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Stock assessment report 2023

Grey Morwong (*Nemadactylus douglasii*)

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Summary

This stock assessment report for Grey Morwong (*Nemadactylus douglasii,* CAAB 37 377002) provides information to inform the current biological status of the "Eastern Australia" biological stock. The stock assessment compiled available catch, effort, biological and landings composition information across the NSW and Commonwealth fisheries.

Assessment outcome and justification

The status of the Eastern Australia biological stock of Grey Morwong is classified as **depleted**. The status is primarily based on the results of a surplus production model, using data from the NSW and Commonwealth fisheries, that estimated biomass at the end of 2021/22 to be approximately 0.11 (95% CI 0.08 – 0.16) of unfished levels. The status of depleted is also supported by:

1. Long-term decline in the average sizes of Grey Morwong landed commercially;
2. Substantial decline in the recreational harvest since 2000/01;
3. Age compositions that lack older individuals.

The available data and results of the various analyses described in this report indicate that the biomass of Grey Morwong was fished down during the 1970s, 1980s and early 1990s, with landings greatly exceeding the estimated Maximum Sustainable Yield (MSY). There has been a substantial reduction in commercial catch and effort towards Grey Morwong since the 1990s, and corresponding declines in estimated recreational harvest; however these reductions have been insufficient to allow the stock to recover.

Introduction

This stock assessment report for Grey Morwong (*Nemadactylus douglasii*) has been compiled to inform the Status of Australian Fish Stocks (SAFS) determination during 2023, and to inform management of the stock and the fisheries catching Grey Morwong. Grey Morwong has a long history of exploitation by trawl, trap and line fisheries. Considerable work was done investigating the biology of Grey Morwong during the early 2000s (Stewart and Hughes, 2009; Fisheries Research & Development Corporation grant 2004/035), and relatively simple stock status assessments have been done mainly on the NSW component of the stock since 2003. Grey Morwong in NSW has been assessed as "overfished" since 2008 (based on data to 2006/07). The "Eastern Australia" biological stock of Grey Morwong in the national Status of Australian Fish Stocks (SAFS) reports has been assessed as "depleted" in 2018 and 2020 using data from state and Commonwealth fisheries. There have been no attempts to recover the stock of Grey Morwong. This stock assessment builds on work that supported previous SAFS reports (Stewart, 2020; Stewart et al., 2015).

Biology and stock structure

Grey Morwong (*Nemadactylus douglasii*) is distributed along the south-eastern Australian coastline in continental shelf waters from Moreton Bay in Queensland to Wilsons' Promontory in Victoria. They can also be found along the east coast of Tasmania to Storm Bay and are present around the north island of New Zealand, where they are known as 'porae'. The common name of this species in Australia has undergone a number of changes in the past, and it has variously been known as rubberlip, blue and Grey Morwong, and is often sold in retail outlets as 'deep sea bream'. Grey Morwong is a demersal fish commonly caught near reefs at depths of 10-100 m. They feed predominantly on fish, crustaceans and invertebrates.

Grey Morwong mature at 22-25 cm fork length (FL) and spawning occurs between April and June. In common with other members of the family Cheilodactylidae, Grey Morwong have a pelagic 'paperfish' larval stage which may last for many months. After settlement to their demersal juvenile habitat, Grey Morwong reach approximately 15 cm FL after one year and 20 cm FL after two years. Growth is variable, but on average males grow faster and attain larger sizes than females. The maximum length and weight of Grey Morwong is approximately 80 cm and 6 kg, but the majority of fish caught in NSW are between 25-35 cm FL in length and 250-500 g in weight. Current catches contain very few fish greater than 50 cm in length.

The Grey Morwong population off NSW is characterized by fluctuations in recruitment strength from year to year. The oldest fish aged to date by NSWDPI was 22 years old (Stewart & Hughes, 2009), however it is likely the longevity of Grey Morwong is much greater than this based on a reported 45 years (Bray and Gomon, 2023, Fishes of Australia, https://fishesofaustralia.net.au/home/species/432#moreinfo) as well as longevity in other closely related species.

In NSW, Grey Morwong are taken predominantly by trap fishers in the Ocean Trap and Line Fishery along the whole coast and by fish trawl south of Smokey Cape. A significant

proportion of the total catch is taken by Commonwealth trawlers. Grey Morwong are an important catch for recreational fishers in ocean waters.

The stock structure of Grey Morwong has not been formally examined through genetics; however based on their reasonably limited distribution along south-eastern Australia, the complex but southerly flowing Eastern Australian Current and an extended pelagic larval phase, it is likely to constitute a single stock. Based on this evidence, the stock status of Grey Morwong is reported at a biological stock level of 'Eastern Australia'.

The data presented in this assessment include the NSW and Commonwealth components of the stock, and as such the results pertain to the entire "Eastern Australia" biological stock.

Fisheries statistics

Catch

The history of the fishery for Grey Morwong has not been well documented. It is likely that Grey Morwong have been exploited since the late 1800's, as they co-occur with Snapper that have had their historical catches well documented (Thurstan et al., 2016, Thurstan et al., 2018). This report collates available data and reconstructs the catch history of Grey Morwong off eastern Australia.

Commercial

It is probable that Grey Morwong were not targeted during the early 1900s based on understanding of the early steam trawl fishery, and the reported lack of interest in the closely related Jackass Morwong (*Nemadactylus macropterus*), (Fay, 2004). Catches from the early steam trawl fishery were assessed during work by Klaer (2001, 2004, 2006, pers. comm). Klaer compiled data from around 1938 to 1959 from the Red Funnel Trawler company in his PhD. The Red Funnel Trawler logbooks between 1938 and 1999 distinguished between Jackass and Grey (rubberlip) Morwong. These data indicated that Grey Morwong represented a very small percent (< 0.5%) of all morwong landed in the steam trawl and early Danish seine fisheries.

Catch statistics summarizing commercial catch from NSW fisheries were published in annual reports from 1883 to 1981. Available data from these annual reports as well as the CSIRO (once that agency ceased work in the 1960s on what was then known as the South East Trawl fishery) between 1940 and 1970 were collated by Pease & Grinberg (1995) and stored in a NSW Departmental database called HCatch. It is assumed that all "Commonwealth" catch was reported into NSW before 1984/85 as instructed on the catch record forms.

During the early 1970s catch was reported on forms 48 (extra-territorial catch) and 50 (inshore ocean and estuary catch). Form 48 only had the species "Morwong (Sea Bream)" and form 50 "Morwong", meaning that catches of Grey and Jackass Morwong were combined in reporting and recorded as "Morwong, Unspecified" in the HCatch database. In 1977, the form 49 catch return was introduced and replaced forms 48 and 50. Form 49 separated "Morwong, Jackass" and "Morwong, Rubberlip". NSW Departmental catch records prior to the 1970s are known to be incomplete but to what extent is unknown.

"Morwong, Mixed/Unspecified" in the HCatch database (1946/47 to 1977/78) were grouped by fishery – being "Extra-territorial", "Steam trawl", "Trap & Line", "Inshore Ocean" and

"Estuary" fisheries. Data were excluded from the "Extra-territorial" and "Steam trawl" fisheries following analysis of the data presented by Klaer (see above) indicating almost the entire catch of "Morwong" from these fisheries was Jackass Morwong.

Between 1977/78 and 1992/93 the morwong species were separated into the main species (plus a mixed group that had minor catches) and listed against "All Ocean" and "Estuary" fisheries. The average annual percentage of rubberlip catch in the combined rubberlip and jackass morwong catch for the years 1978/79 to 1992/93 (43%) (Table 1) was used to split the "Morwong, Mixed/Unspecified" catch (excluding "Extra-territorial" and "Steam trawl" fisheries) for the years 1946/47 to 1977/78.

Table 1. Reported kilograms of morwong by species 1978/79 to 1992/93 from the HCatch database. The ratio of Rubberlip Morwong (overall 43%) was used to estimate catch by species for the years 1946/47 to 1977/78.

Year	Morwong, Jackass	Morwong, Rubberlip	Morwong, Unspecified	Grand Total
78/79	539932	490398		1030330
79/80	523816	677348	215	1201379
80/81	1011437	932718		1944155
81/82	1306040	591061		1897101
82/83	1016820	548366		1565186
83/84	1134739	507131		1641870
84/85	1067166	536074		1603240
85/86	589251	441640	43	1030934
86/87	376837	327524	7	704368
87/88	302861	269409		572270
88/89	402284	262664	4	664952
89/90	160211	252304	9	412524
90/91	254515	193341	332	448188
91/92	228372	149022	1799	379193
92/93	156820	142689	6252	305761
Grand Total	9071101	6321689	8661	15401451

Between 1986 and 1999 some species were known to have been double-counted in catches as a result of logbook requirements of Commonwealth trawl fishing outside of 3 nm on the south-coast landing into NSW ports. While this may have been substantial for some species (e.g. Silver Trevally), it is not for Grey Morwong given the species higher relative abundance in inshore (state) compared to offshore (Commonwealth) areas. There was also a quite large drop in landings between 1985/86 and 1986/87 suggesting minimal duplication had occurred.

