FISHERY ASSESSMENT REPORT

TASMANIAN SCALEFISH FISHERY - 2008/09

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

SFAWG met on 19 November 2009 to consider the draft assessment report and provide input into the assessments. The Working Group participants were:

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Tasmanian Scalefish Fishery - 2008/09

Executive Summary

The Tasmanian scalefish fishery is a multi-species fishery operating in State fishing waters and encompassing a wide variety of capture methods. The Scalefish Management Plan (revised in 2009), provides the management framework for the fishery. Underpinning the rules is a policy document released in 1998 which provides for the explicit identification of performance indicators and reference points that have two primary functions:

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

Fishery Assessment

In this assessment the scalefish fishery is described in terms of species composition, catch and effort. The commercial catch history for the period 1990/91 to 2008/09 is presented, with more detailed analyses of catch and effort by method for the period 1995/96 to 2008/09. In addition to information provided in Tasmanian catch returns, data from Commonwealth logbooks for dual endorsed operators fishing in Tasmanian waters and for species managed under Tasmanian jurisdiction (*i.e.* striped trumpeter and bastard trumpeter) have been incorporated in the analyses.

Dipnet, dropline and squid jig effort expanded to historically high levels following the initial introduction of the management plan in 1998, whereas effort for other methods tended to remain relatively stable or decline over time. By 2008/09, effort levels for all methods, apart from squid jigs, had fallen to within or below reference levels (Table 1). The dramatic increase in squid jig effort occurred primarily in response to the expansion of the southern calamari fishery.

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

Table 1. Effort performance indicator assessment by major fishing methods for 2008/09
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

Species assessments evaluate fishery-dependent information against agreed reference points for the performance indicators, as detailed in the Scalefish policy document (Table 2). These reference points relate mainly to catch, effort and catch rates in reference years from earlier periods of the fishery (typically 1989/90 to 1997/98 for catch and 1995/96 to 1997/98 for effort and catch rates). The policy document also provides for biological characteristics to be used as performance indicators against which stock status can be evaluated and, where such data are available, they have been updated in this assessment.

The fishery has additionally been assessed against an alternative set of reference points (first proposed for the 2007/08 fishery assessment) which account for recent developments in the fishery (Table 3). These alternative performance indicators are intended to replace the existing indicators but have yet to be formally adopted.

Banded morwong

The total commercial catch in 2008/09 was 40 tonnes.

Reference points exceeded:

- State-wide commercial catches as well as catches in the assessment regions 1 (NEC), 2 (EC) and 3 (SEC) were below the 1994/95 to 1997/98 range.
- Catches decreased by more than 30% from the previous year in region 2 (-35%) and 3 (-42%).

Alternative reference points:

- TAC-related reference points were not assessed.
- Catch rates were above 90% of the average catch rate from 2000/01 to 2006/07.

Resource status:

- The stock assessment model suggested banded morwong stocks are currently not overfished. Mature biomass in 2009 relative to 1990 in region 2 (EC) and 3 (SEC) was estimated at 42% and 55%, respectively. Nevertheless, the structure of the fished population has changed substantially in both regions, and the fishery is now largely recruitment-driven.
- Exploitation rates of recent years do not appear sustainable. Current catch levels are likely to continue to reduce spawning biomass, even though stocks are now more productive (faster individual growth and earlier maturity of females) than at the start of the fishery.

Management advice:

- Maintaining the current TAC of 44.4 tonnes is likely to result in a decline in catch rates and spawning biomass within the TAC region. Assuming average recruitment, the model predicted that a TAC reduction to 20 tonnes would be required to increase the probability for sustained mature biomass and catch rates over a 5-year period to above 50%. Given uncertainties about model and stock productivity, the TAC should be lowered to reduce the risks of overfishing.

Southern calamari

The total commercial catch in 2008/09 was 79 tonnes.

Reference points exceeded:

- State-wide commercial catches was above the reference range.
- Catches decreased by more than 30% from the previous year in Great Oyster Bay (-56%)
- State-wide fishing effort was above reference levels.

Alternative reference points:

- Commercial catches were within the reference ranges of 50 tonnes in Great Oyster Bay and Mercury Passage, and 30 tonnes in the south-east. However, they were higher than 25 tonnes outside these areas (35 tonnes).
- Catches decreased in 2008/09 but did not exceed the reference point for consistently declining catch over 3 years by >40% in SE and E waters.

Resource status:

- There is considerable uncertainty about stock status due to the uncertain relationship between spawning stock size and annual recruitment.

Management advice:

- Extended closure of the major spawning grounds and the newly-introduced fishing licences appear to be effective in protecting the main known spawning event. However, catches have increased substantially off the north coast. The further catch development in these areas should be therefore monitored closely.

Striped trumpeter

The total commercial catch in 2008/09 was 13 tonnes.

Reference points exceeded:

- State-wide commercial catches were below the reference range.
- Catch rates for dropline (days fished) were below reference levels.

Alternative reference points:

- The 50 tonnes commercial catch reference point was not exceeded.
- Catch curve assessment was not assessed.

Resource status:

- Resource status is uncertain though potentially depleted due the combined effects of fishing and apparent poor recruitment since 1993/94. Major uncertainties surround the lack of information on the recreational catch and the magnitude of the catch taken by Commonwealth operators.

Management Advice:

- Despite the absence of a rigorous assessment, available data suggest that the stocks are declining and may continue to do so without a period of sustained good recruitment. Further management action is required to align the size limit with size at maturity allowing fish to spawn before they become vulnerable to capture.
- The reduction of the recreational on-water possession limits and introduction of a spawning closure should help to reduce fishing pressure, but may not be enough to lessen the fishing mortality in the event of expansion of the recreational sector in the future.

Bastard trumpeter

The total commercial catch in 2008/09 was 17 tonnes.

Reference point exceeded:

- State-wide commercial catches were below the reference range.

Alternative reference points:

- Pending

Resource status:

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

Management advice:

- The effectiveness of recent management changes (trip limits of 200 kg, increase of size limits to 380 mm, recreational possession limit of 10 fish) should be evaluated.

Sea garfish

The total commercial catch in 2008/09 was 63 tonnes.

Reference points exceeded:

- State-wide catches increased by 103% compared with the previous year.
- State-wide commercial effort for dipnet (gear units) was above the reference limit.

Alternative reference points:

- State-wide catches were below reference levels from 1998/99 to 2006/07.

Resource status:

- Uncertain, but the recent decline in catches appears to be caused by a lack of resource despite high abundance of undersized fish. In 2008/09, stock abundance appeared to be higher in the north-east, but remained depressed in south-eastern waters.

Management advice:

- Since it is not known whether present catch levels are sustainable and to clarify effects of dipnetting on the schooling behaviour of garfish, research on the fishery and stock dynamics is underway. It also would be prudent to consider management options that limit further expansion in this fishery until more is known about the stock dynamics.

Wrasse

The total commercial catch in 2008/09 was 69 tonnes (42 tonnes of blue-throat wrasse, 27 tonnes of purple wrasse).

Reference points exceeded:

- State-wide commercial catches were below the reference range.
- Catch rates for fish traps (gear units) were below the reference levels.

Alternative reference points:

- Catches were within the reference range from 1998/99 to 2006/07.

Resource status:

- The resource status is unknown though the two species are vulnerable to localised economic depletion of legal-size biomass. Increasing catches in previous years indicated continued strong interest in the species, while the catch decline in 2008/09 could be attributed largely to the prohibition of the use of abalone guts as bait in fish traps.
- Minimum size limits provide considerable protection to purple wrasse and female blue-throat wrasse spawner biomass, but not for male blue-throat wrasse which derive from mature females after a sex change, typically at sizes after they have entered the fishery.

Management advice:

- Because there is still a high level of latent effort in the fishery, management options should be considered that limit further expansion in this fishery.

Blue warehou

The total commercial catch in 2008/09 was 27 tonnes.

Reference points exceeded:

- State-wide commercial catches were below the reference range.

Alternative reference points:

- The historic commercial catch level of 318 tonnes was not exceeded.

Resource status:

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

Management advice:

- Management action for stock rebuilding of the major component of the blue warehou fishery has been implemented in the Commonwealth fishery.

Australian salmon

The total commercial catch in 2008/09 was 339 tonnes.

Reference points exceeded:

- State-wide commercial catches were below the reference range.
- State-wide commercial catches increased by more than 30% from the previous year (+32%)

Alternative reference points:

- The commercial catch trigger of 435 tonnes for Australian salmon was not exceeded.

Resource status:

- Catch rates may not be good indicators of abundance for schooling species such as Australian salmon and in any case commercial production is known to be strongly influenced by market demand. While stock status is unknown, the species has sustained substantially higher catches in the past and current commercial and recreational catches would appear sustainable.

Management advice:

- The status quo appears to be acceptable.

Flathead

The total commercial catch in 2008/09 was 53 tonnes (predominantly tiger flathead, as distinct from the sand flathead that forms the bulk of the recreational catch).

Reference point exceeded:

- State-wide effort for hand line (days fished) was above reference levels.

Alternative reference points:

- Regional catch levels, 45 tonnes in the south-east and 63 tonnes in the east, were not exceeded.

Resource status:

- Stocks of tiger flathead are classified as not overfished. The stock status of sand flathead is not known, though undersized fish appear to be highly abundant and the size limits are above size at maturity.

Management advice:

- Status quo appears to be acceptable. As further expansion in the Danish seine fishery is possible it would be prudent to consider spatial management options that avoid the regional concentration of operators.

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

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

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

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

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

Reference point	Banded morwong	Southern calamari	Striped trumpeter	Bastard trumpeter	Garfish	Wrasse	Blue warehou##	Australian salmon	Flathead
Commercial catch in Region 1 > 30% of TAC Region 2 > 65% of TAC Region 3 > 40% of TAC Outside TAC area >10t	na								
Commercial catch is < 90% of TAC	na								
Catch rates are below 0.9 * average from reference period 2000/01 to 2006/07	**N**								
Commercial catch for GOB & MP > 50t Remainder SE > 30t Outside GOB, MP & SE > 25t		N N Y#							
Declining catch trend over 3 consecutive years by a total of > 40% in south-east Tasmanian waters		N							
Commercial catch is > 50t			N						
Catch curve estimated every 3 years as an index of fishing mortality from all sectors: Target: Fishing mortality $F \leq$ Natural mortality M Limit: $F = 1.5*M$			na						
Pending				-					
Catch outside reference range from 1998/99 to 2006/07 (66-102t)					Y↓				
Catch outside reference range from 1998/99 to 2006/07 (72-99t)						N			
Commercial catch limit of 318 tonnes as per Memorandum of understanding (MOU)							N		
Commercial catch limit of 435 tonnes as per Ministerial decision								N	
Catch by Danish Seine > 1.3* the maximum catch from reference period 1998/99 to 2006/07: South-east coast: 45t East coast: 63t									**N** N
Any indicator of stock stress	Y	N	Y	na	na	na	na	na	na

1 Management objectives and strategies

The Scalefish Management Plan was first introduced in 1998 (DPIF 1998) and was reviewed in 2001, 2004 and most recently in 2009. The primary issues tackled in the latest review related to improving gillnet fishing practices (addressed through the introduction of maximum soak times for both commercial and recreational sectors), revision of possession and size limits for key species, protection of vulnerable stocks (mainly addressed through spawning season closures), and implementation of a set line licence for recreational fishers.

The management plan provides the regulatory framework for the fishery, which covers commercial and recreational components. Underpinning the rules is a policy document (DPIF 1998) that 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.

1.3 Performance indicators

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

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

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

- total catch of a key target species is outside the range from 1990/91 to 1997/98; 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, is above 10% of the highest levels from 1995/96 to 1997/98;
- catch rates for a key target species are less than 80% of the lowest levels from 1995/96 to 1997/98;
- 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 1995/96 to 1997/98 records; or when incidental mortality of non-commercial species or undersized commercial fish is unacceptably high;
- significant numbers of fish are landed in a diseased or clearly unhealthy condition; or when a pollution event occurs that may produce risks to fish stocks, the health of fish habitats or to human health; or when,
- any other indication of fish stock stress is observed.

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

2 Fishery assessment

2.1 The fishery

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

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

This report covers the assessment of key scalefish and cephalopod fisheries under Tasmanian jurisdiction. Other species, such as tiger flathead, blue warehou, jackass morwong, ocean perch, blue eye trevalla, blue grenadier, school and gummy shark, are managed under Commonwealth jurisdiction. Formal assessments for these species are undertaken by the Southern and Eastern Scalefish and Shark Fishery Assessment Group (SESSFAG; *e.g.* Tuck 2006) and are summarised in fishery status reports produced by the Bureau of Rural Sciences (e.g. Larcombe and McLoughlin 2007).

This report continues the series of annual assessments of the scalefish fishery and incorporates catch and effort information available up to and including June 2009. Copies of previous assessment reports are available on the TAFI web page - http://www.utas.edu.au/tafi/TAFI_Download.htm.

2.2 Data sources

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

2.2.1 General fishing returns

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

During 1995, a revised General Fishing Return was introduced, replacing the monthly return with catch and effort information reported on a daily basis for each fishing method used. The revised returns provide greater detail about fishing operations, including more explicit specification of fishing method, greater spatial resolution (30nm or ½ degree rather than 1 degree blocks), plus details about effort and depths fished.

Amendments in 1999 included provision to nominate target species and an option to indicate interactions with marine mammals (*e.g.* seals or killer whales). During late 2007, a new logbook was introduced providing finer spatial and operational detail. In analysing General Fishing Returns some data manipulation has been undertaken, details of which are provided in Appendix 2.

2.2.2 Commonwealth catch returns

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

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

2.2.3 Data analysis

For the purposes of this assessment, effort and catch rate analyses are restricted to commercial data provided for the period July 1995 to June 2009. All catch returns from within this period and available as at October 2009 have been incorporated in the analyses. Catch and effort information submitted after this date are included in subsequent assessments and may therefore result in discrepancies in reported catch and effort levels between assessment reports.

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).

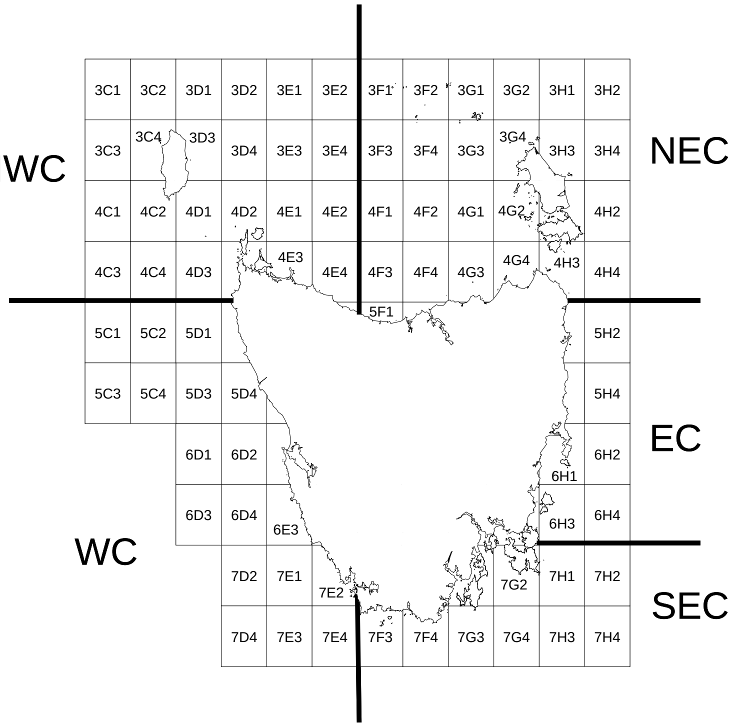

Fig. 2.1: Map of Tasmania with 30 nm fishing blocks and the assessment regions. SEC is south-east coast, EC is east coast, NEC is north-east coast, NWC is north-west coast, and WC is west coast.

Two measures of effort have been examined in past assessments: (i) days fished (*i.e.* number of days on which a method/gear type was reported); and (ii) quantities of gear/time fished using the method. Since a diverse range of gear types are utilised in the fishery, appropriate measures of effort differ with gear type. For instance, gillnet effort has been calculated as a function of the quantity of net set and fishing duration, dropline and longline effort is expressed in terms of number of hooks set, while handline fishing is reported as the product of the number of lines fished and fishing duration. Measures of effort by fishing method are presented in Table 2.1. However, because effort reporting has changed for some gears with the introduction of a new logbook during 2007, some gear related effort measures since 2007/08 are not directly comparable to those in the previous years. Also, confusion about the new reporting requirements may have biased some effort measures.

Table 2.1. Table of effort gear units by fishing method

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

Catch returns for which effort information was incomplete or unrealistically high or low (either due to data entry error or misinterpretation of information requirements by fishers) were flagged and excluded when calculating effort levels based on gear units or catch rates based on catch per unit of gear. Only a small number of fishing records for 2008/09 needed to be excluded in this manner. All records were, however, included for the reporting of catch, days fished and catch per day.

In generating catch rate statistics, the geometric mean rather than the arithmetic mean of all valid individual daily catch records has been calculated, since catch rate data are typically log-normally distributed. The geometric mean is calculated as the 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 the arithmetic mean. The geometric mean has the advantage of being less affected by the few observations that are skewed very high, as often happens with log-normally distributed data.

2.2.4 Recreational fishery

Information on recreational fisheries in Tasmania is relatively sparse. Detailed analyses of the Tasmanian recreational fishery available are based on the 2000/01 National Survey (Lyle 2005) and the 2007/08 state-wide fishing survey (Lyle et al 2009). Additional data are provided by recreational net licence numbers.

2.3 Commercial fishing licences

The number of fishing Scalefish licences A, B and C has slowly declined from a peak in 2000 to 128 active and 336 total licences in 2009 (Table 2.2). The decline was mainly due to a reduction in Scalefish C fishing licences, while the numbers of Scalefish A and B licences have remained reasonably stable. Scalefish C licences were also the licence type that was least often fished, with just 14% of all C licences active in 2009 (down from 35% in 2000). The proportion of actively fished Scalefish A and B licences has also dropped in the last two years, from around 70% up to 2007 to only around 50% in 2009.

In addition to these fishing licences, separate fishing licences allow the use of beach seine (a total of 51 licences in two categories A and B) and small mesh gillnet (10 licences). Fishers with a rock lobster licence (but without Scalefish A or B licence) are also allowed to take scalefish with a limited amount of fishing gear.

Table 2.2. Number of active and total fishing licences (FL) by licence type (A, B or C) since 2000 (licence years from March to February of the following year)

No of active licences	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
FLA	50	44	51	48	46	38	43	47	37	31
FLB	109	104	111	110	109	101	105	105	93	81
FLC	79	62	63	52	47	34	36	33	23	16
Total	238	210	225	210	202	173	184	185	153	128

No of total licences	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
FLA	69	67	70	70	70	66	66	66	66	65
FLB	166	165	164	165	165	162	162	160	159	159
FLC	226	214	205	185	173	152	137	129	120	112
Total	461	446	439	420	408	380	365	355	345	336

2.4 Commercial catch trends

2.4.1 General fishery

Annual commercial scalefish catches have been variable since 1990/91 (Table 2.3) and since the early 1990s, catch trends for the major species have generally been declining (Fig. 2.2). Overall, total scalefish catches (excluding small pelagic species) declined from over 2000 tonnes in the early 1990s to around 600-800 tonnes in recent years. Recent fluctuations in total catches were mainly driven Australian salmon.

The 2008/09 scalefish catch of 748 tonnes was slightly higher compared to 2007/08, mainly due to higher catches of Australian salmon. For most other species, downward catch trends continued. Catches of barracouta, striped trumpeter, bastard trumpeter and flounder were at record low levels in 2008/09. Catches declined for wrasse (-20 tonnes), flathead (-22 tonnes) and banded morwong (-16 tonnes), while only Australian salmon (+83 tonnes) and garfish (+32 tonnes) experienced significant increases. Catches of most other scalefish species were within ± 5 tonnes of 2007/08 levels (Table 2.2 and Fig. 2.2).

Production of small pelagic species such as jack mackerel (+717 tonnes) and redbait (+221 tonnes) caught by purse seine in State waters again increased substantially. It should be noted that almost all catch of jack mackerel and redbait were taken under the separately licensed and managed Tasmanian Mackerel Fishery. Cephalopod production declined slightly for southern calamari (-10 tonnes) and octopus (-39 tonnes), but remained steady for the sporadically occurring Gould’s squid.

When assessing trends within the scalefish fishery it is important to recognise that some species occur seasonally in Tasmanian waters and that availability can differ markedly between years. Such variability does therefore not necessarily reflect changes in stock condition. Species in this category include blue warehou, barracouta and Gould’s squid. By contrast, species such as banded morwong, garfish, wrasse, the trumpeters and calamari are resident species, and variability in catches can reflect a combination of factors, including market forces, management intervention, stock status and intrinsic variability in life history. Catch trends for the key species including banded morwong, southern calamari, striped trumpeter, bastard trumpeter, garfish, wrasse, blue warehou, Australian salmon, and flathead will be discussed in separate chapters.

Table 2.3. Annual 'Tasmanian' scalefish and cephalopod production (whole weight in tonnes) by fishing year since 1990/91 based on General Fishing Returns and Commonwealth (GN01, GN01A and SSJF) logbook returns. Data of the most recent years may be incomplete due to late reporting.

Species	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09
Scalefish (excl. small pelagics)																			
Australian salmon	815.9	651.9	867.0	878.8	682.1	413.2	287.3	476.0	384.7	363.7	485.0	462.1	407.2	167.2	336.5	254.2	115.0	256.1	338.8
Barracouta	351.5	268.3	205.4	59.6	25.2	19.3	53.8	65.2	27.6	25.0	15.1	132.1	65.5	85.2	97.3	60.1	26.7	13.8	13.3
Boarfish	7.2	9.4	7.6	10.1	9.1	7.3	10.4	9.4	7.0	7.2	8.0	5.5	3.6	4.3	3.6	5.0	5.2	4.7	2.6
Cod	10.0	11.3	11.6	14.5	12.7	18.6	12.8	9.5	9.8	9.0	3.8	3.0	2.2	2.1	1.6	2.0	2.9	5.4	4.8
Flathead	165.3	118.1	98.8	121.4	91.1	57.9	51.8	62.9	50.6	60.3	63.4	52.1	40.8	31.2	74.7	91.9	60.0	74.7	52.7
Flounder	44.0	36.8	31.8	27.3	27.1	33.4	29.4	29.7	25.2	18.6	12.4	13.0	12.1	15.1	14.7	10.9	13.0	7.8	5.1
Garfish	80.9	80.1	82.3	82.9	69.3	56.2	91.6	83.0	101.7	91.2	81.4	87.8	92.5	66.2	85.5	89.3	50.0	31.0	63.0
Gurnard	20.5	19.0	19.3	19.3	14.0	13.5	10.4	9.1	7.1	9.9	7.8	5.3	9.7	6.8	6.1	5.1	5.7	5.2	2.7
Leatherjacket	12.2	14.0	13.1	23.3	27.7	14.5	12.6	13.3	12.9	16.5	16.7	16.6	13.7	14.8	10.4	8.5	9.1	6.7	6.4
Ling	5.1	13.6	30.0	41.6	33.2	15.0	13.4	9.0	4.9	2.2	5.1	0.9	0.4	0.8	0.7	0.4	0.4	0.4	0.1
Marblefish	0.2	0.9	0.3	1.0	1.8	3.5	5.6	3.0	2.6	4.2	4.0	4.4	3.1	0.6	1.1	0.5	2.2	2.3	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	45.6	54.3	50.3	52.6	36.9
Morwong, jackass	136.9	111.9	83.2	117.6	63.1	27.1	19.0	34.1	18.2	16.6	13.7	14.8	14.4	16.3	17.5	13.1	11.7	4.6	5.2
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	1.8	1.3	1.3	2.5	1.4
Mullet	31.2	22.2	26.2	19.5	23.8	10.8	11.2	16.0	14.5	21.0	13.7	12.1	7.3	7.5	5.1	7.5	4.5	2.5	1.5
Other	140.2	110.4	97.4	102.0	62.0	31.9	28.5	40.3	24.6	16.2	14.7	11.3	30.1	25.0	26.9	28.2	14.2	12.6	34.3
Pike	10.5	9.5	11.1	12.7	18.8	14.0	18.3	21.6	12.6	14.0	12.5	18.8	17.3	17.7	8.9	13.9	16.6	15.6	12.5
Trevally	20.6	13.6	12.0	8.3	21.6	5.9	4.5	7.8	8.1	3.2	1.6	4.6	5.5	3.4	3.7	6.3	3.6	8.8	4.5
Trumpeter, bastard	63.3	37.2	34.0	54.8	50.8	60.1	51.8	40.7	47.7	36.4	26.1	23.9	21.0	23.2	18.5	23.4	21.3	19.2	16.6
Trumpeter, striped	74.5	58.2	52.7	56.5	72.4	60.3	80.4	81.1	107.4	101.8	49.6	44.8	40.0	40.5	26.2	23.8	22.3	16.1	13.3
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	0.0	0.0	0.1	0.0
Warehou, blue	257.6	317.6	187.7	250.1	205.4	82.3	128.7	189.5	274.3	187.6	36.0	66.4	49.3	27.5	19.7	20.0	29.3	25.3	26.8
Warehou, other	0.7	0.4	4.2	8.8	3.4	14.6	15.6	4.8	1.0	0.0	0.0	0.1	0.2	0.1	0.8	0.1	0.0	0.1	0.6
Whiting	124.2	152.3	84.3	97.9	81.4	25.5	39.6	48.3	30.6	31.7	42.7	40.1	39.9	55.5	38.3	28.3	40.2	39.6	35.0
Wrasse	57.2	71.7	97.3	142.4	178.0	83.4	110.1	100.0	90.7	85.4	88.4	92.3	72.0	75.1	99.4	92.9	113.2	88.5	68.5
Total scalefish (excl. small pelagics)	**2441**	**2141**	**2102**	**2310**	**1888**	**1161**	**1173**	**1435**	**1316**	**1157**	**1041**	**1167**	**1006**	**734**	**945**	**841**	**619**	**696**	**748**

Table 2.3. Continued. Whole weight in tonnes by fishing year

Species	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09
Small pelagic species																			
Mackerel, jack	6.1	11.1	32.8	48.4	39.7	26.2	19.3	19.7	59.8	13.7	8.6	19.4	19.4	41.1	12.8	6.8	2.6	202.8	919.7
Mackerel, other	3.0	2.1	0.3	8.5	5.7	2.0	1.3	1.0	0.5	2.1	0.1	0.0	0.1	0.0	0.5	0.5	0.2	10.3	0.2
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	0.0	0.0	13.2	14.5
Redbait	0.0	0.7	0.0	0.8	0.1	0.1	0.0	0.0	4.0	0.0	0.0	0.0	0.0	3.4	1.0	1.4	0.3	300.1	521.4
Total small pelagic species	**9**	**14**	**37**	**72**	**58**	**35**	**25**	**36**	**67**	**17**	**12**	**20**	**19**	**45**	**15**	**9**	**3**	**526**	**1456**
Cephalopod																			
Calamari, southern	8.2	7.5	5.8	9.7	12.6	33.0	19.0	26.6	94.5	84.6	76.6	104.8	108.8	86.8	114.2	44.6	85.4	89.0	78.6
Cuttlefish	0.5	0.7	0.0	1.1	0.8	0.2	0.3	0.2	0.0	0.0	0.0	0.7	2.4	1.0	0.2	0.4	0.1	0.3	0.3
Octopus maorum	10.8	13.1	15.7	28.1	23.2	18.2	10.6	9.3	24.3	18.3	11.5	31.5	13.2	14.6	11.2	8.7	12.0	18.5	7.5
Octopus pallidus[1]	21.2	21.6	31.3	29.8	30.5	58.7	30.2	34.1	61.2	43.2	50.5	31.6	54.5	56.6	70.4	89.9	90.2	92.6	64.5
Squid, Gould's	35.1	7.2	7.0	7.7	8.6	5.7	7.8	12.9	79.7	480.5	39.7	2.4	1.9	2.1	2.6	1.8	694.3	45.9	47.1
Total cephalopod	**76**	**51**	**60**	**77**	**77**	**116**	**68**	**83**	**260**	**627**	**178**	**171**	**181**	**161**	**198**	**145**	**882**	**246**	**198**
Sharks[2]																			
Elephant shark						58.0	50.1	33.1	29.5	42.7	40.0	18.4	16.5	10.2	7.6	5.7	9.0	1.9	1.5
Gummy shark						750.5	626.6	714.7	798.3	1022	1148	23.5	14.2	24.7	41.6	12.4	13.6	14.0	9.8
Draughtboard shark						0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.7	1.0	0.8	1.3	1.4	3.5	5.5
Sawshark						127.4	88.8	113.4	86.8	109.7	127.9	21.4	20.4	20.6	23.5	5.9	3.4	0.3	0.1
School shark						252.1	196.4	216.1	150.5	136.3	72.1	2.2	1.4	7.0	2.6	0.6	1.8	1.0	0.7
Seven-gilled shark						6.1	7.9	15.6	17.6	33.5	44.5	18.8	7.4	11.5	8.4	3.8	3.9	0.6	2.3
Other shark						32.8	18.9	23.1	19.0	22.3	15.3	7.9	10.8	7.2	1.8	1.1	2.6	2.8	1.1
Total sharks						**1227**	**989**	**1116**	**1102**	**1366**	**1448**	**94**	**71**	**82**	**86**	**31**	**36**	**24**	**21**

[1] Octopus catches in NWC and NEC were assumed to be *Octopus pallidus* (excluding bycatch in rock lobster traps). Catches can also include *Octopus tetricus*.

[2] Since 2001/02, shark catches have been reported in Commonwealth logbooks. Tasmania has jurisdiction of all shark species inside 3nm except gummy and school shark, and fishers are on bycatch possession limits for all species. Includes bycatch from the rock lobster fishery (separate reporting since 2007/08).

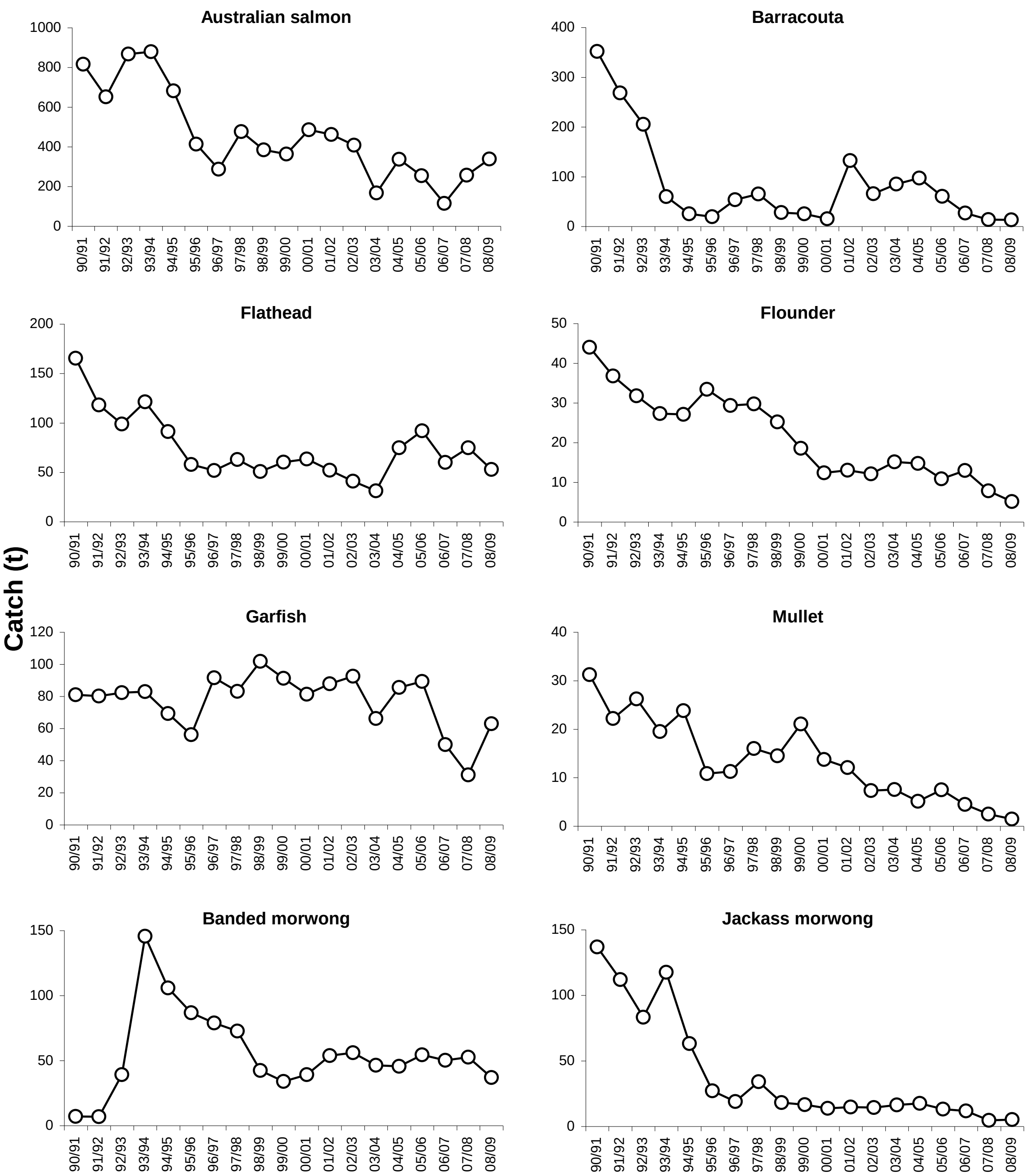

Fig. 2.2. Annual catches for key scalefish species since 1990/91.

