TASMANIAN BANDED MORWONG FISHERY ASSESSMENT 2021/22

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This assessment of the Tasmanian Banded Morwong Fishery is produced by the Institute for Marine and Antarctic Studies (IMAS), using data downloaded from the Department of Natural Resources and Environment Tasmania (NRE Tas) Fisheries Integrated Licensing and Management System (FILMS) database. The information presented here includes all logbook returns up until March 2022.

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Contents

Executive Summary

STOCK STATUS	SUSTAINABLE
Spawning stock biomass (SSB) of Banded Morwong was estimated to be at 40% of initial SSB. Forward projections of the stock assessment model revealed a high confidence (90% probability) that SSB will remain at 39% of initial SSB over the next five years, thereby exceeding a precautionary limit reference point of 30% of initial SSB for this period. The above estimates indicate that the biomass of Banded Morwong is unlikely to be depleted and that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. However, a review of the stock assessment model highlighted important sensitivities in predicted SSB that should be addressed through targeted research for increased confidence in future assessments.	

This assessment of the Tasmanian Banded Morwong Fishery covers the period from 1st March 2021 to 28th February 2022. The assessment examines trends in biological characteristics, catch, effort and standardised catch per unit effort (CPUE), and forecasts biomass levels under current management arrangements.

In Tasmania, Banded Morwong are commercially harvested by a small-scale coastal gillnet fishery. Prior to 1990, the species had little commercial value. In the early 1990s, a targeted fishery for Banded Morwong started to supply domestic live fish markets. All holders of a Tasmanian Fishing Boat Licence were able to take Banded Morwong and, as a result, there was a dramatic increase in effort directed at the species, with reported catches peaking at 145 t in 1993/94. Catches fell dramatically in the late 1990s, with 34.6 t landed in 1999/2000.

A quota management system with a Total Allowable Catch (TAC) was introduced in late 2008 to regulate fishing mortality at key fishing grounds on the east coast. The TAC has undergone a staged reduction from 38.8 t in 2012/13 to 31 t in 2017/18. The TAC remained at 31 t until the current season, 2021/22, where it was set at 35.8 t. The increase was intended to allow the fishing industry to recover from a 23.9% TAC under-catch in 2020/21 that was due to deflated market conditions during the COVID-19 pandemic. In addition, a temporal closure is in place for 1st March to 30th April each year, encompassing the species' peak spawning period. The species is subject to keyhole size limits, which are currently set at a minimum legal size of 360 mm and a maximum legal size of 460 mm.

A sampling program commenced in 1995 to obtain biological information, in particular size and age compositions, to better inform Banded Morwong assessments. Truncations in length and age compositions have been observed over the course of this sampling program, particularly for female fish. In recent years, age compositions appear to have stabilised but remain at levels much lower than when surveys began. Old fish (> 20 years) are rarely observed, and relative proportions of fish < 8 years old have increased. Changes in mean length at age of individuals aged between 2–10 years, and fluctuations in length at maturity, have also been observed.

State-wide catch in 2021/22 was estimated at 26.8 t. The total catch in the TAC area was 24.4 t (1.7 t from the north-east coast (Area 1), 10.8 t from the east coast (Area 2) and 11.9 t from the south-east coast (Area 3)), which represented 68.2% of the 2021/22 TAC of 35.8 t (i.e., a TAC under-catch of 31.8%). The unusually high under-catch was due to the continued deflated market condition during the COVID-19 pandemic in 2021/22. The total catch outside of the TAC area was 2.3 t. State-wide effort, in terms of both days fished and gear units (100 m net hour), increased due to increased effort in Areas 2 and 3. Catch increased in Area 2 and decreased in Areas 1 and 3 while standardised catch per unit effort (CPUE) in the TAC area decreased by 24% relative to 2020/21.

An external review of the assessment model was completed in 2021/22 that highlighted multiple possible improvements that should help increase the accuracy of future assessments. The review considered the existing model to be sufficient for management decision support, and the suggested changes are in line with the direction of anticipated future model improvements identified by the internal model review carried out over the last two years (see assessment reports 2019/20 and 2020/21). Further consideration of suggestions from the external review will be prioritised for the next possible assessment (2022/23) which will include additional biological data.

Based on the current model, SSB was estimated at 39% of initial SSB (35% at the 10th percentile) in 2026, assuming a 26 kg / quota unit and a TAC of 31 t in future years (with the exception of a 30 kg / quota unit and a TAC of 35.8 t in 2022/23). Under more conservative structural assumptions about population sizes and exchange between shallow fished areas and deeper unfished areas, predicted SSB was reduced to 30% of initial SSB (26% at the 10th percentile). Based on the current model, predictions of relative SSB exceed the precautionary limit reference point (i.e. indicating a 90% probability that SSB equals 30% of initial SSB within the next 5 years), which was agreed to be adopted to ensure the sustainability of long-lived and potentially vulnerable Banded Morwong in Tasmanian waters. Based on predictions of the current model, it is unlikely that the biomass of Banded Morwong in Tasmanian waters is depleted and that the current level of fishing mortality will cause the stock to become recruitment impaired. Banded Morwong in Tasmanian waters is thus classified as a sustainable stock.

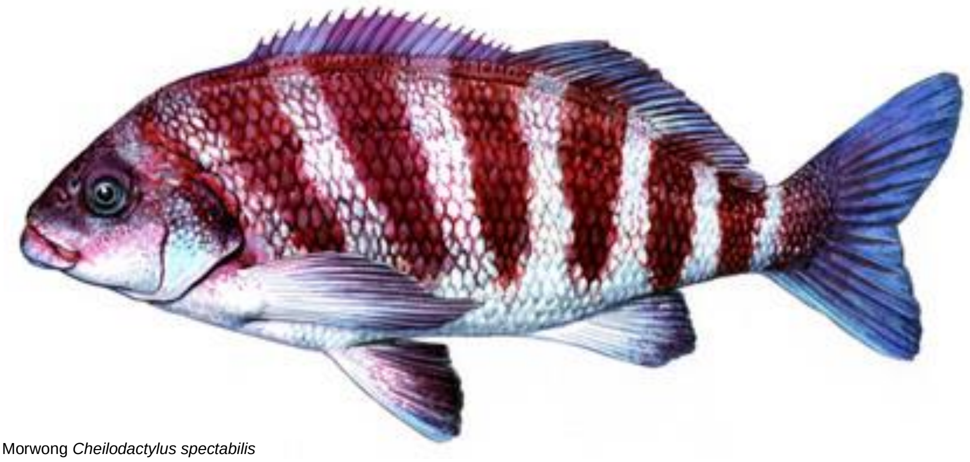
Acknowledgements

This assessment was funded by the NRE Tas and the Institute for Marine and Antarctic Studies (IMAS), University of Tasmania, through the Sustainable Marine Research Collaboration Agreement (SMRCA).

1. Introduction

Species biology

Banded Morwong (*Cheilodactylus spectabilis*; Figure 1) is a large, sedentary fish that inhabits temperate reefs around south-eastern Australia and New Zealand (Gomon et al 1994). In Australia, the species distribution extends from Sydney, through Victorian and Tasmanian waters, to eastern South Australia. The species has occasionally been observed in Western Australia. Banded Morwong are long-lived, and can reach ages of at least 97 years (Ewing et al. 2007). While longevity is similar among sexes, the species displays strong sexual dimorphism in growth, with males growing substantially faster and reaching larger maximum sizes than females (Ziegler et al. 2007a).



Banded Morwong *Cheilodactylus spectabilis*
Source: NRE (by Peter Gouldthorpe)

Figure 1. Banded Morwong, *Cheilodactylus spectabilis*.

The stock structure of Banded Morwong in Australian waters is presently undefined, however observations of a long pelagic larval stage (around 6 months; Wolf 1998) suggests that single genetic stocks may occur over large areas. After settlement, fish are relatively sedentary, with tagging studies indicating little exchange among reefs (Murphy and Lyle 1999) (see Table 1 for a summary of species biology).

Commercial fishery

In Tasmania, Banded Morwong are commercially harvested by a small-scale coastal gillnet fishery. Prior to 1990, the species had little commercial value apart from use as bait by rock lobster fishers (Ziegler et al. 2007a). In the early 1990s a targeted fishery for Banded Morwong started to supply domestic live fish markets, primarily in Sydney and Melbourne. All holders of a Tasmanian Fishing Boat Licence were able to take this species and, as a result, there was a dramatic increase in effort directed at the species, with reported catches peaking at 145 t in 1993/94. Catches fell dramatically in the late 1990s, with 34.6 t landed in 1999/00.

Table 1. Biology of Banded Morwong, *Cheilodactylus spectabilis*.

<table>
<tr><th>Parameters</th><th>Estimates</th><th>Reference</th></tr>
<tr><td>Habitat</td><td>• Rocky reefs down to 50 m depth. Females and juveniles inhabit the shallow section of the reef while males dominate in the deeper section of the reef.</td><td>McCormick (1989a, b)</td></tr>
<tr><td>Distribution</td><td>• South Sydney (New South Wales) through Victoria and Tasmania to eastern South Australia, also in New Zealand.</td><td>Gomon et al. (1994)</td></tr>
<tr><td>Diet</td><td>• Invertebrates, algae, crabs.</td><td>McCormick (1998)</td></tr>
<tr><td>Movement and stock structure</td><td>• Limited movement of juveniles and adults, generally restricted to within 5 km of the release site.
• No information on the stock structure.</td><td>Murphy and Lyle (1999)
Ziegler et al. (2006)
Buxton et al. (2010)</td></tr>
<tr><td>Natural mortality</td><td>• Low. Estimated at $M = 0.05$.</td><td>Murphy and Lyle (1999)</td></tr>
<tr><td>Maximum age</td><td>• Females: 94 years
• Males: 97 years</td><td>Ewing et al. (2007)</td></tr>
<tr><td>Growth</td><td>• Males grow to larger sizes than females
• Growth described by the Schnute and Richards (1990 growth function:
$L = L_{\infty}(1 + \alpha e^{(-at^{c})})^{-\frac{1}{b}}$
where L is the length (mm), t is the age (years), L_{∞} is the average maximum length for the species and α, a, b and c are (year-specific) constants.

• Parameters estimates (for 2007) are:
<table>
<tr><th>Sex</th><th>L_{∞}</th><th>a</th><th>b</th><th>c</th><th>α</th></tr>
<tr><td>Female</td><td>442</td><td>18.8</td><td>3.3e-7</td><td>0.05</td><td>51.4</td></tr>
<tr><td>Males</td><td>516</td><td>2.3</td><td>0.0088</td><td>0.33</td><td>0.1</td></tr>
</table>
• Length-weight relationship for 2007 was estimated at $W = 3.563E^{-5}L^{2.875}$ for females and $W = 3.729E^{-5}L^{2.852}$ for males, where W is weight (g) and L is the fork length (cm).</td><td>Schnute and Richards (1990)

Ziegler et al. (2007a)</td></tr>
<tr><td>Maturity</td><td>• Size-at-50% maturity estimated at 320 mm for females (~2.5 years of age).</td><td>Ziegler et al. (2007a)</td></tr>
<tr><td>Spawning</td><td>• Spawning occurs between mid-February to late May.
• Species is a serial spawner.</td><td>Murphy and Lyle (1999)</td></tr>
<tr><td>Early life history</td><td>• Eggs and larvae are concentrated on the surface.
• Banded Morwong has a pelagic larval stage that is distributed offshore, as suggested by the large amounts of larvae caught off the shelf break of eastern Tasmania.
• Juveniles appear in shallow water on rocky reefs and tide-pools between September and December, after a pelagic phase of 4-6 months.</td><td>B. Bruce, pers. comm.
Wolf (1998)</td></tr>
<tr><td>Gillnet post release survival</td><td>• High: 97% irrespective of gillnet soak duration</td><td>Lyle et al. (2014a)</td></tr>
</table>

Banded Morwong are currently targeted almost exclusively for the live fish market with large mesh gillnets, primarily of 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. Smaller catches have been taken along the south coast and around Flinders Island. While Banded Morwong inhabit depths down to at least 50 m (May and Maxwell 1986), fishing operations are conducted over inshore reefs, with gear set primarily in the 5–20 m depth range, in order to minimise effects of barotrauma and maximise survival for the live fish trade.

The Banded Morwong Fishery in Tasmania is managed using a combination of input and output controls (Table 2). The fishery has undergone numerous management changes over time (summarised in Table 3). The commercial fishery in Tasmania is currently managed as two areas: an area in which individual transferable quotas are used to limit a total allowable catch (TAC; the TAC area), and an area in which it does not (the non-TAC area) (Figure 2). In order to fish for Banded Morwong within the TAC area a person must hold a fishing licence (Banded Morwong) which has uncaught quota units authorised on it. There is no quota management outside the TAC area and any holders of a fishing licence (Banded Morwong) can fish in this region with or without quota authorised to their licence. A temporal closure is in place for 1st March to 30th April in each year, encompassing the species' peak spawning period. The species is subject to keyhole size limits, which are currently set at a minimum legal size of 360 mm fork length (FL) and a maximum legal size of 460 mm FL. A bag limit of two fish and a possession limit of four fish is in place for recreational fishers. For management and assessment purposes, a limit reference point has been agreed to whereby a spawning stock biomass (SSB) of 30% of the initial spawning stock biomass (SSB0) must be exceeded in five years (2026) with a 90% probability. This limit reference point exceed commonly applied thresholds of 20% to account for the longevity and potentially high vulnerability of Banded Morwong.

