FISHERY ASSESSMENT REPORT

TASMANIAN SCALEFISH FISHERY - 2007

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This assessment of the Tasmanian scalefish fishery is produced by the Tasmanian Aquaculture and Fisheries Institute (TAFI) and uses input from the Scalefish Fishery Assessment Working Group (SFAWG).

SFAWG met on 13 December 2007 to consider the draft assessment report and provide input into the assessments. The Working Group participants were:

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Executive Summary

The Tasmanian scalefish fishery is a multi-species fishery operating in State fishing waters and encompassing a wide variety of capture methods. The Scalefish Management Plan (revised in 2004), provides the management framework for the fishery. An important element of the management plan is the explicit identification of performance indicators and reference points that have two primary functions:

- monitor performance of the fishery in relation to catch and effort, and
- provide reference points against which the status of fish stocks can be assessed.

Fishery Assessment

In this assessment the scalefish fishery is described in terms of species composition, catch and effort. The commercial catch history for the period 1990/91 to 2006/07 is presented, with more detailed analyses of catch and effort by method for the period 1995/96 to 2006/07. In addition to information provided in Tasmanian catch returns, data from Commonwealth logbooks for dual endorsed operators fishing in Tasmanian waters and for species managed under Tasmanian jurisdiction (*i.e.* striped trumpeter and bastard trumpeter) have been incorporated in the analyses.

Dipnet, dropline and squid jig effort expanded to historically high levels following the introduction of the management plan, whereas effort for other methods tended to remain relatively stable or decline over time. By 2006/07, effort levels for all methods, apart from squid jigs, had fallen to within or below reference levels (Table 1). The dramatic increase in squid jig effort occurred primarily in response to the expansion of the southern calamari fishery.

Although effort performance indicators were not triggered for most methods, there are continuing concerns regarding the level of latent capacity within the fishery from licence-holders who are currently either not active or participating at low levels.

Table 1. Effort performance indicator assessment by major fishing methods for 2006/07
Y triggered, N not triggered.

	Effort >10% peak 1995/96 - 1997/98 levels	
Method	**Gear units**	**Days fished**
Beach seine	N	N
Purse seine	N	N
Graball net	N	N
Small mesh	N	N
Dropline	N	N
Handline	N	N
Troll	N	N
Fish trap	N	N
Spear	N	N
Dip net	N	N
Squid jig	Y	Y

Species assessments

A detailed assessment was performed for banded morwong, while other key species - southern calamari, striped trumpeter, bastard trumpeter, sea garfish, wrasse, blue warehou, Australian salmon and flathead - were considered more briefly.

Species assessments evaluate fishery-dependent information against agreed upon reference points for the performance indicators, as detailed in the Scalefish Management Plan. Specifically, these reference points relate to defined levels of catch, effort and catch rates. The management plan also provides for biological characteristics to be used as performance indicators against which stock status can be evaluated and, where such data are available, they have been updated in this assessment. For the first time, the fishery has additionally been assessed against an alternative set of performance indicators and reference points which account for recent developments in the fishery. These alternative performance indicators are intended to replace the existing indicators over the next few years.

Banded morwong

Existing reference points

- State-wide, as well as in the Maria, Bicheno and St. Helens fishing regions, catches were outside (below) the 1994/95 to 1997/98 range.
- Gillnet effort for banded morwong was within reference levels at regional and state-wide scales.
- State-wide standardised catch rates were within reference levels, however, standardised catch rates for St Helens remained low and exceeded the reference point for the fourth year running.

Alternative reference points

- TAC-related reference points were not assessed.
- Catch rates in the St. Helens region exceeded the reference points (90% of the average from the reference years 2000/01 to 2005/06).

Resource status

- A regional stock assessment model suggested that exploitation rates in some regions may not be sustainable. Current catch levels are likely to continue to reduce spawning biomass, even though stocks are now more productive (faster growth of individuals and earlier maturity of females) than at the commencement of the fishery.
- The fishery is now mainly dependent on recruitment. Exploitable and mature biomass have (temporarily) recovered in the Tasman and Maria regions due to strong recruitment in the early 2000s. In the Bicheno and St. Helens regions, exploitable and mature biomass have continued to decline.

Management advice

- Management action is required to limit east coast catches. The model predicts a less than 50% probability that mature biomass and catch rates would be maintained at current levels with an east coast catch of 20 tonnes. Management should also explicitly include reference to the spatial distribution of effort.

The fishery for banded morwong expanded in the early 1990s with the development of live fish markets for this species. Annual production declined steadily between 1994/95 and 1999/00, but has since stabilised. The 2006/07 catch of 46 tonnes was close to the average for the past six years. State-wide effort has also stabilised and remained low compared with the reference period. Effort increased in the Tasman, Maria and Bicheno regions, but dropped in the St. Helens region.

Catch rates for the Tasman and Maria regions have dropped sharply after strong increases between 1999/00 and 2005/06. In contrast, Bicheno and St. Helens regions have seen continuously falling catch rates since the mid 1990s. In 2006/07, catch rates improved in the Bicheno region and were just above the reference levels. Catch rates in the St. Helens region remained below reference levels. State-wide, however, catch rates were above reference levels.

The regional age-structured stock assessment models indicated that mature and exploitable biomass have recovered to relatively high levels in both southern regions of Tasman and Maria, mainly due to recent strong recruitment pulses. In the northern regions of Bicheno and St. Helens, recruitment has been only slightly elevated in the 2000s and mature and exploitable biomass have continued to fall to about 35% of the initial levels in 1990. In most regions, harvest rates have remained above the internationally recognised harvest reference points for mature biomass of $H_{40\%}$ and $H_{30\%}$ over an extended period of the fishery.

Stock rebuilding in the southern regions has been based on strong recruitment pulses in the 2000s coupled with higher productivity through increased growth rates and earlier maturity. Similar to the northern region, the fishery is now largely recruitment-driven with only a small proportion of the catch made up of older fish. While the fishery in the southern regions has profited from high recruitment in recent years, even a relatively short period of reduced recruitment could lead to serious declines in catch rates and mature biomass in all stocks. Therefore, reductions in fishing mortality are advisable for all regions to rebuild populations.

The high dependence on new recruitment in all stocks was reflected in the model projections. Model projections predicted an overall 50% probability that the current mature biomass and catch rates could be sustained over a 5-year period for a total East coast catch of 20 tonnes. For catches of 40 tonnes or more, the model predicted a close to 100% chance that biomass and catch rates would decline in all regions.

Despite uncertainty in the underlying data and uncertainty over the dynamics and spatial structuring of the stocks, the assessment suggested that management action is required to ensure that fishing mortality in this fishery is limited to below current levels. Given the limited mobility of this species, management should also explicitly include reference to the spatial distribution of effort.

Southern calamari

Existing reference points

- Catch and effort were outside (above) the reference range.
- The State-wide catch of 83 tonnes represented an 86% increase compared with the previous year and therefore exceeded the rate of change reference point.
- Catch rates were within reference levels.

Alternative reference points

- Commercial catches were within the reference range (50 tonnes in Great Oyster Bay and Mercury Passage; 30 tonnes in the south-east; 25 tonnes for areas outside Great Oyster Bay, Mercury Passage and south-east).
- Catches increased in 2006/07 and therefore did not exceed the reference point for consistently declining catch trends over 3 years by >40% in SE&E waters.

Resource status

- There is a high degree of uncertainty about stock status.

Management advice

- Extended closure of the major spawning grounds appears to be effective in protecting the main known spawning event. However, any major shift in the fishery to increased effort prior to the closure could adversely impact on the spawning stock prior to the main spawning season. Expansion of catches in space and time should be therefore monitored closely.

The fishery for southern calamari expanded markedly in 1998/99 and, reflecting the development of this as a target fishery, subsequent catches have exceeded those for the reference period. The 2006/07 catch of 83 tonnes was almost double that for 2005/06 and was similar to the high catches in the early 2000s. Increased catches were reported in all areas, including Great Oyster Bay and Mercury Passage where the 3-month closure was extended over a larger area compared to 2004/05. While effort remained relatively stable compared to 2005/06, catch rates increased consistently in all regions, mainly in response to better catch rates outside the period of the seasonal closure.

Since the development of the calamari fishery occurred after the introduction of the management plan the application of the generic catch and effort reference points with their specific reference years have little relevance. The fact that catches remain above reference levels is of far less concern than if catches were to fall to within historic levels (suggesting the collapse of the fishery). These shortfalls should finally be overcome by the alternative reference points for catch and effort.

Recent studies indicate that most adult calamari caught on the east and south-east coasts are probably spawned in Great Oyster Bay. This area exhibits a high degree of self-recruitment as well as supplying other parts of the south-east coast with the bulk of recruits. These findings reinforce the efficacy of management arrangements that involve the closure of this region during the main spawning period to ensure relatively high egg production. The extended spatial and temporal closure of the major spawning grounds has appeared to be effective and still allowed major catches to be taken after the spawning closure. However, any major shift in the fishery to increase effort prior to the closure could adversely impact on the spawning stock prior to the main spawning season. Expansion of catches in space and time should be therefore monitored closely and restricted if need be.

Striped trumpeter

Existing reference points

- Striped trumpeter catches were outside (below) the catch reference range.
- Effort was within reference levels.
- Catch rates for dropline (days fished) were below reference levels.

Alternative reference points

- The catch did not exceed the 50 tonnes commercial catch reference point.
- Catch curve assessment was not possible.

Resource status

- Resource status is uncertain though potentially depleted due the combined effects of fishing and apparent poor recruitment in recent years. Major uncertainties surround the lack of information on the recreational catch and the magnitude of the catch taken by Commonwealth operators.

Management Advice

- Although a more rigorous assessment is required to assess the sustainability of the fishery, the expectation is that the stocks are declining and will continue to do so without management action and/or a period of sustained good recruitment. It would be prudent to reduce fishing mortality in both commercial and recreational sectors, to investigate spawning closures, and to review the minimum size limit, which is below the size at maturity.

Commercial catches of striped trumpeter continued to decline during 2005/06 to just 22 tonnes, the lowest catch recorded since the mid 1980s. Commonwealth catches are likely to have been substantially underreported and recreational catches have most likely increased in recent years. After some spatial contraction of the commercial fishery over the past two years, fishing activity in 2006/07 has again been distributed more widely from the east to the south-west. Handline and graball effort were well below levels experienced during the latter half of the 1990s. Dropline effort remained relatively high up until recently, but has fallen in recent years. Catch rates for the hook methods fell very slightly, with dropline (days fished) well below reference levels. Graball catch rates increased again following the sharp fall experienced during 2004/05, which presumably reflected the impact of the size limit increase.

The continued decline in catches since 1999/00 gives rise to concerns about the current status of striped trumpeter stocks. Falling graball net catches (primarily juvenile fish) and reductions in offshore hook catches (mainly adult fish) suggest that the biomass of new recruits and adults have declined significantly. Striped trumpeter exhibit strong recruitment variability resulting in inter-annual variability in fishable biomass. Recent size and age composition data imply that there has been no substantial recruitment recently and that strong cohorts from 1993 and 1994 are still well represented in the population. The average size of hook-caught fish is thus expected to continue to increase as the present cohorts grow but spawner biomass will continue to decline.

The introduction of a 250 kg trip limit may have also contributed to the downturn in commercial catches. There was evidence that the quantities of gear fished each day had declined (presumably to limit catches) and there are reports that some operators have simply decided not to bother targeting the species because of the trip limit. Unfortunately, changes in the behaviour of operators are difficult to assess based on daily logbook returns alone.

Based on yield and spawning biomass-per-recruit analyses and size at maturity, it would appear that the recent increased minimum size limit, while a positive step, was sub-optimal and the risk of growth overfishing and possibly recruitment overfishing remains. Although a more rigorous assessment is required to assess the sustainability of the fishery, stocks are expected to decline further without management action and/or a period of sustained good recruitment. It would be prudent to act to reduce fishing mortality, both commercial and recreational, to investigate spawning closures, and to review the minimum size limit.

Bastard trumpeter

Existing reference points

- State-wide catches were outside (below) the reference range.
- Effort and catch rates were within reference levels.

Alternative reference points

- Pending

Resource status

- Resource status is uncertain though potentially depleted due to the effects of fishing coupled with variable recruitment.

Management advice

- Management options to reduce the total fishing mortality on this species through commercial trip limits and recreational possession limits should be explored.

Bastard trumpeter catches have declined steadily since the mid 1990s. They have remained stable for the past five years with a catch of 20 tonnes in 2006/07. Graball effort and catch rates have also remained stable over the same period.

Catch rates are probably a poor indicator of stock status for bastard trumpeter since the species is now largely taken as by-product and thus total catch may be a better indicator of abundance and/or availability. As such, trends in commercial production suggest that current inshore populations are at low levels. Strong recruitment variability is a feature of this species, with limited evidence of good recruitment in recent years.

The commercial and recreational fishery is almost entirely based on juveniles, giving rise to the possibility of growth overfishing. Increasing the minimum size limit to above the size at maturity would be beneficial to the stock, but would effectively close down inshore fisheries for the species. Reducing the recreational possession limits and discouraging targeting through the introduction of a trip limit for commercial operators may be more suitable alternatives.

Sea garfish

Existing reference points

- State-wide catches were outside (below) the reference range.
- Catches fell by 46% and therefore exceeded the rate of change reference point.
- Effort and catch rates were within reference levels.

Alternative reference points

- State-wide catches were outside (below) reference levels from 1998/99 to 2005/06.

Resource status

- Uncertain, but the recent decline in catches appears to be caused by reduced resource availability.

Management advice

- Since it is not known whether present catch levels are sustainable and to clarify effects of dipnetting on the schooling behaviour of garfish, monitoring research to increase the understanding about the fishery and stock dynamics is recommended. In addition, with the great potential for increased targeted effort, it would be prudent to consider management options that limit further expansion in this fishery.

After years of relative stability in garfish catches at between 80-90 tonnes in most years since the early 1990s, production almost halved in 2006/07 to only 49 tonnes. Decreases were experienced for the main fishing methods (beach seine and dipnet), and in all major fishing regions. Beach seine and dipnet effort fell markedly compared to

2005/06 and overall effort for both methods remained relatively low compared to the reference period. Catch rates for beach seine and dipnet have also fallen, but since sea garfish is a schooling species, catch rate trends are unlikely to be sensitive indicators of abundance.

The catch declines experienced in all major fishing regions and by both major fishing methods during the 2006/07 appeared to be due a lack of resource availability rather than marketing issues. The reason for this, after a long period of apparent stability in the fishery and underlying fish stocks, remains unclear. Since it is not known whether present catch levels are sustainable and to clarify effects of dipnetting on the schooling behaviour of garfish, close monitoring of the fishery including collection of biological samples is recommended to increase the understanding about the fishery and stock dynamics. In addition, since there is potential for targeted effort to expand especially in the dipnet sector, it would be prudent to consider management options that limit further expansion in this fishery until more is known about the stock dynamics.

Wrasse

Existing reference points

- No reference points were exceeded.

Alternative reference points

- Catches were outside (above) the reference range from 1998/99 to 2005/06.

Resource status

- Resource status is unknown though the two species targeted are vulnerable to localised (economic) depletion of legal-size biomass. Minimum size limits provide considerable protection to purple wrasse and female blue-throat wrasse spawner biomass. The size limit does not, however, offer the same level of protection to male blue-throat wrasse which derive from mature females after a sex change, typically at sizes after they have entered the fishery.

Management advice

- Because there is still a high level of latent effort in the fishery, it would be prudent to consider management options that limit further expansion in this fishery. The introduction of the new logbook will result in improved spatial information and species-based reporting that should help to reduce the risk of failing to detect serial depletion.

Catches of the two species involved, namely purple wrasse and blue-throat wrasse, are not currently distinguished in catch returns. Wrasse catch has remained relatively stable since the mid 1990s, but it has increased over the last four years to 108 tonnes in 2006/07 largely due to higher handline catches. Increased effort is reflected by industry reports suggest recent high levels of interest in the fishery.

Catch rates for both handline and fish traps have increased. However, caution needs to be exercised when making inferences about the status of the wrasse stocks, since broad-scale analyses may be relatively insensitive to changes in abundance at the level of individual reefs, the scale at which the fishery impacts the fished populations. Marked regional shifts may have also masked localised depletions, with fishers moving to new or lightly fished areas to maintain catches.

While limited entry has capped participation in the live wrasse fishery, a substantial level of latent effort remains. Increasing catches indicate continued strong interest in the species, and it is unknown whether current effort levels are sustainable. Under present arrangements, there is potential for localised economic depletion of legal-sized wrasse, especially if effort becomes concentrated in particular regions.

There are concerns that blue-throat males may not be adequately protected by the current minimum size limit. This is because blue-throat wrasse change sex, with males derived from mature females generally after they have entered the fishery. When combined with the fact that males are strongly site attached and have higher catchability than females, because they are more aggressive, this suggests that they are potentially vulnerable to over-fishing. In extreme situations localised heavy fishing pressure could result in ‘sperm shortage’ that would affect spawning success even though there may be a robust population of mature (sub-legal) females present.

Blue warehou

Existing reference points

- State-wide catches were outside (below) reference levels.
- Catches increased by 43% to 29 tonnes and therefore exceeded the rate of change reference point.
- Effort and catch rates were within reference levels.

Alternative reference points

- The commercial catch limit of 318 tonnes has not been exceeded.

Resource status

- Stocks are overfished and availability of blue warehou in Tasmanian waters continues to be low.

Management advice

- Management action for stock rebuilding has been implemented in the Commonwealth fishery.

Blue warehou catches in Tasmanian waters have been low for some years. While they increased in 2006/07 to 29 tonnes, catches were still low compared to those reported in the mid-1990s. Graball effort remained low and catch rates were above reference levels.

A range of environmental factors, as well as stock size, influences the availability of blue warehou in Tasmanian waters. Recent depressed catches are almost certainly linked to reduced biomass, the result of overfishing by Commonwealth and State fisheries during the 1990s. In the absence of significant rebuilding, catches are likely to remain low, although there are some signs of stock recovery in the Commonwealth fishery.

Australian salmon

Existing reference points

- Catches were outside (below) the reference range.
- Catches decreased by 55% to 115 tonnes and therefore exceeded the rate of change reference point.
- Effort was within reference levels.
- Beach seine catch rates were below reference levels.

Alternative reference points

- The commercial catch limit of 435 tonnes has not been exceeded.

Resource status

- Catch rates may not be good indicators of abundance for schooling species such as Australian salmon and in any case commercial production is known to be strongly influenced by market demand. Resource status is unknown.

Management advice

- The *status quo* appears to be acceptable.

The catch of Australian salmon has fluctuated strongly over the last few years and in 2006/07 dropped another 55% to 115 tonnes, the lowest on record. Beach seine catch rates have remained low compared to recent years. It is, however, recognised that catch rate estimation is influenced by the extremely skewed nature of the data, *i.e.* the majority of catches are small but the total catch is influenced by a very small number of extremely large catches. In this respect catch rates are not a sensitive fishery performance indicator for a schooling species such as Australian salmon.

Although Australian salmon stocks appear to fluctuate throughout the year in relation to environmental conditions, annual catches are to a large extent linked to market demand (specifically the bait market). There is capacity for industry to expand production to the commercial catch limit should new markets be found. While stock status is unknown, the species has sustained substantially higher catches in the past and current commercial and recreational catches would appear sustainable.

Flathead

Existing reference points

- Catches were within the reference range.
- Catches decreased by 38% to 57 tonnes and therefore exceeded the rate of change reference point.
- Effort and catch rates were within reference levels.

Alternative reference points

- Regional catches in the south-east and east did not exceed reference levels.

Resource status

- Resource status is unknown.

Management advice

- *Status quo* appears to be acceptable. As further expansion in the commercial fishery is likely, it would be prudent to consider spatial management options that avoid the regional concentration of effort.

Of the two main species involved, tiger and sand flathead, tiger flathead taken by Danish seining dominates the commercial catch. By contrast, sand flathead account for the vast majority of the hand line and recreational take. Flathead catches fell by 38% to 57 tonnes in 2006/07 after two years of substantial expansion. Fluctuating flathead catches appear to be mainly due to switching in targeted Danish seine fishing effort between whiting and flathead.

Hand line effort and catch rates remained relatively stable. There is some evidence for increased commercial fishing with lines (presumably targeting sand flathead) but compared with the recreational take, these catches are very minor.

The status of both key flathead species in state waters is unknown, although commercial catches of tiger flathead have been maintained at higher levels in past. In adjacent Commonwealth waters significant quantities of tiger flathead are taken by trawling, but the impact of this fishery on inshore stocks is unknown.

Activation of dormant Danish seine licences is likely in the near future and, as a result, flathead catches are expected to rise further. It would be prudent to consider spatial management options that avoid the regional concentration of effort.

2006/07 performance indicator summary

Summary assessments of existing and alternative performance indicators and reference points for the key species or species groups are summarised in Table 2 and Table 3, respectively.

Table 2 Summary assessment of existing performance indicators and reference points for key species with risk assessment if no management action (i.e. *status quo*) is taken.

Catch history reference period is *1994/95 to 1997/98 and ** 1995/96 to 1997/98; *** main fishery managed by Commonwealth; Y triggered, N not triggered, arrows indicate direction of change, na not assessed, [#] applies only to particular methods or regions; H high risk, M medium risk, L low risk, U uncertain. [##] targeted research required. Changes since previous year in bold.

Species	**Catch below or above 90-97 range**	**Catch decline or increase by >30%**	**Effort >110% of maximum 95-97 range**	**Catch rate < 80% of minimum 95-97 range**	**Biological indicators of stock stress**	**Risk if no manageme nt action**
Banded morwong*	Y ↓[#]	N	N	Y [#]	Y	H
Southern calamari	Y ↑	**Y ↑**	Y	N	N	M
Striped trumpeter	Y ↓	N	N	Y [#]	Y	H
Bastard trumpeter	Y ↓	N	N	N	na	M
Garfish	**Y ↓**	**Y ↓**	N	**N**	na	L[##]
Wrasse**	N	N	N	N	na	L
Blue warehou***	Y ↓	N	N	N	na	-
Australian salmon	Y ↓	**Y ↓**	N	Y	na	L
Flathead	N	**Y ↓**	N	N	na	L

Table 3 Summary assessment of alternative performance indicators and reference points for key species.

[##] Main fishery managed by Commonwealth; Y triggered, N not triggered, arrows indicate direction of change, na not assessed, [#] applies only to particular methods or regions.

Reference point	Banded morwong	Southern calamari	Striped trumpeter	Bastard trumpeter	Garfish	Wrasse	Blue warehou[##]	Australian salmon	Flathead
Commercial catch in Region 1 > 30% of TAC Region 2 > 65% of TAC Region 3 > 40% of TAC Outside TAC area >10t	na								
Commercial catch is < 90% of TAC	na								
Catch rates are below 0.9 * average from reference period 2000/01 to 2005/06	Y[#]								
Commercial catch for GOB & MP > 50t Remainder SE > 30t Outside GOB, MP & SE > 25t		N							
Consistently declining trend in catch over 3 years by a total of > 40% in south-east Tasmanian waters		N							
Commercial catch is > 50t			N						
Catch curve estimated every 3 years as an index of fishing mortality from all sectors: Target: Fishing mortality $F \leq$ Natural mortality M Limit: $F = 1.5*M$			na						
Pending				-					
Catch outside reference range from 1998/99 to 2005/06 (66-102t)					Y↓				
Catch outside reference range from 1998/99 to 2005/06 (72-99t)						Y↑			
Commercial catch limit of 318 tonnes as per Memorandum of understanding (MOU)							N		
Commercial catch limit of 435 tonnes as per Ministerial decision								N	
Catch by Danish Seine > 1.3* the maximum catch from reference period 1998/99 to 2005/06: South-east coast: 45t East coast: 63t									N
Any indicator of stock stress	Y	N	Y	na	na	na	na	na	na

1 Management objectives and strategies

The Scalefish Management Plan was first introduced in 1998 (DPIF 1998) and was reviewed in 2001 and again in 2004. The primary issues tackled in the latest review related to latent effort in the fishery (addressed by introducing non-transferability for class-C and inactive licences), wastage in gillnets (addressed by a prohibition on night netting for recreational fishers and the requirement for commercial operators to be in attendance whilst night netting[1]), a review of recreational possession and size limits and the closing of further selected waters to gillnetting.

The management plan provides the regulatory framework for the fishery, which covers commercial and recreational components. The plan contains the following objectives, strategies and performance indicators.

1.1 Major objectives

- To maintain fish stocks at sustainable levels by restricting the level of fishing effort directed at scalefish, including the amount and types of gear that can be used;
- To optimise yield and/or value per recruit;
- To mitigate any adverse interactions that result from competition between different fishing methods or sectors for access to shared fish stocks and/or fishing grounds;
- To maintain or provide reasonable access to fish stocks for recreational fishers;
- To minimise the environmental impact of scalefish fishing methods generally, and particularly in areas of special ecological significance;
- To reduce by-catch of juveniles and non-target species; and
- To implement effective and efficient management.

1.2 Primary strategies

- Limit total fishing capacity by restricting the number of licences available to operate in the fishery;
- Define allowable fishing methods and amounts of gear that can be used in the scalefish fishery;
- Monitor the performance of the fishery over time, including identification and use of biological reference points (or limits) for key scalefish species;
- Protect fish nursery areas in recognised inshore and estuarine habitats by prohibiting or restricting fishing in these areas;
- Employ measures to reduce the catch and mortality of non-target or undersized fish; and
- Manage developing fisheries under permit conditions.

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[1] Note: some exclusions exist in relation to the gillnet usage changes.

1.3 Performance indicators

In the absence of more quantitatively rigorous stock assessments, the Scalefish Fishery Management Plan identifies a number of performance indicators that are used to define ranges between which the fishery, both in general and for particular species, is deemed to be performing acceptably. If the observed value of a performance indicator falls outside the acceptable range the reference point is said to have been exceeded and this is taken to imply that some management action may be required. Analysis of fishery performance under this (initial) strategy is measured by reference to:

- variations in the total catch from year to year, or between seasons, regions and sectors;
- trends in effort;
- trends in catch rates;
- changes in biological characteristics, such as a changes in size or age structure; and
- other indicators of fish stock stress, for example disease outbreaks.

As part of this strategy, reference or trigger points, or acceptable ranges, have been defined as levels of, or rates of change, that are considered to be outside the normal variation of the stock(s) and the fishery. The trigger points provide a framework against which the performance of the fishery can be assessed and (if necessary) flag the need for management action. Currently, reference points are exceeded when one or more of the following criteria are met:

- total catch of a key target species is outside of the 1990 to 1997 range; or when total catch of a key target species declines or increases in one year more than 30% from the previous year;
- fishing effort for any gear type, or effort targeted towards a species or species group, increases by 10% from the highest of the 1995 to 1997 levels;
- catch rates for a key target species is less than 80% of the lowest annual value for the period 1995 to 1997;
- a significant change in the size composition of commercial catches for key target species; or when monitoring of the size/age structure of a species indicates a significant change in the abundance of a year class (or year classes), with particular importance on pre-recruit year classes;
- a change in the catch of non-commercial fish relative to 1990 to 1997 records; or when incidental mortality of non-commercial species or undersized commercial fish is unacceptably high;
- significant numbers of fish are landed in a diseased or clearly unhealthy condition; or when a pollution event occurs that may produce risks to fish stocks, the health of fish habitats or to human health; or when,
- any other indication of fish stock stress is observed.

The fishery has also been assessed against an alternative set of reference points which account for recent developments in the fishery. These alternative reference points are intended to replace the existing indicators over the next few years.

2 Fishery assessment

2.1 The fishery

The Tasmanian scalefish fishery is a multi-gear and multi-species fishery. The main gear types include gillnet, hooks and seine nets, harvesting a diverse range of scalefish, shark and cephalopod species. Other fishing gears in use include traps, Danish seine, dip nets and spears. A listing of common and scientific names of species reported in catches is presented in Appendix 1.

In many respects the scalefish fishery is dynamic, with fishers readily adapting and changing their operations in response to changes in fish availability and in response to market requirements and opportunities. As a consequence, only a small proportion of the fleet has specialised in a single activity or targeting a primary species. For many operators, scalefish represent an adjunct to other activities, for instance rock lobster fishing.

This report covers the assessment of key scalefish and cephalopod fisheries under Tasmanian jurisdiction. Other species, such as tiger flathead, blue warehou, jackass morwong, ocean perch, blue eye trevalla, blue grenadier, school and gummy shark, are managed under Commonwealth jurisdiction. Formal assessments for these species are undertaken by the Southern and Eastern Scalefish and Shark Fishery Assessment Group (SESSFAG; *e.g.* Tuck 2006) and are summarised in fishery status reports produced by the Bureau of Rural Sciences (e.g. Caton and McLoughlin 2004).

This report continues the series of annual assessments of the scalefish fishery and incorporates catch and effort information available up to and including June 2007. Copies of previous assessment reports are available on the TAFI web page - http://www.utas.edu.au/tafi/TAFI_Download.htm.

2.2 Data sources

Commercial catch and effort data are based on Tasmanian General Fishing Returns, and Commonwealth non-trawl (GN01 and GN01A) and Southern Squid Jig Fishery (SSFJ) logbook returns. Unless noted otherwise, catch and effort data reported in this assessment relate to the commercial sector. Catch and effort information are not routinely collected for the recreational sector.

2.2.1 General fishing returns

General Fishing Returns prior to 1995 provided only monthly summaries of landed catches and limited effort information that was of little value for effort and catch rate analyses (Lennon 1998).

During 1995, a revised General Fishing Return was introduced, replacing the monthly return with catch and effort information reported on a daily basis for each fishing method used. The revised returns provide greater detail about fishing operations, including more explicit specification of fishing method, greater spatial resolution (30nm or ½ degree rather than 1 degree blocks), plus details about effort and depths fished. Amendments in 1999 included provision to nominate target species and an option to indicate interference to fishing operations from marine mammals (*e.g.* seals or killer whales). In analysing General Fishing Returns some data manipulation has been undertaken, details of which are provided in Appendix 2.

2.2.2 Commonwealth catch returns

Following the introduction of the Commonwealth non-trawl logbook (GN01 and subsequent versions) in late 1997, dual endorsed Tasmanian and Commonwealth (South East Non-Trawl and Southern Shark) operators generally commenced recording all of their catch and effort data, including fishing in State waters, in the Commonwealth logbooks. In addition, several dual endorsed squid operators reported some or all of their state waters fishing activity in the Southern Squid Jig Fishery (SSJF) logbook. As most of these operators did not explicitly indicate whether fishing occurred in State or Commonwealth waters, it has been necessary to incorporate all activity reported from coastal fishing blocks in the analyses. For details of data restrictions and manipulations involving Commonwealth logbook data see Appendix 2.

During 2001, dual endorsed fishers were instructed to report all fishing activities under State jurisdiction in the Tasmanian General Fishing Returns. This should have removed the necessity to include subsequent Commonwealth catch and effort data into analyses but it became apparent that there was some confusion amongst fishers about reporting requirements. For example, catches of species such as striped trumpeter taken by Commonwealth operators were not routinely reported in the Tasmania catch returns. Commonwealth logbook data since 2001 have been available for the current assessment. Data were checked for possible double reporting (*i.e.* on both the Tasmanian and Commonwealth catch returns) and where this was not the case, the catch and effort database used in this assessment was updated.

2.2.3 Data analysis

For the purposes of this assessment, effort and catch rate analyses are restricted to commercial data provided for the period July 1995 to June 2007. All catch returns from within this period and available as at September 2007 have been incorporated in the analyses.

A fishing year from 1st July to 30th June in the following year has been adopted for annual reporting. This period reflects the seasonality of the fisheries for most species better than the calendar year, with catches (and effort) generally concentrated between late spring and early autumn. In addition, it better encompasses the biological processes of recruitment and growth for most species.

If not stated otherwise, catches have been analysed State-wide and by region. Five broad assessment regions have been identified, *viz.* south-east coast (SEC), east coast (EC), north-east coast including Flinders Island (NEC), north-west coast including King Island (NWC), and west coast (WC) (Fig. 2.1).

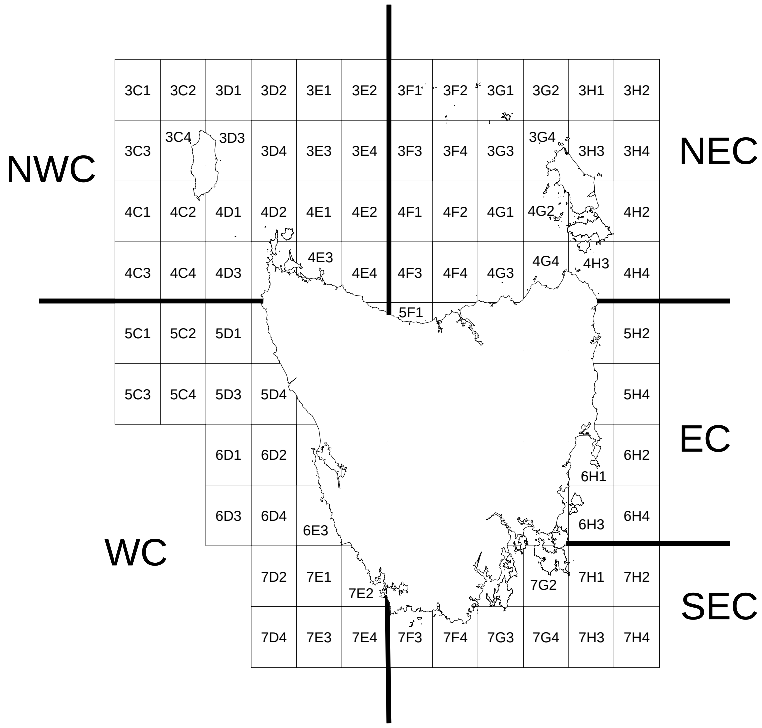

Fig. 2.1: Map of Tasmania with 30 nm fishing blocks and the assessment regions. SEC is south-east coast, EC is east coast, NEC is north-east coast, NWC is north-west coast, and WC is west coast.

Two measures of effort have been examined: (i) days fished (*i.e.* number of days on which a method/gear type was reported); and (ii) quantities of gear/time fished using the method. Since a diverse range of gear types are utilised in the fishery, appropriate measures of effort differ with gear type. For instance, gillnet effort has been calculated as a function of the quantity of net set and fishing duration, dropline and longline effort is expressed in terms of number of hooks set, while handline fishing is reported as the product of the number of lines fished and fishing duration. Measures of effort by fishing method are presented in Table 2.1.

Catch returns for which effort information was incomplete or unrealistically high or low (either due to data entry error or misinterpretation of information requirements by fishers) were flagged and excluded when calculating effort levels based on gear units or catch rates based on catch per unit of gear. Only a small number of fishing records for 2006/07 needed to be excluded in this manner. All records were, however, included for reporting catch, days fished and catch per day.

Table 2.1. Table of effort gear units by fishing method

Method	Effort gear units
Beach seine/purse seine	No. of shots
Graball/small mesh net	100 m net hours
Dropline	100 hook lifts
Handline	Line hours
Fish trap	No. trap or pot lifts
Squid jig	Jig hours
Spear	Fisher hours
Dip net	Dip net hours

In generating catch rate statistics, the geometric mean rather than the arithmetic mean of all valid individual daily catch records has been calculated, since catch rate data are typically log-normally distributed. The geometric mean is calculated as the nth root of the product of the individual rates (y_i)

$$GM_{\bar{y}} = \sqrt[n]{\prod y_i}$$

This is equivalent to computing the arithmetic mean of the natural logarithm of each number, and then taking the exponent:

$$GM_{\bar{y}} = \exp\left[\frac{1}{n}\left(\sum \ln\left(y_n\right)\right)\right]$$

It should be noted that catch rates calculated in this manner may differ slightly from the more simplistic approach of dividing total catch by total effort or using the arithmetic mean. The geometric mean has the advantage of being less affected by the few observations that are skewed very high, as often happens with log-normally distributed data.

2.2.4 Recreational fishery

A detailed analysis of the Tasmanian recreational fishery, based on the 2000/01 National Survey dataset, has been recently completed (Lyle 2005). Apart from recreational net licence numbers, there are no additional data relevant to the recreational scalefish fishery in Tasmania.

2.3 Commercial catch trends

Annual commercial catches have been variable since 1990/91 (Table 2.2) and since the early 1990s, catch trends for the major species (except garfish) have generally been declining (Fig. 2.2). Overall, total scalefish catches declined from over 2000 tonnes in the early 1990s to around 1000 tonnes in recent years.

The 2006/07 catch of 593 tonnes continues this downward trend and represented a decrease of 250 tonnes compared to 2005/06. Australian salmon have consistently dominated the scalefish catch and their catch decline by 140 tonnes has strongly contributed to the overall trend. Catches declined also for barracouta (-34 tonnes), flathead (-35 tonnes), and garfish (-41 tonnes), while only whiting (+36 tonnes) and wrasse (+12 tonnes) experienced an increase. Catches of most other scalefish species were within ± 10 tonnes of 2005/06 levels.

When assessing trends within the scalefish fishery it is important to recognise that some species occur seasonally in Tasmanian waters and that availability can differ markedly between years; such variability does not necessarily reflect changes in stock condition. Species in this category include blue warehou, barracouta and arrow squid. By contrast, species such as banded morwong, garfish, wrasse, the trumpeters and calamari are resident species, and variability in catches can reflect a combination of factors, including market forces, management intervention, stock status and intrinsic variability in life history.

Catch trends will be discussed in separate chapters for the key species such as banded morwong, calamari, striped trumpeter, bastard trumpeter, garfish, wrasse, blue warehou, Australian salmon, and flathead. Interesting trends of other species include (Table 2.2 and Fig. 2.2):

- In the early 1990s, barracouta catches declined sharply from around 350 tonnes to around 60 tonnes by 1993/94. Up until 2001/02, landings remained at low levels reflecting, in part at least, low market demand coupled with reduced availability. The most recent catch of 26 tonnes was lower than in the preceding year, but within the range of reference catch levels.
- Catches of flounder (greenback and long-snouted flounder) declined steadily from over 40 tonnes p.a. during the early 1990s to around 12 tonnes in 2000/01 and have remained low since then. The current catch of 13 tonnes is well below reference catches.
- Corresponding to the reduction in inshore trawl activity in the early 1990s, jackass morwong landings declined from over 100 tonnes p.a. to between 10-20 tonnes in more recent years. The current catch is the lowest on record and thus below reference levels. However, little can be inferred from recent trends as Tasmanian catches represent only a minor component of the fishery for the species relative to the Commonwealth sector. The most recent Commonwealth assessment indicates that the stock is relatively depleted with an estimated spawning biomass close to the limit reference point of 20% unfished spawning biomass.
- Landings of mullet (sea and yellow-eyed mullet) were around 30 tonnes in the early 1990s, but have since declined steadily. The catch of 5 tonnes in 2006/07 was similar to that for 2004/05 and the lowest level on record.
- Whiting catches experienced a marked decline during the early 1990s, largely in response to reduced inshore trawl activity (Lyle and Jordan 1999). Since the mid-1990s, annual landings have stabilised between 30-55 tonnes with the exception of 2005/06. The current catch of 40 tonnes is within reference levels. Market demand and fishing practices (level of targeting flathead and whiting by Danish seine) are considered to be the main factors influencing catch levels.
- The massive increase in cephalopod production at 824 tonnes was mainly due to an increase in the catches for calamari (+39 tonnes) and arrow squid (+693 tonnes), while catches for octopus decreased (-52 tonnes). Arrow squid occur only seasonally and sporadically in Tasmanian coastal waters. Similarly to the peak in 1999/2000, this year's high catches were taken by vessels with automated squid jigs over a short period of time and from a very limited area (Storm Bay near Hobart). After an initial increase in the mid 1990s, total octopus catches grew steadily again until last year to 99 tonnes, but have dropped to 47 tonnes in 2006/07.

Table 2.2. Annual 'Tasmanian' scalefish and cephalopod production (whole weight in tonnes) by fishing year since 1990/91 based on General Fishing Returns and Commonwealth (GN01, GN01A and SSJF) logbook returns.

