been able to assess maturity across the whole size range of the species during the spawning period using reliable histological analysis. Consequently, results from the spawner biomass per-recruit analyses need to be viewed with caution since an A_{50} of age 2 was used. Sensitivity analysis demonstrated that if A_{50} occurred at 3 or 4 years, the status of the stock would change significantly from currently being underfished in the vicinity of $F_{40\%}$, to most likely exceeding the $F_{25\%}$ limit reference point, thus deeming the stock recruitment overfished.

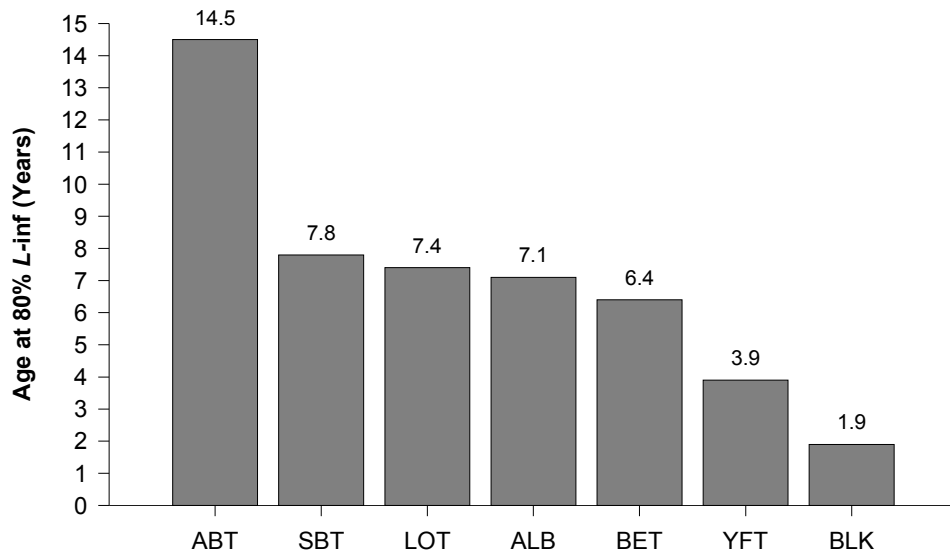


Figure 8.8: Comparison of growth dynamics of seven *Thunnus* species: Atlantic bluefin tuna (*Thunnus thynnus*; ABT) (Neilson and Campana, 2008), southern bluefin tuna (*T. maccoyii*; SBT) (Gunn et al., 2008), longtail tuna (*T. tonggol*; LOT) (Griffiths et al., 2010), albacore (*T. alalunga*; ALB) (Santiago and Arrizabalaga, 2005), bigeye tuna (*T. obesus*; BET) (Farley et al., 2006), yellowfin tuna (*T. albacares*; YFT) (Lessa and Duarte-Neto, 2004) and blackfin tuna (*T. atlanticus*; BFT) (Doray et al., 2004). Age at 80% of L_{∞} was used as a standardised measure of growth dynamics to compare species that attain different maximum lengths.

A lack of understanding of the biology of some tuna species has led to inadequate management and overexploitation in many parts of the world (Fromentin and Powers, 2005; Dankel et al., 2008). For example, after southern bluefin tuna were confirmed to live for at least 32 years (Gunn et al., 2008) and reach sexual maturity at around 12 years of age (Gunn et al., 1996) fishery managers began to realise the severity of the existing stock depletion. This is now clearly evident with the species being listed on the IUCN Red List of Threatened Species as ‘critically endangered’. In light of the similar slow growth of longtail tuna, coupled with its restricted coastal distribution throughout its worldwide distribution (Yesaki, 1993), this species may also be vulnerable to overexploitation if not managed in a precautionary manner until more quantitative biological data is collected, particularly length at sexual maturity. Furthermore, the present study has only provided a minimum catch estimate of longtail tuna catches by the sport fishery in Australia. However, a long-term monitoring program is required to provide a time series of representative catch data that can be used in more rigorous age-structured stock assessment models than the preliminary dynamic pool model used here.

In developing fisheries where little historical data on catch or effort are available, dynamic pool models such as yield per-recruit models can be a useful tool for obtaining a preliminary assessment of the status of a fished population (Gabriel and Mace, 1999). However, fisheries managers need to exercise caution in establishing sensible reference points that will not drive the population below biologically sustainable limits, while at the same time allowing exploitation and equitable access to the resource among fishery stakeholders. Maximising yield by fishing a population at F_{MSY} has been deemed risky because it assumes constant recruitment that is independent of spawning stock size (see review by Gabriel and Mace, 1999). As a result, emphasis is placed on assessing the

status of the longtail tuna stock relative to widely used $F_{0.1}$ reference point, which is more conservative and useful for data-limited fisheries and can reduce the risk of a stock collapse early in the development of a fishery (Gulland and Boerema, 1973). One criticism of yield-per-recruit models is that they do not take into account the stock-recruitment relationship and assume constant recruitment (Quinn and Deriso, 1999), and therefore are unable to detect recruitment overfishing. However, in an attempt to circumvent this problem, F_{MSY} was assessed against the spawning potential ratio reference points $F_{25\%}$ and $F_{40\%}$, which can be used to assess recruitment overfishing (Clark, 1991; Goodyear, 1993; Rosenberg et al., 1994).