Table 2. Summary of management controls for Banded Morwong in Tasmanian waters.

FISHING METHODS	Mainly gillnet
MANAGEMENT METHODS	**Input control:** • Gear licence (Scalefish fishing licence) • Species licence (Banded Morwong licence) • Temporal closure (March-April) **Output control:** • Possession limit of 4 and bag limit of 2 individuals for recreational fishers • Minimum and maximum size (360–460 mm fork length) • TAC of 35.8 t for the 2021/22 quota year (representing a single-year increase from 31 t to compensate for COVID impacts)
MAIN MARKET	Interstate

The quota management system with a TAC was introduced in late 2008. Up to and including the 2015/16 quota year, a given number of fish were allocated to each quota unit and the tonnage associated with the TAC was inferred based on an assumed average weight of 1.3 kg per fish. From 2016/17 onwards, quota has been set in weight. Until 2017/18, the TAC has undergone a staged reduction since 2012/13 (Table 4). As a response to the unusually high under-catch in 2020/21 and 2021/22 due to COVID-19 pandemic-related market forces, the TAC for 2021/22 and 2022/23 was set at 35.8 t following consultation with fishers at the Banded Morwong stakeholder forum and relevant Scalefish Fishery Advisory Committee meetings in 2021. It was agreed that this TAC increase would not extend past 2022/23, and would resume at 31 tonnes thereafter, contingent on future modelling results.

Post-release survival of Banded Morwong under current maximum permitted gillnet soak durations is very high (Lyle et al. 2014a). Gillnetting was considered a medium risk activity to Banded Morwong populations in the Ecological Risk Assessment (ERA) of Bell et al. (2016), with the authors recognising that current management arrangements (namely the TAC and individual catch quotas) have the objective of gradually rebuilding biomass.

Table 3. Management changes in the Tasmanian Banded Morwong Fishery over time (from DPIPWE 2017).

Date	Management changes
Pre 1987	Unrestricted access to Tasmanian Fishing Boat Licences (TFBL); unlimited access to scalefish and shark using all gear types; no restrictions on the amount of gillnet net that could be used; and unrestricted access to all other gear types (i.e., beach seine, purse seine, dipnet, squid jig, fish traps, small mesh gillnets, mullet nets, longlines, droplines and spears).
1987	Tasmanian Fishing Boat Licences were capped at 850.
1990	Restricted gillnetting in Shark Nursery Areas (SNAs). Commercial access to SNAs is limited to holders of non-transferable endorsements (38 endorsees).
31 May 1994	Ministerial warning issued explaining that any catches of Banded Morwong and wrasse taken after that date would not be used towards catch history, should previous catches be used to determine future access to the live fishery.
1994	Minimum size limit of 330 mm fork length and maximum size limit of 430 mm fork length introduced for Banded Morwong.
1995	An annual closed season in March and April was introduced to coincide with the peak spawning period of Banded Morwong.
1996	An interim non-transferable 'live fish' endorsement to take Banded Morwong and wrasse was introduced. Eligibility was based on a demonstrated history of taking one or both species (at least 50 kg between 1 January 1993 to 31 May 1994), and around 90 endorsements were issued.
November 1998	Introduction of a species-specific licence for the Banded Morwong Fishery (live or dead) in State waters. There were 29 licences issued. The minimum size limit was increased to 360 mm and the maximum size limit increased to 460 mm fork length.
November 2001	A daily bag limit of two fish was introduced for recreational fishers.
November 2004	The recreational bag limit of two fish was changed to a personal possession limit of two fish.
October 2008	Introduction of a quota management system for east coast waters from Low Head to Whale Head (excluding the Furneaux Group). A total of 1,169 Banded Morwong quota units were issued.
July 2009	An additional 24 Banded Morwong quota units were issued following a review of a quota allocation, bringing the total number of units to 1,193.
November 2009	Introduction of a 6-hour soak time for commercial gillnets
March 2011	Introduction of the Commercial Banded Morwong Quota Docket for all Banded Morwong fishers.
November 2015	New gillnet free areas for the protection of seabirds such as little penguins (applies to both commercial and recreational gillnets). Bag and possession limits were revised for the recreational fishery – bag limit of two individuals and possession limit of four individuals. New quota management arrangements for the Banded Morwong Fishery introduced as it moved from a number- to a weight-based quota management system for the 2016/17 quota year.
May 2017	New Commercial Banded Morwong Quota Docket and new Commercial Catch, Effort and Disposal Logbook for all Banded Morwong fishers.

Table 4. Total Allowable Catch (TAC) in the Tasmanian Banded Morwong Fishery since 2012/13.

Quota year	TAC (in t)	TAC (in no. fish)	No. of Fish/Quota Unit	kg / Quota Unit
2012/13	38.8	29,825	25	-
2013/14	37.2	28,632	24	-
2014/15	35.7	27,439	23	-
2015/16	35.7	27,439	23	-
2016/17	32.2	N/A	-	27
2017/18	31.0	N/A	-	26
2018/19	31.0	N/A	-	26
2019/20	31.0	N/A	-	26
2020/21	31.0	N/A	-	26
2021/22	35.8	N/A	-	30
2022/23	35.8	N/A	-	30

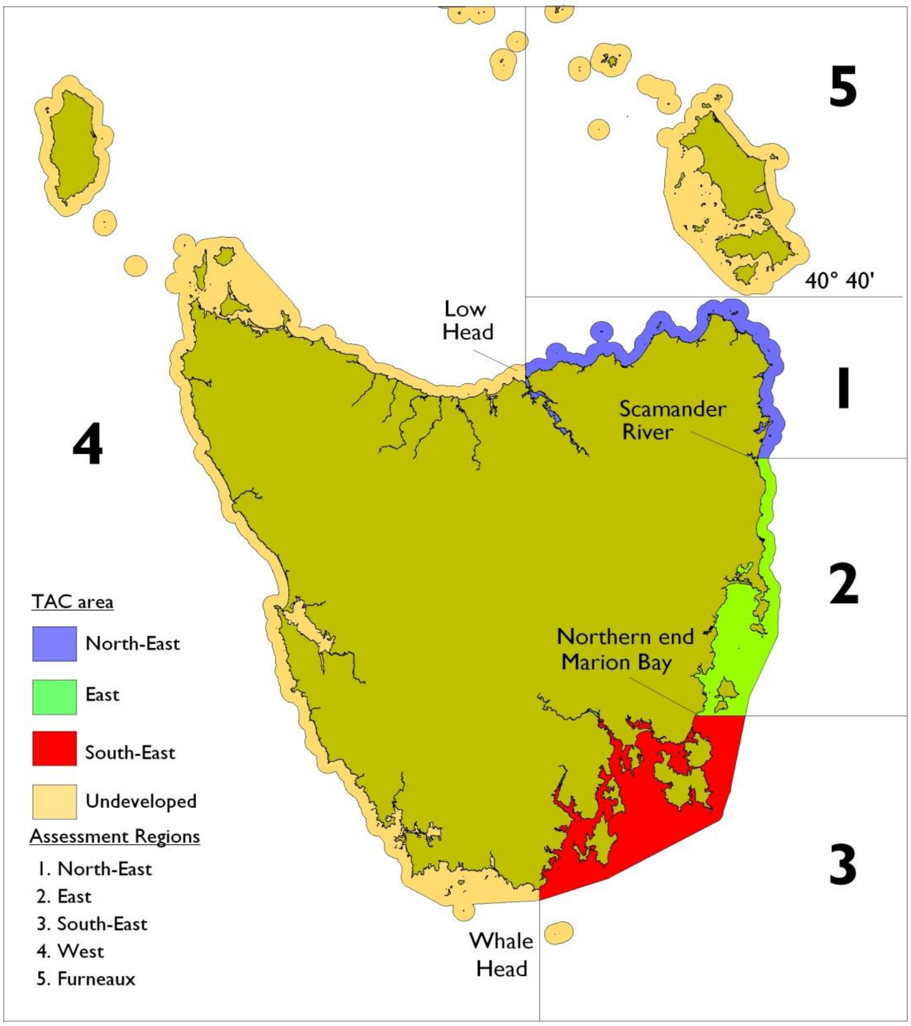


Figure 2. Designated TAC area (areas 1, 2, and 3) and assessment regions for Banded Morwong from Low Head on the north coast to Whale Head in the south. Assessment regions 4 and 5 are currently undeveloped.

Recreational fishery

Banded Morwong are a relatively minor component of the recreational fishery in Tasmania. The most recent survey in 2017/18 estimated the recreational landings of Banded Morwong at 2 tonnes (1,522 fish), making up slightly more than 5% of the total catch (commercial + recreational) during that season (Lyle et al. 2019). A total of 298 individuals were estimated as retained in the 2012/13 recreational fishing survey of Lyle et al. (2014b), equating to a total harvest of 0.5 tonnes, or around 1% of the total Banded Morwong landings for that year. An estimated 1,082 Banded Morwong were retained in 2010 (Lyle and Tracey 2012), representing almost 4% of total Banded Morwong landings in that year. No species-specific catch estimates for Banded Morwong were available in the two previous recreational fishing survey reports (Lyle 2005, Lyle et al. 2009).

2. Methods

Data sources

Biological characteristics

A sampling program commenced in 1995 to obtain biological information, in particular size and age composition, to inform assessments for Banded Morwong. Sampling was conducted annually in 1996, 1997 and between 2001–2005, then every second year from 2007 onwards (i.e., 2007, 2009, 2011, 2013, 2015, 2017, 2019, 2021). In this sampling program, fish are collected during the spawning closure by commercial fishers working under permit and contracted to the Institute for Marine and Antarctic Studies. Sampling sites and general fishing practices (including the use of standard commercial ‘Banded Morwong nets’) have been standardised as much as possible. Approximately 400 fish were collected in each sampling year. For each fish collected, FL (to the nearest 1 mm) and weight (to the nearest 1 g) were measured, and the pair of sagittal otoliths (hereafter otoliths) were removed, cleaned, and stored dry in plastic vials. Gonads were dissected, weighed (to the nearest 0.1 g), sexed and staged macroscopically according to West (1990). As sampling was not conducted in 2022, only the results of the sampling program up to 2021 are included here.

Commercial fishery data

Commercial catch and effort data are collected through compulsory Tasmanian Commercial Catch, Effort and Disposal Returns. The catch and effort logbooks have been amended several times (1995, 1999, 2007, 2010, 2013 and 2019) in an effort to report at finer spatial scales and provide greater operational detail. While the offshore fishing blocks are still at the 30 nm (1/2 degree) spatial resolution, the logbooks introduced in 2010 have redefined the scale of the coastal blocks (Figure 3).

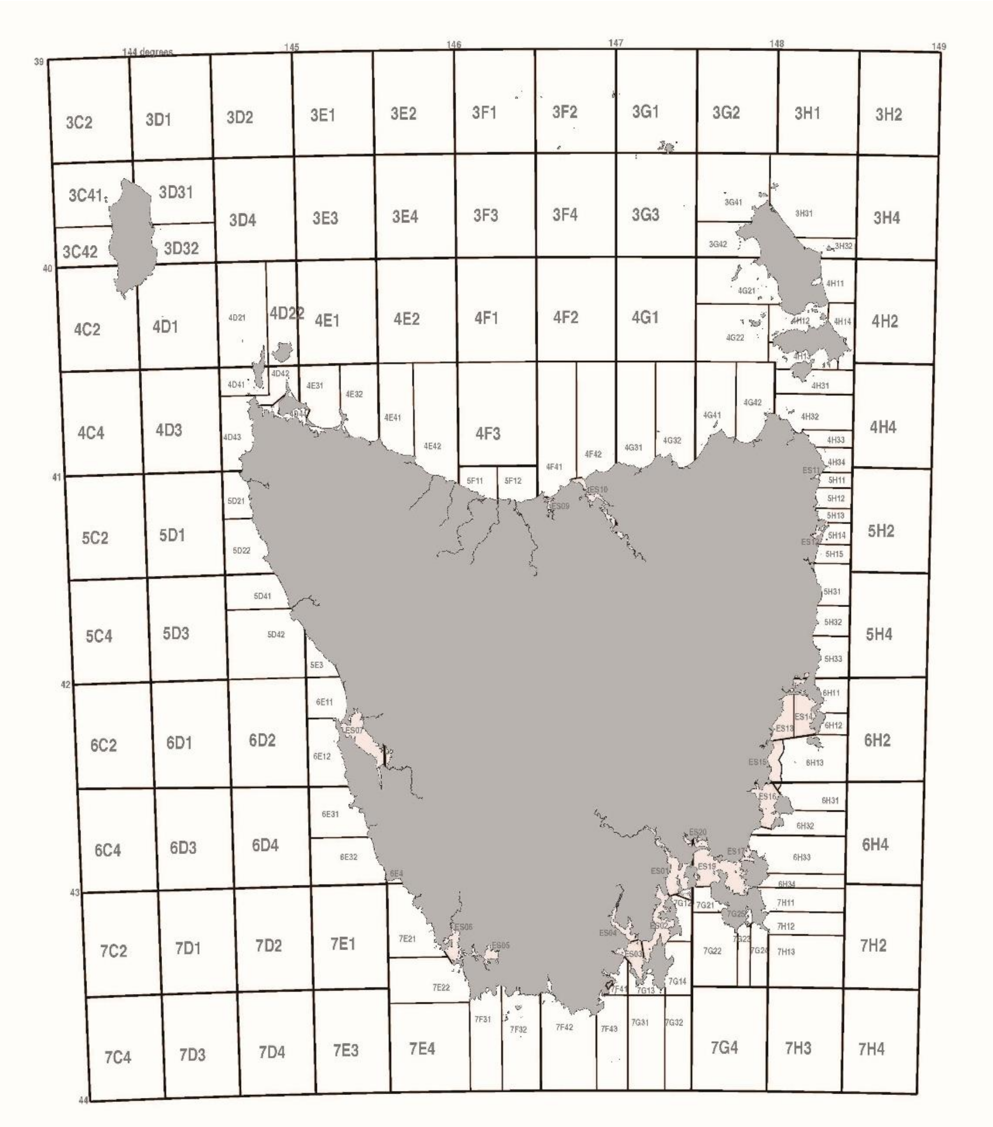


Figure 3. Map of Tasmania displaying the fishing blocks.