Species	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07
Scalefish																	
Australian salmon	815.9	651.9	867.0	878.8	682.1	413.2	287.3	476.0	384.7	363.7	485.0	462.1	407.2	167.2	336.5	254.2	114.9
Barracouta	351.5	268.3	205.4	59.6	25.2	19.3	53.8	65.2	27.6	25.0	15.1	132.1	65.5	85.2	97.3	60.1	25.8
Boarfish	7.2	9.4	7.6	10.1	9.1	7.3	10.4	9.4	7.0	7.2	8.0	5.5	3.6	4.3	3.6	5.0	4.9
Cod	10.0	11.3	11.6	14.5	12.7	18.6	12.8	9.5	9.8	9.0	3.8	3.0	2.2	2.1	1.6	2.0	2.6
Flathead	165.3	118.1	98.8	121.4	91.1	57.9	51.8	62.9	50.6	60.3	63.4	52.1	40.8	31.2	74.7	91.9	56.7
Flounder	44.0	36.8	31.8	27.3	27.1	33.4	29.4	29.7	25.2	18.6	12.4	13.0	12.1	15.1	14.7	10.9	12.5
Garfish	80.9	80.1	82.3	82.9	69.3	56.2	91.6	83.0	101.7	91.2	81.4	87.8	92.5	66.2	85.5	89.3	48.5
Gurnard	20.5	19.0	19.3	19.3	14.0	13.5	10.4	9.1	7.1	9.9	7.8	5.3	9.7	6.8	6.1	5.1	5.6
Leatherjacket	12.2	14.0	13.1	23.3	27.7	14.5	12.6	13.3	12.9	16.5	16.7	16.6	13.7	14.8	10.4	8.5	8.8
Ling	5.1	13.6	30.0	41.6	33.2	15.0	13.4	9.0	4.9	2.2	5.1	0.9	0.4	0.8	0.7	0.4	0.4
Mackerel, jack	6.1	11.1	32.8	48.4	39.7	26.2	19.3	19.7	59.8	13.7	8.6	19.4	19.4	41.1	12.8	6.8	2.6
Mackerel, other	3.0	2.1	0.3	8.5	5.7	2.0	1.3	1.0	0.5	2.1	0.1	0.0	0.1		0.5	0.5	0.2
Marblefish	0.2	0.9	0.3	1.0	1.8	3.5	5.6	3.0	2.6	4.2	4.0	4.4	3.1	0.6	1.1	0.5	2.0
Morwong, banded	7.0	6.9	39.2	145.5	105.8	86.7	79.0	72.6	42.4	33.8	39.2	53.7	56.0	46.4	45.6	54.3	46.2
Morwong, jackass	136.9	111.9	83.2	117.6	63.1	27.1	19.0	34.1	18.2	16.6	13.7	14.8	14.4	16.3	17.5	13.1	11.7
Morwong, other	3.8	5.6	5.2	13.9	8.1	5.4	7.4	7.4	6.3	1.5	0.6	1.4	1.9	1.2	1.8	1.3	1.3
Mullet	31.2	22.2	26.2	19.5	23.8	10.8	11.2	16.0	14.5	21.0	13.7	12.1	7.3	7.5	5.1	7.5	4.5
Other	140.2	110.4	97.4	102.0	62.0	35.4	38.4	41.3	24.6	16.3	15.6	13.0	31.2	25.5	26.9	29.0	14.2
Pike	10.5	9.5	11.1	12.7	18.8	14.0	18.3	21.6	12.6	14.0	12.5	18.8	17.3	17.7	8.9	13.9	16.6
Trevally	20.6	13.6	12.0	8.3	21.6	5.9	4.5	7.8	8.1	3.2	1.6	4.6	5.5	3.4	3.7	5.5	3.5
Trumpeter, bastard	63.3	37.2	34.0	54.8	50.8	60.1	51.8	40.7	47.7	36.4	26.1	23.9	21.0	23.2	18.5	23.5	19.9
Trumpeter, striped	74.5	58.2	52.7	56.5	72.4	60.3	80.4	81.1	107.4	101.8	49.6	44.8	40.0	40.5	26.2	23.8	22.2
Trumpeter, unspec.	0.7	0.0	0.0	0.4	0.1	0.2	0.1	0.6	3.5	0.0				0.0			
Warehou, blue	257.6	317.6	187.7	250.1	205.4	82.3	128.7	189.5	274.3	187.6	36.0	66.4	49.3	27.5	19.7	20.0	28.6
Warehou, other	0.7	0.4	4.2	8.8	3.4	14.6	15.6	4.8	1.0	0.0	0.0	0.1	0.2	0.1	0.8	0.1	0.0
Whiting	124.2	152.3	84.3	97.9	81.4	25.5	39.6	48.3	30.6	31.7	42.7	40.1	39.9	55.5	38.3	28.3	40.2
Wrasse	57.2	71.7	97.3	142.4	178.0	83.4	110.1	100.0	90.7	85.4	88.4	92.3	72.0	75.1	99.4	92.9	108.2
Total scalefish	**2450**	**2154**	**2135**	**2367**	**1933**	**1192**	**1204**	**1457**	**1376**	**1173**	**1051**	**1188**	**1026**	**776**	**958**	**848**	**602**

Table 2.2. cont. Whole weight in tonnes by fishing year

Species	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07
Cephalopod																	
Calamari	8.2	7.5	5.8	9.7	12.6	33.0	19.0	26.6	94.5	84.6	76.6	104.8	108.8	86.8	114.2	44.5	83.3
Cuttlefish	0.5	0.7	0.0	1.1	0.8	0.2	0.3	0.2	0.0	0.0	0.0	0.7	2.4	1.0	0.2	0.4	0.1
Octopus	32.2	35.2	47.4	58.2	55.3	76.9	40.8	43.4	85.5	61.5	62.0	63.1	67.7	71.1	81.4	98.6	46.8
Squid, arrow	35.1	7.2	7.0	7.7	8.6	5.7	7.8	12.9	79.7	480.5	39.7	2.4	1.9	2.1	2.6	1.8	694.3
Total cephalopod	**76**	**51**	**60**	**77**	**77**	**116**	**68**	**83**	**260**	**627**	**178**	**171**	**181**	**161**	**198**	**145**	**824**
Sharks[2]																	
Elephant shark						58	50	33	29	43	40	18	16	10	8	6	9
Gummy shark						750	627	715	798	1021	1148	23	14	25	41	12	13
Sawshark						128	89	113	87	110	128	21	20	21	23	6	3
School shark						253	197	217	150	136	72	2	1	7	3	1	2
Seven-gilled shark						6	8	16	18	34	44	19	7	12	8	4	4
Other shark						36	21	24	19	22	15	10	12	8	3	2	4
Total sharks						**1231**	**991**	**1118**	**1102**	**1366**	**1448**	**94**	**72**	**82**	**86**	**31**	**34**

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[2] Since 2001/02, shark catches have been reported in Commonwealth logbooks. Tasmania has jurisdiction of all shark species inside 3nm except gummy and school shark, and fishers are on bycatch possession limits for all species.

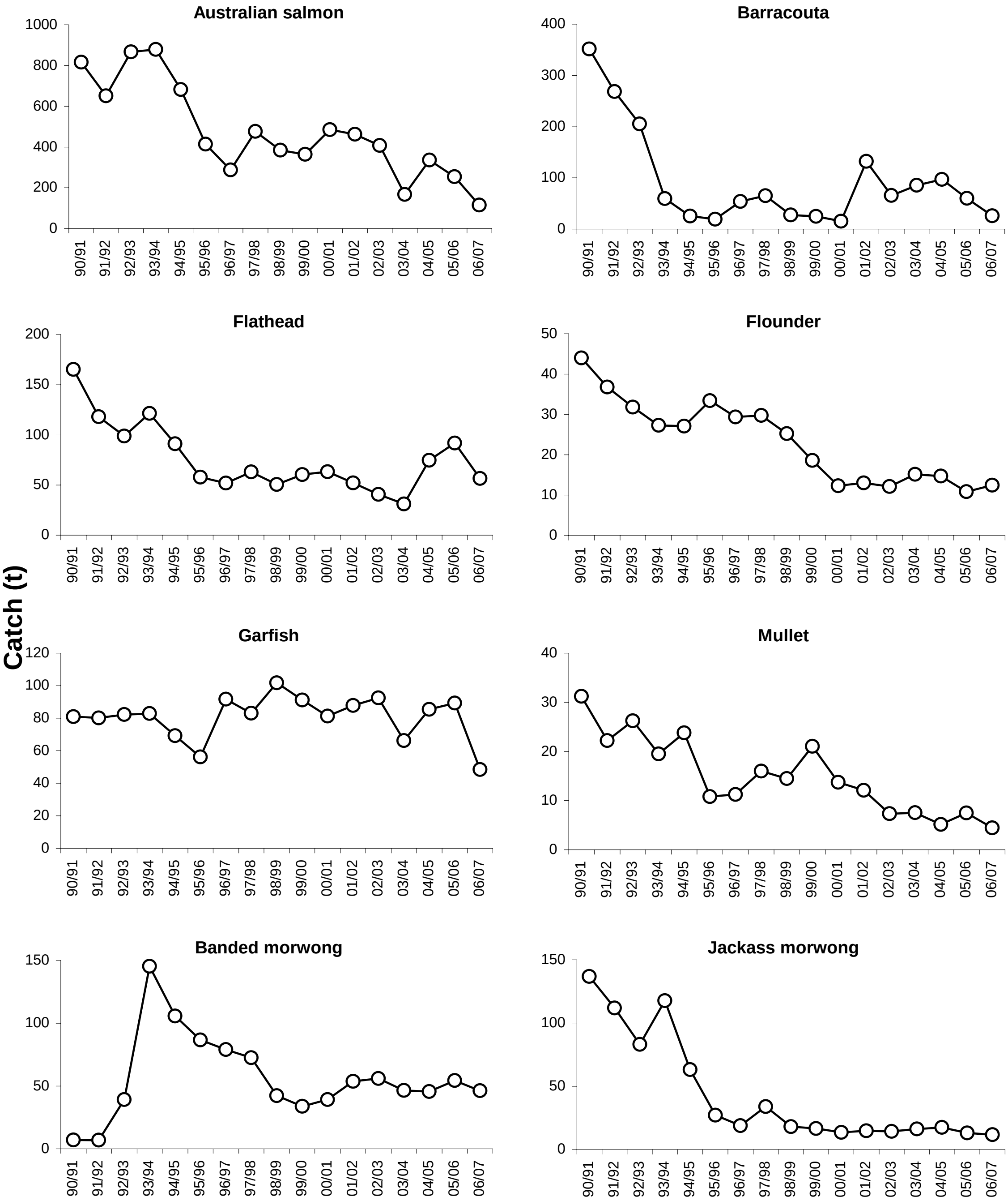


Fig. 2.2. Annual catches for key scalefish species since 1990/91.

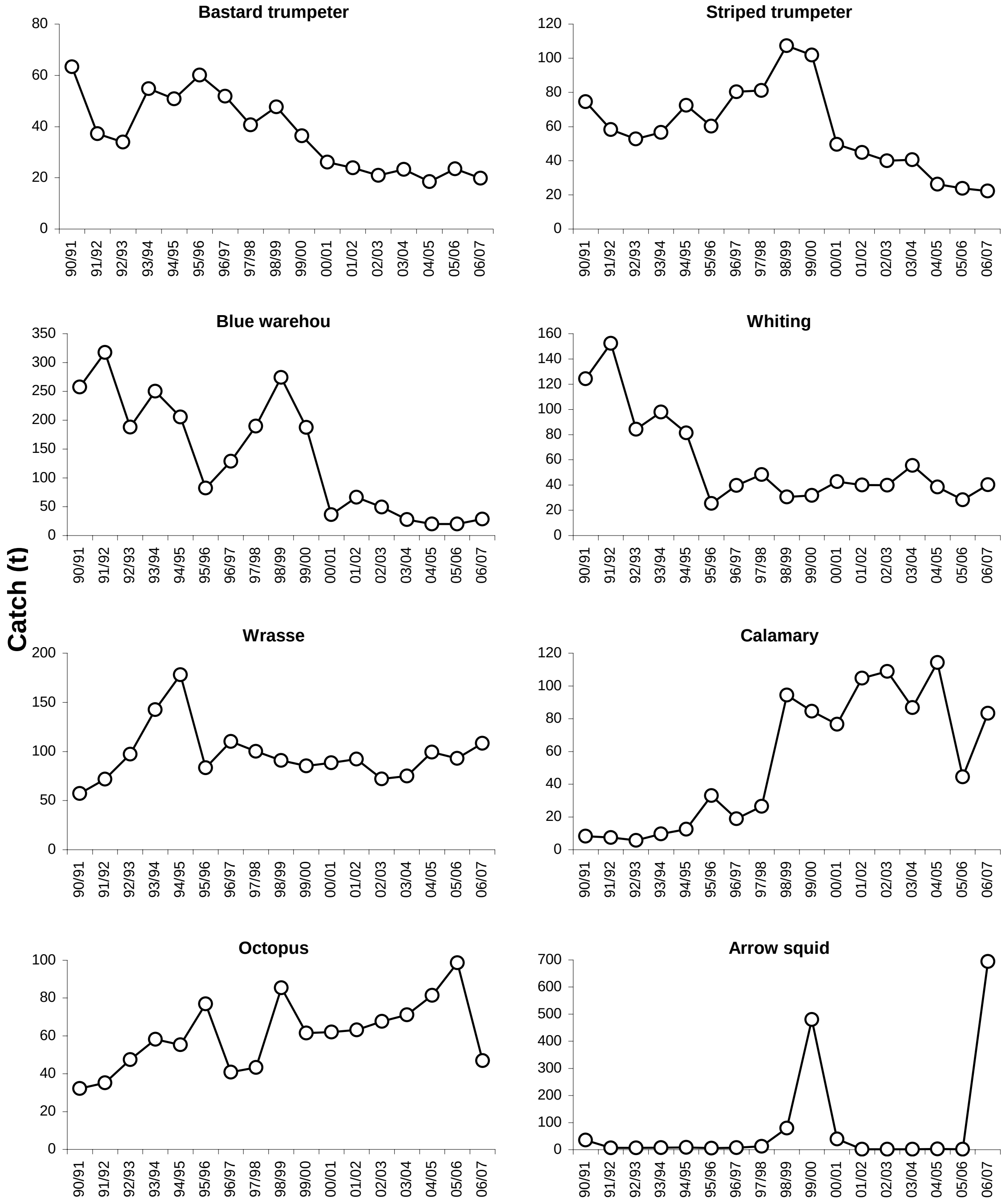


Fig. 2.2. Continued.

2.4 Commercial effort trends

The Scalefish Management Plan contains two trigger points that pertain to fishing effort, one based on effort relating to a particular gear type and the other based on effort directed towards a species or species group. A trigger point is reached when effort exceeds the peak level for the period 1995-1997 by at least 10% (for the present analysis the reference period is taken as 1995/96 to 1997/98).

Catch and effort by the main fishing gear types are presented in Table 2.3. Since a variety of gear types are represented, it has been necessary to express effort in units appropriate to each specific fishing method (Table 2.1). Effort has also been expressed in terms of number of days fished using the specified gear type, irrespective of the amount of gear utilised each day. Although days fished represents a less sensitive measure of effort, it has become apparent that some fishers have misinterpreted reporting requirements for effort. Days fished overcomes any uncertainty about the accuracy of reporting effort units.

For the purpose of analysis, dropline catch and effort up to 1998 was restricted to records that indicated a fishing depth of less than 200 m. This restriction effectively excluded reports of dropline fishing for blue-eye trevalla (since 1998 fishing for blue-eye has been covered in Commonwealth catch returns) but effectively encompassed the target fishery for striped trumpeter (less than 1% of the striped trumpeter catch has been reported from depths greater than 200 m). In addition, shark net and bottom longline catch and effort methods have been excluded since these methods relate specifically to the shark fishery, now managed by the Commonwealth.

Since the mid 1990s effort for the major gear types either declined (beach seine, purse seine, graball and small mesh nets), increased or remained stable initially but has then undergone declines (dipnet, dropline, spear and fish trap), or increased over time (handline and squid jig; Table 2.3 and Fig. 2.3). Following the introduction of the new management arrangements in November 1998, effort based on beach seine, purse seine, graball and handline all fell whereas effort based on dropline, squid jig and dipnet all increased sharply. While a range of factors, including availability of target species and market developments, have had an influence, there is little doubt that management changes have had a direct impact on effort levels. Specifically, methods for which gear allocations or access became more regulated (beach seine, purse seine and gillnets) demonstrated declines in effort whereas there was a shift to and increase in effort for less regulated methods (hooks, jigs and dipnets; i.e. gear that is equally available to all licence-holders).

Effort levels during 2006/07 were generally similar to or lower than in 2005/06 for most gear types, except for squid jig, handline and spear which all increased. The effort performance indicator of 110% from the highest of the 1995 to 1997 levels was only exceeded for squid jig. Notwithstanding this, there are continuing concerns, regarding the level of latent effort from licence-holders who are currently either not active in the fishery or participating at low levels but with access to gear such as gillnets, hooks, dipnets and jigs. The 2004 management plan review has attempted to address this issue through several strategies including non-transferability of C-class licences.

Considering effort by gear type alone can mask important dynamics within the fishery itself, such as shifts in species targeting. This is particularly pertinent where individual species may be targeted using a variety of gear types and where a given gear type can be used to target a number of different species. For instance, beach seines are used primarily to target Australian salmon or garfish (Fig. 2.3). While effort for Australian salmon has remained relatively stable since 1995/96, fluctuations in effort for garfish have had the greatest influence on overall beach seine effort. The decline in purse seine effort (Table 2.3) was driven largely by falls in effort directed at calamari, whereas there has been only minor variation in purse seine effort for garfish in recent years (not shown).

Lyle (1998) noted that there are effectively three main sub-fisheries within the graball fishery, targeting blue warehou, banded morwong and flounder (Fig. 2.3). A variety of other species are also commonly taken as by-product of these sub-fisheries. By analysing graball effort based on the occurrence of these species in the catches, an initial increase in effort for blue warehou was evident. The effort peaked in 1997/98 (gear units) and 1998/99 (days fished) and then rapidly declined especially between 1999/00 and 2000/01. Effort directed at banded morwong declined up until the late 1990s, but then expanded slightly between 2000/01 and 2002/03 and stabilised at a lower level in recent years. By comparison, effort directed at flounder has decreased steadily of over time and is now at a low level.

Striped trumpeter and wrasse are the two main species targeted by handline and these fisheries demonstrate different trends in effort (Fig. 2.3). Handline effort for striped trumpeter increased up until 1999/00 but has gradually fallen since that time. This contrasts the pattern for wrasse, where effort rose to an initial peak in 1996/97, declined to 1998/99 and then climbed gradually to levels higher than the peak reported in the mid 1990s.

Garfish and calamari are the two main species captured by dipnet (Fig. 2.3). The overall dipnet effort closely follows that for garfish, indicating garfish was captured during most dipnet operations. In contrast, the low dipnet catches for calamari (see Section 4) suggest that calamari was mainly caught incidentally or as a bycatch.

A significant expansion in jig effort (particularly evident in days fished; Table 2.3) commenced in 1998/99 and was initially directed at calamari, but in 1999/00 there was also a dramatic increase in effort targeted at arrow squid (graph not shown). Effort for calamari continued to rise up until 2004/05, fell sharply in 2005/06 and increased again to high levels in the most recent year. Concurrently, increased squid jig (and automated jig) effort was directed at arrow squid, after very low levels of effort for this species since the 1999/00 peak.

The remaining methods are used primarily to target single species and as such effort trends tend to reflect the dynamics of the fishery for the target species, i.e. dropline for striped trumpeter, spear for flounder and fish traps for wrasse. Species-based effort trends are also considered in more detail in Chapters 3 to 9.

Table 2.3. Total annual catch, effort and number of vessels by fishing methods - 1995/96-2006/07

Effort units are defined in Table 2.1. * Catch data not shown where five or fewer vessels involved.

Gear	Year	Catch(t)	Effort#	Days fished	Vessels
Beach seine	95/96	469.2	1083	559	54
	96/97	356.3	1352	689	50
	97/98	520.9	1203	582	44
	98/99	440.4	864	397	41
	99/00	422.7	844	428	33
	00/01	528.1	784	372	31
	01/02	570.9	1053	494	30
	02/03	490.7	1061	511	35
	03/04	238.1	1262	458	31
	04/05	397.0	974	368	27
	05/06	308.4	653	304	25
	06/07	139.2	505	217	25
Purse seine	95/96	35.2	417	185	11
	96/97	30.4	336	153	10
	97/98	41.8	319	154	7
	98/99	76.9	246	150	9
	99/00	33.7	244	123	10
	00/01	*	224	104	4
	01/02	*	216	91	5
	02/03	*	139	76	4
	03/04	*	68	45	3
	04/05	*	130	70	5
	05/06	*	122	60	4
	06/07	*	86	41	4
Graball net	95/96	348.0	222350	5440	260
	96/97	378.7	230803	5182	232
	97/98	446.3	230219	5249	216
	98/99	493.3	165759	4689	208
	99/00	359.7	150849	4169	204
	00/01	173.4	86638	3187	186
	01/02	196.0	70735	3303	180
	02/03	231.0	85317	3394	168
	03/04	189.8	68959	2904	160
	04/05	154.6	53727	2491	137
	05/06	170.3	51393	2400	123
	06/07	161.8	53694	2437	132
Small mesh net	95/96	38.7	10995	286	20
	96/97	27.0	7941	260	14
	97/98	21.8	7875	246	17
	98/99	31.2	7772	282	14
	99/00	22.7	6232	210	15
	00/01	20.8	8135	256	14
	01/02	24.7	9808	259	11
	02/03	22.9	10216	284	11
	03/04	23.0	7236	228	11
	04/05	15.9	5982	220	13
	05/06	21.7	5854	191	11
	06/07	16.3	7001	198	11
Dip net	95/96	*	320	83	5
	96/97	24.2	1518	364	11
	97/98	37.8	1888	446	22
	98/99	43.1	2746	569	29
	99/00	29.3	2262	500	35
	00/01	22.8	1422	371	27
	01/02	24.8	1542	387	27
	02/03	18.7	1245	337	20
	03/04	25.6	1553	374	19
	04/05	27.4	1506	305	16
	05/06	39.1	2139	376	18
	06/07	22.4	1282	238	17

Table 2.3. Continued

Gear	Year	Catch(t)	Effort#	Days fished	Vessels
Fish trap	95/96	41.8	8262	1401	67
	96/97	57.2	10707	1796	66
	97/98	49.9	9864	1875	71
	98/99	53.7	10624	1559	56
	99/00	56.1	10909	1637	62
	00/01	54.3	9338	1548	68
	01/02	49.0	6063	1278	62
	02/03	38.2	6158	1246	58
	03/04	48.0	6307	1414	58
	04/05	46.7	7392	1222	55
	05/06	44.4	12238	1419	55
	06/07	43.9	10944	1321	48
Drop line	95/96	19.9	423	158	31
	96/97	30.0	433	203	27
	97/98	24.7	537	222	42
	98/99	31.8	663	309	38
	99/00	30.8	385	291	48
	00/01	15.8	380	248	36
	01/02	12.8	218	258	35
	02/03	18.8	264	350	43
	03/04	19.4	378	281	51
	04/05	14.1	351	219	31
	05/06	9.3	185	204	33
	06/07	7.0	255	130	28
Hand line	95/96	74.3	16801	1612	147
	96/97	94.3	21460	1893	135
	97/98	97.5	21038	1702	145
	98/99	88.2	17638	1278	128
	99/00	87.7	16602	1437	133
	00/01	74.2	13583	1541	130
	01/02	87.3	15413	1601	138
	02/03	72.0	14974	1547	124
	03/04	76.0	15381	1401	126
	04/05	98.0	19761	1773	123
	05/06	82.5	20177	1880	116
	06/07	100.7	20940	2031	129
Squid jig	95/96	10.1	5386	124	22
	96/97	5.7	640	77	14
	97/98	15.2	4381	211	18
	98/99	89.8	10200	613	54
	99/00	161.6	42235	1005	65
	00/01	66.5	13141	793	53
	01/02	85.2	12412	925	65
	02/03	91.8	19182	1228	68
	03/04	69.8	15714	1223	73
	04/05	104.8	22294	1424	79
	05/06	35.3	11131	766	59
	06/07	195.7	16832	1205	68
Spear	95/96	14.0	1382	366	21
	96/97	19.3	1843	463	28
	97/98	16.8	1977	483	41
	98/99	19.8	1804	452	41
	99/00	19.3	2229	475	25
	00/01	14.4	1586	355	22
	01/02	13.1	1296	279	19
	02/03	11.6	1378	247	22
	03/04	10.7	1432	288	22
	04/05	13.5	1569	353	23
	05/06	7.8	1006	270	21
	06/07	15.0	1330	347	19

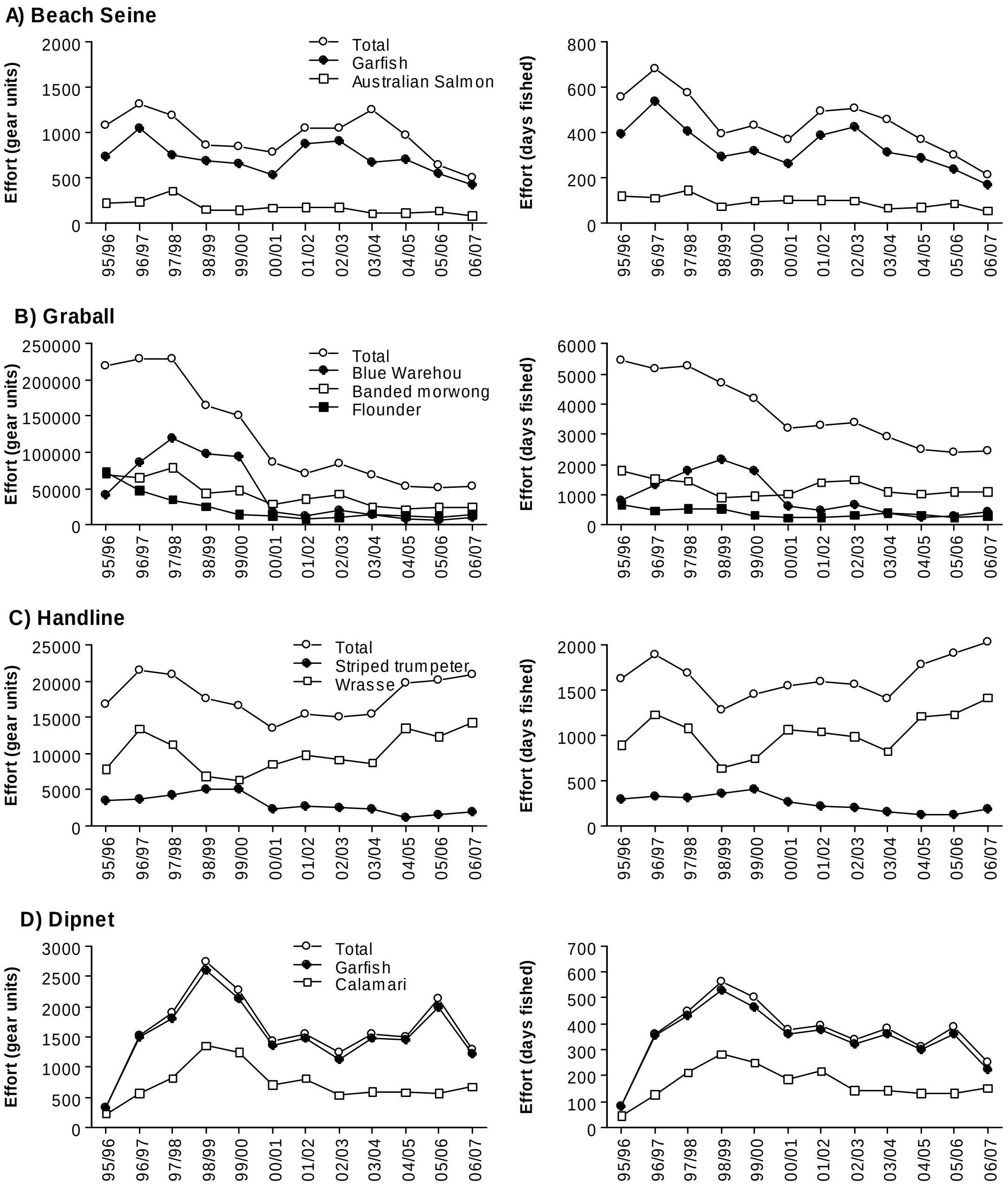


Fig 2.3. Annual effort by selected methods for key species, expressed as gear units (refer Table 2.1) and days fished.

2.5 Catch rates

Catch rate or catch per unit effort (CPUE) is often used in fisheries assessment as a relative index of stock abundance. In the context of the scalefish management plan, a catch rate performance indicator is triggered when catch rates fall below 80% of the lowest value for the reference period (i.e. 1995/96 to 1997/98 unless otherwise specified). Catch rate trends for key species and species groups are considered in some detail in Chapters 3 to 9.

2.6 Recreational fishery

2.6.1 Catch and effort

Catch and effort information are not routinely available for the recreational fishery. A survey of the recreational fishery conducted in 2000/01 provides the only comprehensive snapshot of the Tasmanian recreational fishery (Henry and Lyle 2003, Lyle 2005). A repeat of the recreational survey is underway and will cover fishing activity during the period December 2007 and November 2008. Results will be incorporated in the 2009 fishery assessment.

The 2000/01 survey demonstrated that the recreational catch represented a significant component of the total harvest for many species, either as a proportion of the total harvest or in absolute quantities taken. For instance, recreational catches exceeded commercial catches for flathead, barracouta, jackass morwong, bastard trumpeter, cod, flounder and silver trevally in 2000/01 (Lyle 2005). By contrast, the commercial sector dominated the catches of Australian salmon, southern calamari, arrow squid, wrasse, garfish, whiting and banded morwong. The striped trumpeter catch was shared more or less equally between the two sectors.

In the absence of more recent data few inferences can be made in relation to the relative impacts of recreational catches on the finfish stocks. However, there is no reason to believe that the recreational catch has reduced in importance for those species that are popular recreational targets.

2.6.2 Recreational net licences

Since 1995, the use of recreational nets in Tasmania has been subject to licensing, with fishers able to licence up to two graball nets prior to 2003/04, plus one mullet net and a beach seine. From November 2002 the number of graball nets was reduced to one per person.

Following the introduction of net licences in 1995 the number of licences issued rose rapidly from around 8900 to a peak of over 11000 in 1999/00, stabilising at around 8-9000 in recent years (Table 2.5). However, as indicated by the number of Graball Net 1 licences issued, the actual number of gillnet licence-holders varied only slightly between the late 1990s and 2003/04, since then licence numbers have increased steadily, to about 8700 graball net licences. It is significant that night netting was banned for recreational fishers (with the exception of Macquarie Harbour) in late 2004. Night netting was a common and popular practice amongst recreational fishers (Lyle 2000) but its ban would appear to have had no discernable impact on licence numbers.

Table 2.5. Number of recreational gillnet licences issued by licensing year since 1995/96

na not applicable

Licence type	**95/96**	**96/97**	**97/98**	**98/99**	**99/00**	**00/01**	**01/02**	**02/03**	**03/04**	**04/05**	**05/06**	**06/07**
Graball Net 1	5615	6290	6685	6709	7477	7401	6960	7695	7313	7408	8054	8677
Graball Net 2	2612	2678	2683	2426	2652	2515	1841	na	na	na	na	na
Mullet Net	656	684	738	739	879	845	608	754	753	754	816	877
Total	**8883**	**9652**	**10106**	**9874**	**11008**	**10761**	**9409**	**8449**	**8066**	**8162**	**8870**	**9554**

Although not a direct index of recreational net fishing effort (not all licence holders fish each year and in any case the level of individual fishing effort is highly variable), licence numbers suggest that netting effort may have increased in the last couple of years. With the exception of surveys conducted between 1996-98 (Lyle 2000) and the national survey in 2000/01 (Lyle 2005) there have been no recent assessments of recreational net catch or effort in Tasmania.

2.7 Uncertainties

While considerable attention has been directed at ensuring comparability of commercial data over time (refer Appendix 2), it is acknowledged that some recent administrative changes relating to the reporting of catches may have, nonetheless, exerted some influence on observed catch and effort trends.

Other uncertainties in this assessment relate to limitations in catch and effort data, both in terms of the limited time series available and the level of detail provided. In addition, since the General Fishing Return was designed to accommodate a diverse range of fishing activities, compromises have been necessary, with data collection on a daily rather than operational (set or shot) basis.

It has also become apparent that some fishers have experienced problems in correctly interpreting or complying with reporting requirements, especially in terms of how effort information is reported. There continues to be an urgent need to educate fishers in this regard. The introduction of a new logbook during the 2007/08 season will hopefully help to clarify reporting. Further, the lack of catch verification remains a major issue in relation to data quality. Anecdotal reports suggest that some catch and effort data may be unreliable, particularly prior to the implementation of the management plan in 1998. Recent industry and management workshops have identified the need to improve the quality of catch reporting, including provision for catch verification. The inclusion of catch disposal records in the new logbook is hoped to improve the accuracy of catch reporting.

Catch and effort are influenced by a combination of factors which include fishers matching their fishing operations to changing market requirements and/or resource availability, as well as responses to changing management arrangements. The latter adds further uncertainty regarding the underlying causes of any observed trends in catch and effort. There is, therefore, a need to take account of industry perceptions and information when interpreting fishery dependent information.

Limited information about the recreational fishery remains a major uncertainty, although the 2000/01 survey represents an important baseline about this sector. There is a need to develop an on-going monitoring program for the recreational fishery, since without such information attempts to assess the status of those species with significant recreational catches will be flawed.

Fish mortality due to predation and fishery interactions with Australian and New Zealand fur seals is largely unknown but represents another source of uncertainty. The New Zealand fur seal is restricted to breeding around the Maatsuyker Island group and classified as a threatened species in Tasmania. Their numbers in Tasmania may be as low as several thousand and they have not repopulated traditional areas such as the Bass Strait (http://www.parks.tas.gov.au/threatened/seal.html). In South Australia and Western Australia, the New Zealand fur seal has a total population of approximately

58,000 (Goldsworthy et al. 2003). The Australian fur seal breeds mainly in Bass Strait (Fig. 2.4), with about 20 000 pups born each year, and the total population is estimated to be around 92 000 (National Seal Strategy Group 2005). The population recovery of Australian fur seals appears to be slow (DPIW on http://www.dpiw.tas.gov.au/inter.nsf/WebPages/SJON-52H2EJ?open). However, seals migrate from Bass Strait to southern waters in the late summer, and this migration is often interpreted as a substantial increase in seal numbers around Tasmania. Seals can cause substantial mortality to some of the fish species assessed in this report as well as causing gear damage and influencing the fisher behaviour, factors that impact on catches and catch rates. This tends to be caused predominantly by individual ‘rogue’ seals which learn to target particular fisheries or fishing methods (e.g. the banded morwong gillnet fishery), while the typical diet of seals includes mainly pelagic fish species (Goldsworthy et al. 2003).

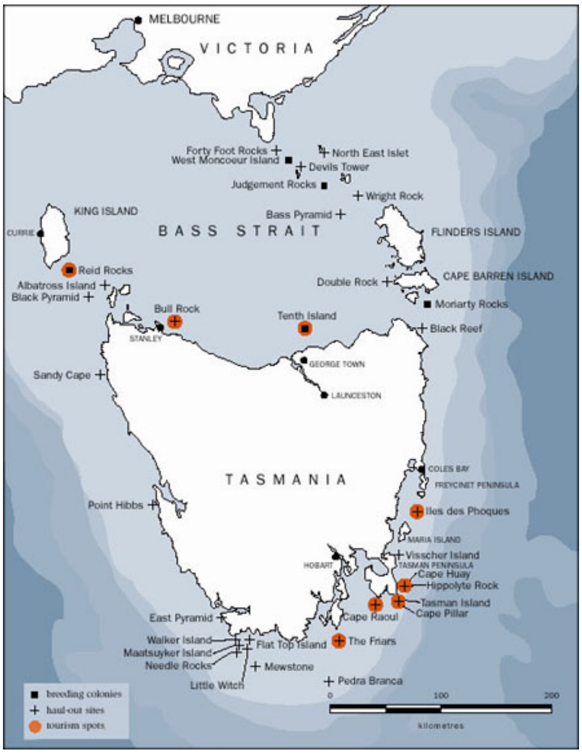


Fig. 2.4: Colonies and haul-out sites for Australian fur seals (from http://www.parks.tas.gov.au /wildlife/care/viewseals.html).

2.8 Implications for management

In the short to medium term, uncertainty will continue to be associated with the scalefish fishery primarily because of the uncertain data quality (lack of verification) and lack of information about recreational catches. There is also a need to review the present ‘generic’ performance indicators to ensure that they are appropriate for each species and that the fishery is managed in accordance with the principles of ecologically sustainable development. For this purpose alternative performance indicators are suggested in this report.

3 Banded morwong (*Cheilodactylus spectabilis*)

3.1 Life-history and stock structure

Banded morwong is a highly sedentary rocky reef species with an unusual combination of high longevity and fast growth:

<table>
<tr><th>Parameter</th><th>Estimates</th><th>Source</th></tr>
<tr><td>Habitat</td><td>Rocky reef down to about 50 m, with females and juveniles inhabiting the relatively shallow sections of the reef and males tending to dominate deeper reef regions. Highly territorial adult males. Depth stratification of populations in southern Tasmania may be less pronounced than in NZ due to large depth changes occurring over short distances.</td><td>McCormick 1989a
McCormick 1989b</td></tr>
<tr><td>Distribution</td><td>From around Sydney south to eastern Victoria and around Tasmania, New Zealand.</td><td>Gomon *et al.* 1994</td></tr>
<tr><td>Movement and Stock structure</td><td>In tagging studies, movement of juvenile and adult banded morwong was limited and generally restricted to within 5 km of the release site.
No known information on the stock structure of banded morwong and thus the relationships of populations throughout the range.</td><td>Murphy and Lyle 1999
Ziegler *et al.* 2006a</td></tr>
<tr><td>Natural mortality</td><td>Low
Estimated at $M = 0.05$</td><td>Murphy and Lyle 1999</td></tr>
<tr><td>Maximum age</td><td>Females: 93 years
Males: 96 years</td><td>Ewing *et al.* 2007</td></tr>
<tr><td>Growth</td><td>Males grow to larger sizes than females
Growth accelerated between 1996 and 2007
Schnute & Richards (1990) growth parameters:
<table>
<tr><th></th><th colspan="6">*Females*</th><th colspan="6">*Males*</th></tr>
<tr><th></th><th>$L\infty$</th><th>a</th><th>b</th><th>c</th><th>α</th><th>σ</th><th>$L\infty$</th><th>a</th><th>b</th><th>c</th><th>α</th><th>σ</th></tr>
<tr><td>1996</td><td>429</td><td>11.9</td><td>3.8E-08</td><td>0.08</td><td>0.01</td><td>18.0</td><td>525</td><td>2.4</td><td>0.022</td><td>0.28</td><td>0.4</td><td>20.3</td></tr>
<tr><td>1997</td><td>446</td><td>19.7</td><td>4.7E-08</td><td>0.04</td><td>18.9</td><td>20.5</td><td>522</td><td>2.7</td><td>0.044</td><td>0.27</td><td>1.0</td><td>22.7</td></tr>
<tr><td>2001</td><td>418</td><td>13.8</td><td>1.2E-05</td><td>0.08</td><td>11.2</td><td>19.2</td><td>520</td><td>10.3</td><td>0.0002</td><td>0.08</td><td>8.2</td><td>20.5</td></tr>
<tr><td>2002</td><td>433</td><td>20.4</td><td>1.1E-07</td><td>0.05</td><td>75.3</td><td>17.6</td><td>538</td><td>11.3</td><td>0.0001</td><td>0.07</td><td>11.0</td><td>18.2</td></tr>
<tr><td>2003</td><td>427</td><td>20.1</td><td>1.3E-07</td><td>0.05</td><td>69.2</td><td>19.3</td><td>522</td><td>7.3</td><td>0.0037</td><td>0.11</td><td>6.8</td><td>18.2</td></tr>
<tr><td>2004</td><td>438</td><td>20.1</td><td>1.3E-07</td><td>0.05</td><td>68.2</td><td>19.5</td><td>526</td><td>5.9</td><td>0.0097</td><td>0.15</td><td>4.4</td><td>21.2</td></tr>
<tr><td>2005</td><td>452</td><td>22.7</td><td>1.3E-08</td><td>0.04</td><td>93.0</td><td>17.9</td><td>547</td><td>7.9</td><td>0.0022</td><td>0.10</td><td>8.1</td><td>17.2</td></tr>
<tr><td>2007</td><td>442</td><td>18.8</td><td>3.3E-07</td><td>0.05</td><td>51.4</td><td>16.2</td><td>516</td><td>2.3</td><td>0.0088</td><td>0.33</td><td>0.1</td><td>19.4</td></tr>
</table></td><td>Ziegler *et al.* 2007a</td></tr>
<tr><td>Maturity</td><td>Early age and small size at onset of maturity
Onset of maturity in 2005 at smaller sizes and younger ages than in 1996
Age at maturity modelled by logistic function:
<table>
<tr><th></th><th>B_0</th><th>B_1</th><th>*50% maturity*</th></tr>
<tr><td>F1996-97</td><td>-3.09</td><td>0.78</td><td>4 years</td></tr>
<tr><td>F2001</td><td>-2.93</td><td>1.08</td><td>2-3 years</td></tr>
<tr><td>F2002-03</td><td>-5.11</td><td>1.94</td><td>2-3 years</td></tr>
<tr><td>F2005</td><td>-5.26</td><td>1.94</td><td>2-3 years</td></tr>
</table></td><td>Ziegler *et al.* 2007a</td></tr>
<tr><td>Spawning</td><td>In a spawning condition between mid to late February to early May, with the size distribution of oocytes in the ovaries indicating they are serial spawners</td><td>Murphy and Lyle 1999</td></tr>
<tr><td>Larval phase</td><td>Eggs and larvae are concentrated on the surface. Considerable numbers of *Cheilodactylus spp.* larvae have been caught some distance off the shelf break of eastern Tasmania, suggesting that banded morwong have a pelagic stage that is distributed in offshore waters.
Juveniles appear in shallow water on rocky reefs and tide-pools between September and December after a pelagic phase of around 4-6 months.</td><td>B. Bruce pers. comm.
Wolf 1998</td></tr>
</table>

3.2 The fishery

The ‘live fish’ fishery for banded morwong began in the early 1990s. All holders of a fishing licence (vessel) were able to take this species and, as a result, there was a dramatic increase in effort directed at the species. Reported landings increased from 7 tonnes in 1991/92 to over 145 tonnes in 1993/94, though the latter figure is considered to be highly unreliable (Ziegler *et al.* 2006a). Between 1994/95 and 1999/00, catches declined steadily from over 100 tonnes to just 34 tonnes, before increasing to over 50 tonnes in 2001/02 (Fig. 3.1). Since then, catches have stabilised around 40-50 tonnes.

