Stock Assessment of Queensland East Coast black jewfish (*Protonibea diacanthus*), Australia, with data to December 2021

September 2022

Queensland Government

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Contents

Summary

This stock assessment indicates that spawning biomass in 2022 is at least 56% of unfished spawning biomass in 1940.

Black jewfish (*Protonibea diacanthus*) are caught on the east coast of Queensland by commercial, recreational, charter and Indigenous fishers. The fishery is focused around Central Queensland, and has recently experienced a large shift in commercial effort and gear types. The species was historically considered a byproduct species within the inshore net fishery, but has now become a targeted line caught species.

In Australia, black jewfish are found from Exmouth Gulf in Western Australia, north and east across Northern Australia, to the east coast of Queensland. Research suggests that stocks cover hundreds of kilometres.

This is the first stock assessment of the Queensland East Coast stock. The stock assessment was conducted on calendar years and included input data through to December 2021.

The assessment implemented a length-and-age population model in the software Stock Synthesis. The model incorporated data spanning the period from 1940 to 2021 including commercial logbook catch (1988–2021), historical commercial catch (1946–1981), recreational catch (1997–2020), and age and length data (2020–2021).

Over the last five years (2017 to 2021), the estimated Queensland East Coast total retained catch averaged 82 tonnes (t) per year, comprising 57 t (69.1%) by the commercial sector, 1 t (1%) by the charter sector, 24 t (28.8%) by the recreational sector and 1 t (1.1%) by the Indigenous sector (Figure 1). The commercial and charter catch were based on logbook reporting whereas the recreational and Indigenous catch were based on survey estimates and interpolated between survey years. The recreational, Indigenous and charter estimates were recorded in numbers of fish and converted to weight in kilograms using average fish weights. The commercial catch was already recorded in kilograms.

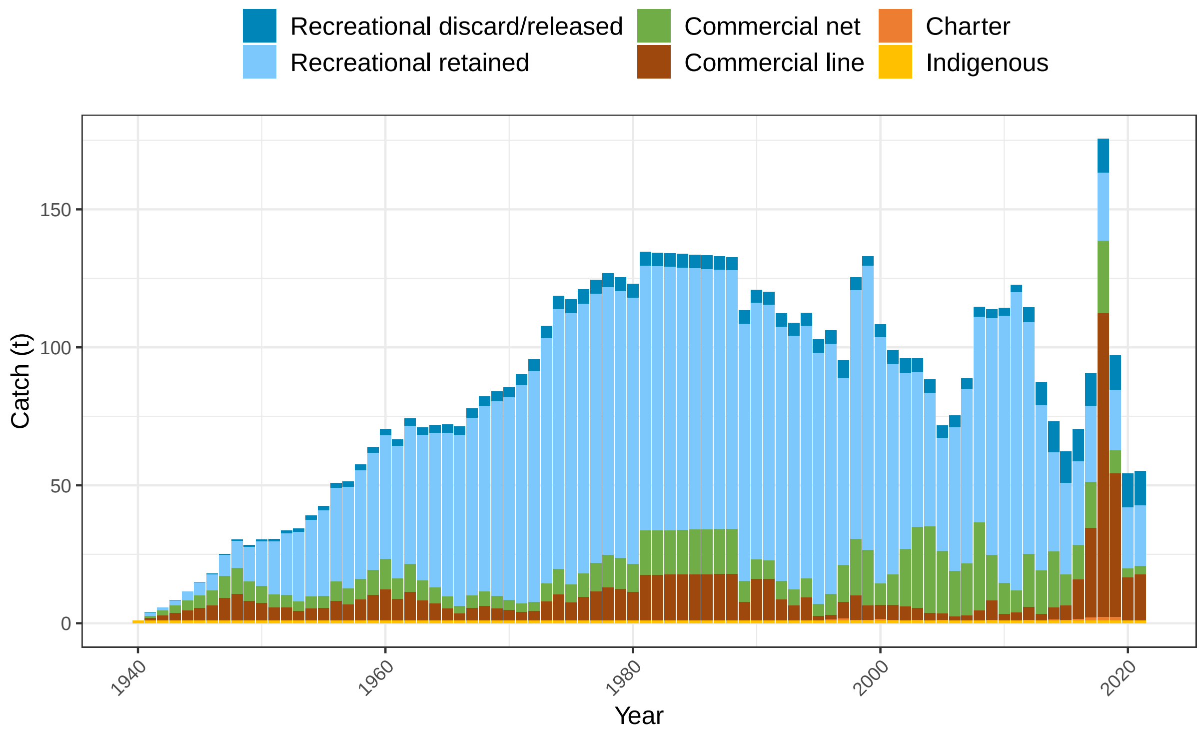

Figure 1: Annual estimated dead catch (retained catch + estimated discard mortality) from commercial, recreational, charter and Indigenous sectors between 1940 and 2021 for black jewfish. All sectors were considered as one fleet (”Line”) in the modelling, as there were insufficient length data from net fishing to define a selectivity function for that sector.

Commercial catch rates were standardised to estimate an index of black jewfish abundance through time. The unit of standardisation was kilograms of black jewfish per fishing operation, per day. Explanatory terms used in the standardisation model were year, fisher, month, Fishery Monitoring region, lunar cycles (both monthly and half-monthly), and (for net fishing) mesh size and net length. All the explanatory variables were categorical (factors), except for the lunar variables which consisted of four continuous variables, two for the monthly cycle and two for the half-monthly cycle.

Standardised catch rates showed very little trend in either the net or line fishing catch rates (Figure 2 and Figure 3), which indicated that either the population was likely to be large or that the catch had been fairly constant for many years.

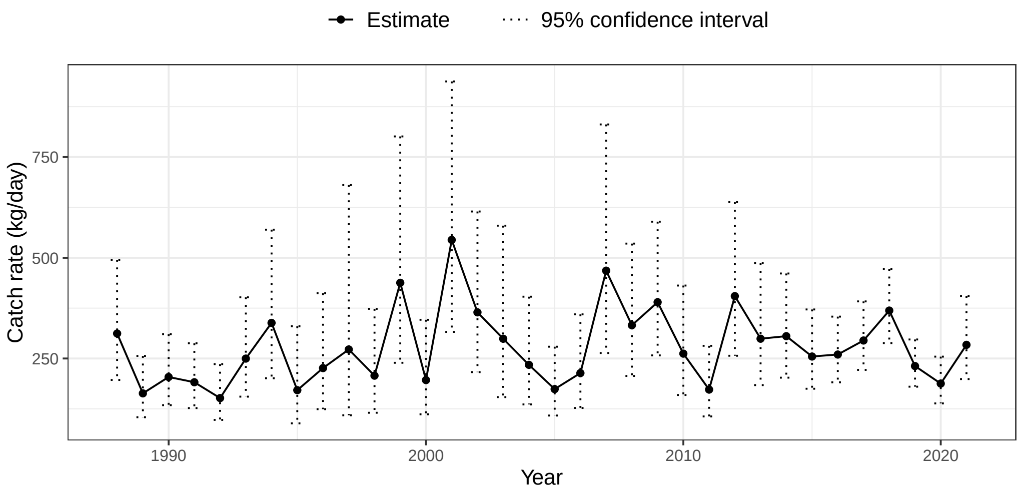

Figure 2: Standardised catch rates for commercial line-caught black jewfish between the years of 1988 and 2021

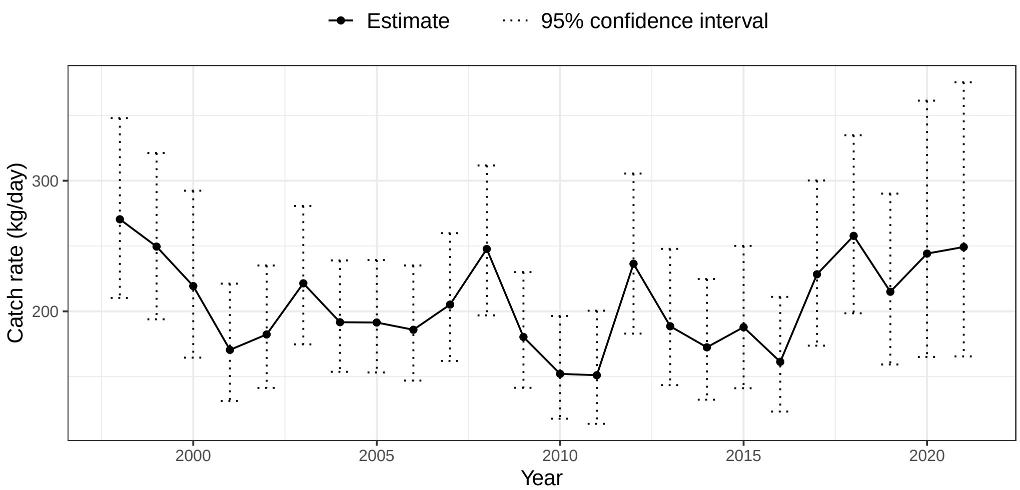

Figure 3: Standardised catch rates for commercial net-caught black jewfish between the years of 1998 and 2021

The catch rates had the most influence on the biomass estimates. Both the line and net catch rates showed little trend over the period of the commercial logbook data (1988–2021 for line, 1998–2021 for net).

Eight model scenarios were run, covering different combinations of recreational dead catch and population steepness (productivity parameter). Base case (preferred) scenario results suggested that biomass declined gradually from the 1940s to the 1980s and has increased slightly since then. The spawning stock level at the beginning of 2022 for base-case scenarios was estimated to be between 56% and 99% with a median estimate of 79%. The estimates from other scenarios ranged from 80% to 92%. Despite high uncertainty around the exact level of biomass, the model outputs indicate that the biomass is probably at or above the target reference point of 60% unfished biomass.

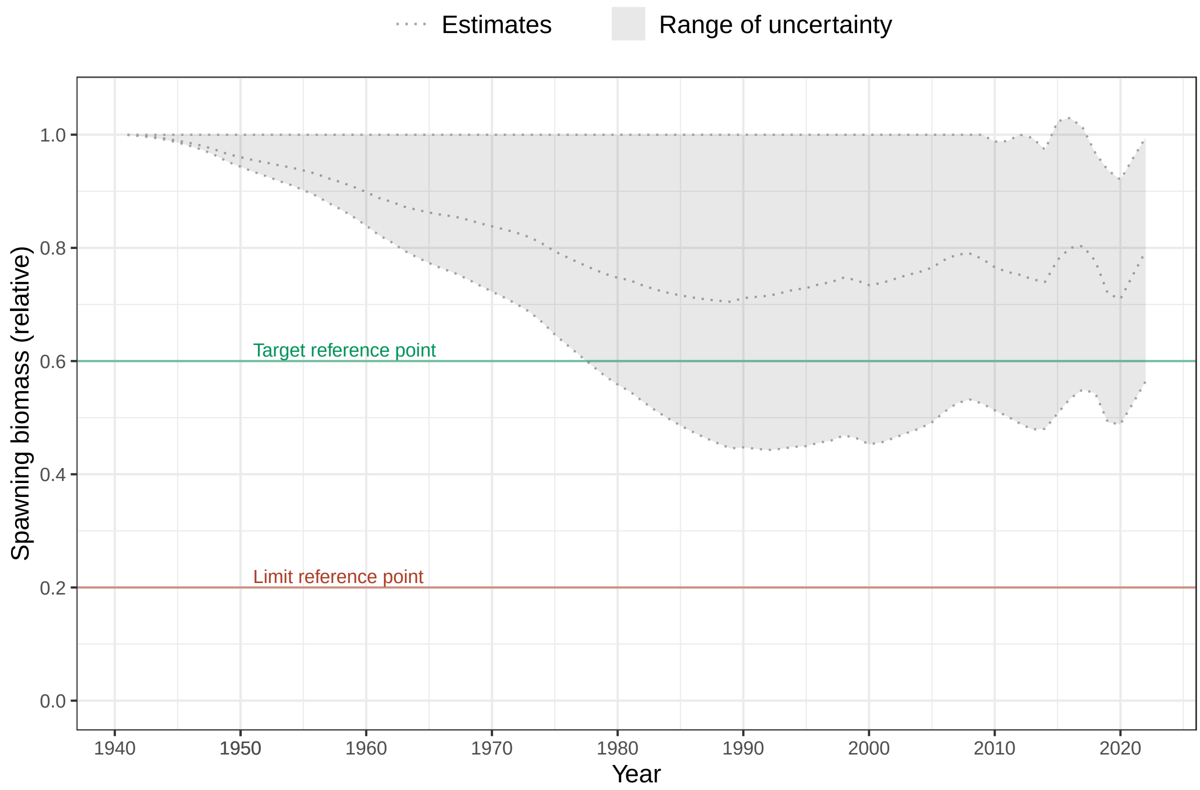

Figure 4: Predicted spawning stock biomass trajectory relative to unfished, from 1940 to 2022; the range of uncertainty arises from different assumed levels of natural mortality (M).

The recommended biological retained catch, consistent with maintaining a long-term biomass ratio of 60% under the Sustainable Fisheries Strategy 2017–2027, has been set on a precautionary basis given the very high uncertainty in the results. As a result, the lower recommended biological catch (RBC) is derived from the lower bound of the base case scenario (model output reflecting 56% biomass at 2022) and indicated there would be little risk in an increase from the 2021 level to 90 t of annual catch (all sectors combined). A range of base case model forecasts indicate that there may be capacity to increase the annual dead catch (all sectors combined) to as much as 180 t. While increasing the dead catch beyond 90 t will represent a greater risk, these higher increases would allow for greater potential contrast in the data and therefore more accuracy in future assessments. Any increase in the annual catch should be complemented by ongoing biological monitoring.

Application of the lower bound of the base case scenario, rather than the median projection of the base case, represents a effective uncertainty discount factor of 0.71

Table 1: Current and target indicators for Queensland east coast black jewfish

Indicator	Estimate
Biomass$^\diamond$ (relative to unfished) at the start of 2022	79% (range 56–99%)
Target biomass (relative to unfished)	60%
Dead catch at 60% biomass target	90 t (90–180 t; lower bound recommended due to high uncertainty)

$^\diamond$ Biomass is defined to be spawning stock biomass.

Acknowledgements

The work was overseen by a project team committee that consisted of the authors and the following scientists, data specialists and managers: Alex Campbell, Ryan Keightley, Darren Roy, Prasadini Salgado, Cherelle Broughton and Ashley Lawson. The role of the committee was collaborative to share interpretation and decision making on data inputs, assessment methods and results.

Agri-Science Queensland provided biological data including fecundity, spawning periodicity, maturity, length and age data in addition to important historical information on black jewfish through a Fisheries Research and Development Corporation (FRDC) funded Project 2019–056. This project, through its collaboration with Infofish Australia, also provided a summary of length data collected by expert recreational anglers. The project was also supported by preliminary data on movement and post-release survival derived from the Integrated Marine Observing System (IMOS) Queensland acoustic telemetry array project, funded by the Department of Environment and Science, Queensland and operated by the Australian Institute of Marine Science.

In addition to their roles on the committee, we would like to thank Prasadini Salgado for assistance with the Queensland commercial catch data; James Webley and Jessica Baker for the provision of, and assistance with, the Queensland boat ramp survey data and Queensland recreational statewide survey data.

We thank all the fishers who supported the collection of biological data as part of the Agri-science Queensland project, and are grateful for their dedication to research and commitment to the future of the fishery. The authors would also like to acknowledge and thank the many fishers who participated in surveys to gather historical information on the fishery, and scientists who contributed to past research on black jewfish.

Sincere thanks to the stock assessment scientists outside of the project team who provided input on a range of technical and conceptual challenges.

Finally, we would like to thank Alex Campbell, in addition to being a member of the project team, for reviewing and providing comments on the draft report. The assessment was funded by the Queensland Department of Agriculture and Fisheries.

Glossary

B_{40}	40% of unfished spawning biomass, a proxy for biomass at maximum sustainable yield
B_{60}	60% of unfished spawning biomass, a proxy for biomass at maximum economic yield
biomass	spawning biomass, the total weight of all adult (reproductively mature) fish in a population, an indicator of the status of the stock and its reproductive capacity
CI	confidence interval
CFISH	Commercial Fisheries Information System, which is the compulsory commercial logbook database managed by Fisheries Queensland
dead catch	retained catch ('harvest') plus catch that dies following release
ECIFF	East Coast Inshore Fin Fishery
fisher–day	a day of fishing by a fishing operator, corresponding to a single daily logbook record (commercial)
fishing year	for black jewfish, fishing year is defined to be the same as calendar year
fleet	a population modelling term used to distinguish types of fishing activity: typically a fleet will have its own selectivity curve that characterises the likelihood that fish of various sizes (or ages) will be caught by the fishing gear
FRDC	Fisheries Research and Development Corporation
GBR	Great Barrier Reef
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
GLM	Generalised linear model
MLS	minimum legal size
MSY	maximum sustainable yield, is defined to be the maximum sustainable dead catch—that is, retained catch plus catch that dies following discarding.
NRIFS	the National Recreational and Indigenous Fishing Survey conducted by the Australian Department of Agriculture, Fisheries and Forestry
RBC	recommended biological catch, is the recommended catch according to the control rule. This is dead catch: retained catch plus catch that dies following discarding.
retained catch	component of the catch that is kept by fishers, also referred to as 'harvest' and 'landed catch'
RFish	recreational fishing surveys conducted by Fisheries Queensland
SFS	Queensland Sustainable Fisheries Strategy 2017–2027
SRFS	Statewide Recreational Fishing Survey
SS	Stock Synthesis software for fishery stock assessment
TL	total length, measured from the tip of a fish's nose to the end of its tail

1 Introduction

Black jewfish (*Protonibea diacanthus*), also known as blackspotted croaker, occurs in coastal waters of the Indo-Pacific region from the Persian Gulf, through Asia, to Japan in the north and northern Australia in the south (AquaMaps 2019). In Australia, black jewfish are found from Exmouth Gulf in Western Australia, north and east across Northern Australia, to the East Coast of Queensland. Research suggests that stocks cover hundreds of kilometres (Taillebois et al. 2017). Preliminary information also suggests that black jewfish show high levels of connectivity between adjacent aggregation sites, with movements ranging over 150km from tagging locations.

Black jewfish are caught on the east coast of Queensland by commercial, recreational, charter and Indigenous fishers, north of about 24.5 °S. In the waters off Queensland's East Coast, black jewfish are distributed throughout the range from Townsville to Gladstone. North of Townsville, the presence of large jewfish aggregations becomes patchy, with only low numbers of fish encountered between Lucinda and Cooktown, before fish readily interact with fishers north of Cape Melville. The stock spawns primarily during summer months and the species can attain lengths of at least 150 cm (total length) and weights of at least 42 kg, and can live up to at least 15 years (DAF, unpublished data). It inhabits waters within the Great Barrier Reef Marine Park, and a number of large aggregation sites are located within no-take areas declared in the 2004 re-zoning.

Black jewfish is known to be susceptible to over-fishing. Phelan (2008) states, "There are numerous examples in the scientific literature which clearly illustrate the health of black jewfish stocks will decline in a rapid and pronounced manner if management arrangements allow over-fishing. Changes are evident as significant declines in both the number and average size of fish. An extreme example of the negative impact of over-fishing on black jewfish catches comes from India. In the 1980s, the Gujarat coast supported a fishery of 3250 to 4550 tonnes of black jewfish per annum. However, in the early 1990s, landings had fallen dramatically and 'these fisheries had become non-existent' (James 1994). Closer to home, over-fishing of black jewfish aggregations in northern Queensland provides a clear example of how rapidly the average size of a caught fish can decline under intense fishing pressure. The FRDC Project 1998/135 (Phelan 2002) revealed that black jewfish landed from aggregations in Cape York were almost exclusively immature fish (< 80 cm TL). Anecdotal reports revealed that large mature fish 150 cm TL were still being caught only five years earlier, but had now disappeared."

Black jewfish is a member of the family Sciaenidae, also known as croakers due to their ability to vocalise through vibration of their large swim bladders. The large swim bladders of black jewfish are considered a premium product in the Chinese wellness market, and are dried for use in soups (known as "maw"). Due to the high value of swim bladders, black jewfish have become a high-demand and high-value species in commercial fisheries throughout their range, including in Australian waters. The major related species with which black jewfish can be confused are mulloway *Argyrosomus japonicus*, silver jewfish *Nibea soldado* and scaly jewfish or "jewel fish" *Nibea squamosa* (Department of Agriculture and Fisheries 2022). Mulloway grows to about the same size as black jewfish but is fairly well separated spatially, occurring mainly south of 24.5 °S. Silver jewfish, although it does not grow as large as black jewfish, is often not distinguished from it in fishery data.

In the Queensland East Coast Inshore Fishery, black jewfish were traditionally recognised as a byproduct species in the commercial net fishery, and a recreational target species for both sport and food.

However, the increase in demand and price in their swim bladders led to large increases in targeted commercial line fishing and subsequent increased fishing mortality. In response, a number of emergency management measures were implemented including a current total allowable commercial catch limit (TACC) of 20 t on the east coast, a recreational in-possession limit of one, declaration of regulated waters at Dalrymple Bay and Hay Point shipping terminals and a closure for all fishing sectors once the TACC was filled. In recent years the commercial fishery has been dominated by line fishers which account for over 85 percent of the catch, with the remainder being taken in nets. For more information on the history of the fishery see Appendix E.

A survey of long-term fishers in the region was undertaken to understand the dynamics and history of the recreational jewfish fishery, which provided the following overview and is supported by data from state wide recreational fishing surveys (see Appendix E). Recreational fishers have been known to target black jewfish throughout Central and North Queensland waters since the 1970s. This targeting was primarily focused around a few near-coastal aggregation sites off Yeppoon, Repulse Bay, Stanage Bay and Bowling Green Bay, which allowed for easy access for small vessels or even from land-based sites (rocky headlands or sea spits). Targeting only occurred seasonally (usually in 2–3 month windows) to coincide with larger aggregations of fish occupying the near-coastal sites. Throughout the late 1900's black jewfish were targeted for food with large numbers of fish (up to 10+ per night) being taken by a small number of vessels/fishers. During the 2004 GBRMPA re-zoning, several of the regularly accessed black jewfish sites, such as those off Stanage Bay, Repulse Bay and Bowling Green Bay became no-take marine reserves. This re-zoning process effectively removed targeted fishing from the latter two areas. Today, black jewfish remain a popular recreational species and have become increasingly characterised as a sports fish, rather than a food fish (due to their large size and fighting ability), with fish now more regularly being released than retained (Taylor et al. 2012). Current recreational effort for jewfish is also split between targeting of smaller fish in rivers or embayments, and offshore sites. Stanage Bay remains the most prominent area for recreational targeting in Queensland waters. Overall it is considered that targeting for the species started in the mid-1970's, with a peak in annual recreational catch occurring in the late 1990's / early 2000's, before a shift in targeting behaviour which has now seen catch recede back to levels equivalent to or slightly below those experienced in the 1970's.

In 2022, the Queensland Department of Agriculture and Fisheries commissioned a stock assessment for black jewfish off the east coast of Queensland. This stock has not previously been assessed. This assessment aims to determine current stock biomass relative to an unfished state, provide estimates of sustainable catch to support Queensland's Sustainable Fisheries Strategy 2017–2027 (Department of Agriculture and Fisheries 2017), and contribute to the Status of Australian Fish Stocks (SAFS) process. The assessment covers the stock between the latitudes of 16.5 °S (Port Douglas) and 24.5 °S (Baffle Creek).

Table 1.1: History of black jewfish management in Queensland

Year	Management
1914	Minimum legal size (MLS) for all jewfish species set to 12 inches (30.5 cm) *Queensland Fish and Oyster Act 1914*
1926–1933	MLS for all species set to 13 inches (33 cm) *Amendments 1926, 1929 and 1933 by Order in Council to The Fish and Oyster Act of 1914*

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Table 1.1 – *Continued from previous page*

Year	Management
1957	MLS for all jewfish species set to 15 inches (38.1 cm) *Fisheries Act 1957*
1975	Inclusion of no-fishing zones in the Great Barrier Reef *Great Barrier Reef Marine Park Act 1975*
1976	MLS for black jewfish set to 30 cm *Queensland Fisheries Act 1976*
1982	Section 35 permit allows recreational fishers to sell excess catch *Fishing Industry Organisation and Marketing Regulation*
1988	Introduction of compulsory commercial logbook reporting
1990	May: Permits under Section 35 allowing recreational fishers to sell catch were repealed *Fishing Industry Organisation and Marketing Regulation*
1993	Black jewfish recreational bag limit set to 10 and commercial and recreational MLS set to 45cm *Fishing Industry Organisation and Marketing Regulation*
1999	Gulf of Carpentaria only: black jewfish less than 60 cm or more than 120 cm are regulated to commercial and recreational fishers. Taking or possessing more than 5 black jewfish or more than 2 black jewfish if the fish are more than 100 cm is prohibited to recreational fishers. Black jewfish must be kept whole while onboard a boat. *GOCIFFF Management Plan*
2004	July: Representative Area Protection and comprehensive rezoning of the Great Barrier Reef (GBR), increasing the proportion of the GBR closed to fishing from 5% to 33% *Great Barrier Reef Marine Park Zoning Plan 2003*
2008	MLS of 75cm and recreational bag limit of 2 introduced for the east coast *Fisheries Amendment Regulation (No. 5)*
2015	Net Free Zones introduced around Cairns, Mackay and Rockhampton *Fisheries and Another Regulation Amendment Regulation (No.1)*
2019	Black jewfish are the highest value fisheries resource in Queensland. Recreational possession limit of 1 per person / 2 per boat (with 2 or more people on board). Black jewfish must be kept whole while onboard a boat. Commercial fishermen who catch and retain black jewfish must check the status of the black jewfish TACC before departing on a fishing trip, give a pre-trip notice before commencing a commercial fishing trip and report catch via logbooks and AIVR so the TACC can be monitored, including a 1 hour report and an immediate weights notice when jewfish is first removed from the boat. May: black jewfish will become a no-take species for recreational and commercial fishermen on the east coast after the TACC of 20 tonnes is reached each calendar year. September: The take and possession of black jewfish in the Dalrymple Bay and Hay Point regulated waters is prohibited, in addition to the North Cape York regulated waters. Gulf of Carpentaria only: 6 t TACC was set for commercial and recreational sectors. *Fisheries Amendment Declaration*

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Year	Management
2020	January: The black jewfish fishery season reopened on 1 January 2020. Black jewfish is a no-take species for commercial and recreational sectors on the east coast after the annual 20 tonnes TACC is reached.
2022	The 20t TACC was regionalised among 4 east coast inshore Management Regions, with Management Regions 3 and 4 being allocated the majority of the TACC (over 19 t combined). Splitting the TACC into regions extended the season through reduced competition in some regions. Black jewfish becomes a no-take species for recreational fishers only when the TACC is reached in all Management Regions.

2 Methods

2.1 Data sources

Data sources included in this assessment (Table 2.1) were used to determine catch rates, age and length compositions, and create an RBC. The assessment period began in 1940 up until and including 2021 based on available information.

Table 2.1: Data used in the Queensland east coast black jewfish stock assessment

Type	Year	Source
Commercial retained catch	1988–2021	Logbook and quota data collected by Fisheries Queensland
	1946–1981	Queensland Fish Board data (Halliday et al. 2007)
Recreational dead catch	1975	Survey of historical recreational catch conducted by Agri-Science Queensland through Fisheries Research and Development Corporation (FRDC) Project 2019–056 (Principal Investigator Samuel M. Williams) (see Appendix E)
	1997, 1999, 2002, 2005	RFish Recreational fishing surveys conducted by Fisheries Queensland (Higgs et al. 2007; McInnes 2008)
	2010, 2013, 2019	Statewide Recreational Fishing Survey conducted by Fisheries Queensland (Taylor et al. 2012; Webley et al. 2015; Teixeira et al. 2021)
	2000	Recreational fishing surveys conducted by the Australian Department of Agriculture, Fisheries and Forestry (the National Recreational and Indigenous Fishing Survey, NRIFS) (Henry et al. 2003)
	1953–2002	Australian historical population statistics (for the state of Queensland), conducted by the Australian Bureau of Statistics, providing a proxy for fishing effort (ABS 2014)
	2015–2021	Boat ramp survey, conducted by Fisheries Queensland, providing length information
Charter retained catch	1988–2021	Logbook data collected by Fisheries Queensland
Indigenous retained catch	2000	Indigenous fishing survey conducted in 2000 by the Australian Department of Agriculture, Fisheries and Forestry (the National Recreational and Indigenous Fishing Survey, NRIFS) (Henry et al. 2003)
Biological data	2020–2021	Biological data provided by Agri-Science Queensland through Fisheries Research and Development Corporation (FRDC) Project 2019–056 (Principal Investigator Samuel M. Williams) (Williams 2020); includes summaries of data provided to this FRDC project by Infofish Australia

2.1.1 Regions

Information within the stock assessment boundary from latitude 16.5 °S (approximately Port Douglas) to latitude 24.5 °S (Baffle Creek) was included in the model inputs. Data on stock structure indicated that fish from management regions 3 and 4 are from the same population, while fish from management region 1 are from a separate stock (DAF unpublished data). Few black jewfish were caught by the commercial fishery around 16.5 °S (Fisheries Queensland, unpublished data), implying that this latitude may be a natural stock boundary. The southern limit was approximately the southern limit of black jewfish and the northern limit of mulloway (DAF unpublished data). The two species were not well distinguished in fishery data.

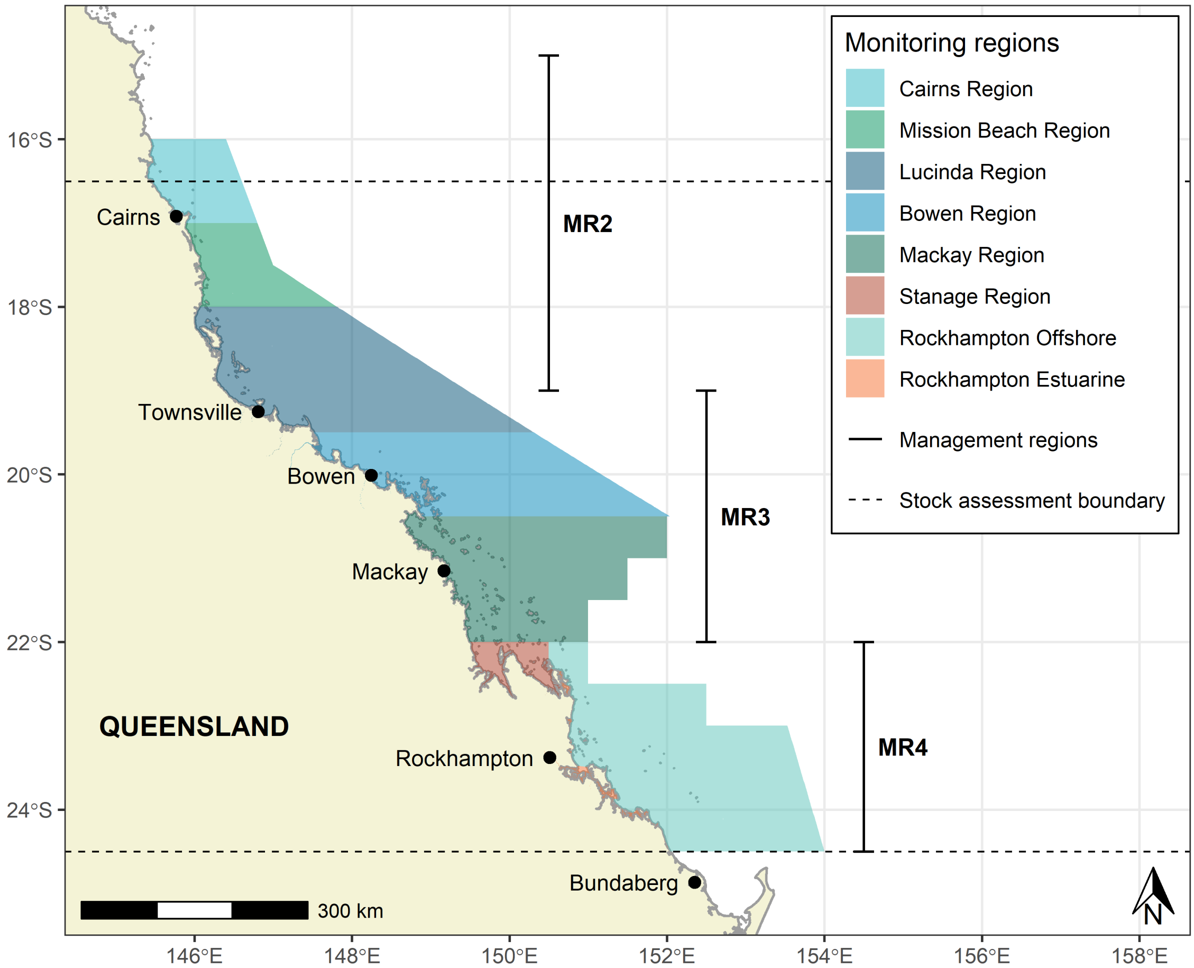

Figure 2.1: East coast black jewfish monitoring regions, management regions and stock assessment boundary from Baffle Creek (latitude 24 °5' S) to Port Douglas (latitude 16 °5' S).

