FISHERY ASSESSMENT REPORT

TASMANIAN SCALEFISH FISHERY - 2005

P.E. Ziegler, J.M. Lyle, M. Haddon, N.A. Moltschaniwskyj and S.R. Tracey

February 2006

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

SFAWG met on 7 December 2005 to consider the draft assessment report and provide input into the assessments. The Working Group participants were:

Malcolm Haddon	TAFI (Acting Chair)
Jeremy Lyle	TAFI
Philippe Ziegler	TAFI
Dirk Welsford	TAFI (Secretary)
Matt Bradshaw	Scalefish Fishery Manager, DPIWE
John Adams	Scalefish Fishery Manager, DPIWE
Howel Williams	Recreational Fishery Manager, DPIWE
Todd Francis	Commercial sector
Sean Larby	Commercial sector
Peter Schulze	Recreational sector
Louisa Fitzpatrick	Recreational sector
Wayne Thompson	Recreational sector

TAFI Marine Research Laboratories, Private Bag 49, Hobart, TAS 7001, Australia. E-mail: Jeremy.Lyle@utas.edu.au. Ph. (03) 6227 7277, Fax (03) 6227 8035

Tasmanian Scalefish Fishery – 2005

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, introduced in 1998, reviewed in 2001 and again 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. Commercial catch history for the period 1990/91 to 2004/05 is presented, with more detailed analyses of catch and effort by method for the period 1995/96 to 2004/05. 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 and bastard trumpeter) have been incorporated in the analyses.

Following the introduction of the management plan dipnet, dropline and squid jig effort expanded to historically high levels whereas effort for other methods tended to remain relatively stable or declined. By 2004/05, 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 calamary fishery.

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

Table 1. Effort performance indicator assessment by major fishing methods for 2004/05
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

Detailed assessments were performed for banded morwong, southern calamary and striped trumpeter, while other key species - sea garfish, wrasse, blue warehou, bastard trumpeter, Australian salmon, flounder and flathead - were considered more briefly.

Species assessments evaluate fishery-dependent information (catch, effort and catch rate trends) against performance indicators detailed in the Scalefish Management Plan. Specifically, these criteria relate to levels of catch, effort and catch rates. The management plan also provides for biological indicators to be used as reference points against which stock status can be evaluated and, where such data are available, they have been updated in this assessment.

Banded morwong

Performance indicators

- Banded morwong catch indicators were triggered state-wide as well as in the main fishing regions during 2004/05, with catches remaining below reference levels.
- The spatial expansion of the fishery into the north east came to a halt with catches from this region declining by more than 30% and therefore triggering the rate of change indicator.
- Gillnet effort for banded morwong did not trigger the effort performance indicator at either regional or state-wide levels.
- State-wide catch rate indicator was not triggered, however, standardised catch rates for Bicheno and St Helens remained low and triggered the performance indicator for the third year running.
- Significant changes in size and age composition and sex ratios indicate that the fishery has impacted on stock structure.

Resource status

- A regional stock assessment model suggests that exploitation rates in some coast regions may not be sustainable.
- Current catch levels are likely to continue to reduce spawning biomass though stocks now exhibit higher productivity (faster growth of individuals, earlier maturity of females) than at the commencement of the fishery.

Management advice

- Management action is required to ensure that catch levels are not allowed to exceed current levels.
- Given the limited mobility of this species, management should 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. Between 1994/95 and 1999/00, annual production declined steadily with catches generally tracking changes in effort. The 2004/05 catch of 42 tonnes represented a slight drop compared with 2003/04. Regional catches remained relatively stable apart from those from the north east coast where the recent expansion of the fishery came to a halt.

State-wide effort continued to decline in 2004/05 and remained low compared with the reference period. Effort in the regions including the north east coast was within or below reference levels. State-wide catch rates were above reference levels, with catch rates for the Maria and Tasman regions having increased recently. By contrast, catch rates for St Helens and Bicheno have trended downward since the late 1990s to less than 80% of the reference level.

Catch and catch rate indicators suggest banded morwong populations were initially impacted that by the fishery, but have stabilised or improved over the last few years. However, this improvement does not necessarily indicate the sustainability of current levels of exploitation due to (i) masking of localised changes in abundance arising from the expansion of the fishery within and outside of traditional fishing grounds; (ii) limited insights of catch rates into stock status for a species such as banded morwong; (iii) changing fleet dynamics, with a general move towards a core group of experienced (effective) fishers; and (iv) issues of data quality of commercial catch returns. Seal interactions continue to represent a significant factor in this fishery, in terms of incidental mortality and impacts on catch rates and fisher activity.

A range of biological measures that relate to fishery performance, including size structure, age structure, and sex ratios of the catch indicate that the character of the stock has changed. Some of these changes are dramatic, for example the decrease of median age for females from around 20 to 7 years and the shift in sex ratio from a strong dominance of females to an equal sex ratio.

A regional age-structured stock assessment model confirmed these trends. However, the model also reflected the uncertainty in the underlying data and uncertainty over the dynamics and spatial structuring of the stock. Because of the spatial mis-match between catch rate data (by 30nm blocks) and stock processes (at reef level), model predictions may be overly-optimistic due to possible masking of serial depletion of stocks. In addition, uncertainty about the regional biomass distribution coupled with generally poor model fits to the biological data did not allow the optimum spatial model structure to be identified.

Many of the scenarios tested using the model predicted high harvest rates over an extended period of the fishery. Only in recent years have harvest rates been reduced towards or below more sustainable levels. All scenarios tested by the model also predicted relatively low estimates of mature biomass in at least some regions. However, predicted mature biomass levels in 2004/05 were higher than 30% or 40% of the initial mature biomass.

A harvest strategy evaluation indicated that maximum future catch levels from the east coast should on average be less than 36 tonnes if the management objective is to maintain or rebuild catch rates and mature biomass. However, model results were based on substantial changes in some life-history characteristics of banded morwong (faster growth of individuals, earlier maturity of females). In effect, predicted stability in the fish biomass and the fishery has been founded mainly on young fish becoming more productive rather than sustainable use of old fish.

Therefore, despite uncertainty in the commercial and biological data, this assessment suggests that management action is required to ensure that fishing mortality in this fishery does not exceed current levels or in fact is reduced in the long term. Given the limited mobility of this species, management should also explicitly include reference to the spatial distribution of effort.

Southern calamary

Performance indicators

- Catch and effort performance indicators for southern calamary were triggered for the seventh consecutive year.

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. The status of populations outside of Great Oyster Bay and Mercury Passage and possible links between areas are unknown. Expansion of catches in space and time will need to be monitored closely.

The fishery for southern calamary 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 reported catch of 113 tonnes in 2004/05 represented an increase of almost 30% compared with 2003/04 and was the highest on record, despite a three-month closure of the major fishing grounds (Great Oyster Bay and Mercury Passage) during the peak catching period. State-wide catch rates increased slightly and were within reference levels during 2004/05.

Egg production showed some potential as an indicator of relative spawning biomass, but may not be useful as a pre-recruit index. However, with the limited time series of data available these observations are only preliminary.

Since the development of the calamary fishery occurred after the introduction of the management plan the application of the generic catch and effort performance indicators and their 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).

Although a high degree of uncertainty is associated with the present assessment, the extended spatial and temporal closure of the major spawning grounds (implemented again in 2005) appears to be effective in protecting the main (known) spawning event and ensuring relatively high egg production. 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. Furthermore, the status of populations outside of Great Oyster Bay and Mercury Passage, and possible links between areas, are unknown. Expansion of catches in space and time will need to be monitored closely.

Striped trumpeter

Performance indicators

- Striped trumpeter catches fell by over 30% in 2004/05 to the lowest level since the mid-1980s, resulting in both catch performance indicators being triggered.
- Dropline, handline and graball effort was below or within reference levels and catch rates for the latter two methods were within or above reference levels. By contrast, dropline catch rates (daily) remained low, triggering the catch rate performance indicator for this method.

Resource status

- Resource status is uncertain though potentially depleted due the combined effects of fishing and apparent poor recruitment in recent years.

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 or a period of sustained good recruitment. It would be prudent to act to reduce fishing mortality, both commercial and recreational, and to review the minimum size limit, which is below the size at maturity.

During 2004/05 only 26 tonnes of striped trumpeter was taken commercially, the lowest catch recorded since the mid 1980s. Handline and graball effort were well below levels experienced during the latter half of the 1990s. Despite a recent fall in dropline effort, effort was still relatively high but within reference levels. There was a sharp drop in graball catch rates, possibly reflecting the impact of the increased minimum size limit introduced in 2004. Graball catches are primarily taken from relatively shallow inshore waters where juvenile (sub-legal) striped trumpeter dominate.

The sharp decline in catches since 2000/01 gives rise to concerns about the current status of striped trumpeter stocks. Falling graball net catches (primarily juvenile fish) over the past five years and reductions in offshore hook catches (mainly adult fish) over the past four years suggest that the biomass of new recruits and adults may have declined significantly. Commercial catches in 1998/99 and 1999/00 were historically very high so fishing may have acted to reduce biomass. However, striped trumpeter exhibit strong recruitment variability and this would act to produce inter-annual variability in fishable biomass.

Recent size and age composition data imply that there has been no substantial recent recruitment and that a particularly strong cohort (now 11 years old) is still strongly 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 also have contributed to the downturn in 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.

Based on yield and spawning biomass-per-recruit analyses and new information about size at maturity it would appear that the recent increased minimum size limit, while a positive step, was sub-optimal and still presents a risk of recruitment overfishing.

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 or a period of sustained good recruitment. It would be prudent to act to reduce fishing mortality, both commercial and recreational, and to review the minimum size limit.

Sea garfish

Performance indicators

- No performance indicators were triggered.

Resource status

- Fishery dependent indicators provide no basis for concern over resource status.

Management advice

- While it is not known whether present catch levels are sustainable, the potential for increased targeted effort is great. It would be prudent to consider management options that limit further expansion in this fishery.

The 2004/05 garfish catch of 75 tonnes was slightly higher than in 2003/04 but within the reference range for the species. Dipnet effort and catch rates fell slightly, while beach seine effort remained stable and catch rates increased. Sea garfish are a schooling species and thus catch rate trends may be neither reliable nor sensitive indicators of abundance.

There is little evidence for concern over the status of the garfish stocks based on the fishery dependent indicators but there is potential for targeted effort to expand, especially in the dipnet sector. While it is not known whether present catch levels are sustainable, it would be prudent to consider management options that limit further expansion in this fishery.

Wrasse

Performance indicators

- State-wide catch increased by more than 30% compared with the previous year and therefore triggered the catch performance indicator.
- Effort and catch rate indicators were not triggered.

Resource status

- Resource status is unknown though the two species targeted are vulnerable to localised 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

- The *status quo* would appear to be acceptable in terms of sustainability. Improvements in the collection of spatial information and species based reporting are required in order to reduce the risk of failing to detect serial depletion.

The development of live fish markets for wrasse in the early 1990s resulted in increased catches. Two species are involved, purple wrasse and blue-throat wrasse, though catches of these species are still not generally distinguished in catch returns. The 2004/05 catch of 95 tonnes represented a 38% increase over 2003/04, mainly the result of increased activity off the east and north-west coasts, but remained within reference catch range.

Catch rates for both handline and fish traps have increased. However, broad-scale analyses may be relatively insensitive to changes in abundance at the level of individual reefs at which the fishery impacts on the fish populations. 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. Because fishery performance indicators ignore the spatial structure of the fishery caution needs to be exercised when making inferences about the status of the wrasse stocks.

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. This, coupled with the fact that males are strongly site attached and have higher catchability than females (being more aggressive) 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

Performance indicators

- Blue warehou catches continued to fall in 2004/05 and reached a historically low level, triggering both catch performance indicators.
- Effort and catch rate indicators were not triggered.

Resource status

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

Management advice

- Management action to reduce catches has been implemented in the Commonwealth fishery.

Recent studies have indicated that there are two stocks of blue warehou in Australian waters, one to the west and one to the east of Bass Strait. The fishery for blue warehou in Tasmanian inshore waters is centred off the southeast coast and thus probably targets the eastern stock. Catches are also taken off the northeast and northwest coasts, the latter potentially involving the western stock.

The blue warehou catch of 18 tonnes in 2004/05 represented a drop of 33% compared with 2003/04 and is the lowest since the fishery developed. Graball effort remained low and catch rates were either within or above reference values.

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 and in the absence of significant rebuilding, catches are likely to remain low.

Bastard trumpeter

Performance indicators

- Current catches of bastard trumpeter were below reference levels, triggering the catch performance indicator for the fifth year.
- Effort and catch rate indicators were not triggered.

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 should be explored.

Bastard trumpeter catches have declined steadily since the mid 1990s and the current catch of 17 tonnes was the lowest since the late 1980s.

Catch rates are probably a poor indicator of stock status for bastard trumpeter since the species is 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.

Australian salmon

Performance indicators

- Australian salmon catch was within the reference range, but increased by more than 30% compared to the previous year and therefore triggered the rate of change performance indicator.
- Effort and catch rate indicators were not triggered.

Resource status

- Resource status is unknown.

Management advice

- The *status quo* appears to be acceptable though there is a possibility of significant expansion if new markets open.

The total catch of Australian salmon in 2004/05, mainly taken by beach seine, recovered from last year's drop and doubled to 335 tonnes. Beach seine catch rates also increased 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 indicator for a schooling species such as Australian salmon.

Commercial catches of Australian salmon are to a large extent linked to market demand (specifically the bait market) and are thus probably not a good indicator of stock status. There is capacity within industry to significantly expand production should new markets be found and under such circumstances management may need to be proactive moderating such expansion.

Flounder

Performance indicators

- Flounder catches in 2004/05 remained below reference levels and thus triggered the catch performance indicator.
- Spear and graball effort for flounder did not trigger the effort performance indicator.
- Graball catch rates based on daily catches, and spear catch rates based on hours fished and daily catches, were less than 80% of the lowest reference levels and therefore triggered the performance indicator.

Resource status

- Resource status is unknown.

Management advice

- *Status quo* appears to be acceptable until more evidence, industry reports, or recreational reports are forthcoming.

Flounder catches of 14 tonnes in 2004/05 remained well below the minimum reference level. Fishing effort for the major methods, spear and graball, has remained stable over the past 4-5 years, with graball effort at low levels. Catch rate trends were variable between methods and depending on the units of effort considered (daily or gear units of effort). Graball catch rates by gear units (kg per 100-m net hour) have increased while daily graball catch rates have declined since the mid-1990s. Catch per hour for spears has exhibited a downward trend over time whereas catch per day fished remained relatively stable and only started to drop in the last two years. These apparently contradictory trends imply some changes in fishery dynamics for flounder, with less graball net effort expended on each day fished and more time fished per day on average with spears.

The degree of interest by the commercial sector in flounder appears to be quite low at present. It is unclear whether this is market or resource driven. The current status of flounder stocks is therefore unknown.

Flathead

Performance indicators

- State-wide catch was within the reference range, but increased by more than 30% compared with the previous year and therefore triggered the catch performance indicator.
- Effort and catch rate indicators were not triggered in 2004/05.

Resource status

- Resource status is unknown.

Management advice

- *Status quo* appears to be acceptable until more evidence, industry reports, or recreational reports are forthcoming.

Flathead catches more than doubled to 74 tonnes in 2004/05, and represented the highest catch reported since the mid 1990s. Danish seine is the primary fishing method and the increase in flathead catch appears to be mainly due to a switch in targeted fishing from whiting to flathead. Catches by hand line and graball nets remained low. Graball effort has declined, while hand line effort and catch rates of both methods remained relatively stable.

Two main species are involved, tiger and sand flathead, with tiger flathead dominating the commercial catch. By contrast, while flathead are the primary species taken by recreational fishers, sand flathead account for the vast majority of the recreational take. 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. In adjacent Commonwealth waters significant quantities of tiger flathead are taken by trawling, the impact of this fishery on inshore stocks is unknown.

2004/05 performance indicator summary

Performance indicator analysis for key species is summarised in Table 2.

Table 2 Summary performance indicator assessment for key species with assessment of risk if no management action (i.e. *status quo*) is taken.
Y triggered; N not triggered; arrows indicate direction of change; na not assessed; $^{\#}$ applies only to particular methods or regions; Catch history reference period is *1994/95 to 1997/98 & ** 1995/96 to 1997/98; H high risk, M medium risk; $^{\times}$ management action being taken in Commonwealth fishery. Change since last 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 management action
Banded morwong*	Y ↓	**Y↓** $^{\#}$	**N**	Y $^{\#}$	Y	H
Southern calamary	Y ↑	N	Y	N	Y	H
Striped trumpeter	Y ↓	**Y↓**	**N**	Y $^{\#}$	Y	M
Garfish	N	N	N	N	na	
Wrasse**	**N**	**Y ↑**	N	N	na	
Blue warehou	Y ↓	Y ↓	N	Y	na	H$^{\times}$
Bastard trumpeter	Y ↓	N	N	N	na	
Australian salmon	**N**	**Y ↑**	N	Y	na	
Flounder	Y ↓	**N**	N	Y $^{\#}$	na	
Flathead	N	**Y ↑**	N	N	na	

Table of Contents

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.

---

[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 performance indicators fall outside the acceptable range 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, 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. Trigger points are reached 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.

2 Fishery Assessment

2.1 The Fishery

The Tasmanian scalefish fishery is a multi-gear and multi-species fishery. Jurisdictional issues complicate its management, with several key species harvested across a number of jurisdictions (Lyle and Jordan 1999).

This report covers the assessment of key scalefish and cephalopod fisheries under Tasmanian jurisdiction. Offshore Constitutional Settlement (OCS) agreements gave the Commonwealth management responsibility for species such as blue eye trevalla, blue grenadier, gemfish, hapuka and shark species, particularly school shark and gummy shark. Assessment of these and a number of other demersal species, including flathead, jackass morwong and ocean perch, is undertaken by the Southern and Eastern Scalefish and Shark Fishery Assessment Group (SESSFAG), and can be found summarised in the Fishery Status Reports produced by the Bureau of Rural Sciences (Caton and McLoughlin 2004). Blue warehou is managed as a quota species in the South East Fishery (SEF), but State catches are subject to a memorandum of understanding with the Commonwealth and managed under status quo arrangements, with catches to remain within historic levels. Formal assessments of blue warehou, incorporating data from the Tasmanian fishery, are undertaken as part of the SESSFAG process.

A wide range of fishing gears, the most important being gillnet, hooks and seine nets, are used to harvest 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 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 represents the eighth in a series of annual assessments of the scalefish fishery and incorporates catch and effort information available up to and including June 2005. Copies of previous assessment reports (Lyle and Jordan 1999, Jordan and Lyle 2000, Lyle and Hodgson 2001, 2002, Lyle 2003, Lyle et al. 2004, 2005) are available on the TAFI web page - http://fcms.its.utas.edu.au/scieng/mrl/index.asp.

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.

2.2.1 General Fishing Returns

General Fishing Returns prior to 1995 only provided monthly summaries of catches (landings) but were often incomplete or very limited in terms of providing effort information. Lennon (1998) discussed in some detail the limitations of these catch returns and, in summary, noted that they provided only basic information about production levels and were of little value for effort and catch rate analyses.

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 (½ degree rather than 1 degree blocks), plus details about effort and depths fished. Recent amendments (1999) to the catch return have included the provision to nominate a target species and indicate interference to fishing operations from marine mammals (e.g. seals or killer whales).

In the analysis of 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 refer to Appendix 2.

During 2001, dual endorsed fishers were instructed to report all fishing activities under State jurisdiction in the Tasmanian General Fishing Returns. This has to some extent removed the necessity to include subsequent Commonwealth catch and effort data into analyses. However, it has become apparent that there may be some confusion amongst fishers about reporting requirements and there are concerns that catches of species, such as striped trumpeter taken by Commonwealth operators, have not been routinely reported in the Tasmania catch returns as instructed. For the current assessment the Commonwealth has provided TAFI a summary of catch data since 2001. A formal request for detailed catch records has been submitted to AFMA and this will be combined with Tasmanian catch returns. Data will be checked for possible double reporting (i.e. on both the Tasmanian and Commonwealth catch returns) and where this is not the case the database for reporting catch and effort data in waters adjacent to Tasmania will be updated and used for subsequent assessments.

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 2005. All catch returns from within this period and available as at October 2005 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).

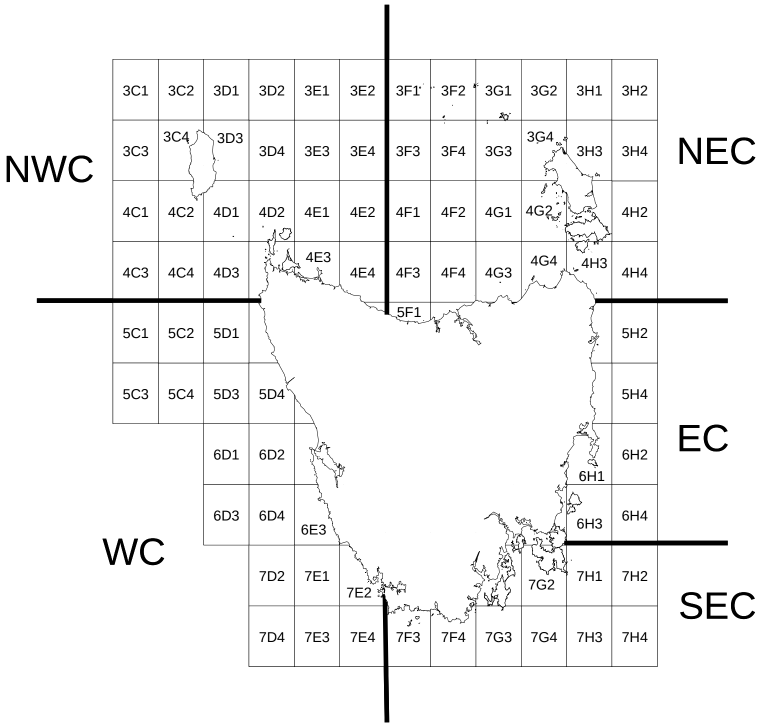


Fig. 2.1: Map of Tasmania with 30 nm fishing blocks and the assessment regions. SEC is south east coast, EC is east coast, NEC is north east coast, NWC is north west coast, and WC is west coast.

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, for dropline and longline, effort is expressed as number of hooks set, while handline fishing as the product of the number of lines fished and fishing time. There are eight different measures of effort that relate to different types of fishing gear (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. Less than 0.2% of all fishing records during 2004/05 were excluded in this manner. All records were, however, included when reporting catches, days fished and catch per day.

Table 2.1. Table of effort gear units by fishing method

Method(s)	*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 arithmetic mean of catch rates does not accurately describe the data. Instead, the geometric 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 n^{th} 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 an arithmetic average of all catch records. The advantage is that they are 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 is no additional data relevant to the recreational finfish fishery in Tasmania.

2.3 Commercial catch trends

2.3.1 Overview

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 2004/05 catch of 916 tonnes represented an increase of about 150 tonnes compared to 2003/04, largely due to an increase in Australian salmon landings. Catches of most other scalefish species were within ± 10 tonnes of 2003/04 levels. Exceptions included whiting and jack mackerel which fell by 19 and 34 tonnes, and wrasse and flathead which experienced increases of 22 and 43 tonnes, respectively.

When assessing trends within the scalefish fishery it is important to recognise that some species only 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 calamary 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.

2.3.2 Key species

Australian salmon have consistently dominated the scalefish catch, with catches in excess of 650 tonnes p.a. prior to 1995/96 (Fig. 2.2). More recent landings of this species have remained lower, fluctuating between about 300-480 tonnes. The 2004/05 catch of 335 tonnes was about double that in 2003/04 but within the catch range for the reference period (1990/91 to 1997/98). Industry reports suggest that the generally lower landings since the mid 1990s have been largely in response to reduced bait-market demand rather than reduced stock abundance.

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 over 90 tonnes was slightly higher than in the preceding year and was within the range of reference catch levels (Fig. 2.2).

Flathead catches declined from over 150 tonnes p.a. in the early 1990s to around 50 tonnes by the mid 1990s (Fig. 2.2), largely due to reductions in inshore trawl (demersal trawl and Danish seine) activity (Lyle and Jordan 1999). The 2004/05 catch of 74 tonnes was more than twice that taken in 2003/04 (the lowest catch on record) and was within reference levels. Demersal trawling was banned in State Fishing Waters in 2001 and there are currently very few active Danish seine operators. Both of these factors have contributed to the fall in catches.

Catches of flounder typically ranged between 30-40 tonnes, but over the past six years have fallen to below 20 tonnes, with 14 tonnes reported in 2004/05 (Fig. 2.2). It is unclear whether this is a reflection of reduced abundance or changed market demand, but recent catches remain well below reference catch levels.

Apart from the mid 1990s, sea garfish production has remained relatively stable at between 80-100 tonnes p.a (Fig. 2.2). Current landings of 75 tonnes represented a slight increase over 2003/04 and remained within the range of reference levels.

The development of live fish markets for banded morwong during the early 1990s resulted in a marked increase in reported landings to 145 tonnes (1993/94), though it is generally accepted that this figure is unreliable and represents a significant overstatement of the real catch. Catches declined from almost 90 tonnes in 1995/96 to less than 35 tonnes in 1999/00 (Fig. 2.2). Over the past five years, reported catches have averaged just under 50 tonnes, the current catch of 42 tonnes representing a slight decline compared with 2003/04.

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 (Fig. 2.2). The most recent catch was slightly higher than in 2003/04 but still below the reference level.

Landings of mullet (sea and yellow-eyed mullet) were around 30 tonnes in the early 1990s but have since declined steadily to less than 5 tonnes in 2004/05, the lowest level on record (Fig. 2.2).

Prior to the mid 1990s, bastard trumpeter catches fluctuated between 35-65 tonnes p.a. Since then annual catches have declined steadily, with only 17 tonnes reported in 2004/05, the lowest level since the late 1980s (Fig. 2.2). By contrast, striped trumpeter production grew during the 1990s to over 100 tonnes by 1999/00 before falling sharply to half this level in the following year. Catches have continued to fall each year with just 24 tonnes of striped trumpeter reported in 2004/05 (Fig. 2.2). The reason for catch declines in both trumpeter species may lie, to some extent, in reduced abundances, exacerbated by a prolonged period of poor recruitment, rather than changes in market demand (which remains high for striped trumpeter).

Annual production of blue warehou fluctuated widely, between 100-300 tonnes, up until 1999/2000 but has averaged less than 40 tonnes p.a. since (Fig. 2.2). The 2004/05 catch of just 19 tonnes was about two-thirds that taken in 2003/04 and was, for the fifth year running, well below the range of reference catch levels.

Whiting catches experienced a marked decline during the early 1990s, largely in response to reduced inshore trawl activity (Lyle and Jordan 1999), but have stabilised since the mid-1990s with annual landings of between 30-55 tonnes (Fig. 2.2). Landings fell in 2004/05 but were within reference levels.

The marked increase in wrasse landings that occurred in the early 1990s was due to the expansion of live fish markets. Subsequent to 1995/96, however, wrasse production generally stabilised at around 85-100 tonnes p.a. (Fig. 2.2). The 2004/05 wrasse catch of 97 tonnes was about 30% higher than in the two previous years and was within reference catch levels.

Cephalopod production, at 195 tonnes, was slightly up on 2003/04, due to increased catches of calamary and octopus. During the latter half of the 1990s there was a marked expansion in the fishery for calamary, with catches rising from less than about 20 tonnes p.a. prior to 1995/96 to about 90 tonnes in 1998/99 (Fig. 2.2). Subsequent catches have averaged about 95 tonnes, with production peaking at 113 tonnes during 2004/05 (Fig. 2.2). Total octopus catches grew steadily from around 30 to 75 tonnes p.a. by the mid 1990s and have fluctuated between 60-80 tonnes p.a. since that time (Fig. 2.2). After a sharp increase in the catch of arrow squid to 480 tonnes (1999/00), subsequent production in Tasmanian waters has fallen to about 2 tonnes p.a., a consequence of several seasons of low arrow squid abundances in inshore waters (Fig. 2.2). At the same period, arrow squid catches in the western Bass Strait off Portland have remained variable, but consistently over 1000 tonnes (Caton and McLoughlin 2004).

Table 2.2. Annual 'Tasmanian' scalefish and cephalopod production (whole weight) between 1990/91 to 2004/05 by species

Based on General Fishing Returns and Commonwealth (GN01, GN01A and SSJF) logbook returns.

	Catch (tonnes)														
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**
Scalefish															
Australian salmon	815.9	651.9	867	878.8	682.1	413.2	287.3	476.0	384.7	363.7	485.0	462.1	407.2	167.2	334.9
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	93.5
Boarfish	7.2	9.4	7.6	10.1	9.1	7.3	10.4	9.4	7.0	7.3	8.0	5.5	3.6	4.3	3.5
Bream	5.7	3.5	1.4	7.4	7.2	2.5	9.9	1.0	0.0	0.1	0.0	0.1	0.4	0.0	0.0
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	1.5
Dory	2.8	1.3	6.0	1.1	1.0	0.4	1.0	1.3	0.2	0.2	0.2	0.1	0.1	0.2	0.2
Eel	0.2	0.5	0.9	2.2	3.1	2.1	1.4	1.7	2.0	1.2	0.6	0.4	0.4	0.2	1.0
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	31.1	74.1
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	13.7
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	75.0
Gurnard	20.5	19.0	19.3	19.3	14	13.5	10.4	9.1	7.1	9.9	7.8	5.3	9.7	6.7	5.9
Latchet	13.9	10.0	6.5	12.4	11.9	6.1	3.3	1.9	1.1	2.3	1.5	0.8	0.8	0.6	0.6
Leatherjacket	12.2	14	13.1	23.3	27.7	14.5	12.6	13.3	12.9	16.5	16.7	16.6	13.7	14.8	10.3
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
Mackerel, blue	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	0.0	0.5
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	6.9
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
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	41.8
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	17.2
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	1.7
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	4.8
Other	106.8	92.1	77.6	60.0	25.2	17.6	18.8	19.9	19.5	11.0	10.1	11.0	33.4	28.7	30.7
Pike, long-finned	0.1	0.0	0.1	0.3	0.2	0.3	3.1	3.9	9.5	10.0	6.6	12.2	10.7	14.0	6.6
Pike, short-finned	10.4	9.5	11.0	12.4	18.6	13.7	15.2	17.7	3.2	4.1	5.9	6.6	6.6	3.7	2.2
Pilchard/anchovy	0.1	0.0	3.8	14.6	12.1	6.6	4.3	15.4	2.8	1.7	3.2	0.7	0.0	0.3	0.8
Stargazer	10.7	3.0	1.2	4.3	1.5	0.2	0.0	0.3	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Trevally, silver	15.0	12.2	2.5	5.9	15.5	5.9	4.5	7.8	8.0	3.2	1.6	4.6	5.5	3.4	3.2
Trevally, unspec.	5.6	1.4	9.5	2.4	6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
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	17.3
Trumpeter, striped	74.5	58.2	52.7	56.5	72.4	58.2	79.4	78.1	98.8	95.0	45.5	39.9	36.5	36.8	23.3
Trumpeter, unspec.	0.7	0.0	0.0	0.4	0.1	0.2	0.1	0.6	3.5	0.0	0.0	0.0	0.0	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	18.2
Warehou, spotted	0.7	0.4	4.2	8.8	3.4	14.6	15.6	4.8	0.0	0.0	0.0	0.0	0.2	0.1	0.8
Whiting	124.2	152.3	84.3	97.9	81.4	25.4	39.3	48.1	30.4	31.4	42.5	39.9	35.9	50.9	31.6
Wrasse	57.2	71.7	97.3	142.4	178	83.4	110.1	100.0	90.7	85.4	88.4	92.3	72.0	75.0	97.1
Total scalefish	**2450**	**2154**	**2135**	**2367**	**1933**	**1190**	**1203**	**1454**	**1368**	**1166**	**1047**	**1183**	**1023**	**772**	**921**
Cephalopod															
Calamary	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	112.8
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	0.1
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	70.9	80.0
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	2.5
Total cephalopod	**76**	**51**	**60**	**77**	**77**	**116**	**68**	**83**	**260**	**627**	**178**	**171**	**181**	**161**	**195**

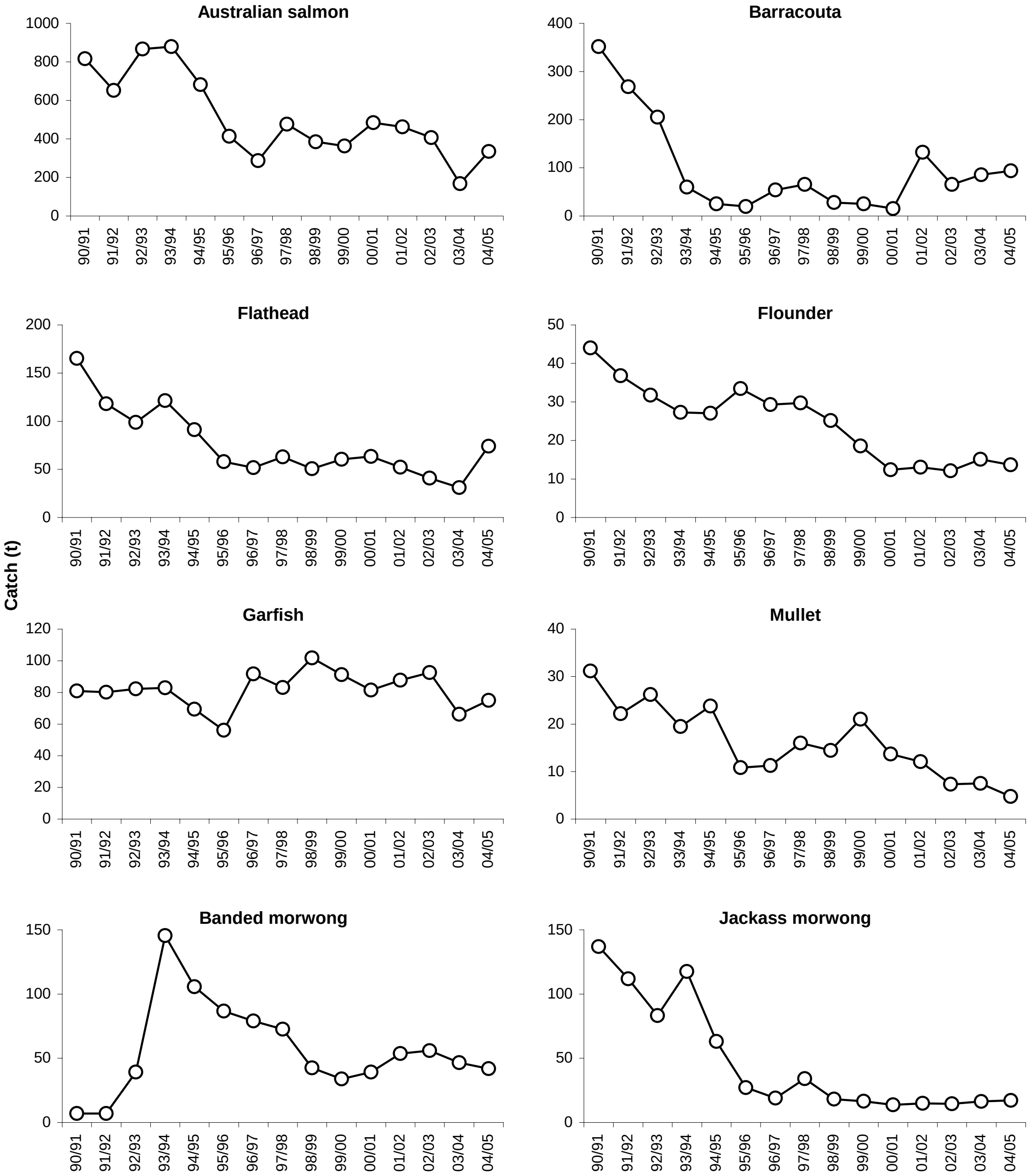


Fig. 2.2. Annual catches for key scalefish species 1990/91 to 2004/05.

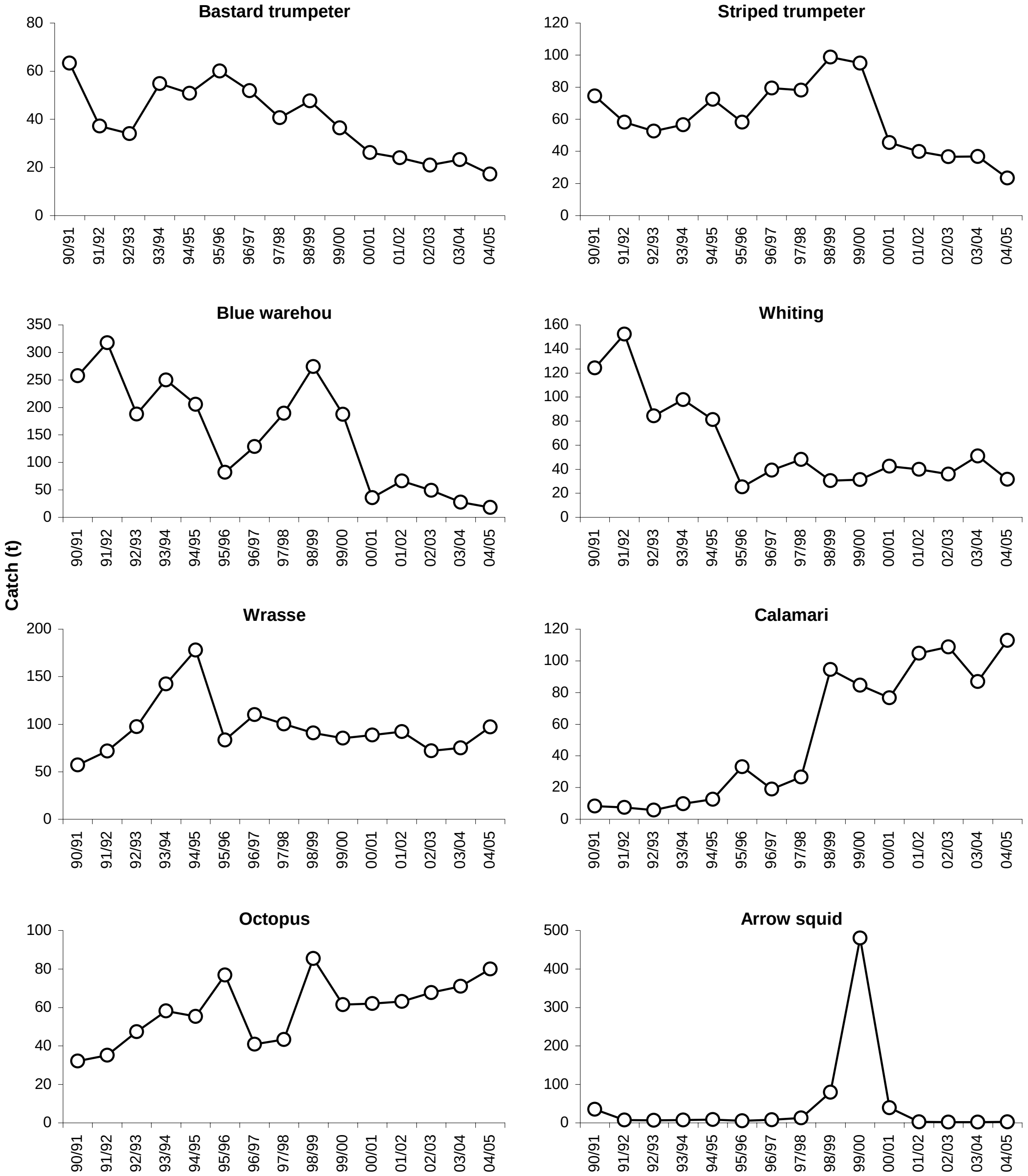


Fig. 2.2. Continued.

