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Status of nearshore finfish stocks in south-western Western Australia

Part 2: Tailor

NRM Project 09003 Final Report

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Contents

Executive Summary

The status of the nearshore finfish resource in the West Coast Bioregion (WCB) of Western Australia (WA) was largely unknown prior to this study. Previously, declining catches of several species had highlighted the risk to their sustainability and the need for greater certainty about the status of this popular resource. Recently, the risk substantially increased due to recent changes to the management of demersal scalefish, which are likely to result in a shift in targeting towards nearshore species. This increase in fishing pressure will be on top of any increase due to the continuing human population growth in the WCB.

The status of the tailor (*Pomamtomus saltatrix*) stock in WA was assessed using a 'weight-of-evidence' approach, which incorporated all available historical and current information about the stock. This species forms part of a small group of indicator species that is used to monitor the status of the nearshore finfish resource in the WCB. The status of the other WCB nearshore indicators Australian herring (*Arripis georgianus*), southern garfish (*Hyporhamphus melanochir*) and whiting (Sillaginidae) will be the subject of other reports.

The current stock status of tailor was mainly determined by examining trends in recruitment and fishery catch rates, and by considering the inherent vulnerability of the stock to exploitation due to biological characteristics. The stock was found to have low inherent vulnerability. Catch rates in the GCB suggested that the current spawning stock abundance is relatively high. Recruitment in the WCB has been increasing since 2004. These indicators suggest that there is currently a low risk to the sustainability of the stock. Given this risk level, no additional management action is required.

In WA, tailor primarily occur along the west coast between Exmouth and Augusta, but low numbers are also found along the south coast (to Esperance). Commercial and recreational fisheries for tailor in WA are spatially separated – commercial landings are mostly in the Gascoyne Coast Bioregion (GCB), recreational landings mostly in the WCB. To date, these fisheries have been managed separately (implying separate stocks) but the evidence outlined in this report suggests that a single stock extends across both Bioregions and that a more integrated management approach is required.

Population structure in WA is complex. The breeding stock comprises multiple spawning groups, which are located in different regions and spawn at different times. Annual recruitment consists of multiple pulses of larvae generated from these multiple spawning events. The source(s) of juvenile recruitment to a particular region may be local or remote, or both. For example, recruits to the Metropolitan Zone in the WCB appear to be derived from spawning in northern areas (the GCB and the Kalbarri Zone of the WCB) and southern areas (mainly South-West Zone), while spawning in the Metropolitan Zone probably supplies the majority of recruits to the South-West Zone. Subsequent adult migration results in extensive mixing of recruits between regions and so the various spawning groups function as a single breeding stock. There is a net northward movement of adults, but a small proportion of adults remain resident in each region. The majority of spawning probably occurs in northern areas due to this net northward movement.

Annual recruitment by age 0+ juvenile tailor has been monitored since 1996 by a volunteer angling program in the Swan-Canning Estuary. This fishery-independent program provides a robust index of recruitment within the Metropolitan Zone of the WCB. Recruitment occurs as two discrete pulses, one derived from winter spawning in northern areas and one from summer spawning in southern areas. Annual recruitment by winter-spawned tailor is highly variable and appears to be partly regulated by wind-driven surface currents, which transport pelagic larvae from the northern spawning grounds. Recruitment by summer-spawned fish is generally lower and less variable. The relative contributions to the adult population by each of these cohorts are yet to be quantified, but it appears that annual recruitment variation of winter-spawned fish more strongly influences catch rate trends in the popular Metropolitan fishery.

Total annual recruitment in the Metropolitan Zone trended downward during 1996–2004 and upward during 2004–2011. The highest observed recruitment occurred in 2008, 2010 and 2011. Higher recreational catch rates reported in the Metropolitan Zone and elsewhere in the WCB in the past few years are probably the result of this strong recruitment.

Precise estimates of the total recreational catch of tailor are not available due to the lack of recent catch estimates for the shore-based sector. The 2000/01 National Recreational and Indigenous Fishing Survey has been the only state-wide recreational fishing survey conducted in WA. Results of this survey provide the only basis for 'scaling up' catch estimates from other more spatially limited recreational fishing surveys to Bioregion or state level. For example, the total recreational catch in each Bioregion/Zone can be calculated from partial catch estimates from boat-based surveys in recent years by applying the catch shares (boat v. shore) from the 2000/01 survey. Using this approach, which assumes that catch shares have not changed since 2000/01, current total recreational landings are estimated to be approximately equal to the total commercial catch (i.e. 20–30 t per year). However, the 2000/01 survey estimated that about 85% of the total WA recreational catch of tailor was taken by shore-based fishers. Hence, estimates of total catch derived from boat-based data are not reliable.

Planned future surveys of boat-based recreational fishing by the WA Department of Fisheries will provide regular estimates of annual boat-based catches of tailor, but not shore-based catches. Boat-based fishers typically capture larger tailor and have a different catch rate of this species compared to shore-based fishers. In the WCB, juvenile tailor typically occur in estuaries and nearshore coastal waters, young adults in nearshore coastal waters and older adults in offshore coastal waters. Therefore, the WCB recreational tailor fishery is comprised of four parts (estuary, ocean shore-based, nearshore ocean boat-based and offshore ocean boat-based) which each target a different component of the stock.

Although recent and historical recreational catch levels are uncertain, there was sufficient anecdotal evidence to suggest a substantial decline in the WCB recreational catch and catch rate during the 1980s and 1990s. Various changes to recreational fishing regulations (bag and size limits) were implemented between 1990 and 2009. These changes were effective in reducing the retained catch of tailor, although the magnitude of the reduction cannot be calculated precisely due to uncertainty about the shore-based catch level.

Current commercial landings of tailor in WA are 20–30 t per year. The majority (80–95%) of the commercial catch is taken in the GCB by the Shark Bay Beach Seine and Mesh Net Managed Fishery. Shark Bay catch rate trends suggested a rapid increase in the availability of tailor in this GCB after 1990, peaking at historically high levels from 1995 to 2000. Catch rates suggest that tailor abundance in the GCB declined after 2000 but is still high compared to historical levels (i.e. pre-1990). Assuming that a major portion of the spawning stock is located in the GCB, then this suggests that the current spawning stock level is relatively high.

The age and length structure of tailor in recreational catches was sampled during 2009–10. The majority of samples were from nearshore waters of the Metropolitan and Mid-west Zones. Under-sampling of northern and offshore areas in 2009–10 probably resulted in a length/age composition biased towards smaller/younger fish. In 2009–10, the majority (97%) of ages were

<4 years. The majority of lengths were 300–550 mm. Compared to historical samples obtained in 1991–99, the length composition in nearshore Metropolitan waters in 2009–10 was slightly truncated (i.e. lower proportion of large fish) and had a lower average length. A comparable sample of the age structure in 1991–99 was not available.

The rate of fishing mortality could not be confidently estimated for the tailor stock in 2009–10, due to the likely bias in the age structure and relatively low samples sizes in each region. A more robust assessment of fishing mortality in the tailor stock would require a more representative sample of the age structure of the stock. This would require an increase in sample size in each region, and also a substantial increase in sampling effort to obtain both inshore and offshore fish in each region. This is not feasible at the current level of resourcing.

This study estimated key biological parameters for tailor in WA, which are important for assessing stock status. The growth rate was relatively fast, with fish attaining an average of 236 mm total length (TL) after 1 year and 368 mm after 2 years. Length-at-maturity ($L_{50\%}$) was estimated to be approximately 320 mm, which is above the current legal minimum length of 300 mm TL. Natural mortality of tailor was estimated to be between 0.34 and 0.42 y^{-1}, based on a maximum age between 10 and 13 years in WA. This moderately high rate of natural mortality and fast growth rate implies moderate resilience of the stock to exploitation.

Several key areas were identified as a focus for future research. Firstly, the current 'low risk' status is based on assumptions about stock structure which need to be verified. Further biological sampling in each Bioregion is required to determine spawning patterns and identify recruitment sources. A tagging study to determine adult movement is also required to quantify connectivity between Bioregions.

Secondly, the largest catch share of tailor is considered to be taken by shore-based recreational fishers in the WCB, although the actual catch level (or trend) is unknown. As the WCB shore-based catch is large and includes a significant proportion of immature fish (up to 31% in estuaries and 17% in nearshore waters), the shore-based catch level has implications for stock sustainability. Regular surveys of WCB shore-based recreational fishing that provided robust estimates of catch and catch rate by this sector would provide valuable information for effective management of this sector and would increase the certainty of stock assessments. However, a better sampling frame would need to be developed to make shore-based surveys cost-effective.

In the near future, it is anticipated that stock assessments of tailor will be almost entirely dependent on data provided by volunteers. Therefore, it is important to maintain these volunteer programs. The Swan-Canning Estuary volunteer angling program provides a robust index of recruitment in the Metropolitan Zone. In the absence of regular shore-based surveys, the catch rates of volunteer logbook fishers (the Research Angler Program) provides an annual index of tailor abundance and information about recreational catch composition in the WCB.

1.0 Introduction

1.1 Background

Nearshore fish species such as tailor (*Pomatomus saltatrix*), Australian herring (*Arripis georgianus*), whiting (Sillaginidae) and southern garfish (*Hyporhamphus melanochir)* have historically dominated shore-based and inshore boat-based landings by recreational and commercial fisheries in the West Coast Bioregion (WCB) of Western Australia (WA) (i.e. Kalbarri to Augusta, including the Perth Metropolitan Zone). Yet, despite their popularity, the status of key nearshore stocks of finfish in the WCB are largely unknown. Results from a boat-based recreational fishing survey in 2005/06, revealed substantial declines in annual catches of tailor and Australian herring of 80% and 21%, respectively, since an earlier survey in 1996/97 (Sumner *et al.* 2008). These declines demonstrated the need for greater certainty about the status of these and other nearshore species, and highlighted the current risk to their sustainability, along with the recreational and commercial fisheries that they support.

The risk to the sustainability of nearshore species has further increased as a consequence of recent management changes to the West Coast Demersal Scalefish Fishery, which were introduced to ensure the ongoing sustainability of inshore demersal stocks. These measures, including an annual two-month closure to recreational fishing for demersal species (commenced in 2009), were designed to achieve a 50% reduction in catch by all sectors (Wise *et al.* 2007, Department of Fisheries 2008). One likely consequence of these changes is that there will be an effort shift, with more recreational fishers targeting nearshore fish during the closed demersal season. This sustainability risk increase will be on top of any increase due to the continuing human population growth in the Perth area and WA in general.

To date, limited management action has been focussed on the sustainability of nearshore stocks. In commercial fisheries, licence buy-backs and fishery closures over a period of decades have successfully reduced the number of operators in temperate nearshore and estuarine fisheries, although the primary focus of these measures was removal of latent effort and resource reallocation, not sustainability. In the recreational fishery, only blunt management tools have been applied (e.g. bag limits and/or size limits), which limit individual catches but do not constrain total catch.

These low-level management approaches are a result of an earlier sustainability risk assignment of 'low' (e.g. Australian herring, sand whiting, mullet, skipjack trevally) or 'medium' (e.g. tailor, King George whiting) to many nearshore species (Prokop 1994). However, there are now many indications (e.g. declining catch levels and low recruitment) that the risk level and the status of the nearshore finfish resource within the WCB should be reviewed.

1.2 Need

The Department of Fisheries uses an indicator species approach to monitor the status of finfish resources throughout the State (Department of Fisheries 2011a). Therefore, the Department's research activities are strongly focused on determining the stock status of the indicator species identified.

Within each Bioregion of WA, finfish resources are assigned to one of five ecological suites: estuarine, nearshore, inshore demersal, offshore demersal or pelagic. Indicator species for each suite have been identified using a risk-based approach, based on the vulnerability of the species/

stock to fishing, as well as social, economic and cultural values (Department of Fisheries 2011a). The collective status of the indicator species is used to indicate the status of an entire finfish suite. The following indicators have been selected to represent the nearshore finfish resources of the WCB: Australian herring, tailor, southern garfish, whitebait (*Hyperlophus vittatus*) and whiting (various species). The whiting species complex has been provisionally selected, subject to resolution of the taxonomic uncertainty about these species in fishery landings. Australian herring is also an indicator species for the nearshore finfish resources of the South Coast Bioregion (SCB).

Concerns about the status of the WCB nearshore indicators, especially Australian herring and tailor, from evidence of declining fishery catches and declining recruitment, combined with the likelihood of increased targeting within the WCB, has highlighted the need for greater detail and precision of assessments to ensure the ongoing sustainable management of the nearshore finfish resource (Smith *et al.* 2012).

1.3 Resource assessment framework – Indicator species

Completing stock assessments for use in the sustainable management of multi-species, multi-sectoral fisheries presents many challenges in both scale and complexity. These were recently addressed in the assessments of demersal finfish resources in the WCB and Gascoyne Coast Bioregion (GCB) that focused on a limited number of indicator species (Wise *et al.* 2007; Marriott *et al*. 2012). In the WCB, a precautionary management approach was applied whereby the indicator species with the poorest status determined the status of the entire inshore demersal suite. In the GCB, a more spatially explicit management approach is being taken. Due to the wide range of species with varying biological traits in the nearshore suite of the WCB, and the diverse range of fisheries that target them, a spatially explicit management approach may also be appropriate.

The benefits of assessing and managing stock suites based on indicator species are twofold: (i) if resources are limited they can be prioritised to allow more frequent assessments of the indicators in order to determine the status of the entire suite; and (ii) management of fishing on the species that comprise the suite is simplified by focusing on management of the indicators.

1.4 Weight of evidence assessment

For fisheries that are considered ‘data limited’, a ‘weight-of-evidence’ approach is now considered to be best practice (Wise *et al.* 2007, Marriott *et al*. 2012). This approach increases the robustness of the assessment, and thereby reduces the uncertainty, by considering all available data sources.

The ‘weight-of-evidence’ approach allows all available biological, fishery-dependent and fishery-independent data to be considered, such as trends in catch, catch rate and recruitment, and other relevant biological, ecological and anthropogenic data (Marriott *et al*. 2010). This approach develops indicators that allow the performance of a stock to be assessed relative to management reference levels. A range of management outcomes are possible – from broad, precautionary actions to very specific actions – depending on the precision of, and level of risk associated with, the estimate(s) of stock status and the inherent vulnerability of the species involved.

For the nearshore indicator species of the WCB, current data limitations meant it was not possible to develop integrated stock assessment models that could reliably estimate spawning stock biomass. Instead, a 'weight-of-evidence' approach was taken, allowing the full range of available information to be considered in each stock assessment.

1.5 Objectives

This State Natural Resource Management funded project was conducted from 2009/10 to 2012/13. The project aimed to assess the status of Australian herring and tailor stocks, and provide preliminary assessments of the status of southern garfish and whiting stocks, in the WCB and SCB. This project aimed to collaborate with key recreational and commercial stakeholders, including Recfishwest and the Western Australian Fishing Industry Council, to assist in data collection and the establishment of a collaborative, long-term monitoring programme for nearshore finfish resources in the WCB and SCB.

In this report, a 'weight-of-evidence' assessment of the status of the tailor stock is presented. Assessments of other nearshore indicator species (Australian herring, southern garfish and whiting) are presented in other reports.

Specific Objectives

1. Develop methods for collecting representative age samples in order to generate robust estimates of fishing mortality.
2. Develop ageing methodologies (if not already available).
3. Estimate fishing mortality and compare the current level with that determined from historical data sets (where available) to determine if the current status is unique or has occurred in the past.
4. Determine catch and catch rate trends from commercial and recreational fishery data.
5. Develop recruitment indices.
6. Evaluate the influence of key environmental variables on recruitment strength and examine relationships between recruitment strength and catch rates of adults.
7. Review, and estimate where required, key biological parameters (growth, reproduction, natural mortality) required to assess inherent vulnerability.
8. Develop an ongoing monitoring regime for assessment of the stock.

1.6 Overview of biological characteristics of tailor

Tailor (*Pomatomus saltatrix*) is a large, fast growing, relatively short-lived species, reaching a maximum total length of 120 cm and maximum age of 13 years (US ref, Gomon *et al.* 2008). In WA, males and females attain maturity in their 2nd year at approximately 320 mm TL (Section 5 this report). Individuals do not change sex. Tailor are multiple (batch) spawners with indeterminate fecundity, since individuals may spawn continuously during the spawning period (Robillard *et al.* 2008). Individual females may release between 200,000 and >1,200,000 eggs in a single batch, and so their total annual fecundity is high. Adults form pelagic schools in nearshore and offshore continental shelf waters. Juveniles occur in nearshore ocean waters and the lower reaches of estuaries. Both adults and juveniles are carnivorous, feeding mainly on smaller fish.

Tailor has a worldwide distribution in subtropical and warm temperate marine waters. The species occurs on the east and west coasts of Australia and South Africa, the north west coast of Africa, the east coasts of North America and South America, the Mediterranean and the Black Sea (www.fishbase.org). In Australia, tailor stocks on the east and west coasts are genetically distinct to each other and to stocks elsewhere (Nurthen *et al*. 1992, Goodbred and Graves 1996).

In WA, tailor primarily occur along the west coast between Exmouth and Augusta, but low numbers are also found along the south coast (to Esperance). WA is assumed to host a single, genetically homogenous population, due to mixing via the dispersal of pelagic larvae and the extensive migrations of adults. Limited differences in otolith chemistry between tailor from different regions in WA are consistent with mixing via adult migration (Edmonds *et al*. 1999).

Although considered to be a single, genetically homogeneous population, the breeding stock in WA comprises multiple spawning aggregations, which are located in different regions and spawn at different times. Annual recruitment consists of multiple pulses of larvae generated from these multiple spawning events (Section 2 this report). The source(s) of recruitment to a particular region may be local or remote, or both. For example, recruits to the Perth Metropolitan Zone appear to be derived from spawning in northern and southern management zones, while spawning in the Metropolitan Zone probably supplies the majority of recruits to the South-West Zone. Subsequently, adult movement results in a mixing of recruits between regions (although a small proportion of adults may remain resident). Also, it is possible that individual adults participate in multiple spawning events as they migrate between regions. For these reasons, the various spawning aggregations should be considered a single breeding stock.

2.0 Tailor recruitment dynamics

Summary

- Annual recruitment by age 0 juvenile tailor to the Metropolitan Zone within the WCB has been monitored since 1996. Recruitment to this Zone occurs as two discrete age cohorts, mainly derived from winter spawning in northern areas (GCB and/or Kalbarri Zone) and summer spawning in central/southern areas (from the Midwest to the South-west Zone). The relative contributions to fishery landings by each cohort are yet to be quantified, although it is likely that annual recruitment strength of winter-spawned fish more strongly influences trends in fishery catch rates.
- Annual recruitment to the Metropolitan Zone by winter-spawned fish is highly variable and is positively correlated with southward wind strength during the spawning period, which would increase transport of pelagic larvae from the northern spawning grounds. Recruitment declined during 1996–2004 and increased during 2004–2011. Recruitment by summer-spawned fish was much less variable but generally displayed higher values during 2005–2011. During 16 years of monitoring, the highest levels of overall annual recruitment occurred in 2008, 2010 and 2011.
- The Point Walter volunteer angling program in the Swan-Canning Estuary provides a robust index of recruitment by 0+ juvenile tailor to the Metropolitan Zone. Limited evidence suggests it may indicate overall recruitment trends in the stock.
- Recruitment patterns and other data (e.g. extensive alongshore migrations by adults) suggest a high level of connectivity between regions in WA. The available evidence indicates that tailor in WA comprise a single breeding stock.
- Additional research is required to quantify the extent of adult movement between Bioregions/ Zones (i.e. a tagging study). Additional biological sampling is also required to determine the timing of spawning within each region of WA to identify the main sources of recruitment to each zone, especially to the Metropolitan Zone which hosts the majority of recreational fishing effort.

2.1 Introduction

Many fish species spread their annual reproductive effort over a wide area or long period. This typically results in the production of multiple pulses (or ‘cohorts’) of age 0 recruits, which represent spawning events at multiple sites and/or times. This bet-hedging strategy increases the chance of maintaining an annual supply of recruits, despite spatially or temporally variable environmental conditions. Under this strategy, the contribution to adult abundance by cohorts is likely to be unequal, and their relative contributions may change from year to year. Also the overall level of recruitment is likely to vary from year to year. Understanding recruitment dynamics and the factors that determine recruitment success is important in fisheries management, particularly when managing short-lived species where adult abundance can be strongly recruitment-driven.

Tailor (*Pomatomus saltatrix)* is a relatively short-lived (<13 years) marine fish that is subject to intense fishing pressure in most regions where it occurs. Genetically distinct populations of this species occur globally in temperate and sub-tropical regions, including the east and west coasts of Australia (Nurthen *et al*. 1992, Goodbred and Graves 1996). The most well studied population occurs along the Atlantic coast of North America. This population is genetically homogenous and managed as a single breeding stock (Graves *et al.* 1992, Woods 2013). The structure of this population is complex due to the extensive migrations of adults and the presence of multiple spawning groups which comprise the breeding stock (Shepherd *et al.* 2006, Weunschel *et al.* 2012). These groups spawn during different periods (spring, summer and autumn), generating multiple pulses of age 0 recruits each year (Weunschel *et al.* 2012). The timing of recruitment is mostly bimodal, reflecting the arrival of the dominant spring- and summer-spawned cohorts and the consistently low abundance of autumn-spawned cohort. The spring- and summer-spawned cohorts make unequal contributions to the adult population, with spring-spawned fish typically comprising the majority of the adult population. During the early 1990s, a dramatic decline in adult abundance coincided with a decline recruitment by spring-spawned fish. Hence, it is hypothesised that the strength of recruitment by the spring-spawned cohort controls adult abundance in this population (Conover *et al.* 2003).

In Western Australia (WA) tailor primarily occur along the west coast between Exmouth and Augusta (Hutchins and Swainston 1986). The structure of this population has not been examined in detail, but is likely to comprise a single, genetically homogenous population, due to mixing via the dispersal of pelagic larvae and the extensive migrations of adults (Lenanton *et al.* 1996, Young *et al.* 1999). Limited differences in otolith carbonate signatures between tailor from different regions in WA are consistent with adult movement between regions (Edmonds *et al*. 1999). Spawning in WA follows a similar pattern to that which occurs in North America, occurring over an extended period and in multiple regions (Lenanton *et al.* 1996, Section 5 this report). In the Metropolitan Management Zone of the WCB, where recruitment has been monitored annually since the mid-1990s, two distinct size classes of age 0 juveniles are evident each year (Young *et al*. 1999). This suggests a bimodal pattern of recruitment that is very similar to that seen in North America. Given the strong similarities in spawning and recruitment patterns between WA and North America, it is likely that fluctuating annual contributions to the adult population by multiple spawning groups also occur in WA and partly explains the variability in adult abundance observed in this population.

The abundance and average size of tailor in WA declined substantially during the 1970s and 1980s (Cribb 1994). Various fishery management measures were introduced after 1990 to substantially reduce fishing mortality (Section 4, this report). Subsequently, annual juvenile recruitment and catch rates in the Metropolitan Zone have increased (Smith *et al.* 2012). However, it is unclear whether environmentally driven variations in recruitment or recent management action are responsible for the apparent recovery.

Objectives of this Section :

- Determine the timing of juvenile recruitment by tailor within each management zone in WA
- Infer the source of recruits in each management zone by comparing the timing of recruitment with the timing of spawning activity in each region of WA.
- Describe trends in annual recruitment strength in the Metropolitan Management Zone and identify environmental factors that are correlated with those trends.
- Discuss implications for stock structure and connectivity of tailor between management Zones in WA.

2.2 Methods

2.2.1 Seining netting

A full description of the methodology used for the sampling of small juveniles by seine netting can be found in Ayvazian *et al*. (2000) and Gaughan *et al*. (2006) and is summarised below.

Sampling was conducted during daylight. Fish were collected using a beach seine net (total length 60.6 m, height 2.0 m), composed of two wings of length 29.1 m (22 mm stretched mesh) and a bunt of length 2.4 m (8 mm mesh). The net was deployed from a small dinghy rowed in an arc from/to the beach. The area swept by the net was approximately 592 m² per haul. Both ends of the net were hauled back onto the beach, where the catch was sorted. At all sites, the area swept by the net was predominantly bare sand, sometimes interspersed with small patches of drifting or fixed vegetation (seagrass or algae).

At each site, 3 or 4 replicate hauls were undertaken each month at each site. Replicate hauls were completed within a single day and swept adjacent, but non-overlapping, areas of habitat at each site. Captured fish and macro-invertebrates were held in an aerated tub of seawater. Fish were identified to the lowest possible taxon (usually species), measured (total length, to the nearest mm) and then released alive. Very abundant species were subsampled before being counted and measured. Fish were released after all hauls were completed to avoid any recaptures. Temperature, salinity and weather conditions were recorded during sampling.

Seine netting catch and effort data was stored within the Department of Fisheries PISCES Database (a Microsoft Access database).

Seine net sampling was commenced by DoF in 1993. The 'optimised' annual sampling regime that has been employed since mid-2005 includes 6 sites, each sampled during multiple months from September to April, following the methods recommended by Gaughan *et al.* (2006). The number of months sampled each year varies between sites, ranging from 4 to 7 months per site. Sampling occurs at 3 sites within the Metropolitan Zone (Pinnaroo Point, Mangles Bay, Warnbro Sound – all located in Perth), 1 site within the South-west Zone (Koombana Bay – located in Bunbury), 1 site in the South Zone (Emu Point – located in Albany) and 1 site in the South-east Zone (Poison Creek – east of Esperance) (Fig. 2.1).

Catch rates of tailor were relatively high at only two sites, Pinnaroo Point (hereafter 'Perth') and Koombana Bay (hereafter 'Bunbury'). Catch rates were low at other sites.

Sampling at Perth and Bunbury occurred in two distinct periods. From January 1995 until June 2002 these sites were sampled monthly. No sampling occurred from June 2002 until September 2005. After September 2005, the majority of sampling at Bunbury occurred during September–December and the majority of sampling at Perth occurred during October–December. No sampling occurred during April–August at either site after 2005.

From July 1995 to December 1998, juvenile fish were sampled monthly at a single site (Carnarvon) in the Gascoyne Coast Bioregion (GCB), following the same sampling protocols used at others sites.

Monthly patterns of juvenile tailor recruitment at Perth, Bunbury and Carnarvon were examined. Analyses were restricted to individuals <150 mm TL, which were estimated to be <6 months of age (see Section 5). Any larger individuals in samples were excluded.

To provide an overview of monthly recruitment patterns at each site, length measurements were aggregated into 5 mm length intervals and length frequencies (using raw catch data) were then aggregated by month at each site. The birth month of each juvenile collected at each site between 1995 and 2002 was estimated, using a known age-length relationship (see Equation 1 in Section 5.3.1). The birth date for each individual was calculated by subtracting the age (in days) from the day of capture.

As the monthly sampling effort (number of net hauls) varied, the number of fish captured each month was standardised by effort and expressed as an average catch rate (number of fish per haul). The standardised frequencies of birth months were then summed from 1995 to 2002 to provide an overall distribution of birth months present at each site. The period 1995–2002 was examined because sampling was monthly over this period, as opposed to restricted sampling during September–December in subsequent years.

At Perth and Bunbury sites, the catch rate (R) in each month sampled was calculated as

$$R = C/E,$$

where C = total number of fish caught and E = total number of seine net hauls.

At each site, average 'seasonal' catch rates, $R_{jan\text{-}may}$ and $R_{sep\text{-}dec}$, were calculated from the average of the monthly catch rates within two specified periods (January–May and September–December) each year. Juvenile tailor captured within these periods were estimated to be predominantly spring/summer-spawned and winter-spawned fish, respectively.

2.2.2 *Volunteer angling*

From 1996 to 2011, the annual abundance of older juvenile tailor in the Perth area was measured by a recruitment index that was derived from the catch rates of volunteer anglers at Point Walter jetty in the lower Swan-Canning Estuary (Perth). Fishing was conducted from February to April, which encompasses the main period of recruitment to the recreational fishery each year. Catches of juvenile tailor also occurred in 1994 and 1995 but effort was not recorded and so catch rate could not be calculated in these years.

The timing of annual recruitment by tailor to the recreational fishery was defined by the occurrence of the smallest (100–150 mm TL) fish in recreational catches. In 1994/95 and 1995/96, the lengths of tailor captured by volunteer anglers in the Swan-Canning Estuary were reported monthly from November to June. No catches were reported from July to October in these years. Data from 1994/95 and 1995/96 suggested an extended period of recruitment to the fishery during the warmer months (November–April), with the highest proportion of small fish in catches during February and March (Fig. 2.2). From this data, February, March and April were selected as the optimal sampling months for ongoing monitoring of annual recruitment to the Swan-Canning fishery.

This timing of recruitment was subsequently supported by data reported by recreational anglers participating in a voluntary logbook program (WA Department of Fisheries Research Angler Program, unpubl. data). From 2004/05 to 2010/11, logbook anglers captured small fish in the Swan-Canning Estuary from December–April, with the highest proportion of small fish in catches during March (Fig. 2.2).

To determine the annual recruitment index, volunteer anglers participated in weekly, 2-hour fishing sessions from February to April each year. Between 10 and 20 volunteers typically fished per session. Sessions commenced at sunset and start times were adjusted over the 3-month fishing period in response to changes in day length. Volunteers used standardised fishing gear that comprised a light rod-and-line rigged with a small gang of three hooks (size 2) as terminal tackle (Ayvazian *et al.* 2002). The small gang was baited with whole whitebait (*Hyperlophus vittatus*).

The start and finishing times of each angler was recorded to the nearest minute so that total effort could be calculated precisely for each 2-hour fishing session. Environmental factors such as the percentage of cloud cover, rainfall (nil, light, moderate, heavy), tide (low falling, low rising, high falling, high rising), moon phase (full, ¾, ½, ¼, nil), sea condition (calm, slight, moderate, rough), wind strength (calm, light, moderate, strong) and direction were recorded during each session. All fish caught were measured (TL to the nearest mm) and released.

All length measurements were aggregated into 5 mm length intervals. Frequencies in each length interval were standardised by effort (number of angler hours) and expressed as a catch rate (number of fish per angler hour). Average monthly length frequencies were then calculated by averaging the catch rates of each length interval from individual sessions within a month.

Monthly length frequency distributions indicated the presence of two well-defined length groupings per year (Recruitment Group 1: <220mm TL, Group 2: 220–290 mm TL), which typically comprised one mode, and occasionally two modes, per month. A third group was also evident in some years (Group 3: >290mm TL). Lengths were used to estimate the approximate age-at-capture of fish in each Groups 1 and 2, based on the von Bertalanffy growth relationship (see Section 5).

Identification of modes within monthly length frequency distributions was undertaken using the Modal Progression Analysis procedures in the FiSat II software package (Gayanilo *et al.* 2005). Potential modes were identified in each monthly length frequency dataset with Bhattacharya's method. Modes were then further resolved with the NORMSEP function, which uses a maximum likelihood method to fit normal distributions to a user-defined number of modes within a sample.

Each month, all individuals were assigned to a Group on the basis of length. The average monthly catch rate of each Group was calculated as

$R_{in} = C_{in} / E_{in}$,

where ,

C_{in} = total catch of individuals within the Group in month *i* in year *n*,

E_{in} = sum of the total monthly effort (angler hours) in month *i* in year *n*.

Relative indices of annual abundance for Groups 1 and 2 were calculated from the average of standardised monthly catch rates. An annual index was not calculated for Group 3 due to limited data in most years. Catch rates were standardised (i.e. normalised) by dividing each monthly value (R_{in}) by the mean of monthly values from all years (mean R_i) , where

mean $R_i = \dfrac{\sum_1^n R_{in}}{n}$, for month *i* during *n* years.

Indices of annual abundance were compared against the following environmental variables :

- Fremantle sea level (FSL),
- Southern Oscillation Index (SOI),
- Indian Ocean Dipole (IOD) index,

- Northward and eastward components of wind speed at Lancelin station (Bureau of Meteorology data),
- Monthly mean sea surface temperature (SST) for 60 x 60 nm coastal ocean blocks adjacent to Carnarvon (Latitude 25˚ S, Longitude 112˚ E), Geraldton (28˚ S, 113˚ E and 28˚ S, 114˚ E), Perth (31˚ S, 115˚ E) and Cape Naturaliste (33˚ S, 114˚ E and 33˚ S 115˚ E) (Reynolds and Smith 1994),
- Water temperature (ºC), conductivity (µS/cm) and dissolved oxygen (mg/L) recorded at Armstrong Point in the lower Swan-Canning Estuary (Swan River Trust, unpubl. data),
- Chlorophyll concentration (mg/m3) (SeaWiFS satellite data, provided by CSIRO) in surface waters in 60 x 60 nm coastal ocean blocks adjacent to Carnarvon (Latitude 25˚ S, 112˚ E), Geraldton (28˚ S, 114˚ E) and Perth (31˚ S, 115˚ E) from 1997/8 to 2009/10.

The average of each variable was calculated for each season that occurred during the sampling period (summer, autumn) and for each season in the preceding year (summer*, autumn*, winter*, spring*). Hence, a total of six values were calculated for each environmental variable.

2.3 Results

2.3.1 Seine netting

Between 1995 and 1998, a total of 1,639 small juvenile tailor were captured at Carnarvon (Fig. 2.3). Captured fish were relatively large (>70 mm) compared to those taken at the other sites. All fish were captured between August and April. No fish were captured during May–July. Within months, the average catch rate of small tailor ranged from zero to 15.7 fish/haul, with the exception of October 1998 when an average of 501 fish/haul were taken. Between 1995 and 1998, the overall average catch rate at Carnarvon was 17.5 fish/haul.

Between 1995 and 2002, a total of 1,041 small juvenile tailor were captured at Perth (Fig. 2.4). Small fish were captured in all months except July. The majority of fish were 30–80 mm in length. Within months, the average catch rate of small juveniles ranged from zero to 14.7 fish/haul. Between 1995 and 2002, the overall average catch rate at Perth was 0.9 fish/haul.

Between 1995 and 2002, a total of 704 small juveniles (<150 mm TL) were captured at Bunbury (Fig. 2.5). At this site, small fish were captured in all months except April and October. The majority of fish were 40–150 mm in length. Within months, the average catch rate of small juveniles ranged from zero to 11.3 fish/haul, with the exception of August 1998 when an average of 42.7 fish/haul were taken. Between 1995 and 2002, the overall average catch rate at Bunbury was 1.3 fish/haul.

Although the monthly catch and catch rates of small juvenile tailor by seine netting were low, the pooled data from all sampling years indicated strongly seasonal recruitment patterns. The pooled distribution of estimated birth dates at each site indicated that recruitment patterns differed markedly between sites (Fig. 2.6). Fish captured at Carnarvon were exclusively spawned during winter, with the vast majority spawned during May–July. At Perth, fish were derived from two distinct spawning periods – a short winter period (peaking sharply in July) and an extended spring/summer period (from October to February). At Bunbury, fish were derived from spawning in all months, although the majority were spawned in autumn (April–June, with a sharp peak in May).

Since the majority of tailor captured by beach seining were estimated to have been 2–3 months old at capture, the average catch rates during September–December and January–May were used to approximately represent the catch rates of winter- and spring/summer-spawned fish at Bunbury and Perth. During September–December, the average monthly catch rate ($R_{sep\text{-}dec}$) at both sites was higher from 1995/96 to 2001/02 compared to 2005/06 to 2011/12 (no sampling in other years) (Figs. 2.7a, b). Thus, seine net catch rates suggested that winter-spawned juvenile tailor were less abundant in recent years at both Perth and Bunbury.

Annual trends in the abundance of spring/summer-spawned fish were less clear and more variable between sites. During January–May, the average monthly catch rate ($R_{jan\text{-}may}$) at Bunbury was relatively low in all years from 1995/96 to 2001/02, compared to higher catch rates observed in 2010/11 and 2011/12 (no sampling in other years) (Figs. 2.7c, d). In contrast, $R_{jan\text{-}may}$ at Perth was variable with no obvious trend over time.

Overall, annual trends in seasonal recruitment strength were uncertain from the catch rates of 0+ juveniles during seine netting at Perth and Bunbury, due to the combination of low average catch rates (typically <2 fish/haul), high variability in catch rates between months at each site, and missing data in multiple years.

2.3.2 Volunteer angling

From 1996 to 2011, the total number of tailor caught during February–April by volunteer anglers in the Swan-Canning Estuary ranged from 109 to 1,500 per year. Total effort ranged from 190 to 501 angler hours per year. The overall average catch rate of tailor during the 3-month sampling period each year ranged from 0.38 to 4.1 fish/angler hour. The length range of captured fish ranged from 112 to 416 mm TL, although the vast majority of fish were between 150 and 280 mm. Visual inspection of monthly length frequency distributions of captured tailor indicated the presence each year of up to three well-defined length groupings (Group 1: <220mm TL, Group 2: 220–290 mm TL, Group 3: >290mm TL), which each typically comprised one mode, and occasionally two modes, per month (Table 2.1, Fig. 2.8).

Lengths were used to estimate the approximate age-at-capture of fish in each Group, using the von Bertalanffy growth relationship (see Section 5). From 1996 to 2011, the mean lengths of modes within Group 1 ranged from 142 to 215 mm (mean value 189 mm), corresponding to estimated ages ranging from 6 to 11 months (mean value 9 months) (Table 2.1). The mean length of modes within Group 2 ranged from 224 to 293 mm (mean value 250 mm), with estimated ages of 11 to 17 months (mean value 13 months). Fish in Group 3 were estimated to be aged > 17 months.

Given the sampling period of February–April each year, fish in Group 1 were estimated to have been spawned in the previous winter (typically June/July) while those in Group 2 were spawned in the previous summer (typically January/February). The spawning period of Group 3 could not be estimated.

Modes were assumed to represent pulses of recruitment to the estuary. The number of modes suggested that each Group was represented in the estuary by 1 or 2 recruitment pulses per year. In some years, progression of modes was clearly evident between months, indicating that they were resident in the estuary during the summer sampling period and grew relatively quickly over this period (Fig. 2.8).

Tailor are known to recruit to the lower sections of the Swan-Canning Estuary at relatively small sizes (50–150 mm) (Loneragan *et al.* 1989, Hoeksema and Potter 2006). Therefore, the scarcity of fish <150 mm in catches during volunteer angling suggests tailor become vulnerable to capture by the fishing gear at approximately this length. A scarcity of fish >280 mm partly reflects the size at which many tailor emigrate from the estuary, but may also reflect fish becoming less vulnerable at this size to capture by the sampling gear. A comparison with the size of tailor caught by other anglers, who generally use larger hook sizes, indicates that larger fish (up to 420 mm) do occur in this estuary (Fig. 2.2).

The catch rate of each Group varied between months. Each year, the average monthly catch rate of Group 1 was typically lower in February than in March or April (Fig. 2.9a). This pattern suggested that Group 1 fish did not become fully recruited (either to the estuary or to the fishing gear) until March each year. The catch rate of Group 2 was typically lower in April than in February or March, suggesting that Group 2 fish typically became less vulnerable to capture (either due to gear avoidance or emigration from the estuary) in April (Fig. 2.9b).

Despite differences in the magnitude of catch rates between months, the annual trends followed by monthly catch rates were generally similar within each Group. The average monthly catch rates of fish in Group 1 declined from 1996 to 1999, remained relatively low until 2006 and then increased until 2011 (Fig. 2.9a). The average monthly catch rates of fish in Group 2 followed less pronounced trends, although each monthly catch rate displayed two distinct periods of activity – relatively low values during 1996–2004 and then higher values during 2005–2011 (Fig. 2.9b).