2.1.2 Commercial

Commercial catches of black jewfish were recorded in the Queensland logbook system. The logbook system consists of daily retained catches (landed weight in kilograms) of all fish species from each individual fishing operator (licence) since 1988. In addition to landed weight, logbooks also record the location of the catch (30 minute or 6 minute grid identifier), net length and mesh size.

2.1.3 Recreational

2.1.3.1 Recreational fishing surveys

All recreational surveys provided estimates of the number of fish caught and discarded per trip, and combined this with demographic information to estimate annual totals for each species (or species group) at national, state and regional scales. See the references listed in Table 2.1 for more detail. For black jewfish, identification was to the species group (Jewfish—unspecified) level for most surveys and individual species information was not available. The 2019–2020 Statewide Recreational Fishing Survey (SRFS) has information down to species level.

Surveys conducted in 2000, 2010, 2013 and 2019 had more effective follow-up contact procedures with diarists resulting in less dropout of participants compared to the other survey years using RFish methodology (Lawson 2015). Rfish estimates were used only as trends, not as absolute catch estimates.

Information on historical targeting and catches of black jewfish by recreational fishers (prior to 2000) was sought through structured interviews of recreational and commercial fishers who had long-term involvement within the fishery (see Appendix E).

2.1.3.2 Boat Ramp Survey

Recreational data were collected by Fisheries Queensland in 8 different regions within the stock assessment boundary on the east coast, extending from Port Douglas (latitude 16.5 °S) to Baffle creek (latitude 24.5 °S) (see Figure 2.1). Staff trained in the survey protocol, and in identifying fish, interviewed recreational fishers at boat ramps during a survey shift. The surveys recorded day and location fished, catch of key species (including discards) and length of retained key species (Northrop et al. 2018; Fisheries Queensland 2017).

Length data for legal-sized black jewfish from Boat Ramp Surveys were used to calculate the average weight of a retained, recreationally-caught black jewfish.

2.1.4 Indigenous

The National Recreational and Indigenous Fishing Survey in 2000 attempted to redress the lack of Indigenous fishing information on a national scale by involving Indigenous communities in the gathering of fisheries statistics. Estimates of total catch for Indigenous communities followed similar procedures (Henry et al. 2003).

2.1.5 Charter

Charter sector catch data for black jewfish has been available from the Queensland charter logbook system since 1993, which has been compulsory for offshore charter fishers since 1996. This provided charter daily catch and releases (in numbers of fish) by species.

2.1.6 Historical

Commercially caught fish were by law marketed through the Queensland Fish Board until 1981. Fish Board records compiled by Halliday et al. (2007) provide estimates of annual black jewfish retained catch by weight for 37 districts across Queensland from 1963 to 1981.

2.1.7 Biological

Important biological length, age, maturity, growth, stock structure and fecundity data were provided by Agri-Science Queensland through a Fisheries Research and Development Corporation (FRDC) funded Project 2019–056 (Williams 2020). The project aimed to provide biological and genetic information that is required to enable a robust stock assessment of east coast black jewfish.

An understanding of the species ecology in Queensland including movement and connectivity of adults and juveniles between management regions and aggregation sites was supported by size and movement information collected through the IMOS acoustic array project and conventional tagging data provided by Infofish Australia.

2.2 Catch estimates

Commercial, charter, recreational and Indigenous catch data and historical catch information was analysed to reconstruct the history of catch from 1940 until the end of 2021 (Figure 2.2). Prior to 1940, black jewfish catch was presumed to be negligible. This section describes how data were combined to create the history of east coast black jewfish catch from the assessment's latitude range (Figure 2.1). Commercial, charter and indigenous catches are retained (landed) catch, and recreational catch refers to dead catch (retained plus a proportion of released).

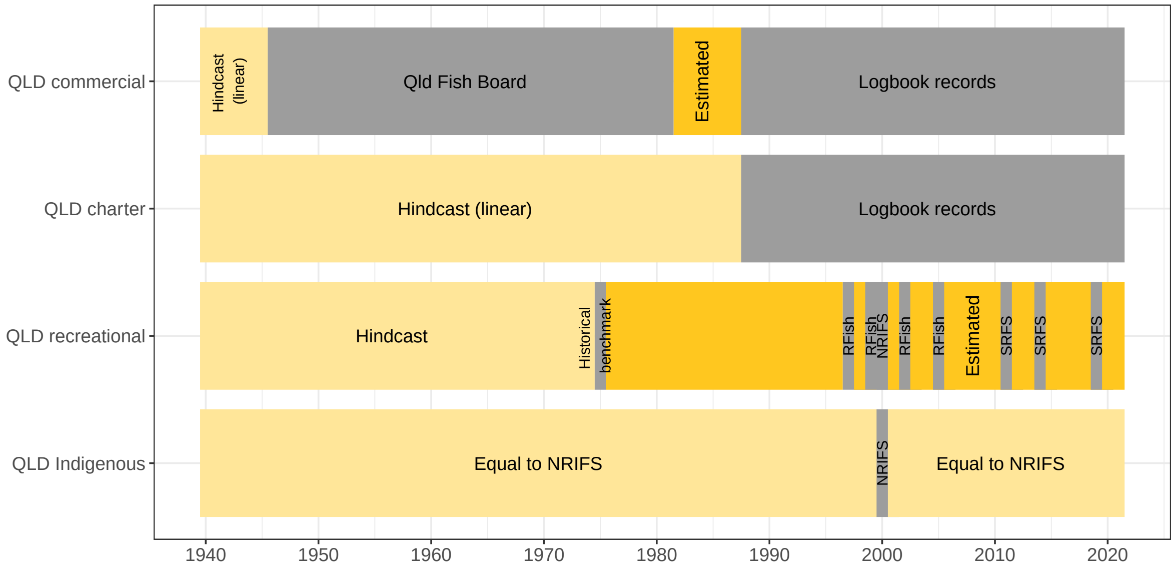

Figure 2.2: Overview of the methods used to reconstruct the history of east coast black jewfish catch

Commercial sector retained catch:

- **1940–1945:** Was assumed zero in 1940, and increased linearly to the value from the Queensland Fish Board in 1946.
- **1946–1981:** Equalled Queensland Fish Board records.
- **1982–1987:** Increased linearly from the last recorded Queensland Fish Board value in 1981 through to the first recorded Queensland logbook value in 1988.
- **1988–2021:** Equalled logbook values.

Charter retained catch:

- **1940–1992:** Was assumed zero in 1940, and increased linearly through to the first recorded Queensland logbook value in 1993.
- **1993–2021:** Equalled logbook values.

Recreational dead catch:

- **1953–1975:** Assumed zero in 1953 and increased proportionally to Queensland population growth through the time series to reach a value decided on by the project team in 1975. This year marks the commencement of targeted recreational fishing for black jewfish and is derived from structured interviews of long-term fishers. The value in 1975 is equal to 1.1 times the NRIFS (2000–2001) value, and is a liberal estimate that is assumed to be representative of the maximum potential recreational catch level during this period.

- **1976–1996 and 1998–1999:** Increased log-linearly from the 1975 project team value through to the NRIFS value (2000–2001).
- **1997, 1999, 2002, 2005:** Set to the rescaled RFish estimates. This rescaled estimate was calculated in the following way:
  - The RFish estimates from 1999 and 2002 were interpolated to obtain a candidate estimate for the year 2000.
  - The rescale factor was calculated as this candidate estimate divided by the NRIFS estimate for the year 2000.
  - This rescale factor was then used to rescale all RFish estimates.
- **2000, 2011, 2014, 2019:** Set to equal the values reported in the NRIFS (2000) and SRFS (2000–2001, 2010–2011, 2013–2014, 2019–2020) surveys.
- **2021:** Estimate for 2021 set to equal the value reported in the 2019–2020 SRFS survey.
- **2003–2004, 2006–2009, 2012 and 2015–2018:** "Missing" records were set to values linearly interpolated between the estimates from the survey years listed above.
- The proportion of black jewfish to silver jewfish in the SRFS 2019–2020 survey was used to split the category "jewfish—unspecified" into black jewfish and silver jewfish in other SRFS survey years. 67% of "jewfish—unspecified" catch was re-allocated to black jewfish catch in SRFS 2000–2001, 2010–2011, 2013–2014 surveys.
- Estimates for all years were converted from numbers of fish into weight of fish using a length–weight equation derived from ASQ data, BRS length values for retained fish, and ASQ length summaries from data provided by Infofish Australia for released fish. The weight of a recreational retained fish was calculated to be 9.9kg and the weight of a recreational released fish was calculated to be 1.4kg. The relatively high weight of a retained fish can be reconsidered in future assessments, given that recreational fishers have difficulty identifying jewfish species.
- Recreational dead catch was set equal to dead catch. This was calculated by adding the total number of fish assumed to have died after being released to the recorded recreational retained catch.

Indigenous retained catch:

- **2000:** Equalled the estimated number of fish caught by Indigenous fishers from the NRIFS survey
- **1940–1999 and 2002–2021:** The proportion of the total catch of black jewfish represented by the Indigenous sector was calculated in 2000. This proportion was then applied to the total catch of black jewfish in each subsequent year to give annual estimates of Indigenous catch for this period.

2.3 Standardised indices of abundance

The time series of abundance for input to the population model came from commercial line and gillnetting catch rates from logbook data. Logbook data were collated to produce one record per fisher-day, with each fisher-day including just one location (the one in which the most fish were caught) and a separate field for each relevant species group. Zero catches of black jewfish were included when species groups commonly associated with black jewfish were caught. These associated species groups were decided on the basis of the average catch of black jewfish over records in which a particular other species was caught. Details of this methodology are given in Leigh et al. (2017). For the net sector, the only species found to be associated with black jewfish was golden snapper (*Lutjanus johnii*), and only between the latitudes 22 °S and 23 °S. No associated species were found for the line sector.

The analysis used the quasi-negative-binomial generalised linear model (GLM), which is similar to the quasi-Poisson model used for tailor (Leigh et al. 2017, Section 3.2). The extension from quasi-Poisson to quasi-negative-binomial allows the variance of the residuals from the GLM to be more closely controlled so that data are weighted optimally and random "noise" in the resulting abundance estimates is minimised (Leigh in prep.).

The quasi-Poisson variance formula is:

$$V(y) = \sigma\mu$$

where V denotes variance, y is the dependent variable (catch in a fisher-day), σ is the dispersion parameter and μ is the mean or expectation of y. The quasi-negative-binomial model extends this to:

$$V(y) = \sigma(\mu + \mu^2/\phi)$$

where ϕ is the negative-binomial shape parameter. The limit $\phi \to \infty$ recovers the quasi-Poisson model.

Explanatory variables included in the GLM were calendar year, month, fisher ID, Fishery Monitoring region, lunar phase, and, for the net sector, mesh size and net length. All explanatory variables other than lunar phase were defined as categorical variables or "factors". Mesh size and net length were converted from continuous variables to categorical ones because the relationships between these variables and catch rates were complex. For example, a shorter net often catches more fish than a longer one, perhaps because many high-catch locations are not suitable for long nets, or because a short net is more transportable and can be easily moved to a new location if it is not catching much. Wind velocity could be included as an additional explanatory variable when the assessment is updated.

The catch-rate GLM used the log link function. This link function produces multiplicative effects: e.g. catch rates in location A may always be twice those in location B, irrespective of the year, time of year or fisher skill level. The year coefficients from the GLM were used as an index of abundance.

2.4 Discards and post-release mortality

Due to the large size of their swim bladder, black jewfish are know to be susceptible to the effects of barotrauma when retrieved from depth. However, the overall post-release mortality of black jewfish from line fishing remains uncertain.

A study from the Northern Territory by Phelan (2008) estimated the potential for mortality, based on signs of injury in during necropsies of captured fish. For the 10–15 m water depth range, 48% of black jewfish were found to have either fatal or critical injuries from the rapid change in water pressure as they were brought to the surface. However, these rates were only based on the assumption of mortality under particular conditions. They were not based on in-situ observations, and so are likely to represent precautionary estimates.

Preliminary results from recent acoustic tagging of black jewfish by a collaborative project between James Cook University, DAF and AIMS indicate that the actual rate of mortality is likely to be far lower. These preliminary results show a mortality rate of around 10–20% from more than 70 fish released with acoustic tags in water depths between 7 m and 20 m. The results also indicate that smaller fish appeared to have increased rates of survival.

Our base case assumes a conservative post-release mortality rate of 48%, based on the Phelan (2008) study, as this estimate would help to account for fish released in waters deeper than 20m. This may turn out to be an overestimate once the complete results of the acoustic tagging work are finalised.

Data from the Queensland SRFS recreational surveys indicated that most releases of black jewfish were made because the fish were below minimum legal size. This information is also supported by the size range reported in the Infofish Australia recreational tagging data.

2.5 Biological information

2.5.1 Fecundity and maturity

Maturity values in the model were age-dependent, as inferred by unpublished data associated with FRDC Project 2019-056.

Spawning period was indicated by the presence of male and female gonad stage in both the running ripe and spent state, as identified in FRDC Project 2019-056. Similarly fecundity estimates provided by FRDC Project 2019-056 were made available to provide estimates of the number of eggs produced by a female black jewfish as proportional to weight.

2.5.2 Weight and length

Length and weight data were provided by Agri-Science Queensland through FRDC Project 2019-056. This information was used to calculate the weight–length relationship:

$$W = 1.4254 \times 10^{-5} \times \mathrm{TL}^{2.9063}$$

where W is weight (kg) and TL is total length (cm).

2.6 Length and age data

Length data were input to the population model in one-centimetre length bins. Age data were input as conditional age-at-length samples.

Sufficient length data to define a "fleet" in the population model were available only from the commercial line sector. Therefore the catch from all sectors was assumed to have the commercial line-fishing selectivity function.

A summary of recreational lengths, including under-sized released fish, was also made available by the FRDC Project 2019–056, using data provided by Infofish Australia. The summary was used to estimate the average weight of recreationally released fish.

2.7 Population model

An annual, single-sex, singe-region population model was fitted to the data to determine the number of black jewfish in each year and each age group using the software package Stock Synthesis (SS; version SS-V3.30.19.01) (Methot et al. 2013). A full technical description of SS is given in Methot et al. (2021). It is programmed in the software AD Model Builder (Fournier et al. 2011). The results were read and interpreted by the R package "r4ss" (Taylor et al. 2020).

As stated above, the model contained only a single fleet, commercial line fishing, and all catch was assumed to have been taken using the length-based selectivity function for this fleet. The selectivity was assumed to be a two-parameter logistic function, the parameters being L_{50}, the length at which 50% of the fish are selected, and $L_{95\,\text{diff}}$, the different between L_{50} and the length at which 95% of the fish are selected.

Released fish were not explicitly modelled. Dead catch was taken to be the total number of fish that died from fishing, including fish that were released but later died.

2.7.1 Model assumptions

The population of black jewfish over the assessments latitude range (16.5 °S to 24.5 °S) was assumed to be a single, well mixed stock.

The model used the Beverton–Holt stock-recruitment relationship (Beverton et al. 1957):

$$R = R_0 \frac{4hS}{(1-h)S_0 + (5h-1)S}$$

where R is the number of recruits in a particular year, R_0 is the corresponding number of recruits for an unfished population, h is the population's "steepness" or productivity parameter, S is the spawning stock size in kg, and S_0 is the corresponding spawning stock size for an unfished population.

Annual, random recruitment deviations were applied for birth years for which age data were present. These were the years 2008–2020. For a random recruitment deviation, R is multiplied by:

$$\exp(\eta - \sigma_R^2/2)$$

where η is the year-specific recruitment deviation and follows a normal distribution with mean zero and variance σ_R^2. The subtraction of $\sigma_R^2/2$ is for bias correction, to prevent the expected biomass in the presence of recruitment deviations from becoming greater than the deterministic unfished biomass.

The instantaneous natural mortality rate, M, was assumed not to depend on age or year.

The fishery catch rate in each year was assumed to be proportional to the abundance of fish in that year.

Notwithstanding the length-based nature of selectivity, pure age-based modelling, without the use of SS's "platoons" feature, was assumed to be sufficient for this assessment.

2.7.2 Model parameters

Parameters were estimated within the model where possible, to enable the best possible fit to available data. Uninformative priors were used. Other parameters were fixed at appropriate levels.

The natural logarithm of the deterministic number of recruits in an unfished population (SR LN(R0)) was estimated within the model.

Beverton–Holt stock recruitment steepness (SR BH steep) was fixed at 0.70 in the base case, which was inferred based on aspects of the species biology including age at maturity, maximum age and fecundity. To test the sensitivity of steepness on the model a lower values for steepness of 0.6 was tested.

Natural mortality rate (M) is the rate of the removal of fish from a population due to causes not associated with fishing: examples include predation or old age.

In many cases, including the base case, M could not be estimated in a stable way through optimisation. This happened mainly due to lack of contrast in the catch rates. In these cases, different levels of M were obtained by starting at a biologically plausible value and then lowering (and raising) M by increments until the negative log-likelihood increased significantly. In this way indicative upper and lower confidence limits on stock assessment outputs were obtained.

Logistic length-based selectivity parameters were estimated in the model for both fleets (parameter names “Size inflection Commercial”, “Size 95 percent width Commercial”, “Size inflection Recreational”, and “Size 95 percent width Recreational”). Separate selectivity curves were estimated for the commercial fleet and the recreational-charter-Indigenous fleet.

The following parameters of the von Bertalanffy growth curve were estimated within the model: length at age 1.5, growth rate (κ), standard deviation of length at age 1.5, standard deviation of length at age 13.5. The length at age 13.5 was fixed at 118.1cm on the basis of a von Bertalanffy growth curve fitted to length-age data.

2.7.3 Model weightings

All likelihood components were given full weighting in the model ($\lambda = 1$). Length and age data were given weights less than 1, as described below.

Fishery stock assessments generally require length and age data to be given weights less than 1 to cover many different characteristics of the way the fish were caught (Francis 2011). The most easily explicable effect in that most fish school by size, so that a sample of a school may capture only one size interval, not the full size distribution of the population.

The data weighting method of Francis (2011) is widely used by Stock Synthesis practitioners, although it works poorly in some assessments (O’Neill et al. 2014). It also worked poorly in this assessment, recommending that the age weighting be reduced by a factor of about 15 no matter by how much it had already been reduced. Using the Francis method as a rough guide, we settled on weightings of 0.2 for length data and 0.3 for age data.

2.7.4 Sensitivity tests

A number of additional model runs were undertaken to determine sensitivity to fixed parameters, assumptions and model inputs. The sensitivity settings and notation used to denote variations, were as follows:

- **Steepness:** Natural-scale median of the steepness priors included:
  - “Mid”: 0.70
  - “Low”: 0.60
- **Recreational dead catch:** To account for uncertainties within the recreational dead catch estimates the following scenarios were tested:
  - “Lower”: lower confidence estimate (SRFS estimate minus 1 standard error)
  - “Mid”: median value (SRFS estimate)
  - “Upper”: upper confidence estimate (SRFS estimate plus 1 standard error)
- **Natural mortality:** In some scenarios, a maximum-likelihood estimate of M could be calculated directly. In other scenarios, M had to be varied manually and the value that produced the highest likelihood was chosen. Scenarios 7 and 8 varied the base case scenario 1: M was fixed at the

upper and lower values which caused twice the difference in negative log-likelihood, compared to the maximum-likelihood case ($M = 0.28$ yr^{-1}), to reach 3.84 (χ^2_1 95% significance level).

Eight combinations of sensitivity settings were tested, as listed in Table 2.2. Scenario 1 was selected by the project team as the base case scenario.

Table 2.2: Scenarios tested to determine sensitivity to parameters, assumptions and model inputs

Scenario	SRFS estimate	Steepness (h)	Discard mortality	Natural mortality (M)
1 (Base case)	Mid	0.7	0.48	0.28 yr^{-1}
2	Mid	0.6	0.48	0.29 yr^{-1}
3	Lower	0.7	0.48	Estimated
4	Lower	0.6	0.48	0.30 yr^{-1}
5	Upper	0.7	0.48	Estimated
6	Upper	0.6	0.48	Estimated
7	Mid	0.7	0.48	0.17 yr^{-1}
8	Mid	0.7	0.48	0.41 yr^{-1}

3 Results

3.1 Model inputs

3.1.1 Data availability

Figure 3.1 summarises the assembled data sets input to the model.

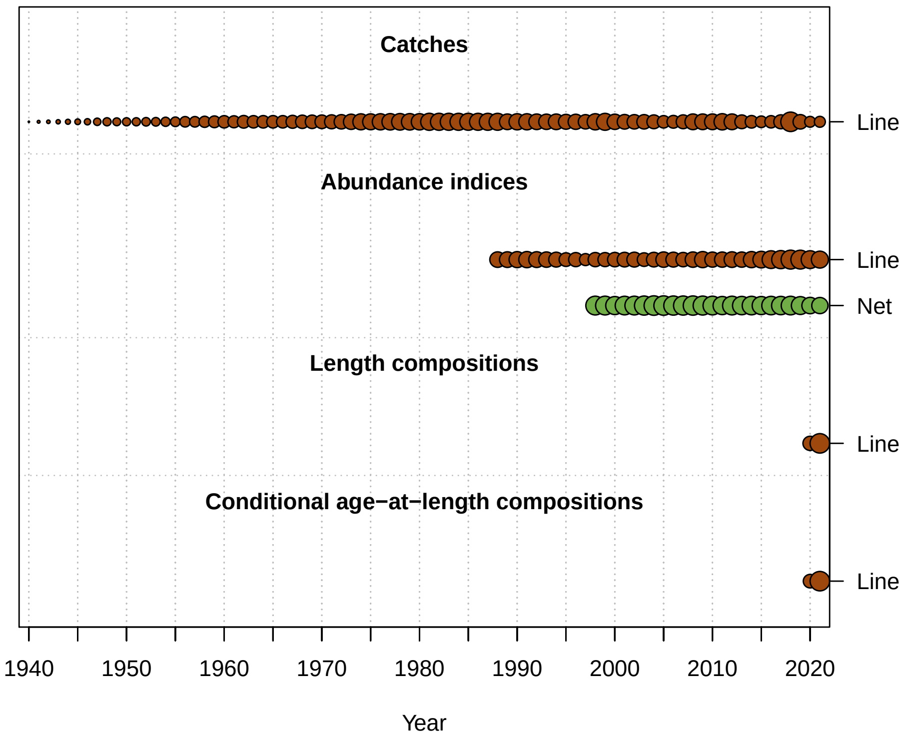

Figure 3.1: Data presence by year for each category of data type and Stock Synthesis fleet

Note: Stock Synthesis uses the term 'fleet' to distinguish data sets (and model processes) associated with different selectivity curves (proportions of fish at different lengths vulnerable to the fishing gear). This assessment involves two fleets: one for the commercial net sector and one for commercial line, recreational, charter line and Indigenous fishing combined. This plot shows data presence by year for each fleet, where circle area is relative within a data type. Circle areas are proportional to total catch for catches; to precision for indices and discards; and to total sample size for compositions. Note that since the circles are scaled relative to maximums within each data type, the scaling between separate data types should not be compared.

3.1.2 Catch estimates

Dead catch (retained catch plus catch that died following release) from commercial, recreational, charter and Indigenous sectors is shown in Figure 3.2. The estimates shown are for Scenario 1, the base case.

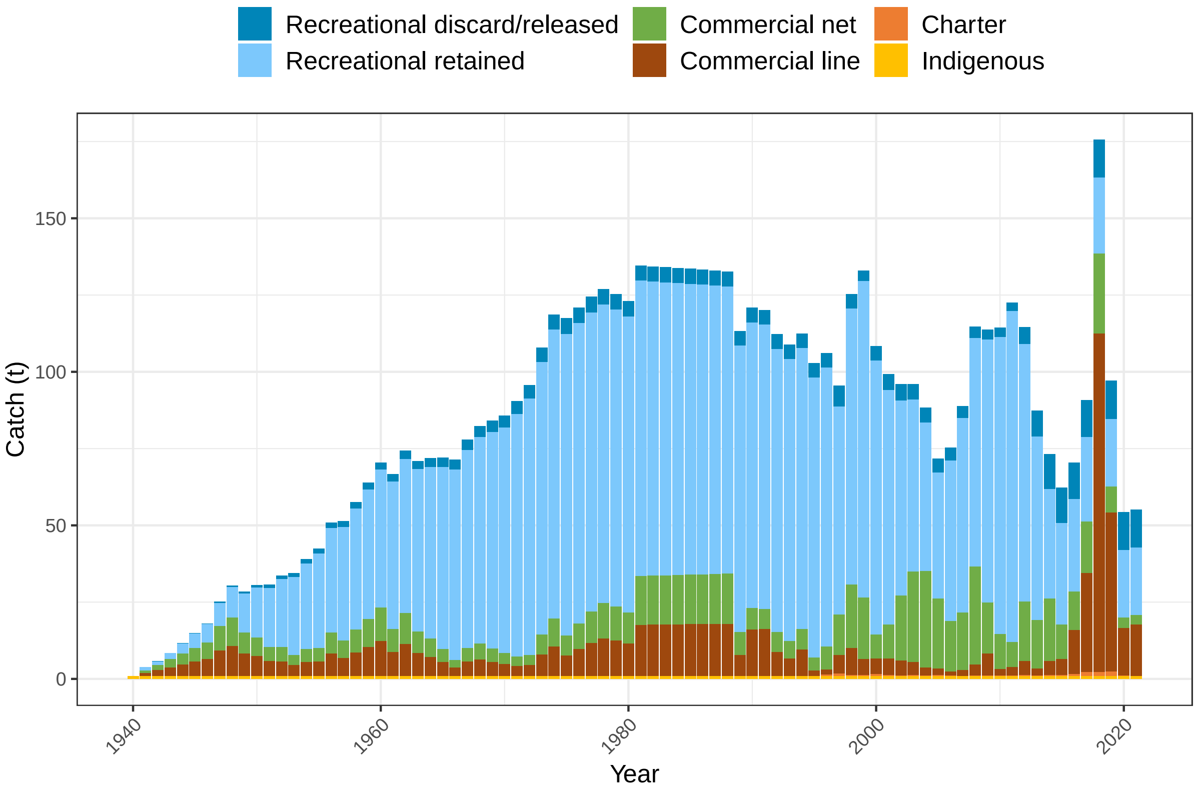

Figure 3.2: Annual estimated dead catch from commercial net, commercial line, recreational, charter and Indigenous sectors between 1940 and 2021 for black jewfish

3.1.3 Standardised catch rates

Catch rates (Figures 3.3 and 3.4) showed little discernible trend over the period of commercial logbook data (1988–2021). Such a result can indicate that the population size is very high, or that the fishery has been in "steady state" for many years, with a relatively constant catch (all fishery sectors combined). The net catch rates showed an increase from 1988 to 1998, but this was ascribed to an increase in fishing power, whereby net fishers improved their ability to catch black jewfish over this period. Therefore, the net catch rates from the period 1988–1997 were excluded from the model inputs (Figure 3.4).

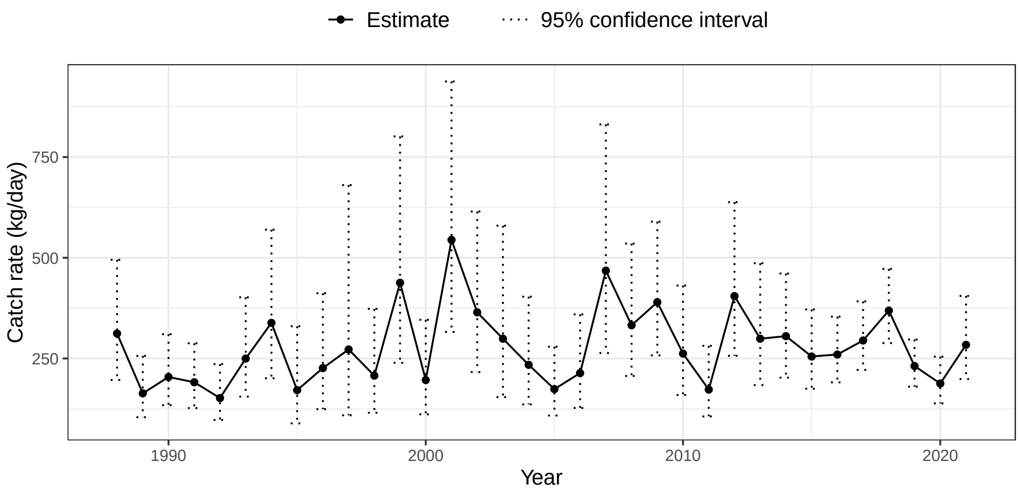

Figure 3.3: Standardised catch rates for commercial line-caught black jewfish between the years of 1988 and 2021

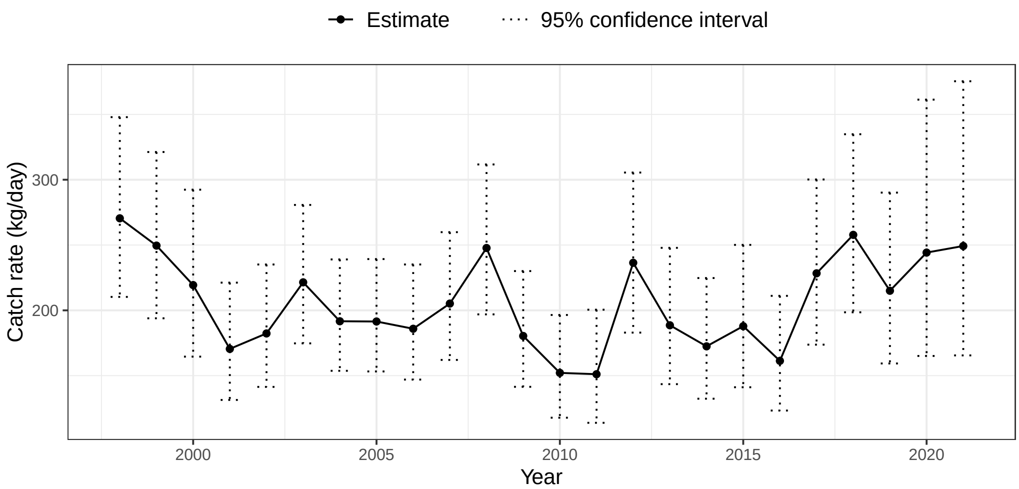

Figure 3.4: Standardised catch rates for commercial net-caught black jewfish between the years of 1998 and 2021

3.1.4 Age composition

Fishery age-composition data were input to the population model in the form of age-at-length distributions. For visualisation purposes, the age composition of the sample in each year is shown in Figure 3.5.