Data analysis

Biological characteristics

Length and age frequency plots were developed for each sampling year. Sex and sampling-year specific patterns in growth of Banded Morwong were modelled using a modified version of the Schnute and Richards (1990) growth function fitted by nonlinear least-squares regression of FL on age. A sample of six recently settled juveniles collected from Bicheno in 1996, estimated to be around 6 months old, were used to anchor the growth functions for all years and sexes.

Generalised linear mixed-effect models (GLMMs) were used to model the length at maturity of female Banded Morwong. Maturity state (immature or mature) was treated as a binomial response variable with logit link function and modelled as a function of FL. Area (i.e., TAC Areas 1, 2 and 3; Figure 2) was modelled as a random effect term in all models to eliminate potential bias or pseudoreplication resulting from the non-independence of samples collected within the same area. Due to low numbers of immature females in the samples, sampling years were combined as follows: 1996–1997, 2001, 2002–2003, 2004–2005, 2011 & 2013, 2015 & 2017 & 2019, and 2021. Samples collected in 2007 and 2009 were excluded due to small numbers of immature females.

Catch and Effort

For the purposes of this assessment, catch, effort and catch per unit effort (CPUE) analyses are restricted to commercial data provided for the period March 1995 to February 2022. The assessment year for Banded Morwong is based on the quota year (1st March to the last day of February the following year) rather than the financial year (July to June) as for other scalefish species. The current Banded Morwong assessment includes data up to and including the 2021/22 quota year (which ended 28 February 2022).

Under the quota management system, commercial catches prior to 2016/17 were reported as numbers of fish rather than weight. These numbers were converted to weight based on a conversion ratio of 1.3 kg per fish. In addition, and particularly prior to the introduction of the quota management system, fish were landed in a variety of forms, including gilled and gutted, trunked, and filleted. In these instances, the equivalent whole weight was estimated by applying a standard conversion factor[1].

Two measures of effort have been examined in this and previous assessments: (i) days fished (i.e., number of days on which a catch of Banded Morwong was reported); and (ii) quantities of gear/time fished using the method (effort gear units). For gillnets (the main fishing method for Banded Morwong), effort gear units are measured in 100 m 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. No fishing records for 2021/22 needed to be excluded in this manner.

Catch per unit effort

In the Banded Morwong Fishery, the amount of gear set and the fishing duration is recorded by fishers, however these data have not been reported consistently over time and among fishers. Accordingly, for the purposes of this assessment, CPUE is calculated using days fished as a measure of effort. Previous work has shown that this is highly correlated with CPUE derived from using gear and soak time where that data is reliably available (IMAS unpublished data).

Following Ziegler et al. (2007b), CPUE for Banded Morwong was standardised in order to remove the influence of confounding effects such as area, depth, season and operator on relative trends in abundance. CPUE was standardised using general linear models (GLMs). Standardisation of CPUE was conducted for an annual time scale, and at four spatial scales (whole of TAC area, and individual north-east, east and south-east areas within the TAC area). Data were restricted to skippers who had reported catches for at least two years.

The GLMs were fitted to different combinations of factors for which information were available, namely skipper, vessel, fishing block, depth zone fished (0–10 m, 11–20 m, 21–30 m, > 30 m), bimonthly period and reported seal interactions (presence or absence). A bimonthly period rather than month was included as a temporal factor to ensure there were sufficient records in each period to give reliable results. Due to the annual spawning season closure in March and April, five bimonthly periods were available for each year. Interaction terms between some of the factors were also considered, but these were limited to combinations for which sensible interpretations could be ascribed.

Standardised CPUE were fitted to natural log-transformed (Ln) catch rate data (assuming a lognormal distribution), using a normal distribution family with an identity link. All GLMs were fitted using a forward approach by manual stepwise addition of each factor starting with the time-step. The optimal model was chosen by minimisation of the Akaike's Information Criterion (AIC;

[1] Conversion factors to whole weights are 2.50 for fillet; 1.50 for trunk; and 1.18 for gilled and gutted.

Burnham and Anderson 1998). Adding new data from 2021/22 resulted in the same model selection as in the 2020/21 assessment (Table 5).

Table 5. General Linear Models (GLMs) used to standardise catch per unit effort of Banded Morwong across the whole TAC area in the 2021/22 assessment, and in Area 1 (north-east coast), Area 2 (east coast) and Area 3 (south-east coast) as defined in Figure 2. Ln = natural log.

TAC Area	Model
Whole TAC area	Ln CPUE = Lnweight ~ BMWyear + Vessel + bimonth + seals + Block + depth + ClientID + Vessel:Block
North-East	Ln CPUE = Lnweight ~ BMWyear + Vessel + bimonth + seals + Block + depth + bimonth:Vessel
East	Ln CPUE = Lnweight ~ BMWyear + Vessel + bimonth + seals + Block + depth + ClientID + bimonth:Vessel
South-East	Ln CPUE = Lnweight ~ BMWyear + Vessel + bimonth + Block + ClientID + seals + Vessel:seals

Stock modelling

Model structure

The 2021/22 assessment was conducted using the Banded Morwong population model implemented in CASAL v 2.30 (Bull et al. 2012). The CASAL framework is widely used for fisheries assessments, including several New Zealand fish stocks. The implementation of the Banded Morwong model in CASAL is mathematically equivalent to the previous model used to assess Banded Morwong stocks developed by Ziegler et al. (2007b). The model for the 2021/22 assessment was updated with catch and CPUE information, and a minor adjustment to the treatment of growth information (Table 6). The spatial configuration, key dynamical processes, and migration rate assumptions in the current model are illustrated in Figure 4. The model is split into two areas, inshore and offshore, and separates processes into two time-steps per year to reflect a 10-month fishing period and a 2-month no-fishing period during the estimated spawning period. The model was run for the entire TAC area instead of each of the three sub-areas individually. This is consistent with recent assessments of Banded Morwong, which have stressed that a greater emphasis should be placed on the whole quota region for TAC setting purposes.

Because the distribution of Banded Morwong extends beyond the depth of the fishery, there is the potential for a component of the TAC area 'stock' to be located in a depth refuge (safe from fishing mortality). The model accounted for this by specifying a fished portion of the stock inshore and an unfished portion offshore. In recent assessment years, the model has consistently estimated that approximately 50% of the adult stock resides in the depth refuge. An alternative, single area, version of the model was also run that does not assume 50% of the adult stock is exempt from fishing pressure. This model configuration estimates spawning stock biomass (SSB) based on the more conservative assumption that individuals escape any risk of fishing mortality solely based on their size (through fishing selectivity and upper size limits), rather than the area in which they reside. Other than this difference, the single area model is identical to the standard, two area model. Estimated SSB from both model configurations are presented in section 3.

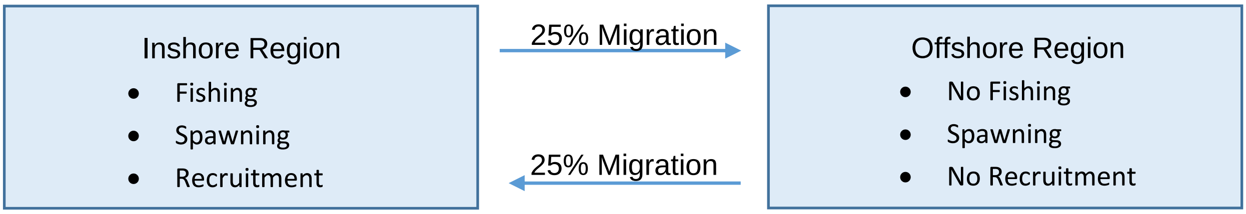


Figure 4. Diagram of spatial configuration of the two-area model implemented in CASAL. The Offshore Region represents a depth refuge where fish avoid exploitation. Migration rates are assumed to be 25% annually from Inshore to Offshore and vice versa. Spawners are assumed to be present in both regions and recruitment to only occur Inshore.

Data weighting of CPUE was performed using the Francis Method (Francis, 2011). Data weighting is a formal method for balancing the relative impact of different data sources in a statistical model. The data weighting procedure developed by Francis (2011) (i.e., the Francis Method) is the accepted method for weighting both CPUE and age composition data in a fishery stock assessment. While both these data types are included in the Banded Morwong model, the Francis Method has only been applied in recent assessments (since 2017/18) and only for CPUE data.

Model inputs

Biological components: Sex-specific lengths-at-ages 1–16 were modelled using the Schnute and Richards (1990) growth function across all fishery areas during the years when biological sampling was conducted (1990–1998 (='1990' in model), 1999–2001 (='1999' in model), 2002–2003 (='2002' in model), 2004–2006 (='2004' in model), 2007, 2009, 2011, 2013, 2015, 2017, 2019, 2021). Early sampling years were aggregated based on similar growth trends and to ensure a large enough sample size following Ziegler et al. (2007b). Interpolated growth was assumed for non-biological sampling years within the time series and extrapolated from the most recent sampling year for projected years. Sex-specific patterns in age-at-maturity were modelled using a logistic function fit to gonad stage. Natural mortality was assumed to be constant across sex, age, and time at M = 0.05.

Consistent with preceding assessments, the fishing selectivity-at-length was assumed to follow a knife-edge curve, selecting fish of both sexes between lengths 360 and 460mm with 100% probability. This selectivity function is a rough approximation to the true selectivity, reflecting the keyhole size limit currently in place for the commercial fishery. The survey selectivity-at-length was specified to follow a dome-shaped curve that reflects every fish retained using a net identical to the commercial net (Murphy and Lyle, 1999). The model converts these selectivity-at-length specifications to sex-specific selectivity-at-age using the length-at-age data.

Fishery (harvest) components: Annual total catches within the TAC area for the period 1990/91–2021/22 and standardised CPUE (described above) for the period 1995/96–2021/22 were used in the model. Catchability was estimated in the model from the relationship between observed CPUE and exploitable biomass.

Recruitment: Recruitment was modelled to occur at the start of each year and was assumed to be equal between males and females and occur uniformly along the entire coastline of the modelled area. All recruitment in the model was assumed to occur to inshore populations, consistent with observations of juvenile Banded Morwong in inshore shallow waters and a gradual outward migration with increasing size (Leum and Choat 1980; McCormick 1989b). Recruitment year class strength (YCS) was estimated in the model from the survey age composition data. The mean and variability from YCS estimates during the period 1986-2017 were resampled by the model to project SSB into the future.

Model outputs

The model was used to estimate SSB trajectories within the TAC area from the start of the fishery to present, and into the future assuming a total allowable catch of 31 t at a unit value of 26 kg / quota unit with the exception of assumed catch for the ongoing 2022/23 season. The TAC for the 2022/23 season is set at 35.8 t to account for a portion of the TAC under-catch in 2020/21 and 2021/22. Model fits to the CPUE (Figure 14) and age composition (Figure 15) indices were evaluated by visual inspection and examination of residuals.

Model review

An external review of the assessment model supporting our evaluation of stock status was performed in May 2022 by a stock assessment expert at the Centre for Environment Fisheries and Aquaculture Science (CEFAS) in the UK. The purpose of the review was to identify key areas of model improvement that could facilitate more accurate and precise estimates of biomass and acquire advice on how best to implement the suggested improvements. The review was requested to ensure the assessment model is in line with current best-practices used by assessment scientists internationally. The review was based on the 2020/21 configuration of the model, which included the changes implemented from our internal model review described in previous assessment reports (see reports from 2019/20 and 2020/21).