NSW state catch

All NSW commercial landings of Grey Morwong from 1992/93 onwards were obtained from the ComCatch (1984/85 to 1996/97) and FishOnline (1997/98 onwards) databases. These databases contained logbook data from commercial fishers (Appendix 2).

Commonwealth catch

Commonwealth landings of Grey Morwong from 1986 onwards were sourced from CSIRO (approved by AFMA).

Recreational harvest

Recreational harvest estimates were available from surveys done in 2000/01 (Henry and Lyle - National survey), 2013/14, 2017/18 and 2019/20. The state-based surveys from 2013/14 onwards were of subsets of recreational fishers, and total recreational harvest for these years was scaled up to be compatible with the 2000/01 survey (unpublished).

Recreational harvest estimates between survey years was interpolated using a piecewise linear function. The function was fitted to these estimates, on the log scale, in order to interpolate the other years. The log-harvest interpolation was then exponentiated (back-transformed) to produce harvest estimates. Recreational harvests prior to 2000/01 were estimated using data from Kleisner et al. (2015). In summary, using human population statistics 84% lived in coastal areas. Annual recreational catches from 1950 to 1970 were determined using a participation rate of 19.5%. Between 1970 to 1980, the national fishing participation rate of 19.5% (for 1970) was linearly interpolated to a 34% participation rate in 1980 in order to account for the estimated increased promotion and participation in recreational fishing at the time. From 1990-2000, the participation rate was linearly interpolated from 34% in 1990 to 19.5% in 2000 to account for possible declines in recreational participation. It is noted that this estimation method may have over-estimated the recreational harvest prior to the 1970s, based on experienced fisher feedback on catch reconstruction of Yellowtail Kingish using this method (Stewart et al., 2021). Feedback was that prior to the 1970s relatively few recreational fishers had boats of sufficient sea-worthiness to fish in offshore waters. Nevertheless, given the uncertainties in the reported commercial landings during this period any over-estimation of recreational harvest is likely to have a relatively minor impact.

Note that trailer-boat harvest estimates from Steffe et al. (1996) for 1993/94 and 1994/95 were 90.8 and 54.9 t respectively. These are considerably smaller than the estimates derived above, but were acknowledged as such by Steffe et al. (1996) as their survey did not include night-time angling, the harvests of anglers that use large cruisers and gameboats, the harvests of the charter fleets outside Sydney, or the harvests of trailer-boat anglers that use medium and small sites to provide them with access to the coastal waters off NSW.

Indigenous

There are no data on the Indigenous harvest of Grey Morwong; however it is acknowledged that fishing is an important and valued practice by Aboriginal people for a wide range of reasons (Smyth et al. 2018).

Total harvest reconstruction

The amount of discarding of Grey Morwong is unknown, but may have been considerable during the early years of the fishery when they had limited market appeal. The Commonwealth assume a low (proportion of 0.07) discard rate for Jackass Morwong before 1994, and a discard rate of 0.4 for years 2007 to 2014 (Tuck et al., 2015). The harvest (landed catch) from all sectors using data described above is presented in Fig. 1. This is the base-case catch reconstruction for use in the assessment as it most closely aligns with the available data. However, the knowledge that catch records before the 1970s were incomplete (Pease and Grinberg, 1995), the switch to Form 49 reporting in 1977, and the observed dip in commercial landings between 1968/69 and 1977/78 in the base-case reconstruction, suggests catch in these years is under-represented in the database. Therefore an alternative

catch reconstruction (scenario 2) was generated by scaling 1968/69 to be the same as 1967/68 and using that scaling factor for all years 1968/69 to 1977/78. This alternative scenario was simply for sensitivity analysis in the assessment.

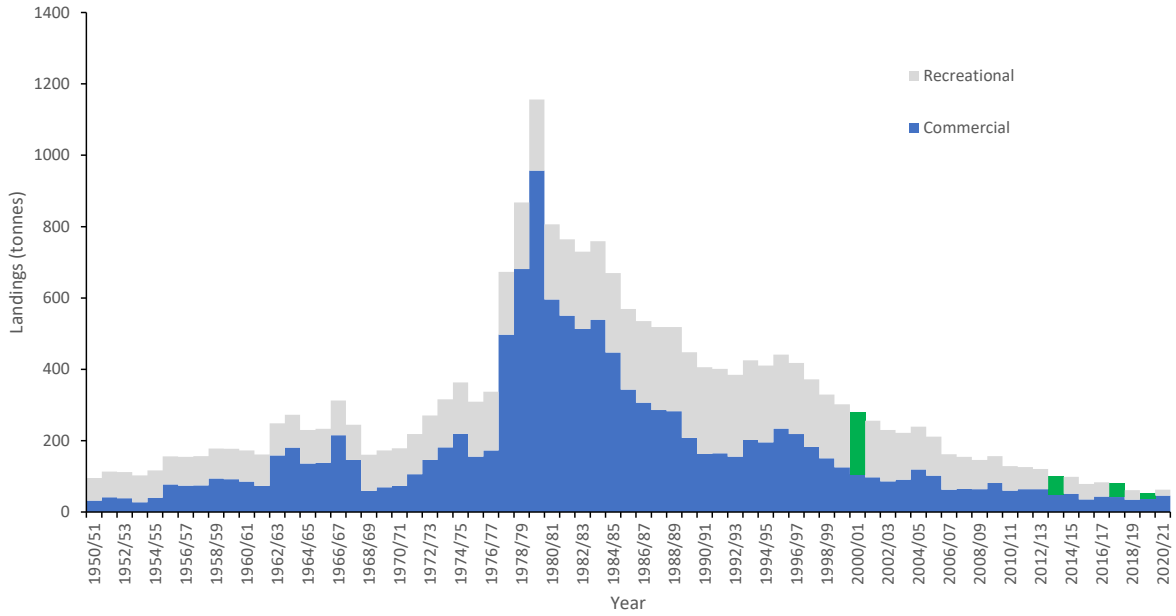

Figure 1 **Landings reconstruction for Grey Morwong 1950/51 to 2020/21. The green represents recreational survey years. This is the base-case catch reconstruction.**

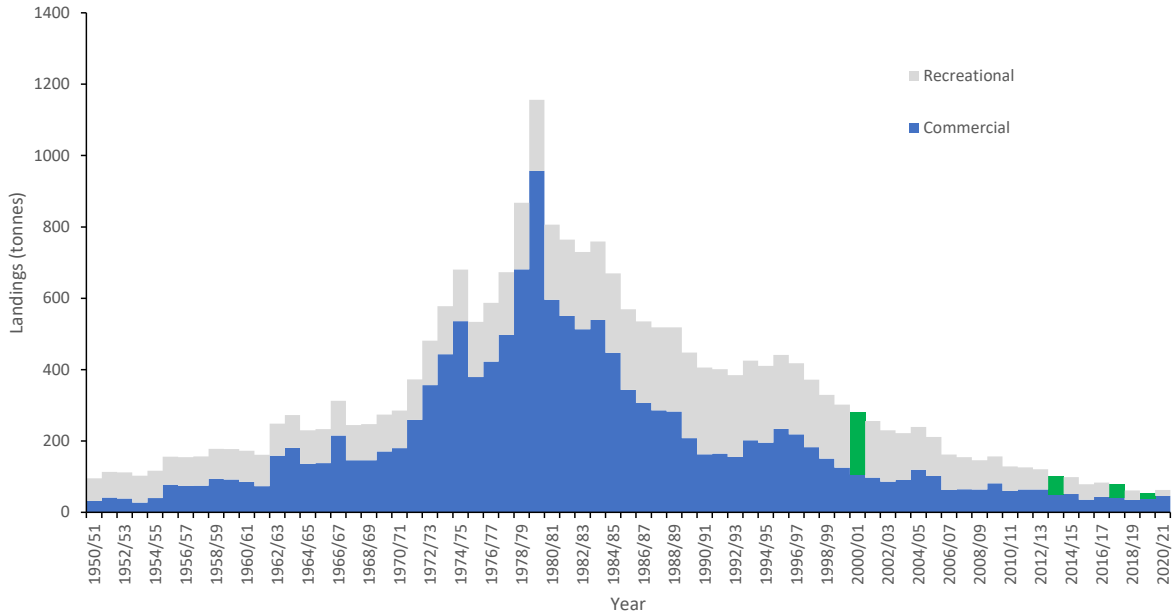

Figure 2 **Alternative landings reconstruction for Grey Morwong 1950/51 to 2020/21. The green represents recreational survey years. Commercial catch 1968/69 to 1977/78 were increased by a scaling factor to make 1968/69 to be the same as 1967/68 due to potentially under-reporting in the database. This is the scenario 2 catch reconstruction simply for sensitivity analysis in the assessment.**

EFFORT

Fishing effort trapping (days fished) in NSW waters, when Grey Morwong were reported have declined substantially since 1997/98 (Fig. 3). These data were from aggregated monthly reports that included the number of days fish trapping in a month when Grey Morwong were reported.