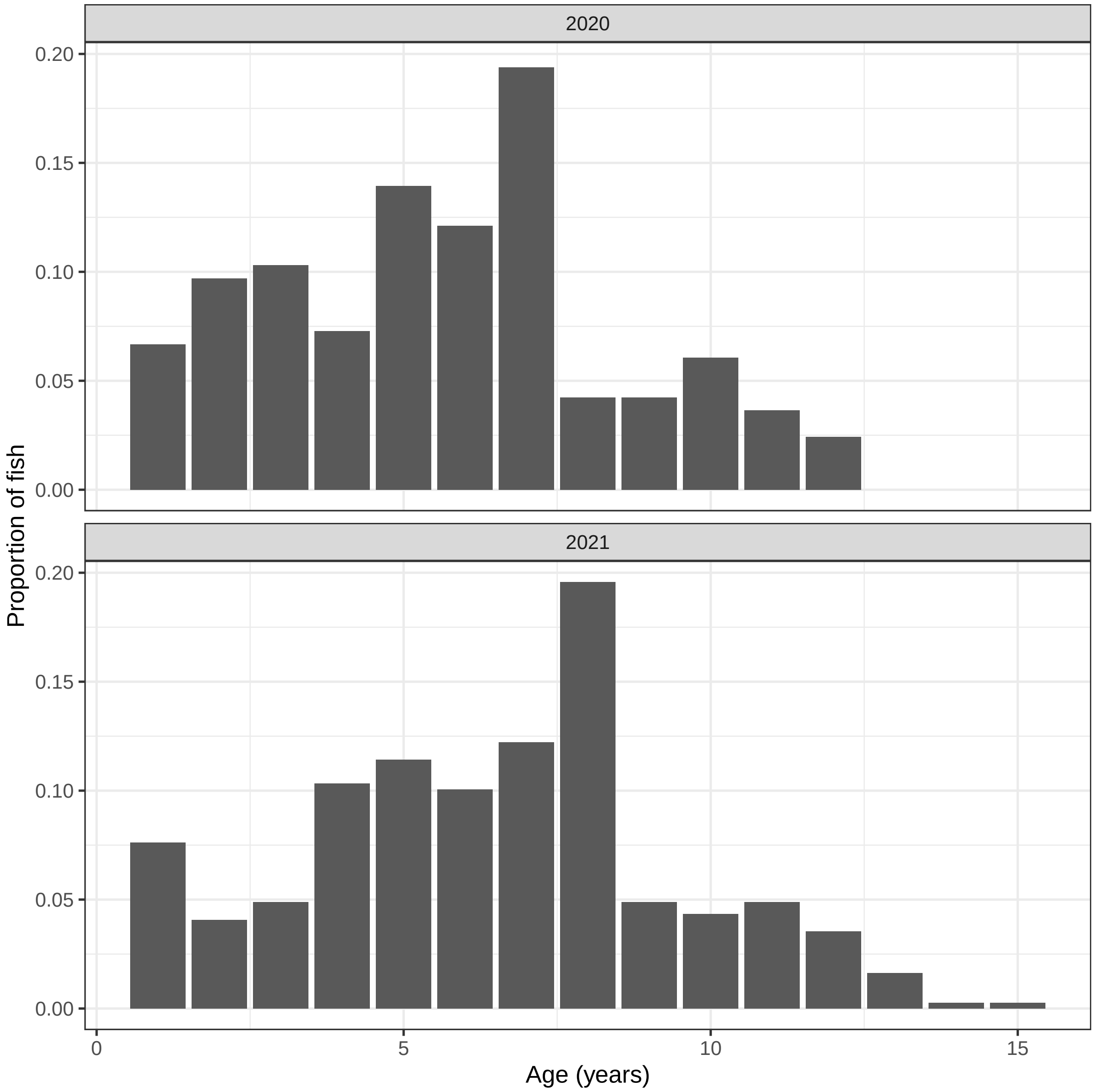

Figure 3.5: Annual age compositions of black jewfish for commercial line-caught fish in 2020 and 2021

3.1.5 Length composition

Fishery length compositions were input to the population model for the commercial fleet (Figure 3.6). Fish from fishery-independent sampling, which targeted small black jewfish, were excluded from the length data input to the model, but were included in the age-at-length data.

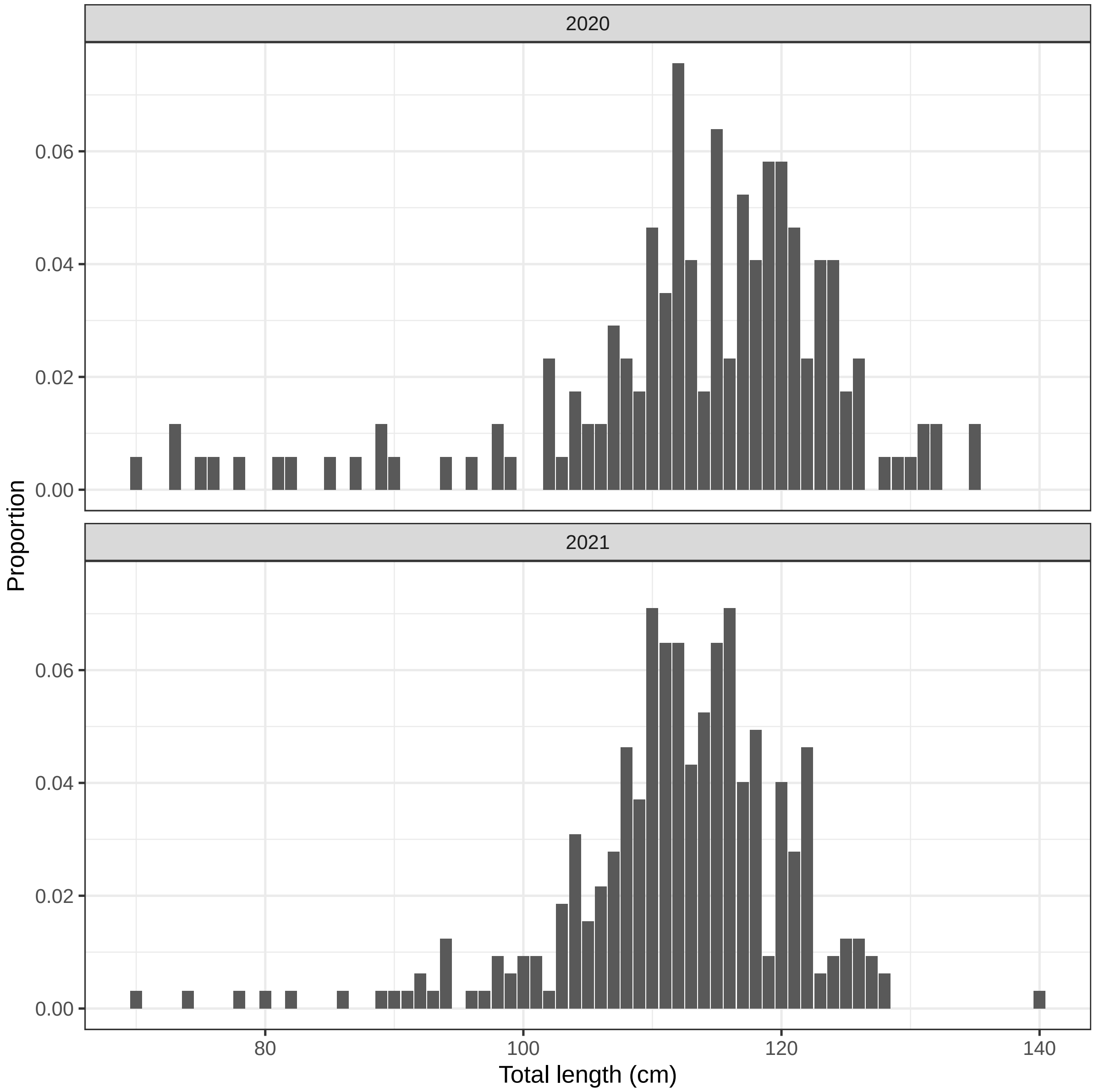

Figure 3.6: Annual length compositions of black jewfish for commercial line-caught fish in 2020 and 2021

3.2 Model outputs

3.2.1 Model parameters

The base-case (Scenario 1) model estimated the parameter values listed in Table 3.1. The natural mortality rate M could not be estimated automatically, and was determined by varying it manually. The results in Table 3.1 are for M fixed to the maximum-likelihood value of 0.28 yr^{-1}. The standard errors for them may therefore be artificially small, especially the unfished-recruitment-size parameter. The steepness in this scenario was also fixed, to the value 0.7, as there were insufficient data to estimate it.

Scenarios 7 and 8 covered variation in M and produced much wider confidence limits than those for fixed M (see Figure C.5 below).

Table 3.1: Summary of parameter estimates from the base population model (single-sex model)

Parameter	Estimate	Standard deviation
Length at age 1 (Female)	64.01	2.37
Von Bertalanffy growth parameter (Female)	0.39	0.03
Von Bertalanffy growth standard deviation (Female young fish)	12.3	1.05
Von Bertalanffy growth standard deviation (Female old fish)	5.07	0.49
Beverton-Holt unfished recruitment (logarithm of the number of recruits in 1940)	11.44	0.18
Catchability of commercial line	-7.26	0.71
Catchability of commercial net	-7.54	0.7
Commercial line selectivity inflection (cm)	114.56	6.9
Commercial selectivity line width (cm)	17.99	4.4

3.2.2 Model fits

Good fits were achieved for all data sets, including abundance indices, length compositions, age compositions and conditional age-at-length compositions (Appendix B.2).

3.2.3 Selectivity

Selectivity of black jewfish was estimated within the model. Selectivity was mirrored between line and net fleets. We note that the model's age-based selectivity doesn't asymptote to 1. It estimates that some fish never grow large enough to be fully selected. Insufficient data are available to verify this result.

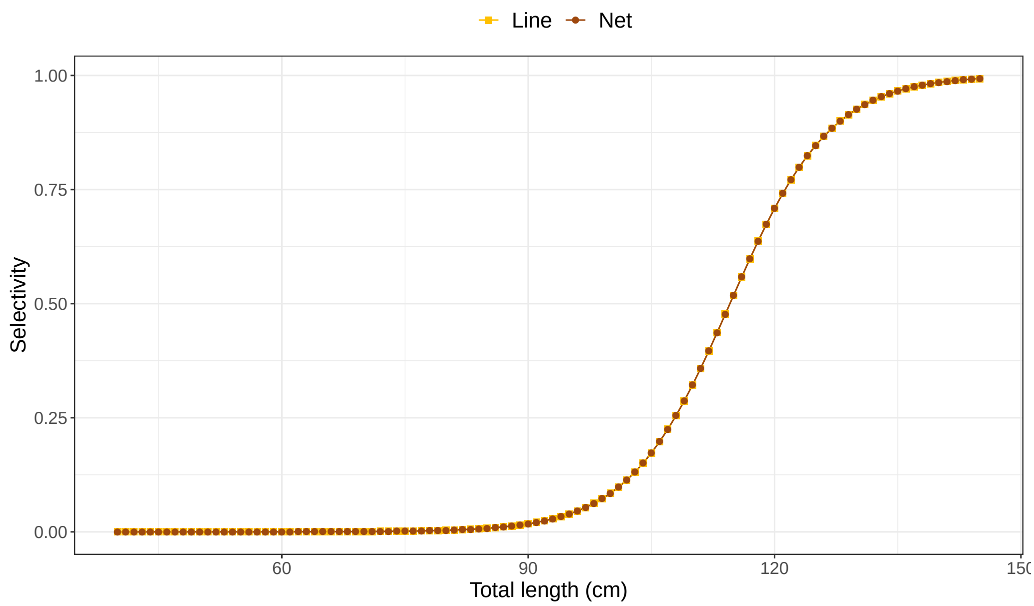

Figure 3.7: Model estimated size-based selectivity for black jewfish by fleet

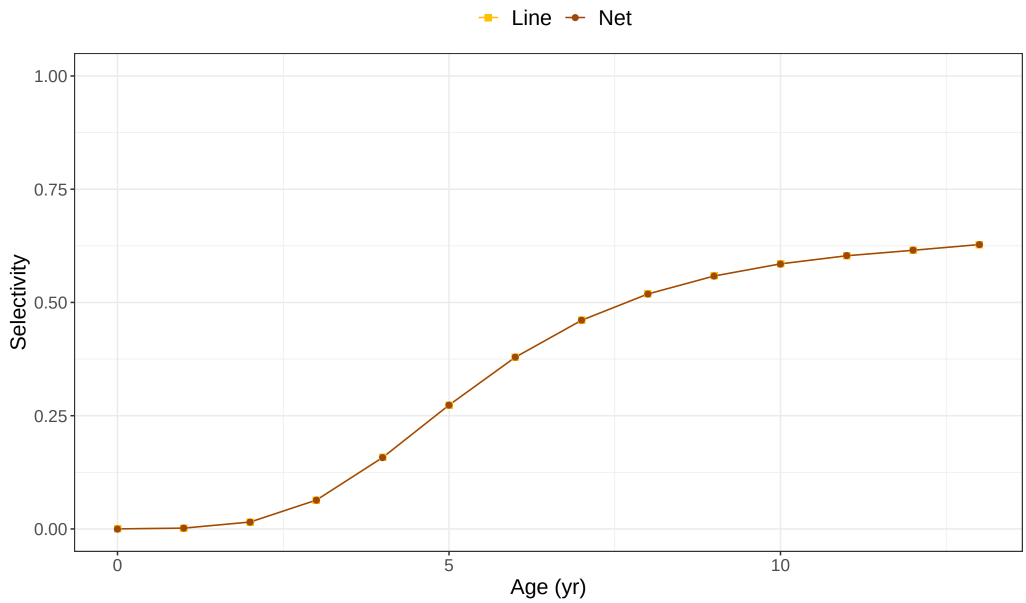

Figure 3.8: Model estimated age-based selectivity for black jewfish by fleet

3.2.4 Growth curve

The von Bertalanffy growth curve, including 95 percent confidence internals.

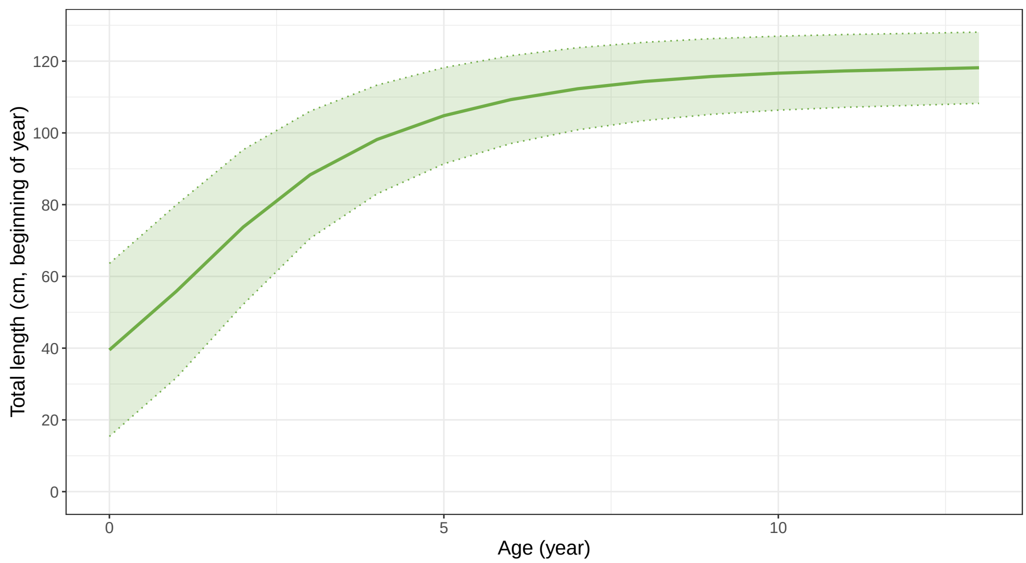

Figure 3.9: Model estimated growth of black jewfish (95% confidence intervals)

3.2.5 Biomass

The base case model estimated that spawning-stock biomass declined between 1940 and 1985 before stabilising thereafter. The latest spawning stock biomass estimate is reported at the beginning of 2022, the year after the input data end (2021). The stock level was estimated to be between 56% and 99% unfished biomass. This range represents the range of natural mortality (M) values above and below the maximum likelihood estimate of 79% according to the method described in Section 2.7.2. The estimates from the alternative Scenarios 2–6 ranged from 80% to 92%.

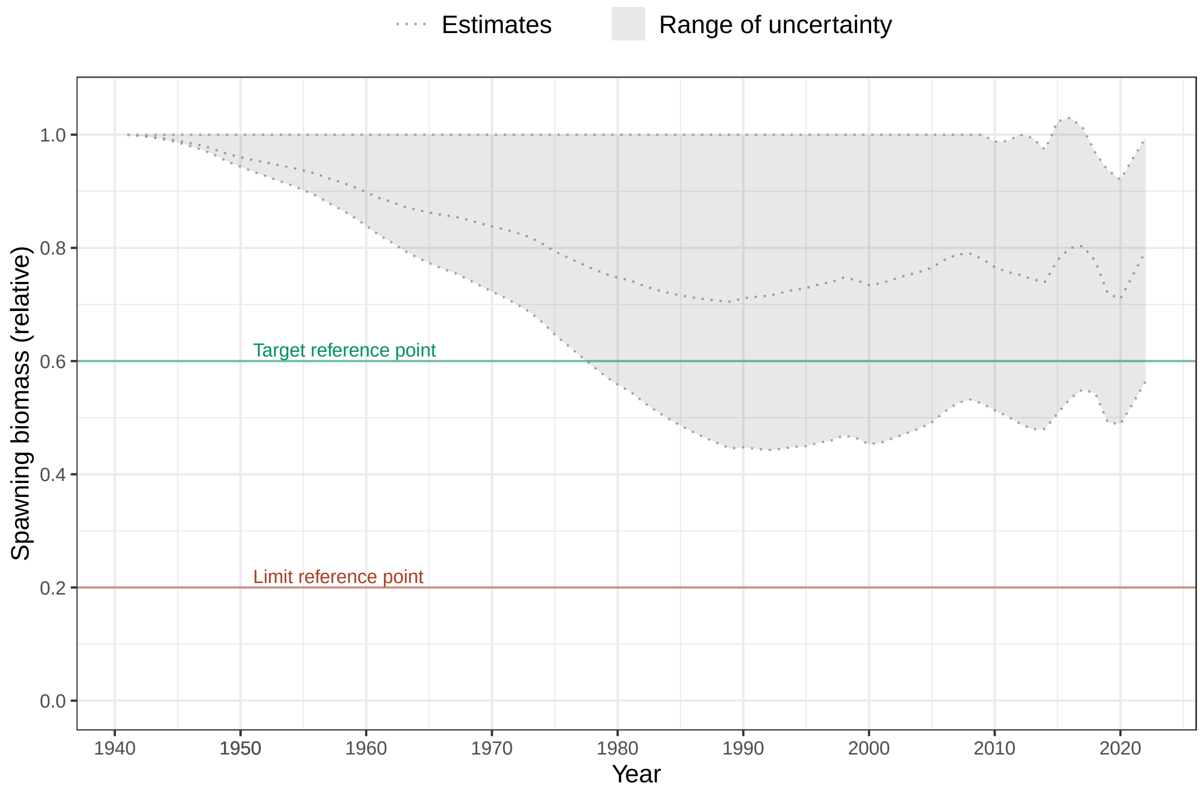

Figure 3.10: Predicted spawning stock biomass trajectory relative to unfished, from 1940 to 2022; the range of uncertainty arises from different assumed levels of natural mortality (M).

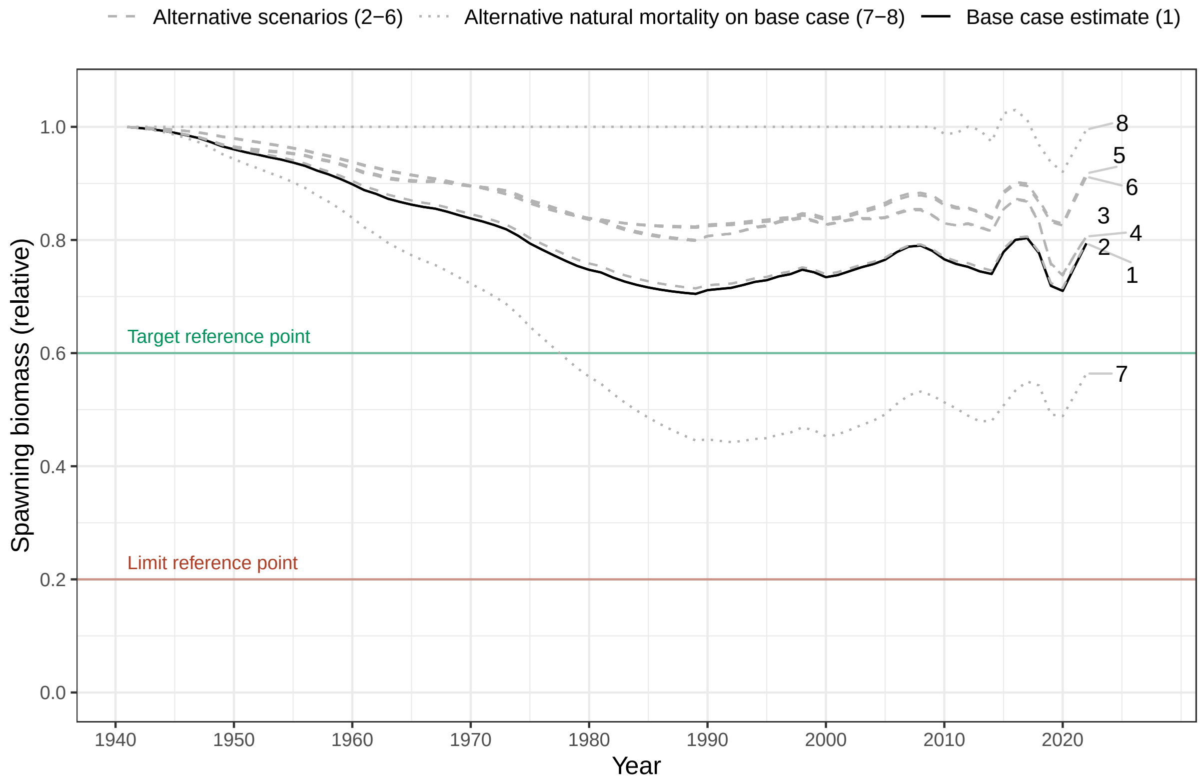

Figure 3.11: Predicted spawning stock biomass trajectory relative to unfished for black jewfish, from 1940 to 2022, for all scenarios

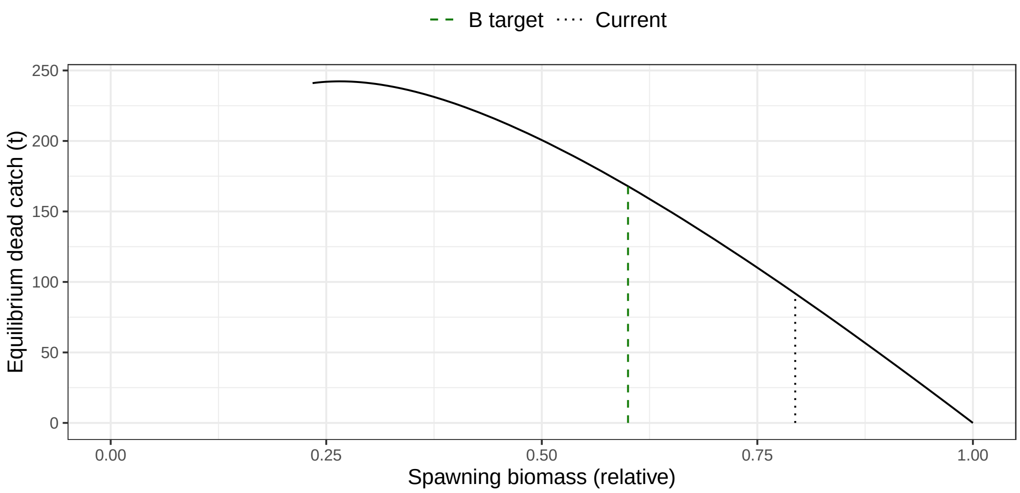

Figure 3.12: Equilibrium dead catch curve for black jewfish

3.2.6 Catch targets

Overall the base case model projections ranged from 56% to 99% and despite high uncertainty around the exact level of biomass, the model outputs indicate that the biomass is probably at or above the target reference point of 60% unfished biomass. **The resulting steady-state (year 2041) annual recommended biological catch (RBC) from base-case model bounds ranged from 90 t to 180 t**. To account for this uncertainty, we propose the lower bound of 90 t to minimise the risk of over-catch. Further increases could be considered after a higher catch level has been in place for some years and the stock is reassessed.

4 Discussion

The results above represent the first assessment of the Queensland East Coast black jewfish stock, which is a data-poor species. Due to the paucity of data, the estimates of biomass and associated recommended biological catch levels are associated with large uncertainty. The results should be viewed with this understanding. The base-case results discussed below should also be considered in the context of stock status variation within the full suite of scenarios investigated.

4.1 Stock status

Results from this assessment suggest that the black jewfish population on the Queensland East Coast experienced declined gradually until about 1985 before stabilising. The lack of contrast in catch rates in response to changes in catch, and the presence of high numbers of old fish in the population, indicate that it is likely that the population has never been fished below MSY. The range of biomass projections indicate that it is also likely to be above 60% of unfished biomass. As management interventions were implemented while commercial catch levels were still increasing, it is likely that this prevented a strong “fish down” of the population which would be required to produce greater contrast in the data.

In consideration of both the base case estimate and aforementioned model uncertainty, we recommend that a moderate increase in catch can be considered. This increase should be supported by routine biological monitoring and regular assessment. The response of biological and fishery data to increased levels of fishing mortality will assist understanding of how changes in mortality affect the population. These insights will support improved precision of model fits and assessment outputs.

4.2 Performance of the population model

The model has performed adequately given the uncertainties in the input data.

Two particular problems are evident in the model results. One is that the Francis (2011) data weighting method for length and age data has performed poorly. Consideration should be given to an alternative method in future assessments.

The second problem is that the model has estimated that some black jewfish never grow large enough to be 100% selected by the commercial line sector. Consideration should be given to making selectivity more length-based rather than age-based in future assessments. One way to do this would be to use the “platoons” feature of Stock Synthesis.

The model would benefit from having three sectors instead of two. The assessment has highlighted that the recreational line sector has a very different length-based selectivity to the commercial line sector. The commercial line sector targets fish over 100 cm long, whereas the recreational sector catches smaller fish and releases many fish less than 75cm in length. The summary of recreational length data provided to the FRDC project by Infofish Australia, with reliable species identification by expert recreational anglers, has been very useful. Sufficient length data from the commercial net sector to estimate a separate selectivity function for this sector may be available for the next assessment.

Recreational catch and discard mortality. The current model assumed that a large component of the catch is taken by the recreational sector. However, the full extent of both retained and released fish in the recreational catch is subject to considerable uncertainty. The use of uncertain recreational release estimates coupled with the use of conservative post-release survival estimates have a high potential to upwardly bias total dead catch from the fishery.

Spatial closures and management change effects. The impact of the DAF fishery management arrangements and GBRMP rezoning in 2004 led to many changes in fishery dynamics, with resulting changes to fishing practice, areas fished and catch reporting. The effect of management changes including GBRMPA rezoning, net free zones, regulated waters at Hay Point and Dalrymple Bay Terminal, and the implementation of a competitive TACC are all likely to have influenced fishing behaviour. These effects were not explicitly accounted for in this model, and a better understanding of changes in fishing behaviour and targeting from this perspective could better inform the catch rate analysis, other model inputs and interpretation of model outputs.

Environmental influences. Given the uncertainties in the fishery data, no significant environmental influences have been found in this assessment. Research underway in the Northern Territory as part of FRDC Project 2018-027 is investigating the relationships between external and physiological drivers and their effects on productivity and recruitment in black jewfish populations. The results of this work should be considered in future assessments of the Queensland East Coast stock.

Mortality estimates. Improved estimates and quantification of other sources of mortality such as shark depredation and post-release survival would reduce assessment uncertainty. Updated information on the rate of post-release survival for black jewfish, from acoustic tagging research that is presently underway, should be incorporated into future assessments. These *in-situ* rates of post release mortality will represent a much more accurate estimate than those inferred through necropsy.

4.3 Recommendations

4.3.1 Data

Currently, Fisheries Queensland measures recreational catch using the Statewide Recreational Fishing Surveys (SRFS). SRFS is a broad-scale, multipurpose 12-month telephone–logbook survey primarily designed to make catch estimates of species that are commonly caught by recreational fishers across broad spatial scales. As black jewfish are not commonly encountered by most recreational fishers, the estimated catch by recreational fishers is subject to substantial uncertainty, as a low number of households contribute to the estimate. This stock assessment has attempted to model this uncertainty by including scenarios where recreational black jewfish dead catch was higher (SRFS estimate plus one standard error) and lower (SRFS estimate minus one standard error) than estimated (see Section 2.7.4). The influence of the recreational catch estimates on the model performance demonstrates the need to be cautious when recommending future catch limits in the fishery. Increasing precision in recreational catch estimates for species that are not commonly caught (such as black jewfish), and areas that are not commonly fished, should be a priority for research and monitoring.

Length data from the Boat Ramp Survey program (BRS) were used to calculate the weight of the average recreationally caught black jewfish. For all scenarios in this assessment, the lengths of undersize black jewfish were excluded from this calculation. This resulted in a relatively high average weight of 9.9 kg for a black jewfish kept by recreational fishers. Given that many fishers struggle to accurately identify black jewfish (possibly confusing them with other jewfish species with no legal size such as scaly jewfish (*Nibea squamosa*) and silver jewfish (*Nibea soldado*), it is possible that some of the black jewfish reported in the 2019 SFRS survey are actually these smaller other species. A precautionary approach was taken with this assessment, using the weight calculated from only legal-sized fish. An important addition to the next assessment would be to conduct scenario testing by using an average fish weight whose calculation includes undersize fish from the BRS program. This may better align with what recreational fishers catch and call black jewfish in both SRFS and BRS.

Future assessments should re-examine historical catch reconstruction and its effect on model performance. The historical catch reconstruction within the current assessment used information derived from a survey of long-term fishers within the fishery. These fishers perceived that historical levels of fishing effort in the 1970s were slightly higher than recent levels (the last 5 years), and below peak effort levels of the 1990s or early 2000s. However, the historical catch reconstruction was set with the recreational catch in 1975 at a level 1.1 times greater than the estimate from the 2000–2001 recreational fishing survey. For future assessments, a value less than 1 for this multiplier may be desired to better reflect the expert advice provided by fishery stakeholders. The 1975 data point was very influential, as it was used to project catches from 1975 back to 1940 and from 1975 forward to 2000.

4.3.2 Monitoring

Routine biological monitoring of the east coast black jewfish population through the collection of age and growth information is of high priority. This monitoring should focus on Management Regions 3 and 4 which account for the majority of the current fishery catch. This recommendation is particularly important given that the impacts of fishing on black jewfish populations elsewhere in the world have been clearly detectable through changes in the age structure, and catch rates may be hyperstable, showing little or no trend as populations contract around major aggregation sites. A long-term length and age data set should provide both the model and end users with greater certainty around the outputs.