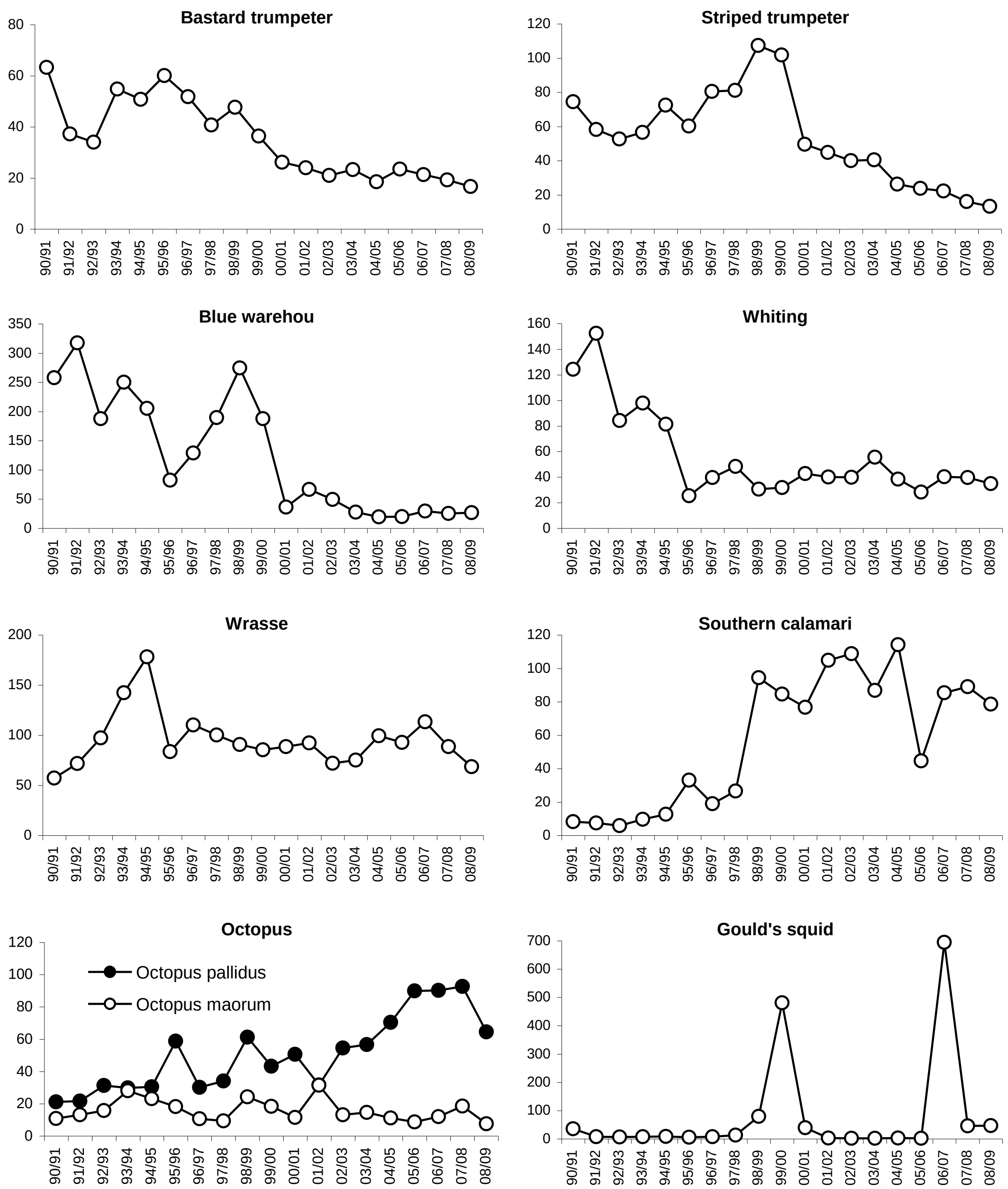

Fig. 2.2. Continued.

2.4.2 Estuarine production

Estuarine production (a subset of the whole general fishery) totalled 93 tonnes in 2008/09 (Table 2.4). Catches came mainly from the southern estuaries of the Derwent River (ES1), Norfolk Bay (ES18), Frederick Henry Bay (ES19), and from the Tamar River (ES10). Whiting, calamari and garfish were the main species caught.

Table 2.4: Total commercial catches (in tonnes) by species in estuaries around Tasmania (a) by fishing year and (b) by species in 2008/09.

a) By fishing year	**ES01**	**ES06**	**ES07**	**ES08**	**ES09**	**ES10**	**ES11**	**ES12**	**ES17**	**ES18**	**ES19**	**ES20**	**Total**
95/96	30.8	0.8	4.4	0.2	0.7	11.4		0.4	2.9	26.4	16.1	3.2	97.3
96/97	37.7	0.3	2.6		0.6	16.6		0.9	6.4	12.3	7.0	1.8	86.2
97/98	59.5	0.2	1.4	0.0	1.0	18.9		2.5	13.4	20.9	15.2	1.4	134.4
98/99	20.4		1.4		1.2	22.3		1.6	11.0	36.5	23.5	4.9	122.8
99/00	11.4		1.0		0.5	16.6	0.1	1.9	21.5	28.5	16.8	2.8	101.1
00/01	20.4		0.2		0.1	18.0	0.0	1.2	16.0	28.0	28.4	1.9	114.2
01/02	14.0		2.2		0.2	81.9		1.2	9.2	64.6	32.6	2.0	207.9
02/03	30.4		8.1		0.2	29.8	0.5	0.8	14.6	35.4	23.4	1.6	144.8
03/04	44.0		6.2		1.0	26.3			5.6	59.5	21.8	0.8	165.2
04/05	29.9		4.9		1.8	35.9		0.0	9.6	25.9	23.1	0.7	131.8
05/06	4.1	0.1	23.2		0.9	34.2	1.3		8.4	14.4	19.6	0.8	107
06/07	31.0	0.3	9.9		2.0	26.3	0.2		8.7	20.3	19.7	1.4	119.8
07/08	38.8	0.0	3.2			17.9		0.0	13.0	26.9	12.3	0.9	113
08/09	33.7		1.1		0.2	22.2		0.0	8.4	15.7	10.5	2.1	93.9

b) By species in 2008/09	**ES01**	**ES06**	**ES07**	**ES08**	**ES09**	**ES10**	**ES11**	**ES12**	**ES17**	**ES18**	**ES19**	**ES20**	**Total**
Australian salmon					0.1	0.9			0.1	0.5	0.1		1.7
Blue warehou					0.1	1.8			0.0	0.1	0.0		2
Calamari						5.8		0.0	3.2	1.9	6.4	0.1	17.4
Flathead	0.4					0.1			0.0	7.1	0.7	0.4	8.7
Flounder	0.0		0.2			0.5			0.8	0.1	1.4	1.5	4.5
Garfish	0.0					7.3			3.6	0.9	0.8	0.0	12.6
Jack mackerel						0.0				1.3			1.3
Mullet						0.2			0.1	0.0	0.0		0.3
Octopus									0.0	1.8		0.0	1.8
Other	0.2		0.9			2.6			0.0	0.8	0.1	0.1	4.7
Pilchard/Anchovy	0.0												0
Redbait													0
Trevally						0.2			0.5	1.3			2
Whiting	33.1					0.1			0.0	0.0	0.5		33.7
Wrasse						2.8			0.1	0.0	0.5	0.0	3.4
Total	**33.7**	**0.0**	**1.1**	**0.0**	**0.2**	**22.2**	**0.0**	**0.0**	**8.4**	**15.7**	**10.5**	**2.1**	**93.9**

ES	**Description**
ES1	Derwent River
ES6	Port Davey
ES7	Macquarie Harbour
ES8	Mersey River
ES9	Port Sorrell
ES10	Tamar River
ES11	Ansons Bay
ES12	Georges Bay
ES17	Blackman Bay
ES18	Norfolk Bay
ES19	Frederick Henry Bay
ES20	Pitt Water

2.5 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 2.5. Since a variety of gear types are represented, it has been necessary to express effort in units appropriate to each specific fishing method (Table 2.1). Effort has also been expressed in terms of number of days fished using the specified gear type, irrespective of the amount of gear utilised each day. Although days fished represents a less sensitive measure of effort, it has become apparent that some fishers have misinterpreted reporting requirements for effort. This problem has been exacerbated with the introduction of the new logbook in 2007. Days fished overcomes any uncertainty about the accuracy of reporting effort units.

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

Since the mid 1990s effort for the major gear types either declined (beach seine, purse seine, graball and small mesh nets), increased or remained stable initially but has then undergone declines (dipnet, dropline, spear and fish trap), or increased over time (handline and squid jig; Table 2.5 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 an 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 2008/09 were generally similar to or lower than in 2007/08 for most gear types, except for dip net and purse seine which both increased. The effort performance indicator of 110% from the highest of the 1995 to 1997 levels was only exceeded for squid jig. Notwithstanding this, there are continuing concerns, regarding the level of latent effort from licence-holders who are currently either not active in the fishery or participating at low levels but with access to gear such as gillnets, hooks, dipnets and jigs. The 2004 management plan review has attempted to address this issue through several strategies including non-transferability of C-class licences.

Table 2.5. Total annual catch, effort and number of vessels by fishing methods.
Effort units are defined in Table 2.1. * Catch data not shown where five or fewer vessels involved unless agreements exist between fishers and government.

Gear	Year	Catch(t)	Effort#	Days fished	Vessels
Graball net	95/96	348.0	223553	5437	257
	96/97	383.3	231140	5186	232
	97/98	446.3	231412	5249	216
	98/99	493.3	166505	4689	204
	99/00	359.7	152144	4169	203
	00/01	173.4	86838	3187	186
	01/02	196.0	71109	3303	180
	02/03	231.0	85628	3395	168
	03/04	189.8	69189	2904	160
	04/05	154.4	53965	2491	137
	05/06	170.2	51591	2402	123
	06/07	170.0	56487	2543	132
	07/08	161.3	59308	2425	115
	08/09	126.8	47450	1975	95
Small mesh net	95/96	38.7	10971	285	19
	96/97	27.0	7965	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	8170	256	14
	01/02	24.7	9863	259	11
	02/03	22.9	10297	284	11
	03/04	23.0	7254	228	11
	04/05	15.3	5982	220	13
	05/06	21.7	5890	191	11
	06/07	16.4	7144	202	11
	07/08	15.3	6447	183	10
	08/09	9.4	4781	151	7
Dip net	95/96	5.6	320	83	5
	96/97	24.2	1518	364	10
	97/98	37.9	1903	449	21
	98/99	43.6	2784	579	29
	99/00	29.4	2319	505	35
	00/01	22.8	1430	371	27
	01/02	24.8	1561	387	27
	02/03	18.7	1259	337	20
	03/04	25.6	1557	374	19
	04/05	27.4	1521	305	16
	05/06	39.1	2167	376	18
	06/07	22.6	1308	244	18
	07/08	15.2	1057	227	17
	08/09	16.4	1229	287	14
Beach seine	95/96	469.2	1086	559	53
	96/97	351.7	1355	685	50
	97/98	520.9	1206	582	44
	98/99	441.7	872	398	40
	99/00	422.9	901	430	33
	00/01	528.4	789	373	31
	01/02	572.2	1070	495	30
	02/03	490.7	1063	511	35
	03/04	238.1	1282	458	31
	04/05	397.0	975	368	27
	05/06	308.4	653	304	25
	06/07	140.6	528	234	25
	07/08	266.3	630	263	17
	08/09	382.6	620	282	12

Table 2.5. Continued

Gear	Year	Catch(t)	Effort#	Days fished	Vessels
Danish seine	95/96	68.2	474	163	2
	96/97	70.7	360	116	1
	97/98	93.1	456	133	1
	98/99	67.6	375	94	1
	99/00	74.5	515	139	2
	00/01	101.4	589	152	2
	01/02	77.7	491	145	2
	02/03	68.1	354	129	3
	03/04	74.1	278	127	2
	04/05	95.9	282	108	2
	05/06	104.9	418	132	3
	06/07	85.8	475	157	3
	07/08	103.2	482	162	3
	08/09	72.9	387	134	3
Purse seine	95/96	35.2	418	185	11
	96/97	30.4	336	153	10
	97/98	41.8	319	154	7
	98/99	76.9	246	150	8
	99/00	33.7	244	123	10
	00/01	24.6	224	104	4
	01/02	21.3	216	91	5
	02/03	18.7	139	76	4
	03/04	14.8	68	45	3
	04/05	17.6	130	70	5
	05/06	16.0	122	60	4
	06/07	8.1	86	41	4
	07/08	527.8	117	121	5
	08/09	1486.3	195	153	3
Hand line	95/96	74.3	16964	1612	147
	96/97	94.3	21542	1893	135
	97/98	97.5	21076	1702	145
	98/99	88.2	17668	1278	127
	99/00	87.8	16688	1439	134
	00/01	74.2	13585	1541	130
	01/02	87.3	15527	1603	138
	02/03	72.2	15025	1552	125
	03/04	76.4	15610	1411	127
	04/05	100.5	19953	1803	123
	05/06	82.6	20247	1884	116
	06/07	107.3	22745	2139	128
	07/08	92.0	19985	2032	119
	08/09	79.7	17786	1725	93
Drop line	95/96	19.9	438	158	31
	96/97	30.0	433	203	27
	97/98	24.7	539	222	42
	98/99	31.8	666	309	38
	99/00	30.8	385	291	48
	00/01	15.8	382	248	36
	01/02	12.8	220	258	35
	02/03	18.8	264	350	43
	03/04	19.4	378	281	51
	04/05	14.1	351	219	31
	05/06	9.3	185	204	33
	06/07	7.1	259	137	28
	07/08	3.0	39	55	19
	08/09	3.1	45	41	18

Table 2.5. Continued

Gear	Year	Catch(t)	Effort#	Days fished	Vessels
Fish trap	95/96	41.8	8264	1401	66
	96/97	57.2	10710	1796	66
	97/98	49.9	9870	1875	71
	98/99	53.7	10657	1559	56
	99/00	56.1	11030	1637	62
	00/01	54.3	9356	1548	68
	01/02	49.0	6098	1278	62
	02/03	38.2	6177	1246	58
	03/04	48.0	6308	1414	58
	04/05	46.7	7409	1222	54
	05/06	44.6	12302	1421	54
	06/07	44.2	11001	1328	47
	07/08	27.9	9761	916	44
	08/09	13.4	5300	566	28
Squid jig	95/96	10.2	5389	125	23
	96/97	5.7	640	77	14
	97/98	15.2	4381	211	18
	98/99	89.8	10200	613	53
	99/00	150.3	39240	989	64
	00/01	66.5	13173	793	53
	01/02	85.2	12544	925	65
	02/03	91.8	19220	1228	68
	03/04	69.8	15764	1223	73
	04/05	104.8	22362	1424	79
	05/06	35.4	11223	767	59
	06/07	74.4	14105	1204	67
	07/08	77.7	16220	1406	52
	08/09	70.9	15218	1073	34
Spear	95/96	14.1	1403	368	21
	96/97	19.3	1853	464	27
	97/98	16.8	1981	483	40
	98/99	19.8	1812	452	38
	99/00	19.3	2233	475	25
	00/01	14.4	1586	355	22
	01/02	13.1	1296	279	19
	02/03	10.3	1366	247	22
	03/04	10.5	1446	289	22
	04/05	13.5	1609	357	24
	05/06	7.9	1009	271	22
	06/07	15.4	1414	362	20
	07/08	9.8	957	255	21
	08/09	5.57933	886	181	14

Considering effort by gear type alone can mask important dynamics within the fishery itself, such as shifts in species targeting. This is particularly pertinent where individual species may be targeted using a variety of gear types and where a given gear type can be used to target a number of different species. For instance, the decline in purse seine effort until 2006/07 (Table 2.5) was driven largely by falls in effort directed at calamari, whereas there was only minor variation in purse seine effort for garfish. Since then, purse seine has been used to target and catch large quantities of jack mackerel and redbait.

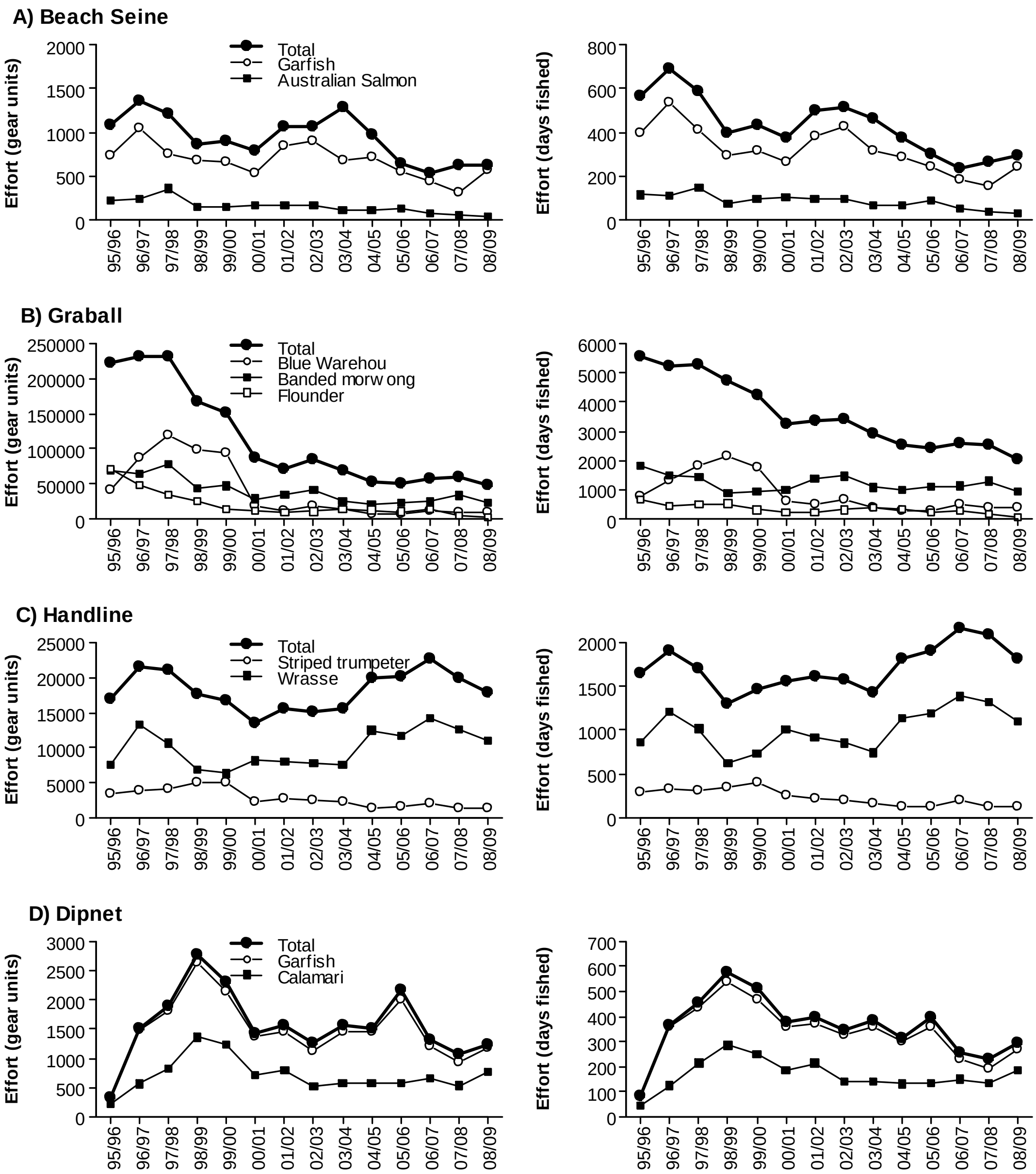

Fig 2.3. Annual effort by selected methods for key species, expressed as gear units (refer Table 2.1) and days fished.

Beach seines are used primarily to target Australian salmon or garfish (Fig. 2.3). While effort for Australian salmon has remained relatively stable since 1995/96, fluctuations in effort for garfish have had the greatest influence on overall beach seine effort.

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

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

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

A significant expansion in jig effort (particularly evident in days fished; Table 2.5) commenced in 1998/99 and was initially directed at calamari, but in 1999/00 there was also a dramatic increase in effort targeted at Gould's squid (graph not shown). Effort for calamari continued to rise up until 2004/05 and fluctuated strongly since. Concurrently, increased squid jig (and automated jig) effort was directed at Gould's squid, after very low levels of effort for this species since the 1999/00 peak.

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

2.6 Catch rates

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

2.7 Recreational fishery

2.7.1 Catch and effort

Catch and effort information are not routinely available for the recreational fishery. Surveys of the recreational fishery conducted in 2000/01 and 2007/08 provide the only comprehensive snapshots of the Tasmanian recreational fishery (Henry and Lyle 2003, Lyle 2005, Lyle et al. 2009).

Recreational fishing surveys have demonstrated that the recreational catch represents a significant component of the total harvest for many species, either as a proportion of the total harvest or in absolute quantities taken (Table 2.6). For instance, recreational catches exceeded commercial catches for flathead, black bream[3], mullet, bastard trumpeter (in 2000/01), barracouta (in 2000/01), jackass morwong, cod, flounder and silver trevally. By contrast, the commercial sector dominated the catches of Australian salmon, wrasse, garfish, whiting, southern calamari, and Gould's squid. In 2007/08, the

[3] It is illegal to retain black bream for commercial sale.

level of statistical uncertainty associated with bastard trumpeter and striped trumpeter catch estimates meant that the species were grouped for reporting purposes.

The most conspicuous differences between years was the decline in the recreational catch of Australian salmon (possibly linked with a decline in overall shore-based fishing effort, refer Lyle et al. 2009), and increases in the recreational catch of southern calamari and Gould's squid. Increased popularity of southern calamari has contributed to this increase, while increased availability of Gould's squid in recent years was a factor in the catch of that species.

2.7.2 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.

Table 2.6 Estimated recreational harvest (numbers and weight) for key scalefish species taken by Tasmanian residents, commercial landings (weight) and proportion of the total (recreational plus commercial) catch represented by the recreational harvest (refer Lyle et al. 2009).

Note: the survey periods do not correspond with fishing years; 2000/01 represented the period May 2000 to Apr2001, and 2007/08 represented the period Dec 2007-Nov 2008.

	2000/01				**2007/08**			
	Rec harvest		**Com.**	**Rec.**	**Rec harvest**		**Com.**	**Rec.**
Species	**No.**	**(t)**	**(t)**	**%**	**No.**	**(t)**	**(t)**	**%**
Flathead	1,236,675	321.5	63.4	*83.5*	1,066,293	292.6	73.2	*80.0*
Australian salmon	300,456	105.2	485.0	*17.8*	110,312	48.1	299.8	*13.8*
Mullet	111,025	30.0	13.7	*68.6*	24,152	6.6	2.4	*73.3*
Flounder	50,582	15.2	10.5	*59.1*	32,436	10.1	7.8	*56.3*
Cod	65,115	30.6	4.0	*88.4*	14,263	8.2	2.5	*76.7*
Jackass morwong	27,041	31.9	13.7	*70.0*	9,979	6.8	3.8	*64.2*
Garfish	15,669	1.9	81.4	*2.3*	14,568	2.0	51.0	*3.7*
Whiting	7,480	0.8	42.5	*1.9*	14,992	3.4	35.4	*8.7*
Black bream	34,336	22.0	0	*100*	13,134	11.4	-	*100*
Barracouta	24,320	46.9	15.1	*75.7*	11,577	10.8	13.9	*43.8*
Wrasse	23,083	13.6	88.4	*13.3*	11,640	10.3	68.5	*13.1*
Blue warehou	16,359	14.6	36.3	*28.6*	8,723	7.0	26.6	*20.8*
Jack mackerel	15,770	3.2	8.6	*26.8*	5,216	1.0	225.7	*0.4*
Striped trumpeter	13,450	29.6	49.6	*37.4*				
Bastard trumpeter	29,130	37.0	26.2	*58.5*				
Trumpeter (grouped)					17,321	19.1	29.3	*39.4*
Leatherjackets	18,706	8.2	16.7	*33.0*	7,619	2.6	4.2	*38.0*
Silver trevally	16,812	4.7	1.6	*74.6*	10,636	4.2	2.0	*67.9*
Southern calamari	29,473	17.7	76.6	*18.8*	40,525	44.6	102.6	*30.3*
Gould's squid	9,903	5.0	39.7	*11.1*	73,236	36.6	45.8	*44.4*

Following the introduction of net licences in 1995, the number of licences issued rose rapidly from around 8900 to a peak of over 11000 in 1999/00 (Table 2.7). Licences then stabilised at between 8000-9000 but climbed again to over 10000 in 2007/08. However, as indicated by the number of Graball Net 1 licences issued, the actual number of gillnet licence-holders varied only slightly between the late 1990s and 2003/04, at around 7000 persons. Since then licence numbers have increased steadily, to about 9200 graball net licences in the current year. 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 2.7. Number of recreational gillnet licences issued by licensing year since 1995/96

na not applicable

Licence type	95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09
Graball Net 1	5615	6290	6685	6709	7477	7401	6960	7695	7313	7408	8054	8677	9185	9172
Graball Net 2	2612	2678	2683	2426	2652	2515	1841	na	na	na	na	na	na	na
Mullet Net	656	684	738	739	879	845	608	754	753	754	816	877	995	1080
Total	**8883**	**9652**	**10106**	**9874**	**11008**	**10761**	**9409**	**8449**	**8066**	**8162**	**8870**	**9554**	**10180**	**10252**

Although not a direct index of recreational net fishing effort (not all licence holders fish each year and in any case the level of individual fishing effort is highly variable), licence numbers suggest that netting effort may have increased in the last couple of years. With the exception of gillnet surveys conducted between 1996-98 (Lyle 2000) there have been no targeted assessments of recreational net catch or effort in Tasmania. General fishing surveys in 2000/01 (Lyle 2005) and 2007/08 (Lyle et al. 2009) do, however, provide some limited information about recreational gillnetting, indicating that there has been a significant (40%) reduction in gillnet effort since the early 2000s (Lyle et al. 2009). A targeted survey of recreational gillnetting is being undertaken during 2010 and findings will be incorporated in future assessments.

2.8 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. The introduction of a new logbook during the 2007/08 season has helped to clarify reporting, but there continues to be an ongoing 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 workshops have identified the need to improve the quality of catch reporting, including provision for catch verification. The inclusion of catch disposal records in the new logbook may also improve the accuracy of catch reporting.

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

Limited information about the recreational fishery remains a major uncertainty and is especially significant in the scalefish assessment given the scale of the recreational relative to commercial catches. While the 2000/01 and 2007/08 surveys represent important baseline information about this sector, there is a need for an on-going monitoring program for the recreational fishery. Without such information attempts to assess the status of those species with significant recreational catches will be incomplete

Fish mortality due to predation and fishery interactions with Australian and New Zealand fur seals is largely unknown but represents another source of uncertainty. Seals can cause substantial mortality to some of the fish species assessed in this report as well as causing gear damage and influencing the fisher behaviour, factors that impact on catches and catch rates. This tends to be caused predominantly by individual ‘rogue’ seals which learn to target particular fisheries or fishing methods (e.g. the banded morwong gillnet fishery), while the typical diet of seals includes mainly pelagic fish species (Goldsworthy et al. 2003).

2.9 Implications for management

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

3 Banded morwong (*Cheilodactylus spectabilis*)

3.1 Life-history and stock structure

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

Parameter	Estimates	Source
Habitat	Rocky reef down to about 50 m, with females and juveniles inhabiting the relatively shallow sections of the reef and males tending to dominate deeper reef regions. Highly territorial adult males. Depth stratification of populations in southern Tasmania may be less pronounced than in NZ due to large depth changes occurring over short distances.	McCormick 1989a McCormick 1989b
Distribution	From around Sydney south to eastern Victoria and around Tasmania, New Zealand.	Gomon *et al*. 1994
Movement and Stock structure	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.	Murphy and Lyle 1999 Ziegler *et al*. 2006
Natural mortality	Low Estimated at $M = 0.05$	Murphy and Lyle 1999
Maximum age	Females: 93 years Males: 96 years	Ewing *et al.* 2007
Growth	Males grow to larger sizes than females Growth accelerated between 1996 and 2007 Schnute & Richards (1990) growth parameters:	Ziegler *et al.* 2007a

	Females						*Males*					
	$L\infty$	a	b	c	α	σ	$L\infty$	a	b	c	α	σ
1996	429	11.9	3.8E-08	0.08	0.01	18.0	525	2.4	0.022	0.28	0.4	20.3
1997	446	19.7	4.7E-08	0.04	18.9	20.5	522	2.7	0.044	0.27	1.0	22.7
2001	418	13.8	1.2E-05	0.08	11.2	19.2	520	10.3	0.0002	0.08	8.2	20.5
2002	433	20.4	1.1E-07	0.05	75.3	17.6	538	11.3	0.0001	0.07	11.0	18.2
2003	427	20.1	1.3E-07	0.05	69.2	19.3	522	7.3	0.0037	0.11	6.8	18.2
2004	438	20.1	1.3E-07	0.05	68.2	19.5	526	5.9	0.0097	0.15	4.4	21.2
2005	452	22.7	1.3E-08	0.04	93.0	17.9	547	7.9	0.0022	0.10	8.1	17.2
2007	442	18.8	3.3E-07	0.05	51.4	16.2	516	2.3	0.0088	0.33	0.1	19.4

Parameter	Estimates	Source
Maturity	Early age and small size at onset of maturity Onset of maturity in 2005 at smaller sizes and younger ages than in 1996 Age at maturity modelled by logistic function:	Ziegler *et al.* 2007a

	B_0	B_1	*50% maturity*
F1996-97	-3.09	0.78	4 years
F2001	-2.93	1.08	2-3 years
F2002-03	-5.11	1.94	2-3 years
F2005	-5.26	1.94	2-3 years

Parameter	Estimates	Source
Spawning	In a spawning condition between mid to late February to early May, with the size distribution of oocytes in the ovaries indicating they are serial spawners	Murphy and Lyle 1999
Larval phase	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.	B. Bruce pers. comm. Wolf 1998

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.* 2006). Between 1994/95 and 1999/00, catches declined steadily from over 100 tonnes to just 34 tonnes, before increasing to over 50 tonnes in 2001/02 (Fig. 3.1). Since then, catches have stabilised around 40-50 tonnes.

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

3.3 Management background

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

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

In addition to the closed season, an interim live fish endorsement to take banded morwong and wrasse was introduced in 1996. Eligibility was based on a demonstrated history of taking one or both of these species (at least 50 kg between 1 January 1993 and 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) that resulted in 29 fishing licences for banded morwong. As the result of concerns about a potential unsustainable expansion of the fishery, a quota management system with a Total Allowable Catch (TAC) along the east coast from Whale Head in the south to Low Head on the north coast (excluding the Furneaux Group) was introduced in October 2008 (Fig. 3.1).