A relative index of annual abundance was calculated for each Group from the average of standardised monthly catch rates (Fig. 2.10). Due to lower sample sizes and evidence of incomplete selection of Group 1 during February and Group 2 during April, the annual index for Group 1 was calculated from the average of catch rates in March and April, while the Group 2 index was calculated from the average of catch rates in February and March.

Group 2 was present in the estuary in all years. A relatively low level of variability in the annual index of abundance (coefficient of variation = 0.57) indicated a relatively consistent level of annual recruitment to the estuary by this Group (Fig. 2.10). In contrast, fish from Group 1 displayed relatively high variability (c.v. = 1.10) in annual recruitment, including being absent or at negligible abundance in certain years (1999, 2001–2004, 2006). There was no correlation between the annual indices of abundance for Group 1 and Group 2 ($r^2 = 0.01$, $p = 0.76$, $n = 16$).

The annual abundance of Group 1 was strongly negatively correlated with northward wind stress during the previous winter ($r^2 = 0.56$, $p < 0.01$, $n = 12$) (Table 2.2). The annual abundance of Group 2 was negatively correlated with sea surface temperature near Geraldton during the previous autumn ($r^2 = 0.41$, $p < 0.01$, $n = 16$) and winter ($r^2 = 0.49$, $p < 0.01$, $n = 16$). (Table 2.2). The annual abundance of Group 2 also displayed a weak positive relationship with chlorophyll levels in the Perth area during the previous summer ($r^2 = 0.46$, $p = 0.02$, $n = 12$).

Neither Group 1 or Group 2 displayed a significant relationship with any large scale oceanographic index (FSL, SOI or IOD) or with any Swan River physico-chemical variable (temperature, conductivity or dissolved oxygen).

2.4 Discussion

Seasonal pulses of recruitment in each management zone

Recently spawned juvenile tailor (aged <3 months) occur in WA during all months of the year and can be found across the geographic range for tailor in WA – including the GCB and the WCB. This suggests that spawning occurs throughout the year and is spatially widespread.

However, at smaller scales (e.g. management Zones) recruitment is restricted to certain periods, the timing of which differs depending on location.

The juveniles observed within each Zone are typically comprised of one or two distinct age cohorts per year, suggesting discrete pulses of recruitment in each Zone. The back-calculated birth dates of juveniles differs between Zones, indicating that recruits to each Zone are sourced from different spawning events. The majority of recently spawned juveniles in the South-west Zone are estimated to be spawned in autumn/winter, while those in the GCB are spawned only in winter. In the Metropolitan Zone, recently spawned juveniles are estimated to be spawned in two period – either winter or spring/summer. Similarly, the back-calculated birth dates of older juveniles (aged 6–17 months) also indicate two annual cohorts, estimated to be spawned mainly during winter and summer, respectively. Hence tailor appear to recruit to the Metropolitan Zone in two distinct pulses of recruitment per year. Both age cohorts then remain in this Zone until they mature and recruit to the local fishery.

Sources of recruitment to each management zone

The source of recruitment to each Zone may be deduced by determining the timing and location of spawning events in WA and then inferring subsequent larval advection by ocean currents. Broadly, observations of gonad development (macroscopic stages and GSI values, see Section 5) suggest an extended spawning period in northern areas (the GCB and perhaps the Kalbarri Zone of the WCB) during the cooler months (autumn, winter, spring) and an extended spawning period in southern areas (Mid-west, Metropolitan and South-west Zones of the WCB) over the warmer months (spring, summer, autumn). Autumn is appears to be the main spawning period in the Metropolitan and South-west Zones, whereas autumn and spring are probably equally important in the Mid-west Zone. Limited observations of tailor larvae during January, April and May in the Metropolitan Zone and during March in the Kalbarri Zone are consistent with these patterns (Chisholm 2004, DoF unpubl. data).

Similar seasonal patterns of spawning were previously proposed by Lenanton *et al.* (1996), who suggested that regional variations in the timing of spawning could arise in response to variations in water temperature. Specifically, they hypothesised that spawning was associated with a preferred water temperature range of approximately 20–25 ºC (see Lenanton *et al.* 1996). More recent observations of gonad development suggest that spawning in each region is associated with local mean monthly water temperatures ranging from 18 to 24 ºC (Section 5.4.2). In summer, temperatures >24 ºC occur frequently in the GCB, and occasionally in the Mid-west Zone (Pearce *et al.* 1999). In winter, temperatures are typically below 18 ºC in southern areas. Globally, spawning by tailor appears to be restricted to 18–27 ºC (Sabates *et al.* 2012). Thus, temperature is likely to be an important factor determining the timing of spawning within each region in WA.

Unfortunately, the evidence for the regional spawning patterns described above is limited, particularly in the Kalbarri and South-west Zones. There are currently insufficient data to confirm the seasonality of spawning in the Kalbarri Zone. In the South-west Zone, a few observations of developed gonads in November, December and March suggest that spawning may occur in spring, summer and autumn (see Section 5). However, no samples have been collected in the South-west Zone during April–August or October and so the possibility of winter spawning cannot be assessed.

Despite these gaps in knowledge, it is still possible to determine the likely source of recruitment to some Zones. For example, recently spawned juveniles observed in the GCB were almost entirely spawned in autumn/winter, coinciding with autumn/winter spawning in the GCB. At this time of year, coastal currents in the region flow predominantly southwards making it unlikely that larvae from any autumn/winter spawning in the WCB would be transported to the GCB. Therefore, juvenile tailor recruiting to the GCB are probably derived from a local (i.e. GCB) spawning event.

In the Metropolitan Zone, spawning in northern areas (GCB and/or Kalbarri Zone) and the South-West Zone are probably the primary sources of juvenile recruits. The annual abundance of winter-spawned juveniles in the Swan-Canning Estuary was positively correlated with average southward wind speed in the WCB during the winter spawning period (i.e. 9 months prior to capture). Since tailor larvae occur near/at the surface, wind driven transport is likely to be an important factor determining the extent of their dispersal (Munch and Conover 2000). During winter, the Leeuwin Current results in a predominantly southward flow in shelf waters of the WCB, although surface currents over the inner shelf are primarily wind-driven and may flow either north or south (Cresswell *et al.* 1989, Feng *et al.* 2006). Thus, the southward advection of tailor larvae over the inner shelf in winter would mainly occur in response to southward winds. The absence of a significant relationship between the abundance of winter-spawned juveniles and Leeuwin Current strength is consistent with larval advection by wind-driven currents over the inner shelf, rather than advection by the Leeuwin Current over the outer shelf. Overall, the relationship between the abundance of winter-spawned juveniles in the Swan-Canning Estuary and southward winds strongly supports a northern origin for these recruits and their likely advection southwards within inner shelf waters.

Modelling of particle dispersal in shelf waters of the GCB and WCB suggests winter-spawned larvae could be transported from the GCB to the Metropolitan Zone in the WCB in <4 weeks (Feng *et al.* 2010). Given that the larval phase of tailor is approximately 25–28 days, followed by a pelagic post-larval phase of up to 45 days, the advection of winter-spawned larvae from the GCB (or Kalbarri Zone) to the Metropolitan Zone is feasible (Able *et al.* 2003).

The origin(s) of summer-spawned juveniles captured in the Metropolitan Zone is less clear. During spring and summer, spawning may occur in the Mid-west, Metropolitan and South-west Zones. From November to February, advection of larvae in inner shelf waters of the lower WCB is likely to be northwards due to the influence of the northward flowing Capes Current (Hanson *et al.* 2005). Therefore, many spring/summer-spawned juveniles could be derived from spawning activity to the south of the Metropolitan Zone. However, during periods of weak Capes Current, the supply of new recruits to the Metropolitan Zone could be maintained by larvae derived from spawning activity in the Mid-west and Metropolitan Zones. A consistent supply of larvae, irrespective of the direction of coastal currents, would explain the low variability in annual recruitment to the Metropolitan Zone by summer-spawned juveniles, compared to the high variability in annual recruitment by winter-spawned juveniles. The observed recruitment patterns for tailor are consistent with modelling of particle dispersal in shelf waters of the WCB, which suggests predominantly southward dispersal during winter and more symmetrical dispersal during summer (Feng *et al.* 2010). In the context of this information, there is no obvious explanation for the negative correlation between the abundance of summer-spawned juveniles in the Swan-Canning Estuary and average autumn/winter sea surface temperatures near Geraldton (Mid-west Zone) (A. Pearce, DoF, pers. comm.).

In the South-west Zone, birth dates of recently spawned juveniles included all months of the year, representing a wider range of birth dates than observed in other Zones. This suggests some level of recruitment throughout the year in the South-west Zone, derived from multiple spawning events located in multiple areas. Modelling of particle dispersal in shelf waters suggests that larval retention rates in Geographe Bay, where the South-west sampling site is located, are likely to be higher than in other areas of the WCB throughout the year (Feng *et al.* 2010). Therefore, once entrained by the Leeuwin Current, larvae derived from any spawning event in the WCB or GCB could potentially be transported to and retained within Geographe Bay.

Although recently spawned juveniles in the South-west Zone were probably derived from multiple spawning events, the majority of these recruits were spawned in late autumn which coincided with the spawning periods suggested for the Metropolitan Zone and GCB. During autumn there is likely to be extensive and rapid southwards transport of planktonic eggs and larvae from the Metropolitan Zone due to the annual peak in flow of the Leeuwin Current. Modelling suggests that larvae spawned in the Metropolitan Zone in autumn could reach Geographe Bay in less than three weeks (Feng *et al.* 2010). The shelf region off Perth experiences the lowest rate of particle retention during autumn (specifically April–June) as the Leeuwin Current accelerates along the coast (Feng *et al.* 2010). The efficient advection of larvae away from the Metropolitan Zone in this period provides an explanation for the scarcity of autumn-spawned juveniles observed in Perth.

It is likely that juvenile tailor recruiting to the South-west Zone are predominantly derived from spawning in the adjacent Metropolitan Zone in autumn. It is possible that some juveniles are also derived from spawning in northern areas, including the GCB, or from local spawning in the South-west Zone. A lack of spawning data from the South-west Zone currently prevents this possibility from being assessed.

Stock structure in WA

Within the WCB, a high level of connectivity is likely to exist between Zones due to northward and southward dispersal of larvae. Additionally, older juveniles and adults are known to undertake extensive (up to 632 km) northward and southward movements between Zones (Young *et al.* 1999). Hence, tailor within the WCB should be regarded as a single stock.

The degree of connectivity between the WCB and GCB is unclear. Winter-spawned juveniles recruiting to the Metropolitan and South-west Zones may originate from the GCB, although it is also possible that these recruits are derived from spawning in the Kalbarri Zone within the WCB. The movement of adults between the WCB and GCB has not been directly demonstrated (e.g. by tagging) but limited differences in otolith chemistry between the WCB (Metropolitan and Mid-west Zones) and GCB suggests some adult movement between these regions (Edmonds *et al.* 1999). Also, the annual abundance of winter-spawned juveniles in the Swan-Canning Estuary is positively correlated with the annual commercial fishery catch rate of tailor in Shark Bay (GCB) four years later, consistent with a net northward migration of fish from the WCB to the GCB (Section 3 this report). Hence, the available evidence suggests that tailor in the WCB and GCB comprise a single stock.

Despite evidence of single stock of the tailor in WA, the structure of the population is still likely to be relatively complex. Globally, tailor stocks are typically comprised of several sub-groups that are distinguished by different migratory behaviours. On the Atlantic coast of the North America there is a spectrum of size-related migratory behaviours, with individuals moving through this spectrum during their life. Young adults typically undertake lengthy alongshore migrations, whereas older adults tend to undertake cross-shelf migrations whilst remaining resident at a particular latitude (Shepherd *et al.* 2006). In this stock young adults spawn during spring in southern waters, then migrate northwards to spawn again during summer. Older fish that are resident in northern waters also spawn in summer. Young adults and juveniles from northern waters migrate southward to over-winter in southern waters, On the south-east coast of South Africa, tailor display a similar range of behaviours, including a northern group of migratory fish and a southern group exhibiting a combination of seasonally transient or resident behaviour (Hedger *et al.* 2010). On the east coast of Australia, mature tailor in NSW migrate northward to join with resident fish in southern Queensland to spawn during autumn/winter. After spawning, a proportion of individuals migrate to southwards while others remain in Queensland (Bade 1977, Garven 1986, Halliday 1990).

In WA, there is circumstantial evidence of a similar suite of migratory behaviours in the tailor population: mature tagged fish have typically moved either northward or offshore (Young *et al.* 1999); anecdotal reports from recreational fishers suggest that the average size of tailor is greater in northern Zones, suggesting northward migration of mature fish; recreational fishers catch large adults around offshore reefs throughout the year in the Metropolitan Zone, suggesting some degree of residency, and acoustically tagged tailor have also demonstrated residency in this Zone (DoF unpubl. data).

Annual trends in recruitment and implications for stock status

Annual recruitment by 0+ juvenile tailor to the Metropolitan Zone in the WCB has been monitored since the mid-1990s by two fishery-independent studies, i.e. i) seine netting and 2) volunteer angling. Seine netting catch rates of tailor are relatively low (<20 fish/month) and display high variability within years. The seine netting program also suffers from multiple years of missing data. For these reasons, seine netting does not provide a reliable index of recruitment for tailor. In contrast, volunteer angling catch rates of tailor are very high (up to 800 fish/month) and display relatively low variability within years. Thus, volunteer angling catch rates have been used to indicate trends in annual recruitment of tailor since this program commenced in 1996.

Despite the short-coming of the seine netting method, both ongoing monitoring programs have clearly demonstrated that recruitment to the Metropolitan Zone occurs as two discrete pulses, derived from winter spawning in northern areas and summer spawning in central/southern areas of the species range in WA. This bimodal recruitment pattern is very similar to that observed on the Atlantic coast of the USA, where spring and summer spawning results in two distinct annual length cohorts of 0+ juveniles (McBride and Conover 1991, Munch and Conover 2000). It is also similar to the recruitment pattern on the east coast of Australia, where summer and winter spawning results in two distinct annual length cohorts of 0+ juveniles (SPCC 1981). In the USA, spring-spawned individuals typically dominate fishery landings and their recruitment success appears to control adult abundance (Conover *et al.* 2003). In WA, the relative contributions to fishery landings by each recruitment cohort are yet to be quantified, although the available evidence suggests that annual recruitment variation of winter-spawned fish more strongly influences local fishery catch rates.

The significance of recruitment variations in the Metropolitan Zone to the entire stock is not yet clear. However, the positive relationship between the abundance of winter-spawned recruits in the Metropolitan Zone and subsequent fishery catch rates in the GCB suggests that this variation is also significant at the stock level.

Since 1996, annual recruitment to the Metropolitan Zone by winter-spawned fish has been highly variable. Overall, their recruitment trended downward during 1996–2004 and upward during 2004–2011. Recruitment by summer-spawned fish was much less variable but also displayed two distinct periods of activity: relatively low values during 1996–2004; and then higher values during 2005–2011. During 16 years of monitoring, the highest levels of overall annual recruitment occurred in 2008, 2010 and 2011. Recent improvements in recruitment are consistent with increasing commercial fishery catch rates in the Peel-Harvey estuary (see Section 3) and with anecdotal reports from recreational fishers of increasing catch rates. Assuming tailor recruitment in the Metropolitan Zone is representative of the stock, the evidence suggests an increasing recruitment and stock abundance of tailor in WA since 2004.

Future monitoring

The Point Walter volunteer angling program should be continued. This program appears to provide a robust fishery-independent index of recruitment in the Metropolitan Zone. The similarity of the trends in this index and in the commercial fishery catch rate in the Peel-Harvey estuary (which has functioned as a recruitment index in recent years due to the dominance of small fish in the catch; see Section 3), provides some validation of the index.

Further evidence is required to confirm that the Point Walter recruitment index is representative of overall recruitment trends in the stock. Until then, the value of this index as an indicator of stock status or predictor of recreational fishery status is presently unclear. Continuing the monitoring of recreational catch rates, potentially using voluntary logbooks or alternative survey methods, would provide an index of adult tailor abundance against which the Point Walter recruitment index could be compared. Monitoring the age composition of recreational landings would provide information about the recruitment strength of individual year classes which could then be compared against the recruitment index.

Futher research is required to more precisely determining the extent of adult movement between Bioregions/Zones and determining the timing of spawning within each area to identify the main sources of recruitment. In particular, information about the timing of spawning (if any) in the Kalbarri Zone would assist in differentiating between recruits from this Zone and those derived from the GCB. This question is of interest because highly variable annual recruitment derived from winter spawning in northern areas appears to be the main source of recruitment variation in the Metropolitan Zone (see below), which hosts the majority of recreational fishing effort.

Table 2.1. Results of modal analysis of length frequencies for each month and year of sampling tailor at Point Walter, 1995 to 2011, showing recruitment Groups.

		Recruitment Group 1				Recruitment Group 2				Recruitment Group 3	
		Mode 1		Mode 2		Mode 3		Mode 4		Mode 5	
Year	**Month**	**Mean**	***s.d.***	**Mean**	***s.d.***	**Mean**	***s.d.***	**Mean**	***s.d.***	**Mean**	***s.d.***
1995	Feb	185.3	*4.2*			262.5	*16.6*				
	Mar	195.9	*32.7*			278.3	*10.4*				
	Apr	188.9	*16.3*			239.2	*7.1*	288.0	*8.6*		
1996	Feb	142.2	*12.4*	205.1	*7.6*	243.7	*9.2*				
	Mar	159.3	*14.6*			228.3	*20.2*				
	Apr	176.3	*18.5*								
1997	Mar	167.8	*15.1*			227.5	*22.2*	280.1	*6.8*		
	Apr	185.6	*13.1*			242.2	*19.1*				
1998	Feb					224.1	*28.2*				
	Mar	174.4	*13.3*			249.3	*14.4*				
	Apr	201.9	*9.0*			250.7	*14.5*				
1999	Feb					237.7	*25.1*				
	Mar	194.1	*11.2*			247.2	*15.2*				
	Apr					239.7	*34.7*				
2000	Feb	183.9	*2.5*			235.4	*40.3*				
	Mar	198.2	*14.3*			265.1	*17.7*				
	Apr	194.0	*14.8*			248.5	*8.3*				
2001	Feb					268.5	*17.4*				
	Mar					256.8	*46.9*				
	Apr	194.7	*11.1*								
2002	Feb					232.1	*14.8*	286.0	*9.2*		
	Mar					249.5	*25.3*				
	Apr					250.9	*31.3*				
2003	Feb					247.7	*11.5*	280.1	*5.4*	310.0	*5.6*
	Mar					258.5	*15.6*				
	Apr	192.0	*19.4*			263.8	*13.2*				
2004	Feb					264.7	*18.9*				
	Mar					251.0	*21.8*				
	Apr	197.6	*16.1*			265.8	*20.9*				
2005	Feb					240.1	*13.5*	292.5	*2.9*		
	Mar	181.3	*8.8*			248.0	*15.7*				
	Apr	200.9	*8.5*			250.1	*20.8*				
2006	Feb					231.9	*17.8*			312.2	*15.9*
	Mar					275.9	*29.3*				
	Apr	192.5	*2.5*			238.7	*7.5*	272.0	*8.9*		
2007	Feb					236.7	*7.7*	270.4	*15.2*		
	Mar	196.0	*14.2*			241.8	*10.9*	282.3	*27.2*		
	Apr	197.6	*16.1*			265.8	*20.9*				
2008	Feb	197.9	*20.8*			247.8	*13.7*			303.9	*17.8*
	Mar	198.4	*18.4*			255.6	*19.9*				
	Apr	183.2	*4.9*	209.5	*20.9*						
2009	Feb	207.6	*21.3*			290.1	*12.9*				
	Mar	196.8	*14.6*			252.8	*4.7*	288.8	*12.5*		
	Apr	194.3	*14.9*			273.1	*23.1*				
2010	Feb	201.4	*18.4*			262.7	*21.2*				
	Mar	169.9	*9.8*	214.8	*28.3*						
	Apr	177.3	*11.0*	206.1	*25.9*						
2011	Feb	205.9	*19.7*			252.1	*23.4*				
	Mar	190.7	*14.1*			227.5	*28.2*	271.5	*2.6*		
	Apr	208.5	*16.2*			266.4	*20.4*				

Table 2.2. R-squared values from pairwise comparisons of the indices of annual abundance for Group 1 and Group 2 against seasonal environmental variables (bold – significant at p<0.01; underline – negative relationship; * – previous year).

					Swan River			Lancelin Wind		SST				Chlorophyll		
	Season	**SOI**	**IOD**	**FSL**	**Temp**	**Oxy**	**Sal**	**North**	**East**	**Carn**	**Ger**	**Perth**	**Cape**	**Carn**	**Ger**	**Perth**
Group 1	Autumn	<0.01	0.06	<0.01	0.03	0.05	<0.01	0.13	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	0.17	0.24
	Summer	0.11	<0.01	0.09	0.23	0.27	0.02	<0.01	0.05	0.15	0.38	0.26	0.26	0.04	0.34	<u>0.34</u>
	Spring*	0.04	<0.01	0.11	0.10	<0.01	0.07	0.04	0.06	0.17	0.25	0.21	0.19	0.11	0.17	0.03
	Winter*	0.17	<0.01	0.05	0.11	0.01	0.03	<u>***0.56***</u>	<0.01	0.02	0.16	0.09	0.08	0.04	<0.01	0.04
	Autumn*	0.04	0.09	0.06	0.20	0.09	0.33	0.03	0.09	0.03	0.15	0.09	0.07	0.04	<0.01	0.02
	Summer*	0.01	0.15	<0.01	0.02	0.37	0.14	<0.01	0.08	0.01	0.02	0.03	<0.01	0.17	0.01	0.32
Group 2	Autumn	<0.01	<0.01	0.01	0.16	0.01	0.08	0.02	<0.01	0.04	0.05	0.06	0.07	0.01	0.04	0.01
	Summer	0.06	0.01	0.16	0.16	0.10	0.32	0.09	0.02	0.04	0.06	0.10	<0.01	<0.01	0.22	0.07
	Spring*	<0.01	0.04	0.11	0.01	<0.01	0.04	0.10	<0.01	0.17	<0.01	<0.01	<0.01	<0.01	0.05	<0.01
	Winter*	<0.01	0.03	0.15	0.11	0.05	0.10	0.05	0.06	0.32	<u>***0.49***</u>	<u>0.29</u>	0.21	0.07	0.05	<0.01
	Autumn*	0.06	0.13	0.14	0.19	0.02	0.05	<0.01	0.15	0.29	<u>***0.41***</u>	0.24	0.18	0.01	<0.01	0.02
	Summer*	<0.01	0.13	<0.01	0.07	<0.01	0.03	0.07	0.06	0.05	<0.01	<0.01	<0.01	<0.01	0.18	0.46

Temp – water temperature; Oxy – dissolved oxygen; Sal – conductivity; North – northward component of wind stress; East – eastward component of wind stress; Carn – Carnarvon; Ger – Geraldton; Cape – Cape Naturaliste.

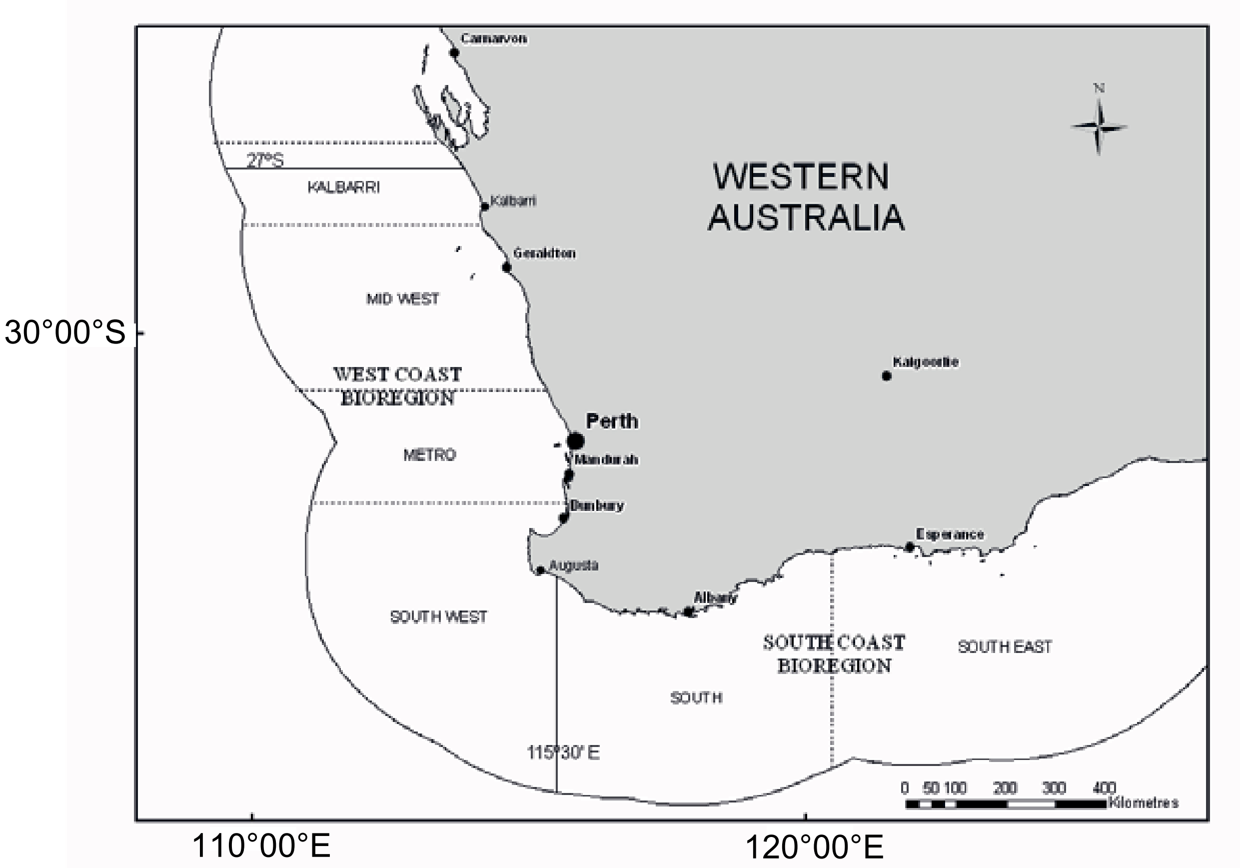


Figure 2.1. Locations of main monitoring sites and boundaries of Bioregions (West Coast, South Coast) and Zones within Bioregions (Kalbarri, Mid-west, Metropolitan, South-west, South, South-east) of south-western Australia.

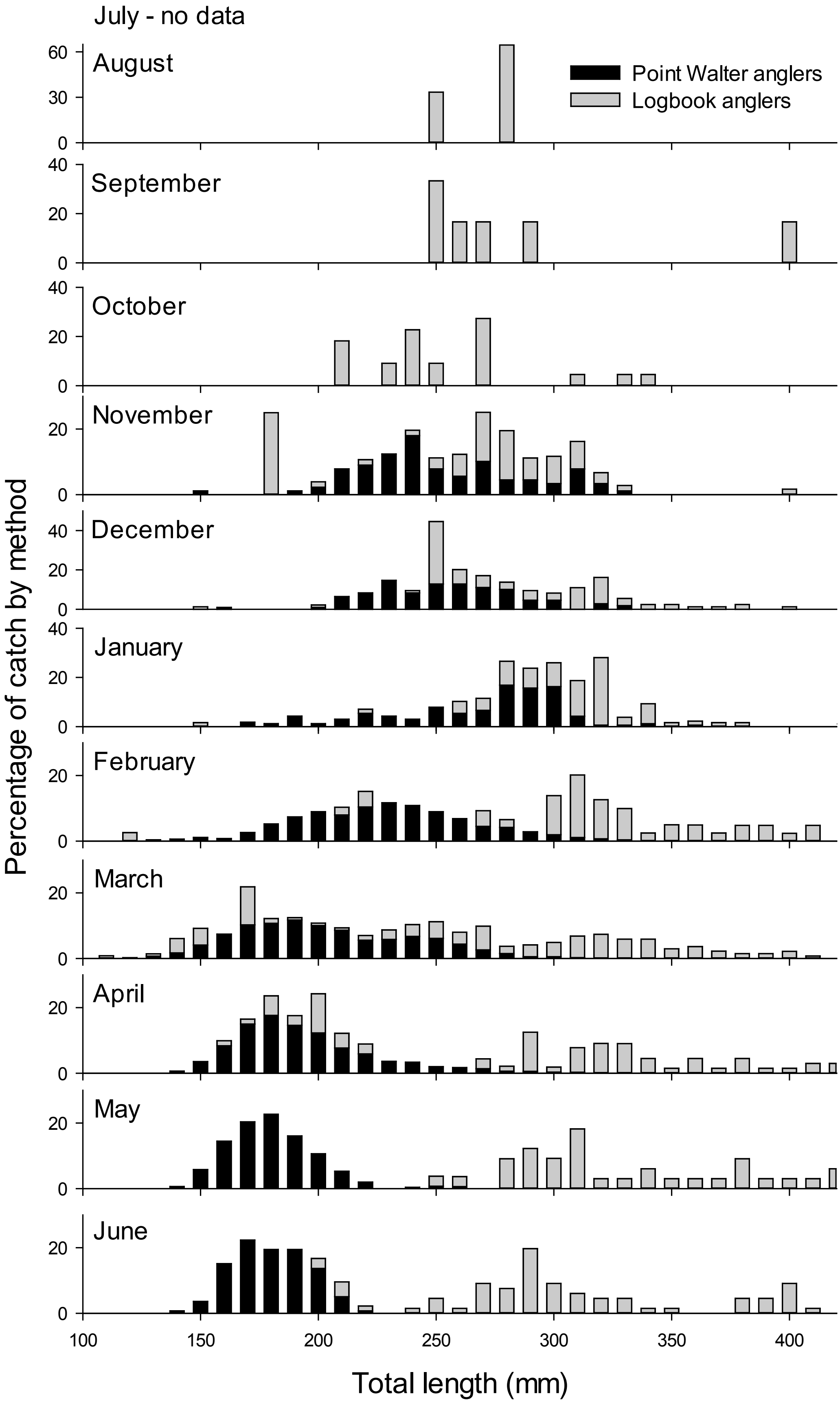


Figure 2.2. Pooled monthly length frequencies of all tailor caught in the Swan-Canning Estuary by volunteer anglers at Point Walter from 1994 to 2011 and by volunteer logbook anglers at all locations in the estuary from 2004 to 2011.

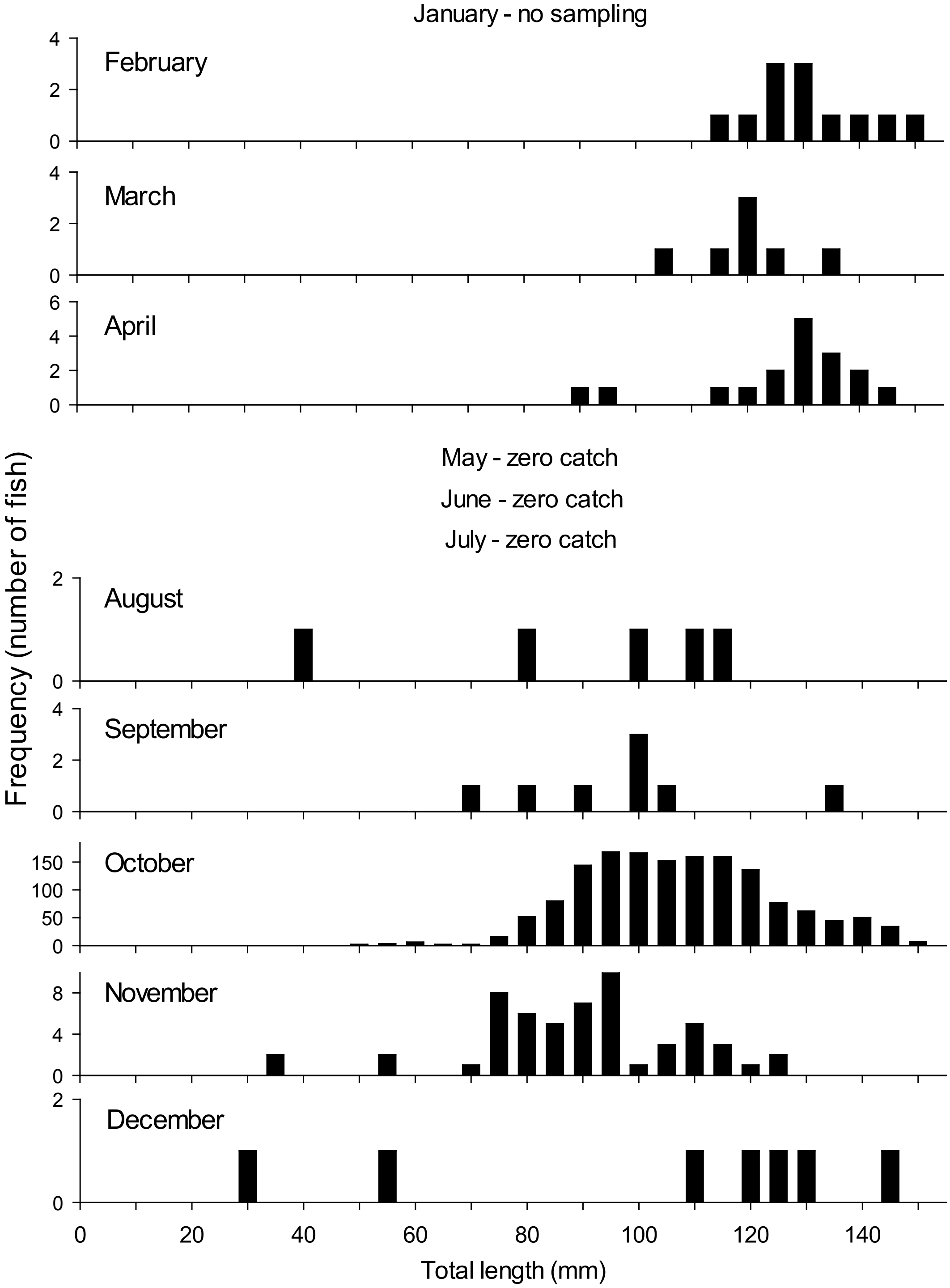


Figure 2.3. Pooled monthly length frequencies of all small (<150 mm TL) tailor caught at Carnarvon from 1995 to 1998 (fish >150 mm not shown).

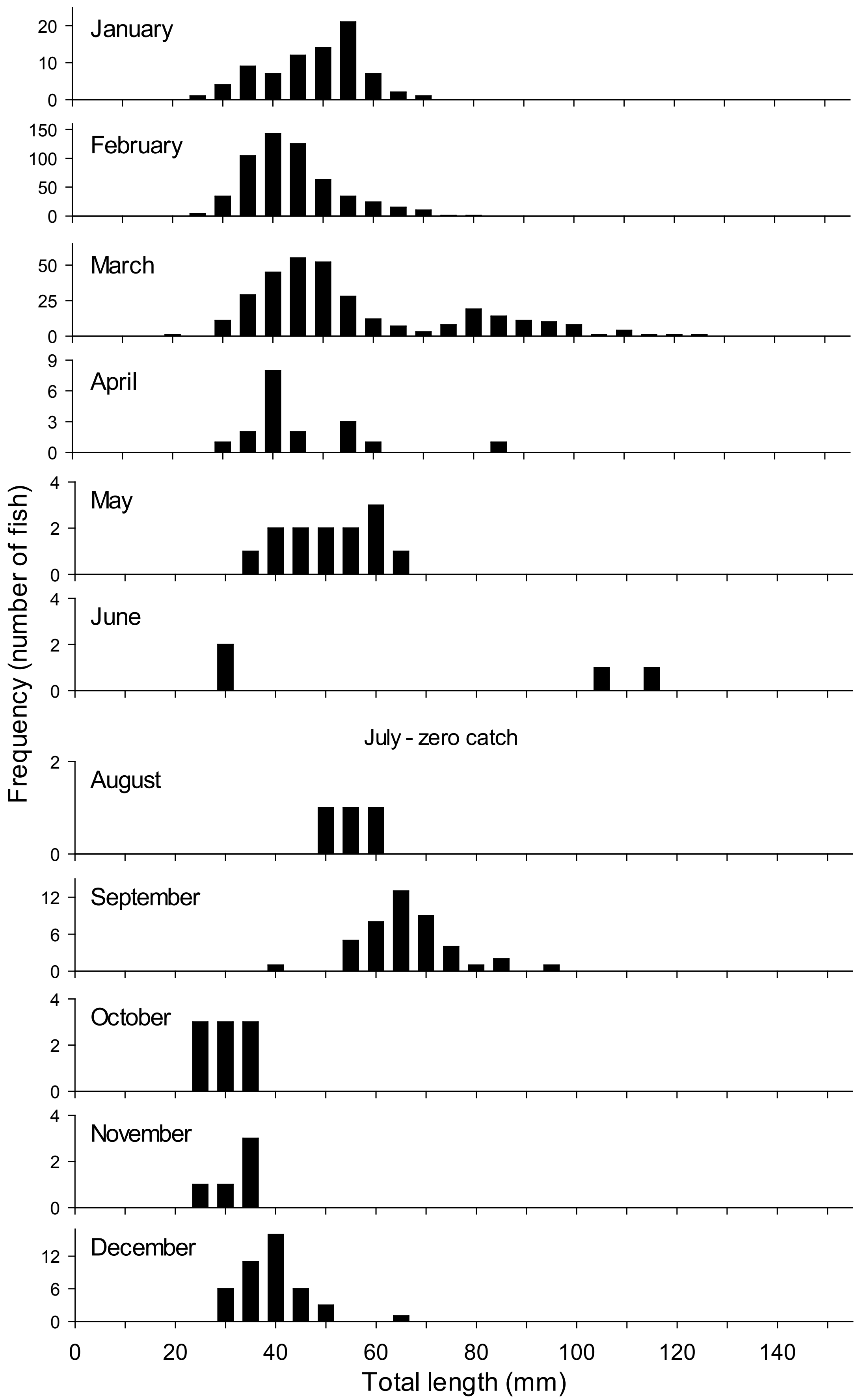


Figure 2.4. Pooled monthly length frequencies of all small (<150 mm TL) tailor caught at Perth from 1995 to 2011 (fish >150 mm not shown).