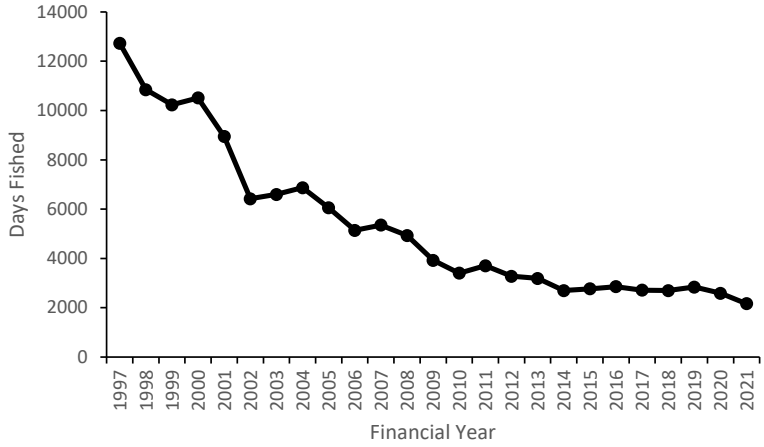

Figure 3 Days fished when Grey Morwong were reported using the method of fish trapping in NSW waters derived from monthly aggregated data.

The distribution of fishing effort using fish traps for Grey Morwong has changed since 1997/98, with a greater proportion of the effort coming from the far south coast (AreaID 1008 to 1010) in more recent years (Fig. 4).

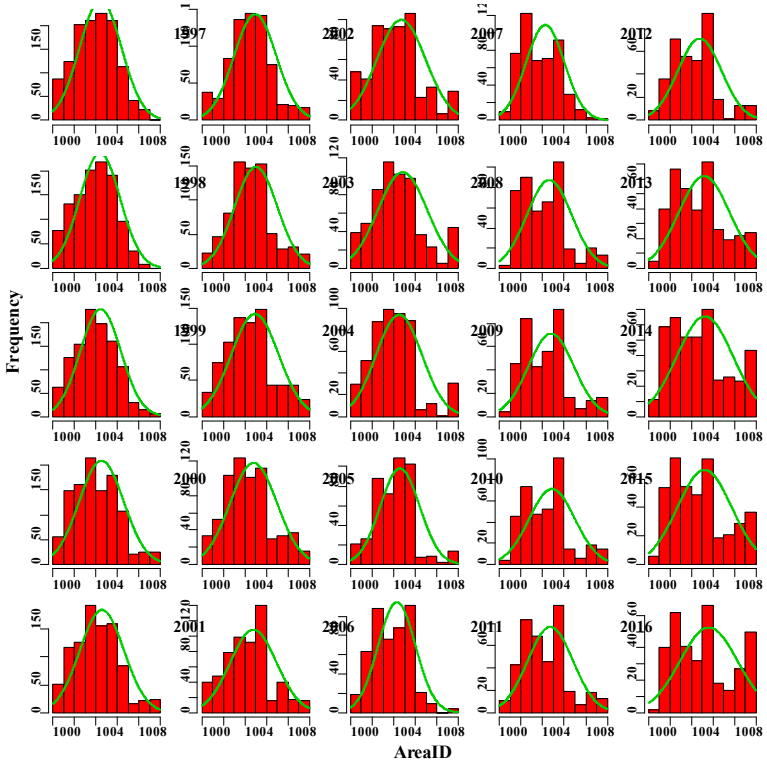

Figure 4 Days fished when Grey Morwong were reported using the method of fish trapping by latitudinal area and year.

Assessment

Approach

A weight-of-evidence approach has been taken to classify the biological status of the Grey Morwong biological stock, using the following lines of evidence:

1) Surplus production model;

2) Time-series of length frequency data;

3) Time series of age frequency data;

Standardised catch rates

Methods

The method of demersal fish trapping comprised the majority (~71%) of the total NSW harvest of Grey Morwong 1997/98 to 2021/22. Trawl comprised around 15% (Fig. 5A). When Commonwealth trawl catches are included during this period the percentage of the catch taken by fish trapping decreased to 47%, whereas the trawl catch increased to 43% (Fig. 5B).

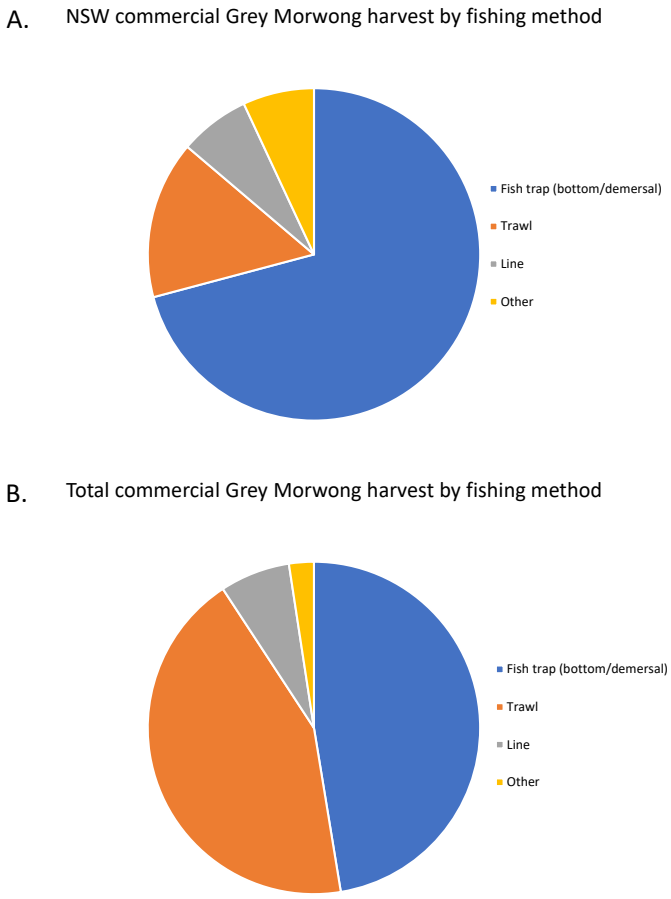

Figure 5 Proportion of Grey Morwong reported by main methods 1997/98 to 2021/22. A. NSW fisheries. B. NSW and Commonwealth fisheries combined.

Catch rates of Grey Morwong using the method of fish trapping were standardized for the periods 1997/98 to 2008/09 and 2009/10 to 2021/22 separately as a result of changes in logbook reporting from monthly to daily records in 1997/98. Catch rates were standardized for month, authorized fisher and latitude of landings for 1997/98 to 2008/09 using the monthly aggregated data. Catch rates were standardized for year, latitude, fisher, month and depth for 2009/10 to 2021/22 using the daily reported data.

Standardization was done using the r-package 'cede', with outputs standardized to 1, and the 2 time series matched by standardizing the catch rates during 2008/09 and 2009/10 (the years before and after the logbook change) to be equal. Comparisons of the monthly and daily derived standardized catch rates for 2009/10 to 2021/22 showed similar overall trends (Fig. 6), providing support for both series being similarly representative.

Catch rate trends

Standardized catch rates for kg/day fish trapping showed a steady decline between 1997/98 and 2015/16, followed by 5 years of a slightly increasing trend before declining in 2021/22 (Fig. 7).

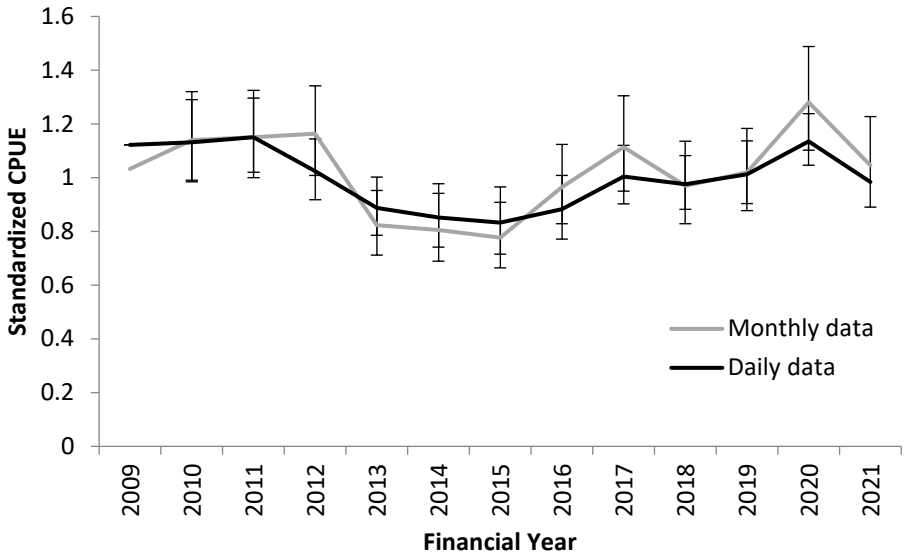

Figure 6 **Standardized catch rates (kg/day fish trapping) with 95% confidence intervals for Grey Morwong derived from daily data and aggregated monthly data 2009/10 to 2021/22.**