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

3.4 Management objectives and strategies

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

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

3.5 Relative vulnerability to fishing

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

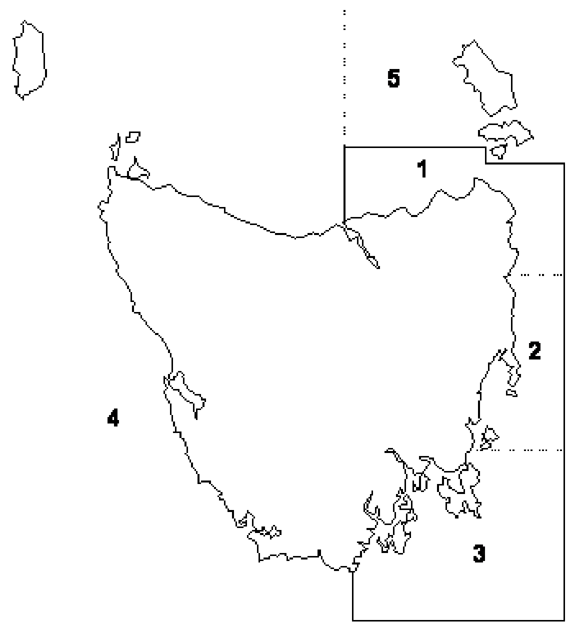

Fig 3.1. Designated TAC area for banded morwong (bold box) from Low Head on the north coast to Whale head in the south, and the five assessment regions separated by the dotted lines.

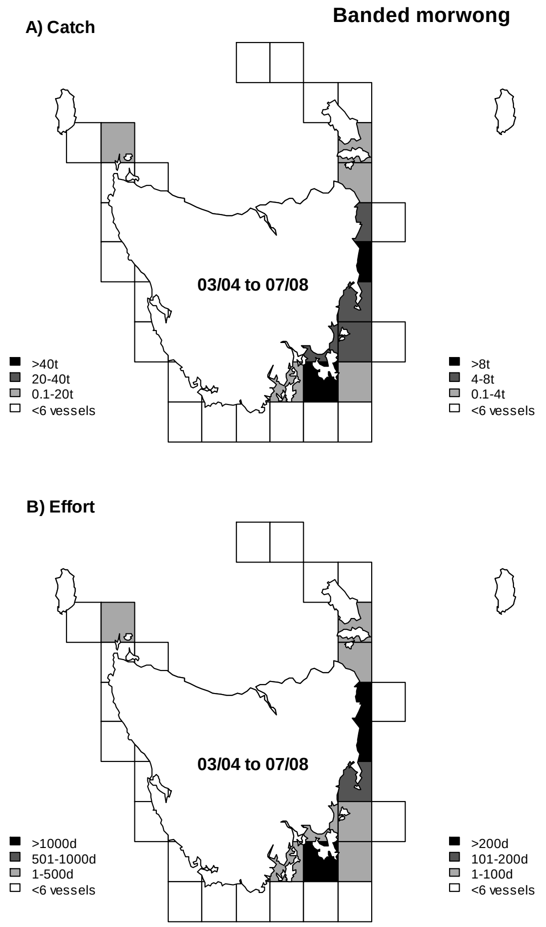

Fig 3.2. (A) Banded morwong catches (tonnes) and (B) effort (days) by fishing block pooled from 2003/04 to 2007/08 (left) and during 2008/09 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

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 block level or for the five assessment regions that have been defined for the fishery (Fig. 3.1). Collectively, catches from the three regions within the TAC area have averaged over 90% of the total banded morwong production each year since the mid-1990s (Fig. 3.2).

As a result of the introduction of a quota system, the analysis for banded morwong follows now the quota year from 1st March to end of February in the following year.

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

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

3.6.1 Catch, effort and catch rates

Catches in the new logbook are reported as number of fish rather than weight. Hence, total catches in 2008/09 were estimated based on an average weight of 1.3 kg per fish.

State-wide reported catches have been relatively stable for some years, but the 2008/09 catch of 40 tonnes was 20% lower compared to that from the previous year (Fig. 3.3). Within the designated TAC area, the reported catch dropped over 15 tonnes to 33.8 tonnes (Table 3.1). Prior to the introduction of the quota management system on 1st October 2008 (i.e. March to September 2008), the catch dropped only slightly by 3.4 tonnes from the previous year to 15.6 tonnes. However, for the period from 1st October 2009 to 28th February 2009 only 18.2 tonnes of the allocated TAC of 25 tonnes were caught. Industry stated structural adjustment problems to the new quota system as the main reason for this shortfall. Quotas were not transferrable during that period because the legislation was subject to disallowance in the Parliament, and leasing practices had not been established between fishers.

Catches decreased in the both assessment regions 2 and 3, but remained stable in assessment region 1 (Table 3.1 and Fig. 3.3). Assessment area 2 between Scamander River and the northern end of Marion Beach still dominated the catches representing just under 50% of the TAC. None of the regional reference points were reached. Catches from outside the proposed TAC areas were low (6.5 tonnes) and thus well below the 10 tonnes reference point per assessment area.

Results of the recreational surveys indicated that the recreational catch of banded morwong is low at around or less than one tonne (Henry and Lyle 2003, Lyle et al. 2009). Thus, recreational catches represent less than 2.5% of the commercial catch.

Table 3.1: Catches in tonnes for 2008/09 inside and outside the designated TAC area.

Assessment Region		**Description**	**Catch**		**% of 08/09 catch**
			07/08	**08/09**	**within TAC area**
Within TAC area	1	North-East coast (NEC): Low Head to Scamander River	7.6	7.8	23%
	2	East coast (EC): Scamander River to Marion Bay	25.6	16.6	49%
	3	South-East coast (SEC): Marion Bay to Whale Head	16.1	9.4	28%
	Total		49.4	33.8	
Outside TAC area	4	West coast & North cost west of Low Head	0.2	1.6	
	5	Furneaux Group	2.2	4.9	
	Total		2.4	6.5	
State-wide	**Total**		51.8	40.3	

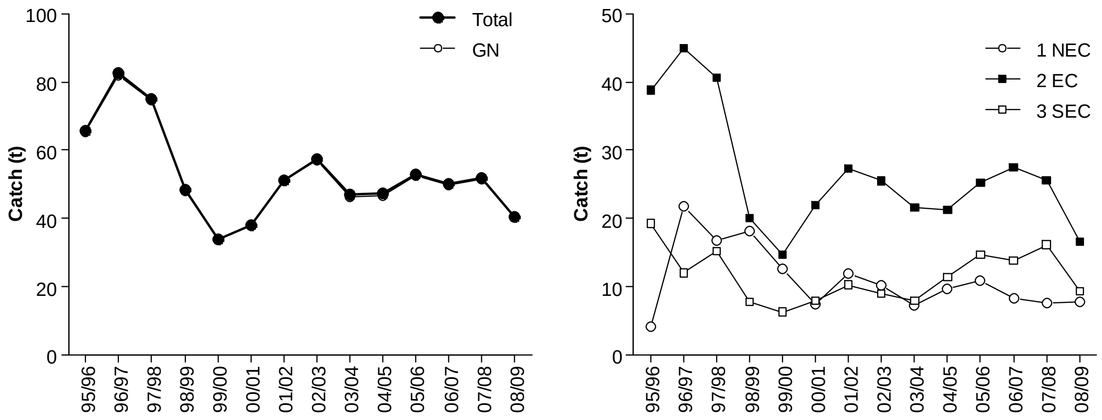

Fig 3.3. Banded morwong catches (tonnes) since 1995/96. Total catches State-wide for all gear types (Total) and by graball net (GN, left); and regional graball catches in the TAC areas 1 NEC, 2 EC and 3 SEC (right).

Total effort expressed as days fished or gear units (100m net hour) has also decreased in 2008/09 (Fig 3.4). Fishers have progressively reduced their fishing activity and deployed less gear on average for each day fished over the last 10 years, indicated by a stronger decline of effort by days fished compared to gear units. There are also numerous industry reports of increasing levels of seal interference over time that have meant that affected fishers have often resorted to fishing with less gear or doing fewer sets each day to reduce losses to seals (Ziegler *et al.* 2006).

Regionally, the most conspicuous trends in effort (days fished) have been sharp drops of effort in assessment regions 2 and 3, in the latter (SEC) after a steady increase over a number of years. Effort on assessment region (NEC) has increased slightly after recent declines.

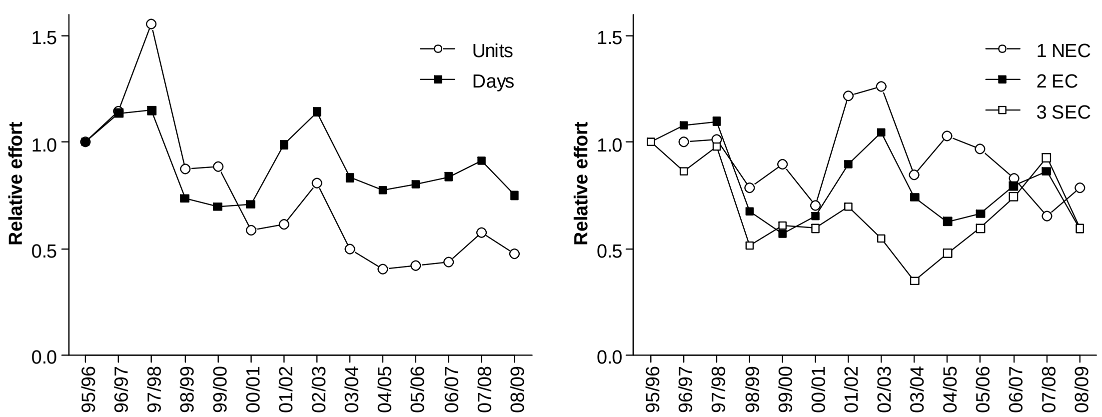

Fig 3.4. Banded morwong graball effort relative to 1995/96 levels. State-wide relative effort based on gear units (Units) and days fished (Days, left); and relative effort in days fished in the TAC areas 1 NEC, 2 EC and 3 SEC (right).

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

Standardisation of catch rates was conducted for an annual time scale (the quota year), at both the scale of the whole TAC area and for three separate assessment regions within the quota area (Table 3.2). 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 500 kg of banded morwong across all of the years they were active in the fishery. These restrictions selected data that accounted for 92% of the total catch reported since 1995/96. Nevertheless, the number of skippers was relatively low in each assessment region (31 in region 1, 54 in region 2, 28 in region 3, 58 in the entire TAC area).

The generalized linear models of catch rate were fitted to different combinations of various factors for which information were available, viz. vessel, skipper, fishing block, depth zone fished (<10 m, 10-20 m, 20-30 m, and >30 m), bimonthly period, and reported seal interference. A bimonthly rather than monthly period 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 a relatively influential factor, despite very inconsistent reporting. Fishing trips with seal interference and very low catch are often not reported at all, and a report of seal interference ('occurrence') does not in any way allow quantification of the severity of the interaction in terms of lost catch or impacts on fishing activity.

Standardised catch rates for banded morwong were fitted to natural log-transformed catch rate data (assuming a lognormal distribution), using a normal distribution family with an identity link. All models were fitted using a forward approach by manual stepwise addition of each factor starting with the time-step. Some interaction terms between various factors were also considered, but these were limited to combinations for which sensible interpretations could be ascribed. The optimal model was chosen based on minimization of the Akaike's Information Criterion (AIC; Burnham and Anderson 2002).

Table 3.2: Generalized linear models (GLM) for the catch rates of banded morwong across the whole east coast of Tasmania, and in the separate St. Helens, Bicheno, Maria and Tasman regions. The adjusted R^2 has been used for the Variation described.

Region		Model	Variation described
Whole TAC area	Ln cpue =	Constant + year + vessel + seals + bimonth + block + skipper +depth + vessel*bimonth	40.3%
1 NEC	Ln cpue =	Constant + year + vessel + bimonth + seals + block + depth + vessel*bimonth	45.6%
2 EC	Ln cpue =	Constant + year + vessel + bimonth + seals + block + skipper + depth + vessel*bimonth	41.2%
3 SEC	Ln cpue =	Constant + year + vessel + bimonth + block + skipper + seals + vessel*bimonth	42.4%

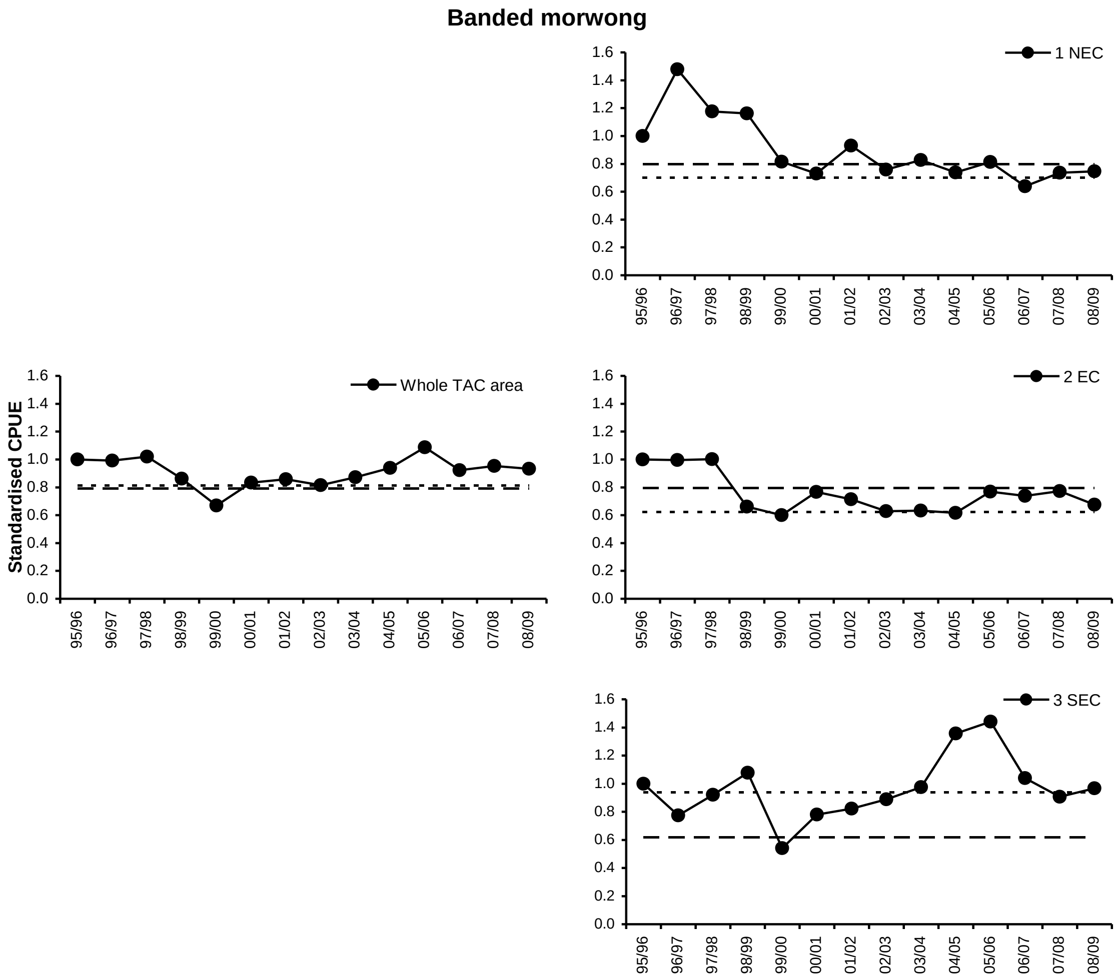

Fig 3.5. Banded morwong standardised graball catch per unit effort (CPUE by days fished) relative to 1995/96 levels from the whole TAC area (left), and in the TAC areas 1 NEC, 2 EC and 3 SEC (right). Dashed lines mark existing reference limits, dotted lines mark alternative reference limits (refer section 3.8).

Overall standardised catch rates in the whole TAC area fell between 1995/96 and 1999/2000, accompanying the declines in catch and effort (Fig. 3.5). Since 1999/2000 overall catch rates have risen back to 1995/96 levels. Catch rates in region 1 (NEC) and region 2 (EC) fell in the late 1990s, but have since stabilised at around 70% of 1995/96 levels. Catch rates in region 3 (SEC) decreased initially to 1999/2000, then increased to levels well above those of 1995/96 by 2005/06. Subsequent catch rates have stabilised but at a lower level. Alternative reference limits have not been triggered in any of the assessment regions, while catch rates were below the existing reference limits in the regions 1 and 2.

3.6.2 Biological data from scientific catch sampling

Banded morwong have been sampled during the spawning season of most years around Bicheno (region 2) and the Tasman peninsula (region 3) since 1995/96, and around St. Helens (region 1) since 2001/02. Age has been determined and validated by analysis of otolith structure (Ewing et al. 2007).

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

In contrast to males, females recruit to the fishery at around 4-5 years of age and typically remain vulnerable for the remainder of their lives (Fig. 3.7). Fishing has had a marked impact on age structure in all regions. While there are still old females present, their relative contribution has decreased significantly in recent years compared to the mid 1990s, and young females now dominate the catches. Around Bicheno and the Tasman Peninsula, the proportion of females up to 10 years of age increased between 1996 and 2009 from 41% to 72%, and from 24% to 82%, respectively.

These data suggest that the fishery has becoming increasingly dependent on new recruits. Relatively strong year classes of 6-year old males and females were evident in the 2009 samples from both sampling sites, along with a strong 4-year old class from Bicheno.

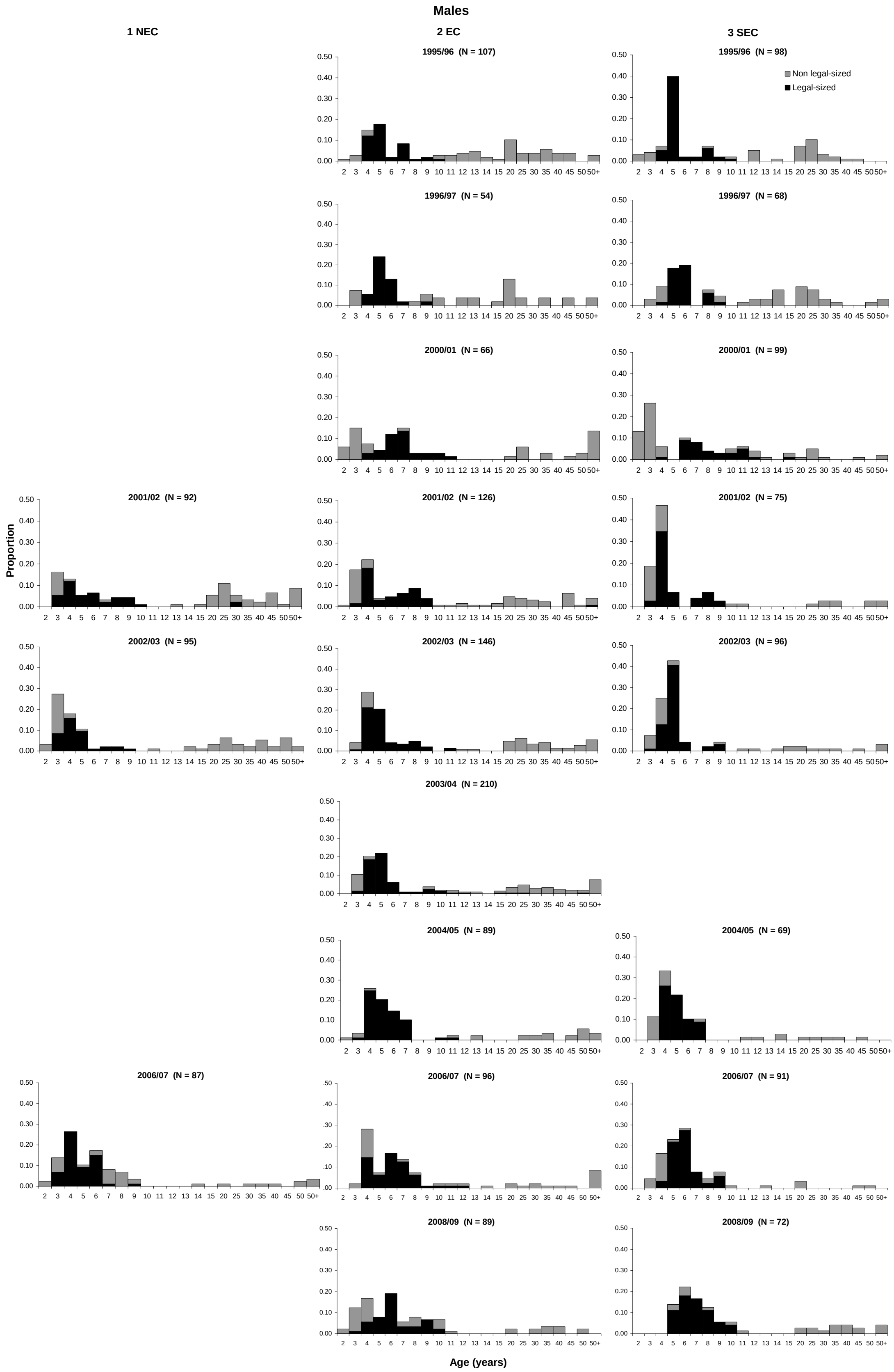

Figure 3.6: Relative age composition of male banded morwong in research catches from the TAC assessment regions 1, 2 and 3 since 1995/96. Black bars refer to legal-sized fish (330-430mm up to 1997), grey bars to non-legal-sized (undersized and oversized) fish. Relative frequencies of 1-year classes (ages 2-15y), 5-year classes (ages 16-50y, values given denote upper limit) and a plus group for fish older than 50 years (denoted as 50+). N is sample size.

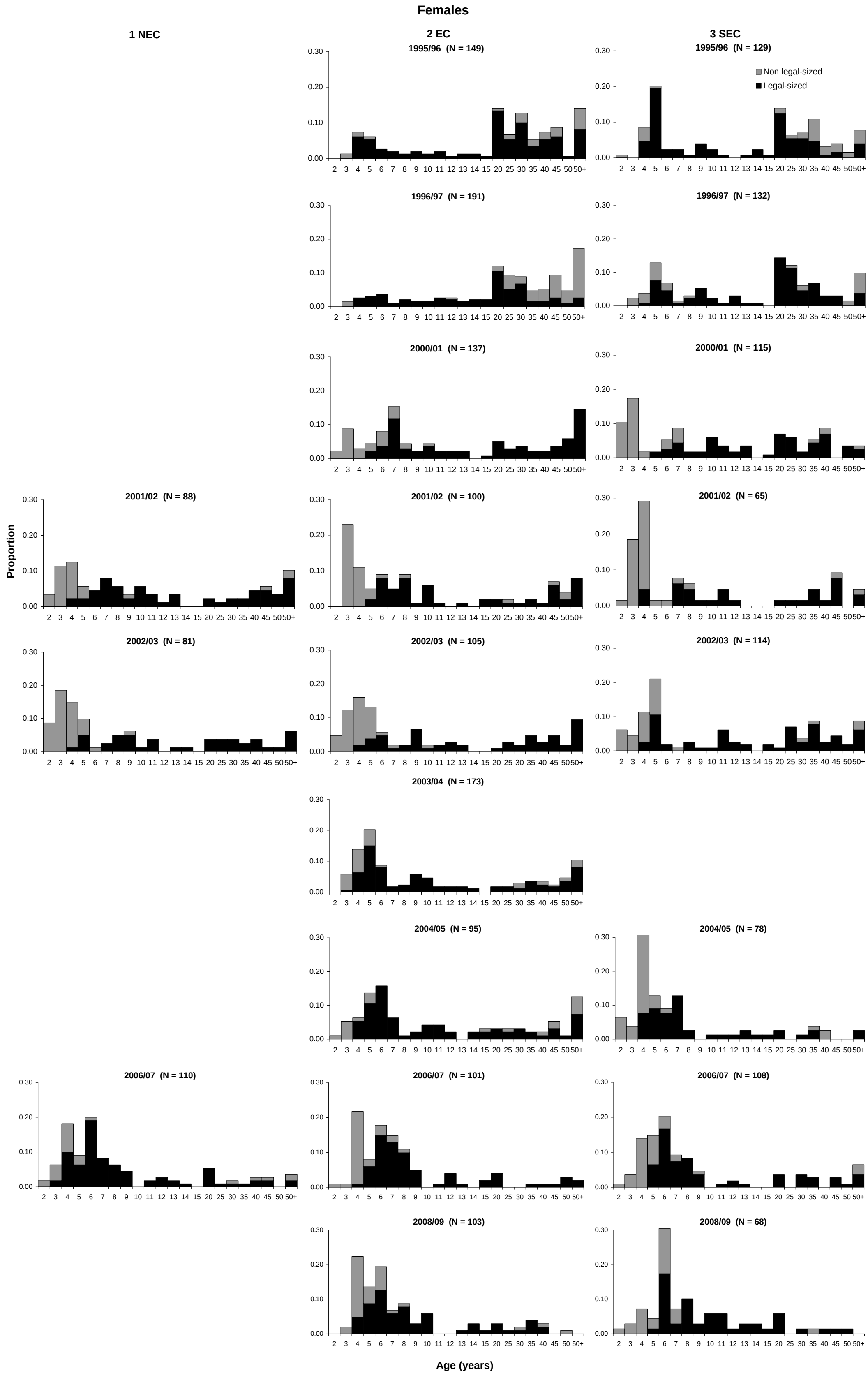

Figure 3.7: Relative age composition of female banded morwong in research catches from the TAC assessment regions 1, 2 and 3 since 1995/96. Black bars refer to legal-sized fish (330-430mm up to 1997), grey bars to non-legal-sized (undersized and oversized) fish. Relative frequencies of 1-year classes (ages 2-15y), 5-year classes (ages 16-50y, values given denote upper limit) and a plus group for fish older than 50 years (denoted as 50+). N is sample size.

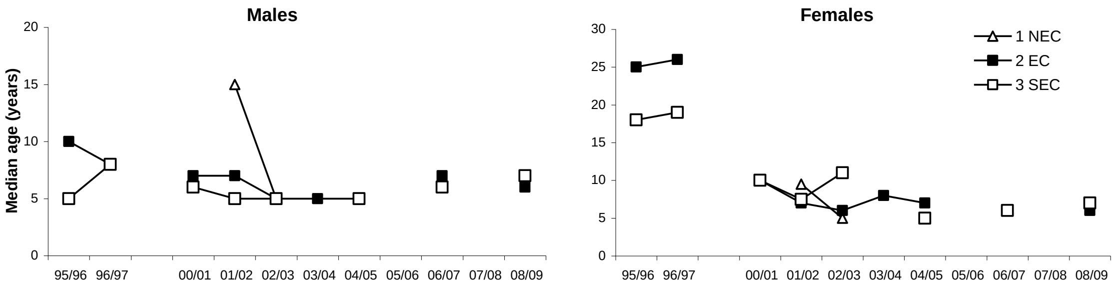

Fig. 3.8. Median age of male and female banded morwong in total research catches from St. Helens (region1), Bicheno (region 2) and the Tasman Peninsula (region 3).

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

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

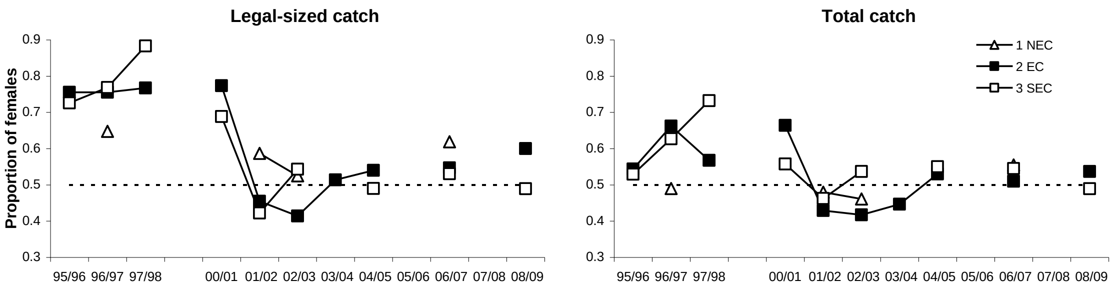

Fig. 3.9. Proportion of female banded morwong in the legal-sized and total catch from St. Helens (region1), Bicheno (region 2) and the Tasman peninsula (region 3). Dotted lines represent a sex ratio of 1:1.

3.7 Stock assessment model

3.7.1 Model structure

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

The models simulated one discrete banded morwong stock in each of the assessment regions 2 (EC) and 3 (SEC). Ideally, the number of stocks would equal the number of individual banded morwong populations on reefs. Given minimal movement rates of adult fish once they have settled on a reef, populations could vary at the spatial scale of kilometres or even hundreds of meters. However, the spatial resolution of the commercial data was limited to the 30 nm fishing blocks, and biological data were only collected from a restricted number of reefs around Bicheno and the Tasman Peninsula. As a result, one stock was assumed per assessment region, with the age composition assumed to be representative for each assessment region.

The only difference between the joint and the independent models was the recruitment pattern. In contrast to the two independent models, the joint model treated both stocks as part of a larger meta-population where larvae mixed across all regions and thus recruitment patterns were similar. This assumption was supported by the extended pelagic larval stage of up to 6 months suggesting that recruitment to different regions could homogenize (Wolf 1998). The approach used a ratio for the recruitment distribution between the two regions. Rather than being estimated internally by the model, different ratio parameters were examined and model performance compared in a sensitivity analysis (Scenarios C1-C3, 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 two assessment regions, where depth contours were available for the mapped reefs, approximately 70-80% of the reef habitat was found onshore within depths of 0-25 m, and 20-30% 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 habitat onshore and available to the fishery to only 75% and 50% onshore (Table 3.2).

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

Data from acoustic tracking studies have indicated that fish from shallow waters only move towards deeper waters around the spawning period (J. Semmens, pers. comm.). However, the movement rates of fish from deeper waters into shallow waters remained unclear. Industry also advocated the hypothesis that the removal of fish from a reef by fishing would trigger an immigration of fish from nearby areas.

In the model, all recruitment of young fish occurred to the onshore population (see below) and only mature fish could move. Movement between onshore and offshore components of the population was considered to be a combination of the proportion of habitat area π_i of the receiving population and mobility *m*, defined as the proportion of the mature population that is capable of shifting between adjoining onshore and offshore populations (see Appendix 3). Thus, the movement rate from onshore population *p* into offshore population *p*+1 can be represented as $m\pi_{p+1}$. Onshore population *p* retains $1\text{-}m\pi_{p+1}$ of its total, but gains $m\pi_p$ from the offshore population *p*+1. This results in larger habitat areas having higher immigration rates. If the proportion of habitat area is equal (*i.e.* 50:50) then the movement rates are symmetrical. However, the numbers of fish moving may be still asymmetrical depending on the size of the onshore and offshore populations. Five different movement rates between onshore and offshore populations were examined (Scenarios A1-A5, Table 3.2). Low and medium proportions of habitat areas onshore were combined with low and high mobility rates, with a base case of 0.75 habitat area onshore and low mobility rates of 0.25. A scenario with all habitat area onshore and therefore the whole fish population accessible to the fishery was also examined (Scenario A1).

Table 3.2: Tested scenarios for proportion of habitat area onshore, mobility rate, seal-related mortality, and regional habitat area distribution (only in joint model).

Scenario	Habitat area onshore π_i	Mobility rate *m*	Seal-related mortality	Regional recruitment distribution in joint model	
				Region 2 (EC)	Region 3 (SEC)
A1	1.0	N/A	Best estimate	0.6	0.4
A2	0.75	1.0	Best estimate	0.6	0.4
A3 (Base case)	0.75	0.25	Best estimate	0.6	0.4
A4	0.5	1.0	Best estimate	0.6	0.4
A5	0.5	0.25	Best estimate	0.6	0.4
B1	0.75	0.25	None	0.6	0.4
B2	0.75	0.25	High after 2000	0.6	0.4
C1	0.75	0.25	Best estimate	0.5	0.5
C2	0.75	0.25	Best estimate	0.7	0.3
C3	0.75	0.25	Best estimate	0.8	0.2

The model operated on an annual time step starting on the 1st of March, and was fitted to 20 years of commercial catch and effort data from the earliest catch reports available in 1989/90 to 2008/09 inclusive. For the purpose of this assessment, the fishing year of 1989/90 is described as 1990, 1990/91 as 1991 and so on. It was assumed that each stock was at a pre-exploitation equilibrium with the corresponding age and sex structure prior to 1990. While the live-fish fishery only started in that year, mainly lobster fishers had previously taken banded morwong for use as bait in their traps. Although the quantity taken each year is unknown, discussions with rock lobster fishers indicated that catches had been low compared to that taken by the targeted fishery in the mid 1990s.

