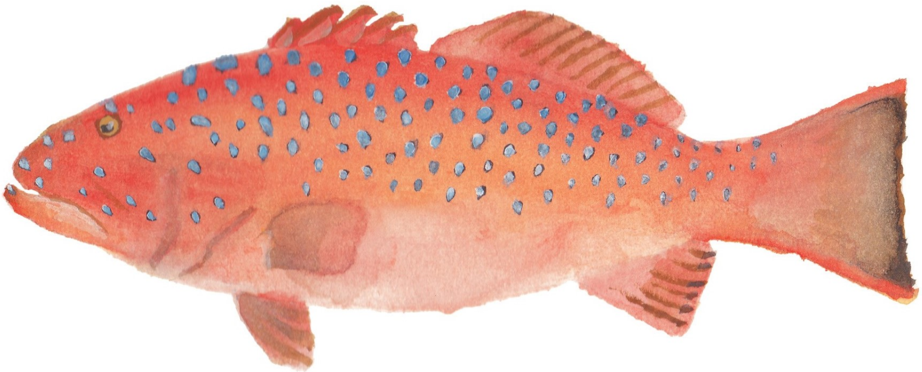

Stock assessment of Queensland east coast common coral trout (*Plectropomus leopardus*), Australia, with data to December 2021

March 2022

Queensland
Government

This publication has been compiled by A.R. Fox, A.B. Campbell and J.D. Zieth of Fisheries Queensland, Department of Agriculture and Fisheries.

Image on cover page painted by Alise Fox and reproduced with permission.

Enquiries and feedback regarding this document can be made as follows:

Email:	info@daf.qld.gov.au
Telephone:	13 25 23 (Queensland callers only)
	(07) 3404 6999 (outside Queensland)
	Monday, Tuesday, Wednesday and Friday: 8 am to 5 pm, Thursday: 9 am to 5 pm
Post:	Department of Agriculture and Fisheries GPO Box 46 BRISBANE QLD 4001 AUSTRALIA
Website:	daf.qld.gov.au

Interpreter statement

The Queensland Government is committed to providing accessible services to Queenslanders from all culturally and linguistically diverse backgrounds. If you need an interpreter to help you understand this document, call **13 25 23** or visit **daf.qld.gov.au** and search for ‘interpreter’.

Contents

Summary

This stock assessment indicates that biomass declined between 1953 and 2011 to 46% unfished spawning biomass. The stock level at the beginning of 2022 was estimated to be 60% unfished biomass.

Queensland's common coral trout (*Plectropomus leopardus*), a species of grouper, is a line-caught fish forming a single population (stock) across the Great Barrier Reef. The stock extends north from the Great Barrier Reef into the eastern Torres Strait where it is under Australian jurisdiction. There is evidence to suggest that common coral trout stay on the same individual reefs after settlement as larvae, and their larvae do not travel long distances after spawning, so the Torres Strait component of the harvest is not considered in the assessment. Common coral trout are protogynous hermaphrodites (born female, many later changing sex to male) and aggregate to spawn during spring and summer. They can grow to more than 5 kg and live for more than 18 years.

This assessment builds on previous assessments that estimated the stock was at 60%, 68% and 59% of unfished biomass in 2012, 2019 and 2020 respectively. This stock assessment includes updates to the input data but keeps the methodology in line with the 2020 assessment.

This stock assessment was conducted on calendar years and included input data through to December 2021. All assessment inputs and outputs will be referenced on a calendar year basis.

This assessment used a single-sex, age-structured population model, fit to age and length data, constructed within the Stock Synthesis modelling framework. The model was spatially structured with two subpopulations: a "blue region" subpopulation, associated with reefs in the Great Barrier Reef that remained open to fishing after the introduction of the Representative Areas Program in 2004; and a "green region" subpopulation, associated with reefs that have been closed to fishing since the introduction of the Representative Areas Program.

The model incorporated data spanning the period from 1961 to 2021 including commercial catch (1988–2021), historical commercial catch (1961–1980), recreational catch (1995–2021), age-length monitoring (1995–2009), and underwater visual surveys (2005–2021).

Over the last five years, 2017 to 2021, the Queensland total retained catch averaged 1002 tonnes (t) per year, including 812 t by the commercial sector, 68 t by the charter sector, 111 t by the recreational sector, and 11 t Indigenous (Figure 1). The commercial and charter catches are based in recent years on logbook reporting, whereas recreational and Indigenous catch is estimated from surveys and interpolated between survey years.

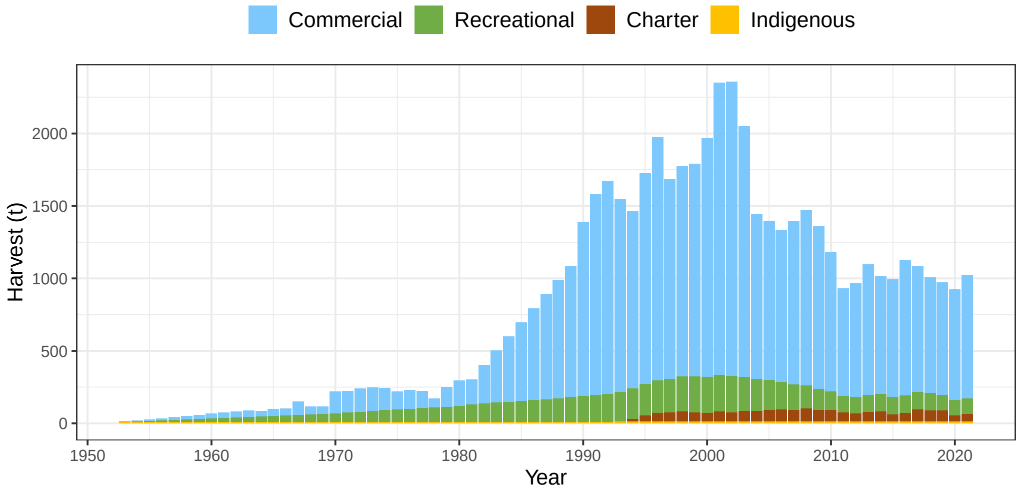

Figure 1: Estimated harvest (retained catch) from commercial recreational, charter and Indigenous sectors between 1953 and 2021

Commercial catch rates were standardised to estimate an index of common coral trout abundance through time (Figure 2). The unit of standardisation was kilograms of coral trout per "operation-day", defined to be a single day of fishing by a primary vessel. Year, month, stratum (grouped Great Barrier Reef bioregions), spatial grid, vessel, number of dories, number of crew and combinations of these were included explanatory terms.

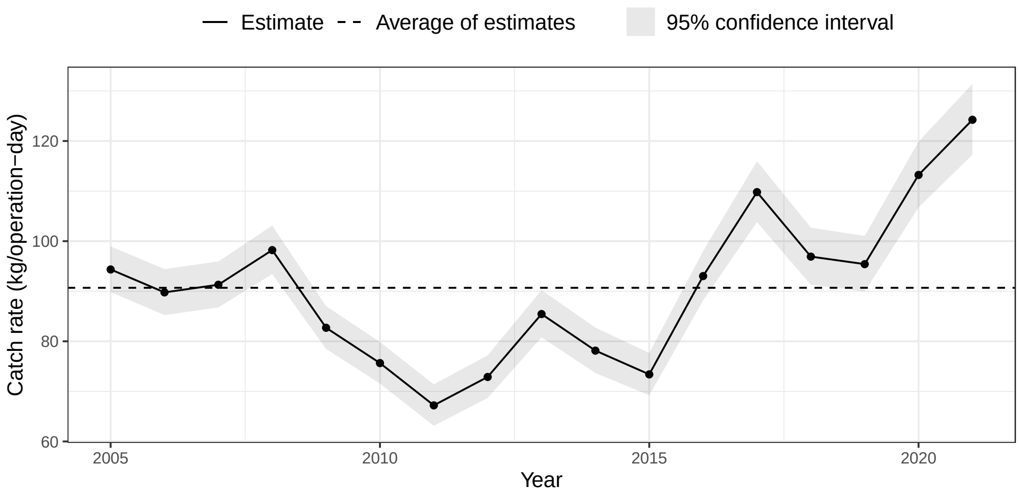

Figure 2: Standardised catch rates for commercial line-caught common coral trout in blue regions (open post-RAP) between the years of 2005 and 2021

Underwater visual survey data were also standardised, to estimate annual indices of common coral trout abundance in the blue region and green region (Figure 3). The unit of standardisation was the number of coral trout observed per underwater transect.

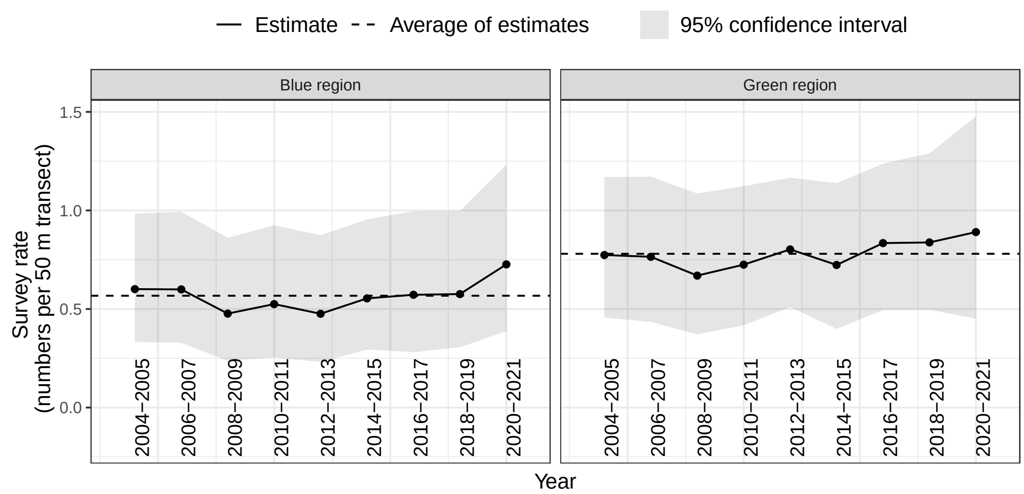

Figure 3: Underwater visual survey standardised index in blue regions (open after the introduction of the Representative Areas Program) and green regions (closed after the introduction of the Representative Areas Program) during two-year periods between 2004 and 2021

Five scenarios were run, covering a range of modelling assumptions. Base case (most plausible) results suggested that biomass declined between 1953 and 2011 to 46% unfished biomass. At the beginning of 2022, the stock level was estimated to be 60% (50–70% range across the 95% confidence interval) of unfished spawning biomass (Figure 4).

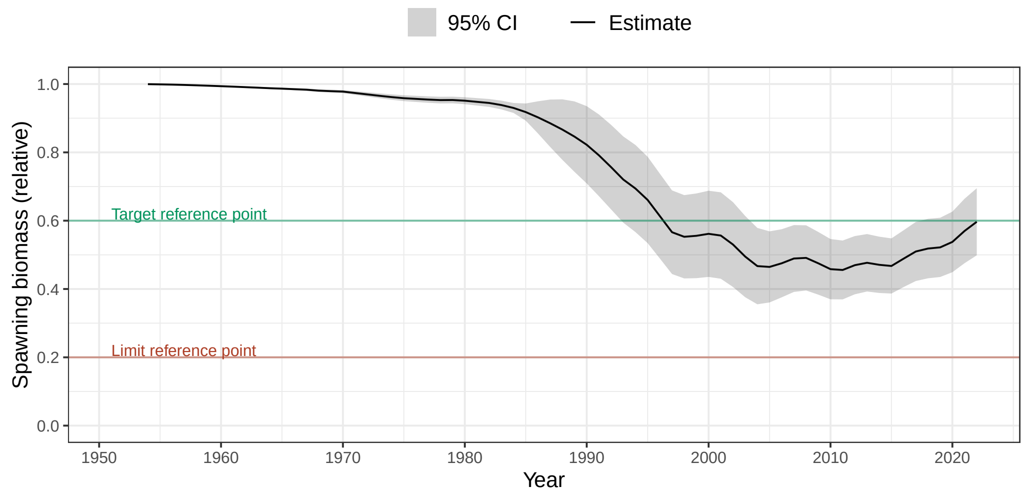

Figure 4: Predicted spawning stock biomass trajectory relative to unfished, from 1953 to 2022

The *Reef Line Harvest Strategy 2020–2025* sets out a fishery objective for all species in the reef line fishery to be maintained at, or returned to, a target spawning biomass level that aims to maximise economic yield (MEY) for the fishery. The assessment recommends a biological catch of 1534 t for 2022, with a retained component of 1199 t (Table 2), to maintain the stock at 60% unfished biomass (proxy for maximum economic yield). This will allow the longer-term biological retained catch target of 1158 t to be reached.

The suggested uncertainty discount factor for this assessment is 0.91.

Table 1: Current and target indicators for Queensland east coast common coral trout

Indicator	Estimate
Biomass$^{\diamond}$ (relative to unfished) at the start of 2022	60% (50% to 70%)
Target biomass (relative to unfished)	60%
Biomass (relative to unfished) at MSY*	32%
MSY*	1946 t
Retained catch component of MSY*	1480 t
Retained catch in 2021	1023 t
Retained catch at 60% biomass target	1158 t
RBC† for 2022 to achieve target	1534 t
Retained component of RBC	1199 t
Time to achieve target	0 years

$^{\diamond}$ Biomass is defined to be spawning stock biomass.
* MSY (maximum sustainable yield) is defined to be the maximum sustainable dead catch—that is, retained catch plus catch that dies following discarding.
† 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.

Acknowledgements

The work was overseen by a project team committee that consisted of the authors and the following scientists and managers: Tony Ham, Carlie Heaven, Ian Jacobson, Joanne Langstreth, Chad Lunow, Tyson Martin, and Anthony Roelofs. The role of the committee was collaborative to share interpretation and decision making on data inputs, assessment methods and results.

The authors would like to thank Philippa Newton and Doug Zahmel for their assistance in answering a number of questions about the commercial harvest data. The authors also thank Tyson Martin and Rachel Janes for provision of and assistance with Queensland recreational harvest data.

Thank you to Dr Mike Emslie of the Australian Institute of Marine Science (AIMS) for providing the underwater visual survey data from the AIMS Long Term Monitoring Program, and for making time to discuss it.

Much of the background information for this assessment came from fisher interviews conducted in 2012, many of which were facilitated by Darren Cameron of the Great Barrier Reef Marine Park Authority. Thank you also to data specialists and cartographers from the Great Barrier Reef Marine Park Authority who provided updated mapping data of the Great Barrier Reef.

Researchers from the Effects of Line Fishing (ELF) Project, represented by Dr Bruce Mapstone and Dr Colin Simpfendorfer, provided length and age-frequency data from structured line surveys. The ELF Project field work ran every year from 1995 to 2005. It was undertaken by CRC Reef with funding from the Australian Government's Fisheries Research and Development Corporation (FRDC, Project No. 97/124).

The authors would also like to acknowledge and thank the many fishers and scientists who contributed to past research on coral trout. They provided valuable information on the history of the fishery, and samples and measurements of fish as part of studies conducted by the Queensland Government, James Cook University, the University of Queensland and the Australian Government—through the Fisheries Research and Development Corporation (FRDC).

We acknowledge Alise Fox for giving permission to reproduce her artwork on the cover page of this report.

Finally, we would like to thank Eddie Jebreen, in addition to members of the committee, for reviewing and providing comments on the draft report. The assessment was supported by the Queensland Department of Agriculture and Fisheries.

Glossary

AIMS	Australian Institute of Marine Science
biomass	spawning stock biomass
blue fishery	associated with the total fishing activity (across all fishing sectors) that has occurred in the blue region
blue region	associated with reefs in the Great Barrier Reef Marine Park that remained open to fishing after the introduction of the Representative Areas Program in 2004, and all areas on the Queensland east coast outside the GBRMP
blue survey	associated with underwater visual surveys that have occurred in the blue region
CI	confidence interval
CRC Reef	Cooperative Research Centre for the Great Barrier Reef World Heritage Area
DAF	Department of Agriculture and Fisheries
dead catch	retained catch ('harvest') plus catch that dies following discarding
ELF	Effects of Line Fishing
fishing year	for common coral trout, 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 a unique curve that characterises the likelihood that fish of various sizes (or ages) will be caught by the fishing gear, or observed by the survey
FRDC	Fisheries Research and Development Corporation
GBR	Great Barrier Reef
GBRMP	Great Barrier Reef Marine Park
green region	associated with reefs that were closed to fishing at the introduction of the Representative Areas Program
green fishery	associated with the total fishing activity (across all fishing sectors) that has occurred in the green region
green survey	associated with underwater visual surveys that have occurred in the green region
harvest	see 'retained catch'
ITQ	individual transferable quota
LMM	linear mixed model
LTMP	Long Term Monitoring Program
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
operation-day	a single day of fishing by a primary vessel, with year, month, stratum, number of dories and number of crew and combinations of these as explanatory terms
overfishing limit	the retained catch that would result from fishing the population in its current state at the fishing pressure consistent with equilibrium 60% biomass
retained catch	component of the catch that is kept by fishers, also referred to as 'harvest' and 'landed catch'
RAP	Representative Areas Program
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.
RFish	recreational fishing surveys conducted by Fisheries Queensland
RLF	Reef Line Fishery
SFS	Sustainable Fisheries Strategy
SRFS	Statewide Recreational Fishing Survey
SS	Stock Synthesis
SST	sea surface temperature
TACC	total allowable commercial catch
UVS	underwater visual surveys conducted by the Australian Institute of Marine Science

1 Introduction

Coral trout forms a species complex and is part of the family Epinephelidae. The complex is found throughout Australia and is comprised of common coral trout (*Plectropomus leopardus*), barcheek coral trout (*P. maculatus*), bluespotted coral trout (*P. laevis*), passionfruit coral trout (*P. areolatus*), highfin coral trout (*P. oligocanthus*), yellow-edge coronation trout (*Variola louti*) and white-edge coronation trout (*V. albimarginata*).

Common coral trout is the primary target species of the commercial Reef Line Fishery (RLF) on Queensland's east coast. It is a species that is important to Indigenous fishing communities and is also a popular species targeted by recreational line fishers able to travel offshore throughout the Great Barrier Reef (GBR). As common coral trout is the primary target species by all fishing sectors it is the focus of this assessment.

Research suggests that common coral trout forms one stock on the Queensland east coast, including the Torres Strait region (van Herweden et al. 2006; van Herweden et al. 2009). van Herweden et al. (2009) sampled common coral trout from the Torres Strait and the Capricorn-Bunker region and found that there was no significant difference in genetics between the two samples. There is evidence to suggest that common coral trout stay on the same individual reefs after settlement as larvae, and furthermore that their larvae do not travel long distances (generally less than tens of kilometres) after spawning (Bergenius et al. 2005; Bergenius et al. 2006; Harrison et al. 2012).

Coral trout are also protogynous hermaphrodites, beginning life as a female, with many later changing sex to male (Ferreira et al. 1995). They spawn in spring and summer months around the new moon (Samoilys 1997).

There are various environmental factors that are thought to influence coral trout or the coral trout fishery, including cyclones, coral bleaching, crown-of-thorns starfish and sea surface temperature. Since 2014, there have been two mass coral bleaching events, one tropical cyclone that severely impacted the GBR, and two crown-of-thorns outbreaks on the GBR (Australian Institute of Marine Science 2021). These have reduced coral cover, which in turn reduces habitat and prey availability for coral trout (Pratchett et al. 2010; Rogers et al. 2017). Bleaching events can also influence coral trout growth rates and spawning output (Hughes 2010; Pratchett et al. 2014). These factors are expanded upon in Section 4.

The RLF is a line-only fishery, except for a small amount of recreational spear fishing. The fishery targets mainly common coral trout for export live to Asia (Thébaud et al. 2014). Secondary target species include other coral trout species (see above), redthroat emperor (*Lethrinus miniatus*), and a large number of reef fish species grouped together into an "Other Species" category for the purposes of management of the commercial fishery. Daily catches are recorded by commercial fishers in logbooks. Prior to September 2021, no distinction was made between coral trout species in logbook records. According to the logbooks, over 2000 tonnes of coral trout were landed annually by all sectors combined in the early 2000s, before individual transferable quotas (ITQs) were introduced in 2004. Since this time, the estimated total harvest has reduced to around 1000 tonnes annually.

There have been various management changes that have influenced the coral trout fishery (Table 1.1; more detail in Leigh et al. (2014)). The most significant of these changes was in 1988 with the introduction of the compulsory logbook system, and in 2004 with a substantial rezoning of the Great Barrier Reef Marine Park.

Table 1.1: History of coral trout management in Queensland

Year	Management change
1950	Commercial coral trout fishery begins
1976	*Fisheries Act 1976* implemented a minimum legal size (MLS) of 35 cm for 'coral trout' (nominally *Plectropomus maculatus*)
1983	Replenishment closures of two Capricorn-Bunker reefs: North Reef and Boult Reef
1986	North Reef and Boult Reef reopen
1988	Commercial logbooks implemented
1990	Recreational fishers are prohibited from selling their catch
1992	Replenishment closure of Bramble Reef near Townsville
1993	*Fishing Industry Organisation and Marketing Amendment Regulation* implemented a MLS of 38 cm and a recreational bag limit of 10 for coral trout (all *Plectropomus* species)
1995	Bramble Reef reopens
1997	Investment warning is issued.
2003	12 Sep: *Fisheries (Coral Reef Fin Fish) Management Plan 2003* revised the recreational bag limit to seven coral trout (all *Plectropomus* species) and 20 reef fish.
2004	1 July: Representative Areas Program (RAP) and comprehensive rezoning of the whole GBR; the proportion of GBR closed to fishing increases from about 5% to 33%.
2004	1 July: *Fisheries (Coral Reef Fin Fish) Management Plan 2003* introduced a Total Allowable Commercial Catch (TACC) of 1350 t and Individual Transferable Quotas (ITQs).
2004	9 Oct: First nine-day coral trout spawning closure begins under the *Fisheries (Coral Reef Fin Fish) Management Plan 2003*, which implements fishery closures around the new moon in October, November and December each year 2004–2008.
2005	TACC reduced to 1288 t by buy-outs under the RAP.
2009	Spawning closures reduced to five-day closures in October and November only.
2021	Changes to logbook reporting; specific coral trout species are recorded.

This is the fourth stock assessment of common coral trout and builds on information published by Leigh et al. (2014), Campbell et al. (2019) and Campbell et al. (2020).

The previous stock assessment was based on the calendar year and included data up to the end of December 2019 (Campbell et al. 2020). The assessment suggested that in the 2020 calendar year biomass was at 59% of its unfished state. The base case model for this assessment was almost identical to the peer-reviewed model published in Campbell et al. (2020), except for the following changes:

- All fish lengths (and subsequent relationships) were converted to fork length instead of total length.
- The Stock Synthesis software was updated to the latest version.
- Data sets used to produce model inputs were updated to end in December 2021.

The assessment used data through to the end of calendar year 2021 and makes a recommendation for total common coral trout harvest in calendar year 2022 to support the harvest strategy (Queensland Department of Agriculture and Fisheries 2020).

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 annual harvests. The assessment period began in 1953 up until and including 2021 based on available information.

Table 2.1: Data used in the Queensland east coast common coral trout stock assessment

Type	Calendar year	Source
Commercial harvest	1989–2021	Logbook and quota data collected by Fisheries Queensland
	1963–1980	Queensland Fish Board data (Halliday et al. 2007)
Recreational harvest	2002, 2005	Recreational fishing surveys (RFish) conducted by Fisheries Queensland (Higgs et al. 2007; McInnes 2008)
	2000, 2011, 2014, 2019	Statewide Recreational Fishing Survey (SRFS) 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)
	1958–1996	Australian historical population statistics (for the state of Queensland), conducted by the Australian Bureau of Statistics, providing a proxy for fishing effort (ABS 2014)
Charter harvest	1989–2021	Logbook data collected by Fisheries Queensland
Indigenous harvest	2000	Indigenous fishing survey conducted 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 monitoring (sex, age, length and weight from the recreational and commercial line fishery) undertaken by Fisheries Queensland (only used in Scenario 2) (Fisheries Queensland 2012b)
	2017–2021	Boat ramp survey data collected by Fisheries Queensland
	1995–2009	Biological monitoring (line surveys) undertaken by the ELF project and Fisheries Queensland (Mapstone et al. 2004; Fisheries Queensland 2012a)
Underwater visual survey	2004–2017	Underwater visual survey data collected by Australian Institute of Marine Science (Australian Institute of Marine Science 2018; Emslie et al. 2018)
Observer	2011	Observer program data collected by Fisheries Queensland

2.1.1 Regions

The data have been grouped into "regions" for analysis. These regions are based on the GBRMP Representative Areas Program (RAP) zoning introduced in July 2004. For analysis, the "green region" is defined to be the area that was closed to fishing on 1 July 2004 (Figure 2.1). The "blue region" refers to all other areas on the Queensland east coast. Although the GBRMP blue and green *zones* change through time, the *regions* as defined in this stock assessment are fixed: they apply from the beginning of the assessment in 1953 through to the last assessed year in 2021, and through the projection period.

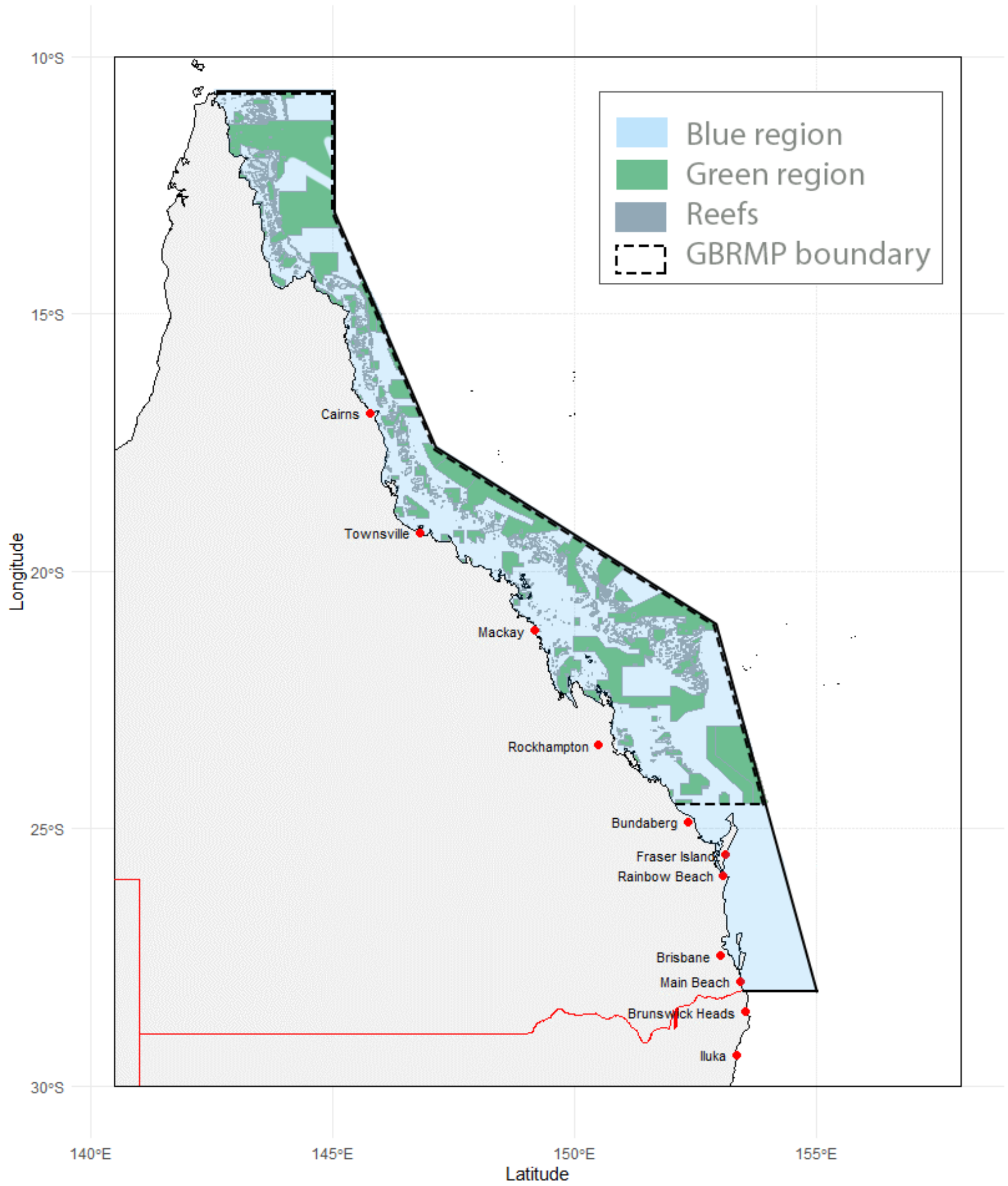

Figure 2.1: Blue and green regions within the Great Barrier Reef Marine Park used to summarise model inputs

2.1.2 Commercial

Commercial harvests of coral trout were recorded in the Queensland logbook system. The logbook system consists of daily harvests (landed weight in kilograms) of all fish species from each individual fishing operator (license) since 1988. Harvests have rarely been recorded to the species level, so only totals for the coral trout species group are used from this source. In September 2021, the format of the logbooks changed to encourage species-level reporting. In addition to landed weight, logbooks also record the location of greatest catch (30 minute or 6 minute grid identifier), the number of boats (dories) that were fishing, and the number of crew.

Since financial year 2004–05, commercial harvest for coral trout have also been available from the quota reporting system where fishers are required to report exact weights, rather than estimated weights (as reported in logbooks).

2.1.3 Recreational

All recreational surveys provided estimates of the number of fish harvested and discarded per trip, and combined this with demographic information to estimate annual totals for each species (or species group) at state and regional scales. See the references listed in Table 2.1 for more detail. For coral trout, identification was to the species group level, individual species information was not available.

Surveys conducted in 2000, 2011, 2014 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).

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 harvest and discard for Indigenous communities followed similar procedures (Henry et al. 2003).

2.1.5 Charter

Charter sector harvest data have been available from the Queensland charter logbook system since 1992. This provided charter daily harvest (landed weight in kilograms) for the coral trout species group.

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 coral trout harvest by weight for 37 districts across Queensland from 1963 to 1981.

2.1.7 Age and length compositions

The Effects of Line Fishing (ELF) project was a major research project run by CRC Reef and partly funded by the FRDC. The ELF Project ran from 1995 to 2005 and sampled 24 reefs in the GBR (four clusters each of six reefs) each year. Line fishing catch surveys were conducted in spring of each year to coincide with the spawning period. These line surveys were done via the charter of an active commercial fishing operation targeting live fish with master fisherman and four dory-fishermen, accompanied for the surveys by four research staff. Fishing gear was standardised among fishers and over time to be comparable with standard contemporary gear used in the commercial Reef Line Fishery on the GBR. In addition to age and length data, where possible, the sex of each fish and its weight were also recorded. For more details see Mapstone et al. (2004).

Following on from this program, Fisheries Queensland continued to collect age and length-composition data at thirteen reefs according to a similar protocol from 2005 through 2009 (Fisheries Queensland 2012a). Fisheries Queensland started a fishery dependent sampling program in 2019, sampling from anywhere in the GBRMP from the Swain Reefs to Cape York. Data from this program (2019–2021) were incorporated into Scenario 2.

2.1.8 Underwater visual survey

Reef fish communities on 46 reefs were mostly surveyed annually by the Australian Institute of Marine Science (AIMS) from 1994 until 2005. Since then reefs were surveyed as part of their Long Term Monitoring Program (LTMP) in alternating years, within six sectors of the Great Barrier Reef (Cooktown/Lizard Island, Cairns, Townsville, Whitsunday, Swain and Capricorn-Bunker sectors). In each of these sectors, with the exception of the Swain and Capricorn-Bunker sectors, three shelf positions—inner, mid and outer—were identified for sampling (shelf position is determined by the position of the reef relative to the coast and continental slope, with inner shelf reefs closest to the coast).

Since 2006, surveys on 46 different reefs and ten of the initial reefs were conducted in alternate years to LTMP surveys as part of the Representative Areas Program (RAP) to assess the effectiveness of the rezoning of the GBRMP in 2004. RAP surveys were conducted in five offshore latitudinal sectors (reefs $>$ 30 km from the coast in the Cairns, Townsville, Pompey, Swain and Capricorn-Bunker sectors) of the GBRMP. This program surveyed No-Take Marine Reserve reefs ("Green Zones") that are paired with similar reefs open to fishing.

In both LTMP and RAP surveys, three sites were surveyed on each reef, each containing five transects lying approximately parallel to the reef crest. Transects were set along the middle of the reef slope, usually at depths between 6 and 9 metres. Counts of large mobile demersal species from a nine families were conducted on 50 metre by 5 metre transects. Estimates of the length of each fish were made to 1 cm, 2 cm or 5 cm bins. For more details of the sampling protocol see Emslie et al. (2018).

Each record provided for this stock assessment corresponded to a fish observation and identified the sector, the reef, the shelf position, the site, the transect number, the sample date and the estimated length of the fish (cm).

2.1.9 Observer

In 2011, limited data were collected by Fisheries Queensland on common coral trout discards for commercial fishers. This was used as a proxy for commercial discard proportion and commercial common coral trout fraction of harvest (species composition).

2.1.10 Boat ramp survey

Recreational data were collected by Fisheries Queensland from 2015 to 2021 in 18 different regions, extending along the entire Queensland coast. Staff trained in the survey protocol, and 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). This was used to infer species composition and discard rates of recreationally caught common coral trout.

2.2 Harvest estimates

Commercial, charter, recreational and Indigenous harvest data were analysed to reconstruct the history of harvest from 1953 until the end of 2021 (Figure 2.2). Prior to 1953 common coral trout harvest is presumed to be negligible. This section describes how this data were combined to create the history of common coral trout harvest in the blue and green regions (Figure 2.1). Unless stated otherwise, all harvest is retained (landed), coral trout species group (rather than common coral trout), and whole of the Queensland east coast.

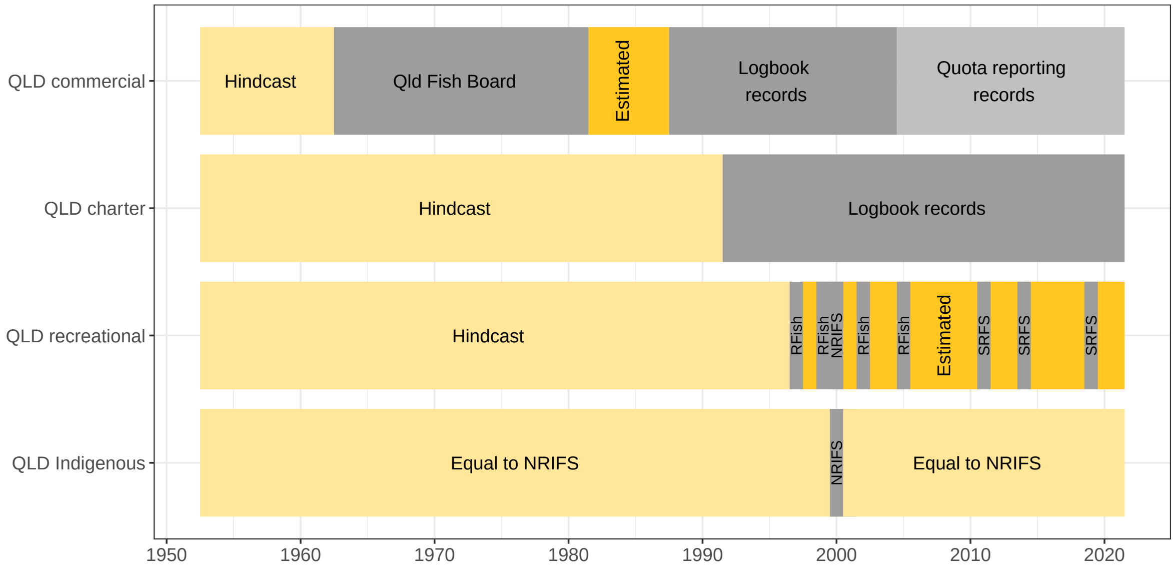

Figure 2.2: Overview of the methods used to reconstruct the history of common coral trout harvest

Commercial sector harvest:

- was assumed zero in 1953, and increased linearly to the value from the Queensland Fish Board in 1963.
- equalled Queensland Fish Board records from 1963 through 1981.
- increased linearly from the last recorded Queensland Fish Board value in 1981 through to the first recorded Queensland logbook value in 1988.
- equalled logbook values from 1988 through the 2004 calendar year.
- equalled quota reporting values from 2005 through 2021 calendar years.
- estimates for all years were multiplied by 0.98, the assumed fraction of the catch that was common coral trout (estimated from Observer program data).