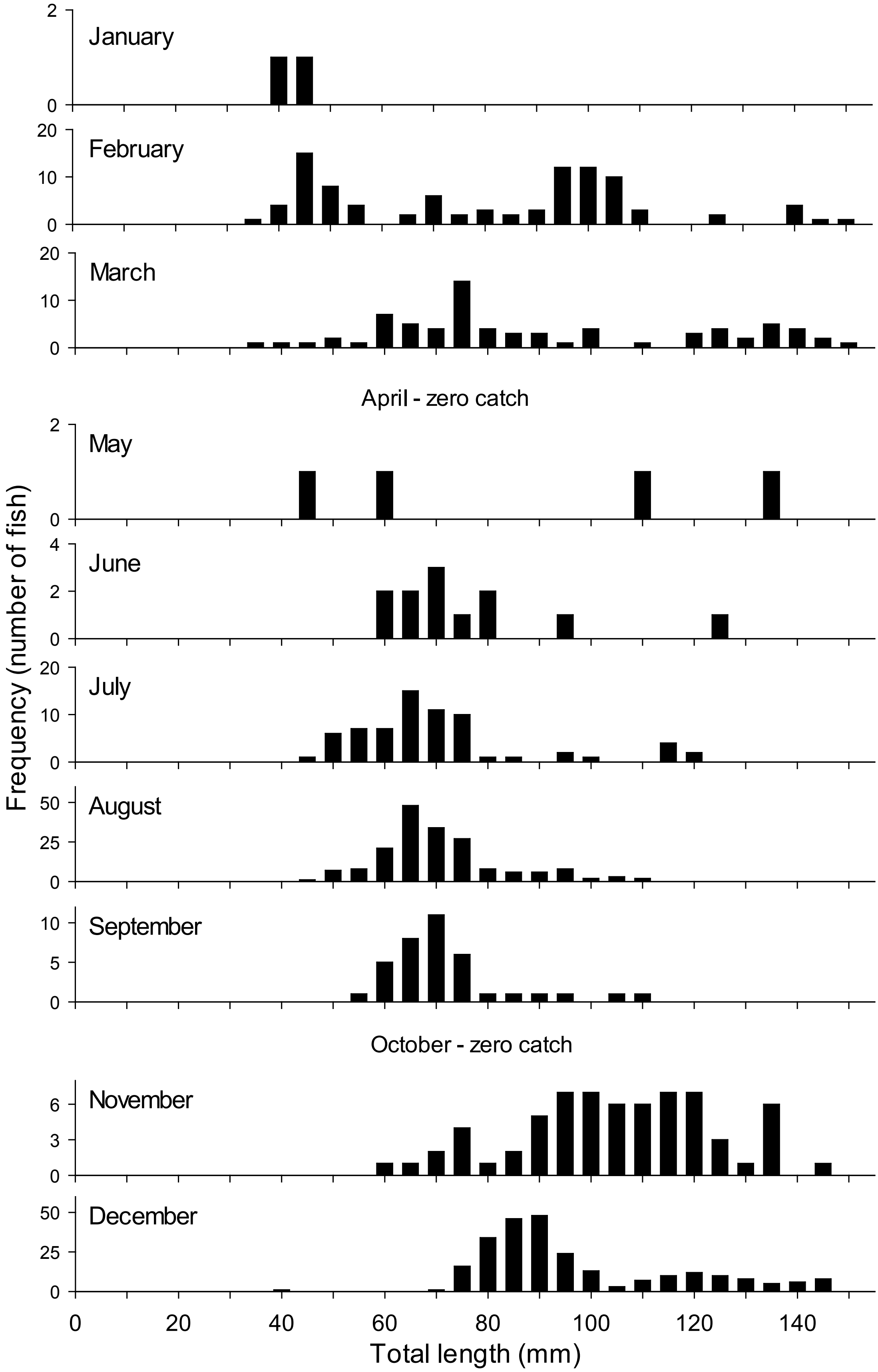


Figure 2.5. Pooled monthly length frequencies of all small (<150 mm TL) tailor caught at Bunbury from 1995 to 2011 (fish >150 mm not shown).

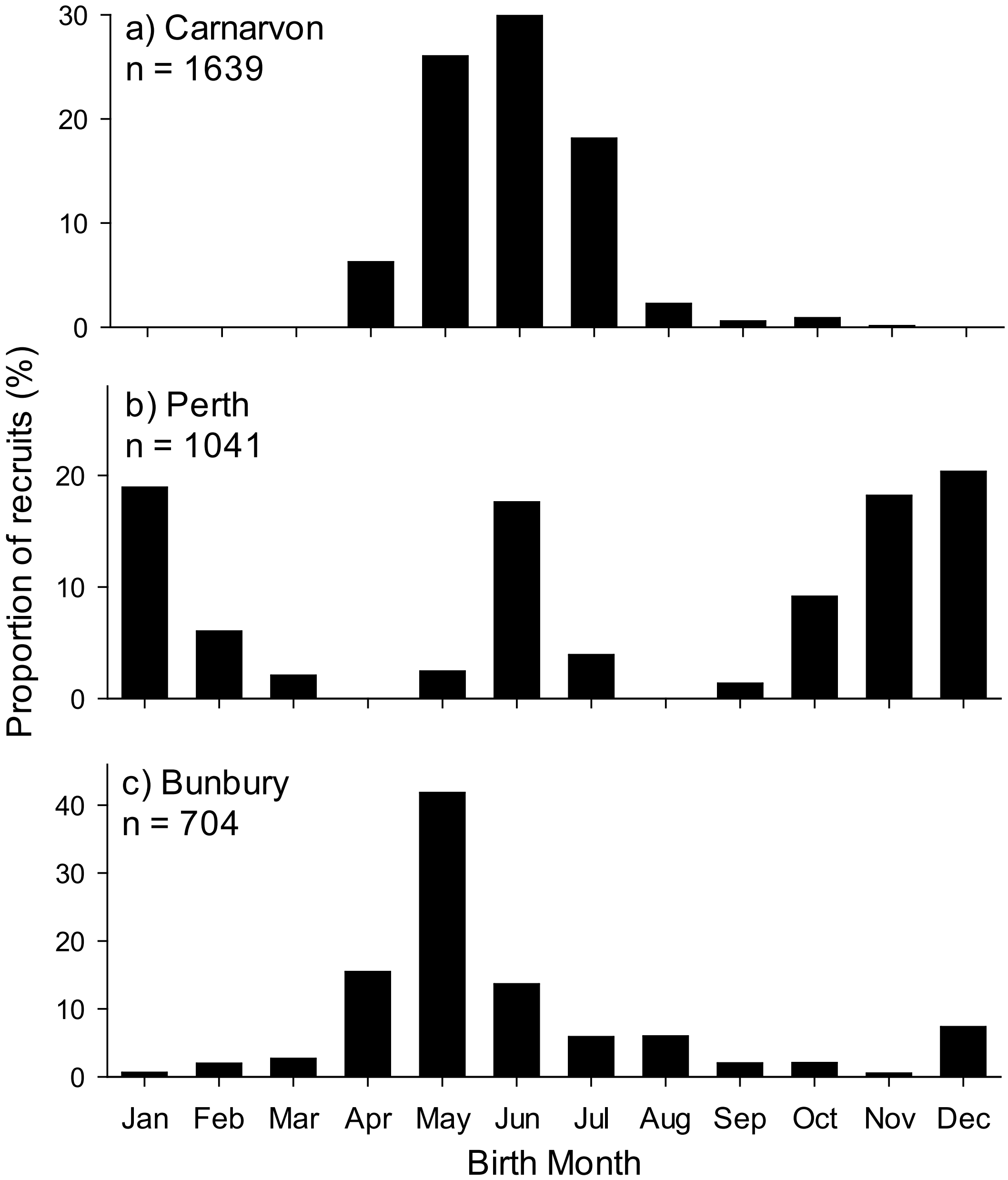


Figure 2.6. Monthly distribution of back-calculated birth months for small tailor (<150 mm TL) sampled monthly at **a)** Carnarvon from July 1995 to December 1998, **b)** Perth from January 1995 to June 2002, and **c)** Bunbury from January 1995 to June 2002.

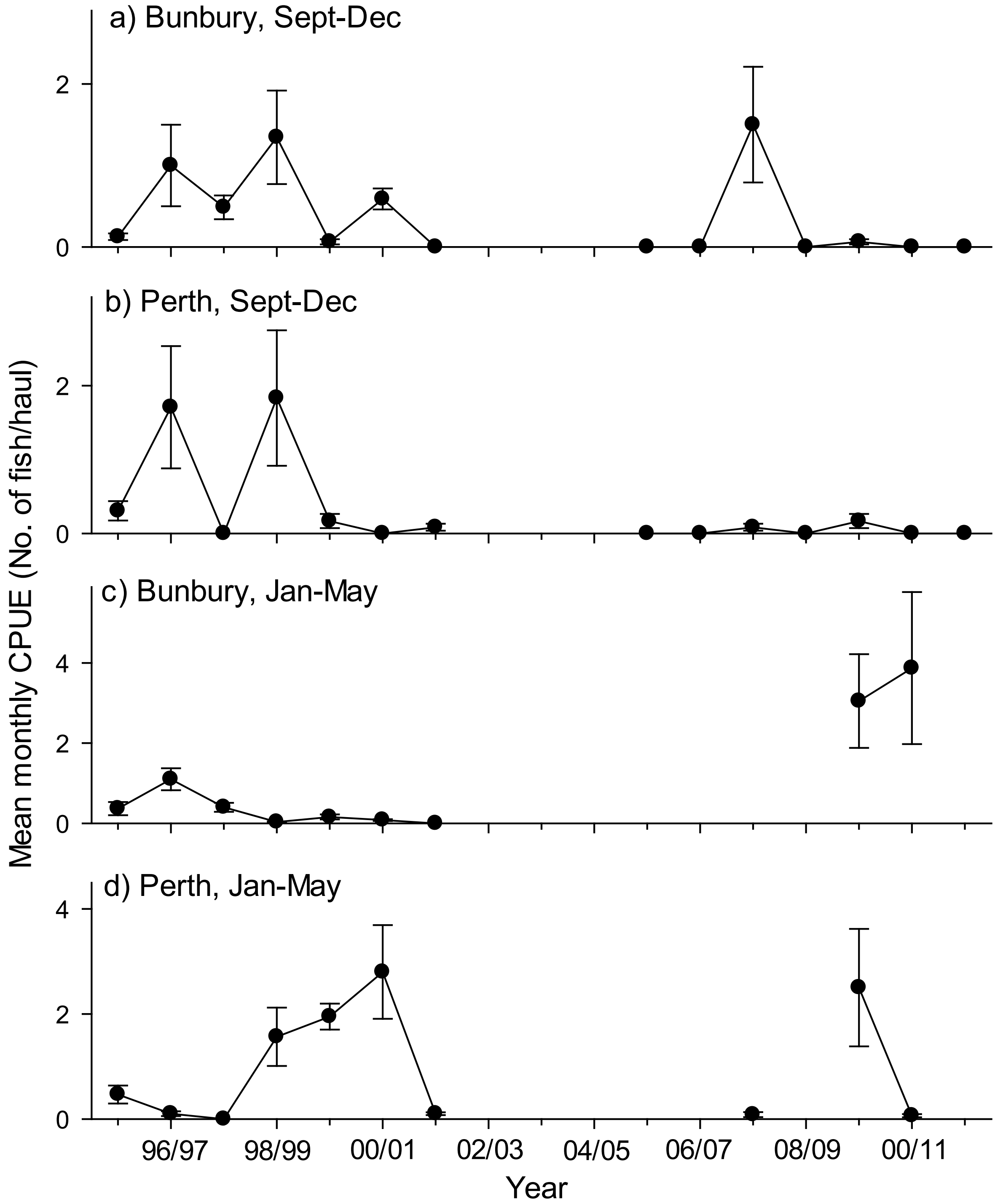


Figure 2.7. Mean monthly catch rate (+ s.e.) of small (<150 mm TL) tailor sampled annually by seine netting at **a)** Bunbury from September to December, **b)** Perth from September to December, **c)** Bunbury from January to May, and **d)** Perth from January to May. No sample collected during some years at each site.

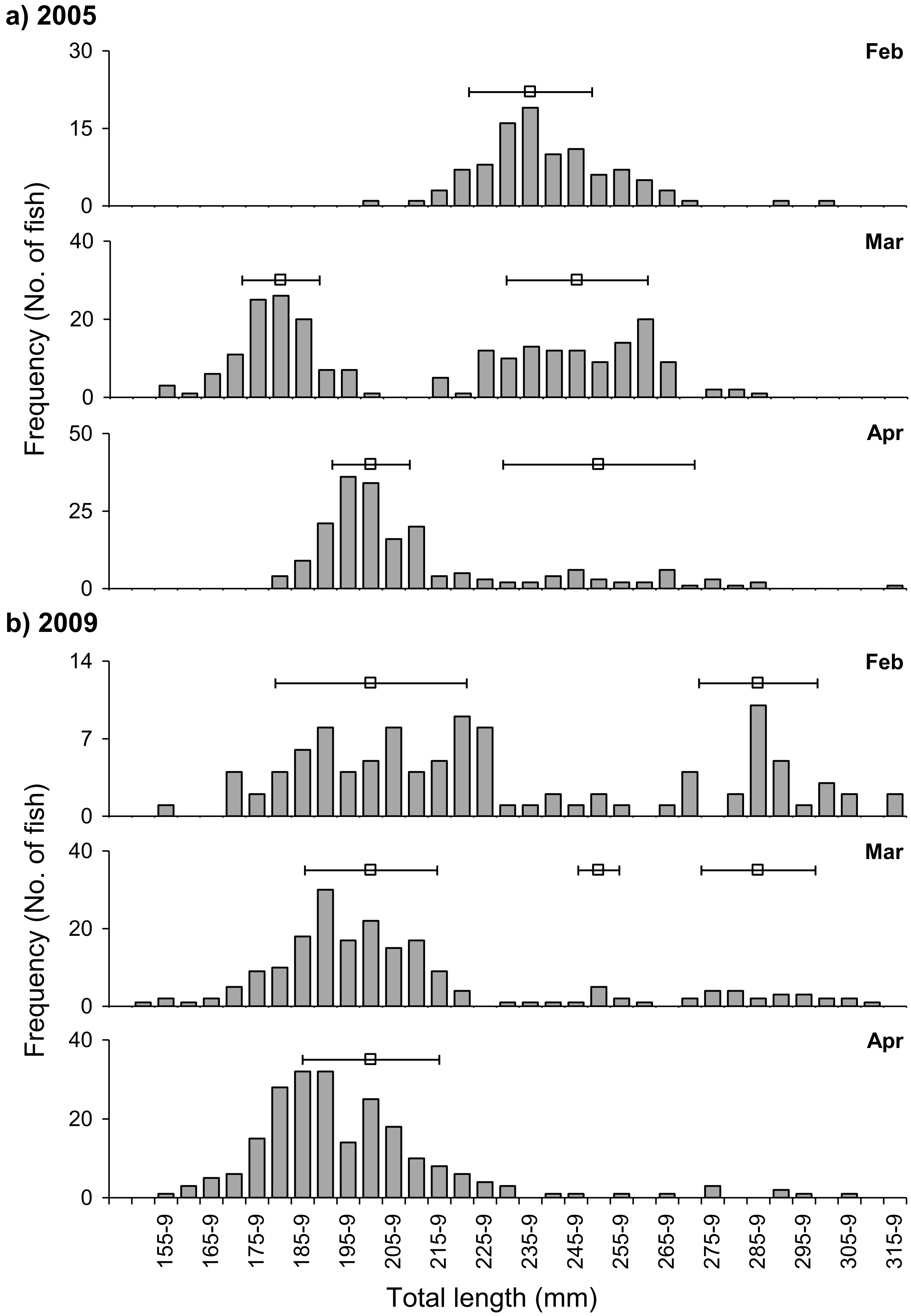


Figure 2.8. Monthly length frequencies of tailor captured by volunteer anglers at Point Walter during two example years **a)** 2005 and **b)** 2009. Estimated mean length (+ s.d.) of modes are shown by the box and whisker plots.

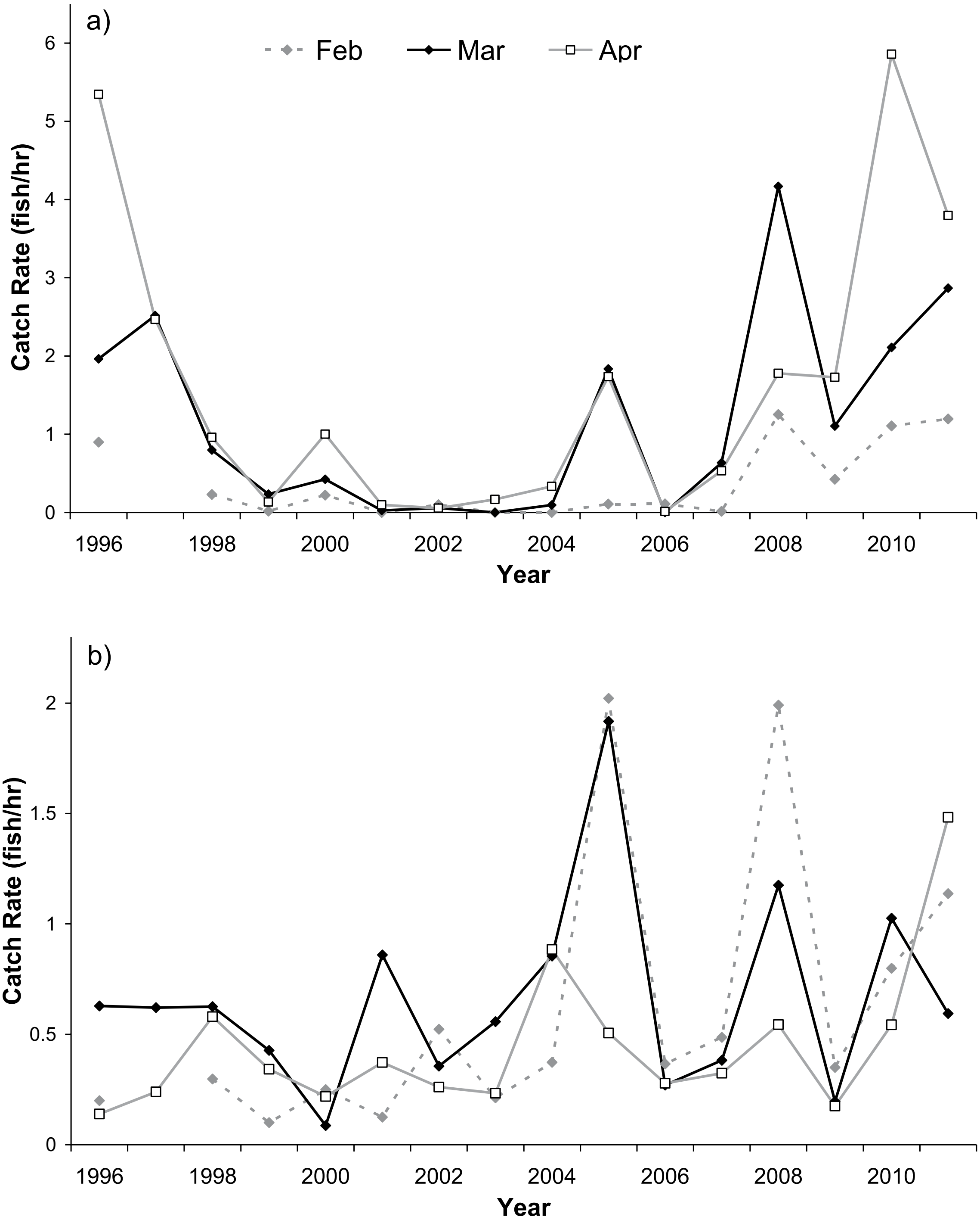


Figure 2.9. Average monthly catch rates of **a)** Group 1 and **b)** Group 2 tailor in February, March and April at Point Walter in the Swan-Canning Estuary, 1996 to 2011.

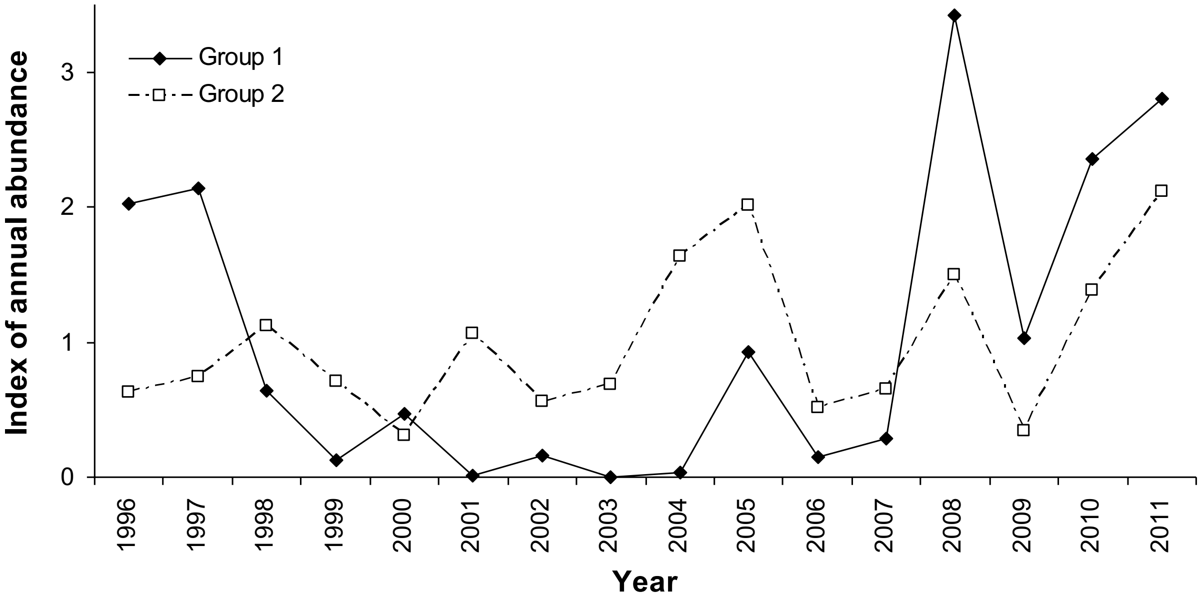


Figure 2.10. Relative indices of annual abundance of tailor in Group 1 and Group 2, at Point Walter in the Swan-Canning Estuary, 1996 to 2011.

3.0 Tailor commercial fishery catch and effort trends

Summary

- Western Australian commercial landings of tailor were 20–30 t annually during recent years (2005–2010). The majority (80–95%) of the commercial catch is taken in the Gascoyne Coast Bioregion (GCB) by the Shark Bay Beach Seine and Mesh Net Managed Fishery.
- Commercial catch rate trends suggested a rapid increase in the availability of tailor in the Shark Bay area from 1990 to 1995, peaking at historically high levels from 1995 to 2000. Catch rates suggested a sharp decline in availability in 2001, followed by a gradual decline between 2002 and 2010. Catch rates suggest current availability is still high compared to historical levels (i.e. pre-1990).
- Given a net northward movement of adults in the stock, a high proportion of the spawning stock is assumed to be located in northern areas, i.e. the GCB and the northern WCB. Hence, the catch rate of tailor in the the GCB is interpreted as an index of spawning stock abundance. GCB catch rates suggest that the current spawning stock level is relatively high.
- The reasons for the rapid increase in GCB catch rate during the early 1990s are unclear. Catch rates in the GCB are negatively correlated with the Southern Oscillation Index, suggesting that environmental factors may determine fish availability. Additionally, the rapid increase in catch rate in Shark Bay also occurred shortly after the implementation of a recreational bag limit for tailor in 1990, which may have reduced the total recreational catch and increased the availability of tailor in the GCB.
- In the WCB, commercial landings of tailor are mainly taken in the Peel-Harvey estuary and are predominantly older juveniles. As such, the Peel-Harvey catch rate functions as a recruitment index. It displays a similar trend to the fishery-independent recruitment index in the adjacent Swan-Canning estuary, which suggests that recruitment patterns of tailor occur at a moderately large spatial scale (i.e. Management Zone). Recruitment of tailor in the Metropolitan Zone of the WCB has been increasing since 2004. Annual recruitment indices during 2008–2011 were the highest since monitoring commenced in 1996.

3.1 Introduction

Tailor (*Pomatomus saltatrix*) is widely distributed in coastal waters and estuaries of Western Australia (WA), from Onslow southwards to Esperance (Hutchins and Swainston 1986). Tailor are highly regarded by some as a table fish with a rich, strong flavour and high oil content. However, the flesh is soft and fish must be bled and chilled immediately with minimal handling for the best results. These characteristics limit the marketability of tailor because it is difficult for commercial fishers to get fish to the market in prime condition. Due to poor quality, large commercial catches of tailor were historically sold as rock lobster bait.

The commercial capture of tailor has a relatively long history in WA, with catch records available from 1912 and records of commercial effort available from the 1950s onwards. As a result, there is a relatively large amount of historical commercial catch and effort information relating to this species from the West Coast Bioregion (WCB) and Gascoyne Coast Bioregion (GCB), some of which may provide insights into the historical abundance of this species.

Objectives of this section;

- Describe the historical and current annual commercial catch and effort relating to tailor by Bioregion and by fishery.

- Evaluate the potential of annual commercial catch rates to provide an index of tailor abundance.
- Compare trends in commercial catch rates with trends in environmental variables and recruitment indices.

3.2 Methods

Commercial catch and effort data for tailor used in this report was obtained from compulsory monthly returns submitted by commercial fishers.

The total annual catches of tailor in WA from 1964/65 to 1974/75 were obtained from the Australian Bureau of Statistics (ABS). Total effort levels and spatial data about total catches were not available from these years. Commercial catch and effort statistics (CAES) from July 1975 onwards were obtained from the WA Department of Fisheries (DoF). CAES records included details of catch and effort for individual fishers summarised by month, by commercial fishing block and by fishing method. From July 1989, CAES records included more specific information on fishing method (e.g. beach seine versus haul net). Additional CAES reporting blocks were also introduced at this time. For example, specific block numbers were assigned to the eastern and western gulfs of Shark Bay and to individual estuaries.

Spatial information about historical catch and effort levels were available for selected locations. Annual catches of tailor and annual effort levels in the West Coast Estuarine Managed Fishery (WCEF) were available from 1912 onwards and in the Shark Bay Beach Seine and Mesh Net Managed Fishery (SBBSMNF) from 1956 onwards (Lenanton 1984, DoF unpubl. data).

3.2.1 Calculation of catch-per-unit-effort (CPUE)

The annual CPUE of tailor was calculated for the two main commercial fisheries in WA that have historically and recently captured tailor – the SBBSMNF and the WCEF (Peel-Harvey estuary only).

These netting fisheries target multiple species using multiple methods. The monthly aggregation of data reported by fishers make it impossible to determine precisely the effort spent specifically targeting tailor by a particular method. Peel-Harvey fishers typically catch tailor as a byproduct while targeting other species and SBBSMNF fishers typically target tailor as a second choice when higher value species are not available. Therefore, trends in the catch rate of tailor may partly reflect the trends in the targeting of other species.

The SBBSMNF operates in the eastern and western gulfs of Shark Bay and uses a combination of beach seines and haul nets to target four key species/groups: whiting *(Sillago schomburgkii* and *S. analis)*, sea mullet *(Mugil cephalus)*, tailor and yellowfin bream *(Acanthopagrus latus)*. The total annual effort (including targeting of all species by all vessels) and the total annual catch of individual species has previously been used to calculate the annual catch rate of key species by the SBBSMNF (Department of Fisheries 2012).

To reduce the likelihood of including fishing effort that was not associated with the capture of tailor, only catch and effort by fishers who regularly landed tailor was used here to re-calculate the annual catch rate by the SBBSMNF. Vessels with a minimum total tailor catch of 5 t in the SBBSMNF (12 vessels) over the period 1996–2010 were included. The format of monthly CAES returns used by fishers changed in 1989, which changed the allocation of effort to particular methods and may have changed the total effort levels reporting by individual fishers. To avoid possible effects on CPUE from this change, the average CPUE by selected vessels was calculated from 1990 onwards.

Each year, an average annual catch rate and average seasonal catch rates were calculated. ‘Seasons’ were defined as January–April, May–August and September–December, reflecting typical activity patterns within this fishery. The average catch rate (CPUE) was calculated for haul and seine netting effort combined. CPUE = C/E **,** where;

C = sum of tailor catches (live weight) by haul and seine nets by all vessels with landings above the threshold limit.

E = sum of fishing days by haul nets and seine nets by vessels with landings of tailor above the threshold limit.

In recent years, the Peel-Harvey fishery has primarily targeted blue swimmer crabs (*Portunus pelagicus*), sea mullet, yellow-eye mullet (*Aldrichetta forsteri*) and yellow-finned whiting (*Sillago schomburgkii*). Tailor is taken as a byproduct when targeting other finfish by netting methods. Tailor are not captured when targeting crabs, which are taken by pots.

Three key factors are likely to have affected the recent catch rates of tailor by the Peel Harvey fishery. Firstly, the Dawesville Cut was opened in 1994, which increased connectivity with the ocean and altered the estuarine environment. The species composition of commercial landings changed in response to this event. Secondly, between 1996 and 2003, this fishery transferred from the use of gill nets to pots to target crabs. Since crabs are the main species targeted by this fishery, this constituted a massive redistribution of annual effort by the fishery. Gill and haul netting effort declined dramatically over this period. Thirdly, in 2003 the legal minimum length (LML) of tailor was increased from 250 to 300 mm TL. This may have limited the catch level of tailor in the Peel-Harvey fishery. To avoid the influence of all of these factors, the annual catch rate of tailor by the Peel-Harvey fishery was calculated from 2003 onwards.

In the Peel-Harvey fishery, the average annual catch rate (CPUE) of tailor was calculated for haul netting and gill netting separately. CPUE = C/E **,** where;

C = sum of tailor catches (live weight) by specified method by all vessels.

E = sum of fishing days by specified method by all vessels.

In the SBBSMNF and the Peel-Harvey estuary fishery, a fishing day (referred to as a ‘block day’ (Bday) in CAES) was defined as a day spent using a particular method within a particular reporting block. If two methods are used within a block, then two Bdays are recorded.

3.2.2 Correlation of CPUE with environmental variables and recruitment indices

Catch rates of tailor by the SBBSMNF were correlated against the annual Southern Oscillation Index (SOI) and annual mean Fremantle sea level (FSL). FSL and SOI were lagged from 0 to -5 years (i.e. 0–5 years prior to catch rate).

The FSL is used as an indicator of Leeuwin Current strength due to a strong linear relationship between Leeuwin Current volume transport and sea level deviation at Fremantle in WA (Feng *et al.* 2003). Over the longer term, FSL and SOI are typically highly correlated.

Catch rates of tailor by the SBBSMNF were correlated against annual recruitment in the WCB. Recruitment indices which measure the strength of annual recruitment by winter-spawned (Group 1) and summer-spawned (Group 1) juvenile cohorts in the Metropolitan Zone were examined separately (see Section 2 for details). Each recruitment index was lagged from 0 to -5 years (i.e. 0–5 years prior to catch rate).

3.3 Results

Commercial catches of tailor in WA are mainly taken using gill nets, haul nets and beach seines with a small proportion also landed by line fishing.

Total annual commercial landings of tailor in WA were highest during the 1960s and early 1970s, including historical peaks in 1965/66 (89 t), 1964/65 (87 t) and 1975/76 (69 t) (Fig. 3.1). From 1976/77 to 1986/87 annual landings were lower on average than in the previous decade but were stable at 30–40 t per year. An abrupt decline in the annual catch occurred in 1986/87, reaching an historical minimum of 14 t. Landings increased and then stabilised at approximately 55 t per year during the period 1994/95–2000/01. Landings declined and then stabilised at approximately 25 t per year during the period 2004/05–2009/10.

During the 1960s and 1970s, the WCB contributed a relatively high proportion (25–30%) of the total state catch of tailor (Fig. 3.1). Effort reductions, particularly in the Swan-Canning and Peel-Harvey estuaries, contributed to the decline in the catch share of tailor from the WCB. Commercial landings of tailor in WA now predominantly occur in the GCB. Since 2001 the vast majority (85%) of total commercial landings of tailor in WA were taken in the GCB, with the WCB and South Coast Bioregion (SCB) contributing 13% and 1%, respectively.

Gascoyne Coast Bioregion

In the GCB, tailor is predominantly landed by the SBBSMNF.

The highest annual landings of tailor by the SBBSMNF occurred during the period 1960–1967, ranging from 34 t in 1960 to an historical peak of 54 t in 1964 (Fig. 3.2a). From 1968 to 2010, landings averaged 25 t per year and ranged from 14 t (in 1986) to 39 t (in 1992 and 2000). After 2000, the annual catch steadily declined to reach 16 t in 2010.

Total fishing effort by the SBBSMNF (including targeting of all species by all vessels) was highest during the 1960s, including an historic peak of 3,339 days in 1965 (Fig. 3.2a). In the period 1968–1992, total effort averaged 1,834 boat days per year (range: 1,280 to 2,507). In the period 1993–2010, total effort averaged 1,134 days per year (range: 979 to 1,262).

The annual catch of tailor by the SBBSMNF followed a similar trend to total annual effort in the fishery until the late 1980s when the two diverged, resulting in a rapid increase in the average annual catch rate of the fishery, from an historic minimum of 8kg/day in 1986 to an historic maximum of 36 kg/day in 1995 (Fig. 3.2b). After 2000, the annual catch rate of tailor by the SBBSMNF declined, reaching 15 kg/day in 2010.

Catches and catch rates of tailor by the SBBSMNF are strongly seasonal. Since 1990, the highest monthly catches typically occurred during January–April, with 40–60% of the annual catch taken in this period. Lowest catches typically occurred during September–December. Catch rates typically peaked during January–April and reached a minimum during May–August (Fig 3.3). Despite persistent differences between seasons in the magnitude of the average catch rate, catch rates in all seasons followed broadly similar annual trends (Fig. 3.3).

Over the period 1990–2010, a significant ($p<0.01$) negative correlation existed between the average commercial catch rate of tailor by the SBBSMNF during January–April and the SOI two years earlier (Table 3.1). The average catch rate during May–August was negatively correlated with both SOI and FSL three years earlier. SOI and FSL were strongly correlated over this period ($r^2 = 0.814$).

Inspection of annual SOI values since 1972 indicated an exceptionally long period of below-average SOI values from 1990 to 1995 (Fig. 3.4). This period coincided with rapidly increasing catch rates, and was followed by historically high catch rates from 1995 to 2000.

Over the period 1996–2010, a significant ($p<0.01$) positive correlation existed between the average annual commercial catch rate of tailor by the SBBSMNF ($r^2 = 0.741$), as well as the average commercial catch rate during January–April ($r^2 = 0.582$), and the strength of annual recruitment to the WCB by winter-spawned recruits four years earlier (Table 3.2).

West Coast Bioregion

In the WCB, the majority of commercial landings of tailor are taken by the West Coast Estuarine Managed Fishery (which includes the Peel-Harvey, Swan-Canning and Leschenault estuaries), with minor quantites also taken by the Geographe Bay net fisheries and Mid-west Zone net fisheries. Tailor is a byproduct of netting operations by these fisheries, which generally target sea mullet, yellow-eye mullet and yellow-finned whiting. The West Coast Estuarine Managed Fishery has primarily targeted blue swimmer crabs in recent years.

In the WCB, the total annual commercial catch of tailor reached an historical peak of 42 t in 1975/76 (Fig. 3.1). Annual landings were much lower in subsequent years. During the period 1976/77 to 2000/01, landings averaged 9 t per year (range: 2 – 17 t). During the period 2001/02 to 2009/10, landings averaged 4 t per year (range: 1 – 8 t). The abrupt decline in annual landings after 2000/01 was mainly due to the closure of the commercial fishery within the Leschenault Estuary and reduced commercial catch and effort levels within the Swan-Canning Estuary (Fig. 3.5). Catch and effort levels in the Swan-Canning fishery have declined substantially since the 1970s as a consequence of a 'voluntary fisheries adjustment scheme' (i.e. licence buy-backs). The number of active fishing vessels declined from about 25 in the mid-1970s to one in 2010.

From 1975 to 2010, approximately 50% of the total commercial catch of tailor in the WCB was caught in the Peel-Harvey Estuary. Since 2000/01, nearly 80% of WCB landings were caught in the Peel-Harvey Estuary.

In the Peel-Harvey fishery, tailor are usually taken as a byproduct while targeting other species using haul and gill nets. Since 2003, about 65% of tailor landings in the Peel-Harvey fishery were taken by haul nets, with the remainder by gill nets. Between 2003 and 2011, the annual catches and catch rates of tailor by haul nets and gill nets followed a similar trend (Fig. 3.6, 3.7). Catches and catch rates were relatively low from 2003 to 2007 and then followed an increasing trend from 2007 to 2011.

3.4 Discussion

The annual catch rate of tailor by the SBBSMNF and the Peel-Harvey fishery can be influenced by many factors, in addition to fish availability. Therefore, trends in catch rates must be interpreted with caution.

Since tailor is often taken as a byproduct while targeting other species, or targeted only when higher value species are not available, the catch rate of tailor in each fishery may be partly determined by the level of targeting of other species. In 1989, a change in the format of monthly CAES returns used by fishers may have altered reported effort levels and so caused an apparent change in catch rates in the years immediately following this event. In the SBBSMNF, local factory processing limitations may constrain landings of tailor, particularly during periods of high catch.

Notwithstanding the above issues, trends in the annual catch rate of tailor by the SBBSMNF suggested a very rapid increase in the availability of tailor in the Shark Bay area from 1990 to 1995, peaking at historically high levels from 1995 to 2000. Catch rates suggested a sharp decline in availability in 2001, followed by a gradual decline between 2002 and 2010. Catch rates suggest current availability is still high compared to historical levels.

The reason(s) for the rapid increase in catch rate during the early 1990s is unclear. This event coincided with an exceptionally long period of below-average SOI values, which may have generated favourable conditions for reproduction by the tailor stock and/or for the aggregation of tailor in the Shark Bay area. However, the potential mechanisms for this are unknown.

The rapid increase in catch rate in Shark Bay also occurred shortly after the implementation of a recreational bag limit of 20 tailor in 1990 and a reduction of the bag limit to 8 tailor in 1994. These actions may have reduced the total WCB recreational catch and increased the availability of tailor in the GCB, assuming the migration of adult tailor from the WCB to the GCB.

There is a large amount of circumstantial evidence to suggest movement of adults from the WCB to the GCB. Firstly, tagging studies have demonstrated a net northward movement along the west coast. Migrations from the southern to northern part of the WCB (Bunbury to Kalbarri, up to 635 km) have been observed, indicating that adults are capable of migrating from all parts of the WCB to the GCB (Young *et al.* 1999). Secondly, the average length of tailor captured by recreational and commercial fishers tends to be larger in the GCB than the WCB, consistent with northward movement by adults (Sections 4 and 5). Thirdy, the correlation between recruitment in the WCB by winter-spawned juveniles (which likely originated in the GCB (see Section 2)) and the catch rate of adult tailor in Shark Bay four years later is also consistent with northward movement from the WCB to the GCB.

Given a net northward movement of adults in the stock, a high proportion of the spawning stock is likely to be located in northern areas, i.e. the GCB and the Kalbarri Zone of the WCB. If so, the catch rates of fish in these northern areas can interpreted as an indices of spawning stock abundance.

High spawning stock levels in the GCB in the 1990s may have contributed to the high levels of recruitment to the Perth area by winter-spawned juveniles in 1996 and 1997 (see Fig. 2.9 in Section 2). These winter-spawned juveniles were probably spawned in the GCB or northern zone of the WCB (see Section 2).

In the Peel-Harvey commercial fishery, annual catch rates of tailor are available only since 2003. From 2003 to 2007, catch rates were relatively low but then increased rapidly between 2007 and 2011. This pattern was very similar to the trend in recruitment of 0+ juvenile tailor observed in fishery-independent sampling in the adjacent Swan-Canning Estuary (Section 2). Given that the majority of tailor captured in WCB estuaries are juveniles, the catch rate in the Peel-Harvey fishery is likely to reflect trends in juvenile recruitment. The agreement between trends in the Swan-Canning and Peel-Harvey estuaries suggests that recruitment patterns of tailor occur at a moderately broad spatial scale (i.e. across a Management Zone). The agreement between these two independent juvenile catch rates also provides some validation for their use as recruitment indices. The Swan-Canning and Peel-Harvey indices both indicate that tailor recruitment in the Metropolitan Zone has been increasing since 2004. Annual recruitment indices during 2008–2011 were the highest since monitoring commenced in 1996.