3.7.2 Biological components

Biological monitoring for the age composition of the catch, age at length and maturity studies occurred during the spawning periods in March and April of 1996 and 1997, and in some years since 2001 around Bicheno and the Tasman Peninsula (Chapter 3.6.2). These samples were taken as representative for the whole assessment regions 2 and 3, respectively

Length at age was modelled by a Schnute and Richards (1990) growth function and maturity at age by logistic functions (Ziegler et al. 2007a). Because growth and maturity were generally similar between the sampling sites, single growth and maturity functions were used across both regions in any given year. However, growth was found to have increased and maturity to have accelerated over time, and periods with specific growth and maturity patterns were identified. For the periods 1990-1998, 1999-2001, 2002-2003, 2004-2006 and 2007-2009 all available data from 1996-1997, 2001, 2002-2003, 2004-205 and 2007-2009, respectively, were pooled by sex across regions. In addition, all data for males and females older than 20 years were pooled by sex and used in all model fits, such that the asymptotic length L_∞ would converge and sex-specific maximum sizes would be constant across all years. Natural mortality was assumed to be constant at $M = 0.05$.

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

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

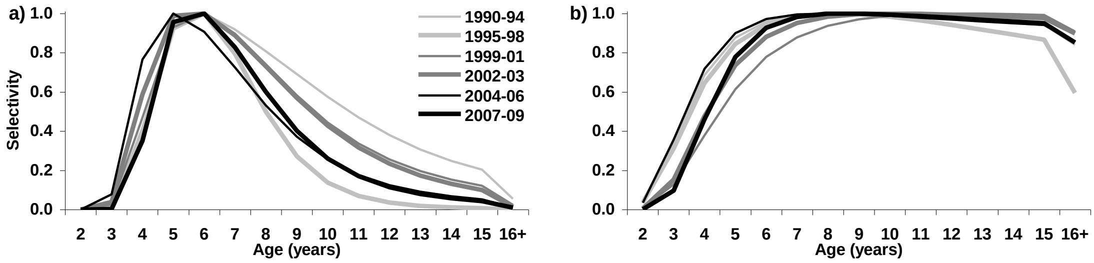

Fig. 3.14: Selectivity at age for (a) male and (b) female banded morwong for 1990-94 (mesh size 133 mm, 33-48 cm size limits and 1996-97, light grey line); 1995-98 (mesh size 137 mm, 33-43 cm size limits and 1996-97 growth, heavy light grey line); 1999-01 (mesh size 137 mm, 36-46 cm size limits and 2001 growth, dark grey line); 2002-03 (mesh size 137 mm, 36-46 cm size limits and 2002-03 growth, heavy dark grey line); 2004-05 (mesh size 137 mm, 36-46 cm size limits and 2004-05 growth, black line); and 2007-09 (mesh size 137 mm, 36-46 cm size limits and 2007-09 growth, heavy black line).

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

3.7.3 Harvest components

Catch and effort data for the models were based on commercial catch and effort information provided by compulsory logbook returns to the Tasmanian Department of Primary Industries, Parks, Water and Environment (DPIPWE). 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. In the new logbooks introduced in 2008, catches are reported as number of fish rather than weight and total banded morwong catches for 2009 were estimated based on an average weight of 1.3 kg per fish.

Because fishers and processors generally believed that catches were substantially over-stated before the introduction of live-fish endorsements in 1996 (Ziegler et al. 2006a), a more plausible catch history was estimated based on the catch returns from the east coast (Fig 3.15). After discussions with industry, catches reported in 1994 and 1995 were reduced by 24.8 tonnes in region 2 and 7.8 tonnes in region 3 by removing some very large catch reports. 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. Based on industry reports, a scaling factor for seal-related mortality was added to the corrected logbook returns to account for total fishery-induced mortality (M. Cuthbertson, pers. comm., Fig. 3.16). Estimated seal-related mortality increased continuously from the mid 1990s and peaked in 2000 when an estimated 60% of the total catch was lost to seals (this equates to a total mortality that is 2.5 times the reported catch). Since then, assumed seal-related mortality has dropped to around 30%. To investigate the influence of the level of seal-related mortality, two alternative scenarios were examined, the first without seal-related mortality (just reported catch) and the second with seal-related mortality that remained high at 50% after 2000 (Scenarios B1-B2, Table 3.2).

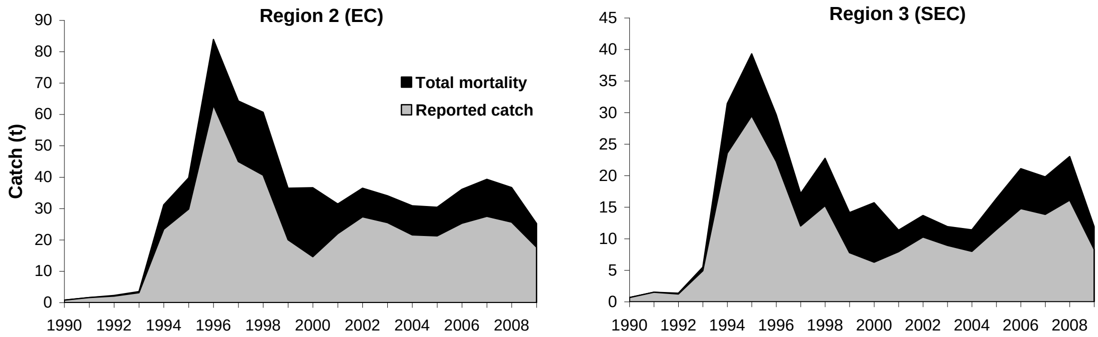

Fig. 3.15: Reported catch history of banded morwong in the assessment regions 2 and 3 (grey) and total fishery-induced mortality that includes an estimate of seal-related mortality (black) since 1990.

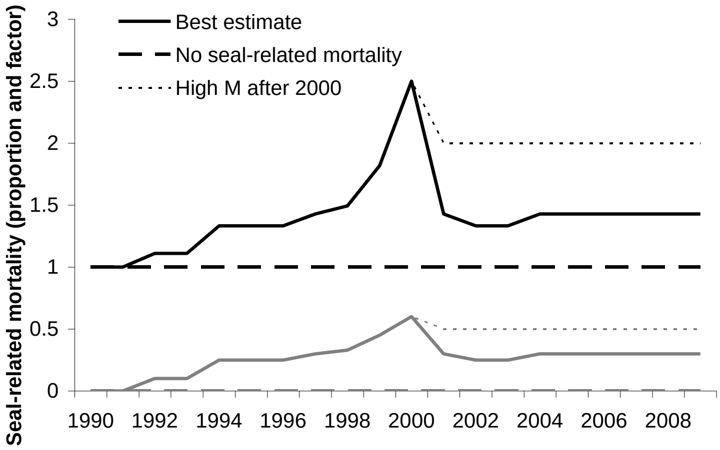

Fig. 3.16: Estimates of seal-related mortality in the banded morwong fishery. Bottom graph (grey lines) shows the proportion of the total catch taken by seals, top graph (black lines) shows the corresponding multiplication factor used for the reported catch to estimate total mortality. Solid lines represent the best estimate by industry, dashed lines represent no seal-related mortality, and dotted lines represent high seal-related mortality after 2000.

The standardised catch rates of the individual regions were used as input variables in the model. Catchability was estimated by the model from the relationship of observed catch rates and exploitable biomass. The catchability coefficient $\hat{q}$ was thereby assumed to be constant and each annual $\hat{q}_y$ to be only an estimate of the overall $\hat{q}$. In 1999, a combination of new management regulations was implemented and seals interactions increased. The former resulted in some restructuring of the fishing fleet, restrictions on the amount of gear used and increased in the size limits. As a result of growing interactions with seal there were substantial changes in fishing practices and losses to seal predation. These two factors combined suggested that the catchability for banded morwong differed between 1996-1999 and 2000-2009, and thus two separate catchability coefficients were estimated for those periods.

3.7.4 Recruitment

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

3.7.5 Model fitting and uncertainty

The model was conditioned on commercial catch data and fitted using maximum log likelihood methods on observed standardised catch rates, catch age-composition (ages 2-15y and a plus-group '16+' with all ages of 16 years and older), and sex ratios within commercial size limits. The latter was a useful parameter due to the sex-specific selectivity. Contributions to the log likelihood of the model fits to catch rate, sex ratio and age composition data were weighted in inverse proportion to their respective variation (*i.e.* less weight to the more variable). Estimated model parameters, 49 in each model, were the equilibrium age composition at the start of the first year in the population along with average recruitment and residual recruitment in each year of the fishery.

Because the spatial structure and associated dynamics were so poorly known, an array of alternative model designs was set up (Table 3.2). This sensitivity analysis tested the impact and influence of different assumptions on the potential separation of stocks in fished onshore and unfished offshore populations and seal-related mortality on the model outcomes. This approach was chosen because estimating these parameters within the assessment model would have lead to a highly over-parameterized model. The model fits of these scenarios were deterministic for any given scenario and compared based on their log likelihood values.

Observation uncertainty of catch rate data was estimated for the base case using bootstrapping. New sets of catch rate data were generated by randomly selecting residuals from the original model (with replacement) and adding them to the estimated catch rates. The model was then re-fitted. This process was repeated 250 times to estimate 90% confidence intervals.

3.7.6 Model fits to data

The separate models for region 2 and 3 with independent recruitment patterns performed better than the joint model with a common recruitment pattern, as indicated by a lower total negative log likelihood of the two models compared to the negative log likelihood of the respective joint models (Table 3.3). This was true for all tested scenarios with different recruitment distribution ratios between the two regions (Scenarios A3 and C1-C3). Using an AIC for model comparison, the joint model prevails since doubling the large number of fitted parameters (49 per model) would heavily penalise the separate models. This result suggests that all models tended to be over-parameterised. Nevertheless, aiming for the best descriptive model of the fished populations, the better-fitting separate models were favoured despite the large number of parameters. Subsequently, only results from these individual assessment models are presented.

Model comparisons indicated that the base case scenarios generally improved overall model fits over other combinations of onshore habitat area and mobility rates (Scenario A1-A5, Table 3.3). The scenario with only an offshore population (Scenario A1) performed even better in the model for region 2 (EC), while in the model for region 3 (SEC) the base case scenario was similar to Scenario A5 with low onshore habitat and mobility rates. For Scenarios A2-A4 with an onshore and offshore population, low movement rates consistently resulted in better fits than high movement rates.

However, the differences between the actual models fitting to the data were very small. (see Fig. 3.17 for a comparison of scenarios A1-A5 for catch rates and the proportion of females in the legal-sized). Given the minor differences compared to the overall quality of the fits, the different scenarios did not allow selecting the best or most plausible model for onshore habitat and mobility rates.

Table 3.3: Negative log likelihood (-LL) of all tested scenarios for separate models in assessment regions 2 (EC) and 3 (SEC), total -LL, and -LL for the joint models.
Base case (Scenario A3) in bold. Smaller -LL value indicate a better fit.

Scenario	Region 2 (EC)	Region 3 (SEC)	Total	Joint models
A1	153.1	103.7	256.8	296.9
A2	163.7	105.7	269.5	307.3
A3	**157.6**	**100.2**	**257.8**	**296.8**
A4	182.4	113.2	295.6	329.9
A5	166.5	100.8	267.3	302.7
B1	156.4	98.2	254.6	292.9
B2	158.2	97.4	255.5	291.4
C1				308.7
C2				286.1
C3				303.8

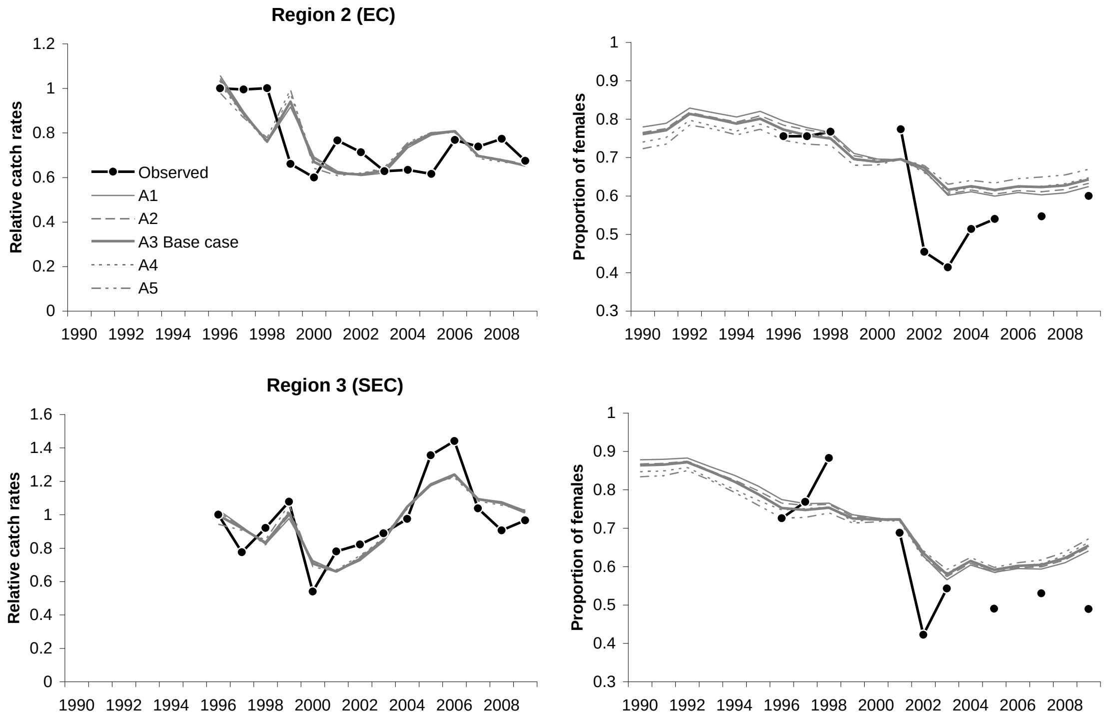

Fig. 3.17: Catch rates and proportion of females in the legal-sized catch in the separate models for region 2 (EC) and 3 (SEC). Observed data (black circles and heavy black lines), and range of model predictions for scenarios A1-A5 with different proportions of habitat area onshore and mobility rates (grey lines).

Fits to catch rates captured the general trends well, however, the recent sex ratios were poorly represented. All model scenarios biased high sex ratio relative to the observed in the commercial catch samples during the 2000s.

The different model scenarios fit to the age composition data also in a similar way and captured strong cohorts reasonably well (base case scenario shown in Figs. 3.18 and 3.19). However, the large variations in age-structure between years, the reason why large recruitment variability was required, may have been at least partly an artefact of the relatively small sampling sizes. The number of males older than 15 years (the '16+' age class) were also badly overestimated by all models. This could have been caused by a poor estimate of the selectivity of the gear for these large fish.

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

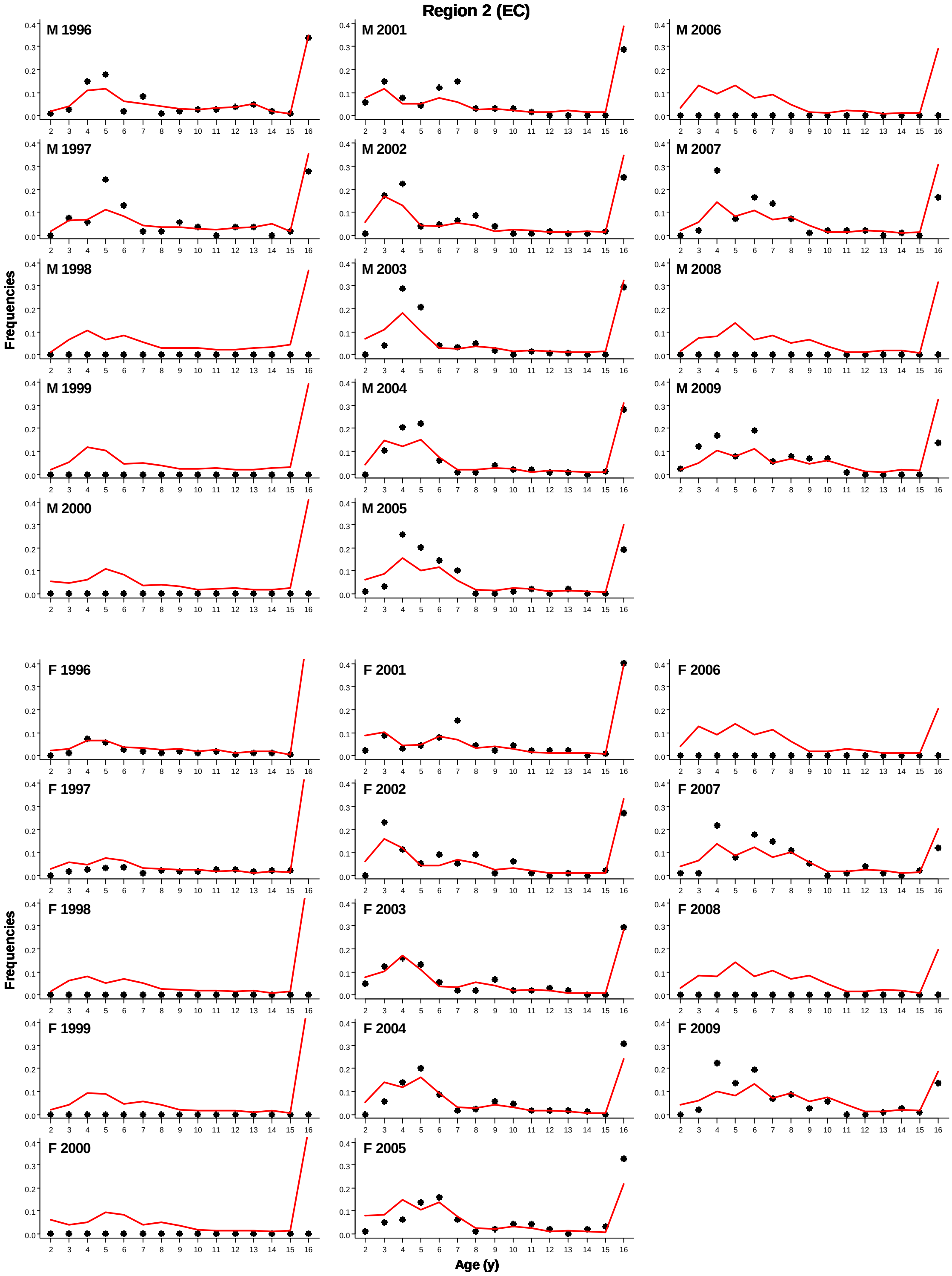

Fig. 3.18: Age composition in relative proportions of male and female banded morwong in assessment region 2 (EC) since 1996. Observed data (black circles) and model fits for the base case scenario A3 with 75% onshore habitat area and a mobility rate of 0.25. Frequencies were limited to 0.4. Age 16 includes all fish 16 years and older. No observations were taken in 1998-2000, 2006 and 2008.

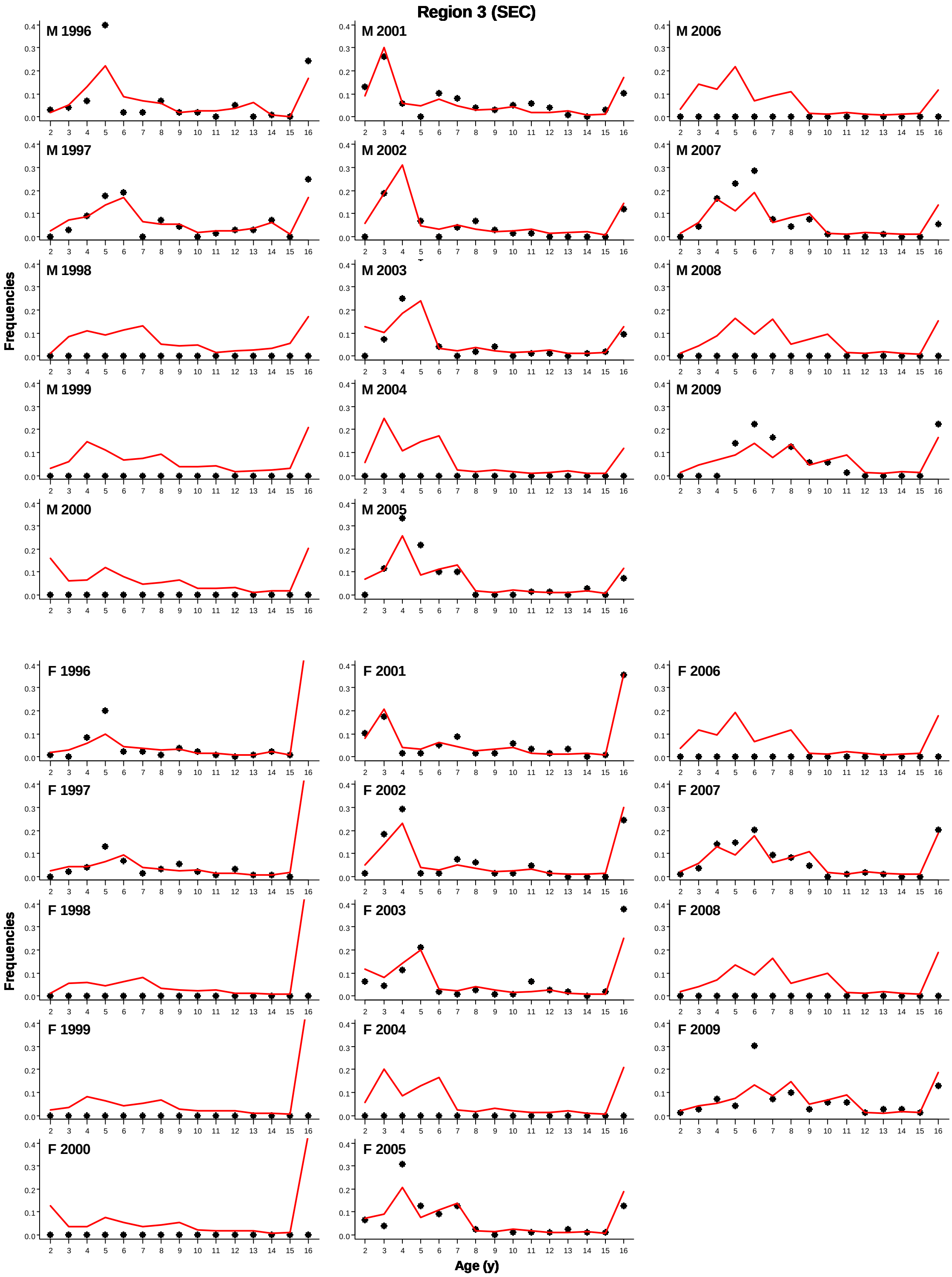

Fig. 3.19: Age composition in relative proportions of male and female banded morwong in assessment region 3 (SEC) since 1996. Observed data (black circles) and model fits for the base case scenario A3 with 75% onshore habitat area and a mobility rate of 0.25. Frequencies were limited to 0.4. Age 16 includes all fish 16 years and older. No observations were taken in 1998-2000, 2004, 2006 and 2008.

3.7.7 Model outputs

While the minor differences in model fits to the observed data helped little to select between the different model scenarios A1-A5 for the potential separation of stocks in fished onshore and unfished offshore populations, the scenarios produced variable estimates of mature biomass, recruitment, exploitable biomass and harvest rates (Figs. 3.20 to 3.22). In other words, the observed patterns of catch rates, sex ratios and age composition could be achieved with all tested combinations of onshore habitat and mobility rates through variable recruitment levels, resulting in different levels of biomass.

The scenarios A1-A4 for high habitat levels onshore and/or a high mobility rate provided similar estimates of total mature biomass. Estimates were all within the 90% confidence intervals of the base case scenario, which predicted the largest mature biomass levels. However, when a lower proportion of habitat onshore was combined with low mobility rates in scenario A5, estimates of mature biomass increased substantially. The lack of real data on the onshore and offshore populations was therefore highly influential on the predicted model outcomes.

In both regions, all scenarios predicted that total mature biomass has fallen since 1990 and largely stabilised after 1998. This pattern is a result of high catches in the mid 1990s, followed by a combination of lower catches, higher recruitment levels since 2000 and increased productivity of the populations due to higher growth rates and earlier maturity of young fish (Ziegler et al. 2007a).

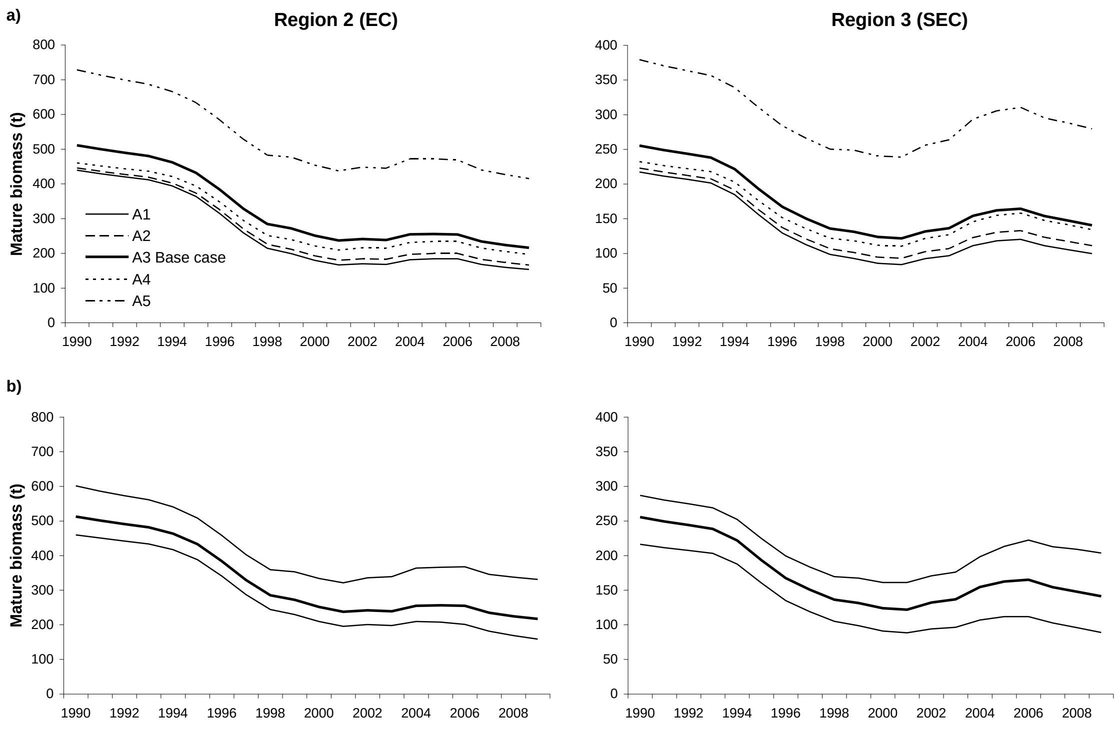

Fig. 3.20: Estimates of total mature biomass in models for region 2 (EC) and 3 (SEC) for (a) model scenarios A1-A5 with different levels of onshore habitat area and mobility rates; and (b) base case scenario A3 with 90% confidence intervals derived from bootstrapping of catch rates.

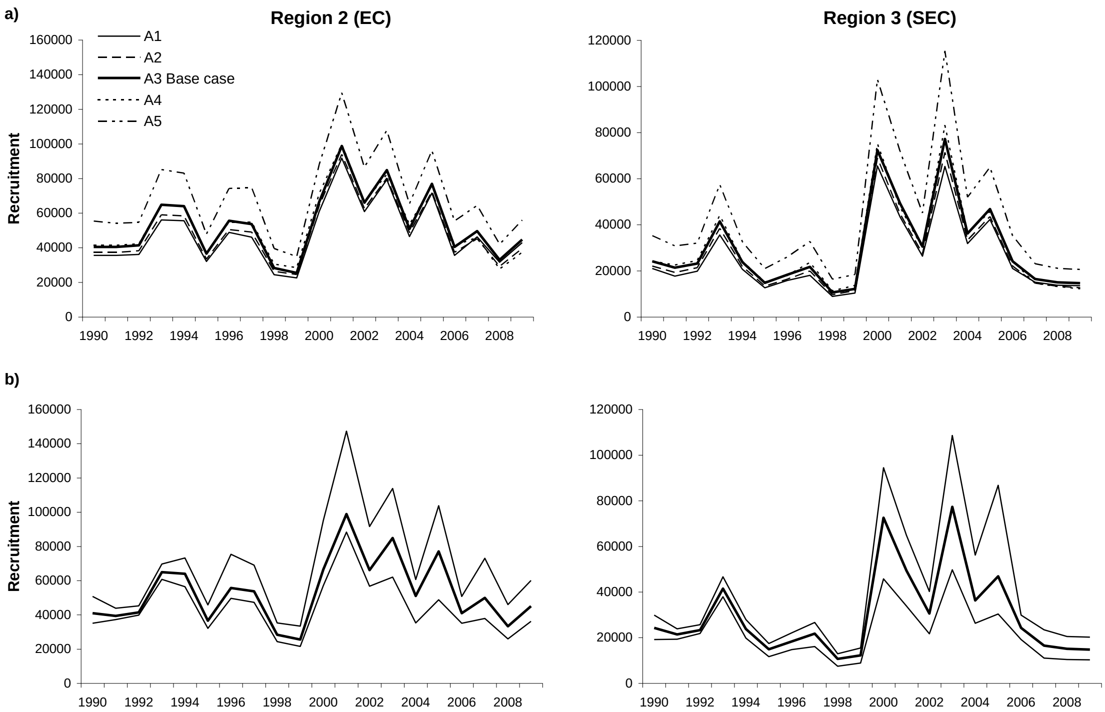

Fig. 3.21: Estimates of annual recruitment in models for region 2 (EC) and 3 (SEC) for (a) model scenarios A1-A5 with different levels of onshore habitat area and mobility rates; and (b) base case scenario A3 with 90% confidence intervals derived from bootstrapping of catch rates.

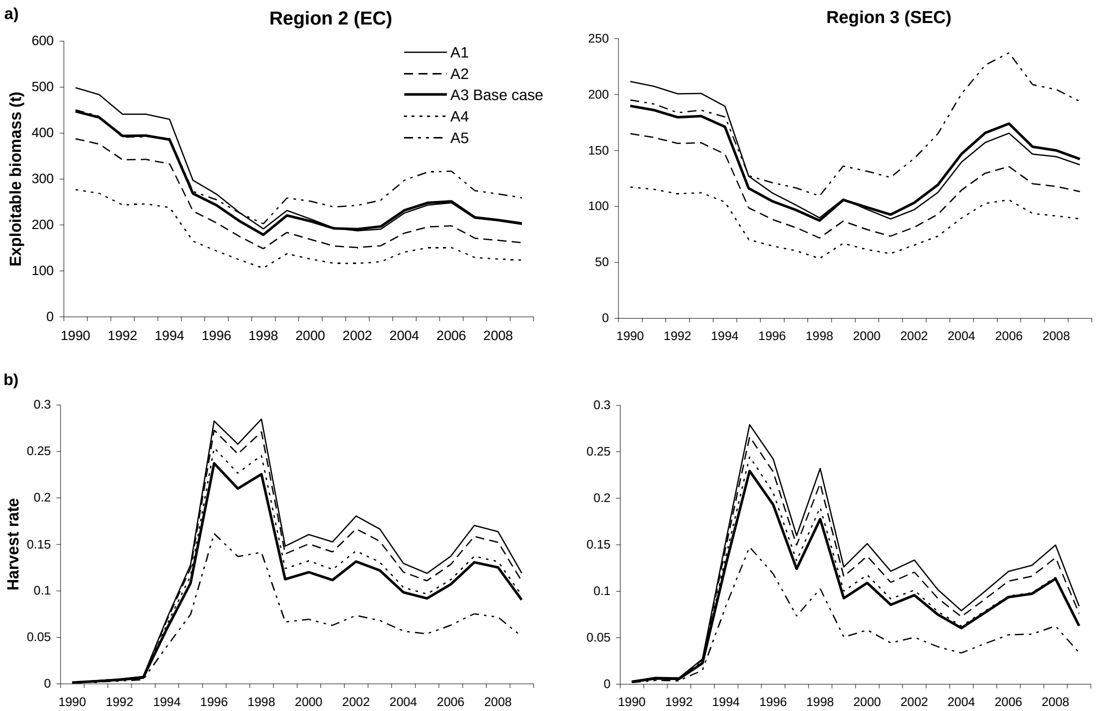

Fig. 3.22: Estimates of (a) exploitable biomass and (b) total harvest rate in models for region 2 (EC) and 3 (SEC) for model scenarios A1-A5 with different levels of onshore habitat area and mobility rates.