Charter sector harvest:

- estimates equalled Queensland charter logbook values from first records in 1992 through 2021.
- estimates for all years were multiplied by 0.98, the assumed fraction of the catch that was common coral trout (estimated from Observer program data).

Recreational harvest:

- was assumed zero in 1953 and increased proportionally to Queensland population growth, through to reach a rescaled RFish estimate in 1997. 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, including the 1997 value which anchored the series that started from zero in 1953.
- estimates for 1999, 2002, and 2005 were set to equal the values from the rescaled RFish estimates.
- estimates for 2000, 2011, 2014 and 2019 were set to equal the values reported in the NRIFS (2000) and SRFS (2011, 2014 and 2019) surveys.
- "missing" recreational harvests in 1998, 2001, 2003, 2004, 2006–2010, 2012–2013, 2015–2018 were set to values linearly interpolated between the above estimates.
- estimates for 2019–2021 were set to equal the value reported in the 2019 SRFS survey.
- estimates for all years were converted from numbers to an estimated retained (landed) harvest using the mean common coral trout fish weight from the 2019–2021 Fisheries Queensland sampling program (1.57 kg, aggregate mean weight over all years).
- estimates for all years were multiplied by 0.8, the assumed fraction of the catch that was common coral trout (estimated from Boat Ramp Survey program data (Fisheries Queensland 2017)).

Indigenous harvest:

- equalled the NRIFS estimate from 2000 for all years from 1953 onwards.

These annual estimates of harvest by sector through time were assigned to the blue region (2/3 of the GBRMP area) or the green region (1/3 of the GBRMP area) for further analysis by multiplying the overall total by the proportion of the GBRMP, by area, that is unfishable from 1 July 2004 onwards. Catch of common coral trout outside the GBRMP is presumed to be negligible, and the allocation was not adjusted to account for this.

Post 2004, some fishing has occurred in GBRMP Green Zones, and hence in the green region of our analysis. The extent of this illegal fishing is unknown but is presumed to have decreased over time. To account for this, in 2005, 20% of the blue region harvest was instead assigned to the green region. This proportion was then reduced by 80% every year from 2006 through to 2019 to model an exponentially declining rate of Green Zone fishing.

2.3 Standardised indices of abundance

2.3.1 Commercial catch rates

Queensland logbook data on commercial line catches (kg whole weight) of coral trout per fishing-operation-day were used as an index of legal-sized fish abundance, after removing the effects of a number of factors not related to abundance. The methods below outline the concepts and procedures used to achieve this standardisation. In the following, the term "catch rate" refers to a standardised catch rate unless otherwise specified.

The catch rate model included every daily coral trout harvest by each individual license (each operation by a primary vessel). When multiple locations were recorded for a single operation in a day, only the first location was used and all harvest allocated to this location. Records were restricted to 2005 onwards, so all data analysed were "blue region" and post-RAP (this is discussed further in Section 4). Records were further restricted to come from vessels that fished for at least two years (anytime during 2005–2021), and accounted for at least 0.01% of the total catch over the time series. A fishing operation-day was defined as a day of fishing by a primary vessel where any one of a suite of commonly co-caught species were landed. This meant that it was possible for 0 kg to be a valid catch of coral trout in an operation-day.

Standardised mean catch rates were modelled using the software R (version 4.1.2, R Core Team (2020)). The analyses used a linear mixed model (LMM). The LMM was calculated by the 'glmmTMB' function, in the glmmTMB package (Brooks et al. 2017), in a restricted maximum likelihood setting (REML = TRUE in the glmmTMB function). The prediction of standardised mean catch rates were determined using the 'predict' function within the R *stats* package (version 4.1.2, R Core Team (2020)).

In addition to the spatial grid, the twelve strata from the 2019 assessment (Campbell et al. 2019) were used as a medium-scale spatial structure and catch rate predictions were made at this scale before being aggregated to a final scalar time series for the blue region. This aggregation was weighted according to the quantity of catch in that stratum, so strata with higher catches contributed relatively more to the final series. 95% confidence intervals were calculated for all predictions. These strata are groupings of GBRMP bioregions and are described in more detail in Campbell et al. (2019, Section 2.2.1).

The model used a Gaussian distribution with the response variable, $\sqrt[3]{\text{harvest}}$, being kilograms of coral trout harvest per fishing operation per day, transformed with a cube root. The variables modelled included additive categorical effects of:

- "year" (calendar year),
- "month",
- "stratum", and
- "excessCrew" (the number of crew in excess of the number of dories, coded as 0 (no excess crew), 1 (1 excess crew) or 2 (2 or more excess crew)).

The full catch rate model was:

$$\begin{aligned}\sqrt[3]{\text{harvest}} \sim\ & \text{year} + \text{month} + \text{stratum} + \text{year:month} + \text{year:stratum} + \text{month:stratum} + \text{excessCrew} + \\ & \text{ndoriescuberoot} + \text{random(vessel)} + \text{random(grid)}\end{aligned}$$

where "doriescuberoot", the cube root of the number of dories used, was a continuous variable, and "vessel" and "grid" (30 minute spatial grid) were random effects.

2.3.2 Underwater visual survey

Underwater visual survey data collected by the Australian Institute of Marine Science were standardised to produce an index of abundance in blue regions and in green regions.

Several models were run to determine the best way to aggregate reefs over space and time. The outcome of these analyses were that data would be aggregated into two-year blocks, and that only surveys from 2004–2005 onwards would be included. This was because many reefs were only visited every two years, and the total number of reefs surveyed increased from 2005.

Standardised mean survey rates were modelled using the software R (version 4.1.2, R Core Team (2020)). The analyses used a generalised linear model (GLM). The GLM was calculated by the 'glm' function in base R. The prediction of standardised mean catch rates were determined using the 'predict' function within the R *stats* package (version 4.1.2, R Core Team (2020)).

Individual reefs were used as a fixed spatial structure, and survey rate predictions were made at this scale before being aggregated to two final scalar time series: one for the blue region and one for the green region. This aggregation was weighted according to total numbers of common coral trout observed on that reef, so reefs with higher abundance contributed relatively more to the final series. 95% confidence intervals were calculated for all predictions.

The full survey abundance index model was:

$$N_{ct} \sim -1 + \text{doubleyear:reef} + \text{offset(log(transects))}$$

where the model response variable, N_{ct}, was the number of common coral trout sighted per 50 m transect per reef-site (each reef had three sites at which transects were carried out) during that $doubleyear$ (two-year block). The statistical offset, $transects$, was the number of transects carried out on that reef-site during that double year. A quasi-poisson distribution was used with a log-link.

2.4 Biological relationships

2.4.1 Fork length and total length

In addition to fork length measurements, the ELF program also recorded some total lengths, and these data were used to estimate a fork length to total length relationship which was then applied to all records to obtain total lengths for further analysis.

The estimated relationship, and its inverse, was:

$$TL = (FL - 3.8217)/0.9343,$$
$$FL = 0.9343 \times TL + 3.82117$$

where TL is total length (mm) and FL is fork length (mm).

2.4.2 Fecundity and maturity

Maturity values in the model were age-based, following the data in Leigh et al. (2014):

- 0% mature at age 1,
- 40% at age 2,
- 70% at age 3,
- 95% at age 4,
- 99% at at 5,
- fully mature from age 6.

The fecundity relationship was based on data in Leigh et al. (2014):

$$fec = W^{1.56}$$

where fec is number of eggs and W is weight (kg).

2.4.3 Weight and length

Length and weight data from the Fisheries Queensland biological monitoring program were used to calculate the weight-length relationship:

$$W = 8.6888 \times 10^{-6} \times FL^{3.1479}$$

where W is weight (kg) and FL is fork length (cm).

2.5 Length and age data

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

2.6 Population model

A single-sex population dynamic model was fitted to the data to determine the number of common coral trout in each year and each age group using the software package Stock Synthesis (SS; version SS-V3.30.18.0). A full technical description of SS is given in Methot et al. (2021).

2.6.1 Model assumptions

A variety of assumptions were made when formulating inputs to the SS model for the common coral trout assessment. These included:

- The Queensland east coast stock is reproductively isolated from all other stocks.
- The fishery began from an unfished state in 1953.
- The fraction of fish that are female at birth is 50% and remains so throughout an individual's life.
- Growth occurs according to the von Bertalanffy growth curve.
- The weight and fecundity of common coral trout are parametric functions of their size.
- The proportion of mature fish depends on age and not size.
- The instantaneous natural mortality rate does not depend on age, size or sex.
- The proportions of fish of a given size that are vulnerable to fishing are identical to those proportions during the age and length composition line surveys (ELF and Fisheries Queensland) for all sectors and for all years.
- Fish do not move between the blue region and the green region.
- The number of fish that recruit to each region is a fixed fraction of a Beverton-Holt function of total (whole of stock) spawning biomass.

The assumption that the sex ratio is 50% throughout life is in conflict with known biology, which indicates female to male sex change (protogyny sequential hermaphroditism). This is expanded on in Section 4.1.

2.6.2 Model parameters

A variety of parameters were included in the model, with some of these fixed at specified values and others estimated. Uniform priors were used unless stated otherwise.

The natural logarithm of virgin spawning stock size ($\ln(R_0)$) was estimated within the model.

In the final "base case" model, natural mortality (M) was estimated with log-normal prior to having (natural scale) median value of 0.3 and standard deviation of 0.219. This prior was based on the meta-analytical approach from Hamel (2015) and Then et al. (2015). The prior is defined as a log-normal distribution with median value (corresponding to the mean in log-space) equal to 5.40 divided by maximum age, and a log-scale standard deviation equal to 0.438. The maximum age across all samples is 18 years, giving $5.4/18 = 0.3$, and the recommended sigma was halved to provide a stronger prior. The sensitivity of the model to this parameter was investigated and is presented in Section 3 (Results).

Stock recruitment steepness (h) was fixed at 0.50 as a base case. This value is equal to the fixed value for the base case from Campbell et al. (2019) and to the value estimated by Leigh et al. (2014). This value would be low for North American groupers (see Section 1.7 of Leigh et al. (2014)), but is plausible for the less productive Australian waters and serves a precautionary purpose in this assessment, offsetting the potentially non-precautionary consequences of dome-shaped selectivity (see below).

Parameters of the von Bertalanffy growth curve were estimated within the model, including coefficients of variation for both young and old fish.

The proportion of recruitment going to each region was estimated.

Dome-shaped length-based selectivity parameters were also estimated for the fishery fleets, using a double normal curve (pattern 23 in SS). Parameters p1 through p5 (peak, top, ascending width, descending width and initial selectivity) were all estimated. Parameter p6, final selectivity (selectivity in the last bin) was fixed at 0.1. Separate selectivity curves were estimated for each region (blue fishery fleet and green fishery fleet).

For the survey fleets (blue and green), a spline was used for length-based selectivity, with four parameters (in each region) estimated. These parameters correspond to the selectivity at the 1st, 2nd, 3rd and 4th knots (knots at 17.3951, 36.3434, 42.3821, and 60.3918 cm), in addition to the gradient of the selectivity curve in the first bin. The sensitivity of the model to the assumption that both the fishery and survey fleets had dome-shaped selectivity was investigated, and is presented in Section 3 (Results).

Undersized fish were subject to a fixed discard mortality of 0.25 across all sizes (based on Brown et al. (2008)), and one parameter of a retention curve was estimated for both fishery fleets. This parameter was the inflection point of an asymptotic (logistic) curve.

Recruitment deviations between 1982 and 2021 improved fits to composition data and abundance indices as annual variability in recruitment allowed for changes in the population on shorter time-scales than fishing mortality alone.

2.6.3 Model weightings

A Francis adjustment (Francis 2011) was applied to all the age and length compositions fits, to attempt to achieve a suitable effective sample size (and thus relative weighting).

2.6.4 Sensitivity tests

Several additional model runs were undertaken to determine sensitivity to fixed parameters and model inputs.

Six fleet model: The Fisheries Queensland biological monitoring program (that commenced in 2019) captures data from fish caught by the live and fresh commercial sectors, as well as the recreational sector, whereas the biological data from 1995 to 2009 represented only the live commercial sector. This means that the data sets are not congruent as they represent different selectivity patterns. In order to include these additional data, a scenario was set up with a fleet structure different to the base case model, separating the live commercial sector out from the others. This split generated additional length and age-at-length data sets, and a different catch rate data set (with the fishing sector included as a covariate) to which the model had to fit. The model was configured to allow for different selectivity across these sectors. The results from this scenario are discussed in Section 4.1.1 and shown in Appendix C.1.

Dome-shaped selectivity: Because dome-shaped selectivity can lead the model to infer a large number of unfishable older individuals that are not observed, it was important to explore what the model would infer if it does not have this option, and a non-dome shaped (or "asymptotic") selectivity setup was tested. The dome-shaped selectivity sensitivity test involved switching the spline-based selectivity on the survey fleets over to an asymptotic logistic curve. For the latter, the inflection point of the curve was estimated, as well as the width of the ascending portion of the curve.

Natural mortality: Natural mortality is a key stock assessment parameter and while the base case was able to estimate it with the aid of a strong prior, it was important to test the sensitivity of the outputs to alternative possibilities. The natural mortality sensitivity test involved fixing M at a presumed "worst case" value of 0.2. This value was chosen based on outputs from a range of life-history based proxy methods, including Hoenig (1983) and Jensen (1997), and on estimates from the previous coral trout stock assessments. Results for this scenario are shown in Appendix C.3

Mirrored selectivity: Campbell et al. (2020) recommended selectivity be mirrored between blue and green regions. This recommendation was adopted for the fishery fleets as an additional scenario for this assessment. Results for this scenario are shown in Appendix **??**.

A run of the model with *SS's hermaphroditism option* switched on was also conducted. This did not lead to plausible results. The implications are discussed in Section 4.1.

2.6.5 Harvest control rule

Stock Synthesis's forecast submodel was used to provide forward projections of biomass and future harvest targets, following a 20:60:60 harvest control rule. This rule has a linear ramp in fishing mortality between 20% biomass, where fishing mortality is set at zero, and 60% biomass, where fishing mortality is set at the equilibrium level that achieves 60% biomass ("F_{B60}"). Below 20% biomass fishing mortality remains set at zero, and above 60% biomass fishing mortality remains set at F_{B60} (Figure 2.3).

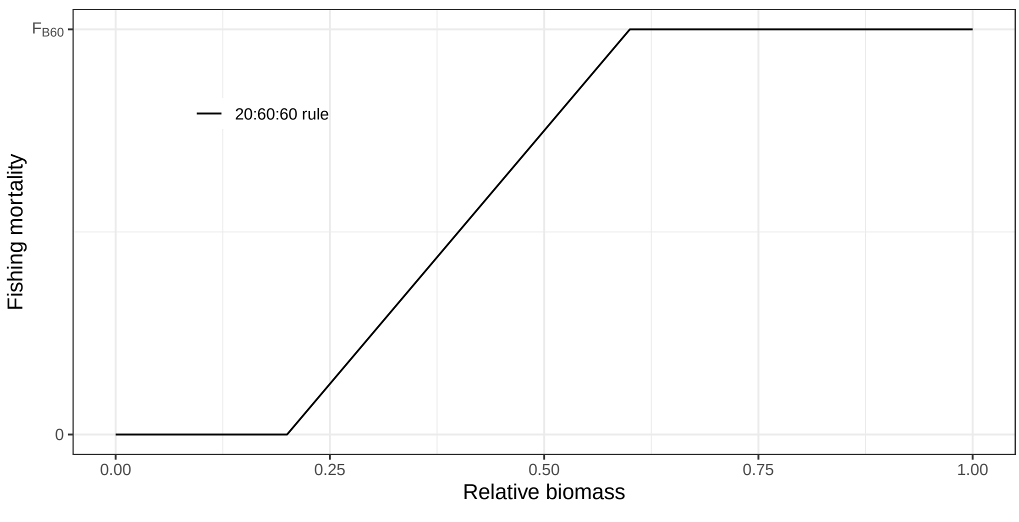

Figure 2.3: The 20:60:60 harvest control rule

3 Results

These model inputs and outputs relate to the ‘base case’ scenario. Results for all other scenarios can be found in Appendix C.

3.1 Model inputs

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

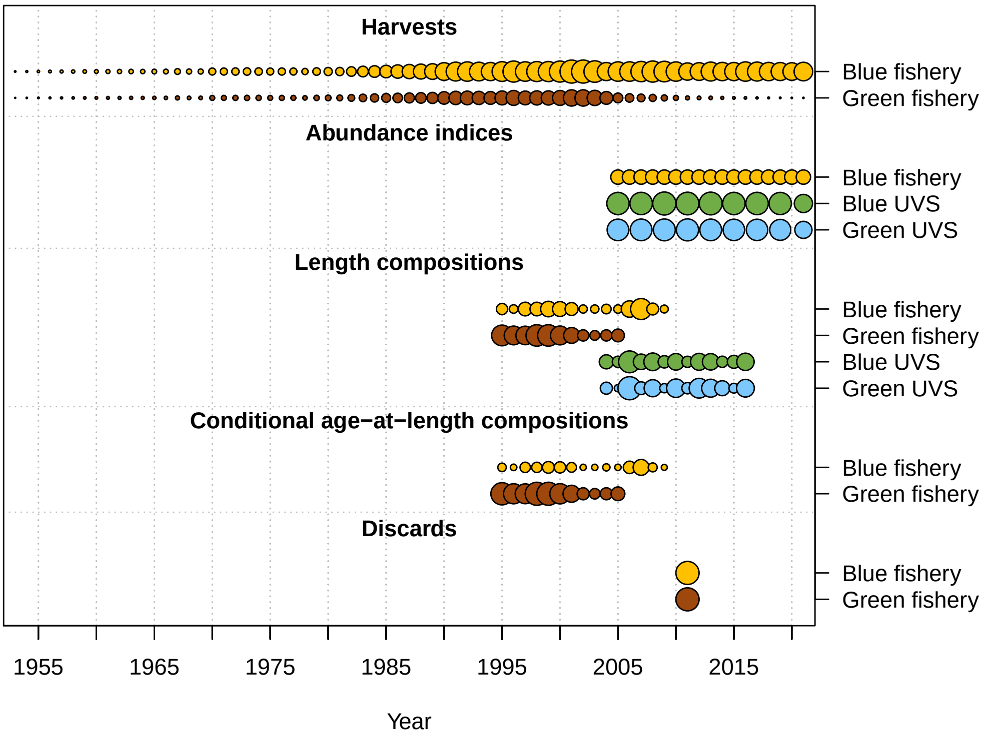

Figure 3.1: Data presence by year for each category of data type and Stock Synthesis fleet

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 four fleets: two fleets for the fishery (all sectors combined) corresponding to the two spatial regions (‘blue fishery’ and ‘green fishery’); and two fleets for the underwater visual survey (‘blue survey’ and ‘green survey’). 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 harvest for harvests; 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 within separate plots should not be compared.

3.1.1 Harvest estimates

Total harvest (landed catch) combined commercial, recreational, charter and Indigenous sectors (Figure 3.2). The majority of the total harvest can be attributed to the commercial sector. Prior to 1980, the total harvest was relatively low. The harvest estimates indicate that over 2000 tonnes of coral trout were landed annually in the early 2000s before individual transferable quotas (ITQs) were introduced in 2004. Since this time, the estimated total harvest has reduced to around 1000 tonnes annually.

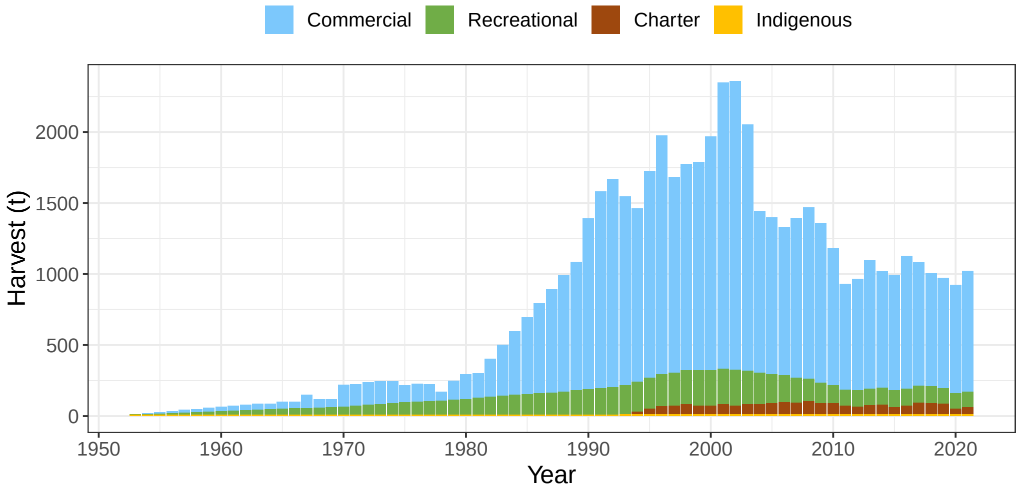

Figure 3.2: Estimated harvest (retained catch) from commercial, recreational, charter and Indigenous sectors between 1953 and 2021 for common coral trout

Harvest was input to the population model by region (Figure 3.3). The rapid decline in fishing in the green region can be seen after the rezoning and implementation of the RAP in 2004.

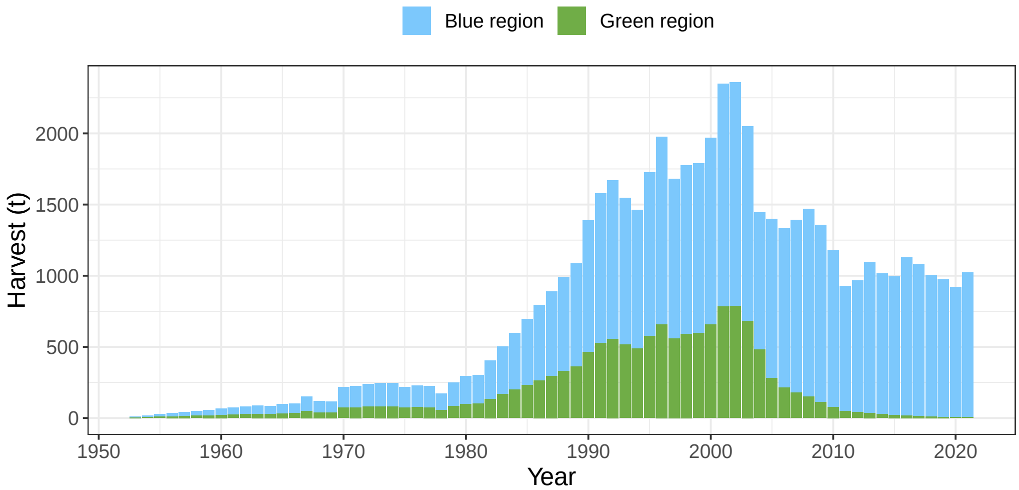

Figure 3.3: Estimated harvest (retained catch) by region between 1953 and 2021

3.1.2 Standardised index of abundance

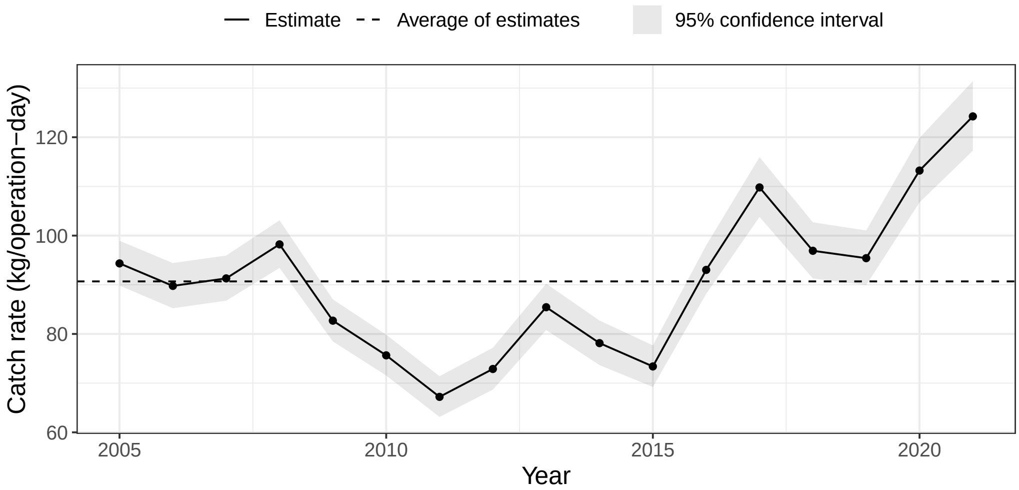

Figure 3.4: Standardised catch rates for commercial line-caught common coral trout in blue regions (open post-RAP) between the years of 2005 and 2021

3.1.3 Standardised underwater visual survey rates

Underwater visual survey rates are markedly higher in the green region than the blue region (Figure 3.5), though for the purposes of population model fitting this is not relevant as abundance indices are rescaled by the estimated catchability. The series are relatively stable, but potentially suggest a similar decline and recovery pattern to the standardised catch rates.

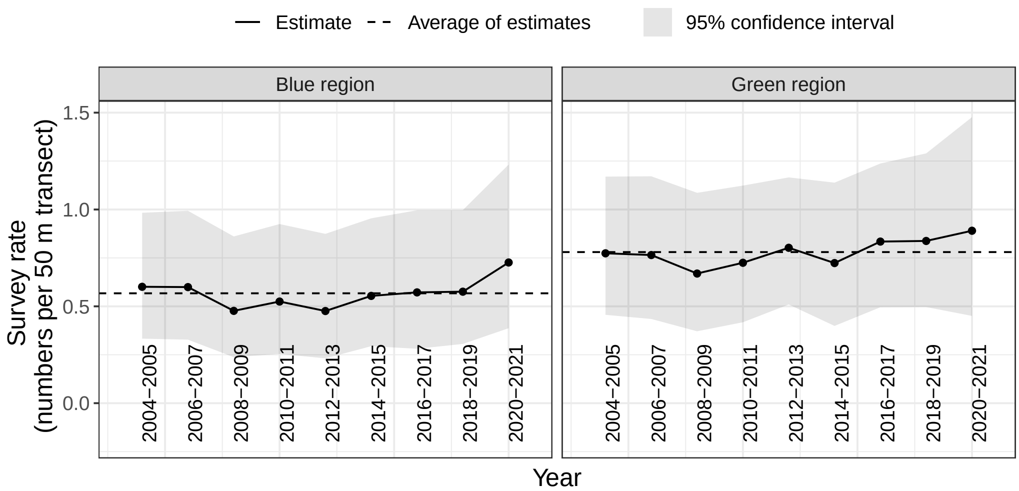

Figure 3.5: Underwater visual survey standardised index in blue regions (open after the introduction of the Representative Areas Program) and green regions (closed after the introduction of the Representative Areas Program) during two-year periods between 2004 and 2021

3.1.4 Age composition

Fishery age-composition data were input to the population model, as part of age-at-length compositions, for the blue region (Figure 3.6) and the green region (Figure 3.7).

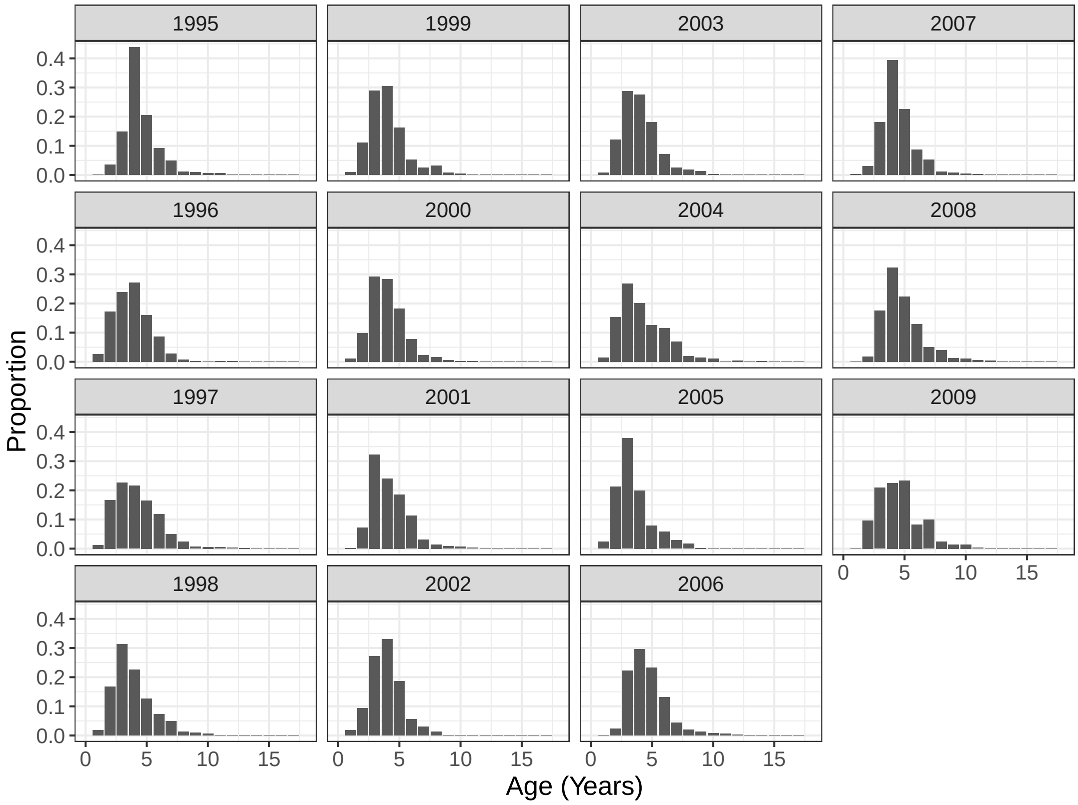

Figure 3.6: Annual age compositions of common coral trout for line-caught fish between 1995 and 2009 in the blue region

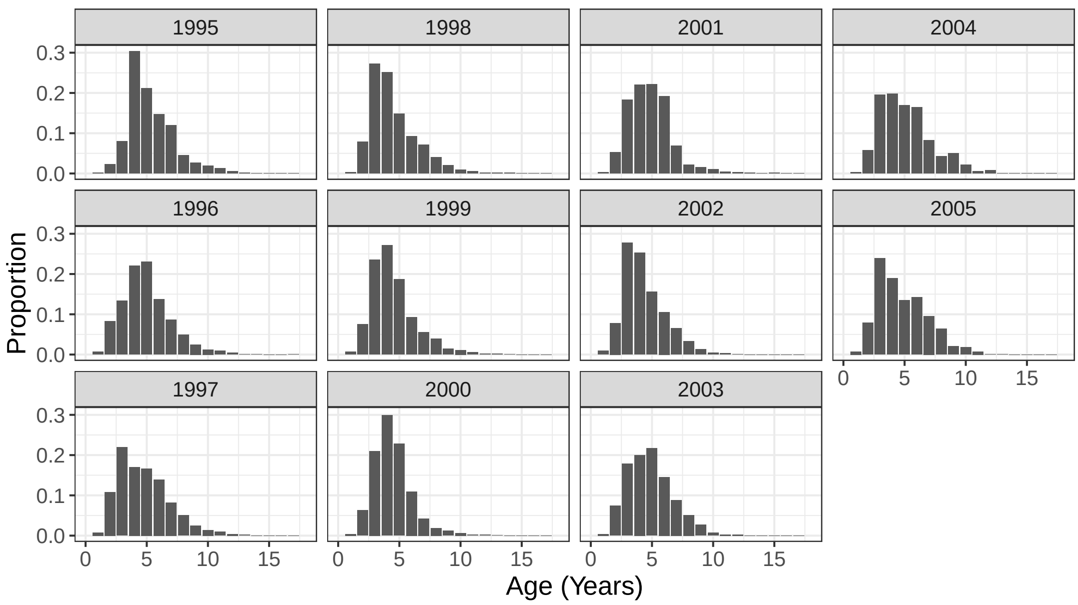

Figure 3.7: Annual age compositions of common coral trout for line-caught fish between 1995 and 2005 in the green region

3.1.5 Length composition

Fishery length compositions were input to the population model for the blue region (Figure 3.8) and the green region (Figure 3.9).

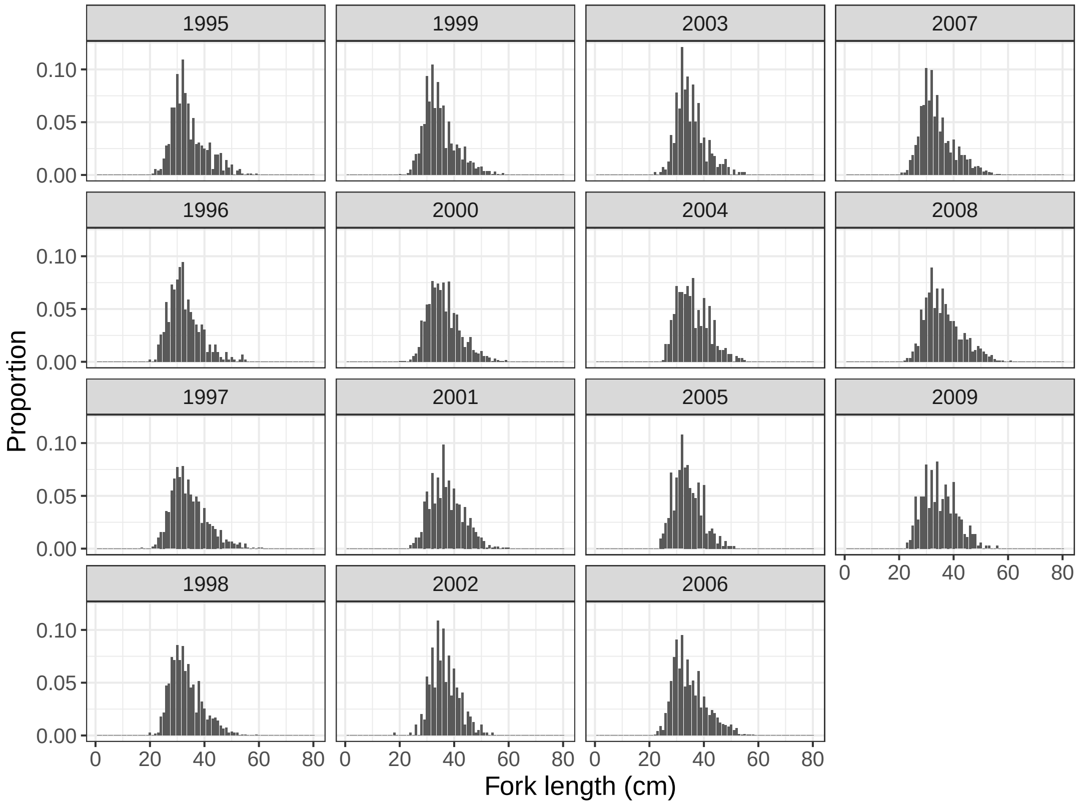

Figure 3.8: Annual length compositions of common coral trout for line-caught fish between 1995 and 2009 in the blue region

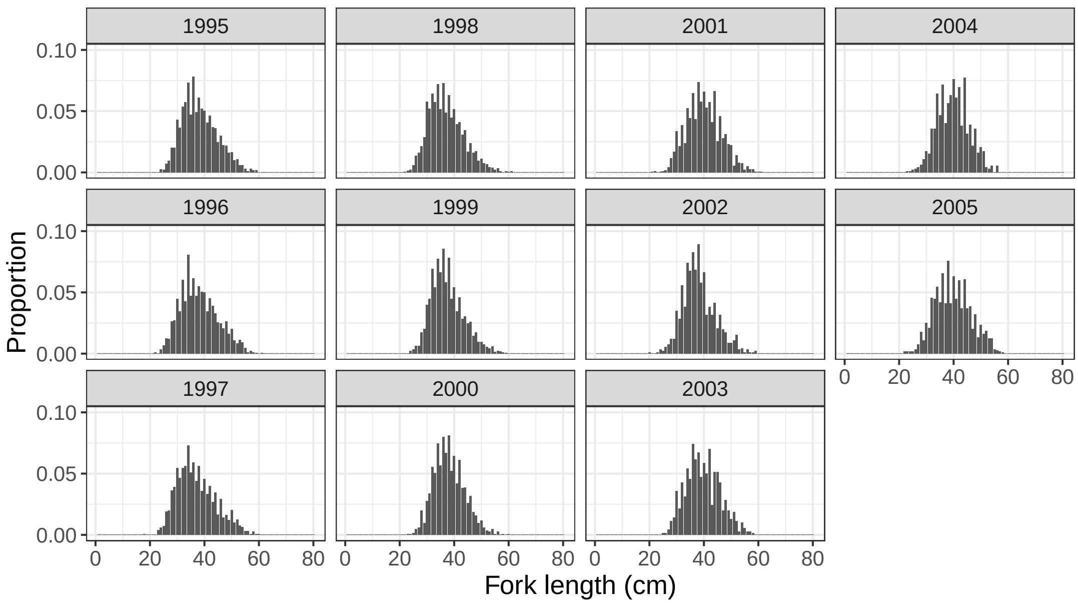

Figure 3.9: Annual length compositions of common coral trout for line-caught fish between 1995 and 2005 in the green region

Survey length compositions were input to the population model for the blue region (Figure 3.10) and the green region (Figure 3.11). Note the smaller sample sizes for these underwater surveys compared to the line-caught data (Table A.1). These sample sizes are input to the model and form a starting point for data set weighting.