Banded morwong are targeted almost exclusively for the live fish market with large mesh gillnets, primarily 130-140 mm stretched mesh. The fishery is centred mainly along the east coast of Tasmania, between St. Helens in the north and the Tasman Peninsula in the south, with the largest catches traditionally coming from around Bicheno (Fig. 3.2). Smaller catches have been taken along the south coast and around Flinders Island. Fishing operations are conducted over inshore reefs, with gear set primarily in the 10-20 m depth range. In addition to targeted fishing, the species occurs as a by-product of netting operations primarily targeted at blue warehou.

3.3 Management background

On 31 May 1994, a Ministerial warning was issued explaining that any catches of banded morwong and wrasse taken after that date would not be used toward catch history, should previous catches be used to determine future access to the live fishery. In the same year, minimum and maximum size limits (330 and 430 mm fork length) were introduced for banded morwong in an attempt to maintain adequate egg production by protecting large adults and to reflect market requirements by restricting the size range to that of highest value. Subsequent research indicated that these size limits offered minimal protection to mature females, since few females actually exceeded the upper size limit and the lower size limit was set close to the size at 50% maturity (Murphy and Lyle 1999). For these reasons, the size limits were revised in 1998 and minimum and maximum sizes were both increased by 30 mm to 360 and 460 mm fork length.

From 1995 onwards, a closed season (March and April inclusive) was introduced to coincide with the peak spawning period. The primary objectives of the closure were to protect spawning fish and to minimise wastage of fish at a time when they are most vulnerable to mortality in captivity.

In addition to the closed season, an interim live fish endorsement to take banded morwong and wrasse was introduced in 1996. Eligibility was based on a demonstrated history of taking one or both of these species (at least 50 kg between 1 January 1993 to 31 May 1994) and around 90 endorsements were issued. These arrangements continued until the scalefish fishery management plan was implemented in late 1998. Under the plan, a specific licence was introduced for the banded morwong fishery (live or dead) in State waters. To qualify for a banded morwong fishing licence, a more stringent catch history requirement was applied (minimum of two tonnes of banded morwong during the period 1 January 1993 to 31 May 1994). There are currently 29 fishing licences for banded morwong.

As the result of concerns about a potential unsustainable expansion of the fishery, a Total Allowable Catch (TAC) for the east coast is planned to start in 2008.

In November 2001, largely as a result of concerns about stock status, a daily bag limit of two fish was introduced for recreational fishers. This was amended in 2004 to a possession limit of two fish.

3.4 Management objectives and strategies

The generic management objectives for the Tasmanian scalefish fisheries apply, although with reference period 1994/95 to 1997/98 for catch and effort.

The species is currently managed by a combination of limited licences, gear limitations (maximum of 1000 m graball nets), size limits (360-460 mm fork length) spawning closure (March-April), and limits on recreational catch (2 fish possession limit).

3.5 Relative vulnerability to fishing

Banded morwong show an unusual combination of high longevity, fast initial growth and early maturity. The high plasticity in growth and onset of maturity, if proven to be a response to high levels of exploitation (Ziegler *et al.* 2007a), would indicate a resilience of the fish stocks to overfishing. However, such significant changes also strongly indicate that stocks have experienced heavy fishing pressure and potentially unsustainable fishing mortality levels. This is all the more important because the species remains site attached after settlement and so is highly vulnerable to localized overfishing and serial depletion.

3.6 Current assessment

Since juvenile and adult banded morwong are largely site attached, populations on individual reefs will remain relatively discrete and therefore catch and catch rate trends should ideally be evaluated at this spatial scale. However, for practical reasons, primarily the spatial resolution of the data (½ degree fishing blocks), analyses have been undertaken at the regional or block level for the main fishing areas. Regions have been defined as north-east coast including Flinders Island (blocks 3F2, 3F4, 3G1, 3G2, 3G3, 3G4, 3H3, 4G2, 4G4, 4H1, 4H2, 4H3 and 4H4), St Helens (5H1), Bicheno (5H3 and 6H1), Maria (6H3 and 6G4) and Tasman (7G2 and 7H1). Collectively, catches from these regions have averaged over 90% of the total banded morwong production each year since the mid-1990s (Fig. 3.2).

This report presents catch and effort analysis and catch rate standardisation, biological information collected during the fishing season, and a summary of results from an updated stock assessment model for banded morwong. This model had been developed for a FRDC-funded project on developing assessments, performance indicators and monitoring strategies for small-scale, data poor temperate reef fish fisheries (FRDC-project 2002/057, Ziegler *et al.* 2006a). Sampling of biological information and an updated assessment is conducted every second year.

The data presented for this assessment derive from the commercial catch and effort logbook returns and have been evaluated against performance indicators specified in the scalefish management plan and detailed in Section 1.3. They are also evaluated against a new set of alternative performance indicators which are intended to replace the existing ones over the next few years.

3.6.1 Catch, effort and catch rates

State-wide reported catches have stabilised and the 2005/06 catch of 46 tonnes represented a decrease of about 8 tonnes compared with the previous year (Fig. 3.1A). At the regional scale, catches have continued to increase in Bicheno, where they had been declining sharply up to 2003/04 (Figs. 3.1B and Fig. 3.2). In most other regions including Tasman, Maria and St. Helens, catches have dropped slightly.

Results of the National Survey indicated that the recreational catch of banded morwong in 2000/01 was low at around one tonne (Henry and Lyle 2003), representing only about 2.5% of the commercial catch. This is consistent with estimated recreational gillnet catch levels from the latter part of the 1990s (Lyle 2000) and confirms that the recreational take relative to the commercial fishery is small.

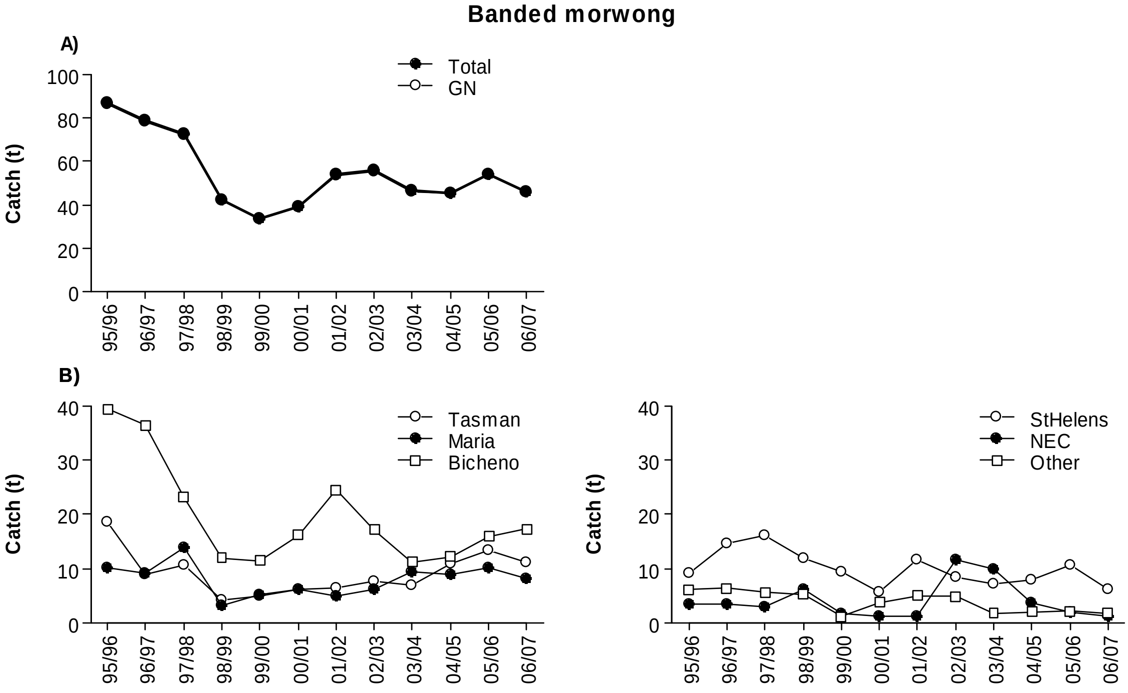


Fig 3.1. Banded morwong graball catches (tonnes) since 1995/96: A) state-wide catches; and B) catches in the Tasman, Maria and Bicheno (Bich) regions (left), and in the St. Helens (StH), north-east coast (NEC) and remaining (Other) regions (right).

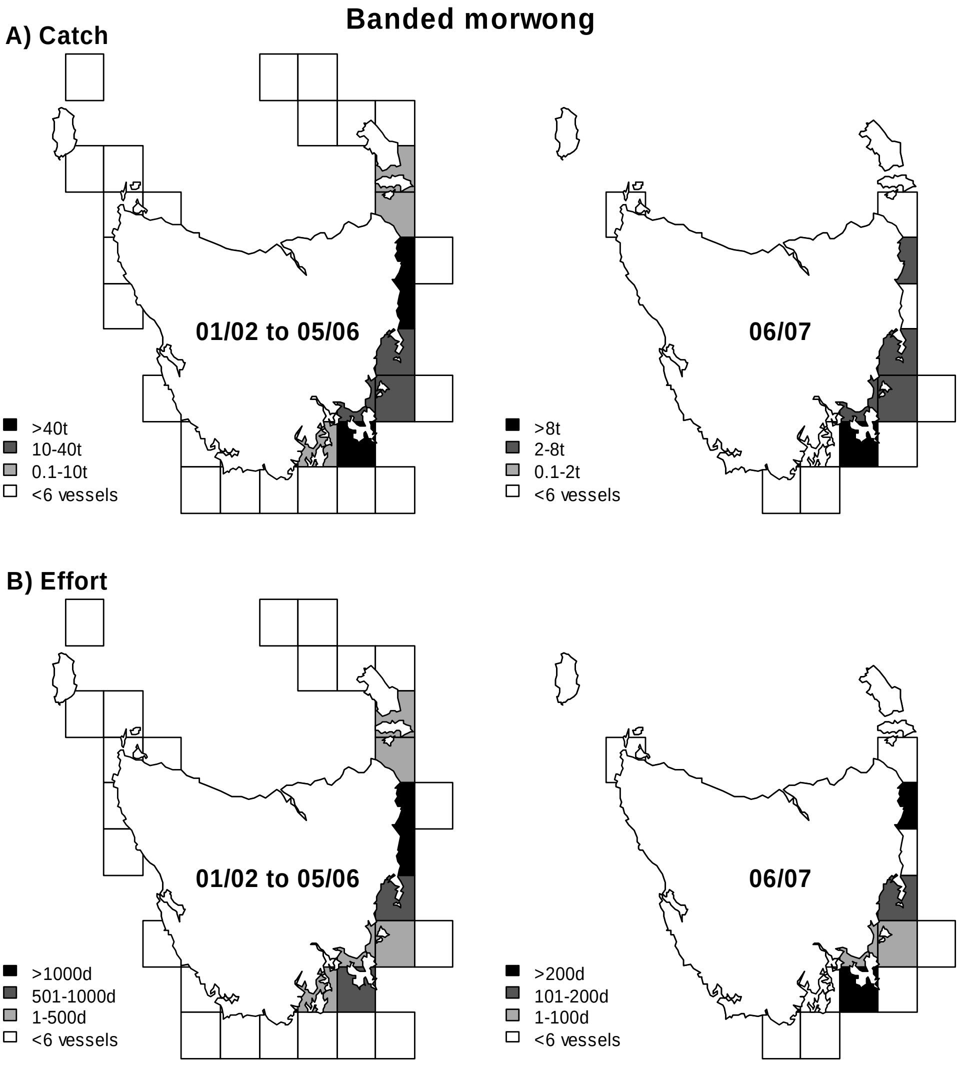


Fig 3.2. (A) Banded morwong catches (tonnes) and (B) effort (days) by fishing block pooled from 2001/02 to 2005/06 (left) and during 2006/07 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

Total effort expressed as days fished or gear units (100m net hour) has further stabilised in 2006/07 (Fig 3.3A). Fishers have progressively reduced their fishing activity and deployed less gear on average for each day fished over the last 10 years, indicated by a stronger decline of effort by days fished compared to gear units. There are also numerous industry reports of increasing levels of seal interference over time that have meant that affected fishers have often resorted to fishing with less gear or doing fewer sets each day to reduce losses to seals (Ziegler *et al.* 2006a).

Regionally, the most conspicuous trends in effort (days fished) have been relative stability of effort in the Bicheno and Maria, the continued increase of effort in the Tasman region, and sharp drop of effort in the St Helens region. The effort in the north-east coast region continued to decrease after a two-year peak between 2002/03 and 2003/04 (Figs. 3.3B and 3.2).

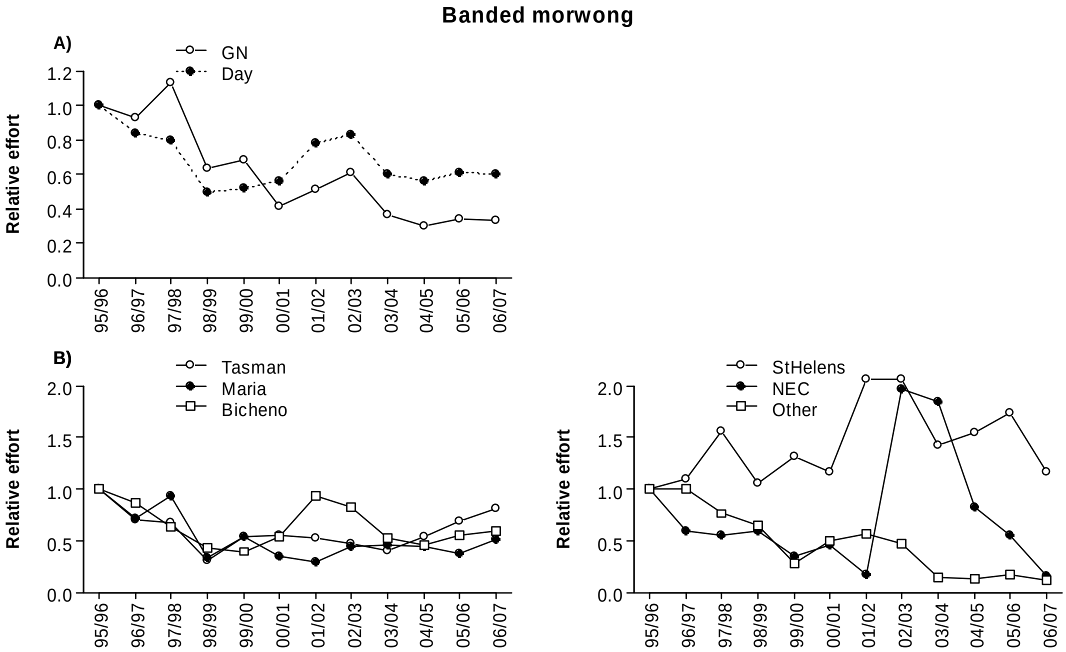


Fig 3.3. Banded morwong graball effort relative to 1995/96 levels: A) state-wide relative effort based on gear units (GN) and days fished (Day); and B) relative effort (days fished) in the Tasman, Maria and Bicheno regions (left), and the St. Helens , north-east coast (NEC) and remaining (Other) regions (right).

Catch rates of banded morwong have been standardised using generalized linear models (GLM) to reduce the impact of obscuring effects such as block, depth, season or skipper on the underlying trends (Kimura 1981, 1988). However, while standardised catch rates are preferred over the simple geometric mean, there remains no guarantee that a direct relation exists between the standardised catch rates and stock size, as other factors may have effects on changes in biomass that are unaccounted for by the statistical model.

Standardisation of catch rates was conducted for an annual time scale, at both the east coast-wide scale and for four separate fishing regions along the east coast (Table 3.1). The data was selected with respect to skippers who had reported catches for at least two years and who had caught a median catch of at least one tonne of banded morwong across all years present in the fishery. These restrictions selected data that accounted for 84% of the total catch reported since 1995/96.

The GLMs were fitted to different combinations of various factors for which information were available, viz. skipper, vessel, fishing block, depth zone fished (<10 m, 10-20 m, 20-30 m, and >30 m), bimonthly period, and reported seal interference. A bimonthly period rather than month was included as a temporal factor because there would have been too few records each month to give reliable results. Due to the annual spawning season closure in March and April, only five bimonthly categories were investigated. Seal interference was included into the analysis, but it rarely turned out to be an influential factor. Reporting of seal interference (in the catch returns seal interference is reported as ‘occurrence’) appeared to be very inconsistent, and fishing trips with seal interference and very low catch are often not reported at all. In any case, a report of seal interference did not in any way allow quantification of the severity of the interaction in terms of lost catch or impact on fishing activity.

Standardised catch rates for banded morwong were fitted to natural log-transformed catch rate data (assuming a lognormal distribution), using a normal distribution family with an identity link. All models were fitted using a forward approach by manual stepwise addition of each factor starting with the time-step. Some interaction terms between various factors were also considered, but these were limited to combinations for which sensible interpretations could be ascribed. The optimal model was chosen based on minimization of the Akaike's Information Criterion (AIC; Burnham and Anderson 1998). Adding the new data from 2006/07 resulted at times in alternative model selection with some differences in the standardised catch rates compared to the previous assessment in 2005/06.

Overall standardised catch rates from the east coast fell steadily between 1995/96 and 1999/2000, accompanying the declines in catch and effort (Fig. 3.5). Since 1999/2000 overall catch rates have risen back to 1995/96 levels. Regionally, catch rates in the Tasman and Maria regions have shown similar trends with initial decreases up to 1999/2000 and subsequent increases to above 1995/96 levels by 2005/06. In both regions, catch rates have dropped sharply in 2006/07. Fishers indicated that increasing seal interactions could have contributed to this decline. In the Bicheno and St. Helens regions, catch rates have fallen continuously since the mid 1990s. While they recovered slightly in the Bicheno region and were just above reference levels in 2006/07, catch rates remained below reference levels in the St. Helens region.

Table 3.1: Generalized linear models (GLM) for the catch rates of banded morwong across the whole east coast of Tasmania, and in the separate St. Helens, Bicheno, Maria and Tasman regions. The adjusted R^2 has been used for the Variation described.

Region		**Model**	**Variation described**
Whole East Coast	Ln cpue =	Constant + year + vessel + bimonth + seals + depth + block + skipper + vessel*bimonth	37.6%
Tasman	Ln cpue =	Constant + year + bimonth + vessel + block + seals + depth + vessel*bimonth	39.5%
Maria	Ln cpue =	Constant + year + vessel + bimonth + depth + block + seals + vessel*bimonth	54.3%
Bicheno	Ln cpue =	Constant + year + vessel + bimonth + depth + seals + block + skipper + vessel*depth	42.1%
St. Helens	Ln cpue =	Constant + year + vessel + seals + bimonth + depth + vessel*bimonth	51.6%

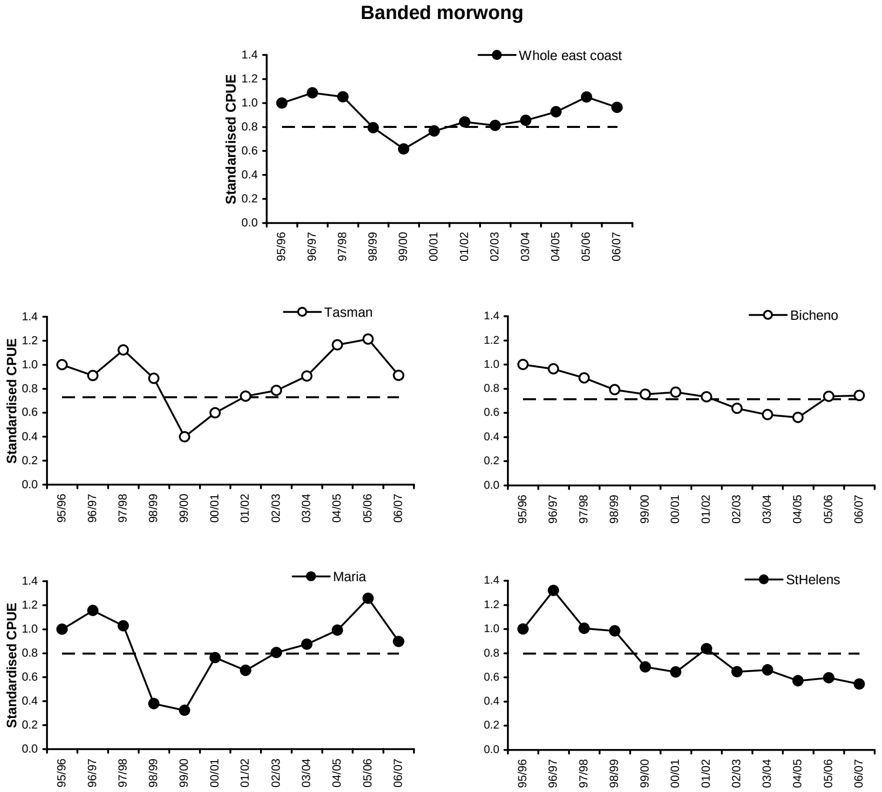


Fig 3.5. Banded morwong standardised graball catch per unit effort (CPUE by days fished) relative to 1995/96 levels from the whole east coast, and from the Tasman, Maria, Bicheno and St. Helens regions. Dotted lines mark the reference limits.

3.6.2 Biological data from scientific catch sampling

Banded morwong have been sampled during the spawning season of most years in the Bicheno and Tasman region since 1995/96, and in the St. Helens region since 2001/02. Age has been determined and validated by analysis of otolith structure (Ewing et al. 2007).

Fishing has impacted on the age composition of both male and female banded morwong. Over time, males and females up to 6 years have become increasingly dominant and represented over 50% in the 2006/07 samples of each region (Figs. 3.6 and 3.7). Males grow rapidly through the legal-size keyhole and most males are susceptible to fishing between the ages of 4-10 years. Individuals older than 10 years have remained proportionally less abundant compared to the samples taken during the mid 1990s, with reductions particularly evident for males aged 10-20 years, age classes that would have been exposed to fishing pressure for some years.

In contrast to males, females recruit to the fishery at around 4-5 years of age and typically remain vulnerable for the remainder of their lives (Fig. 3.7). Fishing has had a marked impact on age structure in all regions. While there are still old females present, their relative contribution has decreased significantly in recent years compared to the mid 1990s, and young females now dominate the catches.

These data suggest that the fishery has becoming increasingly dependent on new recruits. Strong year classes are evident for 4-year and 6-year old males and females in the 2006/07 samples.

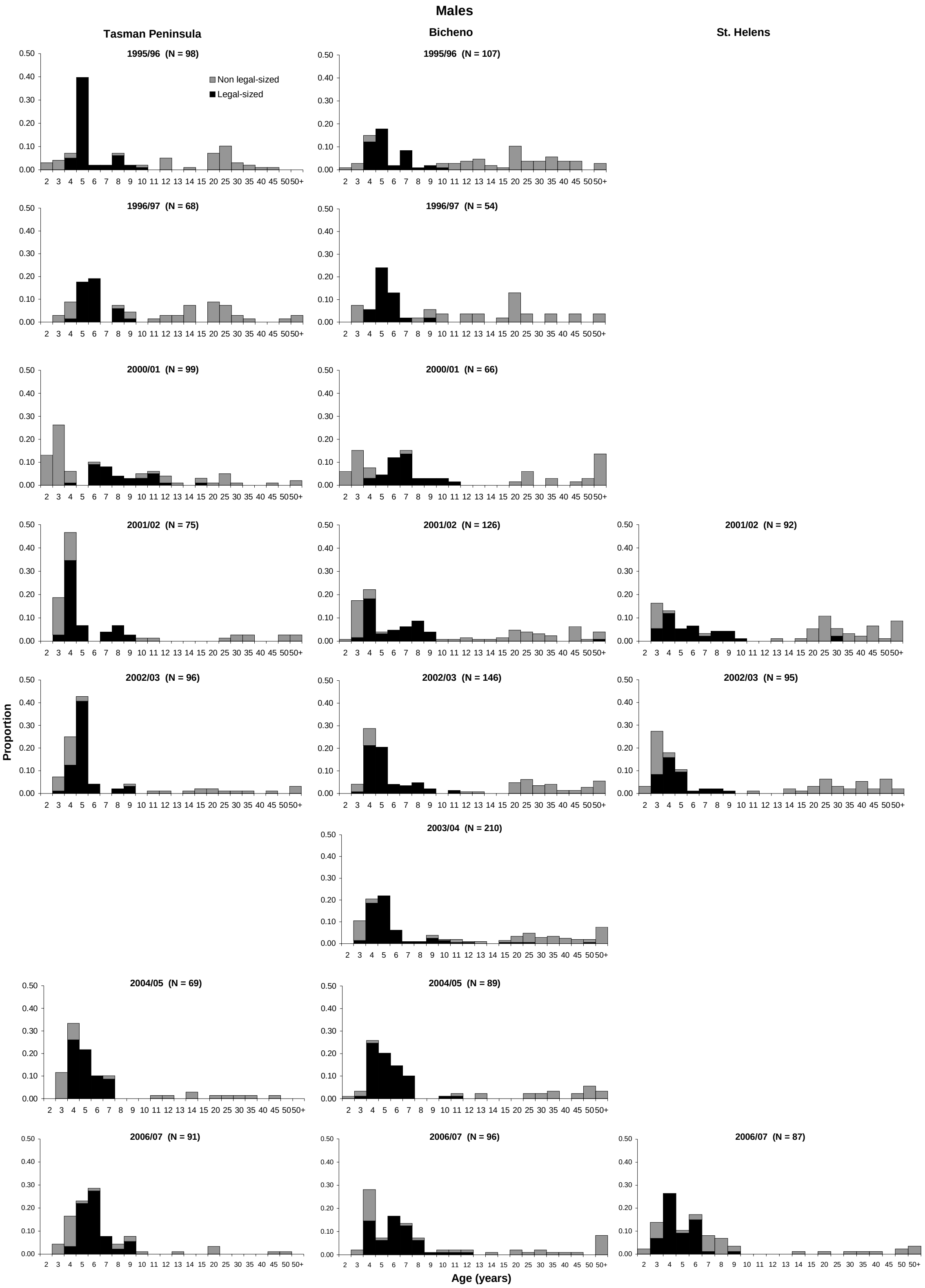


Figure 3.6: Relative age composition of male banded morwong in research catches from the Tasman, Bicheno and St. Helens fishing regions since 1995/96. Black bars refer to legal-sized fish, grey bars to non-legal-sized (undersized and oversized) fish. Relative frequencies of 1-year classes (ages 2-15y), 5-year classes (ages 16-50y, values given denote upper limit) and a plus group for fish older than 50 years (denoted as 50+). N is sample size.

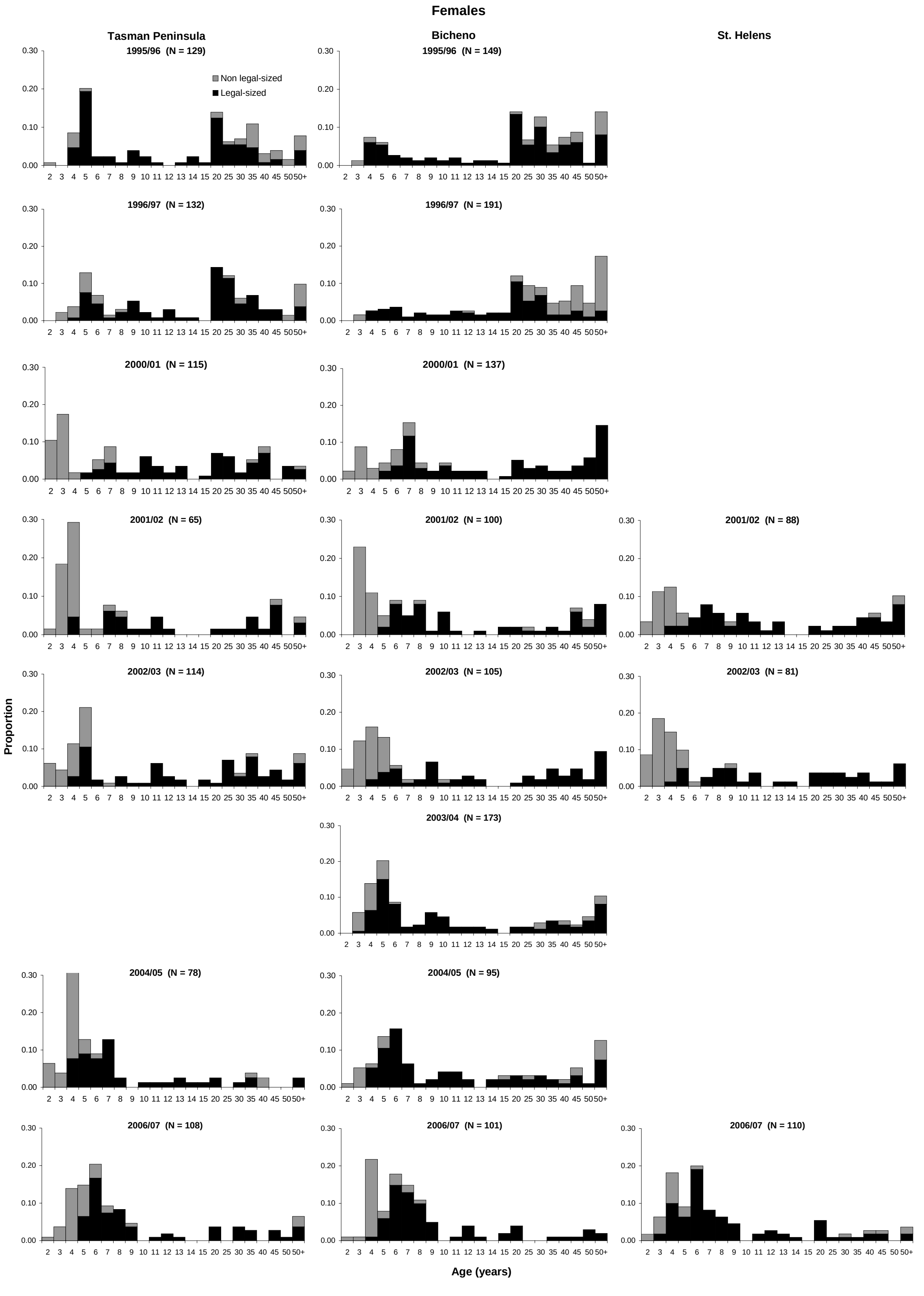


Figure 3.7: Relative age composition of female banded morwong in research catches from the Tasman, Bicheno and St. Helens fishing regions since 1995/96. Black bars refer to legal-sized fish, grey bars to non-legal-sized (undersized and oversized) fish. Relative frequencies of 1-year classes (ages 2-15y), 5-year classes (ages 16-50y, values given denote upper limit) and a plus group for fish older than 50 years (denoted as 50+). N is sample size.

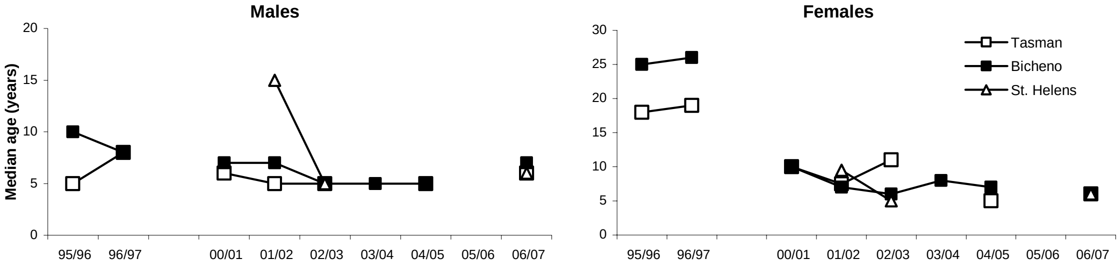


Fig. 3.8. Median age of male and female banded morwong in total research catches of the Tasman, Bicheno and St. Helens regions.

Changes in age composition are reflected in the trends based on median ages (Fig. 3.8). While the median age of males has decreased only slightly (with the exception of St. Helens), the median age of females has fallen dramatically from around 20 to 6 years since the mid-1990s, a trend that is reflected in both Bicheno and Tasman regions.

Sex ratios in legal-sized and total catches continued the trends from previous years, with roughly equal numbers of males and females (Fig. 3.9). The proportion of females in the legal-sized catch has been consistently lower since 2001/02 in all regions. This more balanced proportion of males and females in the catch indicates that the fishery is now selecting males and females almost equally, reflecting the dominance of new recruits into the fishery. Change in sex ratios were also apparent in the total sample but were less extreme when compared with the legal-sized catch.

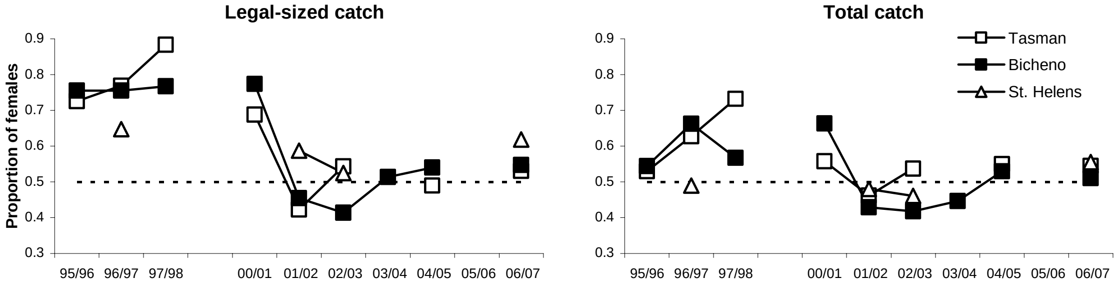


Fig. 3.9. Proportion of female banded morwong in the legal-sized and total catch in the Tasman, Bicheno and St. Helens fishing regions. Dotted lines represent a sex ratio of 1:1.

3.7 Stock assessment model

3.7.1 Model structure

A spatially-structured, statistical catch-at-age population model was developed (Quinn and Deriso 1999, Haddon 2001) and fitted to biological and commercial catch and effort data for banded morwong since 1990 from the east coast of Tasmania. A general description of the model structure can be found in the Appendix 3 and in Ziegler *et al.* 2006b. A number of changes have been implemented compared to the original model, namely the number of regions was reduced to four, two independent models were fitted to the two southern and northern areas, and the growth description was changed from a two-phased von Bertalanffy function to a Schnute & Richards (1990) function.

The models simulated four discrete banded morwong stocks or stock assessment regions (as defined in Section 3.5) along the east coast of Tasmania. The number of stocks used in the models was a compromise between maximum spatial resolution, data availability and fishery dynamics. Ideally, the number of stocks would equal the number of banded morwong populations on reefs, however the spatial resolution of data was limited to the 30 nm fishing blocks. In addition, the data was often so limited and noisy that blocks had to be pooled in order to obtain a workable set of data. The combination of two coastal fishing blocks into the Bicheno stocks was based on the fishery dynamics, with sections of both blocks often being fished within a single day.

The stocks were treated like a meta-population with larval mixing but minimal adult movement. This was supported by the extended pelagic larval stage of up to 6 months suggesting that the stocks would homogenize genetically (Wolf 1998). However, the fishery-dependent and independent information from the separate stocks was insufficient to estimate the biomass in each stock individually. Therefore, the biomass was estimated over a number of stocks and then distributed among the regions to increase the stability of biomass estimate in each stock. Model comparisons indicated that separate recruitment patterns for the two southern areas (Tasman and Maria) and the two northern areas (Bicheno and St. Helens) improved overall model fits over an approach with an overall recruitment pattern in a single model. Subsequently, only results from the approach with individual assessment models for the south and north are presented.

The approach of estimating biomass across a number of stocks required an estimate of relative biomass distribution in each stock. As an initial proxy, the reef habitat area or fished reef area was used, assuming a close link between fish density and reef habitat (including high profile, medium profile, low profile and patchy reef habitat types). Estimates of total habitat area down to a depth of 40 m were available from habitat maps for the Bruny, Tasman and Maria regions (SEAMAP Tasmania Project, http://www.utas.edu.au/tafi/seamap/). Model fits were then compared in a sensitivity analysis for a range of values (Scenarios A and B, Table 3.2).

The fishery for banded morwong targets live fish and it is largely restricted to depths of less than about 25 m in order to minimize effects of barotrauma and thus maximize fish survival. Because the distribution of banded morwong extends beyond the depth of the fishery, there is the potential for an unfished component of the stock in a depth refuge. The model allowed for this by specifying a fished population onshore in depths up to 25 m and an unfished population offshore in depths greater than 25 m with movement occurring between them. This spatial mismatch between the depth range of the fishery and that of the species distribution added complexity and uncertainty to the model structure in relation to the depth structure of biomass and movement rates. In the Tasman and Maria regions, where depth contours were available for the mapped reefs, approximately 70-78% of the reef habitat was found onshore within depths of 0-25 m, and 22-30% offshore within depths of 25-40 m. The extent of reef areas beyond 40 m depth was unknown. For the model, three different scenarios were examined, ranging from all biomass in the onshore population and available to the fishery to only 50% onshore (Table 3.2).

These biomass distributions were combined with different movement rates. Two types of movement were distinguished in the model; (i) movement alongshore between regions and (ii) movement between onshore and offshore populations. Tag-recapture data indicated low movement rates between regions (Murphy and Lyle 1999), and only 0.1% of all fish in a region were assumed to move to the adjacent region each year. Movement was assumed to occur at the end of each year and was restricted to mature fish.