For the base case scenarios A3, the models estimated a decrease in mature biomass between 1990-2009 from 511 tonnes to 216 tonnes or 42% of the initial levels in region 2 (EC), and from 255 tonnes to 141 tonnes or 55% of the initial levels in region 3 (SEC). Relative mature biomass in 2009 compared to 1990 was similar for scenarios A1-A4 and varied between 35-43% in region 2 (EC) and 46-58% in region 3 (SEC). The much higher biomass levels in scenario A5 were estimated to have fallen to 57% and 74% of initial levels in region 2 (EC) and region 3 (SEC), respectively.

Exploitable biomass showed similar trends as mature biomass, although exploitable biomass in region 3 (SEC) strongly recovered from 2000 to 2006 (Fig. 3.22). Estimates for exploitable biomass in 2009 relative to 1990 for scenarios A1-A4 ranged around 40-45% in region 2 (EC) and 65-76% in region 3 (SEC).

Harvest rates (for the total fishing-induced mortality including seal-related mortality) peaked in the late 1990s (Fig. 3.22). In 2009, they were generally around or below 0.1 due to low catches. Nevertheless, the models estimated that harvest rates of most recent years in both regions had been higher that the reference points from spawning biomass-per-recruit analyses at which harvest rate reduces spawning biomass-per-recruit to 40% or 30% of the unfished level, i.e. $H_{40\%}$ = 0.07 or $H_{30\%}$ = 0.11 (Clark 1993, 2002, Mace and Sissenwine 1993, Mace 1994, Ziegler et al. 2006a).

Different total fishing-induced mortality in scenarios B1-B2 had little impact on the general trends for mature biomass and recruitment (Fig. 3.23). When assuming no seal-related fishing mortality in scenario B1, both mature biomass and recruitment levels were lower, but relative mature biomass in 2009 compared to 1990 remained almost unchanged at 43% in region 2 (+0.4%) and at 54% in region 3 (-1.2%). Altering the pattern of seal-related mortality with an increase from 30% to 50% after 2000 in scenario B2 increased estimates of mature biomass and recruitment. Changes to relative mature biomass in 2009 were somewhat larger, with +6.1% in region 2 (EC) and +4.8% in region 3 (SEC).

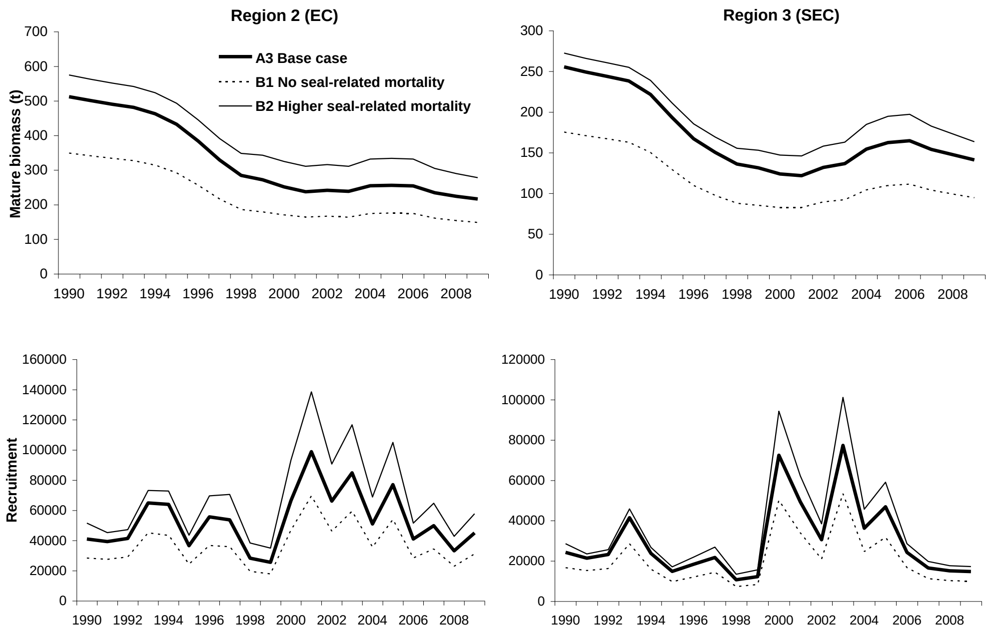

Fig. 3.23: Estimates of mature biomass and recruitment in models for region 2 (EC) and 3 (SEC) for the base case scenario A5 (bold line), scenario B1 with no seal-related mortality (dotted line) and scenario B2 with increased seal-related mortality after 2000 (thin line).

However, given the high uncertainty about the extent of seal-related mortality, the model estimates were surprisingly insensitive to even large changes in the scenarios B1 and B2 and model fits of both scenarios were comparable to the base case scenario A3 (Table 3.3). For relative mature biomass, changes in the pattern appeared to be more influential than simply increasing or decreasing the level of seal-related mortality. Nevertheless, seal-related mortality strongly impacts fishing operations resulting in lower catch and catch rates. In addition, fishers alter their fishing pattern when seals are affecting their operations or even cease fishing. Such changes have not been quantified and are therefore not included in the model.

3.7.8 Risk assessment

Although the model scenarios A1-A5 for a range of proportion of onshore habitat and mobility rates performed slightly differently in terms of negative log likelihood, they provided comparable model fits to the data and did not allow selecting the most plausible model scenario. For the risk analysis, the base case model was chosen as a relatively conservative model that followed closely empirical habitat and mobility estimates and did not assume a large (and unknown) population in the deeper unfished habitat.

In a risk assessment, the performance of different harvest strategies is interpreted relative to particular management objective(s) that have been selected for the fishery. Without explicit objectives relating to the development of banded morwong stocks or its fishery, the objectives used here was defined as to stabilise the current catch rates over a period of 5 years and maintain mature biomass of the fished stock above 40% of unfished levels ($B_{40\%}$).

In the scenarios examined here, reported catch was assumed to be constant over the projected period of 20 years, representing a form of unadjusted allowable catch, where the management control is not altered even when catch rates or effort change substantially. Different TAC levels, ranging from 0t, 10t, 20t, etc. to 60t, as well as the current TAC of 44.4 tonnes were compared. All other management options, including the minimum and maximum legal length limits, were kept constant at present levels.

The TAC was assumed to be taken in all years. The catch was only reduced (so that the harvest rate would not exceed 0.95) when the exploitable biomass was insufficient to support the catch target. Given a total projected TAC, the actual catch taken from a region was assumed to be stable and followed the average catch proportions between 2005-2009, which have remained fairly stable over recent years at around 52% and 28% of the total catch in region 2 (EC) and region 3 (EC), respectively. The remaining 20% were caught in region 1 (NEC) which was not assessed.

The TAC levels referred to the reported catch, but it was assumed that total-induced fishing mortality was higher due to seal-related mortality and cauf mortality. Seal-related mortality was considered to remain similar to that in last year of the historical period and was represented by a bias factor 1.43 (equivalent to 30% seal-related mortality) with random variation $\sigma = 0.05$. Cauf mortality refers to mortality of fish in caufs where they are kept alive after catching and reporting. Therefore, catches tend to be underreported and catch levels were multiplied with a bias factor 1.1 with random variation $\sigma = 0.1$.

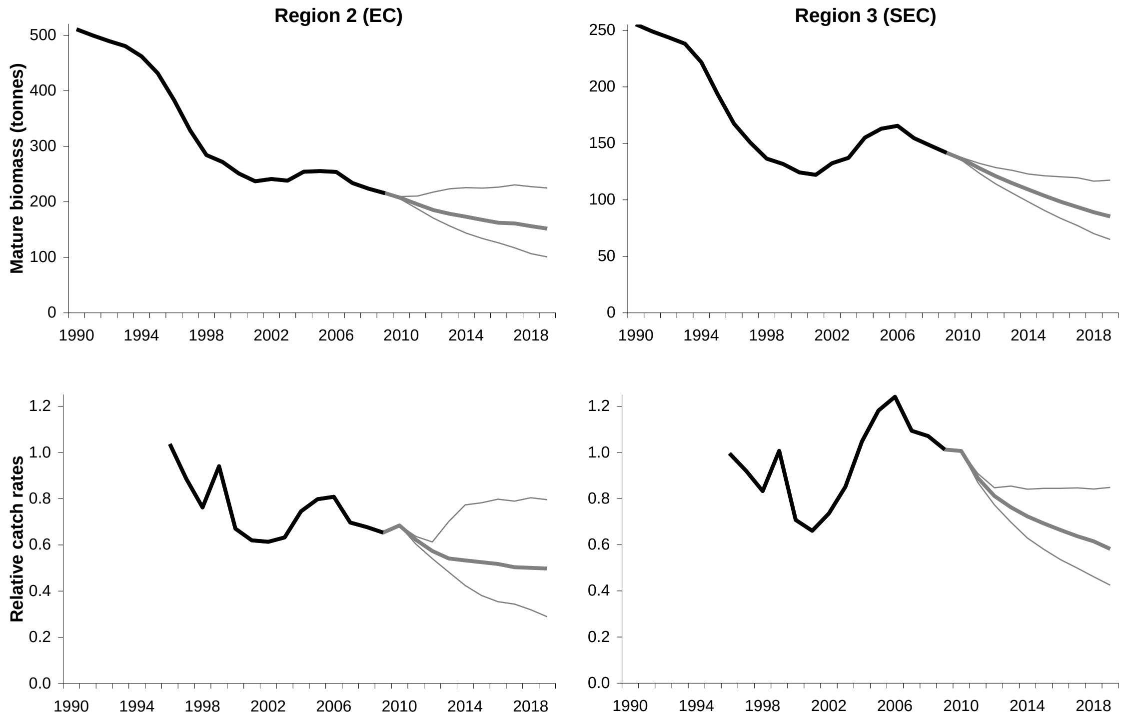

Fig. 3.24: Estimates of mature biomass (top) and relative catch rates (bottom) for historical period (black line) and projected 10-year period with the current TAC (grey lines) in region 2 (EC) and 3 (SEC) for the base case model scenario A3. The current TAC of 44.4 tonnes is equivalent to 23.1 tonnes in region 2 (EC) and 12.4 tonnes in region 3 (SEC). The projections show the median (heavy grey line) and 90% confidence intervals (thin grey lines) based on 200 simulations.

The two regions were treated independently assuming that the fleet dynamics remained the same for the whole period of the projection. Expected recruitment variation in the future was based on the fitted average recruitment and recruitment variation since 1990 in each region.

Under the current TAC of 44.4 tonnes, mature biomass and catch rates have a 90-100% probability to fall over the next 10 years (Fig. 3.24). This decline is slightly less marked in region 2 (EC), and catch rates appear to stabilise at lower levels after 5 years in region 2 (EC).

The effects on mature biomass and catch rates gradually increased with increasing catch (Figs. 3.25 and 3.26). Up to a total TAC of 20 tonnes, the model predicted that the mature biomass has a 50% or higher chance to remain stable. Catch rates were likely to increase in region 2 (EC), but had a high probability to decrease even with such a low TAC.

A TAC of 30 tonnes and higher resulted in a continuously decreasing mature biomass and catch rates and had only a very small chance of sustaining current levels within 5 years time. For the current TAC of 44.4 tonnes, the model predicted an over 90% chance of mature biomass and catch rate to decline in both regions.

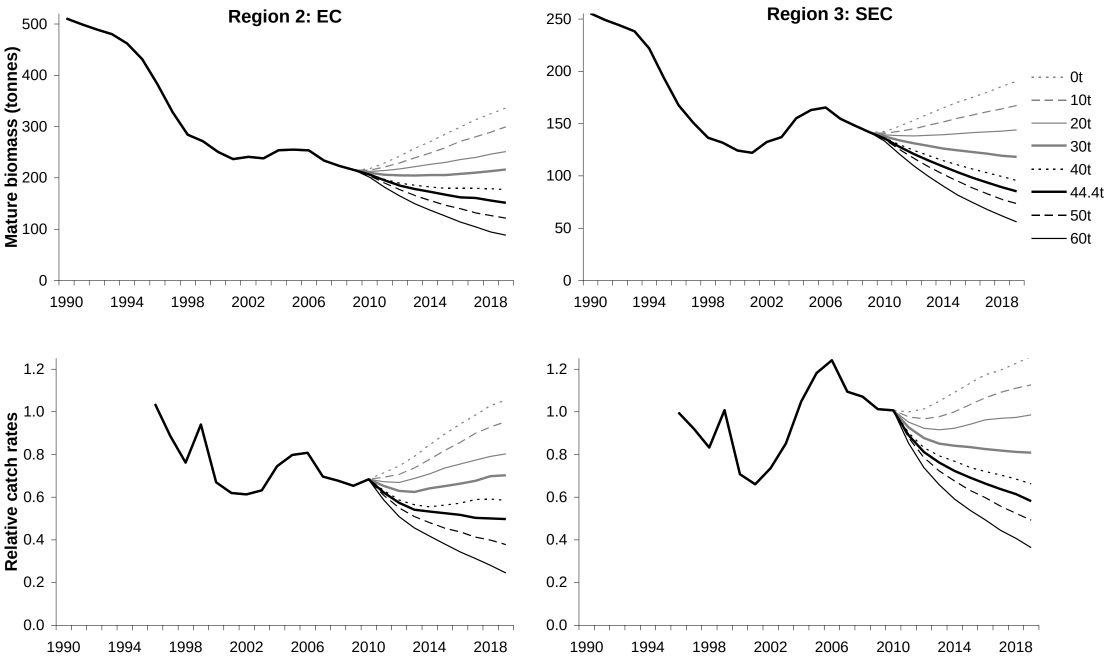

Fig. 3.25: Median estimates of mature biomass (top) and relative catch rates (bottom) for historical period and projected 10-year period under different TACs in region 2 (EC) and 3 (SEC) for the base case model scenario A3 based on 200 simulations. The examined TACs range from 0 tonnes to 60 tonnes (including the current TAC of 44.4 tonnes, heavy black line), of which 52% and 28% are attributed to region 2 (EC) and region 3 (SEC), respectively. Note that the median is not a precautionary level since it only represent a 50% chance that mature biomass or catch rates are above (or below) this level.

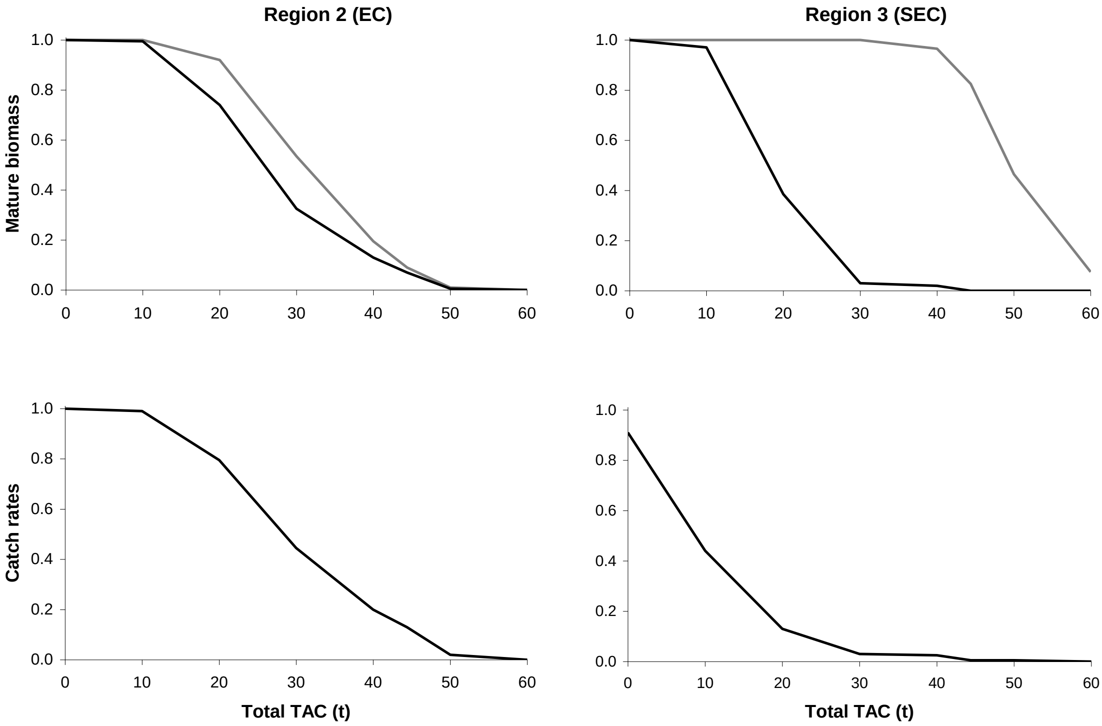

Fig. 3.26: Probabilities of mature biomass (top) and catch rates (bottom) being higher in 2014 than levels in 2009 (black lines) or higher than 40% of unfished levels (grey lines, mature biomass only) in region 2 (EC) and 3 (SEC) for the base case model scenario A3 based on 200 simulations.

For a constant removal of 60 tonnes, mature biomass and catch rates dropped to very low levels within 5 years in both regions and did not recover during the remaining period. In reality, this is unlikely to occur since the fishery would become economically unsustainable, due to the enormous effort required to achieve the catch, well before such low biomass levels were reached. But the scenario demonstrated that the stocks were unlikely to tolerate such high catches over a prolonged period.

Because relative mature biomass in 2009 was estimated 42% in region 2, the probability of mature biomass to fall below a target measure of 40% was similar to that of being higher than the current 2009 levels (Fig. 3.26). In region 3, relative mature biomass was estimated much higher at 55%, and therefore, the stocks in this region were predicted to sustain much higher catches and still remain over a target of 40% within 5 years. Nevertheless, for all TAC levels above around 20 tonnes, relative mature biomass is expected to rapidly decrease and fall below a target level of 40% in the long-term even in region 3. In other words, even though fish stocks in this region may currently not be overfished, overfishing is likely to be occurring with the current TAC of 44.4 tonnes.

3.8 Reference points

Existing reference points	Exceeded?	Alternative RP	Exceeded?
State-wide or regional catches outside the 1994/95 to 1997/98 range (73t-106t)	Yes: ↓ Statewide ↓ Region 1 (NEC) ↓ Region 2 (EC) ↓ Region 3 (SEC)	Commercial catch in Region 1 > 30% of TAC Region 2 > 65% of TAC Region 3 > 40% of TAC Regions 4 or 5 > 10t	No
Catch increase or decline by over 30% from previous year	Yes: Region 2 (-35%) Region 3 (-42%)	Commercial catch is less than 90% of TAC	Not assessed
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	Yes: Region 1 (NEC) Region 2 (EC)	Catch rates are below 0.9 * average from reference period 2000/01 to 2006/07	No
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Yes: Significant changes of age/size composition, acceleration of growth & earlier maturity (see Ziegler et al. 2008)	Any indicator of stock stress	Yes: Significant changes of age/size composition, acceleration of growth & earlier maturity (see Ziegler et al. 2008)

3.9 Implications for management

The combination of estimates for mature and exploitable biomass and harvest rates indicates that banded morwong stocks in both regions are currently not overfished. The fishery with larger catches in the 1990s has reduced stock biomass, but substantial recruitment pulses in the mid 2000s have managed to stabilise mature and exploitable biomass at lower levels. Overall, the model estimated a decrease in mature biomass between 1990 and 2009 in region 2 (EC) from around 511 tonnes to 216 tonnes or 42% of the initial levels, and in region 3 (SEC) from around 255 tonnes to 141 tonnes or 55% of the initial levels.

Nevertheless, the structure of the fished population has changed substantially in both regions. Recent stock rebuilding in the southern stocks was based on strong recruitment pulses in the 2000s coupled with higher productivity through increased growth rates and earlier maturity (Ziegler et al. 2007a). As a result, the fishery in both regions is now largely recruitment-driven with only a small proportion of the catch made up by older females. With continually high harvest rates above the internationally recognised reference points for mature biomass of $H_{40\%}$ or $H_{30\%}$ in recent years, the fishery mainly removes and depends on newly-recruited fish from the populations at a potentially unsustainable rate. While a number of year classes contribute to the fishery, even a relatively short period of low recruitment could lead to substantial declines in catch rates and mature biomass.

The higher dependence on new recruitment in both regions was reflected in the risk assessment. For the current TAC of 44.4 tonnes or more, the model predicted a close to 100% probability that mature biomass and catch rate will decline. Only with a TAC reduction to around 20 tonnes, the model predicted that the probability for sustained mature biomass and catch rates over a 5-year period would increase to above 50%.

Therefore, the TAC should be lowered to reduce the risks of overfishing. However, there is considerable uncertainty in the assessment about the basic population dynamics of banded morwong, mainly in regards to the potential separation of stocks in fished onshore and unfished offshore populations. In addition, the species' productivity appears to be able to respond strongly and quickly to stock biomass changes. These are important issues that need to be taken into consideration in and future management action.

3.10 Research needs

The Scalefish Fishery Research Advisory Group has accorded stock assessment of banded morwong a high priority. Biennial spawning season surveys and stock assessments should continue into 2011 and are expected to provide further insights into the impact of fishing on the size, age and sex structure. However, while sampling needs to be focussed regionally to account for the level of spatial structuring in the fish populations (at the reef level), this degree of sampling intensity is difficult to achieve and justify in a fishery of this size.

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

4 Southern calamari (*Sepioteuthis australis*)

4.1 Life-history and stock structure

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

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

Spawning (cont.)	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. Female calamari have multiple mates with up to 85% of individual egg capsules from the one female sired by multiple fathers. Mating occurs either in temporary pairs with a large dominant male that guards the female, or in extra-pair copulations with a 'sneaker male'. Genetic studies demonstrated that both small and large males sire similar proportions of offspring.	Jantzen and Havenhand 2002 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. Development takes 4-8 weeks, depending on water temperature, bringing the total life span close to annual.	Moltschaniwskyj *et al.* 2003 Steer *et al.* 2002
Early life history	Newly hatched calamari are 2.4-7 mm ML and immediately swim to the surface following hatching. Hatchlings can be found near the spawning grounds for 20-30 days. The habitat and ecology of individuals between about 20-80 days of age is unknown, however at 80-150 days, juveniles have been found in deeper water adjacent to the spawning grounds. Individuals become available to the fishery at approximately 90-120 days of age.	Steer *et al.* 2002 Pecl 2000 Pecl 2004
Recruitment	Highly variable	This report

4.2 The fishery

The fishery for southern calamari in Tasmania expanded rapidly during the latter half of the 1990s, with annual catches rising from less than about 20 tonnes prior to 1995/96 to about 90 tonnes in 1998/99. Since then, catches have fluctuated at high levels. The expansion of the fishery was accompanied by a massive increase in effort, particularly squid jig, which has become the primary capture method in recent years. Calamari are also taken by a variety of other methods including purse seine, beach seine, spear and dipnet. Although some night fishing occurs, calamari are mainly targeted during the day over shallow areas of seagrass and macro-algae where they aggregate to spawn.

4.3 Management background

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

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

In 2005, the closed area was expanded to include all waters between Wineglass Bay and the northern end of Marion Bay and the closure period lasted from mid-September to mid-December. The closure also included recreational fishers, thereby providing effective protection to the spawning stock during the peak of the spawning season. A similar closure was implemented in 2006, and shortened by two weeks in 2007.

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

The fishery was divided into a "developed" region in the south-east and an "undeveloped" region for the rest of Tasmania in October 2008. For the developed region, a specific calamari licence was introduced, with 17 operators qualifying for this licence. Under the new management arrangements the seasonal closure was reduced to one month, from mid October to mid November, for the 2009/10 season.

Following the review of the management plan in 2009 further changes were made to the recreational and commercial rock lobster catch limits for the south-east region. A recreational on-water possession limit of 10 was introduced and commercial rock lobster fishers' take and possession limit was reduced from 15 to 10. These changes were introduced in recognition of the development of the fishery and are commensurate with the changes made to the commercial scalefish sector.

4.4 Management objectives and strategies

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

The species is currently managed by a combination of a specific calamari licence for the developed region of the fishery in the east and southeast (between Lemon Rock and Whale Head), a spawning season closure for commercial and recreational fishers in all waters between Lemon Rock and the northern end of Marion Bay from the start of October to mid-December (to be shortened to one month in 2009/10), a combined possession limit of 30 calamari and arrow squid for all holders of scalefish C licences (excluding those also holding beach seine or purse seine licences), and a possession limit of 15 fish limits on recreational catch.

4.5 Relative vulnerability to fishing

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

4.6 Previous assessments

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

4.7 Current assessment

Extended fishery closures have had large impacts on monthly catches in Great Oyster Bay and Mercury Passage each year since 2003 (Fig. 4.1). Fishing activity has effectively shifted from an August - December focus (1998/99 - 2002/03) to being more heavily concentrated into the single month of December (2003/04 - present).

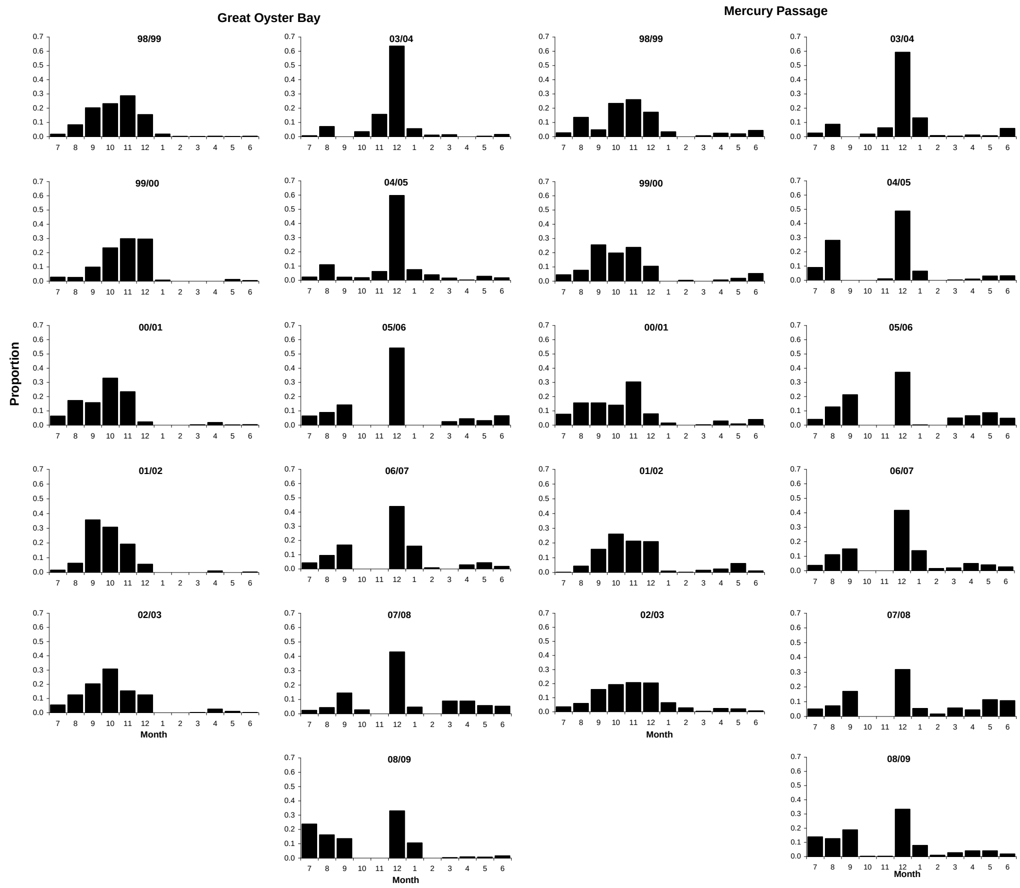

Fig. 4.1. Monthly catch distribution (as proportion of the total catch within the fishing year) for Great Oyster Bay (ES13 and ES14) and Mercury Passage (ES16).

4.7.1 Catch, effort and catch rates

Since 1998/99, a significant fishery for southern calamari has developed in Tasmania, with annual catches expanding rapidly from less than about 30 tonnes prior to 1998/99 to over 100 tonnes (Fig. 4.2A). The expansion of the fishery was almost exclusively due to increased squid jig catches. Catches have fluctuated at high levels since, with the 2008/09 catches of 79 tonnes being 10 tonnes lower compared to the previous year. The two estimates of the recreational calamari catches (18 tonnes in 2000/01 and 45 tonnes in 2007/08) indicate that this sector also contributes significantly to the overall fishing pressure on the species.

