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Fisheries Long Term Monitoring Program

Summary of tailor *(Pomatomus saltatrix)* survey results: 1999–2004

January 2006

Queensland Government
Department of Primary Industries and Fisheries

Fisheries Long Term Monitoring Program

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Natalie Dodt
Sandra O'Sullivan
Jason McGilvray
Eddie Jebreen
Darren Smallwood
Ian Breddin

Department of Primary Industries and Fisheries
Queensland
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Manager, DPI&F Publications
Department of Primary Industries and Fisheries
GPO Box 46
Brisbane Qld 4001

Contents

Figures

Tables

Acronyms

APE	average percent error
CV	coefficient of variation
CFISH	Commercial Fisheries Information System, DPI&F
DPI&F	Department of Primary Industries and Fisheries, Queensland
LTMP	Long Term Monitoring Program, DPI&F
RFISH	Recreational Fisheries Information System, DPI&F

Summary

Tailor (*Pomatomus saltatrix*) is a schooling species with a world-wide distribution in subtropical waters that inhabits the coastal waters of southern Australia (Williams 2002). Its distribution in Australian waters ranges from the northern tip of Fraser Island in Queensland to Onslow in Western Australia (Kailola *et al.* 1993).

Queensland commercial and recreational fishers target these schools on ocean beaches between Fraser Island and the New South Wales border, during their annual spawning migration between late winter and spring (Leigh and O'Neill 2004). The estimated harvest of tailor for the commercial sector is 155 t (2004–05), and between 450 and 540 t (2002) by recreational fishers.

The Queensland tailor fishery is managed by the Department of Primary Industries and Fisheries under the *Fisheries Regulation 1995*. The current management arrangements include spatial and seasonal closures, minimum legal size limit, limited commercial entry, annual commercial quota and recreational possession limit.

The Long Term Monitoring Program (LTMP) monitors the tailor stock by investigating the length, weight, sex and age of the commercially and recreationally caught tailor from the ocean beach sector. This report presents a summary of the data collected from 1999 to 2004.

Since 1999, the LTMP has collected 14 486 tailor with over half of those fish collected from zones not included in the seasonal closures. The modal length frequency of tailor was between 300 and 370 mm for all years, sexes and regions. There was a significant relationship between length and weight of tailor, yet no difference between sex or region. The majority of tailor collected were aged as one and two year olds, with very few tailor collected of age three or older. The growth of tailor was similar for both sexes and all regions.

The majority of the length and age frequency data are representative of the recreational ocean beach fishery on Fraser Island, which is only part of the fishery. It is therefore suggested to extend the monitoring of the commercial catch samples and the recreational catch samples to other regions of the sampling area. There were also limited samples collected of tailor larger than 500 mm and at the age of three years or older. Any extension of the program should also focus on acquiring samples of larger fish to help complete the tailor growth curve.

Long Term Monitoring Program background

The Department of Primary Industries and Fisheries (DPI&F), Queensland, manages the State's fish, mollusc and crustacean species and their habitats. As part of this commitment, DPI&F monitors the condition of, and trends in, fish populations and their associated habitats. This information is used to assess the effectiveness of fisheries management strategies and helps ensure that the fisheries remain ecologically sustainable. DPI&F also uses the information to demonstrate that Queensland's fisheries continue to comply with national sustainability guidelines, so that they may remain exempt from export restrictions under the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999*.

DPI&F initiated a statewide Long Term Monitoring Program (LTMP) in 1999, in response to a need to collect enhanced data for the assessment of Queensland's fisheries resources. The LTMP is managed centrally by a steering committee with operational aspects of the program managed regionally from the Southern and Northern Fisheries Centres located at Deception Bay and Cairns respectively. The regional teams are responsible for organising and undertaking the collection of data to be used for monitoring key commercial and recreational species, and for preparing data summaries and preliminary resource assessments.

A series of stock assessment workshops in 1998 identified the species to include in the LTMP. The workshops used several criteria to evaluate suitability including:

- the need for stock assessment based on fishery independent data
- the suitability of existing datasets
- the existence of agreed indicators of resource status
- the practical capacity to collect suitable data.

Species currently monitored in the LTMP include saucer scallops, spanner crabs, stout whiting, mullet and tailor in southern Queensland, tiger and endeavour prawns and coral reef fish in northern Queensland. Species with statewide monitoring programs include mud crabs, barramundi, spotted and Spanish mackerel and freshwater fish. Various sampling methodologies are used to study each species. The incorporation of fishery independent techniques is preferred, with combinations of fishery dependent and independent techniques being used where appropriate. Data collected in the monitoring program are maintained in a central database in Brisbane.

The primary aim of the LTMP is to collect data for resource assessment (ranging from analyses of trends in stock abundance indices to more complex, quantitative stock assessments) and management strategy evaluations. The greatest value of the growing datasets for each of the species and associated habitats is in the long time series generated by continued sampling, something that is usually required for accurate assessments but is rarely available.

Stock assessment models have already been developed for saucer scallops, spanner crabs, stout whiting, mullet, tailor, barramundi, tiger and endeavour prawns, and spotted and Spanish mackerel. In some cases management strategy evaluations have also been carried out. The data collected in the LTMP have been integral to these activities.

The assessments and evaluations have, in turn, allowed options for improvements to the management of Queensland's fisheries resources to be considered. Enhancements to ongoing monitoring have also been identified, particularly to address the increasing demand for high quality data for dynamic fish population models.

Through the ongoing process of collecting and analysing LTMP data and incorporating these data into regular assessments and refining monitoring protocols as required, DPI&F is enhancing its capacity to ensure that Queensland's fisheries resources are managed on a sustainable basis.

Introduction

Tailor (*Pomatomus saltatrix*) is a schooling species with a world-wide distribution in subtropical waters that inhabits the coastal waters of southern Australia (Williams 2002). Its distribution in Australian waters ranges from the northern tip of Fraser Island in Queensland to Onslow in Western Australia (Kailola *et al.* 1993).

Tailor is a schooling fish most commonly caught along ocean surf beaches and adjacent to rocky headlands. Adult tailor can also be found in estuarine and brackish water (Kailola *et al.* 1993). Tailor form schools of similar sized fish and enter the fishery sexually mature in their second year of life. On the eastern coast of Australia they undertake an annual spawning migration (Leigh and O'Neill 2004). Schools of fish move north to spawning grounds between late winter and spring, although the extent of the migration is currently unknown (Kailola *et al.* 1993). Queensland commercial and recreational fishers target these schools on ocean beaches between Fraser Island and the New South Wales border.

The commercial catch of tailor in 2004–05 was estimated at 155 t (including incidental catch of 100 kg or less), with a Gross Value of Production of approximately half a million dollars (CFISH database, September 2005). The level of recreational fishing activity is estimated to be as much as 3 to 4 times the commercial sector (Leigh and O'Neill 2004), with estimates of the recreationally harvested catch in 2002 between 450 and 540 t[1] (RFISH database, September 2005).

Commercial fishers target tailor with beach seine or haul nets up to 500 m long, along the ocean beaches. Heavy ply multifilament nets are used, as tailor can damage monofilament nets with their sharp teeth. In protected bay and estuarine areas, gill/mesh nets and tunnel nets are the usual commercial fishing methods used, however, some haul nets are used where the structure of the shoreline permits. Tailor are also taken as bycatch in the ocean beach mullet fishery. Fishers try to avoid tailor bycatch because of the damage they cause to the monofilament nets used to catch mullet.

Commercial ocean beach fishers track schools of tailor until they reach a section of beach where the boat can set a net around the fish. Once set, nets are hauled by hand or with a vehicle onto the beach. During hauling, captured fish are concentrated in the codend of the net. Once on the beach, they are loaded by hand for transport to onshore processing facilities.

The commercial catch of tailor is predominately sold on the chilled fresh fish market. In the 1960s and 1970s the Queensland commercial tailor catch peaked at around 400 t. However, since then the total catch has decreased, apparently for reasons other than overfishing such as low market demand. The market demand on the tailor fishery is currently variable and has been generally decreasing since the mid-1970s (Leigh and O'Neill 2004).

Recreational tailor fishers typically fish the ocean beach gutters using three or four ganged 4/0 hooks connected by heavy monofilament or fine wire trace to a relatively light (15–20 lb, approximately 7–9 kg) main line. Tailor are usually the main target in addition to less seasonal species such as dart (*Trachinotus botla [=coppingeri]*), yellowfin bream (*Acanthopagrus australis*) and dusky flathead (*Platycephalus fuscus*).

[1] RFISH estimated annual harvest of tailor was converted to weight of fish by utilising the average weight of recreationally harvested tailor from this survey.

The Queensland tailor fishery is managed by DPI&F under the *Fisheries Regulation 1995*. The current management arrangements include the following:

- commercial fishery—limited entry, spatial and seasonal closures (Figure 1), annual quota and minimum legal size limit
- recreational fishery—minimum legal size limit, spatial and seasonal closures, and possession limit.

A preliminary stock assessment undertaken by Dichmont *et al.* (1999) indicated that the tailor stock could be subject to unsustainable levels of fishing mortality. In response to this finding DPI&F instigated fishery dependent monitoring of the tailor stock. This monitoring was designed to complement the Commercial (CFISH) and Recreational (RFISH) Fisheries Information Systems monitoring projects already taking place. The annual monitoring of tailor population structure by the DPI&F LTMP began in 1999.

Objectives

The LTMP objective is to collect data on the tailor stock that are representative of the recreational and commercial ocean beach catch, to investigate:

- length structure
- length–weight relationship
- sex structure
- age structure.

This report aims to present a summary of the tailor data collected by the LTMP from 1999 to 2004.