Movement rates between onshore and offshore populations could not be determined from tag-recapture data due to a limit to the precision of information with respect to location and depth. Instead, a range of movement rates were tested in the model. Movement between onshore and offshore populations was considered a combination of mobility, m, defined as the proportion of the mature population that becomes vagrant or mobile and becomes capable of shifting from each population to adjoining populations, combined with π_i, the proportion of habitat or biomass in each population (see Appendix 3). Thus, the movement rate from population p into population $p+1$ can be represented as $m\pi_p$. Population p retains $1-m\pi_{p+1}$ of its total, but gains $m\pi_p$ of the neighbouring population $p+1$. If the proportion of habitat is equal (*i.e.* 50:50) then the movement rate equals the mobility, however, if the proportional distribution of the population deviates from 50:50 then the movement rates will become asymmetric. Beside a base case of 0.5, different mobility rates ranging from 1.0 to only 0.25 of all fish being mobile each year were tested in the model (Table 3.2). The different combinations of biomass in the onshore population and movement rates were used as an indication of model uncertainty.

Table 3.2: Biological and model parameters used in the assessment models.

[1] 1 is equivalent to a singe population within the stock, thus movement rates not applicable.

Model parameter	Base case	Regional scenario A	Regional scenario B
Biomass onshore (<25m) in %	0.5 - 1[1]		
Movement rates between on/offshore populations	0.25 - 1		
Regional biomass in northern model:			
St. Helens	0.3	0.4	0.2
Bicheno	0.7	0.6	0.8
Regional biomass in southern model:			
Maria	0.4	0.5	0.3
Tasman	0.6	0.5	0.7

The model operated on an annual time step starting on the 1st of May, and was fitted to 18 years of commercial catch and effort data from the earliest catch reports available in 1989/90 to 2006/07 inclusive. For the purpose of this assessment, the fishing year of 1989/90 is described as 1990, 1990/91 as 1991 and so on. It was assumed that each stock was at a pre-exploitation equilibrium with the corresponding age and sex structure prior to 1990. While the live-fish fishery only started in that year, mainly lobster fishers had previously taken banded morwong for use as bait in their traps. Although the quantity taken each year is unknown, discussions with rock lobster fishers indicated that catches had been low compared to that taken by the targeted fishery in the mid 1990s.

3.7.2 Biological components

Biological monitoring for the age composition of the catch, age at length and maturity studies generally occurred during the spawning periods in March and April between 1996-1997 in the Tasman and Bicheno stocks and in some years since 2001 in the Tasman, Bicheno and St. Helens stocks.

Length at age was modelled by a Schnute and Richards (1990) growth function and maturity at age by logistic functions (Ziegler et al. 2007a). Because growth and maturity were generally similar between stocks, single growth and maturity functions were used across all stocks in any given year. However, growth was found to have increased and maturity to have accelerated over time, and periods with specific growth and maturity patterns were identified. For the periods 1990-1998, 1999-2001, 2002-2003, 2004-2006 and 2007 all available data from 1996-1997, 2001, 2002-2003, 2004-205 and 2007, respectively, were pooled by sex across stocks. In addition, all data for males and females older than 20 years were pooled by sex and used in all model fits, such that the asymptotic length L_∞ would converge and sex-specific maximum sizes would be constant across all years. Natural mortality was assumed to be constant at $M = 0.05$.

The selectivity at age function was determined from the length at age function in conjunction with growth variation, the gear selectivity and the keyhole size limits (see Appendix 3). Mesh selectivity and vulnerability were assumed constant between sexes; the former based on the similar body shape of males and females, the latter assuming similar behaviour of males and females, in particular similar swimming activity within their home range and larger-scale movement between depth strata and stocks. This is probably an over-simplification given the population structuring by sex and size and associated movement patterns observed by McCormick (1989a and 1989b).

Selectivity at age or the number of fish at a given age available to the fishery varied between males and females due to the combination of differences in growth pattern by sex and the keyhole size limits (Fig. 3.14). Females recruit to the fishery at the age of 4-6 years and typically remain vulnerable to fishing for the rest of their lives, while males grow through the size limits within a few years, mainly between 4-10 years. This means that the sex ratio is sensitive to changes in the age structure caused by either heavy exploitation and/or strong recruitment.

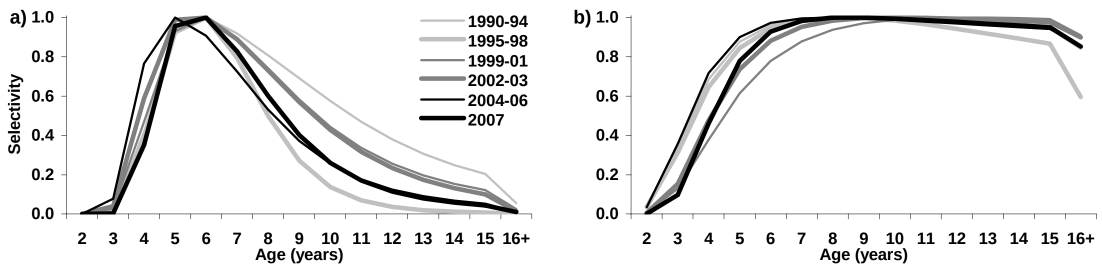


Fig. 3.14: Selectivity at age for (a) male and (b) female banded morwong for 1990-94 (mesh size 133 mm, 33-48 cm size limits and 1996-97, light grey line); 1995-98 (mesh size 137 mm, 33-43 cm size limits and 1996-97 growth, heavy light grey line); 1999-01 (mesh size 137 mm, 36-46 cm size limits and 2001 growth, dark grey line); 2002-03 (mesh size 137 mm, 36-46 cm size limits and 2002-03 growth, heavy dark grey line); 2004-05 (mesh size 137 mm, 36-46 cm size limits and 2004-05 growth, black line); and 2007 (mesh size 137 mm, 36-46 cm size limits and 2007 growth, heavy black line).

Because growth accelerated and size limits changed over the years of the study, different selectivity periods were distinguished. No size limits were in place until 1994 and the mesh size used was predominantly 133 mm. These mesh sizes rarely catch fish smaller than 33 cm and, due to a lack of demand for larger fish, those over approximately 48 cm were usually returned. This dynamic was reflected in the keyhole size limit of 33-43 cm fork length that was introduced for the fishing season 1995. In addition, fishers started to use gillnets with 140 mm mesh size as well as those with 133 mm mesh size. Thus, for all periods with size limits, an average mesh size of 137 mm was assumed for the modelling. The size limits were revised in 1998 and minimum and maximum sizes were increased by 3 cm to 36-46 cm for the 1999 fishing year.

3.7.3 Harvest components

Catch and effort data for the models were based on commercial catch and effort information provided by compulsory logbook returns to the Tasmanian Department of Primary Industry and Water (DPIW). Prior to 1995, catch returns were based on monthly landings by species and one degree fishing blocks. Subsequent catch returns provide daily summaries of fishing operations, including method, location (based on 30nm fishing blocks), fishing depth, effort, catch weights and whether seal interference had occurred. All catch returns are self-reported and unverified, and therefore their accuracy is uncertain.

Because fishers and processors generally believed that catches were substantially over-stated before the introduction of live-fish endorsements in 1996 (Ziegler et al. 2006a), a more plausible catch history was estimated based on the catch returns from the east coast (Fig 3.15). In particular, very large catches reported in 1994 and 1995 were reduced, while thereafter over-reporting was assumed to roughly equal handling mortality and that both have been significantly reduced in recent years. Interactions with seals have become a growing problem for the fishery since the mid 1990s, with a substantial impact on the fishing operation and increased incidental mortality through damage and loss of fish from the nets. A scaling factor to account for seal-related mortality was added to the corrected logbook returns, continuously increasing since 1997 and peaking at 1.3 in 2001-2002. Since 2003, it was estimated to be 1.2 implying that there is 20% extra mortality caused by seal interference, over and above the reported landings.

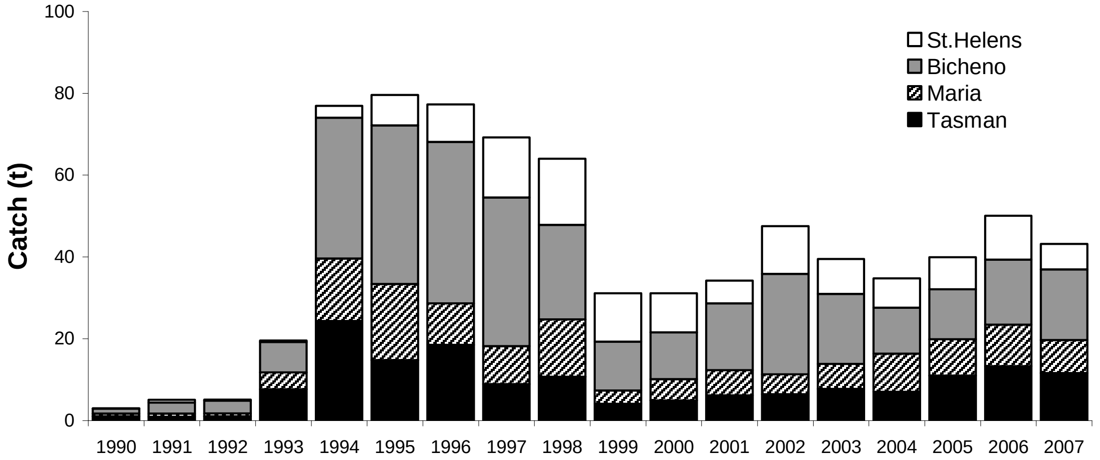


Fig. 3.15: Banded morwong catch history with contribution from each stock since 1990.

The standardised catch rates of the individual regions were used as input variables in the model. Catchability was estimated by the model from the relationship of observed catch rates and exploitable biomass. The catchability coefficient $\hat{q}$ was thereby assumed to be constant and each annual $\hat{q}_y$ to be only an estimate of the overall $\hat{q}$. In 1999, a combination of new management regulations was implemented and seals interactions increased. The former resulted in some restructuring of the fishing fleet, restrictions on the amount of gear used and increased in the size limits. As a result of growing interactions with seal there were substantial changes in fishing practices and losses to seal predation. These two factors combined suggested that the catchability for banded morwong differed between 1996-1999 and 2000-2007, and thus two separate catchability coefficients were estimated for those periods.

3.7.4 Recruitment

Recruitment of two year old fish was modelled to occur at the start of each year with an equal ratio of males and females. With a long larval phase of around 4-6 months, recruitment was assumed to be uniform along the coastline within the southern and northern areas and only dependent on the reef habitat available for settlement, *i.e.* recruitment in each region was proportional to its area. All recruitment in the models occurred to onshore populations, because juveniles are predominantly found in shallow waters and recruitment to shallow waters is followed by a gradual outward migration with increasing size (Leum and Choat 1980, McCormick 1989a). Instead of a pre-defined stock-recruitment relationship such as the Beverton-Holt relationship, average recruitment and recruitment residuals were fitted in the models and constrained by a penalty term contributing to the overall log likelihood. This penalty term was related to the recruitment variability. Recruitment variability was assumed high ($\sigma = 0.6$), since strong variations of year class strengths in the observed age composition data was better represented compared to assuming low variability (e.g. $\sigma = 0.1$; Ziegler et al. 2006b).

3.7.5 Model uncertainty and fitting

In addition to the available biological information, the stock assessment model required a range of assumptions on biological characteristics to be made, that would have resulted in an over-parameterized model. This meant that values of a number of parameters were set rather than estimated. Under such circumstances an array of sensitivity analyses are usually performed to test the impact or influence of the assumptions on the model outcomes. Here, one major sources of variation was immediately apparent, viz. model uncertainty relating to the regional biomass distribution and the potential separation of stocks in fished onshore and an unfished offshore populations. Because the spatial structure and associated dynamics were so poorly known, it was necessary to set up an array of alternative model designs and compare their outcomes. Three different levels of onshore/offshore distribution of biomass and four levels of mobility rates were tested (Table 3.2). The regional biomass distribution was addressed by three different scenarios which were initially based on the relative habitat area estimates, but were adjusted to values which provided improved fits. In total there were 15 model scenarios. Because of the substantial model uncertainty, uncertainty in relation to parameter estimates or samples was not investigated. The model fits were deterministic for any given scenario and compared based on their log likelihood values.

The model was conditioned on commercial catch data and fitted using maximum log likelihood methods on observed standardised catch rates, catch age-composition (ages 2-15y and a plus-group '16+' with all ages of 16 years and older), and sex ratios within commercial size limits. The latter was a useful parameter due to the sex-specific selectivity. Contributions to the log likelihood of the model fits to catch rate, sex ratio and age composition data was weighted in inverse proportion to their respective variation (*i.e.* less weight to the more variable). Estimated model parameters, 30 in total, were the equilibrium age composition at the start of the first year in the population along with average recruitment and residual recruitment in each year of the fishery.

3.7.6 Model fits to data

All models provided similar fits to the changes observed in catch rates, sex ratios and age samples (Fig. 3.16). Fits to catch rates were reasonable and captured the general trends well, however, the recent sex ratios were poorly represented. All model scenarios biased high sex ratio relative to the observed in the commercial catch samples during the 2000s.

The overall fits tended to be best for the regional base case scenarios in the northern model, but were more similar for the base case and regional scenario B in the southern model (log likelihood within 1.94 of each other; Table 3.3). In the northern model, a high proportion of onshore biomass (100% or 75%) provided the best fits, while the same was true in the southern model for the base case, but not for the other two regional scenarios.

Consistently in both models and for all regional scenarios, low movement rates generally resulted in better fits than high movement rates, particularly when the onshore biomass was assumed low (50% onshore). For example, in the regional base case scenarios for the southern model assuming 75% onshore biomass, the negative log likelihood worsened from 123.6 to 128.6 with increasing movement rates from 0.25 to

1.0. Similarly for only 50% onshore biomass, the negative log likelihood rose from 127.8 to 139.7.

The representation of the age composition data captured strong cohorts reasonably well (Fig. 3.17). However, the large variations in age-structure between years, the reason why large recruitment variability was required, may have been at least partly an artefact of the relatively small sampling sizes. The number of males older than 15 years (the '16+' age class) were also badly overestimated by all models. This could have been caused by a poor estimate of the selectivity of the gear for these large fish.

Alternatively, the fact that adult males tend to move less than females (McCormick 1989a) may make them less susceptible to capture than females, and this distinction was not included in the model. In addition, most males in the plus group are oversized and usually released after capture. Because the model has no discard mortality function, the expected numbers of these males may be inflated. Notwithstanding this, being oversized and male, these fish had no effect on estimates of both the (female) mature biomass and harvest rates.

Due to the over-parameterization of the model, these interactions between the various influences of regional biomass distribution, onshore/offshore biomass distribution and mobility could not be clarified further without additional information. Despite significant differences in the log likelihoods, selecting the optimum model purely on quality of fit seemed inappropriate and would have not been necessarily correct without further evidence concerning biomass distributions.

Table 3.3: Negative log likelihood of model fits assuming regional base case scenarios and scenarios A and B for a range of movement rates at different onshore biomass levels.

No movement rates are applicable when 100% of the biomass is onshore. The smaller the relative value the better the fit.

	Biomass onshore	**Base case**	**Scenario A**	**Scenario B**
Northern model	100%	177.5	192.0	190.5
	75%	179.4 - 187.8	191.6 - 199.4	190.8 - 197.9
	50%	188.3 - 208.0	195.9 - 215.8	194.7 - 214.3
Southern model	100%	124.2	127.2	127.4
	75%	123.6 - 128.6	126.7 - 131.1	124.0 - 130.0
	50%	127.8 - 139.7	129.6 - 141.1	124.9 - 139.5

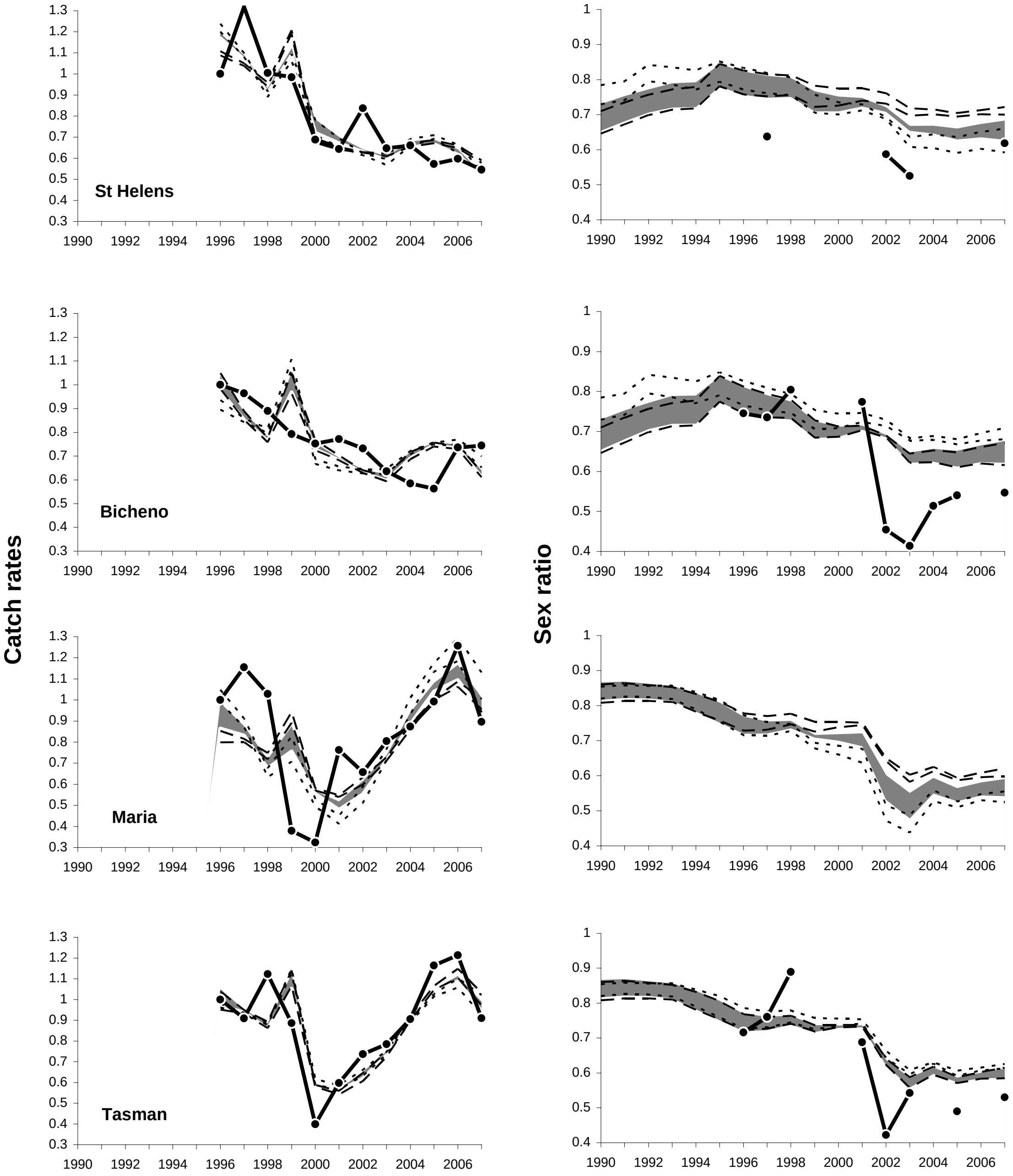


Fig. 3.16: Catch rates and sex ratios in the four assessment stocks. Observed data (black circles and heavy black lines), range of model predictions (grey) of all onshore biomass and movement rate scenarios for base case regional scenario, and minimum and maximum estimates of model predictions of all onshore biomass and movement rate scenarios for regional scenarios A (dashed black lines) and B (dotted black lines).

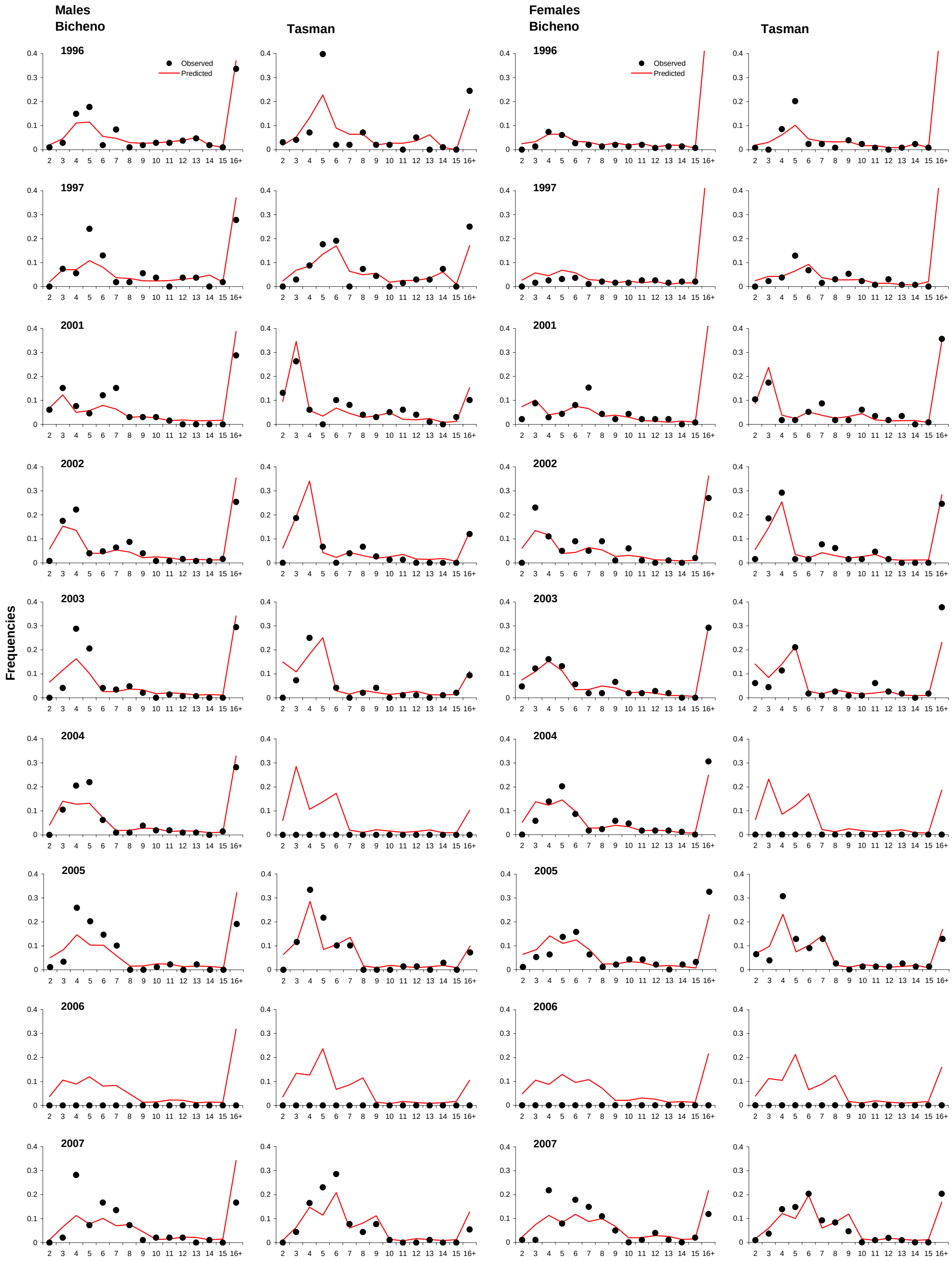


Fig. 3.17: Age composition in relative proportions of male and female banded morwong in biological samples from 1996-1997, and 2001-2007 in the Bicheno and Tasman stocks. Observed data (black circles) and model fits for the base case regional scenario with 75% onshore biomass and a movement rate of 0.5. Proportions limited to 0.4. No samples were taken in the Tasman stock in 2004 and 2006.

3.7.7 Model outputs

Given the substantial model uncertainty in relation to regional biomass distribution, onshore/offshore biomass distribution and mobility, uncertainty in relation to parameter estimates or samples was not investigated. Instead, model uncertainty is presented here based on the range of onshore/offshore biomass distribution and movement rates for 100% and 75% onshore biomass levels. These scenarios provided conservative estimates of total and mature biomass (but not necessarily for exploitable biomass), since the unfished proportion of the population was assumed small (Fig. 3.18). When a lower proportion of biomass was assumed onshore, movement rates became important in determining model outcomes and estimates of mature and exploitable biomass varied considerably. Because the resulting variation tended to obscure the general trends, results from the scenarios with less than 75% onshore biomass are omitted from the graphs.

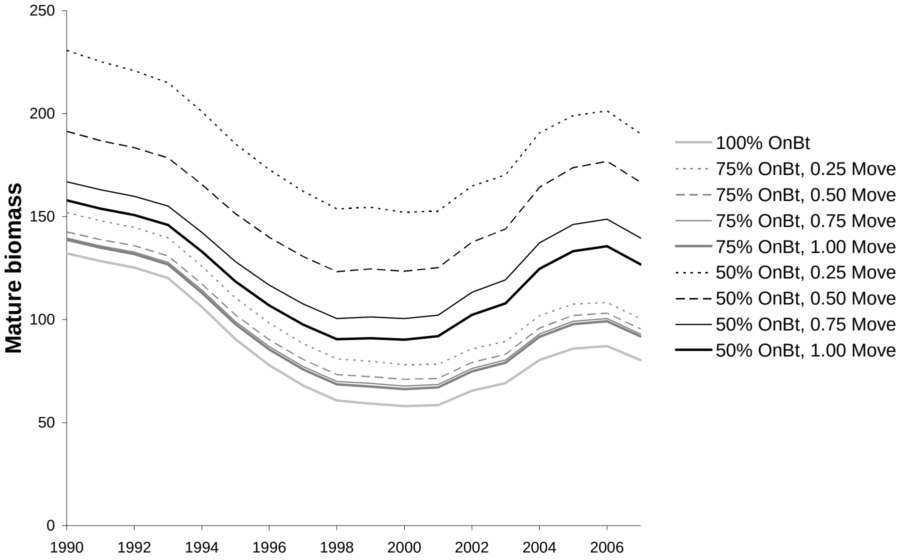


Fig. 3.18: Estimates of exploitable biomass in the Tasman stock for the regional base case scenario with different levels of onshore mature biomass (OnBt) and movement rates (Move).

Despite the relative minor differences in model fits, the regional biomass distribution contributed strongly to the uncertainty surrounding model outcomes and far more than the different onshore biomass and movement rate scenarios. The lack of real data on the regional biomass distribution was therefore extremely influential on the predicted model outcomes with high uncertainty surrounding all model estimates.

Total mature biomass on the east coast had fallen in all scenarios since 1990, mainly due to the high catches in the mid 1990s and stabilised since 1998 at 38% - 58% of the initial levels depending on the regional scenario (Fig. 3.19). This was despite increased productivity in the population due to higher growth rates and earlier maturity of young fish combined with a reduced overall catch. Exploitable biomass showed a similar trend, with estimates between 570t - 900t in 1990 and between 260t - 590t in 2007. Maximum annual harvest rates were estimated at 0.26 in 1998, but they have dropped to 0.09 - 0.16.

At a regional level, estimated relative mature biomass (MatB), exploitable biomass and harvest rates strongly depended on the regional distribution of biomass (Fig. 3.19). In the northern stocks, mature biomass was predicted to have continuously dropped in St. Helens and Bicheno, although more stabilising since 1998 in the latter. For the regional base case scenarios, the model estimated similar $MatB_{07/90}$ in St. Helens (0.28 - 0.34) and Bicheno (0.30 - 0.36). However, estimates varied widely for the scenarios A and B, with higher $MatB_{07/90}$ in either St. Helens (0.50-0.54, scenario A) or Bicheno (0.53 - 0.57, scenario B) and lower $MatB_{07/90}$ in the respective other stock. In the southern stocks, mature biomass was predicted to have recovered substantially since 1998, based on strong recruitment pulses since 2000 (Fig. 3.20). The model estimated relative high $MatB_{07/90}$ of 0.43 - 0.50 in Maria and 0.61 - 0.67 in Tasman. Differences between the three scenarios for regional biomass distribution reflected those in the northern stocks, but were relatively small in Tasman.

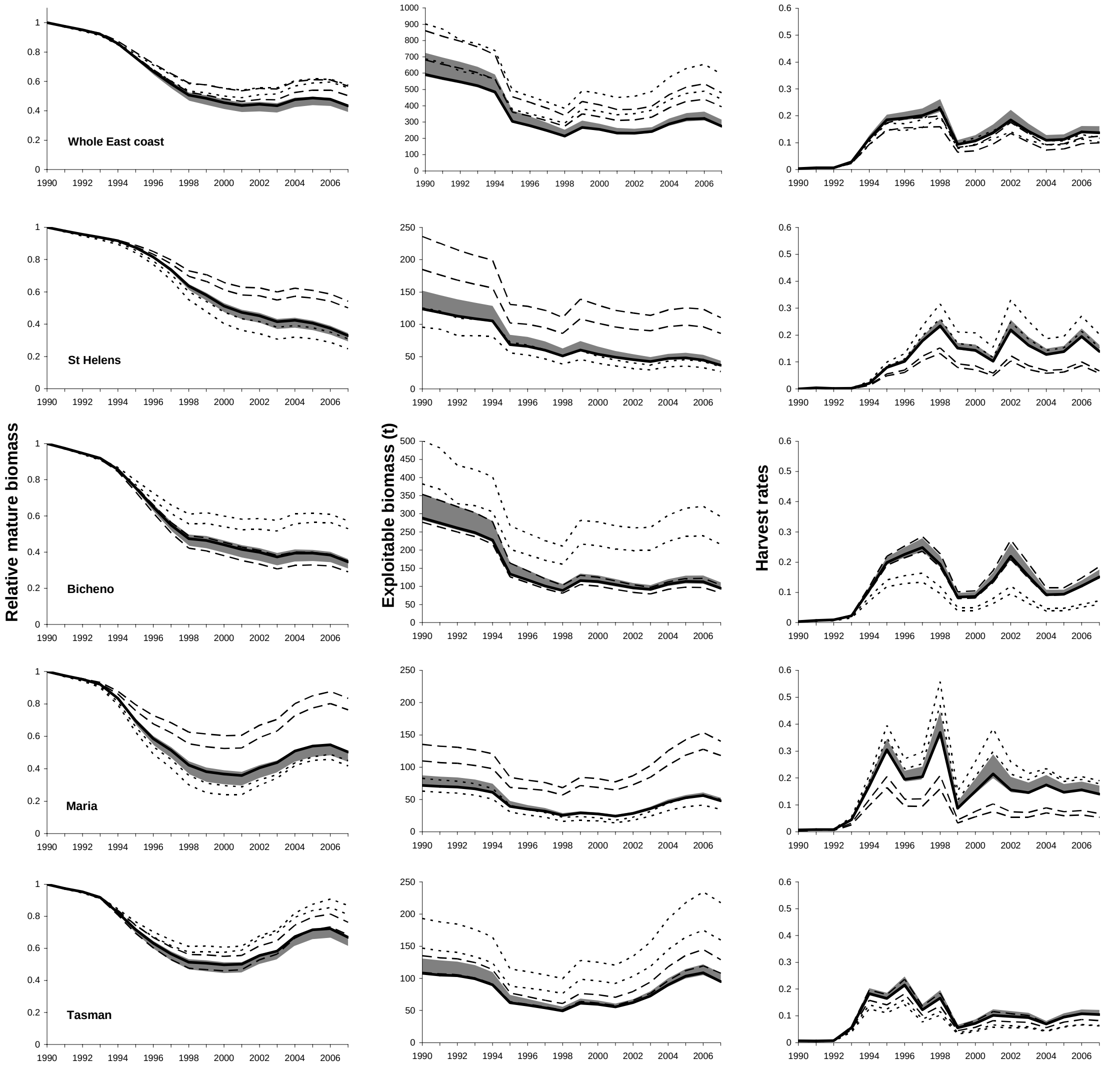


Fig. 3.19: Estimates of mature biomass relative to 1990, exploitable biomass (tonnes) and harvest rates for the whole East coast and in the four assessment stocks. Range of model predictions of all onshore biomass and movement rate scenarios for base case regional scenario (grey) and example for 75% onshore biomass and movement rate of 0.5 (heavy black lines), and minimum and maximum estimates of model predictions of all onshore biomass and movement rate scenarios for regional scenarios A (dashed black lines) and B (dotted black lines).

Exploitable biomass was estimated in the regional base case scenarios to have decreased to about a third of the 1990 levels in St. Helens and Bicheno, but only by little to 60% - 80% in Maria and Tasman. Again, the regional scenarios A and B in the northern and southern model provided conflicting estimates of higher exploitable biomass levels in only one of the two stocks. They also predicted full overall recovery of exploitable biomass in either Maria (scenario A) or Tasman (scenario B).

Harvest rates peaked in the late 1990s and were generally below 0.2 in 2007, although with increasing trend in Bicheno. Only in Tasman, they were below the reference points from spawning biomass-per-recruit analyses at which harvest rate reduces spawning biomass-per-recruit to 40% or 30% of the unfished level, $H_{40\%} = 0.07$ or $H_{30\%} = 0.11$ (Clark 1993, 2002, Mace and Sissenwine 1993, Mace 1994, Ziegler et al. 2006a), but harvest rate were higher than those levels in all other stocks for at least two of the three regional biomass scenarios.

The combination of estimates for mature and exploitable biomass, harvest rates, recruitment and age composition of the stocks indicates that the fishery has removed a high proportion of the standing biomass of old female fish and has become largely depended on recruitment. In the southern stocks, mature and exploitable biomass has recovered to near virgin levels thanks to massive recruitment pulses in the 2000s. In the northern stocks, slightly increased recruitment levels and increased growth rates have not been enough to stop the decline in mature and exploitable biomass.

Nevertheless, the structure of the fished population has changed substantially in all stocks and the fishery mainly removes and depends on recently-recruited fish from the populations at a potentially unsustainable rate. This situation could pose a serious problem in the future if recruitment failure occurs over a succession of years.

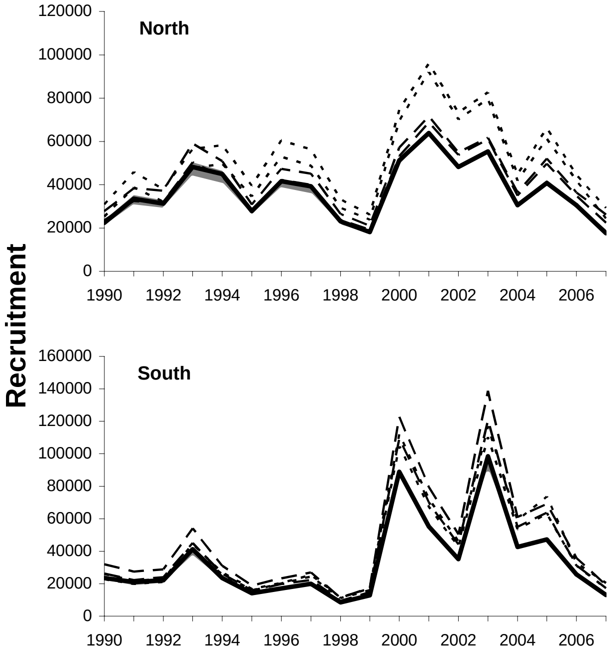


Fig. 3.20: Estimates of total recruitment in the northern (Bicheno and St. Helens) and southern (Tasman and Maria) areas. Range of model predictions of all onshore biomass and movement rate scenarios for base case regional scenario (grey) and example for 75% onshore biomass and movement rate of 0.5 (heavy black lines), and minimum and maximum estimates of model predictions of all onshore biomass and movement rate scenarios for regional scenarios A (dashed black lines) and B (dotted black lines).

3.7.8 Risk assessment

The stock assessment model developed for the east coast fishery of banded morwong was further used as a so-called ‘operating model’ in a risk assessment to assess the future impact of different catch levels on the fished stocks (Ziegler *et al.* 2006b). The results of such an evaluation should be mainly used in a comparative way, rather than as absolute predictions, and the interpretation of its performance obviously depends on the particular management objective(s) selected for the fishery. The objective used here was defined as to stabilise the current catch rates and mature biomass of the fished stock over a period of 5 years.

In the scenarios examined here, reported catch was assumed to be constant over the projected period of 20 years, representing a form of unadjusted allowable catch, where the management control is not altered even when catch rates or effort change substantially. Different ‘reported’ catch levels, ranging from 1t, 10t, 20t, 30t etc. to 80t were compared (Fig. 3.21). This 80t-catch scenario was similar to historically high catches and had relevance given the intention by industry to explore overseas markets for banded morwong (and other live-fish). It was assumed that total-induced fishing mortality was higher than the ‘reported’ catches due to coff-mortality and related underreporting (catch levels were multiplied with a bias factor 1.1 and random variation with $\sigma = 0.1$ resulting in slightly irregular catch levels). In addition, seal mortality was considered to remain high, and was represented by a bias factor 1.2 and random variation with $\sigma = 0.05$.

The total catch allowed was assumed to be taken in all years. Only when this catch target could not be achieved because of insufficient exploitable biomass was the catch reduced so that the harvest rate would not exceed 0.95. Reported effort or catches were assumed to be generally under-reported compared to the actual fish removed from the stocks or killed in the operation because of barotrauma or seals (Ziegler *et al.* 2006a). However, this applied only to legal-sized fish, while all non-legal fish were assumed to be returned live to the sea.

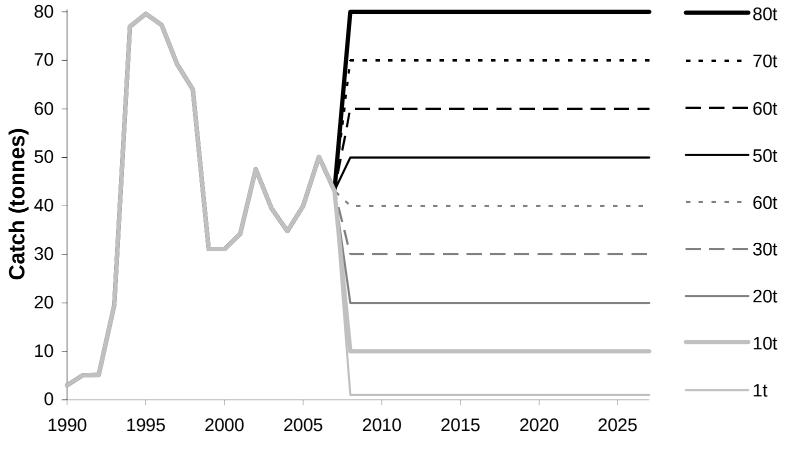


Fig. 3.21. Harvest strategies with ‘reported’ catch levels examined in the model projections.

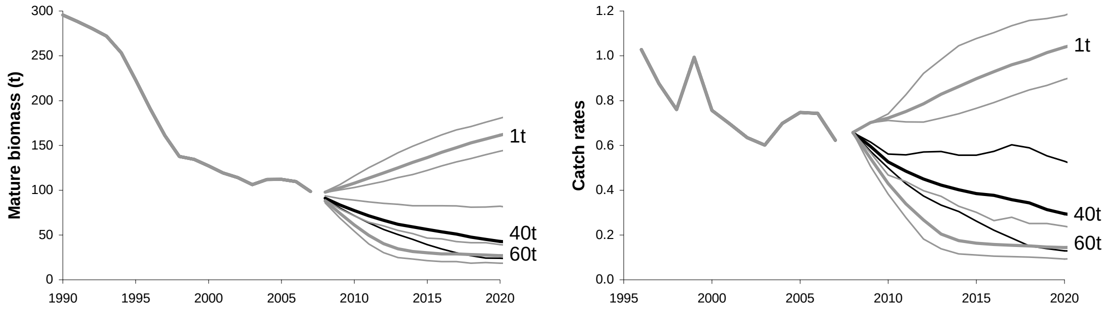


Fig. 3.22: Constant catch simulation for the Bicheno stock with total reported catches of 1t (less than 1t from this stock; top grey lines), 20t (8t from this stock; black lines) and 60t (33t from this stock, bottom grey lines). Heavy lines represent the median, the outer lines represent the 90% confidence intervals. Results shown are based on 200 simulations.