Table 3.1. Correlation coefficients (r-values) from comparisons of Shark Bay commercial fishery catch rates of tailor with lagged environmental variables, from 1990 to 2010 (bold – significant at P<0.01; italics – negative correlation). FSL – Fremantle sea level; SOI – Southern Oscillation Index.

	lag (years)	CPUE Jan-Apr	CPUE May-Aug	CPUE Sep-Dec	Annual CPUE
FSL	0	0.318	*0.188*	*0.094*	0.118
	-1	*0.073*	*0.197*	0.159	*0.017*
	-2	*0.493*	*0.527*	*0.281*	*0.448*
	-3	*0.065*	***0.562***	*0.284*	*0.350*
	-4	0.224	*0.180*	*0.153*	*0.124*
	-5	0.047	*0.293*	*0.313*	*0.313*
SOI	0	0.123	*0.212*	*0.189*	*0.020*
	-1	*0.097*	*0.181*	0.035	*0.081*
	-2	***0.648***	*0.506*	*0.226*	*0.535*
	-3	*0.162*	***0.576***	*0.415*	*0.437*
	-4	0.231	*0.000*	*0.035*	*0.033*
	-5	0.000	*0.119*	*0.317*	*0.289*

Table 3.2. Correlation coefficients (r-values) from comparisons of Shark Bay commercial fishery catch rates of tailor with lagged annual recruitment indices in the WCB (Metropolitan Zone), from 1996 to 2010 (bold – significant at P<0.01; italics – negative correlation). Group 1 – winter-spawned cohort; Group 2 – summer-spawned cohort.

	lag (years)	CPUE Jan-Apr	CPUE May-Aug	CPUE Sep-Dec	Annual CPUE
Recruitment Group 1	0	*0.549*	0.094	0.098	*0.179*
	-1	*0.100*	0.098	*0.169*	*0.014*
	-2	*0.293*	0.000	0.153	0.000
	-3	*0.196*	*0.071*	0.100	0.178
	-4	**0.763**	0.668	0.329	**0.861**
	-5	0.450	0.391	0.505	0.613
Recruitment Group 2	0	*0.2921*	0.0624	0.2867	*0.0583*
	-1	*0.1446*	*0.2893*	*0.4251*	*0.3308*
	-2	0.0735	*0.1005*	*0.0200*	*0.0574*
	-3	*0.3471*	0.2454	0.2728	0.1095
	-4	0.2332	0.0000	*0.0265*	0.1034
	-5	*0.2000*	*0.3030*	*0.0938*	*0.3132*

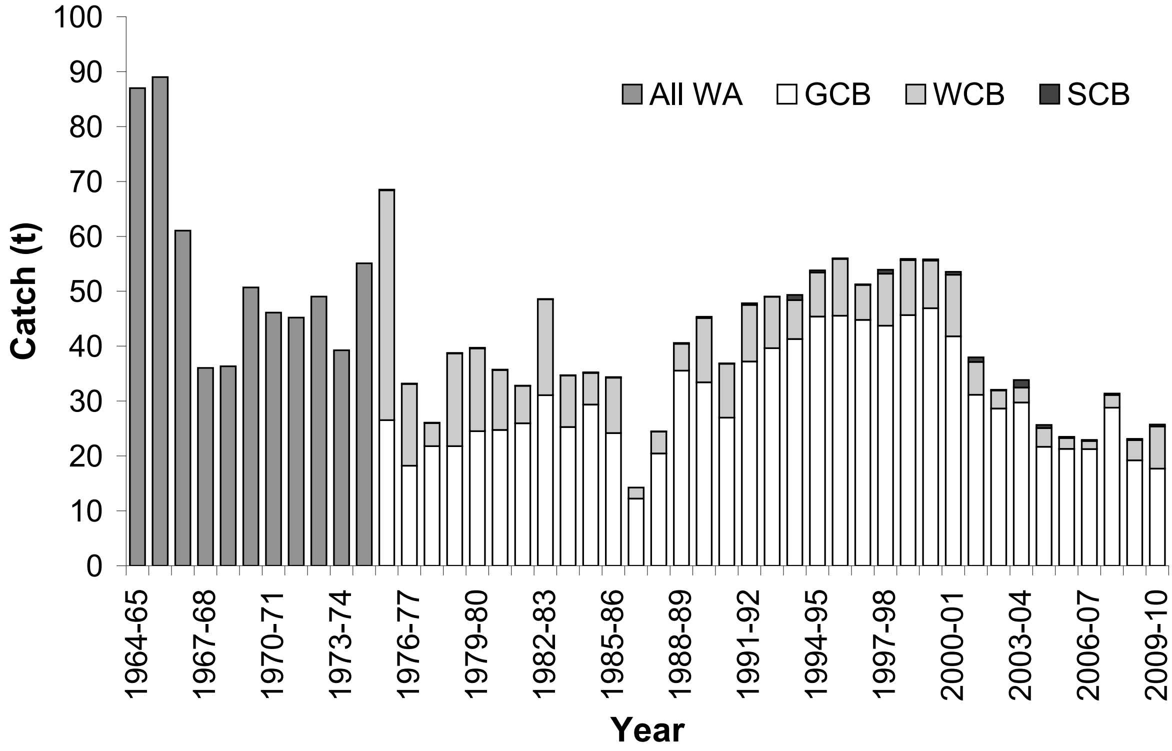
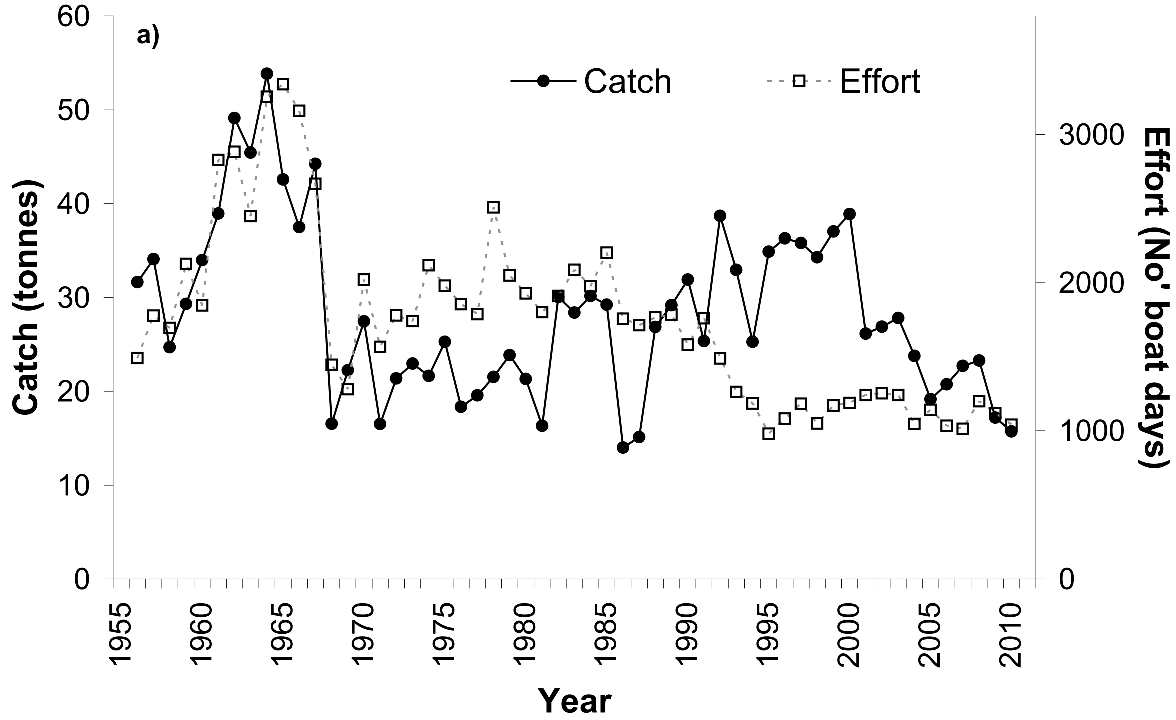


Figure 3.1. Total annual commercial landings of tailor in Western Australia by Bioregion.



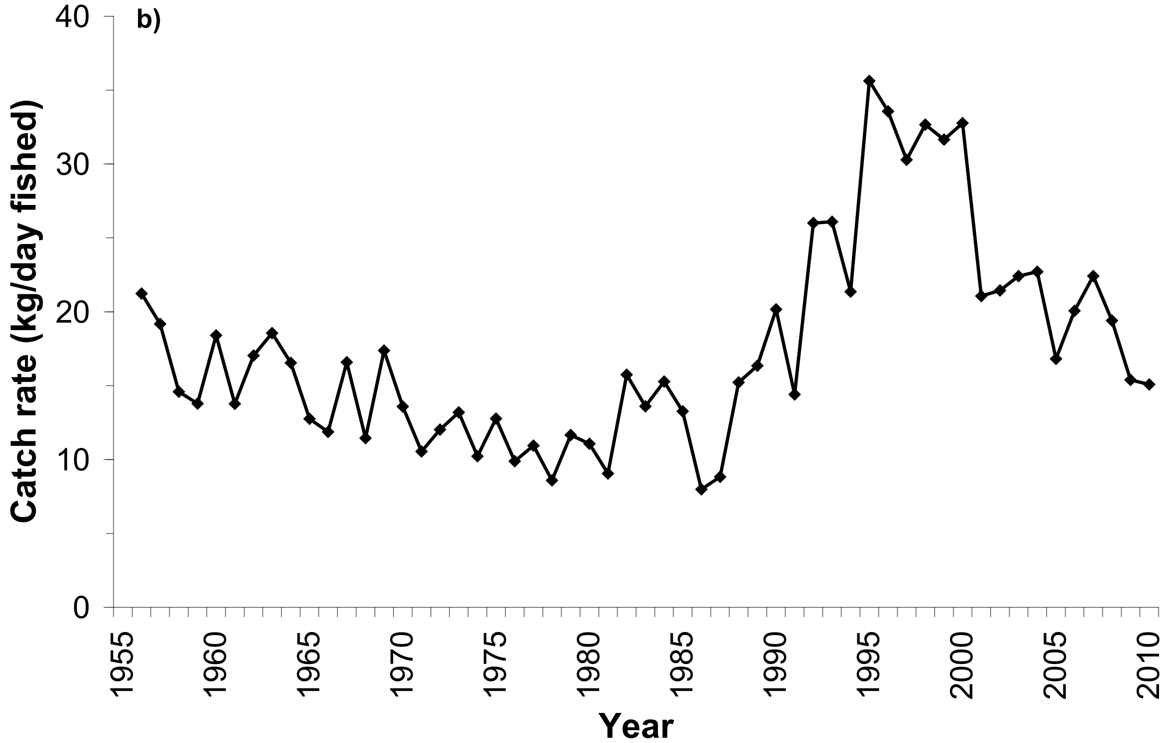


Figure 3.2. **a)** Total annual effort and annual catch of tailor and **b)** average annual catch rate of tailor by all vessels in the SBBSMNF, 1966 to 2010.

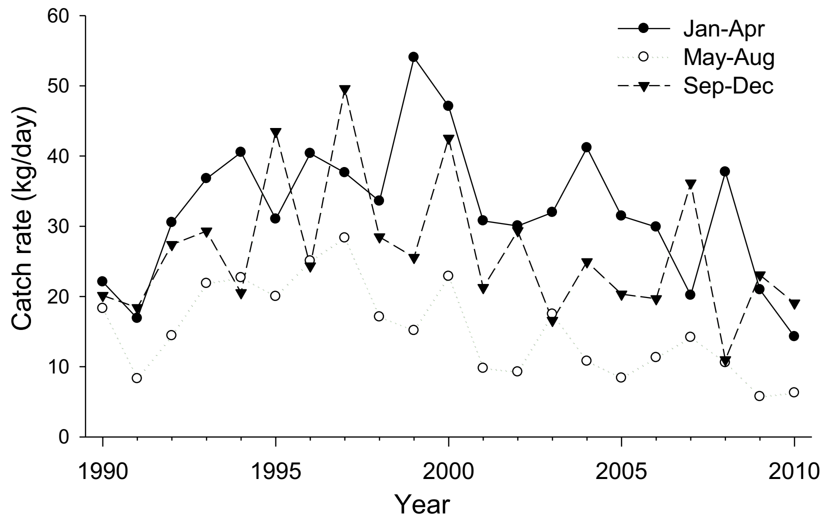


Figure 3.3. Average seasonal catch rates of tailor by selected vessels in the SBBSMNF, 1990 to 2010.

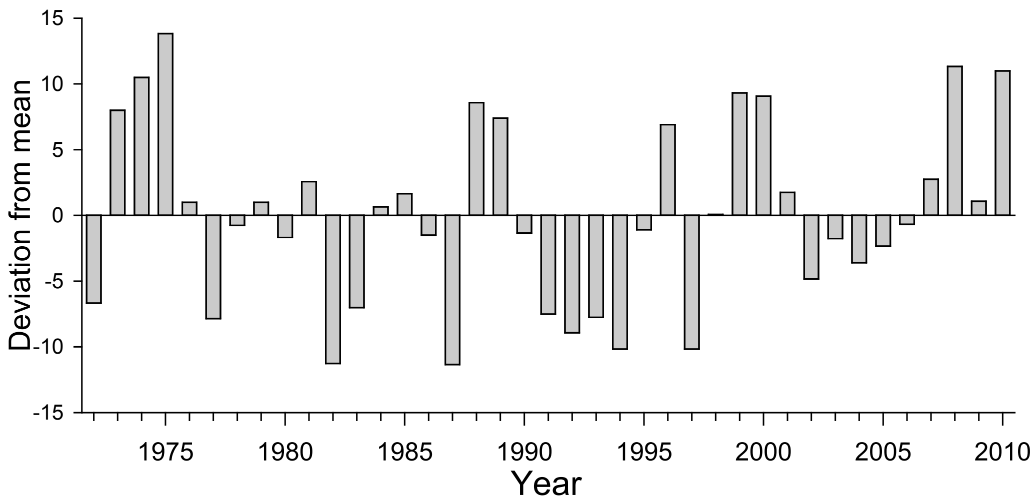


Figure 3.4. Annual deviation from mean Southern Oscillation Index, 1972 to 2010.

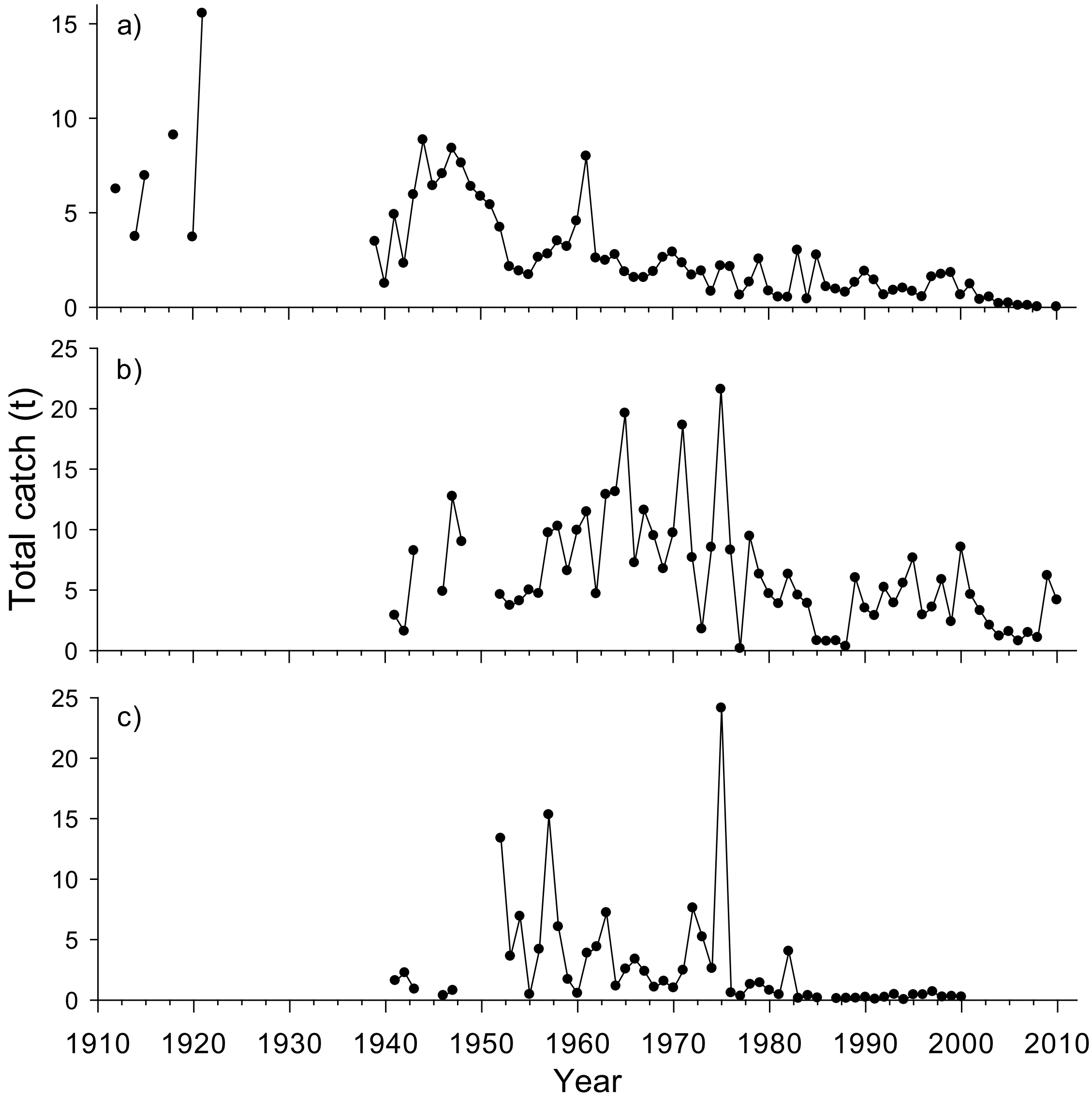


Figure 3.5. Total annual commercial landings of tailor from 1940 to 2010 in the **a)** Swan-Canning, **b)** Peel-Harvey and **c)** Leschenault estuaries. Limited pre-1940 data for the Swan-Canning estuary also shown. (NOTE: Leschenault commercial fishery closed in 2001)

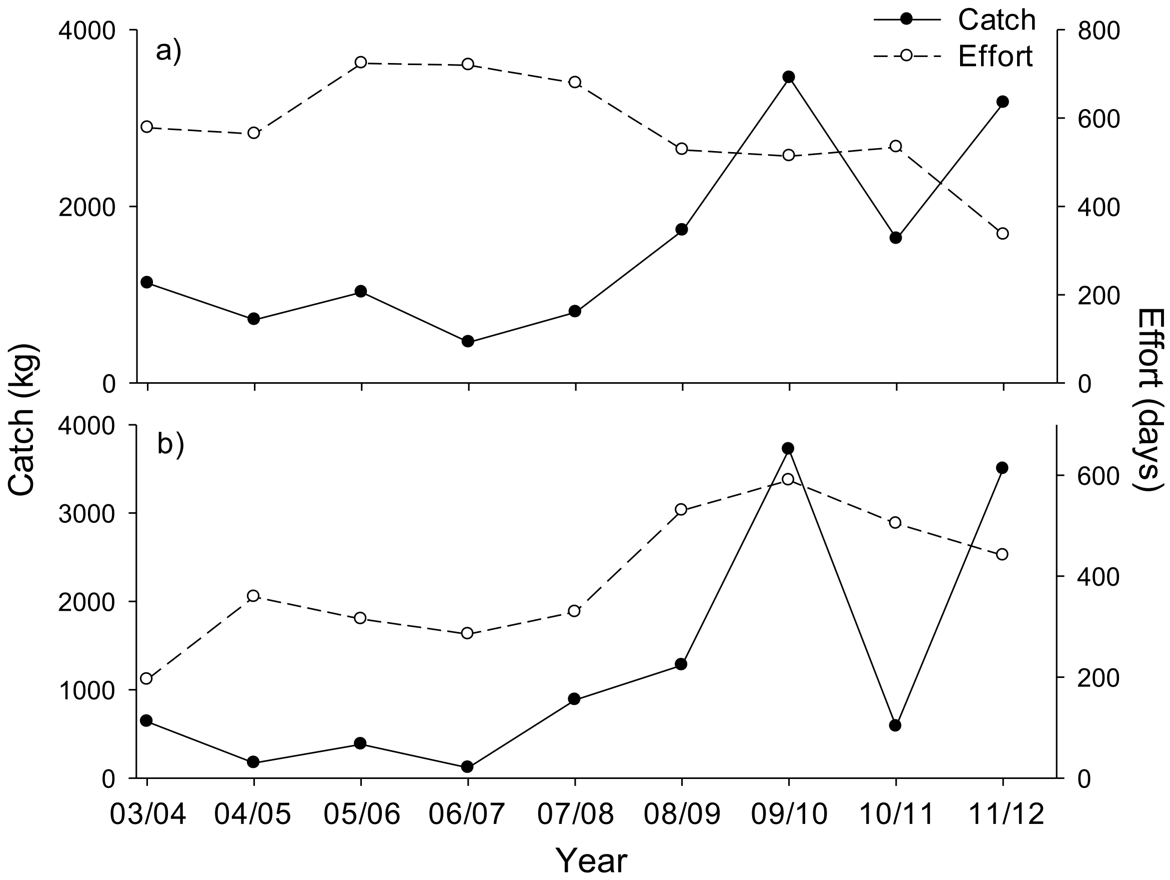


Figure 3.6. Total annual effort and annual catch of tailor by **a)** haul netting and **b)** gill netting in the Peel-Harvey estuary commercial fishery, 2003/04 to 2011/12.

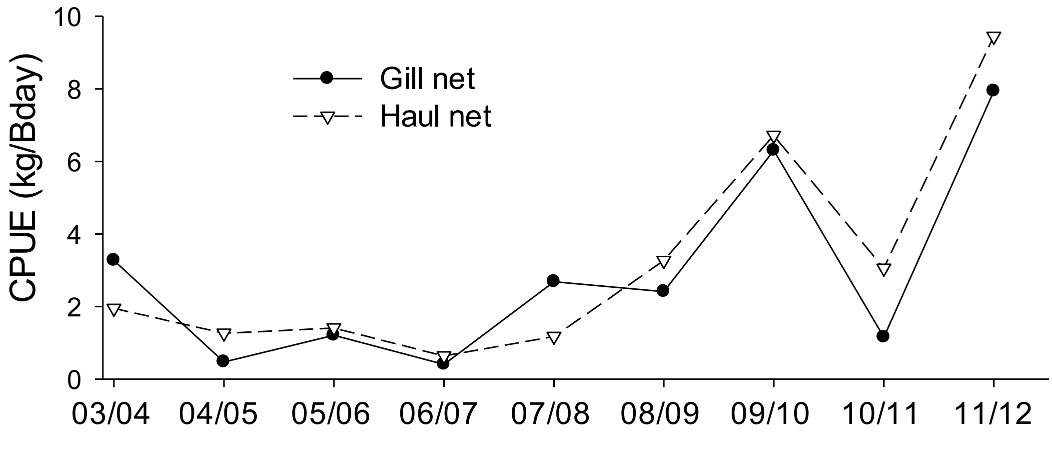


Figure 3.7. Average annual catch rate of tailor by haul netting and gill netting in the Peel-Harvey estuary commercial fishery, 2003/04 to 2011/12.

4.0 Tailor recreational fishery catch and effort trends

Summary

- In WA, tailor is strongly targeted by recreational fishers. A state-wide survey in 2000/1 found tailor to be the 3rd most common finfish species caught by recreational fishers in WA, with most landings occurring in the WCB. Although recent and historical catch levels are highly uncertain, there is sufficient evidence to suggest a substantial decline in the recreational catch and catch rate during the 1980s and 1990s.
- Various changes to recreational fishing regulations (bag and size limits) were implemented between 1990 and 2009. These changes were effective in reducing the retained catch of tailor, although the magnitude of the reduction is unknown due to uncertainty about the shore-based catch.
- The introduction of a recreational bag limit of 20 tailor in 1990 and a reduction in the bag limit to 8 tailor in 1994 was followed by a dramatic increase in the GCB commercial fishery catch rate of tailor from 1995 onwards. However, it is not clear whether these events are related.
- The current recreational catch of tailor in WA in unknown. Since the majority (85%) is taken by shore-based fishers in the West Coast Bioregion (WCB), the current catch cannot be estimated until a survey of shore-based fishing is undertaken. No surveys of shore-based fishing are planned. A suitable sampling frame would need to be developed to enable cost-effective surveys of shore-based fishing. Planned future surveys of boat-based fishing by the WA Department of Fisheries will provide regular estimates of annual catch and effort in this sector, but not the shore-based sector.
- In the absence of shore-based surveys, the average annual catch rate of volunteer logbook fishers could provide an index of tailor abundance. Many logbook fishers are shore-based and located in the WCB. Thus, the logbook program is well suited to monitoring trends in the WCB shore-based sector, which comprised the largest share of the WA recreational tailor fishery. The robustness of the index will depend on maintaining and increasing volunteer participation in the logbook program.
- In the WCB, juvenile tailor typically occur in estuaries and nearshore coastal waters, young adults typically occur in nearshore coastal waters and older adults typically occur in offshore coastal waters. For this reason, the WCB recreational tailor fishery can be considered to be comprised of 4 sectors (estuary, ocean shore-based, nearshore ocean boat-based and offshore ocean boat-based) which each target a different component of the stock. Boat-based fishers typically capture larger tailor and are likely to have a different average annual catch rate of this species compared to shore-based fishers.
- Historical trends in recreational catch rates of tailor (albeit uncertain due to limited data) suggest that the abundance of tailor in the WCB was a slightly lower between 2000 and 2010 than during previous years 1980–2000. However, commercial fishery catch rates in the GCB suggest a relatively high spawning stock biomass since 1995 (assuming a single stock in WA). The abundance of tailor in the WCB (and therefore the WCB recreational catch rate) appears to be partly determined by annual variations in recruitment, which depends on favourable dispersal of larvae from northern spawning grounds. Recreational catch rates in the WCB increased immediately after periods of high 0+ recruitment in 1996–1997 and 2008–2011.

4.1 Introduction

In Western Australia (WA), tailor (*Pomatomus saltatrix*) is targeted by recreational fishers throughout its range. Tailor is a key target species for recreational anglers in estuaries, on beaches and around coastal reef systems on the lower west coast of WA. The species is predominantly taken by recreational line fishing from the shore using either bait or lures but is also taken by boat. Tailor was also historically taken by recreational netting but restrictions on recreational net fishing introduced in 1994 reduced the catch by this method.

The total WA recreational catch of tailor was estimated in 2000/01 during the National Recreational and Indigenous Fishing Survey phone diary survey (Henry and Lyle 2003), which estimated that the largest share (85%) of the total catch was caught by shore-based fishers in the WCB. All other estimates of recreational catches of tailor in WA have been limited to specific regions and mainly derived from surveys of boat-based fishing in the West Coast Bioregion (WCB) and Gascoyne Coast Bioregion (GCB).

A substantial decline in the estimated catch of tailor by WCB boat-based fishers between 1996/97 and 2005/06 generated concern about the sustainability of this stock (Sumner *et al.* 2008). This decline was consistent with earlier anecdotal reports of declines in the recreational catch rate of tailor during the 1980s and 1990s (Cribb 1994).

Despite it's popularity, information about shore-based fishing in the WCB is limited (but see Lenanton and Hall 1976, Ayvazian *et al.* 1997, Smallwood *et al.* 2011) and historical trends in the total catch and catch rate of tailor by shore-based fishers are unknown. The lack of information about shore-based catch and effort levels in the WCB makes it difficult to assess the stock status of tailor in the WCB or develop appropriate management arrangements for the recreational tailor fishery.

Historically, trends in the catch rates of commercial fisheries were used to assess the status of tailor in the WCB. These fisheries are now a less valuable source of information about the status of the stock due to their low catches and catch rates due to limited targeting of tailor. The current annual commercial catch is now low (1–8 t) (see Section 3) and comprises a small proportion of the total catch of tailor in the WCB.

The need for more information on shore-based recreational fishing prompted a recent pilot study to investigate methods of estimating shore-based catch and effort in the WCB (Smallwood *et al.* 2011). The 3-month study, which was restricted to the Perth area, highlighted the challenges of surveying shore-based fishers in the WCB, including surveying large numbers of fishers at a large number of locations, often with limited access. This study concluded that obtaining annual estimates of shore-based catch and effort at a Bioregion-wide level with acceptable levels of confidence would be costly.

Due to the high cost, future surveys of shore-based recreational fishing in the WCB are likely to be conducted infrequently. The development of a better sampling frame (such as a recreational fishing licence-holder database) will be needed to enable cost-effective surveys of shore-based fishing (Smallwood *et al.* 2011). In the interim, management strategies to ensure the sustainability of tailor and other nearshore finfish stocks will need to rely on information from alternative sources, such as surveys of boat-based recreational fishing, voluntary recreational logbooks, fishery-independent studies, historical records from fishing clubs and data from the commercial sector, that can supplement the infrequent data from shore-based surveys.

4.1.1 Objectives

In the absence of shore-based fishing surveys, other sources of recreational catch and effort data such as individual angler diaries, fishing club records and surveys of boat-based fishing, could potentially be used to suggest trends in the recreational tailor fishery and to indicate the status of the stock in the WCB. Hence the objectives of this section were to:

- Describe the currently available sources of recreational catch and effort data relating to tailor in WA.
- Identify any spatial and temporal trends in tailor abundance and distribution in the WCB suggested by available recreational fishing data.
- Evaluate the potential of each data source to provide ongoing information about recreational catch rates and catch composition, especially in the WCB.
- Recommend strategies for monitoring future trends in the WCB recreational tailor fishery.

4.2 Methods

For locations of Bioregions and fishing sites, refer to Figure 2.1.

Individual angler diaries

Although potentially non-representative of the general recreational fishery, the catch rates of individual diary anglers are the only available long-term series of recreational catch rates of tailor and trends may provide useful information.

Personal diaries containing long-term catch and effort data were donated to the WA Department of Fisheries (DoF) by three individual recreational anglers . Each of these anglers operated in ocean waters of the WCB. Catch was reported as number of fish. Only retained catches were recorded by Anglers 1–3 (i.e. released fish not recorded). Lengths of fish were not recorded by Anglers 1–3. The effort data reported by each fisher is summarised below:

Angler 1 (Busselton): Undertook shore-based fishing at various beaches in Busselton area from 1981/82–2009/10. Typically fished 1–5 days per month from October to April. No fishing was undertaken May–September each year. Effort was reported in hours. Each fishing session was typically 2 hours duration. A single session occurred per day. Low annual effort was reported from 1986/87 to 1993/94. Tailor was the 2nd most common species caught by this fisher.

Angler 2 (Perth): Undertook shore-based fishing at various beaches in the Perth area and sites at the mouth of the Swan-Canning Estuary from 1977/78 to 2005/06. Fishing effort tended to occur on beaches during summer and at the estuary mouth in winter. Data from all sites were pooled after inspection of catch rate trends suggested no significant difference in annual trends. Effort was reported as number of fishing days. The number of hours fished per day was not recorded. Low annual effort was recorded from 1987/88 to 1995/96. Tailor was the 11th most common species caught by this fisher.

Angler 3 (Geraldton): Undertook shore-based fishing at various beaches in the Geraldton area from 1976/77 to 2007/08. Lower catch and effort levels were experienced in the last few years, which could reflect his declining health (died in 2010). Effort was reported in hours. Fishing sessions were of variable duration. Typically a single session occurred per day. No effort was recorded from 1986/87 to 1994/95. Annual fishing effort was distributed relatively evenly among all months within each year. Tailor was the 11th most common species caught by this fisher.

Angler 4 (Perth): Undertook boat-based fishing around seven individual offshore reefs in the Perth area from 1996/97 to 2005/06. Fishing effort occurred throughout the year. Effort was reported as number of fishing days. Tailor was the only species targeted by this fisher. Lengths of fish caught (including retained and released) were recorded. Nil catches were recorded.

The total number of tailor caught (C) and the total effort (E) per year were used to calculate an average annual catch rate (R, where R= C/E) for each fisher. Catch rates were expressed as either number of tailor per hour (if hours fished were recorded) or number per day. Catch rate was not calculated for a particular year if E was <10 hours (Angler 1 and 3) or <5 days (Angler 2). Fishing effort was not adjusted to account for any differences between years in fishing efficiency.

Voluntary recreational logbooks

A voluntary recreational fisher logbook program (part of the DoF Research Angler Program (RAP)) commenced in 2005 and is ongoing. Recreational fishers were asked to record fishing date, location, start and finish times of each fishing session, captured species, whether fish were retained or released and the total length of each fish to the nearest millimetre. Tailor are easily identified by recreational fishers. Therefore, mis-identification of tailor by logbook fishers was assumed to be negligible.

From 2005 to 2011, the majority (95.5%) of tailor captured by voluntary logbook fishers were caught in the WCB, with 79% caught by shore-based fishers.

The annual catch rate of tailor was calculated for shore-based logbook fishers operating in ocean waters of the WCB. The catch rate of boat-based fishers was not calculated due to relatively low catch and effort in most years. The total number of tailor caught (C) and the total effort (E) per year by all fishers were used to calculate an average annual catch rate (R, where R= C/E). Catch rate was expressed as 'number of tailor per hour'. Catch included retained and released fish.

Firstly, the sum of catch and effort from all shore-based logbook fishing sessions were used to calculate an average annual catch rate by shore-based fishers. This included a large number of fishing sessions that did not capture tailor (i.e. recorded either non-tailor or nil catches), possibly because tailor was not being targeted in these sessions. A second annual catch rate was calculated for only those shore-based logbook sessions that resulted in the capture of tailor. This rate was more likely to reflect the actual catch rate of shore-based fishers who were targeting tailor. Tailor are usually being targeted when caught recreationally.

Boat-based fishing surveys

On-site survey of boat-based recreational fishing catch and effort in the WCB were conducted by DoF in 1996/97, 2005/06, 2008/09 and 2009/10. Boat-based fishers were interviewed at various boat ramps between Kalbarri and Augusta. Catch information was obtained using the 'bus route' method between ramps within districts, with complete trip information obtained at the time of the interview. Estimates of total catch and effort in the Bioregion were calculated using weightings derived from the distribution of effort observed in the survey. For more information on the survey design and the methods used to estimate the mean of catch and effort in WCB boat-based recreational fishing surveys see Sumner *et al.* (2008).

The effort spent specifically targeting tailor during these surveys could not be accurately determined because only the total number of boating hours per boat was estimated during each survey. Total boating time included time spent travelling and time spent fishing at all locations during a trip (including offshore locations where Australian herring was not targeted).

Therefore, the total number of boating hours was only an approximate measure of boat-based fishing effort spent targeting tailor during each survey. As a consequence, the targeted catch rate of an individual species such as tailor, which represented a relatively small proportion of the total catch, could not be accurately determined.

The lengths of retained tailor were opportunistically sampled during each survey. Sample sizes were relatively small (313 fish in 1996/97; 156 in 2005/06; 120 in 2008/09; and 68 in 2009/10).

4.3 Results

4.3.1 Catch

The total annual recreational catch of tailor in WA was estimated by a national phone diary survey in 2000/01 (Henry and Lyle 2003). In 2000/01, the total WA recreational catch of tailor was estimated to be 587,041 fish (approximately 187 t assuming 0.319 kg/fish), which was the 3rd most commonly retained finfish in WA during the survey (Henry and Lyle 2003). No other estimates of the total annual catch of tailor in WA are available (Table 4.1).

In the 2000/01 survey, the majority of tailor were caught in the WCB (97% of WA total catch) with the remainder caught in the GCB (2%) and the South Coast Bioregion (SCB) (1%). WCB shore-based fishers were attributed with the largest share (85%, or 76% excluding estuaries) of the total WA tailor catch, with the next largest share attributed to the WCB boat-based sector (12%, or 9% excluding estuaries).

The distribution of catch between Bioregions/sectors determined in 2000/01 is the only available information for 'scaling up' the spatially limited catch estimates from other surveys in WA for the purpose of estimating total catch levels in other years. This approach assumes that the distribution of catch has remained constant between surveys.

In addition to estimates by the national phone survey in 2000/01, annual catches by boat-based fishers in ocean waters of the WCB were also estimated by on-site surveys in 1996/97, 2005/06, 2008/09 and 2009/10 (Table 4.1). Tailor was the 12th most commonly retained finfish in 1996/97 and the 16th most common in 2005/06 (Sumner *et al.* 2008). These surveys estimated total annual boat-based catches of 19,664, 4,731, 5,481 and 4,078 fish, respectively (Table 4.1). By comparison, the 2000/01 survey estimated a WCB boat-based catch of approximately 52,800 tailor (i.e. 9% of 587,041).

The estimates of the annual WCB boat-based catch of tailor derived from on-site surveys were substantially lower than that estimated by the 2000/01 phone survey. The onsite surveys may have underestimated tailor landings because they were conducted during daylight hours (9am to 5pm) and did not included night-time catches. The difference in estimated catch is probably also an artefact of differences in the survey method. Problems with the phone survey methodology have been identified (Lyle *et al.* 2010). Comparison with other surveys suggests that a total catch of 187 t in 2000/01 was a substantial over-estimate (Henry and Lyle 2003). The results of onsite surveys suggest that the actual catch may have been as little as 8–37% of this value.

If the phone survey data is disregarded, the on-site surveys suggested a decline of 70–80% in the annual boat-based catch within the WCB between 1996/97 and the late 2000s. If released fish are included in the catch estimate, the decline over this period is 65–70% (Table 4.1).

In 2000/01, tailor captured by boat-based fishers within Shark Bay were estimated to comprise the largest share (61%) of the total tailor catch in the GCB (Henry and Lyle 2003). Since 1998/99, on-site surveys of boat-based fishing within Shark Bay have been conducted almost annually, providing a relatively long time series of comparable data from this sector (Table 4.1). These surveys estimated relatively low annual retained catches, ranging from 369 fish (in 2004) to 2,236 fish (in 2002).

On-site surveys in the WCB and GCB have suggested an increase in the proportion of tailor released by boat–based fishers since the mid-1990s. In the WCB, 11% of captured fish were released in 1996/97, whereas 39–44% were released in the late 2000s (Table 4.1). In Shark Bay, the proportion of tailor released by boat-based fishers was 2–15% in the period 1998/99 to 2003 and increased to 10–34% in the period 2004 to 2010. These increases followed various changes to legal bag and size limits for recreational fishers, which are likely to have led to more tailor being released (Table 4.2).

4.3.2 Catch rate

Voluntary recreational logbooks

In the WCB, the average annual catch rate of tailor during all shore-based logbook fishing sessions, including those that did not capture tailor, increased from 0.6 fish/hour in 2005 to 1.0 fish/hour in 2010 and 2011 (Fig. 4.1). The average catch rate of tailor during fishing sessions that did capture tailor (i.e. excluding sessions resulting in non-tailor and nil catches) was stable at approximately 1.2 fish/hour from 2005 to 2009, and then increased to 1.5 fish/hour in 2010 and 1.4 fish/hour in 2011. Both catch rates suggest a slight increase in the availability of tailor in nearshore waters of the WCB in recent years.

Individual angler diaries

Diary Angler 1 fished in the Busselton area (South-west Zone of the WCB) from 1982/83 to 2009/10 and reported average annual catch rates of tailor ranging from 0 to 1.2 fish/hour (Fig. 4.2a). Annual catches over these years ranged from 0 to 104 fish (Fig. 4.3a). Catch rates from 2000/01 onwards were low (<0.6 fish/hour), compared to catch rates during the 1980s and 1990s.

Diary Angler 2 fished in the Perth area (Metropolitan Zone) from 1977/78 to 2005/06 and reported relatively low average annual catch rates of tailor each year, ranging from 0 to 0.6 fish/day (except for 1.1 fish/day in 1982/83). Annual catches over these years ranged from 0 to 27 fish (Fig. 4.3b). No long-term trend was evident in the annual catch rate of Angler 2.