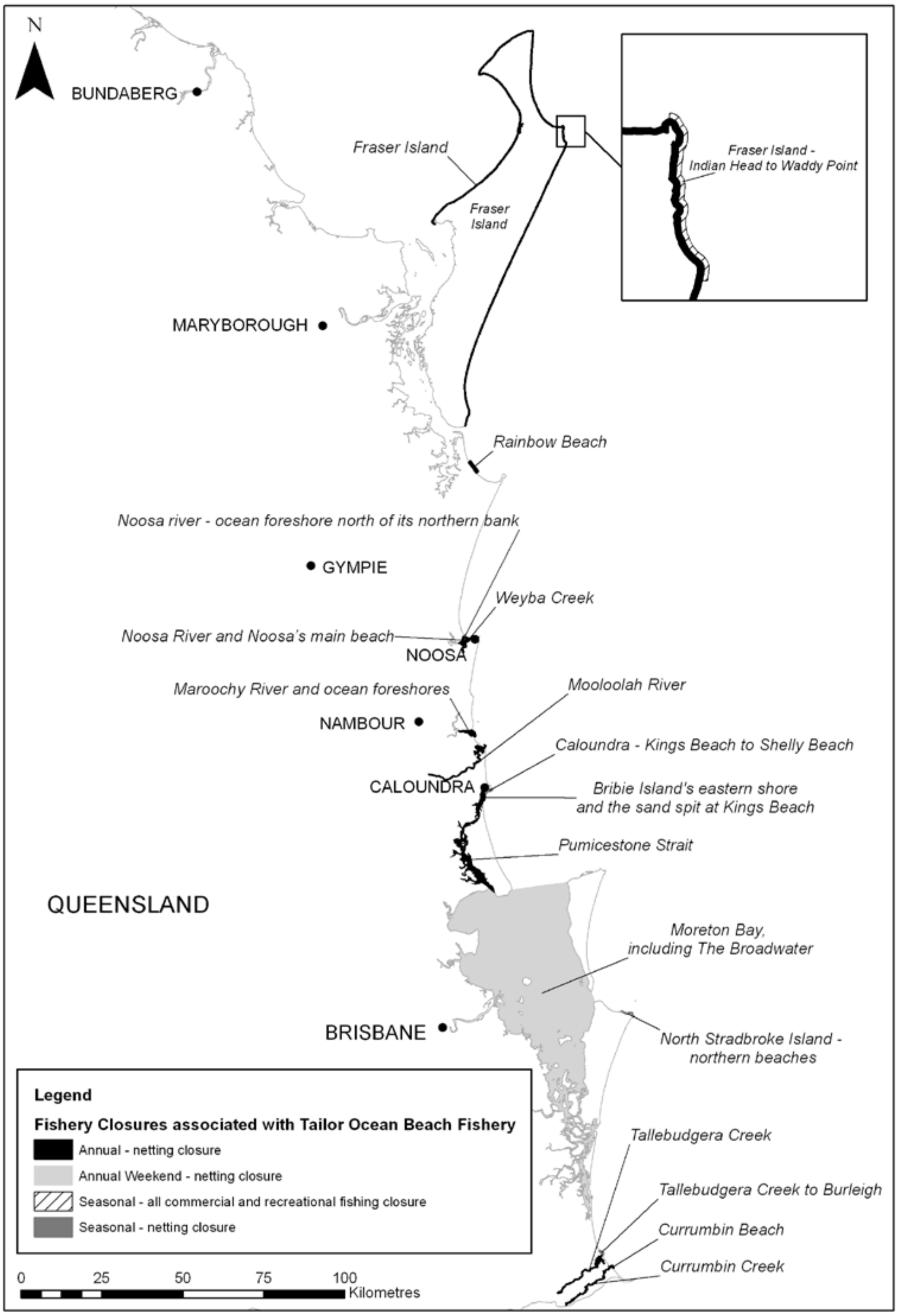

Figure 1. Management and closure areas of the commercial and recreational tailor fishery.

Methods

Sites

For the purposes of the survey, the main Queensland tailor fishing area extending from the Queensland – New South Wales border north to Breaksea Spit on Fraser Island, was divided into 26 smaller zones (Figure 2). These 26 zones were grouped into three regions where fish were collected. These regions were:

- Stradbroke—Queensland–New South Wales border to Comboyuro Point (zones 1–14) including Stadbroke and Moreton Islands
- Sunshine—Bribie Island to Inskip Point (zones 15–19) including Double Island Point
- Fraser—Hook Point to Sandy Cape (zones 20–26).

Tailor were sampled on a fine spatial sampling scale by zone because they exhibit size specific schooling. This means that fish of the same size tend to school together, increasing the spatial complexity of the stock. It was therefore assumed that tailor collected from a particular zone during either a morning or an afternoon fishing session were likely to be from one school.

Samples have been collected directly from recreational fishers on Fraser, Moreton and Stradbroke Islands and at Double Island Point. Except for Fraser Island, these areas yielded few samples due to the few fishers targeting tailor, and during competitions many of the fish were kept whole for weighing and were not available for scientific study. Sampling was therefore concentrated on Fraser Island (zones 20–26) with two six day sampling trips conducted each year until 2001. A third trip was conducted in 2002, 2003 and 2004 following the extension of the seasonal closure to include August.

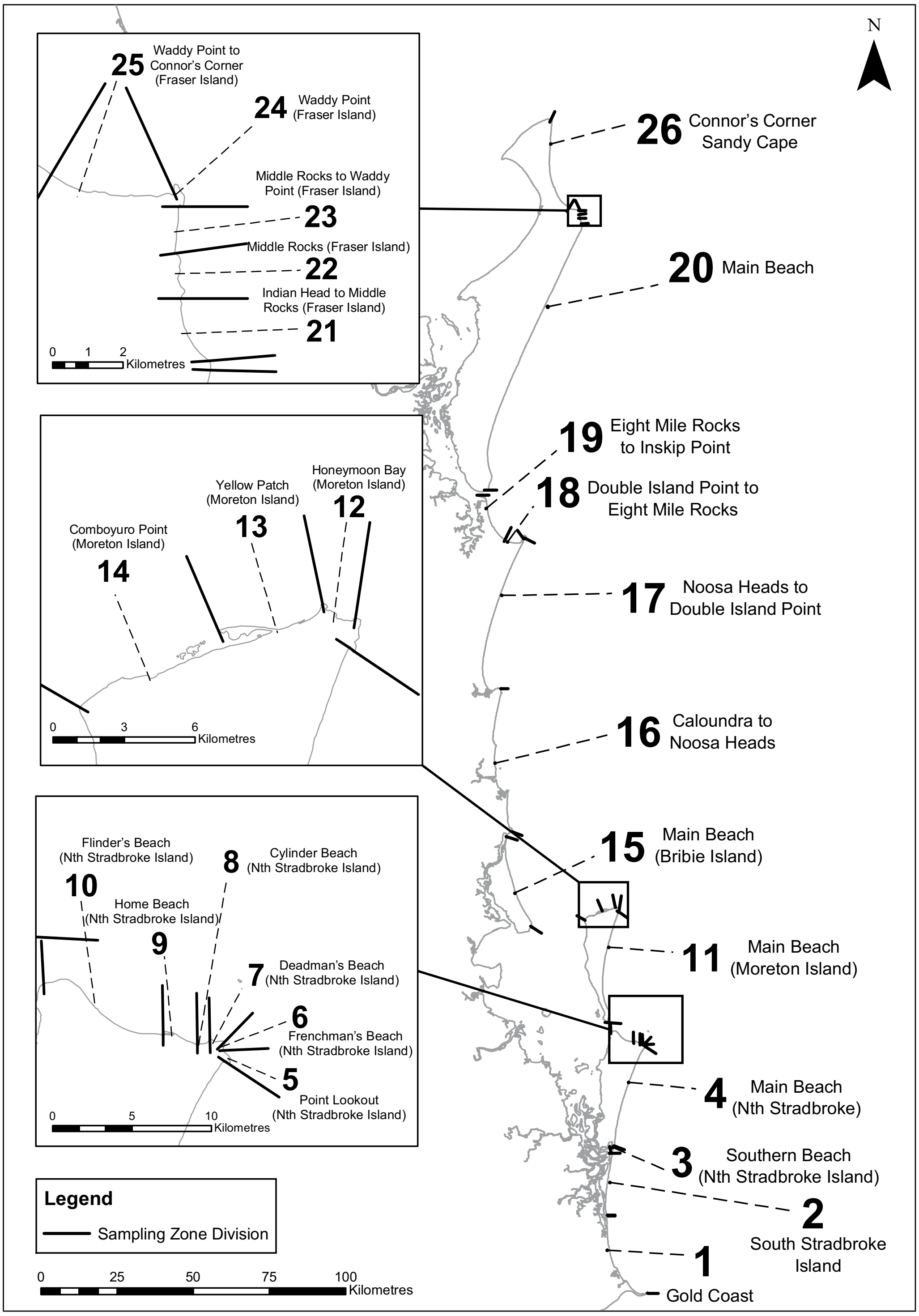

Figure 2. Main fishing area of the ocean beach tailor fishery divided into 26 Long Term Monitoring Program sampling zones, based on geomorphological characteristics.

Times

Tailor samples were collected throughout the peak fishing season (Table 1), starting in July and finishing in late October. Commercial samples were collected haphazardly when available. Recreational sample collection from Fraser Island coincided with pulses in recreational fishing effort. Samples were collected each day in both a morning and an afternoon fishing session, when fishing effort was greatest.

Table 1. Recreational tailor fishery sampling times on Fraser Island (note the spawning closure was extended to include August as well as September in 2002).

Year	Trip 1	Trip 2	Trip 3
1999–2001	Early August—week of the Brisbane Exhibition public holiday	Last week of August—before the seasonal spawning closure	None
2002–2004	Early August—week of the Brisbane Exhibition public holiday (seasonal spawning closure in place around Indian Head–Waddy Point)	Last week of August (seasonal spawning closure in place)	Last week of October in 2002 First week of October for the reopening of the spawning closure in 2003 and 2004

Recreational sampling was also conducted at Moreton (August 1999, July 2000) and Stradbroke Islands (August 2000, 2001), and at the Double Island Point fishing competition (July 2000).

Sampling regime

The current annual survey aimed to collect 1200 individual fish for age determination and as many length frequency measurements as practical for each fishing season. In each fishing session, morning or afternoon for a particular zone, the first 30 fish were retained. Any additional fish collected contributed to the length frequency data only.

The following sources were used to obtain ocean beach caught samples:

- recreational fishers—frames collected from or supplied by:
  - recreational fishers approached by the LTMP survey team
  - recreational fishing clubs.
- commercial fishers:
  - whole fish purchased from commercial ocean beach fishers
  - whole fish or frames supplied by or purchased from processors.

Data collection

The LTMP Tailor Sampling Protocols are described in detail in DPI&F (2005). For every sample collected the information about catch location, fisher details and date caught were recorded.

For all retained fish, the length (caudal fork length to the nearest 5 mm) and sex (male, female or unknown) were recorded. For whole fish, when available, weight (total weight to the nearest gram) was also recorded. The sagittal otoliths were removed, cleaned in water and dried (DPI&F 2005). Estimates of readability were recorded according to protocols detailed in DPI&F (In Prep.).

From 1999 to 2003, each fish was aged three times by two readers. One reader aged each fish twice allowing at least one week between readings. The second reader aged each fish once. In 2004, one reader aged each fish once and then randomly selected 25% to re-read. Each reading was done without prior knowledge of capture data, size or sex. Readers undertook training and calibration readings on a standard sample of tailor otoliths from the reference collection before commencing. All estimates have been made from viewing whole otoliths. In 2004, the appearance of the otolith edge or margin width was also recorded.

Data summaries and analysis

Length frequencies

The length frequency and length–weight data have been summarised by sex, region and years (1999 to 2004). The majority of the tailor surveys were conducted in the Fraser region with recreational fishers, therefore only the data from this region were plotted separately by each year for length frequencies.

Assignment of age

In an attempt to assign age class to increment counts, all edge readings from 2004 were pooled. The edge (margin) interpretations were expressed as a percentage of the monthly sample. A slight peak in opaque material (narrow) was seen in October samples. The majority (> 50%) of otoliths from August to October were classified as having an intermediate edge. Some otoliths (18–32%) displayed a narrow or new opaque edge during each of the sampling months (Figure 3).