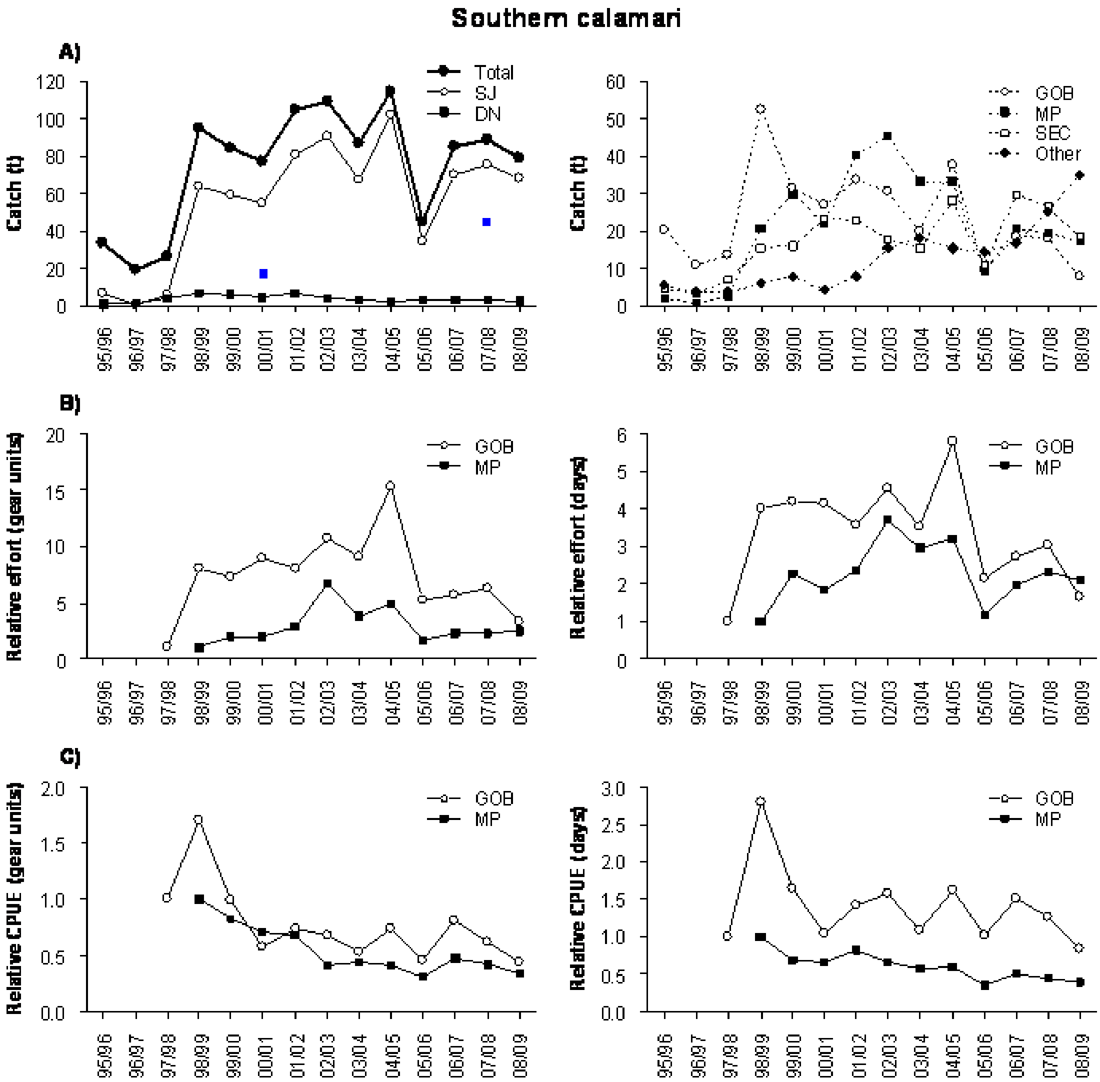

Fig. 4.2. A) Annual commercial catch (tonnes) of calamari by method (left) and by region (right) since 1995/96 reported in Tasmanian logbooks, and best estimates of recreational catches (single squares); B) commercial squid jig effort based on gear units (left) and days fished (right) relative to 1998/99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

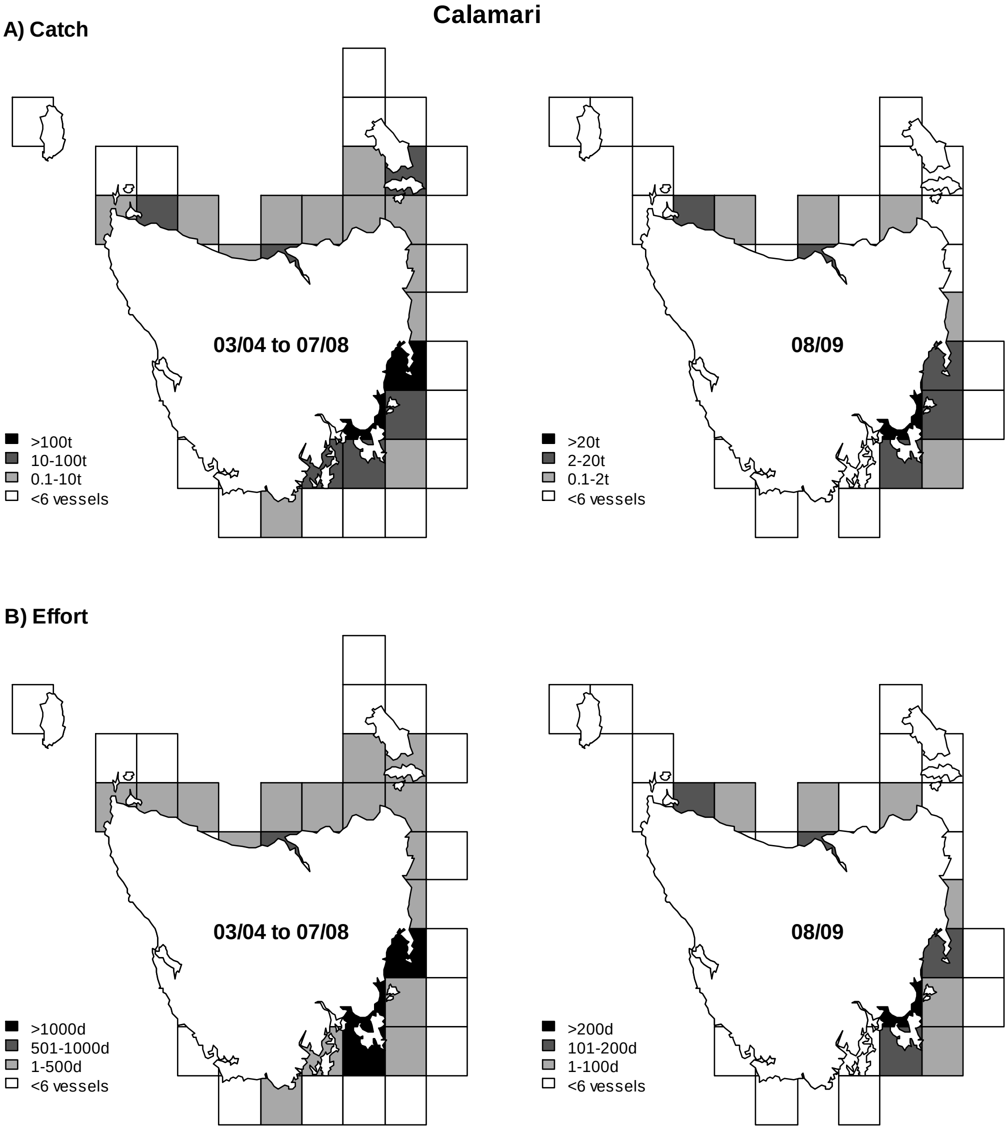

Fig. 4.3. (A) Calamari catches (tonnes) and (B) effort (days) by fishing block pooled from 2003/04 to 2007/08 (left) and during 2008/09 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

The fishery developed initially in the mid-1990s in Great Oyster Bay and then expanded to the south to include Mercury Passage, Maria Island and Tasman Peninsula (Fig. 4.2B). While the main fishery is concentrated off the central east and south-east coasts, catches are now reported from all areas apart from the west coast (Fig. 4.3). The 3-month spawning season closure, introduced in 2004/05 for Great Oyster Bay and Mercury Passage and subsequently extended over a larger area, appears to have been successful in reducing pressure on these main spawning grounds as well as encouraging industry to spread the effort into the wider south-east region and the central east coast. Over recent years, moderate catches of calamari have also been taken from Flinders Island, around the Tamar, and increasingly around Stanley.

The regional distribution of the fishery in terms of effort is, not surprisingly, consistent with the pattern observed for catches (Fig. 4.3). Effort is focussed on Great Oyster Bay, Mercury Passage, the south-east, and Tamar and Stanley in the north. Jig effort in 2008/09 remained low in Great Oyster Bay and Mercury Passage after the sharp fall in the 2005/06, largely influenced by 3-month seasonal closure (Fig. 4.2B).

Catch rates (gear and daily) for jigs were lower in 2008/09 compared with 2007/08 (Fig. 4.2C). In the context of catch and effort, these data imply that the lower catches for calamari in Great Oyster Bay during 2008/09 was in response to generally poorer catch rates outside the period of the seasonal closure.

4.7.2 Reference points

Existing reference points	**Exceeded?**	**Alternative RP**	**Exceeded?**
State-wide or regional catches outside the 1990/91 to 1997/98 range (6t-33t)	Yes: Statewide ↑ (79t)	Commercial catch in: GOB & MP > 50t Remainder SE > 30t Outside GOB, MP & SE > 25t	 No No Yes (35t)
Catch increase or decline by over 30% from previous year	Yes: GOB (-56%)	Declining catch trend over 3 consecutive years by a total of > 40% in south-east Tasmanian waters	No
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	Yes	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	No	-	
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	No	Any indicator of stock stress	No

4.8 Management implications

The alternative reference points for calamari should finally overcome the shortfalls of the existing reference ranges for catch and effort. The existing ranges derived from a period well before the fishery developed and thus compared the fishery between an under-developed (pre-1998/99) and developed state. As a result, catch and effort indicators have been continuously triggered in the past. In contrast, the alternative reference limits relate to a more recent status of the fishery and were not triggered by the catch levels in south-eastern waters.

Species-specific fishing licences for south-eastern waters were introduced in October 2008 in response to continued high interest in calamari in recent years and substantial capacity within the Tasmanian scalefish industry to further increase effort levels. These licences provide 17 fishers access to the region and are expected to limit effort concentration particularly in the major spawning grounds of Great Oyster Bay and Mercury Passage.

Previously, effort on these spawning grounds was controlled exclusively by spawning season closures that were first introduced in 1999 and subsequently extended to three months. These protracted closures represent a rather crude approach to limiting catches and have significantly impacted on the economic viability of the fishery.

Nevertheless, the closures appeared to have been effective in protecting the main known spawning event and ensuring relatively high egg production. Based on cumulative egg production (Ziegler et al. 2007b), closures that encompass the September to November (or early December) period are likely to provide effective protection to the bulk of the spring spawning event in most years. Moreover, since calamari have a life span of generally less than one year, intense fishing pressure immediately after the fishery is opened will often have a limited impact on subsequent recruitment, since most calamari caught would have already spawned and would die naturally within in a short period of time.

As the spawning dynamics and egg production are better understood, future egg surveys could be used in a real-time monitoring to determine appropriate starting times and duration of spawning closures. However, the link between egg production and subsequent recruitment to the fishery is poorly understood. Since growth, reproductive characteristics and survival of individual calamari appear to differ substantially depending upon the timing of hatching and subsequent environmental conditions, environmental factors may ultimately prove as important as egg production and fishing mortality in driving the population structure and dynamics.

Stable isotope analyses of calamari statoliths indicated that most adult calamari caught on the east and south-east coasts are probably spawned in Great Oyster Bay (Ziegler et al. 2007b). These findings highlight the significance of Great Oyster Bay as a source for calamari recruits throughout eastern and south-eastern Tasmania, and reinforce the value and effectiveness of management arrangements that involve the closure of this region during the main spawning period.

Areas in south-eastern waters such as the D'Entrecasteaux Channel, Norfolk and Frederick Henry Bay and Great Oyster Bay are also recognised recreational hotspots. Interest in the species from this sector has remained high and fishing effort directed at the species has increased over the past decade.

In contrast to south-eastern waters, commercial catches outside in the 'undeveloped' regions triggered the alternative reference points. Moderate Catches have been taken from around the Tamar and Flinders Island for some years, but catches increased sharply in a relatively small area around Stanley. Further developments in this area should be therefore 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 calamari populations as high priority research areas.

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

5 Striped trumpeter (*Latris lineata*)

5.1 Life-history and stock structure

Parameter	Estimates	Source
Habitat	Mainly on the continental shelf over rocky bottom to depths of about 300 m, with juveniles associated with shallow inshore reefs.	
Distribution	Distributed throughout southern Australia, from Sydney around to Kangaroo Island in South Australia and including Tasmania. The species is also found in New Zealand, the St. Paul and Amsterdam Islands in the southern Indian Ocean, and the Tristan da Cunha Group and Gough Island in the southern Atlantic Ocean.	Gomon *et al*. 1994
Movement and Stock structure	Uniform stock structure in Tasmanian waters (no significant genetic separation of populations).	Tracey et al 2007b
	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 fork length (FL).	Lyle and Jordan 1999 Tracey and Lyle 2005
	In 2001, a striped trumpeter tagged off the Tasman Peninsula in 1996 was recaptured off St. Paul Island in the Indian Ocean indicating a capacity to undergo wide-scale movements.	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	Gomon *et al*. 1994
	Rapid growth of juveniles, reaching a mean length of around 28 cm FL after two years and 42 cm FL 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 FL.	Murphy and Lyle 1999 Tracey and Lyle 2005
Maturity	Females reach maturity at a smaller size and age (44 cm FL and 5 years) than males (53 cm FL and 8 years).	Hutchinson 1994
	However, more recent data suggest that size at 50% maturity in females is somewhat larger, around 54 cm FL (6.8 years), with male attaining 50% maturity at 53 cm FL (6.2 years).	Tracey *et al*. 2007a
Spawning	Spawning occurs from July to early October, depending on geographical location, with earlier start and finish at lower latitudes.	Ruwald et al. 1991
	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 1992 Hutchinson 1993
Early life history	Larval rearing trials indicate a complex and extended larval phase, with a post-larval 'paperfish' stage of up to nine months prior to settlement.	Ruwald et al. 1991
	The distribution of larvae and recruitment processes have not been studied.	Ruwald 1992
	While no information is available on the size and timing of settlement, juveniles of around 18 cm FL have been caught on shallow reefs off the south-east coast in January.	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.	Murphy and Lyle 1999
	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).	Tracey and Lyle 2005
	Otolith microchemistry supports the hypothesis that inshore reefs represent an important juvenile habitat, with the bulk of the offshore adult population derived that individuals that spent their juvenile phase inshore.	Tracey, unpubl. data

5.2 The fishery

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

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

5.3 Management background

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

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

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

The legal minimum size limit for striped trumpeter was raised from 35 to 45 cm total length (TL, equivalent to about 42 cm FL) in November 2004 in recognition that the smaller size limit was substantially below the size at maturity (54 cm FL for females and 53 cm FL for males). The recreational bag limit was also dropped and replaced by the possession limit of eight fish.

Taking effect in November 2009, the minimum size limit was increased to 50 cm TL and a recreational ‘on water’ possession (bag) limit of four striped trumpeter were introduced. Furthermore, a two month spawning closure (September-October) was implemented for the first time in 2009.

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 (45 cm total length) and recreational possession limit of eight fish (for 2009/10 minimum size is 50 cm total length, the recreational bag limit is four fish there is a season spawning closure during September-October.

5.5 Relative vulnerability to fishing

The spawning potential of striped trumpeter is severely impacted by the current legal size limits that are still well below the size of maturity. Juveniles are also particularly vulnerable to inshore gillnetting and, although the recent size limit increase will offer increased protection of juvenile fish, it is possible that incidental capture of sub-legal striped trumpeter in gillnets may result in 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 mature adult stock.

5.6 Previous assessments

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

5.7 Current assessment

The current assessment examines trends in catch, effort and catch rate for the primary fishing methods, namely dropline, handline and graball net and includes data from the Commonwealth. Opportunistic catch sampling was undertaken since the late 1990s to provide age composition information.

Data presented in this assessment have been evaluated against the reference levels of performance indicators specified in the scalefish management plan (see Section 1.3).

5.7.1 Catch, effort and catch rates

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

1999/00 when over 14 tonnes was taken, reported Commonwealth catches have been relatively low since that time.

Annual production was high at over 110 tonnes in the early 1990s with Victorian vessels taking between 17-39% of the reported catch, but then fluctuated generally between 70-80 tonnes through the 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. This trend was observed by all methods in Tasmania (Fig. 5.1A). The reported catch of 13 tonnes for 2008/09 was again lower that in the previous year and represented the lowest catch reported since the mid 1980s.

However, Commonwealth catches are believed to be substantially underreported and the lack of precise estimates of recreational catches represent a major source of uncertainty in estimating the total mortality. Striped trumpeter have been heavily targeted by the recreational fishery in the past, with an estimated 38 tonnes harvested in 2000/01 (Lyle 2005). Estimates of recreational catches in 2007/08 were highly uncertain but likely to be lower, with an estimated 19 tonnes for combined catches of striped and bastard trumpeter (Lyle et al. 2009). These estimates do not fully represent catches by charter boats.

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

	Catch (tonnes)			
Year	Tasmanian	Victoria	Commonwealth	Combined
1990/91	74.5	37.1		111.6
1991/92	58.2	36.8		95.0
1992/93	52.7	19.8		72.5
1993/94	56.5	16.0		72.5
1994/95	72.4	14.6		87.0
1995/96	60.3			60.3
1996/97	79.7		0.7	80.4
1997/98	75.4		5.7	81.1
1998/99	98.4		8.9	107.4
1999/00	86.3		14.5	101.8
2000/01	41.2		7.5	49.6
2001/02	40.0		4.8	44.8
2002/03	36.8		3.2	40.0
2003/04	36.8		3.7	40.5
2004/05	24.0		2.2	26.2
2005/06	19.1		4.7	23.8
2006/07	18.8		3.5	22.3
2007/08	13.1		3.0	16.1
2008/09	10.5		2.8	13.3

Apart from the north coast, striped trumpeter catches have been reported from all areas around the state, particularly off the south-east and east coasts (Figs. 5.1A and 5.2). The expansion of the fishery during the late 1990s was the result of increased catches from all these areas. Catches strongly declined by 2000/01 and appear to have contracted to the south-east coast over recent years. This area has now also seen a decline to levels observed in other regions.

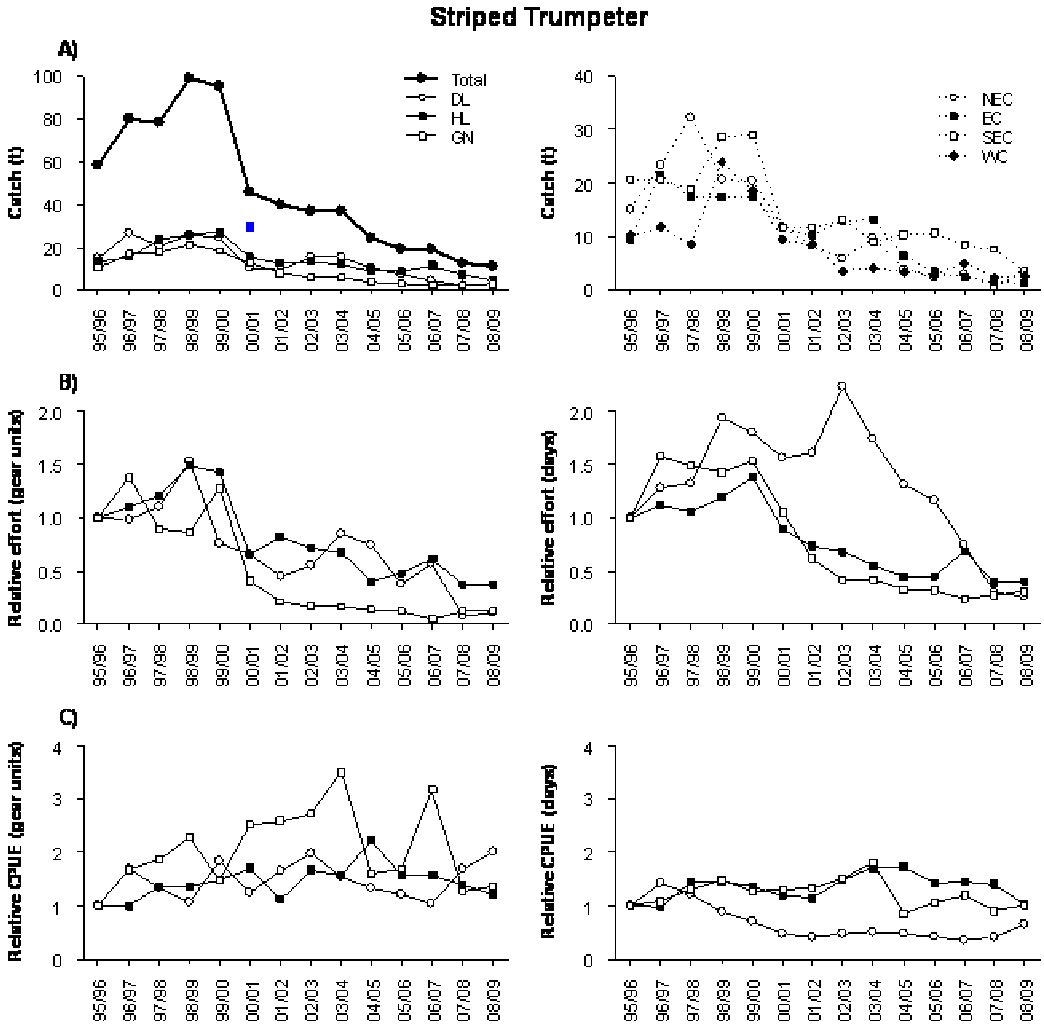

Fig. 5.1. A) Annual commercial catch (tonnes) of striped trumpeter by method (left) and region (right) since 1995/96 reported in Tasmanian logbooks, and best estimates of recreational catches (single squares); B) commercial effort by method based on gear units (left) and by days fished (right) relative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

The observed catch trends mainly reflect the influence of especially strong year classes (1993 and 1994) that entered the fishery between 1995/96 and 1997/98 (see also Section 5.7.2). Larger graball catches in 1998/99 followed by a decline suggest that the 1996 year-class, which would have recruited to the inshore gillnet fishery in 1998/99, was also relatively strong. The subsequent decline in graball catches presumably reflects the movement of the relatively strong year-classes offshore but also suggests that there has been limited recruitment in recent years. Industry representatives also suggest that the trip limit of 250 kg introduced in 2000 has represented a strong disincentive for some operators to fish for the species and may have contributed to the fall in dropline and handline catches since 2000/01.

Fishing effort increased during the latter part of the 1990s, presumably linked to the increased availability of striped trumpeter (Fig. 5.1B). Subsequently, effort for graball and handline declined. Dropline effort has fallen in recent years and continued the trend of more deployed gear on fewer fishing days in 2008/09. Fishing effort focussed mainly on the south-east coast and to a lesser extent off the north-east, south and south-west during the past few years (Fig. 5.2B).

Recent gear-specific trends of catch rates in 2008/09 were based on small catches and are thus unlikely to be informative about availability (Fig. 5.1C). Graball catch rates increased steadily up until 2003/04, despite declining catches during the latter half of the period. The sharp fall in graball catch rates since 2004/05 may have been influenced in part at least by the minimum size limit increase that took effect during 2004. Handline catch rates increased slightly through time but trended downwards in recent years, while dropline catch rates, based on catch per hook-lift and days fished, have increased over the past two years.

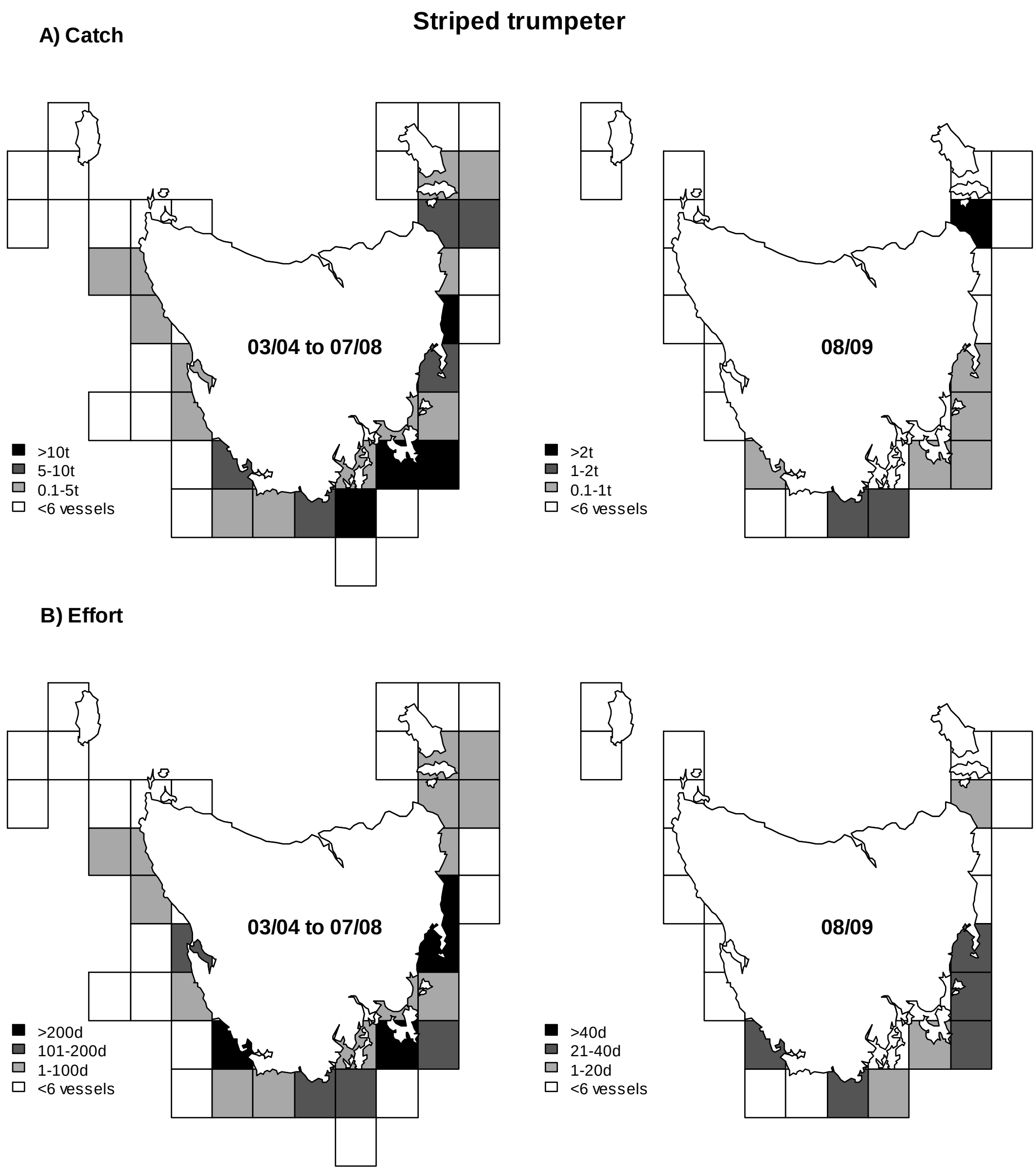

Fig. 5.2. (A) Striped trumpeter catches (tonnes) and (B) effort (days) by fishing block pooled from 2003/04 to 2007/08 (left) and during 2008/09 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

5.7.2. Age composition

The 1993 year class has been prominent in age composition samples obtained from research fishing and commercial catches undertaken since 1999 (5 year olds in 1999, 6 year olds in 2000 etc.; Fig. 5.3). Since sample sizes for most years were low and based on opportunistic sampling, age samples may not fully represent the population age structure. However, it is significant that this cohort, as 13 year olds, was the dominant age class in the 2007 sample with little evidence of strong recruitment in subsequent years. The age structures for 2008 and 2009 were relatively flat between ages 4 (recruitment to the offshore fishery) and 16 years, again providing no clear indication that there had been any strong year classes over the past decade. The fact that 13 and 14 year olds in 2009 (due to aging errors, these animals could be part of 1993 year class) were more common in the sample than most other ages including young fish is an indicator that recruitment in most recent years has remained low. With poor recruitment, adult biomass is expected to continue to decline and the average size of fish will continue to increase in the short-term, at least until such time as there is a period of sustained good recruitment.

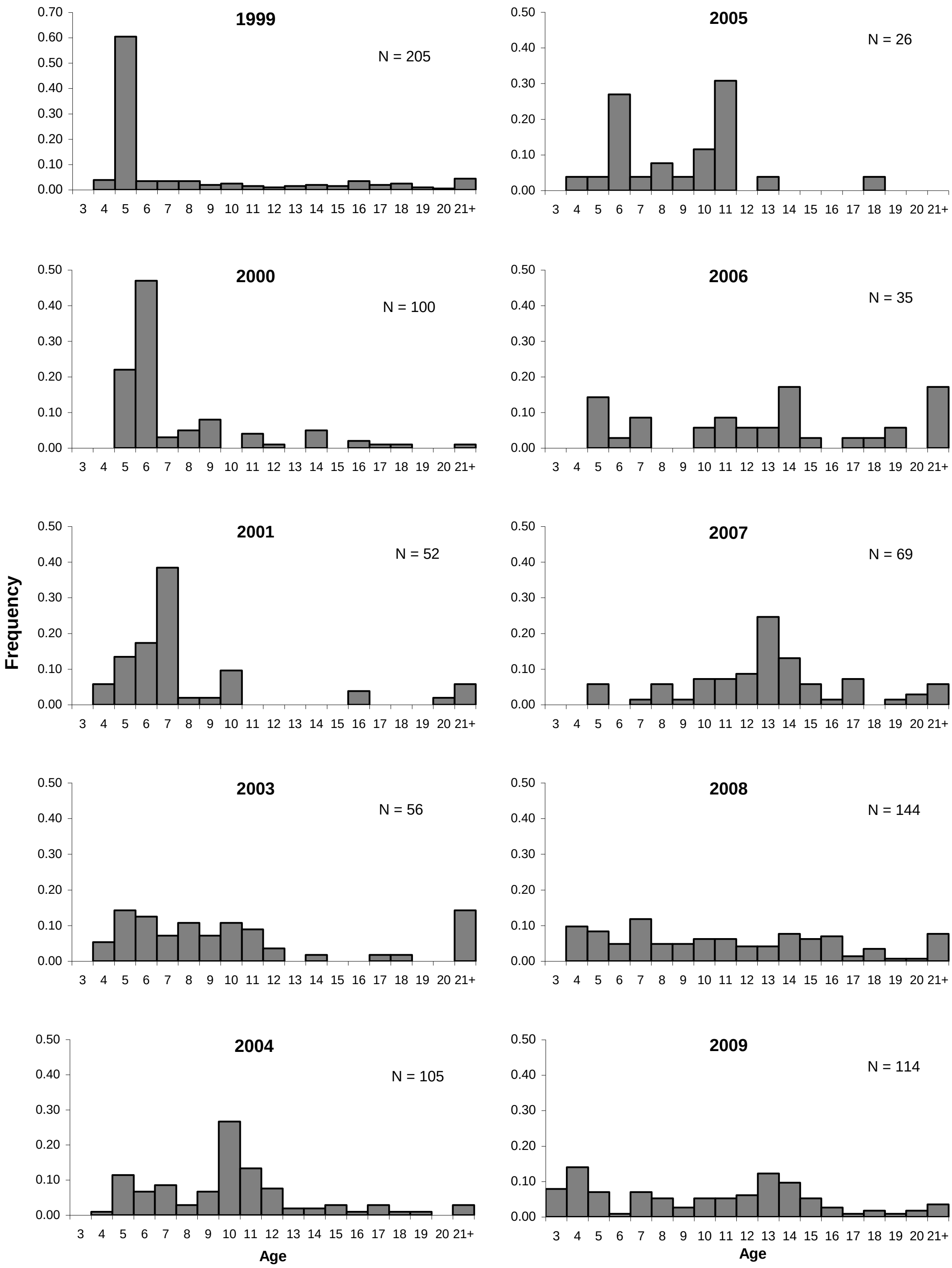

Fig. 5.3. Age composition of striped trumpeter samples by year. N is sample size.

5.7.3 Reference points

Existing reference points	Exceeded?	Alternative RP	Exceeded?
State-wide or regional catches outside the 1990/91 to 1997/98 range (52t- 81t)	Yes: Statewide ↓ (13t)	Commercial catch is > 50t	No
Catch increase or decline by over 30% from previous year	No	-	
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	Yes: Droplines (days fished)	-	
		Catch curve estimated every 3 years as an index of fishing mortality from all sectors: Target range: Fishing mortality $F \leq$ Natural mortality M Limit RP: $F = 1.5*M$	Not assessed
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Yes (lack of strong new recruitment)	Any indicator of stock stress	Yes (lack of strong new recruitment)

5.8 Implications for management

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

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

Catches reported in Commonwealth returns in recent years have averaged about 3 tonnes per year, though industry reports suggest that these figures may be significantly underestimated. There is an urgent need to ensure that such catch and effort information are complete.

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

The low graball catch observed for some years may be linked to a combination of low numbers of striped trumpeter in inshore waters and/or size structuring within the population (immature fish inshore/mature fish offshore) that means that few if any fish captured in the inshore gillnet catch will be of legal size. Spawner biomass-per-recruit analyses (Tracey et al. 2007a) imply that either fishing mortality needs to be reduced or that the minimum size limit should be increased further. The new size limit of 50cm TL is still below the size at maturity.

A spawning season closure during September-October, when fish are particularly vulnerable to capture, was introduced for the first time in 2009. There is little obvious seasonality in catches throughout the year but commercial catch rates do peak in September possibly reflecting increased catchability as the species aggregate to spawn. A spawning closure during September-October is expected to impact on 10-25% of annual commercial production which is typically taken during this period.

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. Further management action is required to align the size limit with size at maturity, allowing fish to spawn before they become vulnerable to capture. The introduction of the recreational on-water possession limits of 4 fish from 1 November 2009 should help to reduce the fishing pressure to some degree, but may not be enough to reduce the recreational fishing mortality if further expansion of this sector occurs in coming years.

5.9 Research needs

The Scalefish Fishery Research Advisory Group has identified the need for research into stock assessment, recruitment variability and gear interactions as areas of high research priority for striped trumpeter. In addition, there is a need to better estimate the recreational catch and reduce uncertainty in the magnitude of the catch by Commonwealth operators. In addition, there is an urgent need to characterize the commercial and recreational fisheries for this species in terms of size composition and age-structure. Finally, there is a need to further examine the impacts of present and alternative harvest strategies.