The major suggestions from the external review included acquiring more data to justify the two-area model and migration rates between areas, reviewing the source and treatment of fishing selectivity specified in the model, and investigating the impact of applying data weighting to all data sources. Additional suggestions included reviewing and updating the assumptions around the stock recruitment relationship and natural mortality for Banded Morwong. The external review thereby confirmed areas of improvement already identified by the internal review. Chiefly among them is the assumption of an offshore region with a migration rate that allows for a large proportion (~50%) of the population to be protected from fishing pressure. Considering this, the one area model will continue to be reported to stakeholders alongside the traditional two area model to adhere to the precautionary approach until research on population biomass and exchange between shallow and deeper reef habitats has been completed. The suggestions from the external review will be further addressed in 2022/23 when additional biological survey data will also become available.

Table 6. Changes made to the Banded Morwong assessment model data inputs since 2020/21.

Year	Type	Alteration
2021/22	Data inputs	Inclusion of catch and standardised CPUE data for 2021/22
	Model parameters	Update the cv on CPUE time series using the Francis (2011) method
		Apply annual proportion of growth according to time step assumptions: 10 months in first time step, 2 months in second time step.

Assessment of stock status

Stock status definitions

In order to assess the Banded Morwong Fishery in a manner consistent with the national approach (and other jurisdictions) we have adopted the national stock status categories used in the Status of Australian Fish Stocks (SAFS) reporting (Table 7). These categories define the assessed state of the stock in terms of recruitment impairment, which is often treated as a limit reference point. Depleted stocks are not generally collapsed but they do have reduced productivity. The scheme used here does not attempt to assess the fishery against any target outcomes.

Performance indicators and reference points

The determination of stock status is based on the consideration of model outputs and the commercial catch and effort data, which are assessed by calculating fishery performance indicators and comparing them with the limit reference point (SSB of 30% of initial SSB must be exceeded in five years (i.e., 2026 for the current assessment) with a 90% probability).

Other measures are also taken into consideration in the determination of stock status such as changes in biological characteristics of the stock, indicators of stock stress and significant external factors related to fishing activity.

Table 7. The stock status classifications that were adopted for this assessment.

Stock status	Description	Potential implications for management of the stock
SUSTAINABLE	Biomass (or proxy) is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (recruitment is not impaired) and for which fishing mortality (or proxy) is adequately controlled to avoid the stock becoming recruitment impaired.	Appropriate management is in place.
RECOVERING ↑	Biomass (or proxy) is depleted and recruitment is impaired, but management measures are in place to promote stock recovery, and recovery is occurring.	Appropriate management is in place, and there is evidence that the biomass is recovering.
DEPLETING ↓	Biomass (or proxy) is not yet depleted and recruitment is not yet impaired, but fishing mortality (or proxy) is too high (overfishing is occurring) and moving the stock in the direction of becoming recruitment impaired.	Management is needed to reduce fishing mortality and ensure that the biomass does not become depleted.
DEPLETED	Biomass (or proxy) has been reduced through catch and/or non-fishing effects, such that recruitment is impaired. Current management is not adequate to recover the stock, or adequate management measures have been put in place but have not yet resulted in measurable improvements.	Management is needed to recover this stock; if adequate management measures are already in place, more time may be required for them to take effect.
UNDEFINED	Not enough information exists to determine stock status.	Data required to assess stock status are needed.

3. Results

Biological characteristics

Length frequency composition

Significant changes in the length frequency composition between the late 1990s and the early 2000s raised concerns about the Banded Morwong stock (Figure 5 and Ziegler et al. 2007a). Female fork length was concentrated in the centre of the legal size limits in the 1990s and has since shifted to concentrating near the lower size limit (Figure 5). On the other hand, the length frequency of males has remained similar across survey years, with a consistent proportion of males larger than the upper size limit from the 1990s to present.

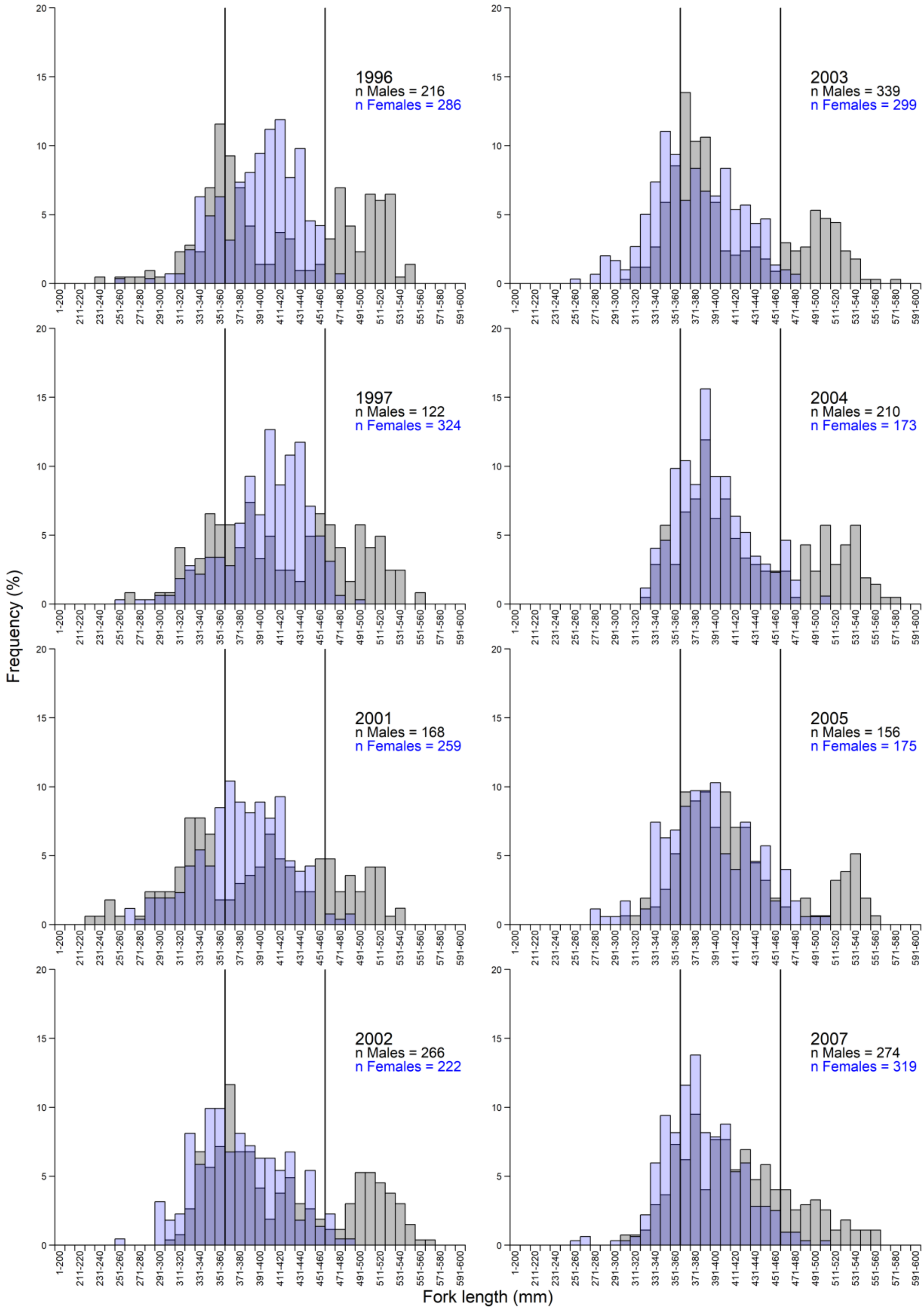


Figure 5. Length composition of sampled Banded Morwong by year for females (transparent blue) and males (solid grey). Dark blue represents overlap between transparent blue and solid grey. The year is the year in which sampling was conducted and 'n' is the sample size of each sex. The solid vertical lines represent minimum and maximum size limits of 360mm and 460mm respectively.

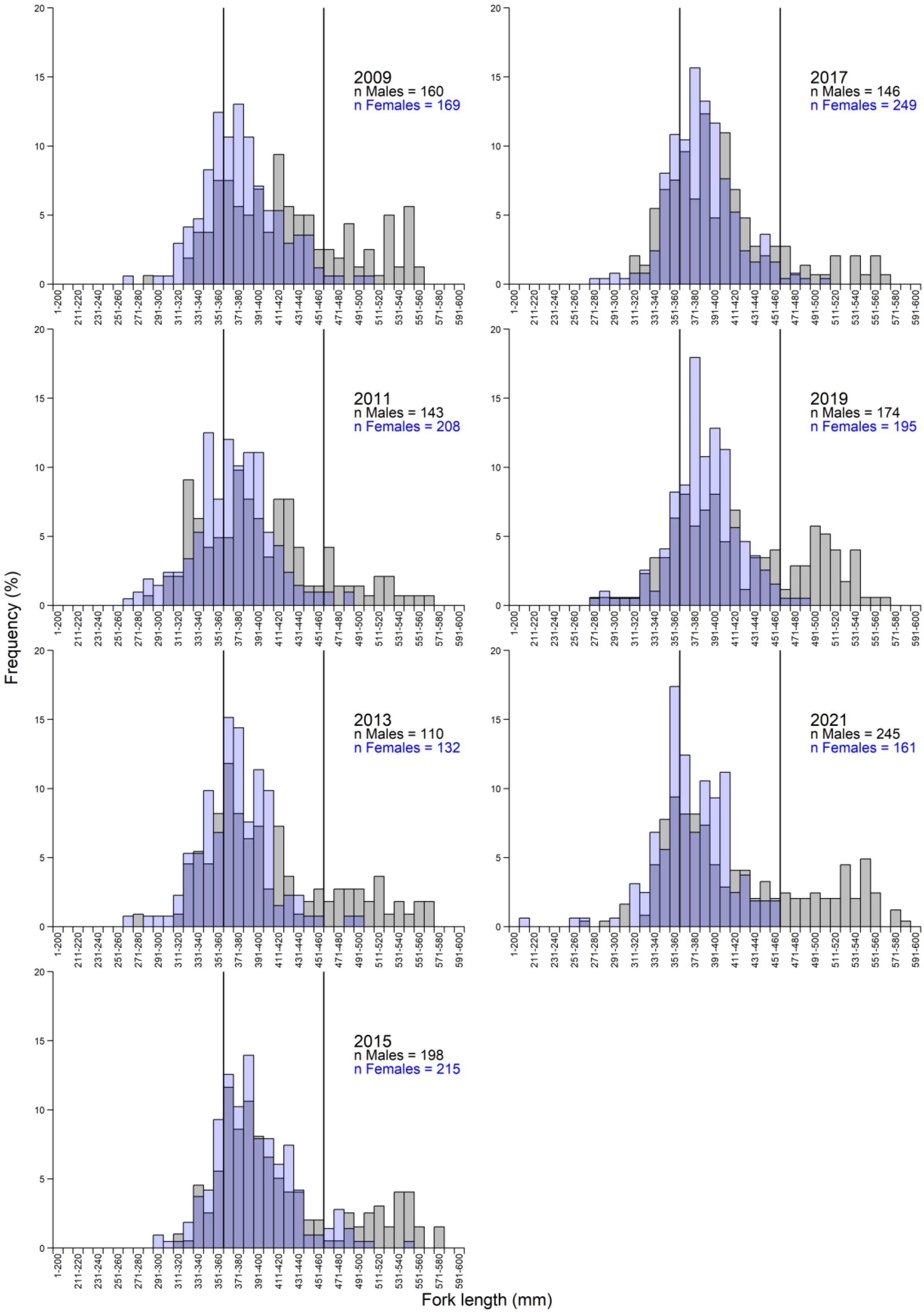


Figure 5. - continued.

Age frequency composition

Age frequency composition also showed signs of change from the late 1990s (Figure 6 and Ziegler et al. 2007a). The age structure shifted from a wide distribution of ages in both females and males in the late 1990s to a concentrated distribution towards younger fish, with very few individuals exceeding 15 years old. By the 2010s, the distribution has increased slightly but remains concentrated towards younger fish compared to the 1990s. Specifically, female fish exceeding 25 years old were common in the 1990s, making up nearly half of the sampled age composition. Since the early 2000s, female fish rarely exceed 25 years, and the bulk of their composition is now concentrated at young fish. Male composition has also decreased, but to a lesser degree compared to females. There were fewer males originally exceeding 25 years in the late 1990s compared to females, and the bulk of their composition has remained closer to those values. The difference between the change in composition in females compared to males is summarized by the change in their average age over time (Figure 7). The average age of females in the survey samples has decreased from approximately 25 years in the 1990s to a stable average of 10 years between 2009 and 2021. The average age of males has remained comparatively stable since the 1990s, remaining between 8 and 15 years through to 2021.