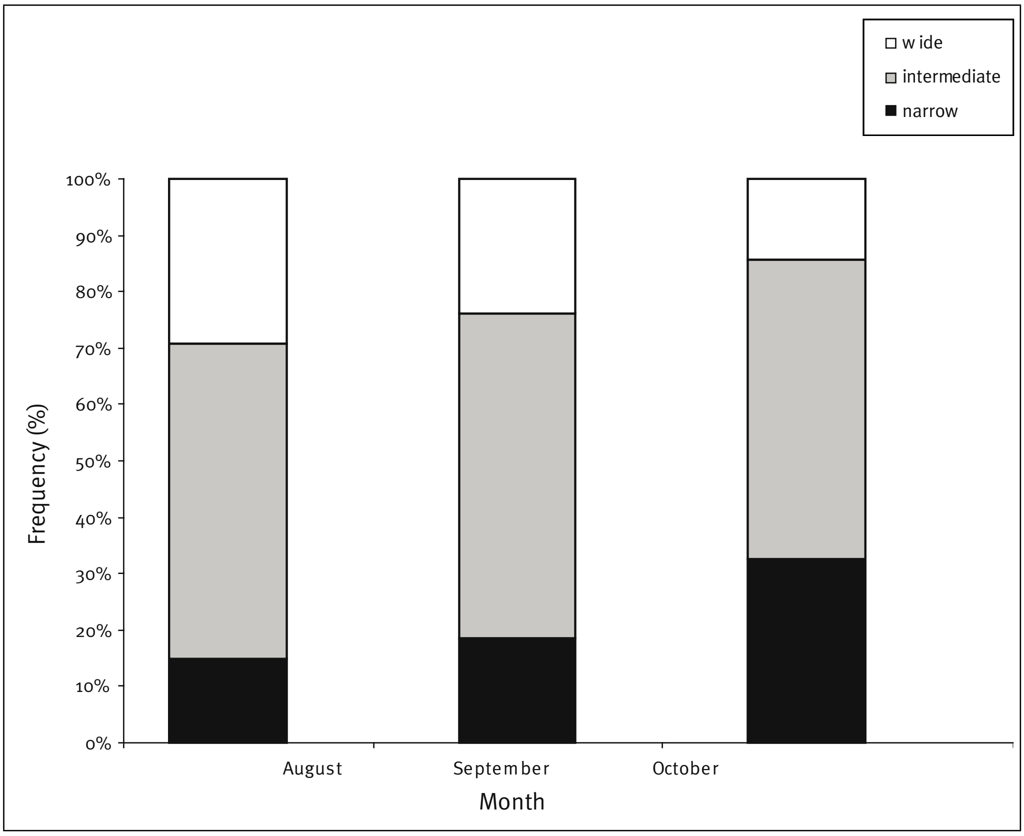

Figure 3. Monthly frequency of edge type for tailor sagittal otoliths collected in 2004 (n = 1107).

Otolith increment counts are usually converted to age class considering period of increment formation, category of edge interpretation and date of capture of the fish. In this study, samples were not available throughout the entire year and the monthly frequency of edge type did not show conclusive evidence that increment formation occurred during the sampling period. Therefore, increment counts were not adjusted.

The quality control assessment of the estimates of ages from tailor otoliths collected by the LTMP is discussed in the Appendix.

Age frequencies and growth

Age frequencies were generated for each sex and region, and for all years (1999 to 2004). Linear growth curves were used to describe the growth rates of tailor collected through the LTMP by sex and region. Linear growth curves are considered adequate for modelling the growth of the Queensland tailor stock due to the absence of older fish in the catch of the Australian east coast fishery (Leigh and O'Neill 2004).

Data limitations

Any interpretation of the results of this study must consider that the method of sample collection was fishery dependent and concentrated on recreationally caught fish from Fraser Island. Therefore, results characterise harvested fish and may not truly represent the tailor population as a whole because of fish and fisher behaviour. Fisher behaviour may impact on the results due to targeting, fishing location, gear selectivity, size and bag limits, and the selective release of fish. Although participation was voluntary, anglers were actively approached by officers on an ad-hoc basis and the participation rate of approached fishers was very high. Therefore, there would be little if any bias caused by the selective involvement of fishers. Sample sizes vary between years, regions and zones.

Results

Between 1999 and 2004, 14 486 tailor were measured by the LTMP survey. The tailor collected by the LTMP survey is summarised for the Fraser region only (Table 2), as that is where the majority of the sampling was undertaken.

Table 2. Summary of the number of tailor sampled within the Fraser region by the Long Term Monitoring Program from 1999 to 2004.

Catch zone	Collection type	Numbers collected by year						
		1999	2000	2001	2002*	2003*	2004*	Total
20	Length only	169	468	833	212	250	313	2245
21	Age	96	340	318	161	415	339	1669
	Length only	307	206	288		99	54	954
22	Age	239	133	200	72	60	118	822
	Length only		40	15				55
23	Age		35	23				58
	Length only			150			4	154
24	Age			97			40	137
	Length only	42	24	55		68		189
25	Age	96	30	60		94	46	326
	Length only	490		99	34		15	638
26	Age	199		139	56		61	455
	Length only	367		668	570	570	477	2652
	Age	115		258	271	412	473	1529
Total		2120	1276	3203	1376	1968	1940	11 883

*Closure extended to include August and September.

Most tailor were collected from zone 20 and 26 within the Fraser region (Table 2). These two zones are the largest in area and lie outside the area of the seasonal closure (zones 21–24)[2]. Zone 21 (within the seasonal spawning closure) yielded the next highest sample numbers, followed by zone 25 (not within the seasonal spawning closure).

Length frequency

The length frequencies of all fish measured by the LTMP are presented by year in Figure 4 and by sex in Figure 5. The length frequency presented in Figure 4 displays a wider distribution of sizes collected in 1999 than in any other year. There was a higher percentage of undersized fish (less than approximately 270 mm fork length)[3] collected in 1999 than any other year. The tailor collected in 1999 also displayed the largest modal size of 370 mm whereas in the other years the modal size classes were between 300 and 340 mm.

The length frequency distributions for males, females and unknowns are similar (Figure 5). The modal fork length is 320 mm for males, 340 mm for females and 330 mm for unknowns.

[2] The zones within the area of the seasonal closure (zones 21–24) are open to fishing for at least one LTMP sampling week each year.

[3] Undersized refers to fish below the legal size limit stated as total length in the Fisheries Regulation 1995. As the LTMP use fork length, Leigh and O'Neill (2004) stated that the minimum legal size limit is equal to 268 mm fork length.

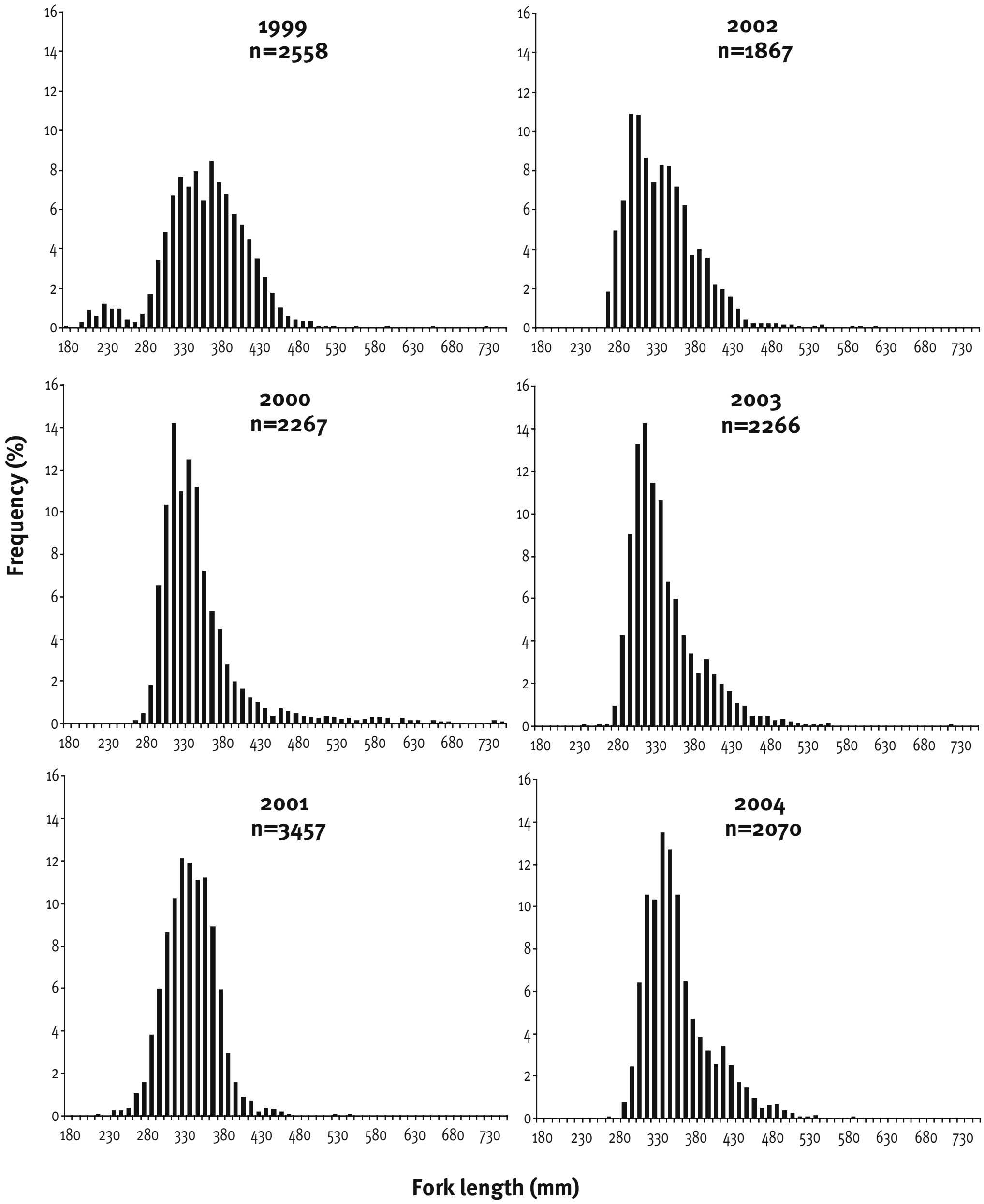

Figure 4. A length frequency plot for tailor for the years 1999 to 2004, sampled by the Long Term Monitoring Program.