6 Bastard trumpeter (*Latridopsis forsteri*)

6.1 Catch, effort and catch rates

Bastard trumpeter catches declined steadily from the mid 1990s. They have remained stable at around 20 tonnes for the past five years with a catch of 17 tonnes in 2008/09 (Fig. 6.1A). Bastard trumpeter are taken almost exclusively by graball from inshore waters off the east, south and west coasts (Fig. 6.2). The species also 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 (Lyle 2005). Estimates of recreational catches in 2007/08 were uncertain but likely to be lower, with an estimated 19 tonnes for combined catches of striped and bastard trumpeter (Lyle et al. 2009).

Graball effort for bastard trumpeter has followed a similar downward trend to catches since the mid-1990s (Figs. 6.1B and 6.2). Daily catch rates have remained relatively stable over time (Fig. 6.1C). This lack of an obvious trend, despite the sharp decrease in catches, presumably reflects the fact that bastard trumpeter are taken primarily as by-product, rather than as a target species.

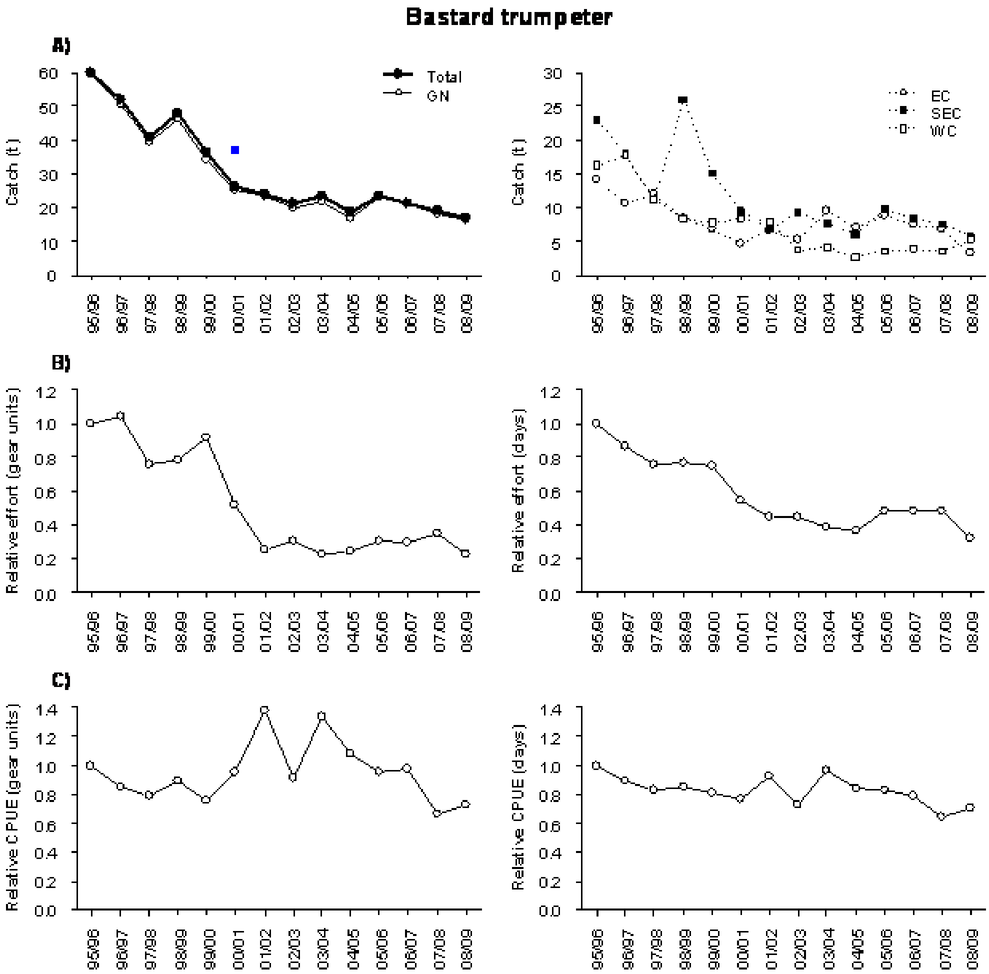

Fig. 6.1. A) Annual commercial catch (tonnes) of bastard trumpeter by method (left) and region (right) since 1995/96 reported in Tasmanian logbooks, and best estimates of recreational catches (single squares); B) commercial effort by method based on gear units (left) and by days fished (right) relative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

6.2 Reference points

Existing reference points	Exceeded?	Alternative RP	Exceeded?
State-wide or regional catches outside the 1990/91 to 1997/98 range (34t-63t)	Yes: Statewide ↓ (17t)	Pending	
Catch increase or decline by over 30% from previous year	No		
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No		
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	No		
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Not assessed		

6.3 Implications for management

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

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

Whilst juvenile biomass may vary widely due to recruitment variability and fishing pressure, no information regarding the adult segment of the population is available. However, it is clear that low levels of fishing pressure are exerted on those adults that evade the inshore fishery. Since commercial and recreational fisheries are based on juveniles, recruitment as well as growth overfishing could be occurring.

From 1 November 2009, the size limit has been increased from 35 cm to 38 cm TL, a new commercial trip limit of 200 kg has been introduced and the recreational possession limit has been reduced from 15 to 10 fish. While the commercial trip limit and the reduction of the recreational possession limits are expected to reduce fishing mortality, the minimum size limit is still well below the size at maturity, which appears to be greater than 50 cm FL. Increasing the minimum size limit to above the size at maturity would be beneficial to the stock but would also effectively close down the current commercial and recreational fisheries for the species.

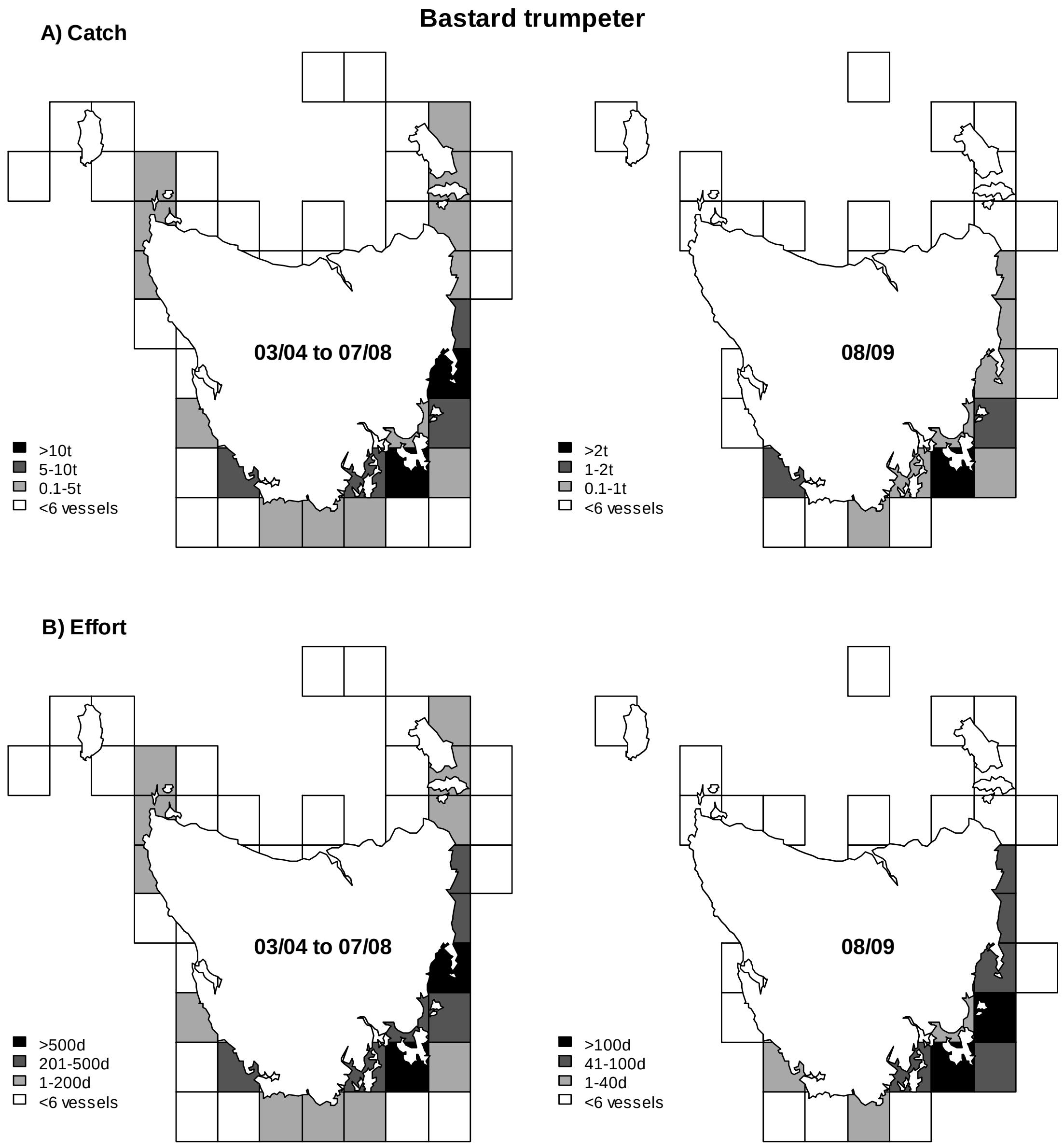

Fig. 6.2. (A) Bastard trumpeter catches (tonnes) and (B) effort (days) by fishing block pooled from 2003/04 to 2007/08 (left) and during 2008/09 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

7 Sea garfish (*Hyporhamphus melanochir*)

7.1 Catch, effort and catch rates

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

After years of relative stability in garfish catches at 80-90 tonnes per annum, catches have strongly fallen between 2005/06 and 20007/08 from 89 tonnes to 30 tonnes (Fig. 7.1A). Decreases were experienced by the two main fishing methods beach seine and dipnets, and in all major fishing regions. In 2008/09, catches increased again to 63 tonnes due to higher catches almost exclusively by beach seine in the north-east, including Flinders Island. Catches from the east and south-east coast have remained at historic low levels.

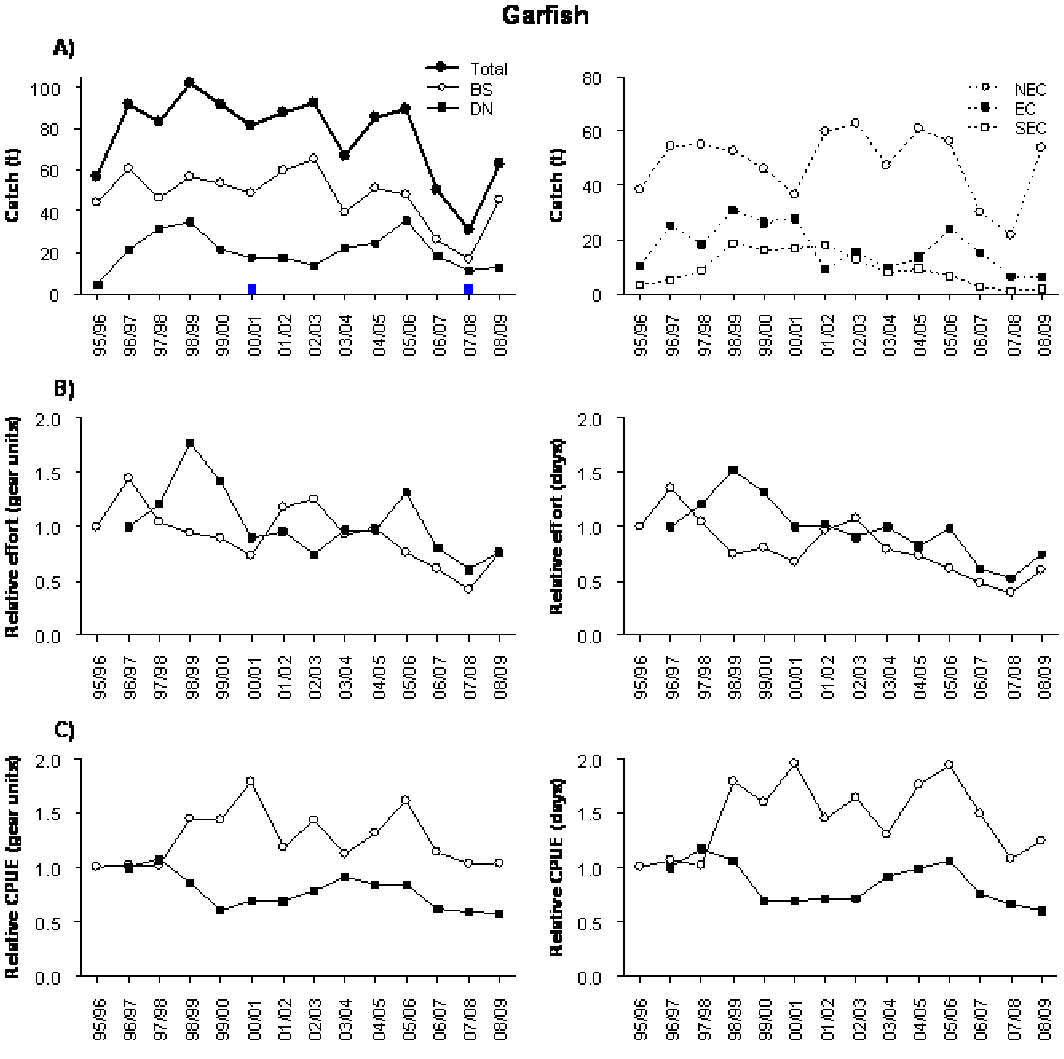

Fig. 7.1. A) Annual commercial catch (tonnes) of garfish by method (left) and region (right) since 1995/96 reported in Tasmanian logbooks, and best estimates of recreational catches (single squares); B) commercial effort by method based on gear units (left) and by days fished (right) relative to 1995/96;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

Recreational garfish catches for 2000/01 and 2007/08 were estimated to be in the order of 2 tonnes in both years (Lyle et al. 2009).

Effort has increased slightly from the low levels in 2007/08, but still only five or fewer fishers operate in most fishing blocks (Fig. 7.2). Dipnet effort increased initially to a peak during 1998/99 but has subsequently decreased to a lower level (Fig. 7.1B, days fished), while beach seine effort experienced a more recent decline.

Catch rates for beach seine fluctuated much more strongly over time than those for dipnet. Beach seine catch rates generally rose during the late 1990s and early 2000s and have fluctuated at a high level since that time (Fig. 7.1C). By contrast, dipnet catch rates have undergone two periods of decline with a recovery period in between. In 2008/09, gear units for both gear types have remained stable, while days fished increased for beach seine. However, in the context of schooling species such as garfish, catch rates may be relatively insensitive to changes in abundance.

7.2 Reference points

Existing reference points	**Exceeded?**	**Alternative RP**	**Exceeded?**
State-wide or regional catches outside the 1990/91 to 1997/98 range (56t-92t)	No (63t)	State-wide catch outside reference range from 1998/99 to 2006/07 (66-102t)	Yes: ↓ (63t)
Catch increase or decline by over 30% from previous year	Yes: Statewide ↑ (103%)	-	
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	Yes: DN (gear units)	-	
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Not assessed	Any indicator of stock stress	Not assessed

7.3 Implications for management

Industry members indicated that the catch declines between 2005/06-2007/08 in all major fishing regions were caused by a lack of resource availability, despite apparently high abundances of undersized fish in some areas. In 2008/09, stock abundance appeared to be higher in the north-east, but remained depressed in south-eastern waters. The reason for these trends, after a long period of apparent stability in the fishery remains unclear. Since it is not known whether present catch levels are sustainable, scientific monitoring of the fishery and fish stock, including collection of biological samples, commenced during 2008. Given current uncertainties it would be prudent to consider management options that limit further expansion in this fishery until more is known about the stock dynamics. The implementation of a one-month spawning closure (mid-November to mid December) for commercial operators during 2009 may also add protection for the species.

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

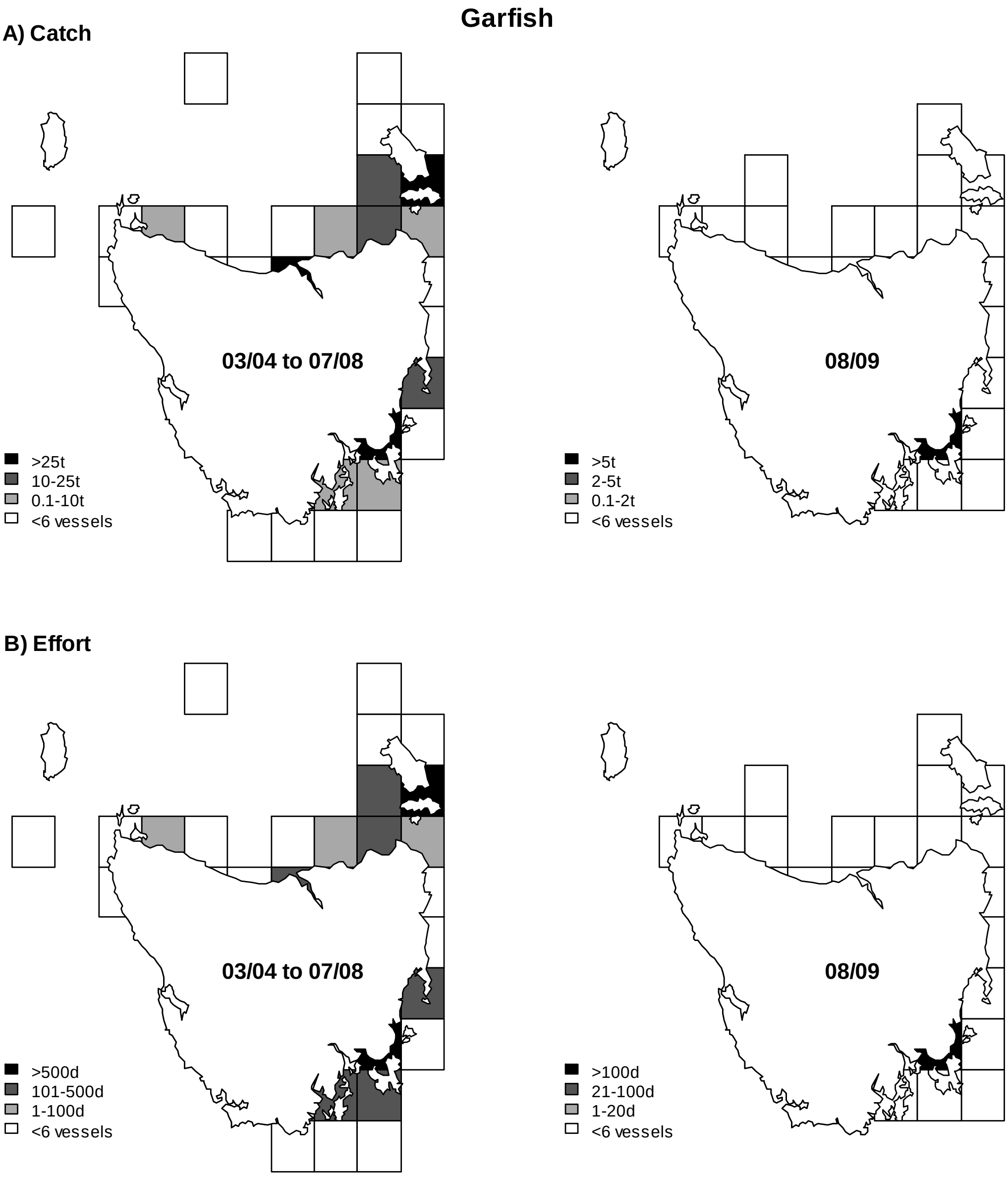

Fig. 7.2. (A) Garfish catches (tonnes) and (B) effort (days) by fishing block pooled from 2003/04 to 2007/08 (left) and during 2008/09 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

8 Wrasse (Fam. Labridae)

8.1 Catch, effort and catch rates

Of the several species of wrasse occurring in Tasmanian waters, purple wrasse (*Notolabrus fucicola*) and blue-throat wrasse (*N. tetricus*) are the main species taken commercially. Wrasse are targeted for the live fish markets as well as being sold as dead product and utilised as bait for rock lobster (bait usage is possibly under-reported). Fish marketed live are distinguished in the logbooks, and live wrasse have accounted for over 90% of the total reported catch since 2001/02. Thus, trends in the live-fish fishery will ultimately be reflected in overall production levels. The two species of wrasse have only been recently distinguished in catch returns. While there is an apparent market preference for blue-throat wrasse, purple wrasse are more robust for live handling.

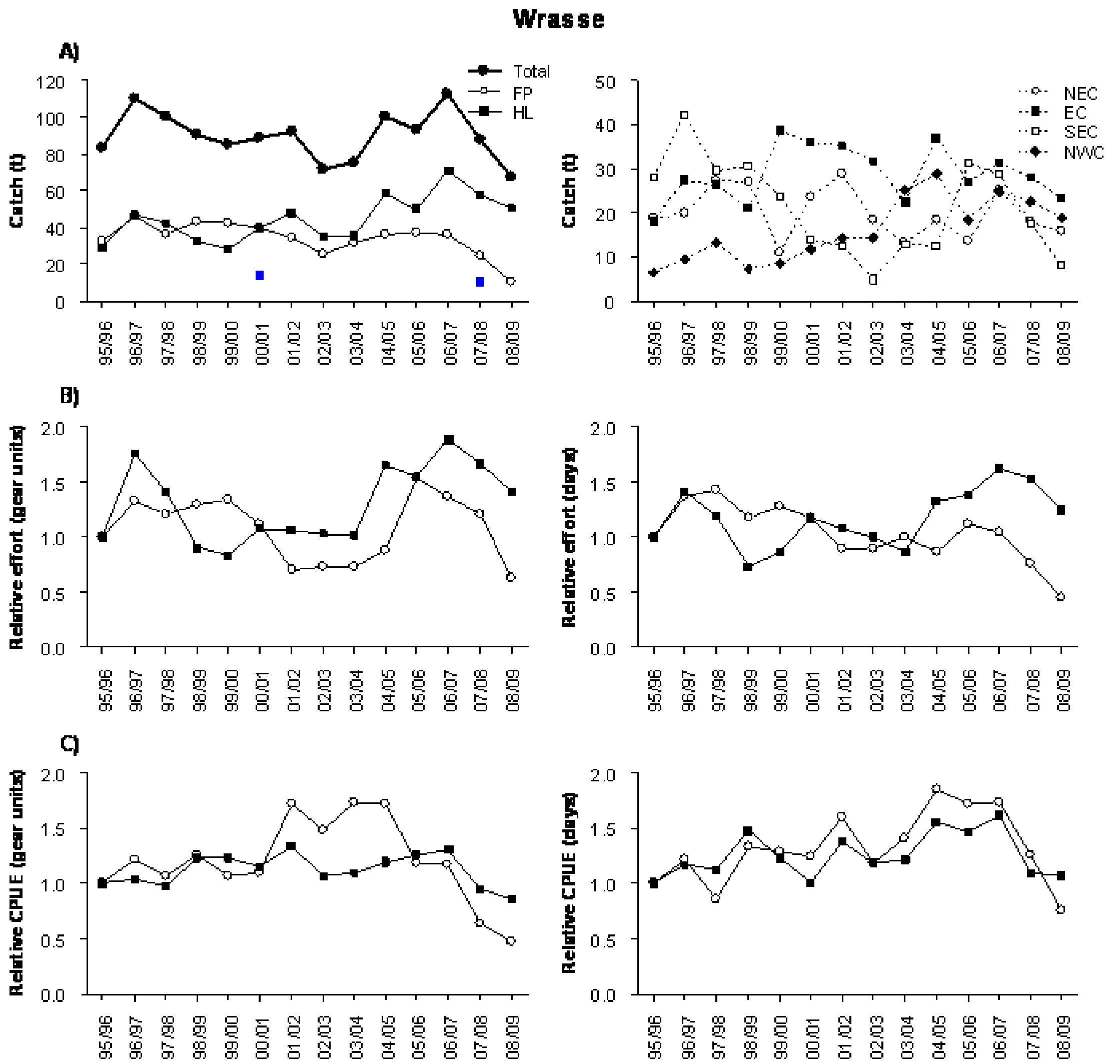

Fig. 8.1. A) Annual commercial catch (tonnes) of wrasse by method (left) and region (right) since 1995/96 reported in Tasmanian logbooks, and best estimates of recreational catches (single squares); B) commercial effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) commercial 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.

Wrasse catches fluctuated between about 75-110 tonnes between 1995/96 and 2007/08, peaking at 113 tonnes in 2006/07(Fig. 8.1A). Reported catches fell in 2008/09 to just 69 tonnes (42 tonnes of blue-throat wrasse, 27 tonnes of purple wrasse). The decline in catches since 2006/07 can be attributed largely to the prohibition on the use of abalone guts as bait in fish traps. This prohibition was a response to the appearance of the abalone viral ganglioneuritis in Victorian waters and has forced fishers to seek alternative but less effective baits. Catches, effort and catch rates subsequently declined for fish traps, particularly in the south-east (Fig. 8.1 and 8.2) where fish traps are the dominant fishing method. Hand line catch and effort has followed similar trends and may reflect the common practice of employing both methods together when fishing for wrasse.

With blue-throat wrasse being more susceptible to line methods and purple wrasse more vulnerable to trap capture, blue-throat wrasse are taken in larger quantities in the live fishery. Gillnets account for the bulk of the remaining catch (< 5 tonnes) but because survival in nets is poor, graball caught wrasse are rarely marketed live.

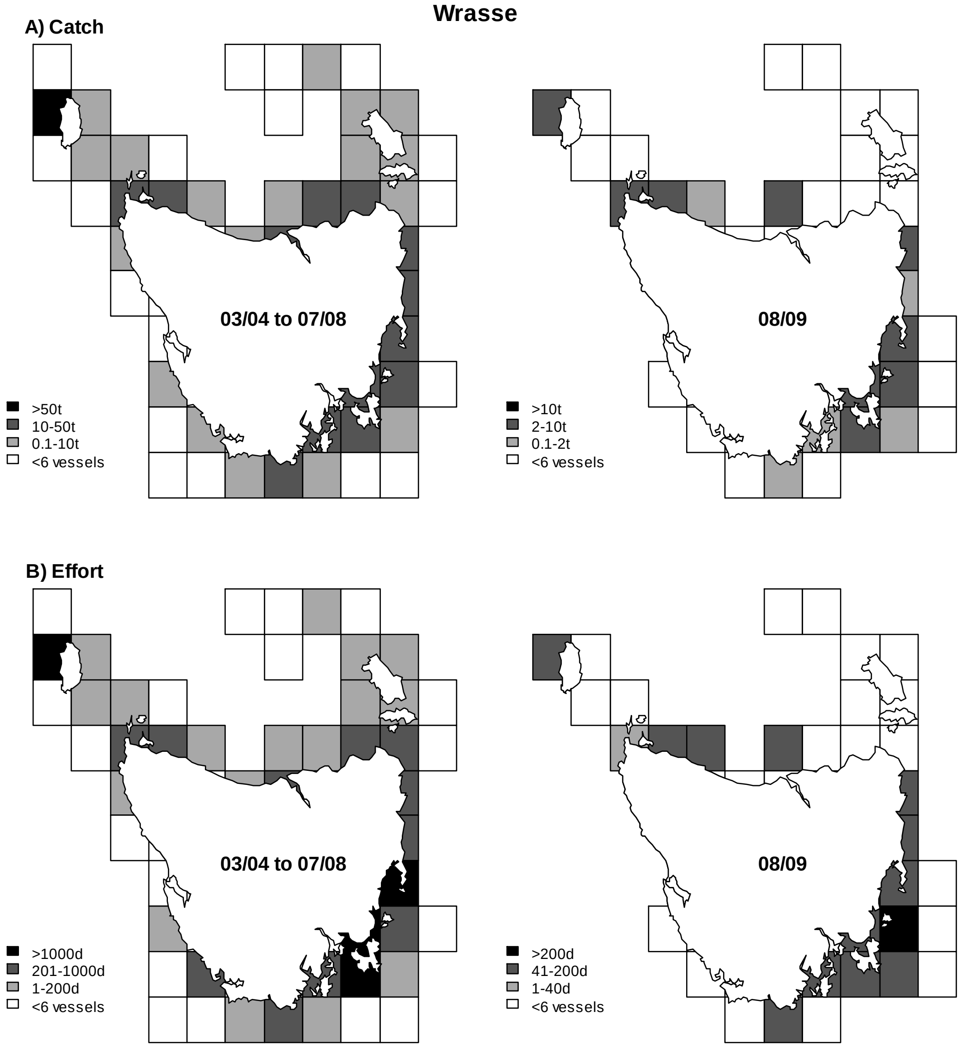

Fig. 8.2. (A) Wrasse catches (tonnes) and (B) effort (days) by fishing block pooled from 2003/04 to 2007/08 (left) and during 2008/09 (right). The levels in the right graphs are 1/5 of those in the left graphs

where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

Catch rate trends imply that wrasse stocks have not been impacted significantly by the fishery until recent years. Since the mid-1990s catch rates for fish traps gradually increased and peaked in 2004/05, but have since declined, largely influenced by changes in permissible bait types (Fig. 8.1C). Similarly, catch rates for handline had remained relatively stable since the mid 1990s prior to recent declines. These latter declines support the evidence that exploitation rates of legal-sized purple wrasse on some east-coast reefs are extremely high (Ewing 2004). Nevertheless, the broad-scale analyses presented here are generally insensitive to changes in abundance at the level of individual reefs at which the fishery impacts the populations. Marked regional shifts of effort have occurred in the fishery over the years and may have masked localised depletions, with fishers moving to new or lightly fished areas to maintain catches.

8.2 Reference points

Existing reference points	**Exceeded?**	**Alternative RP**	**Exceeded?**
State-wide or regional catches outside the 1995/96 to 1997/98 range (83t-110t)	Yes: Statewide ↓ (69t)	State-wide catch outside reference range from 1998/99 to 2006/07 (72-99t)	Yes: ↓ (69t)
Catch increase or decline by over 30% from previous year	No	-	
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	Yes: Fish traps (gear units)	-	
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Not assessed	Any indicator of stock stress	Not assessed

8.3 Implications for management

While input controls (limited entry) have capped participation in the live wrasse fishery, there is still a substantial level of latent effort. Increasing catches in previous years reflected strong interest in the species, but the recent declines in catch rates could indicate that those catch levels were not sustainable. Under present arrangements, there is potential for localised depletions of legal-sized wrasse, especially if effort becomes concentrated in particular regions. There is already evidence for a concentration of effort off the east coast.

The minimum size limit provides good protection (several years after reaching the size at maturity) for the spawning stock of purple wrasse and for populations of female blue-throat wrasse. The limit does not, however, provide the same level of protection for male blue-throat wrasse because males are derived through sex change from mature females, typically at sizes after they have entered the fishery. This coupled with the fact that males are strongly site attached and have higher catchability (being more aggressive than females) suggests that they are vulnerable to over-fishing. In extreme situations it is possible that localised heavy fishing pressure could result in 'sperm shortage' that would affect spawning success even though there may be a robust population of mature (sub-legal size) females present. The removal of the maximum size limit for wrasse (2004) may have exacerbated this potential problem. However, neither in Victoria, where the blue-throat wrasse fishery has been larger, nor in Tasmania are there any clear indications of spawning stock shortages.

9 Key scalefish fisheries shared with Commonwealth / other States

9.1 Blue warehou (*Seriolella brama*)

9.1.1 Catch, effort and catch rates

Blue warehou occur seasonally in Tasmanian inshore waters, the region representing the southern-most extent of the species' distribution. Traditionally, the availability of blue warehou in coastal waters has been assumed to be influenced by prevailing oceanographic conditions and availability of prey species. These factors produce marked inter-annual variability in abundance and hence catches taken from State waters as demonstrated in Fig. 9.1A. Due to low availability since the early 2000s, the species has been rarely targeted. The current catch of 27 tonnes is similar to that for the previous year and low compared to the catches reported during the 1990s.