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 is expected to be 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 (purse seine and graball), increased or remained stable initially but undergone recent declines (beach seine, dipnet, dropline. small mesh nets and fish trap), remained relatively stable (spear and handline) or increased over time (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 2004/05 were generally similar to or lower than that in 2003/04 for most gear types, except for handline, spear, squid jig, and fish traps (gear fished) which increased. By comparison with reference levels, however, effort was either lower (beach seine, purse seine, graball, small mesh, spear and fish traps) or within the range (dipnet, handline and methods) from the reference period (Table 2.3). The amount of gear set during 2004/05 for droplines (number of hook lifts) was lower than during the reference period although the number of fishing days reported was similar to that during the reference years. The introduction of 250 kg trip limits in late 2000 for striped trumpeter, the primary dropline target species, may have resulted in fishers using fewer hooks/lines per day in an effort to restrict catches to within the trip limit. Squid jig effort, by contrast, continued to be significantly higher than during the reference period, a direct consequence of the development of the calamary fishery.

Considering effort by gear type alone, however, 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. 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 (Fig. 2.3). The decline in purse seine effort (Table 2.3) was driven largely by falls in effort directed at calamary, 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 or flounder, with a variety of other species commonly taken as by-product of these sub-fisheries. By analysing graball effort based on the occurrence of these species in the catches it was evident that there was an initial increase in effort for blue warehou, peaking in 1997/98 (gear units) and 1998/99 (days fished), followed by a rapid decline especially between 1999/00 and 2000/01. There was a decline in effort directed at banded morwong up until the late 1990s that was followed by a slight expansion between 2000/01 and 2002/03 and then further declines in more recent years. By comparison, effort directed at flounder has decreased steadily of over time and is now at a low level (Fig. 2.3).

Striped trumpeter and wrasse are the two main species targeted by handlines and these fisheries demonstrate different trends in effort. 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, before climbing steadily once again to levels similar to the peak recorded in the mid 1990s (Fig. 2.3).

A significant expansion in jig effort (particularly evident in days fished) commenced in 1998/99 and was initially directed at calamary, but in 1999/00 there was also a dramatic increase in effort targeted at arrow squid (not shown). Effort for calamary has continued to rise to the present year (days fished), whereas effort directed at arrow squid fell sharply after the 1999/00 peak and has remained very low especially during the last three years.

The remaining key 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. dipnets for garfish, droplines for striped trumpeter, spears for flounder and fish traps for wrasse. Species-based effort trends are also considered in more detail in Chapters 3-6.

In terms of the effort-based performance criterion, only squid jig effort exceeded the effort trigger, reflecting the development of the calamary fishery that occurred largely after the reference period (see Table 2.3). By comparison, effort in 2004/05 for dropline (days fished), handline and spear was within the range reported during the reference period, whereas effort for beach seine, purse seine, graball, small mesh net, dip net and fish trap effort was below these limits. In this comparison dipnet effort for 1995/96 has been excluded from the reference period because of the low number of operators involved. Notwithstanding these observations, 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 recent management plan review has attempted to address this issue through several strategies including making C-class licences non-transferable.

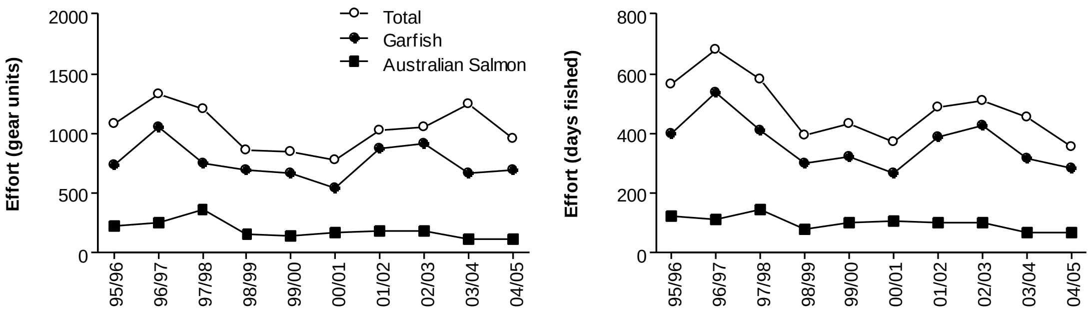
Table 2.3. Total annual catch, effort and number of vessels by fishing methods - 1995/96-2004/05
Effort units are defined in Table 2.1. * Catch data not shown where five or fewer vessels involved.

Gear	Year	Catch(t)	Effort#	Days fished	Vessels
Beach seine	95/96	469.2	1083	559	54
	96/97	354.9	1352	688	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	781	372	31
	01/02	570.9	1027	494	30
	02/03	490.7	1059	511	35
	03/04	238.1	1260	458	31
	04/05	388.4	963	355	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	238	123	10
	00/01	*	224	104	4
	01/02	*	216	91	5
	02/03	*	139	76	4
	03/04	*	68	45	3
	04/05	*	81	37	5
Graball net	95/96	348.0	222349	5440	260
	96/97	378.7	230803	5182	232
	97/98	446.3	230219	5249	216
	98/99	494.1	165298	4706	209
	99/00	360.1	150828	4174	204
	00/01	173.6	86638	3192	186
	01/02	196.0	70705	3303	180
	02/03	231.0	85314	3394	169
	03/04	189.1	77761	2883	162
	04/05	140.4	48940	2330	134
Small mesh net	95/96	38.7	10995	286	20
	96/97	27.0	7940	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	21.9	5810	210	11
	04/05	14.4	5562	202	12
Dip net	95/96	*	320	83	5
	96/97	24.2	1518	364	11
	97/98	33.4	1707	409	22
	98/99	42.4	2690	557	29
	99/00	29.3	2262	500	35
	00/01	22.8	1422	371	27
	01/02	23.9	1491	372	26
	02/03	18.5	1238	335	19
	03/04	15.9	1032	288	18
	04/05	14.1	1001	230	13

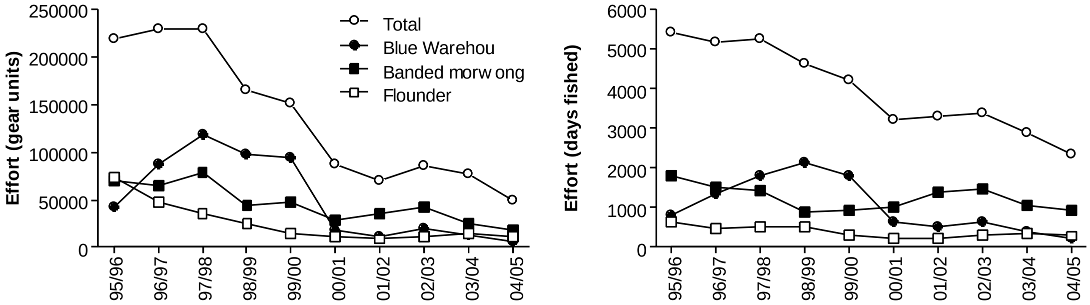
Table 2.3. Continued

Gear	Year	Catch(t)	Effort#	Days fished	Vessels
Fish trap	95/96	41.8	8262	1401	67
	96/97	57.2	10705	1796	66
	97/98	49.9	9864	1875	71
	98/99	53.7	10619	1558	56
	99/00	56.1	10903	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	45.0	6932	1170	54
Drop line	95/96	19.9	423	158	31
	96/97	30.0	433	203	27
	97/98	24.7	536	222	42
	98/99	31.8	663	309	38
	99/00	30.5	376	288	47
	00/01	15.8	380	248	36
	01/02	12.7	218	257	35
	02/03	18.8	263	350	43
	03/04	19.4	378	281	51
	04/05	13.4	342	212	30
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	87.6	17603	1265	126
	99/00	87.7	16501	1436	133
	00/01	74.8	13778	1547	130
	01/02	89.8	15487	1607	138
	02/03	72.3	14956	1544	123
	03/04	76.0	16067	1400	127
	04/05	100.0	20015	1777	124
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	161.5	42198	1002	64
	00/01	65.8	12852	777	48
	01/02	82.8	11759	880	63
	02/03	92.0	27972	1212	65
	03/04	69.4	15545	1208	72
	04/05	100.8	21140	1352	76
Spear	95/96	14.0	1382	366	21
	96/97	19.3	1843	463	28
	97/98	16.8	1977	483	41
	98/99	19.6	1796	449	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	1375	247	22
	03/04	10.7	1432	288	22
	04/05	12.2	1459	328	22

A) Beach Seine



B) Graball



C) Handline

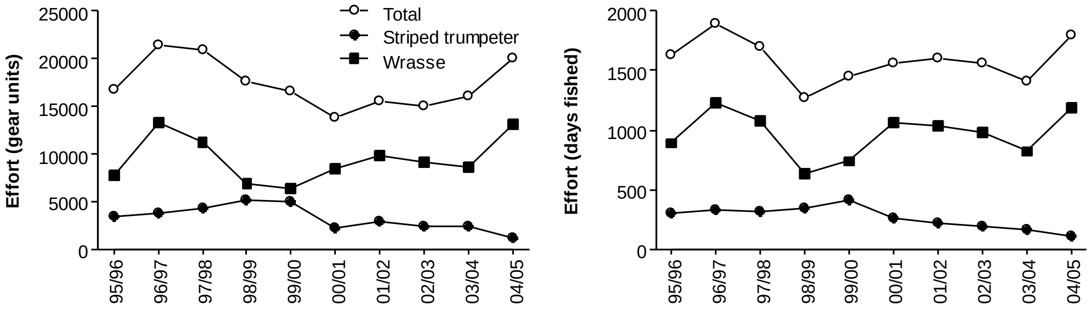


Fig 2.3. Annual effort by selected methods for key species, expressed as gear units (refer Table 2.1) and days fished.

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 3-6.

2.6 Recreational fishery

2.6.1 Catch and effort

Catch and effort information is not routinely available for the recreational fishery. However, a recreational fishing survey conducted between May 2000 and April 2001 does provide the first comprehensive snapshot of the Tasmanian recreational fishery (Henry and Lyle 2003, Lyle 2005). There have been no subsequent surveys to date though there are plans to repeat a state-wide assessment in the near future.

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, the recreational sector accounted for over half of the total catch of flathead, barracouta, jackass morwong, bastard trumpeter, cod, flounder and silver trevally (Lyle 2005). By contrast, the commercial sector dominated the catches of Australian salmon, southern calamary, 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 recreational net licences in 1995 the number of net licences issued rose rapidly from around 8900 to a peak of over 11000 in 1999/00, but have subsequently stabilised at around 8000 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 has varied only slightly since the late 1990s. 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*
Graball Net 1	5615	6290	6685	6709	7477	7401	6960	7695	7313	7408
Graball Net 2	2612	2678	2683	2426	2652	2515	1841	na	na	na
Mullet Net	656	684	738	739	879	845	608	754	753	754
Total licences	**8883**	**9652**	**10106**	**9874**	**11008**	**10761**	**9409**	**8449**	**8066**	**8162**

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 increased towards the end of the 1990s but has fallen over the past 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. 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 logbook design is currently under review and this may go some way to addressing these problems.

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 recent national survey represents an important baseline about this sector. There is a need to consider on-going monitoring of the recreational fishery, since without such information attempts to assess the status of those species with significant recreational catches will be flawed.

2.8 Implications for Management

A major issue confronting the commercial sector at present is that of latent effort. There is general consensus that excess capacity exists in the scalefish fishery, and that options to remove this capacity need to be pursued as a matter of urgency.

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). Related to this is the 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.

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 the population on many southern Tasmanian reefs may be less pronounced than in New Zealand due to large changes in depth occur 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.* 2005</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>Ziegler *et al.* 2005</td></tr>
<tr><td>Growth</td><td>Initially fast for the first 5-6 years (females) or 10-12 years (males)
Males grow to larger sizes than females
Growth accelerated between 1996 and 2004
Growth modelled by 2-phase von Bertalanffy function[1]:
<table>
<tr><th></th><th>$L\infty_1$</th><th>K_1</th><th>$t0_1$</th><th>σ_1</th><th>$L\infty_2$</th><th>K_2</th><th>$t0_2$</th><th>σ_2</th><th>t_{trans}</th></tr>
<tr><td>F95-97</td><td>372.2</td><td>0.58</td><td>0.23</td><td>15.23</td><td>431.1</td><td>0.08</td><td>-15.99</td><td>21.63</td><td>5</td></tr>
<tr><td>F01</td><td>353</td><td>1</td><td>0.33</td><td>12.95</td><td>431.1</td><td>0.08</td><td>-16.18</td><td>21.26</td><td>5</td></tr>
<tr><td>F02-04</td><td>358.3</td><td>0.97</td><td>0.33</td><td>14.66</td><td>431.1</td><td>0.08</td><td>-19.23</td><td>21.15</td><td>5</td></tr>
<tr><td>M95-97</td><td>387.2</td><td>0.58</td><td>0.23</td><td>16.11</td><td>507.6</td><td>0.22</td><td>-0.27</td><td>23.07</td><td>5</td></tr>
<tr><td>M01</td><td>368.5</td><td>0.84</td><td>0.32</td><td>18.77</td><td>507.6</td><td>0.19</td><td>-1.86</td><td>23.35</td><td>5</td></tr>
<tr><td>M02-04</td><td>387</td><td>0.85</td><td>0.32</td><td>16.1</td><td>507.6</td><td>0.21</td><td>-1.24</td><td>21.5</td><td>5</td></tr>
</table></td><td>Ziegler *et al.* 2005</td></tr>
<tr><td>Maturity</td><td>Early age and small size at onset of maturity
Onset of maturity has accelerated and occurred in 2004 at smaller sizes and younger ages compared to 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>F95-97</td><td>-19.8</td><td>0.62</td><td>4 years</td></tr>
<tr><td>F01</td><td>-23.65</td><td>0.76</td><td>2-3 years</td></tr>
<tr><td>F02-04</td><td>-18.9</td><td>0.64</td><td>2-3 years</td></tr>
</table></td><td>Ziegler *et al.* 2005</td></tr>
<tr><td>Spawning</td><td>In a spawning condition between mid to late February and 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>The 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>
<tr><td>Recruitment</td><td>Age structure of banded morwong populations from some east coast sites provides some evidence of year class (recruitment) variability.</td><td>Ziegler *et al.* 2005</td></tr>
</table>

[1] Parameters of the 2-phase von Bertalanffy growth function including the knife-edge age of transition between the two functions (t_{trans}), which were used in the stock assessment model, where data for males and females older than 20 years were pooled by sex and used in all model fits, such that all upper VB functions would converge and sex-specific maximum sizes would be constant across all years

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.* 2005). 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.

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 (33 and 43 cm 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 3 cm to 36 and 46 cm 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.

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 (with reference period 1994/95 to 1997/98).

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 shows 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 exploitation (Ziegler *et al.* 2005), would indicate a resilience of the fish stocks to overfishing. Though the fact that such significant changes have occurred is a strong indication that stocks have experienced heavy fishing pressure and potentially unsustainable fishing mortality levels. This is all the more important because the species is 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).

In addition to catch and effort analysis and catch rate standardisation, biological indicators have been investigated and updated with information collected during early 2005. These indicators include trends in size and age composition and sex ratios. Data for these analyses were derived from fishery dependent and independent sampling in the Tasman, Bicheno and St. Helens regions.

Results from a stock assessment model for banded morwong, 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) are also summarised, including the projections from a harvest strategy evaluation with constant catch scenarios.

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

3.6.1 Catch

State-wide reported catches have continued to decline and the 2004/05 catch of 42 tonnes represented a drop of about 10% compared with the previous year (Fig. 3.1A).

At the regional scale, catches have remained relatively stable compared to the previous year in most regions including Bicheno, where they had been declining sharply up to 2003/04 (Figs. 3.1B and 3.2). The north east coast was the only exception, where the expansion of the fishery seen between 2002/03 to 2003/04 came to a halt and is now relatively unimportant once again (not visible on Fig. 3.2 due to the 5 vessel rule).

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). 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.

Evaluation of 2004/05 catches against performance indicators

- The State-wide catch was below the 1994/95 to 1997/98 range and therefore triggered the performance indicator.
- Catches in the Bicheno and St. Helens fishing regions were below the reference range and therefore triggered the performance indicator.
- The catch in the north east coast declined by more than 30% and therefore the rate of change performance indicator was triggered in both instances.

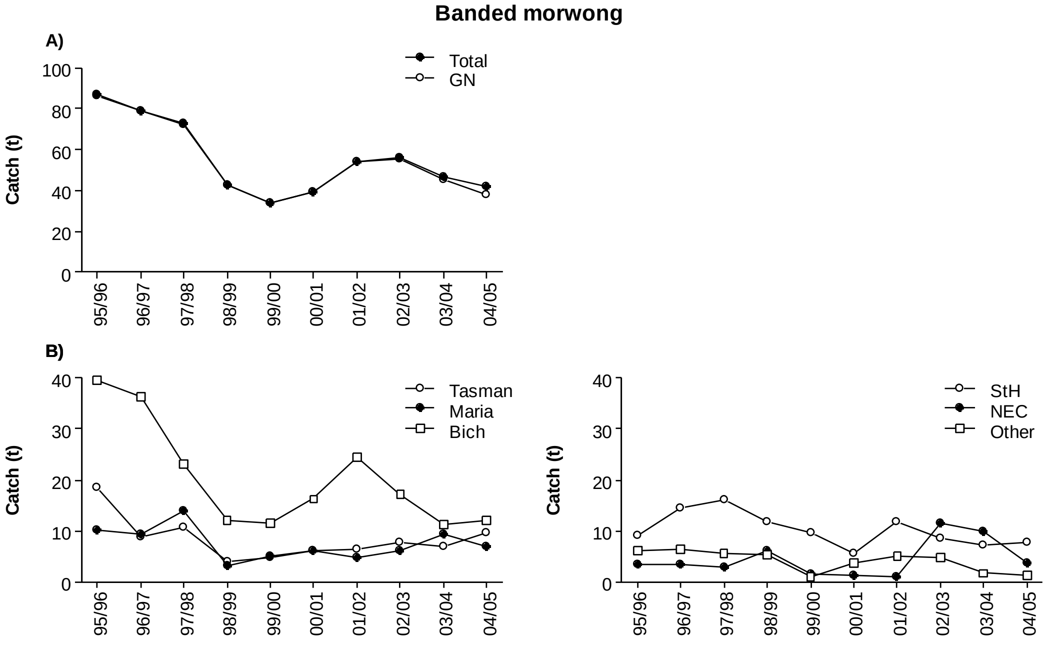


Fig 3.1. Banded morwong graball catches (tonnes) since 1995/96: A) state-wide catches; and B) catches in the Tasman, Maria and Bicheno (Bich) regions (left), and in the St. Helens (StH), north east coast (NEC) and remaining (Other) regions (right).

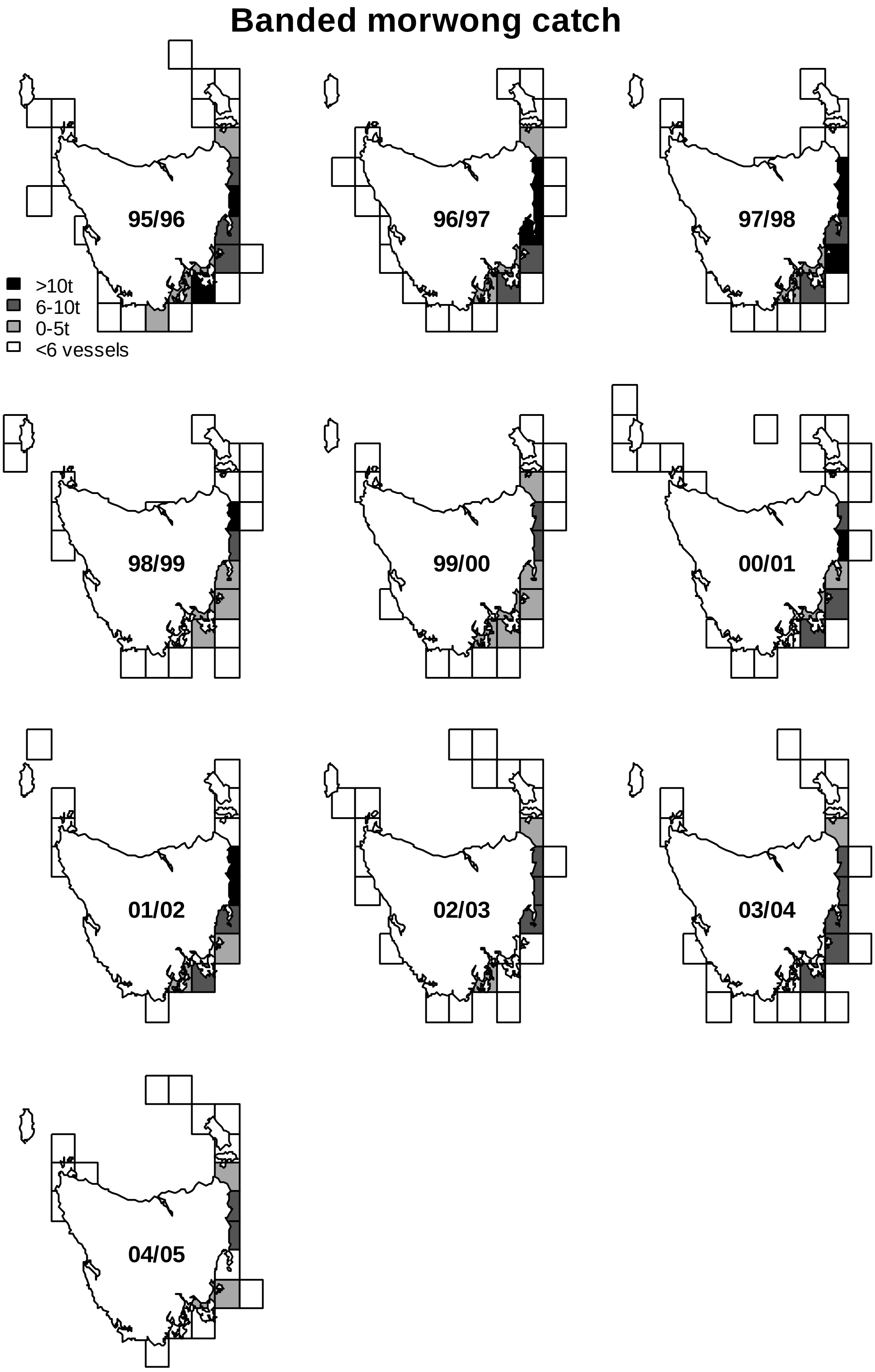


Fig 3.2. Banded morwong catches (tonnes) by fishing block and year since 1995/96.

3.6.2 Fishing effort

Total effort expressed as days fished or gear units (100m net hour) has continued to decline in 2004/05 (Fig 3.3A). This continues the trend since about 2000 after the introduction of gear restrictions as part of the management plan that fishers progressively deployed less gear on average for each day fished. 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.* 2005).

Regionally, the most conspicuous trends in effort (days fished) have been stability in effort in the Bicheno, Maria and Tasman regions, a slight increase of effort in the St Helens region after the drop in the year before, and the sharp decrease of effort in the north east coast region after a massive two-year peak (Figs. 3.3B and 3.4).

Evaluation of 2004/05 effort against performance indicators

- State-wide and regional graball effort has not triggered the performance indicator.

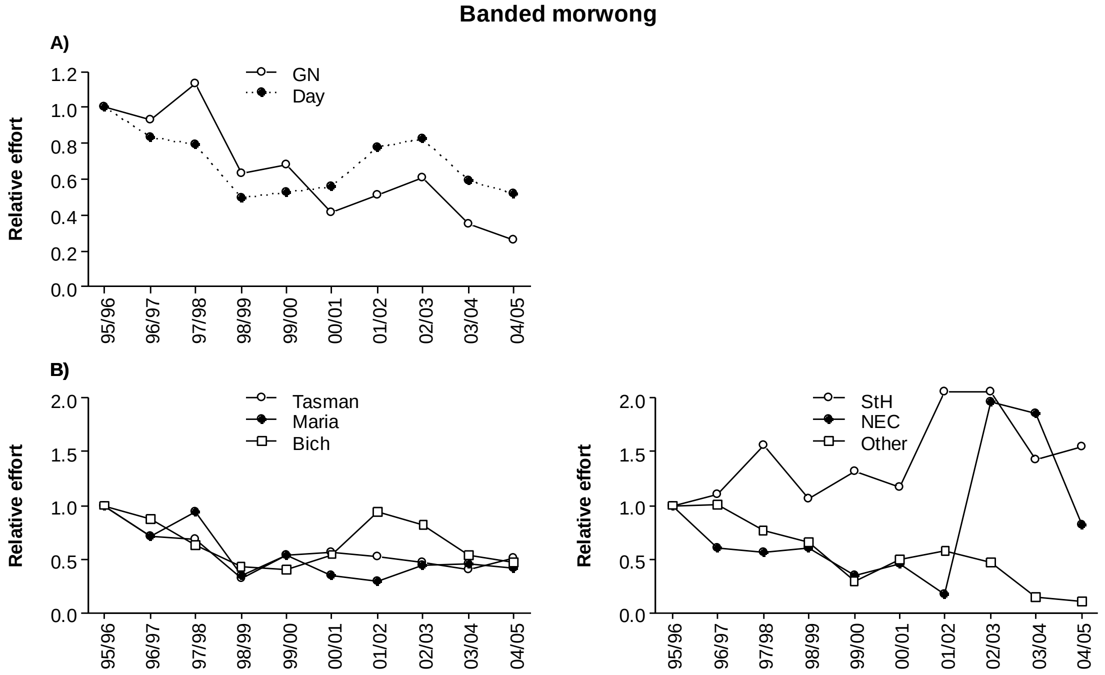


Fig 3.3. Banded morwong graball effort relative to 1995/96 levels: A) state-wide relative effort based on gear units (GN) and days fished (Day); and B) relative effort (days fished) in the Tasman, Maria and Bicheno (Bich) regions (left), and the St. Helens (StH), north east coast (NEC) and remaining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

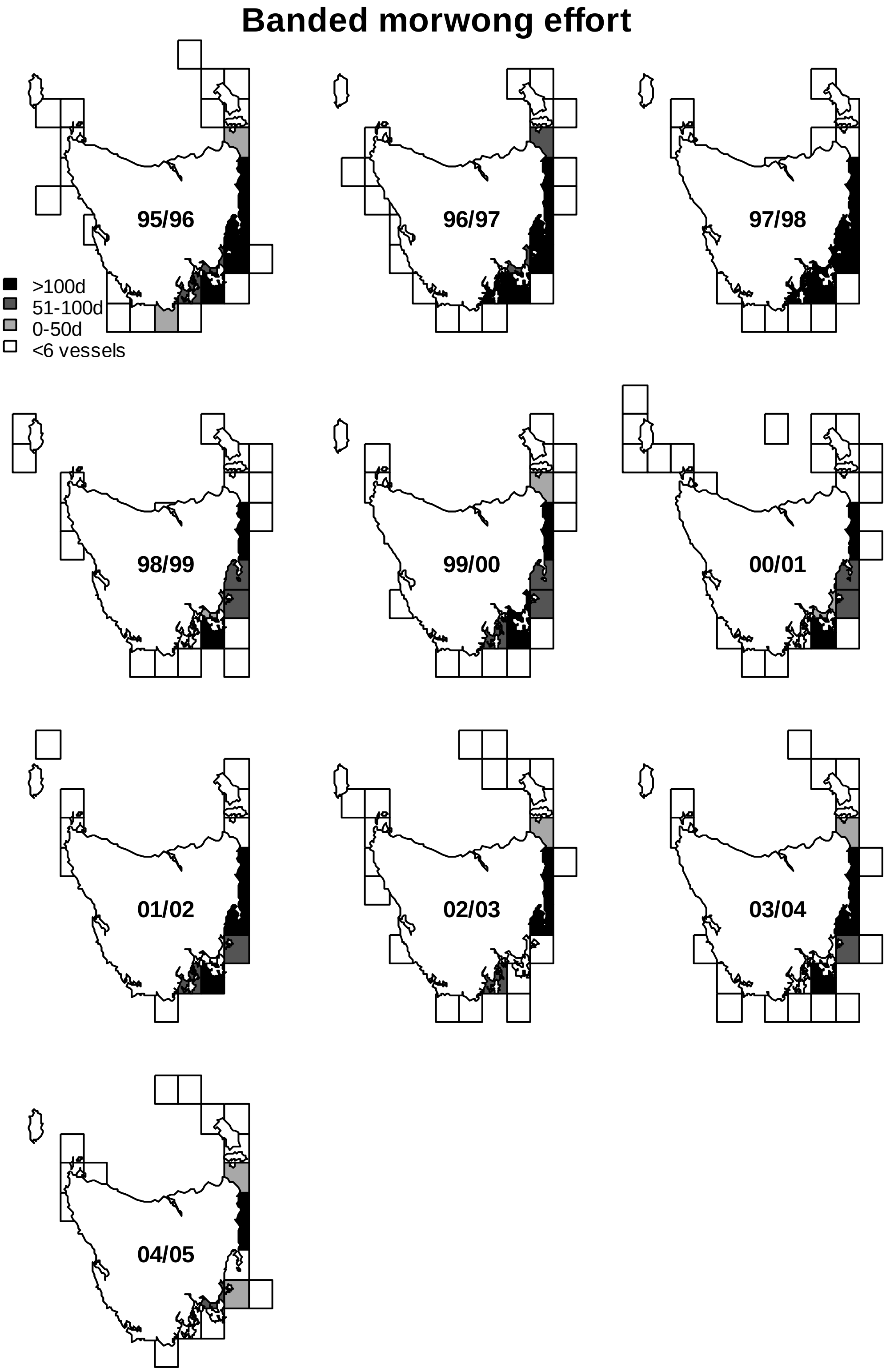


Fig 3.4. Banded morwong effort (days fished) by fishing block and year since 1995/96.

3.6.3 Catch rates

Evaluation of 2004/05 catch rates against performance indicators

- State-wide standardised catch rates have not triggered the performance indicator.
- Standardised catch rates in the Bicheno and St. Helens regions were less than 80% of the lowest value for the 1995-97 period and therefore triggered the performance indicator.

As an alternative to using the geometric mean of catch rates as a stock indicator (Fig. 3.5), catch rates of banded morwong have been standardised using generalized linear models (GLM) to reduce the impact of obscuring effects such as region, depth, season or skipper (Kimura 1981, 1988). However, while standardisation is preferred to the geometric mean, there remains no guarantee that a 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 a state-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 79% 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 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 turned out not to be a very 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 and the Bayesian Information Criterion (AIC and BIC; Burnham and Anderson 1998).

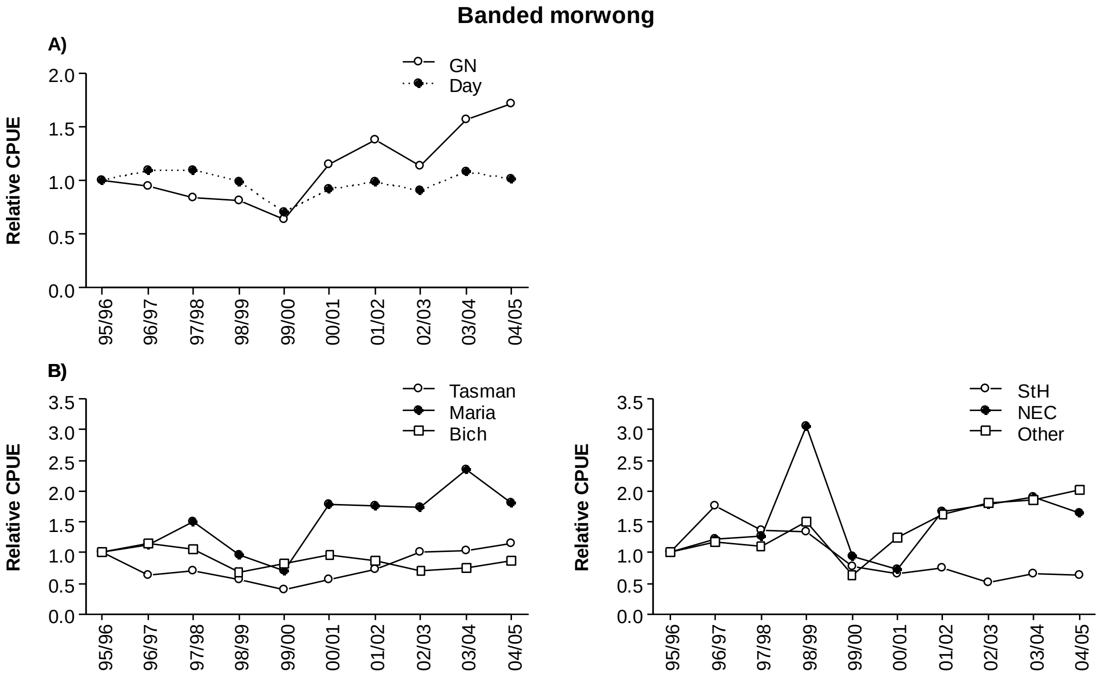


Fig 3.5. Banded morwong graball catch per unit effort (CPUE) relative to 1995/96 levels: A) state-wide CPUE based on gear units (GN) and days fished (Day); and B) relative CPUE (days fished) in the Tasman, Maria and Bicheno (Bich) regions (left), and the St. Helens (StH), north east coast (NEC) and remaining (Other) regions (right).

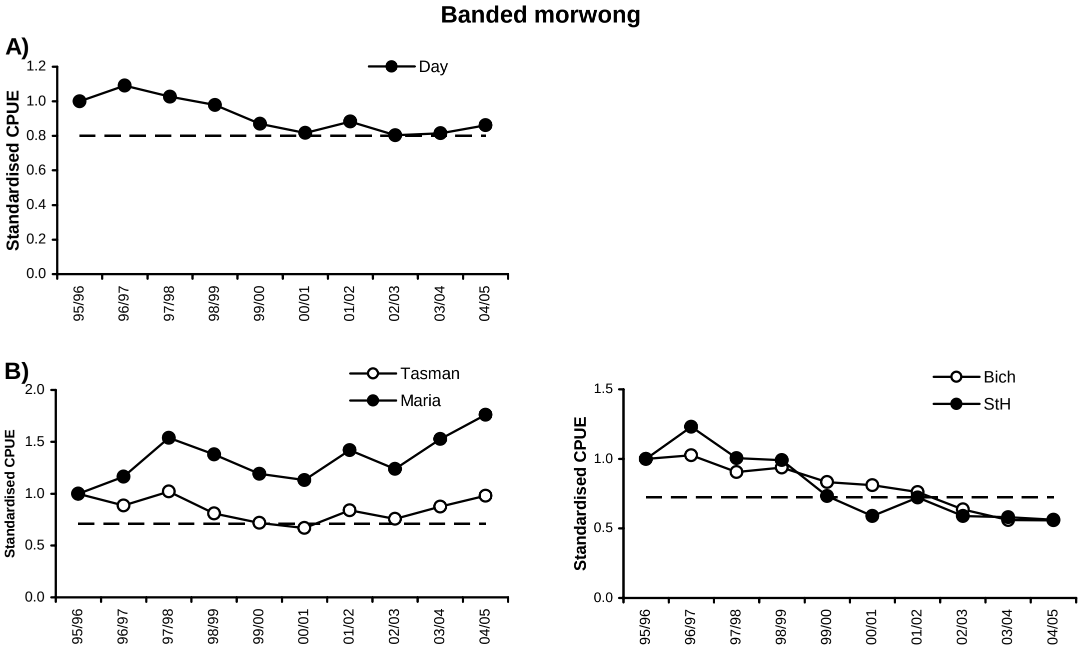


Fig 3.6. Banded morwong standardised graball catch per unit effort (CPUE) relative to 1995/96 levels: A) state-wide CPUE based on days fished (Day); and B) relative CPUE (days fished) in the Tasman and Maria regions (left), and the Bicheno (Bich) and St. Helens (StH) (right). Dotted line marks the reference limit.

State-wide unstandardised and standardised catch rates fell steadily between 1995/96 and 1999/2000, accompanying the declines in catch and effort (Figs. 3.5A and 3.6A). Since then catch per day has stabilised, while catch per gear units has risen to above 1995/96 levels.

Regional trends showed some differences between unstandardised and standardised catch rates (Figs. 3.5B and 3.6B). While unstandardised catch rates in the Maria region dropped in 2004/05 compared to the previous year, the standardised catch rates continued to increase at a high level. Conversely, unstandardised catch rates in the Bicheno region further increased in 2004/05, whereas the standardised catch rates remained stable below reference limits. Both unstandardised and standardised catch rates in the St. Helens region stabilised at low levels (below reference limits), and those in the Tasman region continued to increase.

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.

Region		**Model**	**Variation described**
Whole East Coast	Ln cpue =	Constant + year + vessel + bimonth + seals + block + depth + skipper + block*seals	44.7%
Tasman	Ln cpue =	Constant + year + bimonth + skipper + seals + block + depth + skipper*seals	43.3%
Maria	Ln cpue =	Constant + year + skipper + bimonth	44.8%
Bicheno	Ln cpue =	Constant + year + skipper + bimonth + seals +vessel + block + skipper*seals	43.2%
St. Helens	Ln cpue =	Constant + year + bimonth + vessel + seals + bimonth*seals	50.9%

3.6.4 Size composition

New size composition data available for this assessment collected in 2005 relate to the Bicheno (Fig. 3.4) and Tasman region (Fig. 3.5) and are very similar to those for previous years.

Male size compositions are typically bimodal, however, the relative sizes of the modes have altered over time. The dominant size class dropped from around 51 cm in the samples from the mid 1990s to around 39 cm and 37cm in the Bicheno and Tasman regions, respectively, in the most recent samples. Female size compositions are generally unimodal, but the position of the mode has moved from 41 cm to around 39 cm and 37cm in the Bicheno and Tasman regions and distributions have become skewed towards a greater representation of smaller size classes in recent years.