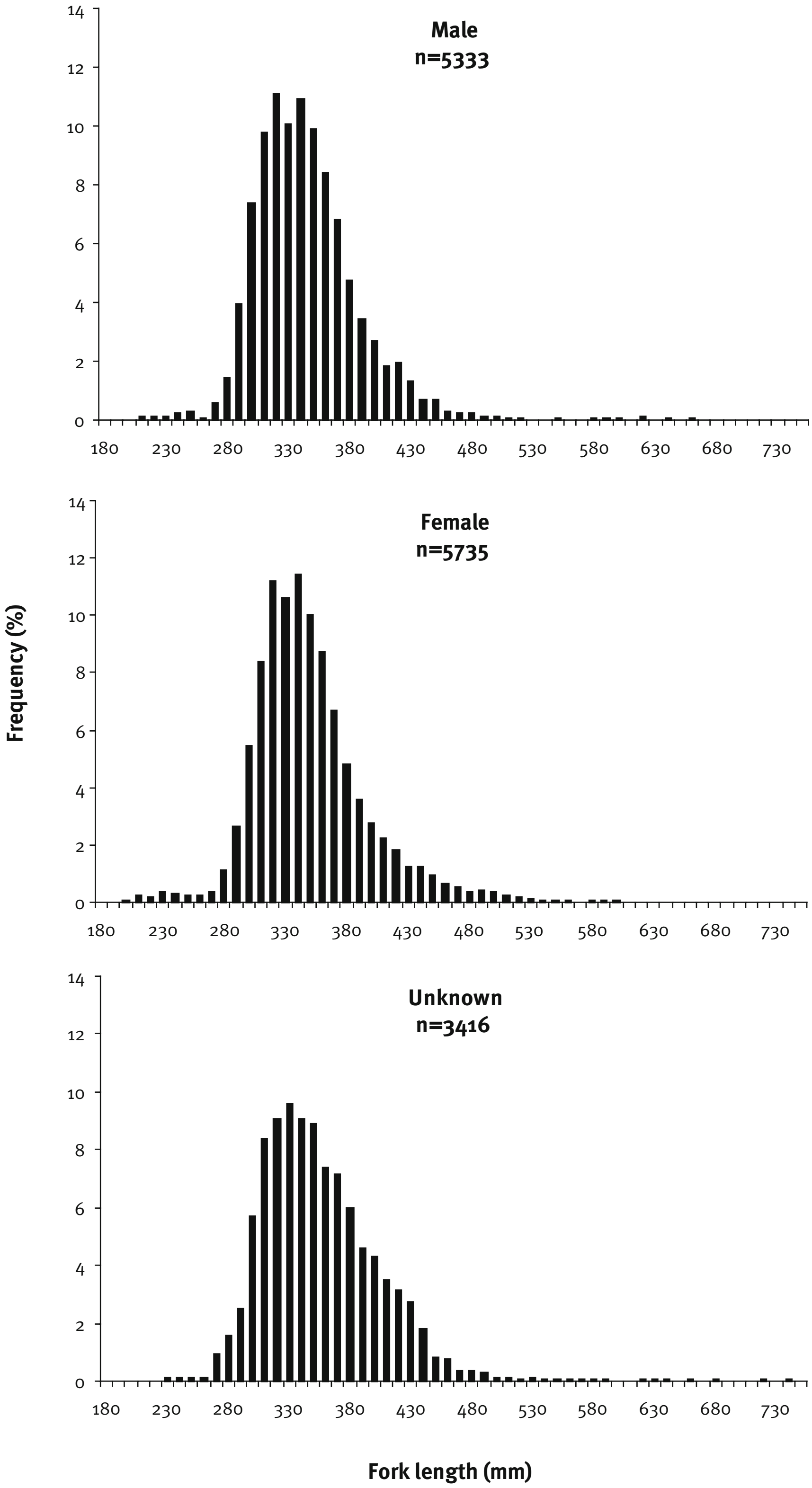

Figure 5. A length frequency plot for tailor by sex for the years 1999 to 2004, sampled by the Long Term Monitoring Program.

Figure 6 depicts the length frequency of tailor per zone sampled. The majority of fish sampled have been from the Fraser region and are from the recreational catch. Only a small number of fish have been sampled from the Stradbroke and Sunshine region over the years 1999 to 2004, with the majority of the Sunshine region tailor sampled from commercial catches.

The modal size for all regions is similar—Fraser at 320 mm, and Stradbroke and Sunshine at 340 mm. The Sunshine region displayed a higher percentage of larger sized fish collected than the other regions, however this region had a small sample size.

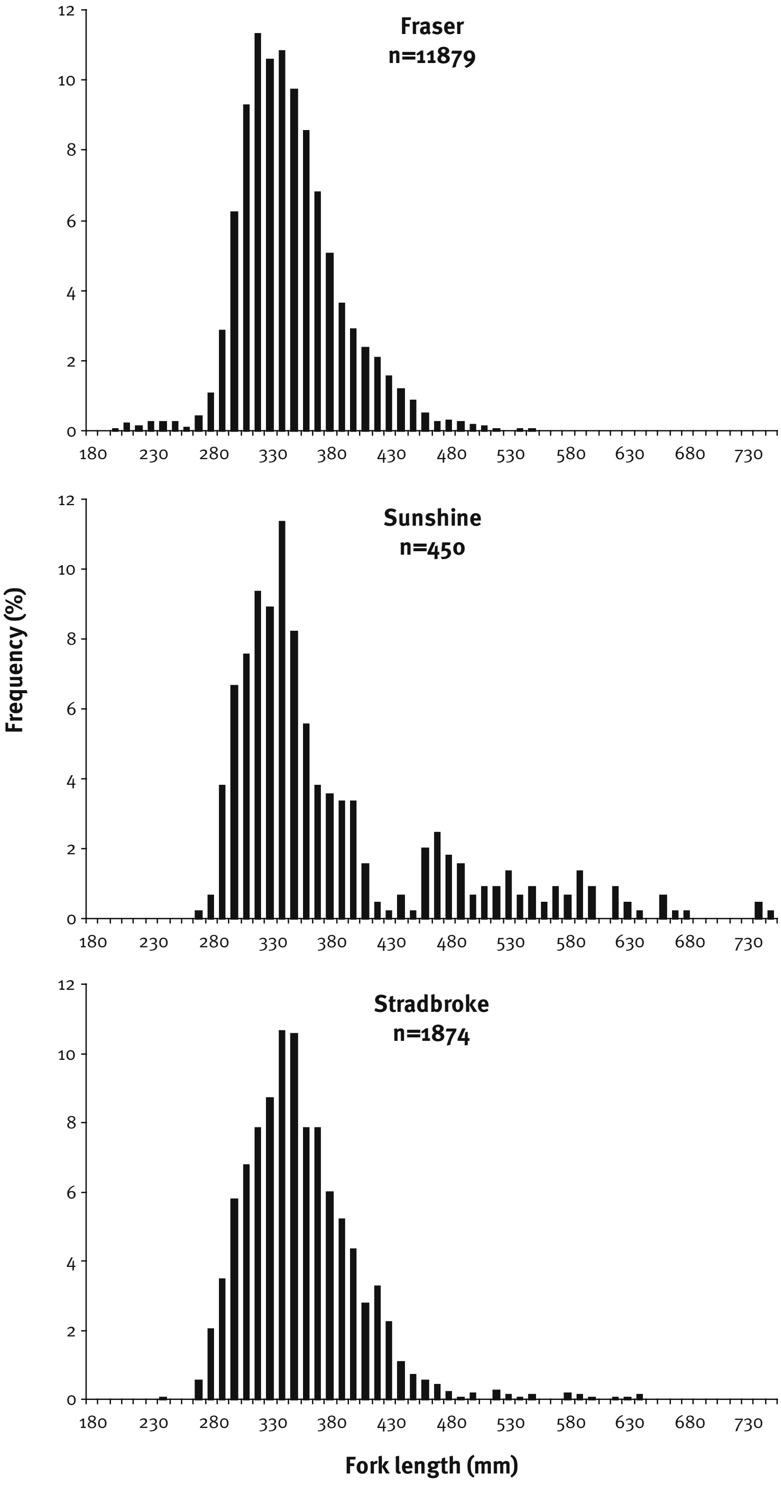

Figure 6. Length frequency plot for tailor by region for the years 1999 to 2004, sampled by the Long term Monitoring Program.

The modal length for males and females from the Fraser region was similar over all years, ranging between 300 and 350 mm for males and 310 and 360 mm for females (Figure 7).

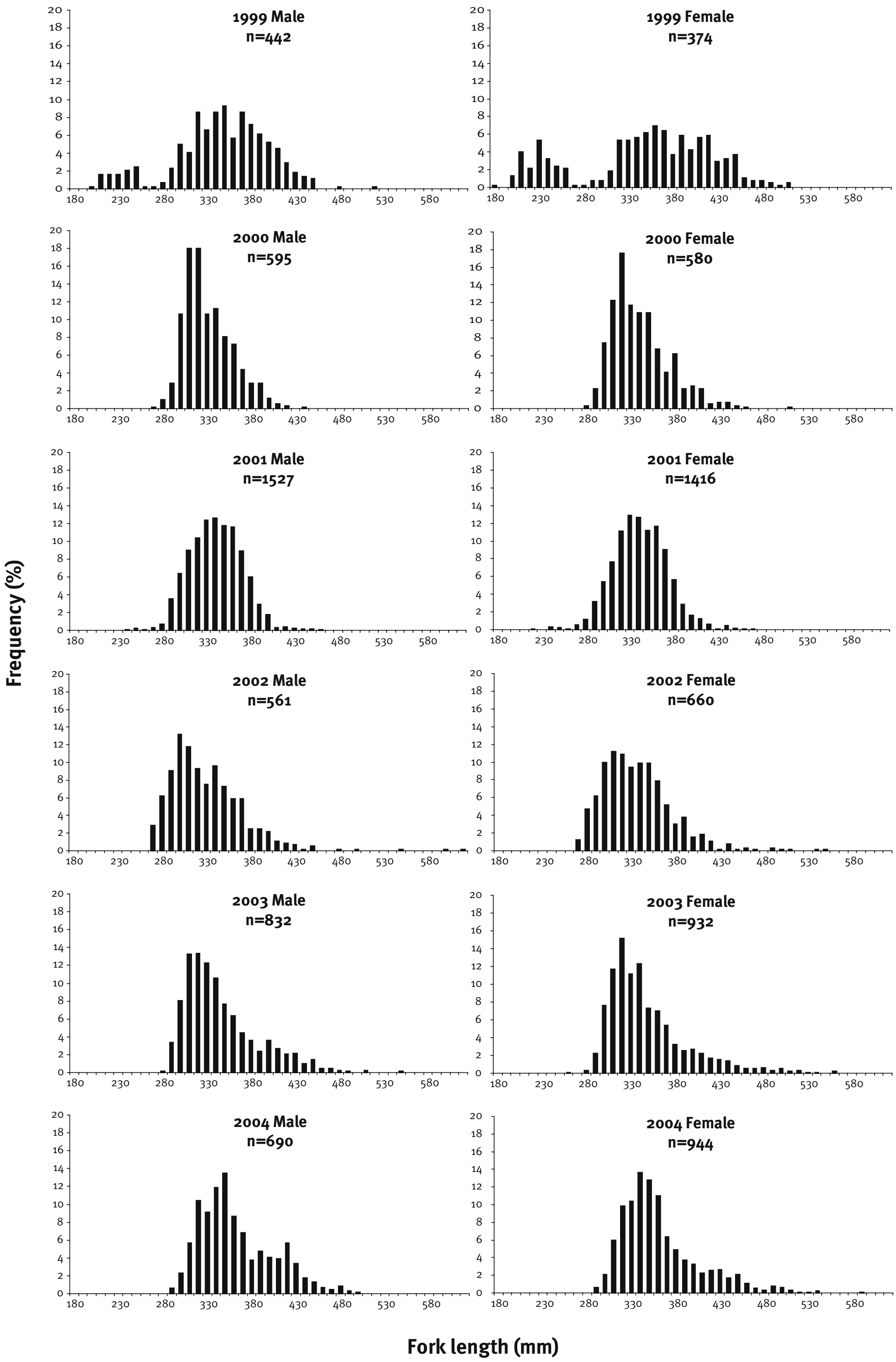

Figure 7. Length frequency by sex for each year from the Fraser region, years 1999 to 2004.

There is a distinct difference in the modal length of tailor collected on Fraser Island between 1999 and 2004, when grouped by month of capture (Figure 8). The modal length increases each month from 300 mm in July to 420 mm in October.