4.3.3 Management

Recommended biological catch level. The recommendation of the stock assessment is that an increase in the annual catch to 90 t would allow the biomass to remain at or above the target reference point. This RBC is highly precautionary, and the model suggests that a level of 180 t may be sustainable. However, future years of biological monitoring would be beneficial before additional increases occur. Based on current catch levels over the different fishing sectors, this recommendation would represent an increase in the total allowable commercial catch (TACC) , and would allow the recreational season to be expanded back to the full year (no longer linked to the TACC) without significant sustainability concerns due to over-catch.

A moderate increase in the TACC would provide additional profit to existing commercial fishers without encouraging an influx of new entrants into the fishery. However, it is unlikely that the proposed TACC increase would remove the current "race to fish" approach in the fishery which sees fishing for black jewfish occurring in poor weather and during sub-optimal periods of catchability.

It should be noted that generation of new data on post-release survival is ongoing and indicates much higher survival rates than previously thought. The new post-release survival rates will affect both the estimates of past dead catch and the recommended future dead catch, so the net effect on the recommended future level of retained catch will be small. Catch shares for the different sectors are usually set based on retained catch, and will also be little affected by new estimates of post-release survival.

Table 4.1: Current and target indicators for Queensland east coast black jewfish

Indicator	Estimate
Biomass◇ (relative to unfished) at the start of 2022	79% (range 56–99%)
Target biomass (relative to unfished)	60%
Dead catch at 60% biomass target	90 t (90-180 t; lower bound recommended due to high uncertainty)

◇ Biomass is defined to be spawning stock biomass.

4.3.3.1 Additional Management Measures

To provide further certainty to the stock and ensure the long-term sustainability of the east coast black jewfish stock, it is recommended that several other measures be considered for adoption. These management measures complement the RBC by ensuring that fishing from all sectors occurs in a way which represents the greatest use of the resource, and are as follows:

- **Post-release survival.** The adoption of approaches for enhancing the survival of released black jewfish should be a primary consideration for reducing unnecessary mortality on this population. Preliminary results from acoustic tagging research that is underway as part of the IMOS Queensland acoustic telemetry array project have demonstrated release weights to be highly effective in overcoming the effects of barotrauma and producing high survival in tagged black jewfish. The work found that use of the technique of ‘venting’ (puncturing the fish’s swim bladder with a sharp point) was far less effective given the increased time a fish spends out of water, clogging of needles due to the thickness of tissue, and the technical knowledge required by fishers. Implementation of release weights within the recreational fishing community needs to be supported by a high level of community level education. Given the level of additional mortality that released recreational fish could have on the population, regulatory approaches such as the mandatory requirements for release weights on vessels such as those which occurs in Western Australia’s demersal fin fish fisheries could be considered.
- **Spawning closure.** seasonal closure for black jewfish on the east coast should be considered. Recent research has identified that black jewfish spawn between November and February each year in Central Queensland (Williams et al., in prep). Currently the fishing season opens on 1 January each year under a competitive TACC, which means that the majority of catch is occurring during the peak period of reproductive activity. Implementing a spawning closure between November and February would provide extra protection by offsetting the time where fishers target and catch black jewfish until spawning is complete.
- **Size limits**. Currently the minimum legal size (MLS) is set at 8 cm below the size at 50 percent maturity. While it is common practice to set the MLS at L_{50}, for this species it is unlikely to have a considerable influence on the sustainability. Currently very few black jewfish below 100 cm are landed by the commercial sector, as it targets aggregations of larger fish in order to maximise profitability. The recreational sector interacts with fish in the 75–83 cm range, although most of these fish are released. Preliminary release-survival results indicate that small black jewfish, which are generally caught in waters of depth less than ten metres, have high post-release survival. As a result, a change in MLS would have very little effect on the overall fishing mortality.

4.3.4 Assessment

Specific recommendations for future black jewfish stock assessments include:

- Consider an alternative data weighting method, especially for length and age data.
- Consider making selectivity length-based rather than age-based.
- Incorporate the latest post-release survival estimates for fish released by recreational fishers.
- Explore the effect of management changes on catch rates, and whether management changes can be explicitly accounted for in the model.
- Consider including the effect of environmental variables in a population model.
- Include additional recreational catch reconstruction scenarios, to provide greater confidence around historical catch levels.

4.4 Conclusion

This assessment was commissioned to establish the stock status of black jewfish on the Queensland East Coast and inform fishery management about the suitability of current management measures. The base-case model scenario suggested that spawning biomass is currently above the target reference point. Despite there being high uncertainty in the model, there is scope for some relaxation of restrictive management measures which were implemented in 2019. An increase in annual catch, coupled with ongoing biological monitoring, should provide greater confidence to future assessments.

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Appendix A Model inputs

A.1 Age and length sample sizes

Table A.1: Raw sample sizes measured and aged input to the model for black jewfish

Year	Commercial length	Age
2020	173	166
2021	323	369

A.2 Conditional age-at-length

Conditional age-at-length composition data were input to the population model (Figure A.1).

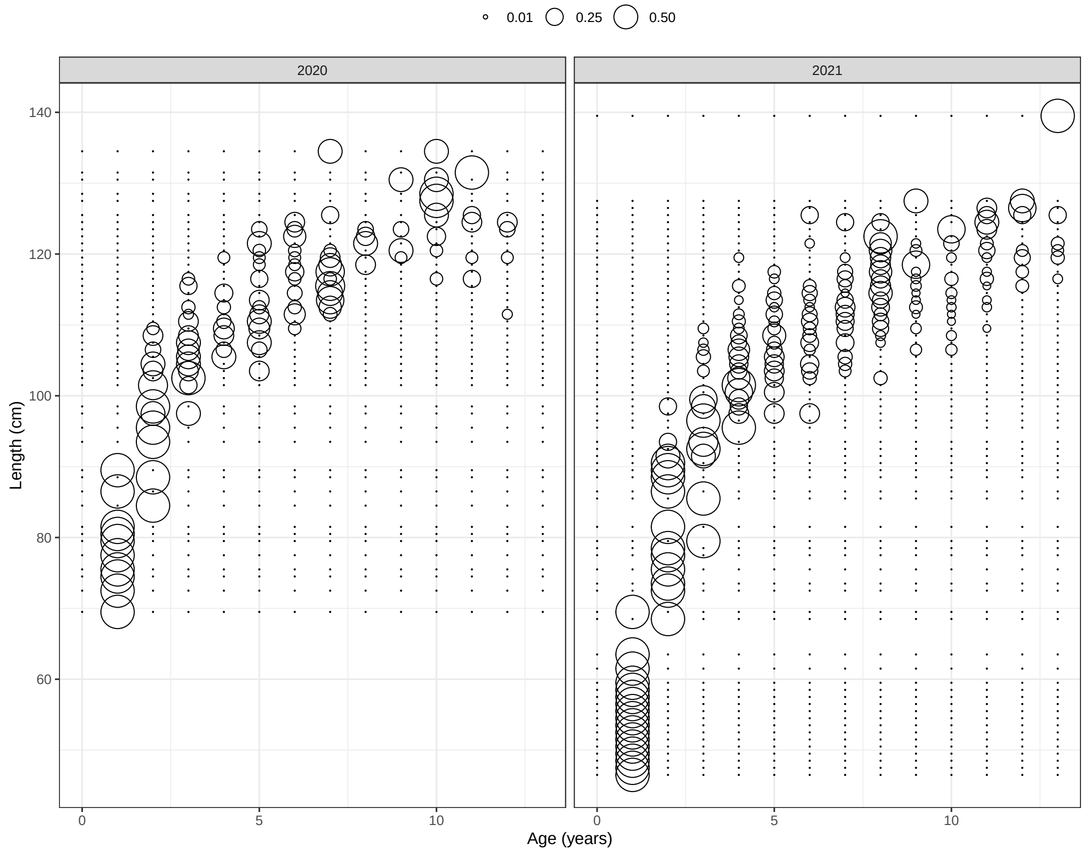

Figure A.1: Conditional age-at-length compositions of black jewfish between 2020 and 2021—circle size is proportional to relative sample size in each bin across rows (i.e. for a given length bin)

A.3 Biological data

A.3.1 Fecundity and maturity

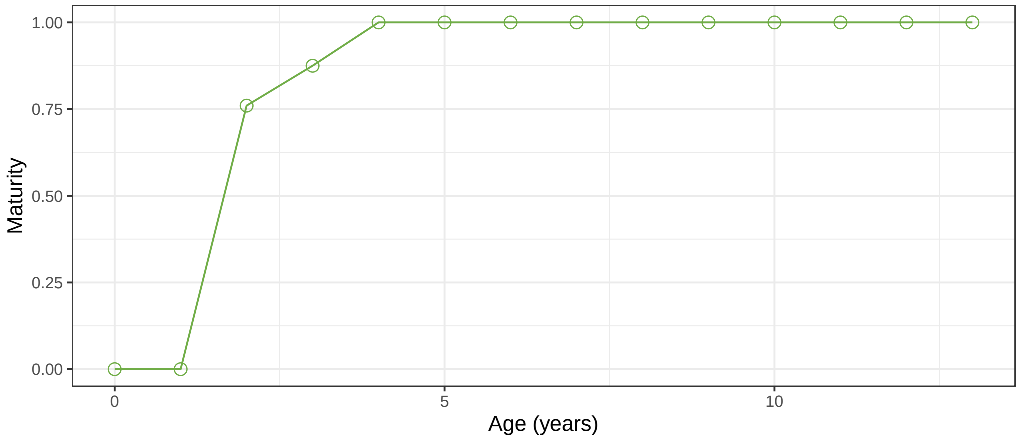

Figure A.2: Maturity at age

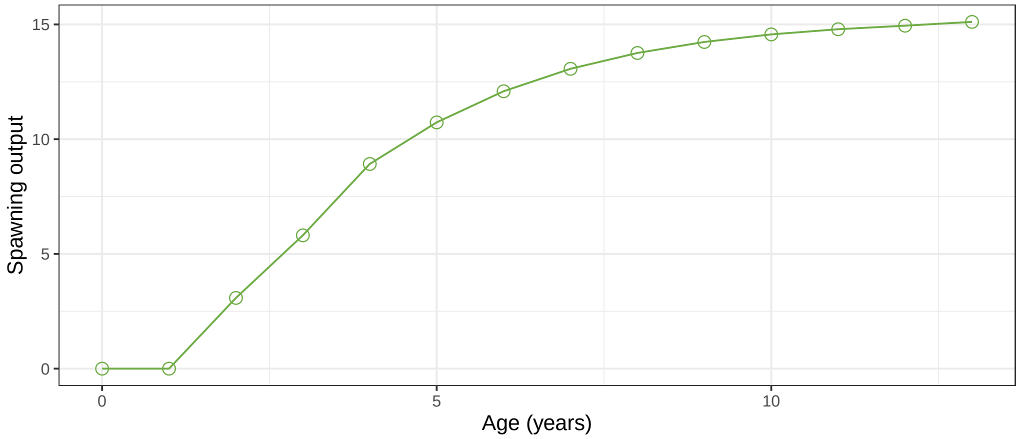

Figure A.3: Spawning output (maturity times fecundity) at age

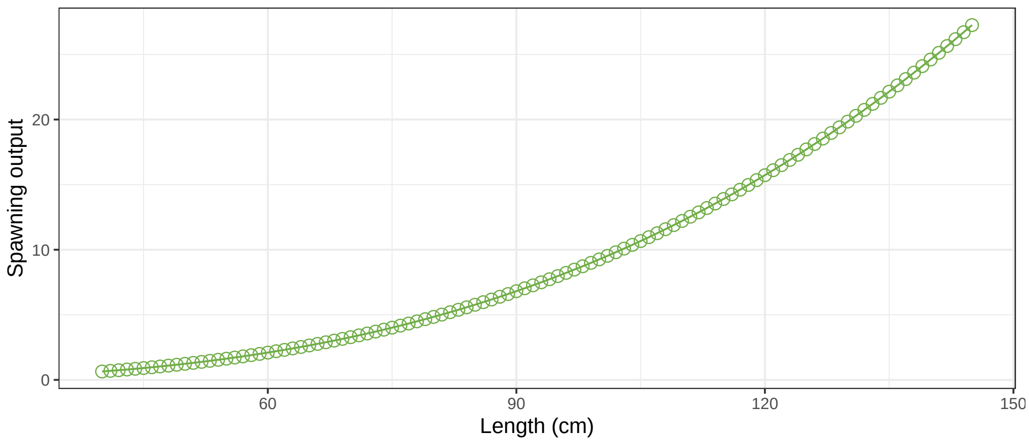

Figure A.4: Spawning output (maturity times fecundity) at length

A.3.2 Weight and length

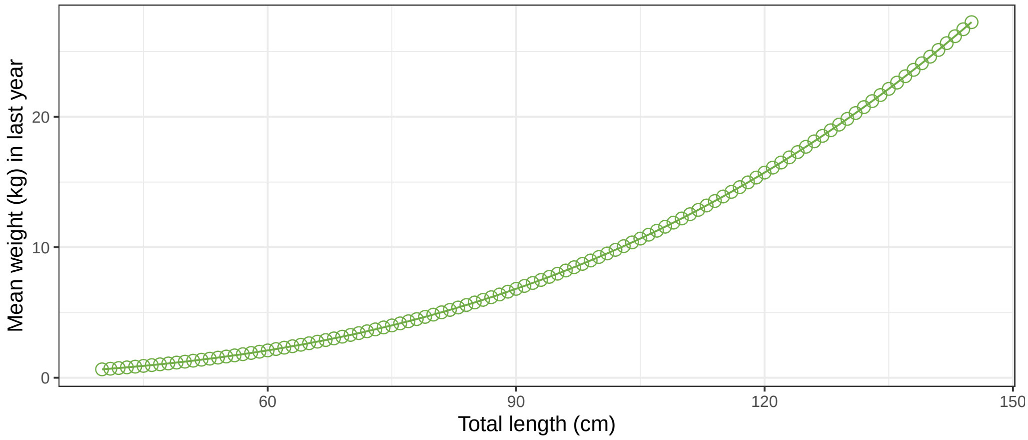

Figure A.5: Weight-length relationship

A.3.3 Discards

All discards were from the recreational sector and were modelled as a part of the catch as dead catch. No commercial discards were used in the model.

As stated in Section 2.4 the base case assumes a conservative post-release mortality rate of 48%, based on the Phelan (2008) study. This estimate would help to account for fish released in waters deeper than 20m.

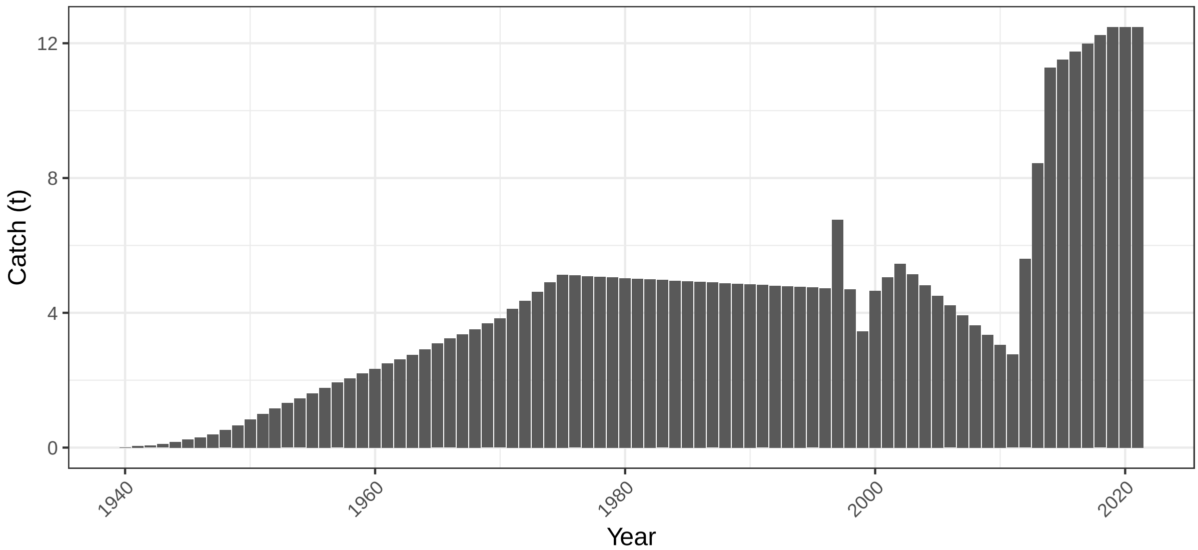

Figure A.6: Annual estimated recreational discards between 1940 and 2021 for black jewfish.

Appendix B Model outputs

B.1 Parameter estimates

Model parameters were estimated by Stock Synthesis, and parameter labels follow a Stock Synthesis specific naming convention (Table B.1). Parameters were estimated for the base case (Table B.2).

Table B.1: Summary of parameter estimates from the base population model

Stock Synthesis Parameter Label	Explanation
L_at_Amin_Fem_GP_1	Length at age 1 (Female)
VonBert_K_Fem_GP_1	Von Bertalanffy growth parameter (Female)
SD_young_Fem_GP_1	Von Bertalanffy growth standard deviation (Female young fish)
SD_old_Fem_GP_1	Von Bertalanffy growth standard deviation (Female old fish)
SR_LN(R0)	Beverton-Holt unfished recruitment (logarithm of the number of recruits in 1940)
LnQ_base_EastCoast_Line(1)	Catchability of commercial line
LnQ_base_EastCoast_Net(2)	Catchability of commercial net
Size_inflection_EastCoast_Line(1)	Commercial line selectivity inflection (cm)
Size_95%width_EastCoast_Line(1)	Commercial selectivity line width (cm)

Table B.2: Stock Synthesis parameter estimates for the base population model for black jewfish

Parameter	Estimate	Phase	Min	Max	Initial value	Standard deviation
L_at_Amin_Fem_GP_1	64.01	3	0	80	59.47	2.37
VonBert_K_Fem_GP_1	0.39	3	0.05	0.7	0.57	0.03
SD_young_Fem_GP_1	12.3	3	2	20	5.84	1.05
SD_old_Fem_GP_1	5.07	3	2	25	5.84	0.49
SR_LN(R0)	11.44	1	5	25	14	0.18
LnQ_base_EastCoast_Line(1)	-7.26	1	-30	1	-6	0.71
LnQ_base_EastCoast_Net(2)	-7.54	1	-30	1	-6	0.7
Size_inflection_EastCoast_Line(1)	114.56	5	90	120	110	6.9
Size_95%_width_EastCoast_Line(1)	17.99	5	2	20	5	4.4

B.2 Goodness of fit

B.2.1 Abundance indices

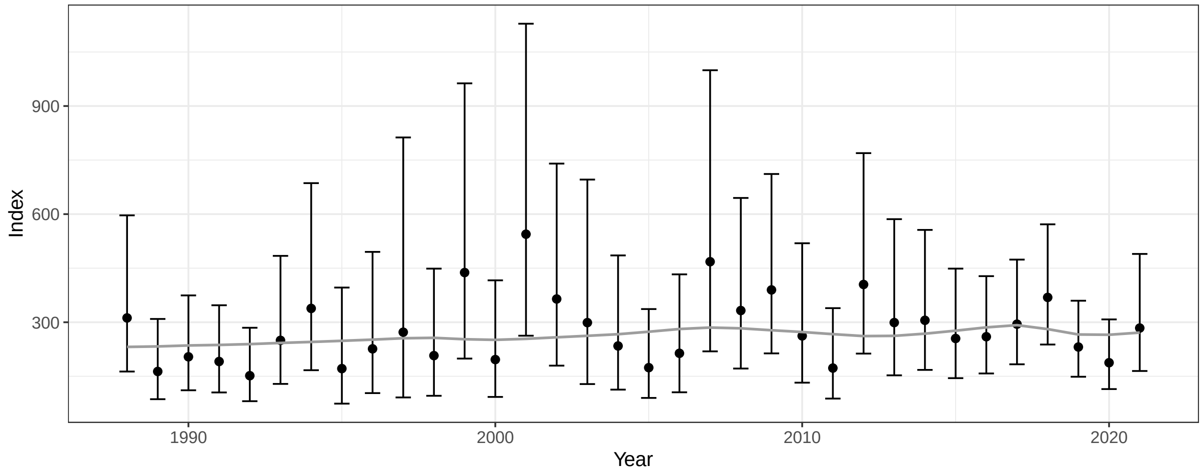

Figure B.1: Model predictions (grey line) to catch rates for commercial line-caught black jewfish

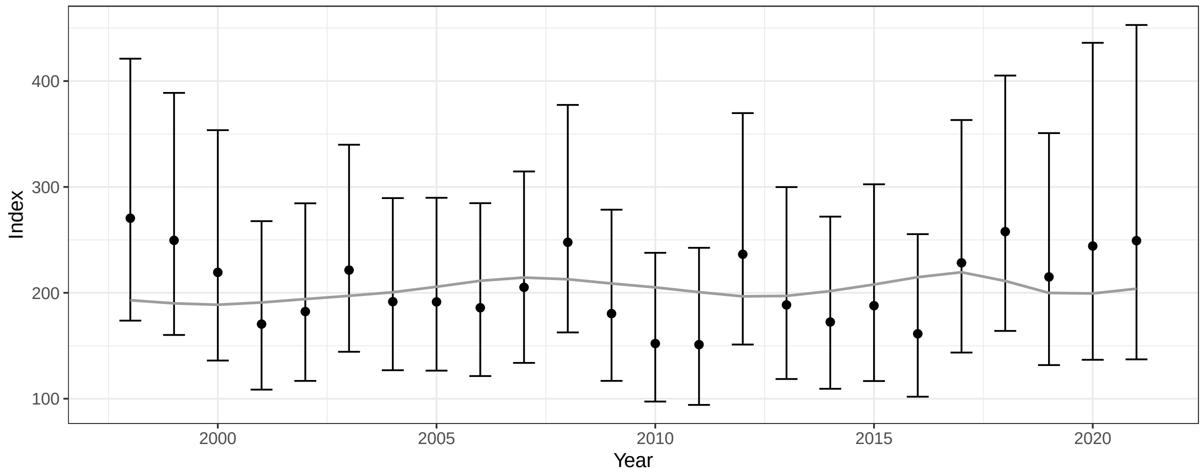

Figure B.2: Model predictions (grey line) to catch rates for commercial net-caught black jewfish

B.2.2 Length compositions

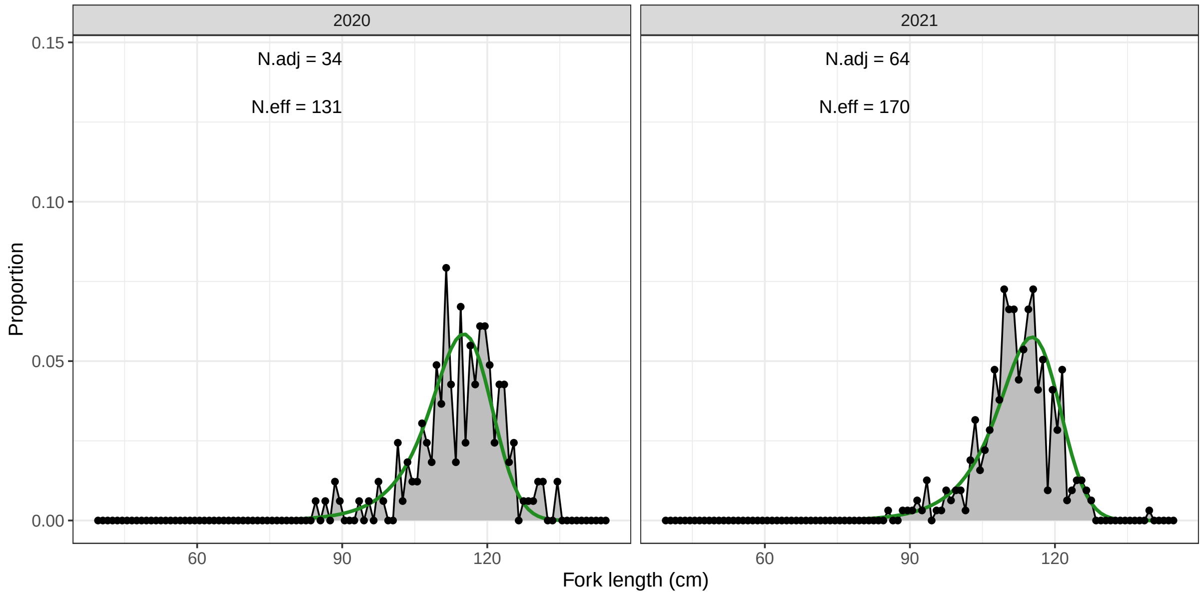

Figure B.3: Length structure for the commercial line fleet for black jewfish

B.2.3 Conditional age-at-length compositions

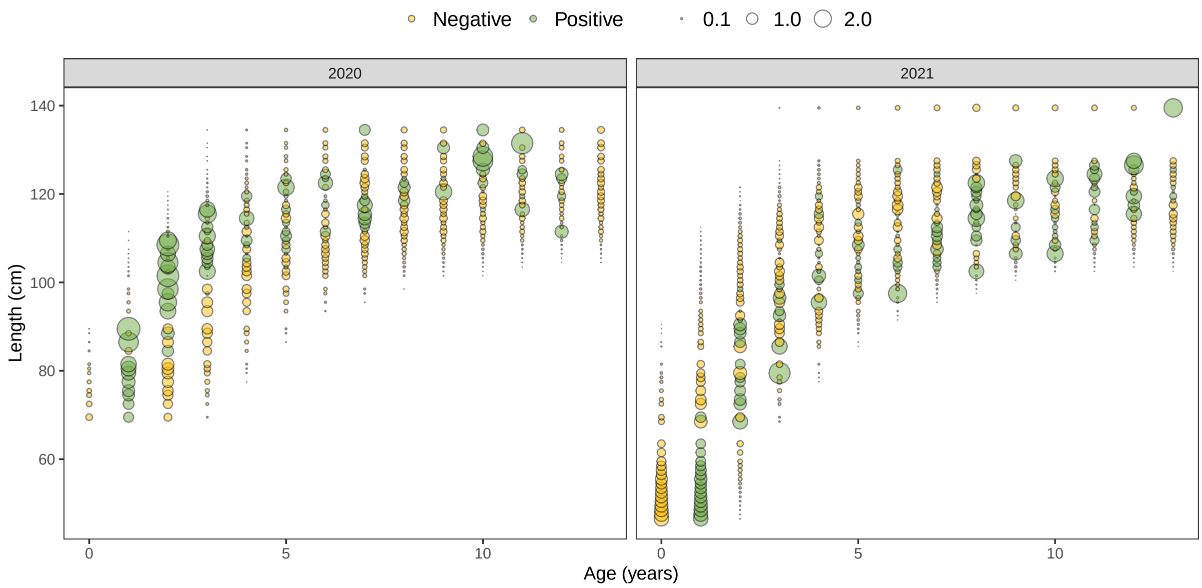

Figure B.4: Pearson residuals for age-at-length compositions for the commercial fleet for black jewfish—circle size represents the magnitude of the Pearson residual

B.3 Other outputs

B.3.1 Phase plot

The purpose of this report and its outputs are to determine the health of the stock and provide information to support Fisheries Queensland management. Additionally, the outputs produced are useful inputs into the SAFS classification of stocks. The SAFS classification system is different to the Fisheries

Queensland harvest strategy requirements. The purpose of this appendix is to document information useful to the SAFS classification system.

The classification system agreed on by the Status of Australian Fish Stocks Reports Advisory Group combines information on both the current stock size and the level of catch into a single classification for Australia's key wild catch fish stocks (fish.gov.au). The status of a stock is classified as a sustainable stock, depleting stock, depleted stock, recovering stock, negligible stock, or undefined stock. To classify stocks into one of these categories, the current abundance and level of fishing pressure are compared with defined biological reference points. The terms 'sustainable stock' and 'stock status' in the Status of Australian Fish Stocks Reports 2020 refer specifically to the biological status of fish stocks and does not consider broader ecological or economic considerations.

A phase plot illustrates the SAFS stock status given its biomass ratio relative to unfished (horizontal axis) and its fishing mortality relative to the fishing mortality which would produce the biomass limit (vertical axis) (Figure B.5). For reference, the red dashed vertical line is the limit reference point (20% relative biomass), the green vertical dashed line is the target reference point (60% relative biomass) and the green horizontal dashed line is the limiting fishing mortality which would produce the biomass target.