The recent declaration of longtail tuna as a 'recreational-only' species by the Commonwealth government may afford the species some protection from any increase in large-scale targeting by commercial fisheries. Although the yield per-recruit analyses revealed the stock is currently at an ideal status for a developing fishery where the precautionary $F_{0.1}$ reference point has not been exceeded, full utilisation of the current catch quota of 70 t for Commonwealth commercial fisheries may begin to contribute to the stock being growth overfished, due to the dominance of small fish in commercial catches. Therefore, it is recommended that close monitoring of the stock continue to better understand the propensity of the population to withstand any increase in fishing mortality either by commercial or sport fisheries.

These results clearly highlight the need for precautionary management until more reliable estimates of biological parameters and fishing mortality are obtained to provide data for a more rigorous assessment of the stock, although it is unclear at this point what the most appropriate measure would entail. Introduction of a minimum legal length is usually one of the few practical management options for reducing the size at first capture, and thus reducing the fishing mortality, on species that have a large sport fishing catch. However, this is not likely to be effective for longtail tuna for two reasons. Firstly, the yield-per-recruit analyses clearly showed that increasing the MLL has a negligible effect on the sustainability of the longtail tuna population. In most cases where a MLL has been successfully used as a management strategy to increase the sustainability of a stock, the MLL has been set to a length that corresponds to the length at which 50% of the population is sexually mature (L_{50}). However, all indications from the limited available data on the reproductive biology of longtail tuna are that they appear to reach sexual maturity early in life at around 60 cm FL (~2 years of age). Consequently, fish have an opportunity to spawn at least once before they become susceptible to capture by both commercial and sport fisheries at around 3 years of age. However, the sensitivity analysis of A_{50} values (Table 8.1) showed that if age-at-maturity occurs later than assumed in the assessment, then the spawner biomass-per-recruit would be significantly lower than reported here. As a result, the current fishing mortality is likely to exceed $F_{25\%}$ and $F_{40\%}$ and reference points and indicate recruitment overfishing.

Secondly, longtail tuna are primarily an incidental catch in most Australian commercial fisheries, such as the N9 fishery, and an increase in size at first capture can only be achieved by increasing the mesh size of gillnets. This would increase the size of fish at first capture, reduce the fishing mortality, and theoretically increase the yield and spawning stock biomass of longtail tuna. However, multi-species fisheries such as the Qld N9 fishery may experience reductions in the catch of their target species, such as small sharks and grey mackerel, and ultimately become unprofitable.

The use of a MLL only becomes an effective management tool if undersized fish have high post-release survivorship. Although post-release mortality was accounted for in the model, species-specific data for longtail tuna was unavailable, and so post-release mortality estimates for juvenile Atlantic bluefin tuna were used (Skomal et al., 2002). Nevertheless, the inclusion of this parameter did not have any significant effect on the model results because the selection probabilities for ages less than the hypothetical MLL were already very low as fish of this size had not yet become fully susceptible to the gear of either the commercial or sport fishery. Therefore, the 28% post-release mortality imposed on the already small proportion of the population that was captured by fisheries less than the MLL resulted in a negligible effect.

If more rigorous stock assessments are to be undertaken in future it will be imperative to obtain species-specific data on post-release mortality, since estimates have been shown to vary significantly among large pelagic fishes (see review by Skomal, 2007). This has been successfully undertaken for tunas and billfishes using pop-up archival tags, which can be programmed to release from the fish a few days after release if the fish survives, or release once the fish ceases to display normal behaviour. Although expensive, the advantage of this approach is that fish are not required to be recaptured to determine their fate post-release, and there is no reliance upon fishers to report the recapture of a tagged fish.

In conclusion, the preliminary stock assessment has demonstrated that longtail tuna are currently probably being fished at biologically sustainable levels, with some scope for a limited increase in fishing mortality. However, there is potential for recruitment overfishing if the true age-at-maturity is higher than the estimate of 2 years used here, despite the stock experiencing relatively low levels of exploitation by the sport fishery. Species of wide-ranging oceanic tunas may be able to withstand the fishing pressure by sport fisheries since fish may spend a large portion of their lives in open ocean areas that are inaccessible by most sport fishers. In contrast, longtail tuna may be particularly vulnerable to overexploitation by sport fishers owing to their restricted coastal distribution and their slow growth (Griffiths et al., 2010).

The yield-per-recruit model was unable to provide any indication of appropriate precautionary management strategies for longtail tuna as 'recreational-only' species, since the methods that can be easily and cost-effectively implemented to help decrease the fishing mortality rate (i.e. MLL and improved post-release survival rates) were ineffective. Further management options need to be explored, such as the implementation of daily catch limits for individual anglers and total catch quotas for the sport fishery (combined with the existing 70 t bycatch limit for commercial fisheries). These scenarios will require more accurate estimates of natural mortality and post-release survival which may be obtained by a tagging program, age-at-50% maturity, as well as collection of long-term representative catch and effort data for the sport and commercial fishery. This will enable more sophisticated stock assessment models to be employed to assess the status of the stock.