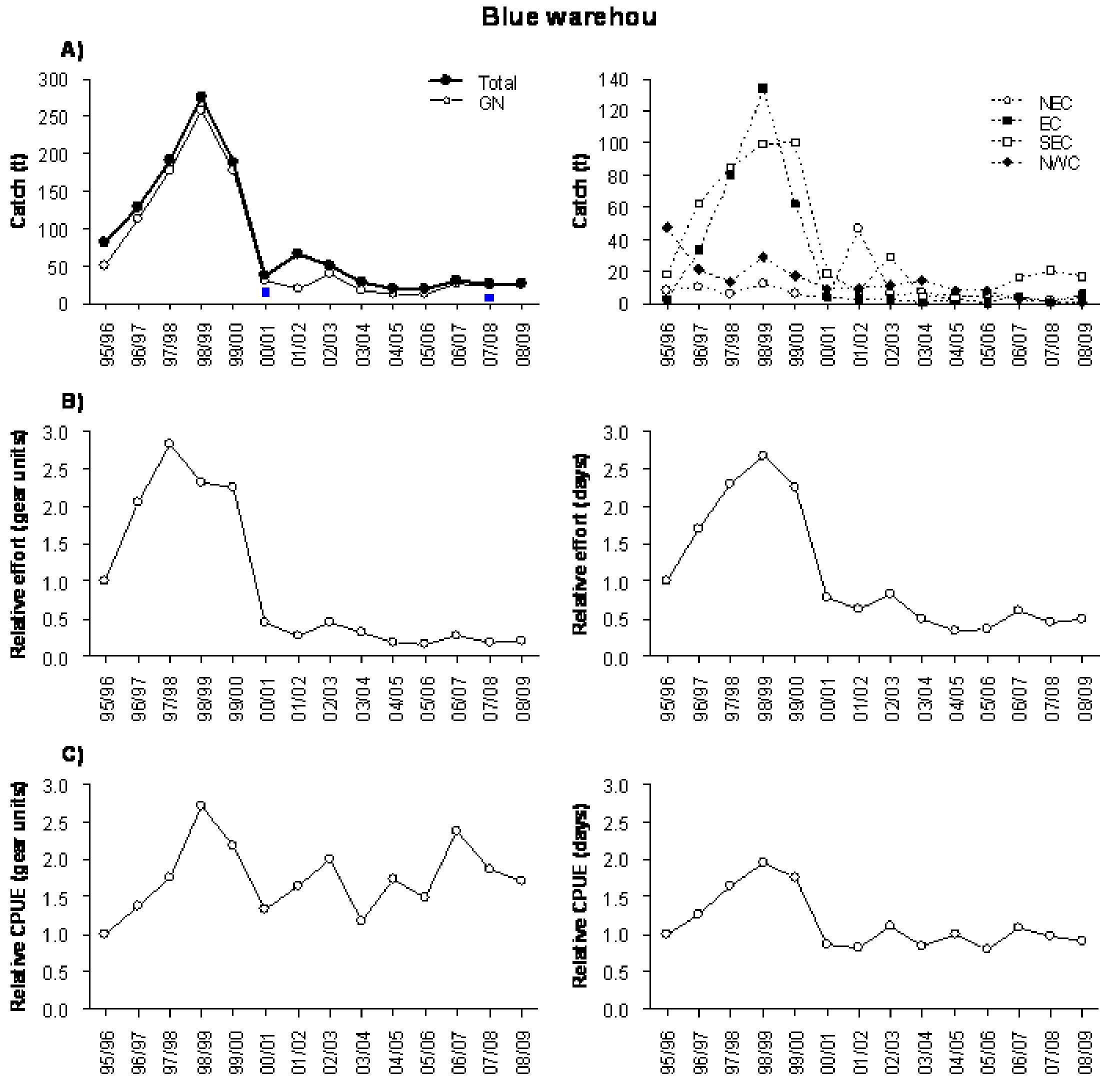

Fig. 9.1. A) Annual commercial catch (tonnes) of blue warehou by method (left) and region (right) since 1995/96 reported in Tasmanian logbooks, and best estimates of recreational catches (single squares); B) commercial effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) commercial 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.

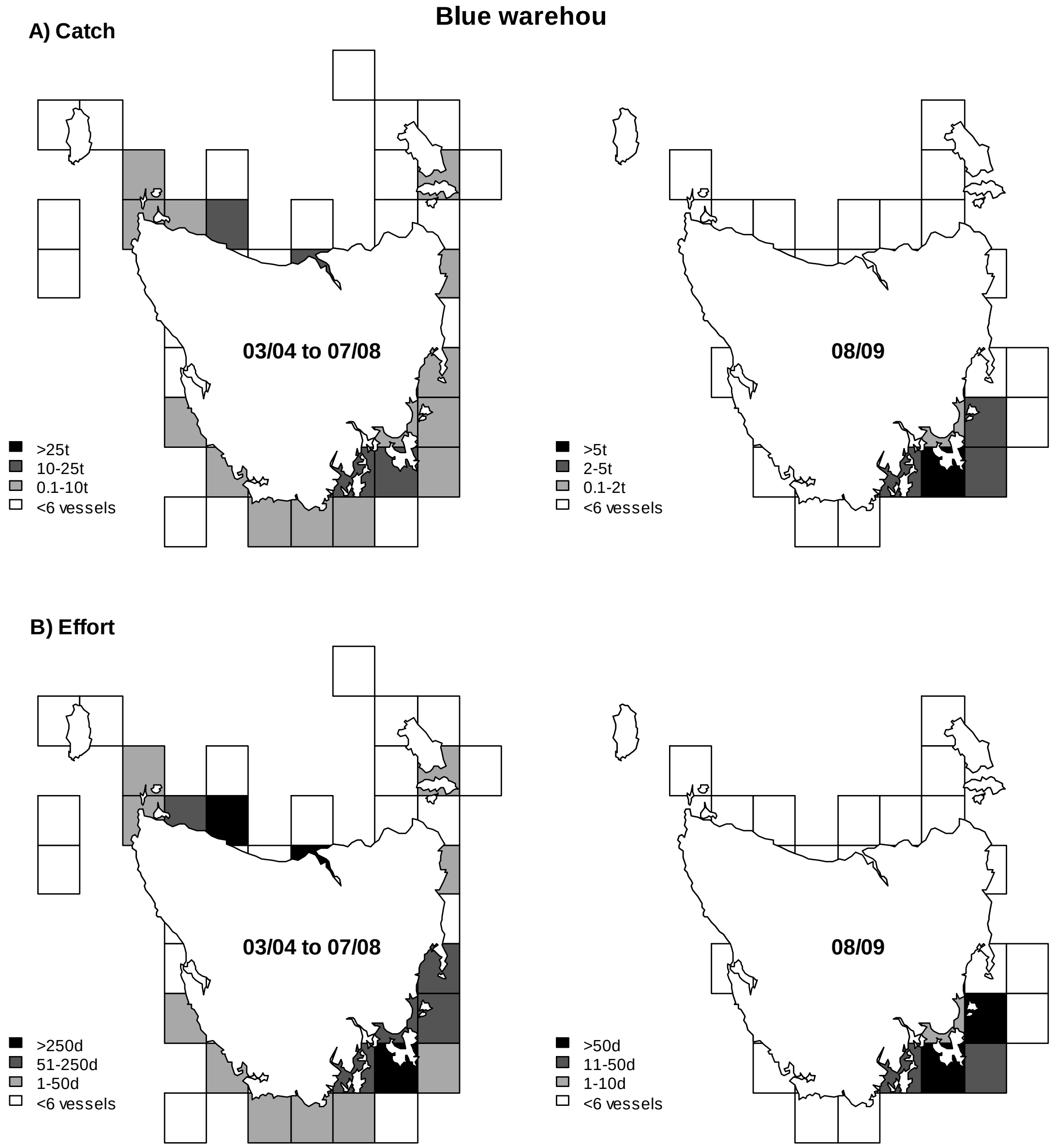

Fig. 9.2. (A) Blue warehou catches (tonnes) and (B) effort (days) by fishing block pooled from 2003/04 to 2007/08 (left) and during 2008/09 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

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

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

Recreational fishers also target the species using gillnets and to a lesser extent line fishing. The estimated recreational harvest in 2000/01 was just 15 tonnes (Lyle 2005), substantially lower than recreational catches taken in 1997 and 1998 (Lyle 2000) but consistent with the depressed state of commercial catches. The recreational catch further declined in 2007/08 to around 7 tonnes (Lyle et al. 2009)

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

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

9.1.2 Reference points

Existing reference points	**Exceeded?**	**Alternative RP**	**Exceeded?**
State-wide or regional catches outside the 1990/91 to 1997/98 range (82t-318t)	Yes: State-wide ↓ (27t)	Commercial catch limit of 318 tonnes as per Memorandum Of Understanding (MOU)	No (27t)
Catch increase or decline by over 30% from previous year	No	-	
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	No	-	
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Not assessed	Any indicator of stock stress	Not assessed

9.1.3 Implications for management

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

The availability of blue warehou in Tasmanian inshore waters is influenced by a range of environmental factors as well as stock size. Recent depressed catches are almost certainly linked to reduced biomass, the result of overfishing by Commonwealth and State fisheries during the 1990s. In 2003, the total allowable catch (TAC) for the Commonwealth fishery was reduced to 300 tonnes per year, down from over 2,000 tonnes in late 1990s, because catches of blue warehou were expected to be poor for the foreseeable future due to overfishing in combination with a lack of good recruitment. The TAC has remained low since and was reduced for 2009 from 365 tonnes to 183 tonnes since both western and eastern stocks were considered to be overfished (Wilson et al. 2009, AFMA 2009).

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

9.2.1 Catch, effort and catch rates

The commercial catch of Australian salmon increased by over 70 tonnes in 2008/09 to 339 tonnes (Fig. 9.3A). The vast majority of the catch was caught by beach seine, predominantly from the north-east and north-west coasts (Figs. 9.3A and 9.4). Despite this, beach seine effort fell to a record low level (Figs. 9.3B and 9.4).

Australian salmon also represent the second most commonly caught species in the recreational scalefish fishery, with an estimated harvest of 111 tonnes in 2000/01 (Lyle 2005) and 48 tonnes in 2007/08 (Lyle et al 2009).

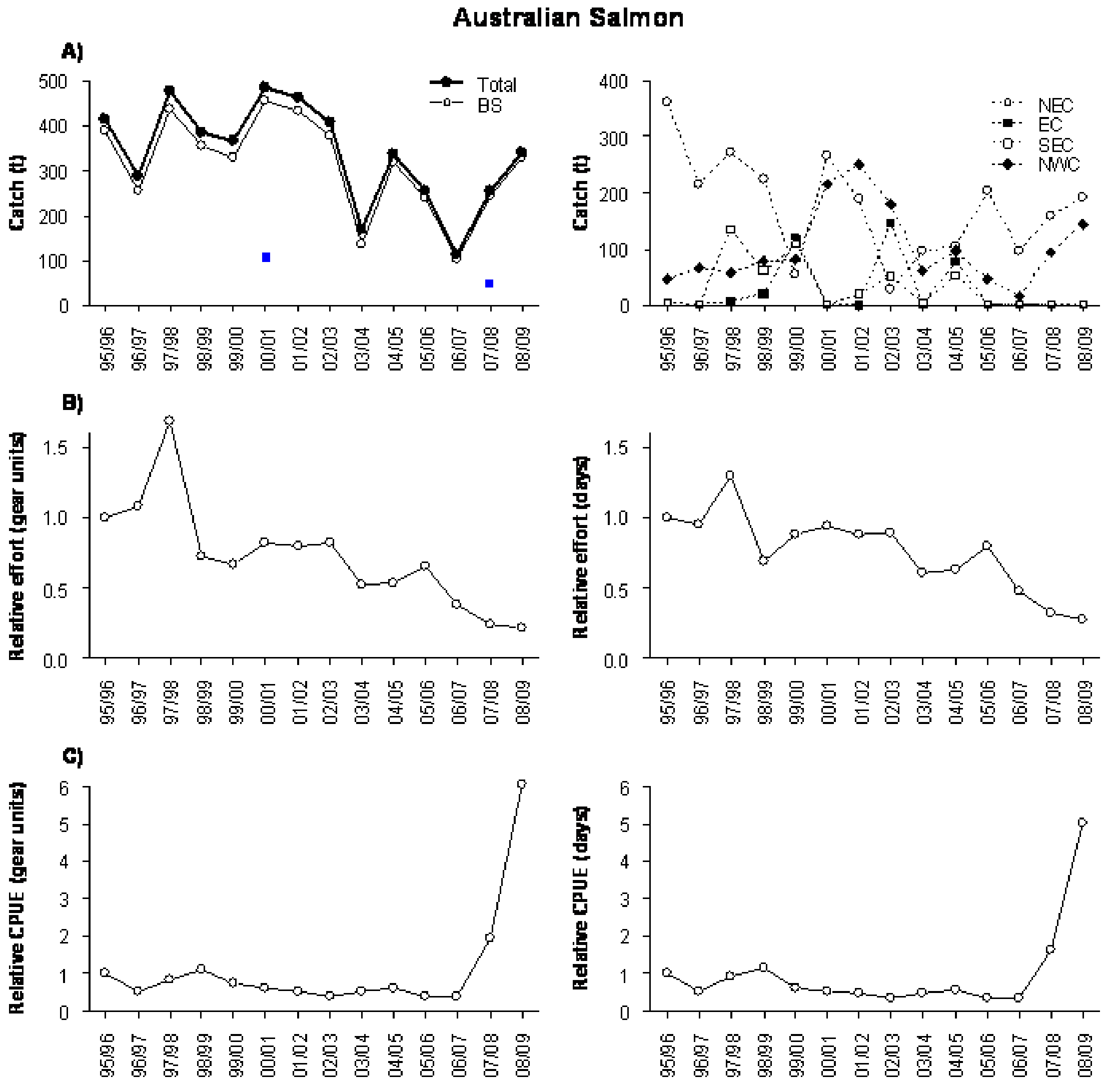

Fig. 9.3. A) Annual commercial catch (tonnes) of Australian salmon by method (left) and region (right) since 1995/96 reported in Tasmanian logbooks, and best estimates of recreational catches (single squares); B) commercial effort by method based on gear units (left) and by days fished (right) relative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

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

9.2.2 Reference points

Existing reference points	**Exceeded?**	**Alternative RP**	**Exceeded?**
State-wide or regional catches outside the 1990/91 to 1997/98 range (287t-879t)	No (339t)	Commercial catch trigger of 435 tonnes (120% of 10-year average for the period 1996/97 to 2006/07) as per Ministerial decision	No (339t)
Catch increase or decline by over 30% from previous year	Yes: State-wide (+32%)	-	
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	No	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	No	-	
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Not assessed	-	

9.2.3 Implications for management

Although Australian salmon stocks appear to fluctuate throughout the year in relation to environmental conditions, annual production is strongly linked to market demand, specifically the bait market, and thus not a good indicator of stock status. There is capacity for industry to expand production to the commercial trigger limit should the market expand or new markets be found. Demand is expected to be influenced in the coming years due to reductions in the allowable catches in southern Australian rock lobster fisheries.

While stock status is unknown, the species has sustained substantially higher catches in the past and current commercial and recreational catches would appear sustainable.

Australian salmon 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 and/or competition for resource access.

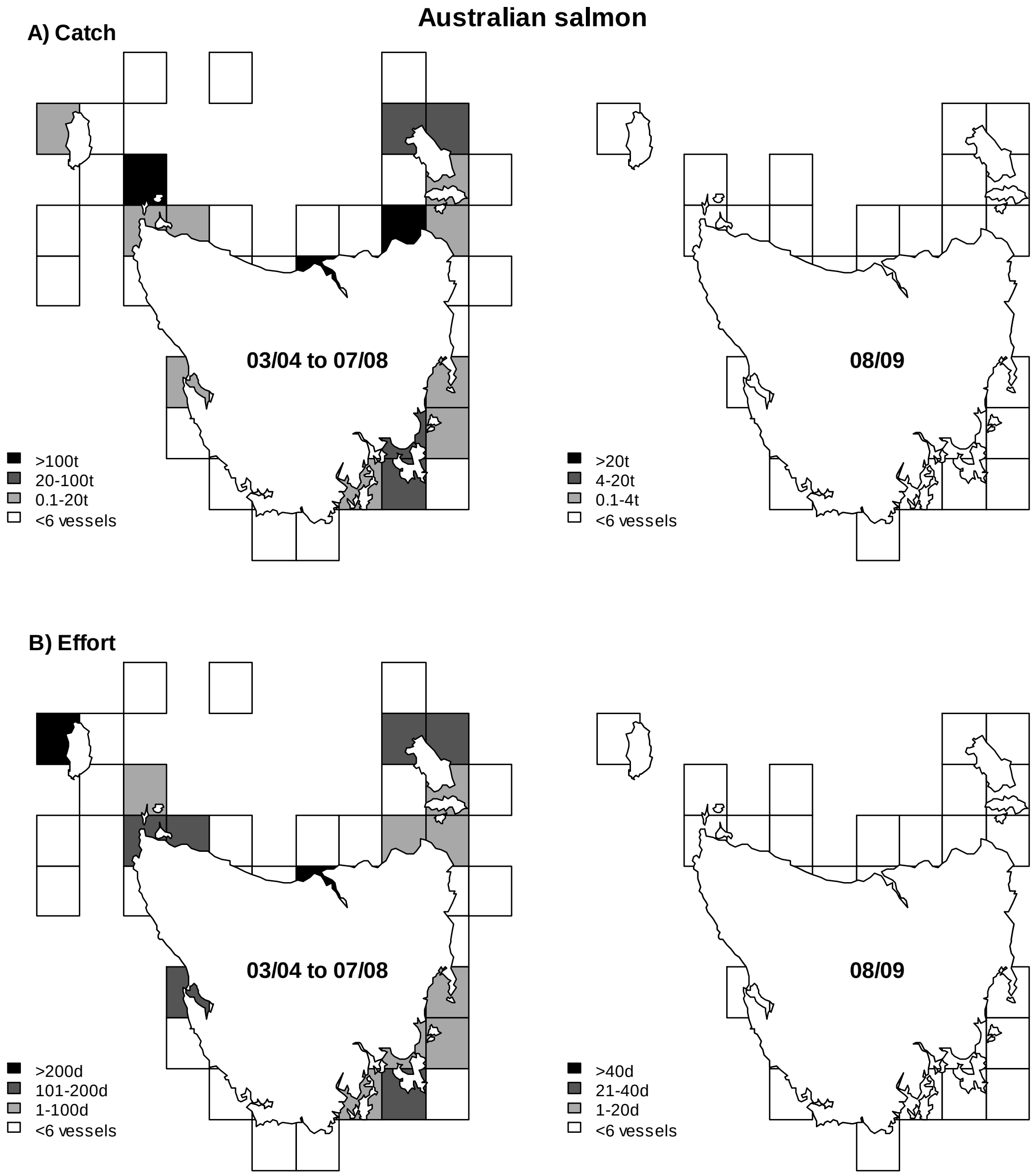

Fig. 9.4. (A) Australian salmon catches (tonnes) and (B) effort (days) by fishing block pooled from 2003/04 to 2007/08 (left) and during 2008/09 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

9.3 Flathead (Fam. Platycephalidae)

9.3.1 Catch, effort and catch rates

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

Flathead catches declined steadily between 2000/01 and 2003/04 but more than doubled in 2005/06 (Fig. 9.5 and Fig. 9.6). After an increase in 2007/08 to 75 tonnes, catches fell by 29% to 53 tonnes in 2008/09. These fluctuations were mainly caused by variability in tiger flathead catches taken by Danish seiners. By contrast, handline catches, mainly targeting sand flathead, have remained stable since the mid 1990s.

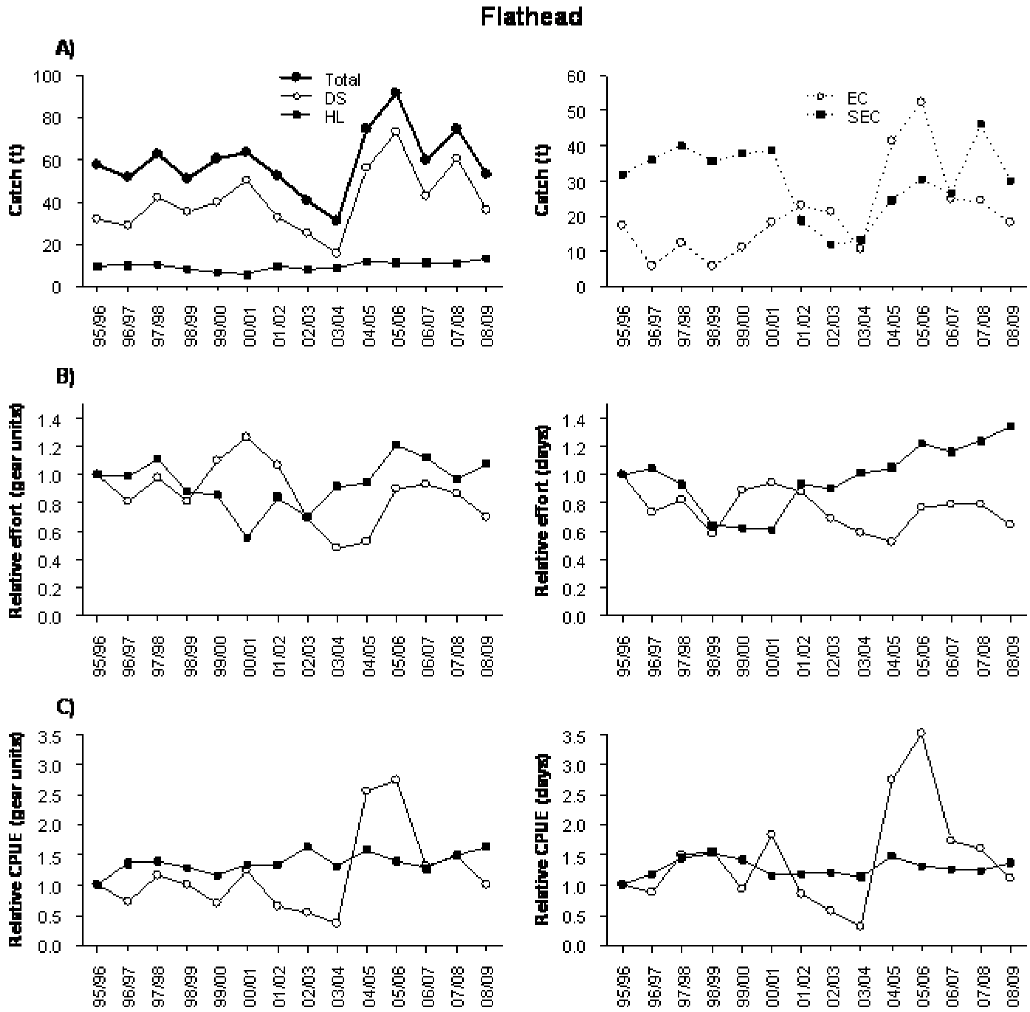

Fig. 9.5. A) Annual commercial catch (tonnes) of flathead by method (left) and region (right) since 1995/96 reported in Tasmanian logbooks. Best estimates of recreational catches (321t in 2000/01 and 293t in 2008/09 not shown); B) commercial effort by method based on gear units (left) and by days fished (right) relative to 1995/96; and C) commercial 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.

Catches were derived mainly from the south-east and east coasts, with smaller quantities also taken from the north-east (including around Flinders Island) and north-west coasts (Figs. 9.5A and 9.6). The increased production of the past years has been mainly focussed in the south-east of the state.

Recreational catches are dominated by sand flathead and estimated to have been 361 tonnes in 2000/01 (Lyle 2005) and 292 tonnes in 2007/08 (Lyle et al. 2009). Tiger flathead comprised only a minor component of the harvest.

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

Hand line catch rates have remained stable over time; whereas Danish seine catch rates have fluctuated strongly in recent years, presumably reflecting the level of targeting for the species (Fig. 9.5C).

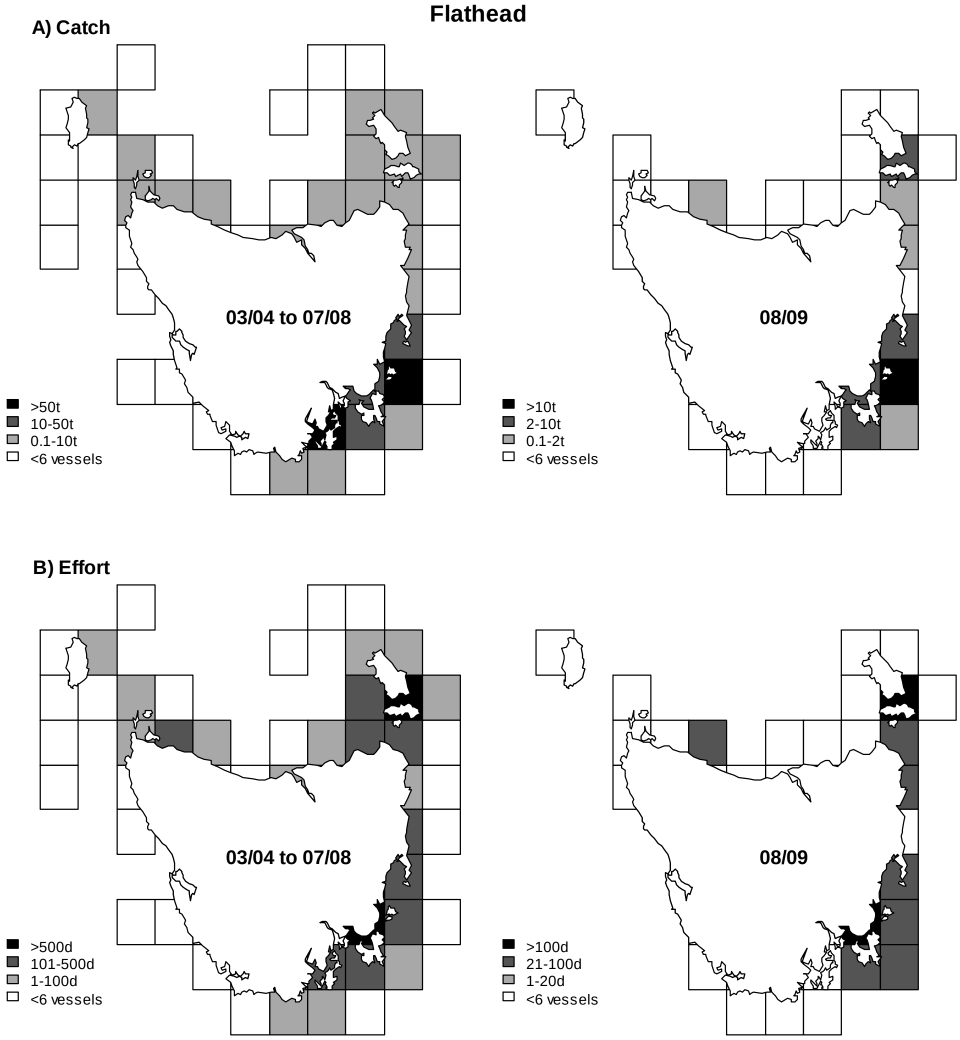

Fig. 9.6. (A) Flathead catches (tonnes) and (B) effort (days) by fishing block pooled from 2003/04 to 2007/08 (left) and during 2008/09 (right). The levels in the right graphs are 1/5 of those in the left graphs where data from 5 years have been pooled. Blocks with less than 6 vessels reporting catch are shown as empty.

9.3.2 Reference points

Existing reference points	Exceeded?	Alternative RP	Exceeded?
State-wide or regional catches outside the 1990/91 to 1997/98 range (52t-165t)	No (53t)	Catch by Danish Seine above 1.3* the maximum catch from the reference period 1998/99 to 2006/07: South-east coast: 45t East coast: 63t	 No (30t) No (18t)
Catch increase or decline by over 30% from previous year	No	-	
State-wide or regional effort over 10% of the highest for the period 1995/96 to 1997/98	Yes: HL (days fished)	-	
State-wide or regional catch rates less than 80% of the lowest annual value for the period 1995/96 to 1997/98	No	-	
Others: - Significant change in size/age composition of catch - Change in catches of non-commercial fish relative to 1990/91 to 1997/98 or high incidental / undersized mortality - Significant catch of unhealthy fish - Any other indicator of stock stress	Not assessed	Any indicator of stock stress	Not assessed

9.3.3 Implications for management

Danish seine catches are highly variable and tend to be inversely related with catches of whiting (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 additional and significant trawl catches of flathead (almost exclusively tiger flathead) that are taken from Commonwealth waters as part of the Southern and Eastern Scalefish and Shark Fishery, with the tiger flathead stocks classified as not overfished (Wilson et al. 2009). Sand flathead stock status is not known, though undersized fish appear to be highly abundant and the size limit is set above the size at maturity. Clearly the main impact on sand flathead stocks is from the recreational sector.

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

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Appendices

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

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

Appendix 2. Data restrictions and adjustments

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

Tasmanian logbook data

i) Correction of old logbook landed catch weights

Prior to 1995, catch returns were reported as monthly summaries of landings. With the introduction of a revised logbook in 1995, catch and effort was recorded on a daily basis for each method used. Since catch data reported in the old general fishing return represent landed catch, it has been assumed to represent processed weights. For example, where a fish is gilled and gutted, the reported landed weight will be the gilled and gutted and not whole weight. By contrast, in the revised logbook all catches are reported in terms of weight and product form (whole, gilled and gutted, trunk, fillet, bait or live). If a catch of a species is reported as gilled and gutted then the equivalent whole weight can be estimated by applying a standard conversion factor[4].

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.

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

Commonwealth logbook data:

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

(i) Area restrictions

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

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

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

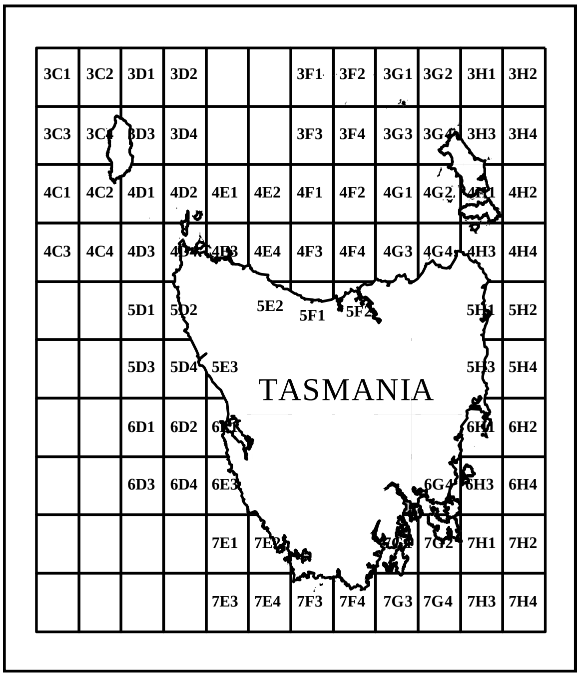

Fig. A1. Numbers for fishing blocks used in calculation of catch figures.

(ii) Duplicate records

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

Appendix 3: Description of banded morwong stock assessment model

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

Basic population dynamics

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

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

where:

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

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

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

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

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:

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

where:	
k	is the movement rate alongshore.

Maturity at age is described by a logistic model:

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

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

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

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

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

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

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

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

Growth

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

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

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

The weight at length relationship is described by:

$$W_{t,y}^{s} = a_s (L_{t,y}^{s})^{b_s} \qquad \text{(A3.9)}$$

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.

Selectivity

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

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

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

Sex-specific selectivity is described by:

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

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

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

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

where:

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

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 growth function $L^s_{t,y}$ and its standard deviation $\sigma^s_{t,y}$.

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*:

$$F^{p,s}_{y,t} = s^s_{t,y}\hat{F}^p_y \tag{A3.14}$$

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:

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

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:

$$\hat{I}^p_y = \hat{q}_p\hat{B}^p_{E,y} \tag{A3.16}$$

where:

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

	with lognormal error: $\ln(\hat{q}_p) = \dfrac{\sum_{y=1996}^{2007} \ln\left(\dfrac{I_y^p}{B_{E,y}^p}\right)}{n}$	(A3.17)
I_y^p	is the observed catch rates in population *p* and year *y*,	
n	is the number of years with catch rates observations between 1996 and 2007.	

Recruitment

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

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

where:	
$R^s_{t_{\min},y}$	is the geometric mean (GM) of the fitted recruitment by sex *s* of age t_{min},
σ_R^2	is the density-dependent parameter that determines the extend of annual variation in recruitment.

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

Catch and catch rates in projections

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

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

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