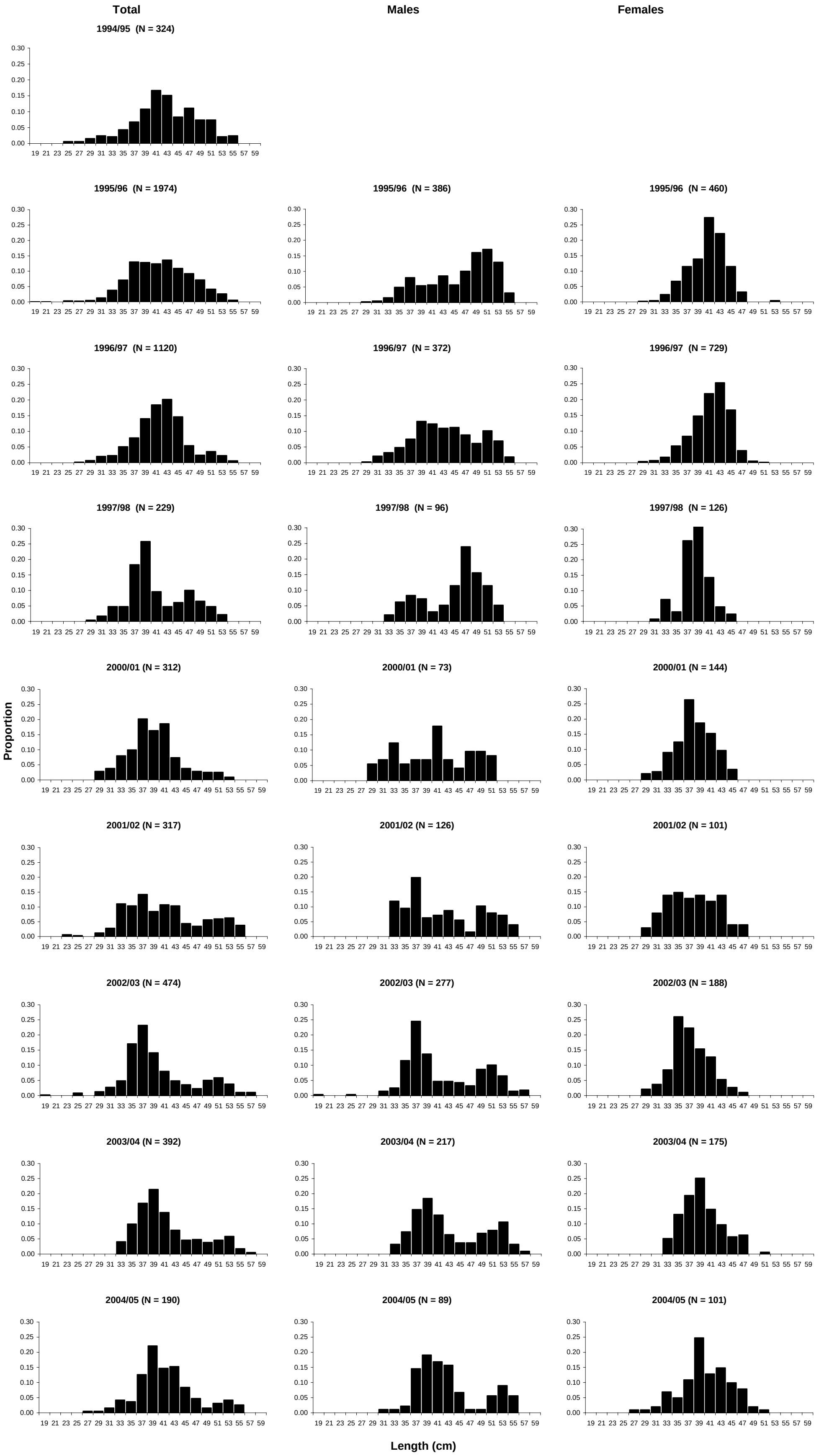
The changes in modal size are reflected in changes in median size, a more appropriate measure than average size (Fig. 3.9). While median sizes varied considerably between years and regions, they have generally declined from the mid 1990s to the early 2000s in all regions to around 39 cm for males and 37cm for females. Since then, median sizes for males and females have slightly increased in the Bicheno region, but remained stable in the Tasman region.

In practice, changes in mesh sizes may have masked even stronger changes in the size composition over time. In the mid 1990s most gillnets used by fishers had mesh sizes of 133 mm whereas in the latter part of the 1990s most fishers had switched to mesh sizes of around 140 mm, which are more selective for larger fish.

While decreases in fish size are consistent with expected impacts of fishing on the stocks, the biological significance of these observations is not clear. Firstly, levels of change that are considered either tolerable or significantly severe have not been defined. Secondly, relative size compositions are not useful for distinguishing between the effects of the removal of larger fish and/or increases in the numbers of smaller fish through recruitment. And thirdly, beside fishing mortality which includes handling mortality and seal-induced mortality, seasonal changes in availability of fish may have also contributed to the observed changes.

Evaluation against size composition performance indicator

- There have been substantial changes in the size structure of banded morwong catches since the mid 1990s, with changes consistent with the impacts of fishing on the stocks. However, the full implications of these changes for the stock status are uncertain.



Total

Males

Females

1994/95 (N = 324)

1995/96 (N = 1974)

1995/96 (N = 386)

1995/96 (N = 460)

1996/97 (N = 1120)

1996/97 (N = 372)

1996/97 (N = 729)

1997/98 (N = 229)

1997/98 (N = 96)

1997/98 (N = 126)

2000/01 (N = 312)

2000/01 (N = 73)

2000/01 (N = 144)

2001/02 (N = 317)

2001/02 (N = 126)

2001/02 (N = 101)

2002/03 (N = 474)

2002/03 (N = 277)

2002/03 (N = 188)

2003/04 (N = 392)

2003/04 (N = 217)

2003/04 (N = 175)

2004/05 (N = 190)

2004/05 (N = 89)

2004/05 (N = 101)

Fig. 3.7. Annual size composition of total sample, male and female banded morwong in catches of the Bicheno fishing region between 1994/95 and 2004/05. Relative frequencies in 2 cm bins (values given denote mid-point).

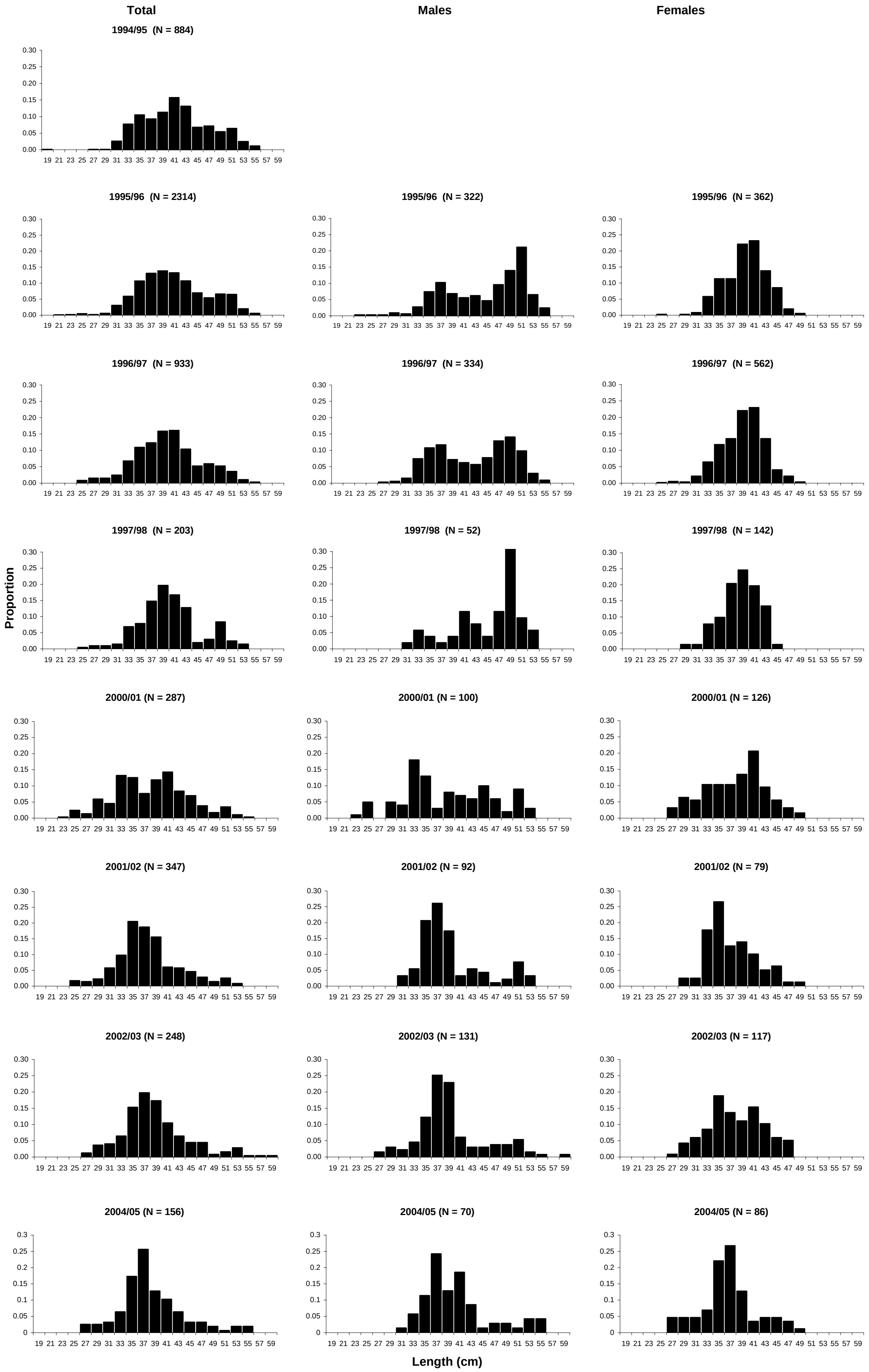


Fig. 3.8. Annual size composition of total sample, male and female banded morwong in catches of the Tasman fishing region between 1994/95 and 2004/05. Relative frequencies in 2 cm bins (values given denote mid-point).

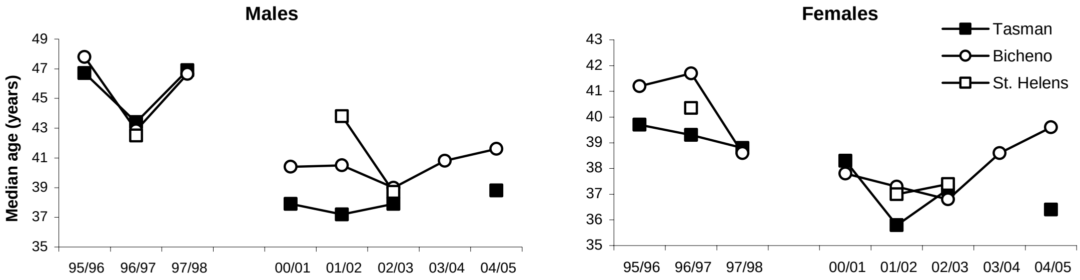


Fig. 3.9. Median size of male and female banded morwong in overall catches of the Tasman, Bicheno and St. Helens regions.

3.6.5 Age composition

Banded morwong have been sampled during the spawning season in the Bicheno and Tasman region between 1995/96 and 2004/05, and in the St. Helens region between 2001/02 and 2002/03. Age has been determined and validated by analysis of otolith structure (Murphy and Lyle 1999). Age composition information is currently available for about 3000 individuals.

Fishing has impacted on the age composition of male and female banded morwong. Over time, individuals up to 6 years have become increasingly dominant in samples of males in all regions, representing 87% and 77% of the 2004/05 Bicheno and Tasman samples (Fig. 3.10). Because males grow rapidly through the legal-size keyhole, most males are susceptible to fishing between the ages of 4-10 years.

Since 2000/01 in the Tasman and Bicheno region, males older than 10 years have been proportionally less abundant compared to the samples taken during the mid 1990s. Reductions are 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. 3.11). Fishing has had a marked impact on age structure in the Tasman and Bicheno regions. While there are still old females present, their relative contribution has decreased significantly in recent years compared to the mid 1990s, such that females up to 6 years, now dominate catches (Fig. 3.8). These data suggest that the fishery is becoming increasingly dependent on new recruits.

Changes in age composition are reflected in the trends based on median ages (Fig. 3.12). 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 7 years since the mid-1990s, a trend that is reflected in both Bicheno and Tasman regions.

Evaluation against age composition performance indicator

- There has been a significant change in the age composition of commercial catches since the mid 1990s that is consistent with a significant fishery impact on the populations.

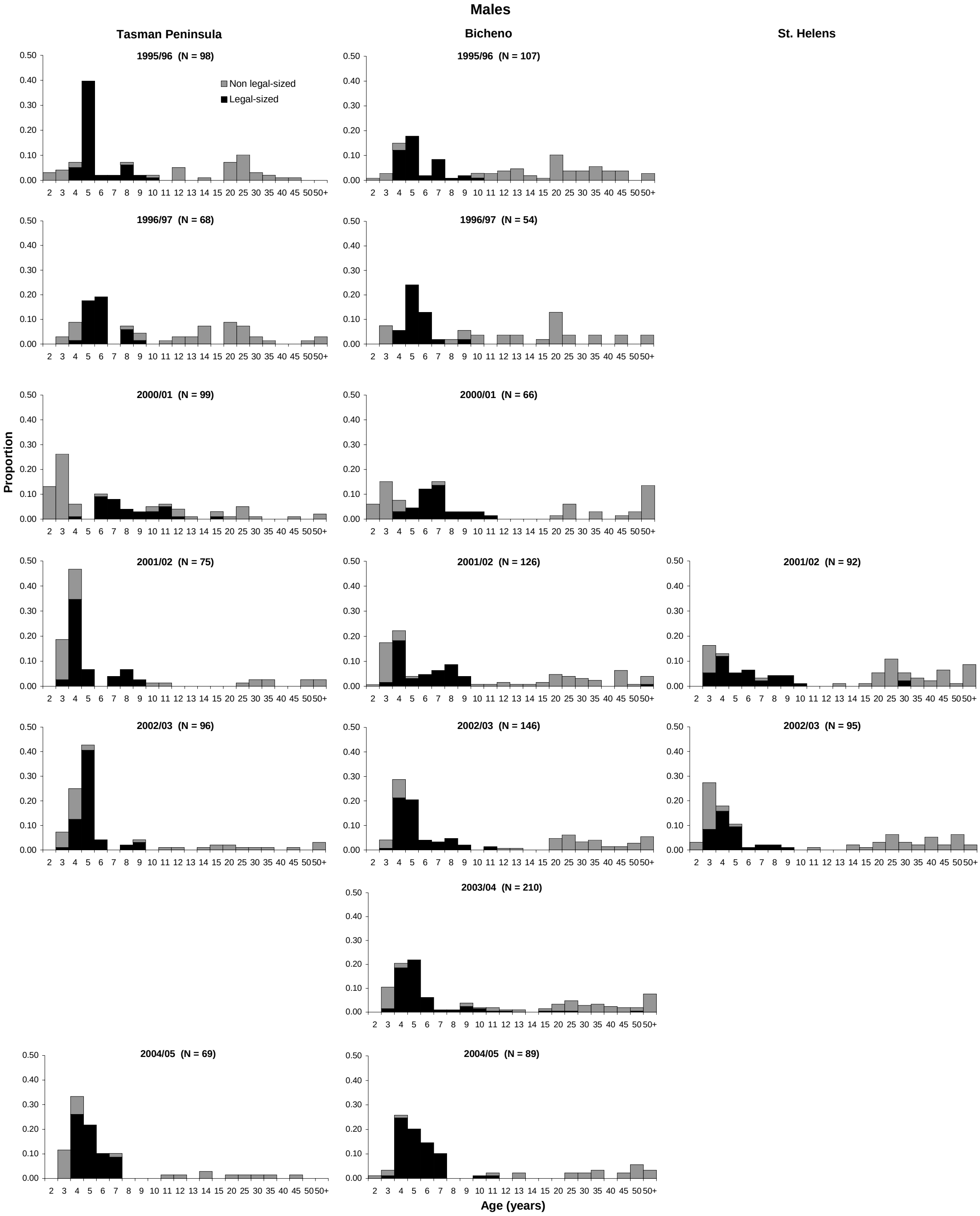


Fig. 3.10. Relative age composition of male banded morwong in research catches from the Tasman, Bicheno and St. Helens fishing regions between 1995/96 and 2004/05. Black bars refer to legal-sized fish, grey bars to non-legal-sized (undersized and oversized) fish. Relative frequencies for fish 16-50 years in 5-year classes, and for fish older than 50 years in a single class (50+).

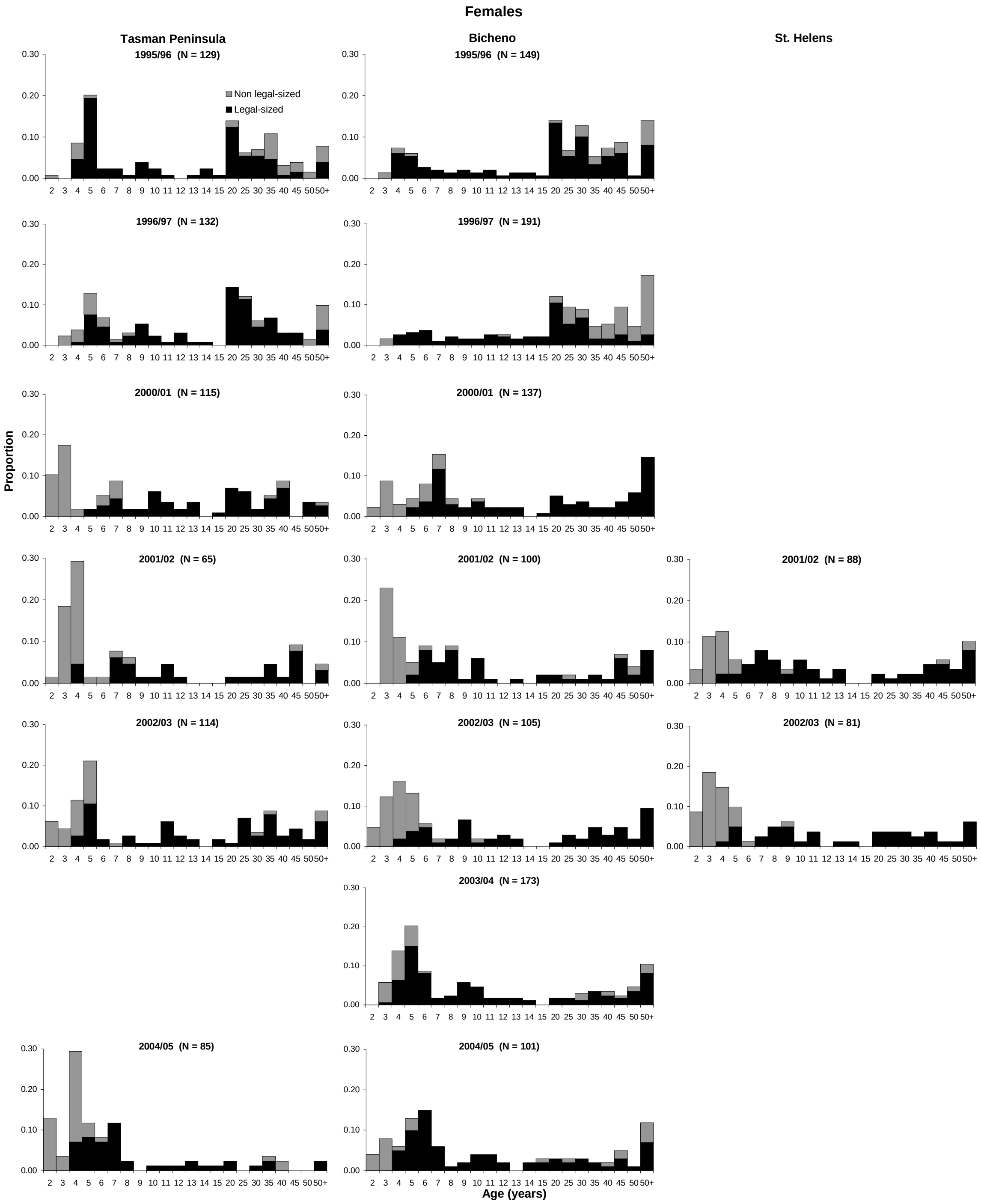


Fig. 3.11. Relative age composition of female banded morwong in research catches of the Tasman, Bicheno and St. Helens fishing regions between 1995/96 and 2004/05. Black bars refer to legal-sized fish, grey bars to non-legal-sized (undersized and oversized) fish. Relative frequencies for fish 16-50 years in classes of 5 years, and for fish older than 50 years in a single class (50+).

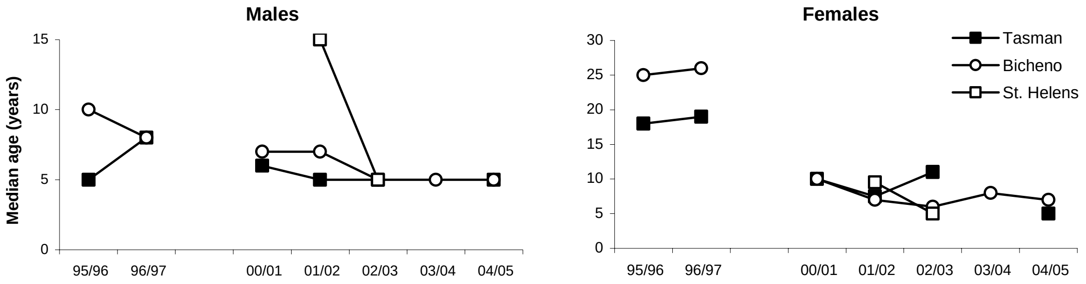


Fig. 3.12. Median age of male and female banded morwong in research catches of the Tasman, Bicheno and St. Helens regions.

3.6.6 Sex ratio

Sex ratios based on spawning season surveys in the Bicheno and Tasman regions have shifted from female dominated (up until 2001) to roughly equal numbers of males and females in the more recent samples (Fig. 3.13). The proportion of females in the legal-sized catch dropped consistently in both regions, which would be at least partly caused by the greater selective fishing pressure on females. The sudden shift in sex ratios between 2000/01 and 2001/02 in both Bicheno and Tasman regions is difficult to explain but may be due to sampling issues, mediated through some fish behaviour. For instance, activity patterns and hence vulnerability may change at different times within a spawning season. Consistency in ratios since 2001/02, however, lends support for a real change in population sex ratios.

Change in sex ratios were also apparent in the total sample but, reflecting the influence of the substantial numbers of undersized recruits of both sexes, were less extreme when compared with the legal-sized catch.

Evaluation of sex ratio performance indicator

- There have been substantial changes in sex ratio that are linked to differential fishing pressure on males and females (due to growth rate differences), providing further evidence for an impact of fishing on population structure.

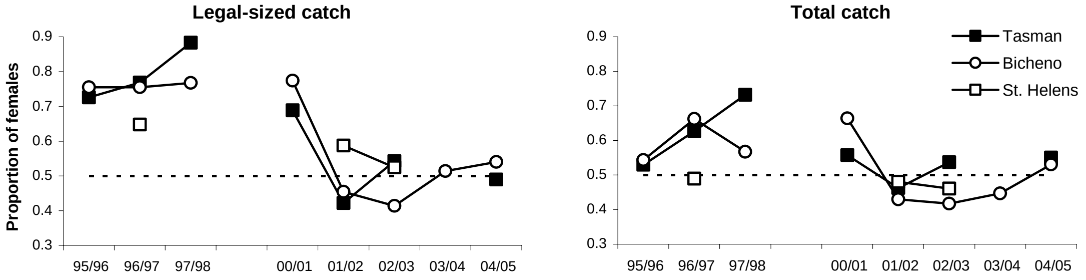


Fig. 3.13. Proportion of female banded morwong in the legal-sized and total catch in the Tasman, Bicheno and St. Helens fishing regions. Dotted lines represent a sex ratio of 1:1.

3.6.7 Other indicators

Catch curve and yield-per-recruit and spawner biomass-per-recruit analyses have not been up-dated and reference should be made to the 2003 assessment for details (Lyle *et al.* 2004).

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 between 1990-2004 from the east coast of Tasmania. A more detailed description of the model structure can be found in the Appendix 3 and in Ziegler *et al.* 2005.

The model simulated five discrete banded morwong stocks in the stock assessment regions (as defined in Chapter 3.5) along the east coast of Tasmania. 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).

The number of stocks used in the model 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.

3.7.2 Biomass distribution

The fishery-dependent and independent information from the separate assessment regions was insufficient to estimate the biomass in each region individually. Therefore, the biomass was estimated for the overall east coast and then distributed among the regions. This increased the stability of the biomass estimate in each region, especially where the available data was limited and noisy such as in the Bruny region. However, on the down side this approach required an estimate of relative biomass distribution in each region. As a proxy the area of reef habitat or fished reef area was used for this, 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/).

To supplement the mapping information and to estimate the reef area in areas without habitat maps, a small number of banded morwong fishers were asked to identify the reefs on coastal charts that are fished for banded morwong or that were believed to be suitable fish habitat. These markings were read into the ArcView GIS program to estimate the total habitat area for each region. When compared with the habitat maps, fishers tended to estimate larger reef habitats. Based on this, estimates of habitat area based uniquely on fisher's descriptions were adjusted to 80% of their estimates. In addition, the actual area fished in the Bruny region was significantly smaller than the total reef area, presumably due to unproductive bottom or different habitat structure particularly in the southern parts. The reef area relevant to the fishery was therefore limited to that in the northern part of the region.

The habitat estimates derived from this process were used as best estimates for biomass in each region. Given the high degree of uncertainty in these estimates relating to estimation errors and the unknown relationship between reef area, reef type and standing biomass, three different scenarios of regional biomass distribution were examined in the assessment model, with the contribution of the Bicheno stock ranging from 30-65%, equal contributions from the Tasman, Maria and St. Helens regions and a smaller contribution from the Bruny region to complement those in the other regions (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).

Table 3.2: Biological and model parameters used in the assessment models.
[1] Biomass onshore as estimated from habitat maps in the Tasman and Maria regions. [2] Equivalent to a singe population within the stock; movement rates not applicable. [3] % relates to the proportion of the whole coast considered

Model parameter	Best estimate	Range of values tested			
Recruitment variability σ	-	0.1	0.2	0.6	
Biomass onshore (<25m) in %	0.70 / 0.78[1]	1.0[2]	0.75	0.5	
Movement rates between on/offshore populations	-	1.0	0.75	0.5	0.25
Regional biomass in 5-stock model (in %)[3]		A	B	C	
St. Helens	0.16	0.1	0.15	0.2	
Bicheno	0.51	0.65	0.5	0.3	
Maria	0.15	0.1	0.15	0.2	
Tasman	0.12	0.1	0.15	0.2	
Bruny	0.06	0.05	0.05	0.1	

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 1998), 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). 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. 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 model operated on an annual time step starting on the 1st of May, and was fitted to 15 years of commercial catch and effort data from the earliest catch reports available in 1989/90 to 2003/04 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 1989. 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, it was believed, from discussions with rock lobster fishers, to have been low compared to that taken by the targeted fishery in the mid 1990s.

3.7.3 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 (Tasman and Bicheno regions), 2001-2003 (Tasman, Bicheno and St. Helens regions), and 2004 (Bicheno region).

Biological characteristics such as growth, age at maturity and natural mortality were assumed to be the same in each region and known without error. Length at age was modelled by a sex-specific 2-phase von Bertalanffy growth function (Ziegler et al. 2005). Because growth and maturity were generally similar between regions, single growth and maturity functions were used across all regions in any given year. However, growth was found to have increased and maturity to have accelerated over time and three periods with different specific growth and maturity patterns were identified. For the periods 1990-1998, 1999-2001 and 2002-2004, all available data from 1996-1997, 2001 and 2002-2004, 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 all upper VB functions would converge and sex-specific maximum sizes would be constant across all years.

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). 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).

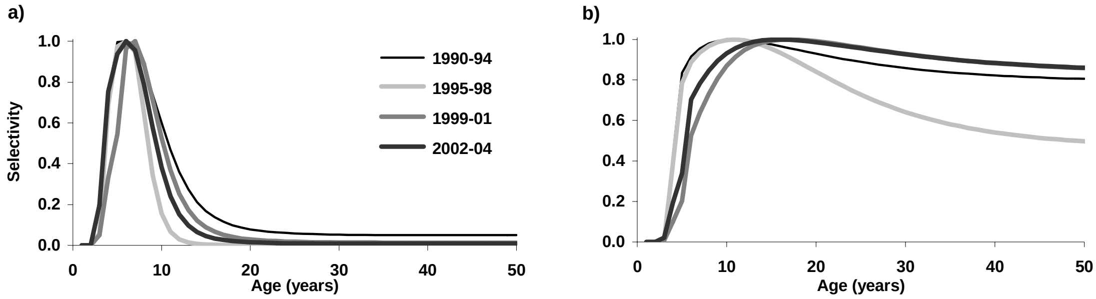


Fig. 3.14: Selectivity at age for (a) male and (b) female banded morwong for mesh size 133 mm, 33-48 cm size limits and growth derived from 1996-97 sampling (light black line); mesh size 137 mm, 33-43 cm size limits and growth derived from 1996-97 sampling (heavy light grey line); and mesh size 137 mm, 36-46 cm size limits and growth derived from 2001 sampling (heavy dark grey line) and 2002-04 sampling (heavy black line).

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.

Because growth accelerated and size limits changed over the years of the study, four 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. The growth acceleration found in the catch samples between 2001 and 2003 impacted on the selectivity curve and was also assumed to have started in 1999.

3.7.4 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, Water and Environment (DPIWE). 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, a more plausible catch history was estimated model based on the catch returns from the east coast (Fig 3.15). Particularly 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 2000-2002.

The standardised catch rates of the individual regions were used as input variables in the model.

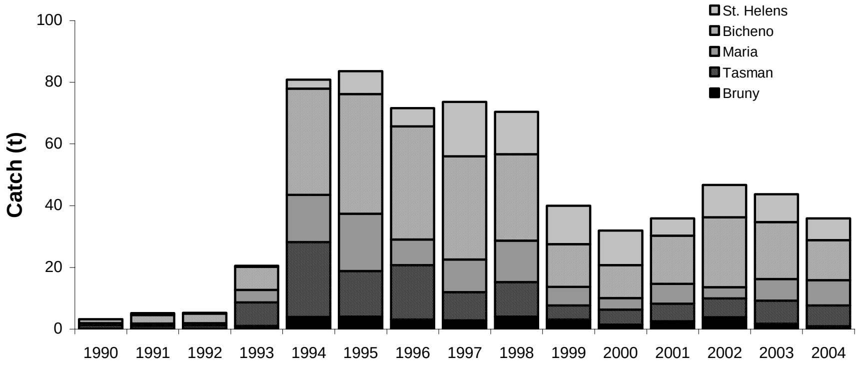


Fig. 3.15: Banded morwong catch history with contribution from each region between 1990-2004.

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 $\hat{q}$. However, the banded morwong catch and effort data indicated that catchability differed between 1996-1999 and 2000-2004, and thus two catchability coefficients were estimated. This change could have been caused by a combination of new management regulations implemented in 1999 and increasing interactions with seals around this period. 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.

3.7.5 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 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 model 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, recruitment was fitted in the model and constrained by a penalty term contributing to the overall log likelihood. This penalty term was related to the recruitment variability, which was varied from low ($\sigma = 0.1$) to high ($\sigma = 0.6$).

3.7.6 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, resulting in an over-parameterized model. Under such circumstances an array of sensitivity analyses are usually performed to test the impact of the assumptions. Here, two major sources of variation were immediately apparent, viz. the familiar recruitment variability and the less commonly investigated 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. In addition to the three levels of recruitment variability, 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 based on the relative habitat area estimates, with the regional biomass allocation to Bicheno ranging from 65% in scenario A, to 50% in scenario B, and 30% in scenario C. This reflected the fact that a significant proportion of the total yield from the fishery came from this stock. In total there were 81 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, and sex ratios. 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 with 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 recruitment levels in each year of the fishery.

3.7.7 Model fitting

While all models provided similar fits to the changes observed in catch rates (Fig. 3.16), the quality of the model fits was largely determined by the fit of both the recruitment variability and depth distribution of biomass combined with movement rates between onshore and offshore populations to the age composition, and the regional biomass distribution. An improved representation of the age composition data were obtained when high recruitment variability was assumed (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 results from model fits with recruitment variability $\sigma = 0.2$ were intermediate or very similar to those with $\sigma = 0.1$ or 0.6, and are therefore usually not presented.

The number of males older than 15 years (pooled in the '16+' age class) were badly overestimated by all models (Fig. 3.17). 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.

The onshore biomass and movement rate scenarios had a strong influence on the fit to the age composition, and the dynamics of the spatial model were primarily determined by the balance between new recruitment and movement from offshore to onshore populations. Not surprisingly, as recruitment variability was allowed to increase the importance of onshore movement from unfished areas reduced in importance. This process was obscured by the biomass distribution scenario. For the strongly aggregated biomass distribution in scenario A, all recruitment variation options indicated best fits with only 50% of biomass onshore and 0.25 mobility. In Scenario B, the same scenarios provided best fits, equalled by the fit of a biomass distribution of 75% onshore with 0.25 mobility as recruitment variability was permitted to rise to $\sigma = 0.6$ (log likelihood within 1.94 of each other, Haddon 2001). When the regional biomass was most evenly distributed in scenario C, the quality of fit was greatly influenced by the onshore biomass, *i.e.* the immediately available biomass. The optimum model fits for the lowest permitted recruitment variability $\sigma = 0.1$ were found with 75% of biomass onshore and mobility rates of 0.25 or 0.5. As recruitment variability was allowed to increase, the optimum conditions of biomass distribution and mobility altered to 100% (with no mobility) or 75% onshore with mobility rates of 0.25.

These interactions between the various influences of regional biomass distribution, recruitment variability, onshore/offshore biomass distribution, and mobility could not be clarified further without additional information due to the over-parameterization of the model. But despite significant differences in the log likelihoods, selecting the optimum model purely on quality of fit seemed inappropriate and would have not necessarily been correct without further evidence concerning recruitment variability and biomass distributions. Given this substantial model uncertainty, uncertainty in relation to parameter estimates or samples was not investigated. Rather model uncertainty is presented here based on the range of onshore/offshore biomass distribution and mobility.

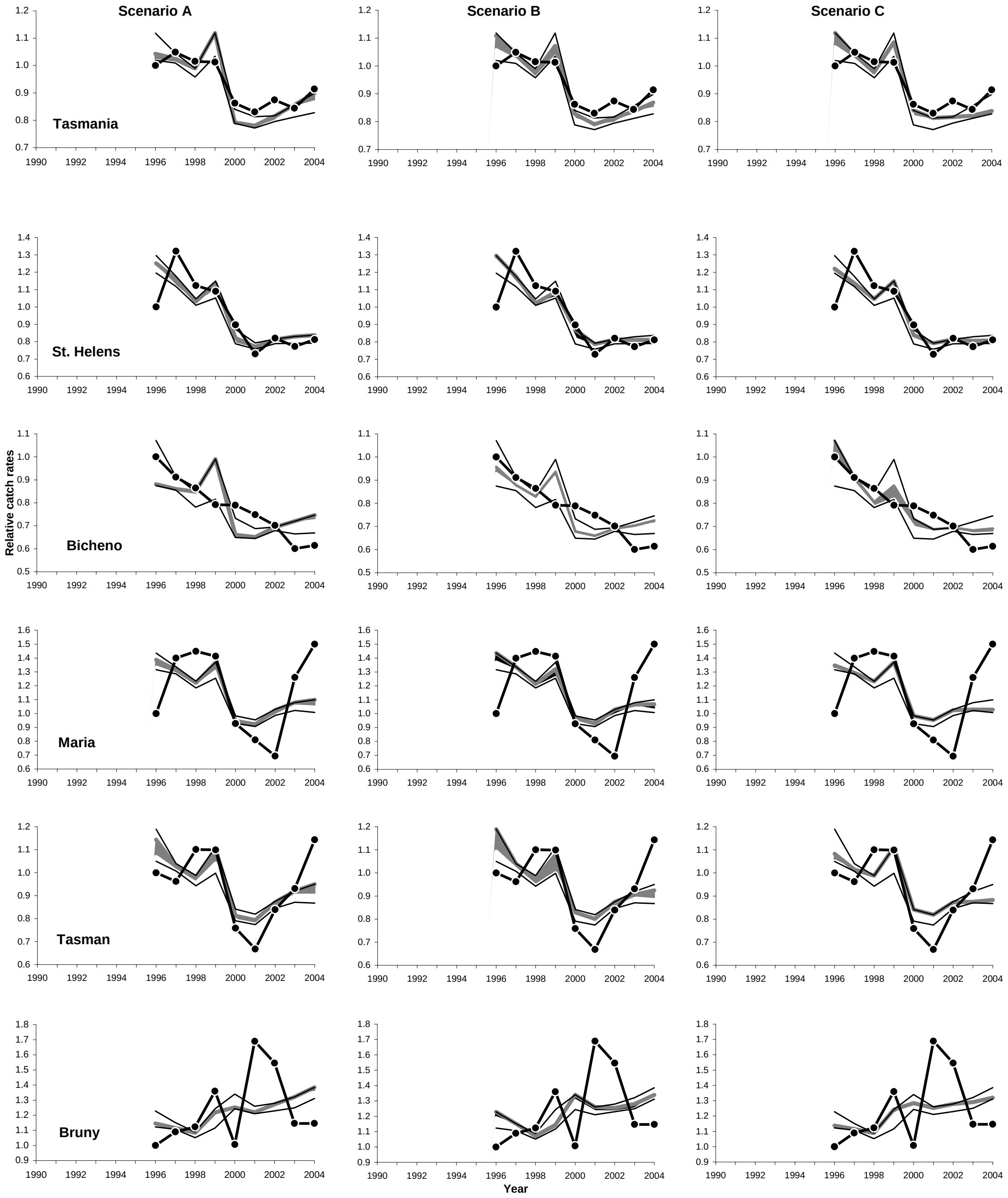


Fig. 3.16: Catch rates for the regional biomass scenarios A, B and C Tasmania-wide and in each of the 5 regions for recruitment variability $\sigma = 0.6$ between 1996-2004. Observed standardised catch rates relative to the levels in 1996 (black circles and heavy black lines), range of model predictions (grey) of all onshore biomass and movement rate scenarios, and minimum and maximum estimates of all regional biomass, onshore biomass and movement rate scenarios (light black lines). Note varying catch rate scales.