Diary Angler 3 fished in the Geraldton area (Mid-west Zone) during two discrete periods, from 1977/78 to 1985/86 and from 1995/96 to 2007/08. Annual catches in these years ranged from 0 to 35 fish (Fig. 4.3c). Higher average annual catch rates were reported in the earlier period (0.1 to 0.5 fish/hour) compared to the later period (<0.2 fish/hour) (Fig. 4.2c).

Diary Angler 4 fished in the Perth area from 1996/97 to 2005/06, targeting tailor around various offshore reefs. Annual catches in these years ranged from 55 to 153 fish (Fig. 4.3d). This boat-based fisher reported average annual catch rates ranging from 3.3 to 8.1 fish/day (Fig. 4.2d).

Overall, shore-based Diary Anglers 1–3 each reported a low average catch rate of tailor, compared to boat-based Diary Angler 4. Angler 4 exclusively targeted tailor, while the other Anglers targeted multiple species during their fishing sessions. The catch rates of tailor by Angler 4, who is considered to be an avid tailor fisher, are probably a relatively high for a recreational fisher in the Perth region.

Although few long-term trends were evident in their catch rates, Diary Anglers 1–3 reported their highest annual catches and catch rates prior to 2000/01, which suggests a lower availability of tailor in the WCB in more recent years.

Also, Diary Anglers 1–3 each reported a localised peak in catch and/or catch rate in the late 1990s. There was a pronounced peak in the catch rate of Angler 1 in 1997/98, following a peak in catch in 1995/96. The catch rates of Anglers 2 and 3 did not display strong peaks in catch rate, but their annual catches peaked strongly in 1997/98 and 1996/97, respectively. Collectively, these data suggested a peak in availability of tailor in the WCB in the late 1990s.

4.3.3 Length composition of recreational catch

During the period 2005–2010, the average size of tailor captured (retained or released) by logbook fishers in ocean waters of the GCB (who were mainly shore-based) was larger than in the WCB, with most fish between 300–500 mm (Fig. 4.4a). However, the number of fish measured in the GCB was relatively low (n=105) and so may not be representative of the recreational catch in this Bioregion.

From 2005 to 2010, the vast majority of tailor captured (retained or released) by shore-based logbook fishers in ocean waters of the WCB were between 200–450 mm (Fig. 4.4b). The length range of fish caught by boat-based logbook fishers was similar (not shown), although the number of tailor measured by these fishers was relatively low (n=149), compared to the number measured by shore-based fishers (n=1,251), and so may not have been representative of the tailor caught by boat-based sector. The average length of tailor captured by shore-based fishers in ocean waters ranged from 359 to 385 mm each year. Fish above 500 mm (the legal maximum length, see Table 4.2) were rarely captured, suggesting that the maximum size limit did not usually constrain the retained catch of these fishers. On the other hand, a significant proportion (19%) of the shore-based catch was below 300 mm (the legal minimum length (LML)) and was released.

Over the same 6-year period, tailor captured by logbook fishers in WCB estuaries (mainly the Swan-Canning and Peel-Harvey estuaries) were mostly between 200 and 350 mm, which was significantly smaller than those caught in ocean waters (Fig. 4.4c). The majority (56%) of fish captured by estuary fishers were below 300 mm, indicating that the LML was very effective in constraining their retained catch. The maximum reported length was 460 mm, except for a single fish measuring 560 mm, indicating that the legal maximum length did not constrain their retained catch.

A comparison between the lengths of tailor reported by shore-based logbook fishers in the WCB (who mainly fished on Perth beaches) and lengths reported by boat-based Diary Angler 4 (who fished at offshore reefs in Perth) suggests that tailor may move offshore with increasing size (Fig. 4.5). Shore-caught fish were typically 320–340 mm in length, whereas fish caught at Reef 1 were typically 400–450 mm and those at Reefs 2–7 were typically 500–550 mm in length. Reef 1 was relatively sheltered (low wave energy) compared to the other reefs fished by Angler 4 (Diary Angler 4, pers. comm.).

Logbook data suggests that a significant number of immature tailor may currently be retained by recreational fishers in estuarine and nearshore ocean water in the WCB. In WA, tailor attain sexual maturity at approximately 320 mm TL ($L_{50\%}$, see Section 5), which is above the LML of 300 mm. Tailor in the length range 300–320 mm comprised 31% of all legal size (≥300mm) fish caught by logbook fishers in estuaries and 17% caught by ocean shore-based fishers.

4.4 Discussion

4.4.1 Catch

Insufficient data are available to confidently estimate the current recreational catch of tailor in WA. There has been only one attempt to estimate the total catch – a phone diary survey in 2000/01. Unfortunately, this survey appeared to have overestimated the total catch of tailor at 187 t. However, if the distribution of landings observed in the 2000/01 survey is assumed to be i) accurate and ii) remained constant in more recent years, then estimates of annual landings by WCB boat-based fishers (= 9% of total WA catch in 2000/01) of approximately 4,000–5,500 fish could be 'scaled up' to suggest a total WA recreational catch of 22–30 t (assuming 0.5 kg/fish) per year. This catch is similar to recent annual commercial landings of tailor in WA (approximately 25 t, see Section 3). However, there are no data to verify that the distribution of recent recreational landings is the same as in 2000/01 and so this estimate of recent total catch is highly uncertain. Since the majority of tailor caught recreationally in WA are taken by shore-based fishers in the WCB, the current recreational catch of tailor cannot be estimated until a survey of this sector is undertaken.

The available evidence suggests that it is inappropriate to extrapolate information obtained from one sector of the recreational tailor fishery to other sectors. For example, boat-based fishers typically capture larger tailor and are likely to have a different average annual catch rate of this species compared to shore-based fishers. This further highlights the need for a survey of shore-based fishers in the WCB.

Information provided by recreational fishers in the WCB indicates that tailor utilise different habitats at each stage of their life. Juvenile tailor typically occur in estuaries and nearshore coastal waters, young/small adults typically occur in nearshore coastal waters and older/larger adults typically occur in offshore coastal waters. For this reason, the recreational tailor fishery in the WCB could be considered to be comprised of 4 sectors – i) estuary, ii) ocean shore-based, iii) nearshore ocean boat-based and iv) offshore ocean boat-based – which each target a different component of the stock. The annual catch rate (retention and release rates) and catch composition (average fish size, proportion of immature fish) is likely to differ between sectors.

Surveys of boat-based fishing indicated that the boat-based catch of tailor (including released fish) in the WCB declined dramatically (by about 70%) between a survey in 1996/97 and later surveys in the late 2000s. Given the lack of data, it is difficult to interpret this finding. Firstly, the decline could reflect a decline in the abundance of tailor in the Bioregion. Alternatively, it may reflect a decline in the level of targeting of tailor by boat-based fishers. Effort specifically directed towards the capture of tailor was not determined in these surveys and so the change (if any) in the targeted catch rate of tailor between surveys is unknown. A shift in the location of boat-based fishing from nearshore to offshore waters could also influence the catch rates and catches of tailor. Also, a shift in effort towards targeting of other species, such as demersal species, would likely result in a decline in the boat-based catch of tailor. An offshore shift in the distribution of overall effort and a substantial increase in the catch of demersal species were observed between surveys in 1996/97 and 2005/06 (Sumner *et al.* 2008). The adoption of larger boats and more technologically advanced equipment (GPS, depth sounders, etc.) is likely to have contributed to these trends.

A steady increase in the average length of tailor sampled during each WCB boat-based fishing survey was consistent with the offshore shift in fishing effort. The average length was 343 mm TL in 1996/97, 376 mm in 2005/06, 387 mm in 2008/09 and 413 mm in 2009/10 (DoF, unpulb.

data). The increase between 1996/97 and 2005/06 was probably partly due to the increase in the LML from 250 to 300 mm, implemented in 2003. The remaining increases may have reflected the increasing average size of fish encountered by the boat-based fishery as it shifted further offshore each year.

Whilst no estimates of the recent shore-based catch of tailor in the WCB are available, the retained catch by this sector, and by the boat-based sector, is likely to have been reduced by various changes to fishing regulations implemented between 1990 and 2009.

The length composition of tailor caught by volunteer logbook fishers suggests that the increase in the LML from 250 to 300 mm, implemented in 2003, was likely to have reduced the retained catch from 72% to 44% of the total catch in estuaries and from 93% to 81% in nearshore ocean waters. By contrast, the introduction of a maximum size limit of 600 mm in 2003 (reduced to 500 mm in 2009) was likely to have had a negligible impact on the retained catch in these areas. This maximum size limit may have somewhat constrained the catch of boat-based fishers, especially those fishing in offshore waters.

The impact on the catch level of a decrease in the daily bag limit from 20 to 8 fish, implemented in 2003, is more difficult to quantify. Surveys of WCB boat-based fishers suggested a decrease after 2003 in the retained catch, from approximately 90% to 60% of the total catch. In nearshore waters, some of this (10% of the total catch) can be attributed to the change in size limit, as discussed above, which suggests that the majority of the additional releases by boat-based fishers after 2003 are attributable to the new bag limit. The impact of the new bag limit on the shore-based catch is unknown.

4.4.2 Long-term trends in tailor availability in WA

The available historical data from the WCB recreational tailor fishery does not provide any reliable long-term indices of annual abundance. The annual catch rates of tailor by the few Diary Anglers examined here were highly variable and provided limited indications of long-term trends in the abundance of the stock in the WCB. The relatively low annual catch and effort levels, especially by Anglers 2 and 3, limited the value of their data. Notwithstanding these problems, the catch rates of Diary Anglers suggested a slightly higher availability of tailor in the WCB during the earlier years 1980–2000 compared to 2000–2010.

Of interest is the strong peak in the catch rate by Angler 1 in 1997/98, following a peak in annual catch in 1995/96. The catch rates of other Anglers did not display strong peaks at this time, although Angler 2 and 3 did record pronounced peaks in their annual catch in 1997/98 and 1996/97, respectively. A peak in the recreational catch rate of tailor in 1997 was also reported by shore- and boat-based recreational fishers during interviews with Volunteer Fisheries Liaison Officers in the Metropolitan Zone from 1995 to 2007 (Smallwood *et al.* 2010) (Fig. 4.6).

These peaks coincided with an extended peak in the catch rate in the Shark Bay commercial tailor fishery in the GCB from 1995 to 2000 (Fig. 4.2b in Section 2) and with a peak in recruitment of 0+ juvenile tailor in the WCB in 1996–1997 (Fig. 2.9 in Section 2).

Overall, these patterns suggested high spawner abundance in the GCB, commencing in 1995 and resulting in high commercial fishery catch rates in the GCB throughout the late 1990s. High spawner abundance in the GCB may have resulted in strong juvenile recruitment to the WCB in 1996 and 1997, followed by higher catch rates in the late 1990s by WCB shore-based recreational fishers who target young adult tailor. In more recent years, trends in the average annual catch rate of volunteer logbook fishers suggests a slight increase in the abundance of tailor in nearshore waters of the Perth area between 2005 and 2010. The increase is likely to be a response to high 0+ recruitment in the WCB from 2008 to 2011 (Section 2).

Various changes to recreational fishing regulations (bag and size limits) for tailor were implemented between 1990 and 2009. The changes were almost certainly effective in reducing the retained catch of tailor in the WCB, although the magnitude of the reduction is unknown due to uncertainty about the shore-based catch. In WA, small (<350 mm) tailor released by recreational fishers have high survivorship (95%) in the short-term (within 2 h of release) (Ayvazian *et al.* 2002). Long-term survivorship has not been assessed. Also, survivorship of large tailor released by recreational fishers in WA waters has not been assessed. Elsewhere, long-term (21 days) survivorship of large tailor (mean length = 715 mm) has been estimated at 61% (Fabrizio *et al.* 2008). Nonetheless, even at moderate rates of survivorship, the high number of additional released fish arising from the new regulations would have led to a reduction in fishing mortality and increased the sustainability of the tailor fishery at the time of implementation. Of course, while bag and size limits effectively constrain the catch of individual fishers, the total catch of the fishery may ultimately continue to increase if total effort increases over time due to increasing numbers of recreational fishers.

Planned future surveys of boat-based fishing by WA DoF will provide regular estimates of annual catch and effort in this sector. However, no surveys of shore-based fishing are planned and so catch levels and trends in this sector will remain unknown. This represents a risk to the sustainability of the tailor stock, given that the majority of the recreational catch is shore-based. An increase in the shore-based catch would be of concern, partly because a significant proportion of it comprises immature fish.

4.4.3 Future monitoring

Since the majority of the recreational tailor catch in WA is caught by shore-based fishers in the WCB, the current lack of information about the shore-based catch leads to considerable uncertainty about the status of the tailor stock and the recreational fishery. Regular surveys of shore-based fishers that provided robust estimates of catches and catch rates in this sector would decrease the uncertainty of stock assessments. A suitable sampling frame will need to be developed to enable cost-effective surveys of shore-based fishers.

In the interim, the average annual catch rate of volunteer logbook fishers appears to provide the most robust index of tailor abundance of any existing data source A high proportion of logbook fishers are shore-based and located within the Metropolitan Zone of the WCB. Thus, the logbook program is well suited to monitoring the trends in the WCB shore-based sector, which comprised the largest share of the WA recreational tailor fishery.

Currently, logbook catch rates are available only from 2005 to 2010. A longer period would be required to confirm trends and enable comparison with trends in other annual data, such as fishery-independent recruitment indices, which may assist in validating logbook catch rates as an index of abundance. The robustness of the index will depend on maintaining and increasing participation in the logbook program and an understanding of the potential biases (e.g. avidity, turnover, etc.) of logbook fishers.

The usefulness of data from boat-based fishing surveys is limited. Boat-based fishers capture a wider size (and presumably age) range of tailor than shore-based fishers. Importantly, the location of fishing (nearshore versus offshore, sheltered versus exposed reef) influences the average size/age of fish captured and could therefore influence the catch rate, given that age classes often have differing abundances. Information about catch location and length composition would be required to correctly interpret tailor catch rate trends obtained from boat-based fishers. Information about released fish would also be required, since the bag/size limits for this species could result in a significant proportion of tailor being released by boat-based fishers, including larger fish.

Shore-based fishers in ocean waters capture a smaller and more consistent size range of tailor than boat-based fishers. For this reason, tailor catch rate trends obtained from shore-based fishers (either from surveys or logbooks) may be easier to interpret. For example, given the smaller average size of fish, shore-based catch rate trends may be more easily related to recruitment trends. However, bag/size limits result in a high proportion of tailor, particularly small fish, being released by shore-based fishers. Therefore, as with boat-based fishing data, information about released fish and the length composition of the catch would be required to interpret shore-based catch rate trends. Logbooks provide this type of data, but surveys often do not.

The extent of connectivity between tailor in the GCB and the WCB is yet to be determined. It is possible that a single stock exists in WA, with the majority of the spawning occurring in the GCB or the northern WCB (see Section 2). Tagging of adult fish to determine movement within and between Bioregions would assist in determining stock structure, including the relationship between the WCB recreational fishery and the GCB commercial fishery.

4.4.4 Summary

The current recreational catch level of tailor in WA is unknown and historical catch rate trends are uncertain. The uncertainty is due to a lack of information about the shore-based catch.

The catch rates of the few Diary Anglers examined here suggested that availability of tailor in the WCB was a slightly lower in 2000–2010 than during the earlier years 1980–2000. However, commercial fishery catch rate trends in the GCB suggest a relatively high spawning stock biomass since 1995 (assuming a single stock in WA). The abundance of tailor in the WCB (and therefore WCB recreational catch rates) is partly determined by recruitment, which depends on favourable dispersal of larvae from northern spawning grounds. Recreational catch rates in the WCB increased immediately after periods of high 0+ recruitment in 1996–1997 and 2008–2011 (Section 2).

Table 4.1 Estimates of annual recreational catches of tailor during recreational fishing surveys in WA, including the 2000/01 National Recreational and Indigenous Fishing phone survey (Henry and Lyle 2003) and various WA Department of Fisheries (DoF) on-site surveys (DoF unpubl. data).

Region	Survey type	Period	Sector	No. kept	% Released
State	Phone	2000/01	All	587,041	37.9
West Coast Bioregion (WCB)	Creel	1996/97	Boat	19,664	10.7
	Phone	2000/01	All	569,727	24.8
	Phone	2000/01	Shore	500,826	24.8
	Phone	2000/01	Boat	68,900	24.9
	Creel	2005/06	Boat	4,731	39.3
	Creel	2008/09	Boat	5,481	39.2
	Creel	2009/10	Boat	4,078	44.5
Swan-Canning Estuary (WCB)	Creel	1998/99	Boat	2,306	10.5
	Creel	1998/99	Shore	406	45.6
Peel-Harvey Estuary (WCB)	Creel	1998/99	Boat	3,051	49.2
	Creel	1998/99	Shore	2,937	69.4
Perth (WCB)	Multiple	Apr–Jun 2010	Shore	1,075	22.2
Gascoyne Coast Bioregion	Creel	1998/99	Boat	2,859	26.4
(GCB)	Phone	2000/01	All	11,254	12.0
	Phone	2000/01	Shore	4,168	16.6
	Phone	2000/01	Boat	7,086	6.9
Shark Bay (GCB)	Phone	2000/01	Shore	2,552	8.1
	Phone	2000/01	Boat	6,882	0
	Creel	1998/99	Boat	2,244	14.8
	Creel	2000/01	Boat	1,334	4.4
	Creel	2001/02	Boat	1,559	8.1
	Creel	2002	Boat	2,236	14.4
	Creel	2003	Boat	1,237	1.6
	Creel	2004	Boat	369	33.9
	Creel	2005	Boat	638	10.5
	Creel	2006	Boat	1,441	10.5
	Creel	2007	Boat	1,217	27.2
	Creel	2010	Boat	1,002	30.7

Table 4.2. Changes to recreational daily bag limits and size limits for tailor (LML=Legal Minimum Length, WCB–West Coast Bioregion, SCB=South Coast Bioregion, GCB=Gascoyne Coast Bioregion).

Date	Regulation (applies in WCB, SCB & GCB)
1913	LML 8 inches
1937	LML 9 inches
1975	LML 25 cm
1990	LML 25 cm; Recreational daily bag limit 20
1994	LML 25 cm; Recreational daily bag limit 8
Oct 2003	LML 30 cm; Recreational daily bag limit 8 including only 2 fish >600mm* (*WCB & SCB only)
Dec 2009	LML 30 cm; Recreational daily bag limit 8 including only 2 fish >500mm (WCB) or >600mm (SCB).

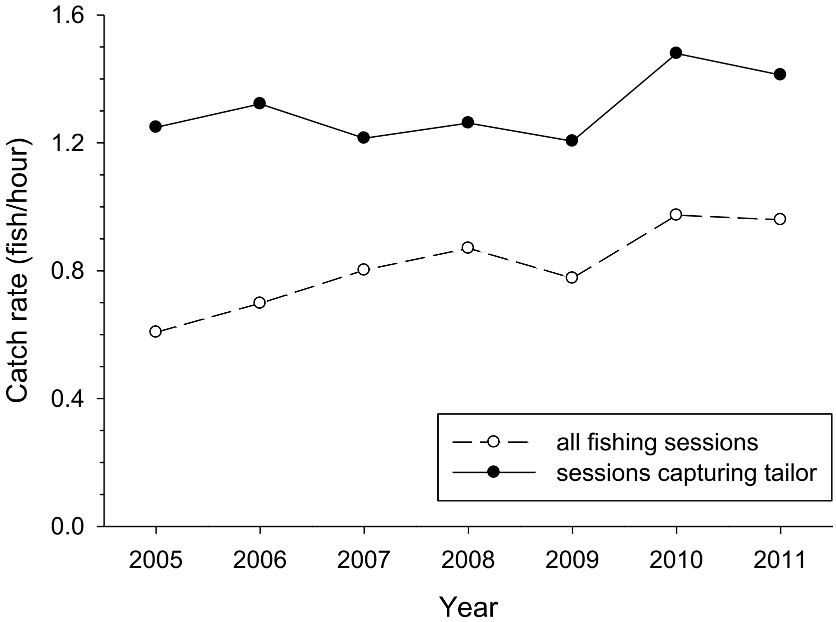


Figure 4.1. Annual catch rate of tailor reported by shore-based voluntary logbook fishers in the West Coast Bioregion. 'All fishing sessions' (solid line) includes fishing sessions resulting in non-tailor and nil catches. 'Sessions capturing tailor' (dashed line) excludes fishing sessions resulting in non-tailor and nil catches. Catch includes retained and released fish.

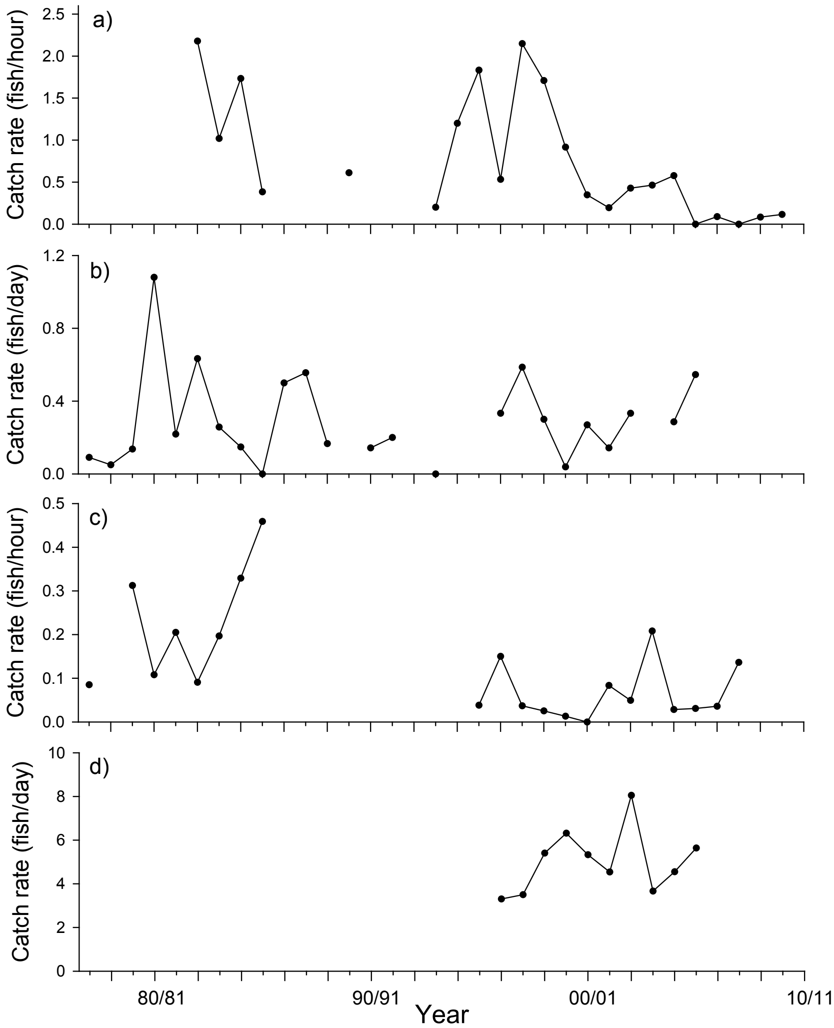


Figure 4.2. Average annual catch rates of tailor recorded in specific areas of the West Coast Bioregion by **a)** shore-based Diary Angler 1 (Busselton), **b)** shore-based Diary Angler 2 (Perth), **c)** shore-based Diary Angler 3 (Geraldton) and **d)** boat-based Diary Angler 4 (Perth).

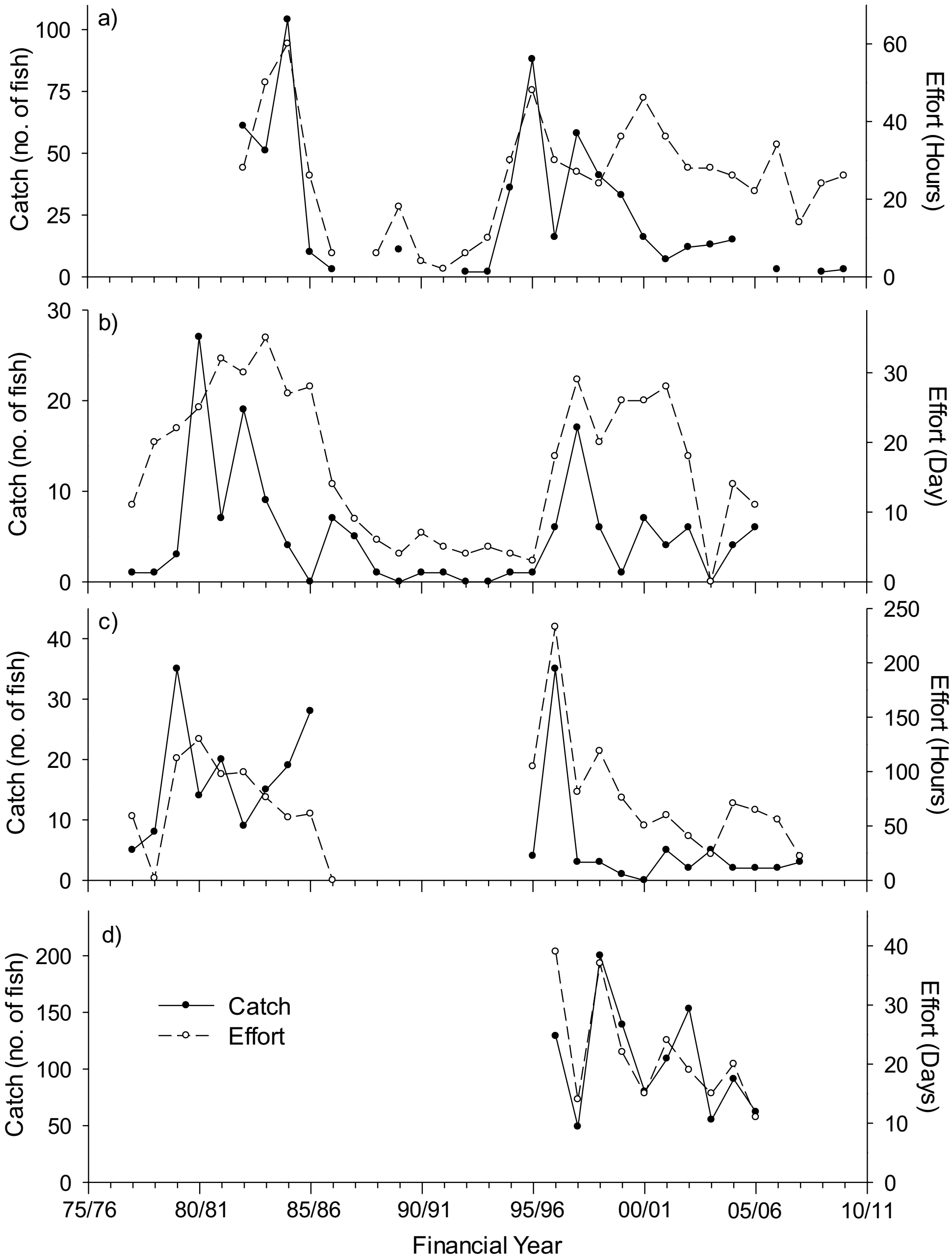


Figure 4.3. Annual catch of tailor (retained fish only) and total annual effort recorded in specific areas of the West Coast Bioregion by **a)** shore-based Diary Angler 1 (Busselton), **b)** shore-based Diary Angler 2 (Perth), **c)** shore-based Diary Angler 3 (Geraldton) and **d)** boat-based Diary Angler 4 (Perth).

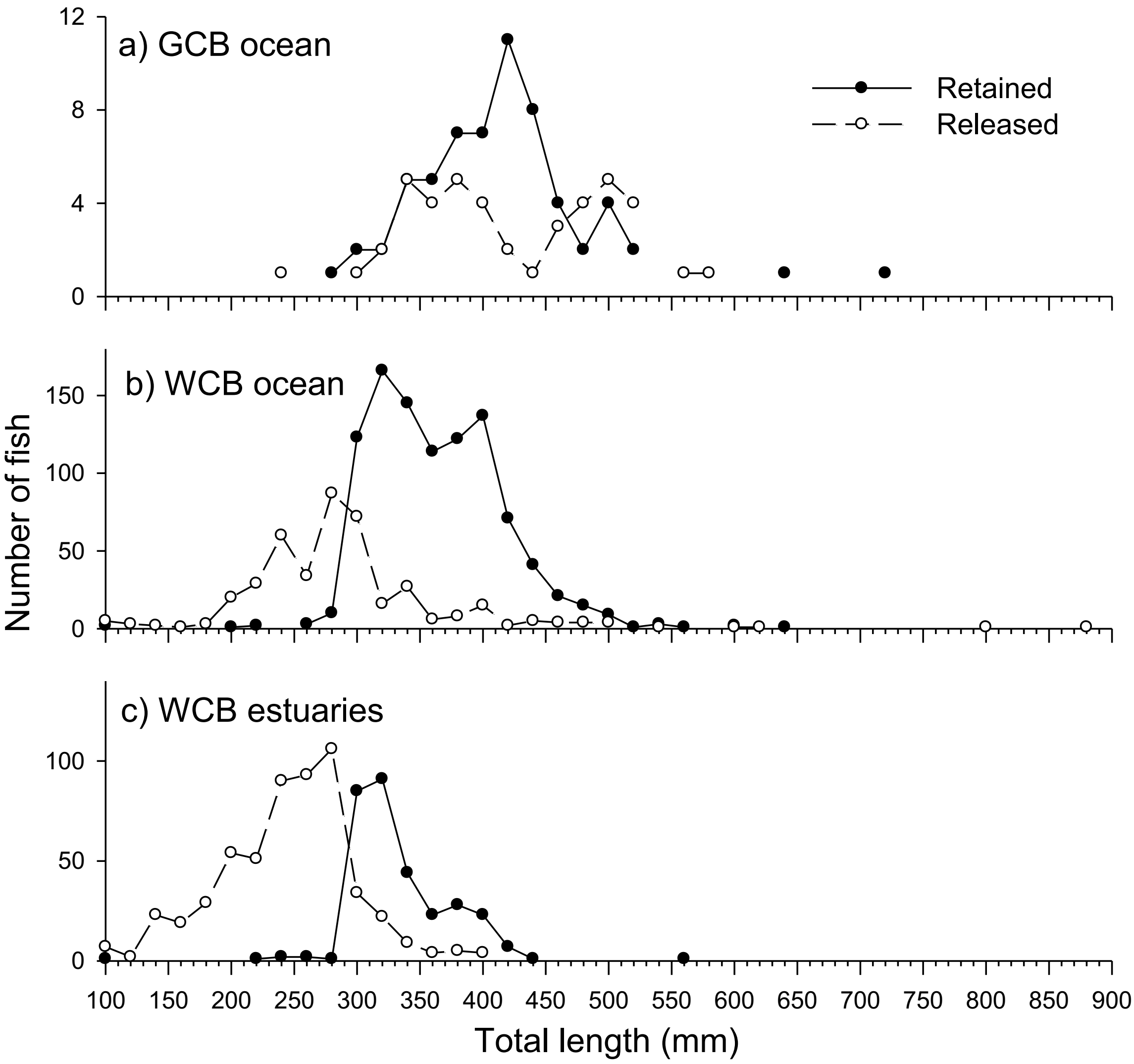


Figure 4.4. Lengths of retained and released tailor reported by volunteer logbook fishers in **a)** Gascoyne Coast Bioregion (GCB) ocean waters, **b)** West Coast Bioregion (WCB) ocean waters (shore-based catch only) and **c)** WCB estuaries (shore- and boat-based catch pooled) from 2005 to 2010. Shore- and boat-based landings pooled.

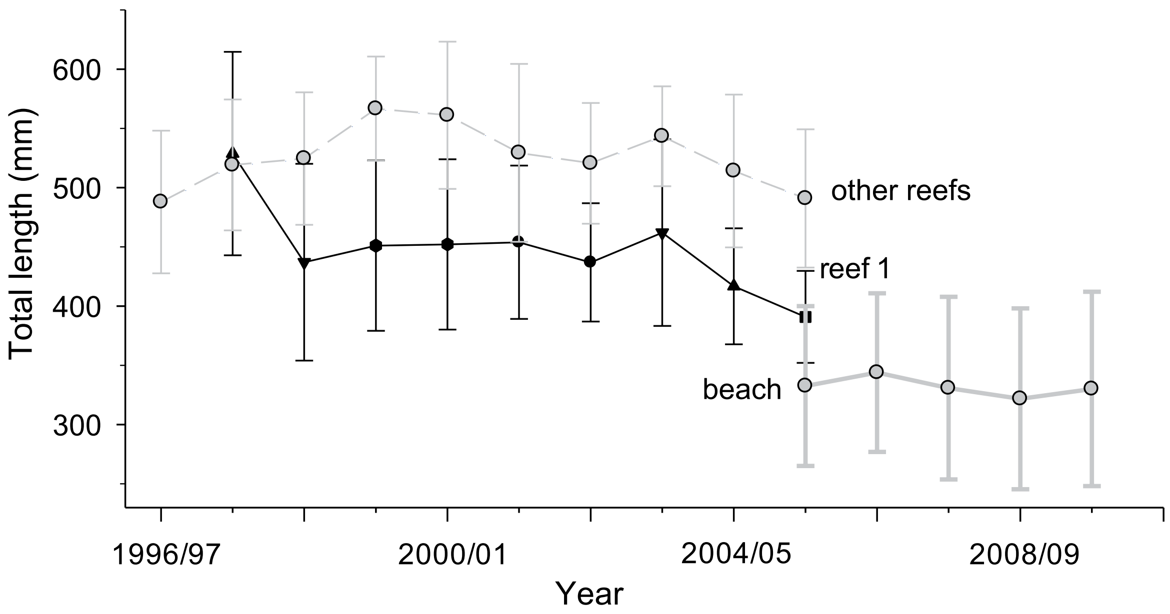


Figure 4.5. Average (± s.d.) annual length of tailor caught by boat-based Diary Angler 4 at Reef 1 (thin black line) and other reefs in the Perth area (dashed grey line) from 1996/7 to 2005/6, and by West Coast Bioregion shore-based logbook fishers in ocean waters (‘beach’, thick grey line) from 2005/6 to 2009/10. (lengths include retained and released fish).

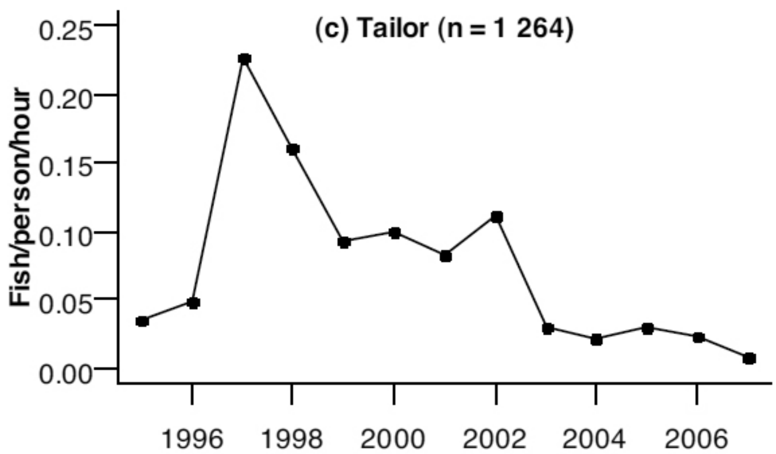


Figure 4.6. Average annual catch rate of tailor (retained fish only) reported by shore- and boat-based recreational fishers during interviews with Volunteer Fisheries Liaison Officers in the Metropolitan Zone from 1995 to 2007 (reproduced from Smallwood *et al.* 2010). (n = 1264 retained fished reported during 1995–2007)

5.0 Tailor biology and assessment

Summary

- Juvenile tailor (0–150 mm TL, age 0–3 months) were aged by enumeration of daily micro-increments in otoliths. Average growth rates ranged from 0.5 to 0.8 mm.d-1, depending on year, region and spawning period. Faster growth rates were associated with higher water temperatures.
- Protocols for ageing adult tailor were developed, based on the enumeration of annual opaque zones observed in whole sagittal otoliths. The annual periodicity of opaque zones was validated.
- Growth was similar for both sexes. The von Bertalanffy growth parameters were: L¥ = 592 mm TL, k = 0.464, t0 = -0.096. Based on these parameters, individuals reach an average of 236 mm TL after 1 year, 368 mm after 2 years and 451 mm after 3 years. Due to limited data for older (>5 y) fish, the growth curve was a poor fit at older ages and these parameters may slightly underestimate growth.
- Length-at-maturity (L50%) for tailor in Western Australia (WA) was estimated to be 320 mm, which is above the current legal minimum length of 300 mm TL.
- The sex ratio in the recreational tailor fishery is biased towards females, which comprised 60% of all samples.
- Spawning by tailor in WA is undertaken by multiple groups of spawners that are spatially and temporally distinct. These groups collectively comprise the total breeding stock. The contribution by each spawning group to annual fishery landings is probably not equal. Identifying these spawning groups and their relative contributions to fishery landings in WA will assist in the sustainable management of this stock.
- Spawning is associated with local mean monthly water temperatures of 18–24 ºC.
- In 2009–10, a total of 650 lengths and 543 ages of tailor were obtained from the recreational fishery. The majority of samples were from nearshore waters of the Metropolitan and Mid-west Zones in the West Coast Bioregion (WCB). Fish from other WCB zones and from the Gascoyne Coast Bioregion (GCB) were under-represented in samples. Fish from offshore waters were also under-represented across all zones.
- There is strong evidence of an ontogenetic shift in distribution in WA waters, with larger/older tailor occurring in northern areas (i.e. GCB and Kalbarri Zone of WCB) and in offshore waters, while smaller adults dominate nearshore habitats in southern areas. Under-sampling of northern and offshore areas in 2009–10 probably resulted in a length/age composition biased towards smaller/younger fish.
- In 2009–10, the majority of fish sampled from the WCB were 300–550 mm in length. The maximum length was 1052 mm. Compared to historical samples obtained in 1991–99, the length composition in the Metropolitan Zone in 2009–10 was slightly truncated (i.e. lower proportion of large fish) and had a lower average length.
- In 2009–10, the ages of tailor sampled from the WCB ranged from 1 to 6 years, (plus a single fish aged 10 years). The majority (97%) were aged <4 years. Historical samples of age composition were not available for comparison.
- Natural mortality (M) of tailor was estimated to be 0.42 y-1, based on an observed maximum age of 10 years in WA.

- A high level of uncertainty was associated with the estimated rate of fishing mortality (F) in 2009–10, due to the likely bias in the age structure and low samples sizes in each region.
- The egg and yield-per-recruit model results were difficult to interpret due to uncertainty about F. However, they did suggest that current management arrangements (bag and size limits) are probably effective in reducing the risk of overfishing.
- A more robust assessment of fishing mortality in the tailor stock in WA would require a more representative sample of the age structure. This would require an increase in sample size in each region, and also a substantial increase in sampling effort to obtain both inshore and offshore fish in each region. In the WCB, obtaining a representative age sample of tailor from the recreational fishery is not feasible at the current level of resourcing.
- Significantly more information is required about the northern portion of the stock (in the GCB and Kalbarri Zone) because this may be the main source of recruitment to the WCB. Sampling in this region can partly be achieved with assistance from the commercial sector.

5.1 Introduction

In Western Australia (WA), tailor (*Pomatomus saltatrix*) is strongly targeted by recreational fishers and also supports a minor commercial fishery. A survey in 2000/01 found tailor to be the 3rd most common finfish species caught by recreational fishers in WA with most landings occurring in the West Coast Bioregion (WCB) (Henry and Lyle 2003). Although recent and historical catch levels are highly uncertain, there is sufficient evidence to suggest a substantial decline in the recreational catch and catch rate during the 1980s and 1990s (Section 4).