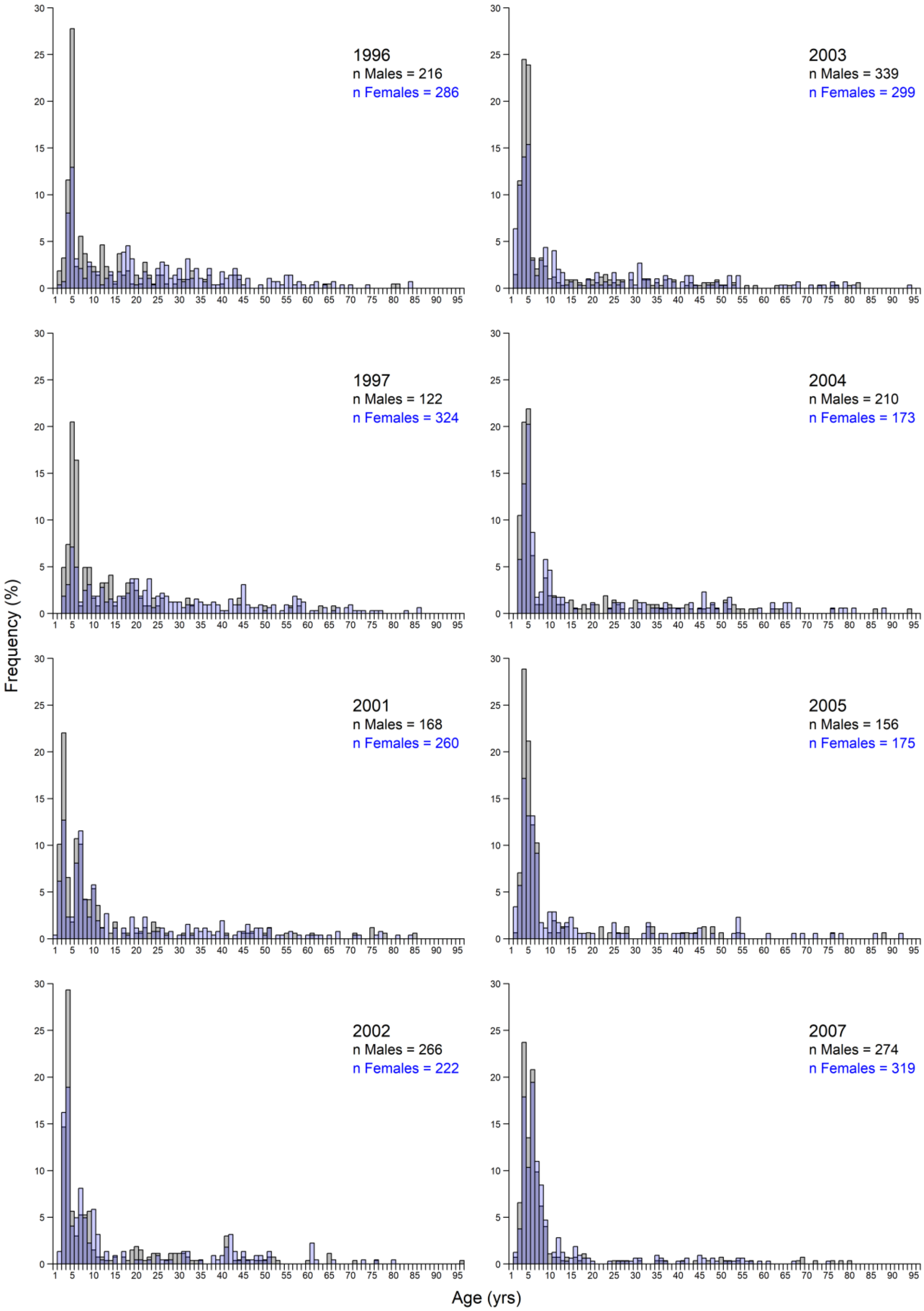


Figure 6. Age composition of sampled Banded Morwong by year for females (transparent blue) and males (solid grey). Dark blue represents overlap between transparent blue and solid grey. The year is the year in which sampling was conducted and 'n' is the sample size of each sex.

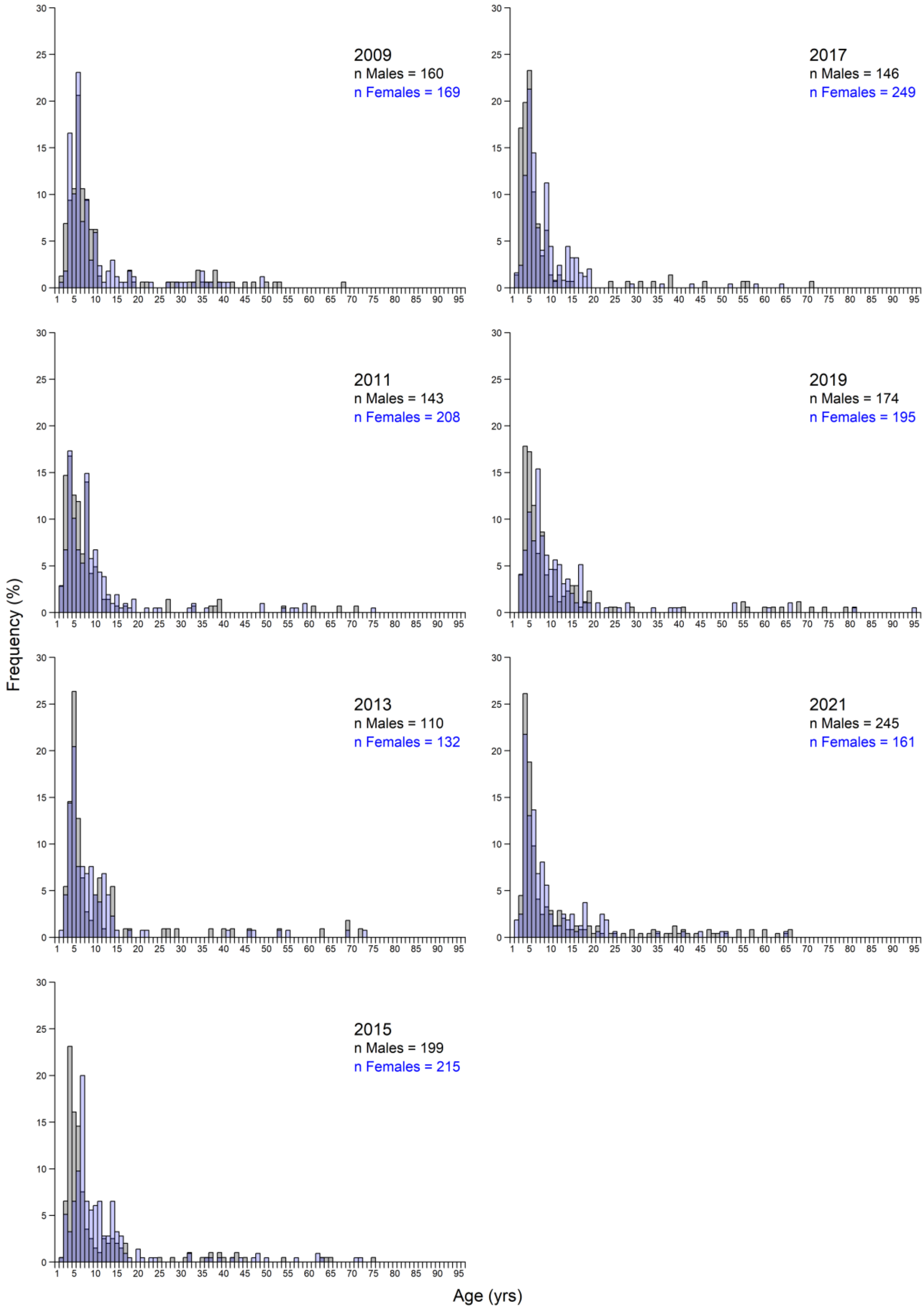


Figure 6. – continued.

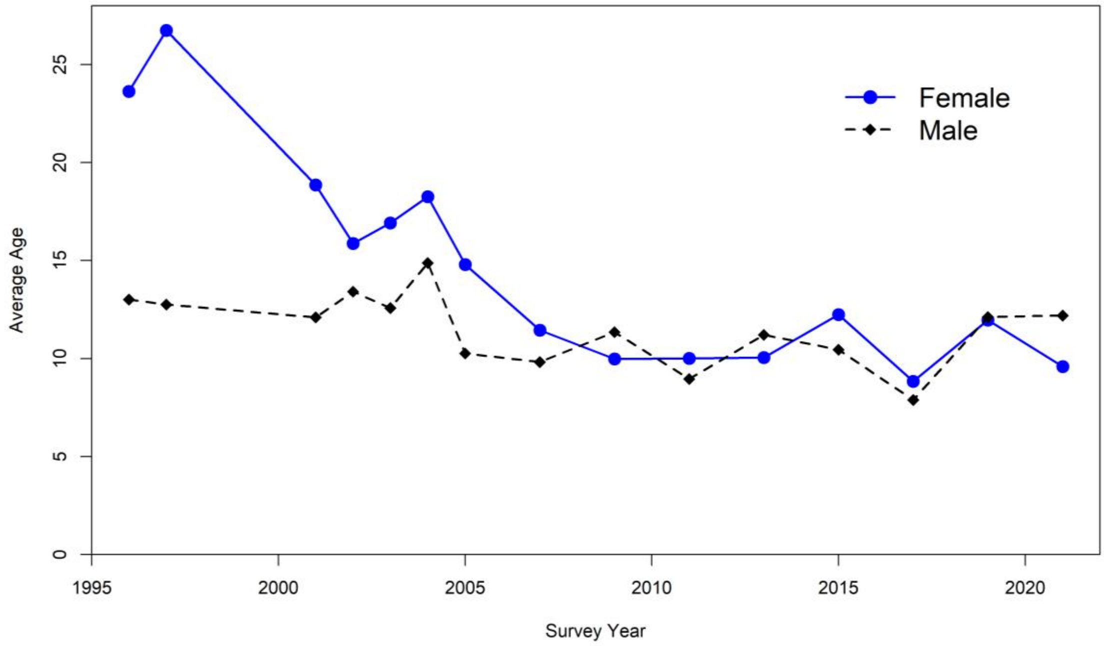


Figure 7. Average age of female (blue solid line) and male (black dashed line) fish from survey samples. Average age of females has decreased since surveys began in 1996 but average age of males has stayed relatively constant.

Growth rates

Growth functions fitted to the length at age data provided evidence for fluctuations in growth over the sampling period (Figure 8). Based on initial sampling between the early 90's and 2007, previous studies found that growth rates for Banded Morwong younger than 10 years old increased through time, possibly indicating impacts of fishery-induced evolution (Ziegler et al. 2007a). However, since 2007, growth rates have fluctuated between 1990 and 2007 levels, suggesting that environmental effects could be another important driver of interannual variation in growth rates. For example, variation in sea surface temperature is a demonstrated driver of fluctuations in fish size (Audzijonyte et al. 2020).

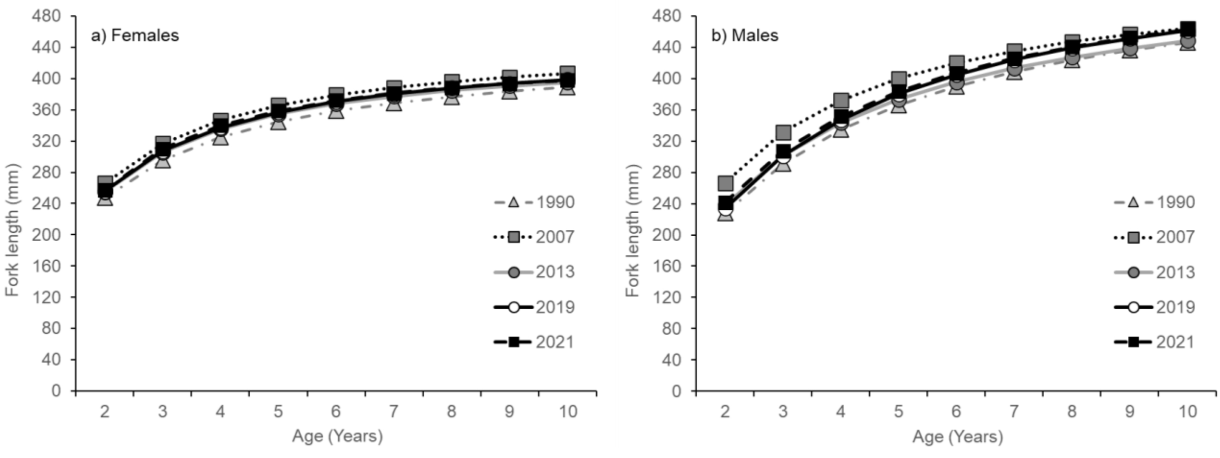


Figure 8. Predicted lengths for female (left) and male (right) Banded Morwong aged 2–10 years from the Schnute and Richards (1990) growth model for samples collected in 1990, 2007, 2013, 2019, and 2020.

Length at female maturity

Fluctuations in the length at which female Banded Morwong mature are evident among sampling years. Length at 50% maturity declined from around 325 mm in 1996–1997 to around 315 mm in 2001, and to below 305 mm in 2002–2003 (Figure 9; Ziegler et al. 2007a). In 2004–2005 length at maturity returned to a similar level to that observed in 1996–1997, a result Ziegler et al. (2007a) attributed to increased length at age by 2004–2005. Length at maturity decreased again after 2005, with 50% of females maturing at around 316 mm in 2011–2013 and 310 mm in 2015–2019. In the latest survey in 2021, length at maturity increased again to around 320 mm.