9. BENEFITS AND ADOPTION

Successful fisheries management relies on high quality stock assessment models that require reliable information on the biology and natural mortality of a targeted species and the mortality imposed by other sources. The national longtail tuna recreational fishing survey constitutes the first attempt to collate existing and new data on the biology, ecology and fisheries of longtail tuna worldwide. In particular, the study obtained first order information on the recreational catch and effort directed towards Australia's newest 'recreational-only' species, as well as profiles of fishers targeting the species. Baseline information on biology and fishery catches is fundamental for modelling the dynamics of the longtail tuna population, to assess the population status, which will ultimately guide management.

Given the small resources available to this project, the recreational fishing data collected by two new sampling methods—time-location sampling and online diaries—and a traditional access point survey are by no means exhaustive and may not be completely representative of the recreational fishery for longtail tuna in all regions around Australia. However, it has provided important information that has improved our understanding of the behaviour and attitudes of participants in the recreational fishery for longtail tuna and how best to design future surveys for longtail tuna and other species supporting specialised recreational fisheries. The biological data mined from various sources combined with the preliminary catch data from the current project also allowed a preliminary stock assessment to be undertaken from which key information gaps have been identified to guide future research.

Managers and researchers in Commonwealth and state fisheries agencies and recreational fishing groups will benefit from this research in two ways. First, managers and researchers can obtain a better understanding of the recreational fishery for longtail tuna and how the species may be managed in their respective jurisdictions. For example, state fishery managers may use the information to revise bycatch limits in commercial fisheries given the new information regarding the relatively slow growth and longevity of longtail tuna. Recreational fishing groups may benefit by demonstrating to fishery managers that they are showing stewardship for the species and that they may be encouraged to play a role in the long-term monitoring of the longtail tuna population.

The second way that researchers and managers may benefit is that they can now assess the suitability of two innovative and cost-effective sampling approaches that have not been widely used in recreational fisheries research. This may allow other researchers to use our proposed methodology and build on our experiences to undertake cost-effective surveys for hard-to-reach components of other recreational fisheries. Furthermore, it may allow fishery managers to have more reliable information on specialised fisheries (e.g. southern bluefin tuna) in order to implement the most appropriate management measures to ensure the sustainability of resources, and allow equitable sharing among sectors sharing the resource.

10. FURTHER DEVELOPMENT

The objective of this study was to collate existing literature on the biology, ecology and fisheries of longtail tuna both in Australia and throughout their global distribution, as well as obtain baseline information on the longtail recreational fishery in Australia. Undertaking recreational fishing surveys to obtain representative quantitative information is statistically and logistically complex, and often expensive. Previous surveys have indicated that the sampling effort required in traditional telephone or creel surveys to obtain meaningful catch and effort estimates for 'rare event' species or fisheries can be enormous, and is often cost prohibitive. This study confirmed this to be the case when comparing results of a traditional access point survey with two new cost-effective survey approaches, time-location sampling (TLS) and online diaries.

Online diaries were clearly unsuitable for obtaining representative data in the specialised recreational longtail tuna fishery, primarily due to the various biases that cannot be accounted for as a result of an unknown population contributing data. In contrast, TLS showed great promise as a means of accessing the hard-to-reach participants in this fishery. Given the limited resources within this project, it was not possible to undertake a comprehensive random stratified TLS sampling regime across Australia. Instead, we attempted to test the general efficacy of TLS for accessing hard-to-reach longtail tuna fishers in remote and metropolitan regions across Australia as a means to guide future surveys of specialised recreational fisheries.

TLS is an efficient way of accessing the hard-to-reach participants in the longtail tuna fishery, particularly non-fishing club members who comprise the vast majority of the recreational longtail tuna fishery. TLS provides a direct link to fishers for a recall survey, or it can serve as a means of recruiting fishers for prospective surveys, such as a diary survey, which often provide estimates of catch and effort that are less affected by recall bias. However, TLS alone can only provide an estimate of the catch from a subset of the population, since the size of the total fishing population is not known in order to estimate total catch by expansion. Estimating total population size of recreational fisheries is possibly the single greatest hindrance in estimating recreational catch for individual species.

Researchers in epidemiology and social sciences have successfully used capture-recapture techniques to estimate the total population size of hidden populations, such as the homeless and illicit drug users. This may be achieved by undertaking multiple TLS surveys and recording the names of respondents during each survey and documenting how many previously surveyed individuals are 'recaptured' in subsequent surveys. Although epidemiologists have approached this problem using various capture-recapture models (Larson et al., 1994; Mastro et al., 1994; Hay, 2000; Dávid and Snijders, 2002; Tate and Hudgens, 2007), further development is required to account for the differential recapture probability relating to a fisher's avidity, assuming that more avid fishers visit tackle stores more frequently than less avid fishers, and the possibility that fishers may visit more than one tackle store.