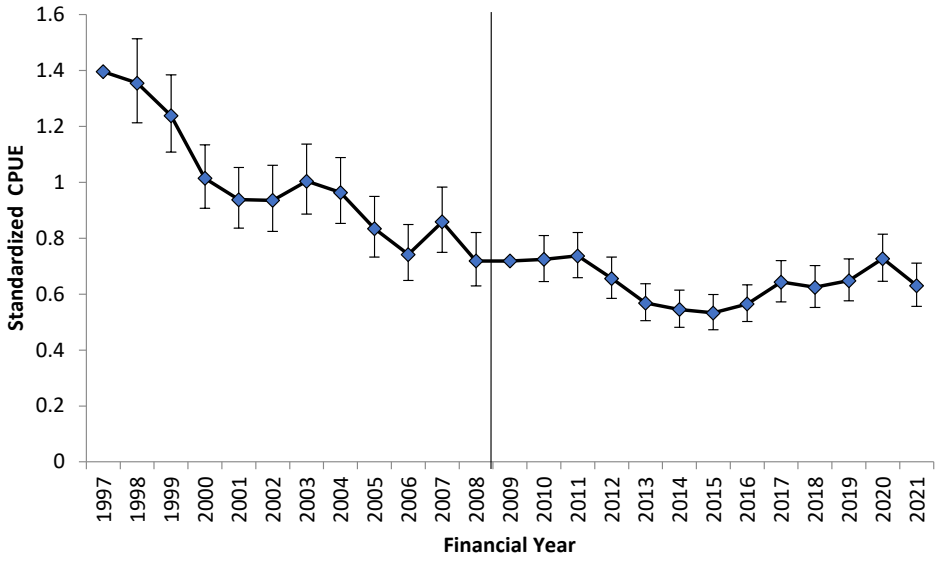

Figure 7 **Standardized catch rates (kg/day fish trapping) with 95% confidence intervals for Grey Morwong 1997/98 to 2021/22. Black line indicates the years before and after were set to be equal due to changes in the logbooks.**

Length compositions

The sizes of Grey Morwong in commercial landings have been monitored through a state-based port monitoring program (that includes fish sold at the Sydney Fish Markets) since the late 1960s (e.g. Stewart et al., 2020). The sizes of Grey Morwong landed by commercial fishers in NSW declined after the 1980s, with relatively few fish greater than 35 cm FL in landings since that time (Fig. 8). The length composition in 2018/19 showed a considerable improvement in the proportion of larger fish, largely due to a greater contribution from fish landed on the far south coast; however the length distribution has reverted to smaller fish during the 2 most recent years (Fig. 8). These observations suggest that the largest fish in the population were fished down during the 1970s and 1980s and that the population has not returned to a more normal size composition since that time.

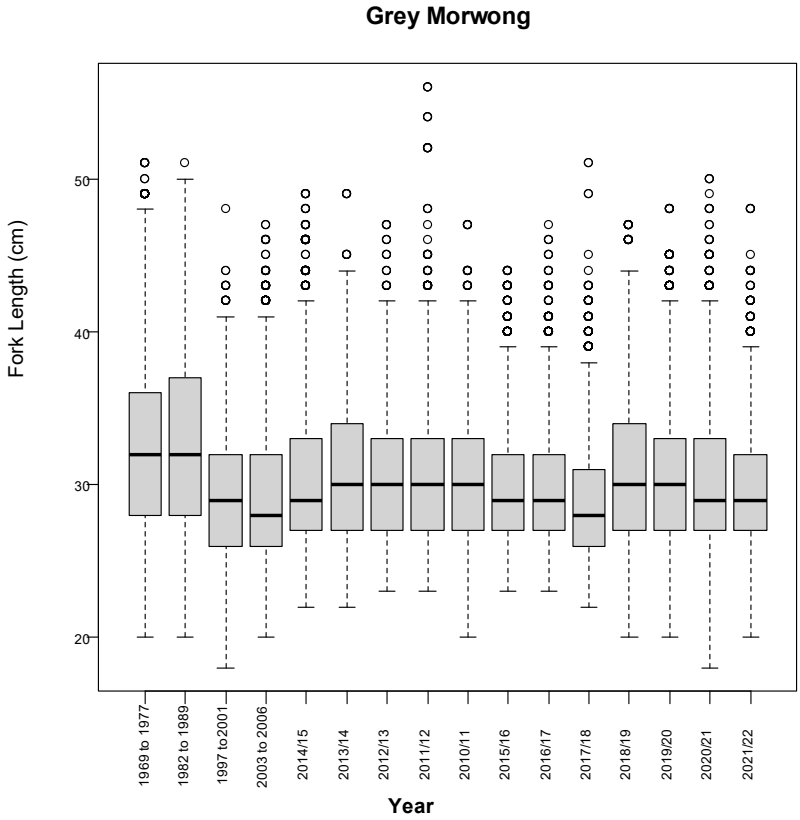

Figure 8 The length distributions of landed Grey Morwong in NSW 1970s to 2021/22.

The sizes of Grey Morwong landed by the NSW charterboat sector differs slightly in not being hard against the MLL (30 cm TL, approx. 25 cm FL), and do not contain many fish greater than 40 cm FL (Figs. 9 and 10).

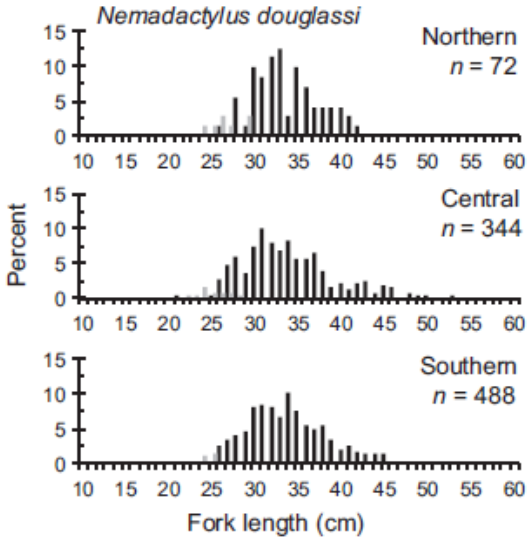

Figure 9 The length distribution of Grey Morwong caught by the NSW charterboat fishery between December 2014 and February 2016. Source: Figure 4 in Gray and Kennelly 2017.

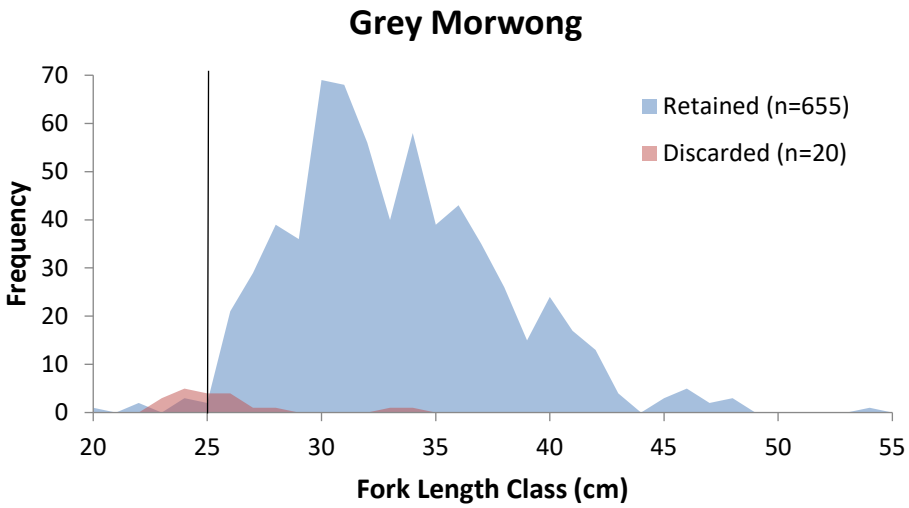

Figure 10 The length distribution of Grey Morwong caught by the NSW charterboat fishery 2020/21. Source: Hughes et al., 2023.

Age compositions and mortality rates

Age compositions were derived through the NSW Commercial Fisheries Port Monitoring Program. Sampling is a 2-stage approach, with representative length monitoring (see above) and age estimation of a subset of individuals. Currently age compositions are derived following otolith-based methods to estimate the age of individuals (see Stewart & Hughes, 2009). The resulting size-at-age data are used to generate annual age-length keys that are then applied to the representative length data (see Stewart & Hughes, 2009).

The age composition of Grey Morwong in landed commercial catches show that they are fully recruited at an age of approximately 4 years (Fig. 10). The 5 years of sampling show similar ranges of ages present, with variable recruitment evident during some periods.

Estimates of Total Mortality (Z) between the ages of 4 and 16 years were made by fitting catch curves to these ages. The slope of the linear fit to the log of the age frequency approximates Z (Fig. 11).

The age compositions and associated catch curves provide some evidence that mortality during the past decade has been reduced. The decline in abundance of ages 4 to 10 years in 2020/21 and 4 to 11 years in 2021/22 is more gradual than in later age classes. The stronger age class of 5 years (or relatively weaker age classes of 6+ years) apparent in 2015/16 has persisted through to 2020/21 and 2021/22 (Fig. 11).