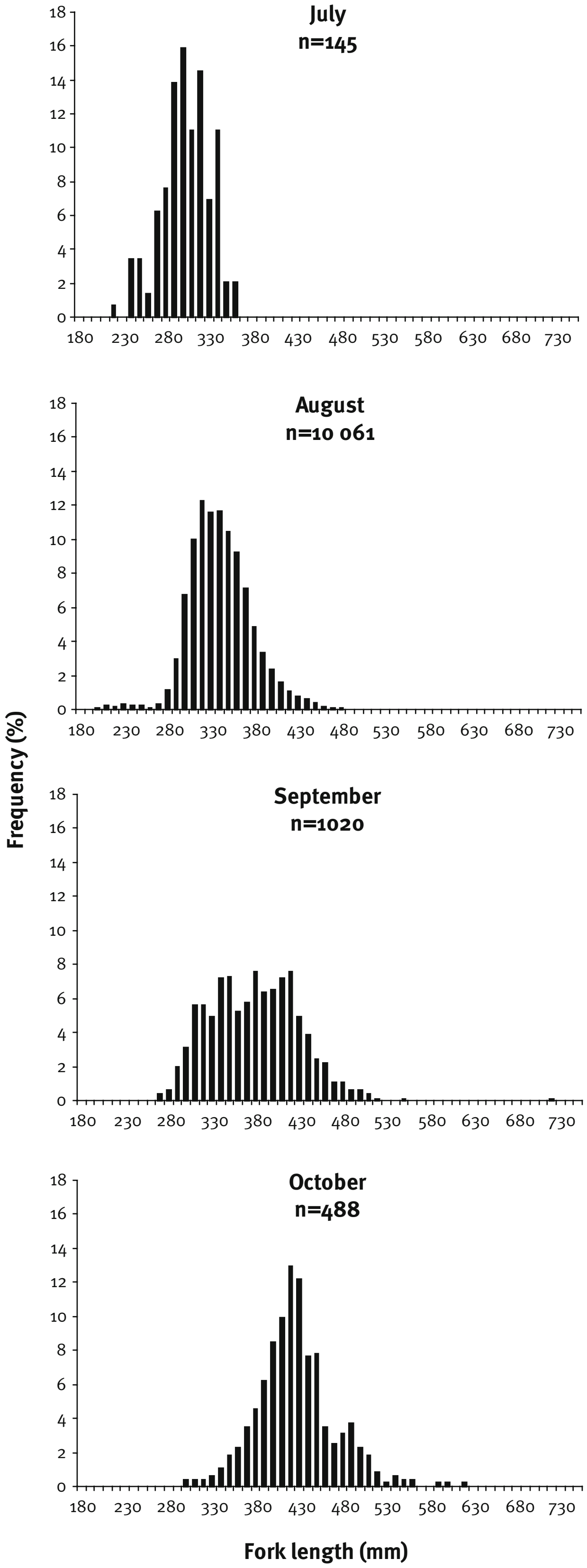

Figure 8. The length frequency of tailor collected in each month by the Long Term Monitoring Program on Fraser Island, grouped for the years 1999 to 2004.

Length–weight

Weight for ocean beach tailor was only collected from a few commercial catch samples in 1999 and 2000. A strong relationship exists between length and weight for both males (R^2 = 0.9738, n = 120) and females (R^2 = 0.9698, n = 125) (Figure 9). There was no distinct difference in the length–weight relationship between each sex or between regions (Figure 10).

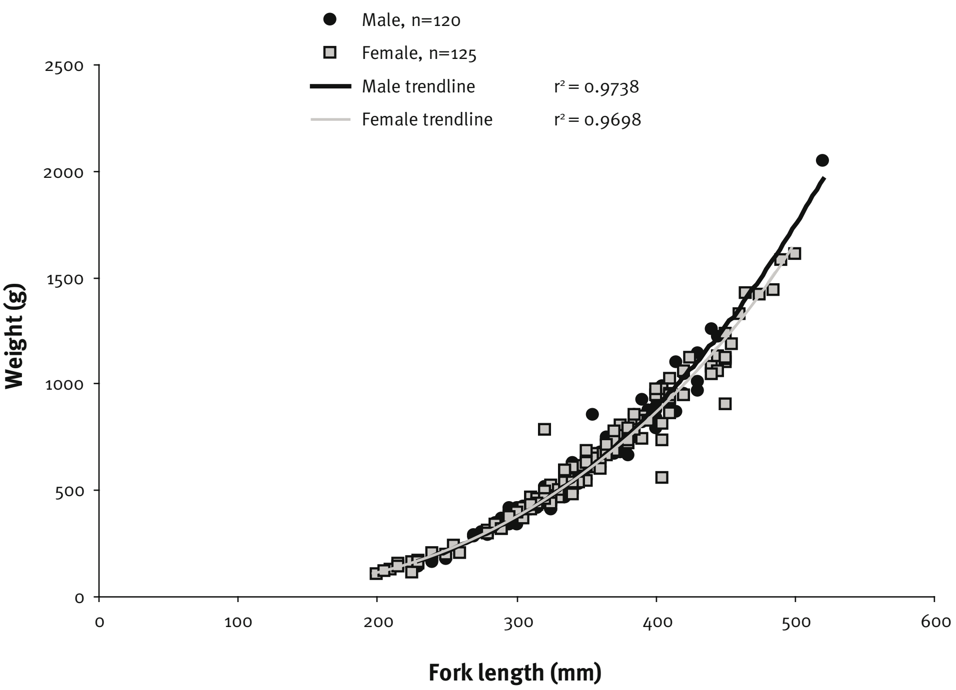

Figure 9. The length–weight data collected in 1999 and 2000 for each sex.

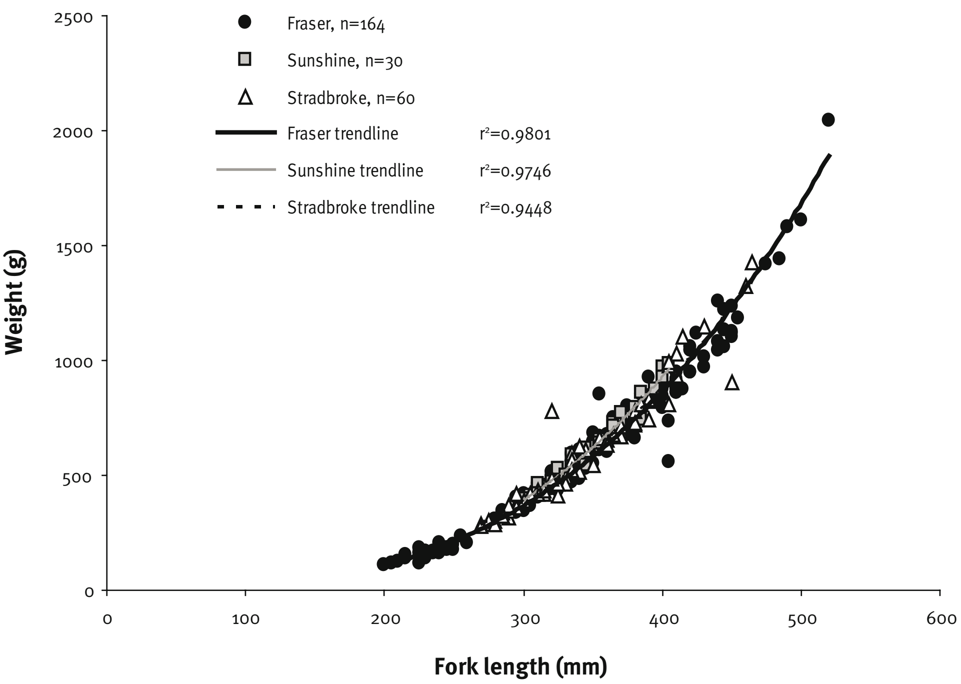

Figure 10. The length–weight relationship for 1999 and 2000 tailor collected by the Long Term Monitoring Program per region.

Age frequency

The LTMP collected 5916 fish for ageing—between 1999 and 2004, the youngest fish aged was less than one year old and the oldest fish was five years old.

Male tailor show a modal age frequency of two years of age and females display a modal age frequency of one year of age. There is approximately a 5% difference between the relative frequency of the one and two year age classes for both male and female tailor. The tailor of unknown sex displayed both the one and two year age class as the most common (Figure 11).

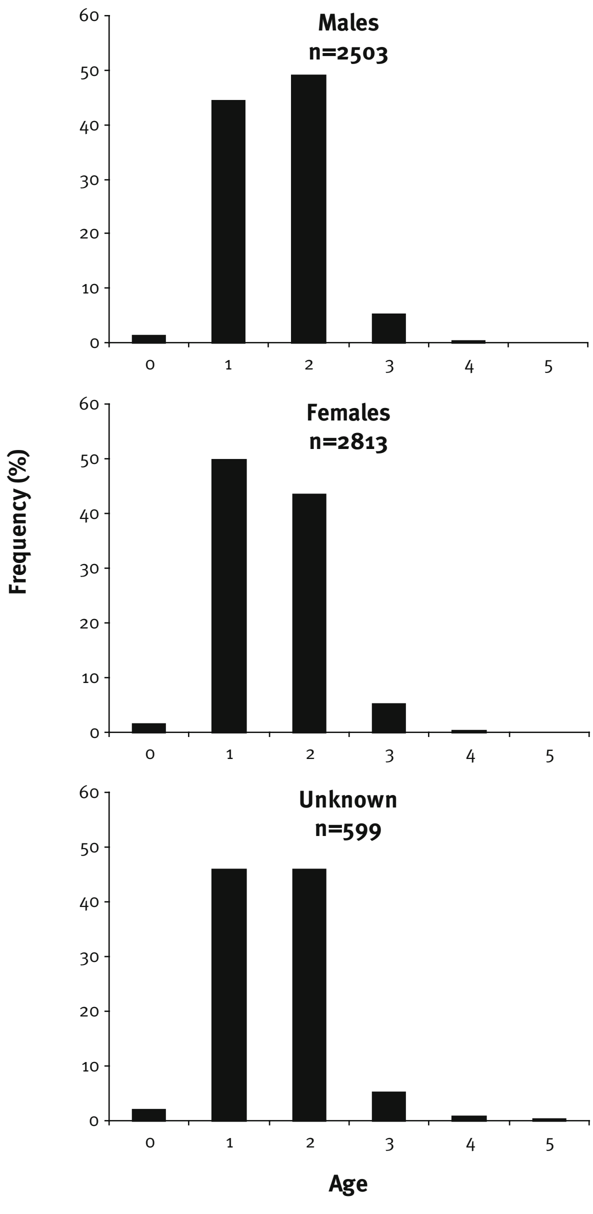

Figure 11. Long Term Monitoring Program tailor age frequency by sex for all sampling regions, years 1999–2004.

The annual frequency distributions for the Fraser region show that the modal fish age is the same between the two sexes for every year except 2004 (Figure 12). One- and two-year-old fish were the strongest age classes for both the male and female fish. The stronger year class can be seen by the larger age class shifts from one year olds in 2000 to two year olds in 2001, and an increase in three year olds in 2002. There is also an increase in the relative proportions of four- and five-year-old fish in 2002 and 2003.