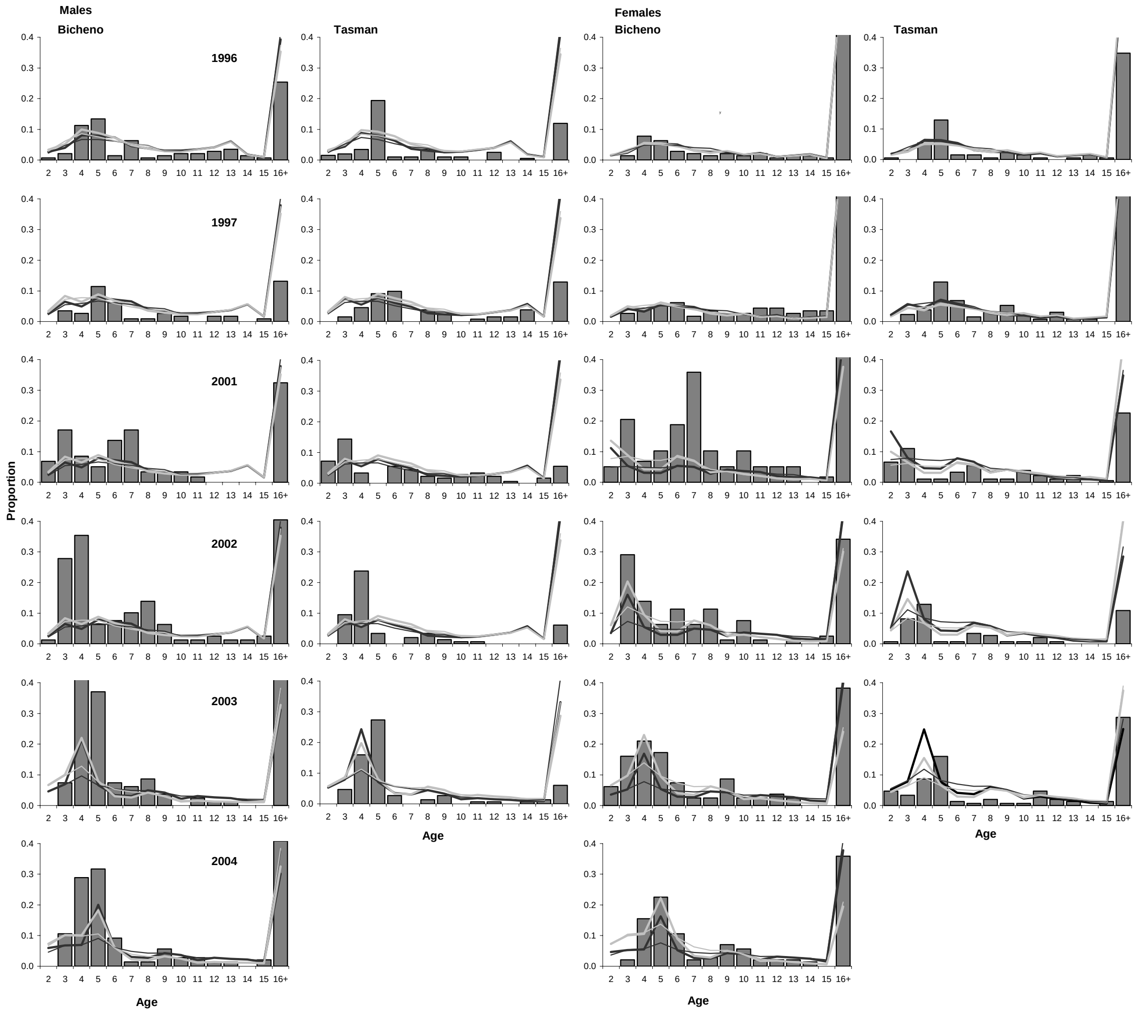


Fig. 3.17: Age composition in relative proportions of male and female banded morwong in biological samples from 1996-1997, and 2001-2004 in the Bicheno and Tasman regions with all biomass onshore and therefore available to the fishery: Observed data (grey columns) and model fits for regional biomass scenarios A with recruitment variability $\sigma = 0.1$ (light black line) and $\sigma = 0.6$ (heavy black line), and regional biomass scenarios C with recruitment variability $\sigma = 0.1$ (light grey line) and $\sigma = 0.6$ (heavy grey line). Proportions limited to 0.4. No samples were taken in the Tasman stock in 2004.

3.7.8 Estimates of mature biomass and harvest rates

Estimates of total initial mature biomass were surprisingly similar between the recruitment scenarios, but varied considerably between the different regional biomass, and onshore biomass and movement rate scenarios (Table 3.3). The latter was mainly a reflection of the amount of fish available to the fishery in the onshore population.

Mature biomass had fallen in all scenarios since 1990, mainly due to the high catches in the mid 1990s, and stabilised since 1998 with only a slight decreasing trend since (Fig. 3.18 for recruitment variability $\sigma = 0.6$ which always provided a better overall model fit to observed data). This was despite of or thanks to increased productivity in the population due to higher growth rates and earlier maturity of young fish combined with a reduced overall catch.

Table 3.3: Model estimates of total initial mature biomass ($MatBt_{90}$) for all onshore biomass (BtOn) and movement rate scenarios for recruitment variability $\sigma = 0.1$ and 0.6.

Bt On	Movement rate	$MatB_{90}$ (t)					
		Sigma = 0.1			Sigma = 0.6		
		A	B	C	A	B	C
1	N/A	1174	727	841	1210	743	869
0.75	1	1288	781	878	1328	794	901
0.75	0.75	1324	798	894	1363	810	917
0.75	0.5	1384	831	933	1403	837	951
0.75	0.25	1473	890	1013	1496	894	1029
0.5	1	1571	911	955	1588	916	974
0.5	0.75	1725	986	1027	1755	988	1046
0.5	0.5	1958	1123	1183	1994	1119	1196
0.5	0.25	2197	1301	1445	2227	1291	1445

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.

Overall, mature biomass in 2004 relative to that in 1990 ($MatB_{04/90}$) differed widely between 0.51 to 0.88 with recruitment variability $\sigma = 0.6$ depending on the regional biomass scenario. The estimated range was comparable assuming recruitment variability $\sigma = 0.1$, but with 0.46 to 0.84 slightly lower. At a regional level, the estimated range of $MatB_{04/90}$ was most pronounced in the Bicheno region, ranging from 0.33 to 0.88 with recruitment variability $\sigma = 0.6$. Differences in the range of estimates of $MatB_{04/90}$ were less extreme in the other stocks, but still ranged considerably from 0.42 to 0.72 in the St. Helens, Maria and Tasman regions, and from 0.49 to 0.81 in the Bruny region where only a small proportion of the biomass was attributed.

Harvest rates were similar for all recruitment variability scenarios and peaked around 1998 (Fig. 3.19 for recruitment variability $\sigma = 0.6$). Again, the regional biomass distribution added uncertainty to that from onshore biomass and movement rates and, harvest rates in the last year (H_{04}) varied substantially from 0.01 to 0.15 in the St. Helens, Bicheno, Maria and Tasman regions, and from 0.01 to 0.05 in the Bruny region. Thus, even though harvest rates tended to be lower than in previous years, estimates of some scenarios still exceeded 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, Lyle et al. 2003).

Due to the relative nature of the biomass distribution, estimates of $MatB_{04/90}$ and H_{04} in one or more stocks were relatively low for any given scenario. Scenario A was generally most optimistic, with low harvest rates in the Bicheno region due to the highest regional biomass allocation and medium harvest levels in the other regions. In the remaining scenarios, low mature biomass levels and high harvest rate levels were estimated in the St. Helens, Maria and Tasman regions in scenarios B, or in the Bicheno region in scenario C.

The reason for the lowest impact of fishing on the stocks in scenario A was linked to high initial biomass and overall recruitment rates (Fig. 3.19). Recruitment variability was also substantially higher than in the other scenarios. In all scenarios, recruitment variation appeared to increase with decreasing population size over the years.

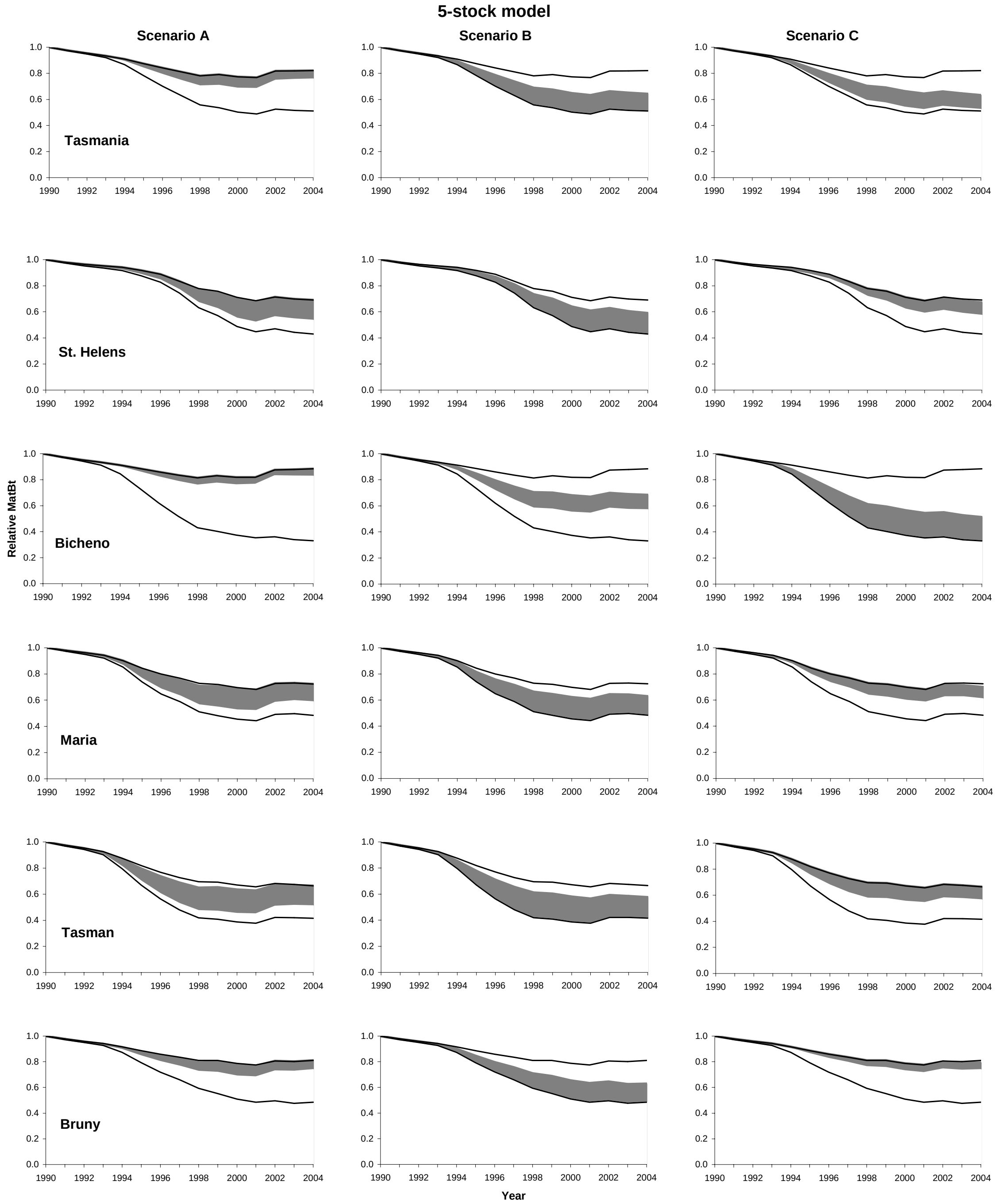


Fig. 3.18: Range of mature biomass estimates relative to the levels in 1990 with regional biomass scenarios A, B and C Tasmania-wide and in each of the 5 regions for recruitment variability $\sigma = 0.6$ between 1990-2004. Range of model predictions (grey) of all onshore biomass and movement rate scenarios, and minimum and maximum estimates of all regional biomass, onshore biomass and movement rate scenarios (light black lines).

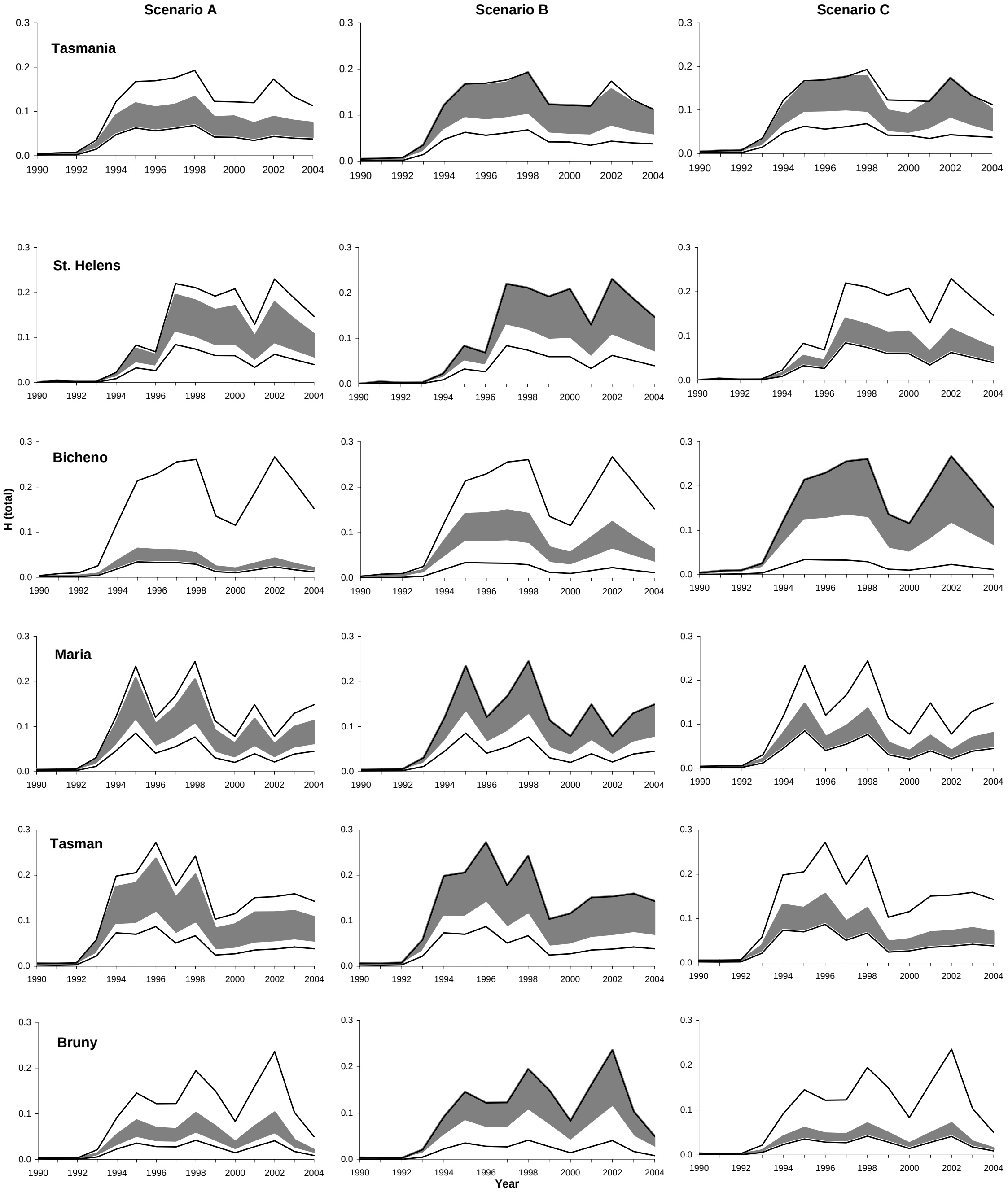


Fig. 3.19: Range of harvest rate estimates with regional biomass scenarios A, B and C Tasmania-wide and in each of the 5 regions for recruitment variability $\sigma = 0.6$ between 1990-2004. Range of model predictions (grey) of all onshore biomass and movement rate scenarios, and minimum and maximum estimates of all regional biomass, onshore biomass and movement rate scenarios (light black lines).

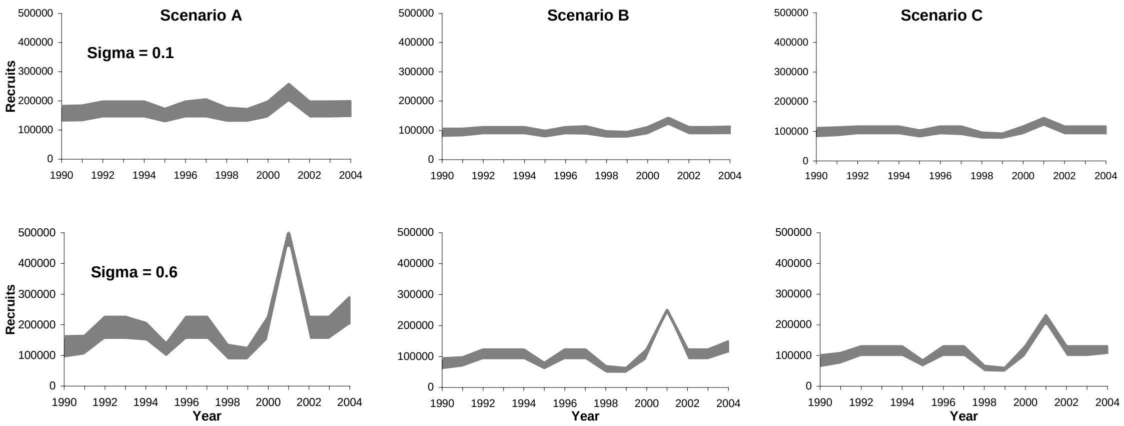


Fig. 3.20: Range of annual total recruitment estimates (in numbers) of all onshore biomass and movement rate scenarios with regional biomass scenarios A, B and C for recruitment variability $\sigma = 0.1$ and 0.6 between 1990-2004.

3.7.9 Harvest strategy evaluation

This stock assessment model developed for the east coast fishery of banded morwong was further used as a so-called ‘operating model’ in a harvest strategy evaluation to assess the future impact of different catch levels on the fished stocks (Ziegler *et al.* 2005). 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 only vaguely defined as to stabilise or rebuild the current catch rates and mature biomass of the fished stock.

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. Largely based on the current and historical catch, four different catch scenarios and their impact on catch rates, the effort required to achieve the catch, and relative mature biomass were examined. A status quo scenario with a total annual catch of 36 tonnes was compared with two scenarios where 2/3 and 4/3 of the status quo were taken, i.e. 24 tonnes and 48 tonnes respectively. Finally, an extreme scenario of 80 tonnes annual catch was investigated. This latter catch scenario was comparable to historically high catches and had relevance given the intention by industry to explore overseas markets for banded morwong (and other live-fish).

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.* 2005). However, this applied only to legal-sized fish, while all non-legal fish were assumed to be returned live to the sea.

Again, all three regional biomass scenarios A, B, and C with recruitment variability σ = 0.1 and 0.6 were investigated for a scenario with 75% of the biomass onshore and a movement rate of 0.5. Figs. 3.21 to 3.24 summarise the results for the reported and total fishing-induced mortality or 'real catch' (including estimated seal- and handling mortality), and for catch rates relative to 1995, effort required to achieve the catch, and mature biomass relative to the initial state in 1990. Regional biomass scenario B produced intermediate results and is not shown.

Generally, trends were similar for both levels of recruitment variability σ = 0.1 and 0.6, although observed variation in catch rates, effort and relative mature biomass was slightly higher for the latter. Depending on the regional biomass distribution the catch removal impacted the regions differently, in particular the Bicheno region. In contrast, the trends in catch rates, effort and mature biomass from all combined regions were surprisingly similar. This clearly illustrates how an overall stock assessment can obscure regional trends. For example, with an 80 tonne harvest strategy and regional biomass scenario C, catch rates dropped much more quickly and biomass was depleted earlier in the Bicheno region than indicated by an assessment of the overall data (Fig. 3.24).

The effects on catch rates, effort, and relative mature biomass gradually increased with increasing catch. With a constant catch scenario of 24 tonnes (equivalent to an average of 29 tonnes total mortality when seal and other mortality sources are included), relative catch rates, effort and relative mature biomass remained stable over the whole projected period of 20 years (Fig. 3.21). When 36 tonnes were taken annually (equivalent to an average of 44 tonnes total mortality), catch rates and mature biomass slightly decreased over time, while the effort required to achieve the catch increased (Fig. 3.22). With a constant catch scenario of 48 tonnes (equivalent to an average of 58 tonnes total mortality), catch rates fell continuously over the 20 years projection to levels well below the current catch rate levels (Fig. 2.23). Mature biomass also continued to decline and the effort required to support the catch increased substantially in all regions except in the Bicheno region with high relative biomass in scenario A.

As a result of a constant (intended) removal of 80 tonnes, catch rates and mature biomass dropped to very low levels within 10 years and did not recover during the remaining period (Fig. 2.24). In fact, the 80 tonnes catch often could not be taken due to lack of sufficient biomass. Rather, the total fishing-induced mortality or real catch stabilised at only 70 tonnes, 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 clearly demonstrated that the stocks could not tolerate such high catches over a prolonged period.

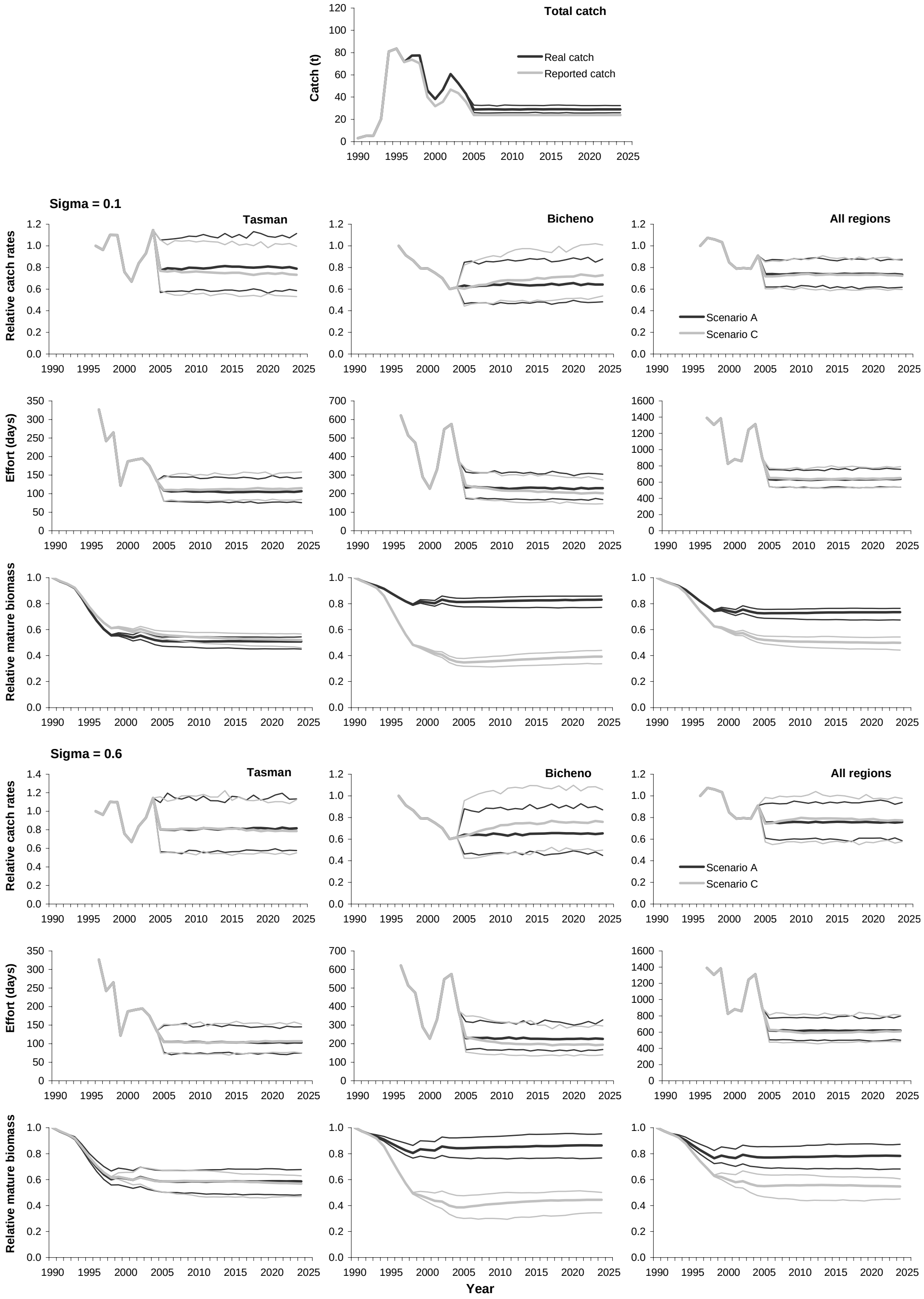


Fig. 3.21: Constant catch simulation with 24 tonnes total reported catch for Tasman and Bicheno region and all regions combined from 2005-2025. Historical data used for 1990-2004. Catch taken (top graph) with reported catch (grey line) and total fishing-induced mortality (‘real catch’, black lines) which is the reported catch multiplied with a bias and random variation for reporting and seal or other fishing-induced mortalities. Observed catch rates and effort, and mature biomass for recruitment variability $\sigma = 0.1$ and 0.6. Catch rates relative to levels in 1995 (catch rates for all regions combined is the catch-weighed geometric mean of all regions); effort in days needed to achieve the removals; and mature biomass relative to virgin levels in 1990 for regional biomass scenarios A (black lines) and C (grey lines) with median (bold lines) and 95% confidence intervals. Scenarios presented are for 75% onshore biomass and movement rates of 0.5. Results shown are based on 500 simulations.

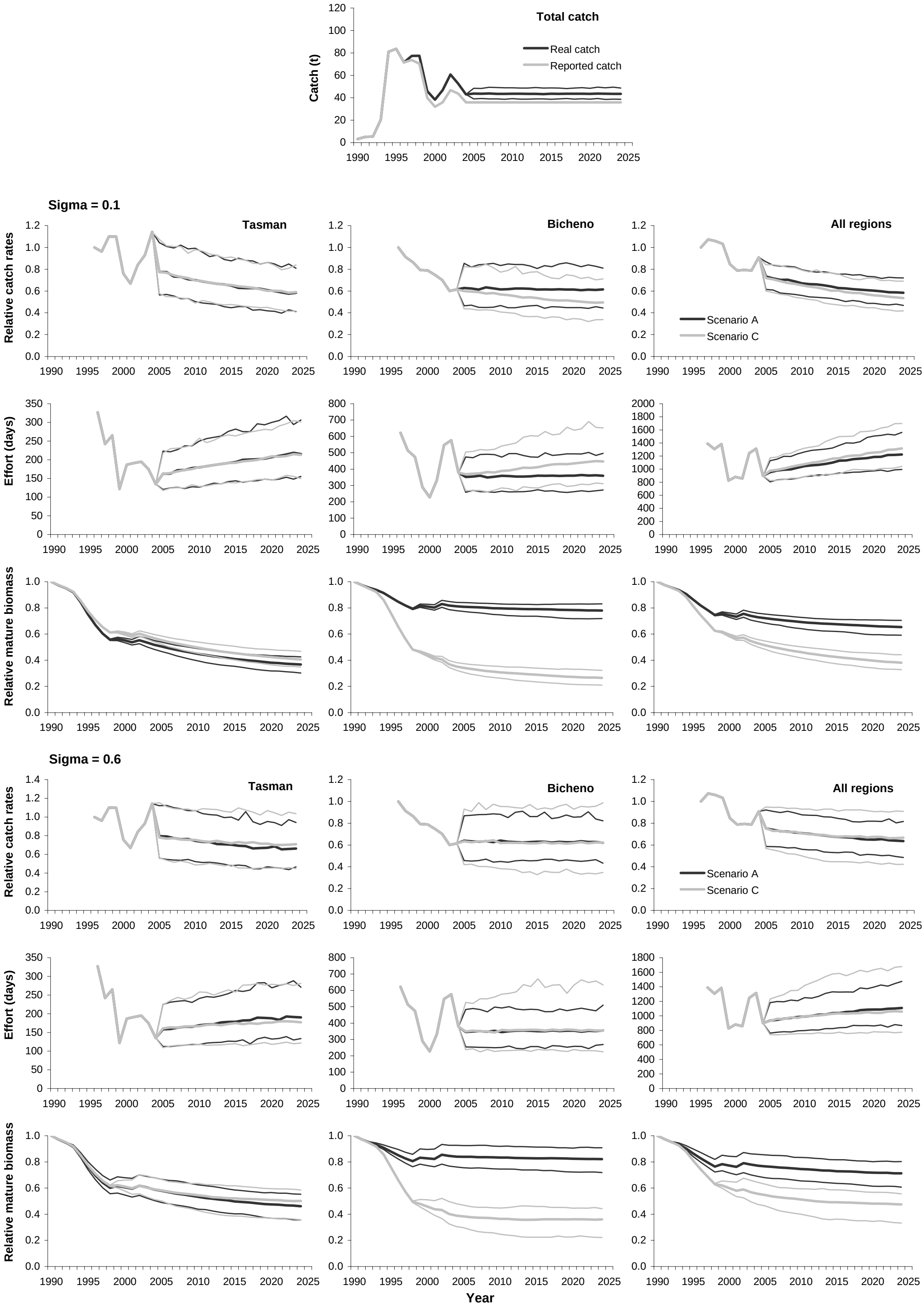


Fig. 3.22: Constant catch simulation with 36 tonnes total reported catch for Tasman and Bicheno region and all regions combined from 2005-2025. See legend to Fig. 3.21 for more details.

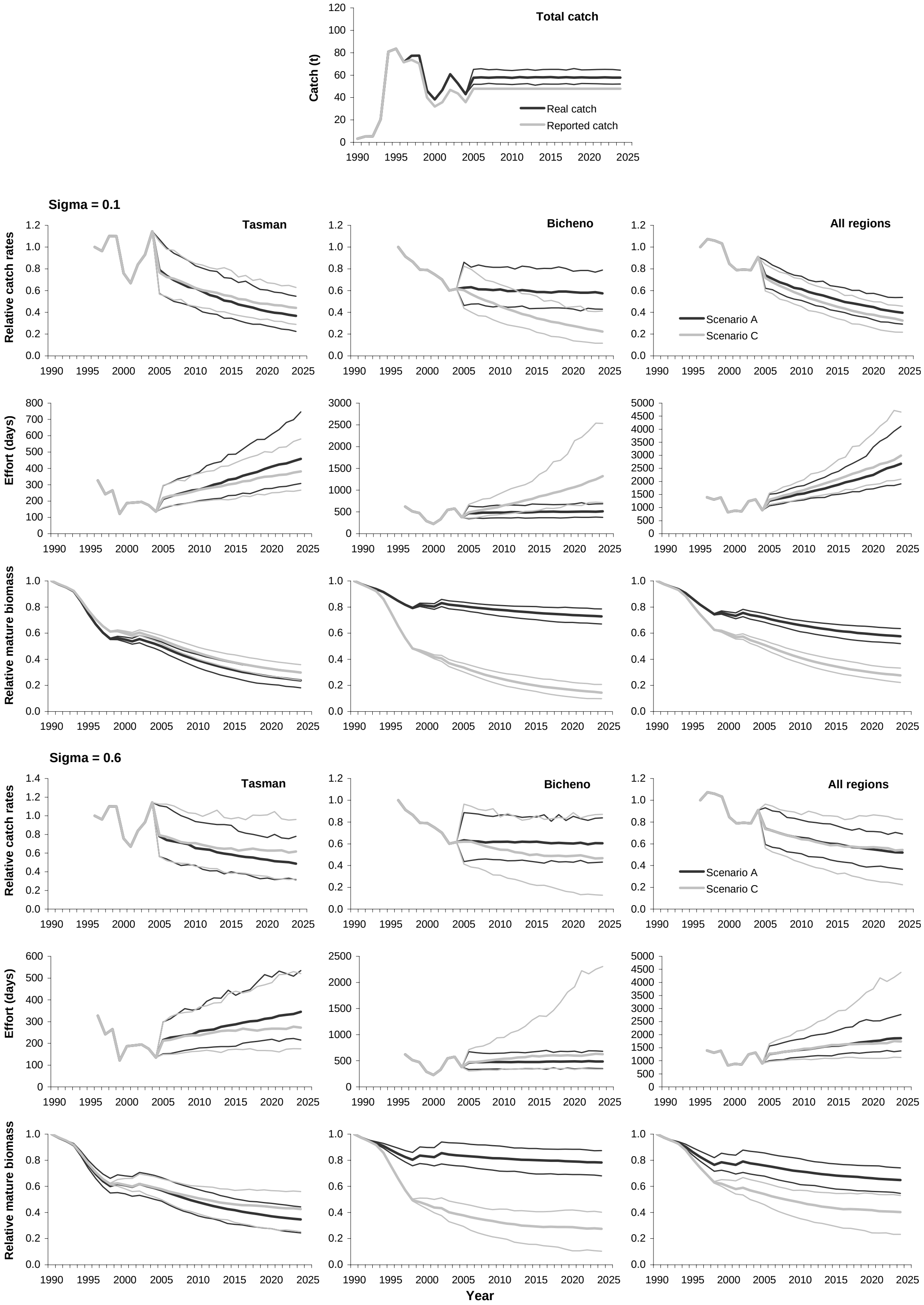


Fig. 3.23: Constant catch simulation with 48 tonnes total reported catch for Tasman and Bicheno region and all regions combined from 2005-2025. See legend to Fig. 3.21 for more details.

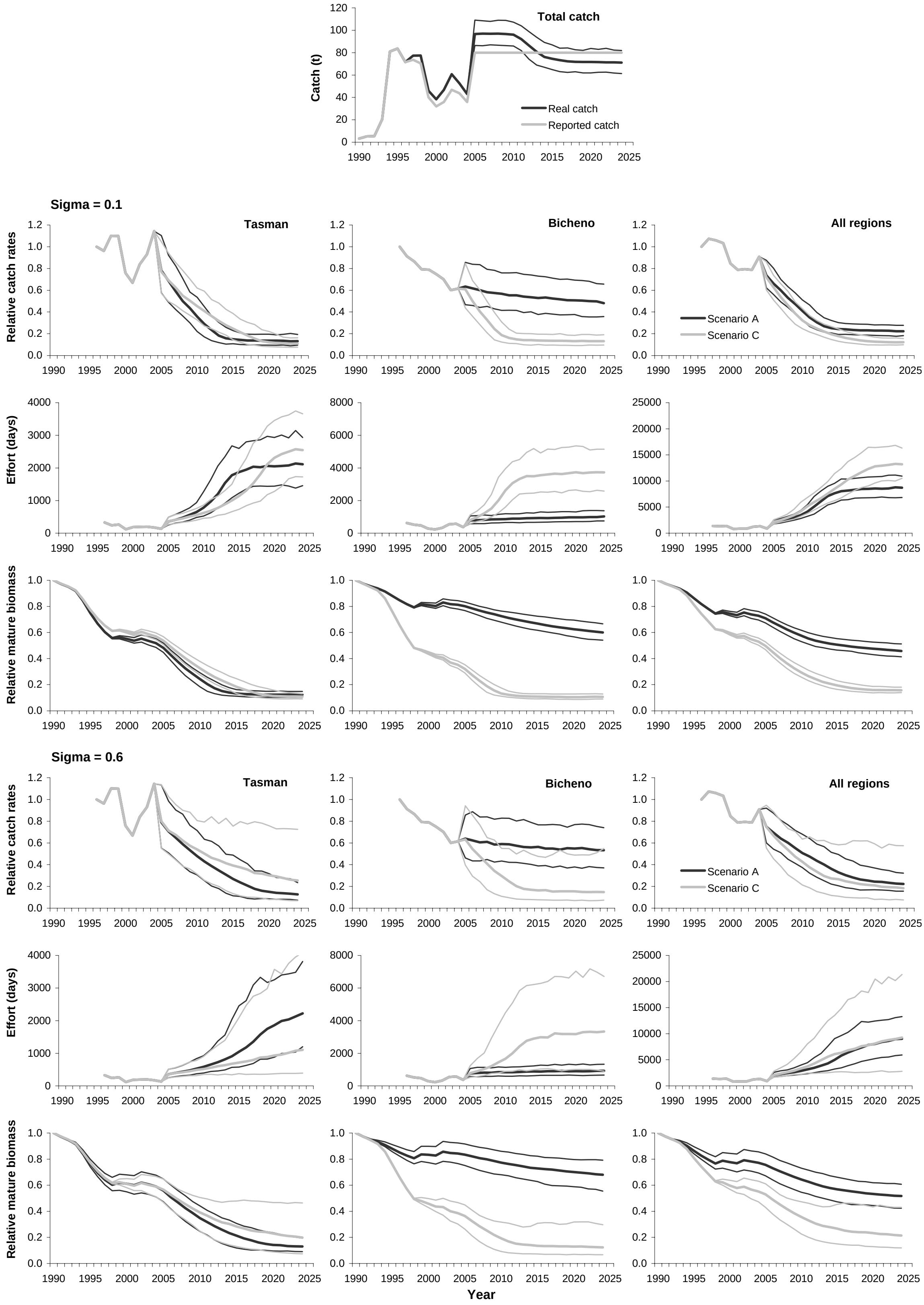


Fig. 3.24: Constant catch simulation with 80 tonnes total reported catch for Tasman and Bicheno region and all regions combined from 2005-2025. See legend to Fig. 3.21 for more details.

3.8 Implications for Management

Catch and catch rate indicators suggest that, initially at least, the fishery impacted heavily on banded morwong populations up the east coast of Tasmania. However, there has been apparent stability in both measures in the last few years, an observation that is consistent with industry perceptions. Unfortunately, this stability in catch statistics is not reflected in stability of selected biological indicators and so it cannot be concluded that current levels of exploitation are sustainable. There are several limitations related to the use of fishery dependent data with such a long-lived site attached species. These limitations include the masking effects on localised changes in abundance arising from the localization of the fishery within the original fishing grounds, and the obscuring effects of expansion of the fishery into new grounds. The mobility of the fishing fleet combined with the site attached nature of banded morwong limit any insights that catch rate data might provide into stock status. Finally, there are serious issues surrounding the data quality of commercial catch returns, especially from early on in the fishery. More specifically:

- State-wide catches have been maintained to some extent by an expansion of fishing effort from traditional fishing grounds on the east coast to new areas, with a significant increase in catches off the north east coast between 2002/03 to 2003/04. However, the effort now expended in the north east coast has since declined precipitously.
- Due to the limited movement of banded morwong, their populations are spatially structured at a relatively small scale of a few kilometres or individual reef. At the same time, fishers operate over relatively wide areas of coast to maintain catches. Because a fishing block, the spatial scale for reporting, is likely to encompass catches from many, potentially independent, populations of banded morwong, localized or serial depletions may not be detected.
- Catches and catch rates ignore the fact that banded morwong can grow very old (over 95 years) and catches do not distinguish between production due to new recruits entering the fishery from the fish-down of accumulated biomass by successively removing the older fish.
- Industry members affirm the view that both the frequency of seal interactions and the quantities of fish lost to seals have increased over the history of the fishery, and that seal interactions are considered to be a more significant factor influencing the downturn in catch and effort than variation in stock abundance. Seal mortality is not reflected in the landed catch records but is nevertheless, fishing related mortality.
- Industry representatives also noted that new participants had entered the fishery (and some experienced operators had exited the fishery) during the late 1990s and early 2000s and this was likely to have depressed catch rates. Over the past few years there has been some stability in terms of participants in the fishery, with experienced operators now accounting for the bulk of the catch. Their experience in the fishery will undoubtedly result in higher catch rates than those achieved by inexperienced operators.
- Over the past few years the domestic market for banded morwong has remained flat, partly due to competition from other live product (including banded morwong from Victoria). As a result, processors influence the level of effort and catch as

they seek to match market requirements. To this end, fishers often operate under what are effectively weekly catch quotas and this undoubtedly impacts on effort.

- Fishers emphasized that the reliability of the commercial catch and effort data was probably poor up until about 2000. In addition, a number of issues were identified in relation to catch and effort reporting, which affect any interpretation of fishery-dependent information, they include:

  (i) there is considerable confusion about how gear units should be recorded;
  (ii) fishers tend to report only the portion of the catch that was sold live and do not include mortalities; and
  (iii) most operators do not consistently report activity on days of heavy seal impacts.

All biological measures investigated indicate that the fishery has impacted on the stocks. Some of these changes, such as the decrease of median age for females from around 20 to 7 years, appear dramatic. Changes in the character of the stock are to be expected with exploitation, however, at sustainable levels of exploitation it would be expected that the biological measures would attain some form of dynamic equilibrium. 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, it would suggest a significant reduction in stock size and as such a precautionary approach to future management is required.

The relative wealth of data available for banded morwong allowed the development of an age-structured stock assessment model. Unfortunately, model uncertainty remained high compared to the simple analyses of commercial catch and effort data and biological monitoring. The model uncertainty mostly stemmed from the uncertainty of the underlying data and uncertainty over the dynamics and spatial structuring of the stock. Selecting the optimum spatial model structure seemed inappropriate given the generally poor fits to the biological data (sex ratio and age composition data). The comparatively small sample sizes coupled with spatial structuring within the population may have influenced the more general applicability of the results. 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.