Further development of key biological parameters (e.g. length-at-maturity) and stock assessment models is required for longtail tuna. The preliminary stock assessment clearly indicated that the results for the spawner biomass-per-recruit model were very

sensitive to the age-at-maturity function used. Varying this parameter by only one year changed the status of the stock from being sustainable to being recruitment overfished. The stock was assessed in the present project using simple dynamic pool models, which can be useful in data-poor developing fisheries (Gabriel and Mace, 1999). However, these models assume a constant stock-recruitment relationship that is independent of the spawning stock size. Therefore, there can be great uncertainty in assessing the status of the stock relative to F_{MSY} . By collecting longer time series of representative catch and effort data from the recreational fishery through an ongoing monitoring program, and refining estimates of age-at-maturity for longtail tuna from quantitative reproductive studies, there are several sophisticated age-structured stock assessment models that can be used to more reliably assess the status of the longtail tuna population in Australia.

10. CONCLUSION

The present study aimed to assess the availability and quality of key biological parameters for longtail tuna and evaluate cost-effective methods for collecting recreational catch data, which together can provide the basis of a stock assessment model for assessing the status of longtail tuna in Australian waters and inform management. A flow diagram of key information requirements for stock assessment is shown in Figure 10.1.

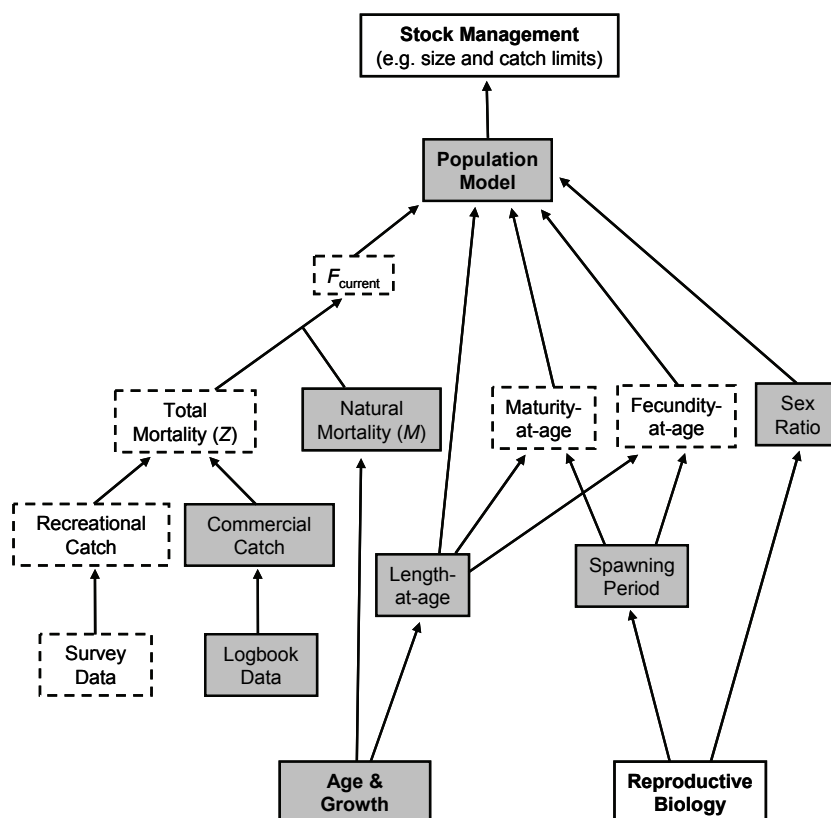


Figure 10.1: Flow diagram showing key information required for stock assessment that is unknown (dashed boxes), known (grey boxes) or partially known (open boxes) for longtail tuna.

The first two objectives of the project involved i) undertaking a thorough review of the global literature and summarising known information on the biology, ecology, movement, and fisheries of longtail tuna, and ii) identifying major data deficiencies in Australia, particularly in relation to recreational fisheries. The review highlighted that, despite commercial catches rapidly increasing in countries neighbouring Australia over the past 20 years, few studies had collected basic quantitative information on the stock structure, growth and reproductive dynamics of longtail tuna. A number of studies in southeast Asia used modal progressions of length-frequency distributions to estimate the age and growth of longtail tuna, which suggested they are a fast-growing and short-lived species that are capable of withstanding high fishing pressure. However, a study published during the course of this project (Griffiths et al., 2010) demonstrated, through the use of validated ages from otoliths, that longtail tuna have slow growth rates and live in excess of 18 years. Because of their slow growth rate and restricted neritic distribution, longtail tuna may be particularly vulnerable to overfishing even under seemingly modest fishing pressure by coastal fisheries.

Despite the importance of longtail tuna to recreational fisheries in Australia, little is known about the extent of catches and size composition of longtail tuna taken by the recreational sector. A few exceptions are fishing club records and tagging data from Industry and Investment NSW's Gamefish Tagging Program. However, these data are not considered to be representative of the entire recreational fishery, and on their own, are not suitable to inform stock assessment.