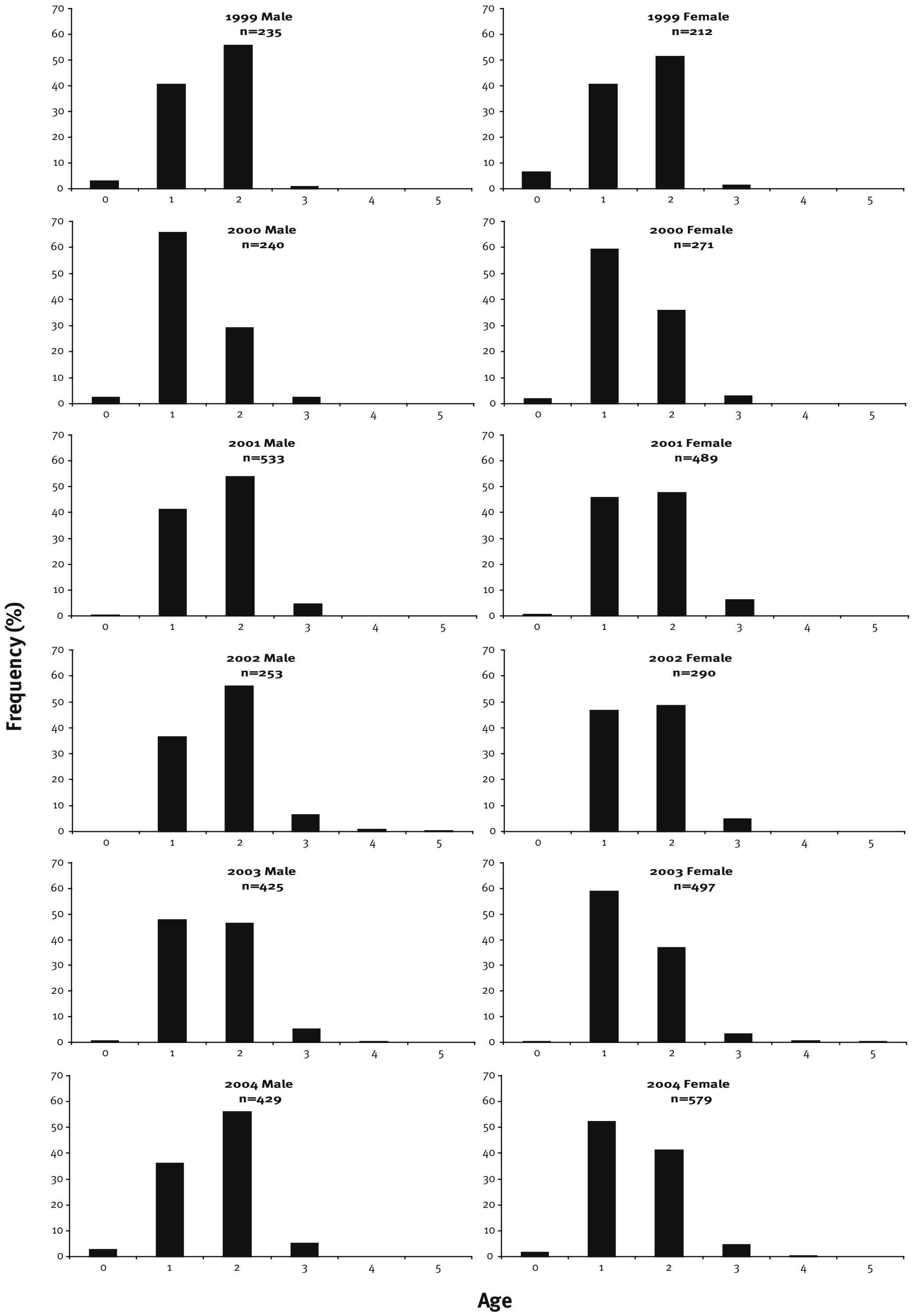

Figure 12. Long Term Monitoring Program tailor age frequency for Fraser region by sex, years 1999–2004.

Growth

There was little difference in the growth rate between sexes for the length–age data (Figure 13). The linear growth curve showed that for male ($R^2 = 0.4104$) and female ($R^2 = 0.4157$) tailor collected by the LTMP from 1999 to 2004, the relationship between length and age was poor.

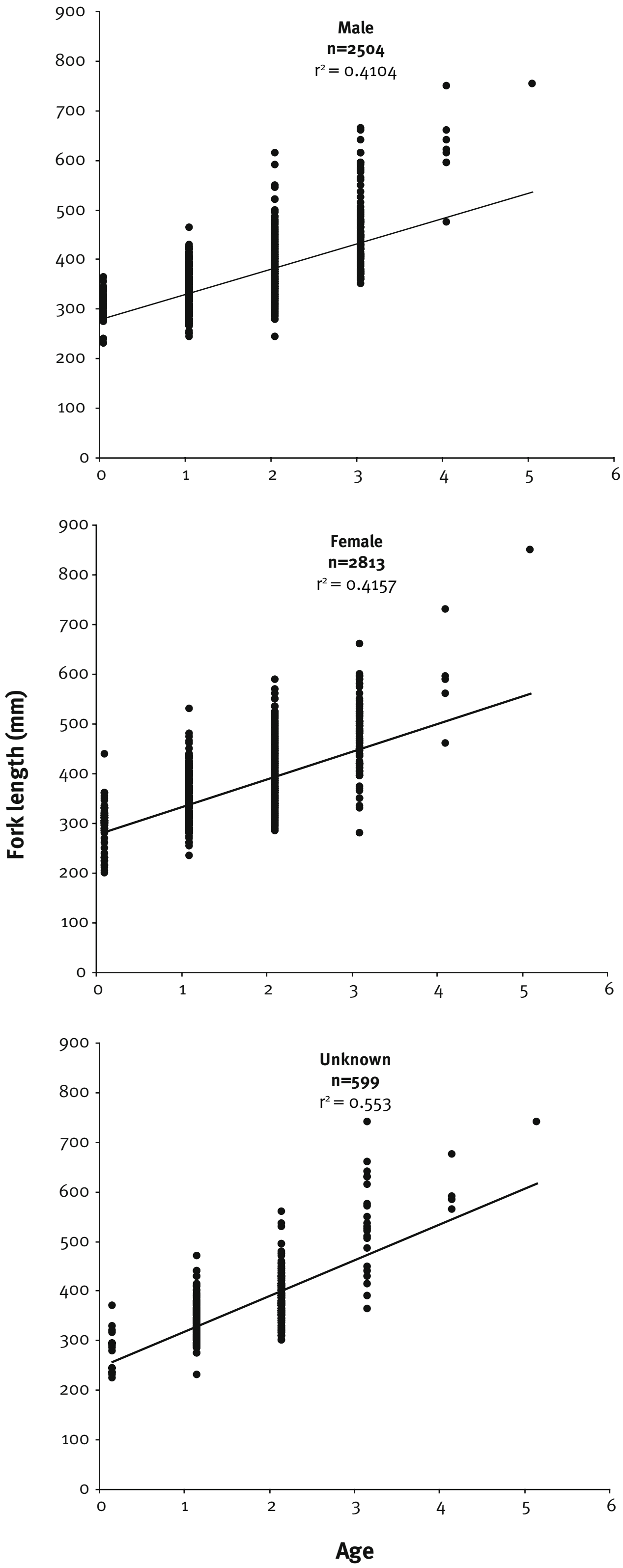

Figure 13. Tailor length at age by sex, collected by the Long Term Monitoring Program from the recreational and commercial fishery.

The growth rates of males and females were similar in each region (Figure 14). There was a poor linear relationship for the length at age for either sex in any region (Figure 14).

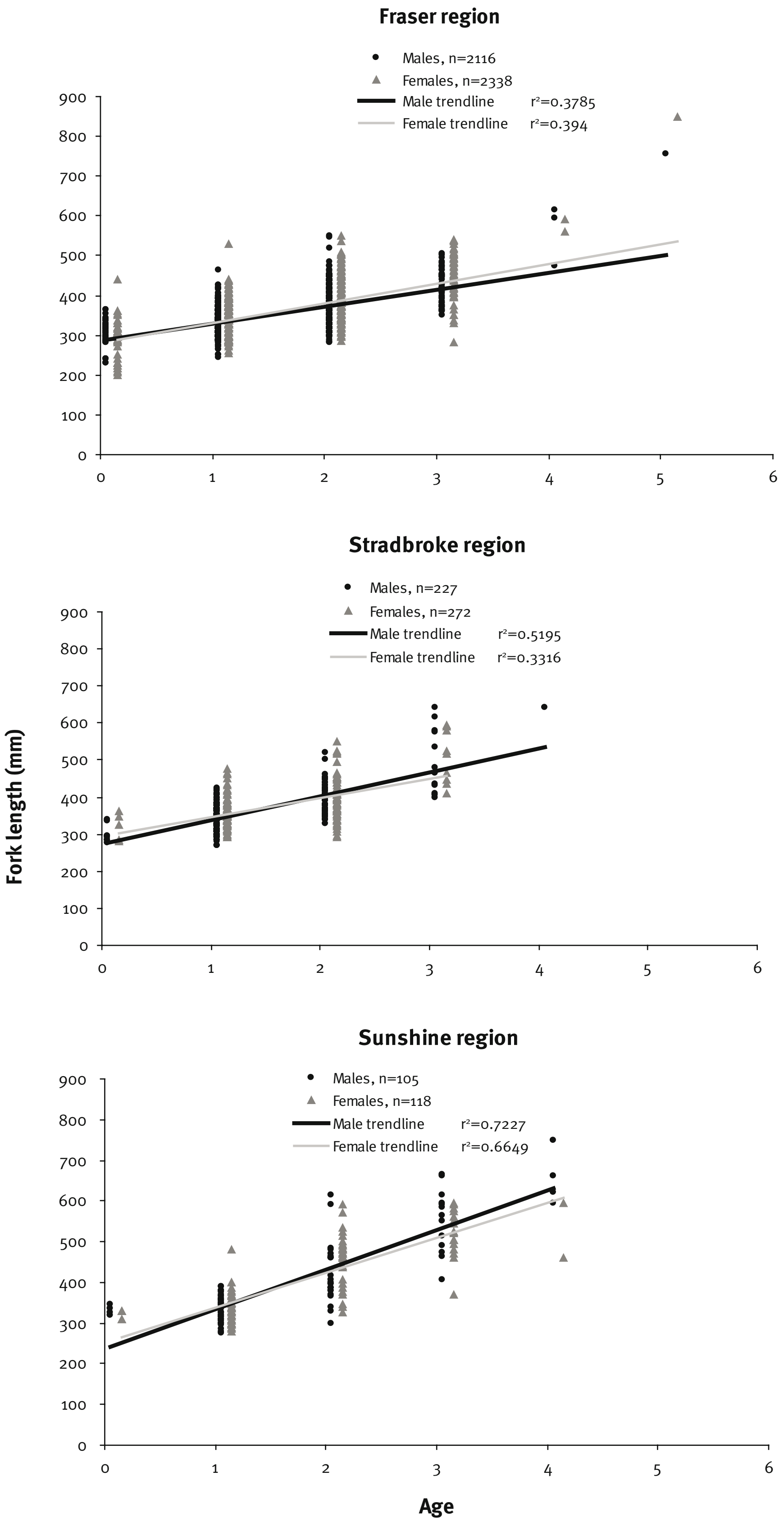

Figure 14. Tailor length at age by sex and sampling region, collected by the Long Term Monitoring Program from the recreational and commercial fishery.

Plots of the length–age relationship for the Fraser region by year and sex are shown in Figure 15. The length–age linear relationship is poor across all years for both males and females.