Despite concerns about data quality, the model provided some useful insights into banded morwong populations and potential future development of the stocks under different catch scenarios. Very different trajectories of mature biomass and harvest rates were predicted in the different scenarios tested. Many scenarios tested indicated high harvest rates over an extended period of the fishery. Only in recent years were these parameters predicted to have been reduced towards or below more sustainable levels within the range of the internationally recognised harvest reference points for mature biomass of $H_{40\%}$ or $H_{30\%}$. All scenarios tested by the model also predicted relatively low estimates of mature biomass in at least some regions. However, the predicted mature biomass levels in 2004 did not particularly decrease in absolute terms, i.e. they were higher than 30% or 40% of the initial mature biomass.

The harvest strategy evaluation indicated that maximum future catch levels from the east coast should on average be less than 36 tonnes (current east coast catch level) if the management objective is to maintain or rebuild catch rates and mature biomass at current levels. Mature biomass was maintained or increased only when the annual catch was below 36 tonnes. This result appeared promising, given recent catch levels have not exceeded this value.

However, all estimates from the stock assessment model and the harvest strategy evaluation are likely to be best-case scenarios because of the potential for masking of serial depletion due the low spatial resolution of catch rates. If this and the high uncertainty of the results are taken into account, there is a considerable risk that the mature biomass overall, in many stocks or on many individual reefs is in a much worse and potentially critical state.

In addition, these model results are based on substantial changes in some life-history characteristics of banded morwong. With faster growing young individuals and earlier maturing females (and maybe also males) the fish stocks are now much more productive than at the start of the fishery and even during the mid 1990s. The effect of this increased productivity was magnified by the model predictions of larger recruitment pulses in recent years. Predicted recent stability in the fish biomass and the fishery may therefore be founded mainly on an increase in young fish, rather than sustainable use of old fish. Both, the changes in life-history characteristics and increased recruitment variability coincided with predicted decreasing population size. It is therefore seems likely that they are mainly a density-dependent response or selection of these characteristics by fishing, indicating heavy exploitation rather than simply being caused by environmental changes such as increasing water temperatures.

3.9 Research Needs

The Scalefish Fishery Research Advisory Group has accorded stock assessment of banded morwong a high priority. Reliable but simple estimators of stock status together with management reference points that take into account the sedentary character and the specific life-history characteristics of the species are urgently needed as an integral component of the stock assessment.

Spawning season surveys continued in 2005 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. As an alternative, commercial catch and effort data needs to be reported at a much finer scale, an issue that is being addressed as part of a current review of the logbook design.

Information about the character or relative abundance of populations in the deeper reef areas or potential mixing rates with the shallower areas is also 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 calamary (*Sepioteuthis australis*)

4.1 Life-history and Stock Structure

Southern calamary 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.	Moltschaniwskyj *et al.* 2003
Distribution	Endemic to southern Australian and northern New Zealand waters	Gomon *et al*. 1994
Movement and Stock structure	Stock structure and large-scale movements unknown. 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 spawning, however, during 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.	G. Pecl unpubl. Data 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 weight: 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 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.	Moltschaniwskyj *et al.* 2003 Pecl 2001

Spawning	Major spawning period in spring/summer in Tasmania, with low levels of spawning occur all year round. The majority of summer caught squid are hatched in winter and vice versa. Multiple spawners with the duration of individual maturity over several months (acoustically-tagged mature females have been tracked moving on and off the spawning grounds for up to 3½ months). Frequency of batch deposition is unknown.	Moltschaniwskyj *et al.* 2003
	Summer spawners can lay larger batches of eggs than winter spawners	Pecl 2001
	Younger females may lay more eggs than older females	van Camp *et al.* 2005
	Spawning aggregations are male-biased, although the exact operational sex-ratio has not been quantified. Female calamary 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'. Most observed matings are between females and large paired males, although genetic studies demonstrated that both small and large males sire similar proportions of offspring.	Jantzen and Havenhand 2002 Pecl et al. 2004 van Camp et al. 2004
	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.	Moltschaniwskyj et al. 2003
	Development takes between 4-8 weeks, depending on water temperature, bringing the total life span close to annual.	Steer et al. 2002
Early life history	Newly hatched calamary 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
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 calamary 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 calamary 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 calamary 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, as a precautionary measure to protect egg production, Great Oyster Bay was closed to fishing for southern calamary for 2 weeks twice between October and December 1999. 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. During 2003 and again in 2004 the commercial fishery in Great Oyster Bay and Mercury Passage was closed for a three month period (September to November, inclusive) to reduce catches from the spawning population. Recreational fishers were permitted to fish for calamary during this period but with a reduced daily bag limit of five calamary 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 (G. Pecl unpubl. data).

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.

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 November 2001, a combined possession limit of 30 calamary and arrow squid was introduced for all holders of scalefish C licences (but excluding those also holding beach seine or purse seine licences) in an effort to limit further expansion of the fishery. Also in November 2001, a daily bag limit of 20 ‘squid’ (southern calamary 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 calamary (and 15 arrow squid).

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 (2005) by a combination of spawning season closure in all waters between Wineglass Bay and the northern end of Marion Bay from mid-September to mid-December (commercial and recreational fishers), a combined possession limit of 30 calamary and arrow squid for all holders of scalefish C licences (excluding those also holding beach seine or purse seine licences), and general limits on recreational catch (possession limit of 15 fish).

4.5 Relative vulnerability to fishing

Vulnerability of calamary 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 recruitment failure. However, if the population is allowed to spawn (during the fishing closures) prior to 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 calamary stocks. Preliminary modelling of catch and effort data for the major fishing areas (Great Oyster Bay and Mercury Passage) was investigated for the 2003 and 2004 assessments using surplus production modelling. 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.

4.7 Current Assessment

The non-equilibrium surplus production model applied in the two previous assessments has not been used for the present assessment since an important underlying model assumption, that the temporal distribution of catch and effort is consistent over time, has been severely violated by the seasonal closure. The impact of the 2003 and 2004 extended fishery closures on monthly catches in Great Oyster Bay and Mercury Passage are clearly evident in 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 - 2004/05).

Surveys of egg production have been conducted in Great Oyster Bay annually since 1999 and are reported here. An aim of this research is to investigate possible relationships between reproductive output, spawning stock size and subsequent recruitment.

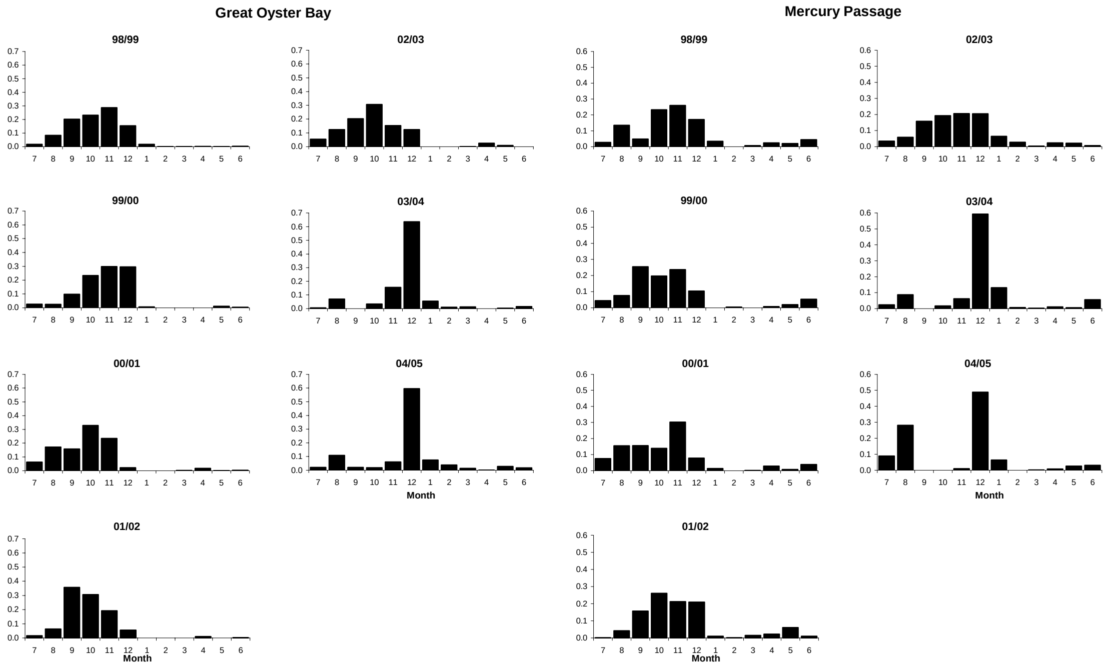


Fig. 4.1 Monthly catch distribution (as proportion of the total catch within the fishing year) for Great Oyster Bay (ES13 and ES14) and Mercury Passage (ES16).

4.7.1 Catch

Over the past seven years a significant fishery for southern calamary 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 calamary catches have been reported from all areas apart from the west coast, the fishery is concentrated off the central east and south east coasts (Figs. 4.2A and 4.3). The fishery developed initially in Great Oyster Bay in the mid-1990s and then expanded to the south to include Mercury Passage, Maria Island and Tasman Peninsular. Over the past couple of years moderate catches of calamary have also been taken from Flinders Island.

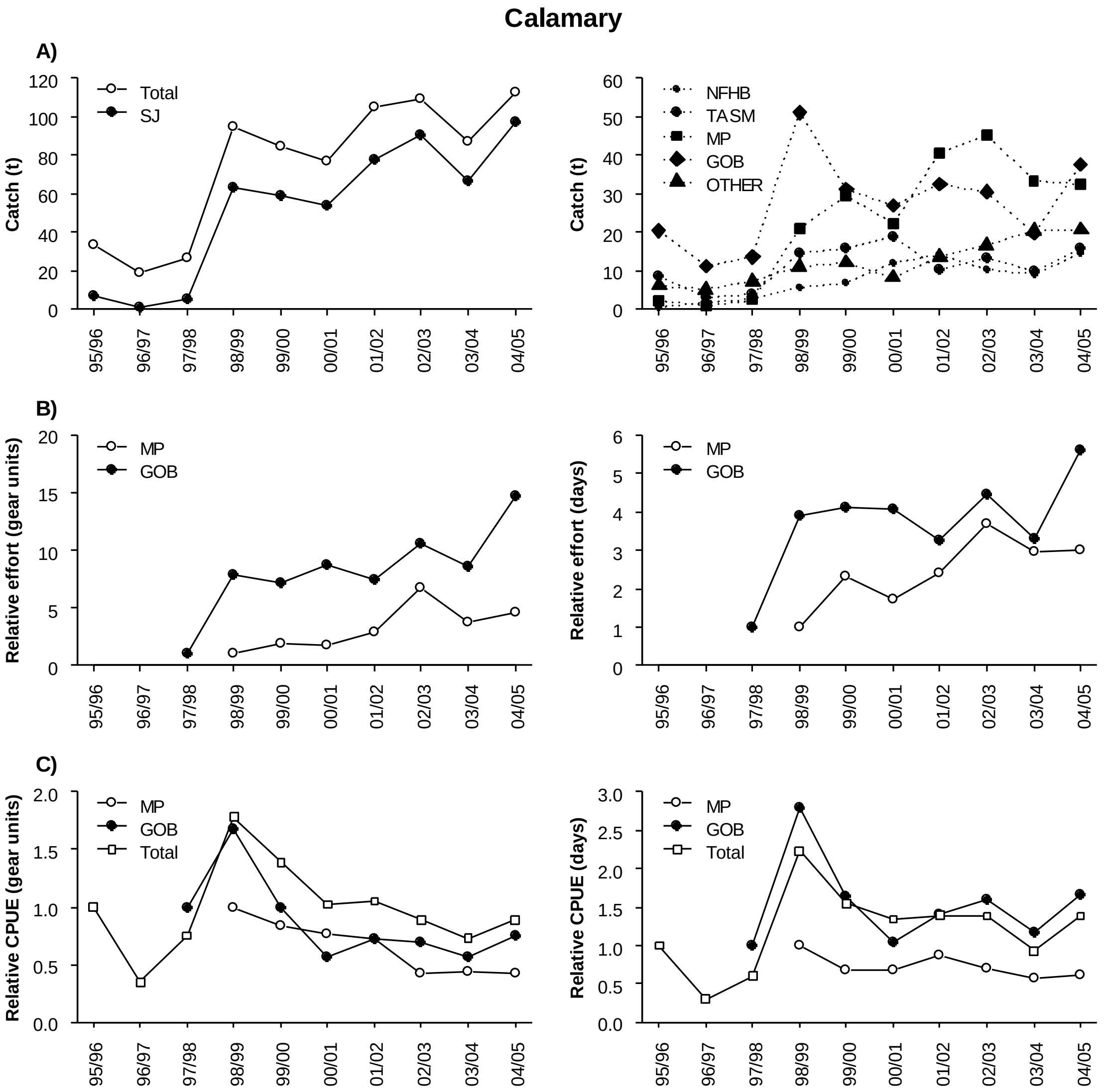


Fig. 4.2 A) Annual catch (tonnes) of calamary by method (left) and by region (right) since 1995/96; B) squid jig effort based on gear units (left) and days fished (right) relative to 1998/99 for MP and 1997/98 for GOB; and C) squid jig catch per unit effort (CPUE) based on weight per gear unit (left) 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 and PS is purse seine; NFHB is Norfolk-Frederick Henry Bay, TASM is Tasman, MP is Mercury Passage, GOB is Great Oyster Bay, and OTHER is all remaining areas. Only years with >5 operators are shown.

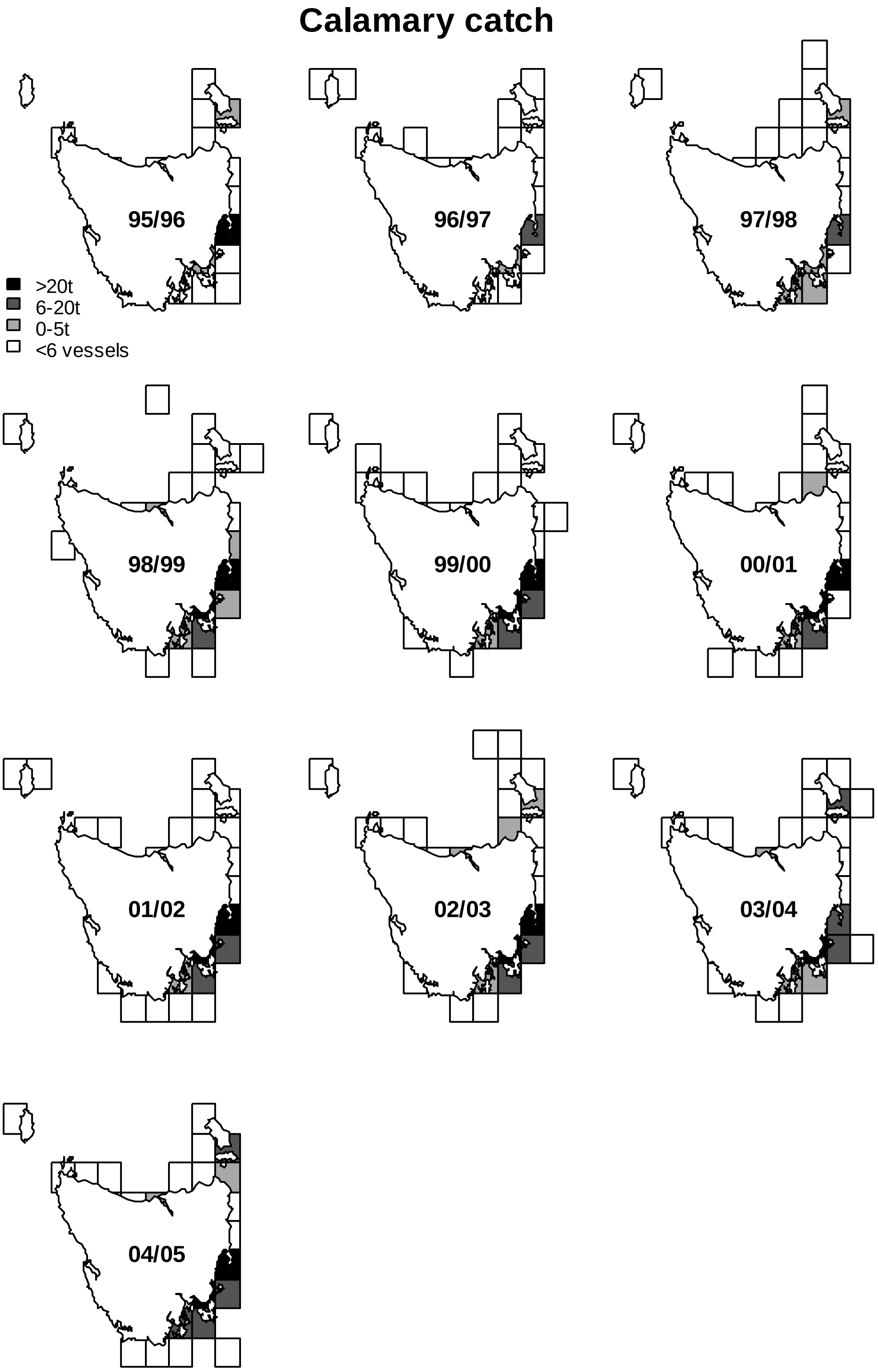


Fig 4.3. Calamary catches (tonnes) by fishing block and year since 1995/96.

The expansion of the fishery was almost exclusively due to increased squid jig catches (Fig. 4.2A). The 2004/05 catch of 113 tonnes represented almost a 30% increase compared with 2003/04 and was the highest on record. It is significant that this occurred despite the three-month closure of the main fishing grounds in Great Oyster Bay and Mercury Passage.

The 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. 4.2A). 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 Norfolk-Frederick Henry Bay (ES17, ES18, ES19), Tasman Peninsula (7G2) and a general increase in catches from the north coast and Flinders Island (OTHER in Fig. 4.2A).

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

Evaluation of 2004/05 catches against performance indicators

- Current State-wide catch was the highest on record and well above the reference catch range; the catch performance indicator was therefore triggered. As the increase was just under 30% compared with 2003/04, the rate of change indicator was not triggered.
- Catches were higher than in 2003/04 for all major regions apart from Mercury Passage, where catches had fallen slightly. As catches were higher than during the reference years, this performance indicator was triggered for all regions.

4.7.2 Fishing effort

The regional distribution and the expansion of the fishery over time is clearly evident in terms of effort (days fished) in Fig. 4.4 and is, not surprisingly, consistent with the pattern observed for catches (Fig. 4.3).

After a period of relative stability, jig effort (based on jig-hours and days fished) in Great Oyster Bay rose sharply in 2004/05 to the highest level on record (Fig. 4.2B). Effort in Mercury Passage also increased compared with 2003/04, but the increase was relatively minor.

Evaluation of 2004/05 effort against performance indicators

- State-wide, jig effort has remained at historically high levels and substantially greater than reference levels, the effort performance indicator was thus triggered.
- Regionally, jig effort in the major fishing regions (Great Oyster Bay and Mercury Passage) remained well above trigger levels despite the imposition of three-month closures.

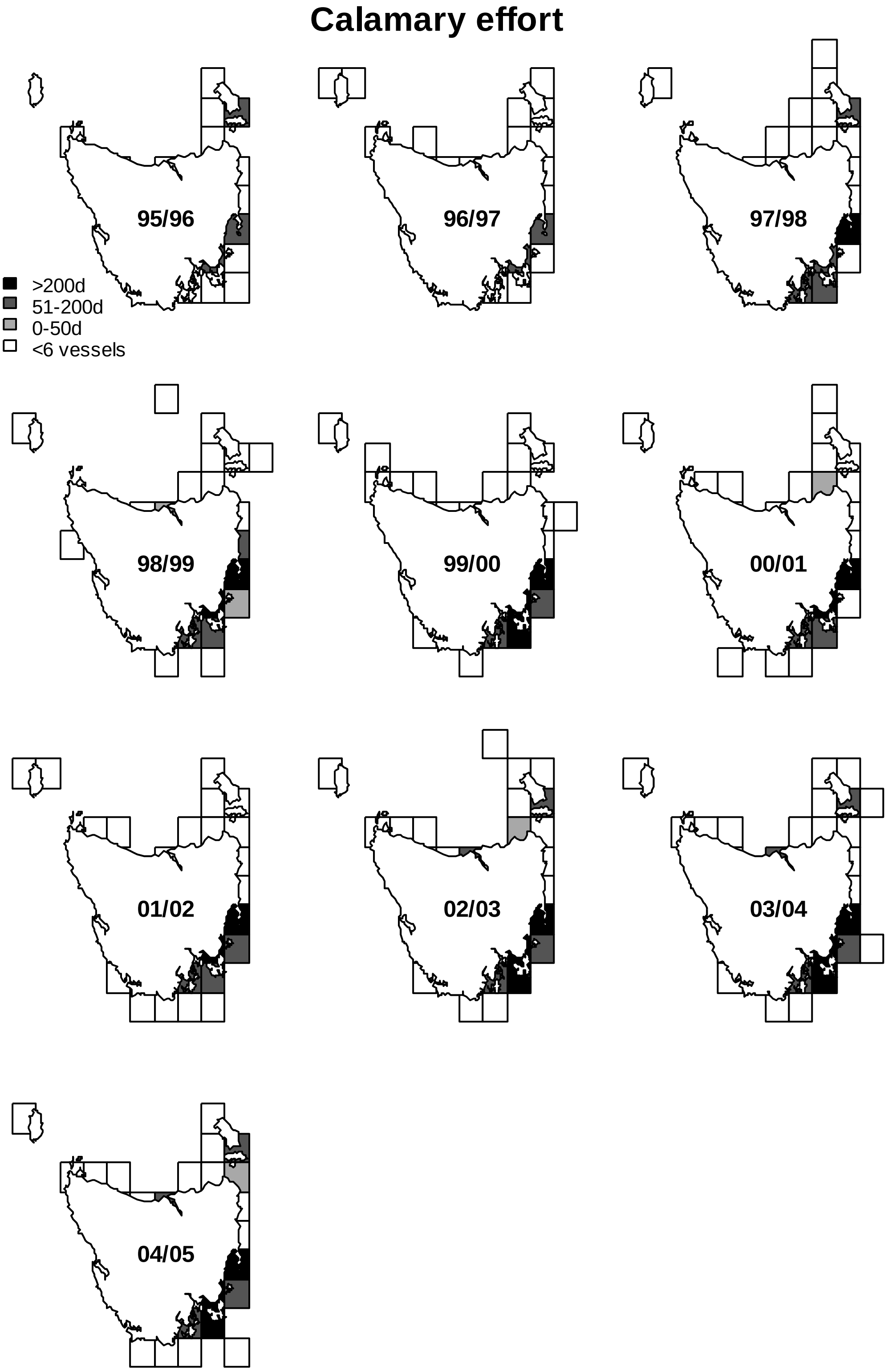


Fig 4.4. Calamary effort (days fished) by fishing block and year since 1995/96.

4.7.3 Catch rates

State-wide, catch rates (gear and daily) for jigs declined after the initial expansion of the fishery in 1998/99 (Fig. 4.2C). In 2004/05, however, catch rates improved slightly compared with 2003/04, influenced mainly by increased catch rates in Great Oyster Bay. By contrast, after initially declining, catch rates in Mercury passage have remained stable, despite significant shifts in the timing of the fishery brought on by fishery closures.

Evaluation of 2004/05 catch rate against performance indicator

- Catch rates in 2004/05 were within reference levels and thus had not triggered the catch rate performance indicator.

4.7.4 Egg production surveys

Southern calamary egg surveys have been conducted annually in Great Oyster Bay since 1999, providing six years of data for analysis.

Surveys are conducted at six sites on the eastern side of Great Oyster Bay, in Coles Bay and Hazards Bay, each site being characterised by a discrete bed of *Amphibolis* seagrass delimited by sand and/or macroalgae. The area of seagrass at each site was determined using differential GPS and a high-resolution depth sounder and ranged from 0.17 to 2.02 ha.

The density of the egg masses was assessed by divers using 20 m^2 belt-transects (10 m by 2 m), the most suitable size based on precision and logistics. The only exception was in 2001 when timed swims were used to estimate egg densities. At most sites 20 belt-transects were used and the seagrass searched for the presence of egg masses. Transects were laid haphazardly within the seagrass beds but did not overlap. The numbers and age (based on developmental stage) of eggs in each egg mass was determined and total egg production estimated as a function of the total number of strands in the egg masses, summed across the sites and times, and scaled for the total area of seagrass within the study area. The total number of eggs was calculated by multiplying the total number of strands in each area of seagrass by 5.5, which is the average number of eggs per strand.

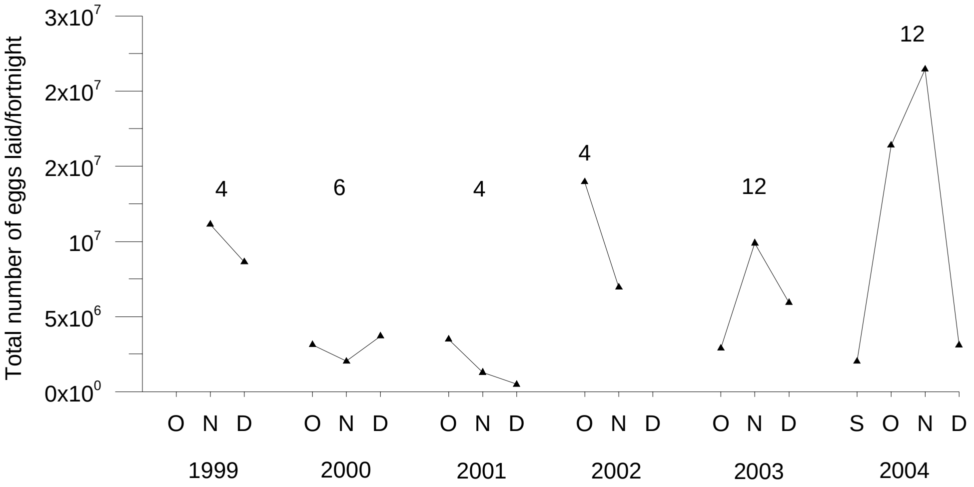


Fig. 4.5 Total estimated egg production over a fortnight period for *Amphibolis* seagrass beds surveyed in Great Oyster Bay, by month sampled. The number of weeks that the fishery was closed is indicated above each year of data.

Estimates of egg production appeared to vary at the time scales of both months and years. Highest egg production typically occurred in November, coinciding with fishing closures during some or all of this month each year since 1999 (Fig 4.5).

The range of egg number estimates varied substantially (Fig. 4.6). In 1999, 2002 and 2004 the total estimated egg production was greater than the average for the six-year period. There was no evidence that variability in total estimated egg production was associated with the length of the fishing closure (*R*=0.40, n=6, *P*=0.43), thus longer fishing closures did not necessarily result in greater egg production.

Cumulative egg production in each year indicated that about 80% of total egg production had occurred by late November (Fig. 4.7), suggesting that fishing closures need to extend at least until this time to provide a high level of spawning protection.

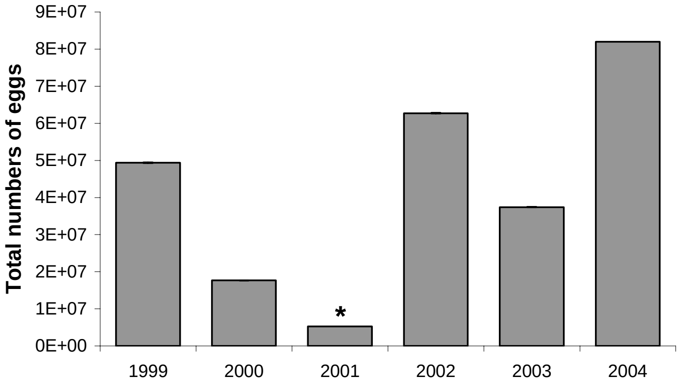


Fig. 4.6 Total estimated egg production for Great Oyster Bay survey sites. * data in this year was estimated from timed counts, not belt transects. The solid line is the mean value across the six years. Error bars are SE, too small to be seen in most years.

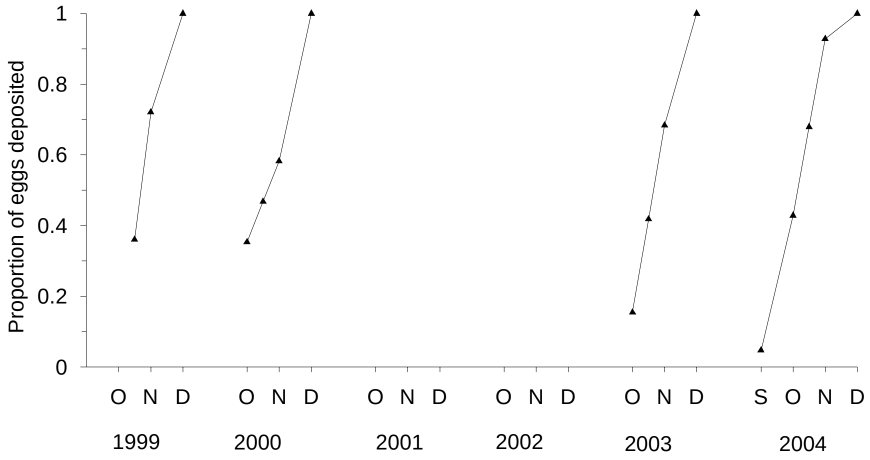


Fig. 4.7 Cumulative proportion of total estimated egg numbers produced by month.

From the surveys there was evidence that egg production may be useful as a fishery independent indicator of stock status, if total commercial catch taken is assumed to be an index of stock size. Total estimated egg production was positively correlated and explained 48% of the variation in total calamary landings of the same year in Great Oyster Bay (Fig 4.8A). By contrast, there was no relationship between egg production and CPUE in the same year. Weak negative relationships were evident between egg production in one year and landings and CPUE in the following year (Fig. 4.8B). The significance of the relationships between egg production and catch and catch rates, however, remain inconclusive at this stage due to the limited time series and the fact that the fishery in each year has been greatly influenced by the management arrangements implemented at the time.

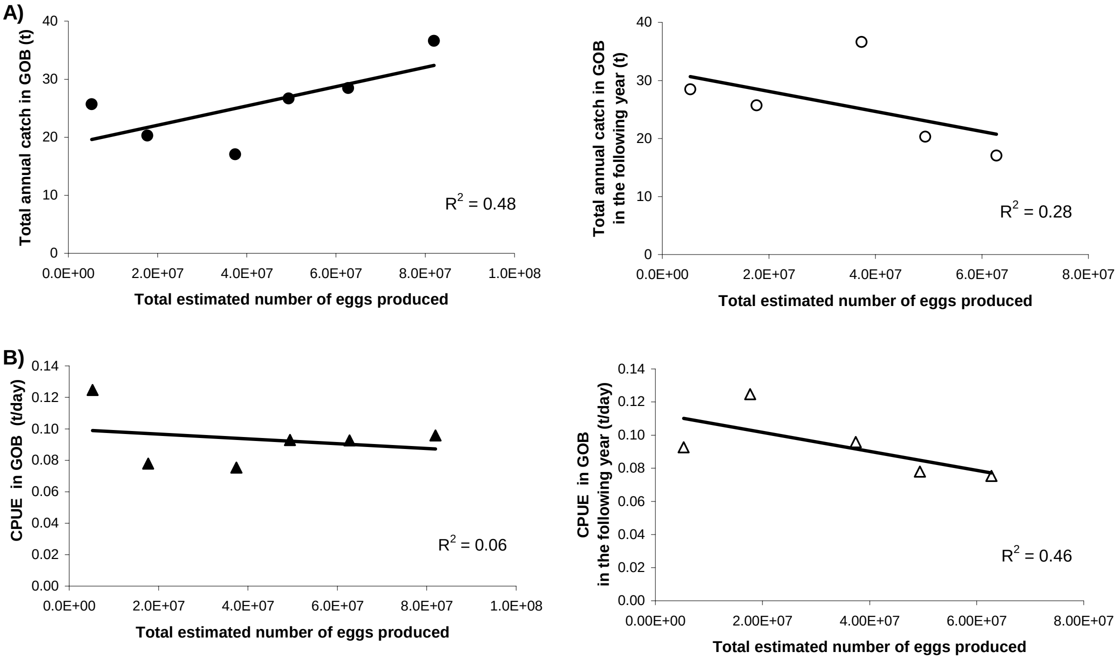


Fig. 4.8 Relationships between the total estimated number of eggs produced in a year and (A) the total annual catch of southern calamary in the same year (left) and the following year (right); and (B) the CPUE of southern calamary in the same year (left) and the following year (right).

4.8 Management Implications

For calamary, the reference ranges of catch and effort defined in the management plan derive from a period well before the fishery developed. As such, comparisons between the fishery in an under-developed (pre-1998/99) and developed state will continually result in catch and effort indicators being triggered. In fact, it would be of greater concern if catches were to fall to within ‘historic’ reference levels rather than remain above them.

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 (from 2003) has, not surprisingly, resulted in substantial changes in the dynamics of the fishery and compromised the validity of several model assumptions; hence it could no longer be used. Despite the extended closure in 2004, catches from Great Oyster Bay and Mercury Passage remained high.

As an alternative assessment approach, egg production shows some potential as an indicator of current year relative spawning biomass, but may not be useful as a pre-recruit index due to the weak (negative) relationship between egg production and catches in the subsequent year. However, with the limited time series of data available these observations are very preliminary.

Based on cumulative egg production, 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 calamary have a life span of generally less than one year, intense fishing pressure immediately after the fishery is opened will have a limited impact on subsequent recruitment, assuming that most calamary 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 are 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 calamary 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.

Interest in the fishery continues at a high level and there is substantial capacity within the Tasmanian scalefish industry to increase effort levels. The same, at a different level, can be said for recreational fishers 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 as hotspots.

Currently there is limited information available on the stock structure of southern calamary in Tasmania. Such information is required to assess the validity of current spatial management and regional analyses reported here. In particular, the relationships between populations fished in Great Oyster Bay and Mercury Passage and other regions need to be further investigated.

Although a high degree of uncertainty is associated with the present assessment, the extended closure of the major spawning grounds (implemented again in 2005) appears to be effective in protecting the main (known) spawning event and ensuring relatively high egg production. 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. Furthermore, the status of populations outside of Great Oyster Bay and Mercury Passage and possible links between areas are unknown. Expansion of catches in space and time will need to be monitored closely.

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 calamary populations as high priority research areas.

Information on the stock structure and level of fishing pressure that can be sustained on southern calamary is required. Integral to this is to determine what populations are being supported by the current closures, therefore quantifying the relationships between reproductive output, spawning stock size and subsequent recruitment remain a priority. Critically the source and sink populations supporting the Tasmanian calamary fishing industry need to be identified to ensure sustainable use of this resource. 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	Unknown stock structure in Australian waters. 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. Such large-scale movements suggest the potential for mixing between widely separated populations. A common stock throughout its range can be assumed for management purposes	Lyle and Jordan 1999 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	Hutchinson 1994 S. Tracey, TAFI pers. comm.
Spawning	Spawning occurs from July to early October, depending on geographical location, with spawning commencing and finishing earlier 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 1994
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 southeast 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).	Murphy and Lyle 1998

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 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 southwest 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 of 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 target 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 bag and possession limit of five 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 8 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 will 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. Catches have been below the reference levels since 2000/01. Dropline effort exceeded the reference levels in 2002/03 and 2003/04 and dropline catch rates have been below reference levels since 1999/00. Yield per recruit analysis was undertaken for the 2003 assessment and indicated that the minimum size limit of 35 cm (TL) was sub-optimal and by raising the size limit the potential yield would be increased. The minimum size limit was raised to 45 cm TL in November 2004. With new information about the size at maturity and fecundity, spawner biomass-per-recruit analysis was conducted for the 2004 assessment and revealed that there remains a risk of recruit overfishing in striped trumpeter and that either fishing mortality needs to be reduced or the minimum size limit be further increased.

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. Catch information since 2001 from Commonwealth waters adjacent to Tasmania were made available for this assessment.

Limited research sampling (handline) was undertaken during 2004/05 and size and age composition data are compared with similar data collected during the 1990s.

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

5.7.1 Catch

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, Commonwealth catches have been relatively low since that time.

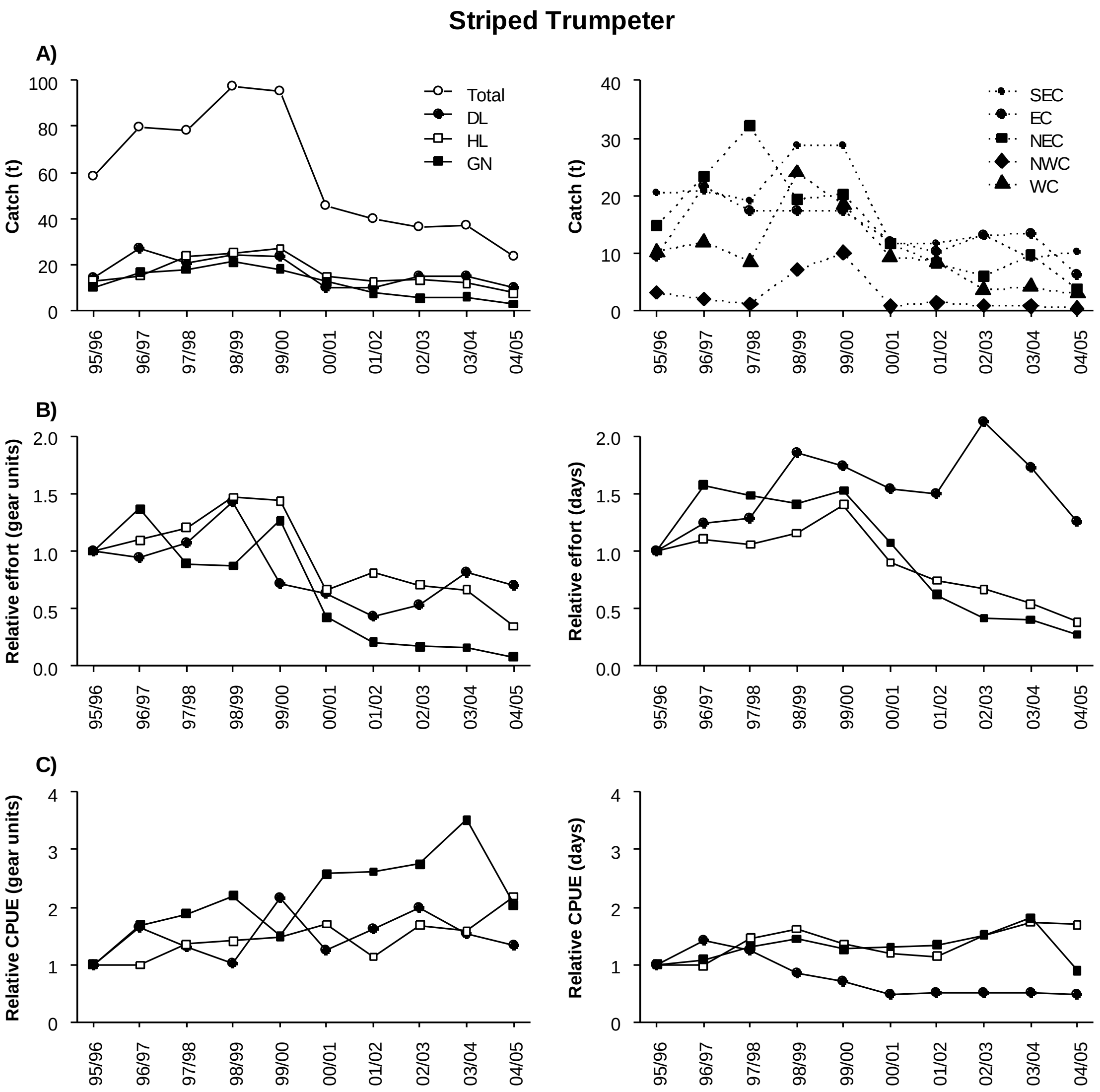


Fig. 5.1. A) Annual catch (tonnes) of striped trumpeter by method (left) and region (right) since 1995/96; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished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

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 26 tonnes (including catches from Commonwealth waters) for 2004/05 was about 35% lower that in the previous year and represented the lowest catch reported since the mid 1980s.