The final objective of the project was to develop potential cost-effective methods for surveying specialised recreational fishers and to test these methods for obtaining representative recreational catch and effort of fishers in Australia's longtail tuna recreational fishery. The two methods tested were online diaries and time-location sampling (TLS), and the results were compared with a traditional access point survey. An online diary system and educational website (www.longtailtuna.com.au) was developed where fishers could volunteer to submit data for individual fishing trips where they caught, targeted, or fished in such a manner as to be able to catch longtail tuna. The study objectives and incentives for participation were advertised nationally on radio and in newspapers, fishing magazines and on internet fishing forums. Although the method was inexpensive and yielded high resolution data for 178 fishing trips, it suffered from severe avidity, volunteerism and differential recruitment bias since the vast majority of fishers submitting data were land-based fishers who fished for 10–30 days per year.

As expected, the access point survey was the most expensive survey method and accounted for only 7 longtail tuna in 41 days of sampling. In contrast, TLS using a recall survey appeared to sample a more representative portion of the sport fishing community, from a range of avidity levels, as well as both fishing club and non-club members. By combining TLS with a diary survey, which was supported by 81% of TLS respondents, high quality data may be collected for individual fishing trips in a cost effective manner. Using this approach, recall bias may be reduced to produce more reliable estimates of the catch and effort. Therefore, this is the recommended method for a long-term recreational fishing monitoring program for longtail tuna in Australia. None of the three methods trialled was able to directly estimate the population size of the recreational fishery from a single survey, and thus the total recreational catch of longtail tuna. However, repeated TLS surveys may be used to estimate population size using

capture-recapture methods, which are widely used in epidemiology and social sciences in the study of hard-to-reach populations. However, the actual method used would require testing before widespread implementation in a monitoring program for longtail tuna.

Biological and commercial catch data mined from the literature, unpublished data sources, and recreational catch data collected from the survey methods trialled in the present study were brought together into a preliminary stock assessment using dynamic pool models. The assessment suggests that the stock is currently being fished at biologically sustainable levels, although any increase in fishing mortality may result in recruitment overfishing owing to the slow rate of the species. However, there was significant uncertainty in a number of areas in the assessment, particularly the lack of quantitative information relating to age-at-maturity. A sensitivity analysis showed that if the actual age at maturity was 3 or 4 years, rather than the assumed 2 years, the longtail tuna stock is probably currently being recruitment overfished.

Several management scenarios were explored to reduce fishing mortality, such as imposing minimum legal lengths of 80 cm, 90 cm and 100 cm TL. Unfortunately, these measures were not useful in reducing fishing mortality since the greatest impact on the population is likely to occur on immature fish before they reach Australian waters from a hypothesised nursery habitat in southeastern Asia. Juvenile fish are relatively rare in Australian waters, but comprise the majority of the commercial catch in southeastern Asia, which exceeds 100,000 t annually. Therefore, if longtail tuna in Australia comprise a single stock throughout the Indo-Pacific, there is a need to establish bilateral management strategies that will ensure the long-term sustainability of the entire stock. Considering there has been very little management interest in longtail tuna throughout the Indo-Pacific region, formal international arrangements, if they are in fact warranted, may not develop for some time. However, the present study has taken the first step towards providing fishery managers with the required information to take the issue forward.

In light of the results from the stock assessment and the literature review, a number of important recommendations are made below, which are listed in descending order of priority:

- Urgent research is required to determine the stock structure of longtail tuna throughout its Indo-Pacific distribution. Two separate studies are recommended; i) a genetic study to determine the connectivity of longtail tuna through its distribution, and ii) a tagging study using electronic satellite tags to better understand the movement dynamics, possible spawning locations of fish found in Australian waters, and post-release mortality from commercial and recreational fisheries.
- A quantitative biological study is required to determine maturity-at-age and fecundity-at-age relationships, and age and growth of longtail tuna younger than 2 years of age in Australian waters in order to reduce the current uncertainty in stock assessment results.

-
- A long-term monitoring program using time-location sampling incorporating a diary survey is required to collect a time series of catch and effort information that is representative of the recreational sector and will allow more sophisticated age-structured models to be used to assess the status of the population in future. Ideally, separate surveys for the boat-based and land-based components of the fishery should be conducted annually. However, given the high cost of surveys, catch and effort estimates obtained every 2–3 years may still be useful to assess the status of the longtail tuna population.

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13. APPENDICES

13.1 Appendix 1

Intellectual property

None arising.

13.2 Appendix 2

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13.3 Appendix 3

Peer-reviewed publications arising from the project

- 1) Griffiths, S.P. (2010) Stock assessment and efficacy of size limits on longtail tuna (*Thunnus tonggol*) caught in Australian waters. *Fisheries Research* 102, 248–257.

Newspaper and magazine publications

- 2) Anglers urged to log longtail tuna catches. *Bluewater Boats and Sportfishing* 78.
- 3) Anglers urged to log longtail tuna catches. *Modern Fishing* April, 20.
- 4) Website seeks record of longtail tuna catch. *Courier Mail*, 29/1/2010.
- 5) Call to record tuna. *Newcastle Herald*, 29/1/2010.
- 6) Open sea catch records. *Daily Liberal*, 29/1/2010.
- 7) Record longtail tuna catch online, CSIRO tells rec fishers. *AAP Newswire*, 29/1/2010.
- 8) Anglers urged to help tuna research. *Cairns Bulletin*, 22/02/2010.