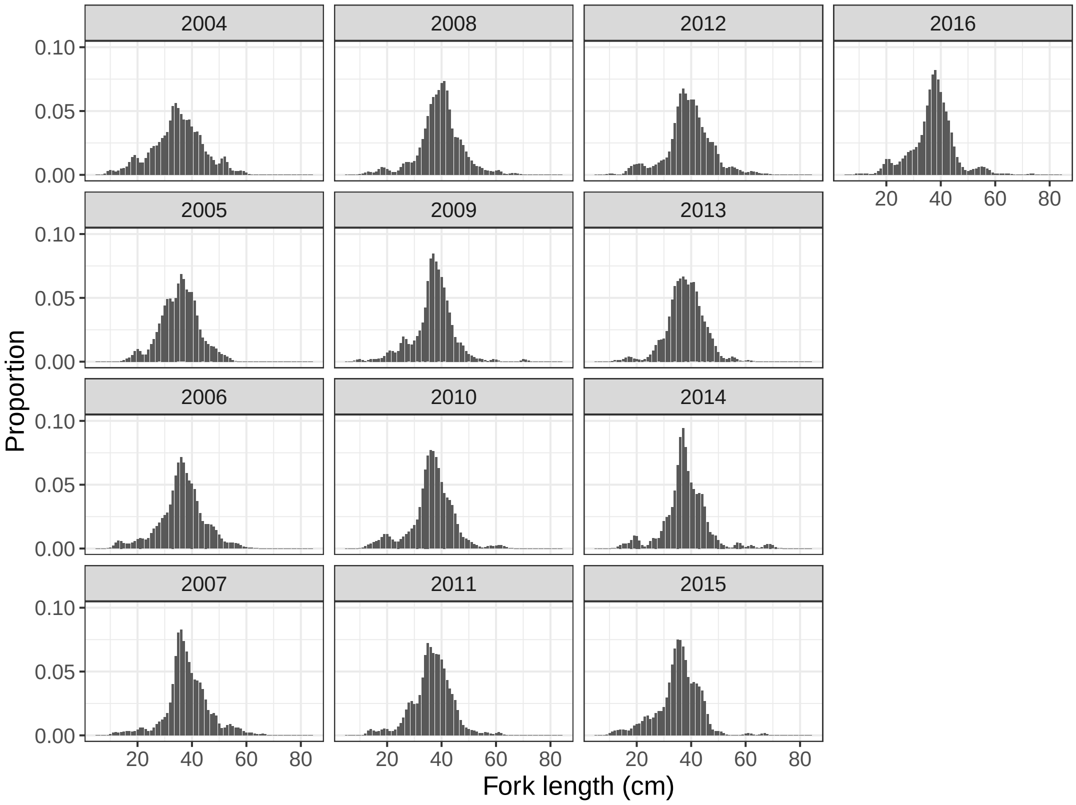

Figure 3.10: Annual length compositions of common coral trout for fish sighted in the underwater visual survey between 2004 and 2016 in the blue region—raw compositions have been smoothed by a kernel with a bandwidth of 1.5

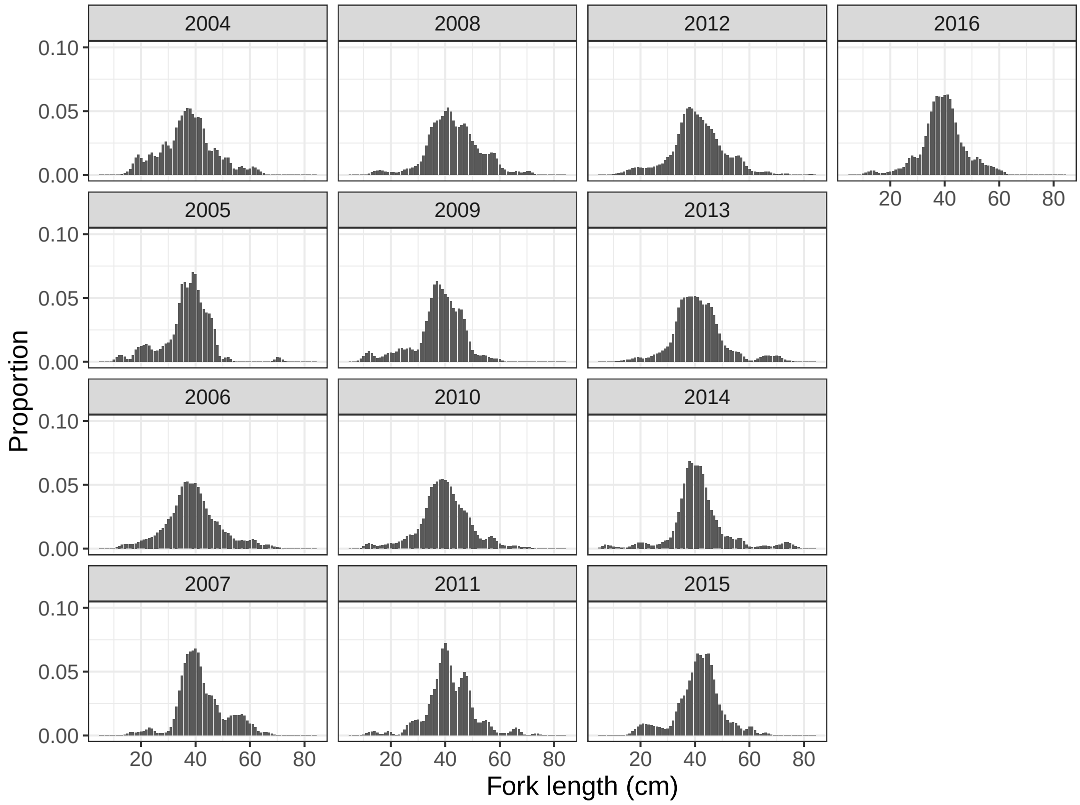

Figure 3.11: Annual length compositions of common coral trout for fish sighted in the underwater visual survey between 2004 and 2016 in the green region—raw compositions have been smoothed by a kernel with a bandwidth of 1.5

3.1.6 Other model inputs

Conditional age-at-length composition data and fixed biological relationships are provided in Appendix A, Sections A.2 and A.3.

3.2 Model outputs

3.2.1 Model parameters

Several parameters were estimated within the base case model (Table 3.1). The full list of estimated parameters for the base case is given in Appendix B.1.

Table 3.1: Summary of parameter estimates from the base population model

Parameter	Estimate	Standard deviation
Natural mortality (per year)	0.4	0.04
Total length at age 1 (cm)	14.17	1.15
Total length at age 18 (cm)	70.3	2.35
von Bertalanffy growth rate (per year)	0.12	0.02
Recruitment going to the green region (logit scale proportion)	-0.04	0.23

3.2.2 Model fits

Model fit diagnostics are detailed in Appendix B.2. Good fits were achieved for all data sets, including abundance indices, conditional age-at-length compositions and length compositions.

3.2.3 Selectivity

The selectivity of common coral trout was estimated within the model (Table B.1, Figure 3.12).

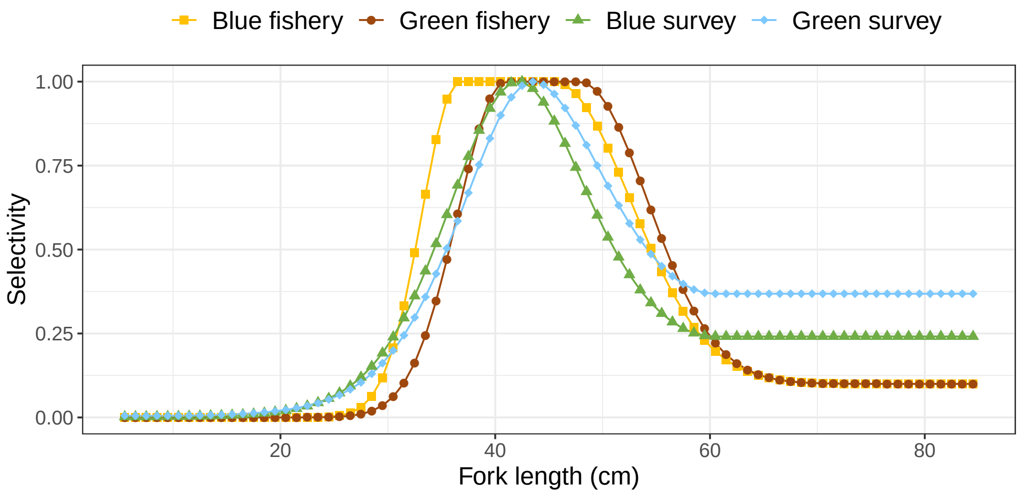

Figure 3.12: Model estimated length-based selectivity by fleet in 2021

3.2.4 Growth curve

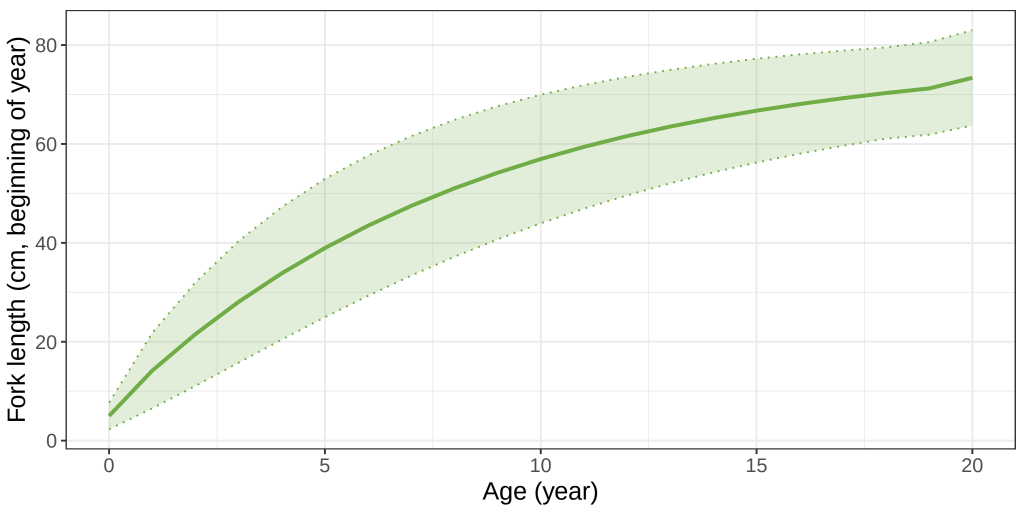

Figure 3.13: Model estimated growth of coral trout (95% confidence intervals)

3.2.5 Biomass

Model results suggested that biomass declined between 1953 and 2011 to 46% unfished biomass. In 2022[1], the stock level was estimated to be 60% unfished total biomass (Figure 3.14).

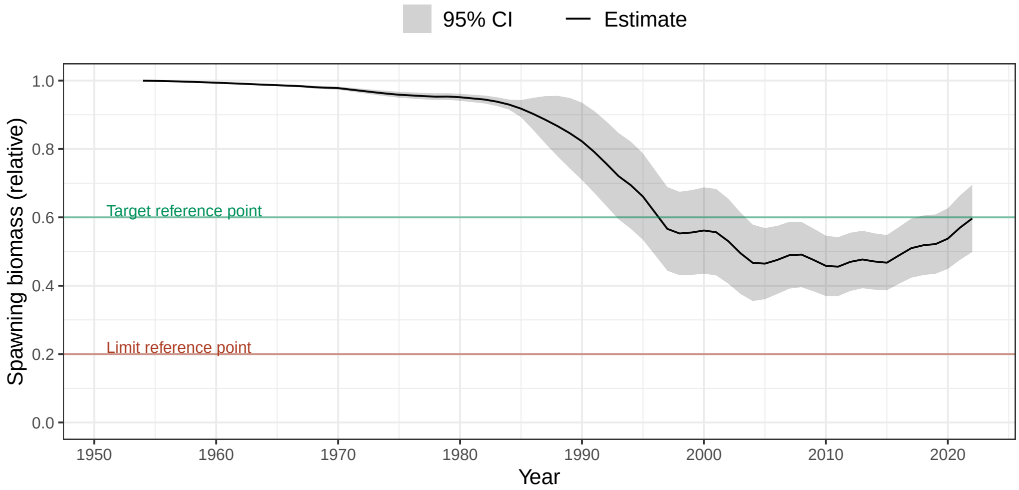

Figure 3.14: Predicted spawning stock biomass trajectory relative to unfished, from 1953 to 2022

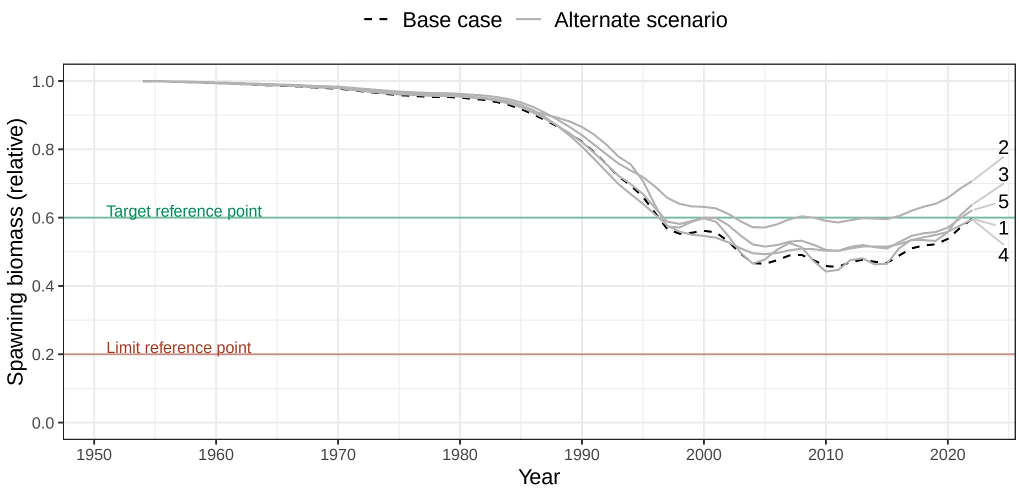

Figure 3.15: Predicted spawning stock biomass trajectory relative to unfished for common coral trout, from 1953 to 2022, for all scenarios (as described in Section 2.6.4)

The relationship between the spawning biomass estimate and fishing mortality are presented in a phase plot (Appendix B.1). The equilibrium harvest informs on the productivity of the stock at different spawning biomass levels (Figure 3.16).

[1] Stock Synthesis reports spawning stock biomass at the beginning of each year, so following this convention the spawning stock biomass estimate is reported for the year after the input data end. In this case, the model inputs end at 2021, so spawning stock biomass for 2022 is reported.

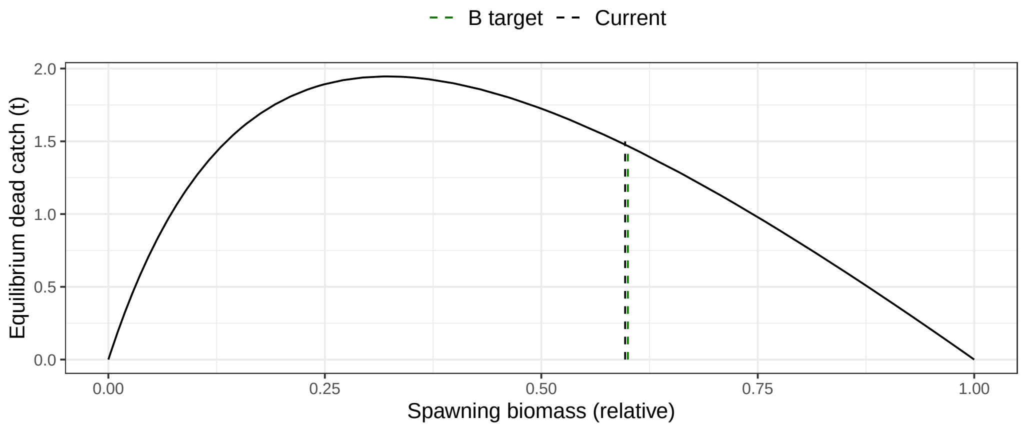

Figure 3.16: Equilibrium dead catch curve for common coral trout

Figure 3.17 shows a comparison of the biomass trajectory from the current assessment to that from the previous assessment (Campbell et al. 2020). In 2020 the Campbell et al. (2020) model was estimating biomass at 59% and the current model estimates the biomass at 54%. The final (2022) biomass estimates for both models were within 1% of each other. The predictions followed similar but offset trajectories between 1997 and 2020. The updated data in the catch reconstruction and standardised catch rates have caused the model to estimate a slightly higher value for natural mortality and a different set of recruitment residuals. This is consistent with a biomass that fluctuates more in response to changing fishing pressure, as can be seen from the lower average value of biomass between 2005 and 2015 and the steeper rate of increase through to 2022.

The confidence intervals for biomass trajectory are more narrow in the current assessment.

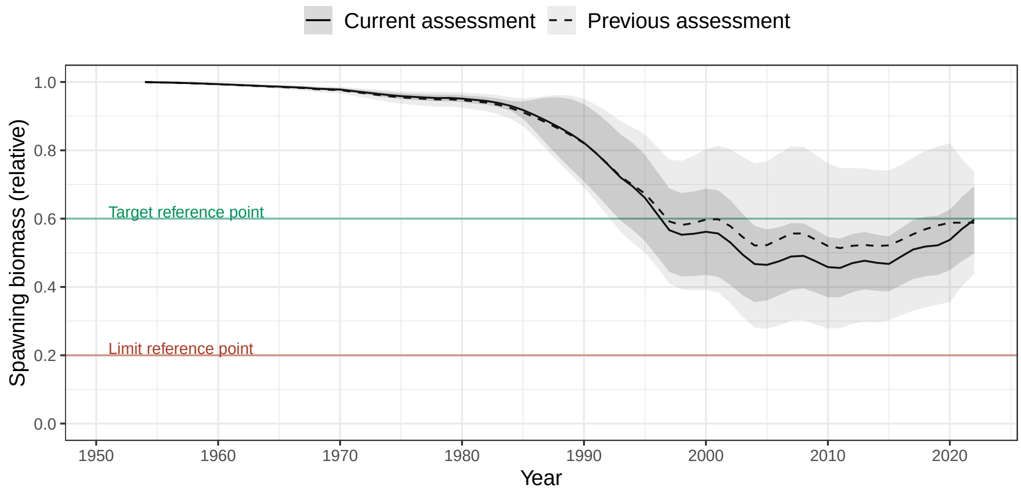

Figure 3.17: Comparison of biomass trajectories between current and previous assessment of common coral trout

The model inputs in Campbell et al. (2020) ended in 2019. To produce Figure 3.17 the retained catch from 2020 and 2021 were input to the previous model using the Stock Synthesis 'forecasted catch' option. This projected the model forward two years, to allow a comparison of biomass in 2022.

3.2.6 Catch targets

Harvest targets have been calculated to maintain spawning biomass at the 60% target reference point for the base model resulting in recommended biological retained catch (RBC) of 1199 t for 2022. This RBC is the first in a schedule of projected recommended harvests following a 20:60:60 harvest control rule. The schedule is presented here for the base case in Table 3.2. Note that these RBC values have not had an uncertainty discount factor applied. For discounted harvest values see Section 4.3.2.

Table 3.2: Estimated total retained harvests and spawning biomass ratios of common coral trout for the base case to rebuild and maintain the stock at the target reference point of 60% unfished spawning biomass following a 20:60:60 control rule

Year	Retained catch (t)	Spawning biomass ratio
2022	1199	0.6
2023	1221	0.6

4 Discussion

Results from this assessment suggest the coral trout population on the Queensland east coast experienced some decline in the period 1953–1985, followed by a steeper decline through 2004. Population levels stabilised in the period 2005–2015, followed by some recovery in the period 2016–2021. The current (2022) population level is around 60% of unfished spawning biomass. The results also suggest that catch levels during the 1990s and early 2000s were higher than would be consistent with a 60% target reference point. Management reforms enacted in 2004 (whether the Representative Area Program rezoning or the influence of the total allowable commercial catch administered through individual transferable quotas or both) appear to have reduced fishing mortality to near target levels.

4.1 Performance of the population model

The base population model fits all data sets well. The base case model was almost identical to the peer-reviewed model published in Campbell et al. (2020), except for the following changes:

- All fish lengths (and subsequent relationships) were converted to fork length instead of total length.
- The Stock Synthesis software was updated to the latest version.
- Data sets used to produce model inputs were updated to end in December 2021.

Two additional scenarios were included in this assessment. One scenario incorporates length and age data from 2020 and 2021. In this scenario, commercial fishery fleets are separated by sector (live or dead coral trout). The other additional scenario mirrors selectivity across the blue and green fishery fleets, as per a recommendation in Campbell et al. (2020).

As highlighted in Campbell et al. (2020), notable model limitations include:

- the productivity parameter "steepness" (h) was fixed;
- regional variation in biological characteristics has not been taken into account;
- hermaphroditism was briefly explored but did not produce sensible results, and the current assessment assumes a reproductive mechanism (males and females in fixed 50% proportion from birth) that does not reflect known biology of common coral trout;
- dome-shape selectivity is probably necessary, but the extent of the dome (i.e. how low selectivity becomes as lengths approach their maximum) is unclear;
- the extent of discarding in the commercial sector remains largely unknown, and the limited data that were available to support an estimate may not be reliable;
- the fraction of harvest that is common coral trout in the commercial sector is based on a very small sample that may not be representative (discussed further in Section 4.3.1.1).

The hermaphroditism issue merits further discussion. By assuming a fixed sex ratio in modelling a species which exhibits sequential hermaphroditism, we may be misrepresenting the interaction between total mortality at age and fertilized egg production. This could result in underestimation of the productivity of the species (more likely if the hermaphroditism is socially controlled) or overestimation (more likely if hermaphroditism is environmentally influenced). Investigating this further should be a priority.

These limitations suggest a cautious interpretation of the current model outputs is needed, and further work will improve model performance.

4.1.1 Scenario 2

Scenario 2—in which fleets were split into live and dead commercial sectors to accommodate the additional biological monitoring data—should be developed further in the next stock assessment.

The selectivity for all fleets were fixed as dome-shaped to reflect the settings of the base case. The model results (i.e. estimated selectivity curve) suggest an asymptotic shape may be more suitable for the fresh commercial and recreational sectors, which is consistent with targeting behaviour in those sectors.

Generally, the model used in Scenario 2 had poorer fits to model inputs compared to the base case model. However this comes with the caveat that the model used in Scenario 2 was required to fit to more data sets and estimate more parameters compared to the base case, which may have compromised the quality of data fits. Further, there was no detailed screening for outliers in the 2019–2021 length and age data set, which may have aided the model fitting, and this should be incorporated into the next assessment. It is likely that when this assessment is repeated, the additional years of data will allow for better model fits and parameter estimation for this scenario.

4.2 Unmodelled influences

4.2.1 Environmental influences

Since 2014, there have been two mass coral bleaching events, one tropical cyclone that severely impacted the GBR, and two crown-of-thorns outbreaks on the GBR (Australian Institute of Marine Science 2021). These events have reduced coral cover, which in turn reduced habitat and prey availability for coral trout (Tobin et al. 2010; Pratchett et al. 2014; Rogers et al. 2017). Loss of coral reef habitat extent and complexity has been found to result in reductions in fisheries productivity of approximately 35% (Rogers et al. 2017). Bleaching events can also influence coral trout growth rates and spawning output (Hughes 2010; Johnson et al. 2010; Pratchett et al. 2014). It is anticipated that increases in sea surface temperature (SST) will affect recruitment, by impacting the timing and duration of spawning events, along with increasing larval growth rates (Welch et al. 2010).

In a review of the potential environmental variables impacting common coral trout, SST and nutrient changes were ranked as high risks to common coral trout, while upwelling and wind/current changes were ranked as medium risks (Welch et al. 2010). More specifically, SST over 28 °C negatively impacts the development of early life stages (Pratchett et al. 2014). While common coral trout in southern areas may be able to spawn at different times when water is cooler, this may be more difficult in northern regions.

Tropical cyclones may also affect the catchability of the fish. Catch rate declines are correlated with anomalous wave heights resulting from cyclone activity (Callaghan 2011b; Callaghan 2011a; Leigh et al. 2014; Courtney et al. 2015). These declines are most likely not associated with declines in stock size, as UVS data do not show the same pattern; instead, catch rates come back strongly one or two years after the cyclone. Further research is needed to explain these correlations.

There is evidence to suggest that climate change will cause cyclones to increase in intensity (Walsh et al. 2016) and bleaching events will become more extensive and more severe (Hughes et al. 2017).

None of these environmental factors have been modelled in this assessment, as the mechanisms that connect them to common coral trout abundance are not well understood and require further investigation. This is a major limitation of this model if these variables are changing systematically over time.

Outcomes from an FRDC project on "Effects of climate change and habitat degradation on coral trout" may be of value in addressing some of these unknowns.

4.2.2 Market influences

The coral trout export market may have influenced the fishing effort and targeting behaviour in ways that have not been captured in the model. In 2021, Australia's largest coral trout buyer had the renewal of its export license to China temporarily delayed (McKillop 2021), requiring a general industrial shift to a domestic market selling fresh (not live) trout. This change in market also meant a change in targeting: live exported coral trout are generally smaller red coral trout, whereas fresh coral trout sold in the domestic market do not have a size restriction.

4.3 Recommendations

4.3.1 Research and monitoring

4.3.1.1 Data

Data utility would be improved by accurate effort measures with fishing time and accurate location recorded for each commercial operation. More frequent measures of recreational harvest and effort, as well as better species identification, would also benefit future assessments. More data should be collected regarding the number of discards, and the size composition of discarded fish from the commercial fishery. Electronic reporting systems may be valuable for achieving these objectives.

Campbell et al. (2020) highlighted the utility of reporting commercial harvest to the species level. Historically, the layout of commercial logbooks contained a field for 'coral trout' (a species complex comprised of common coral trout (*Plectropomus leopardus*), barcheek coral trout (*P. maculatus*), bluespotted coral trout (*P. laevis*), passionfruit coral trout (*P. areolatus*), highfin coral trout (*P. oligocanthus*), yellow-edge coronation trout (*Variola louti*) and white-edge coronation trout (*V. albimarginata*)), with an option to report at a species level. In September 2021, the layout of commercial logbooks changed and fishers are now encouraged to report coral trout harvest to the species level. With time, these data could provide an updated estimate of the species split of 'coral trout' catch, to supersede the estimate from the Observer program. This change to the logbooks might elicit unexpected changes to reporting behaviour, which (with more data) may need to be captured in future standardisation of catch rates.

4.3.1.2 Monitoring

The discontinuation of the Fisheries Queensland reef line monitoring surveys at the end of 2009 led to greater uncertainty in model outputs. In 2019, another biological monitoring program commenced on an annual basis. The data included biological information on fish caught from the live and fresh commercial sectors, as well as the recreational sector, whereas the data from 1995 to 2009 represented only the live commercial sector. This means that the data sets are not congruent as they represent different selectivity patterns. Scenario 2 applied a different fleet structure to the model (splitting the commercial sectors into live and fresh fleets) in order to utilise the post-2019 biological data, however with only two complete years of sampling data available, the model was deemed inappropriate as the base case. Continuation of the biological monitoring program is recommended, ensuring there is an adequate representation of males and females in the data is important and may enable hermaphroditism to be correctly modelled next time.

The underwater visual survey data from AIMS were particularly valuable, and it is recommended that the program continues in its current form.

4.3.2 Management

Management action in the early 2000s appears to have put stock levels on a sustainable track. The *Sustainable Fisheries Strategy* is a sensible way to maintain this as it is underpinned by a harvest control rule. This can buffer against model uncertainty and should remain responsive as modelling and data improve.

The harvest consistent with a spawning biomass ratio of 60% was estimated at 1158 t. The recommended harvest in 2022 is 1199 t in order to maintain this target.

Table 4.1: Current and target indicators for Queensland east coast common coral trout

Indicator	Estimate
Biomass◇ (relative to unfished) at the start of 2022	60% (50.2% to 69.8%)
Target biomass (relative to unfished)	60%
Biomass (relative to unfished) at MSY⋆	32%
MSY⋆	1946 t
Retained catch component of MSY⋆	1480 t
Retained catch in 2021	1023 t
Retained catch at 60% biomass target	1158 t
RBC† for 2022 to achieve target	1534 t
Retained component of RBC	1199 t
Time to achieve target	0 years

◇ Biomass is defined to be spawning stock biomass.
⋆ MSY (maximum sustainable yield) is defined to be the maximum sustainable dead catch—that is, retained catch plus catch that dies following discarding.
† 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

The base case scenario estimated the 2021 east coast common coral trout stock to be 60% of unfished spawning biomass. Note that this estimate is across the full spatial extent of the stock, not just for the GBRMP zones that have been open to fishing since July 2004.

The recommended discount factor for this assessment (Fisheries Queensland 2021) is 0.91 based on a qualitative tier assignment process and Ralston et al. (2011) (σ is 0.36, P^* (risk aversion) is 0.45). Applying this discount factor, the recommended biological harvest results in a discounted 2022 harvest of 1091 t.

4.3.3 Assessment

Limitations with the performance of the current model have been discussed in this document. Specific recommendations for a future assessment are as follows:

- Selectivity be mirrored between green and blue regions
- The extent of selectivity domes be thoroughly sensitivity tested

- The appropriateness of a two-region model that is not spatially contiguous and covers such a broad area be reconsidered
- Hermaphroditism is modelled
- Abundance indices are restandardised with a view to including longer time series in the model, and thorough sensitivity testing is conducted
- An exploration is made of time-varying fraction of recruitment going to each region
- The assessment incorporates newly available age and length composition data from the restarted biological monitoring program
- The assessment investigates how data from the FRDC project on environmental influences (2018-034) be incorporated, if available

4.4 Conclusions

This assessment has informed the status of the common coral trout population on the east coast of Queensland. It suggests that current harvest levels are in line with the target reference point under the Sustainable Fisheries Strategy, with a small amount of rebuilding required to buffer against uncertainty. The results provide recommended biological harvests using a 20:60:60 control rule. Some limitations of the assessment have been noted and recommendations made.

References

ABS (2014). *Australian Historical Population Statistics*. Tech. rep. Catalogue no. 3105.0.65.001. Canberra: Australian Bureau of Statistics. URL: http://www.abs.gov.au/ausstats/abs@.nsf/cat/3105.0.65.001.

Australian Institute of Marine Science (2018). *Long-term Reef Monitoring Program - Annual Summary Report on coral reef condition for 2017/18*. Tech. rep. Author.

— (2021). *Long-term Reef Monitoring Program - Annual Summary Report on coral reef condition for 2020/21*. Tech. rep. Australian Institute of Marine Science, Australian Government.

Bergenius, M. A. J, G. Begg, and B. D. Mapstone (2006). "The use of otolith morphology to indicate the stock structure of common coral trout (Plectropomus leopardus) on the Great Barrier Reef, Australia". In: *Fishery Bulletin* 104, pp. 498–511.

Bergenius, M. A. J, B. D. Mapstone, G. Begg, and C. D. Murchie (2005). "The use of otolith chemistry to determine stock structure of three epinepheline serranid coral reef fishes on the Great Barrier Reef, Australia". In: *Fisheries Research* 72, pp. 253–270.

Brooks, Mollie E., Kasper Kristensen, Koen J. van Benthem, Arni Magnusson, Casper W. Berg, Anders Nielsen, Hans J. Skaug, Martin Maechler, and Benjamin M. Bolker (2017). "glmmTMB Balances Speed and Flexibility Among Packages for Zero-inflated Generalized Linear Mixed Modeling". In: *The R Journal* 9.2, pp. 378–400. URL: https://journal.r-project.org/archive/2017/RJ-2017-066/index.html.

Brown, Ian W., Wayne D. Sumpton, Mark F. McLennan, David J. Welch, John M. Kirkwood, Adam R. Butcher, Amos Mapleston, David G. Mayer, Gavin A. Begg, Matthew D. Campbell, Ian Halliday, and W. Sawynok (July 2008). *National Strategy for the Survival of Released Line-caught Fish: Tropical Reef Species. Final report of FRDC project 2003/019.* Tech. rep. Brisbane: Queensland Department of Primary Industries and Fisheries. URL: http://frdc.com.au/research/Documents/Final_reports/2003-019-DLD.pdf.

Callaghan, Jeff (Sept. 2011a). *Tropical Cyclone Connie February 1959*. Tech. rep. Harden Up Queensland. URL: http://hardenup.org/umbraco/customContent/media/618_Bowen_Cyclone_Connie_1959.pdf (visited on 07/09/2015).

— (Sept. 2011b). *Tropical Cyclone Dinah, 1967*. Tech. rep. URL: http://hardenup.org/umbraco/customContent/media/615_Rockhampton_Cyclone_Dinah_1967.pdf (visited on 07/01/2015).

Campbell, AB and AR Northrop (2020). "Stock Assessment of Common Coral Trout (Plectromomus leopardus) in Queensland". In.

Campbell, Alexander B., George M. Leigh, Pia Bessell-Browne, and Robyn Lovett (2019). *Stock assessment of the Queensland east coast common coral trout (Plectropomus leopardus) fishery*. Tech. rep. Queensland Department of Agriculture and Fisheries.

Courtney, Anthony J., Claire M. Spillman, Ricardo T. Lemos, J. Thomas, George M. Leigh, and Alexander B. Campbell (Dec. 2015). *Physical oceanographic influences on Queensland reef fish and scallops*. Tech. rep. Final Report FRDC project no. 2013/020. Canberra: Fisheries Research and Development Corporation. URL: http://frdc.com.au/research/final-reports/Pages/2013-020-DLD.aspx (visited on 05/04/2016).

Emslie, M. J. and A. J. Cheal (2018). *Visual census of reef fish*. Tech. rep. Australian Institute of Marine Science, Townsville, Australia.

Ferreira, Beatrice P. and Garry R. Russ (1995). “Population structure of the leopard coralgrouper, Plectropomus leopardus, on fished and unfished reefs off Townsville, central Great Barrier Reef, Australia”. In: *Fishery Bulletin* 93.4, pp. 629–642.

Fisheries Queensland (2012a). *DRAFT Fisheries Long Term Monitoring Program Sampling Protocol - Coral Reef Fin Fish: (2005-2007) Section 2. Department of Agriculture, Fisheries and Forestry*. Unpublished report.: Queensland Department of Agriculture and Fisheries.

— (2012b). *Fishery Monitoring Sampling Protocol: Data Protocol (Section 2 - Data Field Descriptions)*. Tech. rep. Brisbane, Australia: Department of Employment, Economic Development and Innovation.

— (2017). *Fisheries Queensland Boat Ramp Survey Sampling Protocol: Section 2*. Tech. rep. Brisbane, Australia.

— (2021). *Draft Harvest Strategy Policy*. Tech. rep. Brisbane, Australia: Department of Agriculture and Fisheries. URL: `https://daf.engagementhub.com.au/draft-harveststrategy-policy`.

Fisheries Research and Development Corporation (2021). *How are the Status of Australian Fish Stocks Reports done?* URL: `https://www.fish.gov.au/about/how-are-the-status-of-australian-fish-stock-reports-done` (visited on 11/10/2021).

Francis, R. I. C. Chris (2011). “Data weighting in statistical fisheries stock assessment models”. In: *Canadian Journal of Fisheries and Aquatic Sciences* 68.6, pp. 1124–1138. URL: `http://dx.doi.org/10.1139/f2011-025`.

Halliday, Ian and Julie Robins (2007). *Environmental Flows for Sub-tropical Estuaries: Understanding the Freshwater Needs of Estuaries for Sustainable Fisheries Production and Assessing the Impacts of Water Regulation*. Tech. rep. Brisbane: Department of Primary Industries and Fisheries. URL: `http://frdc.com.au/research/Documents/Final_reports/2001-022-DLD.PDF` (visited on 11/10/2016).