Because the relative performance was similar between the three regional scenarios and the different onshore biomass and movement scenarios, only the results from the regional base case scenario with 75% onshore biomass and a movement rate of 0.5 are presented. Confidence intervals around the median estimates tended to be widest for intermediate catches (20-40t), but were narrower for very low and very high catches (Fig. 3.22).

The effects on mature biomass and catch rates gradually increased with increasing catch (Fig. 3.23 and Fig. 3.24). They were weakest in St. Helens, but pronounced in all other stocks. Up to a total catch of 20t, the model predicted that mature biomass and catch rates remained fairly stable overall on the whole East coast and in each stock, although after a slight drop in catch rates for the Tasman and Maria stocks. At this catch level, there was a generally less than 50% chance that mature biomass and catch rates were higher in 2012 than in 2007. Catches of 30t and higher resulted in a continuously decreasing mature biomass and catch rates and had only a very small chance of sustaining current levels in 5-years time (less than 10% for mature biomass, 6%-28% for catch rates in the four stocks). For the current 40t and higher catch levels on the East coast, the model predicted a close to 100% chance of biomass and catch rate decline.

A constant (intended) removal of 60t or more, mature biomass and catch rates dropped to very low levels within 10 years in most stocks and did not recover during the remaining period (Fig. 2.23). In fact, these catch levels could often not be taken due to lack of sufficient biomass. Rather, the total fishing-induced mortality or real catch stabilised at much lower levels, and often a substantial part of the existing biomass was taken annually. In reality, this is unlikely to occur since the fishery would become economically unsustainable well before such low biomass levels were reached due to the enormous effort required to achieve the catch. But the scenario demonstrated that the stocks were unlikely to tolerate such high catches over a prolonged period.

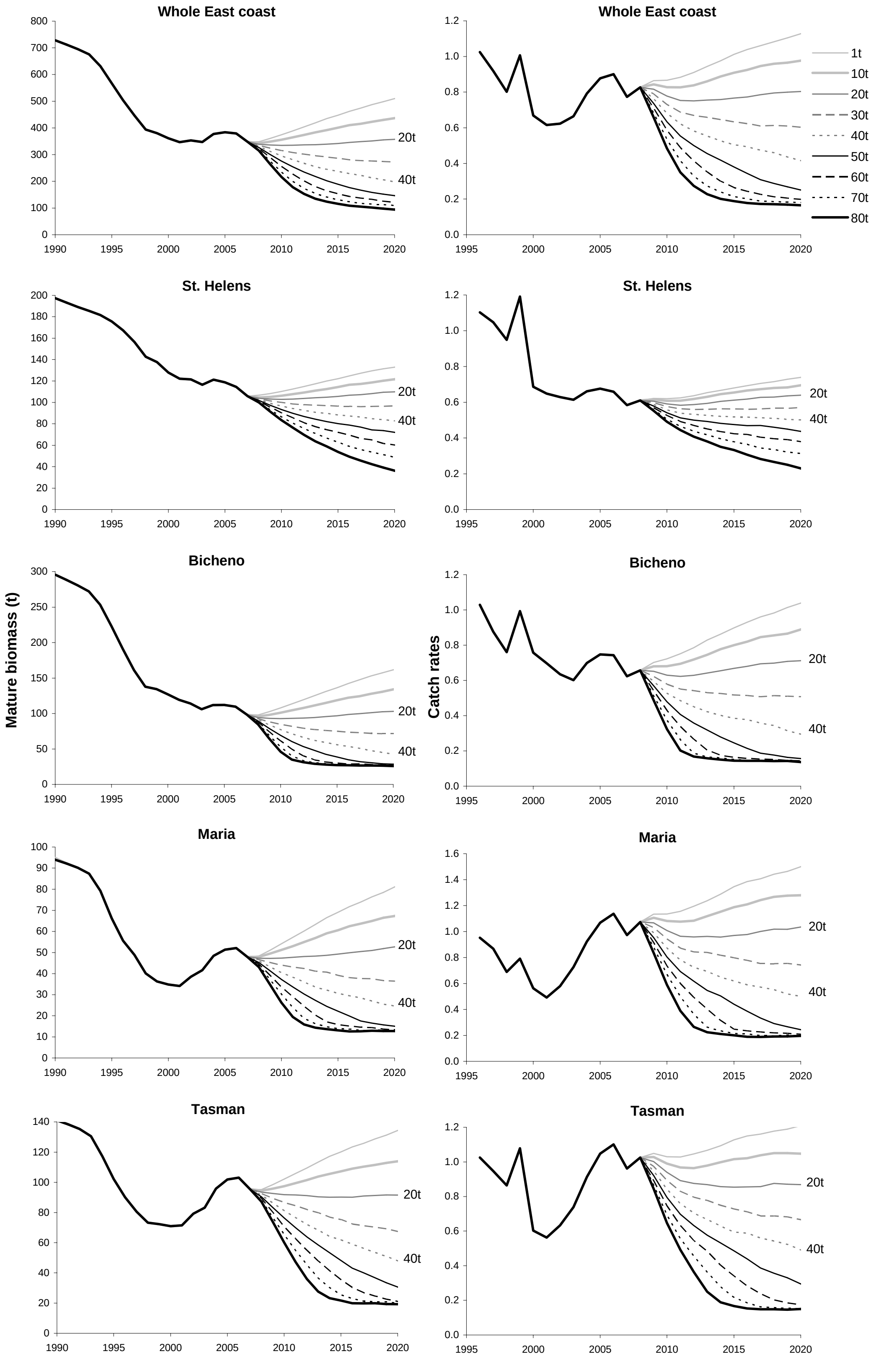


Fig. 3.23: Median mature biomass (left) and catch rates relative to 1996 (right) for whole East coast and the four stocks at different levels of total reported catches between 2008-2020. Catch rates for the whole East coast is the catch-weighed geometric mean of all stocks. Scenarios presented are for 75% onshore biomass and movement rates of 0.5. Results shown are based on 200 simulations. Different scales on the y-axis are shown. Note that the median is not a precautionary level since it only represent a 50% chance that mature biomass or catch rates are below (or above) this level.

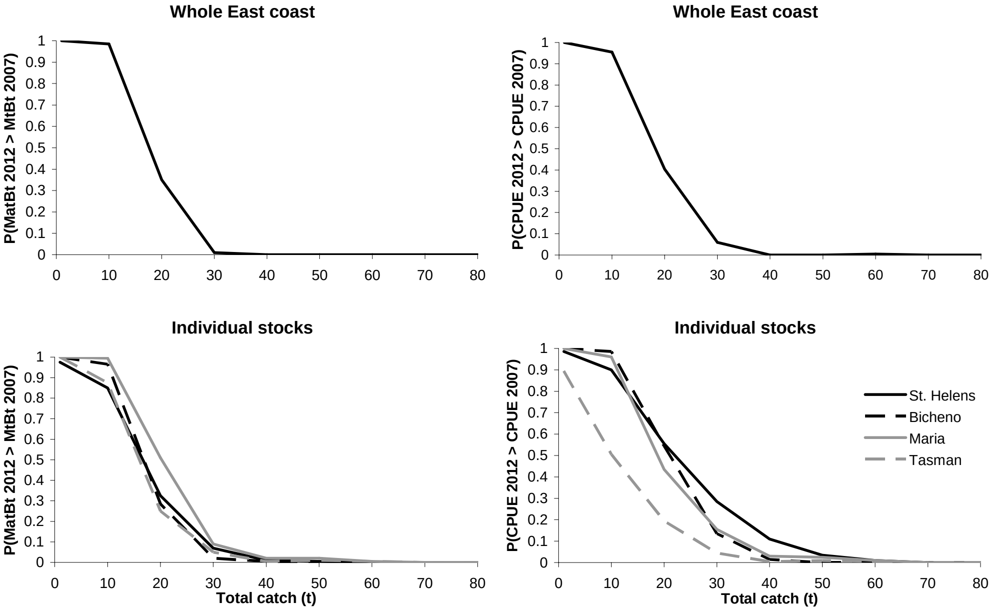


Fig. 3.24: Probabilities of mature biomass (left) and catch rates in 2012 being higher than the current 2007 levels under different levels of total reported catches for the whole East coast (top) and in the four stocks (bottom). Results shown are based on 200 simulations.

3.8 Reference points

Existing reference points	**Exceeded?**	**Alternative RP**	**Exceeded?**
State-wide or regional catches outside the 1994/95 to 1997/98 range (73t-106t)	Yes: Statewide ↓ Yes: Regionally in Maria, Bicheno and St Helens ↓	Commercial catch in Region 1 > 30% of TAC Region 2 > 65% of TAC Region 3 > 40% of TAC Outside TAC area > 10t	Not assessed
Catch increase or decline by over 30% from previous year	No	Commercial catch is less than 90% of TAC	Not assessed
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	Yes: Regionally in St. Helens	Catch rates are below 0.9 * average from reference period 2000/01 to 2005/06	Yes: Regionally in St. Helens
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Yes: Significant changes of age/size composition, acceleration of growth & earlier maturity	Any indicator of stock stress	Yes: Significant changes of age/size composition, acceleration of growth & earlier maturity

3.9 Implications for management

Despite consistently high total catches over 40t on the East coast since 2004, mature and exploitable biomass have remained high in both southern stocks, mainly due to strong recruitment pulses. In the northern stocks, recruitment has been only slightly elevated in the 2000s and mature and exploitable biomass have continued to decrease.

Stabilising current biomass levels and rebuilding populations of old fish, particularly females, appears to be a desirable strategy in the northern stocks of Bicheno and St. Helens, where continued harvest rates above the internationally recognised reference points for mature biomass of $H_{40\%}$ or $H_{30\%}$ have decreased the mature and exploitable biomass to about 30% of the initial levels in 1990 (although there is some uncertainty around these values and the levels could be closer to 50% in one of these stocks).

In the southern stocks, mature and exploitable biomass levels are predicted to be substantially higher with a minimum of 43% in Maria and 61% in Tasman and up to 87% at least in one of the two stocks. While harvest rates were within the range of $H_{30\%}$ in Tasman, they were well above in Maria in two out of three regional scenarios. However, stock rebuilding in the southern stocks was based on strong recruitment pulses in the 2000s coupled with higher productivity through increased growth rates and earlier maturity (Ziegler et al. 2007a). Similar to the northern stocks, the fishery is now largely recruitment-driven with only a small proportion of the catch made up by older females. While the fishery in the southern stocks has profited from strong recruitment in recent years, even a relatively short period of low recruitment could lead to serious declines in catch rates and mature biomass. Therefore, a reduction of fishing mortality to rebuild populations of old fish is advisable also for the southern stocks.

The higher dependence on new recruitment in all stocks was reflected in the risk assessment. The model projections predicted overall about a 50% chance that the current mature biomass and catch rates could be sustained over a 5-year period for a total East coast catch of 20t. While this is a conservative management goal for the southern stocks, higher catches caused more or less stronger declines of biomass and catch rates in all stocks. For 30t, the probability of sustaining current levels dropped to less than 10% for mature biomass and to 6%-28% for catch rates in the four stocks. For catches of 40t or more, the model predicted a rapid biomass and catch rate decline in all stocks. Therefore, should the current catch levels be maintained, the model predicts a stock decline for all regions unless strong recruitment pulses occur in the northern stocks and continue in the southern stocks.

The current risk assessment is more cautious than the previous assessment in 2004/05 (Ziegler et al. 2006) due to several reasons. The previous assessment predicted an around 50% chance of stability with a catch of 36 tonnes. This harvest level has been exceeded by 8 - 16 tonnes every year since. Consistent with the model projections then, biomass and catch rates have fallen in the northern zones as a result. Strong recruitment prevented similar decreases in the southern zones, but the model (based on consistent age samples) indicated that the fishery has become more recruitment-dependent in all regions. In addition, the split into two models fitted separately to the two northern and southern stocks has also contributed to the changes. Using two models substantially improved the fits, but estimated levels of overall recruitment were lower as a result. Because recruitment now forms the dominant source of new biomass in the model projections while the biomass of older female fish remains low, the stocks were predicted to tolerate smaller catches than in the previous assessment.

The model does not project the recruitment patterns of just recent years into the future, but instead estimates the likely recruitment patterns from the whole period between 1990 and 2007. This is a risk-adverse modelling strategy, since the high recruitment levels recently observed in the southern stocks were, on average, not continued in the same way. Implicitly, this approach assumes a long-term carrying capacity and that an increase in the fish population will slow down over time, i.e. increased high recruitment will not continue forever. It also reflects the lack of knowledge about the conditions which can lead to strong recruitment, e.g. why only the southern stocks but not the northern stocks have benefited from the especially strong recruitment pulses.

Limitations related to the use of fishery dependent data with a long-lived site attached species may have also influenced the outcomes of the assessment. There are serious issues surrounding the data quality of commercial catch returns especially from early years of the fishery and issues relating to seal interactions and economic drivers (Ziegler et al. 2005). Since fishers alter their fishing behaviour when seals affect their operations and may fish in sub-optimal locations, variable levels of seal interactions particularly in the southern stocks may have exacerbated fluctuations in catch rates. This would have caused the model to over-estimate recruitment and its impact on the stock rebuilding. Additionally, because of the spatial mis-match between catch rate data and stock processes, catch rates may have masked serial depletion and appeared more stable than they would have been had they been analysed at a finer spatial scale. If this is the case, model predictions may be overly-optimistic.

Generally, high uncertainty in assessment outcomes stemmed from the uncertainty of the underlying data and the dynamics and spatial structuring of the stock. Attempting to select the optimum spatial model structure seemed inappropriate given the generally poor fits to the biological sex ratio and age composition data. Despite these concerns, the model provided useful insights into the banded morwong stocks and their potential future development under different catch scenarios. The results of the assessment agreed with the investigated biological measures indicating that the fishery has substantially impacted on the stocks, especially if the observed growth acceleration and changes in maturity towards onset at an earlier age and smaller size do in fact prove to be mainly a density-dependent response to reduced population size rather than a reaction to increased water temperatures (Ziegler et al. 2007a). It would reinforce the argument that a precautionary approach to future management is required.

3.10 Research needs

The Scalefish Fishery Research Advisory Group has accorded stock assessment of banded morwong a high priority. Bi-annual spawning season surveys and stock assessments will continue in 2009 and should provide further insights into the impact of fishing on the size, age and sex structure. However, given the level of spatial structuring, sampling needs to be focussed regionally, even at the scale of discrete reef areas. This degree of sampling intensity is in practice difficult to achieve and justify in a fishery of this size.

Information about the character or relative abundance of populations in the deeper reef areas or potential mixing rates with the shallower areas is still missing. Fishing surveys of such areas and an understanding of the size and distribution of suitable deep reef habitat relative to the shallow fished reef areas could prove informative in evaluating the potential importance of depth refuges.

4 Southern calamari (*Sepioteuthis australis*)

4.1 Life-history and stock structure

Southern calamari is a very short-lived, fast-growing cephalopod species with spawning aggregations in inshore waters:

Parameter	**Estimates**	**Source**
Habitat	One of the most common cephalopods in coastal shallow waters of southern Australia. Important component of the coastal ecosystem as primary consumer of crustaceans and fishes, and as a significant food source for numerous marine animals.	Gales *et al.* 2003
Distribution	Endemic to southern Australian and northern New Zealand waters	Gomon *et al*. 1994
Movement	Differential habitat use by the sexes during spawning with males accumulating on the beds, as opposed to more frequent small-scale movement on and off the beds by females. Sex-ratio is more even both before and after the closure, however, during the closure spawning activity in aggregations males out-numbered females 10:1. Therefore, although the fishery removes a representative sample of what squid are on the spawning beds at any point in time (squid jigs do not appear to be sex-selective), the fishery is effectively selective for males and will therefore impact both the apparent size of individuals and sex-ratio of the population.	Pecl *et al.* 2006 Hibberd 2005
Natural mortality	High	Pecl *et al.* 2004
Maximum age	The species is short-lived, probably living for less than one year: Maximum recorded ages: males: 275 days, females: 263 days.	Pecl *et al.* 2004
Growth	Rapid rate of growth at 7-8% body weight per day (BW day^{-1}) in individuals less than 100 days old, decreasing to 4-5% BW day^{-1} in squid older than 200 days. Extremely variable growth: At 200 days of age individual males may vary in size by as much as 1.5 kg and females by as much as 0.9 kg. Some of this variability in growth may be explained by temperature or food availability at hatching, with those individuals hatched in warmer seasons or years generally growing faster. Males attain greater size and weight than females: - Maximum recorded length: males 550 mm, females: 480mm dorsal mantle length (ML). - Maximum recorded weight: males 3.6 kg, females: 2.3 kg.	Pecl *et al.* 2004
Maturity	On the east coast of Tasmania, over 90% of females caught in summer are mature, whereas in winter over 50% of the females are either immature or in early stages of maturity. Minimum recorded age and size at maturity for females is approximately 117 days, 0.12 kg and 147 mm ML. Immature females were found to be as old as 196 days and up 0.62 kg and 237 mm ML. Males mature as young as 92 days and as small as 0.06 kg and 104 mm ML.	Pecl 2001 Pecl 2001
Spawning	Major spawning period in spring/summer in Tasmania, with low levels of spawning occurring all year round. The majority of summer caught squid are hatched in winter and vice versa. Multiple spawners with individual spawning activity occurring over several months (acoustically-tagged mature females moved on and off the spawning grounds for up to 3½ months). Frequency of batch deposition is unknown.	Moltschaniwskyj *et al.* 2003 Pecl *et al* 2006

Spawning (cont.)	Summer spawners can lay larger batches of eggs than winter spawners Younger females may lay more eggs than older females. Spawning aggregations are male-biased. Female calamari have multiple mates with up to 85% of individual egg capsules from the one female sired by multiple fathers. Mating occurs either in temporary pairs with a large dominant male that guards the female, or in extra-pair copulations with a 'sneaker male'. Genetic studies demonstrated that both small and large males sire similar proportions of offspring. Several females deposit eggs together in collective egg masses, attaching the finger-like capsules to the substrate by small stalks. Eggs appear to be most commonly attached to *Amphibolis* seagrass, although they are also found attached to other seagrasses and macro-algae, or embedded directly into sand. Individual egg strands contain 4-7 eggs, with 50 to several hundred egg strands joined together to form larger egg mops. Development takes between 4-8 weeks, depending on water temperature, bringing the total life span close to annual.	Pecl 2001 van Camp *et al.* 2005 Jantzen and Havenhand 2002 van Camp *et al.* 2004 Moltschaniwskyj *et al.* 2003 Steer *et al.* 2002
Early life history	Newly hatched calamari are 2.4-7 mm ML and immediately swim to the surface following hatching. Hatchlings can be found near the spawning grounds for 20-30 days. The habitat and ecology of individuals between about 20-80 days of age is unknown, however at 80-150 days, juveniles have been found in deeper water adjacent to the spawning grounds. Individuals become available to the fishery at approximately 90-120 days of age.	Steer *et al.* 2002 Pecl 2000 Pecl 2004
Recruitment	Highly variable	This report

4.2 The fishery

During the latter half of the 1990s there was a marked expansion in the fishery for calamari in Tasmania, with catches rising from less than about 20 tonnes p.a. prior to 1995/96 to about 90 tonnes in 1998/99, accompanied by a trebling of effort. Southern calamari are taken by a variety of methods including purse seine, beach seine, squid jig, spear and dipnet, with squid jigs the primary method in recent years. Although some night fishing occurs, fishing is generally conducted during the day over shallow areas of seagrass and macro-algae where squid aggregate to spawn.

4.3 Management background

The dramatic rise in southern calamari catches prompted a ministerial warning in August 1999 that management arrangements were under review and restrictions on catch, effort and numbers of operators accessing the resource may be introduced in the future. In addition, Great Oyster Bay was closed to fishing for southern calamari for 2 weeks twice between October and December 1999 as a precautionary measure to protect egg production. Similar short-term closures were implemented again in 2000 and 2001, while in 2002 closures were extended to include adjacent fishing grounds in Mercury Passage. In each year from 2003 to 2006, the commercial fishery in Great Oyster Bay and Mercury Passage was closed for a three month period to reduce catches from the spawning population.

In 2003 and 2004, the area was closed from September to November inclusive. Recreational fishers were permitted to fish for calamari during this period but with a reduced daily bag limit of five calamari, and there was some limited research fishing by commercial fishers, operating under permit. The movements of acoustically-tagged squid monitored throughout the closed areas and periods suggests that squid were unlikely to have left the protection of the Great Oyster Bay closed area for the boundaries that were in place for 2003. However, tracking data indicate that some leakage out of the protected area probably occurred during the 2004 closed season where the boundaries were reduced (Pecl *et al.* 2006).

In 2005, the closed area was expanded to include all waters between Wineglass Bay and the northern end of Marion Bay and the closure period lasted from mid-September to mid-December. The closure also included recreational fishers, thereby providing effective protection to the spawning stock during the peak of the spawning season. A similar closure was implemented in 2006.

Growing markets for the species coupled with increasing use of squid jigs, a method available to all holders of scalefish and rock lobster licences to target the species, have contributed to the recent expansion of the fishery. In an effort to limit further expansion of the fishery in November 2001, a combined possession limit of 30 calamari and arrow squid was introduced for all holders of scalefish C licences (but excluding those also holding beach seine or purse seine licences). Also in November 2001, a daily bag limit of 20 ‘squid’ (southern calamari and/or arrow squid) and a possession limit of 30 squid were introduced for recreational fishers. Recreational bag limits for squid were replaced in 2004 with a possession limit of 15 calamari and 15 arrow squid.

Recent deliberations regarding the long-term management of calamari have included consideration of zoning the fishery into “developed” region on the east and south-east coasts and “undeveloped” regions for the rest of Tasmania, along with the introduction of a specific calamari licence for the developed region. Although arrangements have yet to be finalised, it is likely that they will be implemented within the next year.

4.4 Management objectives and strategies

The generic management objectives for the Tasmanian scalefish fisheries apply (with reference period 1995/96 to 1997/98).

The species is currently managed by a combination of spawning season closure for commercial and recreational fishers in all waters between Wineglass Bay and the northern end of Marion Bay from mid-September to mid-December, a combined possession limit of 30 calamari and arrow squid for all holders of scalefish C licences (excluding those also holding beach seine or purse seine licences), and a possession limit of 15 fish limits on recreational catch.

4.5 Relative vulnerability to fishing

Vulnerability of calamari to fishing pressure is unclear but probably high because spawning aggregations can be targeted and the species has an annual or sub-annual life span that renders the stock susceptible to spawning and/or recruitment failure. However, if the population is allowed to spawn (during the fishing closures) prior to the main harvest, the population may be able to sustain high fishing mortality rates without detrimental effects on future recruitment.

4.6 Previous assessments

Previous assessments have involved analyses of catch, effort and catch rate trends. Rising effort and declining catch rates in the main fishing regions were noted and flagged as potential indicators that the fishery had impacted on the calamari stocks. Preliminary analysis of catch and effort data using surplus production modelling for the major fishing areas of Great Oyster Bay and Mercury Passage was investigated for the 2003 and 2004 assessments. Analyses suggested that the unfished, mid-season exploitable biomass was between about 200-275 tonnes but had been reduced to below 50% of this level, implying that harvest rates were very high and not sustainable. Three month closures were implemented as a direct management response to reduce the harvest rates as well as protect the stocks whilst spawning. These closures, however, resulted in a substantial change in the temporal distribution of catch and effort, thereby violating a key model assumption that the distribution of catch and effort is consistent over time. This meant that the surplus production modelling was no longer valid or useful.

4.7 Current assessment

The extended fishery closures had large impacts on monthly catches in Great Oyster Bay and Mercury Passage each year since 2003 (Fig. 4.1). Fishing activity has effectively shifted from an August and December focus (1998/99 - 2002/03) to being heavily concentrated into the single month of December (2003/04 - 2005/06). In the current year, some fishing occurred also in January.

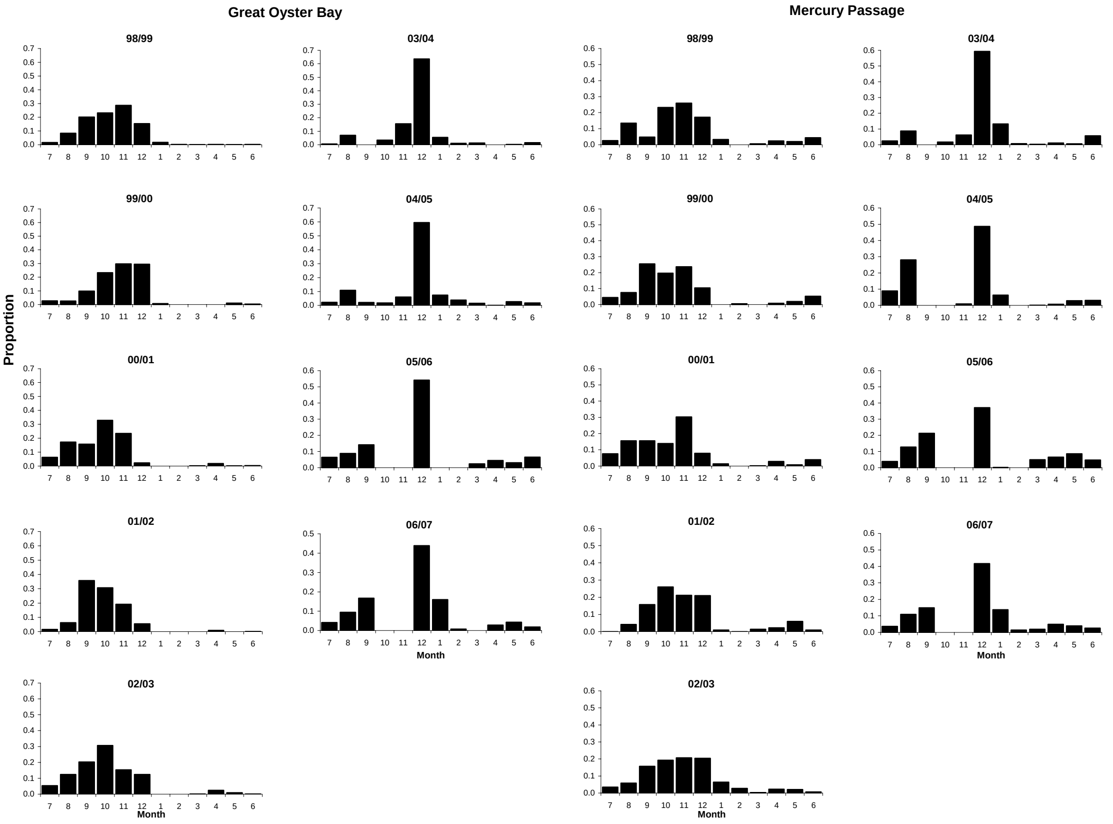


Fig. 4.1 Monthly catch distribution (as proportion of the total catch within the fishing year) for Great Oyster Bay (ES13 and ES14) and Mercury Passage (ES16).

4.7.1 Catch, effort and catch rates

Since 1998/99, a significant fishery for southern calamari has developed in Tasmania, with catches expanding rapidly from less than about 30 tonnes p.a. prior to 1998/99 to over 100 tonnes (Fig. 4.2A). While calamari catches have been reported from all areas apart from the west coast, the fishery is concentrated off the central east and south-east coasts (Fig. 4.3). The fishery developed initially in the mid-1990s in Great Oyster Bay and then expanded to the south to include Mercury Passage, Maria Island and Tasman Peninsula (Fig. 4.2B). Over recent years moderate catches of calamari have also been taken from Flinders Island.

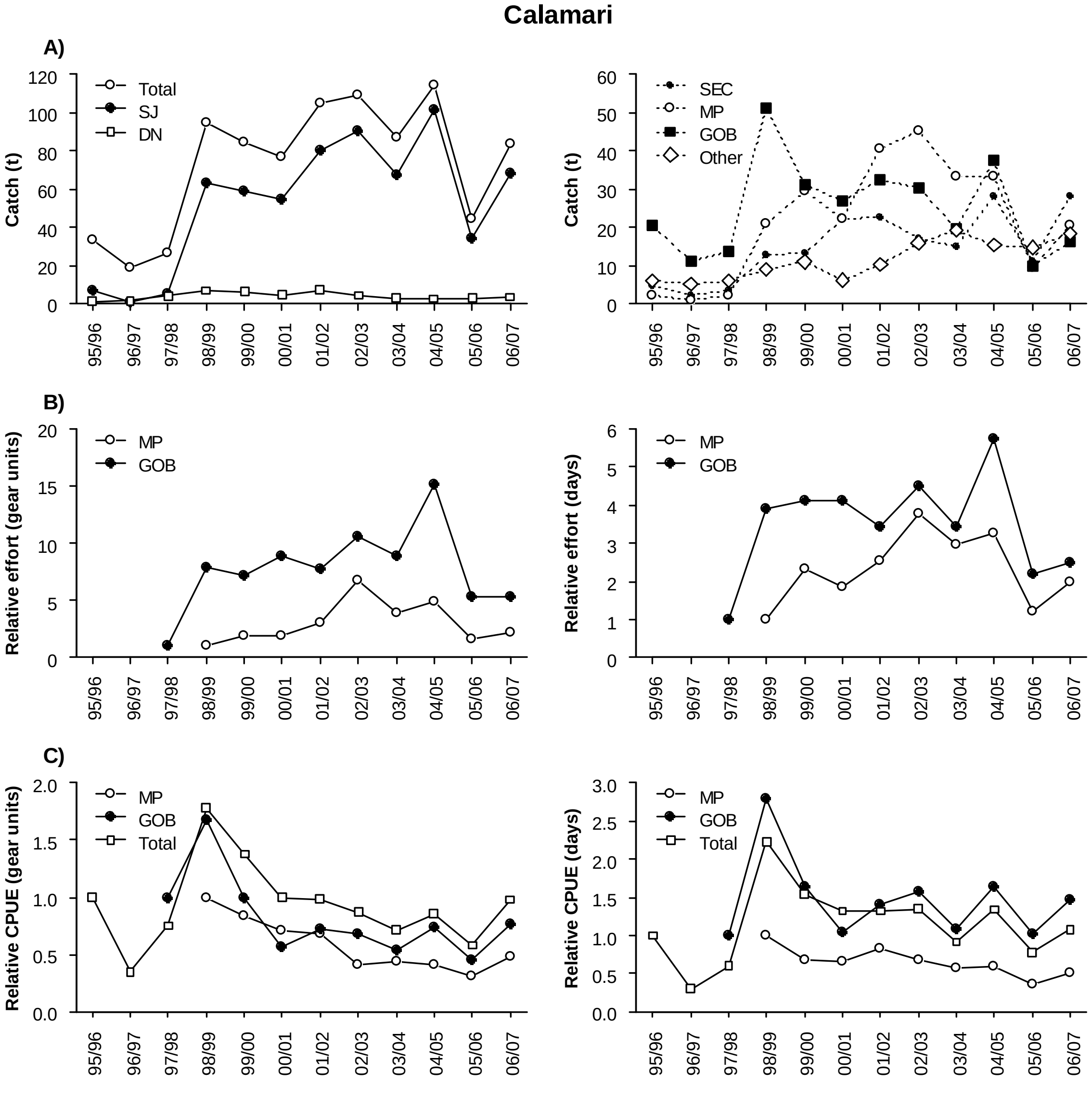


Fig. 4.2 A) Annual catch (tonnes) of calamari by method (left) and by region (right) since 1995/96; B) squid jig effort based on gear units (left) and days fished (right) relative to 1998/99 for MP and 1997/98 for GOB; and C) squid jig catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day (right) relative to 1998/99 for MP, 1997/98 for GOB and 1995/96 for Tasmania (Total). SJ is squid jig, DN is dipnet; SEC is south-east coast, MP is Mercury Passage, GOB is Great Oyster Bay, and Other is all remaining areas. Only years with >5 operators are shown.

The expansion of the fishery was almost exclusively due to increased squid jig catches (Fig. 4.2A). The 2006/07 catch of 83 tonnes was similar to the catches in the early 2000s, but represented almost a doubling compared to the poor catches of 2005/06. While a substantial increase came from the south-east coast, increased production was reported in all areas, including Great Oyster Bay and Mercury Passage where the 3-month closure was extended over a larger area compared to 2004/05.

Expansion of the fishery in Great Oyster Bay (blocks 6H1, ES13 & ES14) and Mercury Passage (6H3, 6G4 & ES16) was primarily responsible for the initial growth of the fishery, though other regions have become increasingly important in recent years (Fig. 4.2B). In addition to reducing pressure on the main spawning grounds, a secondary objective of the fishery closures was to encourage industry to spread the effort into other regions. There is some evidence of this being achieved, with increased catches from the south-east including Norfolk-Frederick Henry Bay (ES17, ES18, ES19) and the Tasman Peninsula (7G2), and a general increase in catches from the north coast and Flinders Island (Other in Fig. 4.2B).

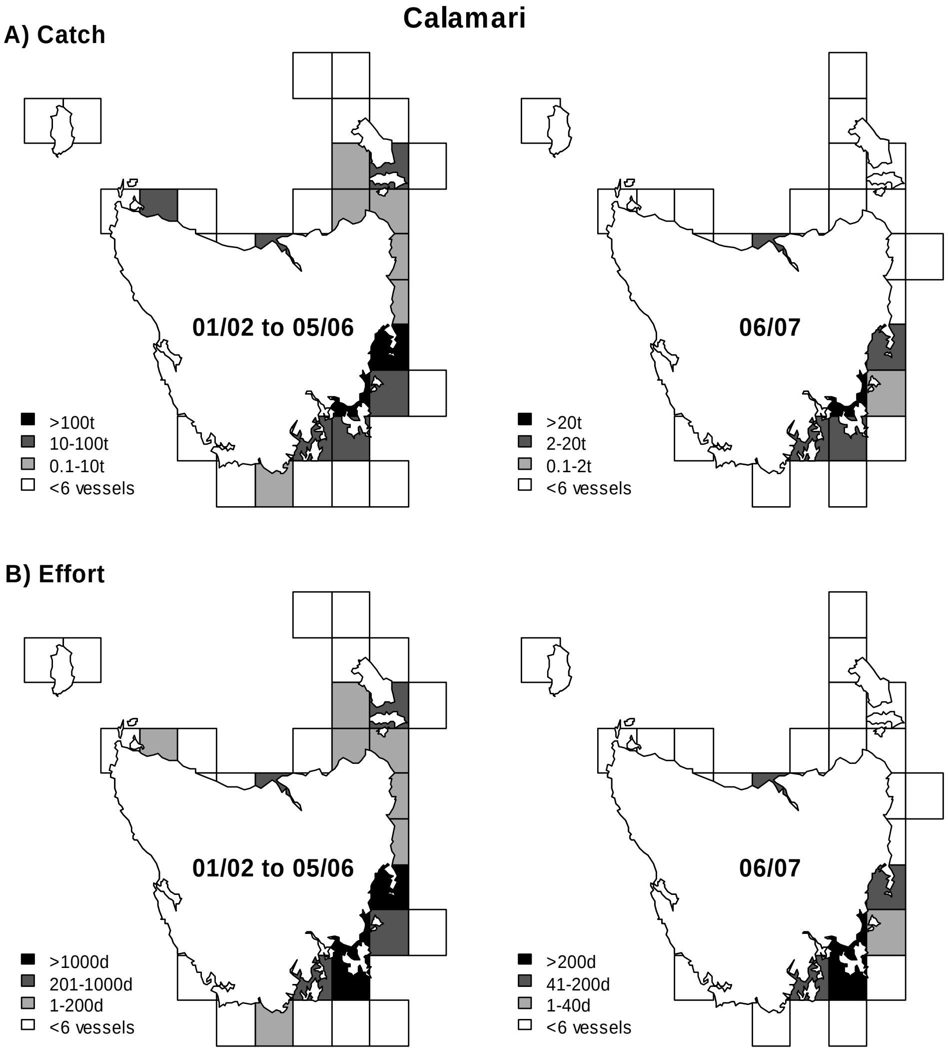


Fig 4.3. (A) Calamari catches (tonnes) and (B) effort (days) by fishing block pooled from 2001/02 to 2005/06 (left) and during 2006/07 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

The only available estimate of the recreational catch of calamari (18 tonnes in 2000/01) indicates that this sector has the potential to contribute significantly to the overall fishing pressure on the species.

The regional distribution of the fishery in terms of effort is, not surprisingly, consistent with the pattern observed for catches (Fig. 4.3). Effort is focussed on Great Oyster Bay, Mercury Passage, the south-east and Tamar in the north. Jig effort in 2006/07 remained low in Great Oyster Bay and Mercury Passage after the sharp fall in the previous year, largely influenced by 3-month seasonal closure (Fig. 4.2B).

State-wide, catch rates (gear and daily) for jigs increased in 2006/07 compared with 2005/06 (Fig. 4.2C). In the context of catch and effort, these data imply that the higher overall catches for calamari during 2006/07 was in response to generally better catch rates outside the period of the seasonal closure.

4.7.2 Reference points

Existing reference points	Exceeded?	Alternative RP	Exceeded?
State-wide or regional catches outside the 1990/91 to 1997/98 range (6t-33t)	Yes: Statewide ↑ (83t)	Commercial catch in: GOB & MP > 50t Remainder SE > 30t Outside GOB, MP & SE > 25t	No (GOB & MP: 37t Remainder SE: 28t Outside GOB, MP & SE: 18t)
Catch increase or decline by over 30% from previous year	Yes: Statewide ↑ (186%)	Consistently declining trend in catch over 3 years by a total of > 40% in GOB, MP and SE Tasmanian waters	No
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	Yes	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	No	-	
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	No	Any indicator of stock stress	No

4.8 Management implications

The alternative reference points for calamari should finally overcome the shortfalls of the existing reference ranges for catch and effort. The existing ranges derived from a period well before the fishery developed and thus compared the fishery between an under-developed (pre-1998/99) and developed state. As a result, catch and effort indicators have been continuously triggered in the past.

Preliminary modelling using surplus production models (2003 and 2004 assessments) implied that, within the main area of the fishery, harvest rates were very high. Closures have been applied to reduce fishing pressure as well as provide protection to the spawning stock. The extension of the closure to three months since 2003 has, not surprisingly, resulted in substantial changes in the fishery dynamics and compromised the validity of several model assumptions. Hence the model could no longer be used.

Based on cumulative egg production (Ziegler et al. 2007b), closures that encompass the September to November (or early December) period are likely to provide effective protection to the bulk of the spring spawning event. Moreover, since calamari have a life span of generally less than one year, intense fishing pressure immediately after the fishery is opened will often have a limited impact on subsequent recruitment, since most calamari caught would have already spawned and would die anyway within in a short period of time. In this context, the current management strategy of spawning closures should have considerable stock benefits. Impacts on the economic viability of operators and markets arising from the resultant pulse fishery are likely but whether management options are available or desirable to modify this behaviour is beyond the scope of this present assessment.

As the spawning dynamics and relationships between egg production and subsequent recruitment are better understood, there may be potential to use egg surveys in a real-time monitoring capability, whereby consideration could be given to shortening or extending closures depending on the level of accumulated egg production at a given point in time. However, since growth and reproductive characteristics of individual calamari appear to differ substantially depending upon the timing of hatching and subsequent environmental conditions, environmental factors may ultimately prove as important as fishing mortality in driving the population structure and dynamics.

Because stable isotope analyses indicated that most adult calamari caught on the east and south-east coasts are probably spawned in Great Oyster Bay (Ziegler et al. 2007b), this area exhibits a high degree of self-recruitment as well as supplying other parts of the south-east coast with the bulk of recruits. These findings reinforce the value and effectiveness of management arrangements that involve the closure of this region during the main spawning period.

Interest in calamari continues at a high level and there is substantial capacity within the Tasmanian scalefish industry to increase effort levels, an issue that is being tackled as part of the current management review through consideration of licensing and limited entry. As for the recreational sector, interest in the species is also high and effort directed at the species is likely to increase. Areas such as the D'Entrecasteaux Channel, Norfolk and Frederick Henry Bay and Great Oyster Bay are recognised hotspots.