Website publications

- 1) West Australian/Yahoo7 News: Record longtail tuna catch online (<http://au.news.yahoo.com/thewest/a/-/national/6732493/record-longtail-tuna-catch-online/>)
- 2) Weekly Times: Push to log longtail tuna catch (http://www.weeklytimesnow.com.au/article/2010/01/28/153061_sport-news.html)
- 3) Seabreeze: Anglers urged to share tales of longtail tuna (http://www.seabreeze.com.au/News/Power%20Boats/Anglers-urged-to-share-tales-of-longtail-tuna_3392333.aspx)
- 4) Powerboat-World: Anglers urged to share tales of longtail tuna (<http://www.powerboat-world.com/Anglers-urged-to-share-tales-of-longtail-tuna/65901/arc>)

- 5) Individual (US): CSIRO: Anglers urged to share tales of longtail tuna (<http://www.individual.com/storyrss.php?story=113719877&hash=09a99ac5658c05fc7fda49e1a7e01ee6>)
- 6) Silobreaker (UK): CSIRO: Anglers urged to share tales of longtail tuna (http://www.silobreaker.com/csiro-anglers-urged-to-share-tales-of-longtail-tuna-5_2263191556234149905)
- 7) M2 (UK): Anglers urged to share tales of longtail tuna (<http://www.m2.com/m2/web/story.php/20107CD523CDF4F13A35802576B900275AE1>) [log-in required to access full article]
- 8) Pacific Islands News Association: Record longtail tuna catch online (<http://www.pina.com.fj/?p=pacnews&m=read&o=4942702794b622ed0c74736d598977&PHPSESSID=f29620c841a39d6e003cb9df38bf4b8f>)

Oral presentations given relating to the project

- 1) Griffiths, S. (2009) *Biology, fisheries and status of longtail tuna (Thunnus tonggol), with special reference to recreational fisheries in Australian waters*. Oral Presentation at the longtail tuna project meeting, CSIRO Laboratories, Cleveland. 6 November, 2009.
- 2) Griffiths, S. (2010) *A synopsis of recent CSIRO research on recreational fisheries and recreationally-important species*. Invited oral presentation at the Recfishing Research Committee workshop, FRDC Board Room, Canberra ACT. 16 March, 2010.

Radio interviews and broadcast announcements

- 1) ABC Radio Kimberly (Broome): 'Fish Heads'. 28/01/2010. (<http://www.abc.net.au/local/audio/2010/01/29/2805243.htm?site=kimberley>)
- 2) ABC Radio Tropical North (Mackay): 6.30am News. 29/01/2010.
- 3) ABC Radio Capricornia (Rockhampton): 6.30am News. 29/01/2010.
- 4) CSIRO podcast: New website for sharing longtail tuna fishing tales (<http://www.csiro.au/multimedia/Longtail-Tuna-fishing-tales.html>)

Media releases relating to the project



Media Release

28 January 2010; Ref 10/06

Anglers urged to share tales of longtail tuna

Coastal anglers are being encouraged to help ensure the long-term sustainability of Australia's newest 'recreational-only' species, the longtail tuna, by reporting catches using a new online system.

The information is being sought by a consortium of recreational fishing groups and scientists led by the CSIRO Wealth from Oceans Flagship. It will contribute to scientific assessments of the condition of the longtail tuna population.

Longtail tuna (often incorrectly called northern bluefin tuna) are commonly caught by anglers fishing in tropical and temperate coastal waters around Australia, and even from the shore.

In recognition of the species' popularity among recreational anglers, longtail tuna was declared a 'recreational-only' species by the federal government in December 2006. A small commercial bycatch of 70 tonnes a year is allowed for Australia's Commonwealth fisheries.

"Longtail tuna may be susceptible to population decline even under seemingly modest fishing pressure given its very narrow coastal distribution," Dr Shane Griffiths of CSIRO says.

"We recently discovered that the species is also slow-growing and lives for at least 18 years.

"Fortunately, longtail tuna have not been heavily fished in Australia, so we can put the right measures in place now to ensure the population remains healthy for future generations of recreational fishers to enjoy."

The Chief Executive Officer of Australia's recreational fishing peak body Recfish Australia, Len Olyott, says that while commercial fisheries are obliged to report their catches, recreational fishers are not required to report their catches of most fish species.

"Without knowing the recreational catch, scientists are unable to assess the condition of Australia's longtail tuna population," Mr Olyott says.

"We are sure that recreational fishers who have had the enjoyment of catching this magnificent species will realise the benefits of this project and will help scientists by recording details of their fishing expeditions."

The website (www.longtailtuna.com.au) features an online logbook that allows recreational anglers to submit fishing trips anonymously. They can also register for free to use the site as a personal fishing diary to store and view details of their fishing trips. Registered users submitting catch data will enter a monthly draw for longtail tuna t-shirts.