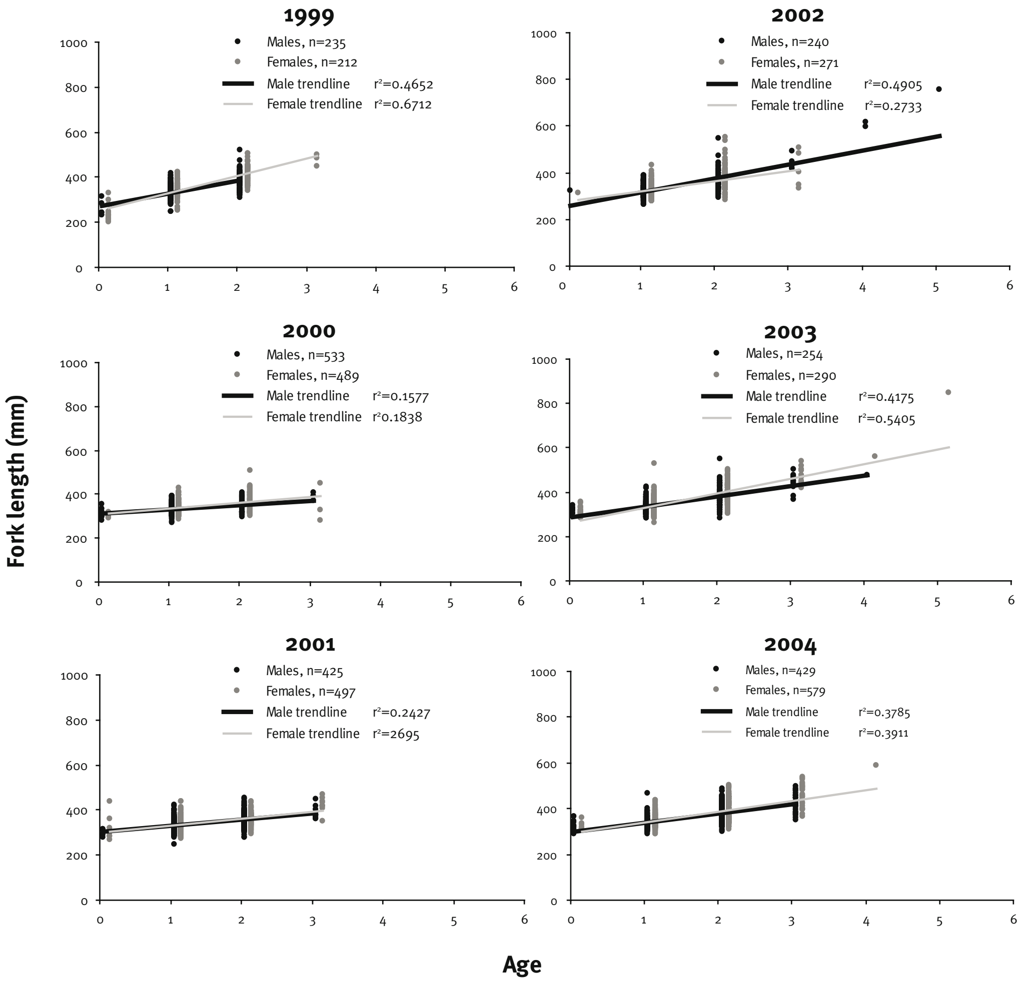

Figure 15. Tailor length at age by sex and year for the Fraser region, collected by the Long Term Monitoring Program from the recreational and commercial fishery.

Discussion

A majority of the tailor samples collected since 1999 have come from the Fraser region and are considered representative of recreational catch in this region. Samples from other regions are not large or comprehensive enough to be considered to be representative of the recreational or commercial catch of those regions and as such will not be discussed further in this report.

The majority of the results presented in this report represent the size structure of the recreational tailor fishery on Fraser Island during late winter to spring between 1999 and 2004.

The difference in sample numbers collected within various zones on Fraser Island could be due to the timing of some LTMP sampling trips coinciding with the seasonal spawning closure, thereby limiting the area being fished by the recreational fishers and the area sampled. Although this may have an impact, it is more likely that the main contributing factors are based around the geomorphological characteristics of each zone and the impacts that this has on the behaviour of recreational tailor fishers. The geomorphology of the zones could alter fisher behaviour due to the accessibility to the area, the physical size of the zone, or the weather influences and available protection within each zone.

Length frequency and length–weight relationships

There were no significant variations in length of tailor between years, sexes or regions. The modal length of tailor collected by the LTMP from the ocean beach fishery supports the previously documented information that tailor enter the fishery and spawn at approximately 300 mm in length[4] and two years of age (Kailola *et al.* 1993).

The length of tailor collected by the LTMP varied considerably within the winter sampling period from July to October, suggesting an earlier northward spawning migration for smaller tailor (July–August) than large tailor (September–October). Leigh and O'Neill (2004) suggested that larger tailor may be migrating offshore and are therefore inaccessible to the fishery until later in the year. However, research conducted by Brown *et al.* (2003) documented the average size of tailor offshore and inshore as similar and therefore migration offshore by larger tailor seemed unlikely.

Tailor length and weight are shown to be closely correlated. There was little difference in the length–weight relationship for tailor in each region or between males and females. However, there was only a small number of fish (254) collected by the LTMP in the years 1999 and 2000 that constructed the length–weight dataset.

[4] Length here is cited as total length, although the LTMP survey collects the fork length of tailor. According to Leigh and O'Neill (2004), 300 mm total length equates to approximately 268 mm fork length of tailor.

Age estimation and age frequencies

An investigation of the monthly frequencies of edge zone formation from tailor collected by the LTMP did not suggest that increment formation occurred during the sampling months of August, September and October. When using edge frequency as a means of validating increment periodicity, it is recommended that the cycle frequency should represent one year in true annuli (Campana 2001). Currently, tailor is only monitored for three months of the year. Previous work on age validation of tailor in Queensland indicated that each annulus represented a year's growth, and suggested increment formation occurred in late September (Brown *et al*. 2003).

Age frequencies for males and females indicated that tailor are not fully recruited to the ocean beach fishery until one and two years of age. This result supports the findings of previous research by Bade (1977). The LTMP surveys also found very few fish over the age of three years. This may be due to high natural mortality, high fishing mortality or that larger fish are migrating offshore out of the fishery (Leigh and O'Neill 2004). Research conducted by Brown *et al.* (2003) documented the average size of tailor offshore and inshore as similar and therefore migration offshore by larger or older tailor seems unlikely.

The age frequency of tailor from the Fraser region displays a slight increase in year class strength from 0 age class in 1999 to the 3 year age class in 2002. However, it is important to note that in 2001 the sample population size was double that of years 1999, 2000 and 2002 and may therefore bias the results.

Growth

The growth of tailor shown here is only representative of young tailor, and as such is not representative of tailor growth through their full life history. For this reason a linear curve has been used instead of a von Bertalanffy growth curve, which produces the maximum length attained by a species (Leigh and O'Neill 2004). Regardless of the poor length and age relationship, the growth was similar for each sex and region. The growth of tailor on the east coast of Australia has been discussed in several documents (e.g. Bade 1977; Dichmont *et al*. 1999). However, results were ambiguous and as such these reports have recommended further investigation into validating the growth of tailor.

Conclusions

The results currently reflect ocean beach catches of young tailor predominately from the Fraser region. The data include only a limited number of samples from commercial catches from the Sunshine and Stradbroke regions. This is primarily due to limited accessibility to commercial samples by the LTMP and a spatial closure on commercial tailor fishing on Fraser Island (*Fisheries Regulation 1995*). However, it is recommended that future monitoring be expanded to include a larger proportion of samples from the commercial sector of the fishery. As the recreational tailor samples are currently collected only from the Fraser region, it is recommended that the sampling be extended to provide more representative sampling of the recreational fishery from both the Sunshine and Stradbroke regions. Leigh and O'Neill (2004) support the need to maximise the truly independent nature of the samples by separating them by either space (e.g. greater than 20 km) or time (e.g. more than a week). By extending the recreational and commercial sampling within the Sunshine and Stradbroke regions, the sample size for these regions would be increased and in turn potentially provide a more representative sample of the Queensland tailor fishery as a whole.

When modifying the survey design to include increased spatial and temporal sampling, it is important to bear in mind that even after further analysis of the sampling design it may still be necessary to maintain the same level of sampling within the Fraser region, in order to obtain a representative sample from that region. The degree to which this expansion would make the sampling more representative of the population available to the fishery is currently unknown (Leigh and O'Neill 2004). Leigh and O'Neill (2004) also noted that sampling at either of the other two regions may in fact lead to fewer schools being available for sampling. They therefore recommended continuing the sampling on Fraser Island, while focusing on taking the samples from the most widely spaced locations. However, they do suggest that the same level of sampling conducted at Fraser Island across the three regions would be preferable (Leigh and O'Neill 2004).

There were limited tailor collected larger than 500 mm (fork length) and at the age of three years or older. It is recommended that a component of the monitoring focuses on collecting larger tailor to help complete the growth curve.

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Appendix—Age estimation quality control measures

Quality control measures

Readability indices were recorded for all otolith readings from 1999 to 2004.

Age readings of tailor were tested for bias and precision.

Bias was tested using age bias plots, where the mean age for one reader was plotted against the age categories reported by another reader. In 2003, bias was tested between readers. In 2003 and 2004, age bias plots were constructed to test bias between the first and second readings by the one reader.

Precision is defined as the reproducibility of repeated measurements on a given structure or) the repeatability of individual readings or age estimates (Kimura and Lyons 1991; Campana 2001). Precision was determined by calculating average percent error (APE) and coefficient of variation (CV).

Beamish and Fournier (1981) recommended the use of APE:

$$APE_j = 100 \times \frac{1}{R} \sum_{i=1}^{R} \frac{\left| X_{ij} - X_j \right|}{X_j}$$

where R is the number of times the fish are aged. X_{ij} is the *i*th age determination of the *j*th fish and X_j is the mean age estimate for the *j*th fish. When APE_j was averaged across many fish it became an index of average percent error (IAPE) (Campana *et al.* 1995).

Chang (1982) devised the CV, expressed as the ratio of the standard deviation to the mean, calculated as follows:

$$CV_j = 100 \times \frac{\sqrt{\sum_{i=1}^{R} \frac{\left(X_{ij} - X_j\right)^2}{R-1}}}{X_j}$$

where R is the number of times the fish are aged. X_{ij} is the *i*th age determination of the *j*th fish and X_j is the mean age estimate for the *j*th fish. As with APE, the CV was averaged across the range of fish to provide a mean CV_j.

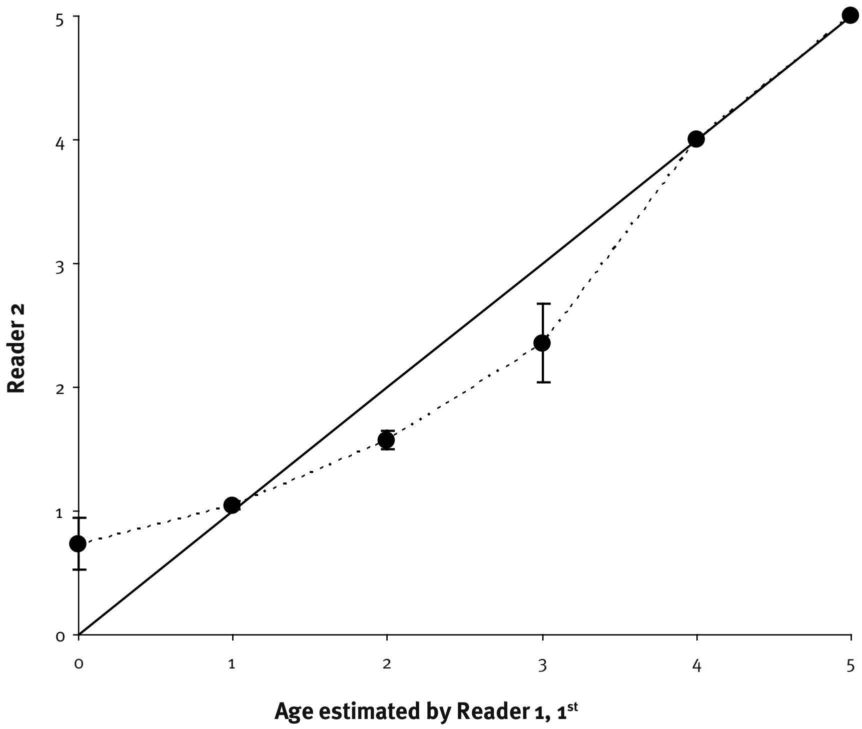
Both inter- and intra-reader precision levels were calculated for 2003 and 2004 age readings.