Hamel, O.S. (2015). “A method for calculating a meta-analytical prior for the natural mortality rate using multiple life history correlates”. In: *ICES Journal of Marine Science* 72, pp. 62–69.

Harrison, Hugo B., David H. Williamson, Richard D. Evans, Glenn R. Almany, Simon R. Thorrold, Garry R. Russ, Kevin A. Feldheim, Lynne van Herwerden, Serge Planes, Maya Srinivasan, Michael L. Berumen, and Geoffrey P. Jones (June 2012). “Larval export from marine reserves and the recruitment benefit for fish and fisheries”. In: *Current Biology* 22.11, pp. 1023–1028. URL: `http://dx.doi.org/10.1016/j.cub.2012.04.008`.

Henry, Gary W. and Jeremy M. Lyle (2003). *The National Recreational and Indigenous Fishing Survey*. Tech. rep. Canberra: Australian Government Department of Agriculture, Fisheries and Forestry. URL: `http://eprints.utas.edu.au/2526/1/Henry_Lyle_Nationalsurvey.pdf`.

Higgs, Jim, Len Olyott, and Kirrily McInnes (2007). *Experimental Results from the Third Statewide Recreational Fishing Information System Diary Program (2002)*. Tech. rep. Brisbane: Queensland Department of Primary Industries and Fisheries.

Hoenig, John M. (1983). “Empirical use of longevity data to estimate mortality rates”. In: *Fishery Bulletin* 81.4, pp. 898–903. URL: `http://fishbull.noaa.gov/81-4/hoenig.pdf` (visited on 07/27/2016).

Hughes, T. P. (2010). *Marine and Tropical Sciences Research Facility, Milestone Report for program 2.5i.3*. Report to the Australian Government Department of the Envrionment, Water, Heritage and the Arts. Australia: James Cook University.

Hughes, Terry P., James T. Kerry, Mariana Álvarez-Noriega, Jorge G. Álvarez-Romero, Kristen D. Anderson, Andrew H. Baird, Russell C. Babcock, Maria Beger, David R. Bellwood, Ray Berkelmans, Tom C. Bridge, Ian R. Butler, Maria Byrne, Neal E. Cantin, Steeve Comeau, Sean R. Connolly, Graeme S. Cumming, Steven J. Dalton, Guillermo Diaz-Pulido, C. Mark Eakin, Will F. Figueira, James P. Gilmour, Hugo B. Harrison, Scott F. Heron, Andrew S. Hoey, Jean-Paul A. Hobbs, Mia O. Hoogenboom, Emma V. Kennedy, Chao-yang Kuo, Janice M. Lough, Ryan J. Lowe, Gang Liu, Malcolm T.

McCulloch, Hamish A. Malcolm, Michael J. McWilliam, John M. Pandolfi, Rachel J. Pears, Morgan S. Pratchett, Verena Schoepf, Tristan Simpson, William J. Skirving, Brigitte Sommer, Gergely Torda, David R. Wachenfeld, Bette L. Willis, and Shaun K. Wilson (2017). "Global warming and recurrent mass bleaching of corals". In: *Nature* 543, p. 373. URL: https://doi.org/10.1038/nature21707.

Jensen, AL (1997). "Origin of relation between K and Linf and synthesis of relations among life history parameters". In: *Canadian Journal of Fisheries and Aquatic Sciences* 54, pp. 987–989.

Johnson, J. E. and D. Welch (2010). "Marine fisheries management in a changing climate: a review of vulnerability and future options." In: *Reviews in Fisheries Science* 18, pp. 106–124.

Lawson, Ashley (2015). *An Investigative Analysis of Queensland's Statewide Recreational Fishing Surveys: Identifying Bias in Self-reported Catch and Effort Data*. Tech. rep. Brisbane: Department of Agriculture and Fisheries.

Leigh, G. M., A. B. Campbell, Chad P. Lunow, and M. F. O'Neill (2014). *Stock assessment of the Queensland east coast common coral trout (Plectropomus leopardus) fishery*. Monograph. URL: http://era.daf.qld.gov.au/4547/ (visited on 06/30/2015).

Mapstone, Bruce D., Campbell R. Davies, L. Richard Little, André E. Punt, Anthony D. M. Smith, F. Pantus, Dong C. Lou, Ashley J. Williams, Annabel Jones, A. M. Ayling, Garry R. Russ, and A. D. McDonald (2004). *The Effects of Line Fishing on the Great Barrier Reef and Evaluations of Alternative Potential Management Strategies. Report of FRDC project 97/124.* Tech. rep. Townsville: CRC Reef Research Centre.

McInnes, Kirrily (2008). *Experimental Results from the Fourth Queensland Recreational Fishing Diary Program (2005)*. Tech. rep. Brisbane: Department of Primary Industries and Fisheries.

McKillop, Charlie (Feb. 25, 2021). "China pulls the plug on Australia's biggest live reef fish exporter". In: *ABC Rural*. URL: https://www.abc.net.au/news/rural/2021-02-25/coral-trout-rout-as-china-pulls-plug-on-export-licence/13190640 (visited on 02/25/2021).

Methot, Richard D., Chantel R. Wetzel, Ian G. Taylor, Kathryn L. Doering, and Kelli F. Johnson (2021). *Stock Synthesis User Manual Version 3.30.18*. Tech. rep. Seattle, WA: National Oceanic and Atmospheric Administration, U.S. Dept. Commer.

Northrop, Amanada, Michael F. O'Neill, George M. Leigh, and Chad Lunow (2018). *Monitoring requirements for common coral trout*. Tech. rep. Brisbane: Queensland Department of Agriculture and Fisheries.

Pratchett, M. S., A. S. Hoey, and S. K. Wilson (2014). "Reef degradation and the loss of critical ecosystem goods and services provided by coral reef fishes". In: *Current Opinion in Environmental Sustainability* 7, pp. 37–43.

Pratchett, M. S., V. Messmer, A. Reynolds, J. M. Martin, T. D. Clark, P. L. Munday, A. J. Tobin, and A. S. Hoey (2010). "Effects of climate change on reproduction, larval development, and adult health of coral trout (*Plectropomus* spp.)" In: *Final Rep to Fish Res Dev Corp Proj 2010/554, FRDC, James Cook University, Australia*.

Punt, André E, Anthony DM Smith, David C Smith, Geoffrey N Tuck, and Neil L Klaer (2014). "Selecting relative abundance proxies for B MSY and B MEY". In: *ICES Journal of Marine Science* 71.3, pp. 469–483.

Queensland Department of Agriculture and Fisheries (2020). *Reef line fishery harvests strategy 2020-2025*. Tech. rep. Brisbane.

R Core Team (2020). *R: A language and environment for statistical computing*. Vienna. URL: http://www.R-project.org/.

Ralston, Stephen, André E Punt, Owen S Hamel, John D DeVore, and Ramon J Conser (2011). "A meta-analytic approach to quantifying scientific uncertainty in stock assessments." In: *Fishery Bulletin* 109.2.

Rogers, Alice, Julia L. Blanchard, and Peter J. Mumby (2017). “Fisheries productivity under progressive coral reef degradation”. en. In: *Journal of Applied Ecology*, DOI: 10.1111/1365–2664.13051. URL: http://onlinelibrary.wiley.com/doi/10.1111/1365-2664.13051/abstract (visited on 01/15/2018).

Samoilys, Melita A. (July 1997). “Movement in a large predatory fish: Coral trout, Plectropomus leopardus (Pisces: Serranidae), on Heron Reef, Australia”. In: *Coral Reefs* 16.3, pp. 151–158. URL: http://dx.doi.org/10.1007/s003380050069.

Taylor, Stephen, James Webley, and Kirrily McInnes (2012). *2010 Statewide Recreational Fishing Survey*. Tech. rep. Brisbane: Department of Agriculture, Fisheries and Forestry. URL: http://era.daf.qld.gov.au/id/eprint/6926/2/2010%20SWRFS-Final%20V4.pdf.

Teixeira, Daniella, Rachel Janes, and James Webley (2021). *2019/20 Statewide Recreational Fishing Survey Key Results*. Project Report. Brisbane, Australia. URL: http://era.daf.qld.gov.au/id/eprint/7879/.

Thébaud, Olivier, James Innes, Ana Norman-López, Stephanie Slade, Darren Cameron, Toni Cannard, Sharon Tickell, John Kung, Brigid Kerrigan, Lew Williams, and L. Richard Little (Jan. 2014). “Microeconomic drivers of profitability in an ITQ-managed fishery: An analysis of the Queensland Coral Reef Fin-Fish Fishery”. In: *Marine Policy* 43, pp. 200–207. URL: http://dx.doi.org/10.1016/j.marpol.2013.06.001.

Then, Amy Y., John M. Hoenig, Norman G. Hall, and David A. Hewitt (Jan. 2015). “Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species”. en. In: *ICES Journal of Marine Science* 72.1, pp. 82–92. URL: https://academic.oup.com/icesjms/article/72/1/82/2804320 (visited on 01/30/2018).

Tobin, Andrew J., A. Schlaff, Renae C. Tobin, A. Penny, A. M. Ayling, A. L. Ayling, B. Krause, David J. Welch, Stephen G. Sutton, Bill Sawynok, N. Marshall, P. Marshall, and J. Maynard (2010). *Adapting to Change: Minimising Uncertainty About the Effects of Rapidly-changing Environmental Conditions on the Queensland Coral Reef Fin Fish Fishery*. Tech. rep. Townsville: James Cook University, Fishing & Fisheries Research Centre.

van Herweden, L., J. H. Choat, C. L. Dudgeon, G. Carlos, S. Newman, A. Frisch, and M. van Oppen (2006). “Contrasting patterns of genetic structure in two species of the coral trout Plectropomus (Serranidae) from east and west Australia: introgressive hybridisation or ancestral polymorphisms”. In: *Molecular Phylogenetics and Evolution* 41, pp. 420–435.

van Herweden, L., J. H. Choat, S. Newman, M. Lerray, and G. Hillesroy (2009). “Complex patterns of population structure and recruitment of Plectropomus leopardus (Pisces: Epinephelidae) in the Indo-West Pacific: implications for fisheries management”. In: *Marine Biology* 156, pp. 1595–1607.

Walsh, Kevin J.E., John L. McBride, Philip J. Klotzbach, Sethurathinam Balachandran, Suzana J. Camargo, Greg Holland, Thomas R. Knutson, James P. Kossin, Tsz-cheung Lee, Adam Sobel, and Masato Sugi (Jan. 2016). “Tropical cyclones and climate change”. en. In: *Wiley Interdisciplinary Reviews: Climate Change* 7.1, pp. 65–89. URL: http://onlinelibrary.wiley.com/doi/10.1002/wcc.371/abstract (visited on 01/17/2018).

Webley, James A. C., Kirrily McInnes, Daniella Teixeira, Ashley Lawson, and Ross Quinn (2015). *Statewide Recreational Fishing Survey 2013–14*. Tech. rep. Brisbane, Australia: Department of Agriculture and Fisheries. URL: http://era.daf.qld.gov.au/id/eprint/6513/1/2013-14SRFS%20Report.pdf.

Welch, D. J., T. Saunders, J. Robins, A. Harry, J. Johnson, J. Maynard, R. Saunders, G. Pecl, B. Sawynok, and A. Tobin (2010). *Implications of climate change on fisheries resources of northern Australia. Part 1: Vulnerability assessment and adaptation options*. FRDC Project 2010/565. Australia: James Cook University.

A Model inputs

A.1 Age and length sample sizes

The sample sizes in Table A.1 are input to the model and form a starting point for data set weighting.

Table A.1: Raw sample sizes measured and aged input to the model for common coral trout

Year	Blue fishery (length)	Green fishery (length)	Blue survey (length)	Green survey (length)	Blue fishery (age)	Green fishery (age)
1995	724	3138			724	3138
1996	423	2562			423	2562
1997	1074	2509			1074	2509
1998	1066	3380			1066	3380
1999	1387	3374			1387	3374
2000	1278	2606			1278	2606
2001	964	1835			964	1835
2002	396	918			396	918
2003	397	700			397	700
2004	530	919	210	235	530	919
2005	417	1190	134	87	417	1190
2006	1562		504	865	1562	
2007	2543		255	265	2543	
2008	805		331	473	805	
2009	364		161	138	364	
2010			293	553		
2011			132	208		
2012			304	631		
2013			286	522		
2014			134	363		
2015			179	154		
2016			318	507		

A.2 Conditional age-at-length

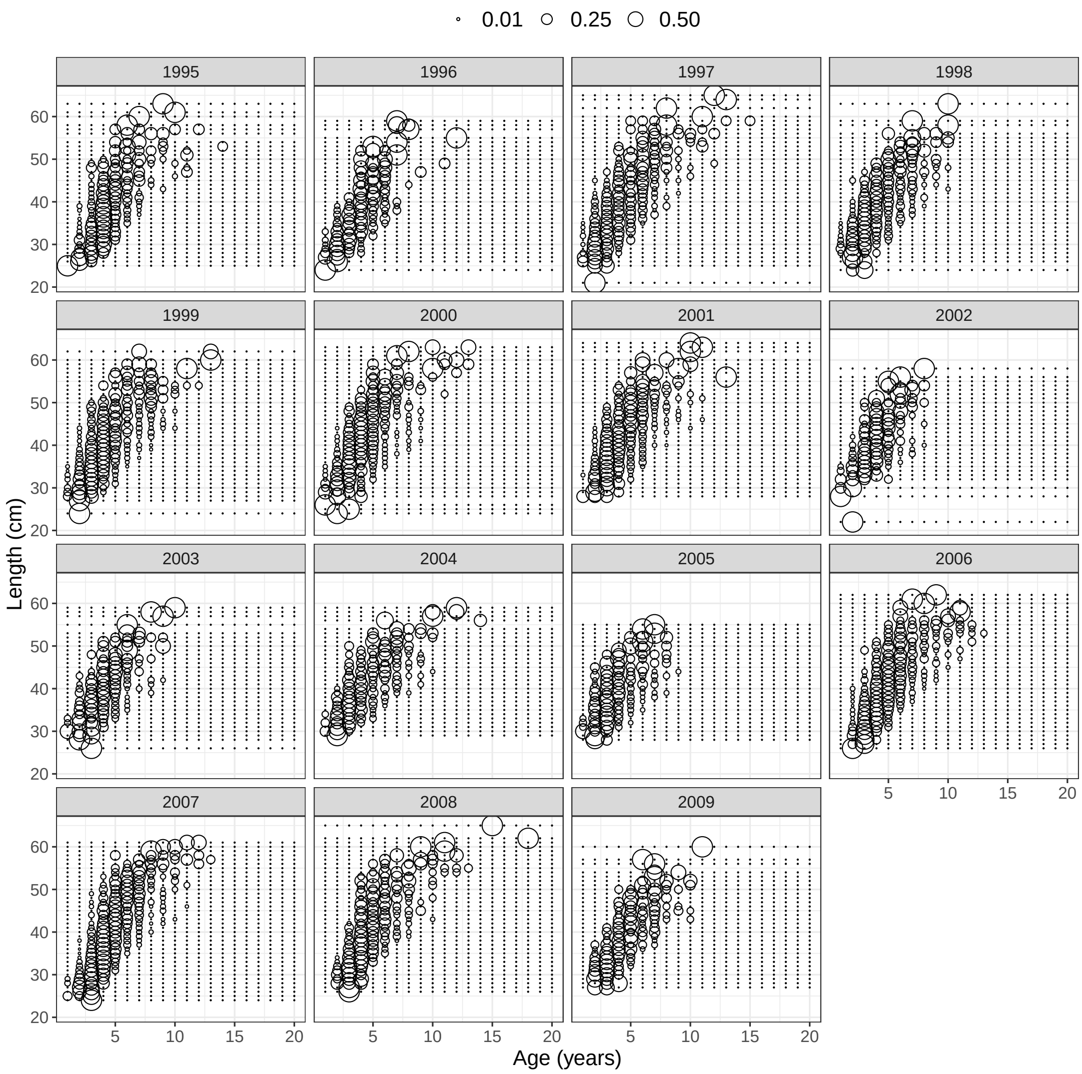

Figure A.1: Conditional age-at-length compositions for line caught fish between 1995 and 2009 in the blue region—circle size is proportional to relative sample size in each bin across rows (i.e. for a given length bin)

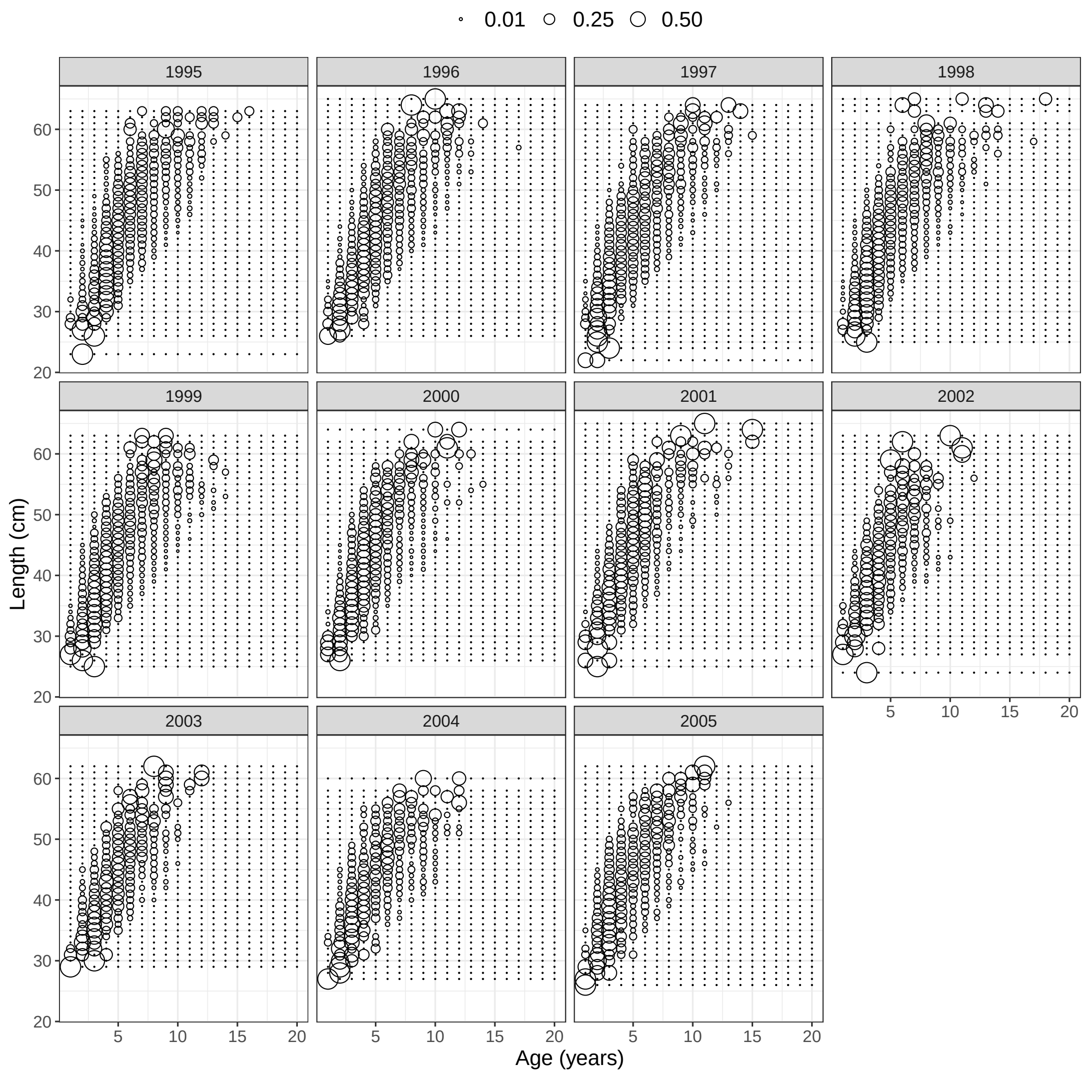

Figure A.2: Conditional age-at-length compositions of coral trout for line caught fish between 1995 and 2005 in the green region—circle size is proportional to relative sample size in each bin across rows (i.e. for a given length bin)

A.3 Biological data

A.3.1 Fecundity and maturity

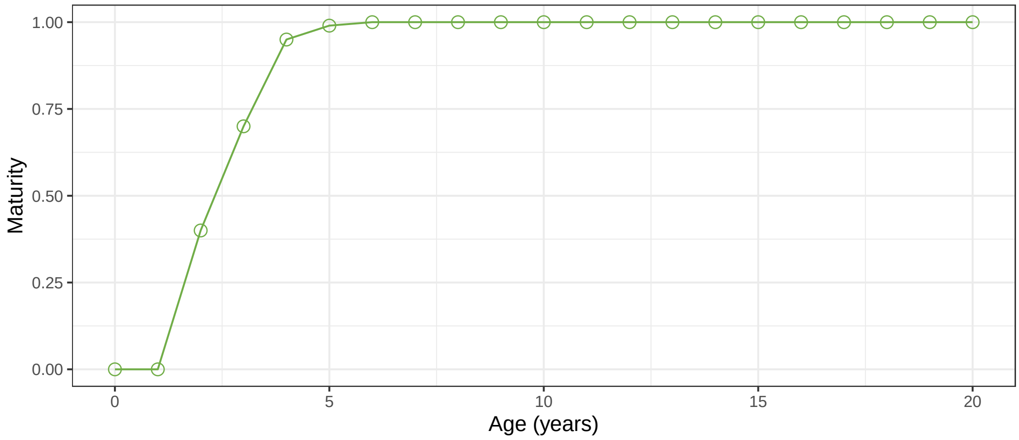

Figure A.3: Maturity at age

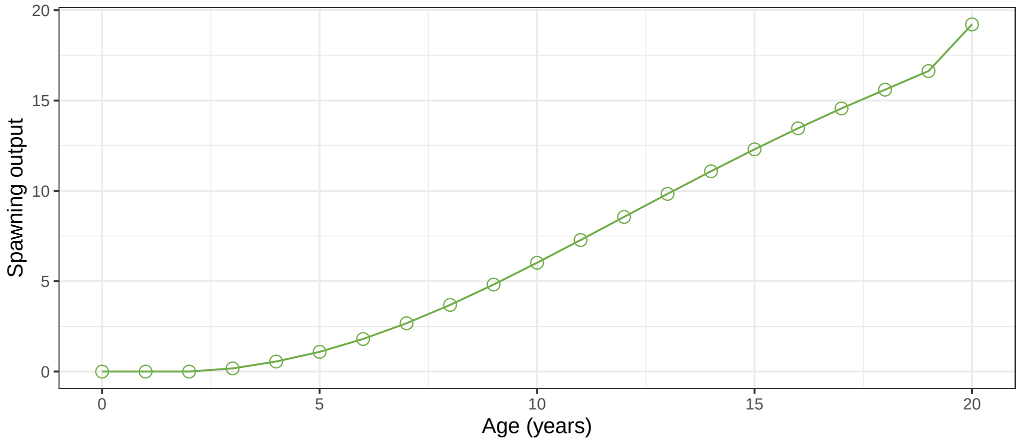

Figure A.4: Spawning output (maturity times fecundity) at age

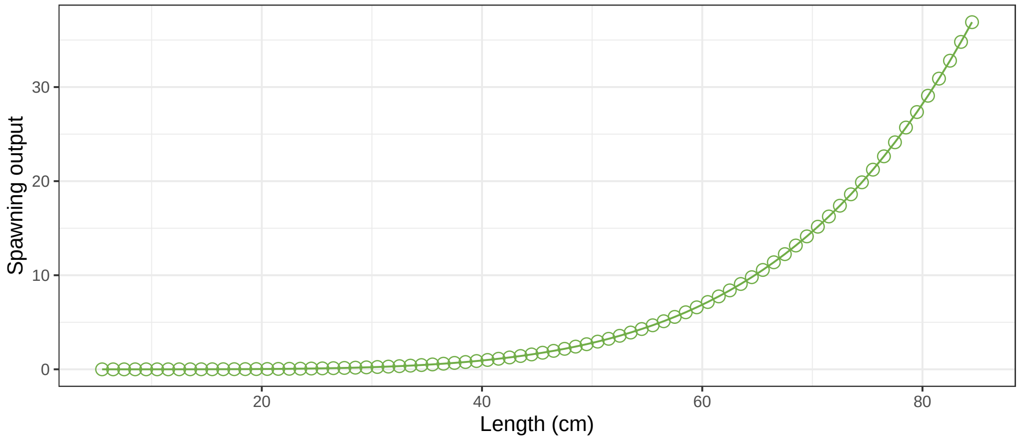

Figure A.5: Spawning output (maturity times fecundity) at length

A.3.2 Weight and length

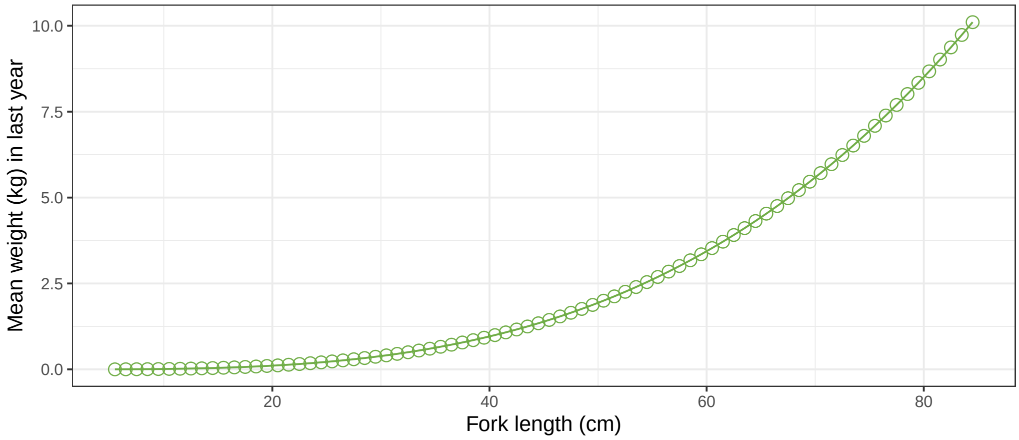

Figure A.6: Weight-length relationship

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). In addition, recruitment deviations were estimated between 1982 and 2021.

Table B.1: Parameter label explanation

Parameter	Estimate
NatM_uniform	Natural mortality (M)
L_at_Amin	Total length at Age 1 (TL1)
L_at_Amax	Total length at Age 18 (TL18)
VonBert_K	von Bertalanffy growth parameter (kappa)
CV_young	Coefficient of variation in total length at Age 1
CV_old	Coefficient of variation in total length at Age 18
RecrDist_GP_1_area_2_month_1	Proportion of recruitment going to the green region (phi; logit scale)
SR_LN(R0)	logarithm of the number of recruits in 1953
SizeSel_P1_FISHERY_BLUE	Blue fishery selectivity, pattern 23, parameter p1 – peak: beginning size for the plateau (cm)
SizeSel_P2_FISHERY_BLUE	Blue fishery selectivity, pattern 23, parameter p2 - top: width of plateau, as logistic between peak and maximum length (cm)
SizeSel_P3_FISHERY_BLUE	Blue fishery selectivity, pattern 23, parameter p3 - ascending width: parameter value is ln(width; cm)
SizeSel_P4_FISHERY_BLUE	Blue fishery selectivity, pattern 23, parameter p4 - descending width: parameter value is ln(width; cm)
SizeSel_P5_FISHERY_BLUE	Blue fishery selectivity, pattern 23, parameter p5 - initial:selectivity at first bin, as logistic between 0 and 1
Retain_L_infl_FISHERY_BLUE	Blue fishery retention, asymptotic, parameter p1 - ascending inflection (cm)
SizeSel_P1_FISHERY_GREEN	Green fishery selectivity, pattern 23, parameter p1 – peak: beginning size for the plateau (cm)
SizeSel_P2_FISHERY_GREEN	Green fishery selectivity, pattern 23, parameter p2 - top: width of plateau, as logistic between peak and maximum length (cm)
SizeSel_P3_FISHERY_GREEN	Green fishery selectivity, pattern 23, parameter p3 - ascending width: parameter value is ln(width; cm)
SizeSel_P4_FISHERY_GREEN	Green fishery selectivity, pattern 23, parameter p4 - descending width: parameter value is ln(width; cm)

Continued on next page

Table B.1 – *Continued from previous page*

Parameter	Estimate
SizeSel_P5_FISHERY_GREEN	Green fishery selectivity, pattern 23, parameter p5 - initial:selectivity at first bin, as logistic between 0 and 1
Retain_L_infl_FISHERY_GREEN	Green fishery retention, asymptotic, parameter p1 - ascending inflection (cm)
SizeSpline_GradLo_SURVEY_BLUI	Blue survey selectivity, pattern 27 (spline), parameter p2 - gradient at the first node
SizeSpline_Val_1_SURVEY_BLUE	Blue survey selectivity, pattern 27 (spline), parameter p8 - selectivity at the first node
SizeSpline_Val_2_SURVEY_BLUE	Blue survey selectivity, pattern 27 (spline), parameter p9 - selectivity at the second node
SizeSpline_Val_4_SURVEY_BLUE	Blue survey selectivity, pattern 27 (spline), parameter p11 - selectivity at the fourth node
SizeSpline_GradLo_SURVEY_GREI	Green survey selectivity, pattern 27 (spline), parameter p2 - gradient at the first node
SizeSpline_Val_1_SURVEY_GREEI	Green survey selectivity, pattern 27 (spline), parameter p8 - selectivity at the first node
SizeSpline_Val_2_SURVEY_GREEI	Green survey selectivity, pattern 27 (spline), parameter p9 - selectivity at the second node
SizeSpline_Val_4_SURVEY_GREEI	Green survey selectivity, pattern 27 (spline), parameter p11 - selectivity at the fourth node

Table B.2: Stock synthesis parameter estimates for the base population model

Stock Synthesis parameter label	Estimate	Phase	Min	Max	Initial value	Standard deviation
NatM_uniform	0.404	8	0.01	0.99	0.3	0.0364
L_at_Amin	14.2	2	0	30	15	1.15
L_at_Amax	70.3	3	50	90	70	2.35
VonBert_K	0.122	2	0.01	0.3	0.14	0.0184
CV_young	0.275	4	0.05	0.5	0.27	0.0249
CV_old	0.067	6	0.001	0.2	0.1	0.0164
RecrDist_GP_1_area_2_month_1	-0.0387	4	-5	5	0	0.23
SR_LN(R0)	10.4	1	5	15	10	0.223
SizeSel_P1_FISHERY_BLUE	36.6	5	30	50	36	0.666
SizeSel_P2_FISHERY_BLUE	-1.58	5	-25	15	-6	1.18
SizeSel_P3_FISHERY_BLUE	3.17	5	0	5	3	0.191

Continued on next page

Table B.2 – *Continued from previous page*

Stock Synthesis parameter label	Estimate	Phase	Min	Max	Initial value	Standard deviation
SizeSel_P4_FISHERY_BLUE	4.62	5	3	9	5	1.22
SizeSel_P5_FISHERY_BLUE	-15.9	5	-40	30	-12	134
Retain_L_infl_FISHERY_BLUE	36.9	4	20	50	36	1.59
SizeSel_P1_FISHERY_GREEN	40.9	5	30	50	43	0.908
SizeSel_P2_FISHERY_GREEN	-1.79	5	-5	3	-1	0.516
SizeSel_P3_FISHERY_GREEN	3.67	5	0	7	4	0.176
SizeSel_P4_FISHERY_GREEN	4.37	5	2	8	5	0.5
SizeSel_P5_FISHERY_GREEN	-16.2	5	-25	15	-12	90.1
Retain_L_infl_FISHERY_GREEN	39.8	4	30	55	42	2.5
SizeSpline_GradLo_SURVEY_BLUE	0.224	3	-0.001	0.4	0.19	0.0252
SizeSpline_Val_1_SURVEY_BLUE	-5.61	2	-8	-1	-5	0.283
SizeSpline_Val_2_SURVEY_BLUE	-1.39	2	-5	0	-2	0.104
SizeSpline_Val_4_SURVEY_BLUE	-2.42	2	-6	0	-3	0.376
SizeSpline_GradLo_SURVEY_GREE	0.174	3	-0.001	0.4	0.18	0.0266
SizeSpline_Val_1_SURVEY_GREEN	-5.36	2	-7	-2	-5	0.286
SizeSpline_Val_2_SURVEY_GREEN	-1.54	2	-5	0	-2	0.101
SizeSpline_Val_4_SURVEY_GREEN	-1.98	2	-5	0	-2	0.254

B.2 Goodness of fit

B.2.1 Abundance indices

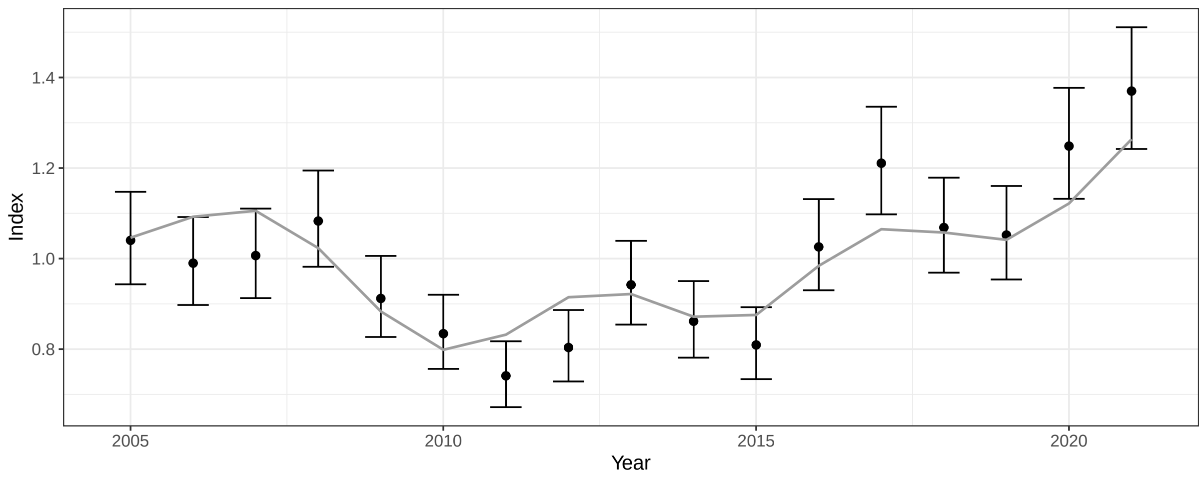

Figure B.1: Model predictions (grey line) to fishery blue catch rates for common coral trout

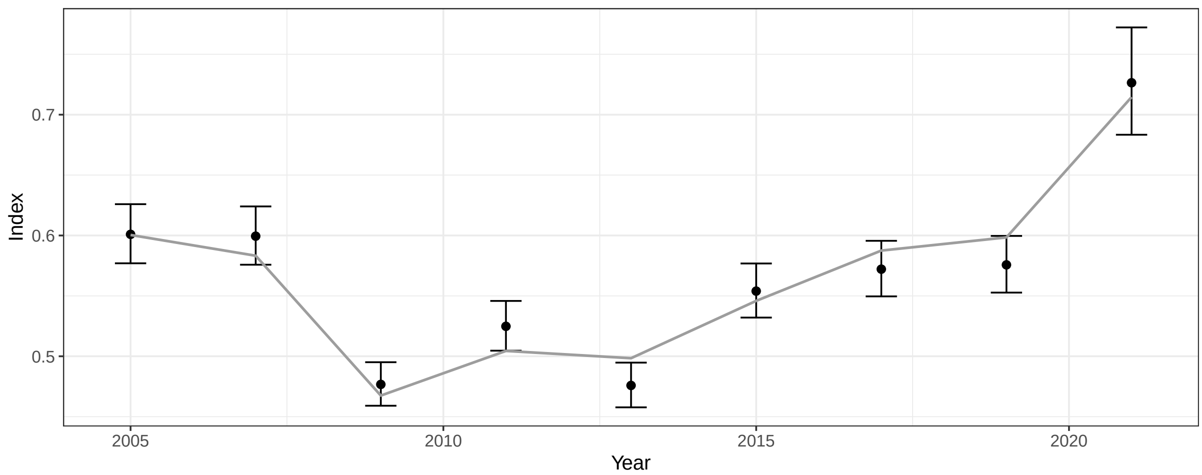

Figure B.2: Model predictions (grey line) to survey blue catch rates for common coral trout