The extended closure of the major spawning grounds (implemented again in 2006) appears to be effective in protecting the main known spawning event and ensuring relatively high egg production. Major catches can still be taken even after the spawning closure. However, any major shift in the fishery to increased effort prior to the closure could adversely impact on the spawning stock prior to the main spawning season. Expansion of catches in space and time should be therefore monitored closely and restricted if need be.

4.9 Research needs

The Scalefish Fishery Research Advisory Group has recognised stock assessment, evaluation of critical habitat requirements, impact of management arrangements and gear interactions on calamari populations as high priority research areas. The continued lack of information concerning the recreational catch, especially from Great Oyster Bay, remains a significant hole in the assessment of calamari.

Information on the stock structure and level of fishing pressure that can be sustained on southern calamari is required. Integral to this is the need to quantify the relationships between reproductive output, spawning stock size and subsequent recruitment. Critically the source and sink populations supporting the Tasmanian calamari fishing industry need to be identified to ensure sustainable use of this resource. While recent research has progressed in this area, it is important to note that calamari is a highly variable species and the observed patterns may not be valid in all years. Our understanding of the variability and plasticity in the life cycle, and the subsequent application of population modelling techniques, would also benefit from more detailed research into determining links between environmental factors and growth, reproductive, and survival characteristics. Given the vulnerability to recruitment failure, the impact of fishing activities on the spawning behaviour of the aggregations needs to be addressed.

5 Striped trumpeter (*Latris lineata*)

5.1 Life-history and stock structure

Parameter	Estimates	Source
Habitat	Mainly on the continental shelf over rocky bottom to depths of about 300 m, with juveniles associated with shallow inshore reefs.	
Distribution	Distributed throughout southern Australia, from Sydney around to Kangaroo Island in South Australia and including Tasmania. The species is also found in New Zealand, the St. Paul and Amsterdam Islands in the southern Indian Ocean, and the Tristan da Cunha Group and Gough Island in the southern Atlantic Ocean.	Gomon *et al.* 1994
Movement and Stock structure	Uniform stock structure in Tasmanian waters (no significant genetic separation of populations). Tagging studies suggest that juveniles tend to remain around shallow reefs for several years, with only limited movement, before moving into deeper offshore reefs. This pattern is supported by data from the commercial fishery that shows fish do not recruit to the offshore hook fishery until about 45 cm. In 2001, a striped trumpeter tagged off the Tasman Peninsula in 1996 was recaptured off St. Paul Island in the Indian Ocean indicating a capacity to undergo wide-scale movements.	Tracey et al 2007b Lyle and Jordan 1999 Tracey and Lyle 2005 Lyle and Murphy 2001
Natural mortality	Estimated as $M = 0.1$	Tracey and Lyle 2005
Maximum age	Maximum age is estimated to be 43 years (while this has yet to be fully validated, the incremental structure in sectioned otoliths is clear and unambiguous)	Tracey and Lyle 2005
Growth	Growth up to 1.2 m in length and 25 kg in weight Rapid growth of juveniles, reaching a mean length of around 28 cm after two years and 42 cm after four years, with most growth occurring during summer and autumn. Older fish grow significantly more slowly, with a large range in size-at-age for fish over about 50 cm.	Gomon *et al.* 1994 Murphy and Lyle 1999 Tracey and Lyle 2005
Maturity	Females reach maturity at a smaller size and age (44 cm and 5 years) than males (53 cm and 8 years). However, more recent data suggest that size at 50% maturity in females is somewhat larger, around 54 cm (6.8 years), with male attaining 50% maturity at 53 cm (6.2 years).	Hutchinson 1994 Tracey *et al.* 2007a
Spawning	Spawning occurs from July to early October, depending on geographical location, with earlier start and finish at lower latitudes. Multiple spawners, highly fecund (100,000 to 400,000 eggs for females weighing 3.2 and 5.2 kg, respectively) and produce small pelagic eggs (1.3 mm diameter) with a single oil droplet.	Ruwald et al. 1991 Ruwald 1992 Hutchinson 1993
Early life history	Larval rearing trials indicate a complex and extended larval phase, with a post-larval 'paperfish' stage of up to nine months prior to settlement. The distribution of larvae and recruitment processes have not been studied. While no information is available on the size and timing of settlement, juveniles of around 18 cm fork length (FL) have been caught on shallow reefs off the south-east coast in January.	Ruwald et al. 1991 Ruwald 1992 Murphy and Lyle 1999
Recruitment	Recruitment is highly variable, with evidence of a particularly strong year class spawned in 1993 and indications of good recruitment from the 1994 and 1996 cohorts. Recruitment in intervening years has apparently been poor (based on anecdotal reports of low numbers or absence of juvenile fish observed associated with inshore reefs). Otolith microchemistry supports the hypothesis that inshore reefs represent an important juvenile habitat, with the bulk of the offshore adult population derived that individuals that spent their juvenile phase inshore.	Murphy and Lyle 1999 Tracey and Lyle 2005 Tracey, unpubl. data

5.2 The fishery

Striped trumpeter has had a long history of commercial exploitation in Tasmania, being highly esteemed for its eating qualities. There is also a high and apparently increasing level of interest in the species from recreational fishers and charter boat operators.

The species is taken by a variety of fishing methods, with hooks and gillnets being the primary methods. Juvenile striped trumpeter are taken predominantly by graball net in inshore waters (within 3 nautical miles) and usually in depths <50 m, whereas adult fish are taken in deeper offshore waters by hook methods (dropline, handline, bottom longline, trotline) and as by-product in large mesh gillnets (shark nets). Catches are concentrated off the east coast, including Flinders Island, as well as off the south and south-west coasts of Tasmania. Limited catches are taken off the west coast.

5.3 Management background

Responsibility for the management of striped trumpeter was passed to Tasmania in 1996 through an Offshore Constitutional Settlement (OCS) arrangement with the Commonwealth. A memorandum of understanding accompanied the OCS, specifying trip limits for Commonwealth only fishers to 100 kg for South East Non-Trawl (SENT) permit holders and 20 kg for all other permit holders.

When the Tasmanian scalefish fishery management plan was implemented in 1998, gear restrictions were introduced for all commercial scalefish fishers operating in State waters. However, after the introduction of the management plan, those fishers who held a Tasmanian licence and a Commonwealth permit to fish in the southern shark or SENT fisheries were effectively allowed to target unrestricted quantities of striped trumpeter in offshore waters using their Commonwealth gear allocations (this was a significant change to their original 20 kg or 100 kg restrictions). In addition, Tasmanian rock lobster fishers were also allowed to take unrestricted quantities of striped trumpeter in offshore waters using their State scalefish gear allocations.

In August 2000, the State Government introduced a combined 250 kg trip limit for striped trumpeter, yellowtail kingfish and red snapper for all fishers (Commonwealth and State) in inshore and offshore waters relevant to Tasmania. This measure was introduced to limit the potential for expansion of effort directed at these species. A daily bag limit of five and possession limit of eight striped trumpeter was also introduced for recreational fishers.

The legal minimum size limit for striped trumpeter was raised from 35 to 45 cm total length (TL) in November 2004 in recognition that the smaller size limit was substantially below the size at maturity. The recreational bag limit was also replaced with a possession limit of eight fish.

5.4 Management objectives and strategies

The generic management objectives for the Tasmanian scalefish fisheries apply (with reference period 1995/96 to 1997/98).

The species is currently managed by a combination of trip limit (250 kg) for commercial operators, a minimum size (450 mm total length) and recreational possession limit of eight fish.

5.5 Relative vulnerability to fishing

Juvenile striped trumpeter are particularly vulnerable to inshore gillnetting and although the recent size limit increase will offer protection, it is possible that incidental capture of sub-legal striped trumpeter in gillnets may result in significant post release mortality.

Marked recruitment variability appears to be a feature of striped trumpeter, and although the species is long-lived, prolonged periods of poor recruitment combined with the impacts of fishing and natural mortality have the capacity to severely deplete the size of the adult stock.

5.6 Previous assessments

Previous assessments have been largely limited to the examination of catch, effort and catch rate trends, and reporting against performance indicators. Yield-per-recruit analyses have been conducted and refined since the 2003 assessment. Size and age composition data and a spawner biomass-per-recruit analysis in 2005 indicated that striped trumpeter recruitment had been generally poor over the past decade and a further increase in the minimum size limit was required to reduce the risk of recruitment and growth overfishing.

5.7 Current assessment

The current assessment examines trends in catch, effort and catch rate for the primary fishing methods, namely dropline, handline and graball net and includes Commonwealth data up to 2006/07. Opportunistic catch sampling was undertaken during 2005/06 and 2006/07 and age composition data are compared with similar data collected during the 1990s.

Data presented for this assessment have been evaluated against the reference levels of performance indicators specified in the scalefish management plan and detailed in Section 1.3.

5.7.1 Catch, effort and catch rates

The recent catch history in waters south of latitude 39° 12’S (i.e. waters incorporated within the OCS agreement for striped trumpeter), including catches reported in Victorian and Commonwealth logbooks, is presented in Table 5.1. In the early 1990s catches by Victorian vessels were significant, peaking at around 37 tonnes. Since the mid 1990s, data from this sector have been unavailable, though it is assumed that subsequent catches have been reported in Commonwealth logbooks. Apart from 1999/00 when over 14 tonnes was taken, reported Commonwealth catches have been relatively low since that time.

Annual production was high at over 110 tonnes in the early 1990s with Victorian vessels taking between 17-39% of the reported catch, but then fluctuated generally between 70-80 tonnes through the early to mid 1990s before increasing again to over 100 tonnes by the late 1990s (Table 5.1). Catches almost halved in 2000/01 to less than 50 tonnes and have remained low since that time. The reported catch of 22 tonnes for

2006/07 was slightly lower that in the previous year and represented the lowest catch reported since the mid 1980s. However, Commonwealth catches are believed to be substantially underreported and, together with an unknown level of recreational catch, represent a major source of uncertainty in estimating the total mortality.

Striped trumpeter catches have been reported from all areas apart from the north coast, with catches from around the state, particularly off the south-east and east coasts (Figs. 5.1A and 5.2). With the decline in catches over recent years the fishery area appears to have contracted and catches are now concentrated off the south-east coast.

The most conspicuous trend in catches was the initial increase in production for all methods up until 1999/00, followed by general declines in catches for all methods (Fig. 5.1A). In 2006/07, graball and dropline catches declined again, while handline catches rose slightly. Regionally, expansion of the fishery during the late 1990s was the result of increased catches from all areas. Catches strongly then strongly declined by 2000/01. South-east coast catches have since remained relatively stable at around 10 tonnes per annum, while catches from the other regions have fallen further with only around 3 tonnes taken from each of the east, north-east and west coasts during 2006/07.

Table 5.1. Annual commercial catches of striped trumpeter (tonnes) south of latitude 39° 12'S. Based on Tasmanian (General Fishing Return), Victorian and Commonwealth catch returns. Commonwealth catches are likely to be underreported.

	Catch (tonnes)			
Year	Tasmanian	Victoria	Commonwealth	Combined
1990/91	74.5	37.1		111.6
1991/92	58.2	36.8		95.0
1992/93	52.7	19.8		72.5
1993/94	56.5	16.0		72.5
1994/95	72.4	14.6		87.0
1995/96	60.3			60.3
1996/97	79.7		0.7	80.4
1997/98	75.4		5.7	81.1
1998/99	98.4		8.9	107.4
1999/00	86.3		14.5	101.8
2000/01	41.2		7.5	49.6
2001/02	40.0		4.8	44.8
2002/03	36.8		3.2	40.0
2003/04	36.8		3.7	40.5
2004/05	24.0		2.2	26.2
2005/06	19.1		4.7	23.8
2006/07	18.7		3.5	22.2

The observed catch trends mainly reflect the influence of especially strong year classes (1993 and 1994) that entered the fishery between 1995/96 and 1997/98 (see also Section 5.7.2). Larger graball catches in 1998/99 followed by a decline suggest that the 1996 year-class, which would have recruited to the inshore gillnet fishery in 1998/99, was also relatively strong. The subsequent decline in graball catches presumably reflects the movement of the relatively strong year-classes offshore but also suggests that there has been limited recruitment in recent years.

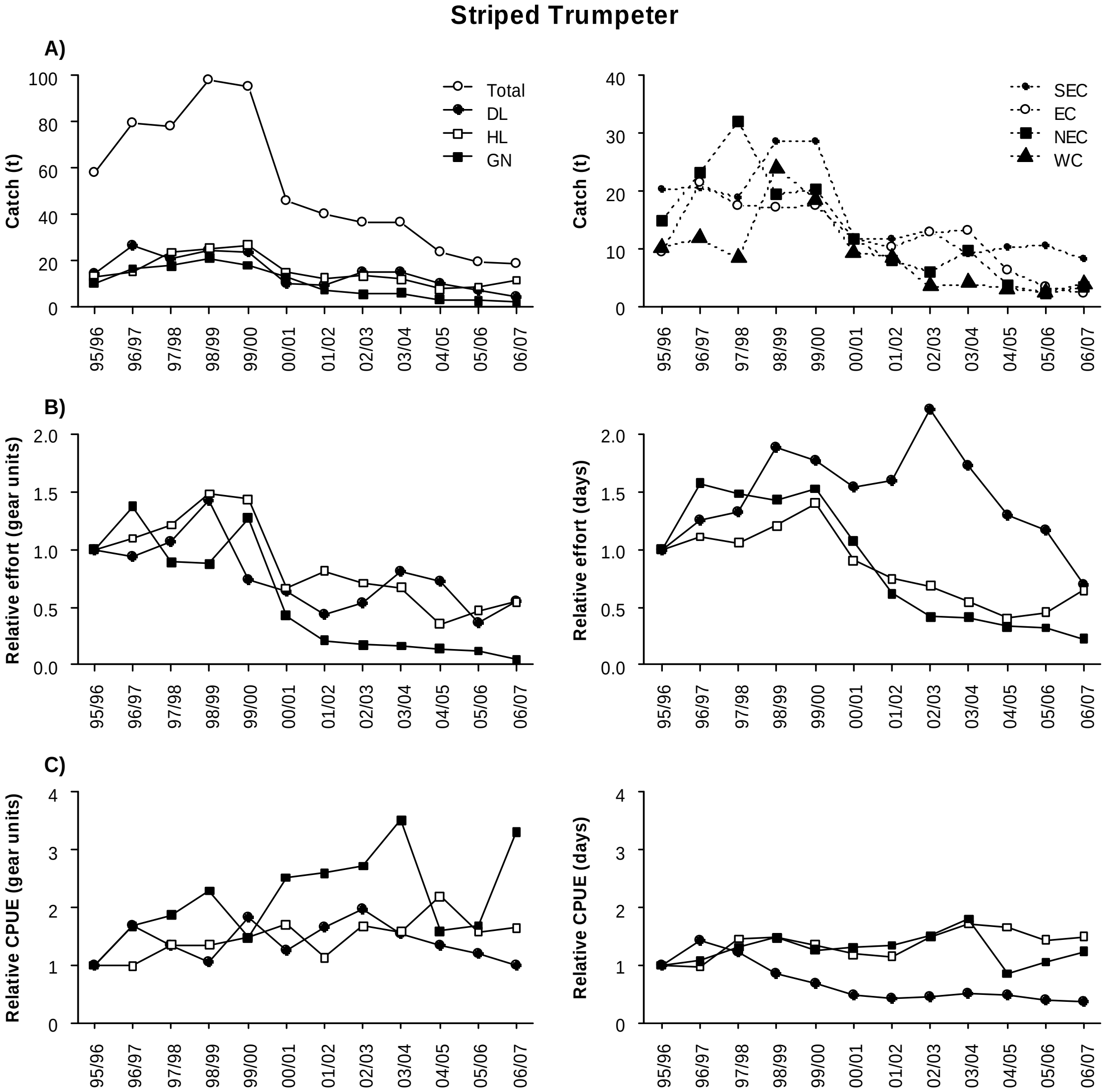
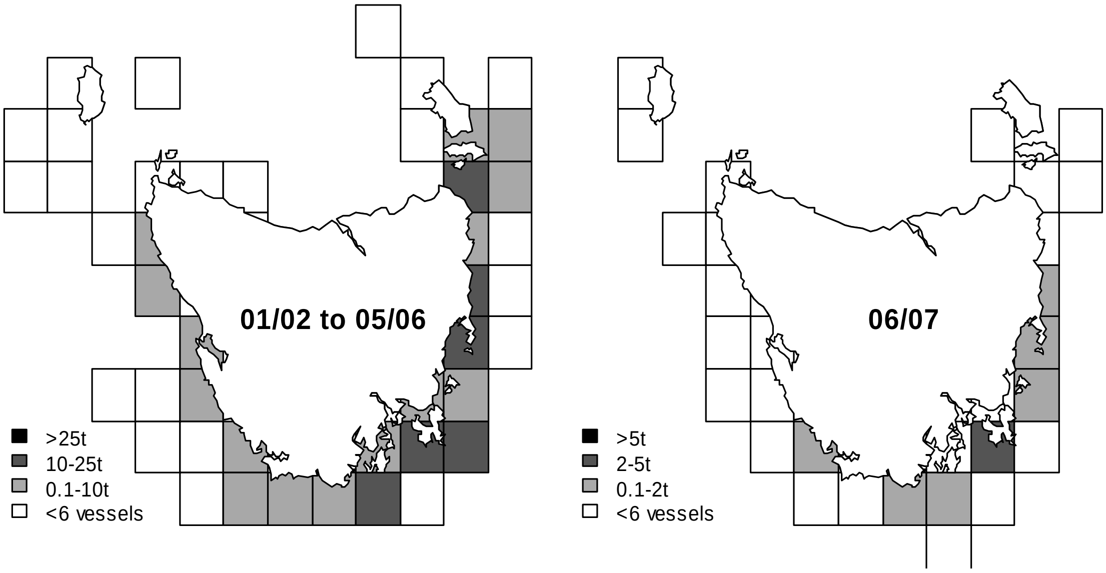


Fig. 5.1. A) Annual catch (tonnes) of striped trumpeter by method (left) and region (right) since 1995/96 reported in Tasmanian logbooks; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished (right) relative to 1995/96. DL is dropline, HL is handline and GN is graball; SEC is south-east coast, EC is east coast, NEC is north-east coast, and WC is west coast.

Striped trumpeter

A) Catch



B) Effort

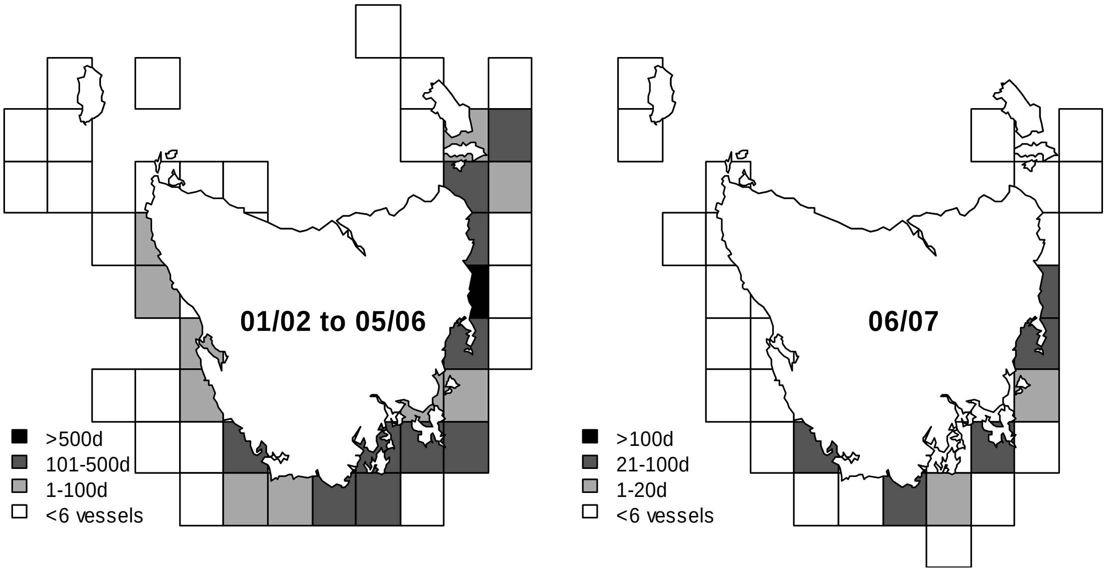


Fig. 5.2. (A) Striped trumpeter catches (tonnes) and (B) effort (days) by fishing block pooled from 2001/02 to 2005/06 (left) and during 2006/07 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

Industry representatives also suggest that the trip limit of 250 kg introduced in 2000 has represented a strong disincentive for some operators to fish for the species and may have contributed to the fall in dropline and handline catches since 2000/01. Unfortunately, these reports cannot be clarified from the logbook records. Logbook data suggest that few daily catches were affected by the trip limit. Less than 5% of daily catches exceeded 250 kg annually prior to the introduction of the trip limit in August 2000 (Fig. 5.3). The impact on the overall daily catches was also minimal with relatively stable geometric means over the year (Fig. 5.4). However, trips often last several days and changes in the behaviour of operators are difficult to assess based on daily logbook returns alone.

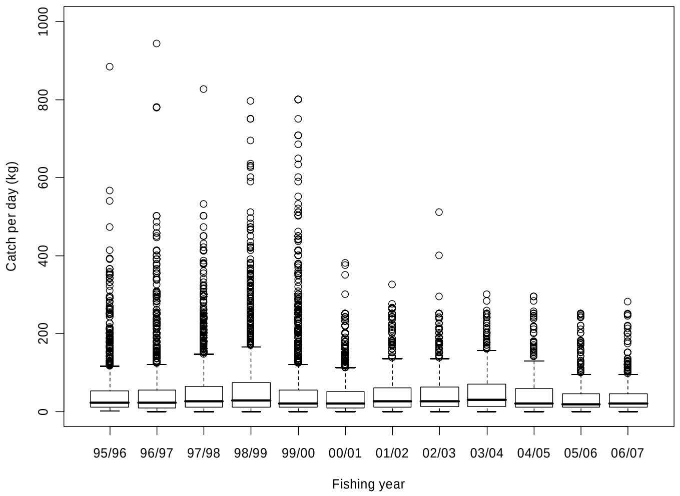


Fig. 5.3. Distribution of striped trumpeter records for catch per day (kg) by fishing year since 1995/96. The bold horizontal line shows the median, the bottom and top of the box show the 25 and 75 percentile, the horizontal lines joined to the box by the dashed line show 1.5 times the interquartile range, and points beyond this are drawn individually.

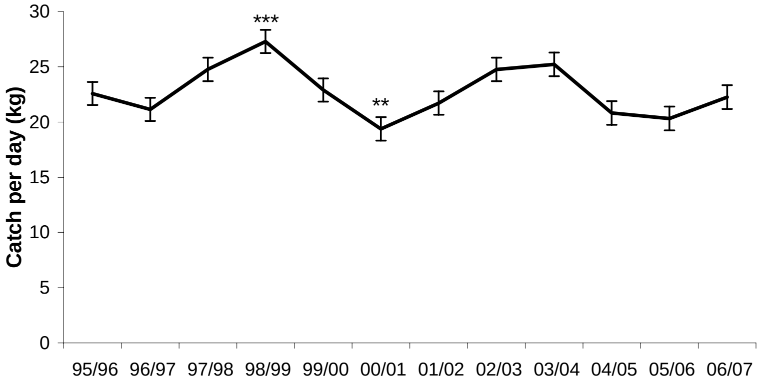


Fig. 5.4. Geometric mean with standard errors of daily reported catches for striped trumpeter since 1995/96. Daily catches were not significantly different from those in 1995/96 with the exception of 1998/99 (***, $P < 0.001$) and 2000/01 (**, $P < 0.01$).

Striped trumpeter have also been heavily targeted by the recreational fishery. An estimate of the recreational take of striped trumpeter (48 tonnes in 2000/01) indicates that the recreational catch may well be comparable to the commercial catch and, therefore, a significant component of the overall fishery. While more recent estimates of recreational catches are not available, recreational fishing activity targeting the species has almost certainly increased in recent years.

Fishing effort increased during the latter part of the 1990s, presumably linked to the increased availability of striped trumpeter (Fig. 5.1B). Subsequently, effort for graball and handline declined. Dropline effort has fallen in recent years and continued the trend of more deployed gear on fewer fishing days in 2006/07. Fishing effort has been focussed mainly on the east coast and to a lesser extent off the north-east, south and south-west during the past few years (Fig. 5.2B).

Graball catch rates increased steadily up until 2003/04, despite declining catches during the latter half of the period (Fig. 5.1C). The sharp fall in graball catch rates since

2004/05 may have been influenced in part at least by the minimum size limit increase that took effect during 2004. Increased catch rates in 2006/07 are based on very small catches and are thus unlikely to be informative about availability. Handline catch rates increased slightly through time but over the past two years remained unchanged. Dropline catch rates, based on catch per hook-lift, have fallen slightly over the past four years but were still within the range of reference values. Daily catch rates have changed little since 2000/01, remaining at about half of the minimum reference level.

5.7.2. Age composition

The 1993 year class has been consistently prominent in age composition information obtained from research fishing and commercial catch sampling undertaken since 1999 (5 year olds in 1999, 6 year olds in 2000 etc.) (Fig. 5.5). Although sample sizes for most years were low and hence may not fully represent the population age structure, it is significant that this cohort, as 13 year olds, was the dominant age class in the most recent aged sample and evidence of strong recruitment in subsequent years was lacking. This is despite the fact that fish generally recruit to the offshore hook fishery at around 5 years of age. With poor recruitment, adult biomass is expected to continue to decline and average size of hook-caught fish will continue to increase in the short-term, at least until such time as there is a period of sustained good recruitment.

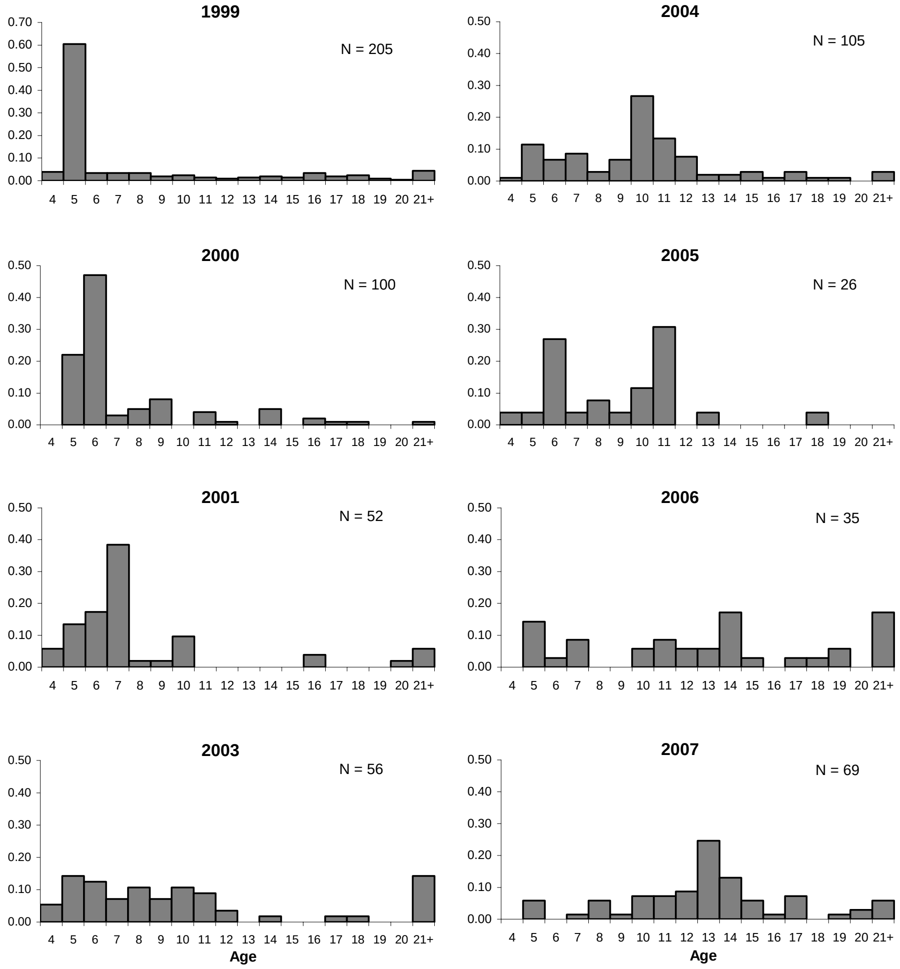


Fig. 5.5. Age composition of striped trumpeter samples by year. N is sample size.

5.7.3 Reference points

Existing reference points	Exceeded?	Alternative RP	Exceeded?
State-wide or regional catches outside the 1990/91 to 1997/98 range (52t- 81t)	Yes: Statewide ↓ (22t)	Commercial catch is > 50t	No
Catch increase or decline by over 30% from previous year	No	-	
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	Yes: Droplines (days fished)	-	
		Catch curve estimated every 3 years as an index of fishing mortality from all sectors: Target range: Fishing mortality $F \leq$ Natural mortality M Limit RP: $F = 1.5*M$	
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Yes (lack of strong new recruitment)	Any indicator of stock stress	Yes (lack of strong new recruitment)

5.8 Implications for management

The sharp decline in catches since 2000/01 gives rise to concern about the current status of striped trumpeter stocks. As suggested in previous assessments, strong recruitment variability could result in marked variation in population size, especially if there is a prolonged period of poor recruitment, with the fishery becoming dependent upon relatively few year classes. Age composition data imply that this may in fact be the case for striped trumpeter, with no evidence of strong recruitment for over a decade and the prevalence of the strong 1993 cohort in the adult population. Based on this assessment, the average size of hook-caught fish will continue to increase as recruited cohorts grow but spawner biomass will decline as a consequence of natural and fishing mortality acting on the adult population. Furthermore, if catch declines do in fact reflect falling abundance, then it is likely that fishing mortality is too high and may lead to recruit overfishing, a situation exacerbated by the minimum size limit still being set smaller than the size at maturity.

However, as noted in previous assessments the impact of recent management changes cannot be discounted as a contributing factor to the downturn in catches. Reduced incentives for fishers to target striped trumpeter due to the 250 kg trip limit appear to have been reflected in reduced line fishing effort over the past three years.

Catches reported in Commonwealth returns in recent years have averaged about 3 tonnes per annum, though industry reports suggest that these figures may be significantly underestimated. There is an urgent need to ensure that catch and effort information are comprehensive and approaches have been made to the Commonwealth to this end.

Growing interest from the recreational sector coupled with declining commercial catches suggest that recreational catches has become an increasingly significant component of the total mortality and thus should be factored explicitly into the future assessment and management of this fishery.

The low graball catch observed for some years may be linked to a combination of low numbers of striped trumpeter in inshore waters and/or size structuring within the population (immature fish inshore/mature fish offshore) that means that few if any fish captured in the inshore gillnet catch will be of legal size. Spawner biomass-per-recruit analyses (Tracey et al. 2007a) imply that either fishing mortality needs to be reduced or that the minimum size limit should be increased further, noting that the current limit of 45 cm is still below the size at maturity at about 53-54 cm. Spawning season closures could also improve the spawning potential of the species.

Although a more rigorous assessment is required to assess the sustainability of the fishery, the apparent lack of recent recruitment means that the stock will continue to decline. Management action is required in all sectors to reduce fishing mortality, including review of catch limits for recreational fishers, recognising that this sector is likely to have expanded over the past five years.

5.9 Research needs

The Scalefish Fishery Research Advisory Group has identified the need for research into stock assessment, recruitment variability and gear interactions as areas of high research priority for striped trumpeter. In addition, there is a need to estimate the recreational catch and reduce uncertainty in the magnitude of the catch by Commonwealth operators.

There is an urgent need to characterize the commercial and recreational fisheries for this species in terms of size composition and age-structure. Quantification of the recreational harvest remains a major uncertainty and hence a priority for the fishery assessment. There is a need to further examine the impacts of present and alternative harvest strategies.

6 Bastard trumpeter (*Latridopsis forsteri*)

6.1 Catch, effort and catch rates

Bastard trumpeter catches declined steadily from the mid 1990s. They have remained stable at around 20 tonnes for the past five years with a catch of 20 tonnes in 2006/07 (Fig. 6.1A). Bastard trumpeter are taken almost exclusively by graball from inshore waters off the east, south and west coasts (Fig. 6.2). The species has also significance to recreational fishers. The estimated 43 tonnes taken in 2000/01 was almost double the size of the commercial catch for the corresponding period.

Graball effort for bastard trumpeter has followed a similar downward trend to catches since the mid-1990s (Figs. 6.1B and 6.2).

Catch rates have remained relatively stable over time (Fig. 6.1C). This lack of an obvious trend, despite the sharp decrease in catches, presumably reflects the fact that bastard trumpeter are taken primarily as by-product, rather than as a target species.

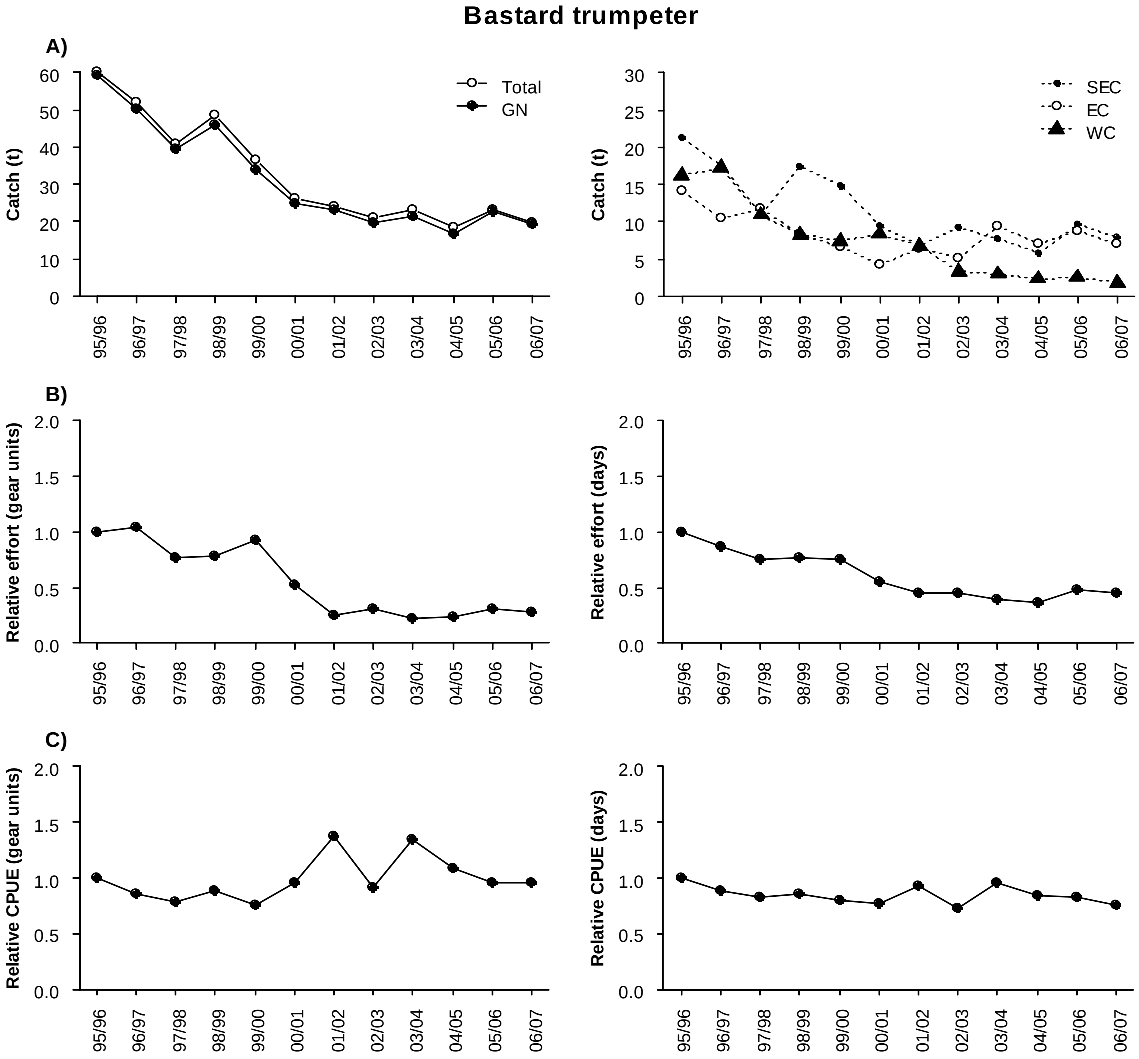


Fig. 6.1. A) Annual catch (tonnes) of bastard trumpeter by method (left) and region (right) since 1995/96; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished (right) relative to 1995/96. GN is graball; SEC is south-east coast, EC is east coast and WC is west coast.

6.2 Reference points

Existing reference points	Exceeded?	Alternative RP	Exceeded?
State-wide or regional catches outside the 1990/91 to 1997/98 range (34t-63t)	Yes: Statewide ↓ (20t)	Pending	
Catch increase or decline by over 30% from previous year	No		
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No		
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	No		
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Not assessed		

6.3 Implications for management

Total catch rather than catch rates may be a better indicator of abundance/availability for bastard trumpeter and as such, the trend in commercial production suggests that current inshore populations are at historically low levels. In accordance with this observation, industry and recreational representatives have expressed concerns about the scarcity of the species in recent years.

Two aspects of bastard trumpeter life history have direct relevance when assessing the status of the fishery. Firstly, the fishery is based almost entirely on juveniles. As the fish grow they appear to move offshore and are rarely caught. Secondly, the species exhibits strong recruitment variability that can result in short-term variability in catches and such variability has been a feature of the fishery over the past century (Harries and Croome 1989). Anecdotal reports and low inshore catches suggest that recruitment levels have been low in recent years, although higher numbers have been reported from the Tasman Peninsula in 2007.

Whilst juvenile biomass may vary widely due to recruitment variability and fishing pressure, no information regarding the adult segment of the population is available. However, it is clear that low levels of fishing pressure are exerted on those adults that evade the inshore fishery. Since commercial and recreational fisheries are based on juveniles, recruitment as well as growth overfishing are possibilities. Increasing the minimum size limit to above the size at maturity, which appears to be greater than 50 cm FL, would be beneficial to the stock but would also effectively close down the current commercial and recreational fisheries for the species. Reducing the recreational possession limits and discouraging targeting by the commercial fishery through the introduction of trip limits may be possible management measures to reduce mortality, although commercial beach prices for bastard trumpeter have been low for some time.