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

Table 5.1. Annual catches of striped trumpeter (tonnes) south of latitude 39° 12’S. Based on Tasmanian (General Fishing Return), Victorian and Commonwealth catch returns.

	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

Catches by the primary fishing methods are presented in Fig. 5.1A. The most conspicuous trend was the initial increase in production for all methods up until 1999/00, followed by general declines in catches for graball and handline methods. By contrast, dropline catches rose slightly between 2002/03 and 2003/04 but declined again in 2004/05. Regionally, the expansion of the fishery during the late 1990s was the result of increased catches from all areas. Subsequent declines also occurred in all regions, with the most recent drop in catches influenced particularly by falls in landings from north-east and east coast regions.

Strong 1993 and 1994 year-classes entered the fishery between 1995/96 and 1997/98 and influenced subsequent catches (and catch rates). There is circumstantial evidence to suggest that the 1996 year-class was also relatively strong and would have recruited to the inshore gillnet fishery in 1998/99. The subsequent decline in graball catches since 1998/99 presumably reflects the movement of the strong year-classes offshore but also suggests that there has been limited recruitment in recent years. Industry representatives suggest that the trip limit of 250 kg 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.

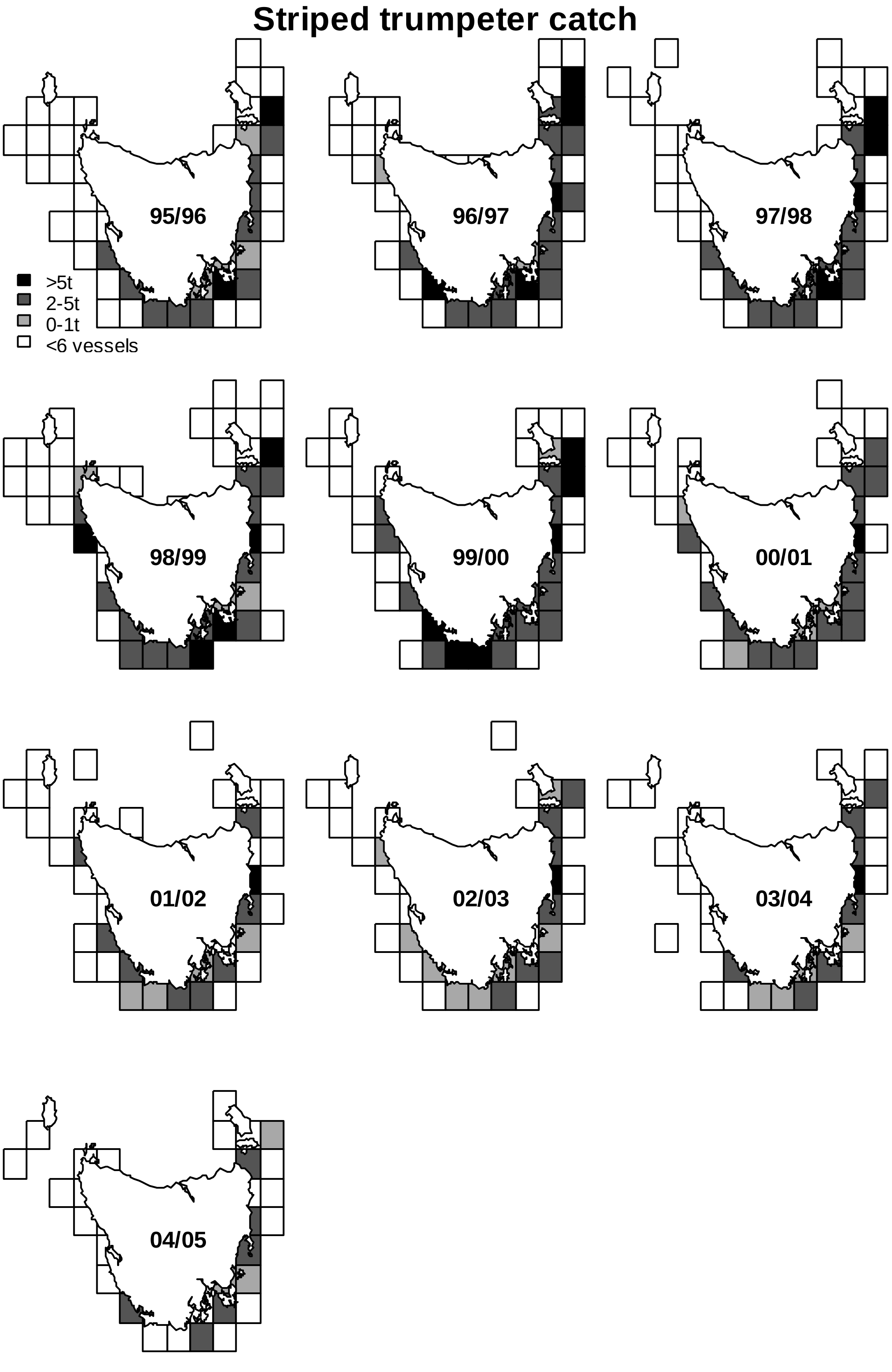


Fig. 5.2. Striped trumpeter catches (tonnes) by fishing block and year since 1995/96.

A recent 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. The introduction of a voluntary logbook for the charter boat sector during 2003 should provide on-going catch information and may have some potential as an indicator of trends in the broader recreational fishery.

Evaluation of 2004/05 catches against performance indicators

- State-wide catch was over 30% lower than in 2003/04 and well below the reference catch range; both catch performance indicators were triggered.

5.7.2 Fishing effort

The regional distribution and the expansion of the fishery over time is clearly evident in terms of effort (days fished) in Fig. 5.3 and is, not surprisingly, consistent with the pattern observed for catches (Fig. 5.2).

During the latter part of the 1990s, effort for the major fishing methods increased, presumably linked to the increased availability of striped trumpeter (Fig. 5.1B). Since then effort has generally declined (gear units and days fished) for graball and handline methods. Against these trends, dropline effort was relatively high in 2002/03 and again in 2003/04 but fell sharply in terms of days fished in 2004/05.

Evaluation of 2004/05 effort against performance indicator

- Handline and graball effort were well below reference levels and dropline effort (days fished) was within 10% of the peak reference level, therefore effort indicators were not triggered for any method.

5.7.3 Catch rates

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 2004/05 may have been influenced particularly by the increase in the minimum size limit that took effect during 2004. Catch rates for handlines have also tended to rise over time but unlike graball, appear to have been maintained in 2004/05. Dropline catch rates based on catch per hook-lift have fallen slightly over the past two years though are still within the range of reference values. Daily catch rates for droplines have changed little since 2000/01, remaining at about half of the minimum reference level

The influence of the trip limit on catch rates (daily catches) is unclear, although logbook data suggest that few operators would have been affected by the trip limit, at least on the basis of trips of a single day’s duration (i.e. daily catch rates rarely exceeded 250 kg).

Evaluation of 2004/05 catch rate against performance indicator

- Catch rates for handline and graball net effort were above reference values. By contrast, dropline catch rates were below 80% of the lowest reference level and triggered the catch rate performance indicators for the sixth year in a row.

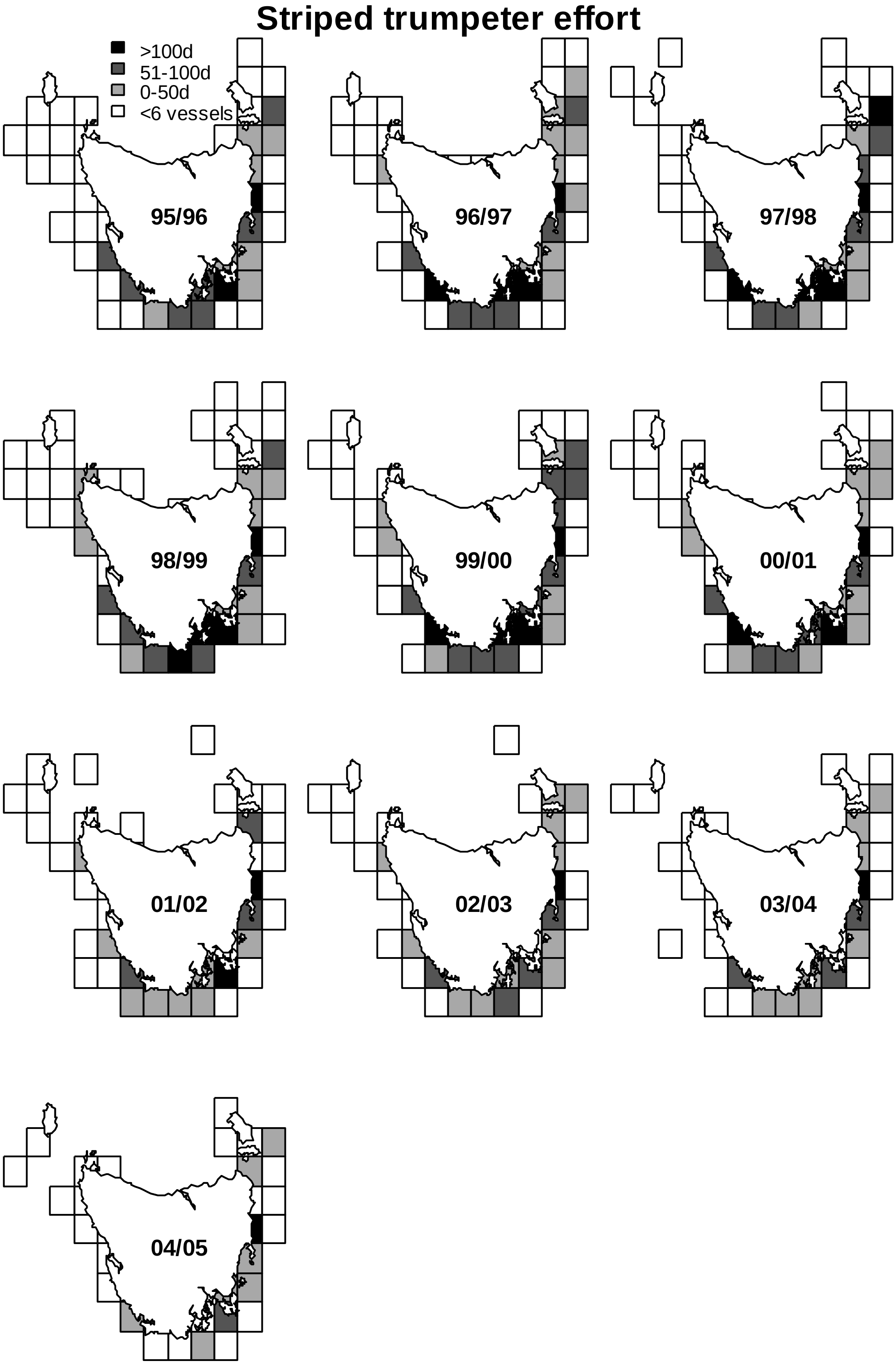


Fig. 5.3. Striped trumpeter effort (days fished) by fishing block and year since 1995/96.

5.7.4 Size and age composition

Size composition information obtained from research fishing and commercial catch sampling (hook catches) are presented in Fig. 5.4. The 1991/92 size composition was dominated by a broad mode of fish in the 50-70 cm size range with a peak at 55 cm. By comparison, the 1998/99 and 1999/00 size distributions were shifted to the left (i.e. generally smaller fish) with modes between 48-60 cm and peaks at 51-52 cm. From the age structure information it was apparent that the 1993 year class (5 year olds in 1999 and 6 year olds in 2000) clearly dominated these samples. The shift in the size structure towards larger fish in 2002/03 and 2004/05 is consistent with the growth of this cohort over time. Significantly, the 1993 cohort still dominated in 2004 (10 year olds) and 2005 (11 year olds). Recent age distributions support the observation that the 1996 cohort may also have been relatively strong (7 year olds in 2004 and 8 year olds in 2005) but clearly not as big as the 1993 cohort.

Of particular concern is the lack of fish smaller than 50 cm in the 2004/05 sample, implying that recruitment has been poor over several years (noting that fish generally recruit to the offshore hook fishery at around 45 cm or 5 years of age). This observation is borne out in the age composition, where as noted above, 11 year old fish dominate (Fig. 5.5). Under this scenario, adult biomass is expected to continue to decline and average size of hook-caught fish will increase in the short-term, at least until such time as there is a period of sustained good recruitment.

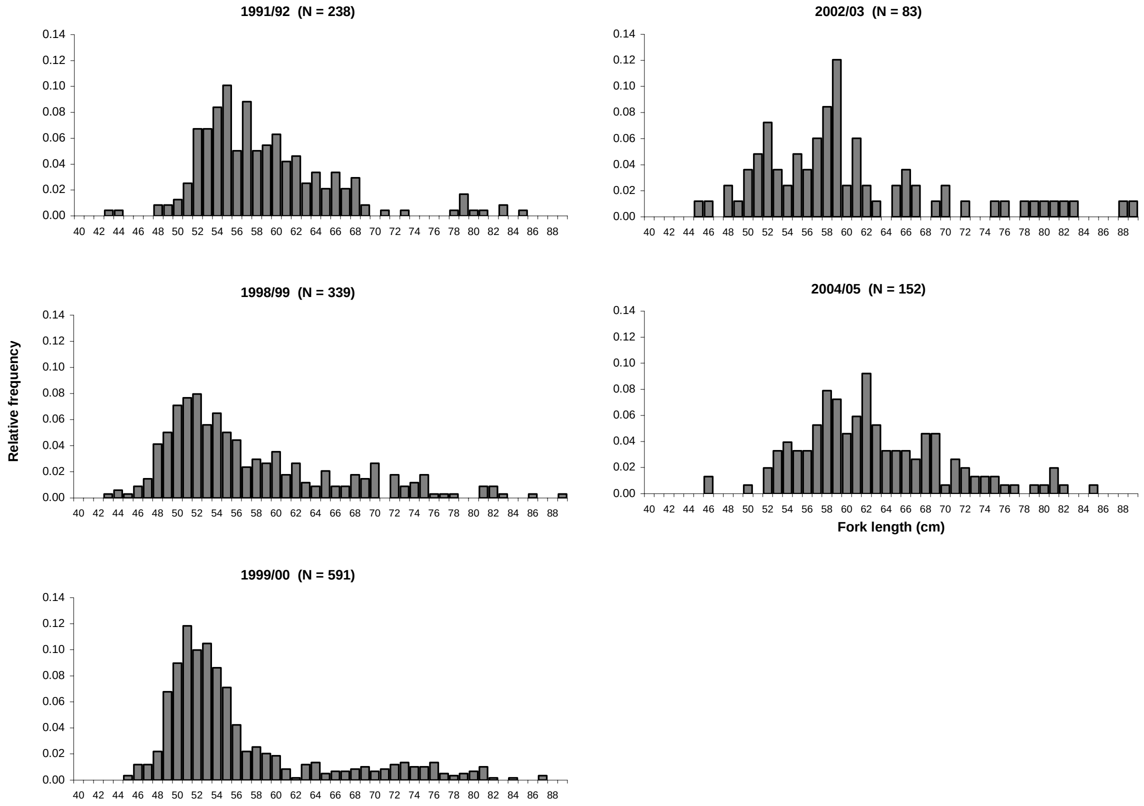


Fig. 5.4. Length frequency distributions of hook caught striped trumpeter collected in 1991/92, 1998/99, 1999/00 and 2004/05. *N* denotes sample size.

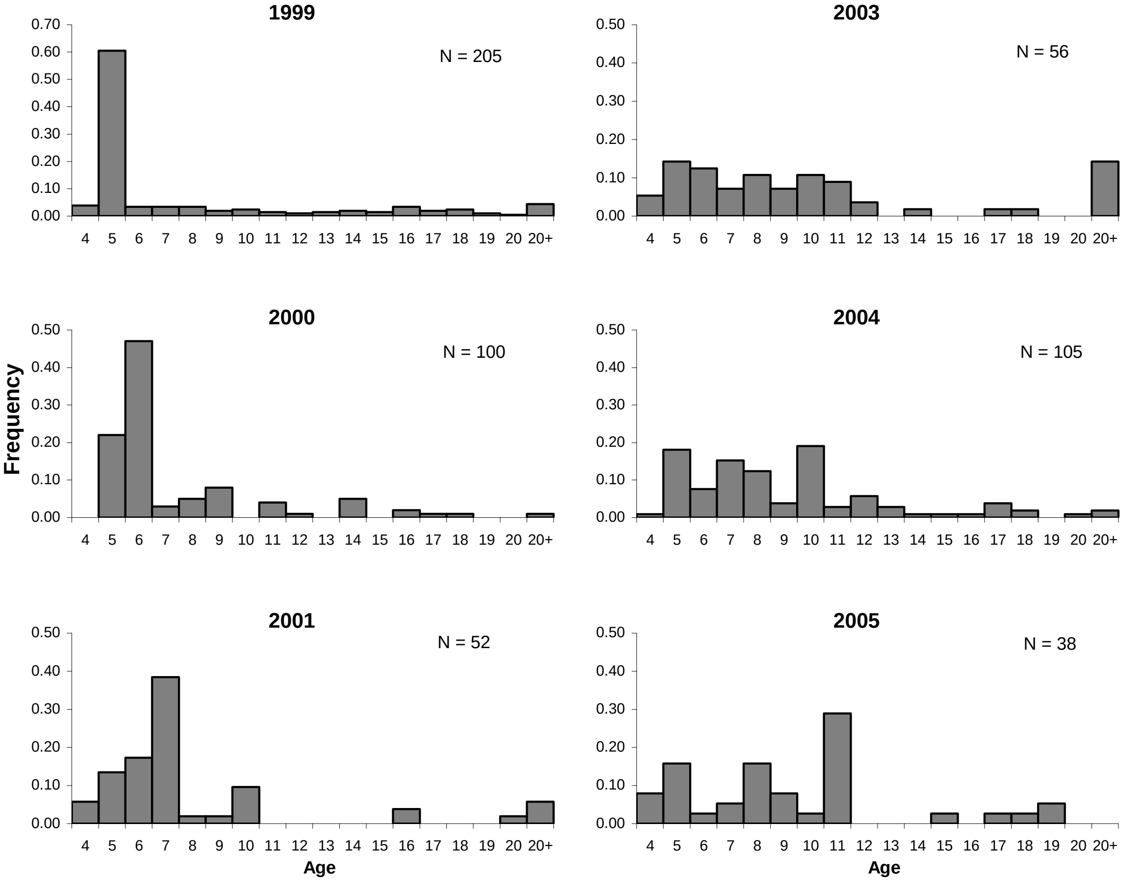


Fig. 5.5 Age composition of striped trumpeter samples by year. N is sample size.

5.7.5 Spawner biomass and yield-per-recruit

Yield-per-recruit (YPR) analysis reported in the 2003 assessment indicated that maximum yield could be achieved if the size at first capture (minimum legal size) was above 45 cm (FL). This analysis did not, however, take account of the relationship between size at first capture and fishing mortality on potential mature spawner biomass. More recent information about size at maturity and fecundity in striped trumpeter (S. Tracey, unpublished data) has enabled spawner biomass-per-recruit (SPR) analysis to be undertaken using an estimate of natural mortality *M* = 0.1 (Fig. 5.6). Based on fishing mortality estimate *F* = 0.15 (best estimate from Tracey and Lyle 2005) this analysis indicated that with the current minimum size limit of 45 cm TL (42.5 cm FL) SPR was less than 20% of the unfished level. At a size at first capture of 55 cm FL (equivalent to the size at 50% maturity), SPR was just over 35% whereas at 60 cm FL this increased almost 50%. Under each of these scenarios, however, YPR was optimized at an *F* of approximately 0.15 (Fig. 5.6).

Internationally, *F* that results in 40% SPR has been adopted as a target reference point whereas *F* that reduces SPR to 30% or below is considered a recruitment overfishing limit (Clark 1993, 2002, Mace and Sissenwine 1993, Mace 1994). Based on these criteria and the assumptions about mortality rates, the current size limit would appear to be sub-optimal and there is still a risk of recruit overfishing in striped trumpeter.

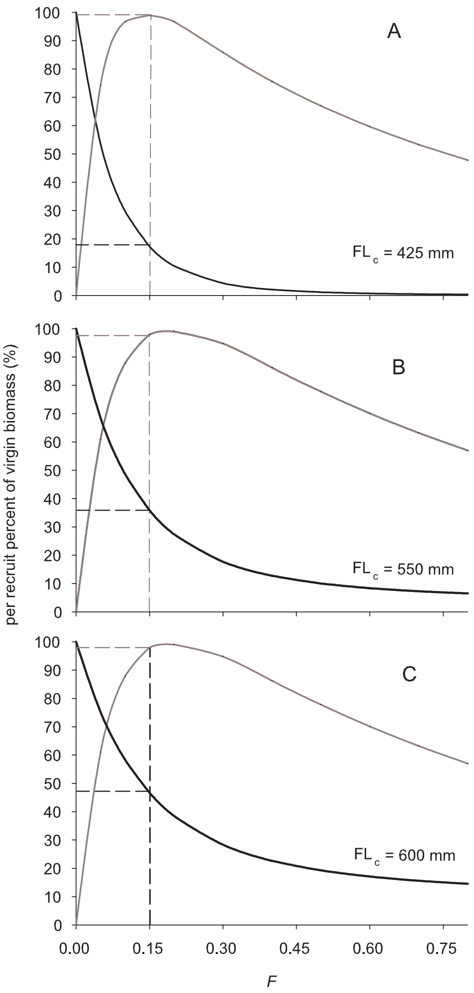


Fig. 5.6. Spawner biomass-per-recruit (dark line) and yield-per-recruit (grey line) for female striped trumpeter estimated with length at first capture of A) 425 mm FL (current size limit); B) 550 mm FL; and C) 600 mm FL. Dashed vertical lines represent best estimate of current fishing mortality (*F* =0.15) and horizontal lines represent corresponding estimates of percent spawner biomass and yield per recruit from the predictive curves.

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 variations in population size, especially if there is a prolonged period of poor recruitment, with the fishery becoming dependent upon relatively few year classes. Recent size and age composition data in fact imply that there has been no substantial recent recruitment and that a particularly strong cohort (now 11 years old) is still strongly represented in the population. The average size of hook-caught fish is thus expected to continue to increase as the present cohorts grow and spawner biomass will continue to decline. Furthermore, if the decline in catches does represent a decline in abundance, then it is likely that fishing mortality is too high and may lead to recruitment overfishing, a situation exacerbated by the minimum size limit still being set smaller than the size at maturity.

The impact of recent management changes, however, 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 handline effort over the past three years. There is also concern that the decline in commercial catches may be due, in part at least, to changes in reporting requirements for Commonwealth operators. Although these operators have been requested to provide catch information in Tasmanian catch returns for species under Tasmanian jurisdiction (including striped trumpeter) and for fishing within State waters, this may not have routinely occurred. Catches reported in Commonwealth returns over the past three years have averaged about 3 tonnes per annum, though industry reports suggest that these figures may be underestimated. There is an urgent need to resolve this matter with the Commonwealth and ensure that catch and effort information are comprehensive.

As commercial catches decline, it is likely that interest by the recreational sector will grow and there is evidence that this sector may already account for a significant component of the total mortality. There are anecdotal reports to support this trend and, in addition, the National Survey has demonstrated that the recreational take is at least comparable to the commercial catch (Lyle 2005).

The sharp fall in the graball catch observed in 2004/05 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. Interestingly, during 2005 there have been anecdotal reports of juvenile striped trumpeter present in some coastal areas, suggesting recent recruitment success, although the relative size of the cohort is unknown.

Spawner biomass-per-recruit analyses 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.

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.

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.

There is an urgent need to characterize the commercial and recreational fisheries for this species in terms of size composition and age-structure. There is a need to refine life history and population parameters for striped trumpeter (including growth and mortality, reproductive biology, movements, etc) and examine the impacts of present and alternative harvest strategies.

Fishery independent gillnet surveys have the potential to assess the relative abundance/presence of pre-recruits which could be valuable in predicting and interpreting future catch trends.

6 Other key scalefish

6.1 Sea Garfish (*Hyporhamphus melanochir*)

6.1.1 Catch

Garfish catches have remained relatively stable since the early 1990s, at between 80-90 tonnes in most years (Fig. 6.1A). Catches in 2004/05 recovered slightly, to 75 tonnes, from the drop that occurred in the previous year. This was largely due to an increase in the beach seine catch, the primary capture method for the species. Following an initial expansion in dipnet catches to 34 tonnes in 1998/99, catches taken by this method have generally declined, to just 12 tonnes in the current year.

Regionally, the north east coast including Flinders Island has dominated catches (Figs. 6.1B and 6.2). The east coast was of secondary importance until 2000/01, but catches have fallen since. There has been only limited variability in catches from the south east coast. Dipnetting is the preferred method in the south east and east coasts, accounting for around 85% and 70%, respectively to the total catch in these regions. By contrast, north east coast catches are almost exclusively taken by beach seines.

Evaluation of 2004/05 catches against performance indicators

- The catch performance indicators were not triggered.

6.1.2 Fishing effort

Dipnet effort increased initially to a peak during 1998/99 but has subsequently declined (Fig. 6.1B). On the other hand, beach seine effort has fluctuated without obvious trend over time, with effort in the current year being similar to levels that persisted during the late 1990s. Fishing occurred mainly in the north east coast and south east coast, consistent with the regional catch distribution (Fig. 6.3).

Evaluation of 2004/05 effort against performance indicators

- The beach seine and dipnet effort performance indicators were not triggered.

6.1.3 Catch rates

Beach seine and dipnet catch rates have been relatively stable over the past 4-5 years, the former being slightly higher than during the mid-1990s (Fig. 6.1C). However, for schooling species such as garfish, catch rates may be relatively insensitive to changes in abundance.

Some industry members have expressed concerns 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, which could reduce opportunities to use beach seines to target the species and even impact on beach seine catch rates. In regard to the latter, there was no evidence of a decline in beach seine catch rates as dipnet effort increased, though such impacts may have been localised and masked in this broad-scale analysis.

Evaluation of 2004/05 catch rates against performance indicator

- Beach seine and dipnet catch rates performance indicators were not triggered.

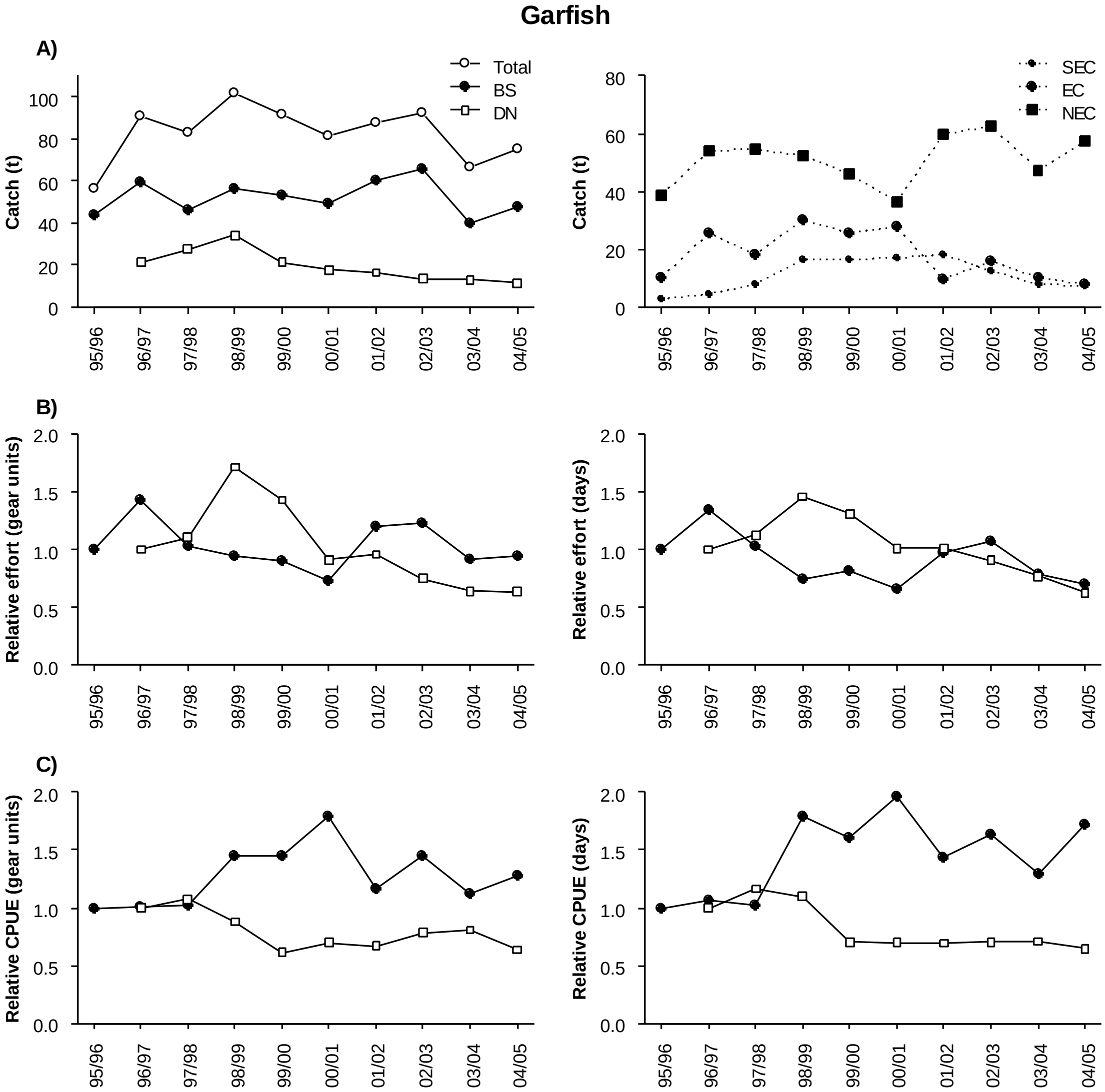


Fig. 6.1. A) Annual catch (tonnes) of garfish by method (left) and region (right) since 1995/96; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished (right) relative to 1995/96. BS is beach seine and DN is dip net; SEC is south east coast, EC is east coast, and NEC is north east coast.

6.1.4 Implications for management

The fishery data provide no evidence to support concern over garfish stock status. There remains, however, potential for effort to expand, particularly within the dipnet sector.

While it is not known whether present catch levels are sustainable, it would be prudent to consider management options that limit further expansion in this fishery.

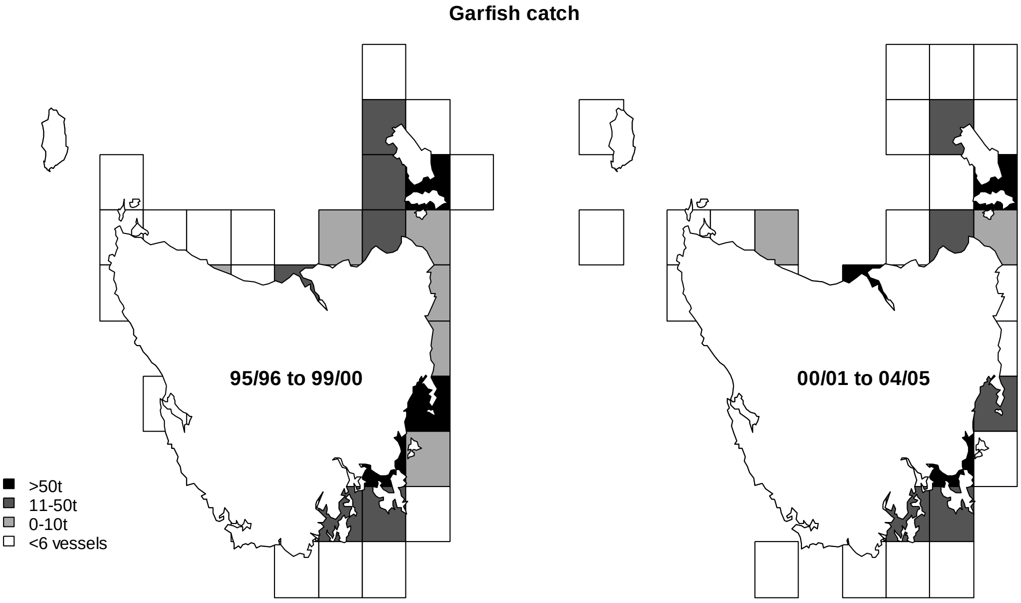


Fig 6.2. Garfish catches (tonnes) by fishing block and for the periods 1995/96 - 1999/00 and 2000/01 - 2004/05.

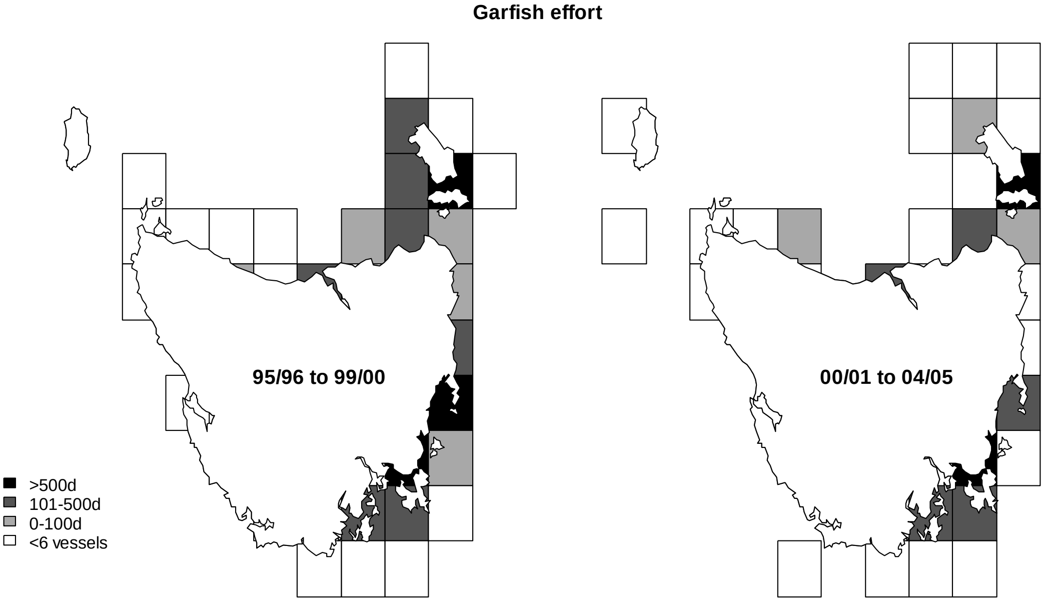


Fig 6.3. Garfish effort (days fished) by fishing block and for the periods 1995/96 - 1999/00 and 2000/01 - 2004/05.

6.2 Wrasse (Fam. Labridae)

6.2.1 Catch

Several species of wrasse occur in Tasmanian waters with purple wrasse (*Notolabrus fucicola*) and blue-throat wrasse (*N. tetricus*) 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. Over the past four years 'live' wrasse have accounted for between 66-76% of the total reported catch, and 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.

Between 1997/98 and 2001/02, wrasse catches were relatively stable at between 85-100 tonnes. After two years of lower catches, catches increased by 38% to 97 tonnes in 2004/05 (Fig. 6.4A). This increase was mainly due to higher handline catches, up from 35 to 57 tonnes. At the same time, fish trap catches increased 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 it would appear blue-throat wrasse are now taken in larger quantities in the live fishery. Gillnets account for the bulk of the remaining catch (< 4 tonnes in 2004/05). Because survival in nets is poor, graball caught wrasse are rarely marketed live.

Since the mid 1990s the focus of the fishery has shifted from the south east to the east coast (Fig. 6.4A and 6.5). Catches from the north east coast including Flinders Island increased up to 2001/02 but fell subsequently and have now stabilised. Recent increases in total catches derive mainly from the north west coast. 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.

Evaluation of 2004/05 catches against performance indicators

- Current State-wide catch was within the reference catch range, but increased by more than 30% compared with the previous year, indicating that catch performance indicator was triggered.

6.2.2 Fishing effort

Trends in fish handline and trap effort generally reflected those of catches with increased handline effort and stable (gear units) or slightly falling (days fished) trap effort (Fig. 6.4B). Regionally, most effort is now concentrated along the east coast (Fig. 6.6).

Evaluation of 2004/05 effort against performance indicator

- Trap and handline effort were either within or slightly below reference levels, and therefore did not trigger the effort performance indicators.

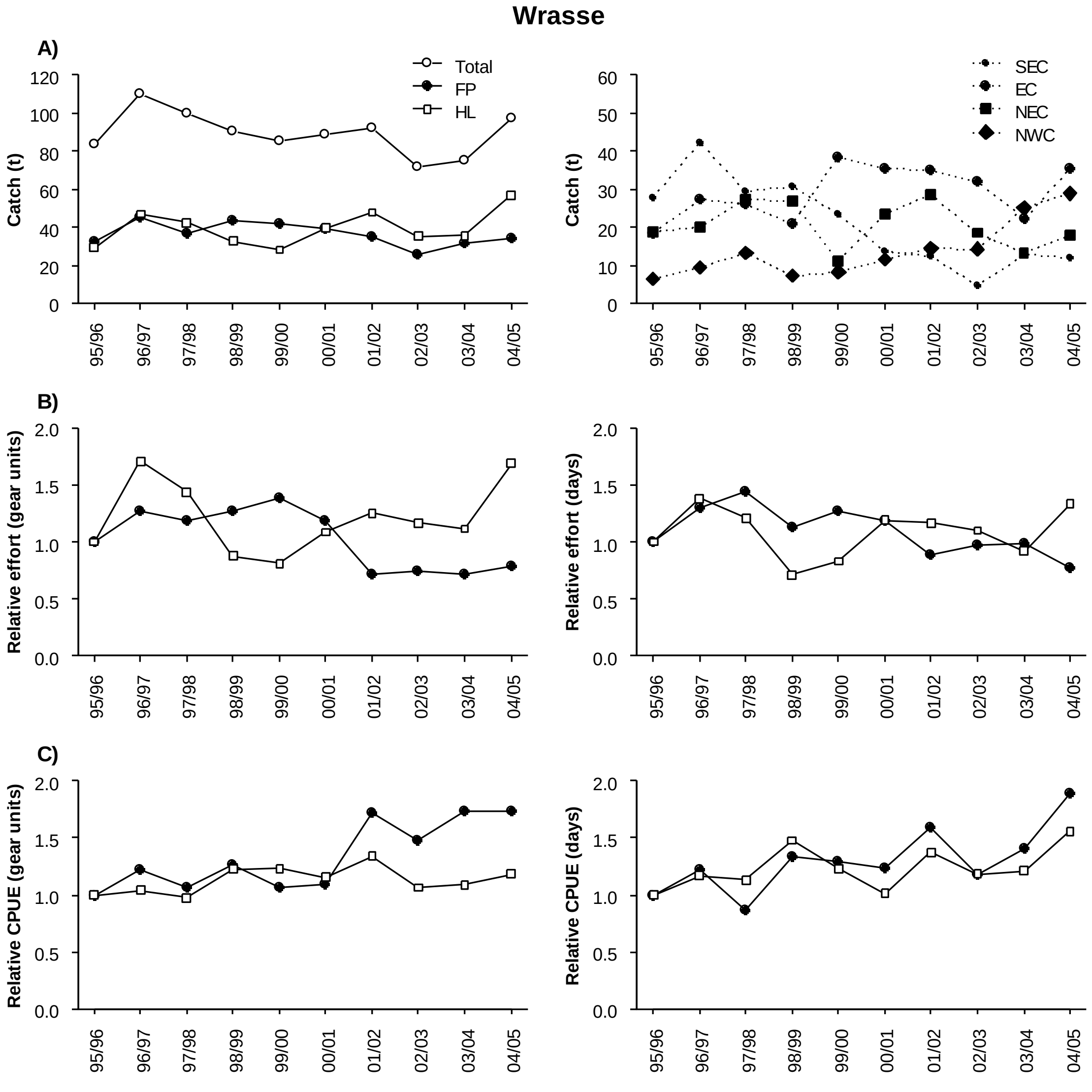


Fig. 6.4. A) Annual catch (tonnes) of wrasse by method (left) and region (right) since 1995/96; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished (right) relative 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.