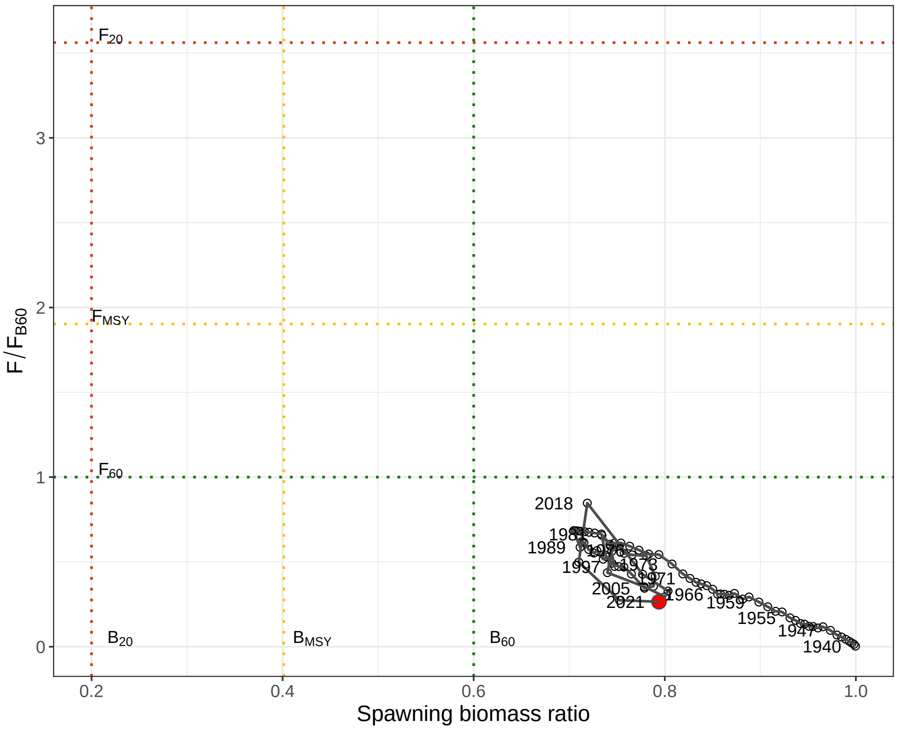

Figure B.5: Phase plot for black jewfish

The horizontal axis is the spawning biomass ratio of black jewfish relative to unfished and the vertical axis is the fishing mortality relative to the fishing mortality which would produce the SFS spawning biomass target of 60%. The red dotted vertical line is the limit reference point (20% relative spawning biomass) and the green dotted vertical line is the target reference point (60% relative spawning biomass)

B.3.2 Stock-recruit curve

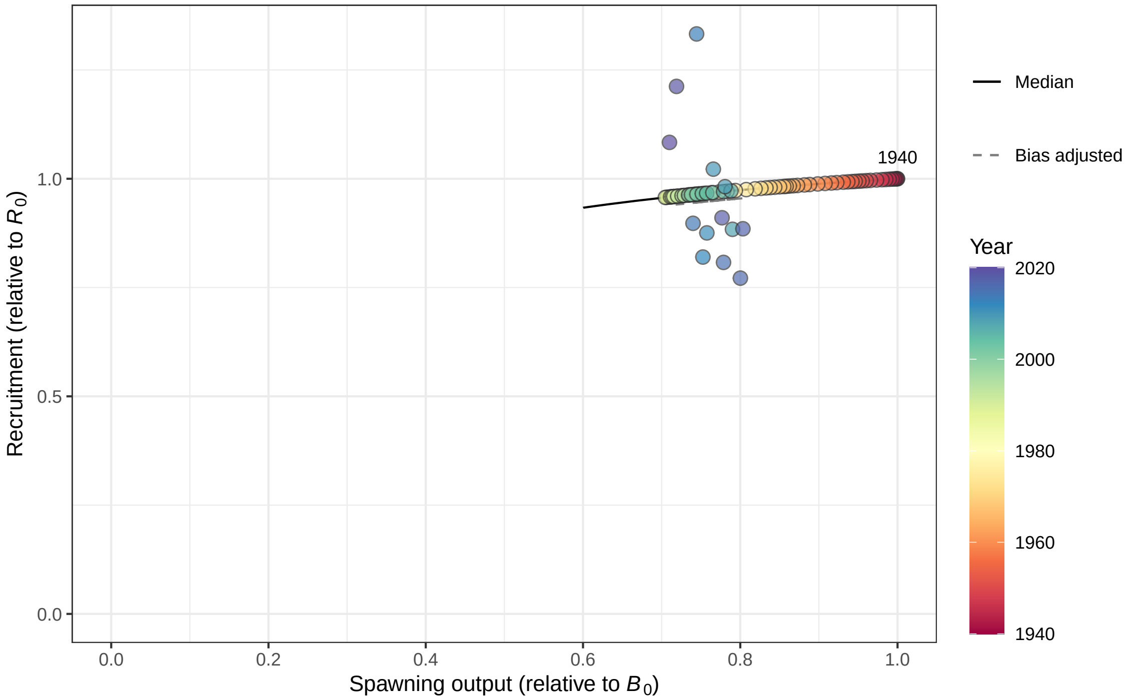

Figure B.6: Stock-recruit curve for black jewfish by spawning output —point colors indicate year, with warmer colors indicating earlier years and cooler colors in showing later years

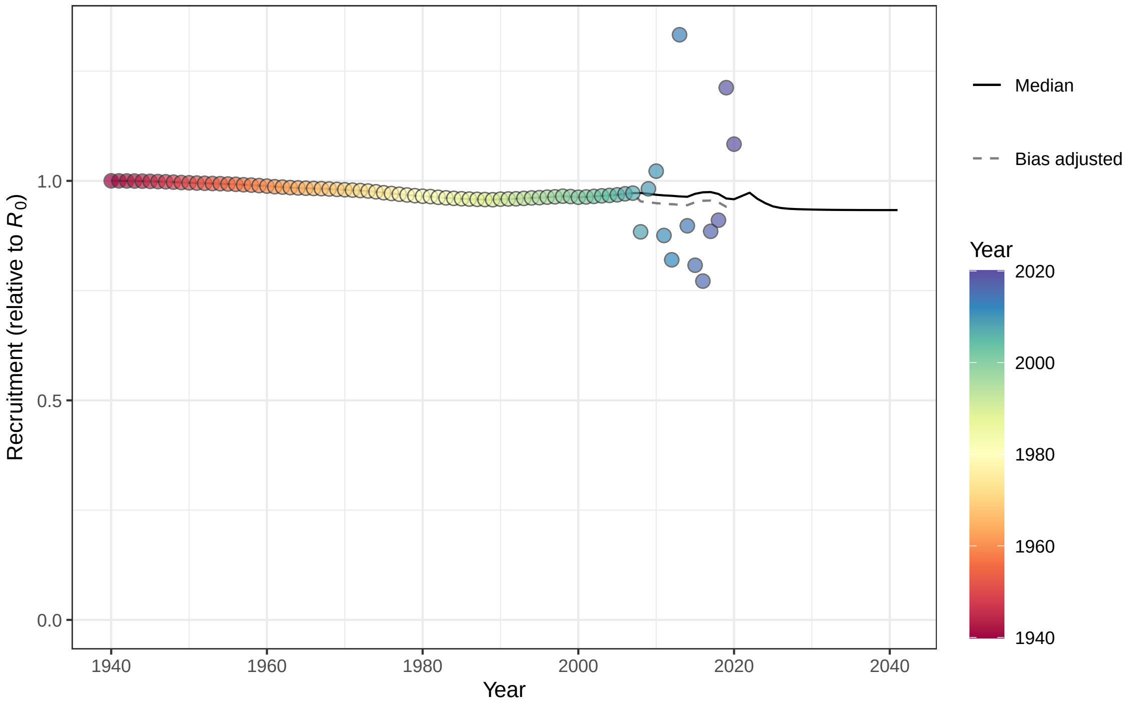

Figure B.7: Stock-recruit curve for black jewfish by year —point colors indicate year, with warmer colors indicating earlier years and cooler colors in showing later years

Appendix C Sensitivity tests: model outputs

C.1 Scenario 2

Table C.1: Stock synthesis parameter estimates for the Scenario 2 population model

Parameter	Estimate	Phase	Min	Max	Initial value	Standard deviation
L_at_Amin_Fem_GP_1	63.97	3	0	80	59.47	2.37
VonBert_K_Fem_GP_1	0.39	3	0.05	0.7	0.57	0.03
SD_young_Fem_GP_1	12.29	3	2	20	5.84	1.05
SD_old_Fem_GP_1	5.07	3	2	25	5.84	0.49
SR_LN(R0)	11.58	1	5	25	14	0.2
LnQ_base_EastCoast_Line(1)	-7.31	1	-30	1	-6	0.74
LnQ_base_EastCoast_Net(2)	-7.6	1	-30	1	-6	0.73
Size_inflection_EastCoast_Line(1)	114.7	5	90	120	110	6.91
Size_95%_width_EastCoast_Line(1)	17.91	5	2	20	5	4.34

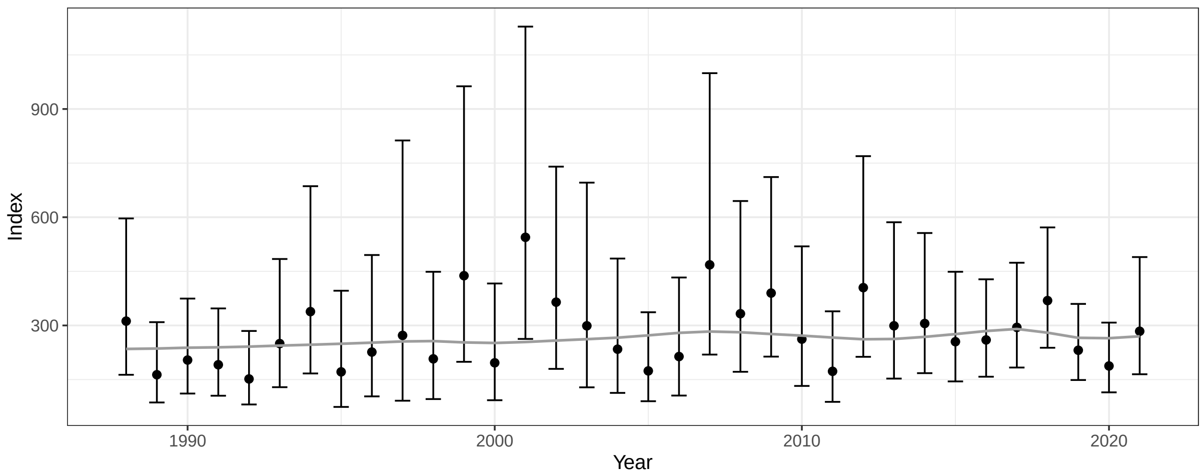

Figure C.1: Scenario 2: Model predictions (grey line) to catch rates for commercial line-caught black jewfish

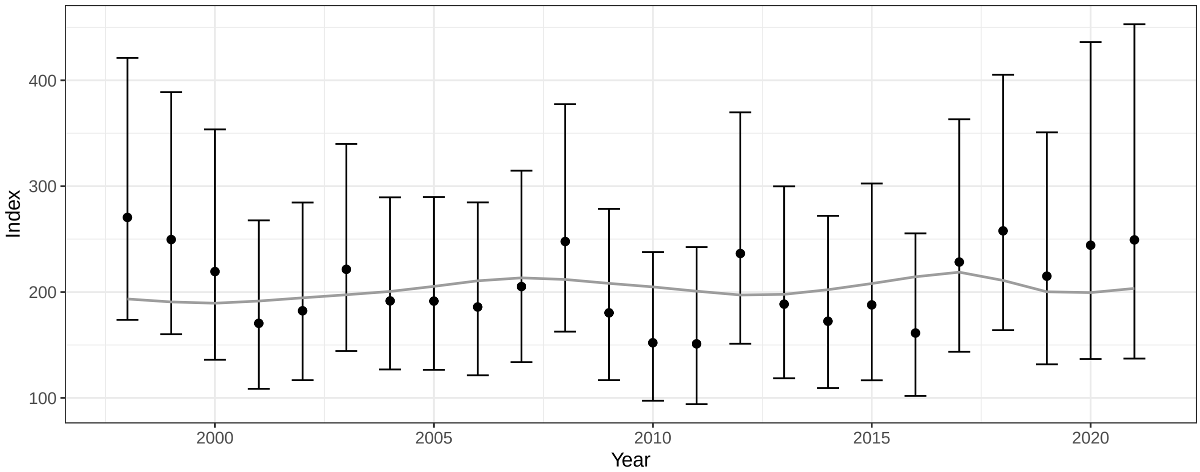

Figure C.2: Scenario 2: Model predictions (grey line) to catch rates for commercial net-caught black jewfish

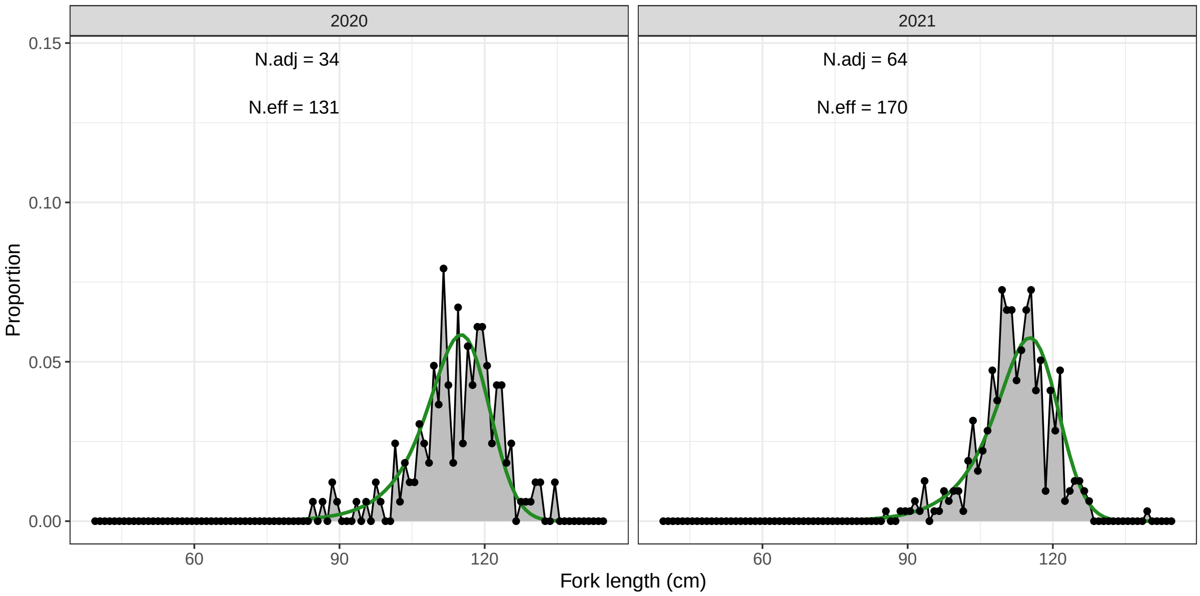

Figure C.3: Scenario 2: Length structure for the commercial line fleet for black jewfish

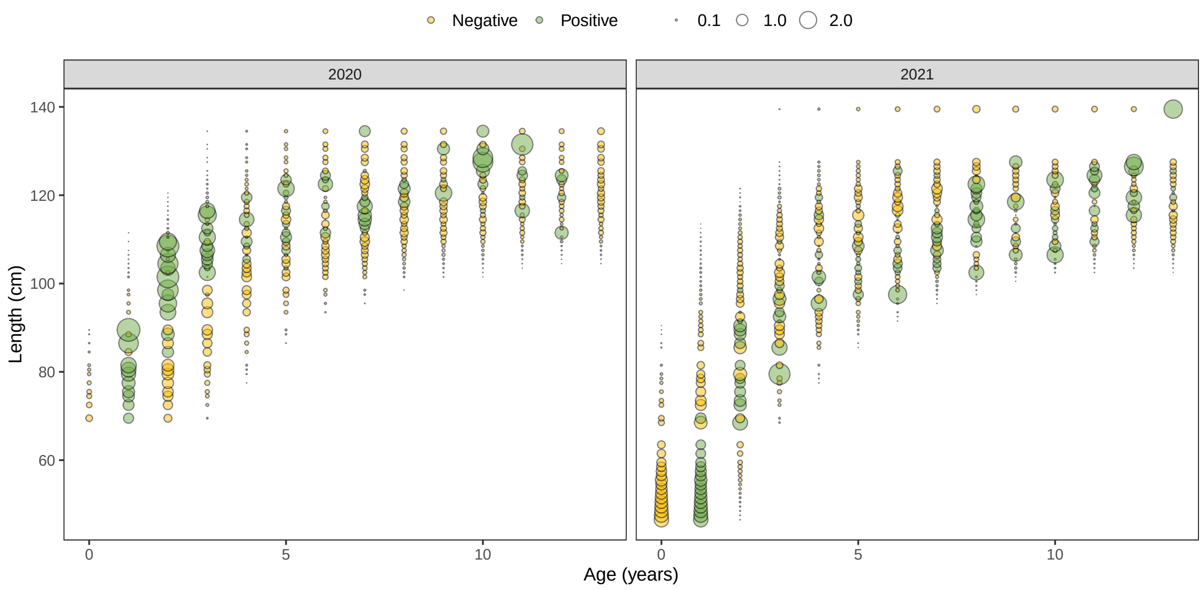

Figure C.4: Scenario 2: Pearson residuals for age-at-length compositions for the commercial fleet for black jewfish—circle size represents the magnitude of the Pearson residual

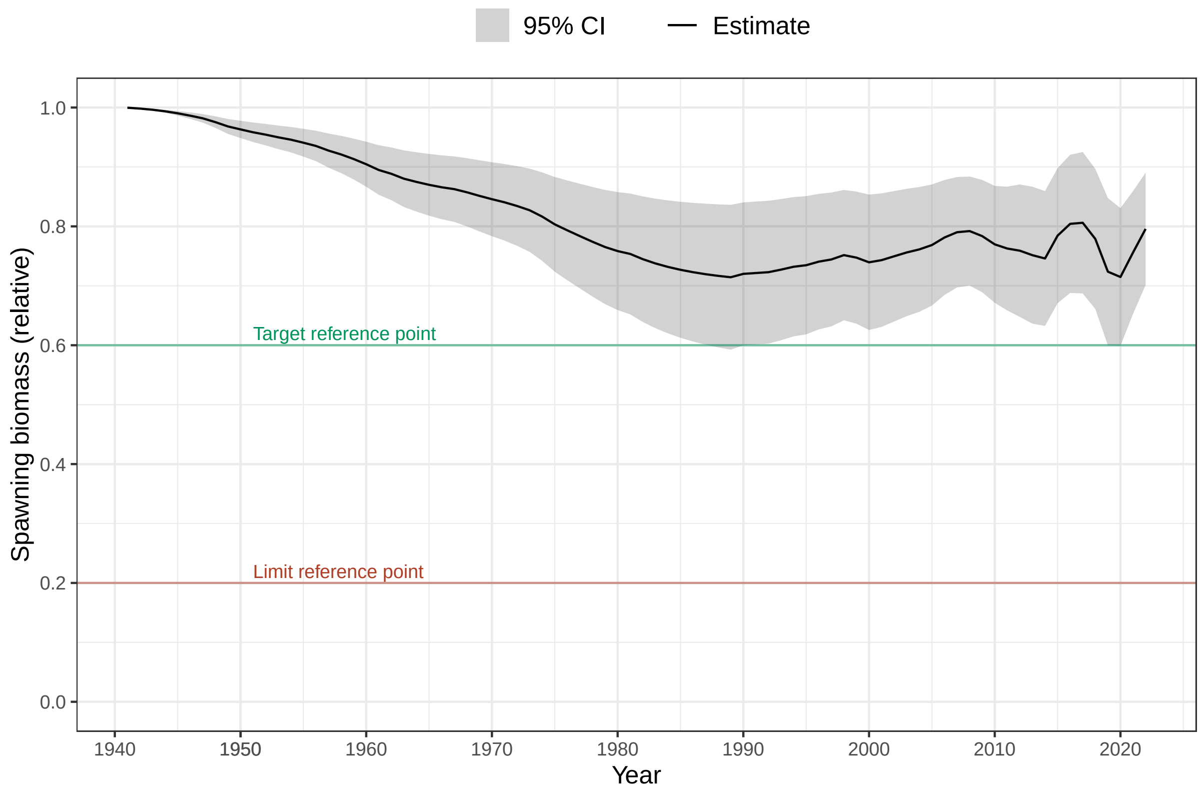

Figure C.5: Scenario 2: Predicted spawning stock biomass trajectory relative to unfished, from 1940 to 2022. Please note that confidence levels are artificially low because M is constrained.

C.2 Scenario 3

Table C.2: Stock synthesis parameter estimates for the Scenario 3 population model

Parameter	Estimate	Phase	Min	Max	Initial value	Standard deviation
L_at_Amin_Fem_GP_1	0.29	3	0.05	0.7	0.3	0.12
VonBert_K_Fem_GP_1	63.86	3	0	80	59.47	2.46
SD_young_Fem_GP_1	0.39	3	0.05	0.7	0.57	0.04
SD_old_Fem_GP_1	12.32	3	2	20	5.84	1.08
SR_LN(R0)	5.07	3	2	25	5.84	0.49
LnQ_base_EastCoast_Line(1)	11.4	1	5	25	14	1.64
LnQ_base_EastCoast_Net(2)	-7.26	1	-30	1	-6	1.16
Size_inflection_EastCoast_Line(1)	-7.54	1	-30	1	-6	1.13
Size_95%_width_EastCoast_Line(1)	114.45	5	90	120	110	6.98

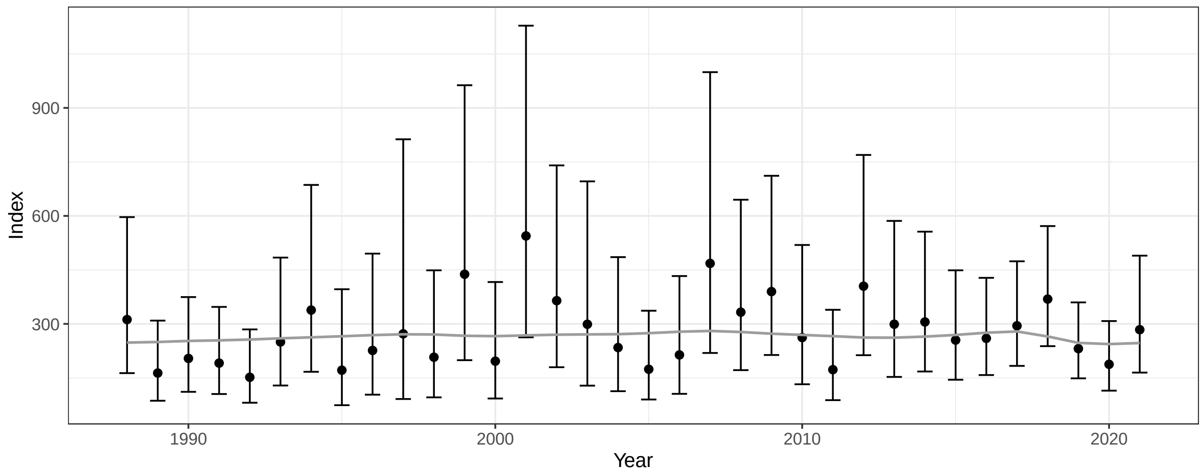

Figure C.6: Scenario 3: Model predictions (grey line) to catch rates for commercial line-caught black jewfish

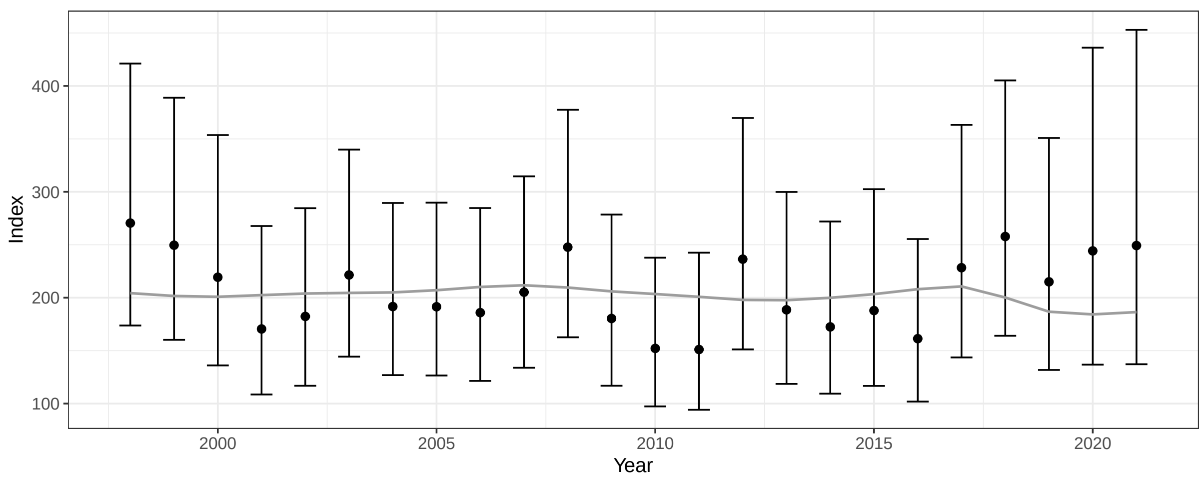

Figure C.7: Scenario 3: Model predictions (grey line) to catch rates for commercial net-caught black jewfish

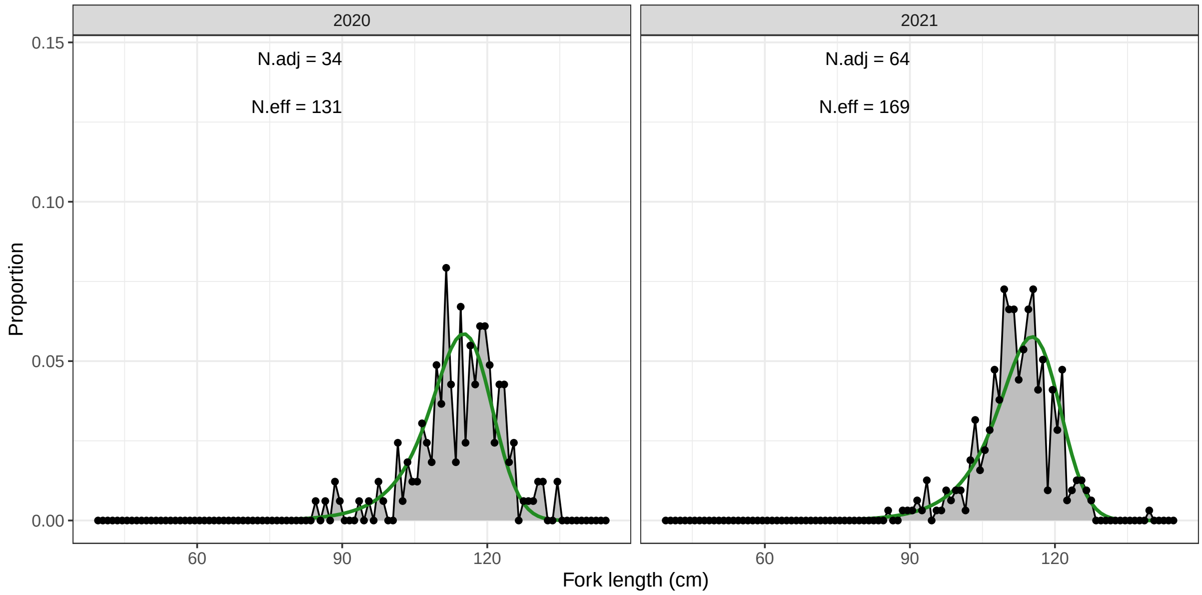

Figure C.8: Scenario 3: Length structure for the commercial line fleet for black jewfish

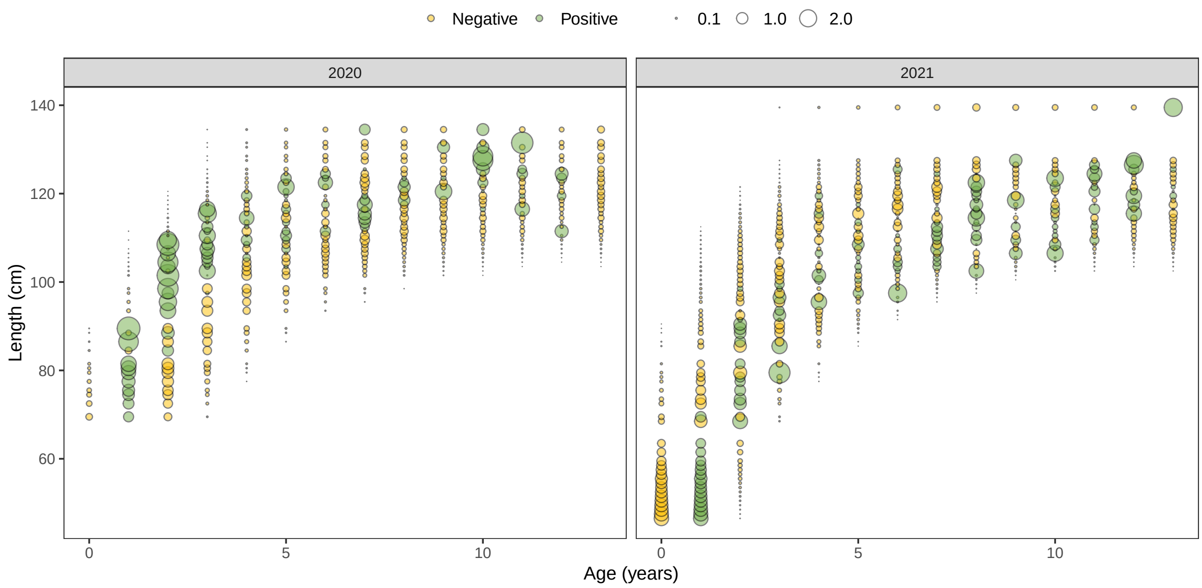

Figure C.9: Scenario 3: Pearson residuals for age-at-length compositions for the commercial fleet for black jewfish—circle size represents the magnitude of the Pearson residual

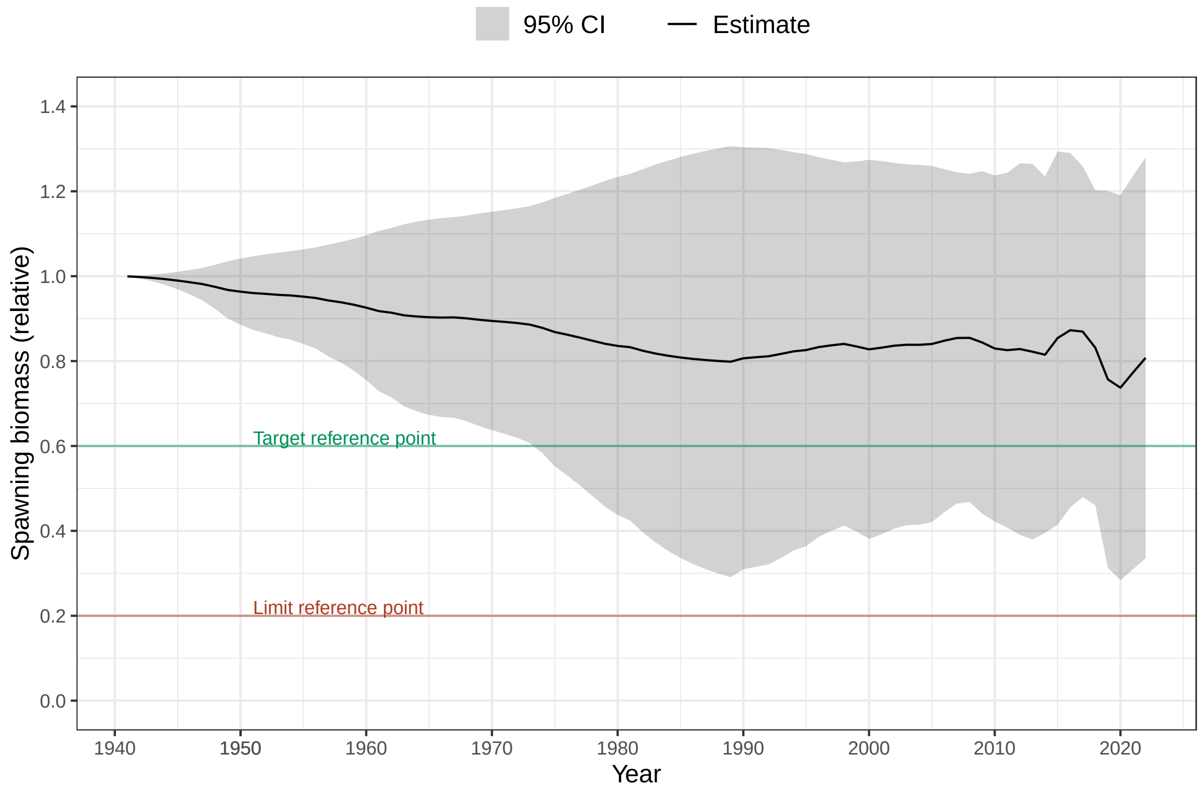

Figure C.10: Scenario 3: Predicted spawning stock biomass trajectory relative to unfished, from 1940 to 2022. Please note that confidence levels are artificially low because M is constrained.