The most likely estimate of Natural Mortality (M) is 0.14 based on the assumption that 5% of the population attain the maximum observed age of 22 years (Hoenig, 1983). A second estimate based on Then et al. (2014) and assuming that Grey Morwong longevity is potentially as much as other Cheilodactylids of 40+ years was similar at 0.17. These estimates suggest that currently F and M are of similar magnitudes (F = Z-M); however mortality estimates are highly uncertain.

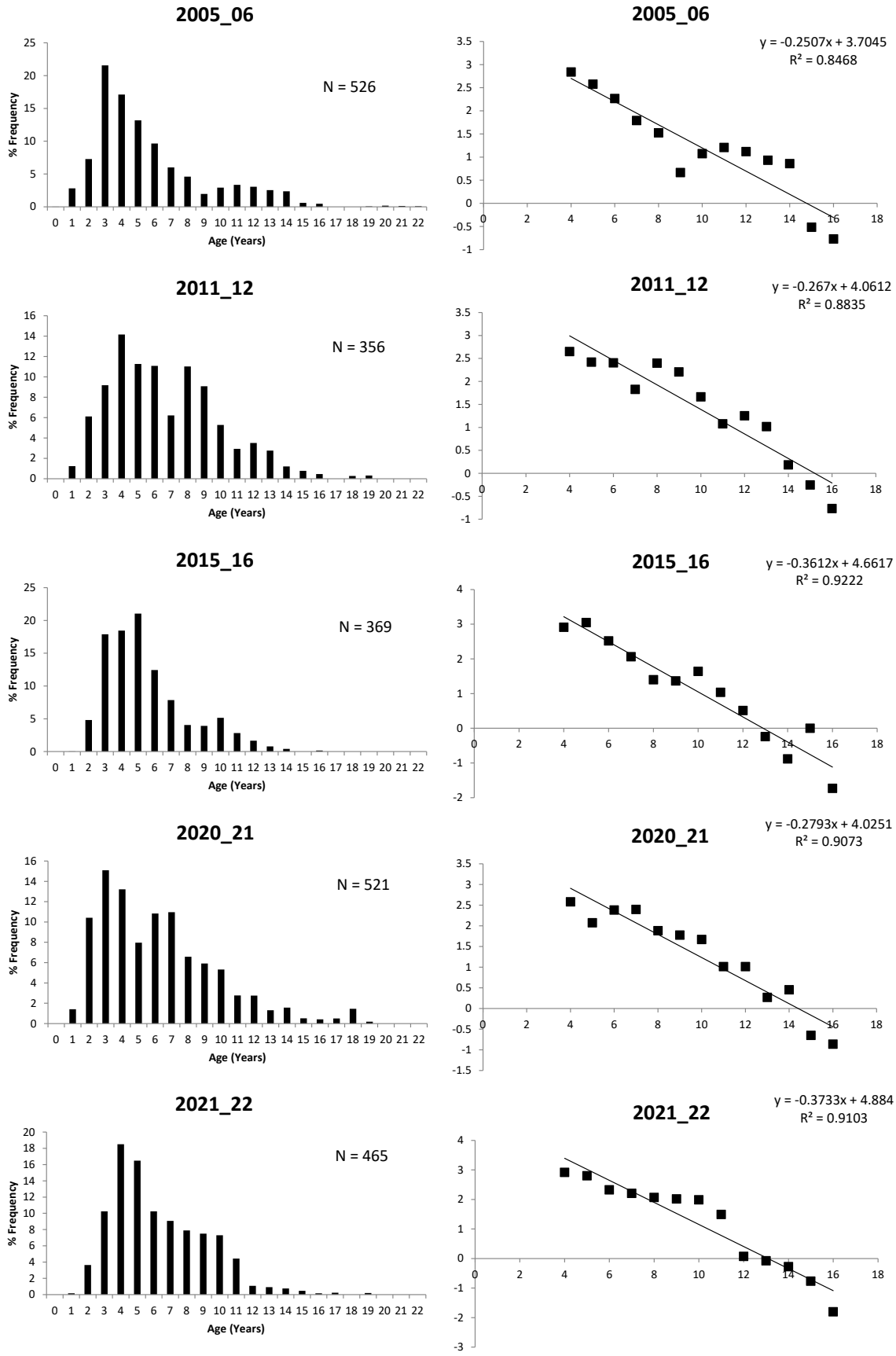

Figure 11 The age compositions of Grey Morwong in NSW commercial landings and derived catch curves 2005/06, 2011/12, 2015/16, 2020/21 and 2021/22.

Surplus production modelling

Methods

A surplus production model was used that is a Bayesian state-space implementation of a modified Schaefer surplus production model (BSM) using the package CMSY+ (Froese et al., 2019). The BSM method relies on catch time series and relative abundance data, such as catch/effort (CPUE) data. The BSM method generates estimates of the intrinsic growth rate of a population (r) along with an estimate of its carrying capacity (k); from these, time series of biomass (B) and fishing mortality (F) can be computed, including the biomass (BMSY) from which maximum sustainable yield (MSY) can be extracted given FMSY.

The base-case surplus production model incorporated catch data being the base-case catch reconstruction presented above (Fig. 1) for 1950/51 to 2021/22 (Commonwealth and recreational catch for 2021/22 were missing so were set equal to 2020/21 levels). Relative abundance was the standardized and calibrated catch rate data from 1997/98 to 2021/22, as presented in Fig. 7. Resilience was set at 'low' based on Fishbase. Initial biomass depletion was set at between 0.4 and 0.8.

Several alternative sensitivity scenarios were run, including using the alternative landings reconstruction (Fig. 2), the base-case surplus production model with varying levels of priors for resilience from Fishbase (very low, medium. high), and the base-case model with a wider range of possible final depletion levels.

Results

The model estimated that in 2021/22 the biomass of Grey Morwong relative to unfished levels was 0.11 (95% CI 0.08 – 0.16) (Fig. 12). The biomass depleted rapidly during the 1980s and 1990s, falling below the default limit reference level of 0.2 in 2000. Biomass has been low (around 0.1) for the last decade. Diagnostic plots were reasonable in all cases (Appendix 1). Maximum Sustainable Yield (MSY) was estimated to be 356 t (95% CI 259 to 490 t) (Appendix 1).

The various scenarios supported the base-case surplus production model in producing similar median estimates of final depletion (Appendix 1). The scenario using a High resilience range for r failed to find realistic pairs of r and k in any runs. The base-case produced far more viable biomass trajectories than scenarios with alternative priors for resilience.

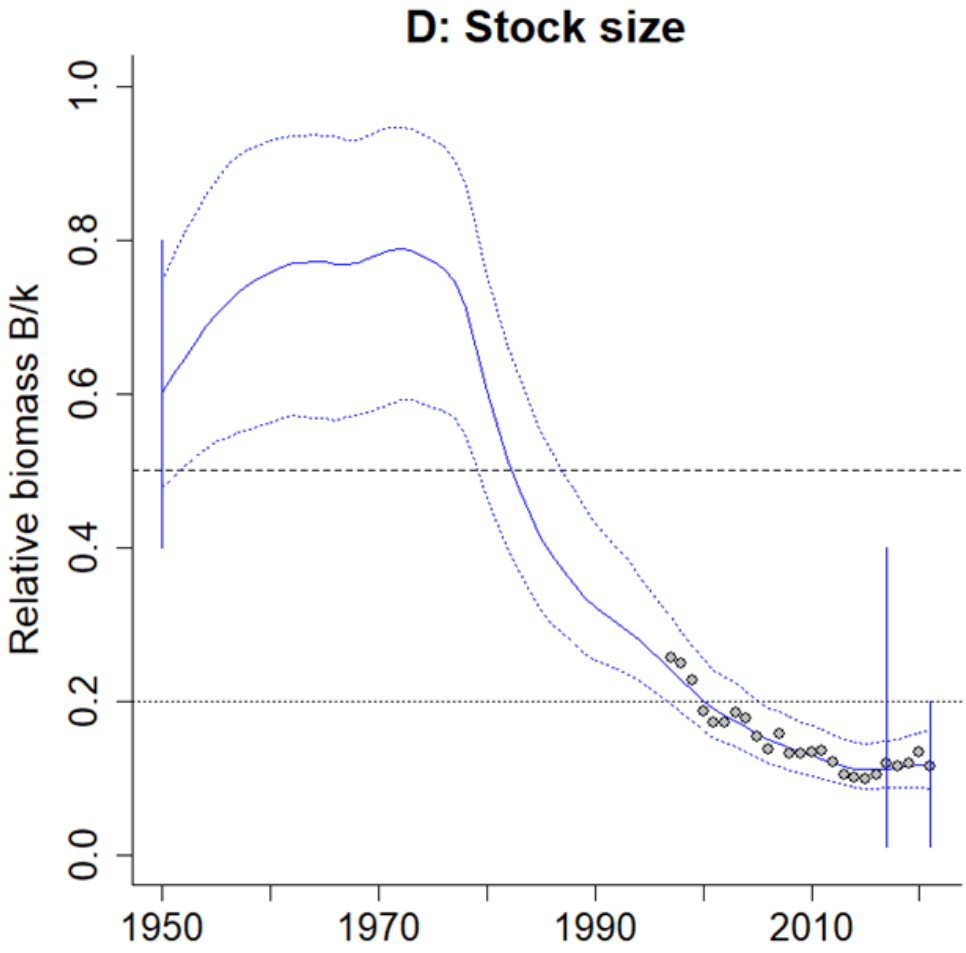

Figure 12 Model predicted biomass relative to unfished levels with approximate 95% confidence limits, for Grey Morwong 1950/51 to 2021/22. The vertical blue lines indicated the prior biomass ranges for the initial, intermediate and final years.