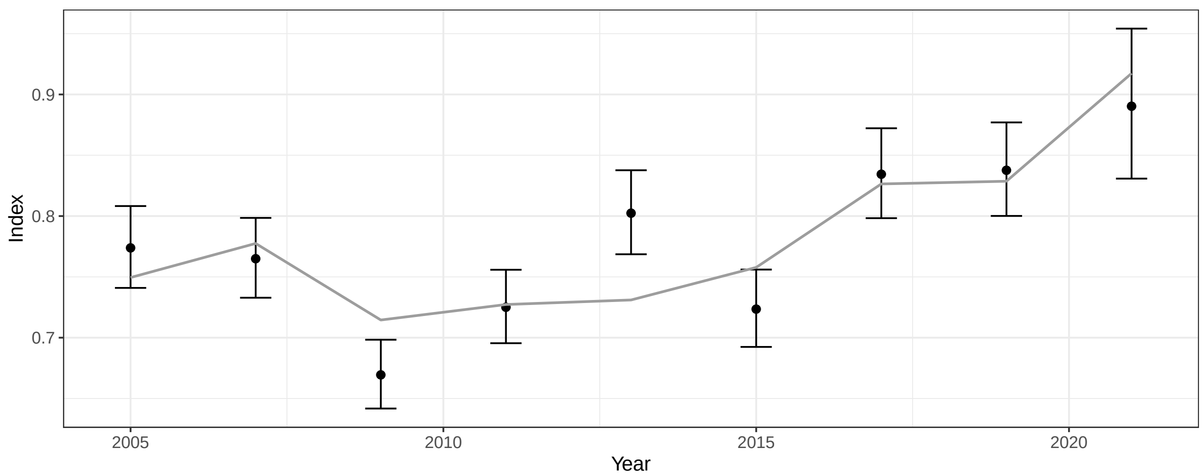

Figure B.3: Model predictions (grey line) to survey green catch rates for common coral trout

B.2.2 Length compositions

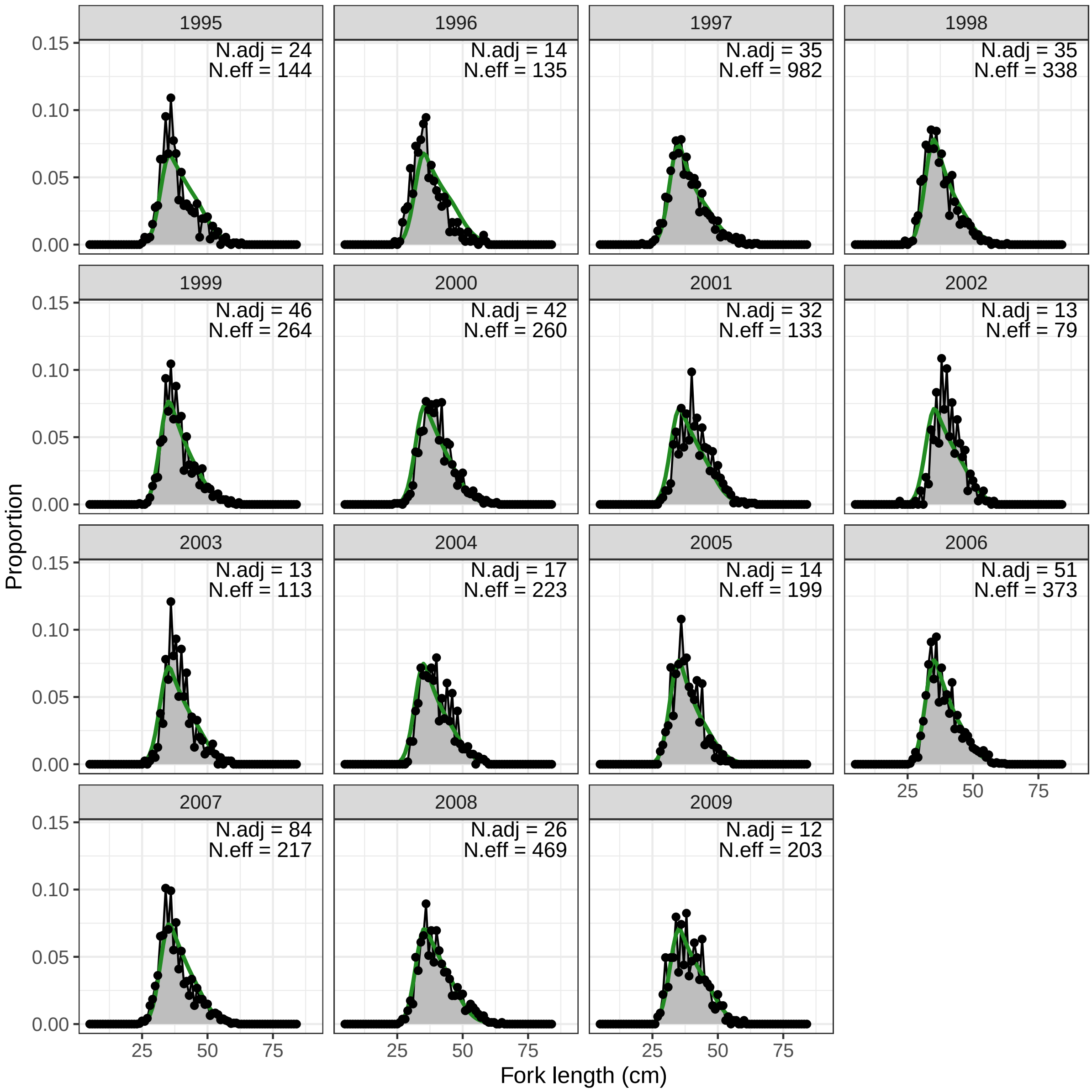

Figure B.4: Fits to length structures for the blue fishery fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

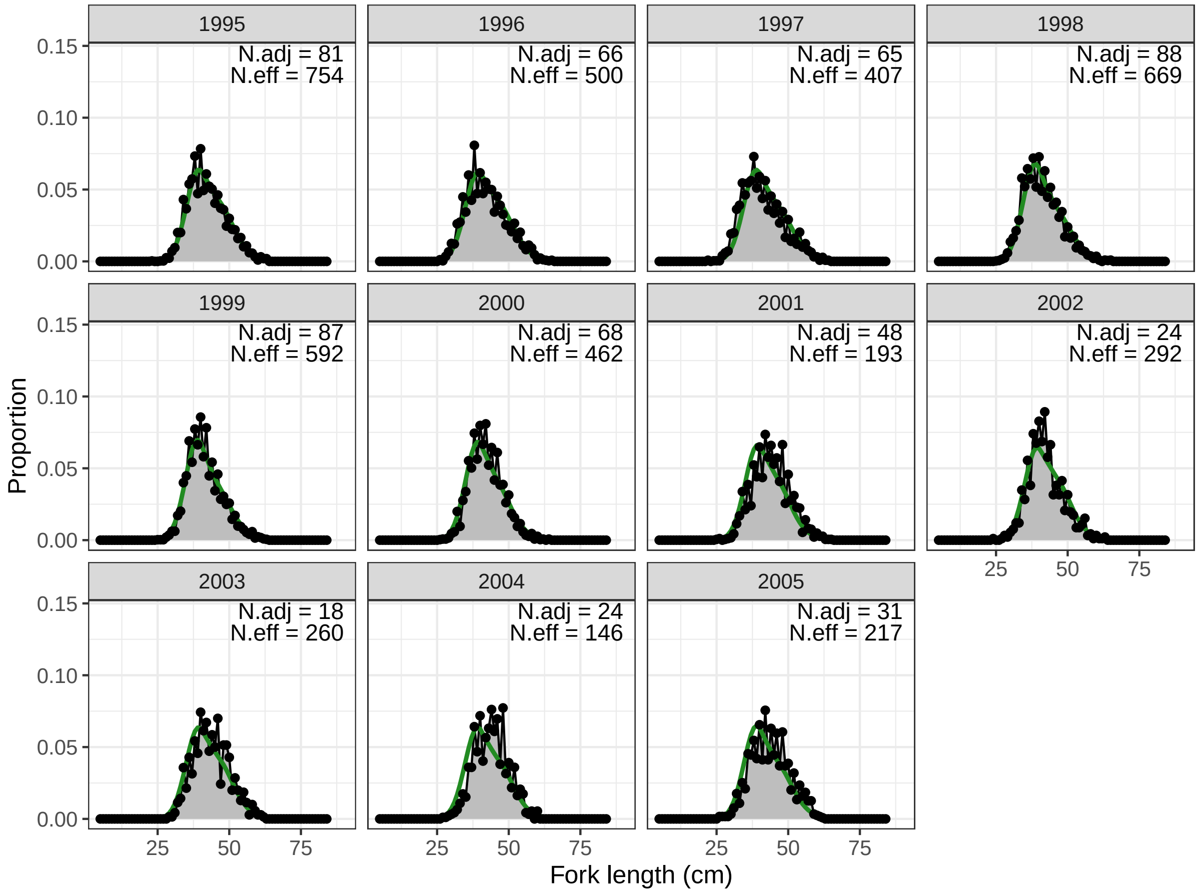

Figure B.5: Fits to length structures for the green fishery fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

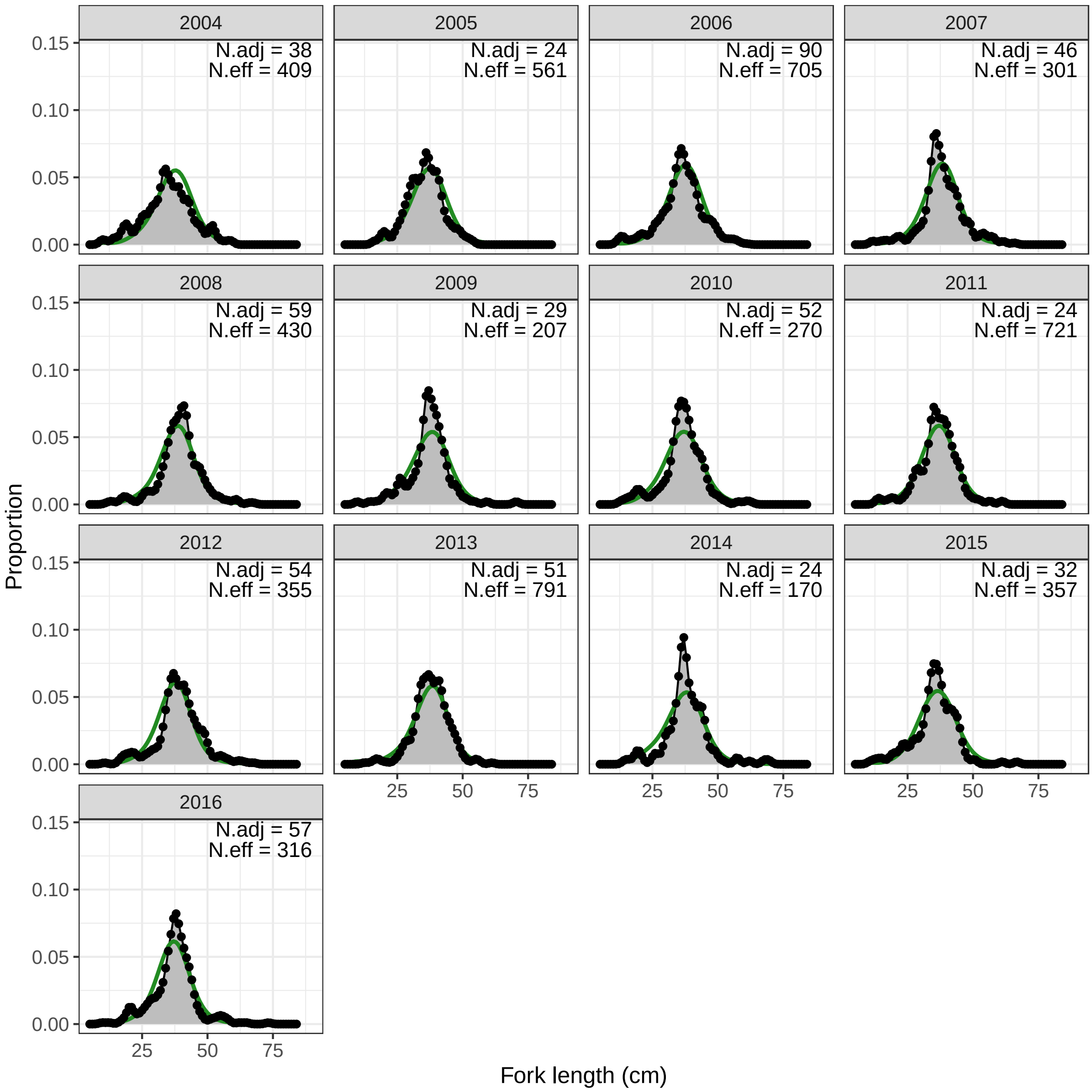

Figure B.6: Fits to length structures for the blue survey fleet

Note: ‘N adj.’ is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method’

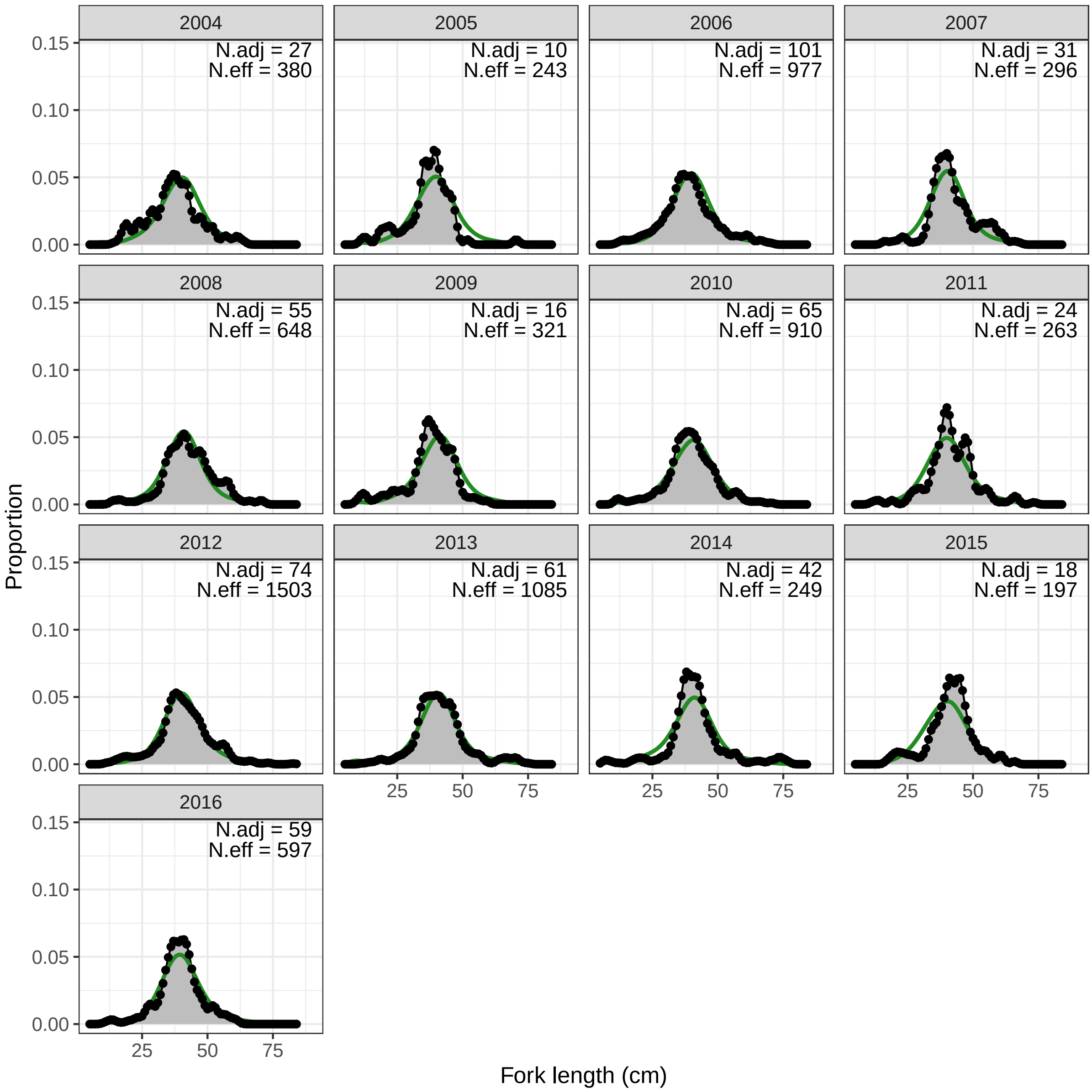

Figure B.7: Fits to length structures for the green survey fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

B.2.3 Conditional age-at-length compositions

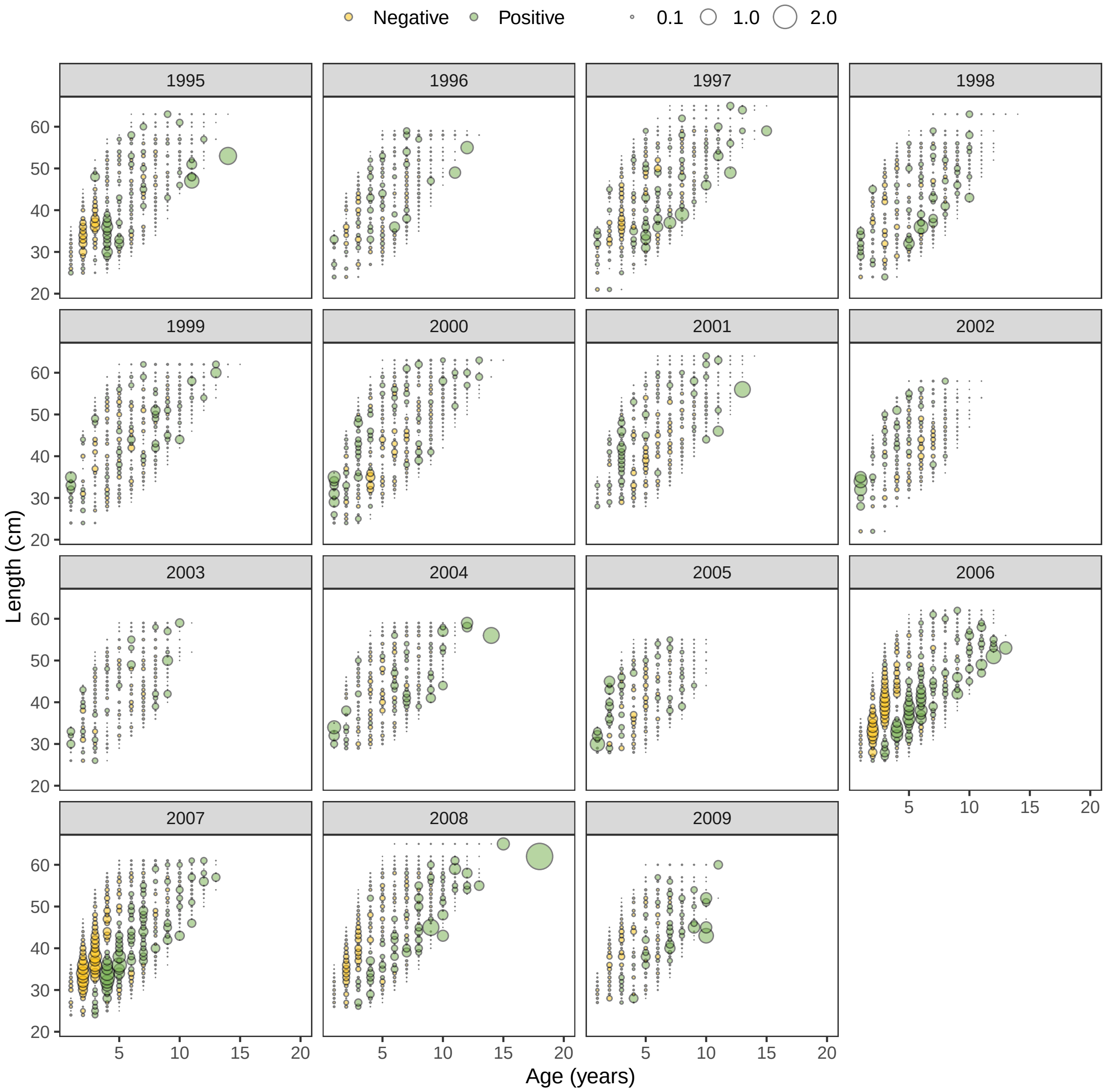

Figure B.8: Pearson residuals for age-at-length compositions for the blue fishery for coral trout—circle size represents the magnitude of the Pearson residual

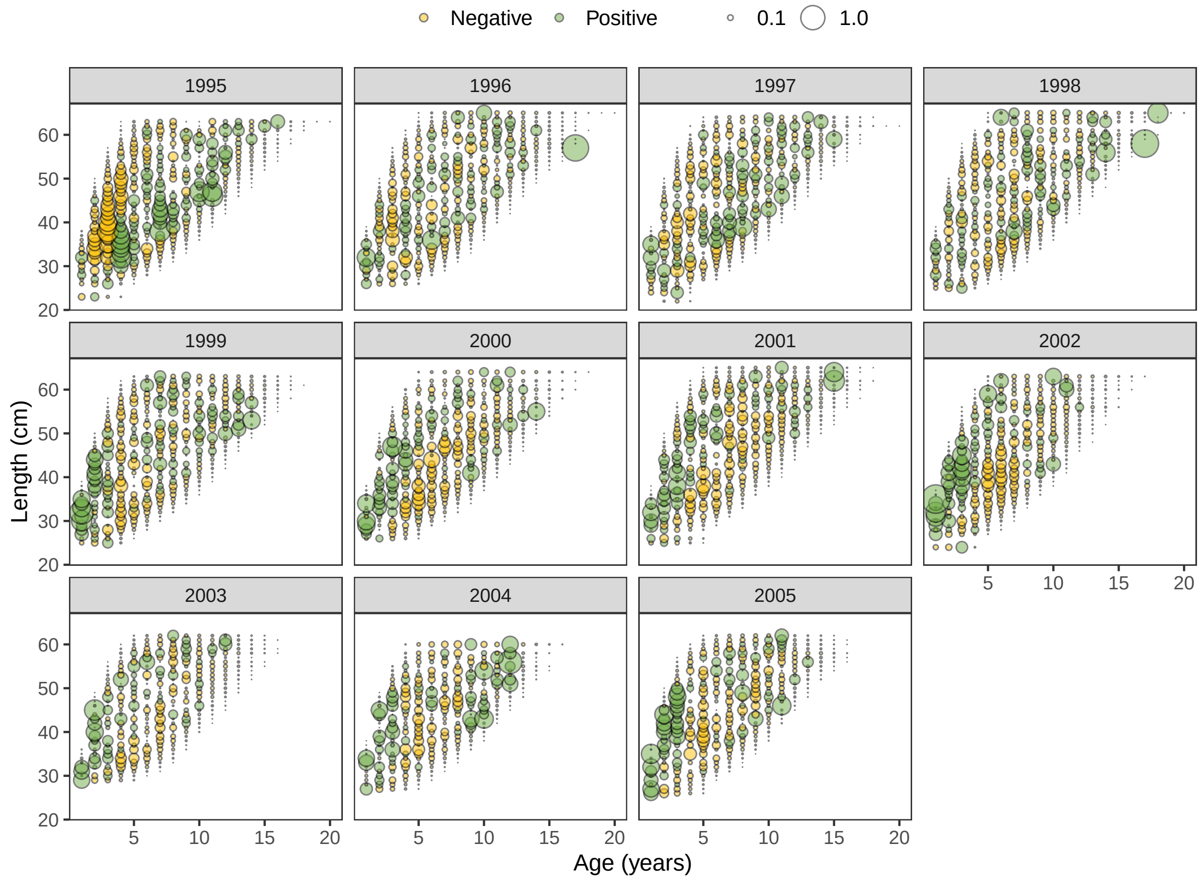

Figure B.9: Pearson residuals for age-at-length compositions for the green fishery for coral trout—circle size represents the magnitude of the Pearson residual

B.2.4 Discard fraction

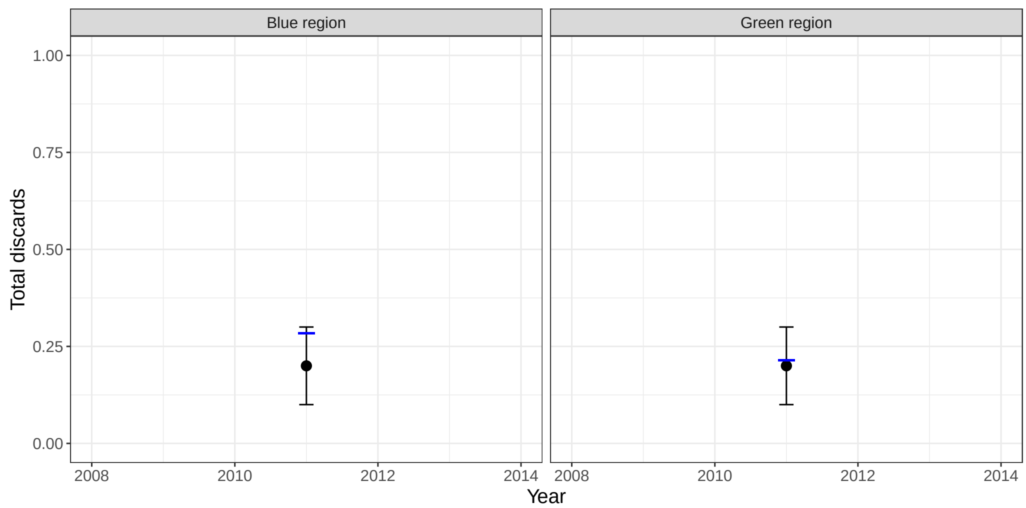

Figure B.10: Fit to discard fraction for the blue fishery (left) and green fishery (right)

B.3 Other outputs

B.3.1 Phase plot

The purpose of this stock assessment was to report on the health of the stock and provide information to support fishery management. Results were assessed and classified against fishery target and limit reference points outlined in the harvest strategy and harvest strategy policy for Queensland.

Separate to this report and other Queensland government reporting, stock assessment results may be used and cited in separate 'Status of Australian Fish Stocks' (SAFS) reports (www.fish.gov.au). The SAFS classification system applies different inferences and reference points.

The SAFS classification system was designed by the Status of Australian Fish Stocks Reports Advisory Group. The classification system evaluates the status of a stock based on the fishing mortality (F) and biomass (B) relative to a 20% biological limit reference point. The status of a stock is classified as sustainable, depleting, depleted, recovering, negligible or undefined. The terms 'sustainable stock' and 'stock status' in the Status of Australian Fish Stocks Reports 2020 refer specifically to the biological status against the limit reference point.

Broader biological, economic or social considerations are not yet classified in SAFS, such as biomass reference points at maximum sustainable yield (B_{MSY}) or biomass at maximum economic yield (B_{MEY}). B_{MSY} generally ranges 35–40%, when harvest from surplus production (the annual amount by which the fish population would increase from growth and recruitment) is maximized (Punt et al. 2014). B_{MEY} generally ranges 50–60%, minimising potential loss in profit (Punt et al. 2014).

A phase plot assists in defining SAFS stock status relative to limit reference points for biomass and fishing mortality (FRDC 2021). The plot tracks the annual stock biomass ratio relative to the unfished level, and fishing mortality relative to the target reference point for the biomass limit (Figure B.1).

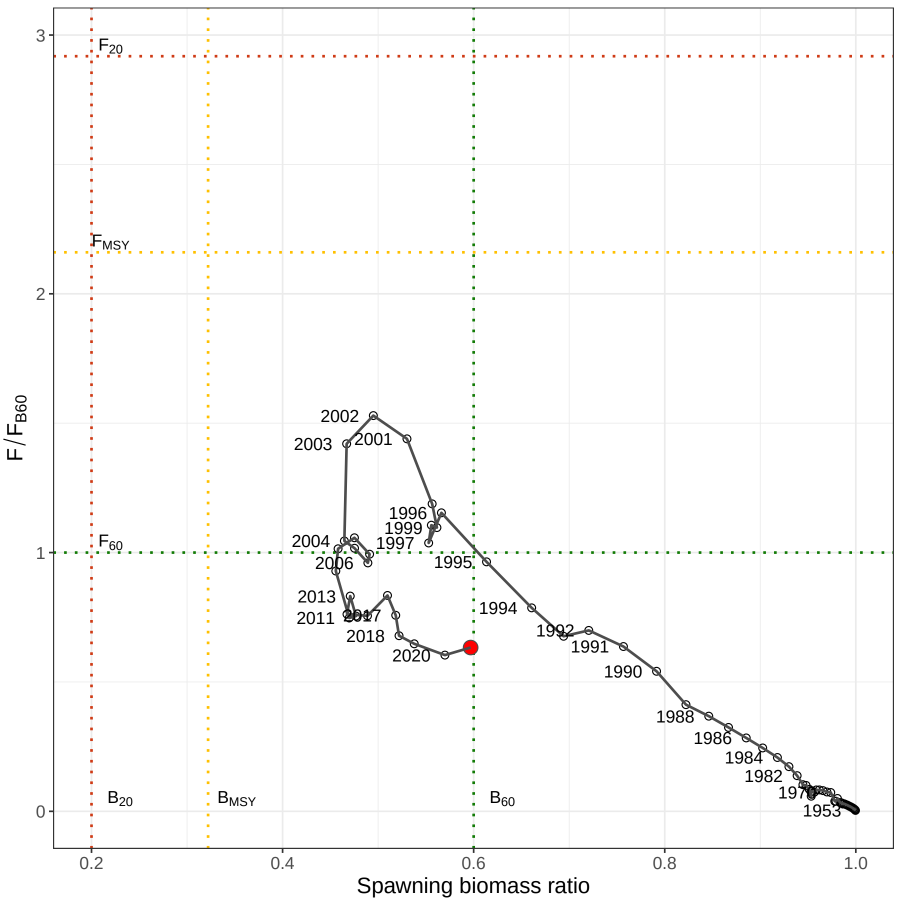

Figure B.11: Phase plot for common coral trout

The horizontal axis is the spawning biomass ratio of Queensland common coral trout 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

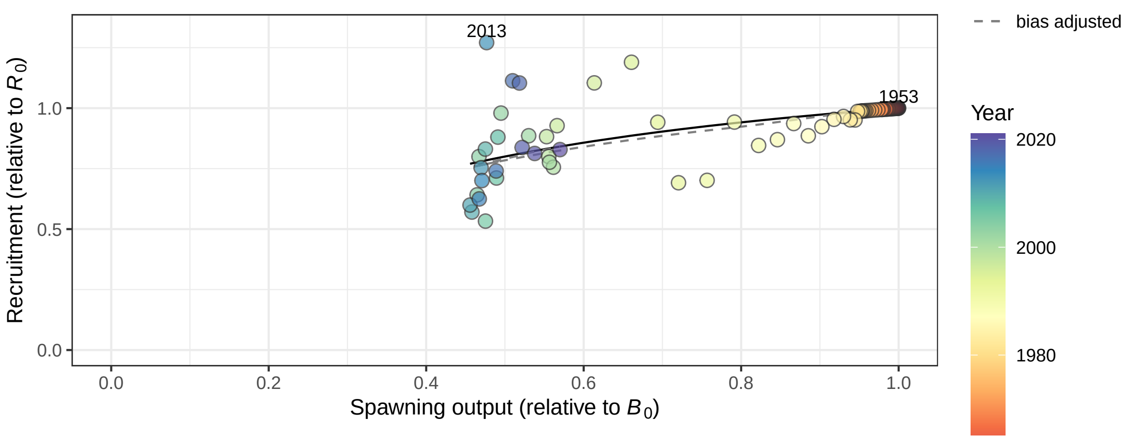

Figure B.12: Stock-recruit curve for common coral trout

C Sensitivity tests: model outputs

C.1 Scenario 2: Six fleets

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

Stock Synthesis parameter label	Estimate	Phase	Min	Max	Initial value	Standard deviation
NatM_uniform	0.276	8	0.01	0.99	0.3	0.0187
L_at_Amin	11.9	2	0	30	15	1.01
L_at_Amax	69	3	50	90	70	1.07
VonBert_K	0.164	2	0.01	0.3	0.14	0.0101
CV_young	0.307	4	0.05	0.5	0.27	0.0227
CV_old	0.076	6	0.001	0.2	0.1	0.0103
RecrDist_GP_1_area_2_month_1	0.081	10	-5	5	0.018	0.277
SR_LN(R0)	9.65	1	5	15	10	0.192
SizeSel_P1_FISHERY_BLUE	37.7	5	30	50	36	0.693
SizeSel_P2_FISHERY_BLUE	-2.13	5	-25	15	-6	0.416
SizeSel_P3_FISHERY_BLUE	3.35	5	0	5	3	0.183
SizeSel_P4_FISHERY_BLUE	4.4	5	3	9	5	0.279
SizeSel_P5_FISHERY_BLUE	-16.3	5	-40	30	-12	164
SizeSpline_GradLo_SURVEY_BLUE	0.217	3	-0.001	0.4	0	0.0221
SizeSpline_Val_1_SURVEY_BLUE	-4.78	2	-8	-1	-5	0.19
SizeSpline_Val_2_SURVEY_BLUE	-1.15	2	-5	0	-2	0.0804
SizeSpline_Val_4_SURVEY_BLUE	-3.59	2	-6	0	-3	0.27
SizeSpline_GradLo_SURVEY_GREEN	0.175	3	-0.001	0.4	0.18	0.0242
SizeSpline_Val_1_SURVEY_GREEN	-4.72	2	-7	-2	-5	0.218
SizeSpline_Val_2_SURVEY_GREEN	-1.39	2	-5	0	-2	0.082
SizeSpline_Val_4_SURVEY_GREEN	-2.83	2	-5	0	-2	0.194
SizeSel_P1_FISHERY_BLUEDEADREC(5	42.2	5	30	50	38	0.207
SizeSel_P2_FISHERY_BLUEDEADREC(5	-1.98	5	-25	15	-6	0.166
SizeSel_P3_FISHERY_BLUEDEADREC(5	2.95	5	0	5	3	0.0674
SizeSel_P4_FISHERY_BLUEDEADREC(5	5.53	5	3	9	5	0.221
SizeSel_P5_FISHERY_BLUEDEADREC(5	-11.4	5	-40	30	-12	8.01

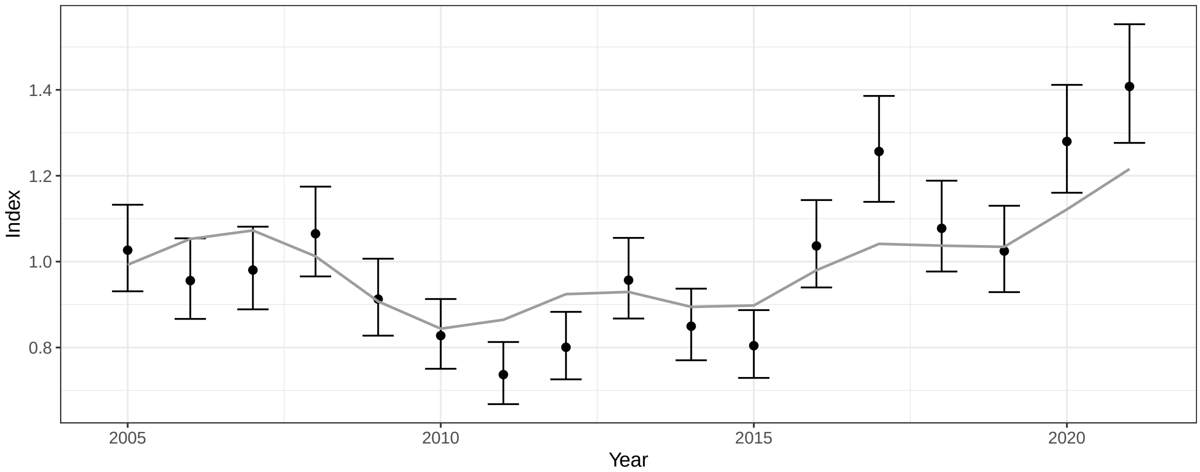

Figure C.1: Scenario 2: Model predictions (grey line) to fishery blue catch rates for live common coral trout