C.3 Scenario 4

Table C.3: Stock synthesis parameter estimates for the Scenario 4 population model

Parameter	Estimate	Phase	Min	Max	Initial value	Standard deviation
L_at_Amin_Fem_GP_1	63.84	3	0	80	59.47	2.39
VonBert_K_Fem_GP_1	0.39	3	0.05	0.7	0.57	0.04
SD_young_Fem_GP_1	12.32	3	2	20	5.84	1.06
SD_old_Fem_GP_1	5.07	3	2	25	5.84	0.49
SR_LN(R0)	11.49	1	5	25	14	0.28
LnQ_base_EastCoast_Line(1)	-7.31	1	-30	1	-6	0.8
LnQ_base_EastCoast_Net(2)	-7.59	1	-30	1	-6	0.79
Size_inflection_EastCoast_Line(1)	114.44	5	90	120	110	6.96
Size_95%_width_EastCoast_Line(1)	17.93	5	2	20	5	4.37

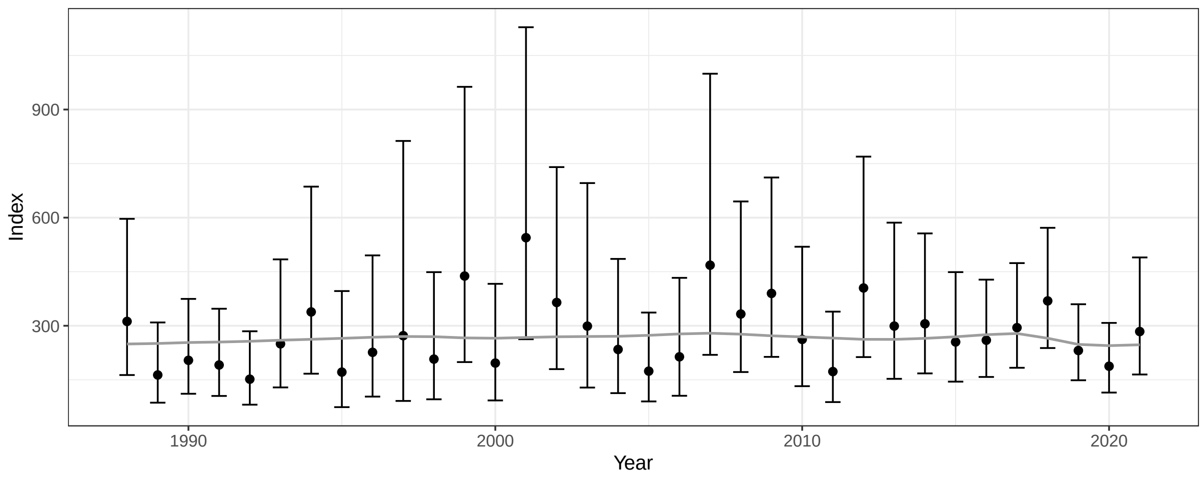

Figure C.11: Scenario 4: Model predictions (grey line) to catch rates for commercial line-caught black jewfish

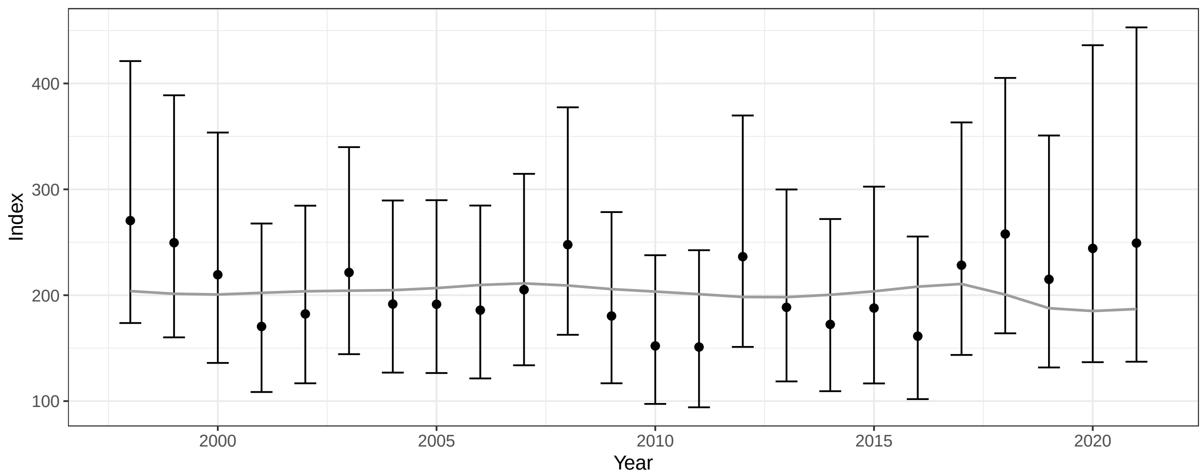

Figure C.12: Scenario 4: Model predictions (grey line) to catch rates for commercial net-caught black jewfish

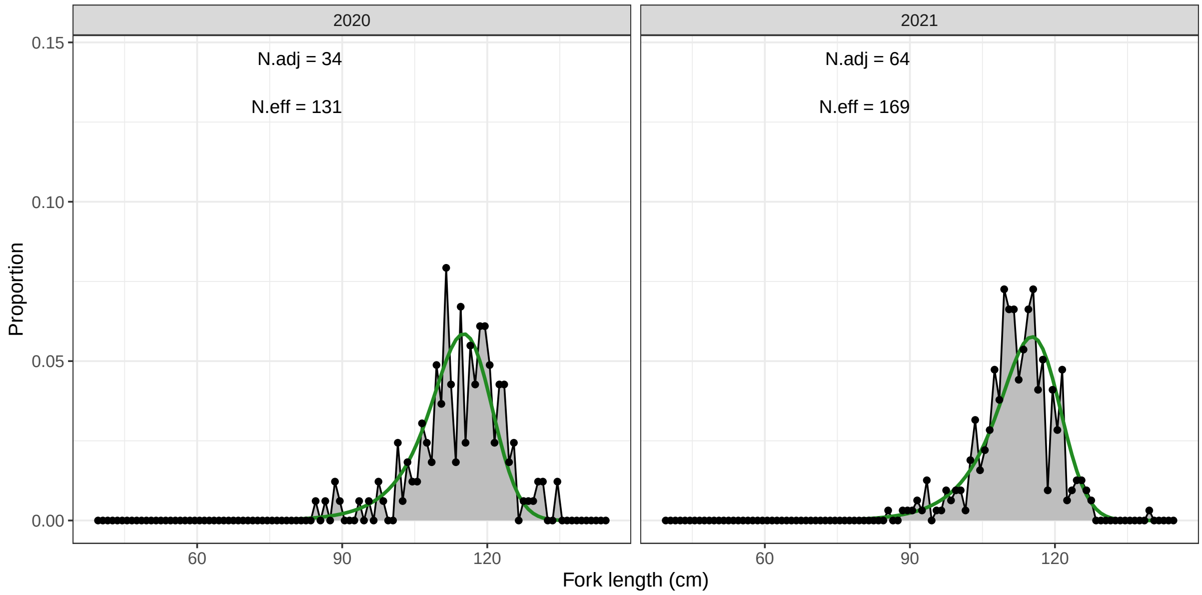

Figure C.13: Scenario 4: Length structure for the commercial line fleet for black jewfish

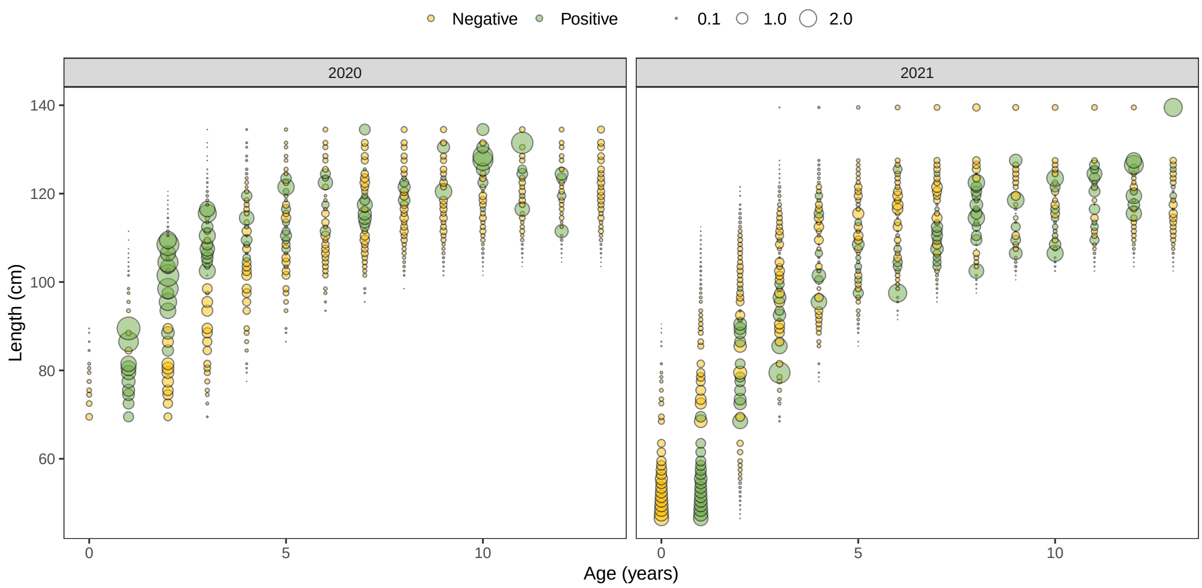

Figure C.14: Scenario 4: Pearson residuals for age-at-length compositions for the commercial fleet for black jewfish—circle size represents the magnitude of the Pearson residual

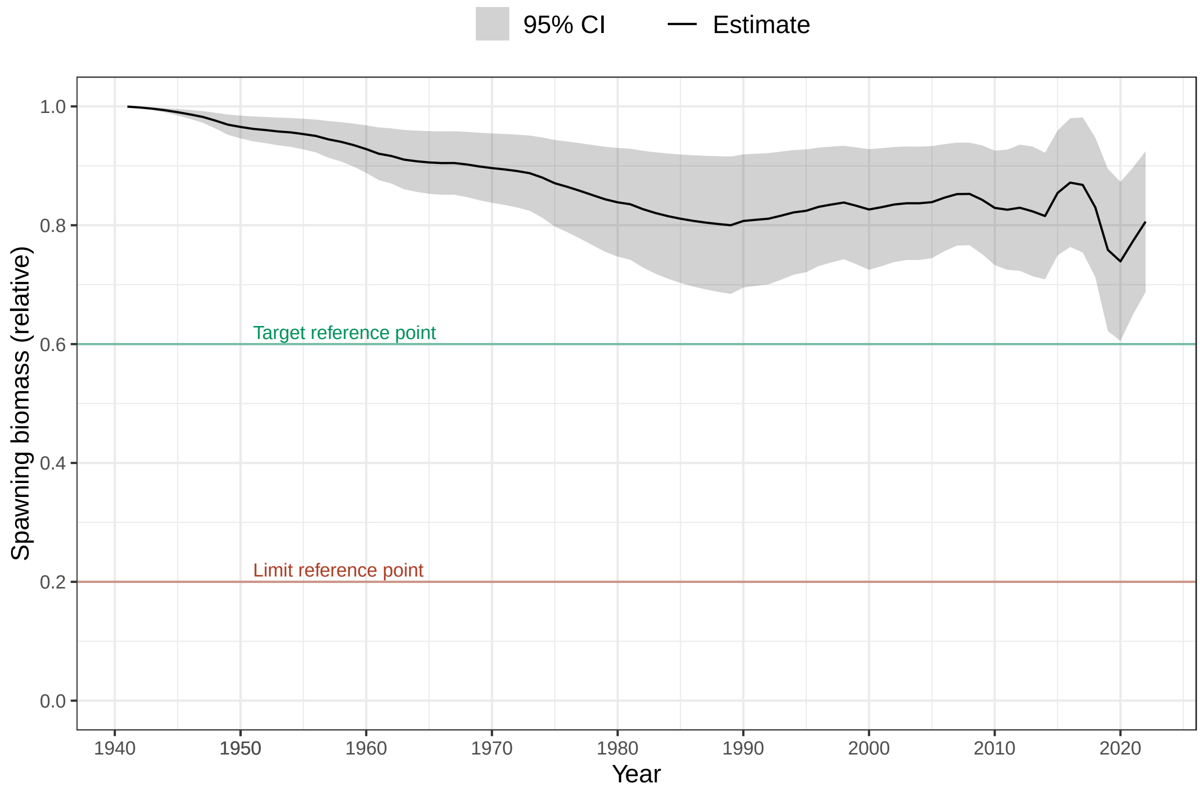

Figure C.15: Scenario 4: Predicted spawning stock biomass trajectory relative to unfished, from 1940 to 2022. Please note that confidence levels are artificially low because M is constrained.

C.4 Scenario 5

Table C.4: Stock synthesis parameter estimates for the Scenario 5 population model

Parameter	Estimate	Phase	Min	Max	Initial value	Standard deviation
L_at_Amin_Fem_GP_1	0.34	3	0.05	0.7	0.3	0.06
VonBert_K_Fem_GP_1	63.57	3	0	80	59.47	2.34
SD_young_Fem_GP_1	0.39	3	0.05	0.7	0.57	0.04
SD_old_Fem_GP_1	12.21	3	2	20	5.84	1.06
SR_LN(R0)	5.12	3	2	25	5.84	0.49
LnQ_base_EastCoast_Line(1)	12.66	1	5	25	14	0.76
LnQ_base_EastCoast_Net(2)	-8.16	1	-30	1	-6	0.79
Size_inflection_EastCoast_Line(1)	-8.44	1	-30	1	-6	0.78
Size_95%_width_EastCoast_Line(1)	114.04	5	90	120	110	6.22

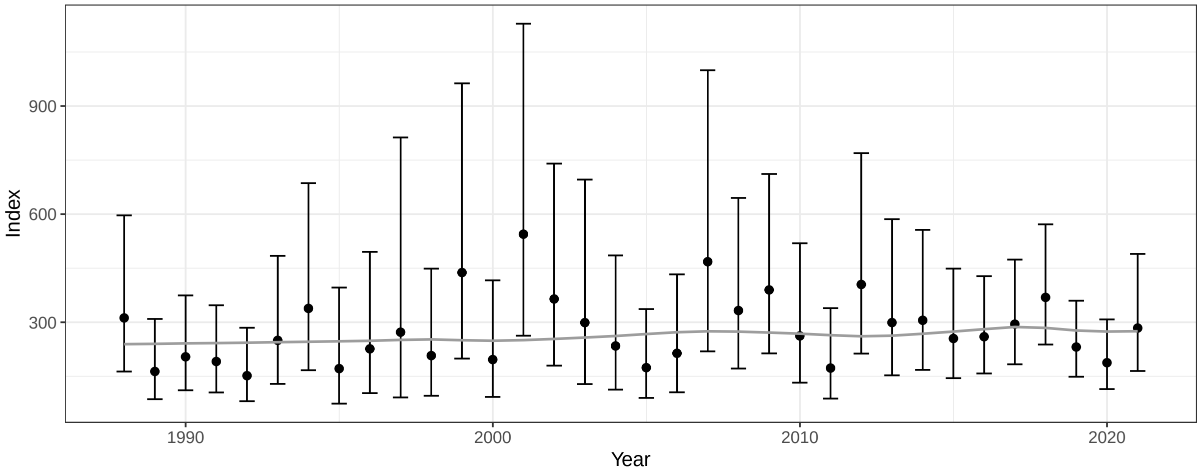

Figure C.16: Scenario 5: Model predictions (grey line) to catch rates for commercial line-caught black jewfish

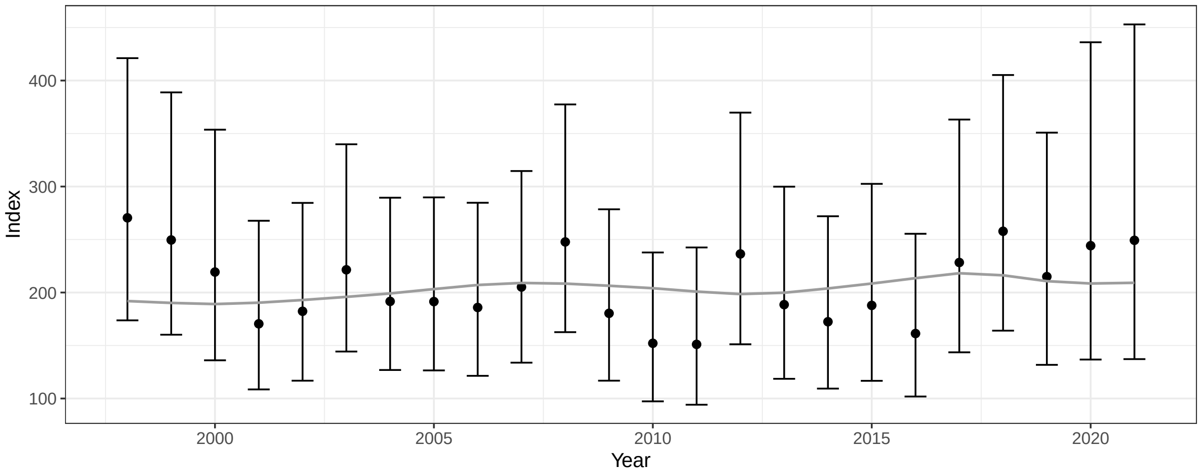

Figure C.17: Scenario 5: Model predictions (grey line) to catch rates for commercial net-caught black jewfish

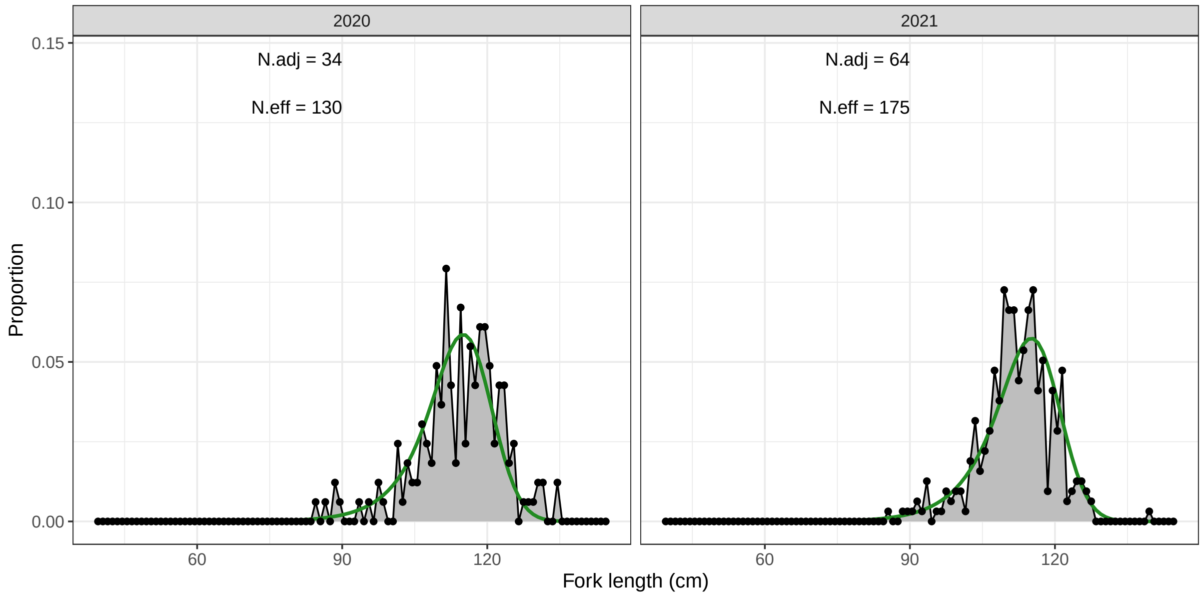

Figure C.18: Scenario 5: Length structure for the commercial line fleet for black jewfish

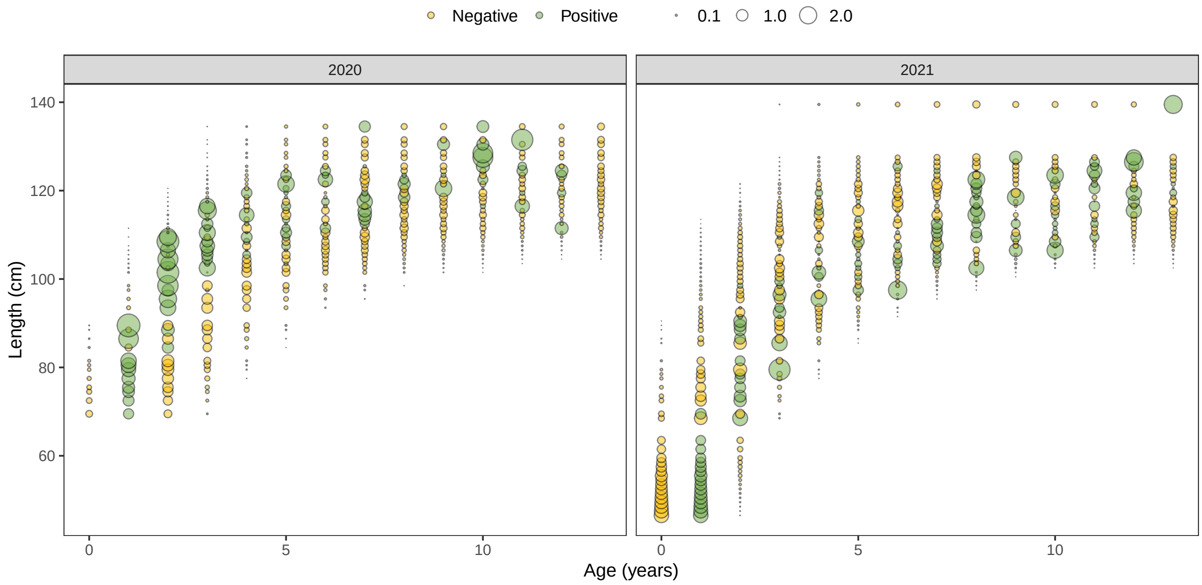

Figure C.19: Scenario 5: Pearson residuals for age-at-length compositions for the commercial fleet for black jewfish—circle size represents the magnitude of the Pearson residual

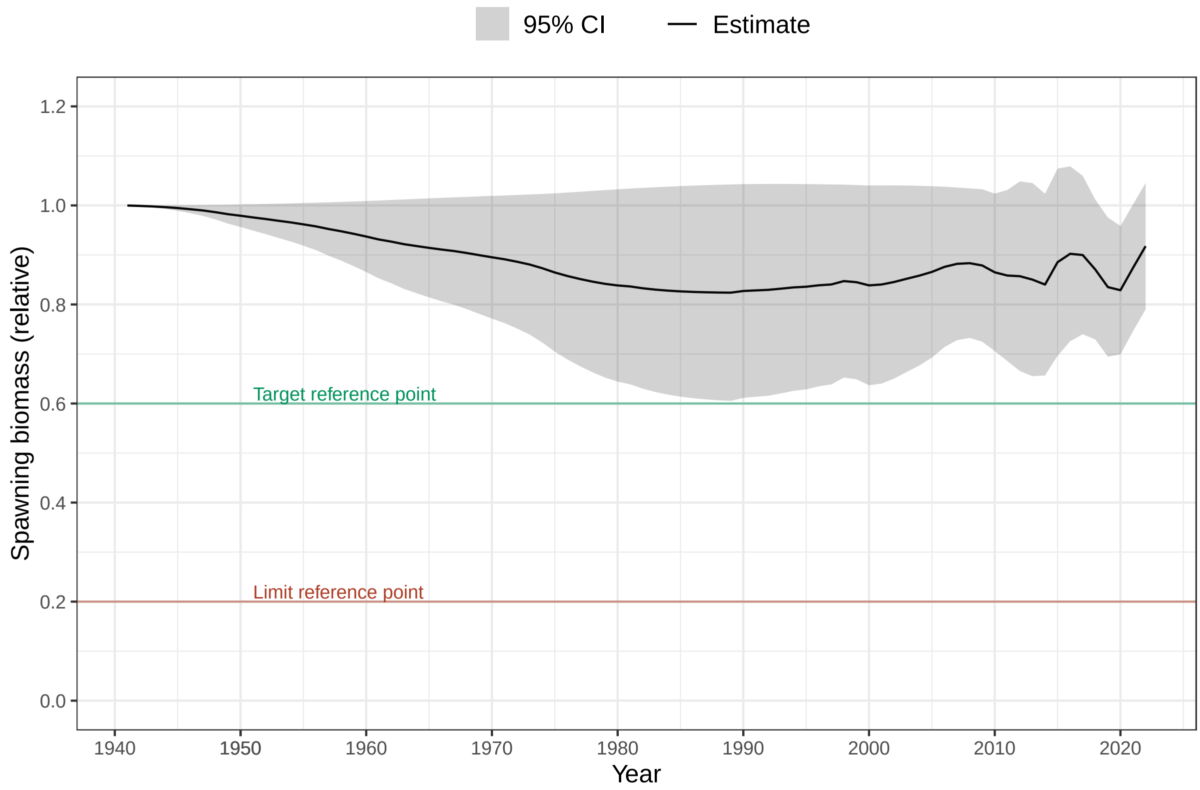

Figure C.20: Scenario 5: Predicted spawning stock biomass trajectory relative to unfished, from 1940 to 2022. Please note that confidence levels are artificially low because M is constrained.

C.5 Scenario 6

Table C.5: Stock synthesis parameter estimates for the Scenario 6 population model

Parameter	Estimate	Phase	Min	Max	Initial value	Standard deviation
L_at_Amin_Fem_GP_1	0.35	6	0.05	0.7	0.3	0.06
VonBert_K_Fem_GP_1	63.56	3	0	80	59.47	2.34
SD_young_Fem_GP_1	0.39	3	0.05	0.7	0.57	0.04
SD_old_Fem_GP_1	12.21	3	2	20	5.84	1.05
SR_LN(R0)	5.12	3	2	25	5.84	0.49
LnQ_base_EastCoast_Line(1)	12.73	1	5	25	14	0.76
LnQ_base_EastCoast_Net(2)	-8.21	1	-30	1	-6	0.81
Size_inflection_EastCoast_Line(1)	-8.48	1	-30	1	-6	0.8
Size_95%_width_EastCoast_Line(1)	114.09	5	90	120	110	6.23

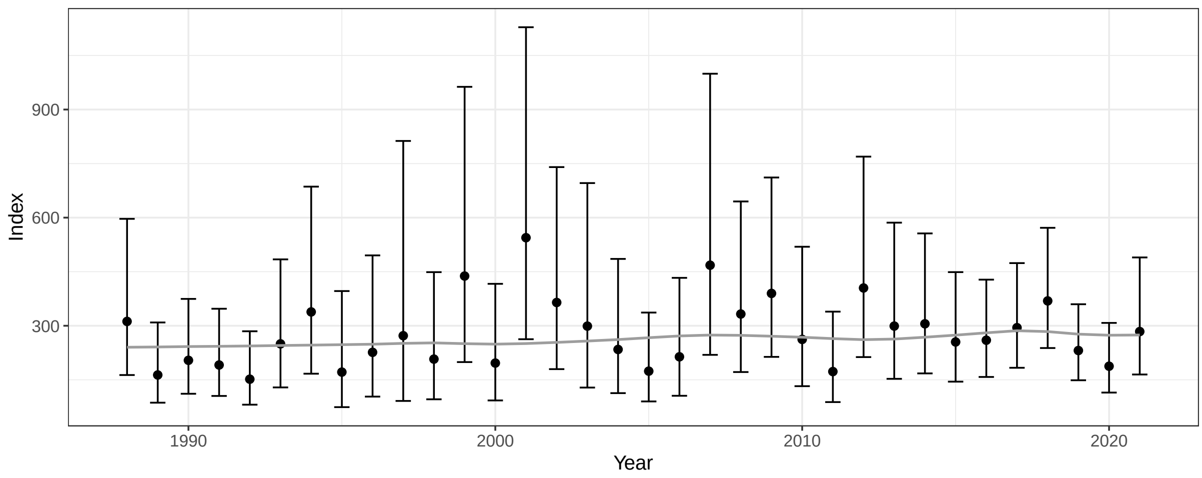

Figure C.21: Scenario 6: Model predictions (grey line) to catch rates for commercial line-caught black jewfish

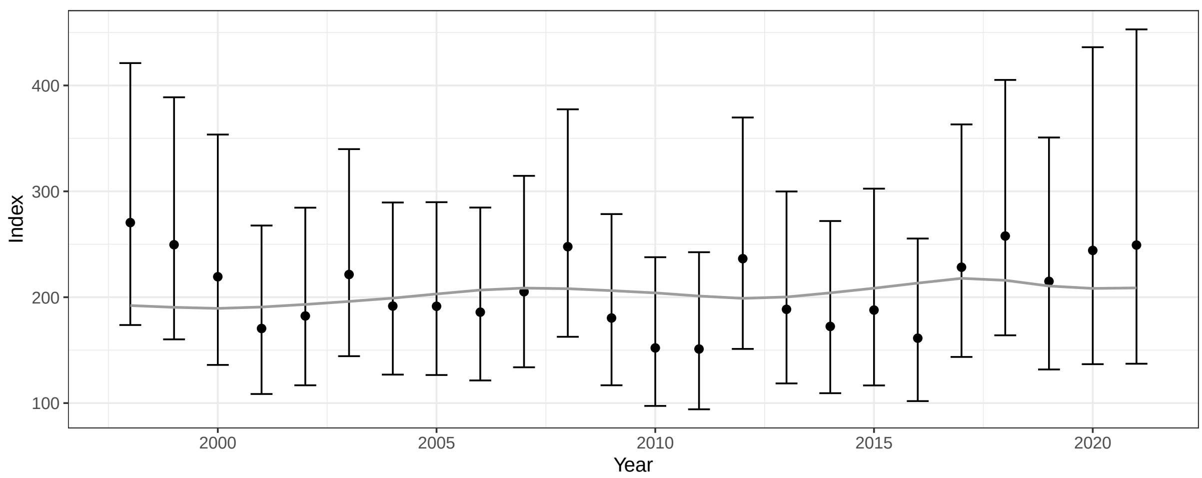

Figure C.22: Scenario 6: Model predictions (grey line) to catch rates for commercial net-caught black jewfish

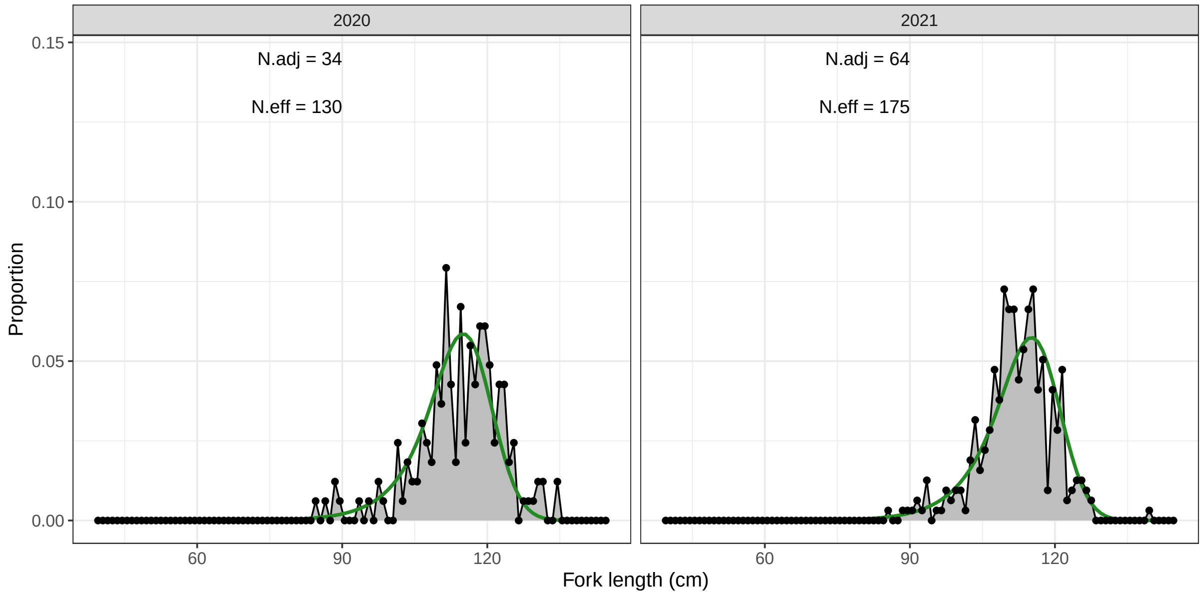

Figure C.23: Scenario 6: Length structure for the commercial line fleet for black jewfish