Assessment outcome

The status of the Eastern Australia biological stock of Grey Morwong is classified as **depleted**.

The status is based on the results of the surplus production model that estimated a biomass at the end of 2021/22 to be approximately 0.11 (95% CI 0.08 – 0.16) that of unfished levels and is supported by:

1. Long-term decline in the average sizes of Grey Morwong landed commercially;
2. Substantial decline in the recreational harvest in NSW since 2000/01;
3. Age compositions that lack older individuals.

The available data and results of the various analyses described in this report indicate that the biomass of Grey Morwong was likely fished down during the 1970s and into the 1990s, with landings greatly exceeding the estimated MSY. There has been a substantial reduction in commercial fishing effort towards Grey Morwong since the 1990s, and corresponding declines in estimated recreational harvest; however it appears as if these reductions have

been insufficient to allow the stock to recover. Grey Morwong was classified as overfished in NSW in 2008 based on data up to 2005/06 (Stewart et al., 2015). Since that time management changes aimed at reducing fishing mortality in NSW waters have been introduced, including: an increase in the minimum legal length from 28 to 30 cm total length in 2007; a decrease in the recreational bag limit from 20 to 10 fish in 2007, and; the introduction of escape panels in demersal fish traps in 2008.

The slight increases in standardized catch rates between 2016/17 and 2020/21, and increases in average sizes of fish landed, are associated with an increase in fishing effort on the south-coast of NSW. This shift in fishing effort likely exploited a part of the population that had not received intense fishing pressure for a considerable time. These positive trends appear to have plateaued or declined as of 2021/22.

Limitations and uncertainty

Accounting for fishing mortality throughout the entire history of the fishery for Grey Morwong is challenging due to a lack of species-specific records prior to the 1970s. Nevertheless, compilation of available information largely done by Klaer (2001, 2004, 2006) and in this assessment report, has enabled a catch reconstruction. One substantial limitation is a lack of information on historical discarding, something that may have been significant before market acceptance of Grey Morwong. Unfortunately the rate of discarding is likely to have been inconsistent through time, so applying a set rate across the time series is inappropriate. Increased catch (retained and discarded) during the earlier years in the fishery may result in an increase in the estimated MSY; however the large declines in catch, catch rates and average sizes occurred during the latter part of the time series when catch reporting was more robust, and as such the unknown discarded component of the historical catch will not affect the conclusion that the biomass of the stock is depleted.

Changes in commercial logbook reporting have created difficulty in generating a long time-series of catch rate information, mainly due to inconsistencies in the way fishing effort was reported rather than landings. The method used in this assessment to standardize each time series of catch and effort data separately, and to combine these standardized catch rates to make the years either side of the logbook change (2008/09 and 2009/10) equal, should not bias any overall trend. Future adoption of more complex and sophisticated stock assessment software may enable the disparate time series of catch rates to be combined within the model.

Despite compiling available information from the NSW and Commonwealth fisheries, data from the NSW fishery had a greater influence on the stock assessment. Standardized catch rates were only done for NSW trap fishing, and it is unknown whether Commonwealth trawl catch rates would show similar trends. There is overlap in the distribution of fishing effort between the Commonwealth trawl and NSW trap fisheries (mainly off the south-coast of NSW); however landings are affected by differing gear selectivity and management rules.

Recreational harvest was estimated to be significant, with harvest comparable to commercial harvest. Recent surveys of recreational harvest of Grey Morwong have been done on a subset of recreational fishers only, and have also produced imprecise estimates (due to low sample sizes and high CVs). The method of hindcasting recreational harvest prior to the first recreational survey in 2000/01 is also highly uncertain.

The extended pelagic larval paperfish stage of Grey Morwong increases the likelihood that environmental and oceanographic conditions may affect recruitment success in Grey Morwong. Knowledge of the influence of the strengthening East Australian Current (EAC) on larval recruitment will be important for understanding the role of fishing in any recovery of the stock.

Future assessment and research

Assessment

The current stock assessment builds on previous work and has provided estimates of relative biomass. Despite considerable uncertainties in the catch and effort data, future stock assessments would benefit from application of a complete biomass dynamic model, rather than the surplus production model and trends in fishery performance used here.

Research

Areas of research that would improve certainty in the stock assessment and contribute to future stock rebuilding and harvest strategies include:

- Discard rates across all major fishing methods (commercial and recreational);
- Discard/release survival rates across all major fishing methods (commercial and recreational);
- Improved recreational harvest estimates that encompass total catch;
- Population structure of Grey Morwong across its distribution;
- Movement patterns of all life-history stages;
- Recruitment dynamics, including source-sink larval patterns and influences of oceanographic conditions;