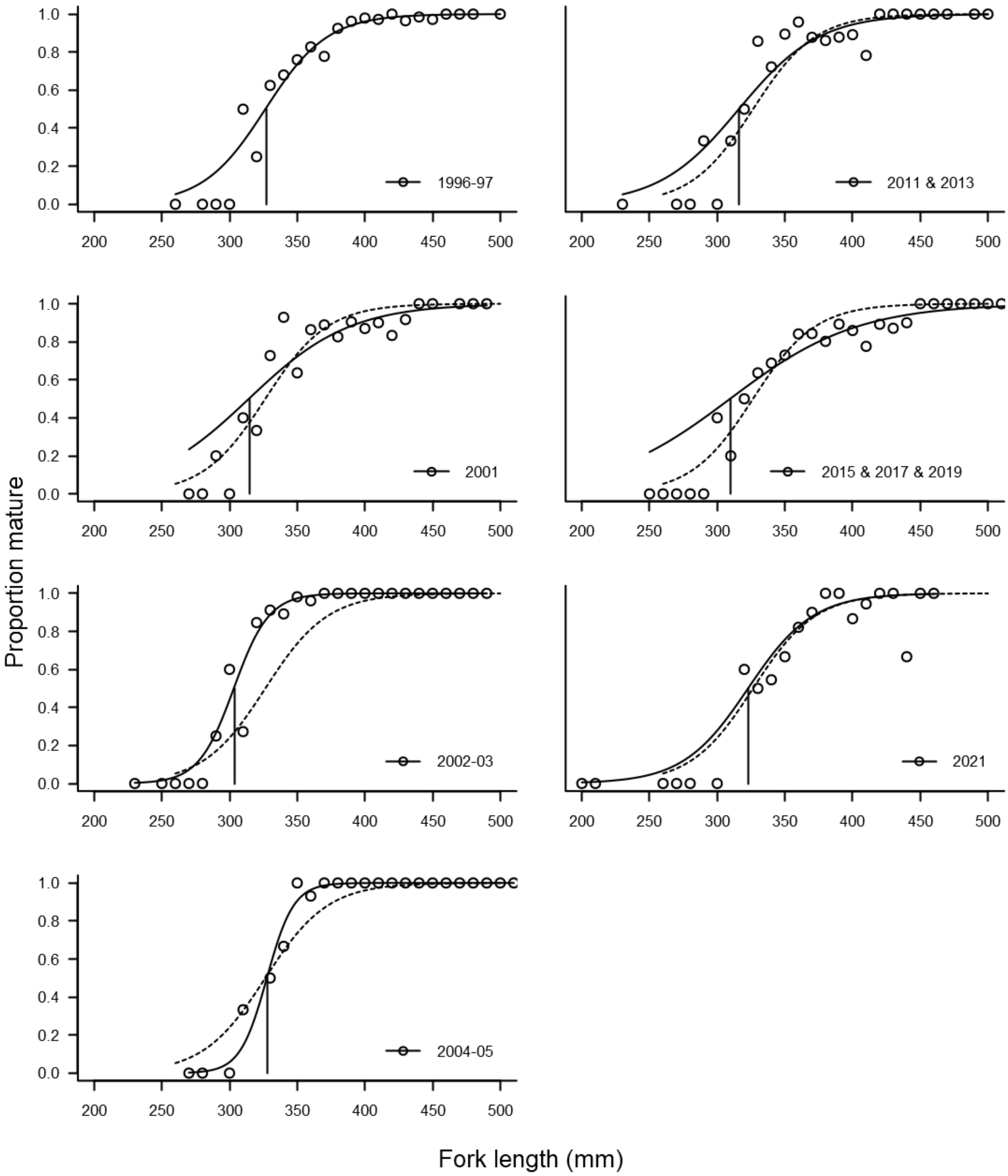


Figure 9. Predicted proportion of mature female Banded Morwong from generalised linear mixed-effects models examining the effect of fork length and sampling period on maturity. Circles represent the proportion of mature females in each 10 mm length class. Data were pooled into the period 1996–1997, 2001, 2002–2003, 2004–2005, 2011 & 2013, 2015 & 2017 & 2019, and 2021. The model fitted to the 1996–1997 data is shown in plots for subsequent sampling years as a dashed line as a reference. The solid vertical line represents the length at 50% maturity. Note data collected in 2007 and 2009 were excluded due to small numbers of immature individuals.

Catch, effort and catch rates

Catch and effort

State-wide commercial catches have been relatively stable since the introduction of the quota system in 2008/09, and in 2021/22 were estimated at 26.8 t (Figure 10). The total catch in the TAC area (Areas 1–3 in Figure 2) in 2021/22 was 24.4 t (comprising 1.7 t from the north-east coast (NEC; Area 1), 10.8 t from the east coast (EC; Area 2) and 11.9 t from the south-east coast (SEC; Area 3), which represented 68.2% of the 2021/22 TAC of 35.8 t (i.e., a TAC under-catch of 31.8%). Catches on the north-east and south-east coasts decreased relative to 2020/21 whereas they increased on the east coast (Figure 10). The unusually high under-catch was due to the deflated market condition related to the COVID-19 pandemic in 2020/21 and 2021/22. The total catch in the non-TAC area (Areas 4 and 5 in Figure 2) in 2020/21 was 2.3 t. The most recent estimate of recreational catch during the 2017/18 season was 2 t (Lyle et al. 2019).

In 2021/22 State-wide effort in both days fished and gear units (100 m net hour) increased relative to 2020/21 (Figure 11). Effort (in days fished) decreased on the north-east coast relative to 2020/21 but increased on the east and south-east coasts (Figure 11; Figure 12).

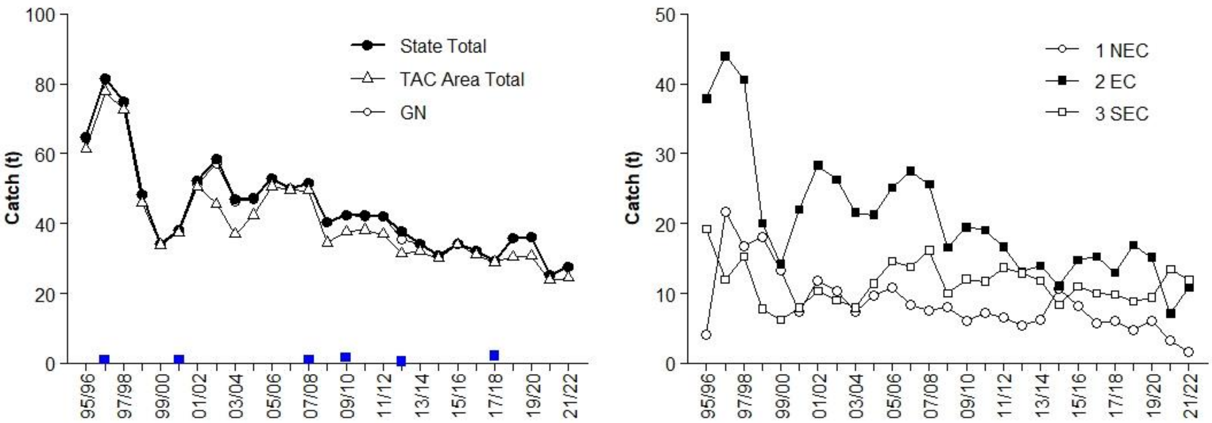


Figure 10. Banded Morwong commercial catches (t). Left: Total state-wide (State Total) and gillnet (GN) catches, Total TAC Area catches, and best estimates of recreational catches (blue squares); Right: regional gillnet catches in the TAC areas 1 NEC, 2 EC and 3 SEC.

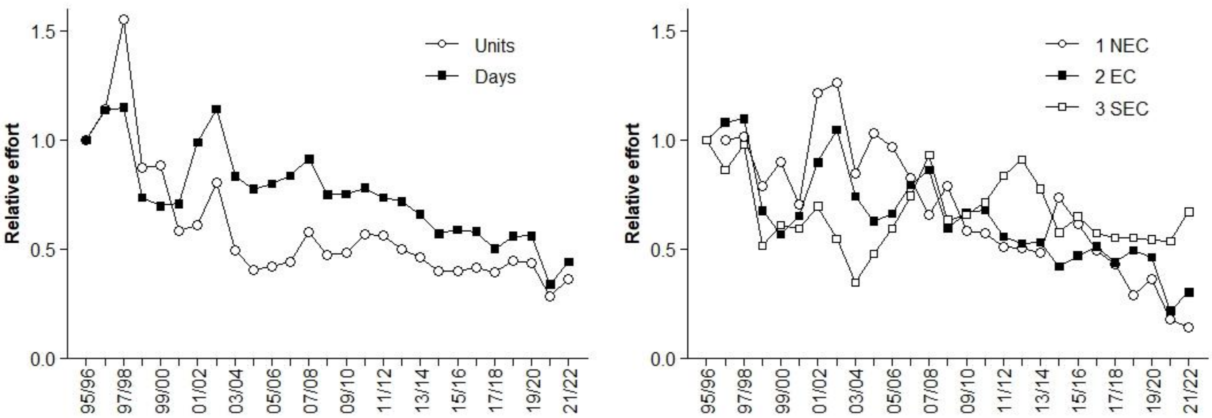


Figure 11. Left: State-wide commercial effort based on gear units and days fished relative to 1995/96. Right: Commercial effort in days fished in the TAC areas 1 NEC, 2 EC and 3 SEC relative to 1995/96.

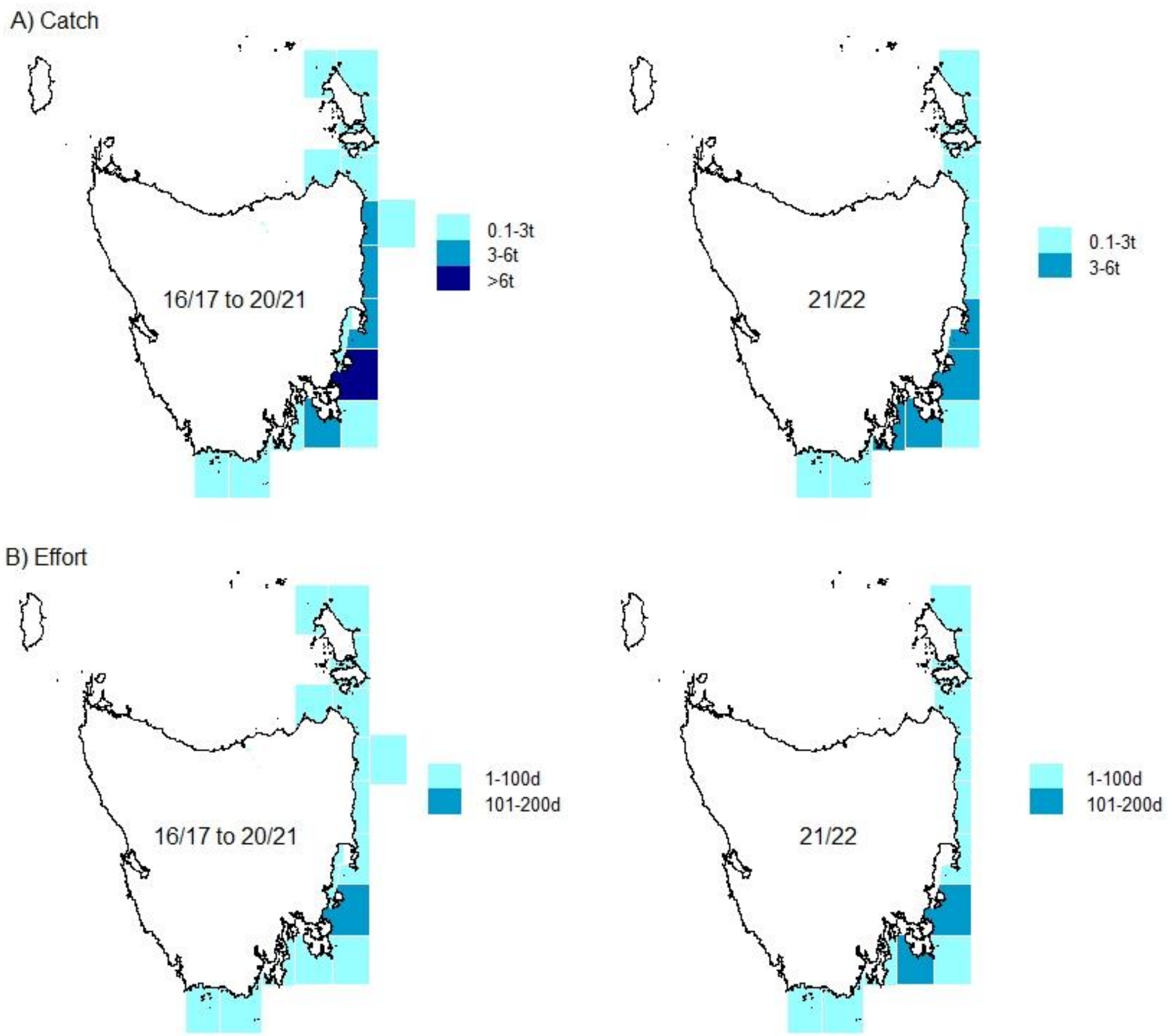


Figure 12. A) Banded Morwong total catches (tonnes per year) and B) effort (days per year) by fishing block. The left-hand column displays spatial patterns in total catch (top) and effort (below) by block averaged from 2016/17 to 2020/21, while the right-hand column displays spatial patterns in total catch (top) and effort (below) observed by block during 2021/22.