The longtail tuna project is funded by CSIRO and the Fisheries Research and Development Corporation, Recfish Australia, the Australian Fishing Trade Association, Sunfish, the NSW Recreational Fishing Trust, Recfishing Research and the Australian National Sportfishing Association.

CSIRO initiated the National Research Flagships to provide science-based solutions to Australia's major research challenges and opportunities. The 10 Flagships form multidisciplinary teams with industry and the research community.



Courier Mail
29-Jan-2010
 Page: 28
 General News
 Region: Brisbane
 Circulation: 216563
 Type: Australian Capital City Daily
 Size: 46.61 sq.cms
 MTWTFS-

Website seeks record of longtail tuna catch

COASTAL anglers are being encouraged to record on a website the number of longtail tuna they catch so scientists can monitor the fish population.

Longtail tuna, often mistakenly referred to as northern bluefin tuna, is caught by recreational fishermen around Australia's coastline.

Although it was declared a "recreational only" species in December 2006, 70 tonnes of commercial bycatch is

still bagged each year. Longtail tuna may be susceptible to population decline even under modest fishing conditions, according to the CSIRO.

"We recently discovered that the species is also slow-growing and lives for at least 18 years," CSIRO's Dr Shane Griffiths said.

Recreational anglers are invited to log their catches and details of their fishing trips, anonymously, on the www.longtailtuna.com.au website.

Daily Liberal
29-Jan-2010
 Page: 8
 General News
 Region: Dubbo NSW
 Circulation: 5276
 Type: Regional
 Size: 23.54 sq.cms
 MTWTFS-

Open sea catch records

Coastal anglers are being encouraged to record on a website the number of longtail tuna they catch so scientists can monitor the fish population. Longtail tuna, often mistakenly referred to as northern bluefin tuna, is commonly caught by recreational fishermen around Australia's coastline. CSIRO want to track population figures and hope figures entered onto their site will help achieve this.



AAP Newswire
28-Jan-2010
 National
 Region: Australia
 Region: Australia
 MTWTFSS

Fed: Record longtail tuna catch online, CSIRO tells rec fishers

CANBERRA, Jan 28 AAP - Coastal anglers are being encouraged to record on a website the number of longtail tuna they catch so scientists can monitor the fish population.

Longtail tuna, often mistakenly referred to as northern bluefin tuna, is commonly caught by recreational fishermen around Australia's coastline.

Declared a "recreational only" species in December 2006, 70 tonnes of commercial bycatch is still caught each year.

Longtail tuna may be susceptible to population decline even under modest fishing conditions, the commonwealth's scientific agency CSIRO says.

"We recently discovered that the species is also slow-growing and lives for at least 18 years," the agency's Dr Shane Griffiths said in a statement.

However, numbers of the tuna have, so far, not been affected.

"We can put the right measures in place now to ensure the population remains healthy for future generations of recreational fishers to enjoy," he said.

Recreational fishers, unlike commercial fisheries, are not obliged to report their catches, said Recfish Australia chief executive Len Olyott.

"We are sure that recreational fishers who have had the enjoyment of catching this magnificent species will realise the benefits of this project and will help scientists by recording details of their fishing expeditions," Mr Olyott said in a statement.

Recreational fishers can log their catches and even details of their trips, anonymously, via the www.longtailtuna.com.au website.

AAP srj/sb/dep

13.4 Appendix 4

Survey materials for time-location sampling

National Longtail Tuna Survey “Sampling Protocol”



Dear Project Team Member,

Thank you for taking the time to assist with data collection for the National Longtail Tuna Survey. In order for the project to collect the highest quality data, sampling needs to be undertaken in accordance to a rigid sampling protocol.

To provide some background to the project, one of the main objectives is to test potential cost-effective methods for surveying fishers who catch longtail tuna as a target or bycatch species. This is needed if a long-term monitoring program is established in future, since funding is likely to be very limited. The two methods we are testing are: 1) online reporting, where fishers enter their fishing trip details on the project website www.longtailtuna.com.au and 2) “Time-Location Sampling” which attempts to intercept a *representative* sample of the recreational fishing community at locations where fishers tend to aggregate, such as tackle/boat shows or tackle stores on a Thursday night or Saturday morning.

Please follow the following steps for undertaking tackle store surveys

- 1) Contact the store owner/manager at least a few days prior to conducting a survey to obtain permission to stand outside the store.
- 2) Each survey needs to be conducted for a 3-hour period. Please discuss the best time to intercept the highest number of fishers with the store manager. Peak customer times can vary considerably between stores. We have conducted most surveys on Thursday nights (5pm–8pm) or Saturday mornings (9am–12pm) on advice from store owners, but feel free to select other high-traffic times.
- 3) Only approach store customers as they EXIT the store.
- 4) As a person exits the store, approach them quickly in a friendly manner and politely ask if they are interested in taking part in the survey (see script on “Fisher Interview Sheet”)
- 5) If a person refuses to respond or participate (they usually keep walking and say “not interested” or “too busy”) do not try to persuade them to participate, just politely thank them for their time. Record the person in the “Refusal” category on the “Daily Tally Sheet”.
- 6) If a person is interested, you need to establish whether they are eligible to participate in an interview. If the person has not fished for gamefish in the past 12 months, they are ineligible so thank them for their time and refer them to the longtail website for more information. These ineligible people need to be recorded in the “Not Eligible” category on the “Daily Tally Sheet”.