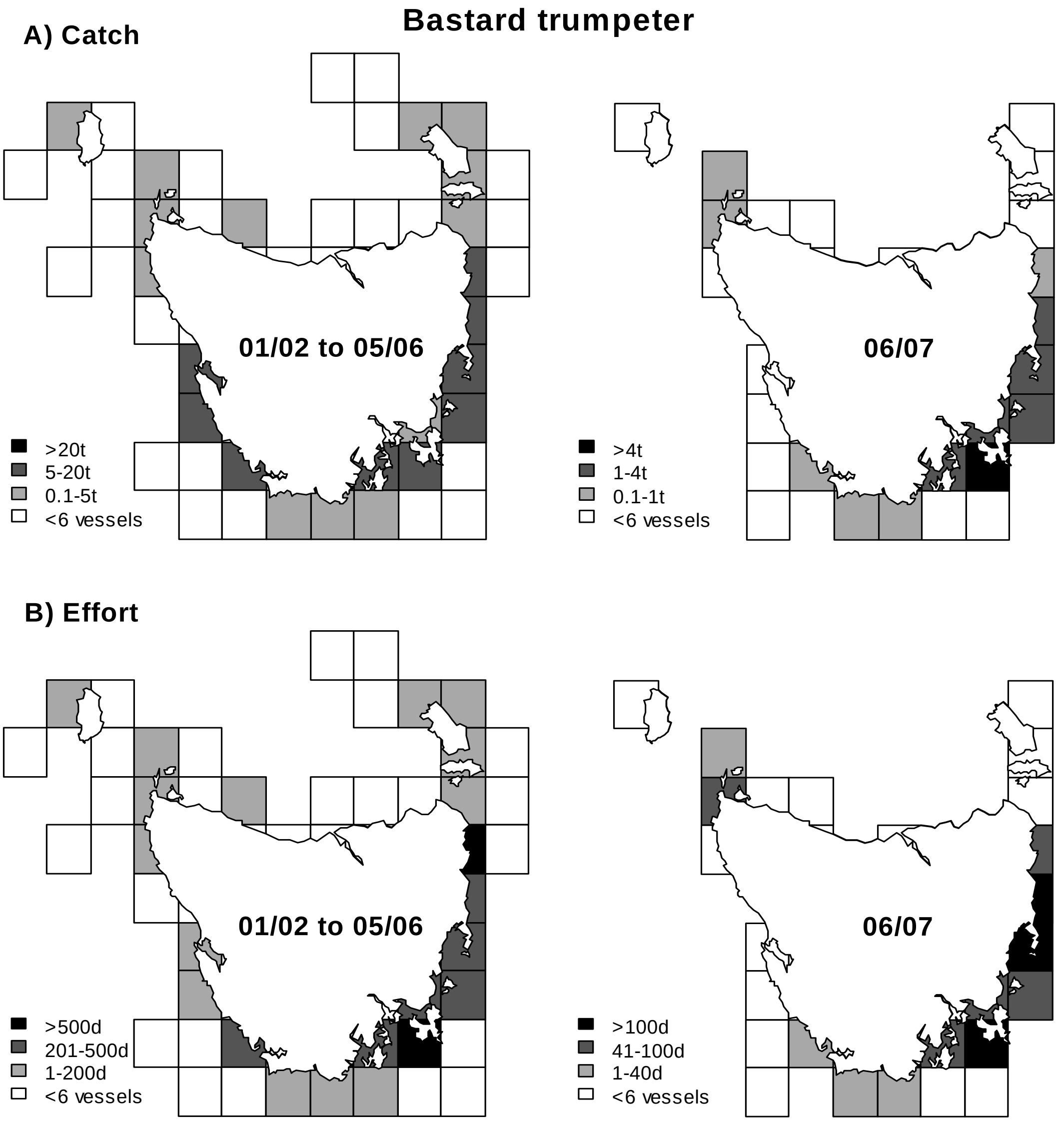


Fig. 6.2. (A) Bastard trumpeter catches (tonnes) and (B) effort (days) by fishing block pooled from 2001/02 to 2005/06 (left) and during 2006/07 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

7 Sea garfish (*Hyporhamphus melanochir*)

7.1 Catch, effort and catch rates

The southern sea garfish (*Hyporhamphus melanochir*) is caught in Tasmania almost exclusively taken by beach seine on the north-east coast, but mainly by dipnets off the south-east and east coasts. In these regions, dipnetting accounts for around 85% and 70%, respectively to the total catches.

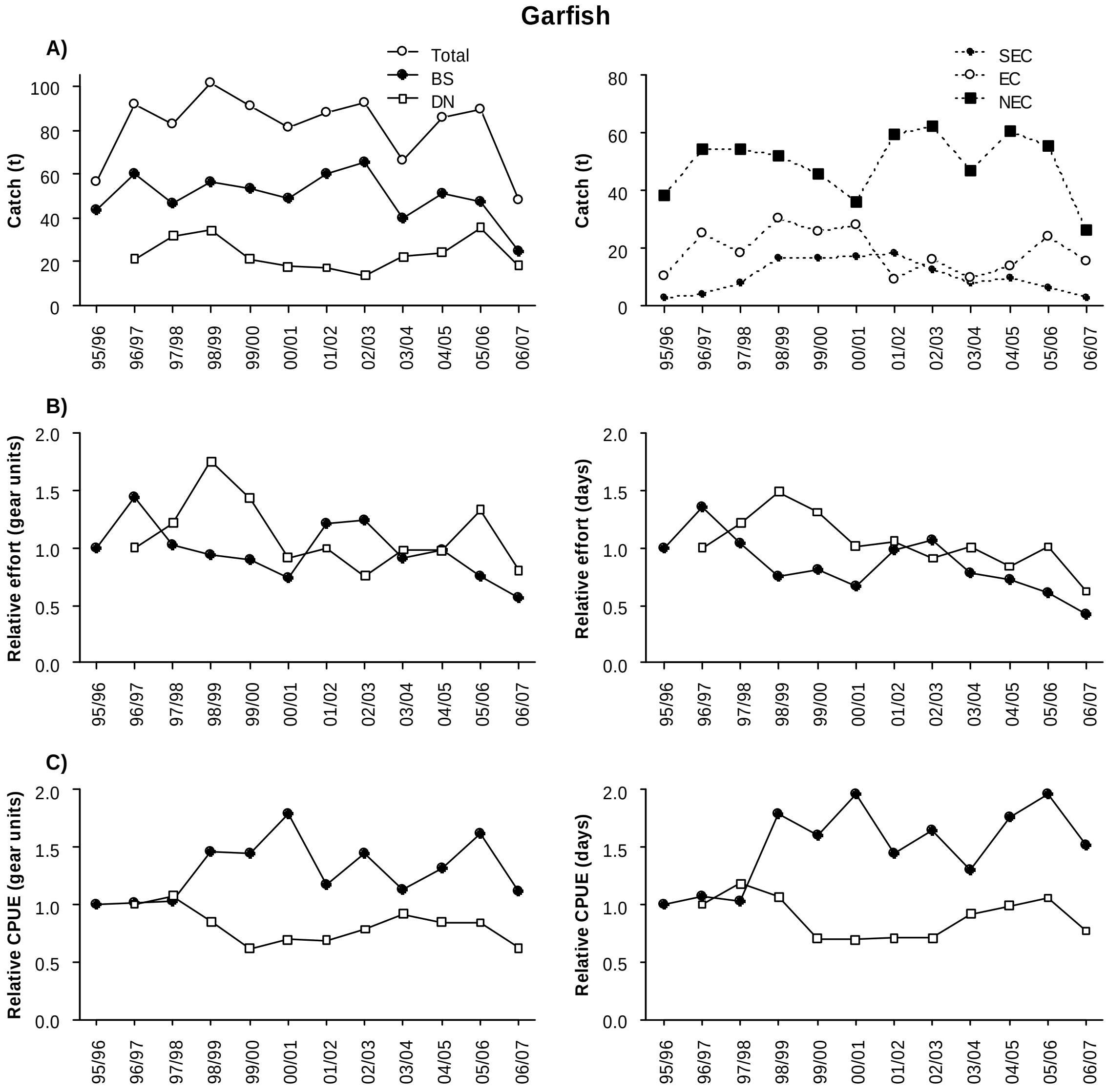


Fig. 7.1. A) Annual catch (tonnes) of garfish by method (left) and region (right) since 1995/96; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished (right) relative to 1995/96 (BS) and 1996/97 (DN). BS is beach seine and DN is dip net; SEC is south-east coast, EC is east coast, and NEC is north-east coast.

Effort has fallen markedly compared to 2005/06 and five or fewer fishers now operate in most fishing blocks (Fig. 7.2). Dipnet effort increased initially to a peak during 1998/99 but has subsequently decreased to a lower level (Fig. 7.1B, days fished). Beach seine effort experienced a more recent decline, and is now at the lowest levels since 1995/96.

Catch rates for beach seine have experienced much stronger fluctuations over time than those for dipnet, with both falling markedly in 2006/07. Beach seine catch rates generally rose during the late 1990s and early 2000s and have fluctuated at a high level since that time (Fig. 7.1C). By contrast, dipnet catch rates underwent an initial decline but had since recovered. However, in the context of schooling species such as garfish, catch rates may be relatively insensitive to changes in abundance.

7.2 Reference points

Existing reference points	Exceeded?	Alternative RP	Exceeded?
State-wide or regional catches outside the 1990/91 to 1997/98 range (56t-92t)	Yes: Statewide ↓ (49t)	Catch outside reference range from 1998/99 to 2005/06 (66-102t)	Yes: ↓ (49t)
Catch increase or decline by over 30% from previous year	Yes: Statewide ↓ (46%)	-	
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	No	-	
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Not assessed	Any indicator of stock stress	Not assessed

7.3 Implications for management

Industry members indicated that the catch declines in all major fishing regions and experienced by both major fishing methods during the 2006/07 fishing year were caused by a lack of resource. The reason for this, after a long period of apparent stability in the fishery and underlying fish stocks, remains unclear. Since it is not known whether present catch levels are sustainable, close monitoring of the fishery and fish stock including collection of biological samples is recommended to increase the understanding about the fishery and stock dynamics. In addition, it would be prudent to consider management options that limit further expansion in this fishery until more is known about the stock dynamics.

Some industry members have expressed concern about the effects of dipnets on the schooling behaviour of garfish. Specifically, it has been suggested that intensive dipnet activity tends to cause schools to break up reducing opportunities to use beach seines to target the species and possibly affecting catch rates. Since such interactions tend to be localised, analyses at the spatial resolution of fishing blocks are unlikely to be sensitive enough to detect such impacts.

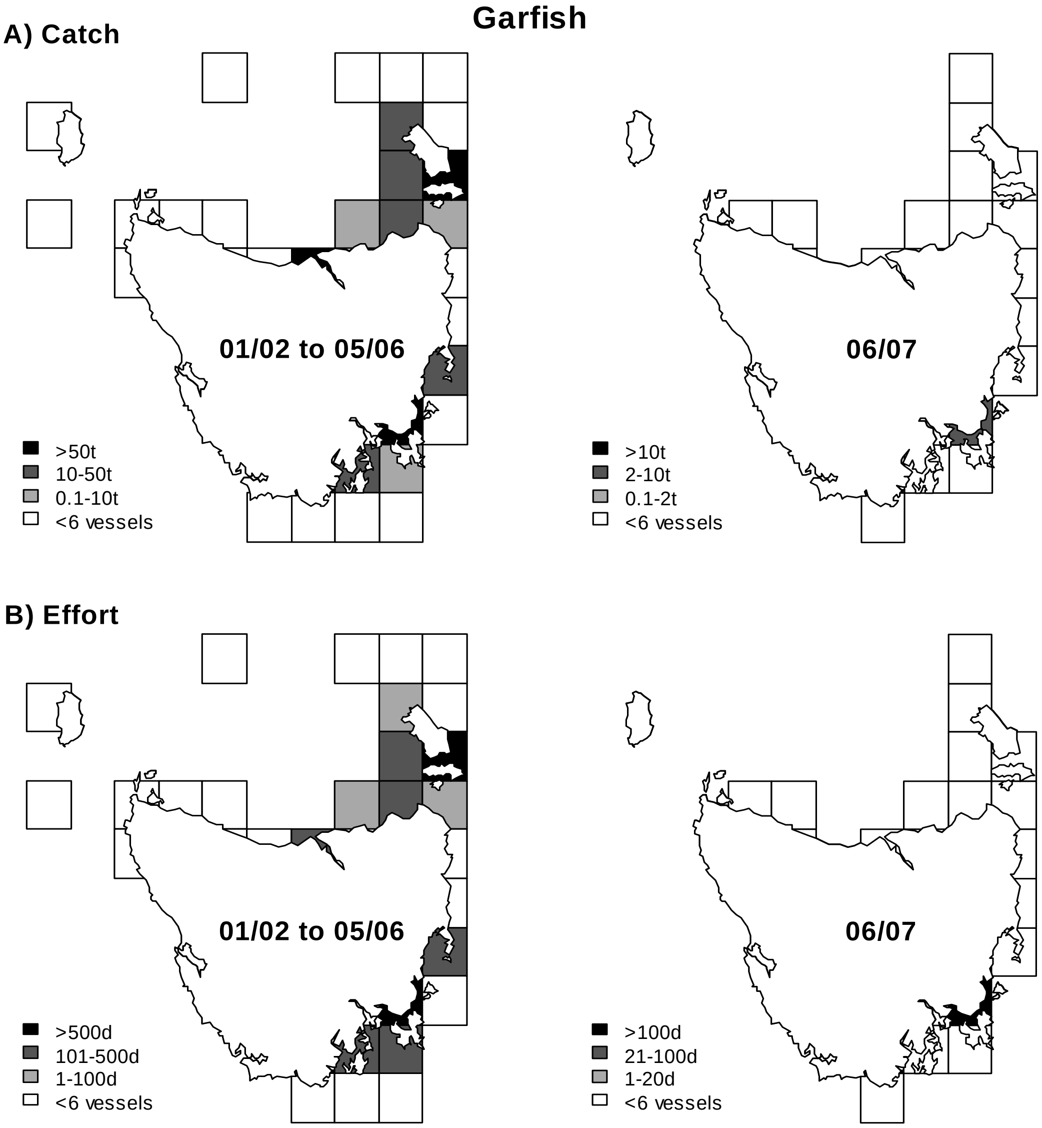


Fig 7.2. (A) Garfish catches (tonnes) and (B) effort (days) by fishing block pooled from 2001/02 to 2005/06 (left) and during 2006/07 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

8 Wrasse (Fam. Labridae)

8.1 Catch, effort and catch rates

Of the several species of wrasse occurring in Tasmanian waters, purple wrasse (*Notolabrus fucicola*) and blue-throat wrasse (*N. tetricus*) are the main species taken commercially. Wrasse are targeted for the live fish markets as well as being sold as dead product and utilised as bait for rock lobster (bait usage is possibly under-reported). Fish marketed live are distinguished in the logbooks, and live wrasse have accounted for over 90% of the total reported catch since 2001/02. Thus, trends in the live-fish fishery will ultimately be reflected in overall production levels. The two species of wrasse are not routinely distinguished in catch returns. While there is an apparent market preference for blue-throat wrasse, purple wrasse are more robust for live handling.

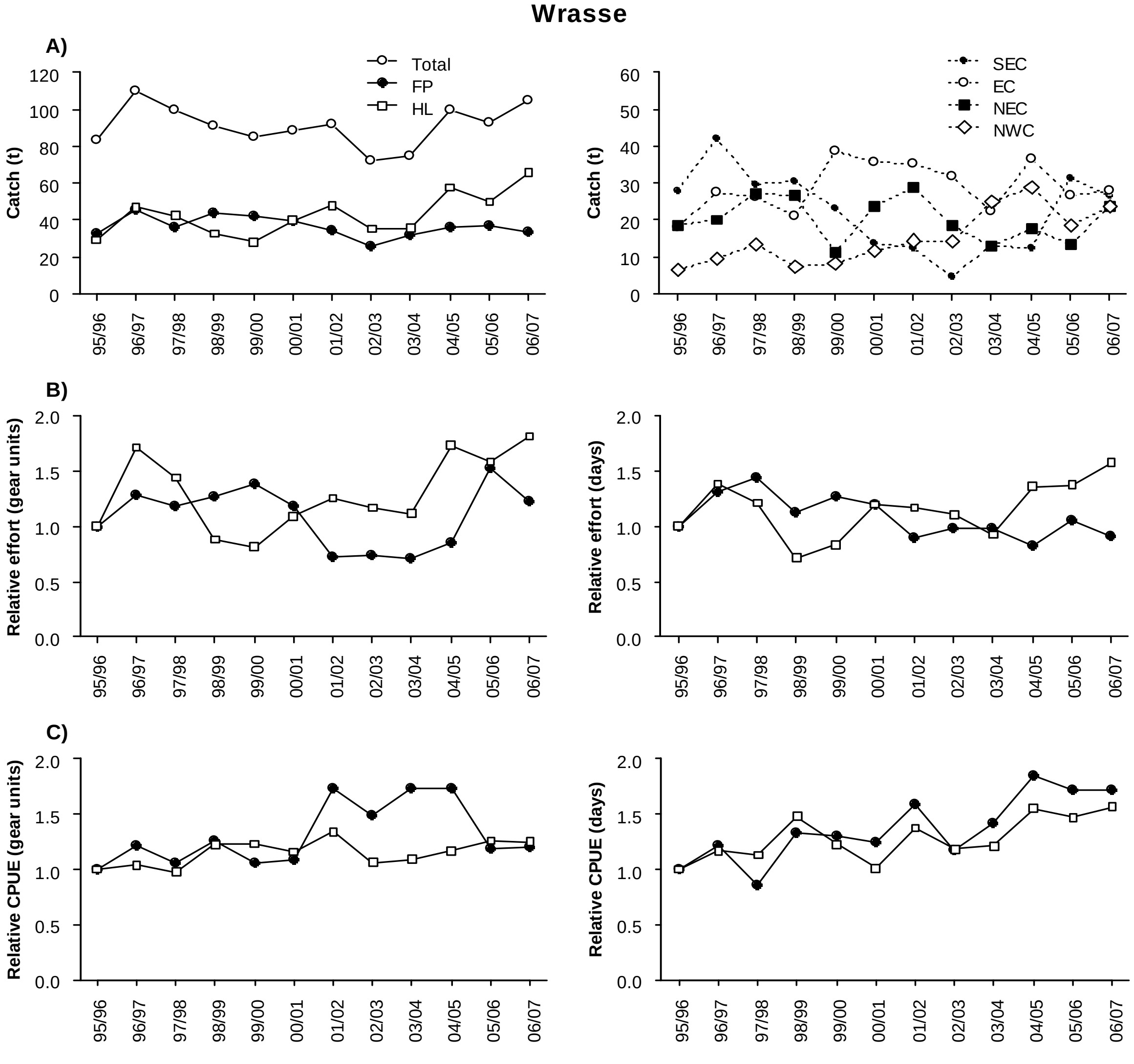


Fig. 8.1. A) Annual catch (tonnes) of wrasse by method (left) and region (right) since 1995/96; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished (right) relative to 1995/96. FP is fish trap and HL is hand line; SEC is south-east coast, EC is east coast, NEC is north-east coast, and NWC is north-west coast.

Since 1995/96, wrasse catches were relatively stable and consistently over 70 tonnes (Fig. 8.1A). Over the last five years, they have generally increased and reached 108 tonnes in 2006/07, largely due to higher handline catches. Fish trap catches decreased only marginally. Handline and fish trap represent the primary capture methods for wrasse, with blue-throat wrasse more susceptible to line methods and purple wrasse more vulnerable to trap capture. On this basis, blue-throat wrasse appear to be taken in larger quantities in the live fishery. Gillnets account for the bulk of the remaining catch (< 5 tonnes in 2006/07) but because survival in nets is poor, graball caught wrasse are rarely marketed live.

After the substantial increase in catches from the south-east in 2005/06, all areas contributed similar amounts to the total catch, with catches increasing mainly in the north-east and north-west (Fig. 8.1A and 8.2). The underlying drivers for the regional shifts in the fishery have not been investigated but may relate to fishers entering and exiting the fishery and/or species availability and market influence.

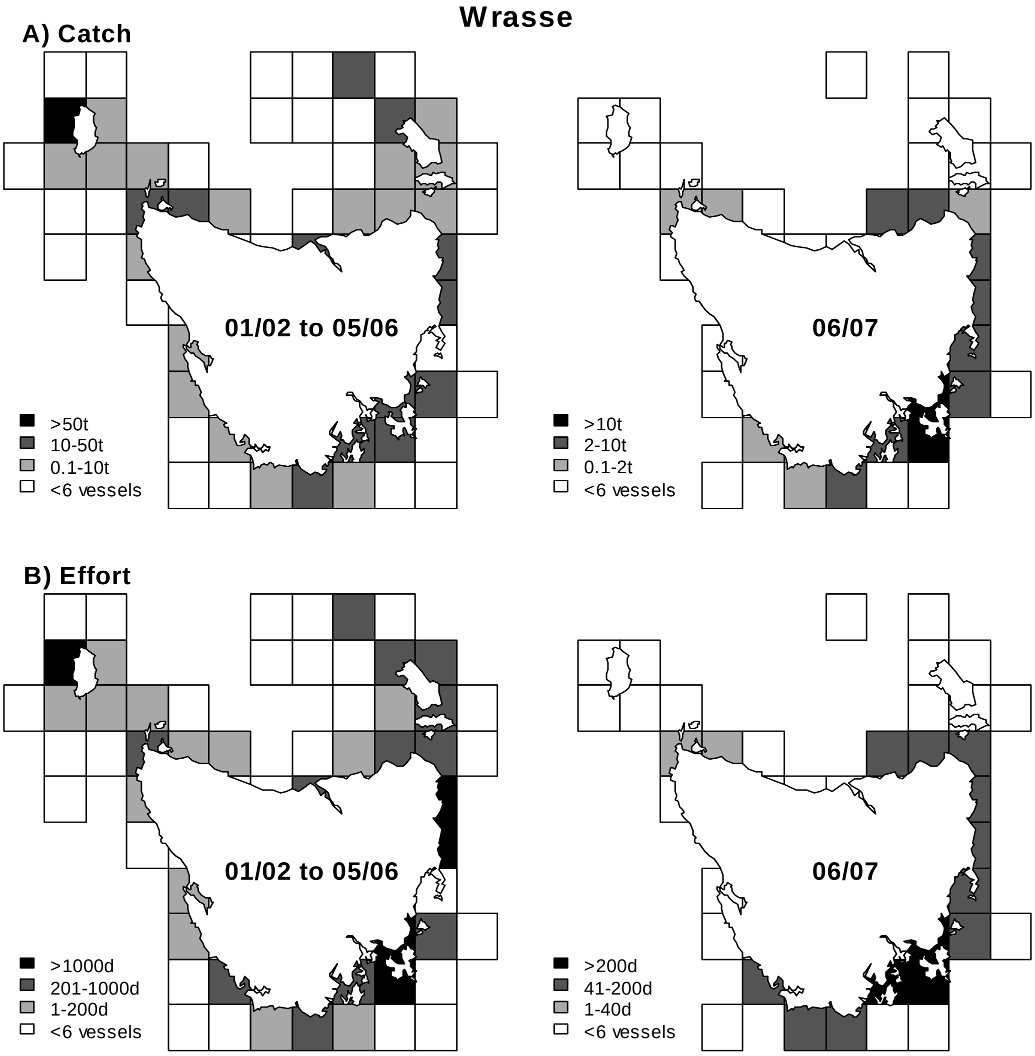


Fig. 8.2. (A) Wrasse catches (tonnes) and (B) effort (days) by fishing block pooled from 2001/02 to 2005/06 (left) and during 2006/07 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

Trends in handline effort generally reflected those of catches. Trap effort indicated a decrease in gear units (trap-lifts), but remained relatively stable in terms of days fished (Fig. 8.1B).

Since the mid 1990s, catch rates based on gear units for handline (kg per line hour) have remained stable, whereas trap catch rates (kg per trap lift) fell, after a 4-year period at high levels, to levels experienced during the 1990s (Fig. 8.1C). Daily catches for both handline and trap methods have increased gradually since the mid-1990s.

Catch rate trends imply that wrasse stocks have not been impacted significantly by the fishery. However, these broad-scale analyses are insensitive to changes in abundance at the level of individual reefs at which the fishery impacts the populations. In fact, there is evidence on some east-coast reefs that exploitation rates of legal-sized purple wrasse are extremely high (Ewing 2004). The marked regional shifts that have occurred in the fishery may also mask localised depletions, with fishers moving to new or lightly fished areas to maintain catches. As a consequence, caution needs to be exercised when making inferences about the status of the wrasse stocks though key fishery indicators do not suggest significant fishery impacts.

8.2 Reference points

Existing reference points	Exceeded?	Alternative RP	Exceeded?
State-wide or regional catches outside the 1995/96 to 1997/98 range (83t-110t)	No (108t)	Catch outside reference range from 1998/99 to 2005/06 (72-99t)	Yes: ↑ (108t)
Catch increase or decline by over 30% from previous year	No	-	
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	No	-	
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Not assessed	Any indicator of stock stress	Not assessed

8.3 Implications for management

While input controls (limited entry) have capped participation in the live wrasse fishery, there is a substantial level of latent effort. Increasing catches indicate continued strong interest in the species, and it is unknown whether current effort levels are sustainable. Under present arrangements, there is potential for localised depletions of legal-sized wrasse, especially if effort becomes concentrated in particular regions. There is already evidence for a concentration of effort off the east coast.

The minimum size limit provides good protection (several years post size at maturity) for the spawning stock of purple wrasse and for populations of female blue-throat wrasse. The limit does not, however, provide the same level of protection for male blue-throat wrasse because males are derived through sex change from mature females, typically at sizes after they have entered the fishery. This coupled with the fact that males are strongly site attached and have higher catchability (being more aggressive than females) suggests that they are vulnerable to over-fishing. In extreme situations it is possible that localised heavy fishing pressure could result in ‘sperm shortage’ that would affect spawning success even though there may be a robust population of mature (sub-legal size) females present. The removal of the maximum size limit may have exacerbated this potential problem. However, neither in Tasmania nor in Victoria, where the blue-throat wrasse fishery has been larger, are there any clear indications of spawning stock shortages.

9 Key scalefish fisheries shared with Commonwealth / other States

9.1 Blue warehou (*Seriolella brama*)

9.1.1 Catch, effort and catch rates

Two stocks of blue warehou occur in southern Australian waters, east and west of Bass Strait (Bruce *et al.* 2001). The fishery for blue warehou in Tasmanian waters is mainly centred off the south-east and east coast and thus probably targets the eastern stock (Figs. 9.1A and 9.2). Catches are also taken off the north-east and north-west coasts, the latter potentially involving the western stock.

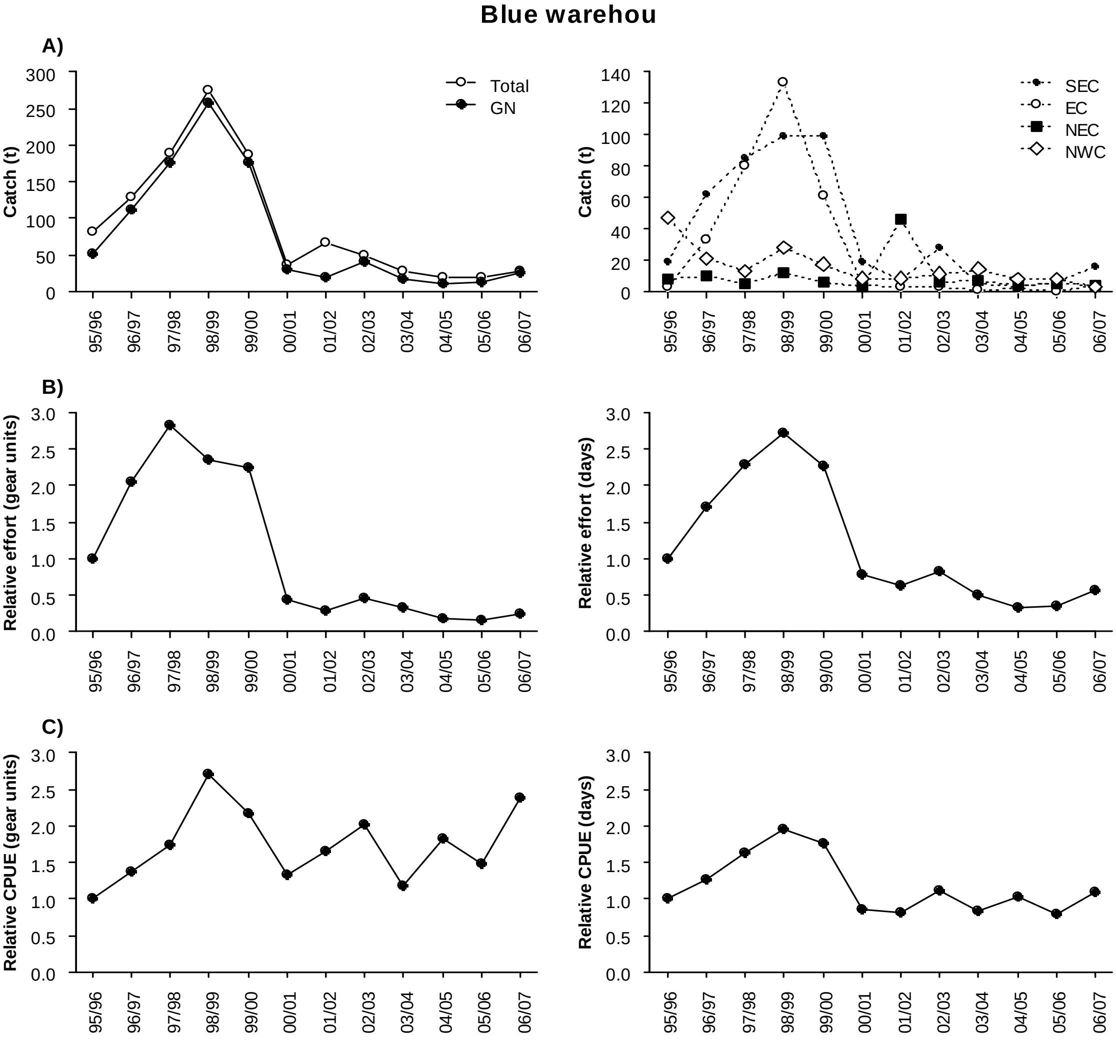


Fig. 9.1. A) Annual catch (tonnes) of blue warehou by method (left) and region (right) since 1995/96; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished (right) relative to 1995/96. GN is graball; SEC is south-east coast, EC is east coast, NEC is north-east coast, and NWC is north-west coast.

Blue warehou occur seasonally in Tasmanian inshore waters, the region representing the southern-most extent of the species' distribution. Traditionally, the availability of blue warehou in coastal waters has been assumed to be influenced by prevailing oceanographic conditions and availability of prey species. These factors produce marked inter-annual variability in abundance and hence catches taken from State waters as demonstrated in Fig. 9.1A. Due to low availability since the early 2000s, the species has been rarely targeted. The current catch of 29 tonnes is 43% higher than that for the previous year, but still low compared to the catches reported during the 1990s.

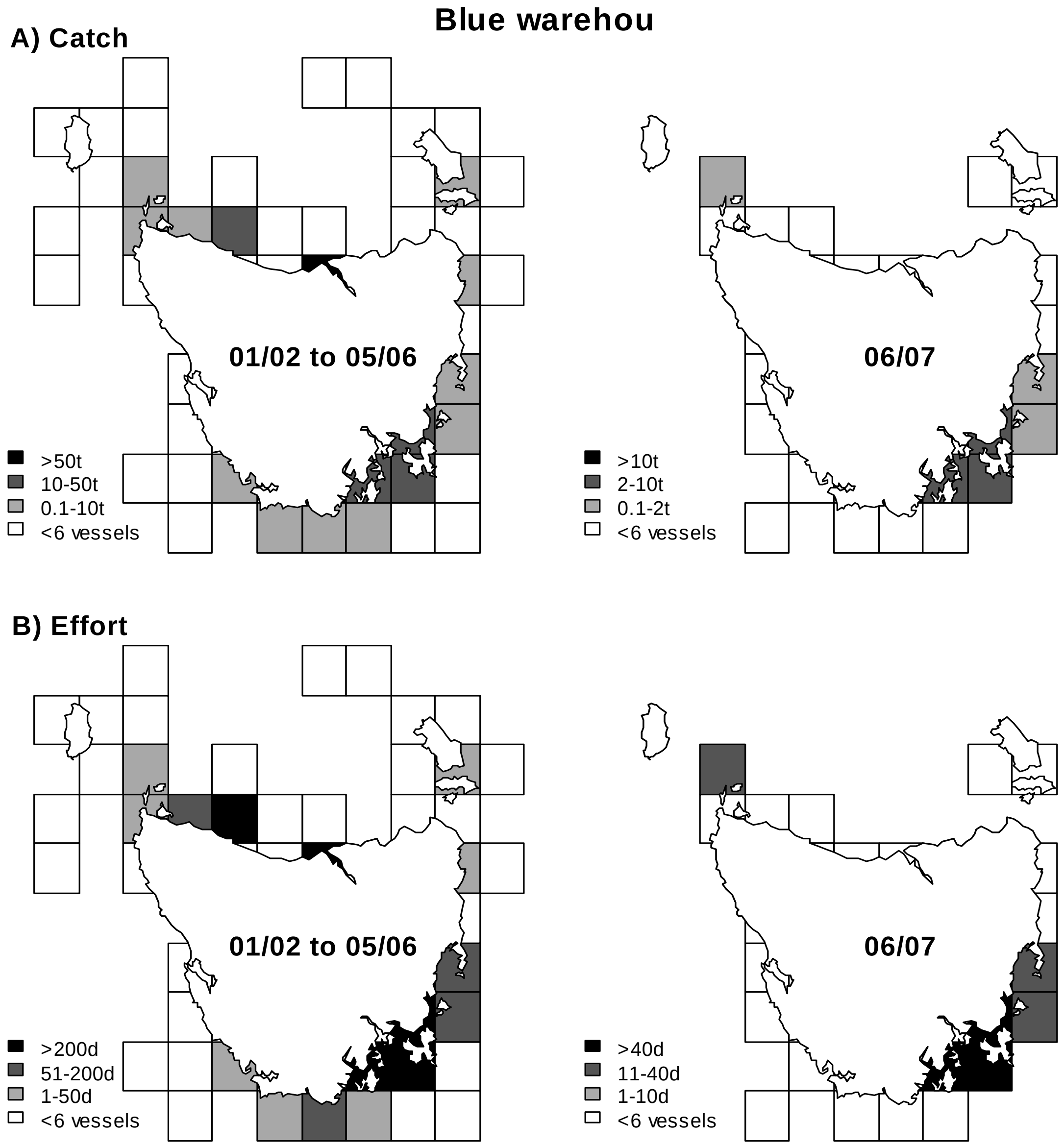


Fig. 9.2. (A) Blue warehou catches (tonnes) and (B) effort (days) by fishing block pooled from 2001/02 to 2005/06 (left) and during 2006/07 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

The species is taken primarily in graball nets (Fig. 9.1A), with a range of other capture methods used including other gillnet categories (small mesh and shark net) and seine nets. In 2001/02 about half the catch was taken by beach seine off the north-east coast and in many respects this was unusual, with fishers reporting the presence of large schools of fish off some beaches at that time.

Recreational fishers also target the species using gillnets and to a lesser extent line fishing. The estimated recreational harvest in 2000/01 was just 16 tonnes (Lyle 2005), substantially lower than recreational catches taken in 1997 and 1998 (Lyle 2000) but consistent with the depressed state of the commercial catches.

Following an increase in graball effort between 1995/96 and 1998/99 that resulted in increased catches, effort has since fallen to a substantially lower level and was only slightly elevated in the present year (Fig. 9.1B). Low effort is largely in response to the reduced availability of the target species.

Graball catch rates increased markedly between 1995/96 and 1998/99 reflecting increased availability and targeting of warehou around Tasmania at the time (Fig. 9.1C). Since then catch rates have declined fluctuated around levels similar to the mid-1990s.

9.1.2 Reference points

Existing reference points	**Exceeded?**	**Alternative RP**	**Exceeded?**
State-wide or regional catches outside the 1990/91 to 1997/98 range (82t-318t)	Yes: ↓ (29t)	Commercial catch limit of 318 tonnes as per Memorandum Of Understanding (MOU)	No
Catch increase or decline by over 30% from previous year	Yes: ↑ (43%)	-	
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	No	-	
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Not assessed	Any indicator of stock stress	Not assessed

9.1.3 Implications for management

Blue warehou is a Commonwealth managed species and a Memorandum Of Understanding (MOU) exists to cover catches from Tasmanian State Fishing Waters. Within the context of this MOU, State catches of blue warehou are to be managed within historic levels.

The availability of blue warehou in Tasmanian inshore waters is influenced by a range of environmental factors as well as stock size. Recent depressed catches are almost certainly linked to reduced biomass, the result of overfishing by Commonwealth and State fisheries during the 1990s. In 2003, the total allowable catch (TAC) for the Commonwealth fishery had been set at 300 tonnes per year, down from over 2,000 tonnes in late 1990s, because catches of blue warehou were expected to be poor for the foreseeable future due to overfishing in combination with a lack of good recruitment. The 2004/05 stock assessment of the Commonwealth fishery concluded that the blue warehou stocks required a stock rebuilding strategy (Tuck 2006), however the TAC has been increased again to 650 tonnes for 2006 (100 tonnes for eastern stock, 550 tonnes for western stock) due to some signs of stock recovery in the west.

9.2 Australian salmon (*Arripis trutta and A. truttaceus*)

9.2.1 Catch, effort and catch rates

The commercial catch of Australian salmon dropped by a further 55% from the catch in 2005/06 to 115 tonnes in 2006/07 and was the lowest on record (Fig. 9.3A). Beach seines account for the vast majority of the catch. While Australian salmon were caught predominantly in the north-east coast until 1998/99, more recent catches have been spread more evenly between the south-east, east, north-east and north-west coasts (Figs. 9.3A and 9.4).

Australian salmon also represent the second most commonly caught species in the recreational fishery, with an estimated harvest of 111 tonnes in 2000/01 (Lyle 2005).

Beach seine effort also decreased to a record low level since the late 1990s (Figs. 9.3B and 9.4).

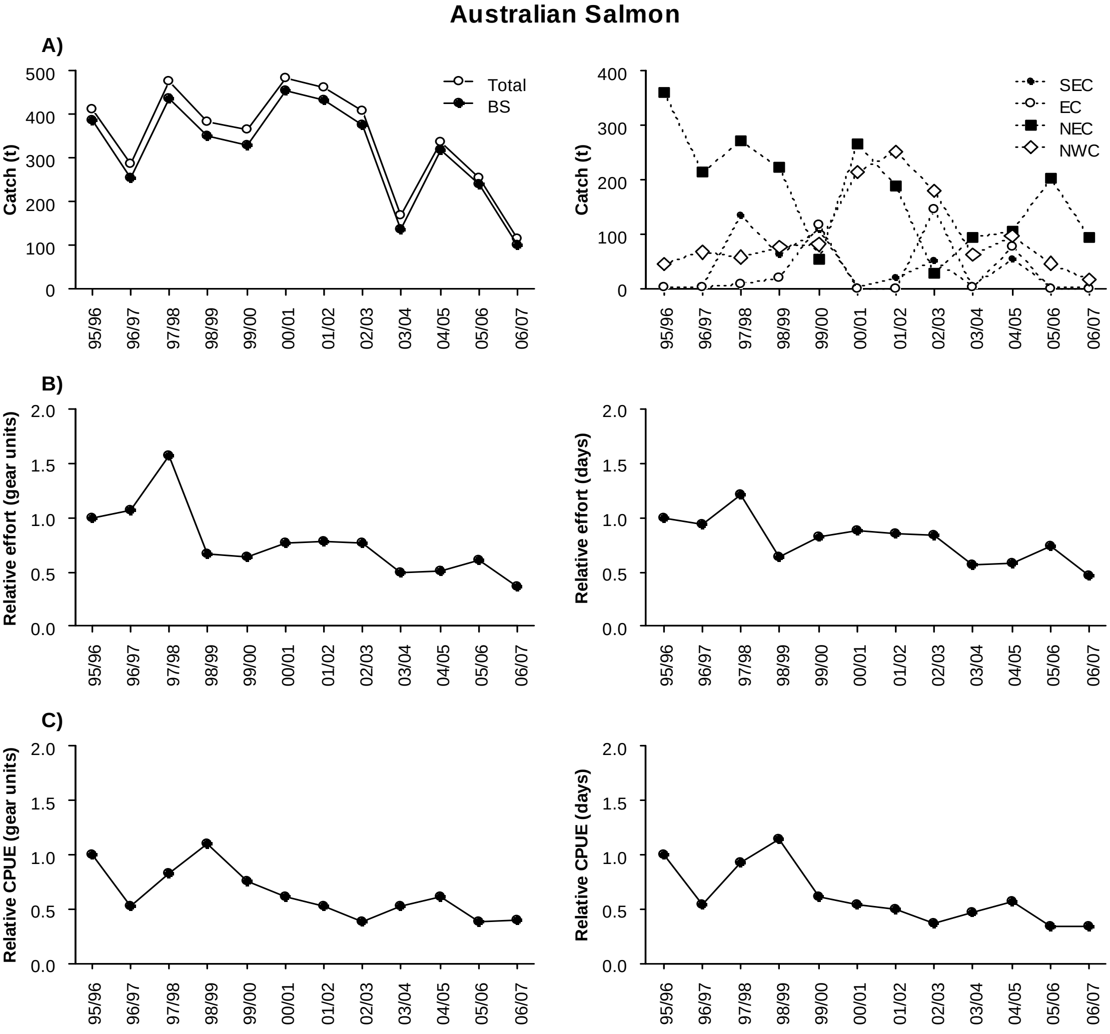


Fig. 9.3. A) Annual catch (tonnes) of Australian salmon by method (left) and region (right) since 1995/96; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished (right) relative to 1995/96. BS is beach seine; SEC is south-east coast, EC is east coast, NEC is north-east coast, and NWC is north-west coast.