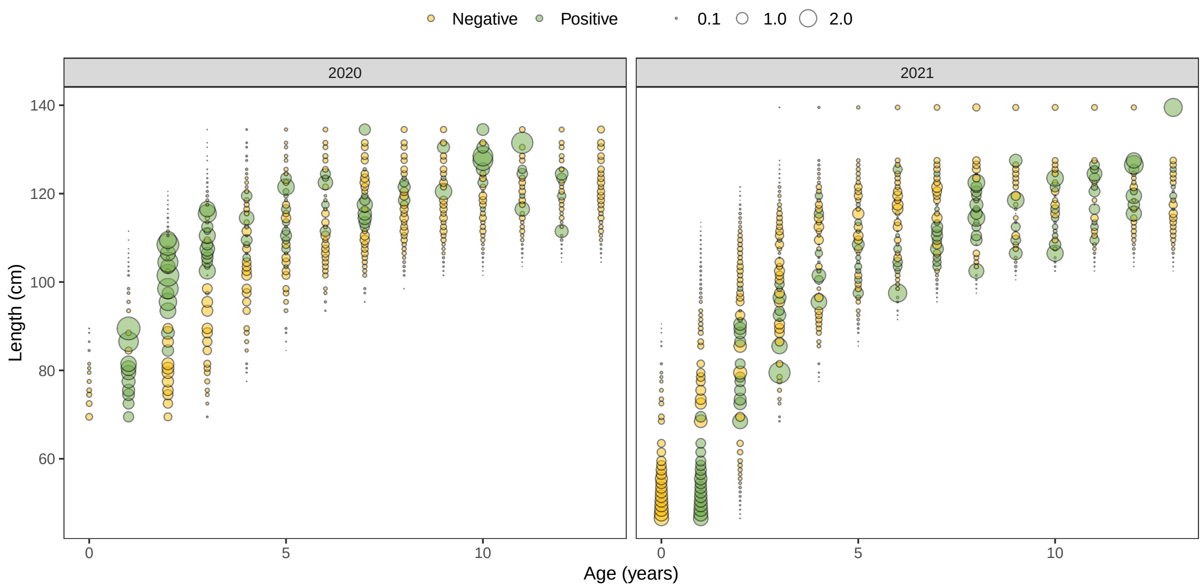

Figure C.24: Scenario 6: Pearson residuals for age-at-length compositions for the commercial fleet for black jewfish—circle size represents the magnitude of the Pearson residual

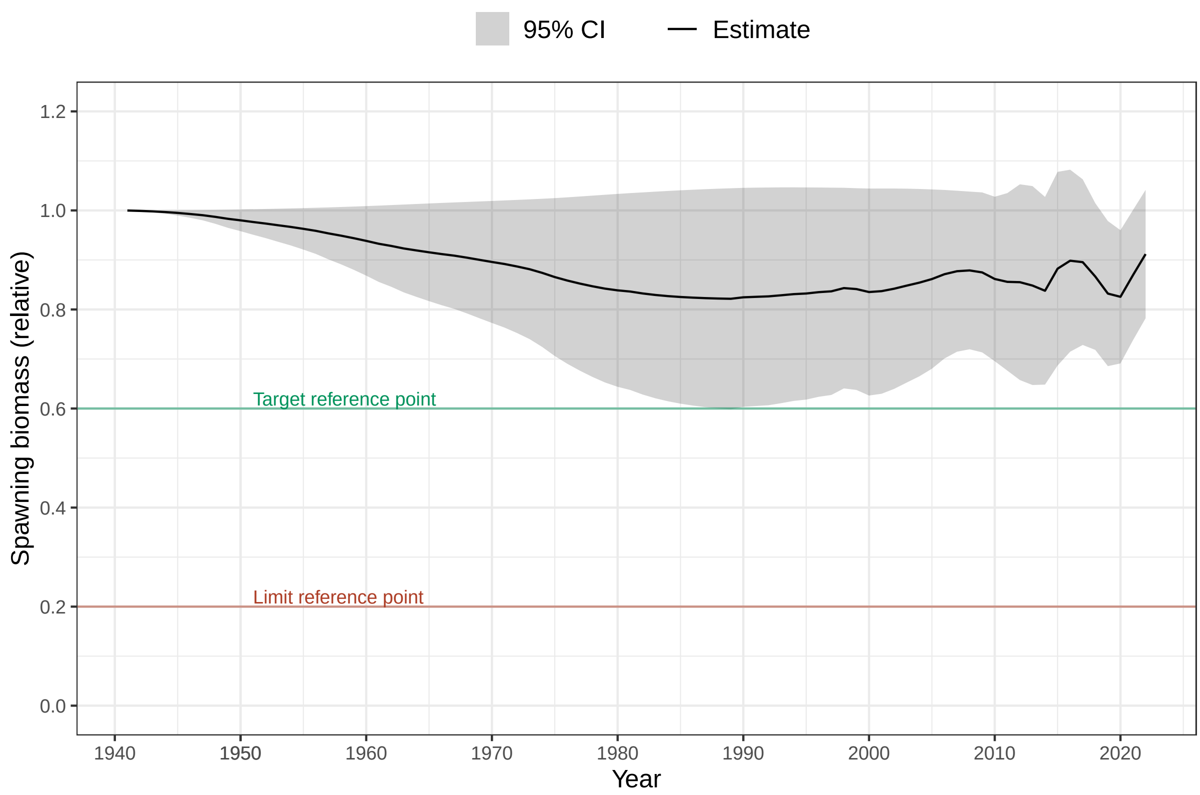

Figure C.25: Scenario 6: Predicted spawning stock biomass trajectory relative to unfished, from 1940 to 2022. Please note that confidence levels are artificially low because M is constrained.

C.6 Scenario 7

Table C.6: Stock synthesis parameter estimates for the Scenario 7 population model

Parameter	Estimate	Phase	Min	Max	Initial value	Standard deviation
L_at_Amin_Fem_GP_1	64.24	3	0	80	59.47	2.44
VonBert_K_Fem_GP_1	0.42	3	0.05	0.7	0.57	0.03
SD_young_Fem_GP_1	12.58	3	2	20	5.84	1.14
SD_old_Fem_GP_1	5.09	3	2	25	5.84	0.46
SR_LN(R0)	10.46	1	5	25	14	0.06
LnQ_base_EastCoast_Line(1)	-7.07	1	-30	1	-6	0.51
LnQ_base_EastCoast_Net(2)	-7.36	1	-30	1	-6	0.5
Size_inflection_EastCoast_Line(1)	111.84	5	90	120	110	6.41
Size_95%_width_EastCoast_Line(1)	18.78	5	2	20	5	5.17

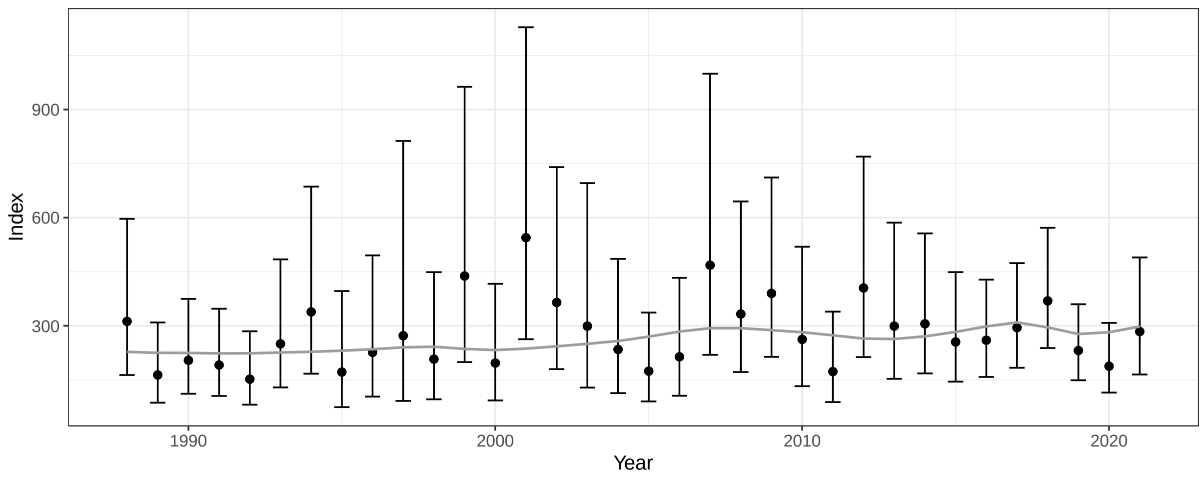

Figure C.26: Scenario 7: Model predictions (grey line) to catch rates for commercial line-caught black jewfish

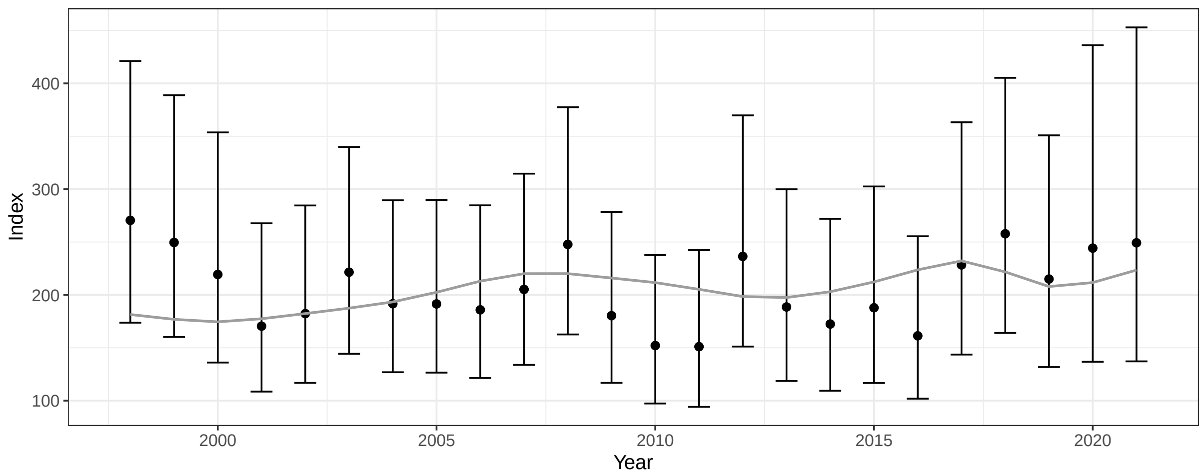

Figure C.27: Scenario 7: Model predictions (grey line) to catch rates for commercial net-caught black jewfish

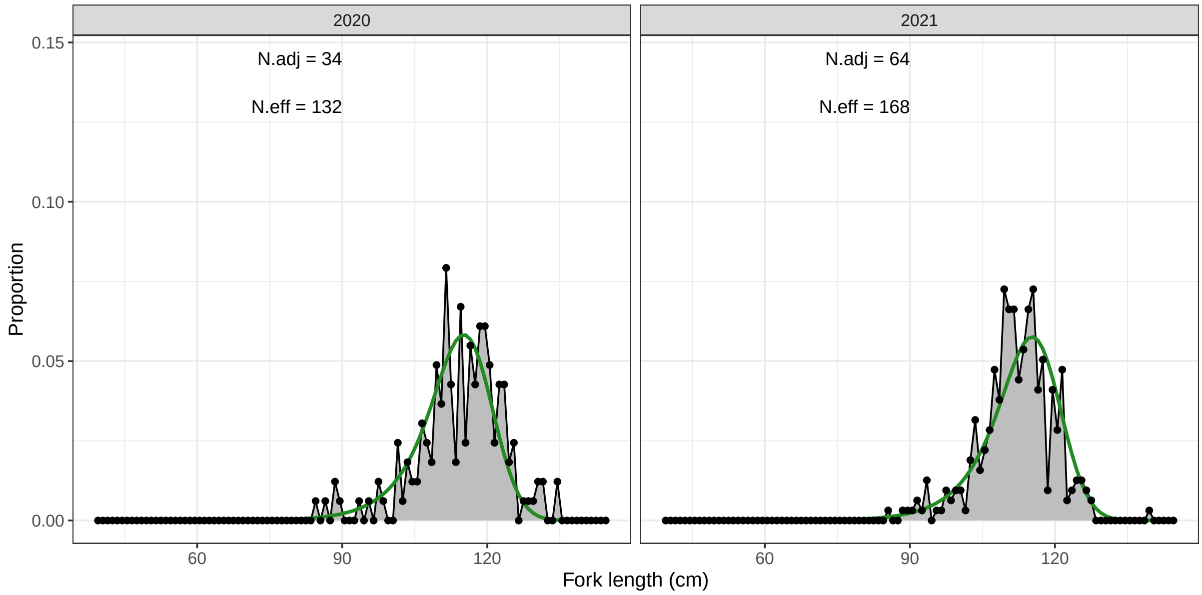

Figure C.28: Scenario 7: Length structure for the commercial line fleet for black jewfish

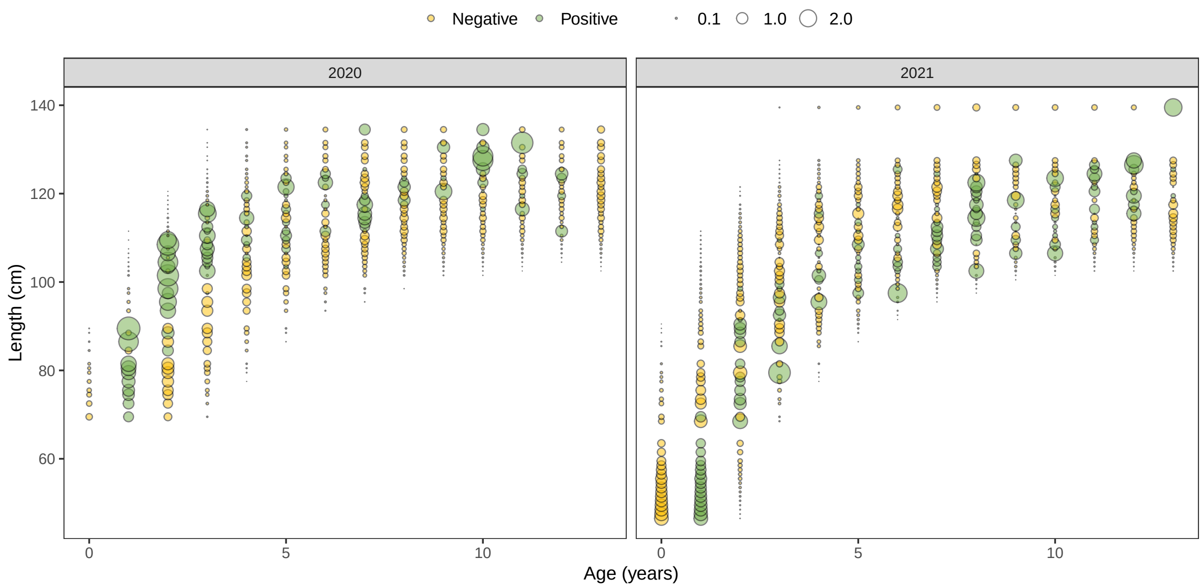

Figure C.29: Scenario 7: Pearson residuals for age-at-length compositions for the commercial fleet for black jewfish—circle size represents the magnitude of the Pearson residual

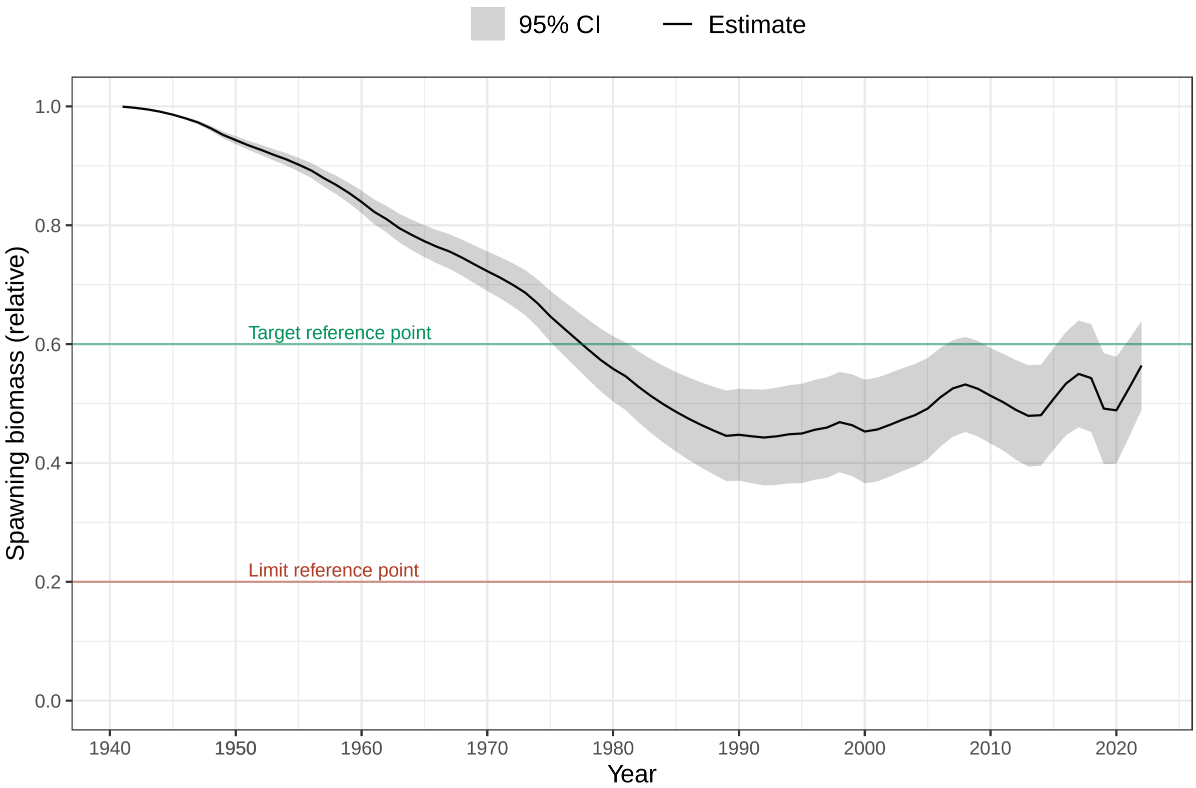

Figure C.30: Scenario 7: Predicted spawning stock biomass trajectory relative to unfished, from 1940 to 2022. Please note that confidence levels are artificially low because M is constrained.

C.7 Scenario 8

Table C.7: Stock synthesis parameter estimates for the Scenario 8 population model

Parameter	Estimate	Phase	Min	Max	Initial value	Standard deviation
L_at_Amin_Fem_GP_1	0.41	3	0.05	0.7	0.3	0
VonBert_K_Fem_GP_1	63.08	3	0	80	59.47	0
SD_young_Fem_GP_1	0.39	3	0.05	0.7	0.57	0
SD_old_Fem_GP_1	12.13	3	2	20	5.84	0
SR_LN(R0)	5.16	3	2	25	5.84	0
LnQ_base_EastCoast_Line(1)	24.58	1	5	25	14	0
LnQ_base_EastCoast_Net(2)	-19.8	1	-30	1	-6	0
Size_inflection_EastCoast_Line(1)	-20.06	1	-30	1	-6	0
Size_95%_width_EastCoast_Line(1)	113.76	5	90	120	110	0

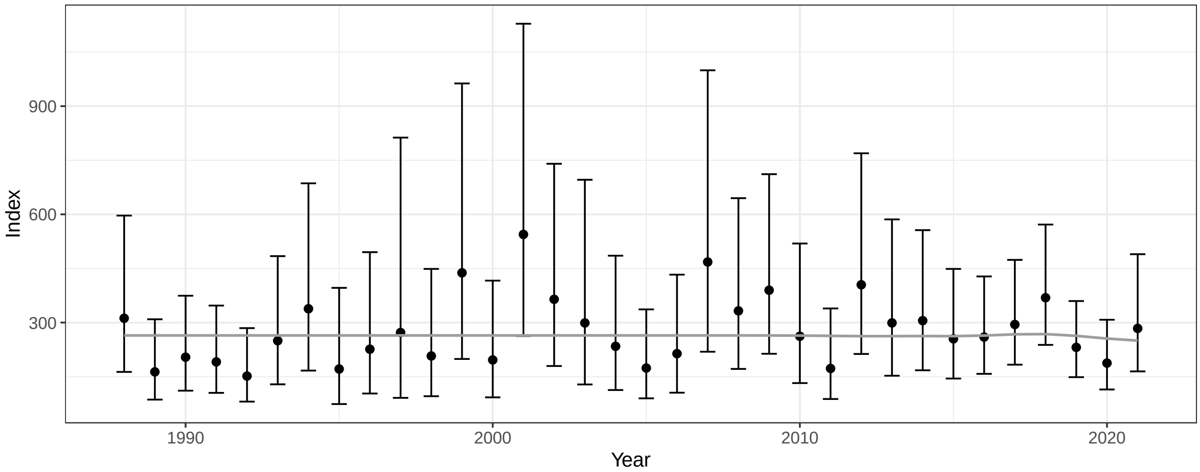

Figure C.31: Scenario 8: Model predictions (grey line) to catch rates for commercial line-caught black jewfish

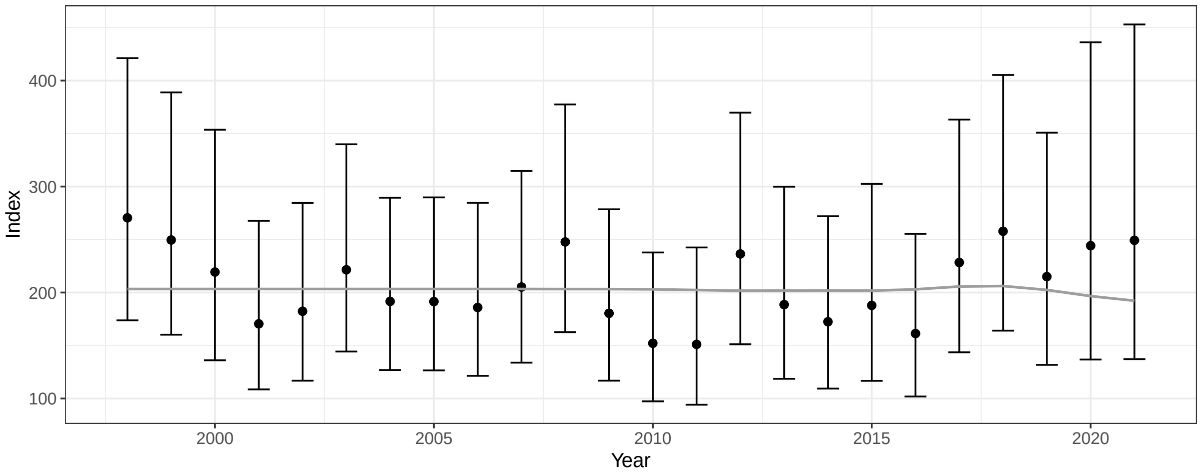

Figure C.32: Scenario 8: Model predictions (grey line) to catch rates for commercial net-caught black jewfish

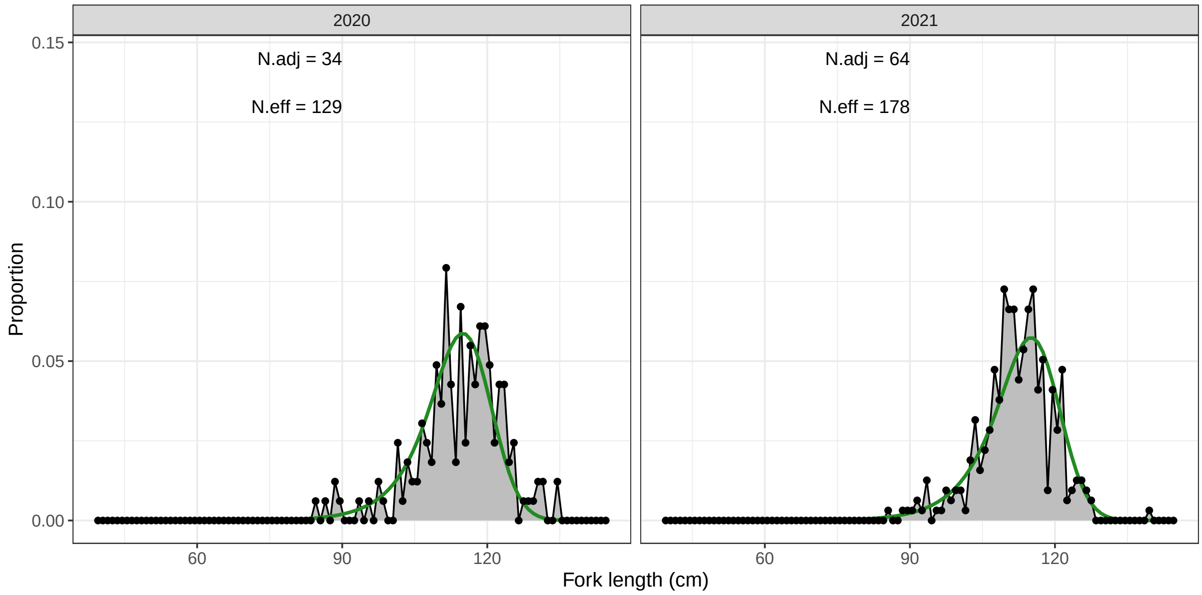

Figure C.33: Scenario 8: Length structure for the commercial line fleet for black jewfish

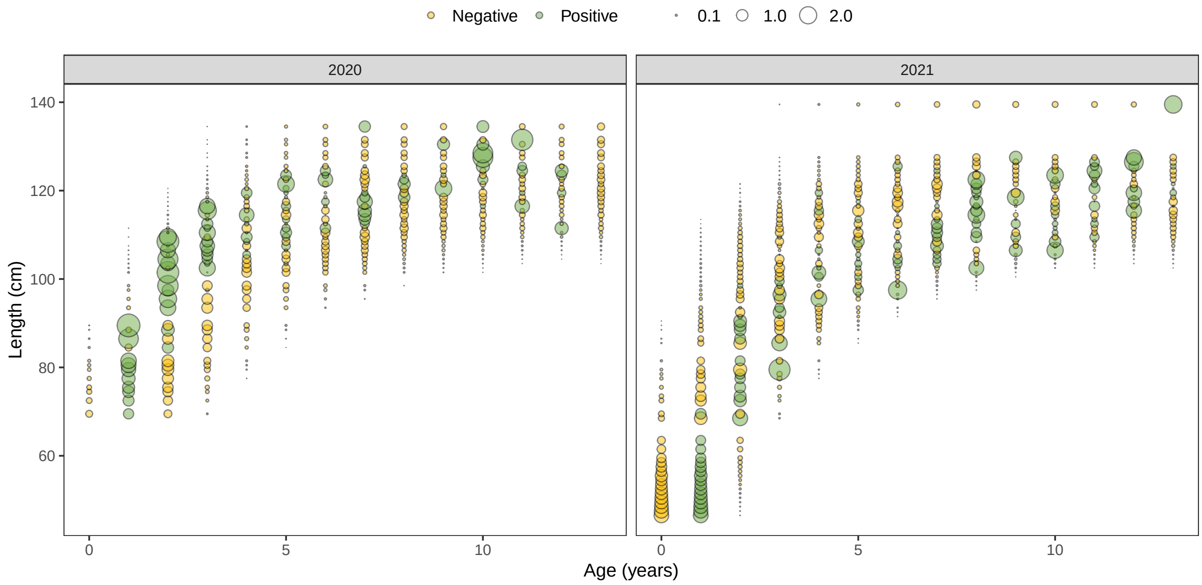

Figure C.34: Scenario 8: Pearson residuals for age-at-length compositions for the commercial fleet for black jewfish—circle size represents the magnitude of the Pearson residual

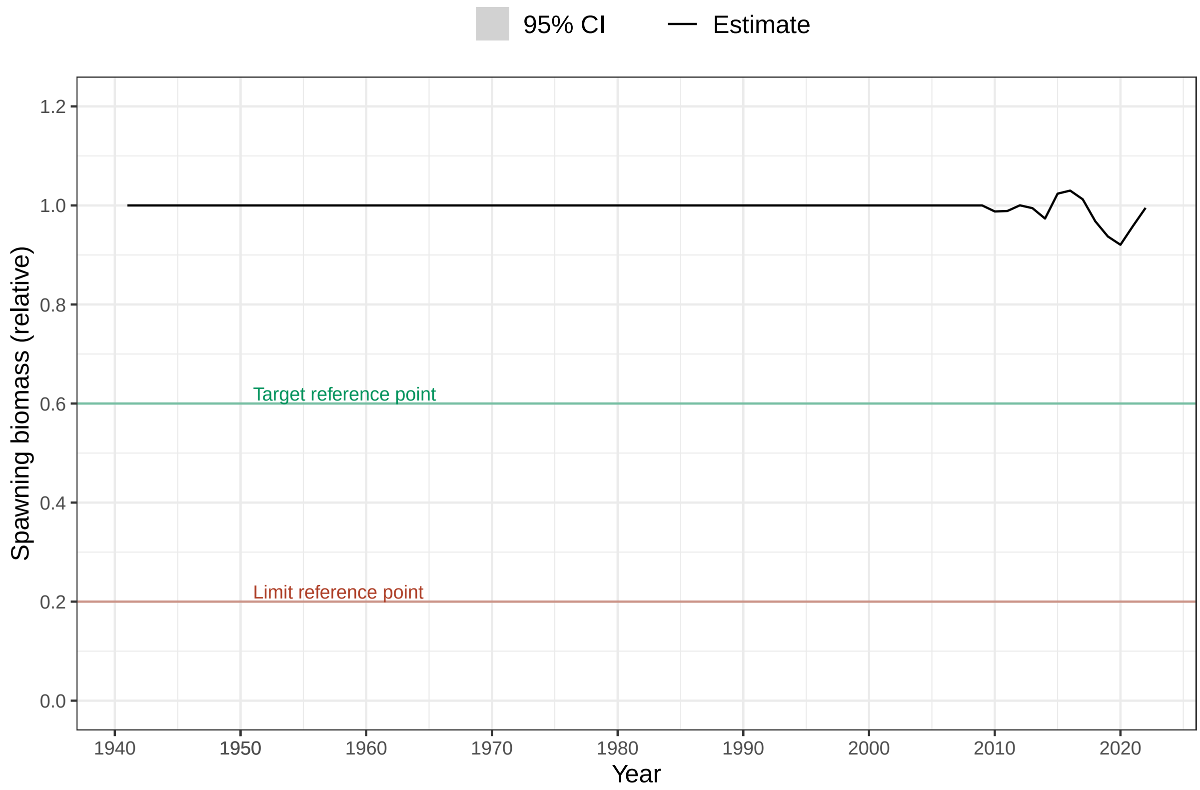

Figure C.35: Scenario 8: Predicted spawning stock biomass trajectory relative to unfished, from 1940 to 2022. Please note that confidence levels are extremely narrow because the estimated biomass is extremely high