7) If a person is eligible for the survey, quickly ask them if they would spare 90 seconds for a survey on “sport fishing and gamefishing”. When they agree, you can then briefly explain the project objectives.

8) In conducting an interview, we are first trying to find out some information on sport/game fish anglers in general, and then determine if these anglers ever target or catch longtail as bycatch. We have found many people say they don’t catch or target longtail, but after probing we find the angler has spent many hours casting or trolling lures for mackerel and actually caught or fished for longtail tuna or says something like “If a school of longtail pops up I usually try to catch them”. This is important information, as we are trying to establish that if longtail isn’t always a target species, it is in fact an important bycatch species. So in order to obtain good effort information from anglers we need to know how long they spend fishing in a manner where they could have caught longtail tuna. This means casting schools at mackerel or bonito, where longtail often pop up on the edges, live baiting for mackerel, and trolling for sailfish or mackerel in coastal regions. Record the interview details on the “Fisher Interview Sheet”.

9) Towards the end of the interview we ask if the respondent would be willing to participate in a diary survey over 6–12 months should a larger project be established in future. Most people will immediately say no, because they don’t specifically target longtail, or only catch very few so they think their information is not valuable. These people are valuable, so the question is more for establishing whether the angler is opposed to participating (i.e. refusal) in the survey. In most cases they will only refuse because they are too busy, or would forget to complete the diary.

10) On completion of the survey thank the person for their time and refer them to the project website for further information and encourage them to enter their future fishing trip details online. Explain that they have the option of remaining anonymous when submitting trip details and that their data will remain confidential. However, if they decide to register with the website for free using their email address, they go into monthly draws for limited edition longtail tuna t-shirts.

11) Try to keep an accurate tally of the people exiting the store that you missed whilst you were attending to other customers.

12) At the end of your 3-hour period, hang around for a little longer to get those people who entered the store during the 3 hours but have not yet exited the store. This may only be possible for smaller stores.

Thanks again for assisting with this important research. Please feel free to contact me if you have any question or comments regarding the survey or the project in general. I certainly welcome any feedback.

Shane Griffiths

**National Longtail Tuna Survey
“Daily Tally Sheet”**



Date: Time: Location: Interviewer initials: _____

* This sheet is for recording people who are not eligible for the survey or people who refuse to participate

Category	Reason	Tally	
		Male	Female
NOT ELIGIBLE	Does not fish at all		
	Does not fish for sport fish		
	Did not fish for sport fish in past 12 mths		
	Did not sport fish in past 12 mths but intends to in next 12 mths		
	Missed		
REFUSAL	Too busy		
	Not interested		
	Political reasons		
	Language difficulties		
	Other		

**National Longtail Tuna Survey
“Fisher Interview Sheet”**



ID: Date: Location: Interviewer initials:

*** Only complete for persons who have fished for gamefish in the past 12 months**

Hello, my name is _____ and I’m working on behalf of the CSIRO conducting a national survey on sport and gamefishing, and in particular, longtail tuna (otherwise known as “northern bluefin tuna”). Would you have 90 seconds to participate in this survey? **If no, ask why and record on the “Daily Tally Sheet”**

1. Interviewee gender **Male / Female**
2. In the last 12 months, did you target marine gamefish (tuna, billfish, pelagic sharks, mackerel, kingfish, cobia, bonito)? **Yes / No**
3. Are you currently a member of a fishing club? **Yes / No**
4. Have you been a member of a fishing club within the past 5 years? **Yes / No**
5. In the last 12 months, did you catch, target, or fish in a manner where you could have caught longtail tuna (e.g. spinning for spotties, or live baiting for Spanish mackerel, etc)? **Yes / No (If ‘no’ go to 12)**
6. Where did you primarily catch or target longtail tuna? _____
7. How many longtail did you catch (including releases) in the last 12 months? _____
8. How many days do you think you spent targeting longtail, or fished in a manner where you were able to catch longtail tuna in the past 12 months? _____
9. On each of these fishing days where you could have captured longtail tuna, how many hours would you say you fished for on average? (Searching for schools needs to be included) _____
10. What is your main mode of fishing for longtail? **Boat / Land-based**
11. What technique(s) do you use for longtail? **Casting lures / Live bait / Dead bait / Trolling (lures) / Trolling (bait) / Fly / Spear/**
12. Were you aware that longtail tuna is now a “recreational-only” species in Australia? **Yes / No**
13. If CSIRO was to undertake a more comprehensive longtail tuna survey, would you be willing to provide your contact details and complete a fishing diary over a 6–12

months period? **Yes / No**

If no, why _____

14. Do you have access to the internet? Yes / No

15. For the current project, would you be willing to record your fishing trip details for longtail tuna over the next 6 months using our online diary at www.longtailtuna.com.au? Yes / No

If no, why _____

Thank you! (Distribute leaflet and refer to website)



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