Quality control results

Since 1999, otoliths from 5916 fish have been examined. The majority of otoliths (44%) were assigned a readability of four (readable but not totally confident). Readers assigned approximately 14% of the otoliths with a readability of five (able to be read with total confidence).

Bias and precision

Age bias plots showed some deviation between readers and readings. In 2003, deviations were seen between readers for the ages of zero and again for two and three years (Figure 16). The magnitude of biases that existed between reader 2 and reader 1, 1st reading, and between reader 2 and reader 1, 2nd reading were relatively small (½ year).



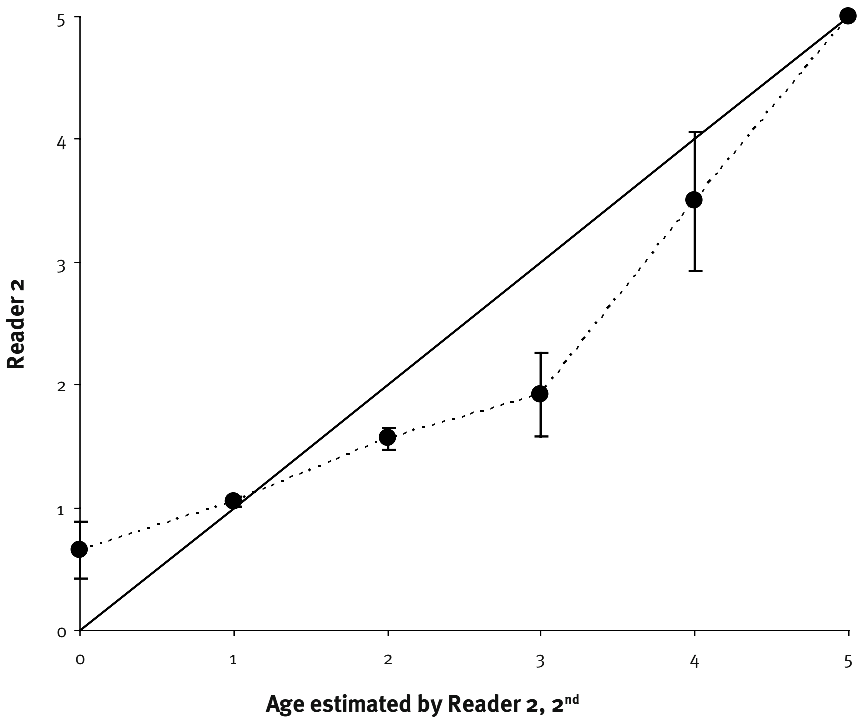


Figure 16. Age bias graphs between readers for 2003. Each error bar represents 95% confidence interval. The 1:1 equivalence line (solid line) is also indicated.

In 2003, when both readings from the same reader were compared, a slight deviation existed for those tailor aged zero years in reading 1 (Figure 17). In 2004, when readings from the same reader were compared, deviations were evident between reading 2 and reading 1, with an overestimation for ages of zero and one years and an underestimation for ages of two and three years (Figure 18).

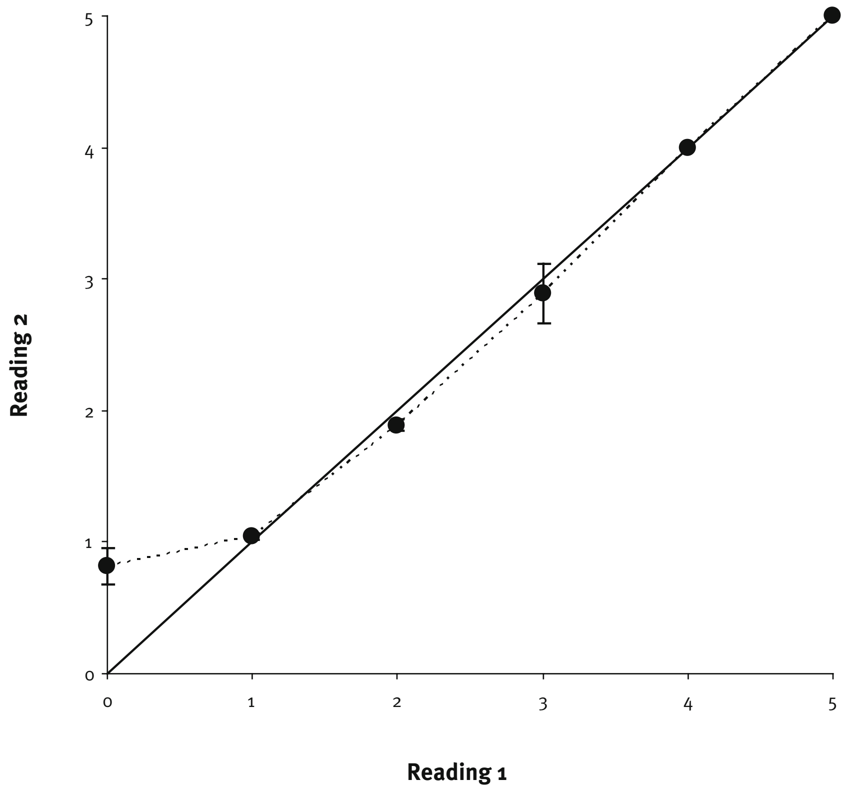


Figure 17. Age bias plots between reading 1 and reading 2 for reader 1 for 2003. Each error bar represents 95% confidence interval. The 1:1 equivalence line (solid line) is also indicated.

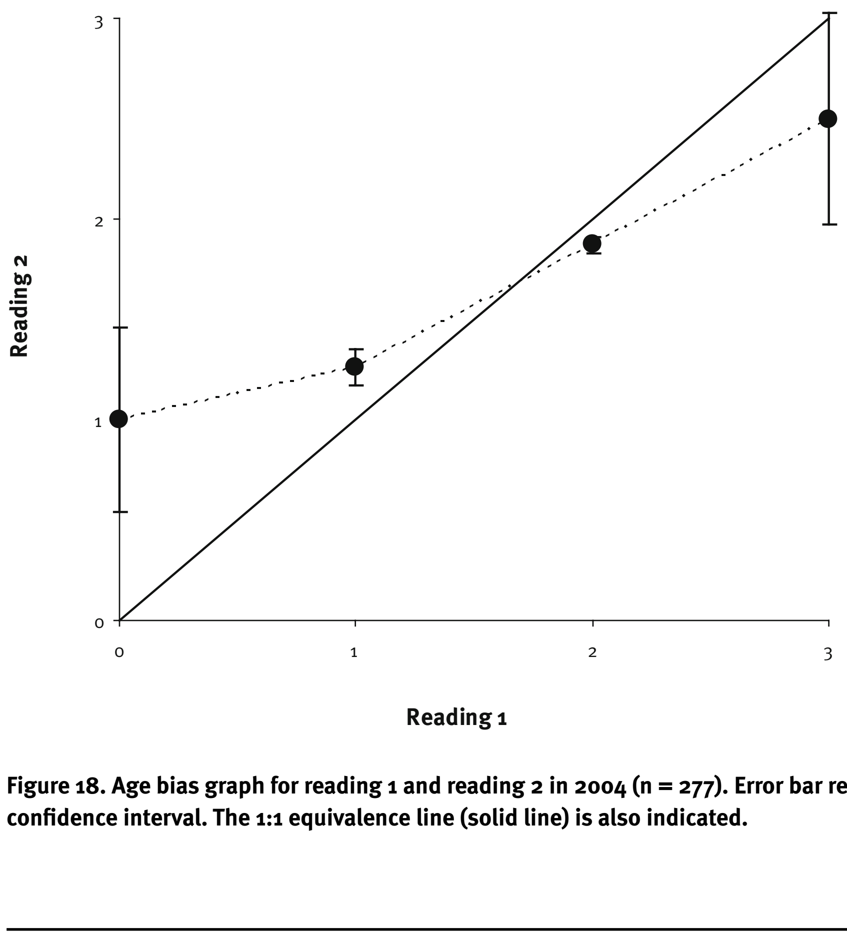


Figure 18. Age bias graph for reading 1 and reading 2 in 2004 (n = 277). Error bar represents 95% confidence interval. The 1:1 equivalence line (solid line) is also indicated.

Inter- and intra-reader precision levels were calculated for 2003 and 2004 (Table 3). Inter-reader APE levels for 2003 ranged from 16.66 to 17.94%. Intra-reader APE levels were 7.67% in 2003 and 10.81% in 2004.

Table 3. Levels of inter- and intra-reader precision for tailor otolith readings.

Statistic or index	Reader 1, 1st v Reader 2 (2003)	Reader 1, 2nd v Reader 2 (2003)	Reading 1 v 2 (2003)	Reading 1 v 2 (2004)
APE	16.66	17.94	7.67	10.81
CV	23.55	25.37	11.27	15.28
n	1038	1038	1040	277

APE = average percent error

CV = coefficient of variation

n = sample size

Quality control discussion

The age estimation of tailor is a challenging process, this being reflected by the low levels in reader confidence. From 5916 otoliths in total, only 14% were classified as being clear (obvious) to read.

The quality control monitoring indicated that some bias existed between readers in 2003. Yet the magnitude of the bias, as indicated by the vertical interval between the 1:1 line and the data points, was relatively small (½ year).

A certain amount of bias was exhibited by reader 1 in 2003 and again in 2004 for the zero-year-old fish. These biases are a reflection of the complex internal structure of tailor otoliths, where some otoliths have several spurious annuli, including a false or first check, inside the first annulus (Brown *et al.* 2003). It is known for many species that the identification of the first annulus is often more problematic than that of the first check, since the latter is often clearly visible as it represents a hatch check (Campana 2001). An ageing protocol for whole tailor otoliths has been developed through an age validation project in Queensland (Brown *et al.* 2003). The LTMP readers have followed these guidelines, which divide the internal structure into regions preceding the formation of the first annulus to aid with interpretation.

The measures of both inter- and intra-reader precision indicated good reproducibility and consistency for the ageing of this species. The intra-reader APE levels were seen to be lower in 2003 compared with 2004. The increase in APE levels may have been due to the shift in methods in 2004, with reading two representing a 25% re-read rather than the entire sample. The large reduction in numbers being analysed in 2004 most probably inflated the APE levels. All measures of precision are artificially inflated by any bias that exists (Campana 2001). Therefore, when all bias is eliminated the precision levels will improve even further.

It is envisaged, with the recent construction of a reference collection, that quality assurance protocols will be carried out annually. Reference collections are mandatory as a first step for quality assurance in any ongoing ageing program and must be used continuously to ensure that age interpretation remains consistent over time and between different readers (Campana *et al.* 1995; Gröger 1999; Campana 2001). In future age estimation of tailor within the LTMP, otoliths from the reference collection will be read prior to the readings of the current year's otoliths. Bias will be looked at initially, as the presence of bias will confound the interpretation of most measures of precision (Campana *et al.* 1995). Following this, precision levels will be calculated using index of APE and CV. If unacceptable levels of error are encountered, these will be addressed with training and the reference collection will be re-read.

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