Appendix D Sensitivity tests: other outputs

Scenario 2

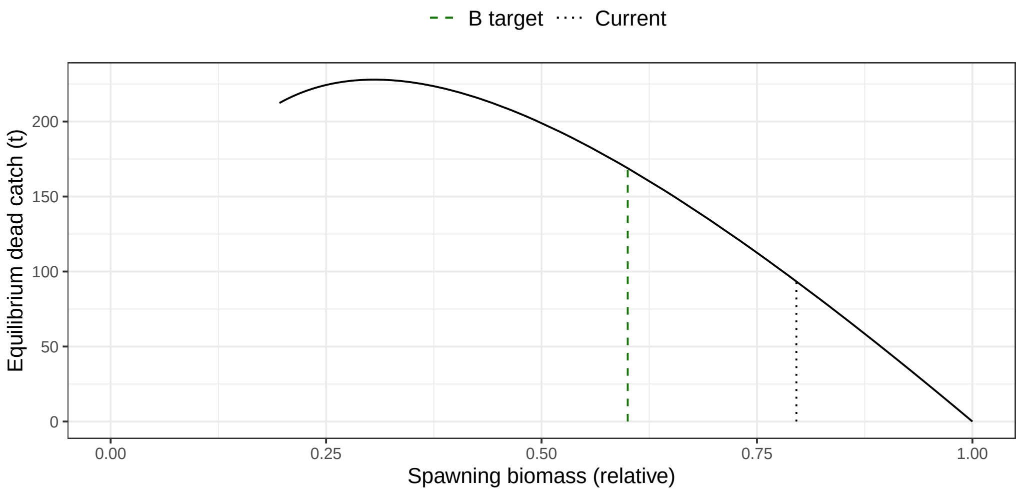

Figure D.1: Scenario 2: equilibrium harvest curve for black jewfish

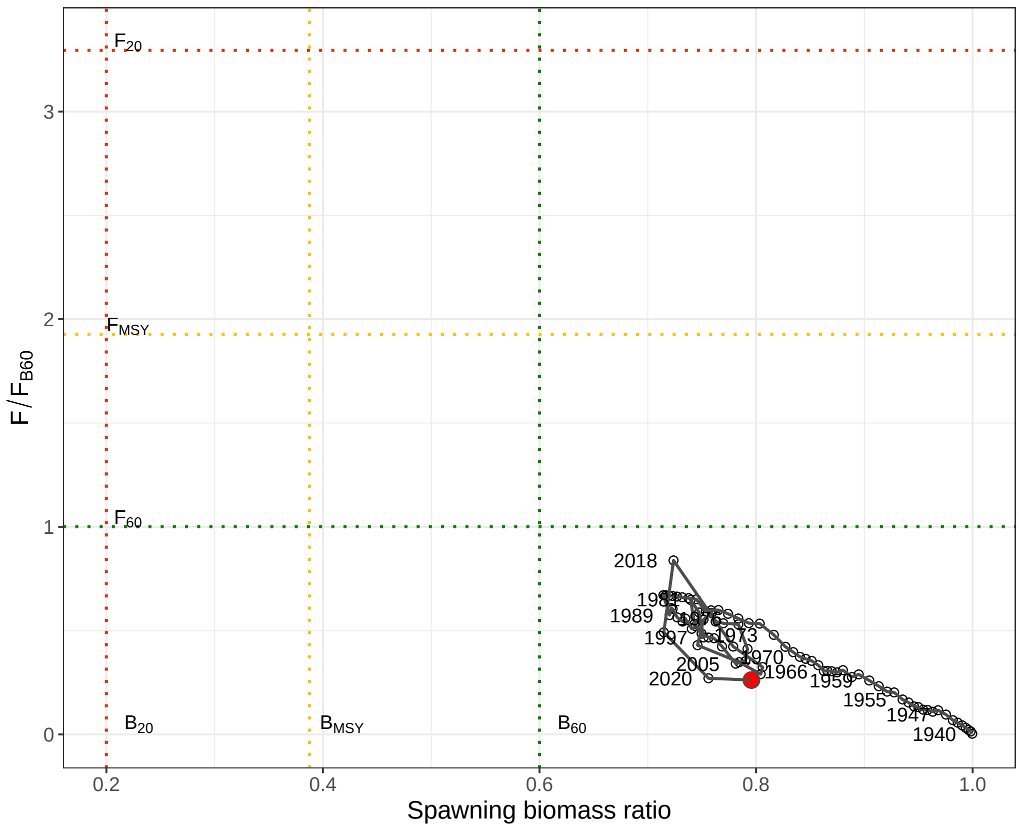

Figure D.2: Scenario 2: phase plot for black jewfish

Scenario 3

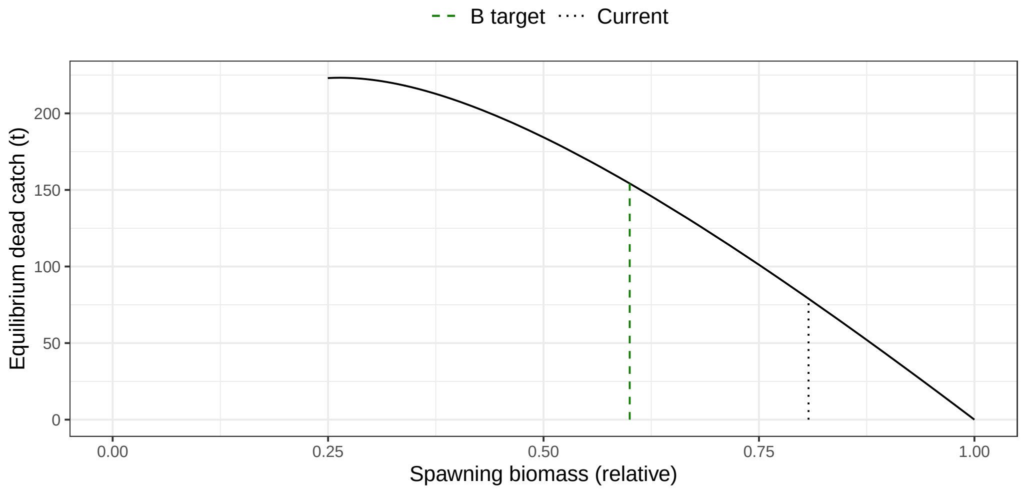

Figure D.3: Scenario 3: equilibrium harvest curve for black jewfish

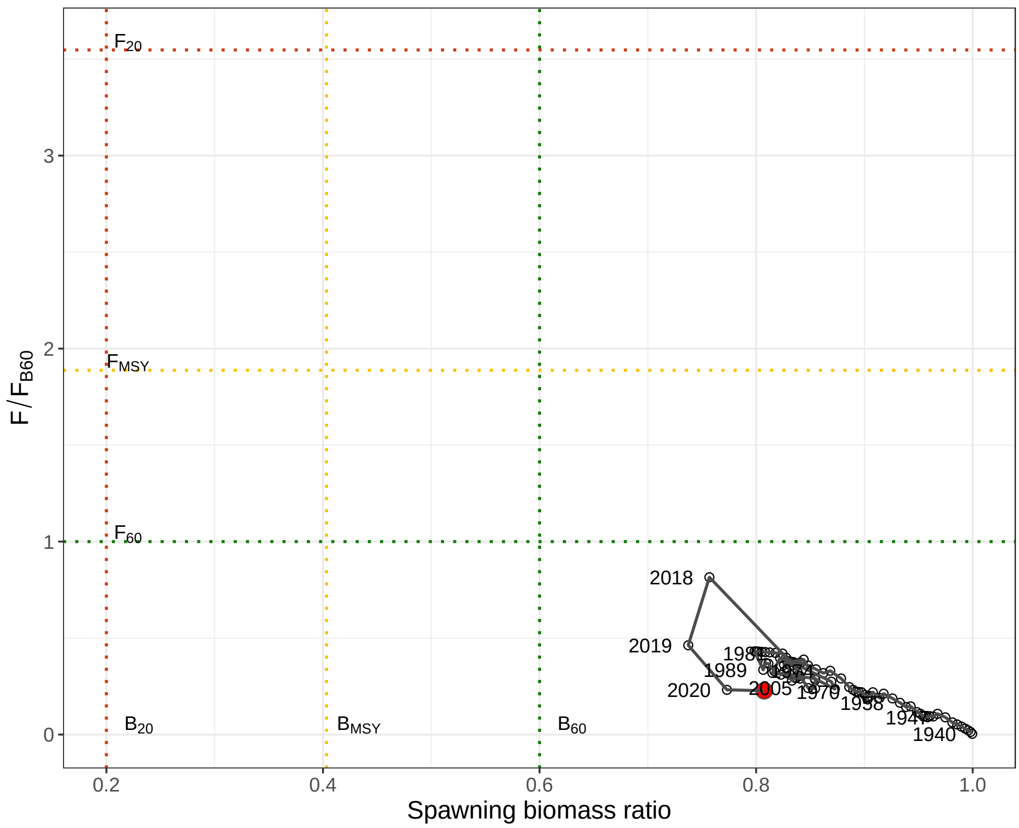

Figure D.4: Scenario 3: phase plot for black jewfish

Scenario 4

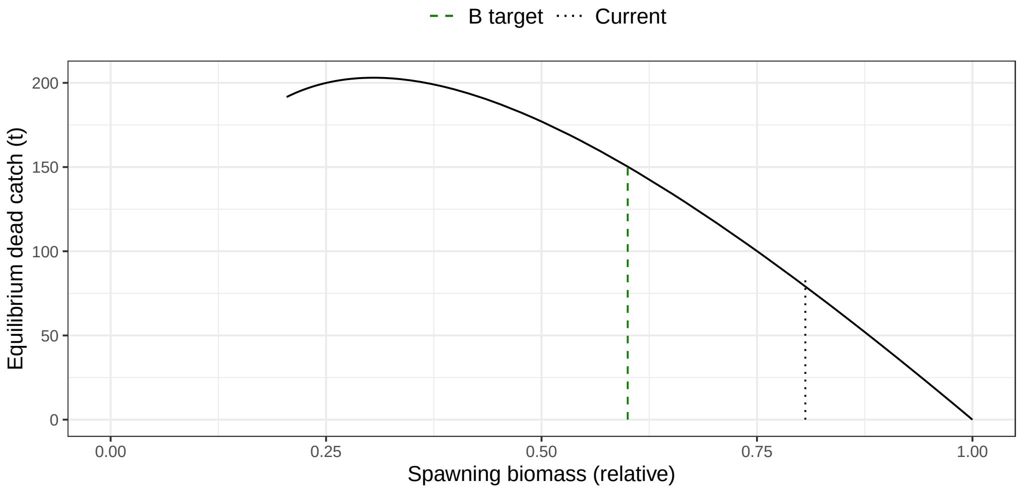

Figure D.5: Scenario 4: equilibrium harvest curve for black jewfish

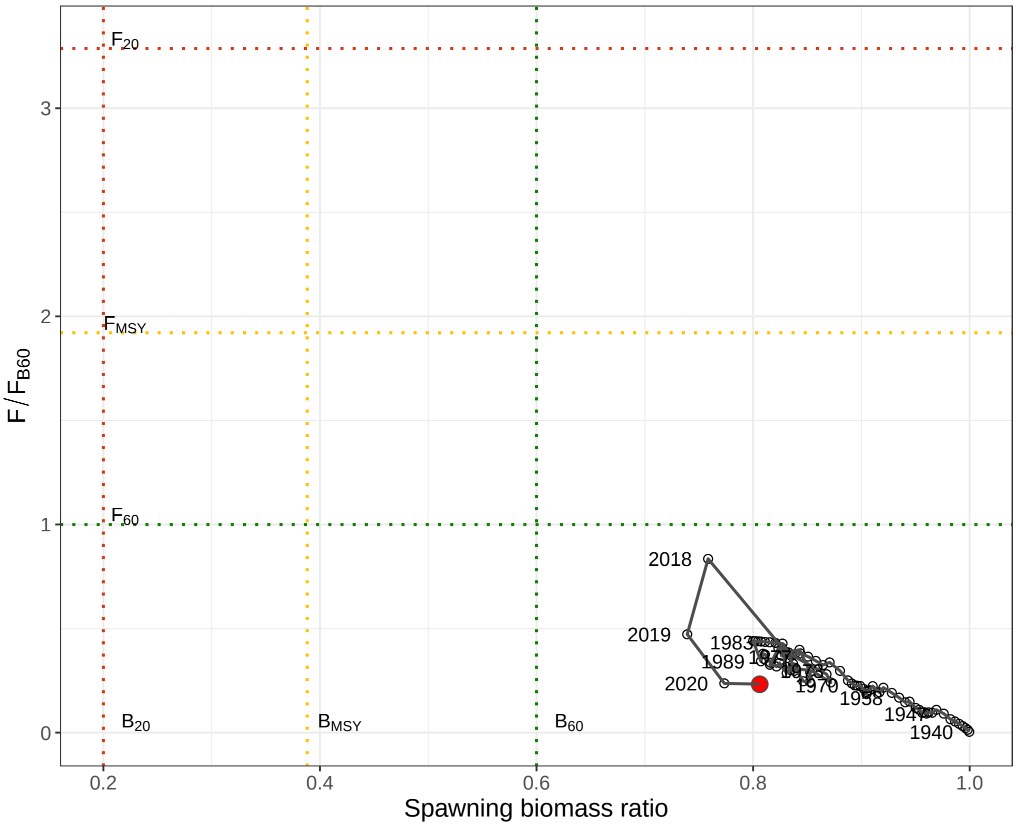

Figure D.6: Scenario 4: phase plot for black jewfish

Scenario 5

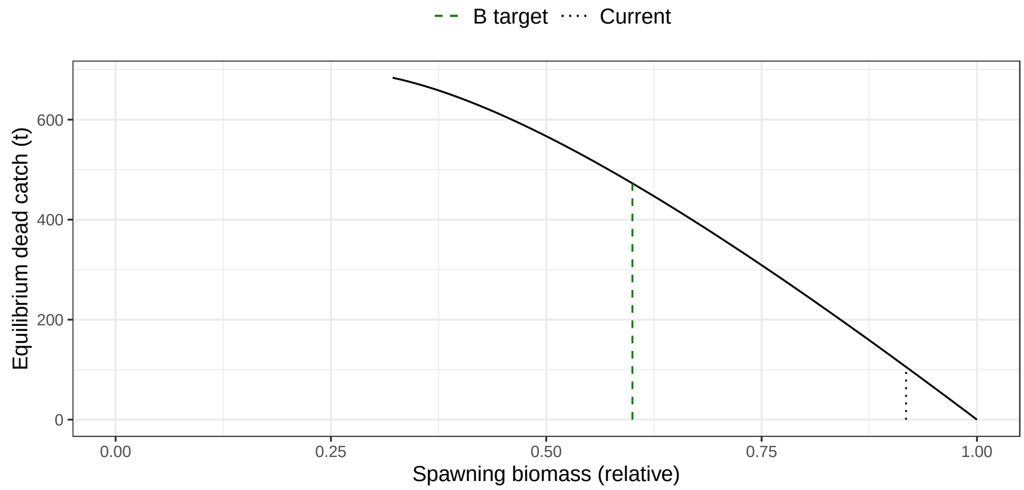

Figure D.7: Scenario 5: equilibrium harvest curve for black jewfish

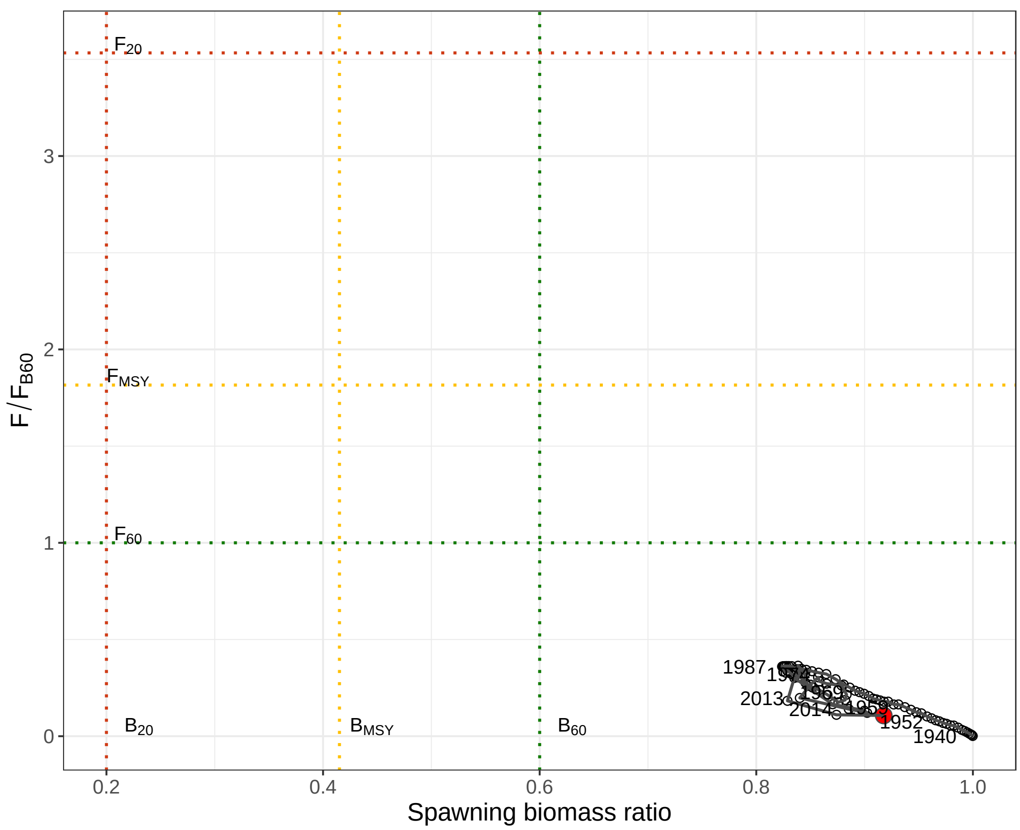

Figure D.8: Scenario 5: phase plot for black jewfish

Scenario 6

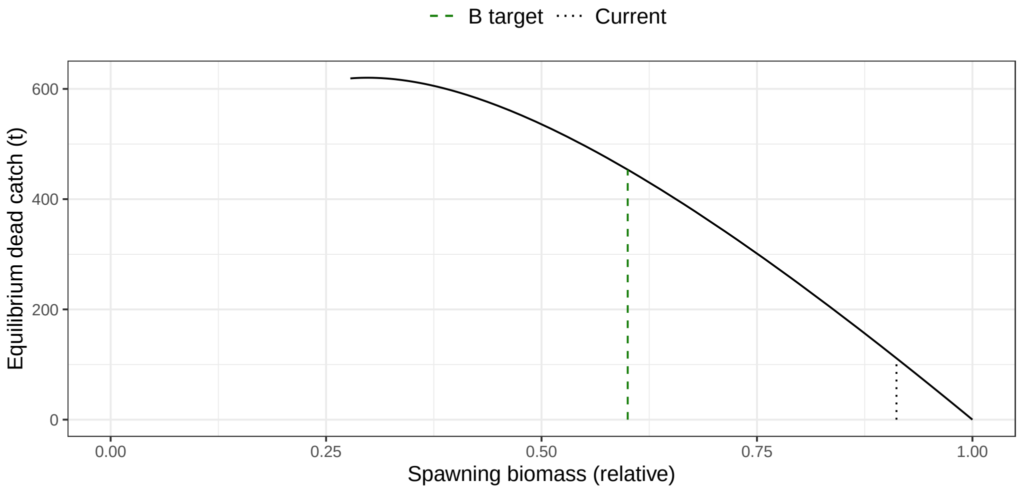

Figure D.9: Scenario 6: equilibrium harvest curve for black jewfish

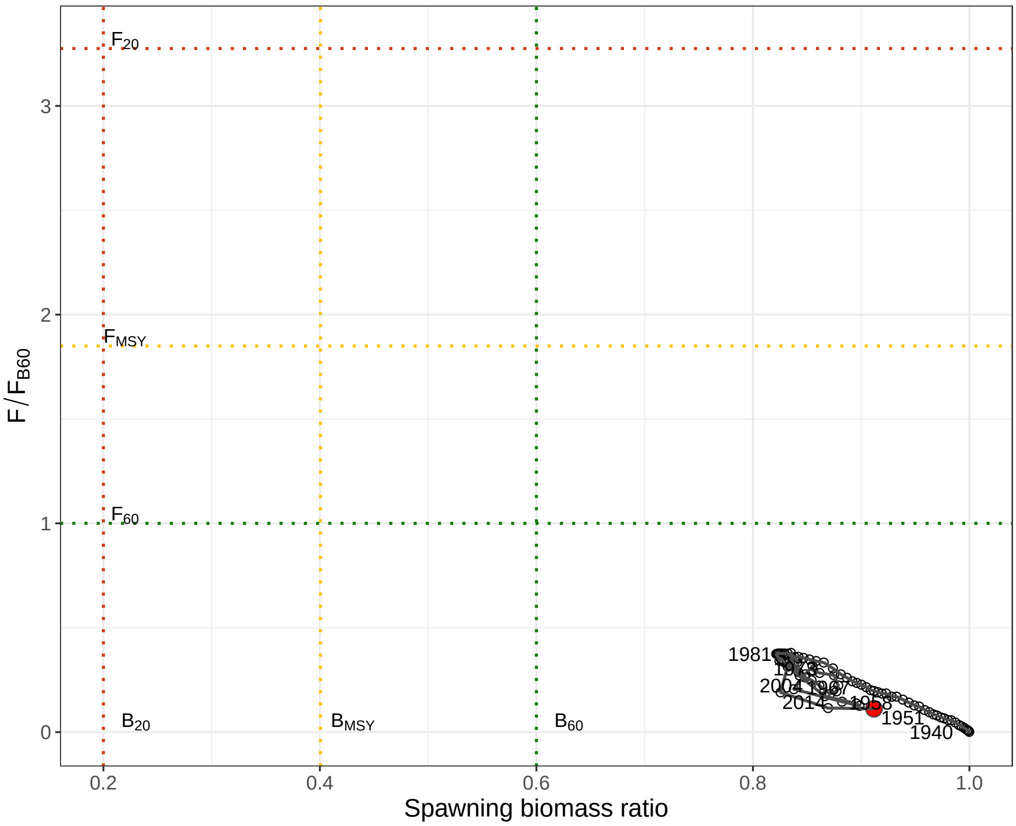

Figure D.10: Scenario 6: phase plot for black jewfish

Scenario 7

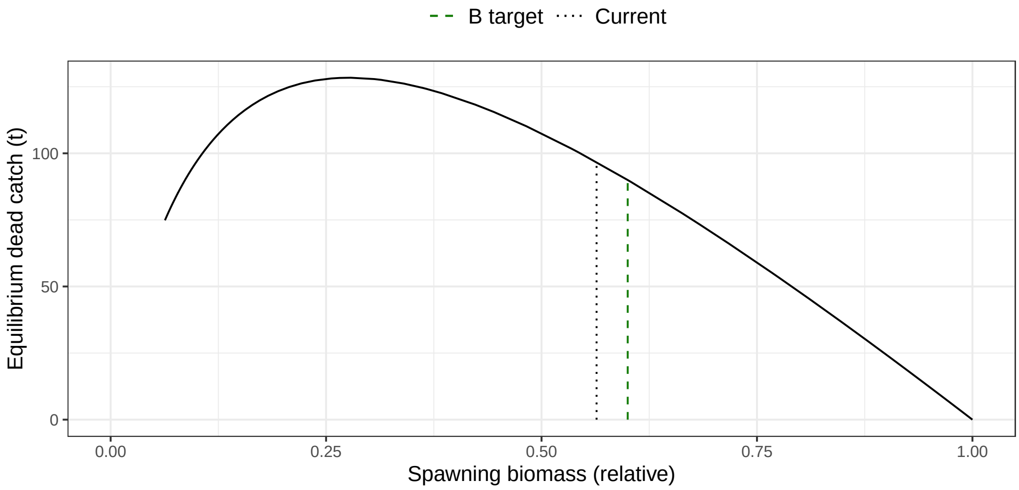

Figure D.11: Scenario 7: equilibrium harvest curve for black jewfish

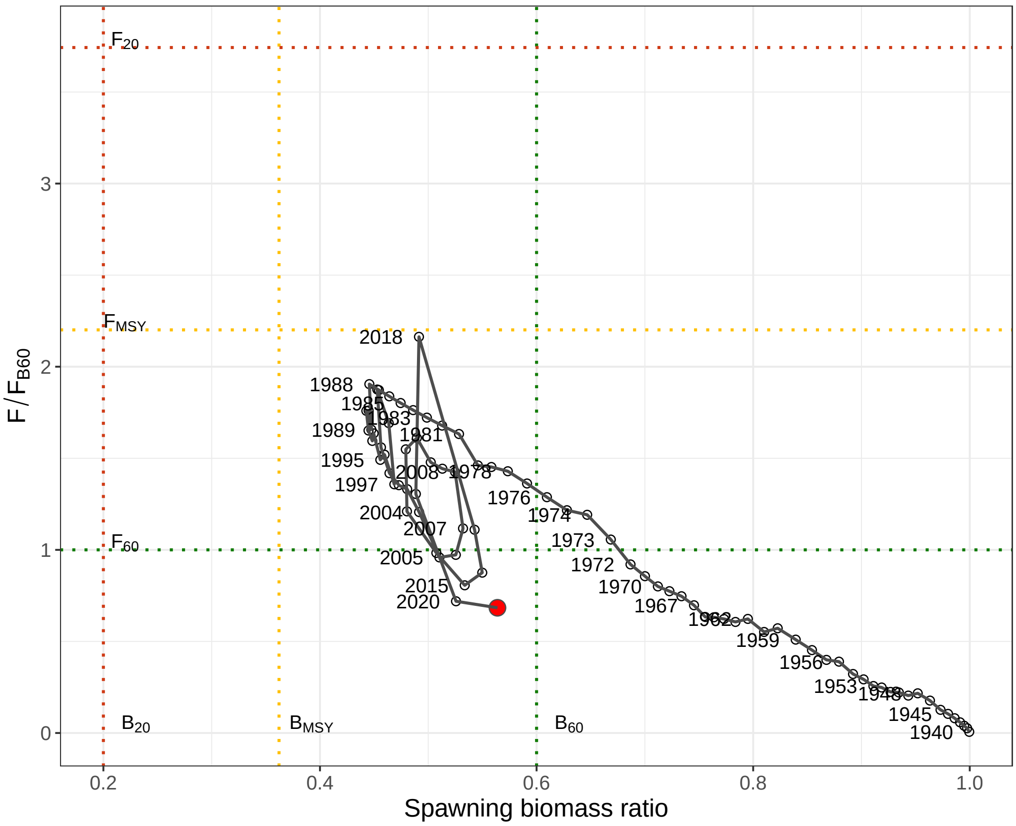

Figure D.12: Scenario 7: phase plot for black jewfish

Scenario 8

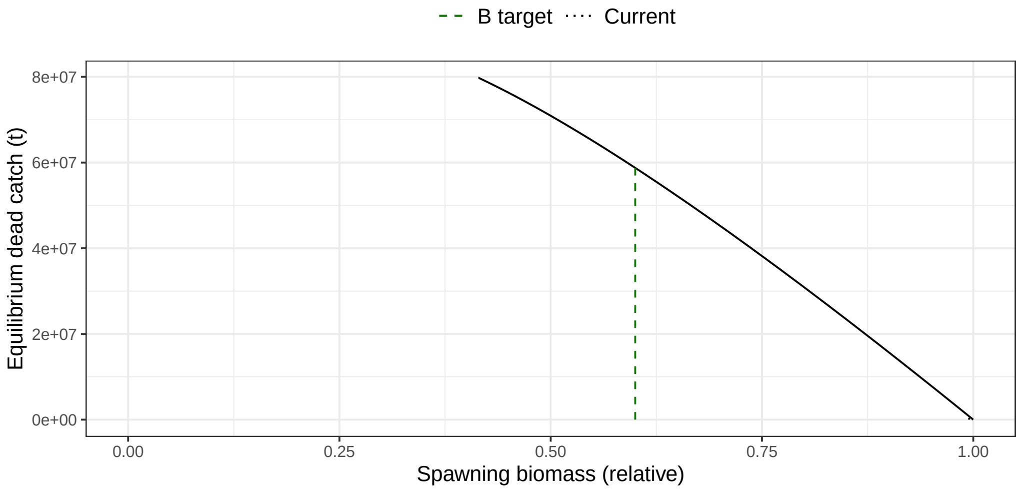

Figure D.13: Scenario 8: equilibrium harvest curve for black jewfish

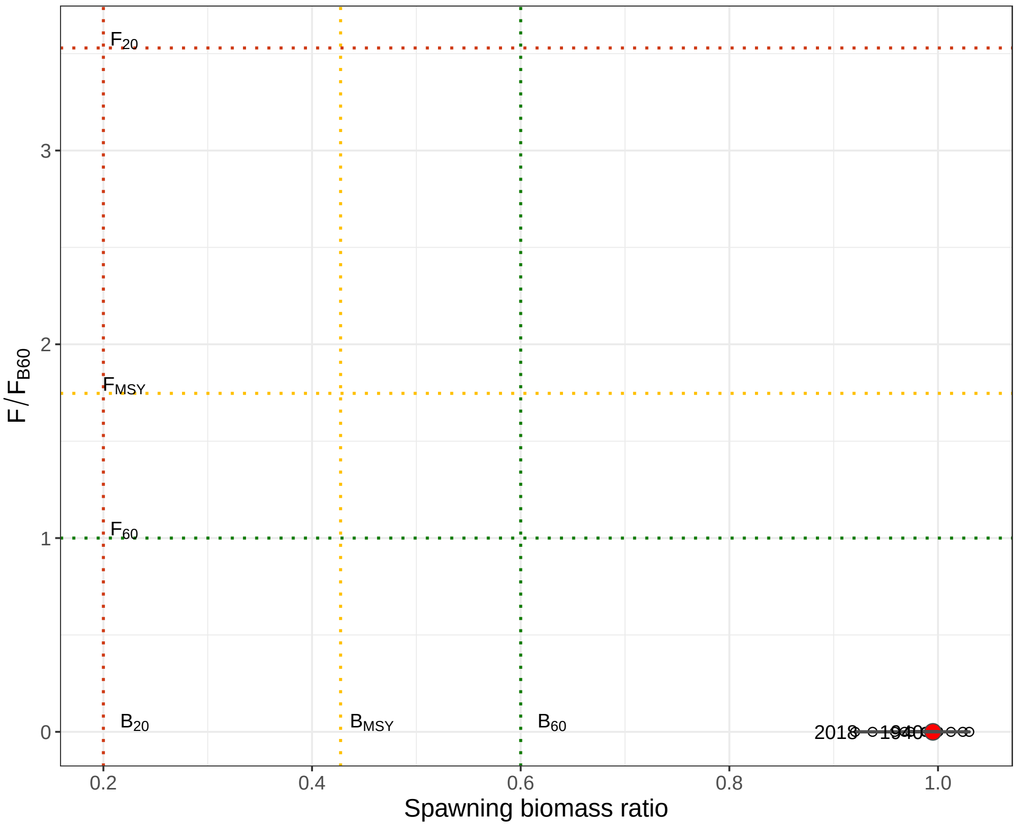

Figure D.14: Scenario 8: phase plot for black jewfish

Appendix E Survey of historical recreational catch

In early 2022 interviews were undertaken with recreational and commercial fishers who had long-term knowledge around black jewfish fisheries in their local area.

Black jewfish survey questions:

- What is the regional area you have primarily fished for black jewfish?
- When fishing for black jewfish have you done as a commercial fisher, recreational fisher or both?
- Approximately what year did you first start fishing for black jewfish?
- When did you first start targeting black jewfish?
- What year do you first recall recreational fishers starting to catch black jewfish?
- What year do you first recall recreational fishers starting to target black jewfish?
- From your understanding, how would you categorise the difference in recreational fishing effort for black jewfish from in the year XXXX (based on answer from start fishing date), in comparison to effort in recent years (last 5 years and in the absence of recent management changes)? Options are: much lower, lower, the same, higher, much higher.
- What year or period was recreational catch for black jewfish the highest.

Eight long-term fishers were interviews each of which had local knowledge to either the Whitsundays/Repulse Bay, Mackay/Sarina, Stanage Bay or Yeppoon areas. Key outcomes consistent across all surveyed participants were as follows:

- The commencement of targeted fishing for black jewfish by recreational fishers occurred in the 1970s for all regions.
- There has been a shift in the recreational fishery from a “food fish” to a “sports fish” or secondary target when targeting other species.
- Peak recreational catch levels were presumed to occur in the 1990s or early 2000s.
- Recreational effort levels in the 1970s were considered to be similar or slightly above current catch levels due to the recent shift in behaviour away from catching black jewfish for food, exclusion from historical areas due to GBRMPA re-zoning and acknowledging increases in the number of recreational fishers through time.