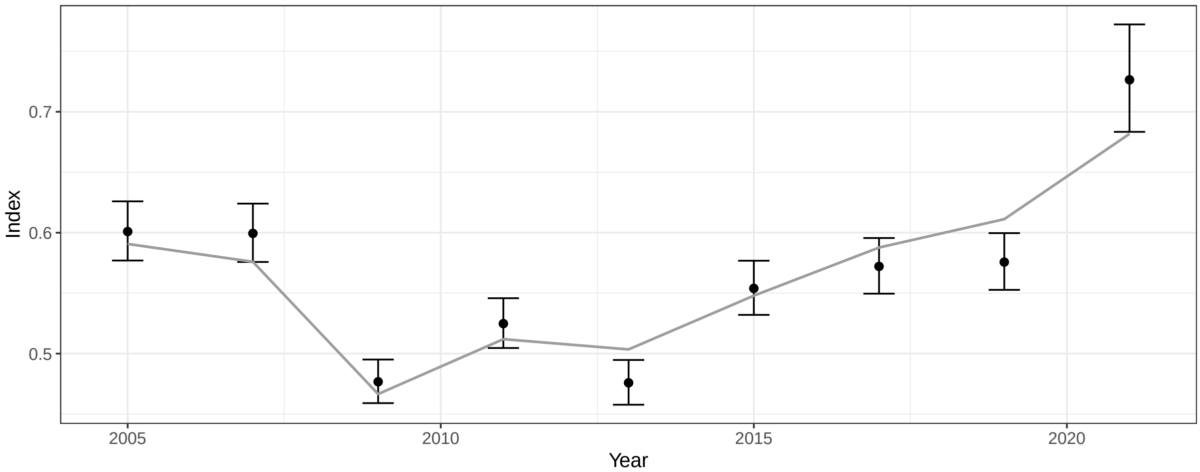

Figure C.2: Scenario 2: Model predictions (grey line) to survey blue catch rates for common coral trout

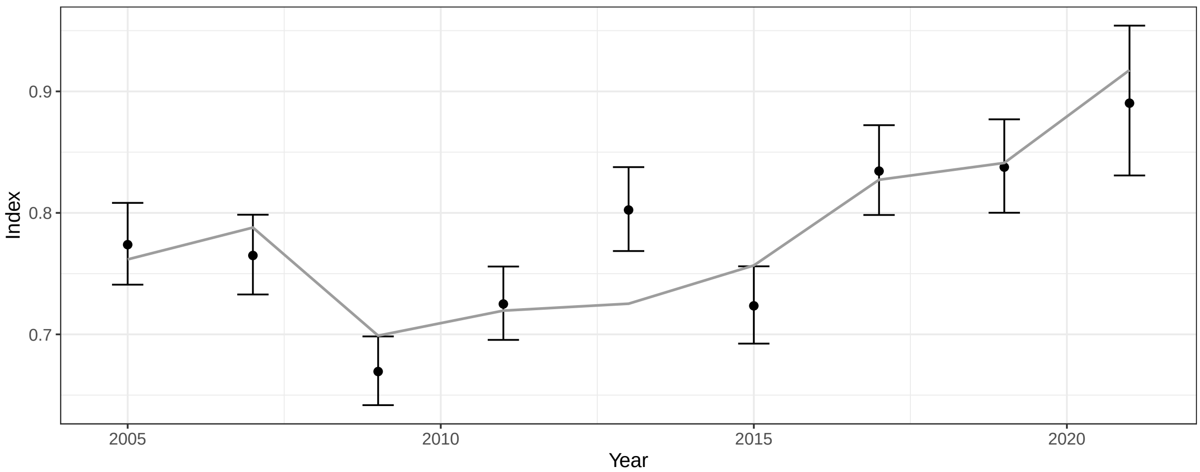

Figure C.3: Scenario 2: Model predictions (grey line) to survey green catch rates for common coral trout

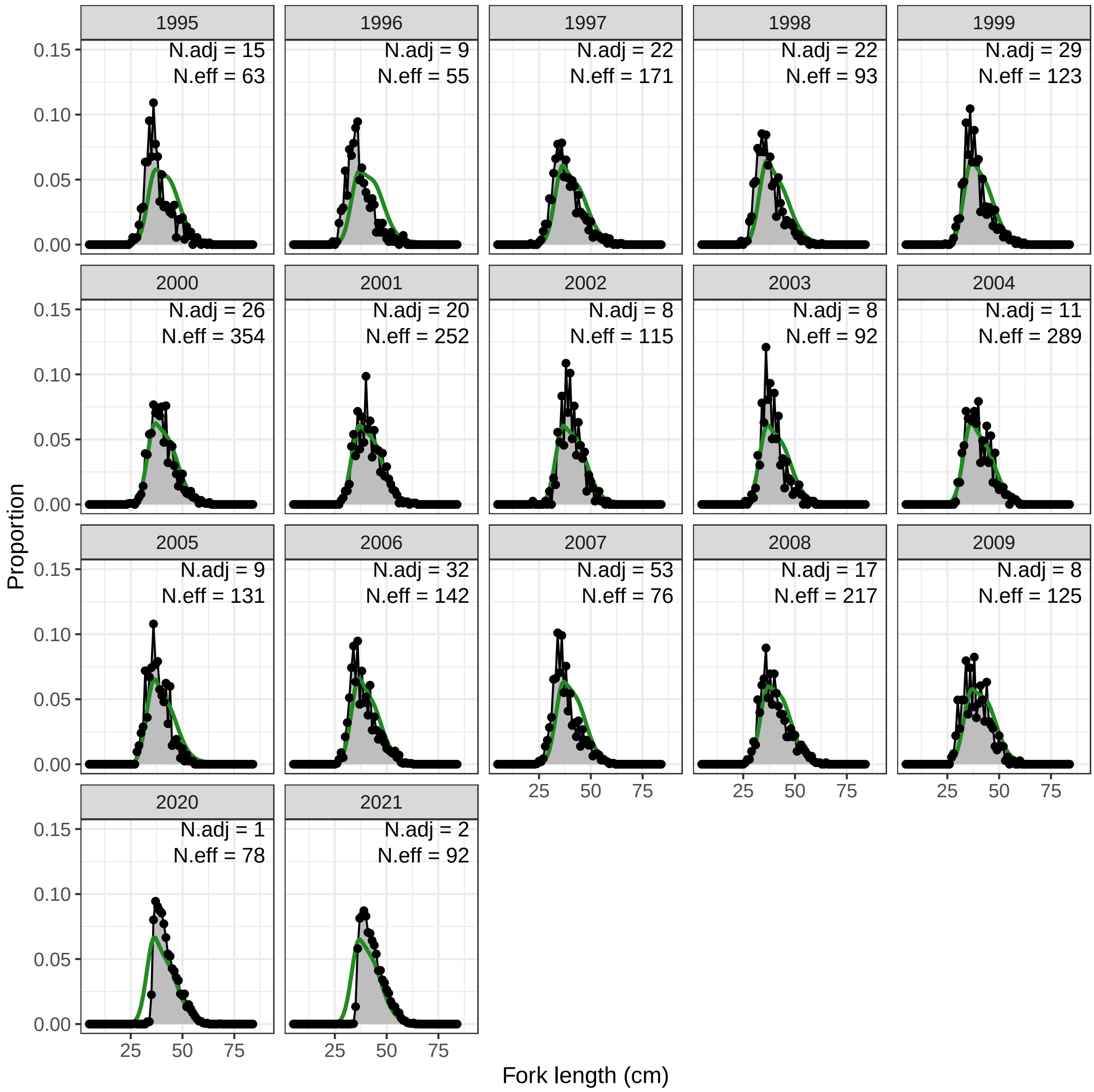

Figure C.4: Scenario 2: Fits to length structures for the blue live fishery fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

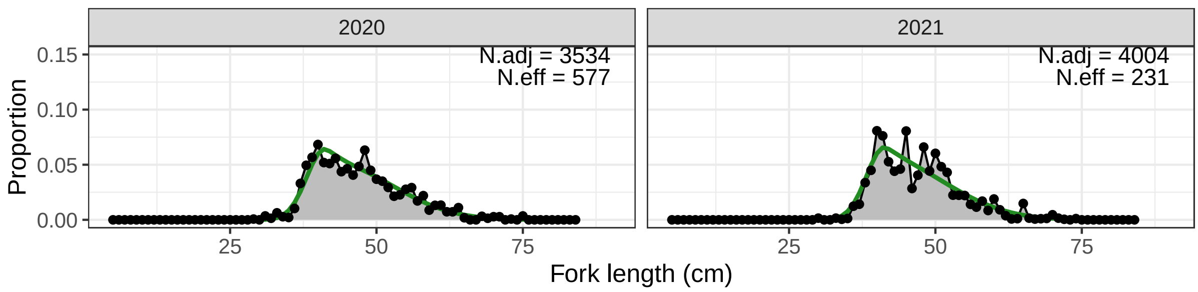

Figure C.5: Scenario 2: Fits to length structures for the blue dead and recreational fishery fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

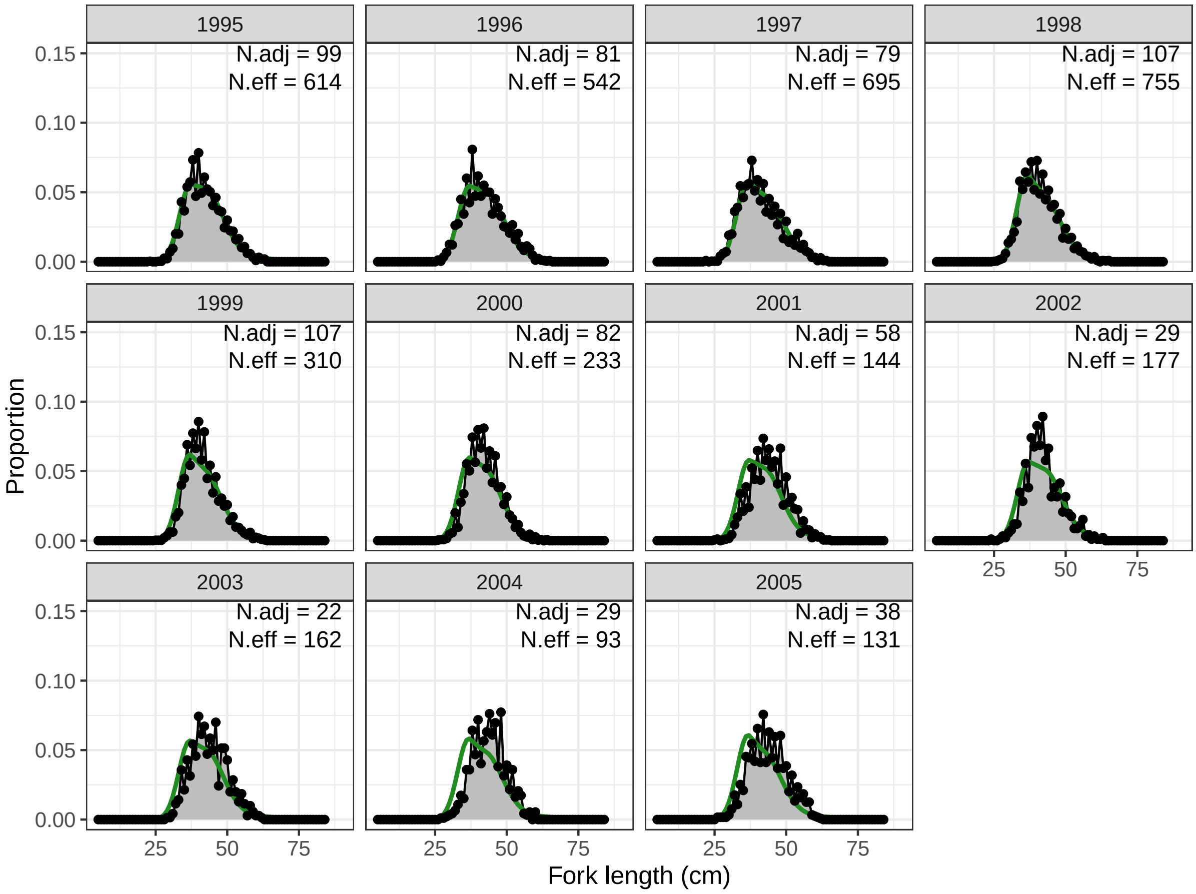

Figure C.6: Scenario 2: Fits to length structures for the green fishery fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

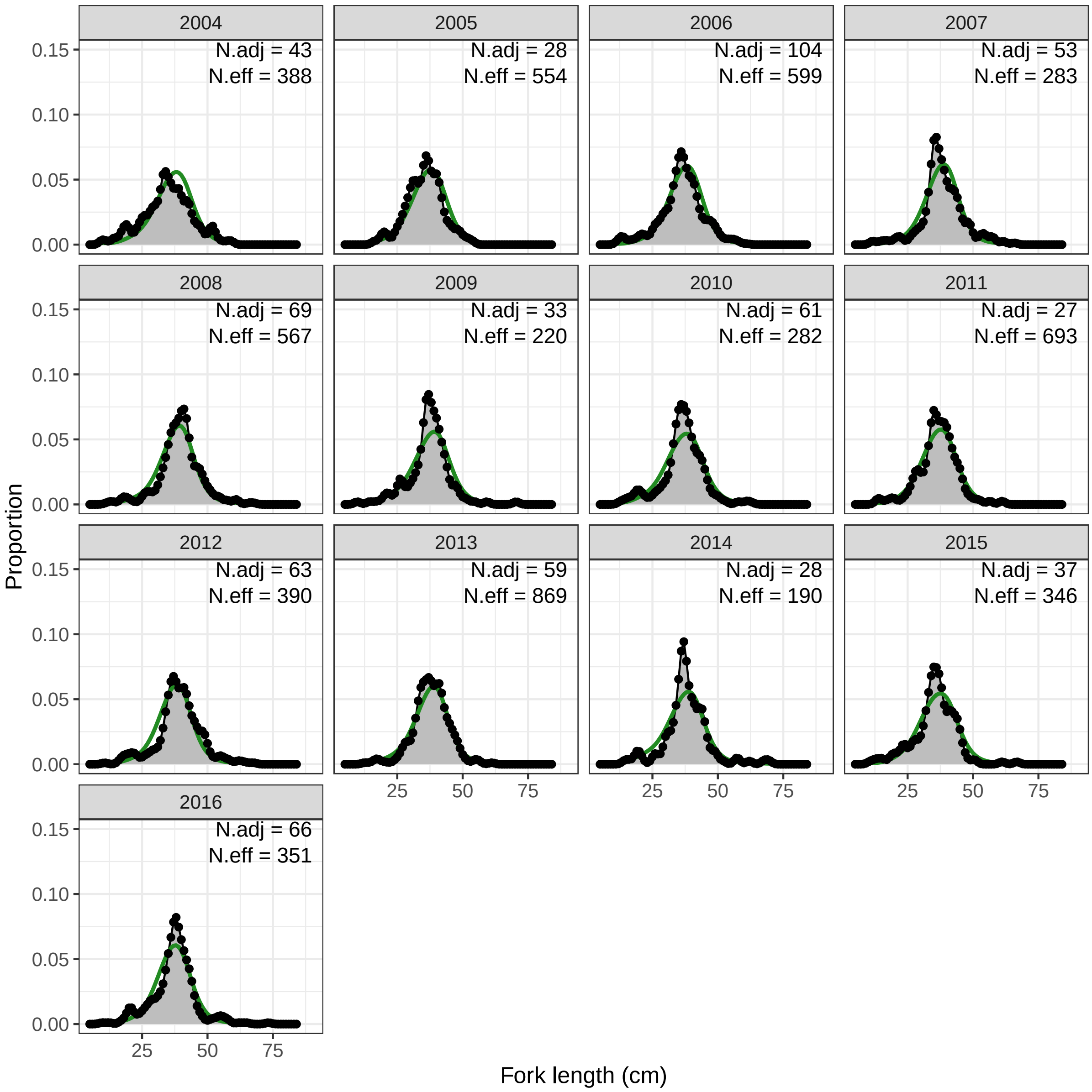

Figure C.7: Scenario 2: Fits to length structures for the blue survey fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

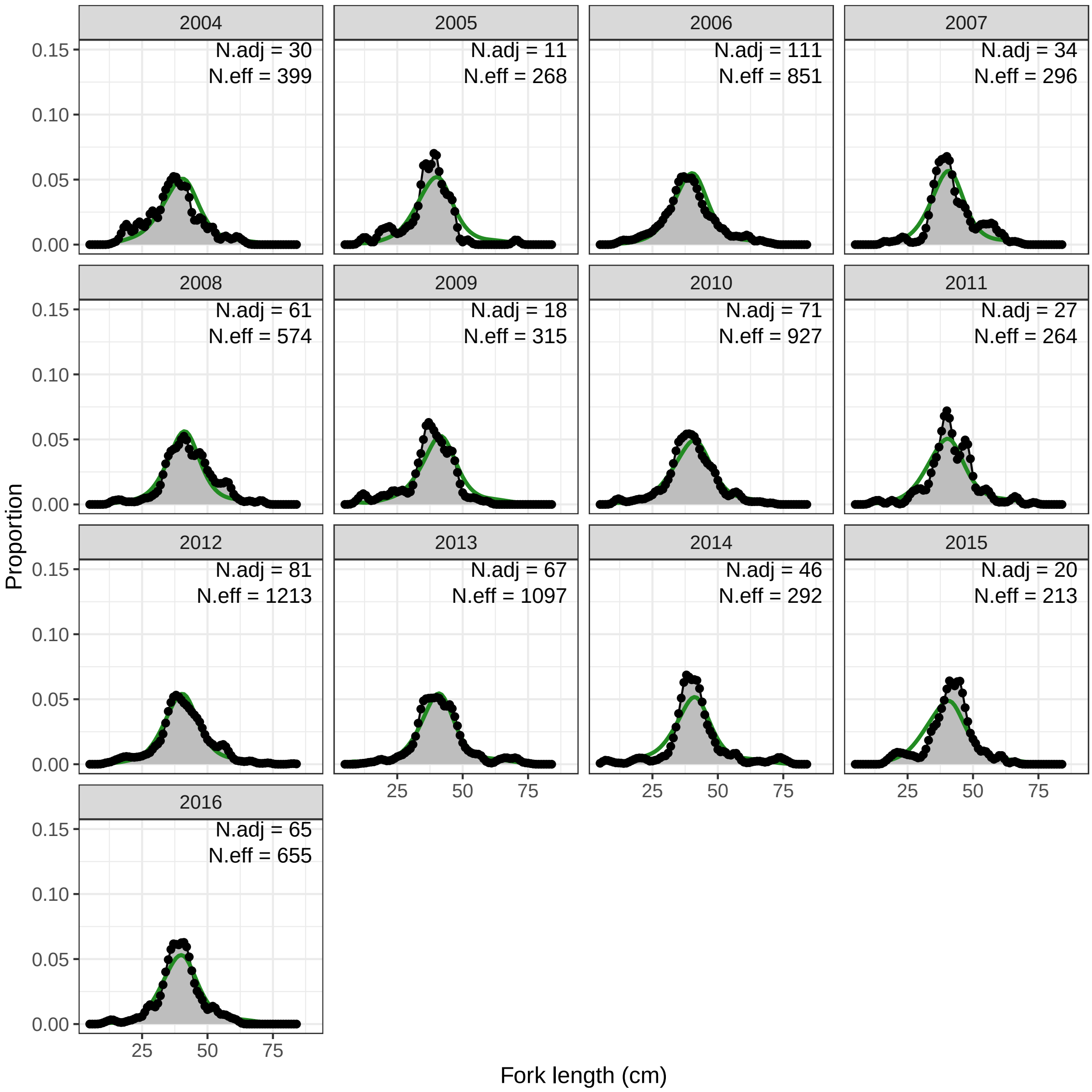

Figure C.8: Scenario 2: Fits to length structures for the green survey fleet

Note: ‘N adj.’ is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method’

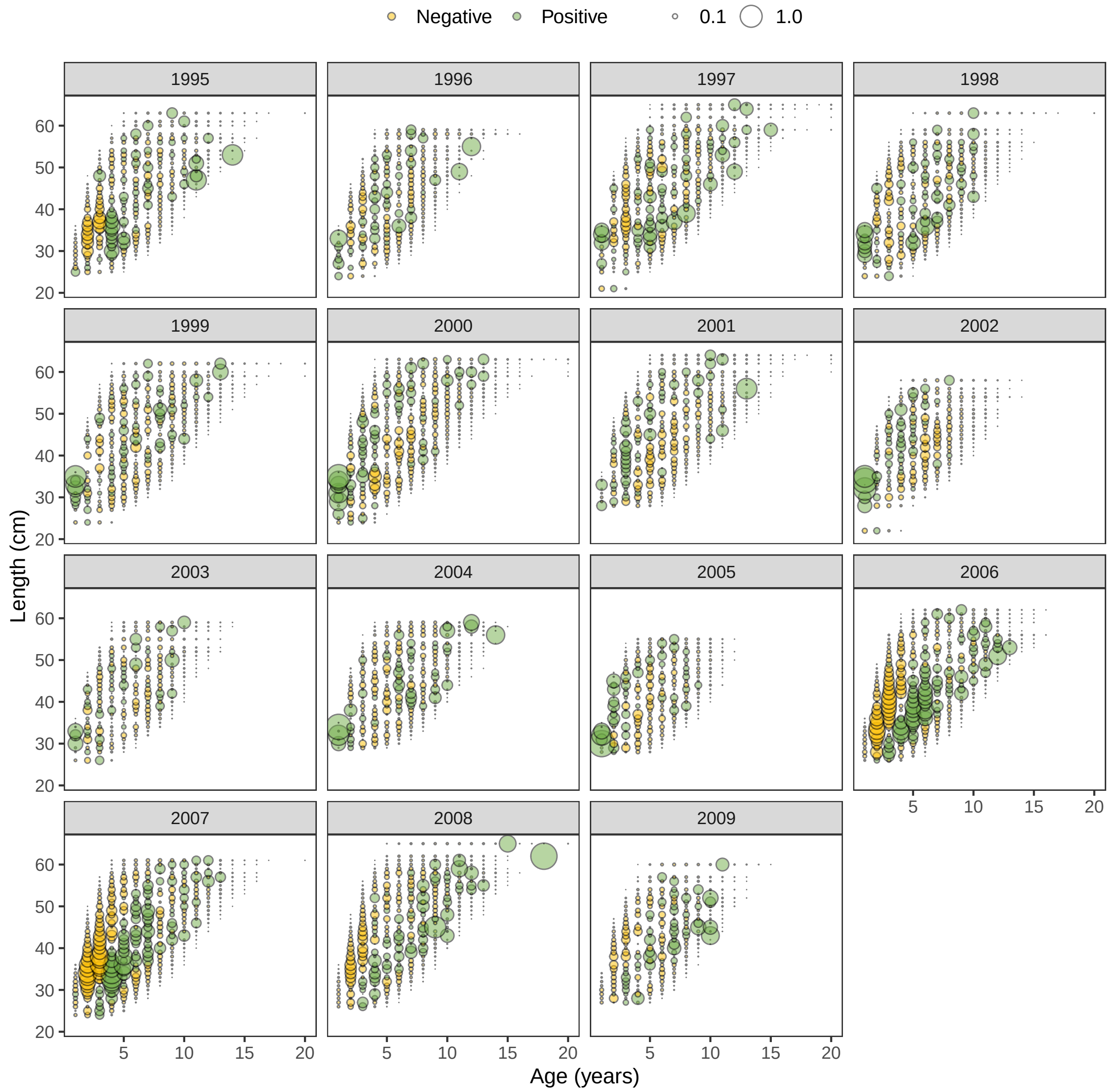

Figure C.9: Scenario 2: Pearson residuals for age-at-length compositions for the blue fishery for coral trout—circle size represents the magnitude of the Pearson residual

Figure C.10: Scenario 2: Pearson residuals for age-at-length compositions for the blue fishery for coral trout—circle size represents the magnitude of the Pearson residual

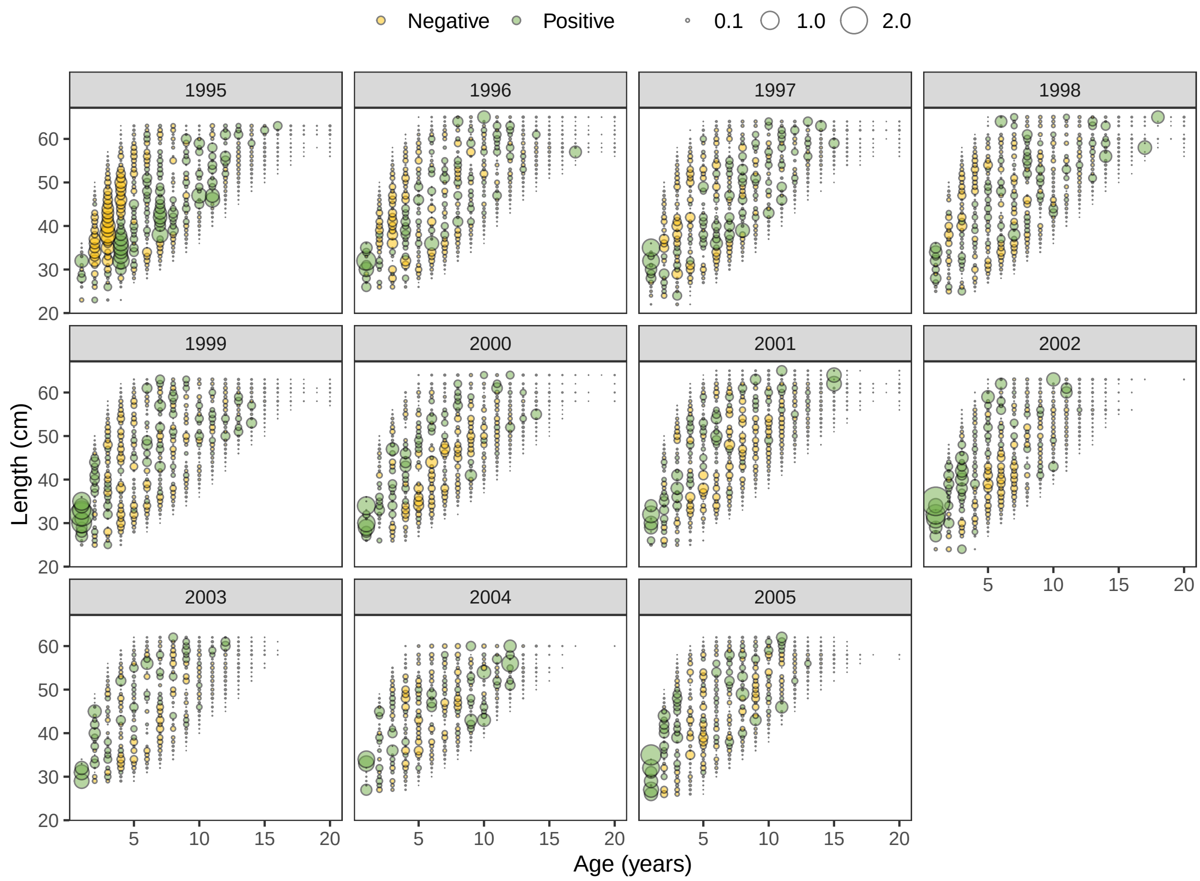

Figure C.11: Scenario 2: Pearson residuals for age-at-length compositions for the green fishery for coral troutr—circle size represents the magnitude of the Pearson residual

C.2 Scenario 3: Asymptotic selectivity

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

Stock Synthesis parameter label	Estimate	Phase	Min	Max	Initial value	Standard deviation
NatM_uniform	0.58	8	0.01	0.99	0.3	0.0355
L_at_Amin	13.8	2	0	30	15	0.908
L_at_Amax	69.7	3	50	90	70	3.23
VonBert_K	0.1	2	0.01	0.3	0.14	0.0188
CV_young	0.29	4	0.05	0.5	0.27	0.0252
CV_old	0.0762	6	0.001	0.2	0.1	0.0247
RecrDist_GP_1_area_1_month_1	0	-4	0	0	0	NA
SR_LN(R0)	11.4	1	5	15	10	0.244
SizeSel_P1_FISHERY_BLUE	37.9	5	30	50	36	0.899
SizeSel_P2_FISHERY_BLUE	-0.654	5	-25	15	-6	0.478
SizeSel_P3_FISHERY_BLUE	3.31	5	0	5	3	0.215
SizeSel_P4_FISHERY_BLUE	3.73	5	3	9	5	1.67
SizeSel_P5_FISHERY_BLUE	-17.3	5	-40	30	-12	163
Retain_L_infl_FISHERY_BLUE	39.6	4	20	50	36	1.43
SizeSel_P1_FISHERY_GREEN	43.4	5	30	50	43	0.933
SizeSel_P2_FISHERY_GREEN	-1.04	5	-5	3	-1	0.666
SizeSel_P3_FISHERY_GREEN	3.9	5	0	7	4	0.15
SizeSel_P4_FISHERY_GREEN	3.75	5	2	8	5	1.5
SizeSel_P5_FISHERY_GREEN	-17.4	5	-25	15	-12	83.8
Retain_L_infl_FISHERY_GREEN	35.4	4	30	55	42	3.83
Size_inflection_SURVEY_BLUE	36.3	5	20	50	35	0.691
Size_95%width_SURVEY_BLUE	10	5	1	12	5	0.486
Size_inflection_SURVEY_GREEN	38	5	20	50	35	0.853
Size_95%width_SURVEY_GREEN	11	5	1	12	5	0.579

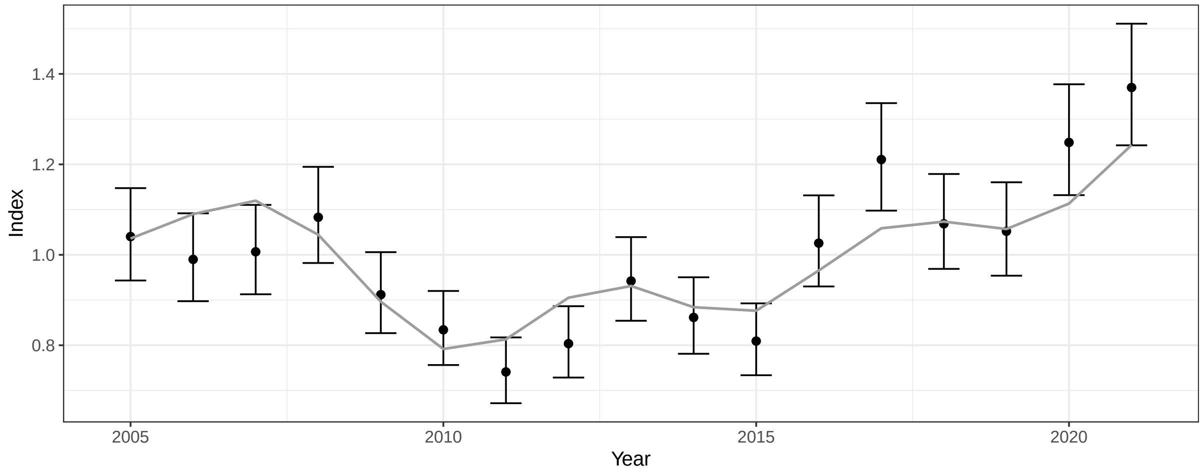

Figure C.12: Scenario 3: Model predictions (grey line) to fishery blue catch rates for live common coral trout

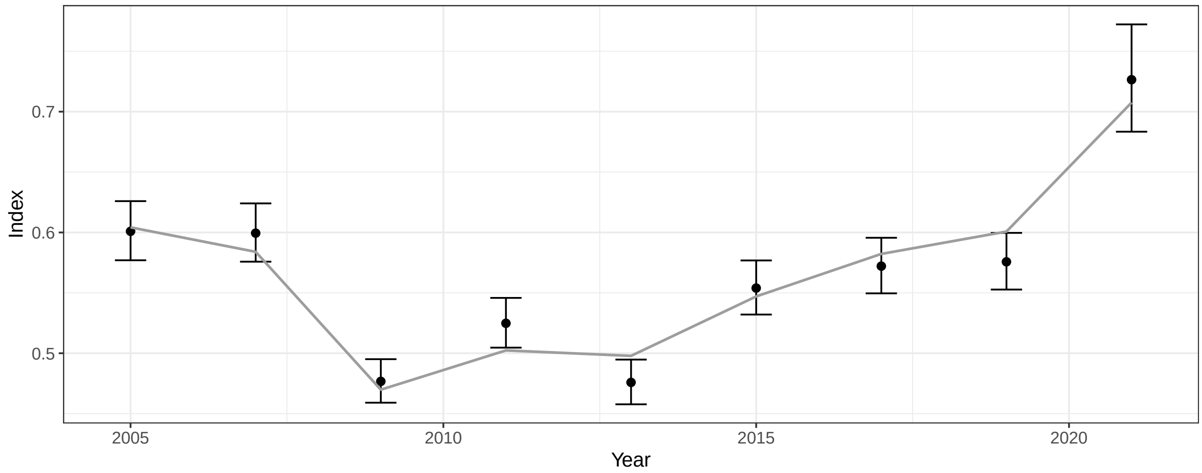

Figure C.13: Scenario 3: Model predictions (grey line) to survey blue catch rates for common coral trout

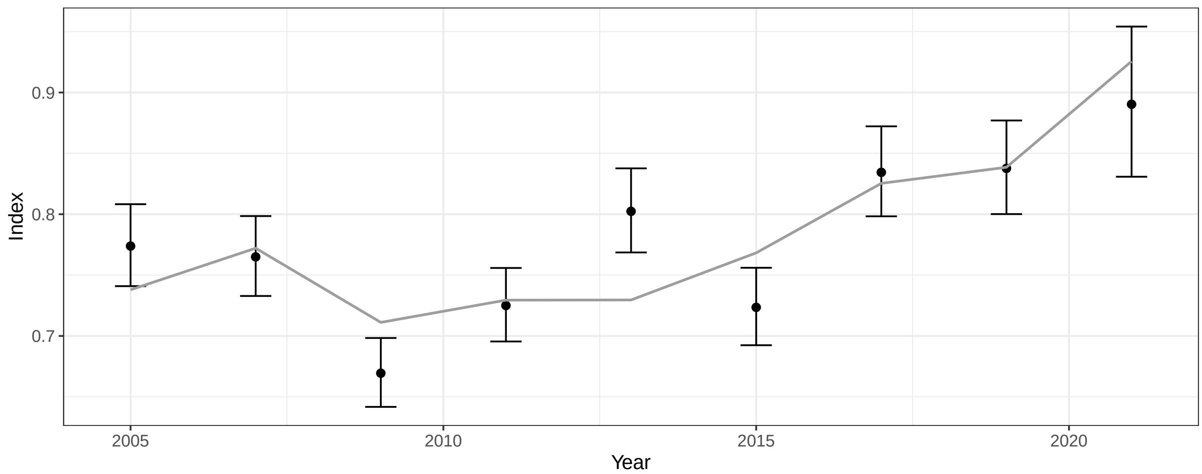

Figure C.14: Scenario 3: Model predictions (grey line) to survey green catch rates for common coral trout

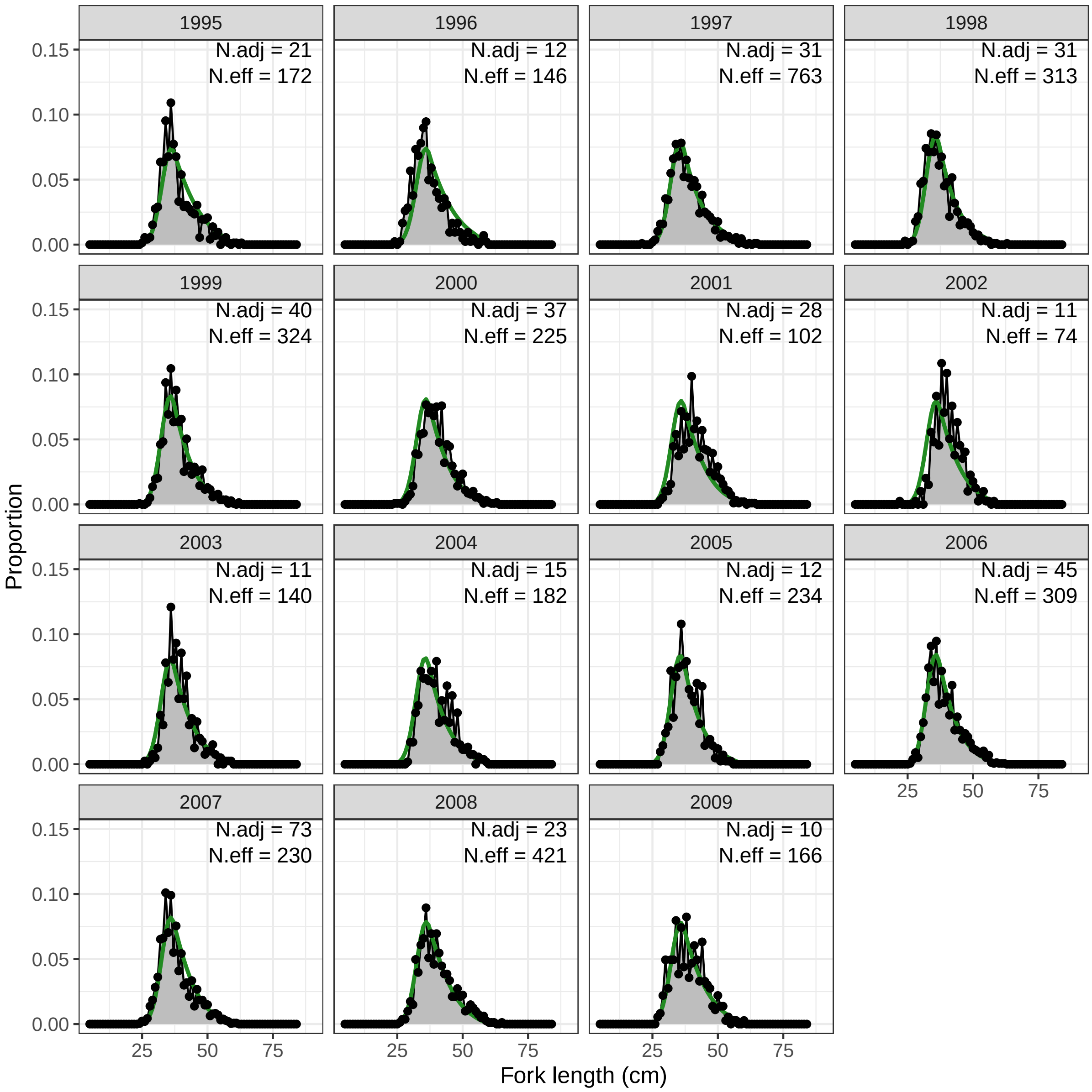

Figure C.15: Scenario 3: Fits to length structures for the blue live fishery fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