6.2.3 Catch rates

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) have increased and stabilised at high level over the past four years (Fig. 6.4C). Daily catch rates for both handline and trap increased over the last two years, implying that handline fishers tended to exert greater effort for each day fished.

Catch rate trends imply that stocks of both wrasse species 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 on the fish 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.

Evaluation of 2004/05 catch rates against performance indicator

- Catch rate performance indicators were not triggered.

6.2.4 Implications for management

While input controls (limited entry) have capped participation in the live wrasse fishery, it is unknown whether current effort levels are sustainable. Under present arrangements, there is potential for localised depletions, 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 purple wrasse and for 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.

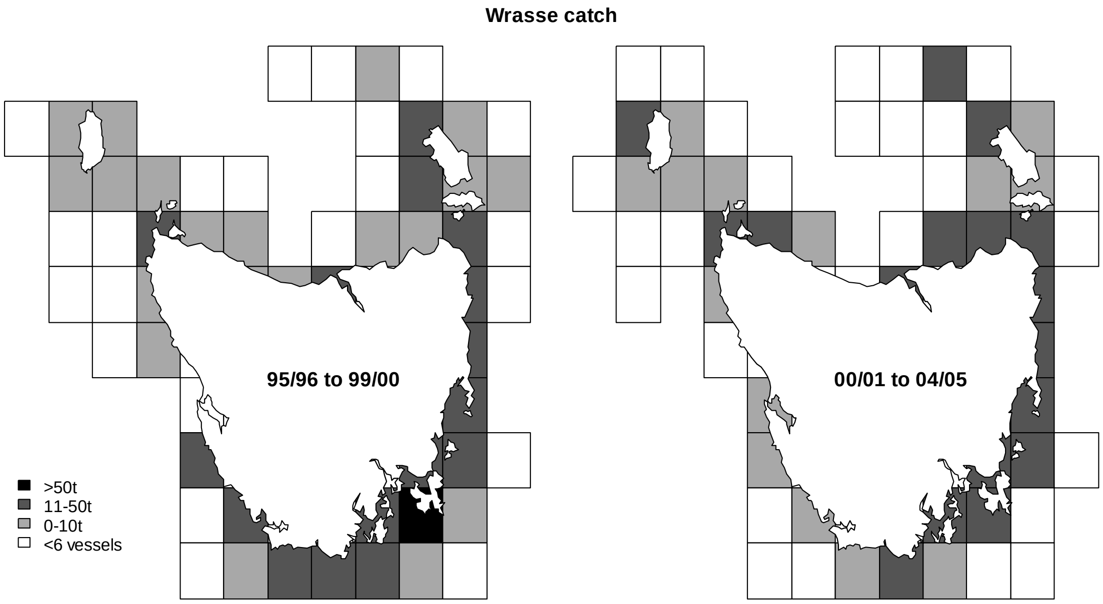


Fig. 6.5. Wrasse catches (tonnes) by fishing block and for the periods 1995/96 - 1999/00 and 2000/01 - 2004/05.

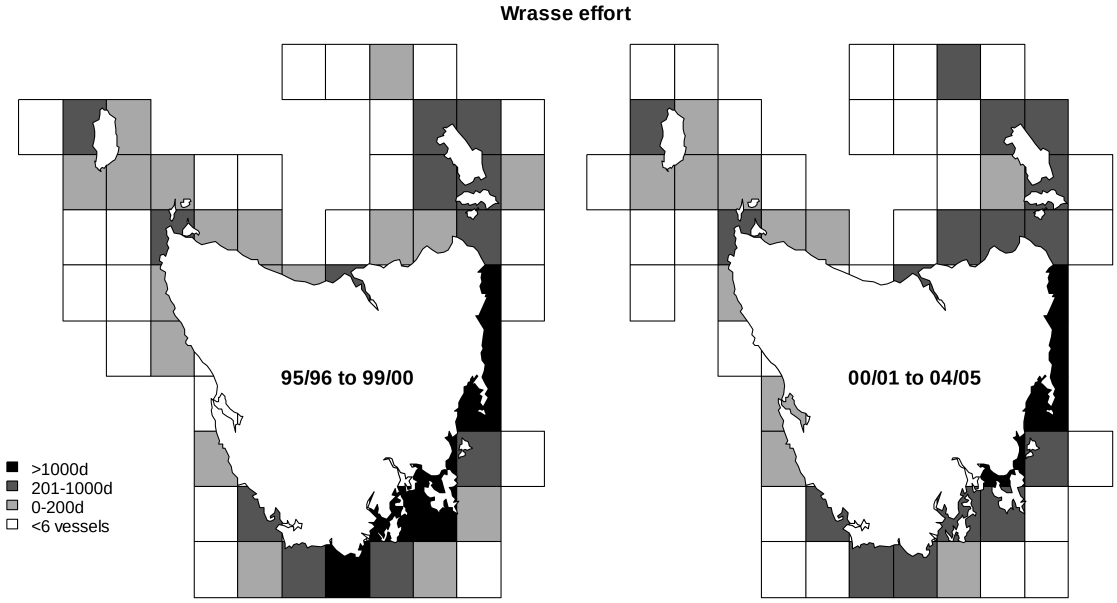


Fig. 6.6. Wrasse effort (days fished) by fishing block and for the periods 1995/96 - 1999/00 and 2000/01 - 2004/05.

6.3 Blue warehou (*Seriolella brama*)

6.3.1 Catch

Recent studies have indicated that there are two stocks of blue warehou in 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 southeast and east coast and thus probably targets the eastern stock (Figs. 6.7A and 6.8). Catches are also taken off the northeast and northwest coasts, the latter potentially involving the western stock.

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 combine to produce marked inter-annual variability in abundance and hence catches taken from State waters, as demonstrated in Fig. 6.7A. Due to low availability since the early 2000s, the species has been rarely targeted. The current catch of 18 tonnes represented a 33% reduction compared to the already low levels from the previous year, and was the lowest catch reported since the mid-1980s. The species is taken primarily in graball nets (Fig. 6.7A), 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 and Henry 2003), substantially lower than recreational catches taken in 1997 and 1998 (Lyle 2000) but consistent with the depressed state of the commercial catches.

Evaluation of 2004/05 catches against performance indicator

- Current State-wide catch declined by greater than 30% compared with the previous year and was outside (below) the reference catch range; therefore both catch performance indicators were triggered.

6.3.2 Fishing effort

Graball effort increased sharply between 1995/96 and 1998/99 resulting in increased catches over this period (Fig. 6.7B). Effort has since fallen and continued to decrease slowly for the last three years, largely in response to the reduced availability of the target species. This trend was consistent across all regions (Fig. 6.9).

Evaluation of 2004/05 effort against performance indicator

- Graball effort performance indicators were not triggered.

6.3.3 Catch rates

Graball catch rates increased markedly between 1995/96 and 1998/99 in response to the increased availability of warehou around Tasmania (Fig. 6.7C). However, since then catch rates have declined to levels similar to the mid-1990s, reflecting the fact that the species was rarely targeted in recent years.

Evaluation of 2004/05 catch rates against performance indicators

- Catch rate performance indicators were not triggered.

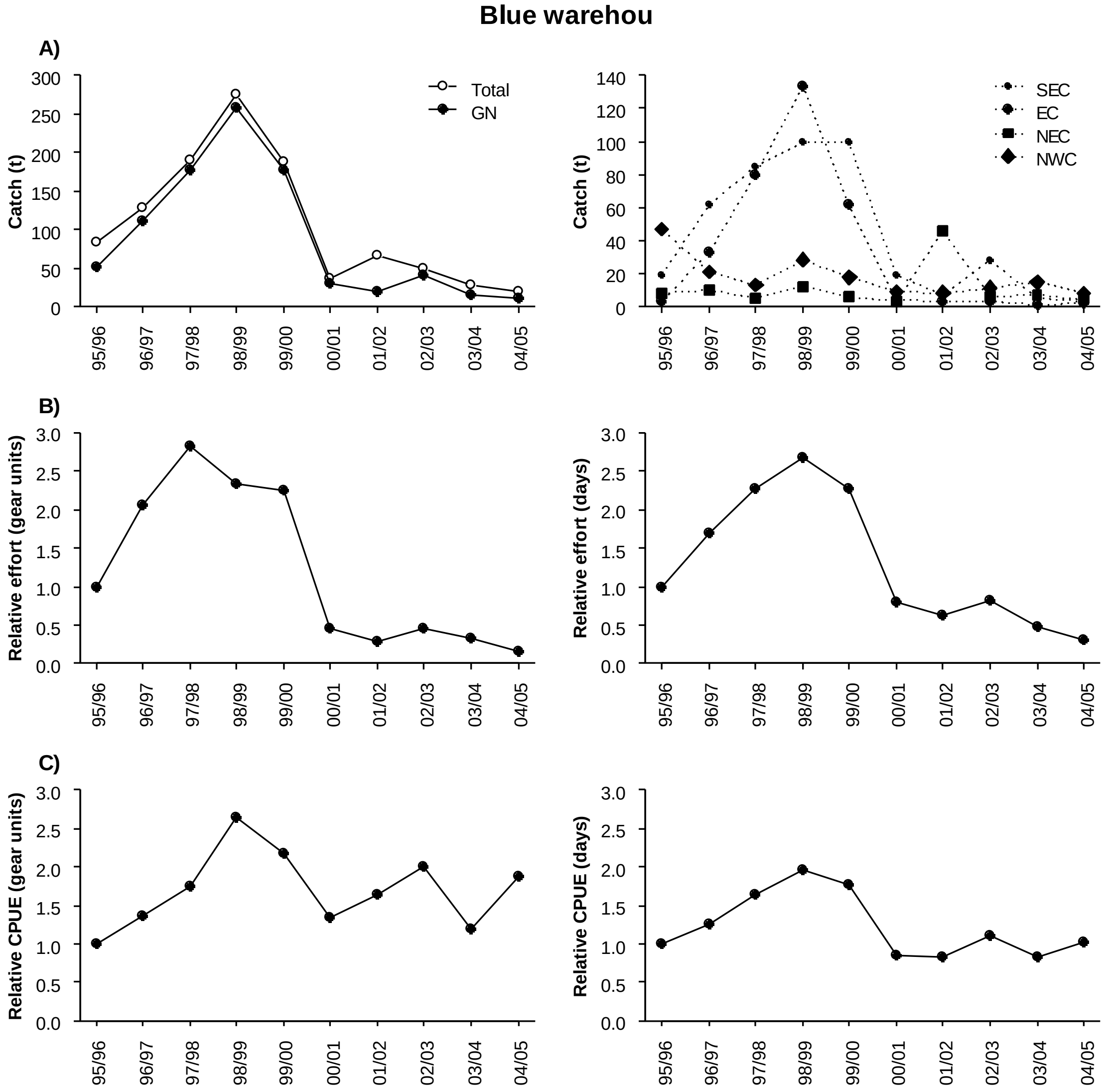


Fig. 6.7. A) Annual catch (tonnes) of blue warehou by method (left) and region (right) since 1995/96; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished (right) 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.

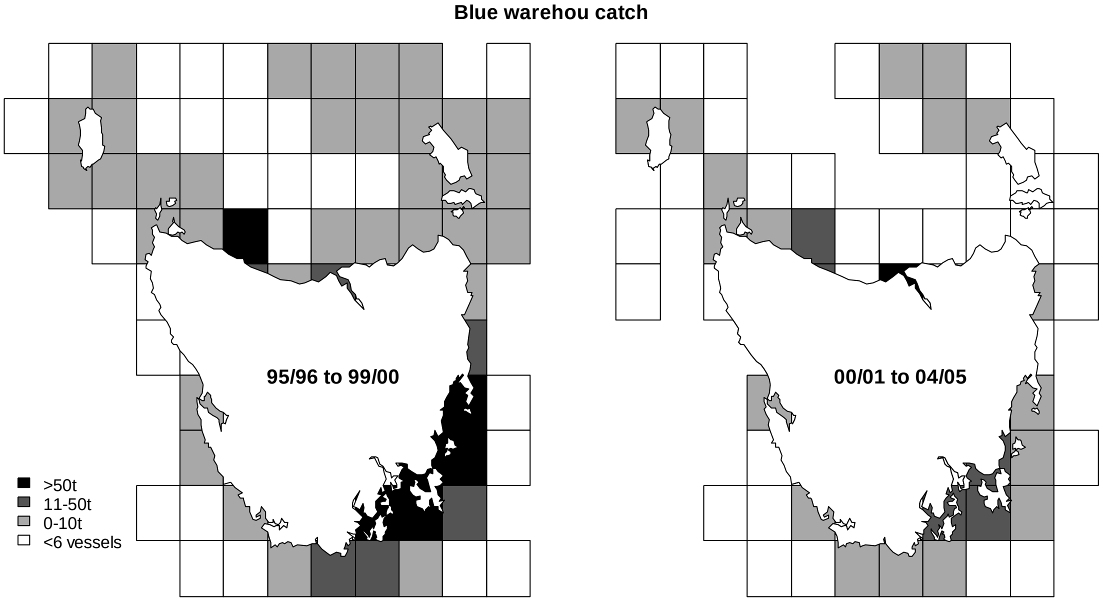


Fig. 6.8. Blue warehou catches (tonnes) by fishing block and for the periods 1995/96 - 1999/00 and 2000/01 - 2004/05.

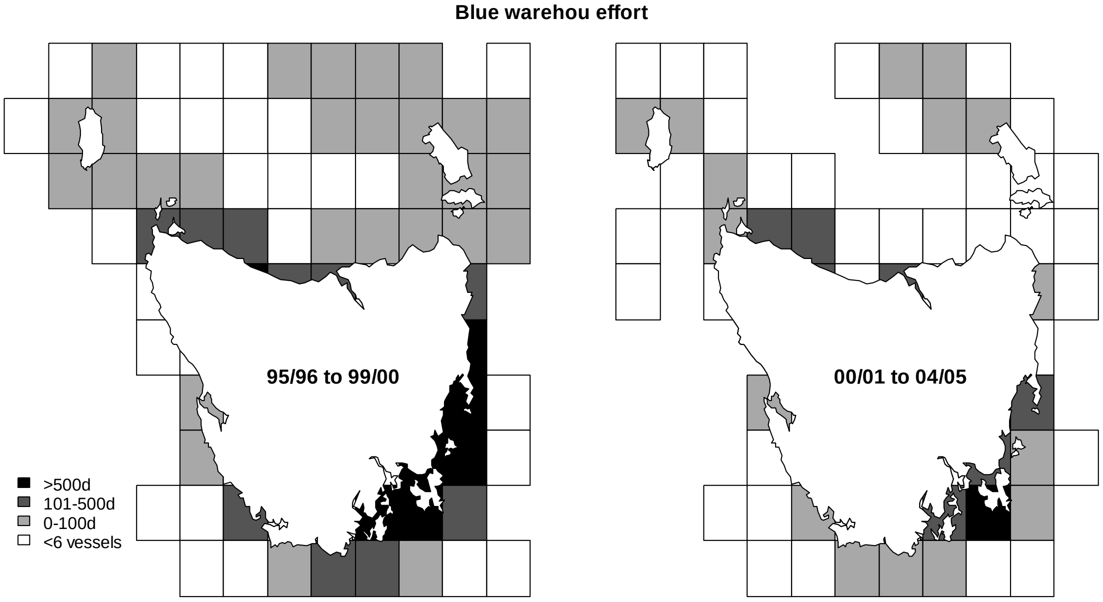


Fig. 6.9. Blue warehou effort (days fished) by fishing block and for the periods 1995/96 - 1999/00 and 2000/01 - 2004/05.

6.3.4 Implications for management

Blue warehou is a Commonwealth managed species and an 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 2002 South East Fishery stock assessment for blue warehou concluded that the blue warehou stocks had experienced a serious decline since the early 1990s and that a stock rebuilding strategy was required (Smith and Wayte 2002, Caton and McLoughlin 2004). In the absence of significant rebuilding through recruitment, catches of blue warehou are expected to be poor for the foreseeable future. The total allowable catch (TAC) for the Commonwealth fishery has been set at 300 tonnes per year since 2003, down from over 2,000 tonnes in late 1990s, reflecting concerns over stock status.

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

6.4 Bastard trumpeter (*Latridopsis forsteri*)

6.4.1 Catch

Bastard trumpeter catches have declined steadily since the mid 1990s to just 17 tonnes in 2004/05 (Fig. 6.10A), the lowest level since the late 1980s. Bastard trumpeter are taken almost exclusively by graball from inshore waters off the east, south and west coasts (Fig. 6.11).

The species has 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.

Evaluation of 2004/05 catches against performance indicators

- The current catch was again below the reference catch range; triggering the catch performance indicator for the fifth year.

6.4.2 Fishing effort

Graball effort for bastard trumpeter has followed a similar downward trend to catches since the mid-1990s (Figs. 6.10B and 6.12).

Evaluation of 2004/05 effort against performance indicators

- Graball effort was at its lowest level since 1995/96 and did not trigger the effort performance indicator.

6.4.3 Catch rates

Catch rates have remained relatively stable over time (Fig. 6.10C). This lack of an obvious trend, despite the sharp decrease in catches, presumably reflects the fact that bastard trumpeter are primarily taken as by-product, rather than as a target species.

Evaluation of 2004/05 catch rates against performance indicator

- The catch rate performance indicator was not triggered.

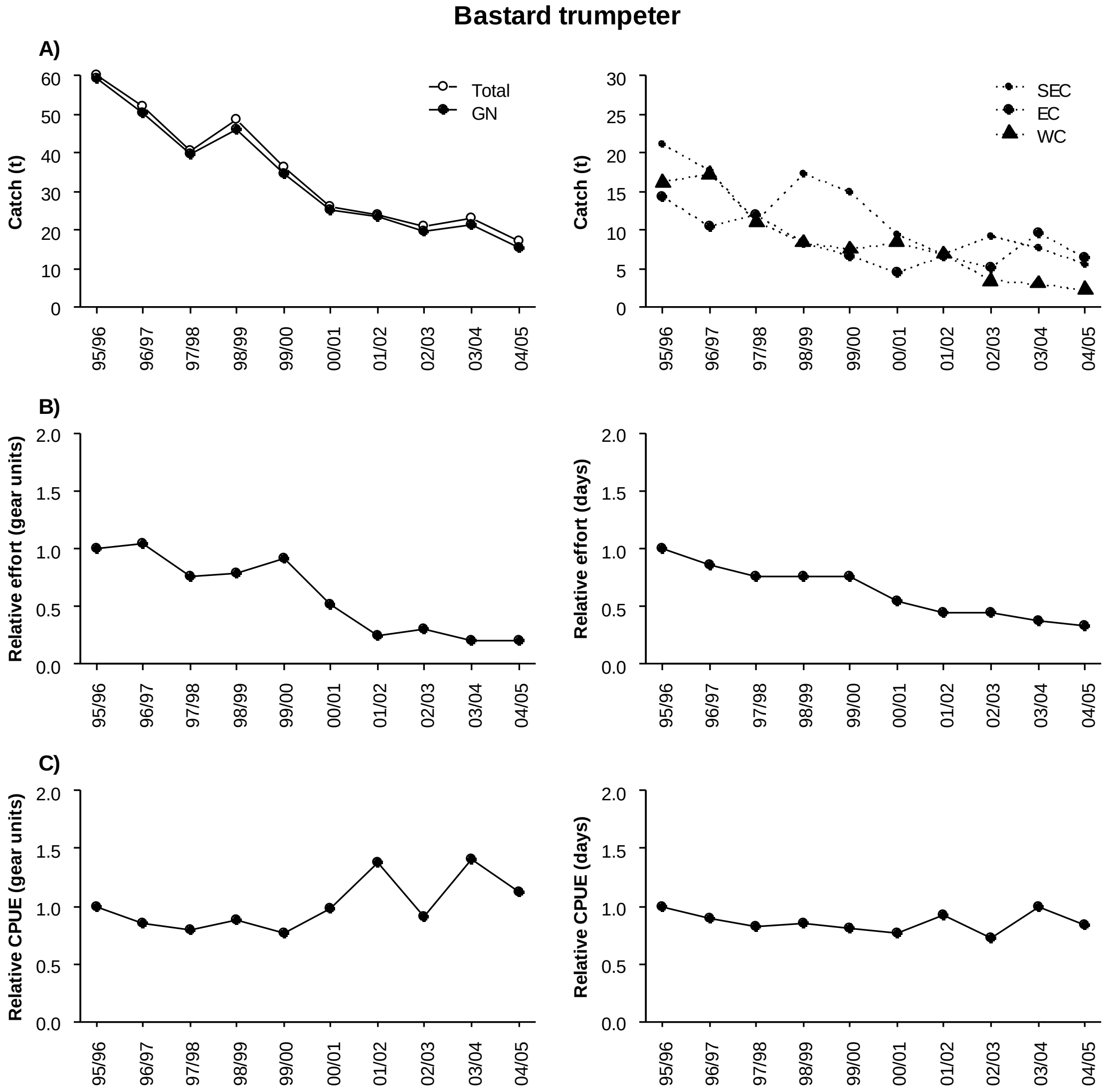


Fig. 6.10. A) Annual catch (tonnes) of bastard trumpeter by method (left) and region (right) since 1995/96; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished (right) relative to 1995/96. GN is graball; SEC is south east coast, EC is east coast and WC is west coast.

6.4.4 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 conclusion, 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 suggest that recruitment levels have been low in recent years, an observation reflected in the declining catches. Whilst juvenile biomass may vary widely due to recruitment variability and fishing pressure, we have no information regarding adult biomass. However, fish that evade the inshore fishery will be subject to very low levels of fishing pressure as adults. 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 have the effect of effectively closing down the current commercial and recreational fisheries for the species.

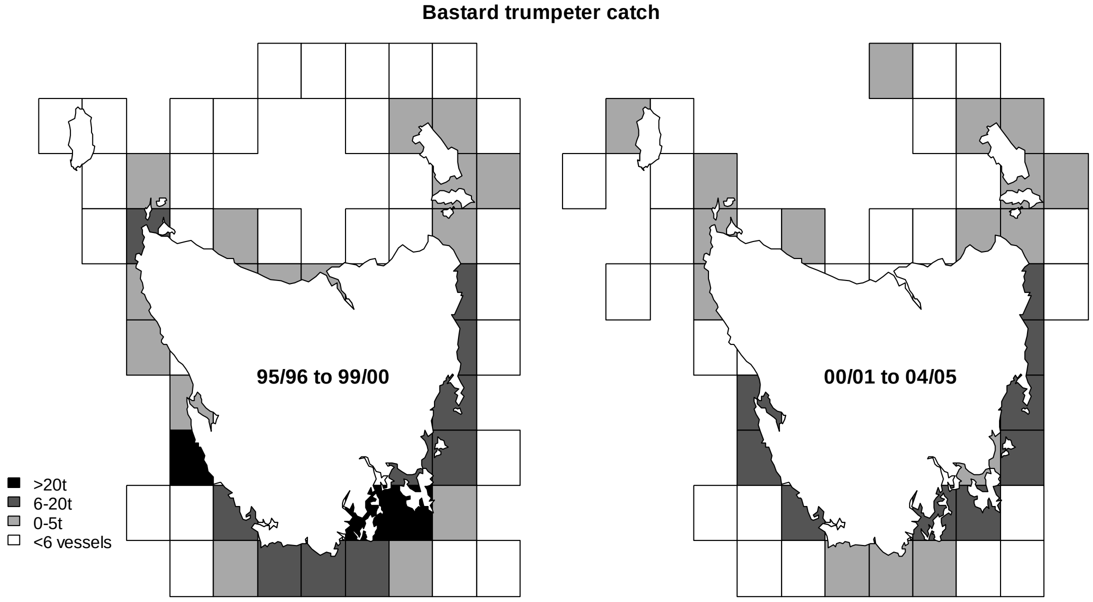


Fig. 6.11. Bastard trumpeter catches (tonnes) by fishing block and for the periods 1995/96 - 1999/00 and 2000/01 - 2004/05.

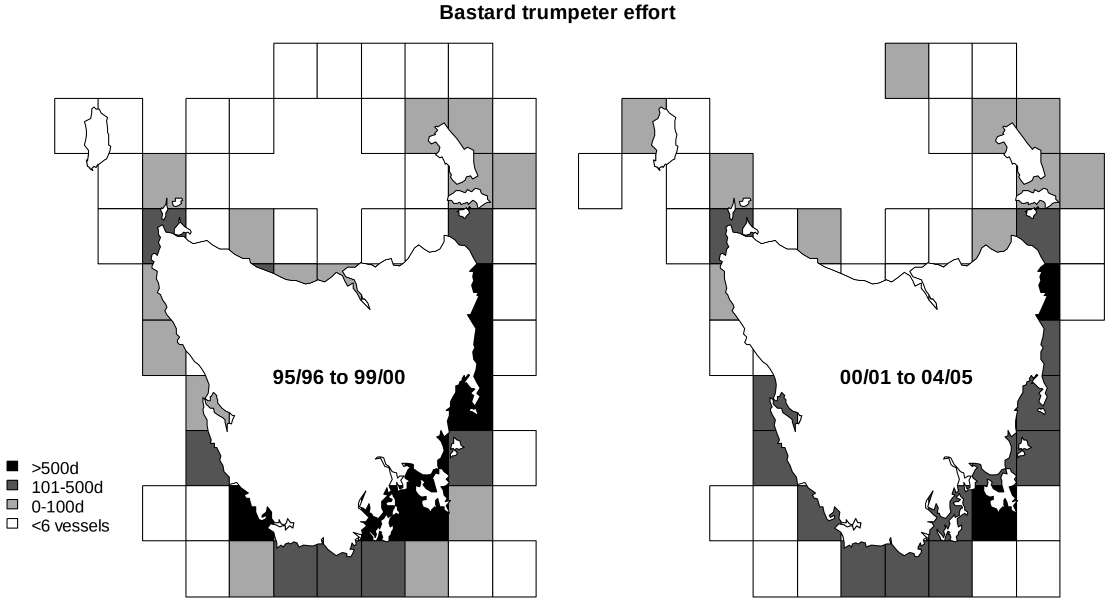


Fig. 6.12. Bastard trumpeter effort (days fished) by fishing block and for the periods 1995/96 - 1999/00 and 2000/01 - 2004/05.

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

6.5.1 Catch

The commercial catch of Australian salmon recovered from the drop in 2003/04, more than doubling to 335 tonnes in 2004/05 (Fig. 6.13A). 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. 6.13A and 6.14)

Australian salmon represent the second most commonly caught species in the recreational fishery, with an estimated harvest of 111 tonnes in 2000/01 (Henry and Lyle 2003).

Evaluation of 2004/05 catches against performance indicator

- Current State-wide catch was within the reference range, but had increased by more than 30% compared to the previous year and therefore triggered the rate of change performance indicator.

6.5.2 Fishing effort

Beach seine effort was virtually unchanged compared with 2003/04 and has remained at a relatively low level since the late 1990s (Figs. 6.13B and 6.15).

Evaluation of 2004/05 effort against performance indicator

- Beach seine effort has remained at the lowest level since the mid-1990s and therefore the effort performance indicator was not triggered.

6.5.3 Catch rates

Beach seine catch rates were slightly higher during 2004/05 compared to previous years (Fig. 6.13C). 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. In any case, for schooling species such as Australian salmon catch rates that do not take account of search time will not be a particularly sensitive indicator of stock condition.

Evaluation of 2004/05 catch rates against performance indicator

- Beach seine catch rates did not trigger the performance indicator.

6.5.4 Implications for management

Australian salmon catches are, to a large extent, linked to market demand, specifically the bait market, and are thus not a good indicator of stock status. There is capacity for industry to significantly expand production should new markets be found (there is interest in developing export markets) and under such circumstances management may need to be proactive in moderating such expansion. While stock status is unknown, the species has sustained substantially higher catches in the past and therefore in the absence of indicators to the contrary 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.

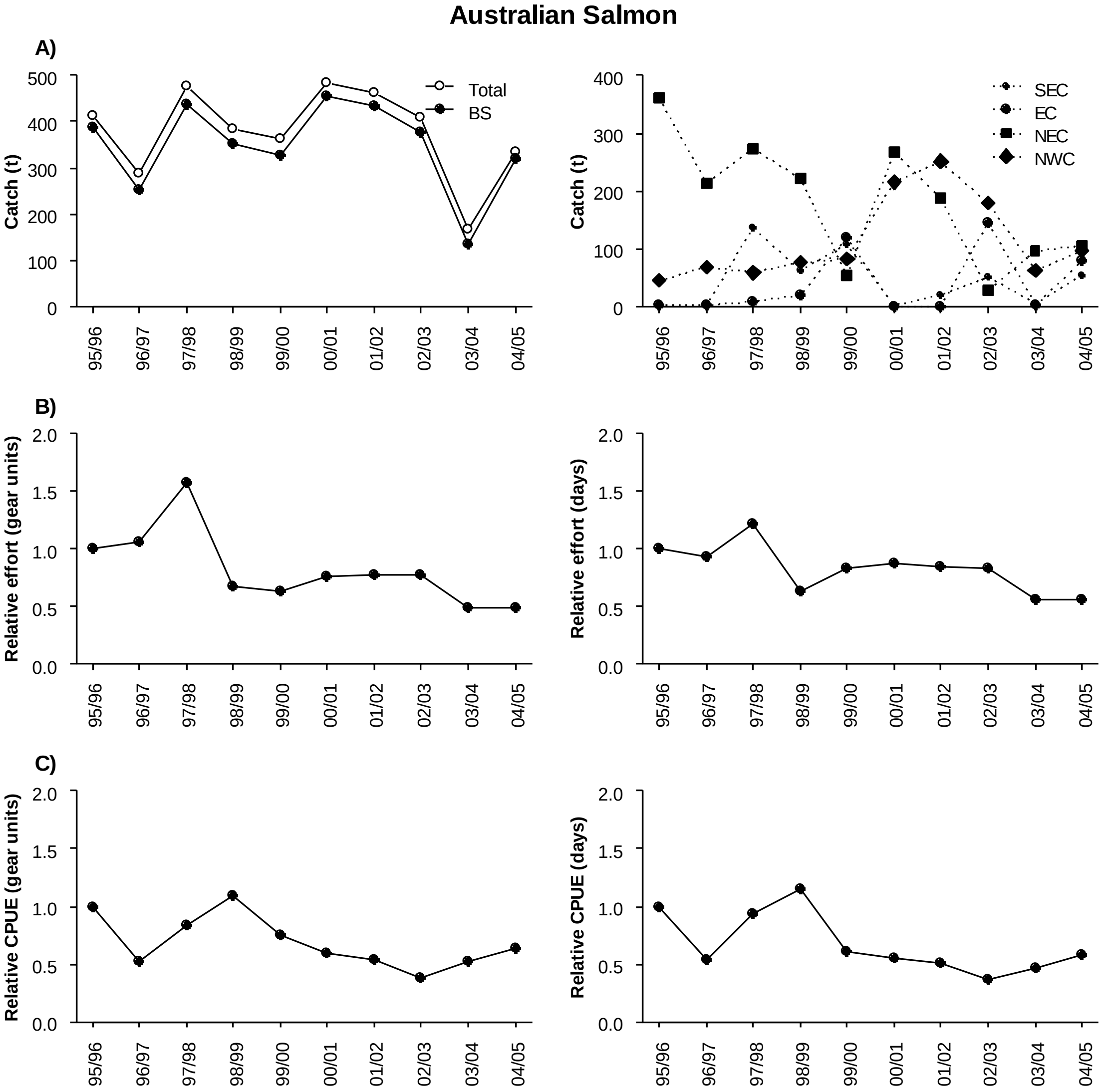


Fig. 6.13. A) Annual catch (tonnes) of Australian salmon by method (left) and region (right) since 1995/96; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished (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.

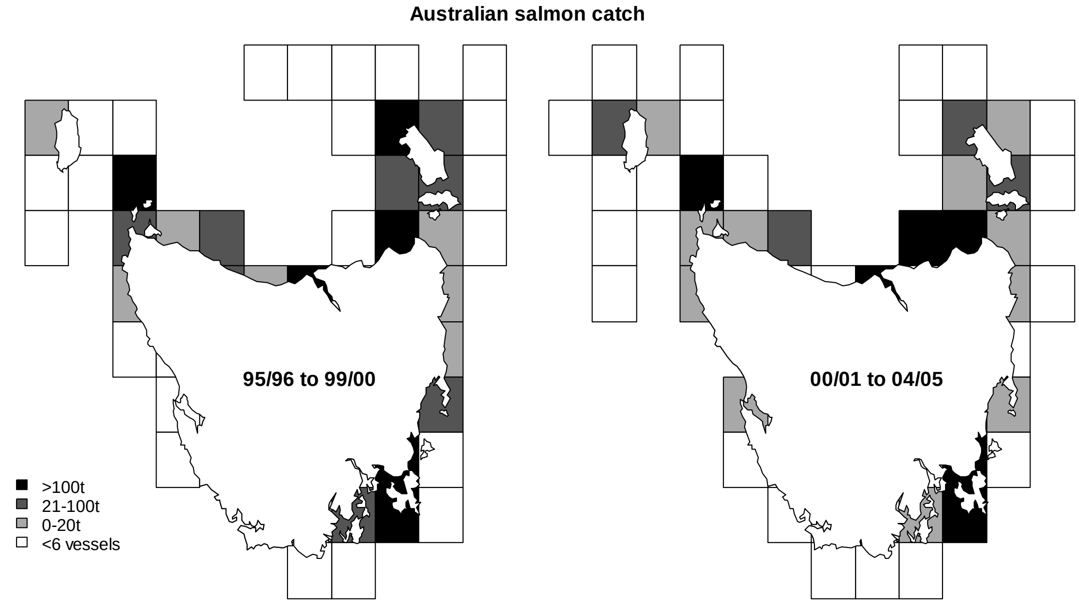


Fig. 6.14. Australian salmon catches (tonnes) by fishing block and for the periods 1995/96 - 1999/00 and 2000/01 - 2004/05.

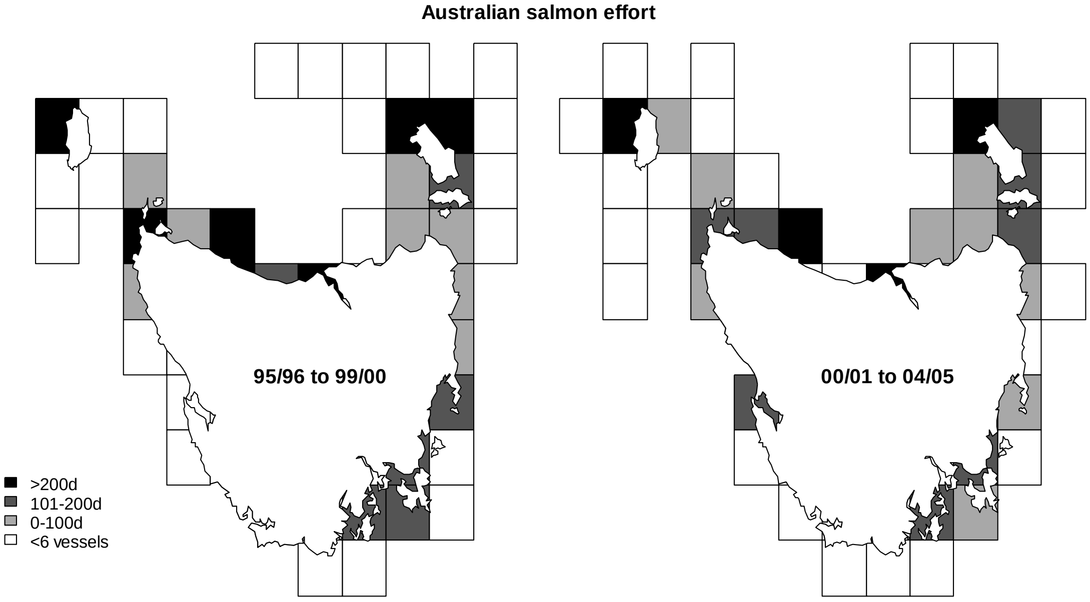


Fig. 6.15. Australian salmon effort (days fished) by fishing block and for the periods 1995/96 - 1999/00 and 2000/01 - 2004/05.

6.6 Flounder (Fam. Pleuronectidae)

6.6.1 Catch

Several species of flounder occur in Tasmanian waters, but catches are dominated by greenback flounder (*Rhombosolea tapirina*) and to a lesser extent long-snouted flounder (*Ammotretis rostratus*).

Flounder catches 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 (Fig. 6.16A). The current catch of 14 tonnes was well below reference catches. Graball ('flounder') nets and spears represent the primary fishing methods for flounder. Flounder is mainly caught in shallow waters of the south east, east and north east coasts (Figs. 6.16A and 6.17).

The estimated recreational catch of flounder in 2000/01 of 21 tonnes was double the size of commercial catch for the corresponding period, indicating the relative importance of the recreational component of this fishery (Lyle 2005).

Evaluation of 2004/05 catches against performance indicator

- Current State-wide catches were outside (below) the reference range, triggering the catch performance indicator for the seventh year running.

6.6.2 Fishing effort

Graball effort for flounder declined steadily since 1995/96 whereas spear effort increased initially and then fell over a period of several years up to 2000/01. During 2004/05, spear effort remained stable compared to the previous year and was within reference levels (Fig. 6.16). The overall regional distribution of effort based on days fished has changed little over time (Fig. 6.18).

Evaluation of 2004/05 effort against performance indicator

- Graball and spear effort did not trigger the effort performance indicator.

6.6.3 Catch rates

Graball catch rates based on gear units have increased over time whereas daily catch rates declined and then stabilised at about 70% of the minimum level during the reference period (Fig. 6.16C). In effect this suggests that fishers are deploying less gear on average for each day fished. Spear catch rates, based on hours fished, have steadily declined, with 2004/05 representing the lowest reported since the mid-1990s (about 70% of the lowest reference value). Daily catches started to drop in the last two years and to be 77% of the minimum level during the reference period to be just below the reference limit.