Beach seine catch rates by gear units and days fished during 2005/06 remained at the lowest levels on record (Fig. 9.3C). It should be noted however, that catch rate estimation is influenced by the extremely skewed nature of the data, *i.e.* the majority of catches are small but the total catch is influenced by only a small number of extremely large catches. In this respect, even the geometric mean approach to calculating catch rates may provide biased estimates. Notwithstanding this, for schooling species such as Australian salmon catch rates will not be particularly sensitive indicator of stock condition especially if search time is not taken into account.

9.2.2 Reference points

Existing reference points	**Exceeded?**	**Alternative RP**	**Exceeded?**
State-wide or regional catches outside the 1990/91 to 1997/98 range (287t-879t)	Yes: ↓ (115t)	Commercial catch limit of 435 tonnes (120% of 10-year average for the period 1996/97 to 2005/06) as per Ministerial decision	No
Catch increase or decline by over 30% from previous year	Yes: ↓ (55%)	-	
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	Yes: Gear units and days fished	-	
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Not assessed	-	

9.2.3 Implications for management

Although Australian salmon stocks appear to fluctuate throughout the year in relation to environmental conditions, annual catches are to a large extent linked to market demand, specifically the bait market, and thus not a good indicator of stock status. There is capacity for industry to expand production to the commercial catch limit should new markets be found. While stock status is unknown, the species has sustained substantially higher catches in the past and current commercial and recreational catches would appear sustainable.

Australian salmon also have commercial and recreational significance across several other southern states and thus a coordinated approach to management of stocks across jurisdictions would have the advantage to minimising potential conflicts, especially if there is a change in the market situation.

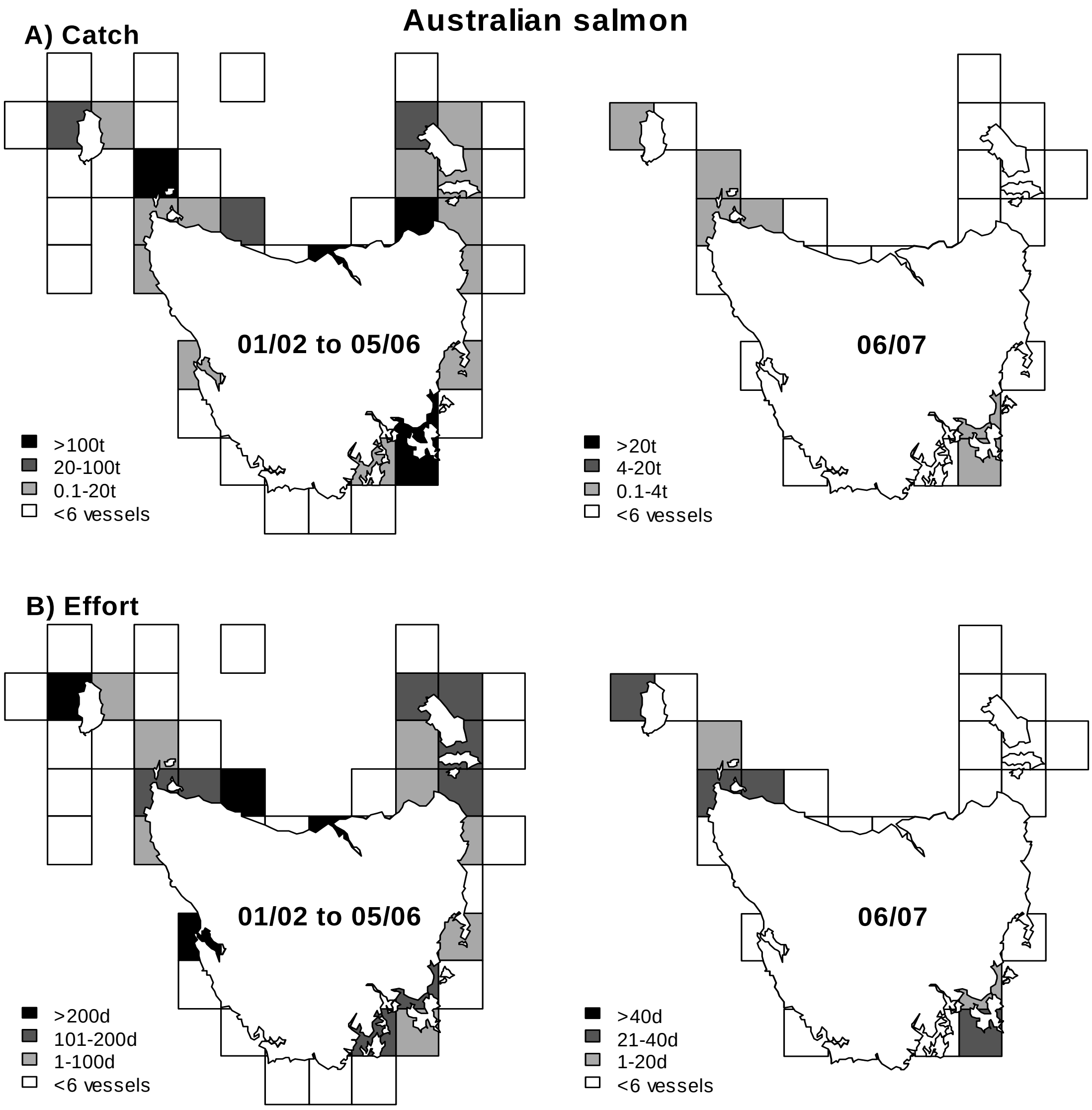


Fig. 9.4. (A) Australian salmon catches (tonnes) and (B) effort (days) by fishing block pooled from 2001/02 to 2005/06 (left) and during 2006/07 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

9.3 Flathead (Fam. Platycephalidae)

9.3.1 Catch, effort and catch rates

Several species of flathead occur in Tasmanian waters, but commercial catches are dominated by tiger flathead (*Neoplatycephalus richardsoni*) taken by Danish seine. Sand flathead (*Platycephalus bassensis*) are caught to a lesser extent by handline. However, the two species are not routinely distinguished in catch returns and catches by species are inferred by the gear taking the catch.

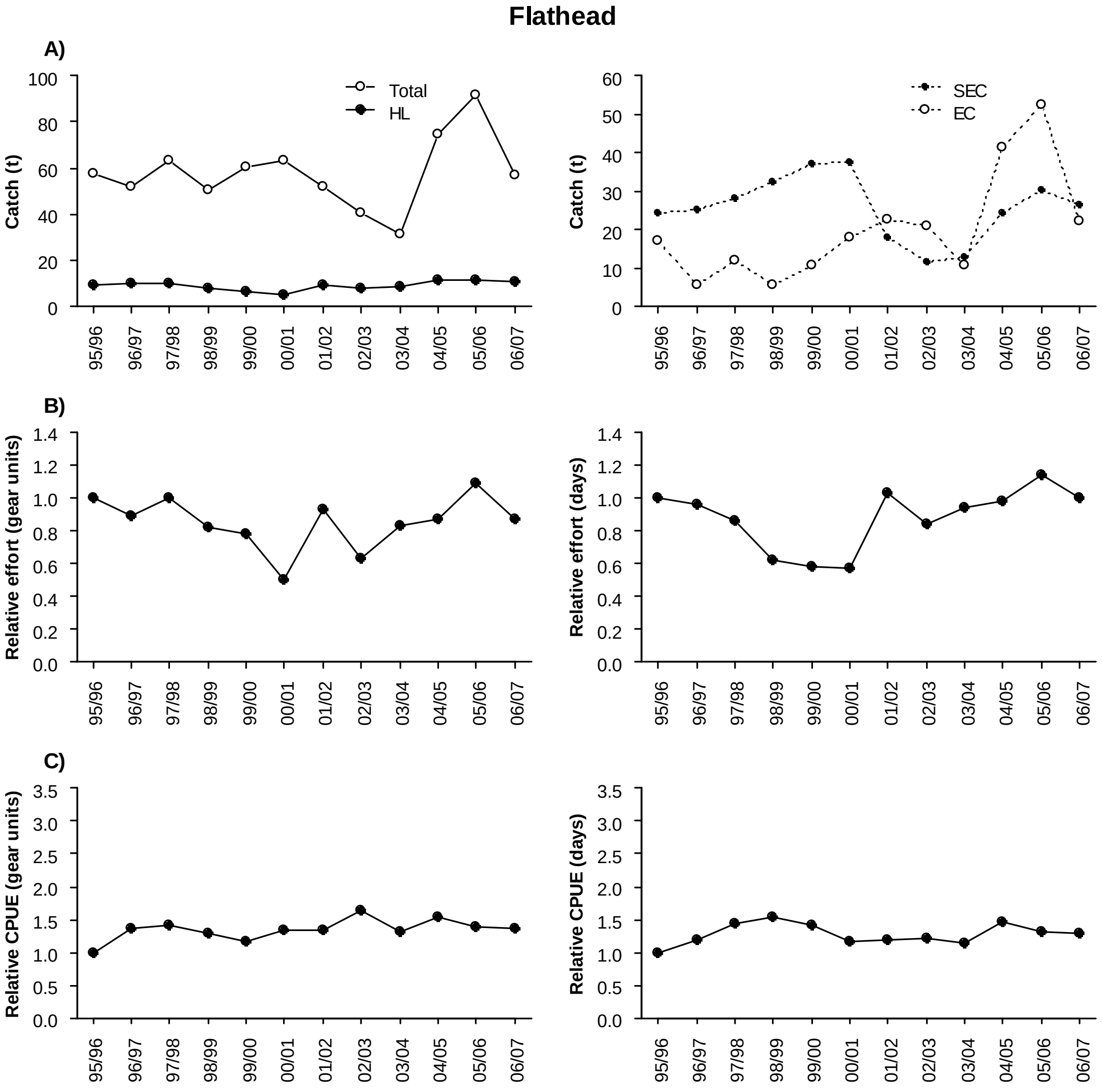


Fig. 9.5. A) Annual catch (tonnes) of flathead by method (left) and region (right) since 1995/96; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished (right) relative to 1995/96. HL is hand line; SEC is south-east coast and EC is east coast.

Flathead catches declined steadily between 2000/01 and 2003/04 but had more than doubled to 91 tonnes by 2005/06 (Fig. 9.5 and Fig. 9.6). In 2006/07, catches dropped again by 38% to 57 tonnes. These fluctuations were mainly caused by tiger flathead taken by Danish seine catches (not shown due to 5-vessel rule), while handline catches, mainly targeting sand flathead, have remained stable since the mid 1990s. Catches were derived mainly from the south-east and east coasts, with smaller quantities also taken from the north-east (including around Flinders Island) and north-west coasts (Figs. 9.5A and 9.6). The increased production of the past years has been mainly focussed in the east and south-east of the state.

Although the estimated recreational catch of flathead in 2000/01 was 361 tonnes, recreational catches are dominated by sand flathead, with tiger flathead only comprising a minor component of the harvest (Lyle 2005).

Effort for both gear types has fluctuated without obvious trend and, overall, has remained relatively stable since the mid 1990s (only handline shown, 9.5B). The regional distribution of effort has changed little from previous years, with commercial effort particularly concentrated off the south-east, east and north-east coasts (Fig. 9.6).

Hand line catch rates have remained stable over time (Fig. 9.5C). Danish seine catch rates dropped again after two years of elevated levels and presumably reflect the impact of initially increased and now decreased targeting for the species.

9.3.2 Reference points

Existing reference points	**Exceeded?**	**Alternative RP**	**Exceeded?**
State-wide or regional catches outside the 1990/91 to 1997/98 range (52t-165t)	No	Catch by Danish Seine above 1.3* the maximum catch from the reference period 1998/99 to 2005/06: South-east coast: 45t East coast: 63t	No
Catch increase or decline by over 30% from previous year	Yes: ↓ (38%)	-	
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	No	-	
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Not assessed	Any indicator of stock stress	Not assessed

9.3.3 Implications for management

Recent increases in Danish seine catches is mainly due to a switch in targeting from whiting to flathead (refer Table 2.2 and Fig. 2.2). While stock status of both key flathead species in state waters is unknown, commercial catches of tiger flathead have been maintained at higher levels in past. There are however, additional and significant trawl catches of flathead (almost exclusively tiger flathead) that are taken from Commonwealth waters as part of the South East Fishery, with the tiger flathead stock classified as not overfished (Tuck 2006). Sand flathead stock status is not known, though clearly the main impact on stocks is from the recreational sector.

Increased interest from commercial operators is likely, as evidenced in the recent Danish seine catches, with rising market prices and reduced access to and availability of other scalefish species. Future catch trends should be monitored closely along with those taken by recreational fishers. Given the possibility that Danish seine effort may increase it would be prudent to consider spatial management options that avoid the regional concentration of effort.

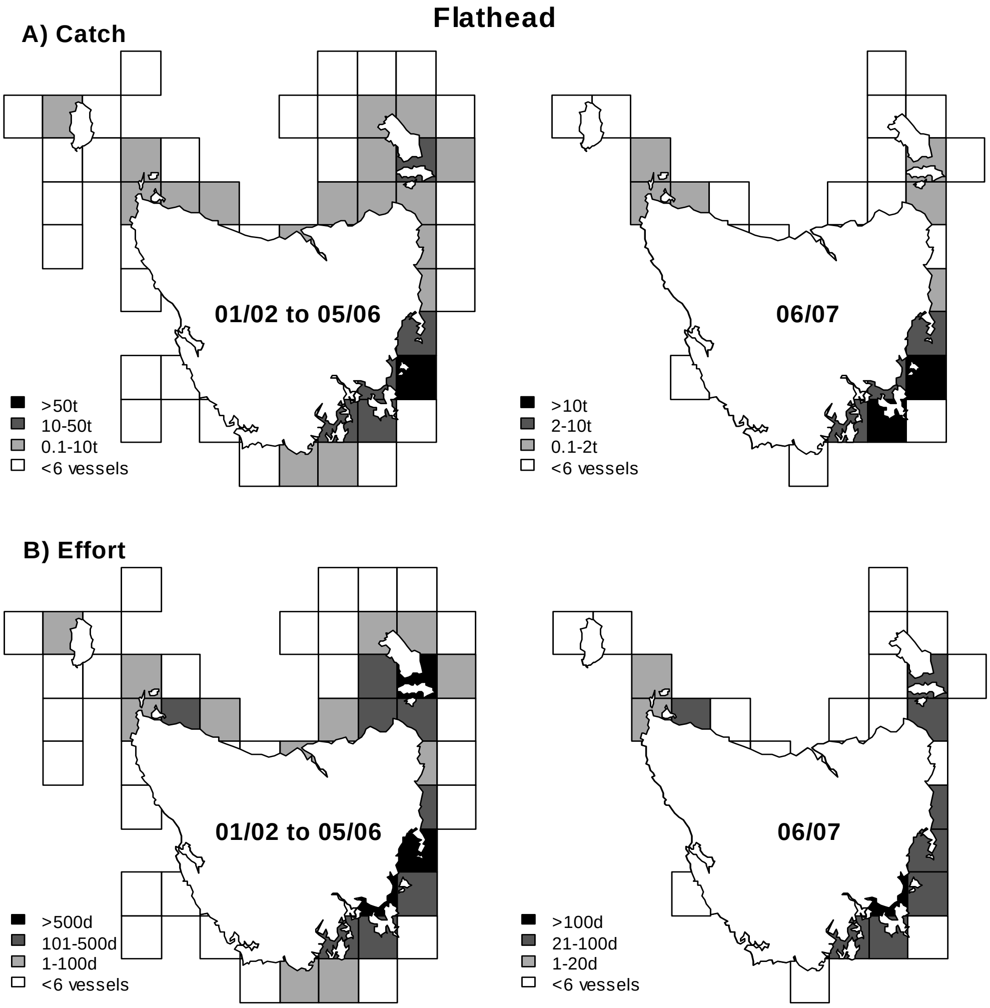


Fig. 9.6. (A) Flathead catches (tonnes) and (B) effort (days) by fishing block pooled from 2001/02 to 2005/06 (left) and during 2006/07 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

Acknowledgements

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Appendices

Appendix 1. Common and scientific names for species reported in catch returns.

Common name	Scientific name	Common name	Scientific name
Alfonsino	*Beryx* spp.	Pilchard	Fam. Clupeidae
Anchovy	Fam. Engraulidae	Rays bream	Fam. Bramidae
Atlantic salmon	*Salmo salar*	Redbait	*Emmelichthys nitidus*
Australian salmon	*Arripis* spp.	Red fish	Fam. Berycidae
Barracouta	*Thyrsites atun*	Red mullet	*Upeneichthys* spp.
Boarfish	Fam. Pentacerotidae	Silverfish	Fam. Atherinidae
Bream	*Acanthopagrus butcheri*	Snapper	*Pagrus auratus*
Butterfish	Spp unknown	Stargazer	Fam. Uranoscopidae
Cardinal fish	Fam Apogonidae	Sweep	*Scorpis* spp
Cod deep sea	*Mora moro*	Tailor	*Pomatomus saltatrix*
Cod, bearded rock	*Pseudophycis barbata*	Thetis fish	*Neosebastes thetidis*
Cod, red	*Pseudophycis bachus*	Trevalla, white	*Seriolella caerulea*
Cod, unspec.	Fam. Moridae	Trevally, silver	*Pseudocaranx dentax*
Dory, john	*Zeus faber*	Trout, rainbow	*Oncorhynchus mykiss*
Dory, king	*Cyttus traversi*	Trumpeter, bastard	*Latridopsis forsteri*
Dory, mirror	*Zenopsis nebulosus*	Trumpeter, striped	*Latris lineata*
Dory, silver	*Cyttus australis*	Trumpeter, unspec.	Fam. Latridae
Dory, unspec.	Fam. Zeidae	Warehou, blue	*Seriolella brama*
Eel	*Conger* spp.	Warehou, spotted	*Seriolella punctata*
Flathead	Fam Plactycephalidae	Whiptail	Fam. Macrouridae
Flounder	Fam. Pleuronectidae	Whiting	Fam. Sillaginidae
Garfish	*Hyporhamphus melanochir*	Whiting, King George	*Sillaginoides punctata*
Gurnard	Fam. Triglidae & Fam. Scorpaenidae	Wrasse	*Notolabrus* spp.
Gurnard perch	*Neosebastes scorpaenoides*	**'Commonwealth' spp**	
Gurnard, red	*Chelidonichthys kumu*	Blue grenadier	*Macruronus novaezelandiae*
Hardyheads	Fam. Atherinidae	Gemfish	*Rexea solandri*
Herring cale	*Odax cyanomelas*	Hapuka	*Polyprion oxygeneios*
Kingfish, yellowtail	*Seriola lalandi*	Oreo	Fam. Oreosomatidae
Knifejaw	*Oplegnathus woodwardi*	Trevalla, blue eye	*Hyperoglyphe antartica*
Latchet	*Pterygotrigla polyommata*	**Tunas**	
Leatherjacket	Fam. Monocanthidae	Albacore	*Thunnus alalunga*
Ling	*Genypterus* spp.	Skipjack	*Katsuwonus pelamis*
Luderick	*Girella tricuspidata*	Southern bluefin	*Thunnus maccoyii*
Mackerel, blue	*Scomber australasicus*	Tuna, unspec.	Fam. Scombridae
Mackerel, jack	*Trachurus declivis*	**Sharks**	
Marblefish	*Aplodactylus arctidens*	Shark, angel	*Squatina australis*
Morwong, banded	*Cheilodactylus spectabilis*	Shark, blue whaler	*Prionace glauca*
Morwong, blue	*Nemadactylus valenciennesi*	Shark, bronze whaler	*Carcharhinus brachyurus*
Morwong, dusky	Fam. Cheilodactylidae	Shark, elephant	*Callorhynchus milii*
Morwong, grey	*Nemadactylus douglasii*	Shark, gummy	*Mustelus antarcticus*
Morwong, jackass	*Nemadactylus macropterus*	Shark, saw	*Pristophorus spp.*
Morwong, red	Fam. Cheilodactylidae	Shark, school	*Galeorhinus galeus*
Morwong, unspec.	Fam. Cheilodactylidae	Shark, seven-gilled	*Notorynchus cepedianus*
Mullet	Fam. Mugilidae	Shark, spurdog	Fam. Squalidae
Nannygai	*Centroberyx affinis*	**Cephalopods**	
Perch, magpie	*Cheilodactylus nigripes*	Calamari	*Sepioteuthis australis*
Perch, ocean	*Helicolenus* spp.	Cuttlefish	*Sepia* spp.
Pike, long-finned	*Dinolestes lewini*	Octopus	*Octopus* spp.
Pike, short-finned	*Sphyraena novaehollandiae*	Squid, arrow	*Nototodarus gouldi*

Appendix 2. Data restrictions and adjustments

There have been a number of administrative changes that have affected the collection of catch and effort data from the fishery. The following restrictions and adjustments have been applied when analysing the data as an attempt to ensure comparability between years, especially when examining trends over time.

Tasmanian logbook data

i) Correction of old logbook landed catch weights

Prior to 1995, catch returns were reported as monthly summaries of landings. With the introduction of a revised logbook in 1995, catch and effort was recorded on a daily basis for each method used. Since catch data reported in the old general fishing return represent landed catch, it has been assumed to represent processed weights. For example, where a fish is gilled and gutted, the reported landed weight will be the gilled and gutted and not whole weight. By contrast, in the revised logbook all catches are reported in terms of weight and product form (whole, gilled and gutted, trunk, fillet, bait or live). If a catch of a species is reported as gilled and gutted then the equivalent whole weight can be estimated by applying a standard conversion factor[3].

Without correcting for product form, old logbook and revised logbook catch weights are not strictly compatible. In an attempt to correct for this and provide a ‘best estimate’, a correction factor was calculated using catch data from the revised logbook and applied to catches reported in the old logbook. A species based ratio of the sum of estimated whole weights (adjusted for product form) to the sum of reported catch weights was used as the correction factor (Lennon 1998).

ii) Effort Problems

Records where effort (based on gear units, Table 2.1) was zero or null, or appeared to be recorded incorrectly (implausible), were flagged. The catch was included in catch summaries but the records were not included in gear unit effort and catch rate calculations. These records were, however, used in calculating days fished and daily catches.

iii) Vessel restrictions

In all analyses of catch and effort, catches from six vessels (four Victorian based and two Tasmanian based) have been excluded. These vessels were known to have fished consistently in Commonwealth waters and their catches of species such as blue warehou and ling tended to significantly distort catch trends. In fact, all four Victorian vessels and one of the Tasmanian vessels ceased reporting on the General Fishing Returns in 1994. With the introduction of the South East Fishery Non-Trawl logbook (GN01) in 1997, the remaining Tasmanian vessel ceased reporting fishing activity in the Tasmanian logbook.

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[3] Conversion factors to whole weights are 1.00 for whole, live or bait; 2.50 for fillet; 1.50 for trunk; and 1.18 for gilled and gutted.

Commonwealth logbook data:

Commonwealth logbook data from Australian Fisheries Management Authority was included in the analyses so that the assessment reflected all catches from Tasmanian waters.

(i) Area restrictions

Commonwealth logbook records were only included if the catch was taken in fishing blocks adjacent to Tasmania and the maximum depth of the fishing operation was less than 200 m. These conditions were applied to all records except where striped or bastard trumpeter were caught. All records that included catches of these species were included for analysis, because these species are managed under Tasmanian jurisdiction in all waters adjacent to Tasmania.

Fishing blocks adjacent to land and used in the analyses (refer Fig. A1) include:

3C2, 3D1, 3F1, 3F2, 3G1, 3G2, 3C4, 3D3, 3F4, 3G3, 3G4, 3H3, 3H4, 4C2, 4D1, 4D2, 4E1, 4G2, 4H1, 4H2, 4D4, 4E3, 4E4, 4F4, 4G3, 4G4, 4H3, 4H4, 5D2, 5E2, 5F1, 5F2, 5H1, 5D4, 5E3, 5H3, 6E1, 6H1, 6E3, 6G4, 6H3, 7E1, 7E2, 7G1, 7G2, 7H1, 7E4, 7F3, 7F4, 7G3.

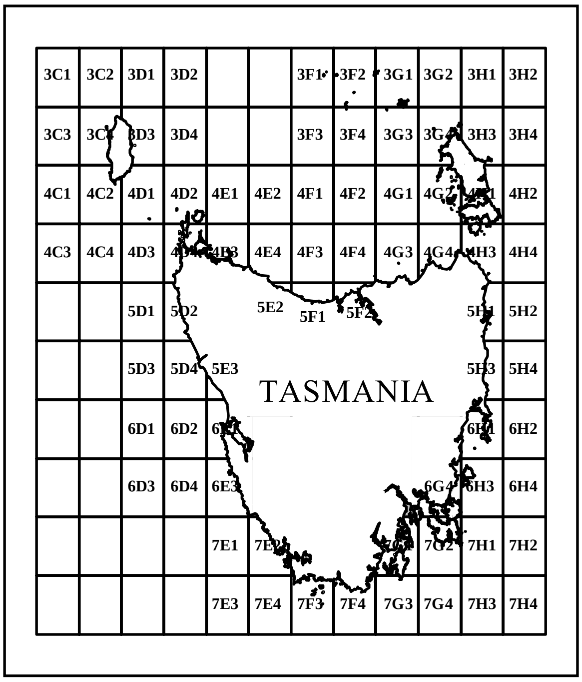

Fig. A1. Numbers for fishing blocks used in calculation of catch figures.

(ii) Duplicate records

A number of records in Commonwealth logbooks had matching records (fisher, date, gear type) in the Tasmanian database. Such records were examined individually and decisions made as to whether it was more appropriate to keep the Tasmanian record, the Commonwealth record or both. In most situations the Tasmanian logbook entry was kept and the Commonwealth record excluded. The only exceptions were records with extra information in the Commonwealth record, e.g. catch of a Commonwealth species that was not recorded in the Tasmanian logbook.

Appendix 3: Description of banded morwong stock assessment model

The population dynamic in the operating model is represented by an age-structured model, described in the following.

Basic population dynamics

Numbers at age were described by the standard age-structured model equations modified to account for multiple populations and by an expression summarizing movement between those populations:

$$\hat{N}^{p,s}_{t,y+1} = \begin{cases} \pi_p R^s_{t_{\min},y+1} & t = t_{\min} \\ N^{p,s}_{t-1,y} e^{-\left(Z^{p,s}_{y,t}\right)} & t_{\min}+1 \le t \le t_{\max-1} \\ N^{p,s}_{t_{\max}-1,y} e^{-\left(Z^{p,s}_{y,t}\right)} + N^{p,s}_{t_{\max},y} e^{-\left(Z^{p,s}_{y,t}\right)} & t = t_{\max} \end{cases} \qquad \text{(A3.1)}$$

where:

$\hat{N}^{p,s}_{t,y+1}$	is the predicted numbers of fish in population p of sex s and age t, in year y+1,
π_p	is the proportion of available recruits to be found in population p,
$R^s_{t_{\min},y+1}$	is the fitted recruitment of sex s of age t_{min},
t_{min}, t_{max}	are the minimum and maximum age group, with the latter referred to as the plus age-group because it combines ages $t_{\max}$ and all older ages that are not modelled explicitly,
$Z^{p,s}_{y,t}$	is the total mortality of fish in population p of sex s at age t in year y, with fishing mortality occurring only in inshore populations : $$Z^{p,s}_{t,y} = \begin{cases} M + s^s_t \hat{F}^p_y & \text{if } p = \text{ onshore population} \\ M & \text{if } p = \text{ offshore population} \end{cases} \qquad \text{(A3.2)}$$
s^s_t	is the sex, s, and age, t, specific selectivity,
M	is the instantaneous rate of natural mortality assumed constant through all ages,
$\hat{F}^p_y$	is the estimated fully selected instantaneous rate of fishing mortality in population p in year y.

Equation (A3.1) was combined with the equation for movement. Movement was assumed to occur separately between onshore and offshore populations and between populations adjacent to each other alongshore. Movement was generally restricted to mature fish and acted at the end of each year to generate the final numbers at age in each population.

Between onshore and offshore populations, movement was assumed to be a combination of mobility rate and the relative proportion of suitable habitat into which the animals can move:

$$\hat{N}_{t,y+1}^{s,p} = \left(1 - m\pi_{p+1}\right)\mu_{t,y}N_{t,y+1}^{s,p} + m\pi_p\mu_{t,y}N_{t,y+1}^{s,p+1} \qquad \text{(A3.3)}$$

where:

m	is the proportion of the mature population that becomes vagrant or mobile and becomes capable of shifting from each population to adjoining populations,
π_p	is the proportion of habitat/biomass in each population *p,*
$\mu_{t,y}$	is the proportion of age class *t* in year *y* that is sexually mature. The potential for variation among years was included because this was observed in Tasmanian populations of banded morwong.

Thus, the movement rate from population p into the neighbouring population p+1 can be represented as $m\pi_p$. Population p retains $1\text{-}m\pi_{p+1}$ of its total and gains $m\pi_p$ of population p+1. If the proportion of habitat is equal (i.e. $\pi_p = 0.5$) then the movement rate equals the mobility, however, if the proportional distribution of the population deviates from 50:50 then the movement rates will become asymmetric. Thus, this approach to describing movement includes both the propensity to move within a population and the area over which it can spread. A fish may begin to move and its probability of settling in one of the available areas is related to the relative area inhabited by the two populations.

In models with more than one region, consisting of a set of onshore and offshore populations, movement occurred alongshore between all neighbouring populations onshore and all neighbouring populations offshore. Outer regions were assumed to be in equilibrium with adjacent areas not represented in the model and thus, no net movement occurred along the outer borders. Movement was assumed to be a combination of mobility rate and a constant movement rate alongshore:

$$\hat{N}_{t,y+1}^{s,p} = \begin{cases} N_{t,y+1}^{s,p} - mk\mu_{t,y}N_{t,y+1}^{s,p} + mk\mu_{t,y}N_{t,y+1}^{s,p+2} & p = 1,2 \\ N_{t,y+1}^{s,p} - 2mk\mu_{t,y}N_{t,y+1}^{s,p} + mk\mu_{t,y}N_{t,y+1}^{s,p+2} & 3 \le p \le p_{\max} \\ \qquad + mk\mu_{t,y}N_{t,y+1}^{s,p-2} & \\ N_{t,y+1}^{s,p} - mk\mu_{t,y}N_{t,y+1}^{s,p} + mk\mu_{t,y}N_{t,y+1}^{s,p-2} & p = p_{\max} - 1, p_{\max} \end{cases} \qquad \text{(A3.4)}$$

where:

k	is the movement rate alongshore.

Maturity at age is described by a logistic model:

$$\mu_{t,y} = \frac{e^{(a_y + b_y l_t)}}{1 + e^{(a_y + b_y l_t)}} \qquad \text{(A3.5)}$$

where:

$\mu_{t,y}$	is the proportion of age class *t* in year *y* that is sexually mature,
a_y, b_y	are the maturity parameters in year *y*.

Given maturity at age and knowledge of numbers in each population and sex, the mature or spawning biomass in year y after removing half of the annual natural and fishing mortality was determined using:

$$\hat{B}^{p}_{S,y} = \sum_{t=t_{\min}}^{t_{\max}} \sum_{p=1}^{NPops} \mu_{t,y} W^{s}_{t,y} \hat{N}^{p,s}_{t,y} e^{-Z^{p,s}_{t,y}/2} \tag{A3.6}$$

where:

$\hat{B}^{p}_{S,y}$	is the predicted spawning biomass in population *p* in year *y,*
$\hat{N}^{p,s}_{t,y}$	is the number of fish in population *p* of age *t* in year *y* where the sex *s* is female,
$W^{s}_{t,y}$	is the weight at length for sex *s* at age *t* in year *y,*
t_{min}, t_{max}	is the minimum and maximum age group (plus-group).

The predicted exploitable biomass was defined as the fishable biomass in onshore populations in year y after removing half of the annual natural and fishing mortality using:

$$\hat{B}^{p}_{E,y} = \sum_{s=1}^{2} \sum_{t=t_{\min}}^{t_{\max}} W^{s}_{t,y} s^{s}_{t,y} N^{p,s}_{t,y} e^{-Z^{p,s}_{t,y}/2} \tag{A3.7}$$

where:

$\hat{B}^{p}_{E,y}$	is the exploitable biomass in year *y* where population *p* is onshore,
$s^{s}_{t,y}$	is the selectivity of age class *t* for sex *s* in year *y*.

Growth

Growth is described in terms of length at age and weight at length by a Schnute and Richards (1990) equation:

$$L^{s}_{t,y} = L^{s}_{\infty,t}\left(1+\alpha_y^{\,(-a_y t^{c_y})}\right)^{-\frac{1}{b_y}} + \varepsilon^{s}_{y} \tag{A3.8}$$

where:

$L^{s}_{t,y}$	is the length at age *t* in year *y* for sex *s,*
$L^{s}_{\infty,t}$	is the average maximum length for the species in year *y* for sex *s,*
a, b, c,	are the parameters of the growth function,
α	is the parameter of the growth function,
ε^{s}_{y}	is a normal random residual in year *y* for sex *s*.

The weight at length relationship is described by:

$$W^s_{t,y} = a_s (L^s_{t,y})^{b_s} \tag{A3.9}$$

where:

$W^s_{t,y}$	is the weight at length for sex *s* at age *t* in year *y,*
a_s, b_s	are the coefficients define the power relationship between length and weight.

Selectivity

Mesh selectivity was estimated using the SELECT method (Share Each Length class's Catch Total; Millar 1992; Millar and Fryer 1999). It is described by the gamma selection function rather than the normal selection function, indicating that many large fish are retained in the net mainly by wedging and tangling rather than by gilling, and not thought to be influenced by sex (Murphy and Lyle 1999):

$$r_l = \left(\frac{l}{\alpha k m}\right)^{\alpha} e^{\left(\alpha - \frac{l_t}{km}\right)} \tag{A3.10}$$

where:

r_t	is the mesh selectivity,
l_t	is the length of age class *t,*
m	is the mesh size of the nets used,
α, *k*	are the selectivity parameters.

Sex-specific selectivity is described by:

$$s^s_{t,y} = \frac{s^s_{t,y}}{\max(s^s_{t,y})} \tag{A3.11}$$

where:

$s^s_{t,y}$	Is the sex-specific selectivity at age *t* in year *y* for the lower and upper size limits relative to selectivity at age.

Sex-specific selectivity is approximated by summing up sex-specific selectivity at age and size $s^s_{t,l,y}$ by 5 mm intervals *l* between 0 and 600 mm:

$$s^s_{t,y} = \sum_{l=lower}^{upper} r_l s^s_{t,l,y} * \sum_{l=0}^{600} r_l s^s_{t,l,y} \tag{A3.12}$$

where:

$$s^s_{t,l,y} = \int_{l}^{l+1} N(L^s_{t,y}, \sigma^s_{t,y}) \Delta l \tag{A3.13}$$

where:

$s_{t,y}^{s}$	is the selectivity of age class t for sex s in year y,
$s_{t,l,y}^{s}$	is the selectivity of age class *t* and 0.5 cm size interval *l* for sex *s* in year *y*, estimated from the growth function $L_{t,y}^{s}$ and its standard deviation $\sigma_{t,y}^{s}$.

Fishing mortality, catch and catch rates

The fishing mortality rate for each age class in population *p* is defined in terms of the fully selected instantaneous fishing mortality rate $\hat{F}_{y}^{p}$ in year *y* combined with the selectivity for each age class *t* and sex *s*:

$$F_{y,t}^{p,s} = s_{t,y}^{s}\hat{F}_{y}^{p} \qquad \text{(A3.14)}$$

where:

$s_{t,y}^{s}$	is the relative selectivity of age class *t* for sex *s* in year *y* in population *p*,
$\hat{F}_{y}^{p}$	is the fitted fully-selected fishing mortality in population *p* and year *y*.

The predicted catch in onshore populations in each year *y* was defined as the sum of the predicted catch at age multiplied by the weight at age:

$$\hat{C}_{y}^{p} = \sum_{s=1}^{2}\sum_{t=t_{\min}}^{t_{\max}} W_{t,y}^{s}\frac{F_{t,y}^{p,s}}{F_{t,y}^{p,s}+M}N_{t,y}^{p,s}\left(1-e^{-\left(M+F_{y,t}^{p,s}\right)}\right) \qquad \text{(A3.15)}$$

where:

$\hat{C}_{y}^{p}$	is the predicted catch in year *y* where population *p* is onshore. All fishing is assumed to occur instantaneously in the middle of the year.

The predicted catch rates were determined by:

$$\hat{I}_{y}^{p} = \hat{q}_{p}\hat{B}_{E,y}^{p} \qquad \text{(A3.16)}$$

where:

$\hat{I}_{y}^{p}$	is the predicted catch rates in population *p* and year *y*,
$\hat{q}_{p}$	is the predicted catchability in population *p*, determined by a closed form of the equation using observed catch rates assuming that the catchability coefficient is a constant and each $\hat{q}_{p}$ is only an estimate of the overall

$\hat{q}_p$ with lognormal error: $\ln(\hat{q}_p) = \dfrac{\sum_{y=1996}^{2007} \ln\left(\dfrac{I_y^p}{B_{E,y}^p}\right)}{n}$ (A3.17)

I_y^p is the observed catch rates in population p and year y,

n is the number of years with catch rates observations between 1996 and 2007.

Recruitment

Recruitment in each year was based on the geometric mean of the fitted recruitment parameters and the density-dependent standard deviation σ_R of recruitment:

$$R^s_{t_{\min},y} = GM(\bar{R}^s_{t_{\min},90-07})e^{\varepsilon_{R,90-04}} \quad \varepsilon_{R,y} \sim N(0,\sigma_R^2) \tag{A3.18}$$

where:

$R^s_{t_{\min},y}$ is the geometric mean (GM) of the fitted recruitment by sex s of age t_{min},

σ_R^2 is the density-dependent parameter that determines the extend of annual variation in recruitment.

The standard deviation used in the projections was considered to be density-dependent and influenced by the population numbers in the previous year y-1. To estimate the relationship between population numbers and recruitment standard deviation, the 18 historical years were ranked by population numbers and split in four groups with the last group consisting of 6 years. The geometric recruitment mean of each group was estimated and a regression calculated. This regression represented the density-dependent effect of population numbers on recruitment variability. The range of recruitment variability was limited to the estimated range from the historical period. This limitation capped very large recruitment events at low population size, effectively reducing the productivity of the stocks and resulting in more conservative rebuilding scenarios. On the other hand, recruitment was assumed to occur under any circumstances, *i.e.* even when there was virtually no standing biomass left in the model populations.

Catch and catch rates in projections

With catch as the unit which was controlled by management, the total fishing-induced mortality or ‘real catch’ in projected years was calculated from the reported catch modified by the reporting seal or bycatch bias by:

$$\hat{C}_y^p = C_y^p L_y D_y e^{\varepsilon_{L,y}} e^{\varepsilon_{D,y}} \quad \varepsilon_{L,y} \sim N(0,\sigma_L^2), \quad \varepsilon_{D,y} \sim N(0,\sigma_D^2) \tag{A3.19}$$

where:

$\hat{C}_y^p$	is the predicted total catch in year y where population p is onshore. All fishing is assumed to occur instantaneously in the middle of the year,
C_y^p	is the observed reported catch in year y where population p is onshore,
L_y	is the logbook reporting bias,
σ_L^2	is the parameter that determines the extend of annual variation in logbook reporting rates,
D_y	is the discard and seal-induced mortality in year y where population p is onshore,
σ_D^2	is the parameter that determines the extend of annual variation in discarding and seal-induced mortality.

The predicted catch rates were again determined by Equation (A3.16). Catch and catch rates were calculated on a regional base, and summarised (catch) or the catch-weighted geometric mean taken (catch rates) to estimate the results for all regions combined.