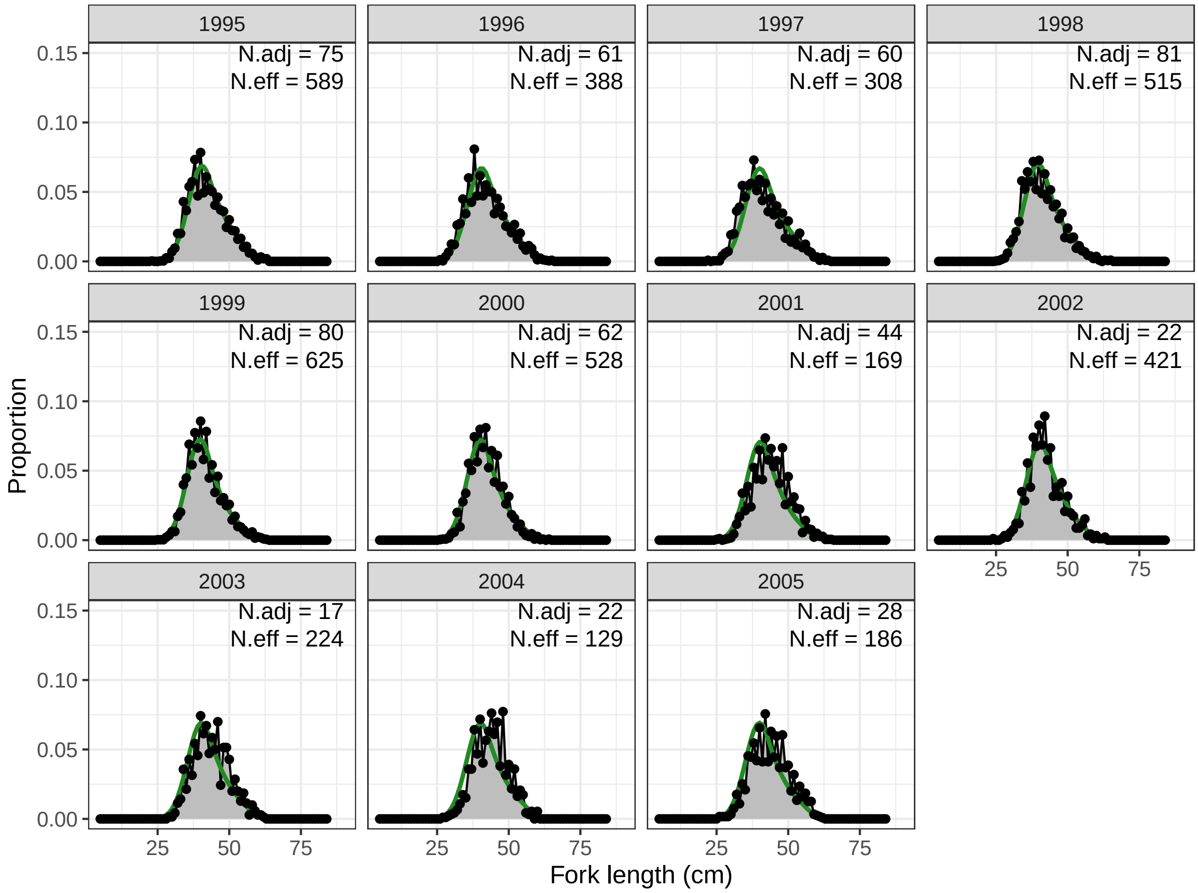

Figure C.16: Scenario 3: Fits to length structures for the green fishery fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

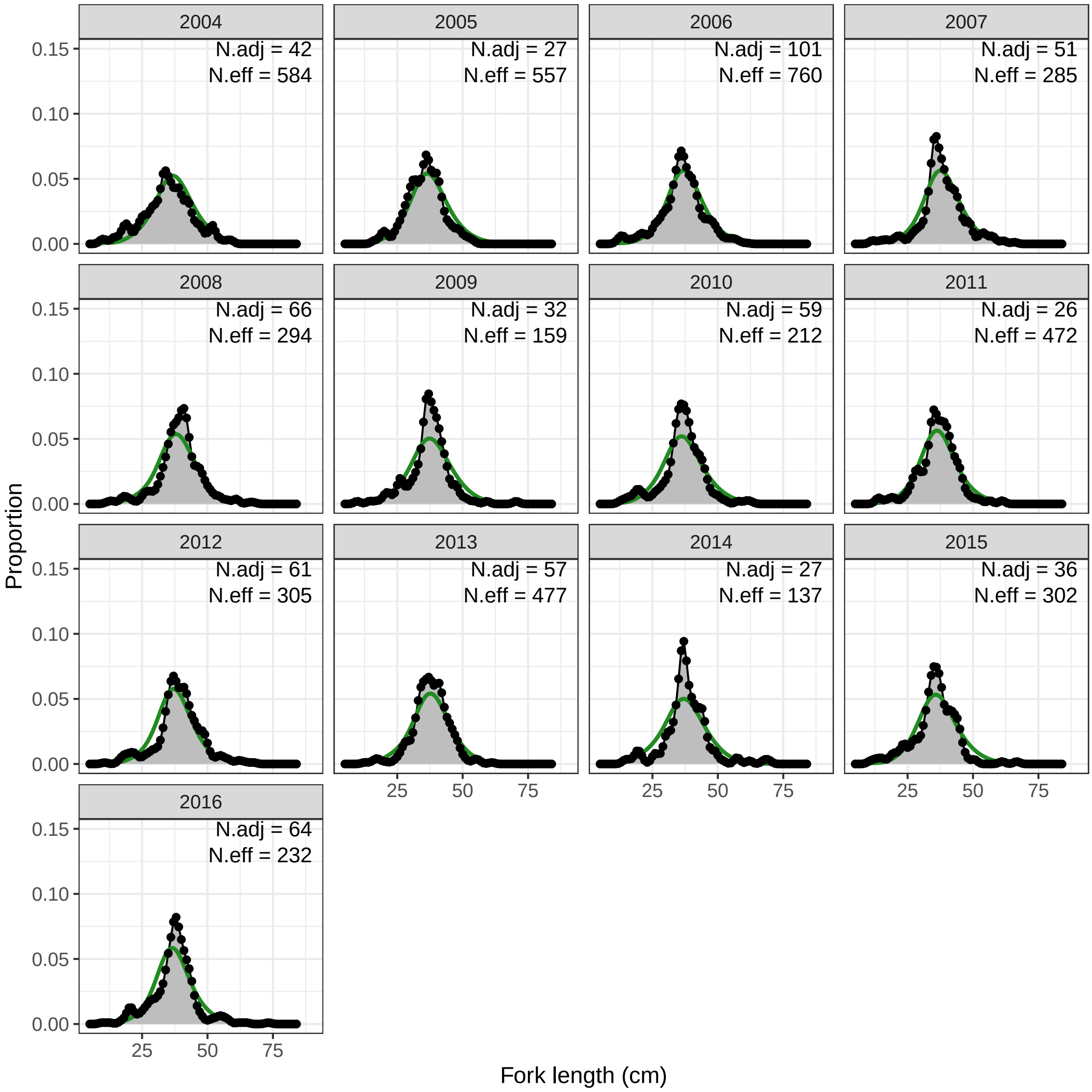

Figure C.17: Scenario 3: Fits to length structures for the blue survey fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

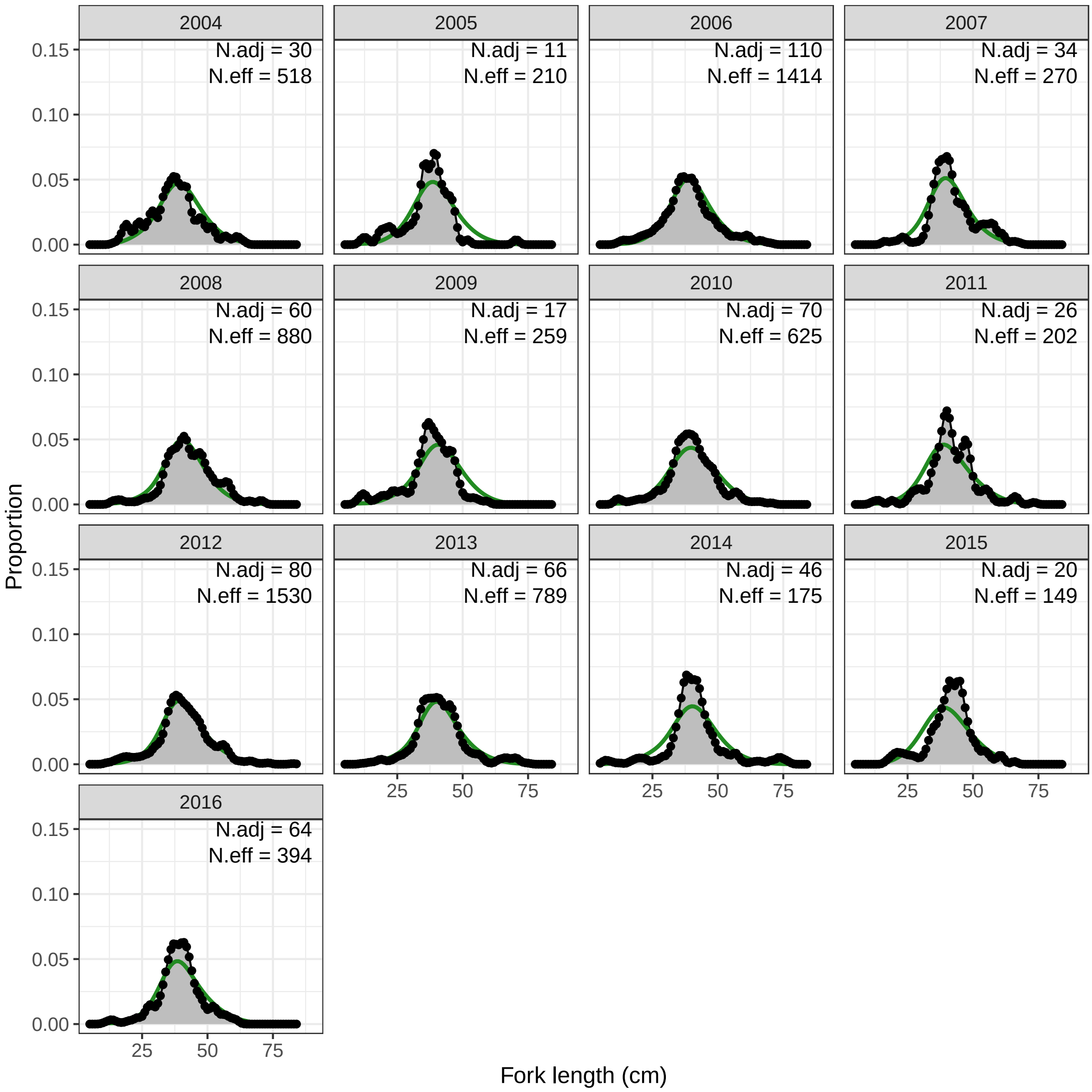

Figure C.18: Scenario 3: Fits to length structures for the green survey fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

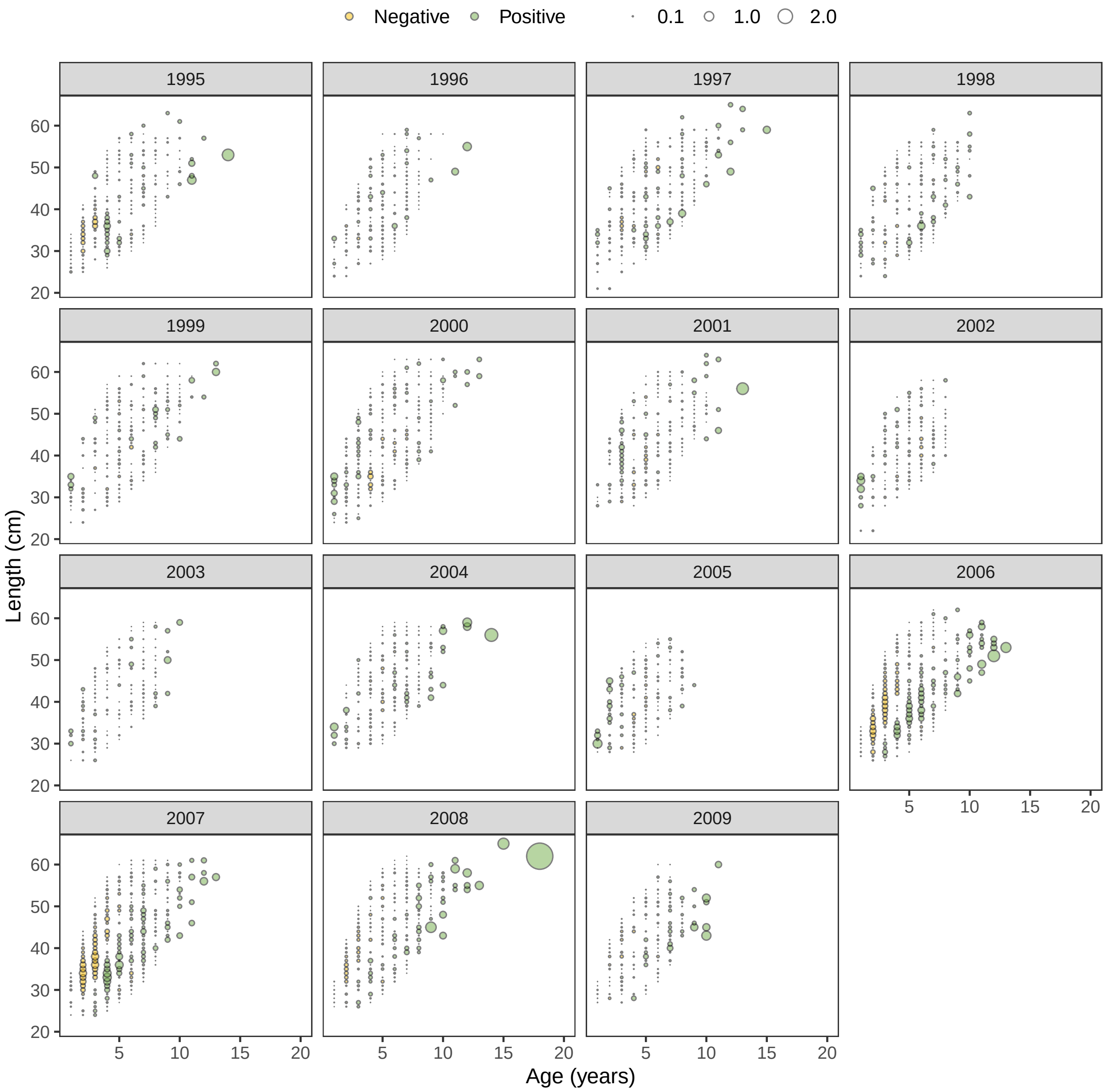

Figure C.19: Scenario 3: Pearson residuals for age-at-length compositions for the blue fishery for coral trout—circle size represents the magnitude of the Pearson residual

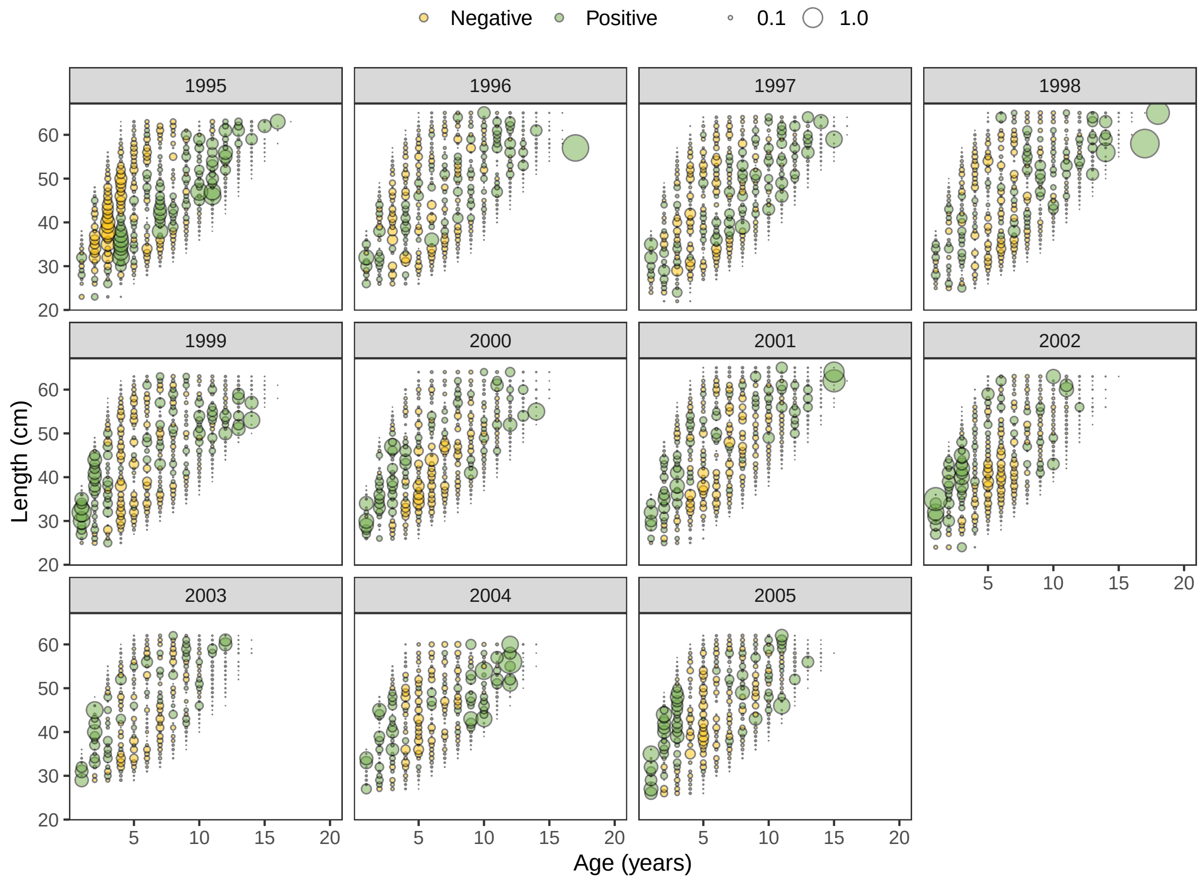

Figure C.20: Scenario 3: Pearson residuals for age-at-length compositions for the green fishery for coral troutr—circle size represents the magnitude of the Pearson residual

C.3 Scenario 4: M

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

Stock Synthesis parameter label	Estimate	Phase	Min	Max	Initial value	Standard deviation
NatM_uniform	0.2	-8	0.01	0.99	0.2	NA
L_at_Amin	14	2	0	30	15	1.08
L_at_Amax	65.2	3	50	90	70	1.17
VonBert_K	0.176	2	0.01	0.3	0.14	0.0136
CV_young	0.272	4	0.05	0.5	0.27	0.0203
CV_old	0.0646	6	0.001	0.2	0.1	0.00809
RecrDist_GP_1_area_2_month_1	0.355	4	-5	5	0	0.265
SR_LN(R0)	9.27	1	5	15	10	0.127
SizeSel_P1_FISHERY_BLUE	35.7	5	30	50	36	0.737
SizeSel_P2_FISHERY_BLUE	-2.53	5	-25	15	-6	0.818
SizeSel_P3_FISHERY_BLUE	3.06	5	0	5	3	0.232
SizeSel_P4_FISHERY_BLUE	4.68	5	3	9	5	0.358
SizeSel_P5_FISHERY_BLUE	-14.1	5	-40	30	-12	77.6
Retain_L_infl_FISHERY_BLUE	34.5	4	20	50	36	1.88
SizeSel_P1_FISHERY_GREEN	38.8	5	30	50	43	0.769
SizeSel_P2_FISHERY_GREEN	-2.23	5	-5	3	-1	0.487
SizeSel_P3_FISHERY_GREEN	3.45	5	0	7	4	0.203
SizeSel_P4_FISHERY_GREEN	4.24	5	2	8	5	0.307
SizeSel_P5_FISHERY_GREEN	-14.8	5	-25	15	-12	89.9
Retain_L_infl_FISHERY_GREEN	41.2	4	30	55	42	2.69
SizeSpline_GradLo_SURVEY_BLUE	0.2	3	-0.001	0.4	0.19	0.0238
SizeSpline_Val_1_SURVEY_BLUE	-4.74	2	-8	-1	-5	0.203
SizeSpline_Val_2_SURVEY_BLUE	-1.19	2	-5	0	-2	0.09
SizeSpline_Val_4_SURVEY_BLUE	-3.38	2	-6	0	-3	0.299
SizeSpline_GradLo_SURVEY_GREE	0.15	3	-0.001	0.4	0.18	0.0261
SizeSpline_Val_1_SURVEY_GREEN	-4.39	2	-7	-2	-5	0.213
SizeSpline_Val_2_SURVEY_GREEN	-1.29	2	-5	0	-2	0.0863
SizeSpline_Val_4_SURVEY_GREEN	-3.1	2	-5	0	-2	0.182

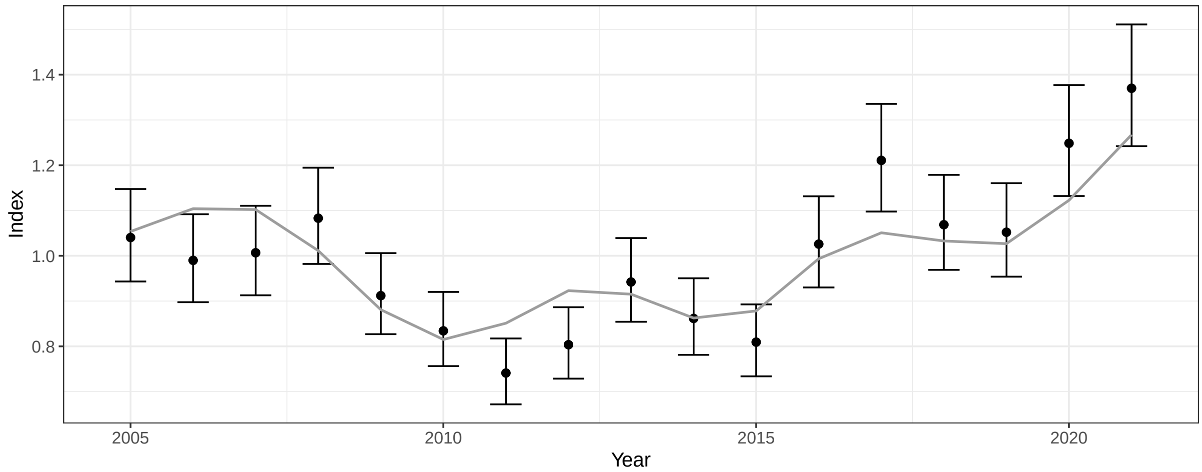

Figure C.21: Scenario 4: Model predictions (grey line) to fishery blue catch rates for live common coral trout

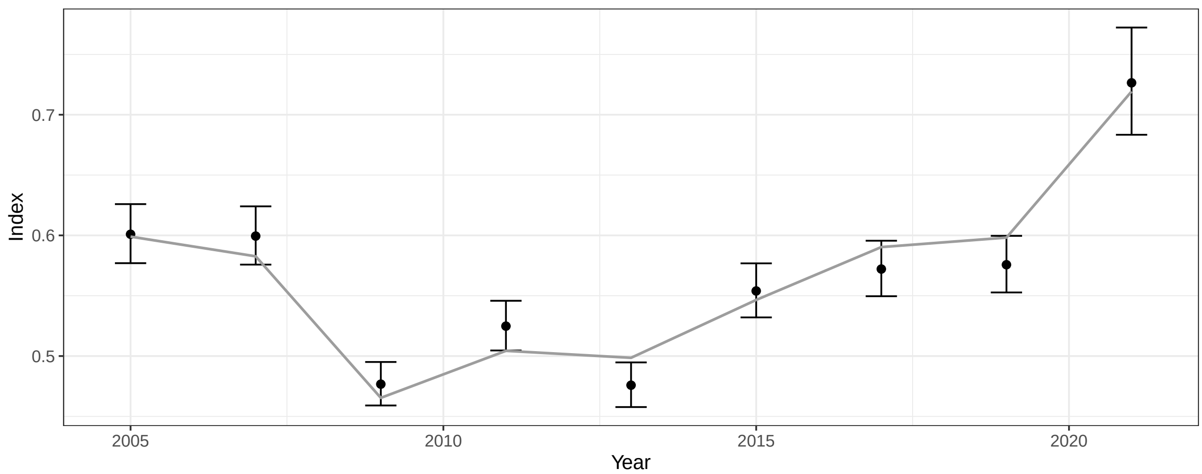

Figure C.22: Scenario 4: Model predictions (grey line) to survey blue catch rates for common coral trout

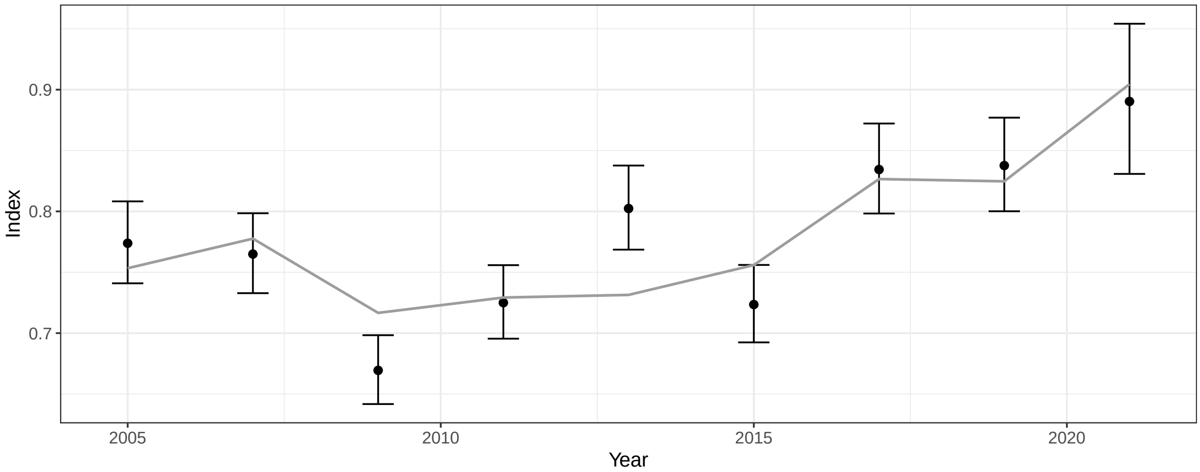

Figure C.23: Scenario 4: Model predictions (grey line) to survey green catch rates for common coral trout

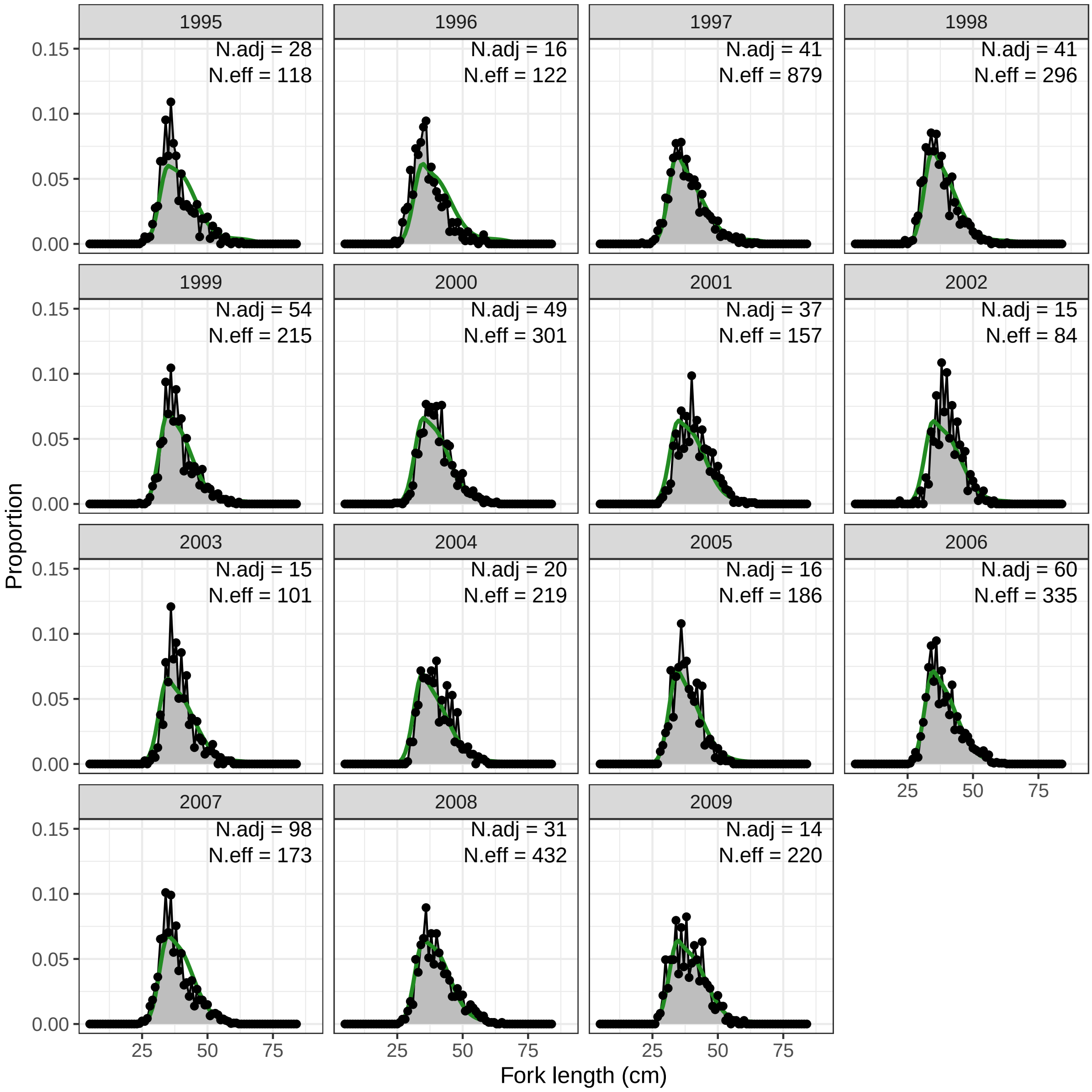

Figure C.24: Scenario 4: Fits to length structures for the blue live fishery fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

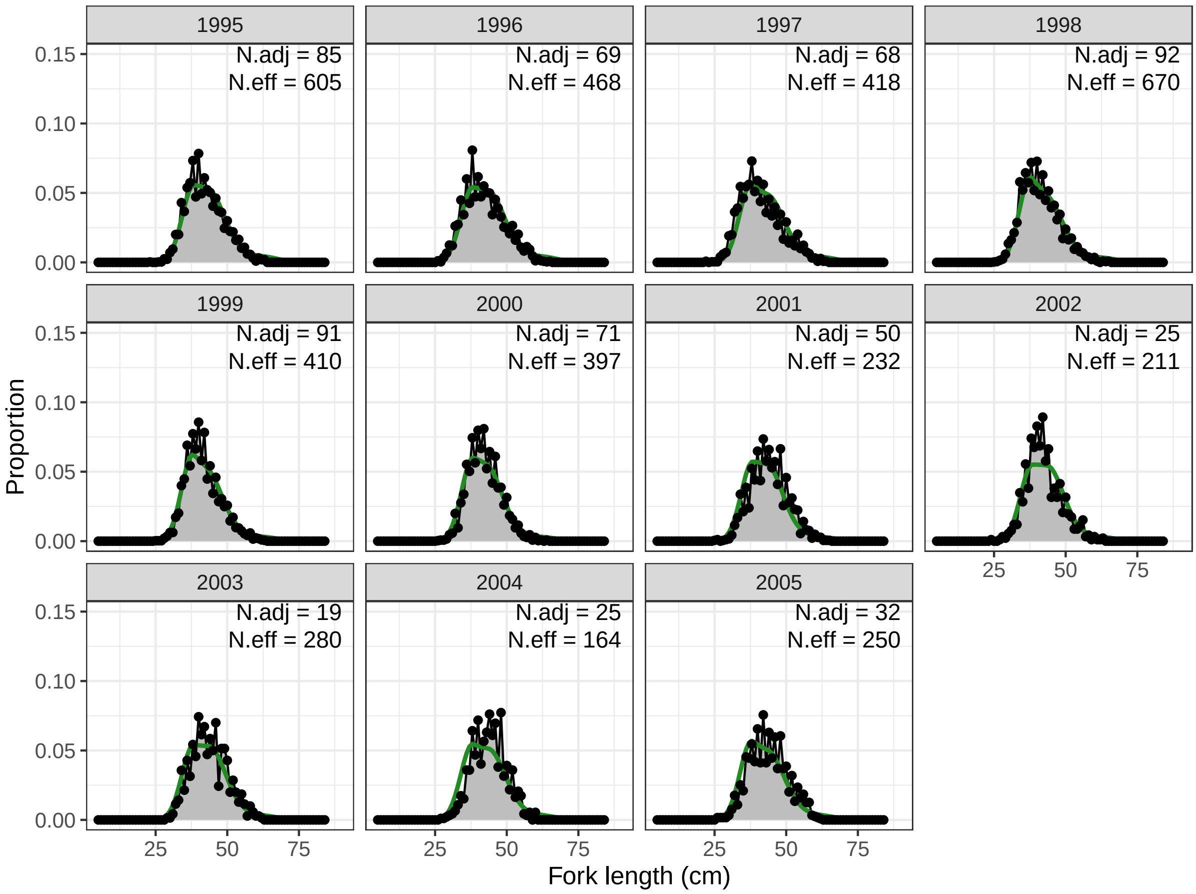

Figure C.25: Scenario 4: Fits to length structures for the green fishery fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