Concerns about a decline in stock abundance prompted various fishery management changes in the 1990s to reduce recreational fishing pressure. Since then there have been encouraging signals, such as increasing recruitment and higher commercial catch rates (Sections 2, 3), that suggest a recovery of the stock. However, the stock status remains unclear due to a lack of information about the recreational fishery, the absence of a reliable index of spawning stock abundance and uncertainty about stock structure.

Until these gaps in knowledge can be addressed, it may be possible to gain a better understanding of the risks to the sustainability of this stock by examining the range of biological data that are available for tailor in WA. In this Section, recent and historical biological information from the WCB are used to determine biological characteristics and estimate levels of mortality to provide additional information about the current status of this stock.

Specifically, this Section aims to:

1. Identify a reliable ageing technique for tailor in WA.
2. Evaluate the historical and current length and age structure of the main fished populations.
3. Determine spatial and temporal spawning patterns.
4. Determine growth and reproductive parameters.
5. Estimate rates of total, natural and fishing mortality.
6. Provide recommendations for future monitoring and assessment of the tailor stock in WA.

5.2 Methods

5.2.1 Sample collection

The WA Department of Fisheries (DoF) has intermittently collected biological data from tailor in WA since the 1990s. Samples of juvenile tailor have been collected during fishery-independent sampling using beach seine nets and line fishing methods since 1994 (see Section 2). Adult tailor were sampled from recreational landings in the WCB during two main periods, from 1991 to 1999 and during the current project from July 2009 to December 2010. In the WCB, the majority of fishery landings of tailor are taken by the recreational sector, with minor commercial landings that are usually a byproduct of targeting other species (Sections 3 and 4). The current project did not sample commercial landings of tailor.

From 1991 to 1999, a total of 1,420 tailor were sampled from the recreational fishery in the WCB. The majority were collected from the Metropolitan Zone (82%), with the remainder from the Mid-west (11%), South-west (7%) and Kalbarri (<1%) Zones. During this period, an additional 514 tailor (mainly juveniles) were collected by fishery-independent sampling (seine netting) in the WCB and Gascoyne Coast Bioregion (GCB) (see Section 2 for details of juvenile sampling).

In 2009–10, a total of 682 tailor were sampled from the recreational fishery in the WCB. The majority were collected from the Mid-west (49%) and Metropolitan (33%) Zones, with the remainder from the South-west (12%) and Kalbarri (6%) Zones. In 2009–10, an awareness campaign and prize incentives were introduced to encourage donations of tailor from recreational fishers. An additional 411 juvenile tailor were collected (313 by seine netting and 98 by line fishing in the Swan Estuary).

For each fish collected from the recreational fishery, the total length (TL) was recorded to the nearest millimetre and total weight (if available) was recorded to the nearest 0.1 gram. Samples from recreational fishers were mostly fish frames (fillets removed) so total weight could not be recorded. Gonads were removed and weighed to the nearest 0.01 g, sex determined and the gonads were assigned a macroscopic developmental stage (see section 5.2.4). Otoliths were not usually obtained from fish collected in 1991–99. In 2009–10, otoliths were removed from each fish, cleaned and stored in paper envelopes. All otoliths collected in 2009–10 were processed for age determination.

For each juvenile fish, the total length was recorded to the nearest millimetre and otoliths were removed. Subsamples of juvenile otoliths collected in 1991–99 (n=136) and 2009–10 (n = 113) were processed for age determination.

5.2.2 Juvenile age and growth

The otoliths of juvenile tailor (TL <150 mm) collected from the WCB (Metropolitan and South-west Zones) and GCB were processed for enumeration of daily increments. The daily periodicity of micro-increments in tailor otoliths has been validated (Nyman and Conover 1988). Each whole juvenile otolith was mounted to a glass slide with distal surface upmost using thermo polymer Crystalbond 509. The otolith was polished for short intervals, initially on 1200 grit wet and dry sanding paper and subsequently on 9 μm lapping film, and regularly examined under a compound microscope to determine the proximity of the primordium to the surface and the readability of the micro-increments. Polishing continued until the primordium became visible, then a final layer of Crystalbond was applied to seal and enhance the optical properties of the processed otolith.

Micro-increments were counted by an experienced reader along dorsal and ventral transects using a compound microscope (Olympus, CH) (Fig. 5.1). Where counts for a particular otolith differed by >10%, the otolith was re-read. If disagreement still occurred, the otolith was discarded.

Regressions of length versus age were used to assess temporal and spatial differences in growth rates. These age-length equations were also used to estimate ages and birthdates of juvenile tailor.

5.2.3 Adult age and growth

Tailor were aged by enumeration of annual increments in their sagittal otoliths, which provide more reliable age estimates for this species than scales, vertebrae or other calcified structures (Robillard *et al.* 2009). The otoliths of Australian tailor are characterised by relatively poor readability (Brown *et al*. 2003; Gaughan *et al*. 2006). In eastern Australia, where captured fish are relatively young age (<6 years, <450 mm TL), whole and sectioned otoliths have similar readability (Brown *et al.* 2003). In other regions, particularly where larger fish are present, sectioned otoliths have higher readability (e.g. Sipe and Chittenden 2002).

In this project, the readability of whole and sectioned otoliths, including some prepared by the baking and polishing' method of Robillard *et al.* (2009), were initially investigated. For fish up to 10 years old, whole otoliths were usually found to display annuli with fair or good readability. Whole otoliths required less preparation time than other methods and so were used to estimate age. The majority of fish in this project were <4 years old. Sectioned otoliths may be more suitable when analysing samples with a higher proportion of older fish.

A full description of the methodology used by the DoF to age tailor is provided by Lewis *et al.* (in prep). Briefly, whole otoliths were immersing in a 70% glycerol solution and examined under reflected light with a stereo microscope (Nikon SMZ745T) fitted with a digital video camera (Jenoptik ProgRes® Model C7). Video processing software (ProgRes® CapturePro 2.7.6) was used to capture images. The number of opaque zones (annuli) on the otoliths were counted and the otolith margin was assigned to one of three categories: 1) opaque zone at margin, 2) translucent zone at margin, width <50% of previous translucent zone 3) translucent zone at margin, width >50% of previous translucent zone.

The annual periodicity of the opaque zones in tailor sagittal otoliths from WA was validated in this study by marginal increment analysis. Annual opaque zones in tailor otoliths elsewhere have also been validated by this method (Bagenal and Tesch 1978; Robillard *et al.* 2009).

The distance from the core to the inner edge of the first opaque zone (RI) was measured along the otolith rostrum (Fig. 5.2). Winter-spawned fish had a shorter RI than summer-spawned fish. Thus, RI was used to assign an approximate birth date.

Age (in months) was assigned to winter- and summer-spawned tailor, using the following equations:

If RI <0.45 (winter-spawned fish)

If M_c>9 and MI = 3

$$Age\ (months) = (C+1) \times 12 + M_c - 9 + 3$$

If M_c>9 and MI = 1 or 2

$$Age\ (months) = C \times 12 + M_c - 9 + 3$$

If M_c<10 Age (months) = C x 12+M_c+3

If RI >0.45 (summer-spawned fish)

If M_c>9 and MI = 3

$$Age\ (months) = (C+1) \times 12+M_c-9+10$$

If M_c>9 and MI = 1 or 2

$$Age\ (months) = C \times 12+M_c-9+10$$

If M_c<10

$$Age\ (months) = C \times 12+M_c+10$$

where RI = distance from core to inner edge of 1st opaque zone (in mm), M_c = month of capture, MI = marginal increment category, C = number of opaque zones (excluding the core).

Growth was investigated by fitting a von Bertalanffy growth function (VBGF) to length-at-age data for both sexes (pooled data) and each sex separately, and for the WCB (pooled data) and for each Zone within the WCB using non-linear least-squares regression (von Bertalanffy 1938). The ages of juvenile fish calculated from daily increments were included to increase the accuracy of t_0 (hypothetical time at which length is equal to 0).

The von Bertalanffy growth equation used was;

$$L_t = L_\infty (1 - e^{-k(t - t_0)})$$

where L_t is the predicted mean total length (mm) of fish at age t (years), L_∞ is the asymptotic mean total length (i.e. the mean length the fish would reach if they were to grow indefinitely), k is the growth coefficient (year^{-1}) (i.e the rate at which L_∞ is approached), t is the estimated age (years) and t_0 is the hypothetical age (years) at which length is equal to zero.

5.2.4 Reproduction

A gonadosomatic index (GSI) for each fish was calculated as gonad weight (g) divided by the whole body weight (g). If whole weight was not available, an estimated whole weight was calculated from

Whole body weight = 0.0000115 x $TL^{2.97}$ (Gaughan *et al*. 2006)

where TL is total length in millimetres.

Gonads were assigned to one of the following macroscopic gonad developmental stages (Laevastu 1965) :

1. Virgin/immature
2. Maturing virgin/resting adult
3. Developing
4. Partially developed
5. Pre-spawning
6. Spawning
7. Spent
8. Recovering spent

To determine the timing of reproduction, gonads at stage 1 were omitted and those at stages 2 and 8 was grouped as these are functionally similar and difficult to distinguish when viewed macroscopically. Stages 3 to 7 were considered indicative of the reproductive period. Peaks in mean monthly GSI values were also used to indicate the timing of spawning.

The lengths at which 50% (L_{50}) and 95% (L_{95}) of individuals are mature were estimated for male and female tailor in the WCB by logistic regression analysis, which fitted a logistic curve to the probabilities of fish being mature at each specified length. Only samples collected during the reproductive period (defined as October to April) were included. Fish at macroscopic gonad stages 3–7 were classified as mature. Any relatively large fish (>400 mm TL) with gonads at stage 2 or 8 during October–April were also classified as mature.

5.2.5 Mortality

Estimates of the instantaneous rate of total mortality (Z) were calculated from catch-at-age data using the 'catch curve analysis' equation (Ricker 1975):

$$log_e (N_t) = log_e (N_0) - Zt ,$$

where N_t is the number of tailor sampled at age (t) years, Z is the total mortality and N_0 is the number of tailor in the zero age class.

The catch curve procedure involved fitting a linear regression equation to the natural logarithm of the frequency of fish from the most abundant age class in each sample (age 1 or 2), up to the maximum age from that sample. The Z estimate was the slope of the resulting regression equation. For further details of the catch curve method see Section 5.2.4 of Smith *et al.* (2013).

The instantaneous rate of natural mortality (M) was estimated by the general regression equation method of Hoenig (1983);

$$\log_e Z = 1.44 – 0.982 \log_e t_{max}$$

where t_{max} is the maximum age in years either observed in the stock or found in the literature. This method assumes that 1% of individuals reach the maximum attainable age of the species.

Fishing mortality (F) was calculated by subtracting M from Z ($F = Z – M$). A range of F was estimated by subtracting the upper and lower 95% confidence intervals of Z.

F estimates were compared to the biological reference points of F_{target} (=2/3 M), $F_{threshold}$ (= M) and F_{limit} (= 1.5 x M) as described in Section 5.2.4 of Smith *et al.* (2013).

5.2.6 Yield and egg per recruit

Yield per recruit (YPR) models have traditionally been used to predict optimal rates of harvest, corresponding to simulated changes in F, and to avoid the prospect of growth overfishing (where the relative yield from catches starts to decline with increasing F). Egg per recruit (EPR) models have traditionally been used to predict effects of simulated changes in F on relative rate of egg production of the fished stock, whilst avoiding the prospect of recruitment overfishing (where the relative egg production has fallen below some critical reference level). Refer to Section 5.2.5 of Smith *et al.* (2013) for details of the general models used and assumptions.

Management of tailor in the WCB uses a combination of size and bag limits (i.e. legal minimum length (LML) of 300 mm TL; bag limit of eight fish per day with only two fish over 500 mm

TL). To account for the variable selectivity in the upper size limit, yield per recruit (YPR) and egg per recruit (EPR) models were run under two different scenarios with a 'knife-edge' selectivity of either 0 or 1 for fish above 500 mm. An age-at-first capture of 1 year was used, corresponding to the LML of 300 mm TL (Table 5.1). EPR and YPR under these scenarios were compared at each of the *F* values used as target reference points. The actual YPR and EPR were likely to be somewhere between the results of the two scenarios. In the EPR model, whole body weight was used as a proxy for relative egg production. For EPR the *F* at 20% of virgin egg production is regarded as a limit to maintain egg production at sustainable levels (Goodyear 1993, Mace and Sissenwine 1993). For YPR the *F* value that intercepts the YPR curve at 10% of the origin, $F_{0.1}$ of YPR (Hilburn and Walters 1992), is used to predict the sustainable fishing rates rather than the *F* that attains maximum yield (F_{max}).

5.3 Results

5.3.1 Juvenile age and growth

The lengths-at-age of small (TL <150 mm) tailor indicated average growth rates during the early juvenile phase of 0.53–0.81 mm/day, depending on region and sampling period (Table 5.2, Fig. 5.3). The slowest growth was displayed by winter-spawned juveniles in the Metropolitan Zone of the WCB, and the fastest by winter-spawned juveniles in the GCB. Within the WCB, summer-spawned juveniles grew faster than winter-spawned juveniles and those sampled during 2009–10 grew faster than those sampled in 1991–99. A more rigorous assessment which included a higher number of samples that were more evenly distributed across years, seasons and regions would be required to confirm these spatio-temporal trends in growth.

The overall age-length relationship for juvenile tailor in WA (GCB and WCB pooled) was

Age (days) =1.2728 x TL (mm) – 7.90 ($r^2 = 0.868$)

5.3.2 Adult age and growth

Length structure

In 1991–99, tailor collected from the WCB recreational fishery were mostly between 300 and 600 mm TL, with a mean length of 432 mm (Table 5.3, Fig. 5.4). This distribution essentially reflected that of the Metropolitan Zone, which provided the majority (84%) of length samples over this period. The mean lengths of fish from the Mid-west and South-west Zones were slightly smaller (389 and 424 mm, respectively) than those from the Metropolitan Zone (437 mm). In 1991–99, only 2 fish were obtained from the Kalbarri Zone, which were both relatively large (~500 mm).

In 2009–10, the majority of tailor were obtained from the Metropolitan and Mid-west Zones, which collectively provided 82% of samples. The mean lengths in these zones were relatively similar (395 and 399 mm, respectively) with most fish ranging from 300 and 550 mm (Table 5.3, Figure 5.4). The mean length of fish collected in the South-west Zone was slightly larger (411 mm) and the mean length in the Kalbarri Zone was substantially larger (441 mm).

A comparison of samples from 1991–99 and 2009–10 suggests some consistent spatial patterns. In both periods, a small number of exceptionally large (800–1100 mm) fish were obtained from the South-west Zone (Fig. 5.4). Also, fish in the Kalbarri Zone tended to be larger than those in other zones in both periods.

Within the Metropolitan Zone, a comparison of samples suggests a slight truncation in the length distribution (from a typical maximum length of 600 to 550 mm) and a reduction in the mean length between 1991–99 and 2009–10. Over this period, fish >400 mm declined from 54% of samples to 39% and fish >500 mm declined from 25% to 1%.

The changes in the length distribution of Metropolitan samples between 1991–99 and 2009–10 occurred despite an increase in the legal minimum length from 250 to 300 mm over this period. When fish <300 mm were excluded from samples collected in 1999–1999, to provide a sample comparable to that collected in 2009–10, then the decline in mean length was more pronounced, from 447 mm to 395 mm (Fig. 5.4).

The decline in mean length may partly reflect a shift in capture location. In 1991–99, the majority (84%) of Metropolitan samples were supplied by boat-based recreational fishers who fished offshore. In 2009–10, the majority (83%) of samples were supplied by shore-based fishers. In both sampling periods, offshore fish displayed a larger mean length than inshore (shore-caught) fish (Fig. 5.5). However, when the effect of capture location was removed, there was still evidence of a decline in length over this period in Metropolitan samples. Specifically, the mean length of inshore (shore-caught) fish declined from 430 to 386 mm, while the mean length of offshore fish declined from 450 to 439 mm (Fig. 5.5).

Age structure

The annual periodicity of annual opaque zones in tailor otoliths collected from the WCB was validated by monthly marginal increment analysis. Otoliths with 0–6 opaque zones were analysed, plus a single otolith with 10 zones. Opaque material was deposited at the otolith margin during the latter part of each year, with a peak during September–November (Fig. 5.6). This annual opaque zone became fully delineated in summer at the commencement of a marginal translucent zone. The translucent zone began to form in December.

A total of 543 tailor collected from the WCB in 2009–10 were aged. Otolith readability was classified as ‘poor’ for 11% of these fish, with the remainder being ‘fair’ (46%), ‘good’ (43%) or ‘excellent’ (<1%). A very low proportion (<1%) of the otoliths collected in 2009–10 were classified as ‘unreadable’ and were not aged, mainly due to naturally occurring deformities within the otolith or damage during processing.

The majority of aged fish were from the Mid-west (n=269) and Metropolitan Zones (n=200), with relatively few fish obtained from the Kalbarri (n=20) or South-west Zones (n=54) (Fig. 5.7). Overall, the ages of tailor sampled from the WCB in 2009–10 ranged from 1 to 6 years, with the exception of a single fish aged 10 years. The majority (97%) were aged <4 years (Fig. 5.7).

The dominant age class in the Kalbarri and Mid-west Zones was 2 y, whereas the 1 and 2 y age classes were equally dominant in the Metropolitan and South-west Zones. Tailor aged ≤2 years of age (which includes a large proportion of immature fish, see below) comprised 70% of Kalbarri samples, 82% of Mid-west samples, 90% of Metropolitan samples and 74% of South-west samples.

Growth

The von Bertalanffy growth curve was a poor fit at older (>5 y) ages, due to the lack of data for older fish. Apparent differences in the estimated growth parameters between males and females in the WCB were driven by the presence of a single 10 year old male. When this individual was excluded, the estimated parameters were similar for both sexes (Fig. 5.8). The von Bertalanffy growth parameters (sexes pooled) were: L_{∞} = 592 mm TL, k = 0.464, t_0 = -0.096 (Table 5.4). Based on these parameters, individuals reach an average of 236 mm TL after 1 year, 368 mm after 2 years and 451 mm after 3 years.

The two largest (and oldest) tailor observed during this project were males, which were captured at Augusta in the South-west Zone of the WCB. A 1,052 mm male (age unknown) was caught in 1998 and a 1,033 mm male (age 10 years) was caught in 2010 at this site. The largest females observed were 799 mm (caught at Carnarvon (GCB) in 1995, age unknown) and 703 mm in 2010 (caught at Jurien (Mid-west Zone WCB) in 2010, age 6 years). The maximum age recorded for tailor in WA is 10 years (this project).

5.3.3 Reproduction

Length-at-maturity

The L_{50} values for female and male tailor in the WCB were estimated to be 292 and 322 mm, respectively (Table 5.5). The logistic regressions describing the probability of maturity at a given length were significantly different for females and males (likelihood ratio test, $p < 0.001$).

The vast majority of female gonads at macroscopic stages 0, 2, 3, 7 and 8 had GSI values of <0.02, while GSI values >0.02 were mainly associated with macroscopic stages 4, 5 and 6. Hence, GSI >0.02 was indicative of reproductive activity. GSI values >0.02 were not observed in females <288 mm and were relatively common in females >370 mm, suggesting that maturity was attained over this length range (i.e. 288–370 mm) (Fig. 5.9a). Similarly, in males GSI >0.005 appeared to be indicative of reproductive activity. GSI values suggested that maturity in males was attained over a length range of 279–340 mm (Fig. 5.9b). These length ranges are in agreement with the estimated L_{50} for females. The maximum observed GSI values for females and males were 0.13 and 0.05, respectively.

Spawning period

Monthly GSI trends differed between zones, suggesting different spawning periods in each area (Fig. 5.10). In the GCB, relatively high average GSI values were observed over an extended period (April–December), with localised peaks around May and October. Few samples were available from the Kalbarri Zone of the WCB, but these suggested similar monthly GSI values and trends to those observed in the GCB. Within each zone, the average monthly GSI trend was similar for males and females (Fig. 5.10).

In northern areas (i.e. GCB, Kalbarri Zone) average monthly GSI values were typically higher than those in southern areas (Mid-west, Metropolitan and South-west Zones) (Fig.5.10). In southern areas, GSI peaked in autumn and spring/early summer although the timing and magnitude differed slightly between zones. In the Mid-west Zone, GSI peaked at similar levels in April/May and November/December. In the Metropolitan Zone, there was a pronounced GSI peak in March with only slightly elevated levels in spring/early summer. In the South-west Zone there was a pronounced GSI peak in April with only slightly elevated levels in spring/early summer.

The occurrence of ‘spawning’ stage gonads (i.e. macroscopic stage 5/6) in each zone was consistent with the spawning periods indicated by GSI values. In the GCB, stage 5/6 gonads were observed over an extended period (March to November) (Figs. 5.11, 5.12). In southern areas (Mid-west, Metropolitan and South-west Zones), stage 5/6 gonads were mainly observed in autumn and spring/early summer. Some stage 5/6 gonads were also observed in late summer (January/February) in southern areas.

Overall, the available reproductive data suggests an extended spawning period in the GCB, and perhaps also in the Kalbarri Zone, over the cooler months (autumn, winter, spring), with a peak in activity during spring. In southern areas, there is an extended spawning period over the warmer months (spring, summer, autumn), with peaks in activity during autumn and spring. A greater level of spawning activity appears to occur in autumn than spring in the Metropolitan and South-west Zones.

Sex ratio

The sex ratio in commercial and recreational landings of tailor in the WCB was typically biased towards females, ranging from 50 to 72 % female depending on month and sector (Fig. 5.13). Within both sectors, the proportion of females was higher during autumn than in other seasons. From 1991–2010, the overall proportion of females in landings from each sector was 60%. The overall sex ratio was significantly different from parity in both sectors (chi squared tests: WCB commercial, n=409, $P<0.01$; WCB recreational, n=2085, $P<0.01$).

The female bias in WCB landings was persistent across years. For example, WCB recreational landings comprised 53 to 67% females per year (Fig. 5.14). The female bias was also persistent across length classes. In the WCB, females comprised 53–80% of fish in each 50 mm length class (Fig. 5.15).

The sex ratio of tailor in fishery landings in the GCB is uncertain due to limited sampling. Females comprised 54% of all fish sampled from this Bioregion. However, a total of only 396 fish were collected from the GCB (sectors combined) during 1991–1996.

5.3.4 Mortality

Natural mortality

Based on a maximum age of 10.4 years recorded for tailor in WA, natural mortality in this stock was estimated to be $0.42.yr^{-1}$. A maximum age of 13 years has been reported globally for tailor. Using this value, natural mortality was estimated to be $0.34.yr^{-1}$.

Total and fishing mortality

Estimates of total mortality (Z) and fishing mortality (F) with 95% confidence intervals for tailor were derived from the age composition of total recreational fishery landings in the WCB (all zones pooled). The age of fish sampled in the WCB in 2009–10 ranged from 0 to 6 years, with the exception of a single fish aged 10 years collected from the South-west Zone. This single fish had a large effect on the Z estimated from catch curve analysis. Therefore, Z was estimated from catch-at-age datasets including and excluding the single 10 year old fish. The median Z value derived from the full WCB dataset was $0.67.yr^{-1}$, resulting in a median estimate of F of $0.25.yr^{-1}$ (just below F_{target}) (Table 5.6, Fig. 5.16). The removal of the single oldest fish increased the median estimate of Z to $1.22.yr^{-1}$, and the median F estimate to $0.80.yr^{-1}$ (above F_{limit}).

Estimates of mortality were also derived from the age composition of recreational landings in only the Mid-west and Metropolitan Zones, where the majority of WCB samples were collected

(Fig. 5.16). A median *F* value of 0.98.yr^{-1} (above F_{limit}) was estimated from the pooled data from these regions (Table 5.6). Sample sizes within each zone were relatively low (<300 fish) and so these mortality estimates should be interpreted with caution due to the potentially unrepresentative nature of the samples.

Overall, the confidence intervals around all mortality estimates for tailor were relatively wide, reflecting a high level of uncertainty about these estimates (Fig. 5.16).

5.3.5 Yield and egg per recruit

Due to the size-related daily possession limit for tailor (i.e. recreational fishers are restricted to only two fish >500 mm TL in the WCB) and the inability to assign selectivity values to fish above this size, estimates of EPR and YPR were generated under two scenarios (with and without a maximum legal length, MaxLL) (Fig. 5.17). In reality, estimates are likely to be between those bracketed by these scenarios.

At F_{limit}, the EPR without MaxLL was 20.0% of virgin egg production (Table 5.7). With MaxLL, EPR increased to 25.2% virgin egg production at F_{limit}, indicating that the inclusion of the MaxLL increased the resilience of this stock to the prospect of potential recruitment overfishing. For both scenarios, the EPR at $F = 1.5M$ approximated or was slightly above the level at 20% of the EPR_0, suggesting that $F = 1.5M$ may be an appropriate limit reference level for this stock, if reliable estimates of *F* exist for comparison. Unfortunately, however, current estimates of *F* are highly uncertain, and so are not available to assess against these reference levels.

The calculated YPR was lower under the scenario with MaxLL (500 mm), particularly for the lower values of *F* (Table 5.7). For example, YPR at F_{target} was only 75.5% of $F_{0.1}$, compared to 99.5% without MaxLL. This suggests that tailor are more resilient to growth overfishing under the scenario with MaxLL.

5.4 Discussion

5.4.1 Growth rate

The growth rates estimated in this study for early juvenile tailor (0.5–0.8 mm/day over the first 3 months) are slightly slower than those reported for tailor on the Australian east coast (0.7–1.3 mm/day (Juanes *et al.* 1996)) and the north American east coast (0.7 to 2.1 mm/day (McBride and Conover 1991, Creaser and Perkins 1994, Juanes 1996, Able *et al.* 2003)).

In the WCB, a growth rate of 0.42–0.44 mm/day was previously estimated for older juvenile tailor (size range of 150–250 mm TL, age 6–18 months) during a tag-recapture study (Young *et al.* 1999). This suggests that the growth rate of tailor in WA slows after fish attain an age of 6 months.

The range of growth rates estimated for early juveniles in WA may reflect spatial and temporal variations in water temperature. The fastest growth was exhibited by winter-spawned juveniles in the GCB and the slowest by winter-spawned juveniles in the Metropolitan Zone of the WCB. In winter, mean monthly temperatures are 2–4 °C higher in the GCB than in the Metropolitan Zone (Pearce *et al.* 1999). Within the WCB, summer-spawned juveniles grew faster than winter-spawned juveniles, consistent with temperatures in this zone that are 5–7 °C higher in summer than in winter. Also, growth was faster in 2009–10 than in 1991–99, which is consistent with a general warming trend in ocean temperature around the south-west coast of WA.

The growth parameters estimated for adult tailor in WA (L_∞ = 518.3 mm TL, k = 0.46, t_0 = -0.096) differ to those reported for tailor populations elsewhere, including a relatively low L_∞ and high k value (Bade 1977, Krug and Haimovici 1989, Govender 1999, Robillard *et al.* 2009). These differences may partly reflect actual variations in growth rates between populations, but the parameters for WA are also likely to be inaccurate due to under-sampling of older fish. Despite tailor attaining a maximum age of at least 10 years in WA, few fish >5 years old have been collected by DoF since sampling commenced in the early 1990s. The von Bertalanffy growth model was a poor fit at older (>5 y) ages, mainly due to the lack of data for older fish. The inclusion of older fish would increase the value of L_∞ and decrease the value of k (L_∞ and k are inversely related, Gallucci and Quinn 1979). Growth parameters should be revised when samples of older fish become available.

5.4.2 Age & length composition

In both sampling periods (1991–99 and 2009–10) the lengths of tailor collected in nearshore and offshore waters of the Metropolitan Zone suggested that larger (and presumably older) tailor occur around offshore reefs in this region, which is consistent with previous research (Young *et al*. 1999) and anecdotal reports from recreational fishers. Also, limited sampling suggested that the average length and age of tailor in the Kalbarri Zone is greater than those caught in other WCB zones. This is consistent with evidence of a net northwards migration by adult tailor along the west coast and an accumulation of spawning stock in northern areas (Kalbarri Zone and the GCB) (Section 2). The lengths of tailor reported by volunteer logbook fishers also indicated a larger average length in the GCB (Section 4). Overall, there is strong evidence of larger/older tailor occurring in northern areas and in offshore waters, while smaller adults dominate nearshore habitats in southern areas. Similar ontogenetic shifts in distribution have been observed in other tailor stocks (Lund and Maltezos 1970, Salerno *et al.* 2001, Lucena *et al*. 2002, Shepherd *et al.* 2006).

Given this distribution, the scarcity of samples from offshore and northern areas in 2009–10 is of concern. It is likely that under-sampling of these areas resulted in length and age compositions that were biased towards smaller and younger fish. In future, obtaining a sample that was more representative of the stock would require additional sampling effort in these areas to capture the older components of the stock.

The bias towards smaller and younger fish is potentially exacerbated by the current recreational fishery management arrangements, including a possession limit of only two fish over 500 mm, which could restrict the sampling of larger/older fish. However, lengths of retained and released fish reported by volunteer logbook fishers indicated that a negligible number of fish >500 mm were taken in recent years (Section 4). This suggests that the maximum size limit had little impact on the composition of the 2009–10 sample. In future, the maximum size limit could be a significant source of bias, especially when sampling offshore and northern areas.

The length composition of tailor sampled from the WCB recreational fishery in 2009–10 was truncated relative to those collected in 1991–99, particularly in the Metropolitan Zone. Several confounding factors may have contributed to this difference, including differences in capture location (mostly offshore in 1991–99 versus mostly nearshore in 2009–10) and changes in management arrangements (bag and size limits) between periods. However, after accounting for these effects, length truncation was still evident. Fish collected in 1991–99 were not aged and so any change age composition over this period could not be assessed.

5.4.3 Reproduction

As in other tailor populations (e.g. Robillard *et al.* 2009), male and female tailor in WA were found to grow at a similar rate during their adult life, although females in WA appeared to attain maturity at a slightly smaller size than males ($L_{50\%}$ of 292 mm versus 322 mm). In other tailor populations both sexes attain maturity at a similar size (van der Elst 1976, Bade 1977, Salerno *et al.* 2001) and this may also be the case in WA. In future, a histological analysis of gonads and more sampling of older fish in northern and offshore areas could provide a more accurate estimate of the length-at-maturity of tailor in WA. In the interim, an approximate $L_{50\%}$ value of 320 mm should be considered for both sexes.

The sex ratio of tailor sampled from recreational fishery landings in WA showed a consistent bias towards females that existed across size classes, regions and years. Overall, females comprised 60% of samples obtained from the recreational fishery. Females may naturally be more prevalent in the population or may be more susceptible to capture by recreational line fishing. In future, a comparison with the sex ratio of commercial landings (which are netted) would assist in identifying any selectivity bias in the recreational fishery. In other tailor populations, sex ratio is 1:1 (van der Elst 1976, Bade 1977, Shepherd and Packer 2006).

Current knowledge of spawning times and locations by tailor in WA waters is limited. The available data suggest an extended spawning period in northern areas (the GCB and the Kalbarri Zone of the WCB) over the cooler months (autumn, winter, spring), with a peak in activity during spring. In southern areas (Mid-west, Metropolitan and South-west Zones of the WCB), there is an extended spawning period over the warmer months (spring, summer, autumn), with peaks in activity during autumn and spring. Autumn is apparently the main spawning period in the Metropolitan and South-west Zones, whereas autumn and spring are probably equally important in the Mid-west Zone.

The spawning periods identified in each region are associated with local mean monthly water temperatures ranging from 18 to 24 ºC, suggesting this may be the preferred range for spawning by tailor (Pearce *et al.* 1999). In summer, temperatures >24 ºC occur frequently in the GCB, and occasionally in the Mid-west Zone. In winter, temperatures are typically below 18 ºC in southern areas. A preferred temperature range of 20–25 ºC was previously suggested by Lenanton *et al.* (1996), based on a limited number of observations of tailor in WA waters. Globally, spawning by tailor appears to be restricted to 18–27 ºC (Sabates *et al.* 2012).

These spawning periods have been inferred from relatively low levels of sampling in each region, with the exception of the Metropolitan Zone. Given the high level of spawning activity that evidently occurs in the GCB and Kalbarri Zone, and the potential importance to the stock as the main source of recruitment (see Section 2), significantly more data should be obtained to elucidate the timing and location of spawning in these northern areas.

Another area of special interest is the Houtman-Abrolhos Islands. The reproductive data (GSI and macroscopic stage) for the Mid-west Zone presented in this Section excluded samples collected from these islands, which are located approximately 80 km offshore within this Zone. During 1994–1998, a total of 110 tailor were collected from the Houtman-Abrolhos Islands. However, sampling was restricted to June, October and November only. In each of these months almost all fish displayed signs of imminent/recent spawning activity (i.e. stages 3–7). In total, 84% of females and 96% of males possessed gonads at stage 3–7. The Houtman-Abrolhos Islands are located near the edge of the continental shelf and experience the continuous influence of the warm southward Leeuwin Current. Although maximum summer water temperatures can exceed 24 ºC, the mean monthly temperatures remain between 18 and 24 ºC all year, suggesting that this area may provide suitable spawning conditions throughout the year.

Although there are many gaps in knowledge about the spawning times and locations, it is clear that spawning by tailor in WA occurs in multiple discrete events, which indicates the existence of multiple groups of spawners that are spatially and temporally separated. These groups collectively comprise the total breeding stock. This stock structure is similar to that observed in tailor populations elsewhere (Shepherd *et al.* 2006, Hedger *et al.* 2010). In other populations, the contribution by each spawning group to annual fishery landings is not equal (Conover *et al.* 2003). Hence, identifying the spawning groups in WA and their relative contributions to fishery landings is likely to assist in ensuring the sustainable management of this stock.

5.4.4 Assessment

The estimated rate of natural mortality (M) for tailor used in the assessment of fishing mortality was $0.42.yr^{-1}$, based on an observed maximum age of 10.4 years in WA. Globally, the maximum age reported for tailor is 13 y (Robillard *et al.* 2009). If this value occurred in the WA population then the true value of M would be $0.34.yr^{-1}$.

Estimates of total mortality (Z) and fishing mortality (F) in 2009–10 were considered unreliable due to biases in the age composition and low sample sizes. The under-representation of older fish is likely to have resulted in over-estimates of Z and F. Rates of $Z = 0.67.yr^{-1}$ and $F = 0.25.yr^{-1}$ were estimated, based on the age composition of pooled samples from the WCB which included all older fish sampled during 2009–10, but actual mortality rates may be lower. In addition, the number of fish aged within each zone was <300 which has been recommended as the minimum sample required for a robust estimate of total mortality (Craine *et al*. 2009). Therefore, sample composition within each Zone, and in the pooled WCB sample, may be unrepresentative.

The very wide 95% confidence interval around the median F value of $0.25.yr^{-1}$ reflects the high level of uncertainty in this estimate (Fig. 5.16). This interval extends from below the F_{target} (i.e. sustainable) to well above the F_{limit} (i.e. unsustainable), making the F-based assessment uninformative.

The YPR and EPR model results support the selection of $F = 1.5M$ as an appropriate limit reference point for this stock. At $F = 1.5M$, YPR was similar to the yield at $F_{0.1}$ and EPR was 20–25% of virgin egg production. YPR at $F_{0.1}$ and EPR at 20% virgin level relate to widely used benchmarks for fisheries management based on historical experience globally. Unfortunately, current estimates of F for the tailor stock are highly uncertain and so not available to assess against these reference levels.

A wide range of potential F values from 0.25 to $0.98.yr^{-1}$ were estimated, although these are not equally likely. At the highest estimate of $F = 0.98$ (the 'worst case scenario'), EPR is between 11.4 and 13.6 % of virgin production. However, 0.25 is likely to more closely reflect the current F level. At $F = 0.25$, which is just below F_{target}, EPR is between 46.5 and 56.1% of virgin production.

The YPR and EPR model results suggest that current management arrangements (LML of 300 mm, bag limit of 8 with only 2 fish >500 mm) are effective in reducing the risk of growth or recruitment overfishing. This assumes a high rate of post-release survival, which is likely to be true for smaller fish (<350 mm) (Ayvazian *et al.* 2002).

The YPR and EPR analyses are based on an assumption of constant annual recruitment, which is clearly not the case for tailor (Section 2). Variable recruitment is characteristic of many fish species and is a common source of uncertainty when conducting per recruit analyses.

A more robust assessment of fishing mortality in the tailor stock in WA would require a more representative sample of the age structure. This would require an increase in sample size in each region, and also a substantial increase in sampling effort (perhaps including a fishery-independent survey) to obtain both inshore and offshore fish in each region.

In 2009–10, a total of only 543 tailor were sampled and aged over an 18 month period, with <300 fish from each zone, even in the popular Metropolitan Zone. Minimal samples were obtained from the South-west and Kalbarri Zones. This outcome suggests that obtaining a representative age sample of tailor from the recreational fishery is not feasible at the current level of resourcing. A further problem with sampling the recreational fishery is the potential bias due to management restrictions (size and bag limits) that may limit the number of older fish retained.

Significantly more information is required about the northern portion of the stock (in the GCB and Kalbarri Zone) because this may be the main source of recruitment to the WCB. Sampling in this region could partly be achieved with assistance from the commercial sector.

Table 5.1. Parameters used in Egg Per Recruit and Yield Per Recruit models for tailor under the scenarios i) without Legal Maximum Length and ii) with Legal Maximum Length (500 mm TL).

Parameter	Value
L_∞ (in mm)	592
k	0.464
t_0	-0.096
$L_{50\%}$ (in mm)	292
$L_{95\%}$ (in mm)	393
Alpha Weight	0.0000164
Beta Weight	2.9013
Full selectivity (age, in years)	1
Natural mortality (M)	0.423
Maximum age (in years)	10.4
Alpha Fecundity	-9.9703
Beta Fecundity	21.429

Table 5.2. Size range, average growth rate (from slope of regression) and r^2 values for regression of age (in days) versus length for juvenile tailor by region, year and spawning period.

Region	Year	Spawning period	No.	Size range (mm)	Growth rate (mm/day)	r^2
GCB	1995 & 1998	Winter	23	56–121	0.811	0.418
Mid-west zone (WCB)	2010	Summer	22	44–92	0.740	0.829
Metropolitan zone (WCB)	1998	Winter	21	57–94	0.532	0.406
	1999	Summer	29	34–71	0.640	0.303
	2010	Summer	65	29–70	0.717	0.417
South-west zone (WCB)	1997–2000	Winter	63	41–109	0.620	0.378
	2010	Summer	26	66–112	0.782	0.646

Table 5.3. Average total length (TL in mm) and number of tailor collected from recreational fishers in each zone of the West Coast Bioregion (WCB) during 1991–99 and 2009–10. Note: only tailor above the Legal Minimum Limit (LML) at the time, i.e. 250 mm in 1991–99 and 300 mm in 2009–10, are included. Samples from 1991–99 included some fish below the LML but it is unclear whether these were representative of the recreational catch at the time or were obtained specifically for biological analysis.

Zone	1991–99		2009–10	
	Average TL	Number	Average TL	Number
Kalbarri	506	2	441	38
Mid-west	389	123	399	316
Metropolitan	437	1136	395	217
South-west	424	86	414	79
WCB (all Zones)	432	1347	400	650

Table 5.4. Estimated von Bertalanffy growth parameters (L_∞, k and t_0) with standard error (s.e.) and 90% confidence interval, male and female tailor sampled in the West Coast Bioregion (WCB) in 2009–10.