Standardised catch per unit effort

Standardised CPUE in the whole TAC area decreased to 73% of the 1995/96 level in 2021/22 (Figure 13). Regionally standardised CPUE decreased in all TAC areas, with the most dramatic decrease on the south-east coast relative to 2020/21. This represents the sharpest decline in standardised CPUE in the TAC area since 2012/13, primarily due to the decrease on the south-east coast region.

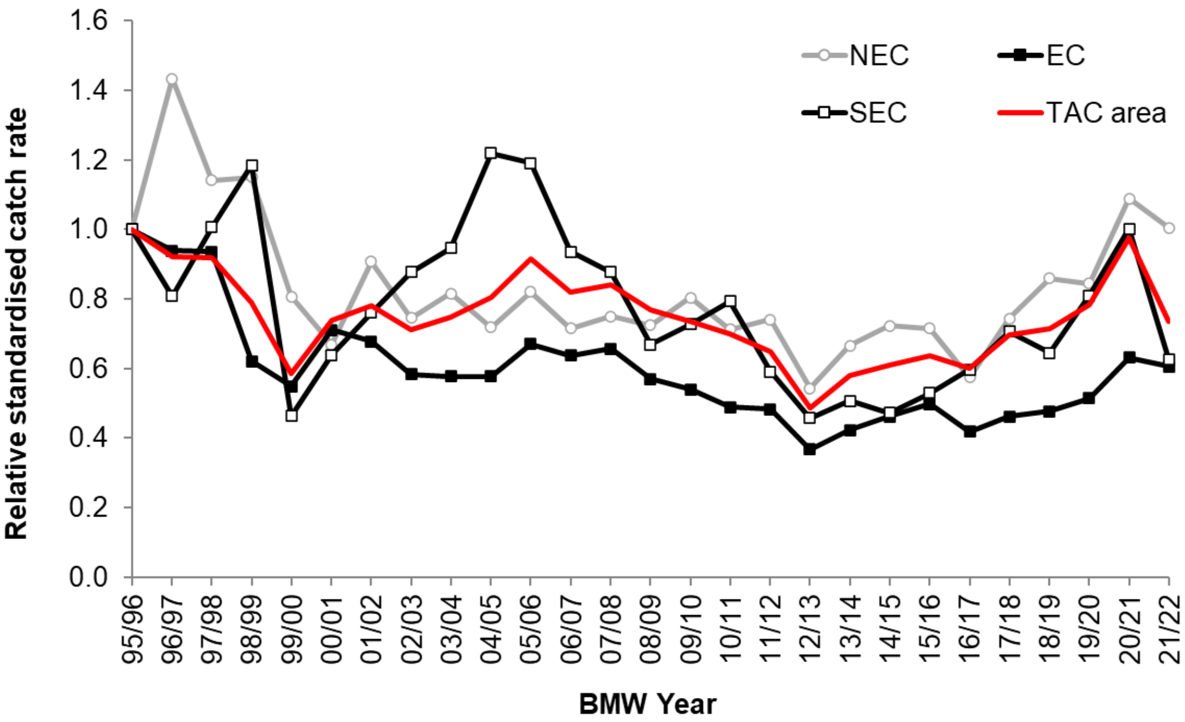


Figure 13. Banded Morwong standardised gillnet catch per unit effort (CPUE by days fished) relative to 1995/96, in the TAC areas North-East Coast (NEC), East Coast (EC) and South-East Coast (SEC), and from the whole TAC area (red line).

Selected stock modelling results and stock status

The model fit to CPUE and age composition data from the biological survey was carefully considered (Figure 14; Figure 15). The model captured the general trends in both CPUE and age composition over time. CPUE was accurately modelled in 2021/22, while the increasing trend was slightly underestimated in preceding years (Figure 14).

The relative weight awarded to each of these data sets within the model also contributes to how well the model fits to them and how much the model relies on each data type to inform estimates of SSB0 and predictions of SSB used to set catch limits. Applying the Francis Method (Francis, 2011) for weighting data resulted in a CV of 0.130 (assuming a lognormal distribution) for the CPUE data. A similar value was used in the 2020/21 assessment and updating it in this assessment did not result in a significant change in SSB predictions.

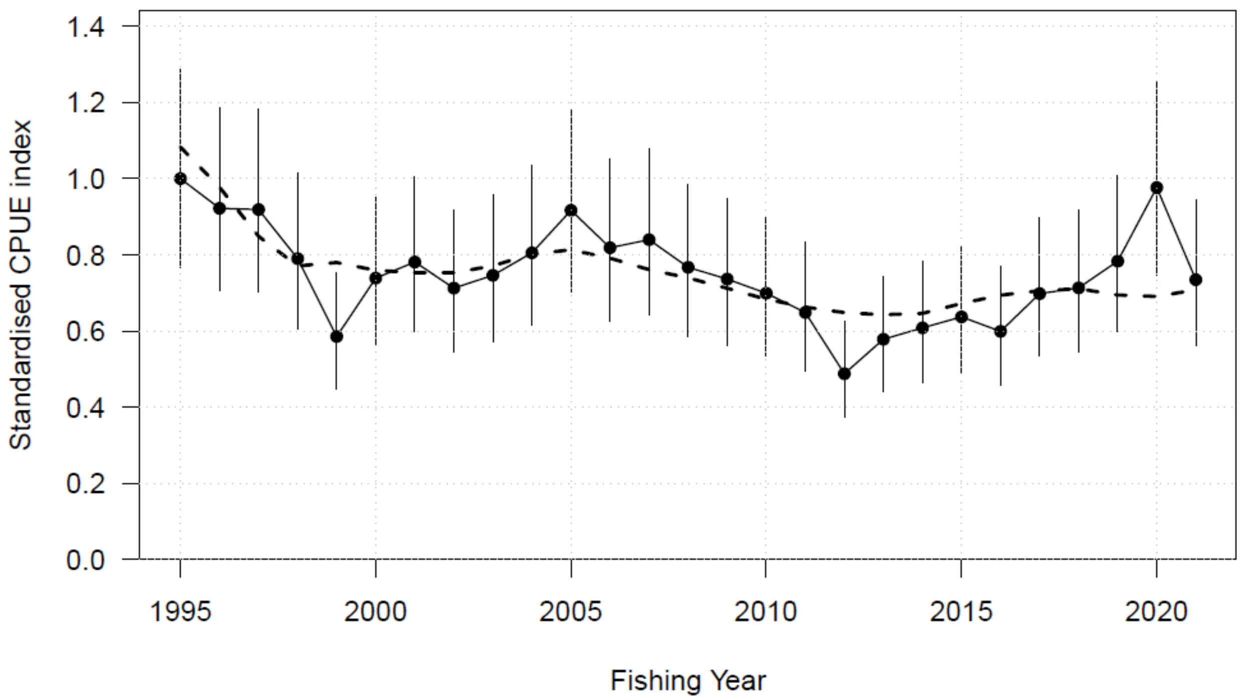


Figure 14. CASAL model fits to the catch per unit effort (CPUE) index. The solid line is the observed (standardised) CPUE, and the dashed line is the model fit. Solid bars represent 95% confidence intervals around the observations.

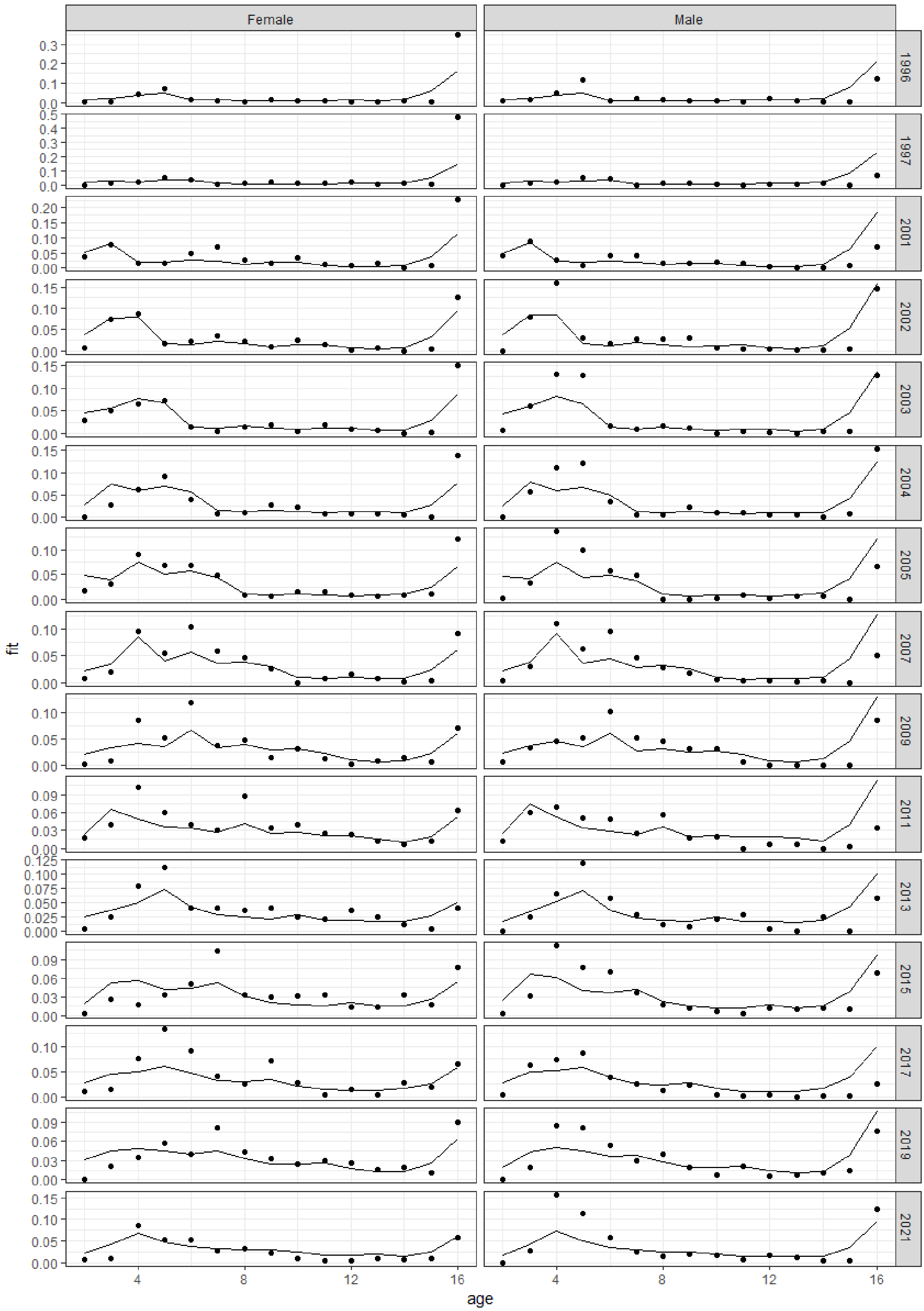


Figure 15. CASAL model fits to the age composition data from the biological surveys. The dots represent the observed age class proportional abundances for females (left) and males (right), and the solid line is the model fit.

The standard two area assessment model estimated SSB to be at 39% of initial SSB (35% at the 10th percentile) 5 from years from now (2021/22 season), representing a slight decrease compared to predictions in 2020/21. These predictions indicated that the current harvest strategy (i.e., 26 kg / quota unit and a TAC of 31 t in all future years (except for 30 kg / quota unit in 2022/23) with 0% projected future TAC under-catch is sufficient to meet the limit reference point of 30% of that of initial SSB within a 5-year period with 90% probability (Figure 16).

The more conservative, single area, version of the stock assessment model estimated SSB in 5 years to be at 30% of initial SSB (26% at the 10th percentile) (Figure 17).

Estimates based on the standard two area model indicate that at a jurisdictional stock level the biomass of Banded Morwong is unlikely to be depleted, and that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. Based on that estimate, Banded Morwong in Tasmanian waters is classified as a **sustainable stock**.