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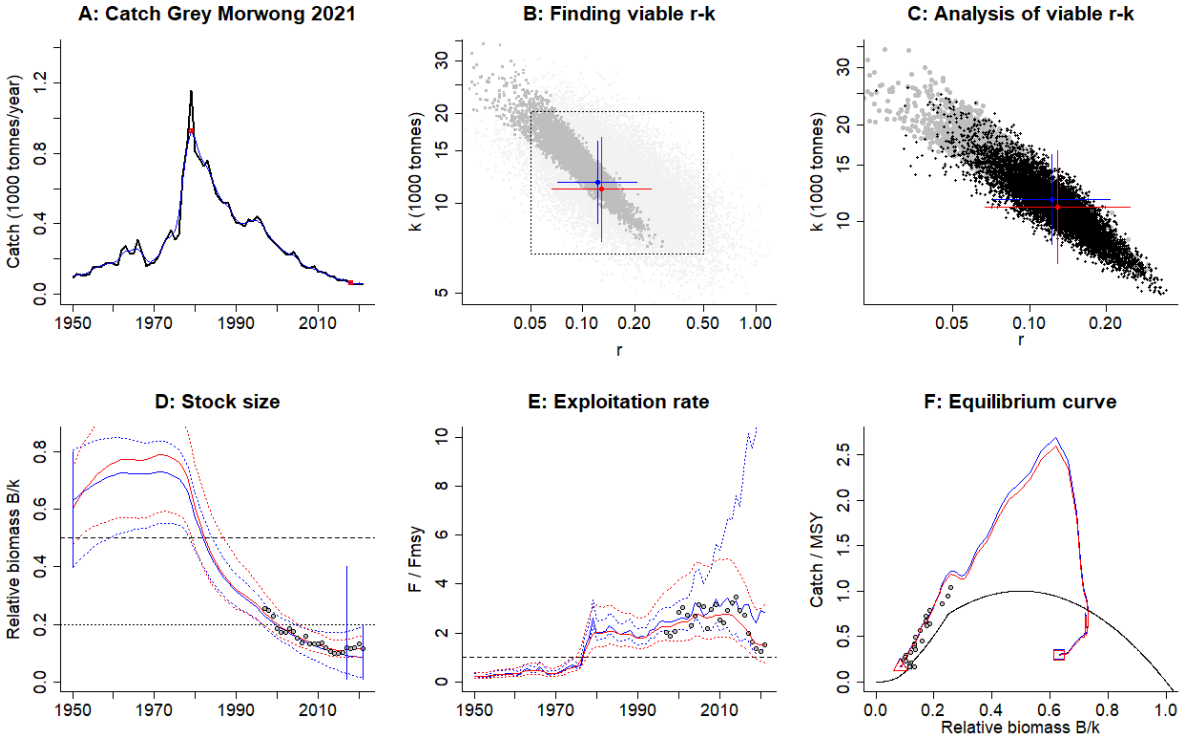
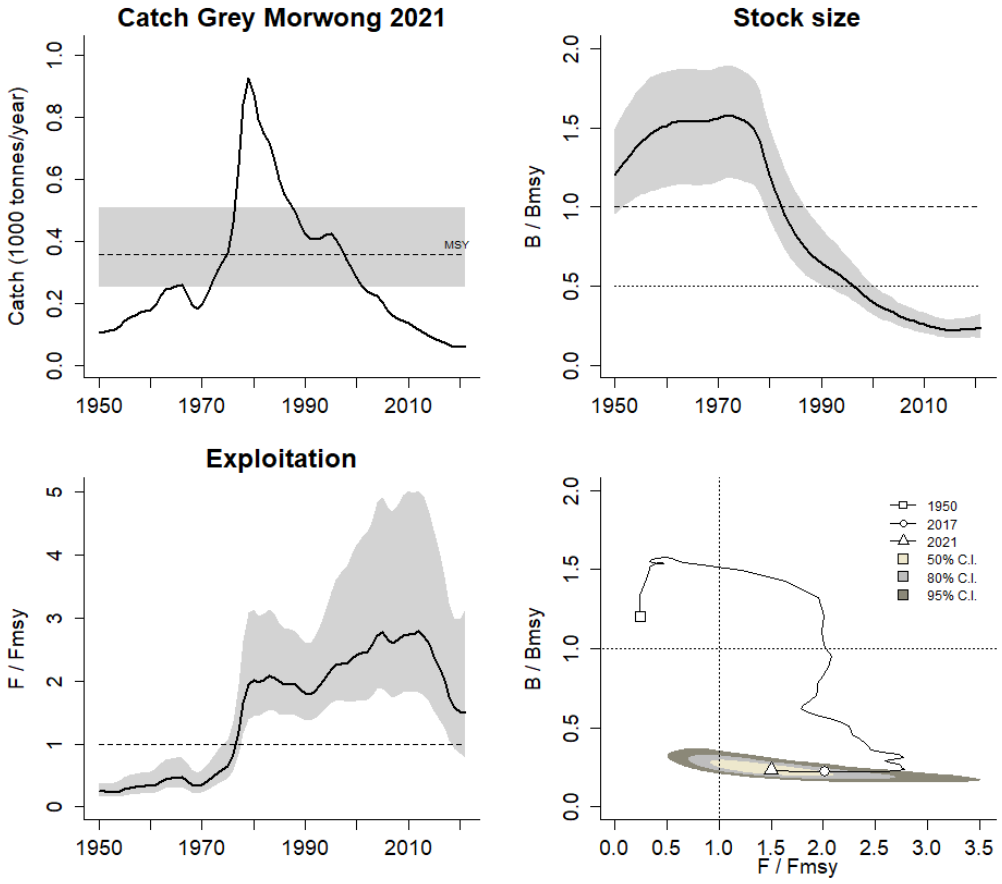
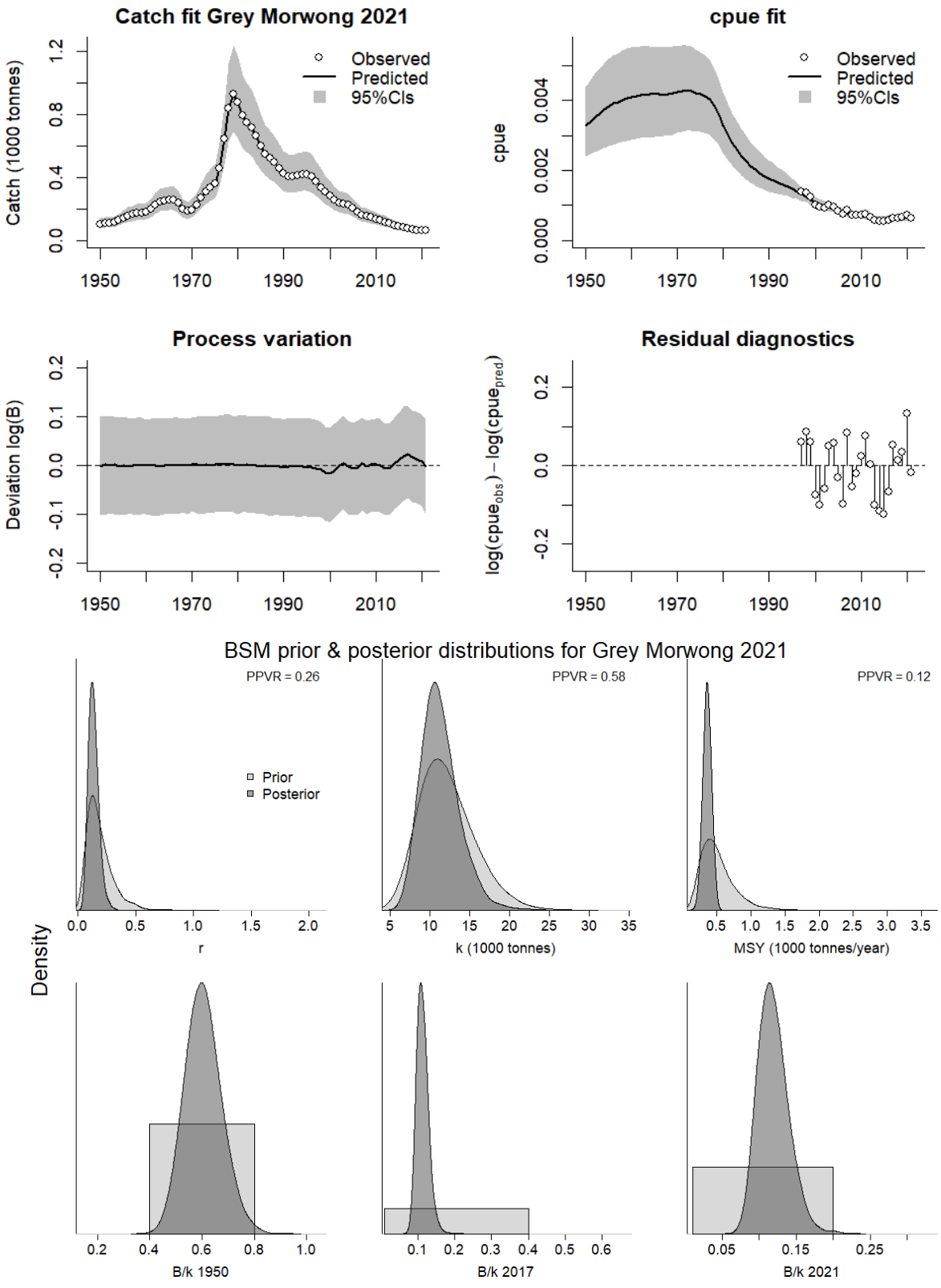
Appendix 1.

Outputs and diagnostic plots from the CMSY+ Bayesian state-space implementation of the modified Schaefer surplus production model for the base-case model.






Catch fit Grey Morwong 2021
Catch (1000 tonnes)
Observed
Predicted
95%CIs
cpue fit
cpue
Process variation
Deviation log(B)
Residual diagnostics
log(cpue_obs) − log(cpue_pred)
BSM prior & posterior distributions for Grey Morwong 2021
PPVR = 0.26
PPVR = 0.58
PPVR = 0.12
Prior
Posterior
Density
r
k (1000 tonnes)
MSY (1000 tonnes/year)
B/k 1950
B/k 2017
B/k 2021

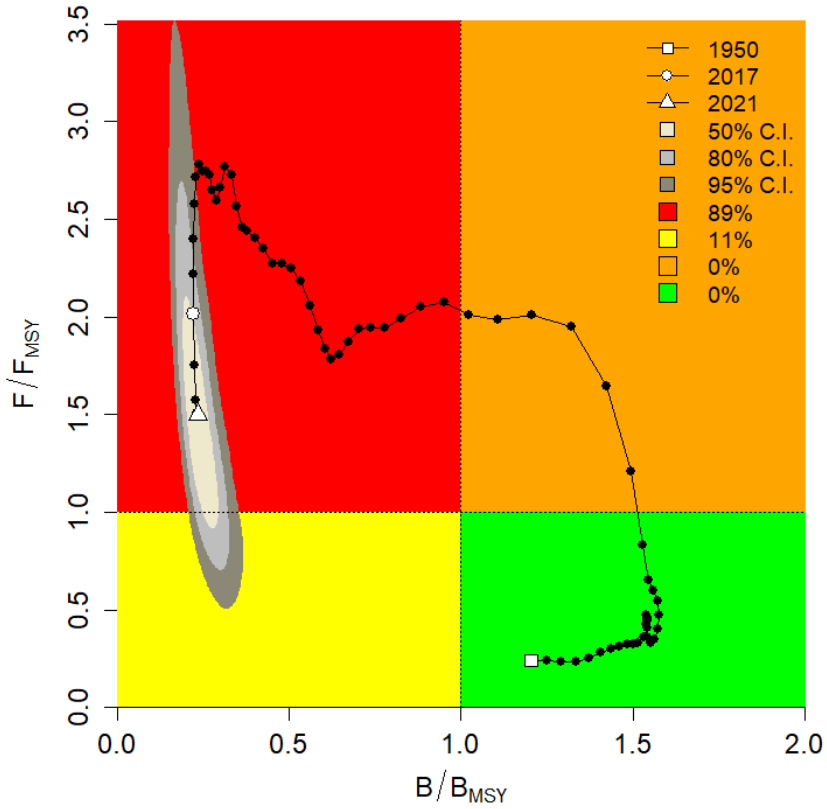


Table 1 Summary of posterior estimates (medians) and 95% Bayesian Credibility Intervals (C.I.s) of parameters for Grey Morwong from the various sensitivity scenarios for the surplus production model.