	L_∞			k			t_0		
	Est	s.e.	90% CI	Est	s.e.	90% CI	Est	s.e.	90% CI
Overall	592	15	562–622	0.464	0.026	0.413–0.515	-0.096	0.020	-0.135–0.057
Male	660	33	596–724	0.369	0.035	0.300–0.438	-0.130	0.027	-0.183–0.077
Female	546	11	525–568	0.569	0.027	0.516–0.622	-0.036	0.013	-0.062–0.010

Table 5.5. Lengths-at-maturity (L_{50} and L_{95} , total length, in millimetres) for tailor in the WCB (n = number of .samples).

	L_{50}	L_{95}	n
Males	322	393	647
Females	292	393	990

Table 5.6. Samples size (*n*), total mortality rate (*Z*) with 95% confidence intervals (CI), natural mortality rate (*M*) and fishing mortality rate (*F*) for tailor sampled from WCB recreational landings, 2009–10. (* oldest fish excluded).

Zone	*n*	*Z* (95% CI)	*M*	*F*
All WCB	543	0.67 (0.51–1.49)	0.42	0.25
All WCB*	542	1.22 (0.93–1.57)	0.42	0.80
Mid-west + Metropolitan	469	1.40 (1.10–2.07)	0.42	0.98
Mid-west	269	1.52 (1.21–2.01)	0.42	1.10
Metropolitan	200	0.81 (0.58–1.10)	0.42	0.39

Table 5.7. Outputs of Yield Per Recruit (YPR) and Egg Per Recruit (EPR) models for tailor under scenarios with and without a Maximum Legal Length (MaxLL), compared at various *F*-based reference points.

Model	Scenario	Reference point	*F* value	Value	% of $F_{0.1}$	% of EPR_{Virgin}
YPR	Without MaxLL	F_{Target}	2/3 *M*	114	99.5	
		$F_{Threshold}$	*M*	121	105.8	
		F_{Limit}	1.5 x *M*	119	103.6	
		$F_{0.1}$	0.288	115	100	
		F_{Max}	0.466	122	106.1	
	With MaxLL	F_{Target}	2/3 *M*	71	75.5	
		$F_{Threshold}$	*M*	87	91.7	
		F_{Limit}	1.5 x *M*	97	102.6	
		$F_{0.1}$	0.559	94	100.0	
		F_{Max}	0.839	99	104.9	
EPR	Without MaxLL	Virgin	0	559		100
		F_{Target}	2/3 *M*	239		42.8
		$F_{Threshold}$	*M*	171		30.6
		F_{Limit}	1.5 x *M*	112		20.0
	With MaxLL	Virgin	0	559		100
		F_{Target}	2/3 *M*	292		52.2
		$F_{Threshold}$	*M*	215		38.6
		F_{Limit}	1.5 x *M*	141		25.2

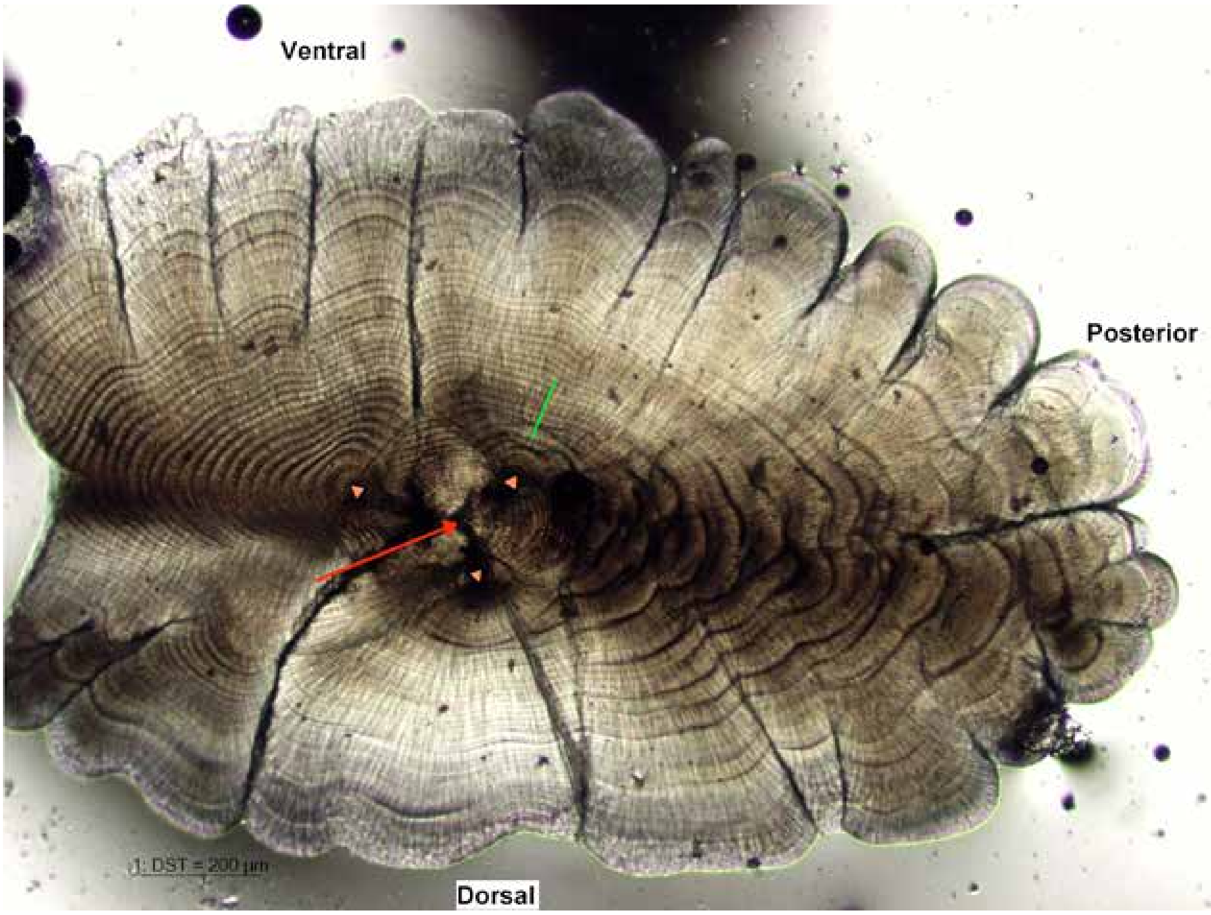


Figure 5.1. Polished whole juvenile tailor otolith (TL = 62 mm, micro-increment count = 67) (red arrow – primordium; orange triangle – secondary growth nucleus; green line – 10 micro-increments in secondary growth zone).

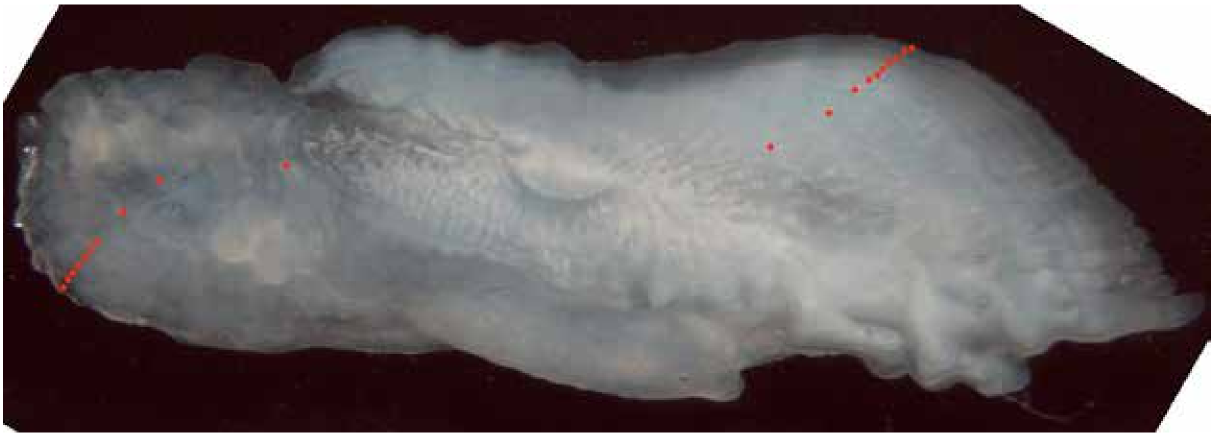
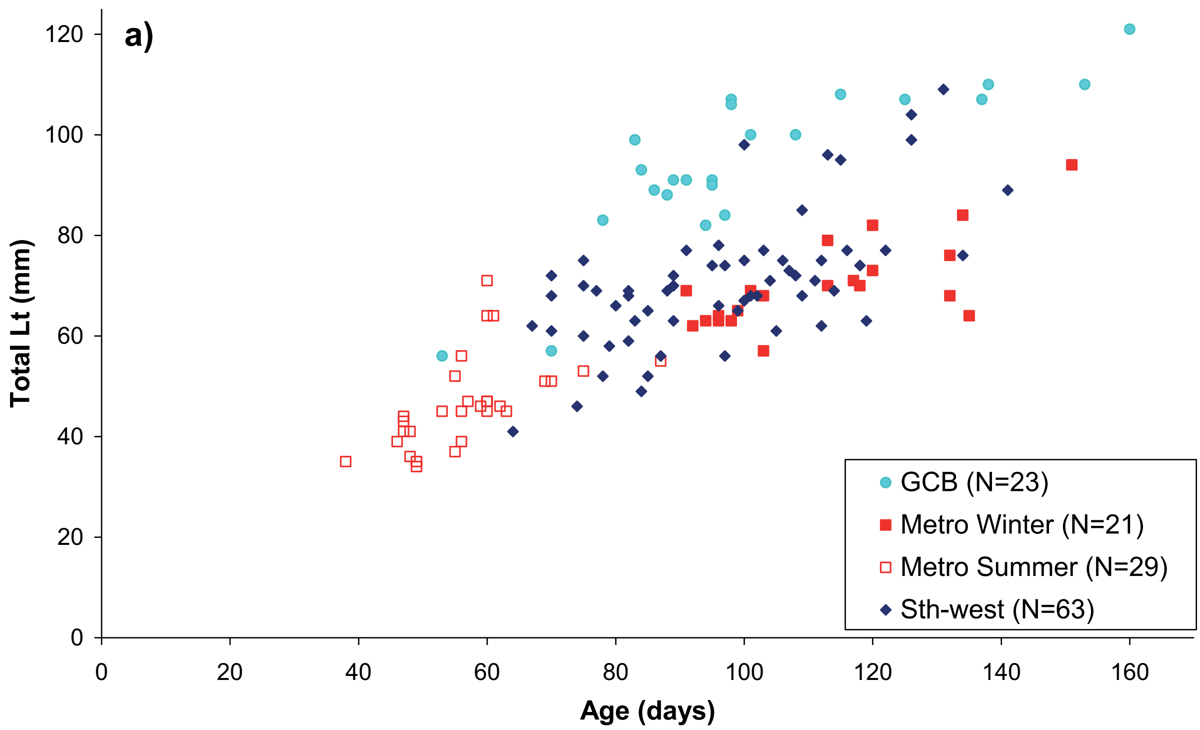


Figure 5.2. Whole sagittal otolith of adult tailor (TL = 1040 mm) with red dots indicating 10 annuli on the rostrum (bottom left) and posterior dorsal (top right) areas.



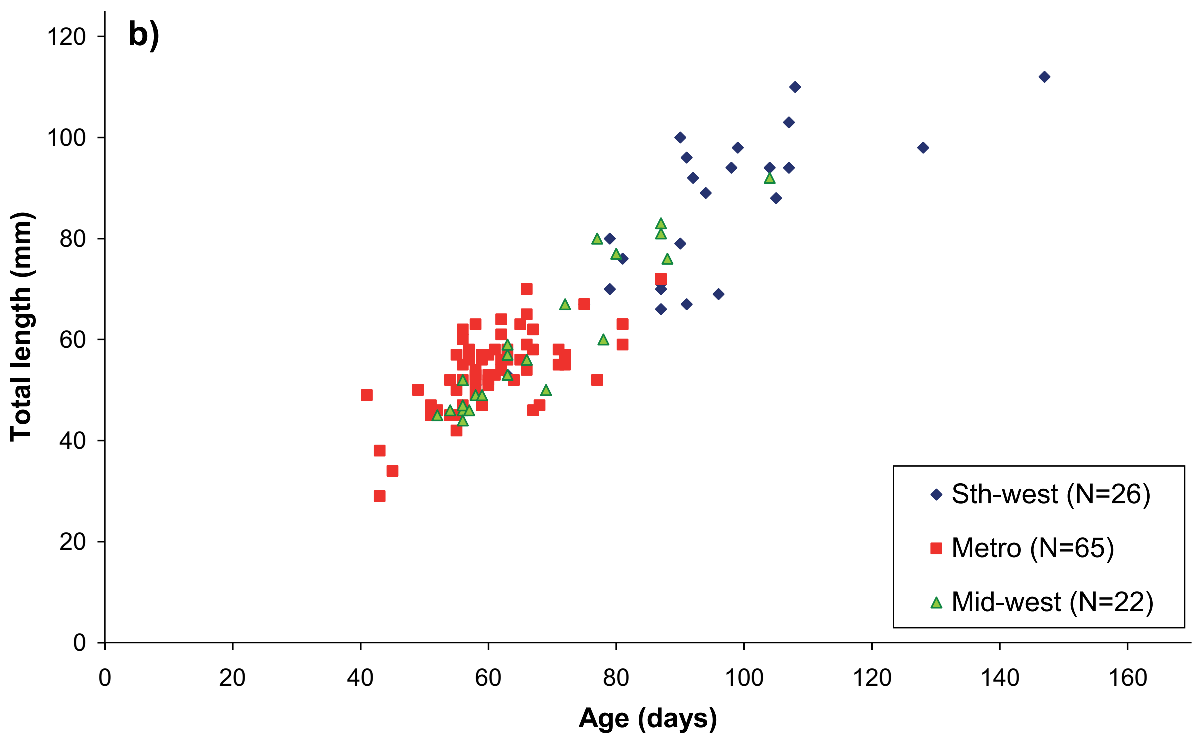


Figure 5.3. Length versus age of juvenile tailor from the GCB and various WCB Zones in **a)** 1991–1999 and **b)** 2009/10.

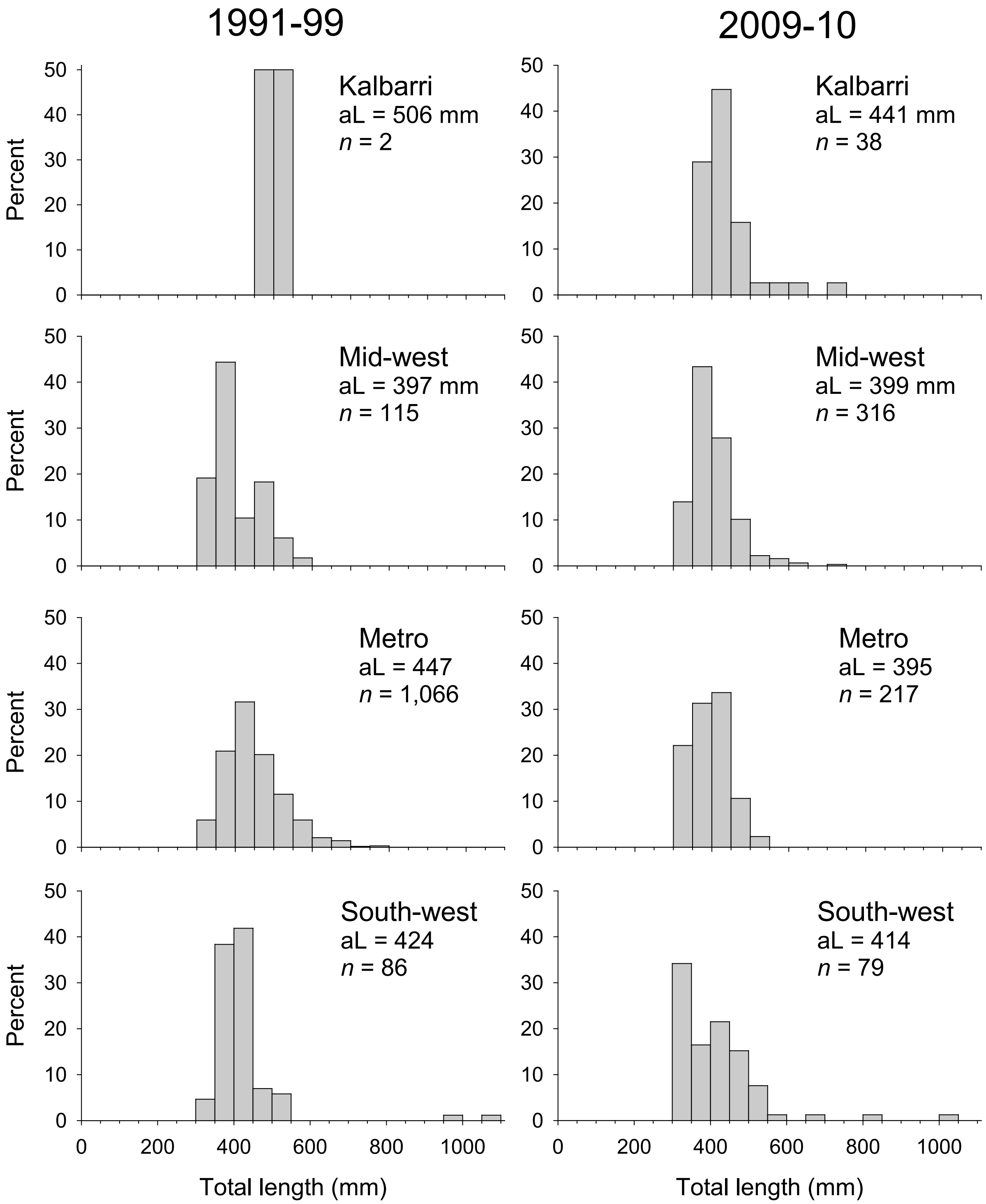


Figure 5.4. Length composition of recreationally caught tailor by sampling period (1991–99 and 2009–10) for the four management Zones of the West Coast Bioregion. (n – number of fish measured; aL – average length of fish in sample; fish <300 mm not shown).

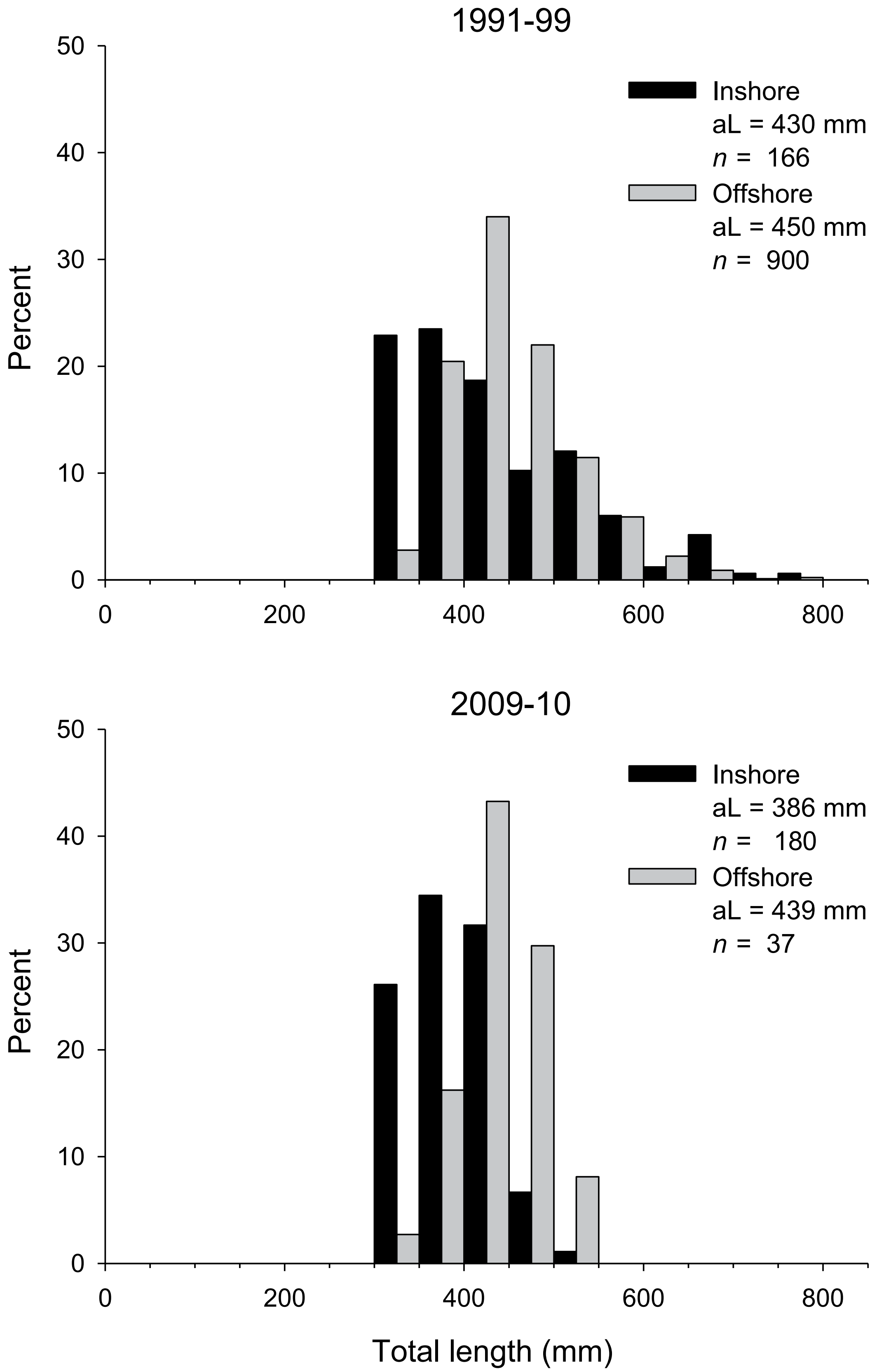


Figure 5.5. Length composition of recreationally caught tailor in the inshore and offshore areas of the Metropolitan Zone by sampling period (1991–99 and 2009–10). (n – number of fish measured; aL – average length of fish in sample).

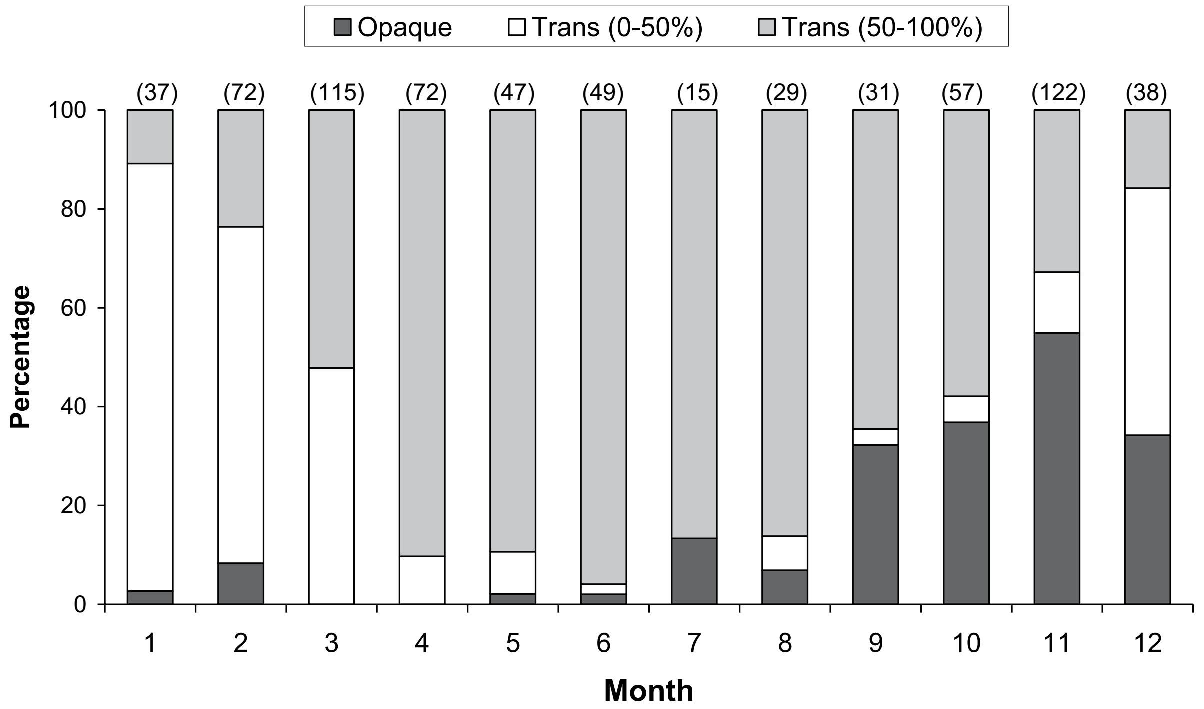


Figure 5.6. Proportions of marginal increment categories in tailor otoliths sampled monthly during 2009–10 in the West Coast Bioregion (monthly sample size given above bars; ‘trans’ – translucent).

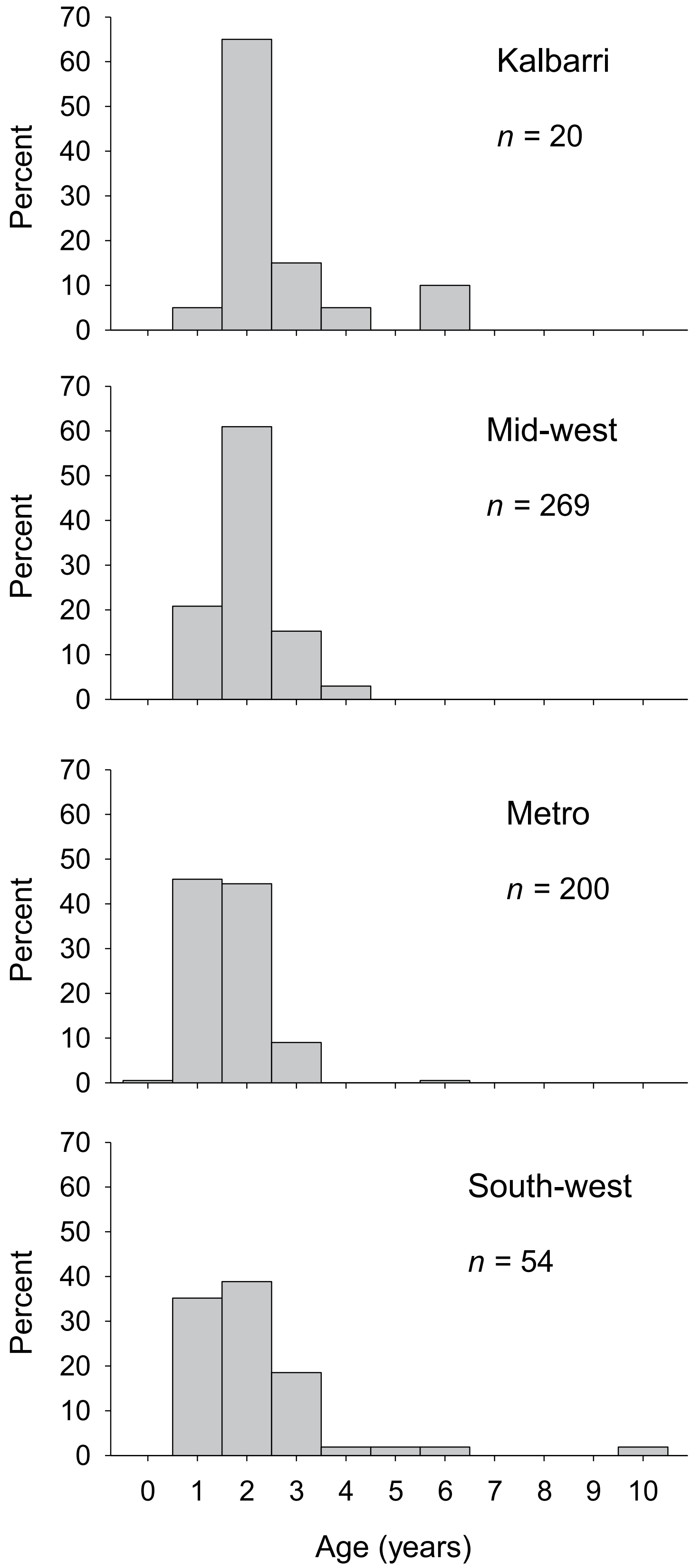


Figure 5.7. Age composition of tailor sampled from the WCB recreational fishery during 2009–10 in each of the four management Zones of the West Coast Bioregion. (n – number of fish aged).

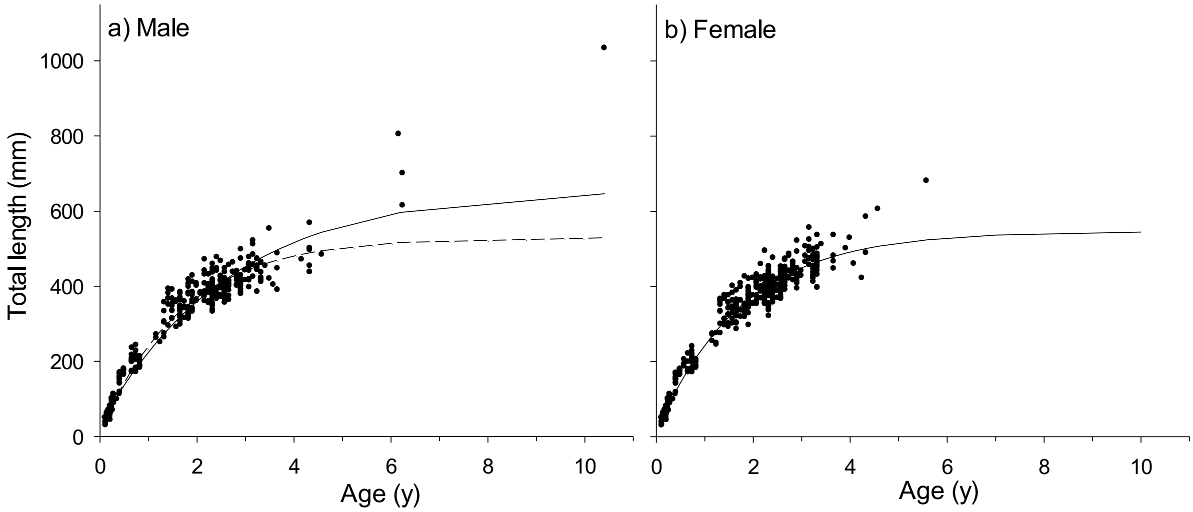


Figure 5.8. Observed length versus age of **a)** male tailor, fitted with growth curve calculated from all observations (solid line) and without oldest fish (dotted line) and **b)** female tailor, fitted with growth curve calculated from all observations, sampled in the West Coast Bioregion, 2009–10.

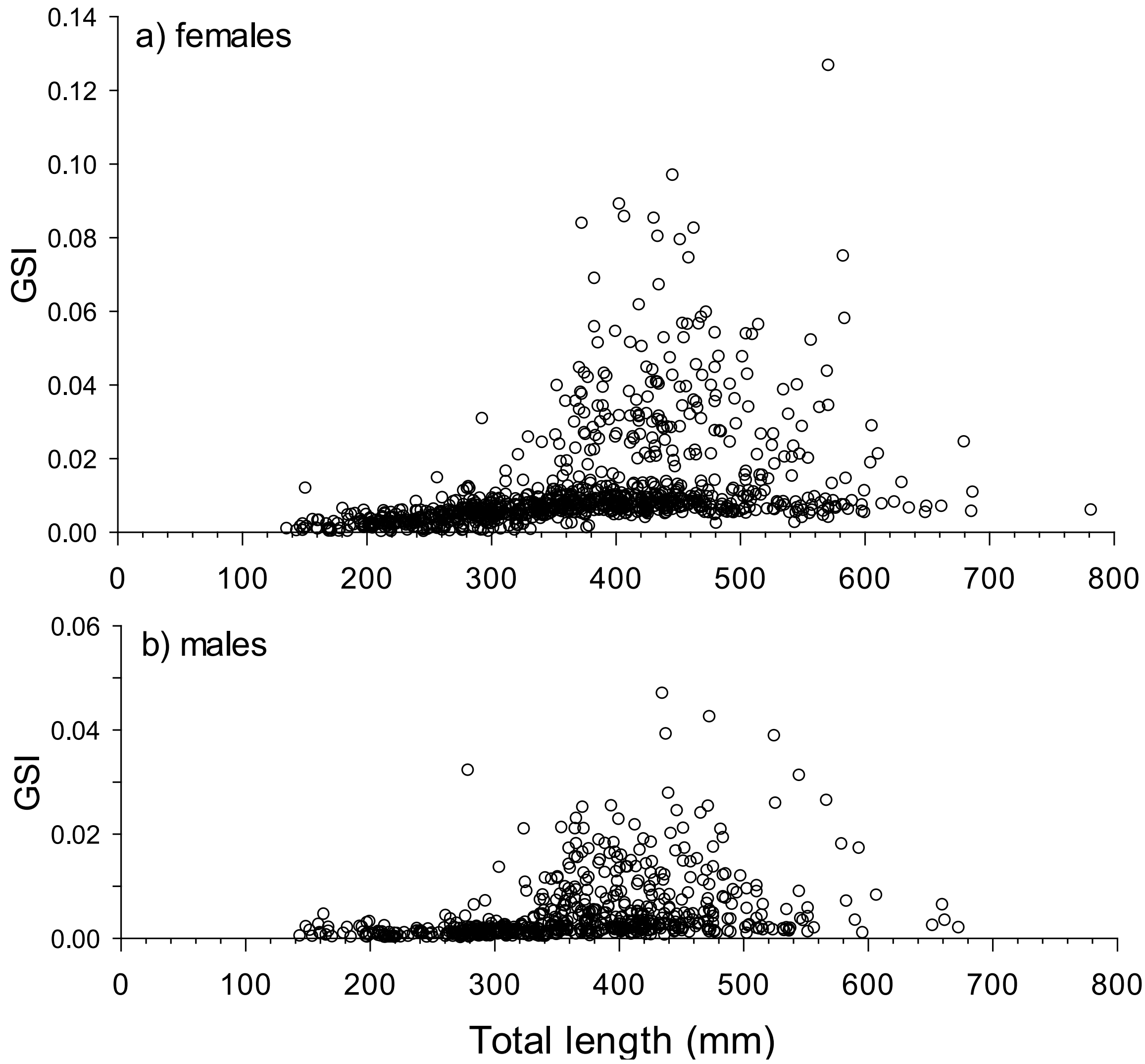


Figure 5.9. Gonadosomatic Index (GSI) versus length of **a)** female and **b)** male tailor sampled from the West Coast Bioregion during October–April, 1991–2010.

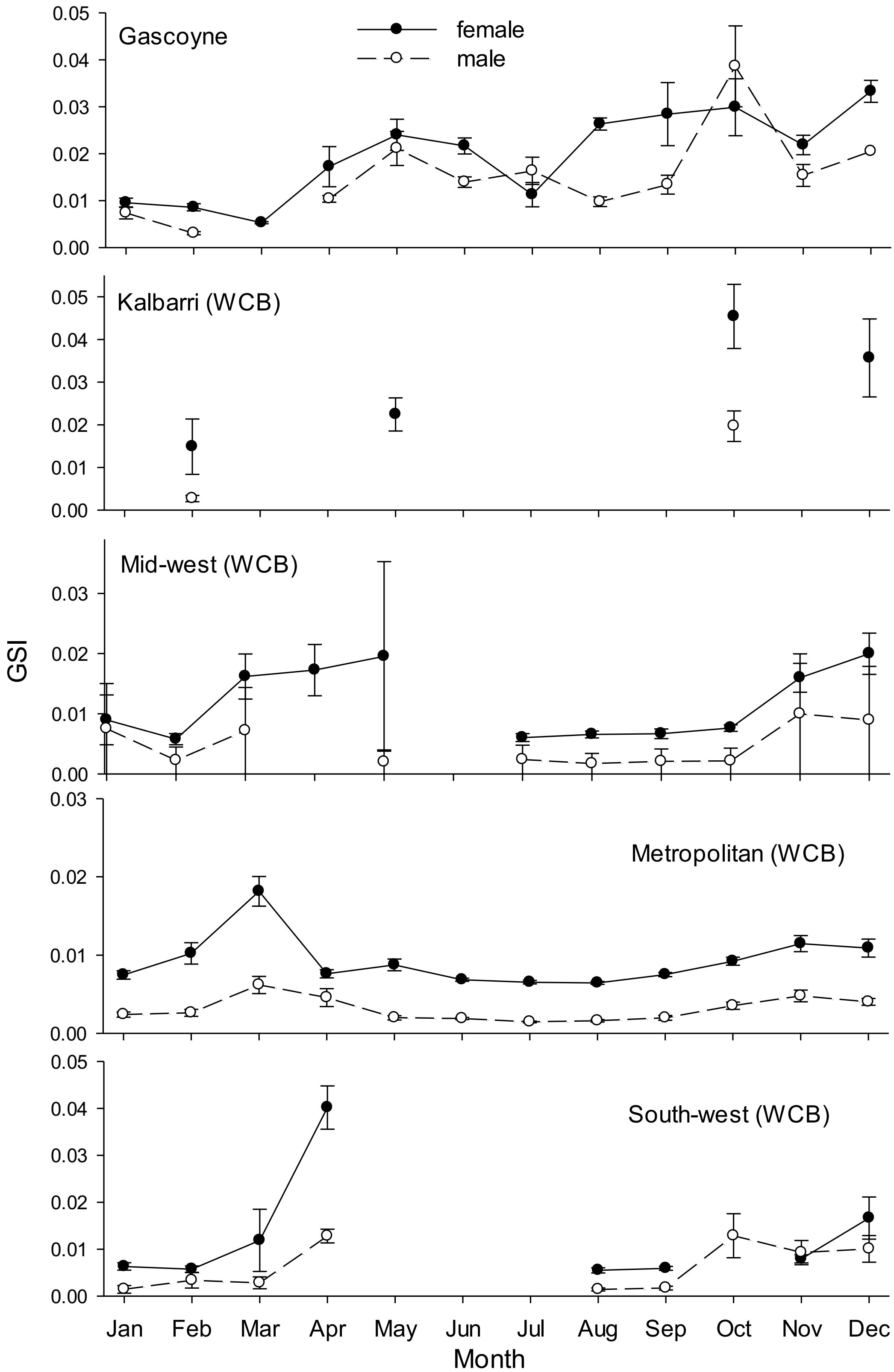


Figure 5.10. Mean monthly Gonadosomatic Index (GSI) and standard error for female and male tailor in the Gascoyne Coast Bioregion (GCB) and in the Kalbarri, Mid-west, Metropolitan, South-west Zones of the West Coast Bioregion (WCB), 1991–2010. (excludes fish <300 mm TL; Mid-west Zone excludes fish from the Abrolhos Islands).