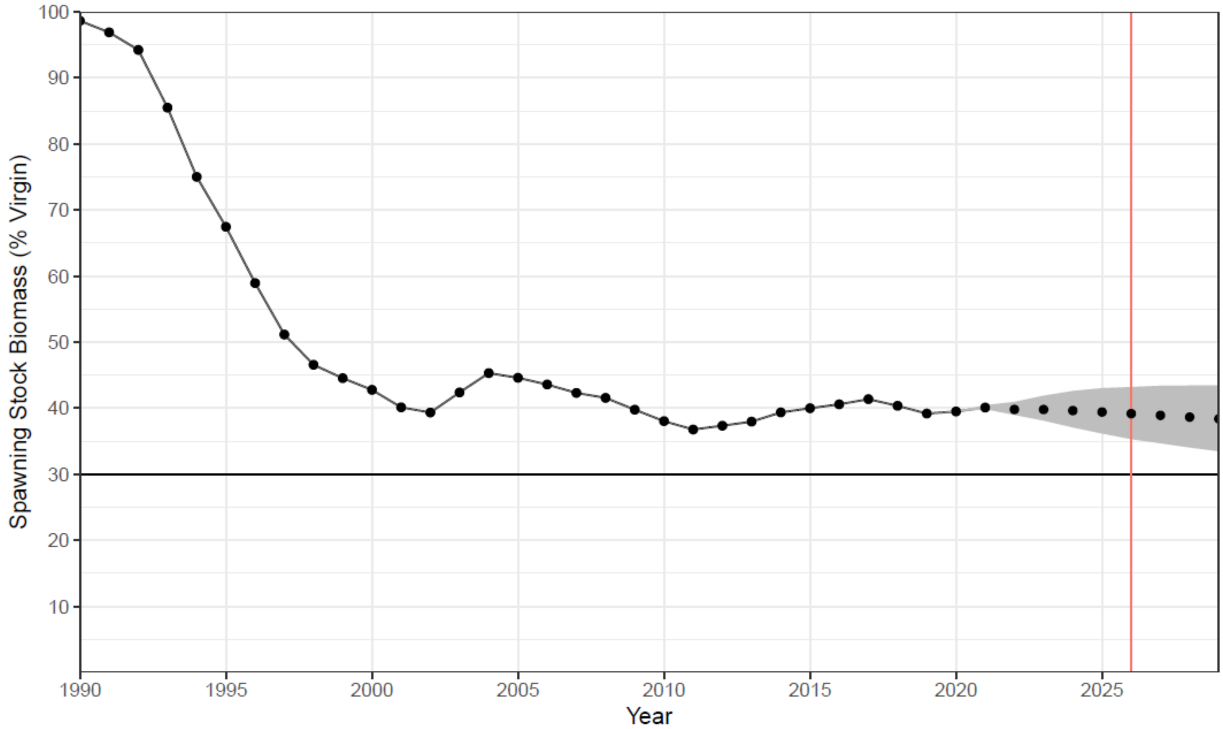


Figure 16. Current status and forward projections (to 2029) of Banded Morwong spawning stock biomass (SSB) expressed as a percentage of the unfished SSB, based on the harvest strategy of 26 kg / quota unit (with the exception of 30 kg / quota unit in 2022/23) and a future under-catch of 0%. The red vertical line indicates the 5-year period in which SSB is required to meet the limit reference point of 30% of initial SSB (indicated by the grey horizontal line) with a 90% probability (as shown by the dark shaded area).

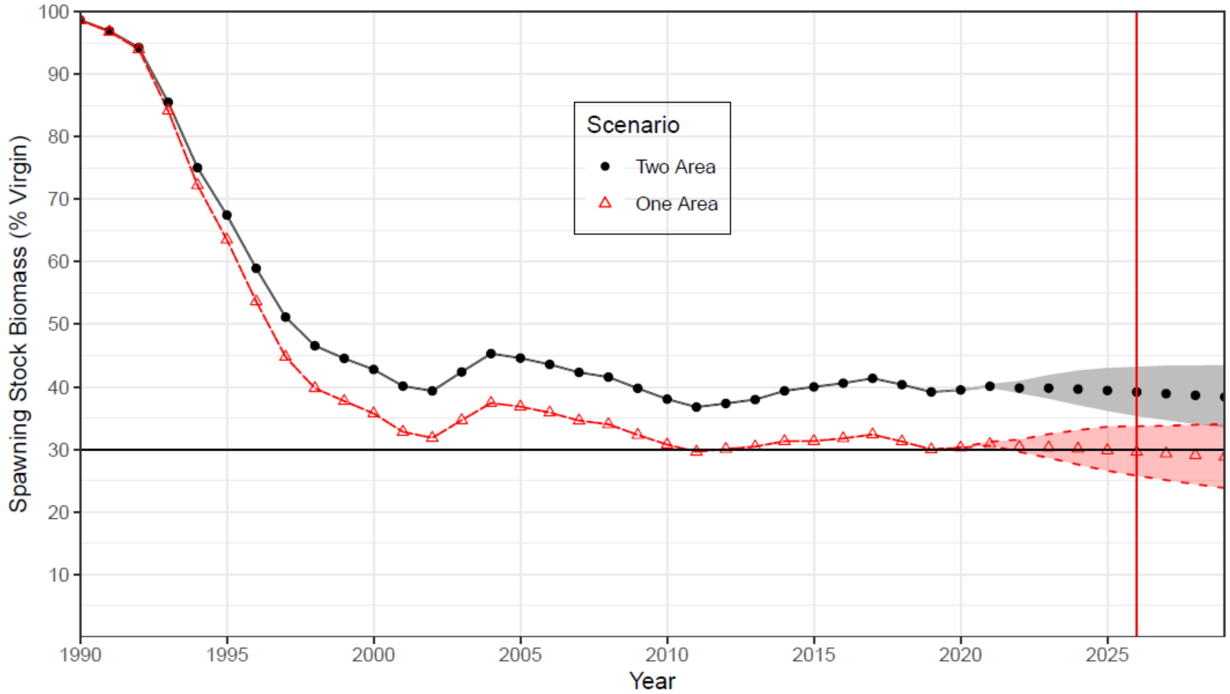


Figure 17. Current status and forward projections of Banded Morwong spawning stock biomass (SSB) assuming a two area model (grey) and a one area model (red).

4. By-product and protected species interactions

By-product in the Banded Morwong Fishery is low, which is due in part to the large mesh sizes used for Banded Morwong fishing (~140 mm mesh size). In an ecological risk assessment (ERA) published by Bell et al. (2016), no species achieved a ranking of high vulnerability within the Banded Morwong Fishery due to the minimal gillnet effort on the west coast, the shallow nature of fishing operations relative to depths inhabited by bycatch species, low selectivity of smaller by-product and bycatch species given the large mesh sizes imposed in the fishery, and high post-release survival of many of the key by-product and bycatch species.

During the 2020/21 quota year, Banded Morwong comprised 85% (up 11% compared to the previous quota year) of all fish caught during targeted Banded Morwong fishing trips, with Bastard Trumpeter and Bluethroat Wrasse constituting the most commonly caught by-product species (4% and 3% of the total catch for 2021/22, respectively) (Figure 18).

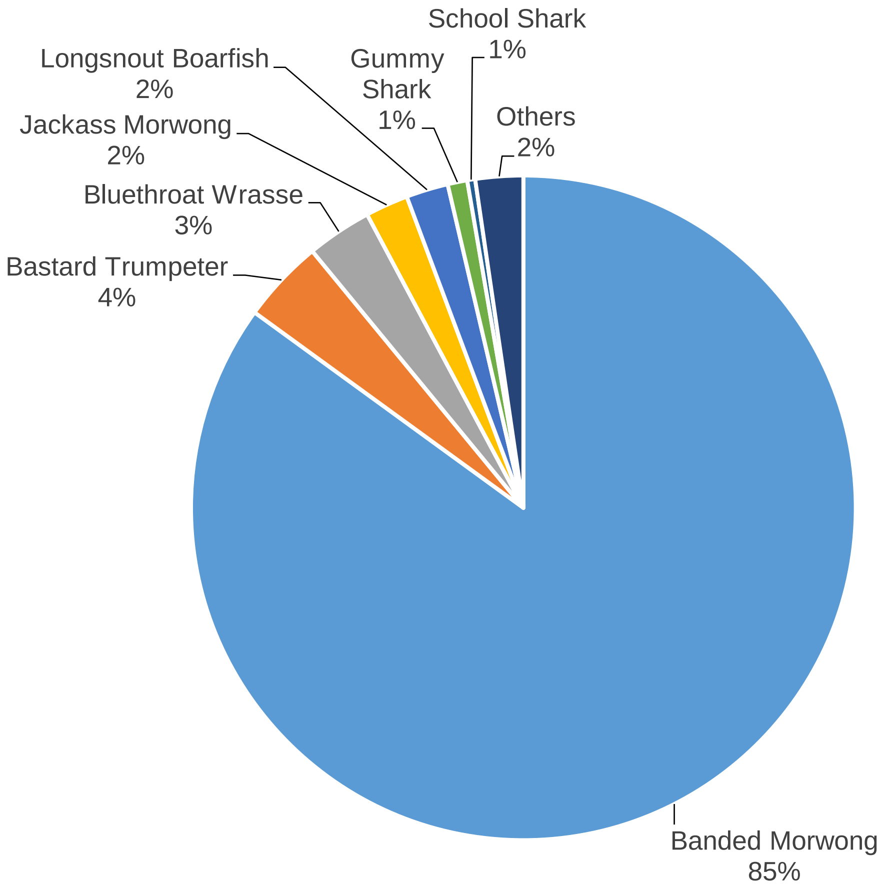


Figure 18. Catch composition of targeted Banded Morwong gillnet fishing trips in 2021/22. A targeted Banded Morwong fishing trip was defined as a trip on a given day by a given fisher where Banded Morwong were retained.

Mortality of Banded Morwong and other scalefish species due to predation and fishery interactions with Australian and New Zealand fur seals is largely unknown and represents another source of uncertainty in the assessment. Seals could cause substantial mortality to Banded Morwong, and are known to damage fishing gear and influence fisher behaviour, all of which is likely to impact catches and catch rates. This is believed to be caused predominantly by individual ‘rogue’ seals which learn to target Banded Morwong gillnet fishing. The proportion of shots in which fishers reported a seal interaction increased in 2021/22 relative to 2020/21, with seal interactions being reported for around 36% of all shots (Figure 19). However, it has been historically unclear how consistently fishers interpret and report a seal interaction, or the effect seal predation has on catches (i.e., how many fish are lost). Additionally, effects on fisher behaviour are poorly understood. A number of fishers have indicated that they are setting a proportion of their nets as a decoy to reduce catch losses through seal interactions. The remainder of their gear is set elsewhere, but the effect of additional nets on seal interactions, or on fisher catch metrics (e.g., effort), is poorly understood.

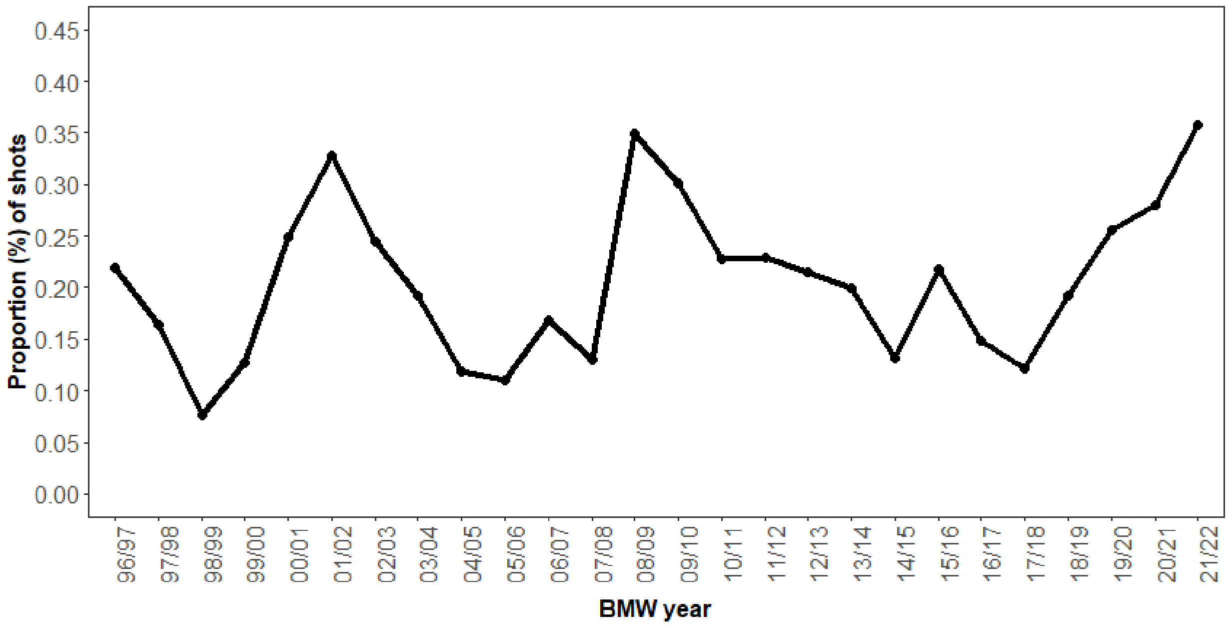


Figure 19. The proportion of shots in which fishers reported an interaction with a seal or seals. Interactions constitute physical interactions with the fishing gear, vessel, or catch.

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