Evaluation of 2004/05 catch rates against performance indicator

- Graball catch rates based on daily catches and spear catch rates based on hours fished and daily catches were less than 80% of the lowest reference levels and therefore triggered the performance indicator.

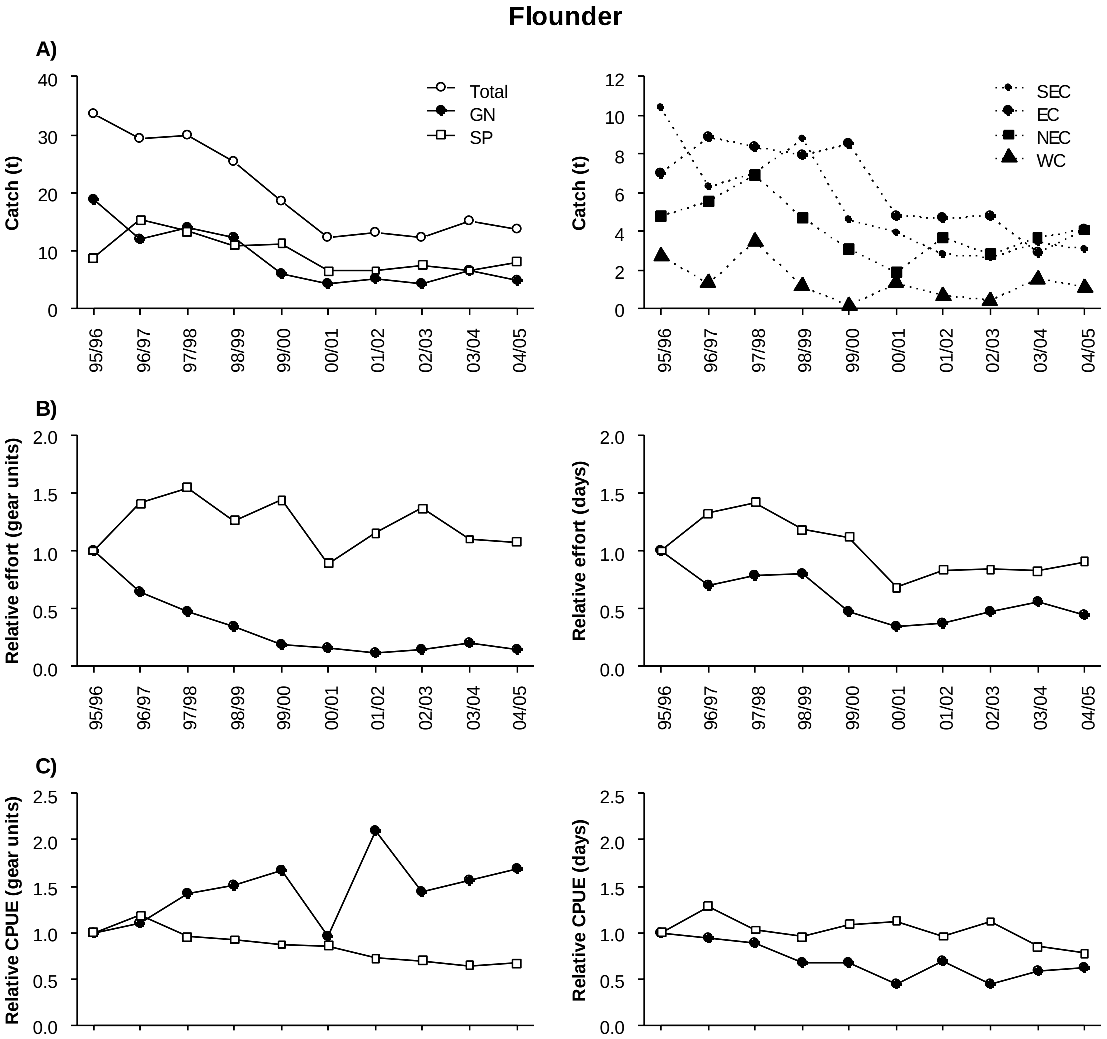


Fig. 6.16. A) Annual catch (tonnes) of flounder by method (left) and region (right) since 1995/96; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished (right) relative to 1995/96. GN is graball and SP is spear; SEC is south east coast, EC is east coast, NEC is north east coast and WC is west coast.

6.6.4 Implications for management

Industry members have commented that while there have been declines in flounder stocks, there have also been market changes for the species that have impacted on the amount of effort directed at flounder.

The current status of the flounder stocks is unknown, but it appears that they have declined in recent years. Recreational catches of flounder clearly represent a significant component of the harvest and trends in that fishery may be more informative of stock condition.

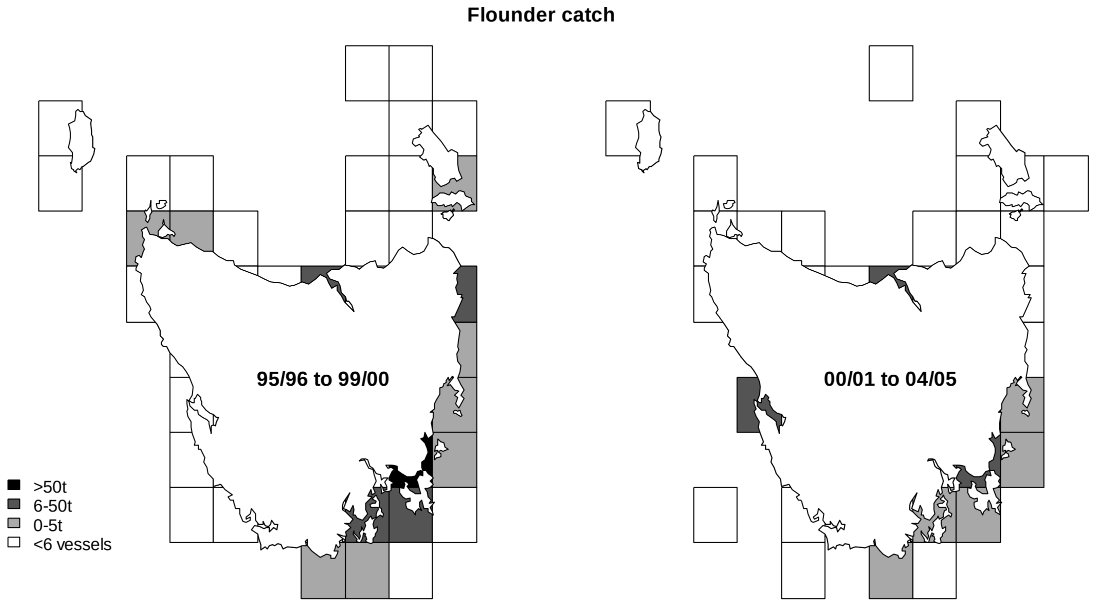


Fig. 6.17. Flounder catches (tonnes) by fishing block and for the periods 1995/96 - 1999/00 and 2000/01 - 2004/05.

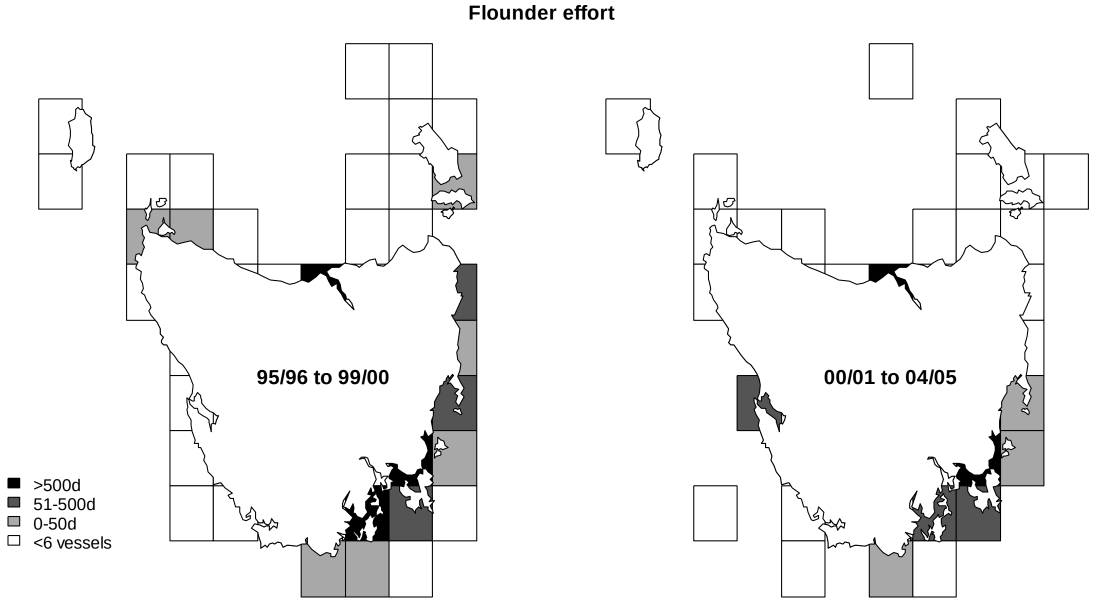


Fig. 6.18. Flounder effort (days fished) by fishing block and for the periods 1995/96 - 1999/00 and 2000/01 - 2004/05.

6.7 Flathead (Fam. Platycephalidae)

6.7.1 Catch

Several species of flathead occur in Tasmanian waters, but catches are dominated by tiger flathead (*Neoplatycephalus richardsoni*). Sand flathead (*Platycephalus bassensis*) is caught to a lesser extent, but the two species of flathead are not routinely distinguished in catch returns.

Flathead catches declined steadily between 2000/01 and 2003/04 but in 2004/05 more than doubled to 74 tonnes, a level more consistent with catches taken during the early 1990s (Fig. 6.19A). Increased production was mainly due to Danish seine catches (not shown due to the 5 vessel rule), the primary commercial fishing method for tiger flathead in State waters. By contrast, handline catches, mainly targeting sand flathead, have remained stable since the mid 1990s. Small quantities of flathead were also taken by graball nets and spears. 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. 6.19A and 6.20)

By contrast, recreational catches are dominated by sand flathead, tiger flathead comprise only a minor component of the harvest (Lyle 2005). The estimated recreational catch of flathead in 2000/01 was 361 tonnes, almost six times the size of commercial catch (63 tonnes) for the corresponding period.

Evaluation of 2004/05 catches against performance indicator

- State-wide catch was within the reference range, but increased by more than 30% compared with the previous year and triggered the rate of change performance indicator.

6.7.2 Fishing effort

Hand line effort has fluctuated without obvious trend and, overall, has remained relatively stable since the mid 1990s (6.19B). The regional distribution of effort has changed little since the mid 1990s, with commercial effort particularly concentrated off the south east, east and north east coasts (Fig. 6.21).

Evaluation of 2004/05 effort against performance indicator

- Flathead effort did not trigger the performance indicator.

6.7.3 Catch rates

Hand line catch rates have remained stable over time (Fig. 6.19C). Although not shown, Danish seine catch rates increased sharply in 2004.05, presumably reflecting increased targeting for the species.

Evaluation of 2004/05 catch rates against performance indicator

- Flathead catch rates did not trigger the performance indicator.

6.7.4 Implications for management

The recent increase in the Danish seine catches was 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 (Caton and McLoughlin 2004). 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, particularly 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.

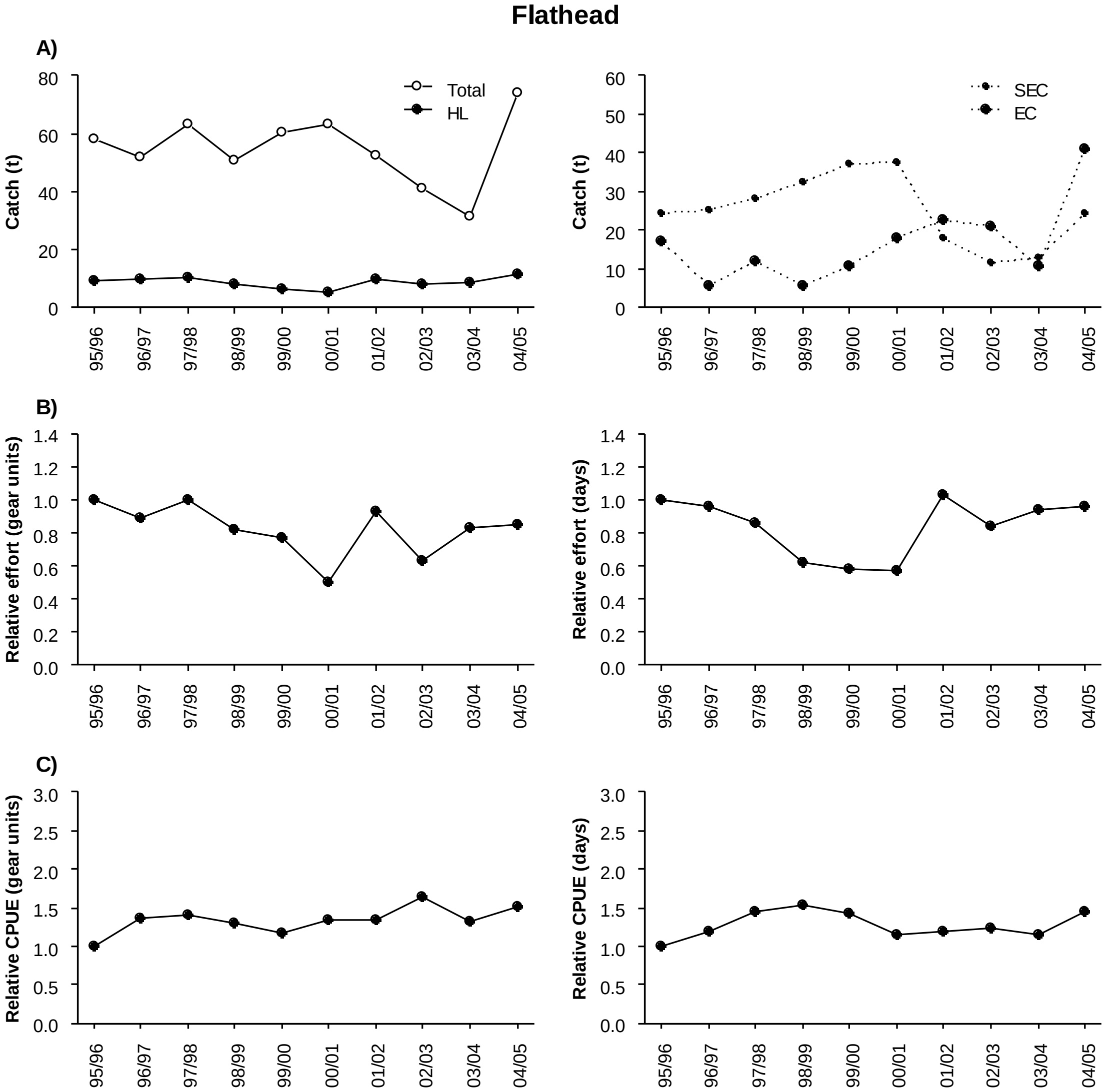


Fig. 6.19. A) Annual catch (tonnes) of flathead by method (left) and region (right) since 1995/96; B) effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) catch per unit effort (CPUE) based on weight per gear unit (left) and weight per day fished (right) relative to 1995/96. HL is hand line; SEC is south east coast and EC is east coast.

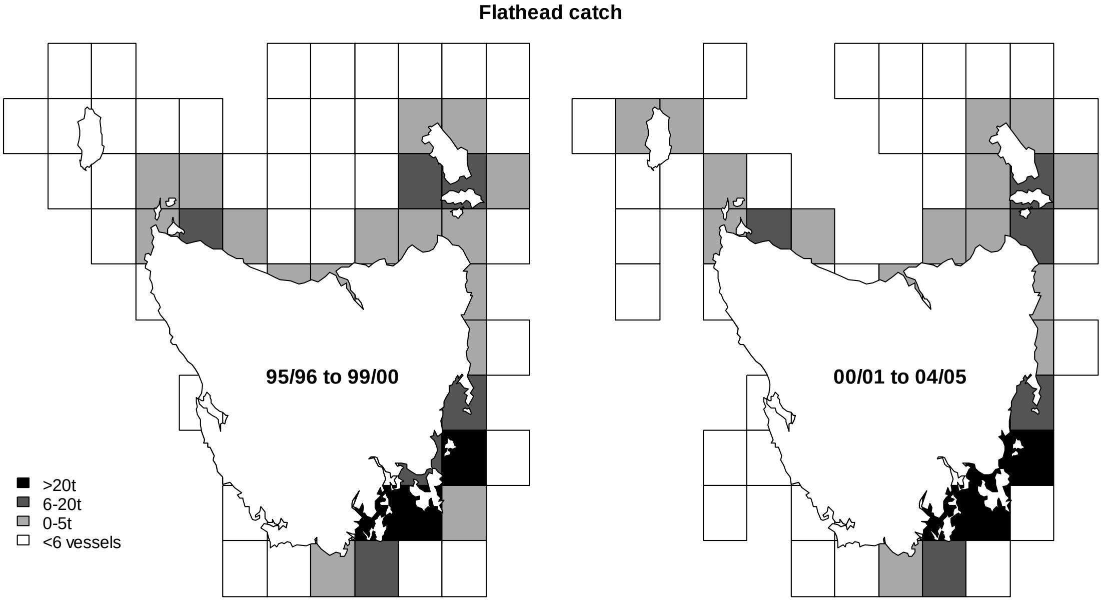


Fig. 6.20. Flathead catches (tonnes) by fishing block and for the periods 1995/96 - 1999/00 and 2000/01 - 2004/05.

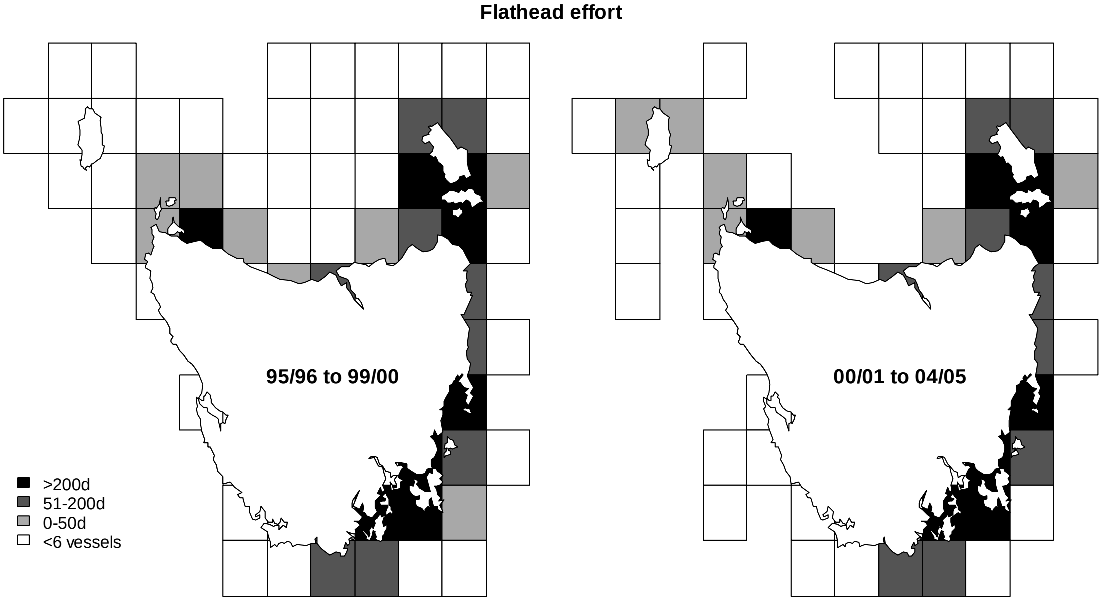


Fig. 6.21. Flathead effort (days fished) by fishing block and for the periods 1995/96 - 1999/00 and 2000/01 - 2004/05.

Acknowledgements

In addition to the contributions of SFAWG members, Gretta Pecl provided a valuable input into this report.

References

Agnew, D.J., Baranowski, R., Beddington, J.R., des Clers, S., and C.P. Nolan (1998) Approaches to assessing stocks of *Loligo gahi* around the Falkland Islands. *Fisheries Research* **35**, 155-169.

Bruce, B.D., Neira, F.J. and R.W. Bradford (2001) Larval distribution and abundance of blue and spotted warehous (*Seriolella brama* and *S. punctata*: Centrolophidae) in south-eastern Australia. *Marine and Freshwater Research* **52**: 631-636.

Caton, A. and K. McLoughlin (eds.) (2004) Fishery Status Reports 2004: Status of Fish Stocks Managed by the Australian Government. Bureau of Rural Sciences, Canberra.

Clark, W.G. (1993) The effect of recruitment variability on the choice of a target level of spawning biomass per recruit. *In*: G. Kruse, D.M. Eggers, R.J. Marasco, C. Pautzke, and T.J. Quinn II (eds.), International symposium on management strategies for exploited fish populations. Alaska Sea Grant College Program Report. pp. 233-246.

Clark, W.G. (2002) $F_{35\%}$ revisited ten years later. *North American Journal of Fisheries Management* **22**:251-257.

DPIF (1998) Scalefish fishery: Policy Document. Department of Primary Industry and Fisheries.

Ewing, G.P. (2004) Spatial and temporal variation in growth and age composition of the temperate wrasse *Notolabrus fucicola* in Tasmanian waters. MSc Thesis, University of Tasmania.

Gomon, M.F., Glover, J.C.M. and R.H. Kuiter (1994) The fishes of Australia’s south coast. State Print, Adelaide.

Haddon, M. (2001) *Modelling and Quantitative Methods in Fisheries.* Chapman & Hall/CRC Boca Raton. 406p.

Harries, D.N. and Croome, R.L. (1989) A review of past and present inshore gill netting in Tasmania with particular reference to the bastard trumpeter, *Latridopsis forsteri* Castelnau. *Papers and Proceedings of the Royal Society of Tasmania* **123**:97-110.

Henry, G.W. and J.M. Lyle (2003) National recreational and indigenous fishing survey. Final Report to FRDC Project 99/158, 188p.

Hibberd, T. (2005) Population dynamics of southern calamary (*Sepioteuthis australis*) on the east coast of Tasmania. Honours Thesis, University of Tasmania.

Hutchinson, W. (1993) The reproductive biology and induced spawning of striped trumpeter, *Latris lineata.* M.Sc. thesis, University of Tasmania.

Jantzen, T.M. and J.N. Havenhand (2002) Preliminary field observations of mating and spawning in the squid Sepioteuthis australis. *Bulletin of Marine Science* **71**, 1073-1080.

Jordan, A.R. and J.M Lyle (2000) Tasmanian scalefish fishery assessment - 1999. *TAFI Fishery Assessment Report*, 51p.

Lennon, S.M. (1998) General fishing returns and Tasmanian scalefish fishery catch data for the period 1990-96. *Stock Assessment Background Report 98/01*.

Lyle, J.M. (1998) Overview of the Tasmanian scalefish fishery based on 1995-1997 catch returns. *Stock Assessment Background Report 98/02*.

Lyle, J.M. (2000) Assessment of the licensed recreational fishery of Tasmania (Phase 2). Final Report to FRDC, Project No. 96/161, 102p.

Lyle, J.M. (2003) Tasmanian scalefish fishery assessment - 2002. *TAFI Fishery Assessment Report*, 70p.

Lyle, J.M (2005) 2000/01 survey of recreational fishing in Tasmania. *TAFI Technical Report* **24**, 97p.

Lyle, J.M. and K. Hodgson (2001) Tasmanian scalefish fishery assessment - 2000. *TAFI Technical Report No.* **19**, 70p.

Lyle, J.M. and K. Hodgson (2002) Tasmanian scalefish fishery assessment - 2001. *TAFI Fishery Assessment Report*, 88p

Lyle, J.M. and A.R Jordan (1999) Tasmanian scalefish fishery assessment - 1998. *TAFI Fishery Assessment Report*, 88p.

Lyle, J.M., Ziegler, P.E., Haddon, M., Tracey, S.R. and P. Burch (2004) Tasmanian scalefish fishery assessment - 2003. *TAFI Fishery Assessment Report*, 88p.

Lyle, J. and R. Murphy (2001) Long distance migration of striped trumpeter. *Fishing Today* **14**(6): 6.

Leum, L.L. and J.H. Choat (1980) Density and distribution patterns of the temperate marine fish *Cheilodactylus spectabilis* (Cheilodactylidae) in a reef environment. *Mar. Biol.* **57**: 327-337.

Mace, P.M. (1994). Relationships between common biological reference points used as thresholds and targets of fisheries management strategies. *Canadian Journal of Fisheries & Aquatic Sciences* **51**:110-122.

Mace, P.M, and M.P. Sissenwine (1993) How much spawning per recruit is enough? *Canadian Special Publication in Fisheries and Aquatic Sciences* **120**:101-118.

McCormick, M.I. (1989a) Spatio-temporal patterns in the abundance and population structure of a large temperate reef fish. *Marine Ecology Progress Series* **53:** 215-25.

McCormick, M.I. (1989b) Reproductive ecology of the temperate reef fish *Cheilodactylus spectabilis* (Pisces: Cheilodactylidae). *Marine Ecology Progress Series* **55:** 113-120.

Moltschaniwskyj N.A., Pecl G.T. and J. Lyle (2002) An assessment of the use of short-term closures to protect spawning southern calamary aggregations from fishing pressure in Tasmania. *Bulletin of Marine Science* **70**: 501-514.

Moltschaniwskyj N.A., Pecl G.T., Lyle. J.M., Haddon, M. and M.A. Steer (2003) Population dynamics and reproductive ecology of the southern calamary (*Sepioteuthis australis*) in Tasmania. Final Report to FRDC Project 2000/121.

Murphy, R. and J.M. Lyle (1999) Impact of gillnet fishing on inshore temperate reef fishes, with particular reference to banded morwong. Final report to FRDC, Project No. 95/145, 135p.

Pecl, G.T. (2000) Comparative life-history of tropical and temperate Sepioteuthis squids in Australian waters. PhD Thesis, James Cook University, Townsville.

Pecl, G.T. (2001) Flexible reproductive strategies in tropical and temperate *Sepioteuthis* squids. *Marine Biology* **138**: 93-101.

Pecl, G.T. (2004). The in situ relationships between season of hatching, growth and condition in the southern calamary, Sepioteuthis australis. *Marine and Freshwater Research*, **55**. In press

Pecl, G., Moltschaniwskyj, N. A., Tracey, SR and A. Jordan (2004). Inter-annual plasticity of squid life history and population structure: ecological and management implications. *Oecologia*, **139**: 515-524.

Steer, M., N.A. Moltschaniwskyj, and F.C. Gowland (2002) Temporal variability in embryonic development and mortality in the southern calamary *Sepioteuthis australis*: a field assessment. *Marine Ecology Progress Series* **243**: 143-150.

Ruwald, F.P. (1992) Larval feeding trials with striped trumpeter, *Latris lineata*. In *Larval biology. Australian Society for Fish Biology Workshop, Hobart, 20 August 1991.* Ed by Hancock, D.A. *Bureau of Rural Resources Proceedings No. 15,* AGPS, Canberra.

Ruwald, F.P., Searle, L.D. and L.A. Oates (1991) A preliminary investigation into the spawning and larval rearing of striped trumpeter, *Latris lineata*. *Department of Primary Industry, Sea Fisheries Division Technical Report* **44.**

Schaefer, M.B. (1954) Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. *Bulletin, Inter-American Tropical Tuna Commission* **1**: 27-56.

Schaefer, M.B. (1957) A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. *Bulletin, Inter-American Tropical Tuna Commission* **2**: 247-285.

Smith, A.D.M. and S.E. Wayte (eds) (2002) The South East Fishery 2002. Fishery Assessment Report compiled by the South East Fishery Assessment Group. AFMA, Canberra.

Tracey, S.R. and J.M. Lyle (2005) Age validation, growth modeling and mortality estimates for striped trumpeter (*Latris lineata*) from southeastern Australia: making the most of patchy data. *Fishery Bulletin* **103**: 169-182.

Trianifillos, L. (1998) Southern Calamary. South Australia Fisheries Assessment series No 98/08 SARDI Aquatic Sciences, Adelaide.

van Camp, L.M., Donnellan, S.C., Dyer, A.R. and P.G. Fairweather (2004) Multiple paternity in field and captive-laid egg strands of *Sepioteuthis australis* (Cephalopoda: Loliginidae). *Marine and Freshwater Research* **55**, 819-823.

van Camp, L.M., Fairweather, P.G., Steer, M.A., Donnellan, S.C. and J.N. Havenhand (2005) Linking male and female morphology to reproductive success in captive southern calamary (*Sepioteuthis australis*). *Marine and Freshwater Research* **56**, 933-941.

Wolf, B. (1998) Update on juvenile banded morwong in Tasmania. *Fishing Today* **11**(4): 30.

Ziegler P.E., Haddon M. and J.M. Lyle (2005) Sustainability of small-scale, data poor commercial fisheries: Developing assessments, performance indicators and monitoring strategies for temperate reef species. Tasmanian Aquaculture and Fisheries Institute, FRDC Project Draft Report No. 2002/057.

Appendices

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

Common name	*Scientific name*
Alfonsino	*Beryx* spp.
Anchovy	Fam. Engraulidae
Atlantic salmon	*Salmo salar*
Australian salmon	*Arripis* spp.
Barracouta	*Thyrsites atun*
Boarfish	Fam. Pentacerotidae
Bream	*Acanthopagrus butcheri*
Butterfish	Spp unknown
Cardinal fish	Fam Apogonidae
Cod deep sea	*Mora moro*
Cod, bearded rock	*Pseudophycis barbata*
Cod, red	*Pseudophycis bachus*
Cod, unspec.	Fam. Moridae
Dory, john	*Zeus faber*
Dory, king	*Cyttus traversi*
Dory, mirror	*Zenopsis nebulosus*
Dory, silver	*Cyttus australis*
Dory, unspec.	Fam. Zeidae
Eel	*Conger* spp.
Flathead	Fam Plactycephalidae
Flounder	Fam. Pleuronectidae
Garfish	*Hyporhamphus melanochir*
Gurnard	Fam. Triglidae & Fam. Scorpaenidae
Gurnard perch	*Neosebastes scorpaenoides*
Gurnard, red	*Chelidonichthys kumu*
Hardyheads	Fam. Atherinidae
Herring cale	*Odax cyanomelas*
Kingfish, yellowtail	*Seriola lalandi*
Knifejaw	*Oplegnathus woodwardi*
Latchet	*Pterygotrigla polyommata*
Leatherjacket	Fam. Monocanthidae
Ling	*Genypterus* spp.
Luderick	*Girella tricuspidata*
Mackerel, blue	*Scomber australasicus*
Mackerel, jack	*Trachurus declivis*
Marblefish	*Aplodactylus arctidens*
Morwong, banded	*Cheilodactylus spectabilis*
Morwong, blue	*Nemadactylus valenciennesi*
Morwong, dusky	Fam. Cheilodactylidae
Morwong, grey	*Nemadactylus douglasii*
Morwong, jackass	*Nemadactylus macropterus*
Morwong, red	Fam. Cheilodactylidae
Morwong, unspec.	Fam. Cheilodactylidae
Mullet	Fam. Mugilidae
Nannygai	*Centroberyx affinis*
Perch, magpie	*Cheilodactylus nigripes*
Perch, ocean	*Helicolenus* spp.
Pike, long-finned	*Dinolestes lewini*
Pike, short-finned	*Sphyraena novaehollandiae*
Pilchard	Fam. Clupeidae
Rays bream	Fam. Bramidae
Redbait	*Emmelichthys nitidus*
Red fish	Fam. Berycidae
Red mullet	*Upeneichthys* spp.
Silverfish	Fam. Atherinidae
Snapper	*Pagrus auratus*
Stargazer	Fam. Uranoscopidae
Sweep	*Scorpis* spp
Tailor	*Pomatomus saltatrix*
Thetis fish	*Neosebastes thetidis*
Trevalla, white	*Seriolella caerulea*
Trevally, silver	*Pseudocaranx dentax*
Trout, rainbow	*Oncorhynchus mykiss*
Trumpeter, bastard	*Latridopsis forsteri*
Trumpeter, striped	*Latris lineata*
Trumpeter, unspec.	Fam. Latridae
Warehou, blue	*Seriolella brama*
Warehou, spotted	*Seriolella punctata*
Whiptail	Fam. Macrouridae
Whiting	Fam. Sillaginidae
Whiting, King George	*Sillaginoides punctata*
Wrasse	*Notolabrus* spp.
'Commonwealth' spp	
Blue grenadier	*Macruronus novaezelandiae*
Gemfish	*Rexea solandri*
Hapuka	*Polyprion oxygeneios*
Oreo	Fam. Oreosomatidae
Trevalla, blue eye	*Hyperoglyphe antartica*
Tunas	
Albacore	*Thunnus alalunga*
Skipjack	*Katsuwonus pelamis*
Southern bluefin	*Thunnus maccoyii*
Tuna, unspec.	Fam. Scombridae
Sharks	
Shark, angel	*Squatina australis*
Shark, blue whaler	*Prionace glauca*
Shark, bronze whaler	*Carcharhinus brachyurus*
Shark, elephant	*Callorhynchus milii*
Shark, gummy	*Mustelus antarcticus*
Shark, saw	*Pristophorus spp.*
Shark, school	*Galeorhinus galeus*
Shark, seven-gilled	*Notorynchus cepedianus*
Shark, spurdog	Fam. Squalidae
Cephalopods	
Calamary	*Sepioteuthis australis*
Cuttlefish	*Sepia* spp.
Octopus	*Octopus* spp.
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 factor2.

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.

---

[2] 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.

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.

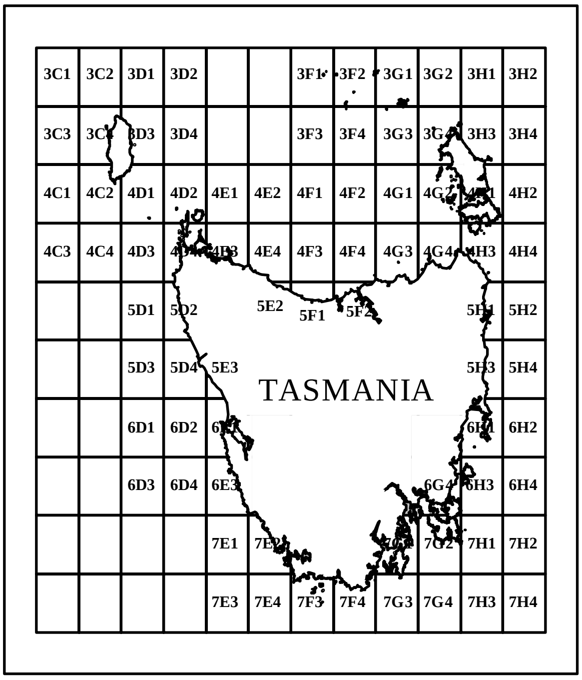


Fig. A1. Numbers for fishing blocks used in calculation of catch figures.

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.

A3.1 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:

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

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 :

$$Z^{p,s}_{t,y} = \begin{cases} M + s^{s}_{t}\hat{F}^{p}_{y} & \text{if } p = \text{ onshore population} \\ M & \text{if } p = \text{ offshore population} \end{cases} \tag{A3.2}$$

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:

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

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*.

A3.2 Growth

Growth is described in terms of length at age and weight at length by a 2-phased von Bertalanffy equation:

$$L_{t,y}^{s} = \begin{cases} L_{\infty 1,t}^{s}\left(1 - e^{-K_{1,y}^{s}\left(t - t_{01,y}^{s}\right)}\right) + \varepsilon_{y}^{s} & t \le t_{trans}^{s} \\ L_{\infty 2,t}^{s}\left(1 - e^{-K_{2,y}^{s}\left(t - t_{02,y}^{s}\right)}\right) + \varepsilon_{y}^{s} & t > t_{trans}^{s} \end{cases} \tag{A3.8}$$

where

$L_{t,y}^{s}$	is the length at age *t* in year *y* for sex *s*
$L_{\infty,t}^{s}$	is the average maximum length for the species in year *y* for sex *s*
K_{y}^{s}	is the Brody growth coefficient in year *y* for sex *s*
$t_{0,y}^{s}$	is the age at a hypothetical length of zero in year *y* for sex *s*
t_{trans}^{s}	is the age transition between growth function 1 and growth function 2 for sex *s*
ε_{y}^{s}	is a normal random residual in year *y* for sex *s*.

The weight at length relationship is described by:

$$W_{t,y}^{s} = a_{s}(L_{t,y}^{s})^{b_{s}} \tag{A3.9}$$

where

$W_{t,y}^{s}$	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.

A3.3 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):

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

where r_t is the mesh selectivity and l_t the length of age class *t*, *m* is the mesh size of the nets used, and α and *k* are the selectivity parameters. Mesh selectivity was not thought to be influenced by sex (Murphy and Lyle 1999).

Sex-specific selectivity $s^s_{t,y}$ at age *t* in year *y* for the lower and upper size limits is estimated as the relative selectivity at age:

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

and 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:

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

where:

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

where

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

A3.4 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 $\hat{F}^p_y$ in year *y* combined with the selectivity for each age class *t* and sex *s*:

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

where

$s^s_{t,y}$	is the relative selectivity of age class *t* for sex *s* in year *y* in population *p*,
$\hat{F}^p_y$	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:

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

where

$\hat{C}^p_y$	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:

$$\hat{I}_y^p = \hat{q}_p \hat{B}_{E,y}^p \tag{A3.16}$$

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:

$$\ln(\hat{q}_p) = \frac{\sum_{y=1996}^{2004} \ln\left(\frac{I_y^p}{B_{E,y}^p}\right)}{n} \tag{A3.17}$$

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 2004.

A3.5 Projection

Each simulation run consisted of a historical period from 1990-2004 and a projected period of 20 years from 2005-2024.

A3.6 Recruitment

To initialise the age structure for each simulation run at the start of the projection when a management strategy is applied, the populations within each region was projected from the pre-exploitation equilibrium in 1990 to the start of 2005 with random variation in recruitment and under subject of the reported catches from 1990-2004. 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:

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

where

$R_{t_{\min},y}^s$ 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 15 historical years were ranked by population numbers and split in four groups with the last group consisting of only 3 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.

A3.7 Catch, catch rates and effort

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:

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

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), and total predicted effort estimated by:

$$\hat{E}_y^p = \frac{\hat{C}_y^p}{\hat{I}_y^p} \qquad \text{(A3.20)}$$

where

$\hat{E}_y^p$	is the total predicted fishing effort in population *p* in year *y*,
$\hat{I}_y^p$	is the predicted catch rates in population *p* and at the start of year *y*,

Reported effort is then determined from the total predicted effort by:

$$E_y^p = \frac{\hat{E}_y^p}{L_y e^{\varepsilon_{L,y}}} \quad \varepsilon_{L,y} \sim N(0, \sigma_L^2) \tag{A3.21}$$

where

E_y^p	is the observed reported effort in year *y* where population *p* is onshore,
$\hat{E}_y^p$	is the predicted total effort 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.

Observed catch rates were determined by dividing reported catch by reported effort:

$$I_y^p = \frac{C_y^p}{E_y^p} \tag{A3.22}$$

Catch, catch rates and effort were calculated on a regional base, and summarised (catch and effort) or the catch-weighted geometric mean taken (catch rates) to estimate the results for all regions combined.