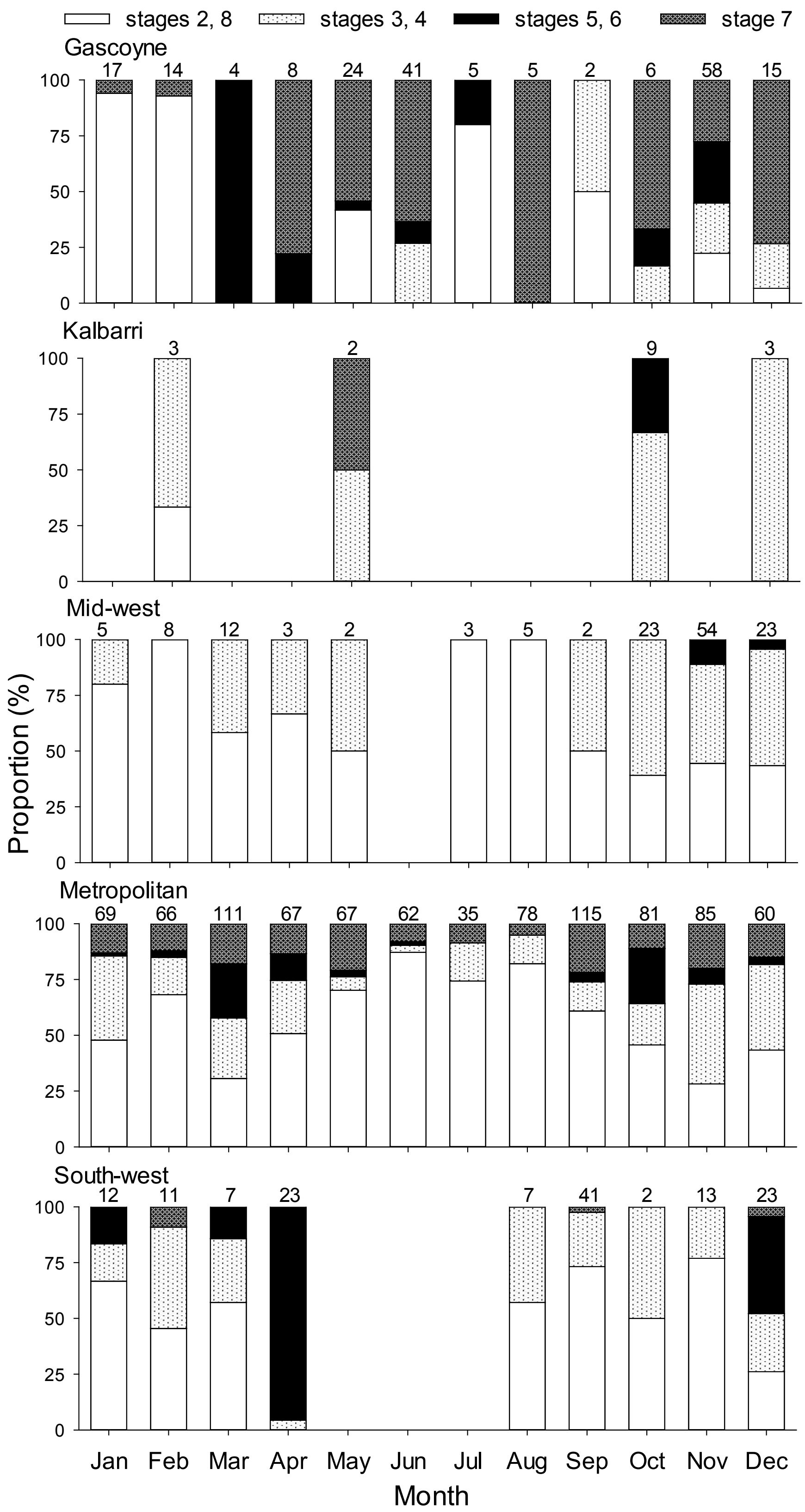


Figure 5.11. Monthly proportions of macroscopic gonad stages 2–8 for female tailor in the Gascoyne Coast Bioregion and in the Kalbarri, Mid-west, Metropolitan, South-west Zones of the West Coast Bioregion, 1991–2010. Numbers above bars indicate sample size. (excludes fish <300 mm TL; Mid-west Zone excludes fish from the Abrolhos Islands).

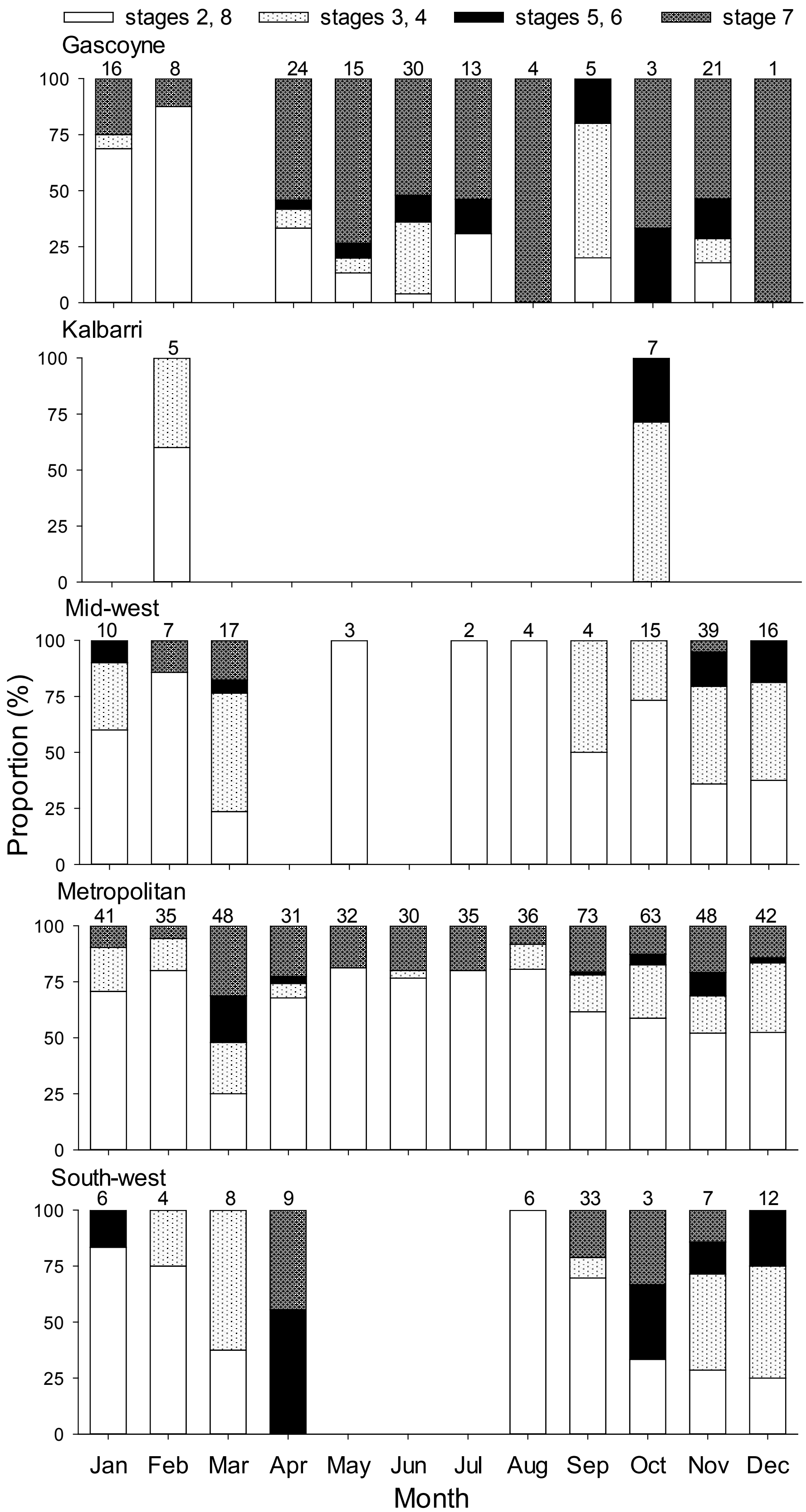


Figure 5.12. Monthly proportions of macroscopic gonad stages 2–8 for male tailor in the Gascoyne Coast Bioregion and in the Kalbarri, Mid-west, Metropolitan, South-west Zones of the West Coast Bioregion, 1991–2010. Numbers above bars indicate sample size. (fish <300 mm TL excluded; Mid-west Zone excludes fish from the Abrolhos Islands).

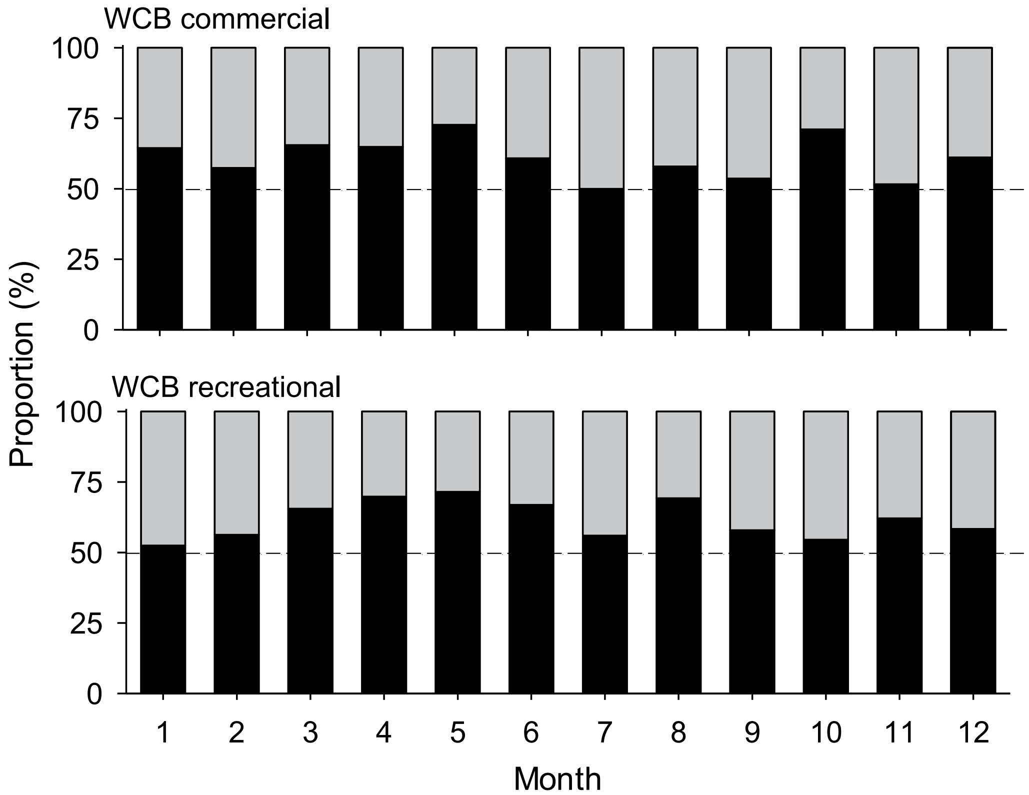


Figure 5.13. Monthly sex ratio of tailor sampled from WCB commercial and recreational landings, 1991–2010. Dashed line represents parity. Sample size >50 fish each month.

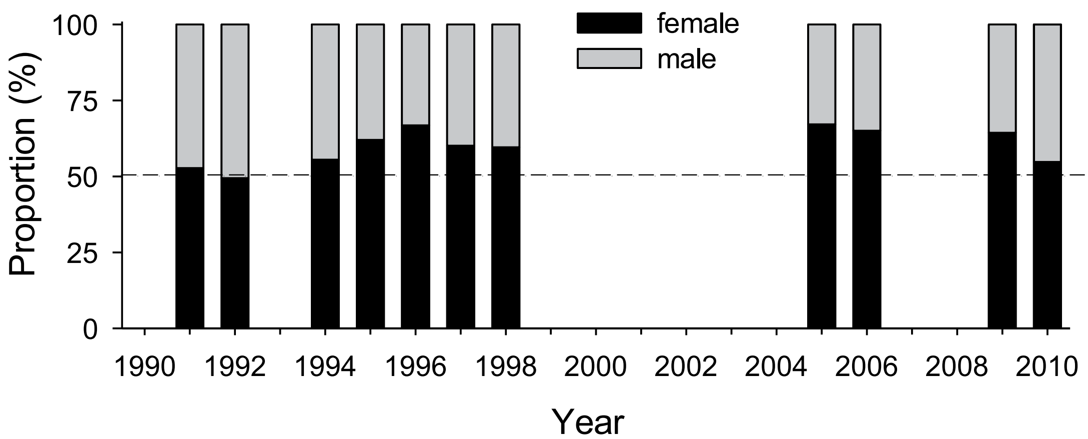


Figure 5.14. Annual sex ratio of tailor sampled from recreational landings in the West Coast Bioregion. Dashed line represents parity. Year not shown if sample size was <50 fish.

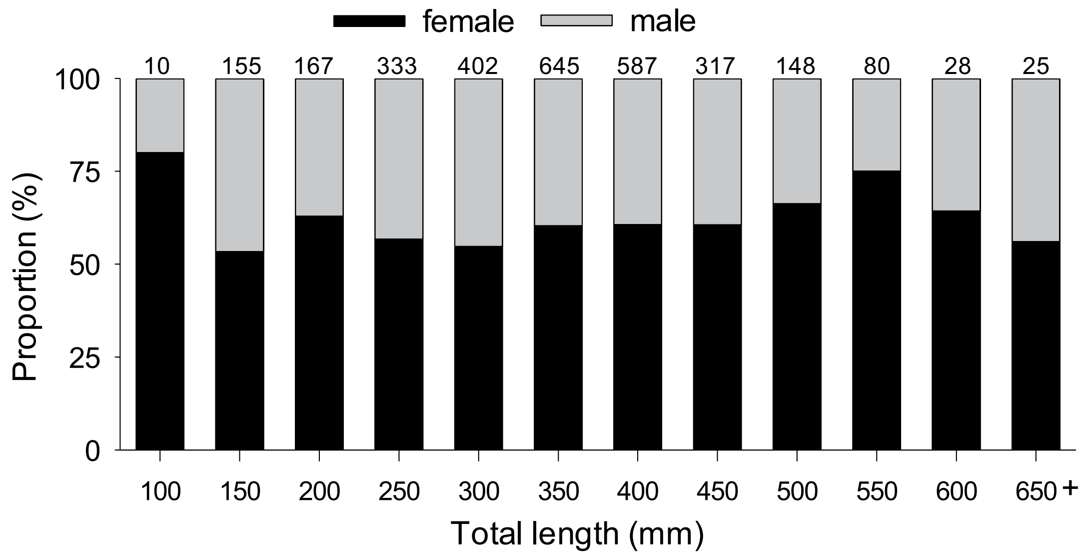


Figure 5.15. Sex ratio of tailor in each 50 mm length class sampled from fishery landings in the West Coast Bioregion (recreational and commercial sectors pooled), 1991–2010. Sample sizes shown above bars.

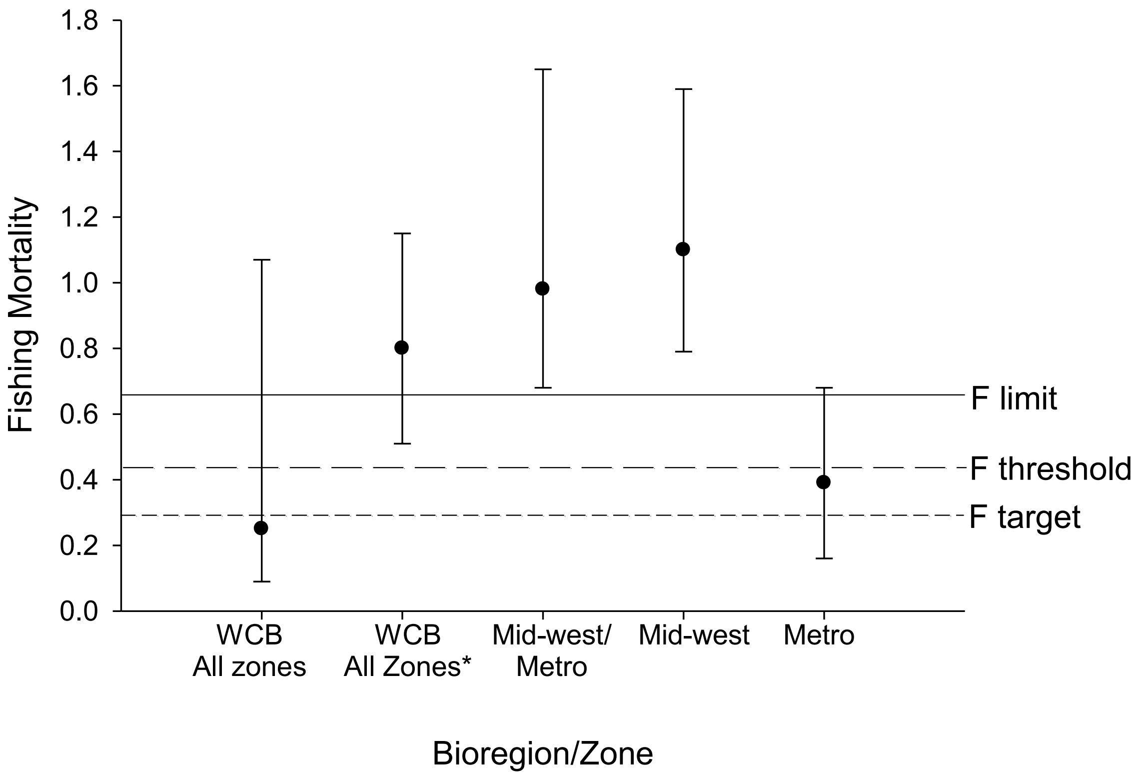


Figure 5.16. Tailor fishing mortality estimates (95% Confidence Interval) derived from the age structure of recreational landings in the West Coast Bioregion (all zones pooled; *excluding single oldest fish), in the Mid-west and Metropolitan Zones (combined and individually). Other zones not examined individually due to low sample size (<200 fish). Biological reference points (F_{limit}, $F_{threshold}$ and F_{target}) are shown.

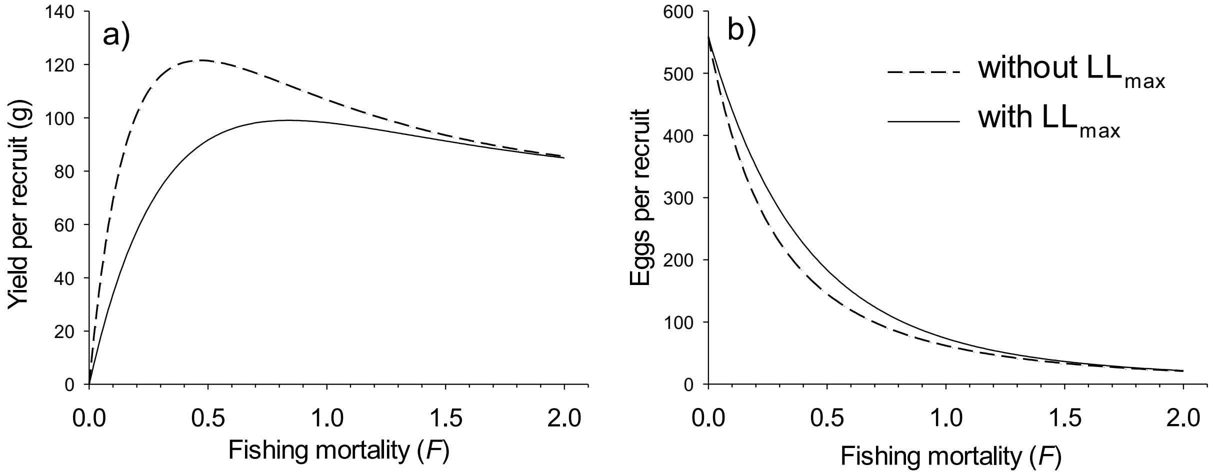


Figure 5.17. **a)** YPR and **b)** EPR model outputs for tailor, comparing scenarios with and without maximum legal length.

6.0 'Weight-of-evidence' assessment and implications

6.1 Introduction

The sustainable management of fish stocks requires sufficient information to be available to enable suitably robust stock assessments to be completed so that their current risk profile can be reliably estimated. While the most sophisticated assessments require a substantial amount of high quality data, the majority of the world's fisheries are relatively 'data-poor' or 'data-limited', which restricts the assessment methods that can be applied (Cochrane *et al.* 2010).

WA's nearshore finfish species, including tailor (*Pomatomus saltatrix*) and other West Coast Bioregion (WCB) indicator species, were classified as data-poor or data-limited. The status of these nearshore resources was previously monitored through examination of trends in recruitment indices, trends in catch rates of small-scale commercial fisheries and/or from limited recreational catch and effort data. Due to the levels of uncertainty in each of these data sources, the stock status of each species could not be reliably determined through the simple application of Level 1 or 2 assessments (Table 6.1). Consequently, this project collected additional age structure data and conducted catch curve analyses to estimate the level of mortality in each stock, which permitted a higher level of assessment (Level 3 Assessment in Table 6.1). The estimated fishing mortalities (*F)* were assessed against various reference levels (F_{Target}, $F_{\mathrm{Threshold}}$, F_{Limit}) to assist in determining the sustainability risk. These additional data were then used in conjunction with the other available information to complete a 'weight of evidence' (*sensu* Wise *et al.* 2007) assessment for these two indicator species.

A 'weight of evidence' approach was initially applied in WA to successfully determine the status of inshore demersal finfish stocks in the WCB (Haddon 2007, Wise *et al*. 2007, O'Neill 2009). The outcomes of this approach led to the implementation of significant management reforms for the associated commercial and recreational fisheries, which have reduced the sustainability risks for this suite of species (Fairclough *et al.* in prep.). The approach has also recently been successfully used to determine the status of inshore demersal finfish stocks in the Gascoyne Coast Bioregion (GCB) (Marriott *et al.* 2012, Morison 2011).

In a 'weight of evidence' assessment, the information from all suitable data sources is used, with or without the results of a catch curve analysis, to assess the status of a stock. Where available, F-based reference levels can be used by fishery managers as performance measures (Table 6.2) but with the overall level of risk, and level of management response, being refined according to other evidence such as their relative vulnerability (Table 6.3). Where F cannot be reliably estimated, a range of other performance measures can be developed, such as target catch rates or recruitment indices.

Within a 'weight of evidence' approach, the appropriate level of management response can be refined based on the productivity (i.e. biological characteristics such as rates of growth and reproduction) of the species which reflects their intrinsic resilience to the effects of fishing (Table 6.3). Similarly, the appropriate types of management arrangements can be selected based on an assessment of their relative susceptibility (i.e. attributes related to catchability), which can be managed.

Where adequate information exists for a high level assessment (e.g. Level 5), the management responses to ensure sustainability of the stock, given the current risk level and projected future harvest scenarios, can be relatively specific. In more data limited situations there is typically greater uncertainty in assessment results and therefore coarser (and more precautionary) management responses are often more appropriate.

6.2 Summary of stock status

The majority of commercial fishery landings of tailor occur in the GCB while the majority of recreational landings occur in the WCB. Overall, the catch shares between these sectors are approximately equal. In this project, fishery catch composition and recruitment trends were assessed only in the WCB. Fishery catch and catch rate trends were assessed in both sectors/Bioregions. *F* estimates were determined using data from the WCB recreational sector. (Table 6.4).

Stock structure : The stock structure of tailor is unclear, mainly due to uncertainty about the extent of connectivity between WCB and GCB populations. These populations have historically been treated as separate management units. However the evidence presented in this report suggests that a single stock extends across both Bioregions. Under the single stock hypothesis, the majority of spawning occurs in northern areas (the GCB and the Kalbarri Zone of the WCB) due to a net northward movement of adults. Some adults remain permanently or temporarily in the WCB, where they spawn. Recruitment to the WCB is generated from both regions.

Recruitment : There is high confidence in the trends observed in the annual recruitment of tailor. In 16 years of fishery-independent monitoring there has been considerable inter-annual variability, but with an increasing trend in recruitment since 2004 and the highest recorded values occurring during 3 of the past 4 years (i.e. since 2008). The commercial fishery catch rate in the Peel-Harvey estuary, which functions as a recruitment index, followed a similar recent trend. This agreement adds to the high level of confidence about recruitment trends. The current tailor recruitment trend and level are consistent with the spawning stock being at an adequate level.

Fishery catch and catch rates : While the commercial catch level of tailor is known, the fishing effort directed specifically towards tailor is difficult to quantify. Commercial catch rate trends suggest there was a rapid increase in the abundance of tailor in the GCB from 1990 to 1995, reaching historically high levels from 1995 to 2000. Catch rates have subsequently declined but are still relatively high compared to historical levels. Under the single stock hypothesis, this suggests there is currently a relatively high spawning stock abundance.

The majority of the WCB commercial catch is taken in the Peel-Harvey estuary, where only small fish are captured. Therefore this catch rate provides an additional index of recruitment, rather than adult abundance. The Peel-Harvey catch rate trend implies an increase in tailor abundance in the WCB since 2008, due to high 0+ recruitment.

Very limited catch and effort data are available from the recreational sector. There was low confidence in long-term trends in recreational catch rates, which were available from only a few individual diary fishers. The total recreational catch is unknown, due to lack of information about the shore-based sector which takes the vast majority of the catch.

The catch rates of shore-based volunteer recreational logbook fishers were considered moderately reliable, due to high effort levels. However, these data were available only in recent years. Logbook catch rates suggested an increase in tailor abundance in the WCB since 2008, probably due to high 0+ recruitment.

Catch rate levels and trends in the GCB and WCB are consistent with the spawning stock and recruitment being at adequate levels.

Fishery catch composition : In 2003 the legal minimum length was increased from 250 to 300 mm. Volunteer logbook data suggests that the proportion of immature fish in the recreational catch is now relatively low (up to 31% in estuaries and 17% in nearshore ocean waters, given maturity ($L_{50\%}$) is attained at 320 mm).

Fishing mortality : There were two major sources of uncertainty associated with F estimates. Firstly, the age composition was believed to be biased by under-sampling of older fish, leading to an over-estimation of F by the catch curve method. Secondly, small sample sizes (<300 fish) may have resulted in age compositions that were not representative of each region.

Due to an upper and lower size limit for this species, and a bag limit, a significant number of both large and small tailor may be released which could increase fishing mortality. Post-release survival of small fish (<350 mm) is high in the short-term (95% survivorship after 2 hours). Longer term survival is unknown. Post-release survival of larger fish is unknown but could be higher than for small fish.

Egg- and yield-per-recruit: At $F = 1.5M$, the YPR approximated the level calculated at $F_{0.1}$ and the EPR was calculated to be 20–25% of the calculated EPR at unfished levels. This evidence supported the selection of 1.5xM as an appropriate limit reference point (F_{limit}) for this stock.

The YPR and EPR model results suggested that current management arrangements (LML of 300 mm, bag limit of 8 with only 2 fish >500 mm) are effective in reducing the risk of potential growth and recruitment overfishing respectively, at high levels of fishing mortality. This assumes a high rate of post-release survival, which is likely to be true for smaller fish (<350 mm) (Ayvazian *et al.* 2002).

Overall vulnerability : The overall vulnerability of tailor is currently rated as 'low'. The stock has a relatively high productivity and a relatively low susceptibility to fishing (Table 6.5).

Summary : Management actions since 1990 have increased the resilience of the stock to fishing pressure by reducing the proportion of immature fish retained in the recreational catch. Spawning stock abundance is believed to be relatively high (assuming a single stock). Catch rates have been increasing in the WCB since 2008, in response to local recruitment which has been increasing since 2004. These indicators suggest that the overall risk status of this stock is at an acceptable level.

6.3 Implications for management – Decision rules

Localised performance measures related to WCB recruitment, GCB commercial catch rates and WCB recreational catch rates can be developed for tailor. However, the relevance of these performance measures to the overall stock is difficult to determine, due to current uncertainties about the stock structure of tailor. Based on the current assumptions about stock structure and the acceptable risk status of the tailor stock, no reduction in fishing effort and/or catch is required.

6.4 Future monitoring and assessment

Avialable evidence suggests tailor throughout WA comprise a single stock. This project focused on the WCB component of the population. Future monitoring and assessment should include information about the Gascoyne component, given that this may be the source of recruitment to the WCB.

A robust age-based assessment of tailor is not currently available due to significant biases in the recreational catch sample. Much greater sampling effort (perhaps including fishery-independent sampling) would be needed, especially in offshore and northern areas to generate unbiased F estimates. This is not currently resourced. An age-based assessment approach is currently not considered feasible for tailor.

The annual index of tailor recruitment in the WCB (sampled at Point Walter in the lower Swan-Canning Estuary) is the most robust component of the current stock assessment. The longevity of this volunteer fishing program is very important to assessing future WCB tailor population levels. The tailor catch rate in the Peel-Harvey commercial fishery follows a similar trend to the Point Walter recruitment index. A limited period of monitoring to confirm the age/length composition of this catch would validate the catch rate as an alternative recruitment index, which could be used if the Point Walter index was unavailable in future.

The RAP voluntary recreational fisher logbook appears to provide the most reliable index of adult tailor abundance currently available in the WCB. Continuation and improvement of this program will provide an ongoing indicator of catch rate and catch composition in the WCB recreational fishery, particularly in the absence of shore-based fishing surveys. Further analysis is required to identify any biases and ensure the representativeness of the data, including comparisons with data from recent surveys as these become available.

Shore-based fishers take the majority of the recreational catch of tailor in WA. The implementation of regular surveys of recreational fishing that provided robust estimates of the shore-based catch of tailor would reduce uncertainty about stock status and provide valuable information for managing this sector. A better sampling frame will need to be developed to enable cost-effective shore-based surveys.

The current ‘low’ risk status of the tailor stock is based on assumptions about stock structure. More information is required to verify these assumptions. Tailor in the WCB almost certainly comprise a single stock but the extent of connectivity with the GCB is unclear. Recruitment to the WCB is partly derived from non-local spawning events, which could be located in either the northern WCB (i.e. Kalbarri Zone) and/or the GCB. Further biological sampling in each region to determine spawning patterns is required to identify recruitment sources. A tagging study to determine adult movement is also required to determine connectivity between Bioregions.

Table 6.1 Application of the 'weight of evidence' rationale for the assessment of the status of stocks of exploited finfish. (F = fishing mortality, I = fishery-independent index, B = biomass).

Research project to gather more data for quantitative assessment

DATA SOURCE

Monitoring	Level 1 & 2	Level 3 & 4	Level 5
	Catch, effort and catch rate data	+ fishery-dependent &/or independent data	+ data integration in model framework

ASSESSMENT METHOD

Model development	*WEIGHT OF EVIDENCE approach* *Examine all available data*		
	Catch/catch rate	F &/or fishery-independent indices Catch/Catch rate Other biological data	Integrated model

HARVEST STRATEGY

Stock status	*Define threshold reference point* *Compare current level to threshold level*		
	Catch range	$F_{threshold}$, $I_{threshold}$	$B_{threshold}$, $F_{threshold}$

Performance indicators	*Define limit and target reference points* *Compare current level to limit/target levels*		
	Catch level	F_{limit}, F_{target} I_{limit}, I_{target}	B_{limit}, B_{target} F_{limit}, F_{target}

Scientific Advice	*Decision tables*		
	Risk status	Risk status	Probability of achieving objective
	General category level advice on options	Advice on the range of options	Specific advice on impact of options

MANAGEMENT STRATEGY

Management response	*Management action (harvest tactics – input/output controls)*		
	Highly precautionary settings	Precautionary settings	Precise settings
	Basic research	Further research	Specific research

Table 6.2. General decision rules based on a target, threshold and limit reference points for F (adapted from Wise *et al.* 2007).

Fishing mortality (F) estimates are available but no biomass estimates	Provides for a decision rule related to fishing pressure
$F<F_{target}$	Fishing effort (and/or catches) may increase
$F_{target}<F<F_{threshold}$	Fishing effort (and/or catches) to remain constant
$F_{threshold}<F<F_{limit}$	Fishing effort (and/or catches) reduced, e.g. 10–50%
$F>F_{limit}$	Fishing effort (and/or catches) reduced, e.g. 50–100%

Table 6.3. Attributes indicating vulnerability of stock(s) of indicator species (adapted from Wise *et al*. 2007).

Attribute	Type	Low Vulnerability	Medium Vulnerability	High Vulnerability	Reference*
Growth (von Bertalanffy K)	Productivity	Rapid growth: Steep growth trajectory e.g., $K > 0.25$	Intermediate growth trajectory e.g. $0.25 \geq K \geq 0.15$	Slow growth: gradual growth trajectory. e.g. $K < 0.15$	2, 4.
Trophic level**	Productivity	Low e.g. < 3	Intermediate e.g. 3 to 4	High order predator e.g. > 4	2, 3***
Longevity (maximum age = t_{max})	Productivity	Short lifespan e.g., $t_{max} < 10$ yr	Intermediate lifespan e.g. $10 \geq t_{max} \geq 30$ yr	Long lifespan e.g. $t_{max} > 30$ yr	1, 4
Age at maturity (t_{mat})	Productivity	Early maturing e.g., < 2 yr	Intermediate maturing e.g. $2 \geq t_{mat} \geq 8$ yr	Late maturing e.g. > 8 yr	4
Selectivity and availability	Susceptibility	Low overlap (by depth and/or area) and/or selectivity to fishing gear e.g. < 25% of stock is available to fishery. ≤ 50% of age classes selected by fishing gear	Moderate overlap (by depth and/or area) with fishery and/or fishing gear selects a low proportion of immature fish e.g. 25–50% of stock is available to fishery. $t_c \geq t_{mat}$	High overlap (by depth and/or area) with fishery and/or fishing gear selects a high proportion of immature fish e.g. > 50% of stock is available to fishery. $t_c < t_{mat}$	2****
Schooling/ aggregation behaviour	Susceptibility	Extended spawning period and/or do not form dense schools at any time. e.g. spawning > 4 months	Limited spawning period and/or forms aggregations that are not predictable in time and space, but are highly catchable e.g. spawning 3 – 4 months; not associated with lunar phase and/or spawning aggregation sites unknown/ not well defined.	Forms predictable aggregations in time and space that are highly catchable e.g. spawning 1 – 2 months; and/ or associated with particular lunar phase(s) – e.g., full and/or new moons; known spawning aggregation sites.	1, 4
Mode of reproduction	Susceptibility	Straightforward gonochoristic mode of reproduction (i.e. not sex-changing)	Mode of somewhat complex reproductive development, e.g. pre-maturational sex change or diandric sex change, with males and females found over a broad overlapping range of sizes and ages	Complex mode of reproduction, e.g., functional monandric sex change, with most of the larger older individuals comprised only of one sex.	1
Fecundity (per spawning event) at age of first maturity	Productivity	High e.g. > 10^4	Intermediate e.g. 10^2 - 10^3	Low e.g. < 10^2	2

Attribute	Type	Low Vulnerability	Medium Vulnerability	High Vulnerability	Reference*
Recruitment variability and breeding strategy	Productivity	Regular, or consistent recruitment that is predictable on an annual basis, and/or propagules widely dispersed (e.g. 100s of kms) during pelagic phase or juvenile stage e.g. broadcast spawner with lower (~ 20% annual range) recruitment variability	Average recruitment is consistent but variable among years over short time periods and/or propagules have limited dispersed capacity (e.g. 10s of kms) during pelagic phase or juvenile stage e.g. broadcast spawner with recruitment varying over a range of ~50% within an average 3 year period	Infrequent, highly variable recruitment over time that cannot be predicted (e.g. annual range 0–100%), and/or restricted dispersal of eggs, larvae, juveniles e.g. demersal egg layer or live bearer	1, 3
Distribution and movement of adults	Susceptibility	Widespread distribution, and/or highly mobile e.g. capacity to move 100s of kms along coastline	Limited distribution, and/or limited mobility e.g. adults move 10s of kms along coastline	Restricted/endemic and/or sedentary (longshore movement restricted), possibly inshore-offshore movements only e.g. adult home range < 10km	1
Post-release mortality	Susceptibility	Generally high survivorship post-release. Large amount of evidence of post-release and survival. e.g. probability of survival > 67%	Survivorship largely dependent on capture method and depth of capture. Intermediate levels of post-release survival. e.g. probability of survival 33 – 67%	Majority dead or in poor health/showing signs of barotrauma when released, regardless of depth of capture or capture method. e.g. probability of survival < 33%	2
Resilience to other sources of mortality	Productivity	Highly adaptable to variable environments and/or environments/ habitats are healthy and in an optimum condition	Moderate levels of resilience, and/or environments/habitats are not in an optimum condition but are recovering	Limited adaptability to change and/or environments/habitats are degraded and/or under threat	1
Level of Uncertainty	All	Most attributes known e.g. 0 – 3 unknown	Some attributes known e.g. 4 – 8 unknown.	Few attributes known e.g. 9 – 12 unknown	
Overall Productivity		Most productivity attributes are low	Most productivity attributes are medium	Most productivity attributes are high	
Overall Susceptibility		Most susceptibility attributes are low	Most susceptibility attributes are medium	Most susceptibility attributes are high	

* Reference: Examples for vulnerability criteria consistent with reference levels developed in the following publications: 1 = Wise *et al.* (2007); 2 = Patrick *et al.* (2010); 3 = Hobday *et al.* (2011); 4 = Department of Fisheries (2012).

** Trophic level scores can be obtained from FishBase (Froese and Pauly 2011)

*** Example cut-off scores derived by rounding up the cut-off scores from Patrick *et al.* (2010) and Hobday *et al.* (2011) to the nearest whole integer. This seems to be appropriate for scalefish indicator species, because most targeted species are likely to have higher trophic status than the broader range of species categorised for Ecological Risk Assessments.

**** Example levels of availability consistent with those in Patrick *et al.* (2010). Example selectivity levels for medium and high vulnerability categories consistent with convention that the MLL should be set at approximately the length at mean maturity (**Ricker 1969**). t_c = mean age at first capture; t_{mat} = mean age at first maturity.

Table 6.4. Summary of qualitative assessments for tailor. (WCB – West Coast Bioregion; SCB – South Coast Bioregion; comm. – commercial fishery; rec. – recreational fishery).

Method	Result	Confidence	Implication for stock status
0+ recruitment trend	Currently relatively high in WCB, increasing since 2004.	High	No evidence of a reduction in recruitment potential
Fishery catch rate trend	GCB comm. – currently above long-term (50 y) average. WCB comm. – increasing, reflects recruitment. WCB rec. – increasing or stable in past 5 y.	Medium	No evidence of any reduction in recruitment potential
Fishery catch trend	GCB comm. – variable, non-directional long-term trend. WCB comm. – declining long-term trend due to effort reductions. Rec. – unknown.	High (comm.) Low (rec.)	Consistent with normal variations in abundance
% immature fish in catch	Probably low % in rec. catch. Uncertainty due to lack of shore-based recreational catch estimate.	Medium	Not likely to cause a problem to spawning stock
Age & length structure	WCB – truncated, likely undersampling of older fish due to fishery bias. GCB – unknown.	Low	No conclusions can be made

Unacceptable	Uncertain	Acceptable

Table 6.5. Summary of productivity and susceptibility attributes and implications for vulnerability of tailor (as defined in Table 6.3). The vulnerability scores for Productivity were mostly low, which indicates that this stock has high productivity. The vulnerability scores for Susceptibility ranged from low to high, which indicates that this stock is moderately susceptible to fishing. Overall vulnerability level for the total WCB/GCB stock is LOW.

West Coast	Type	Sustainability Risk		
		Low	Medium	High
Growth (von Bertalanffy K)	Prod.	✓		
Trophic level**	Prod.			✓
Longevity (maximum age = t_{max})	Prod.	✓		
Age at maturity (t_{mat})	Prod.	✓		
Selectivity and availability	Susc.			✓
Schooling/aggregation behaviour	Susc.		✓	
Mode of reproduction	Susc.	✓		
Fecundity (per spawning event) at age of first maturity	Prod.	✓		
Recruitment variability and breeding strategy	Prod.	✓		
Distribution and movement of adults	Susc.	✓		
Post-release mortality	Susc.	✓		
Resilience to other sources of mortality	Prod.	✓		
Overall level of uncertainty	**Low**			

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