Scenario	Viable trajectories	r			K (1000 t)			Depletion 2021		
		median	2.5%	97.5%	median	2.5%	97.5%	median	2.5%	97.5%
Base case	7,164	0.13	0.06	0.24	11.1	7.43	16.6	0.11	0.08	0.16
Scenario 2. Alternative catch reconstruction	5,746	0.13	0.07	0.26	11.7	7.8	17.7	0.11	0.08	0.15
Scenario 3. Resilience very low	447	0.03	0.01	0.06	42.6	24.8	73.2	0.07	0.03	0.12
Scenario 4. Resilience medium	890	0.34	0.23	0.51	5.8	4.4	7.8	0.12	0.09	0.15
Scenario 5. Resilience High	None									
Base case, prior final relative biomass 0.05 to 0.8	13,350	0.127	0.07	0.24	11.2	7.6	16.6	0.12	0.09	0.16

Appendix 2.

NSW Commercial logbook reporting changes

NSW catch and effort logbook data vary spatially and temporally across different eras, delineated by changes in catch reporting requirements and management. This section briefly summarises the catch and effort data available for each era and associated limitations and caveats (Table A1 - 1).

(1) Historical data (pre-1984) – annual catches (kg) reported by port of landing or individual estuaries, which can be aggregated into the ten broad ocean zones and seven estuary regions used in later eras (Figure A1 - 1). No information on fisher, vessels or effort is available, and catch could only be assigned to individual methods if a single method was used by a fisher in any given month. Given the lack of appropriate effort data for this era, it is not possible to compile a CPUE series for any species in NSW state waters prior to July 1984.

(2) Historical data (July 1984 to June 1997) – monthly catches (kg) reported by ten broad ocean zones or individual estuaries (Figure A1 - 1). Details on fishers, boats and effort by gear type (in days fished per month) are available. Catch could only be assigned to individual methods if a single method was used by a fisher in any given month. Therefore, CPUE data for this period include only a subset of catch records for each species. No depth information is available. Trawl catches taken in offshore Commonwealth waters south of Barrenjoey Point and landed at a NSW port were included on NSW log sheets.

(3) Recent data (July 1997 to June 2009) – monthly catches (kg) reported by ten broad ocean zones or individual estuaries (Figure A1 - 1). Details on fishers, boats and effort by gear type (in days fished per month) are available. Method was assigned to all catches. No depth information is available. Trawl catches taken in offshore Commonwealth waters south of Barrenjoey Point and landed at a NSW port were no longer included on NSW reporting. Catch, effort and CPUE data (in kg per fisher day) are available for this era.

(4) Recent data (July 2009 to June 2021) – daily catches (kg) reported to individual estuaries and a finer spatial scale (0.1° x 0.1° C-square grid) for ocean waters. Many species complexes were split and catches reported by individual species. Details on fishers, boats and effort by gear type (by a single effort unit, e.g. hours fished, number of hooks or traps, or net length). Depth information is not reported by fishers but can be interpolated from location data (from the mean or median depth of the reported C-square). To construct a longer time series of data (from 1984/85 or 1997/98 to present), these daily records can be re-aggregated into monthly catches (kg) by fisher and gear type, with effort in days per month estimated from the number of distinct fishing dates in each month where the method was used, irrespective of whether the species was reported on those days, to be consistent with earlier reporting. Catch, effort and CPUE data (in kg per effort unit or kg per fisher day, using re-aggregated data) are available for this era. Significant reductions in effort (and consequently spikes in CPUE) are evident in some species' data following these logbook changes in July 2009; long time series of CPUE that cross this period need to be interpreted with caution.

NB: Mixed zone reporting – prior to July 2009, some catches were reported against mixed ocean zones (e.g. OZ1 and OZ2 combined). To report by zones, these catch and effort data are divided and reallocated evenly to each of the zones involved. Most of the mixed zone records were for just two zones and less than 3% involved three or more zones. After June 2009, all catches were reported according to the finer-scale C-squares.

Table A2 - 1 Data sources of commercial fishery records and changes to fisher reporting requirements through time.

Fishery	Time period	Data source	Reporting requirements
	Pre-1984	HCatch	Catch unit – kg per month No fisher, vessel or effort information available Spatial scale – port of landing
	July 1984 – June 1997	ComCatch	Catch unit – kg per month Effort unit – days fished per month Catch data not linked to individual methods, therefore, effort only assigned to catches when a single method was used in a given month. Spatial scale – 10 broad ocean zones
	July 1997 – June 2009	ComCatch	Catch unit – kg per month Effort unit – days fished per month Catch data provided for each method used Spatial scale – 10 broad ocean zones
	July 2009 - present	FishOnline	Catch unit – kg per fishing event (within each day) Effort unit – various depending on method (days fished per month can be extracted from re-aggregated daily data). Catch data provided for each method used Spatial scale – 0.1° x 0.1° C-square grid Voluntary E-reporting of catch records since 2011

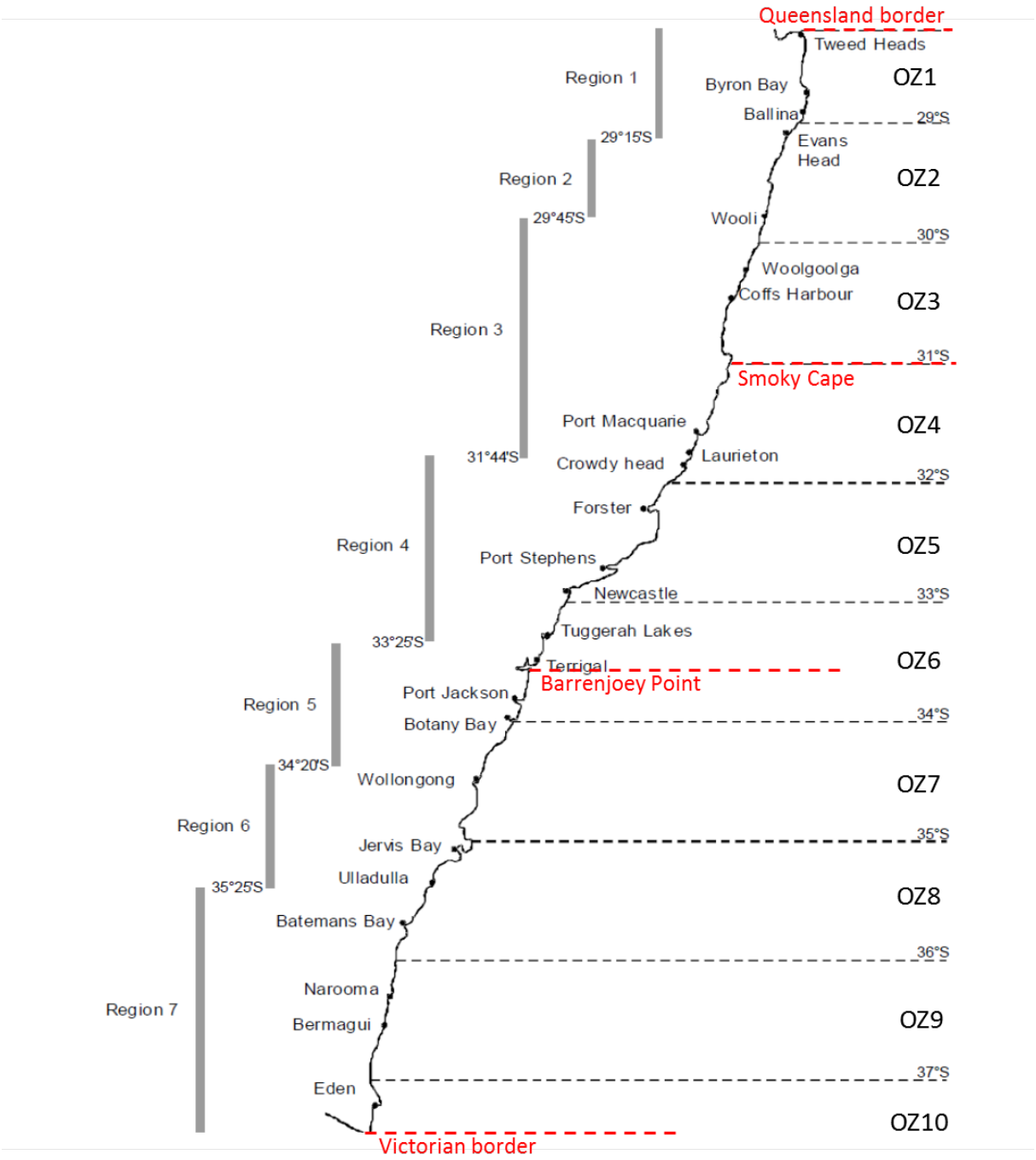


Figure A2 - 1 Map of NSW coastline indicating the main ports of landing, broad ocean fishing zones (OZ1 to OZ10) and estuary fishing regions (Regions 1 to 7) for catch and effort reporting. Important management landmarks, including Smoky Cape, Barrenjoey Point and the Queensland and Victorian borders are also indicated by dashed red lines.