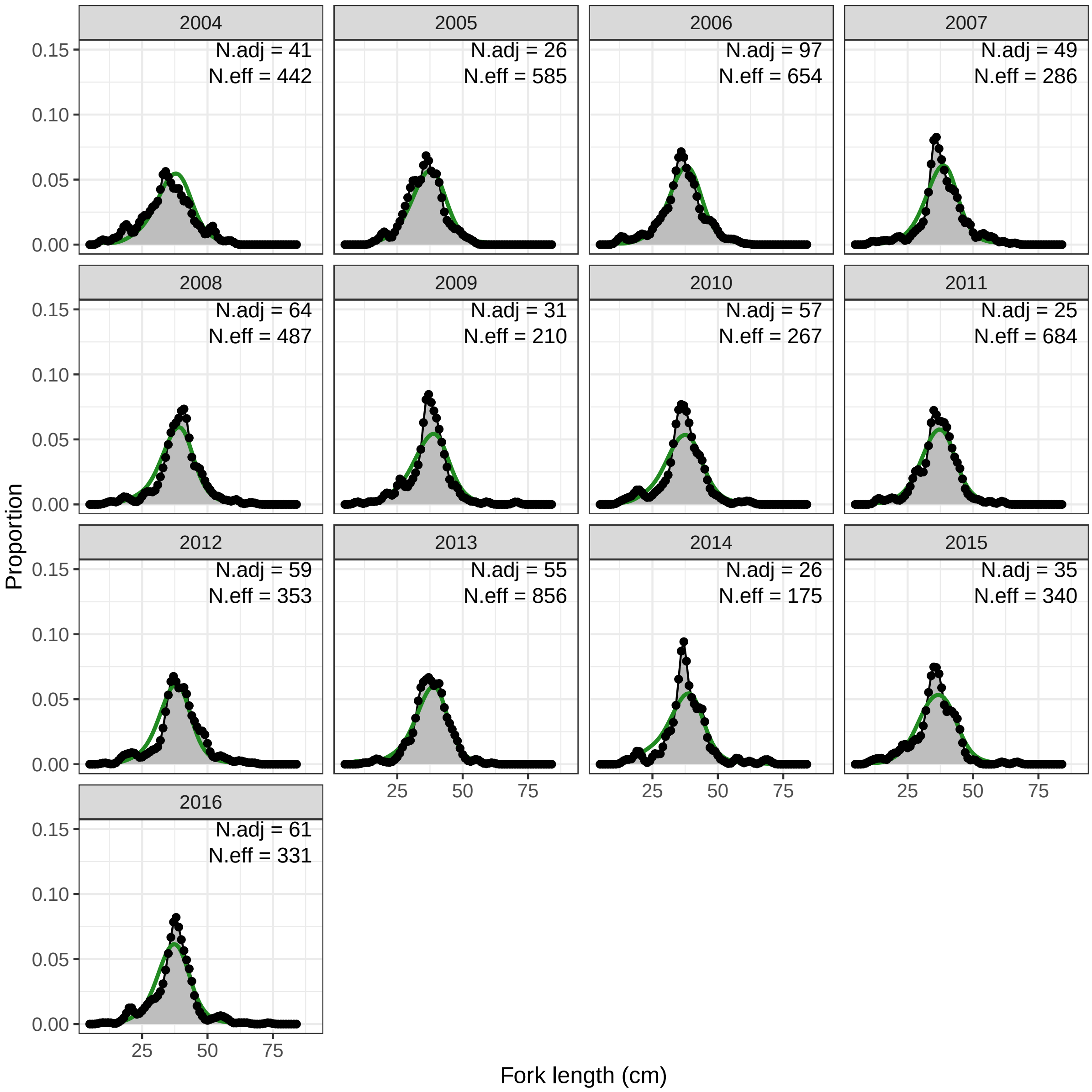

Figure C.26: Scenario 4: Fits to length structures for the blue survey fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

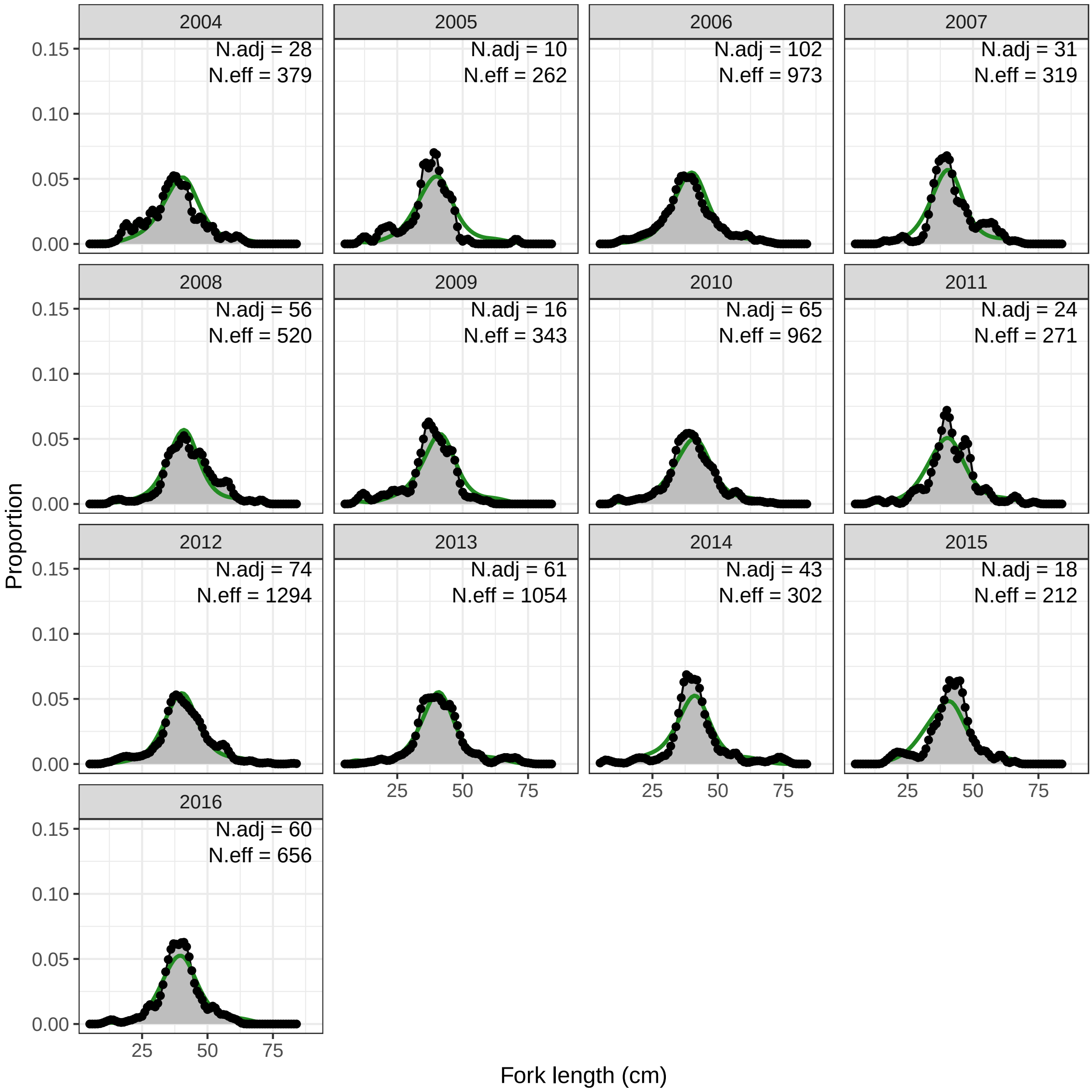

Figure C.27: Scenario 4: Fits to length structures for the green survey fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

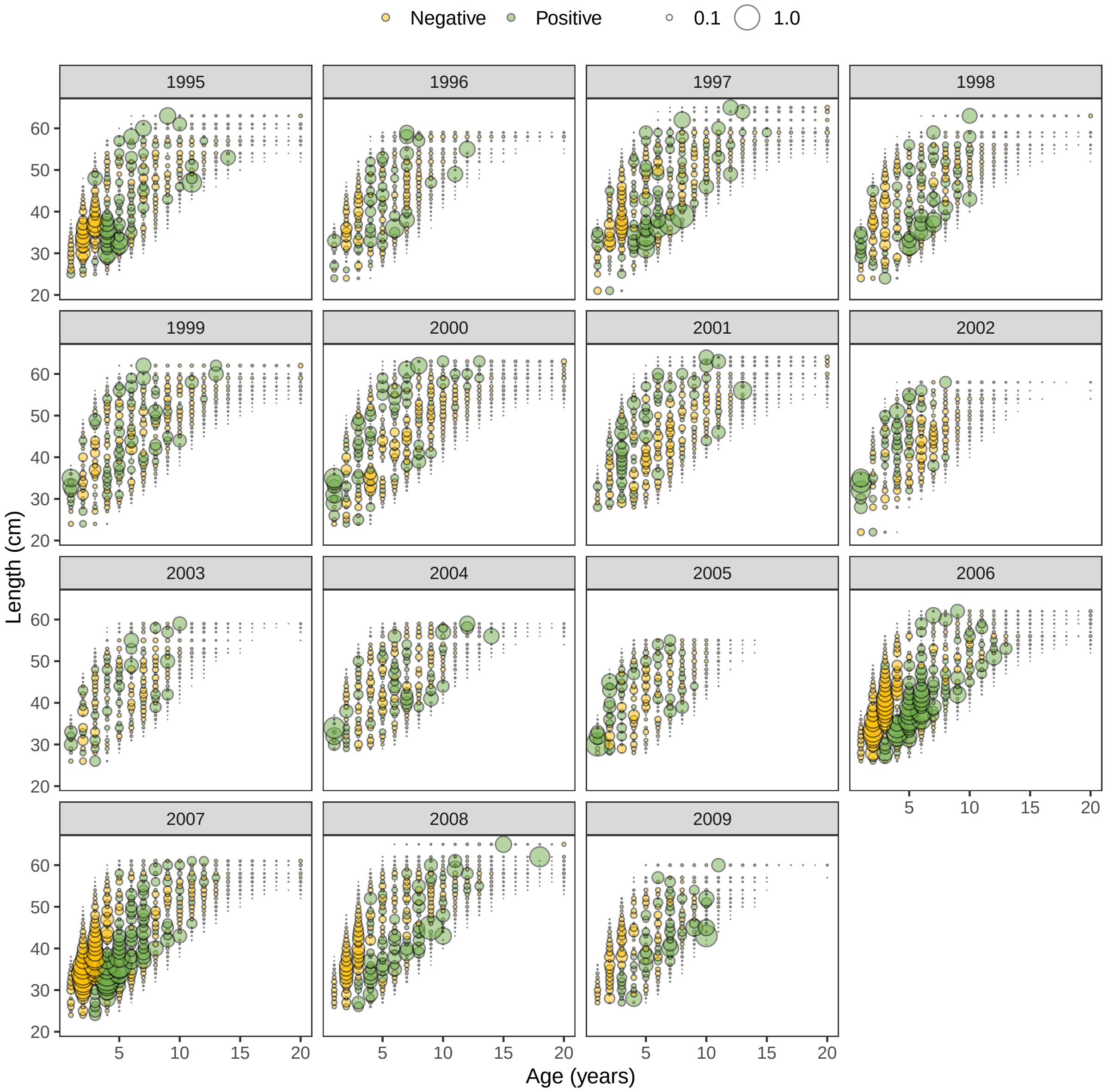

Figure C.28: Scenario 4: Pearson residuals for age-at-length compositions for the blue fishery for coral trout—circle size represents the magnitude of the Pearson residual

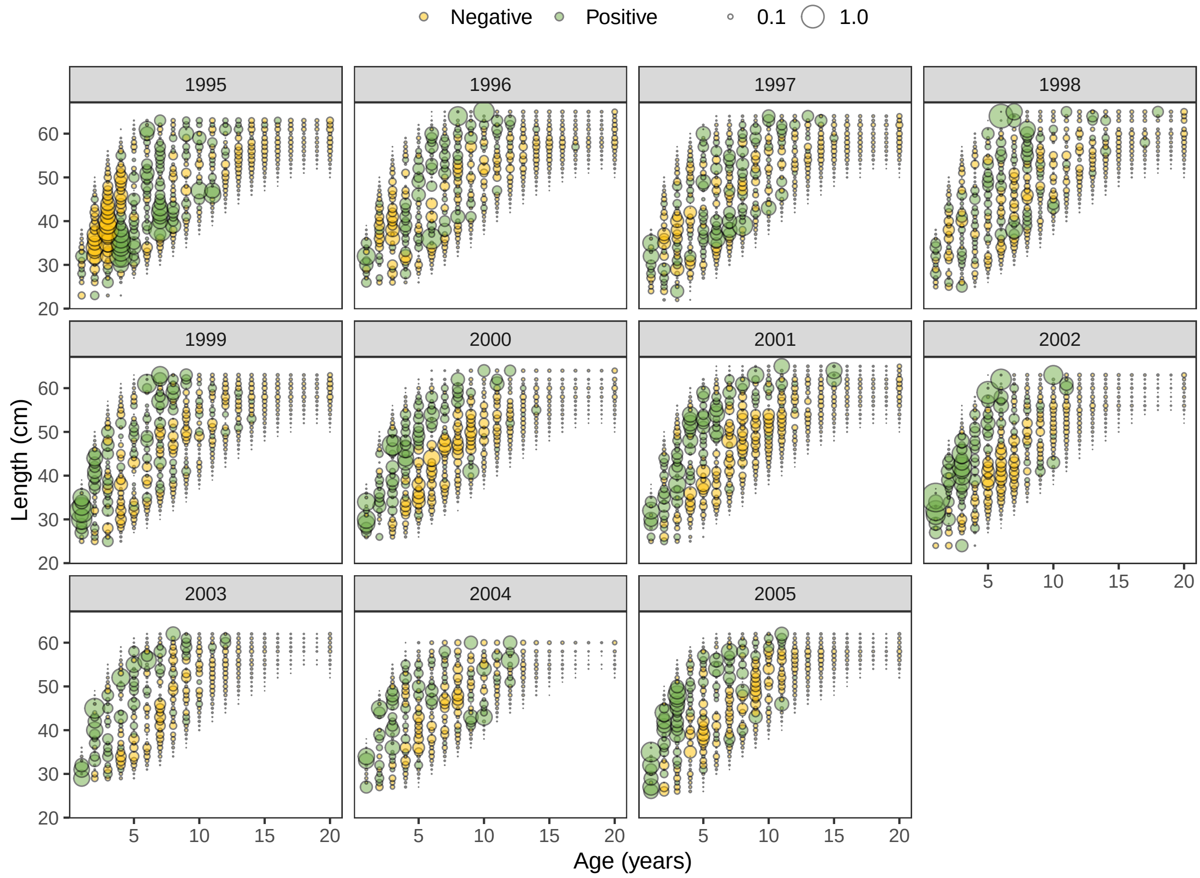

Figure C.29: Scenario 4: Pearson residuals for age-at-length compositions for the green fishery for coral troutr—circle size represents the magnitude of the Pearson residual

C.4 Scenario 5: Mirroring

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

Stock Synthesis parameter label	Estimate	Phase	Min	Max	Initial value	Standard deviation
NatM_uniform	0.368	8	0.01	0.99	0.3	0.0315
L_at_Amin	14.4	2	0	30	15	1.15
L_at_Amax	68.5	3	50	90	70	2.08
VonBert_K	0.137	2	0.01	0.3	0.14	0.0176
CV_young	0.265	4	0.05	0.5	0.27	0.0239
CV_old	0.0679	6	0.001	0.2	0.1	0.015
RecrDist_GP_1_area_2_month_1	0.371	4	-5	5	0	0.211
SR_LN(R0)	10.2	1	5	15	10	0.214
SizeSel_P1_FISHERY_BLUE	39.2	5	30	50	36	0.624
SizeSel_P2_FISHERY_BLUE	-1.62	5	-25	15	-6	0.428
SizeSel_P3_FISHERY_BLUE	3.54	5	0	5	3	0.127
SizeSel_P4_FISHERY_BLUE	4.37	5	3	9	5	0.446
SizeSel_P5_FISHERY_BLUE	-17.6	5	-40	30	-12	184
Retain_L_infl_FISHERY_BLUE	38.2	4	20	50	36	1.35
SizeSpline_GradLo_SURVEY_BLUE	0.218	3	-0.001	0.4	0	0.0259
SizeSpline_Val_1_SURVEY_BLUE	-5.53	2	-8	-1	-5	0.258
SizeSpline_Val_2_SURVEY_BLUE	-1.39	2	-5	0	-2	0.0989
SizeSpline_Val_4_SURVEY_BLUE	-2.18	2	-6	0	-3	0.345
SizeSpline_GradLo_SURVEY_GREE	0.165	3	-0.001	0.4	0.18	0.0278
SizeSpline_Val_1_SURVEY_GREEN	-5.14	2	-7	-2	-5	0.274
SizeSpline_Val_2_SURVEY_GREEN	-1.5	2	-5	0	-2	0.0997
SizeSpline_Val_4_SURVEY_GREEN	-2.17	2	-5	0	-2	0.25

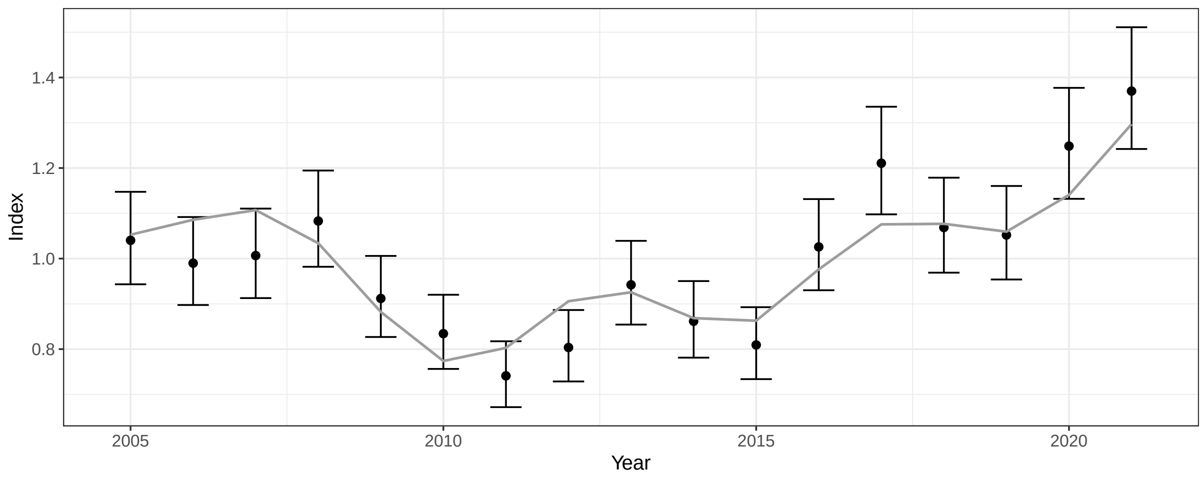

Figure C.30: Scenario 5: Model predictions (grey line) to fishery blue catch rates for live common coral trout

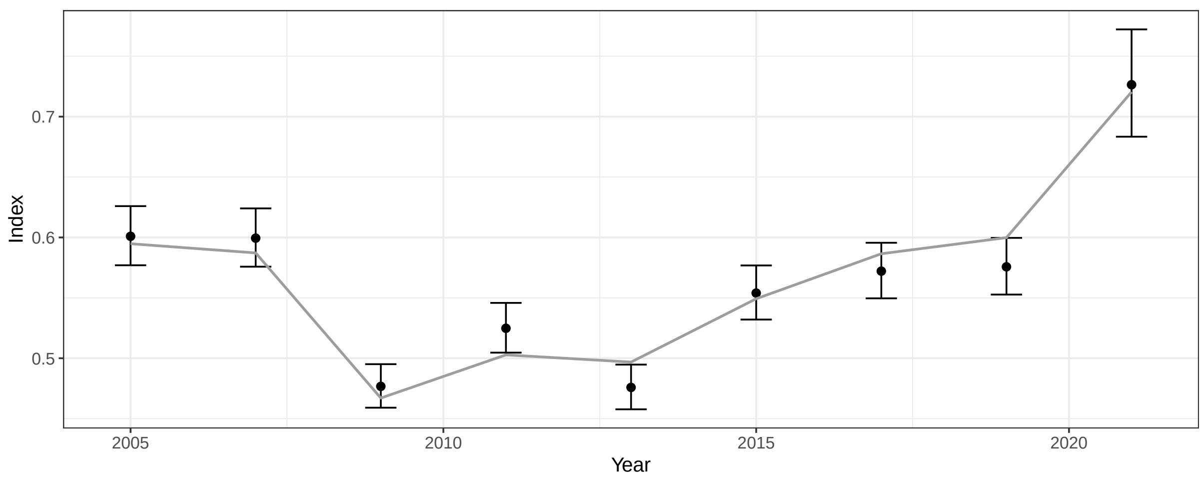

Figure C.31: Scenario 5: Model predictions (grey line) to survey blue catch rates for common coral trout

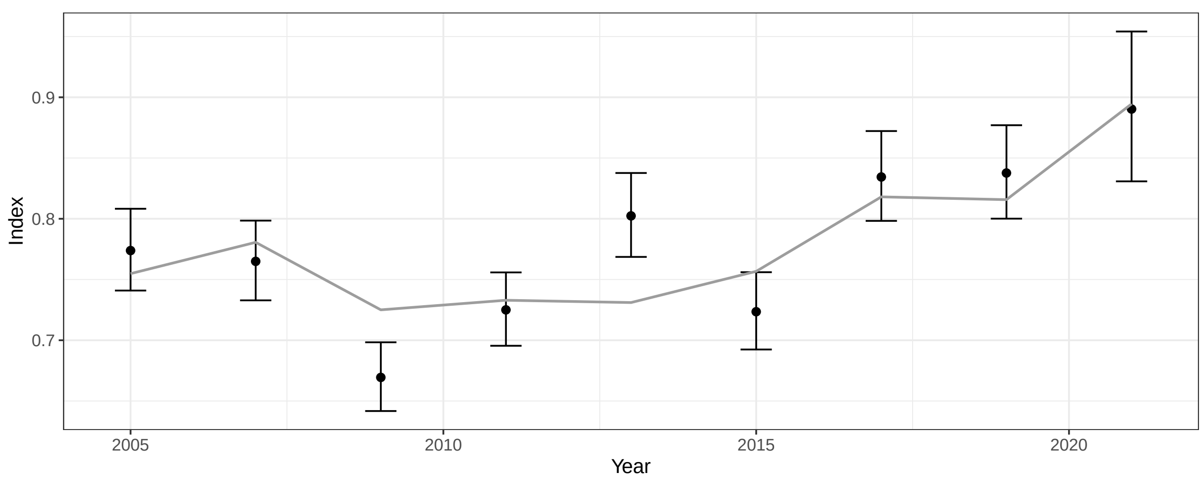

Figure C.32: Scenario 5: Model predictions (grey line) to survey green catch rates for common coral trout

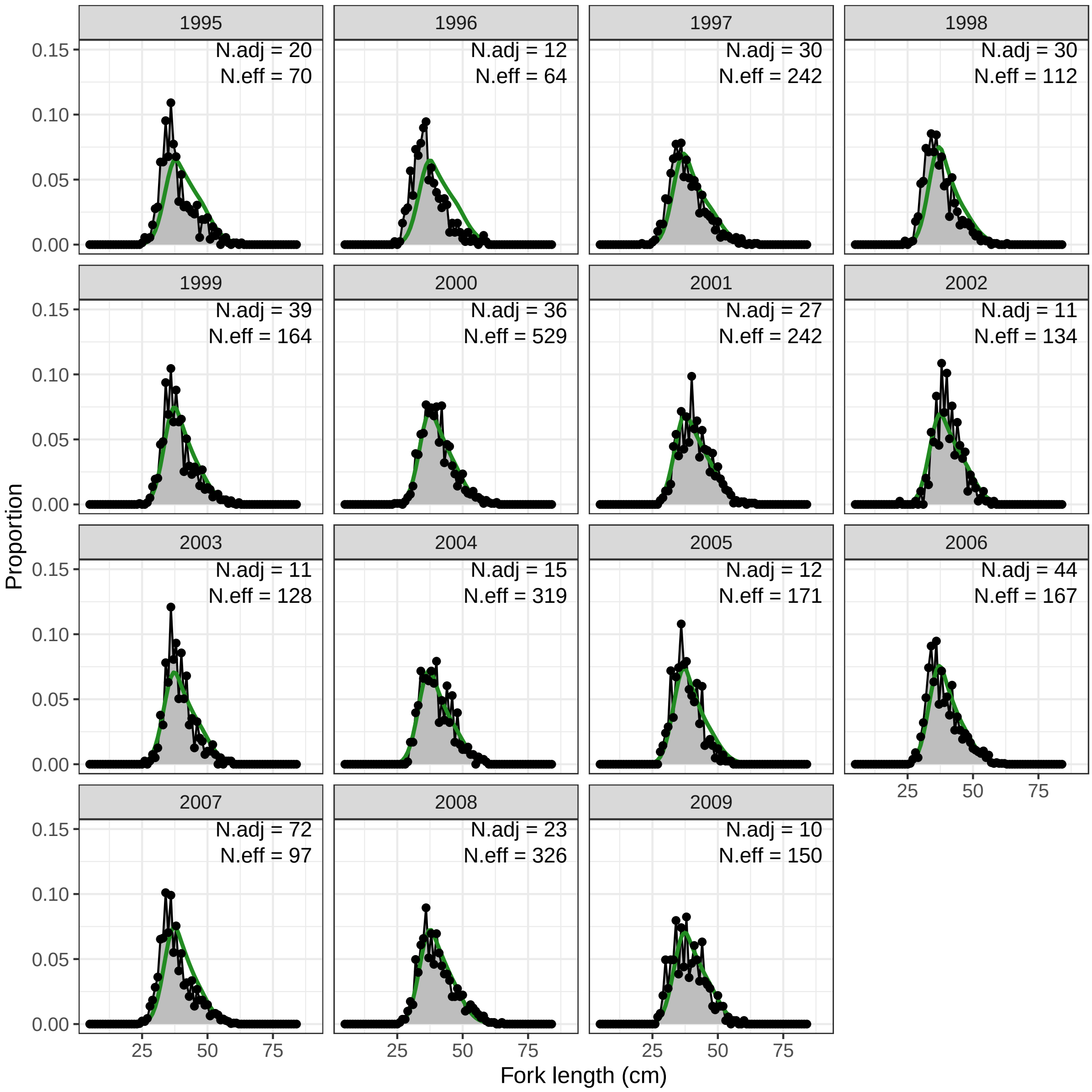

Figure C.33: Scenario 5: Fits to length structures for the blue live fishery fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

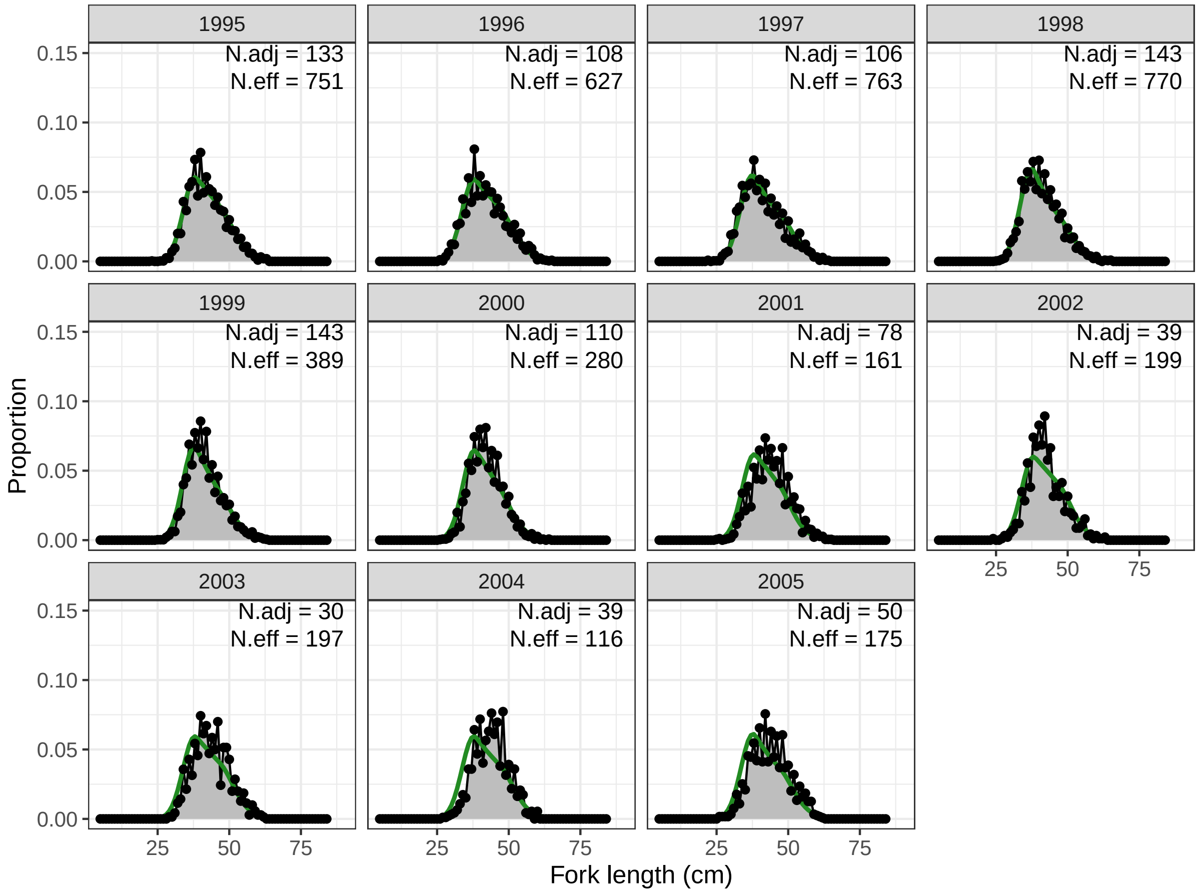

Figure C.34: Scenario 5: Fits to length structures for the green fishery fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

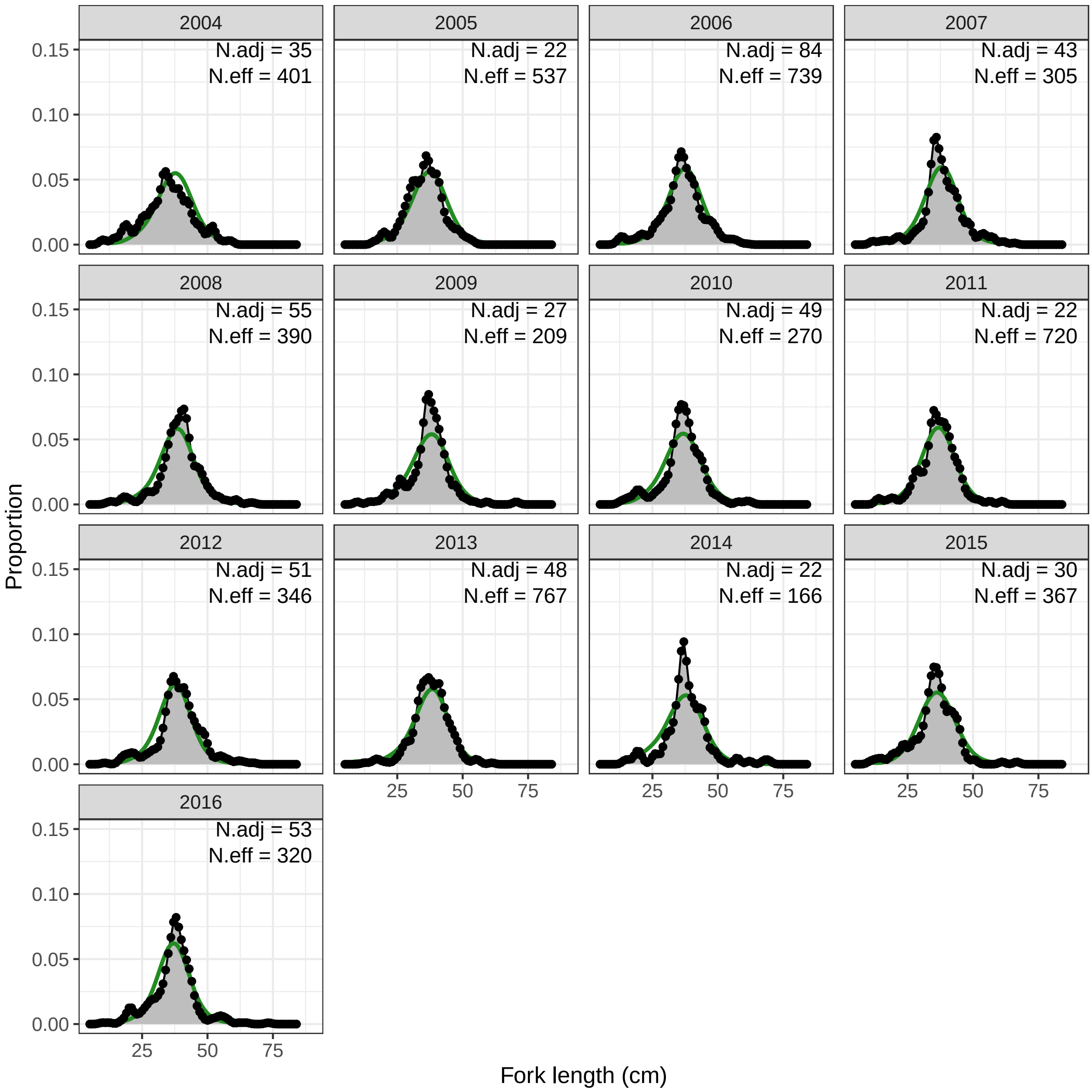

Figure C.35: Scenario 5: Fits to length structures for the blue survey fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

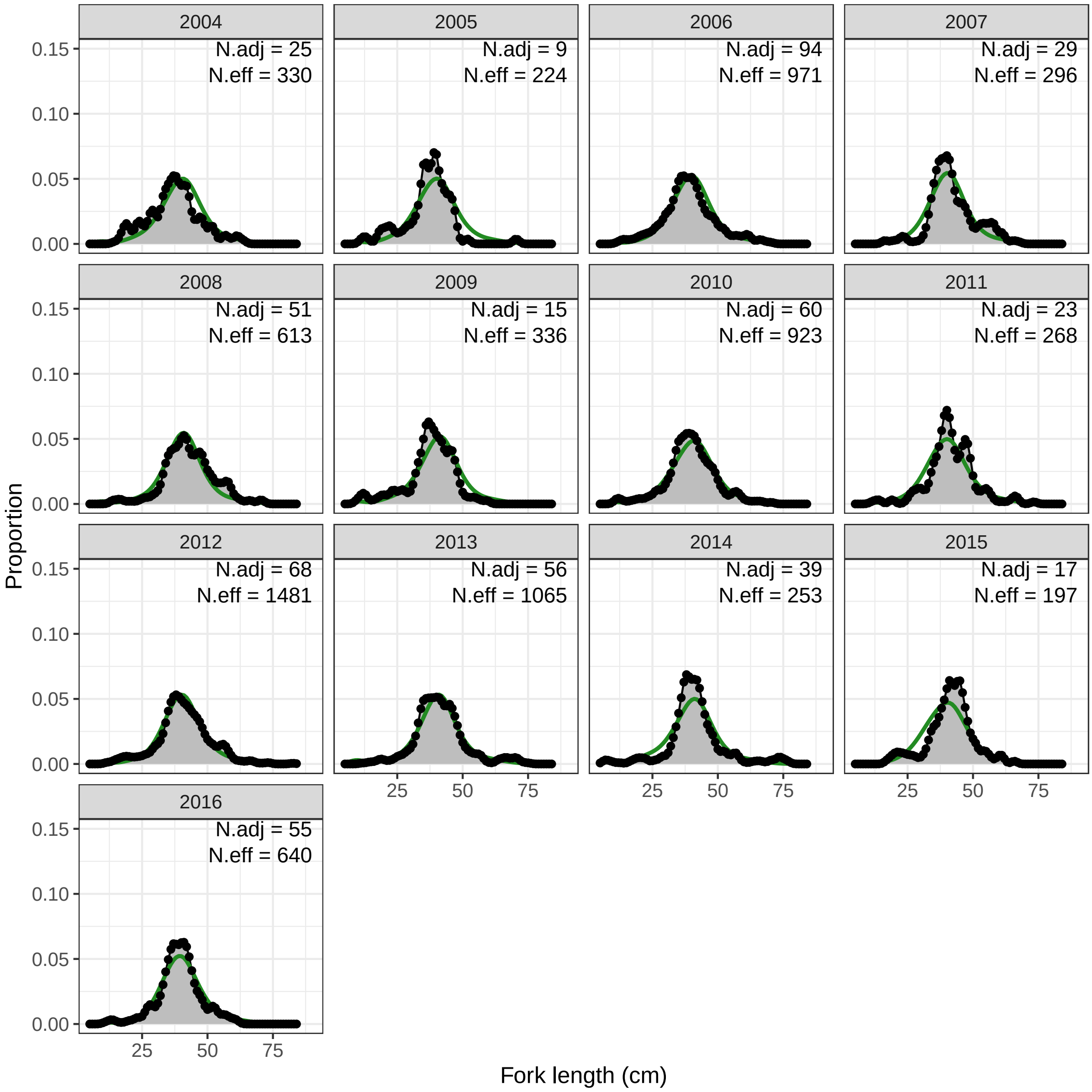

Figure C.36: Scenario 5: Fits to length structures for the green survey fleet

Note: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method'

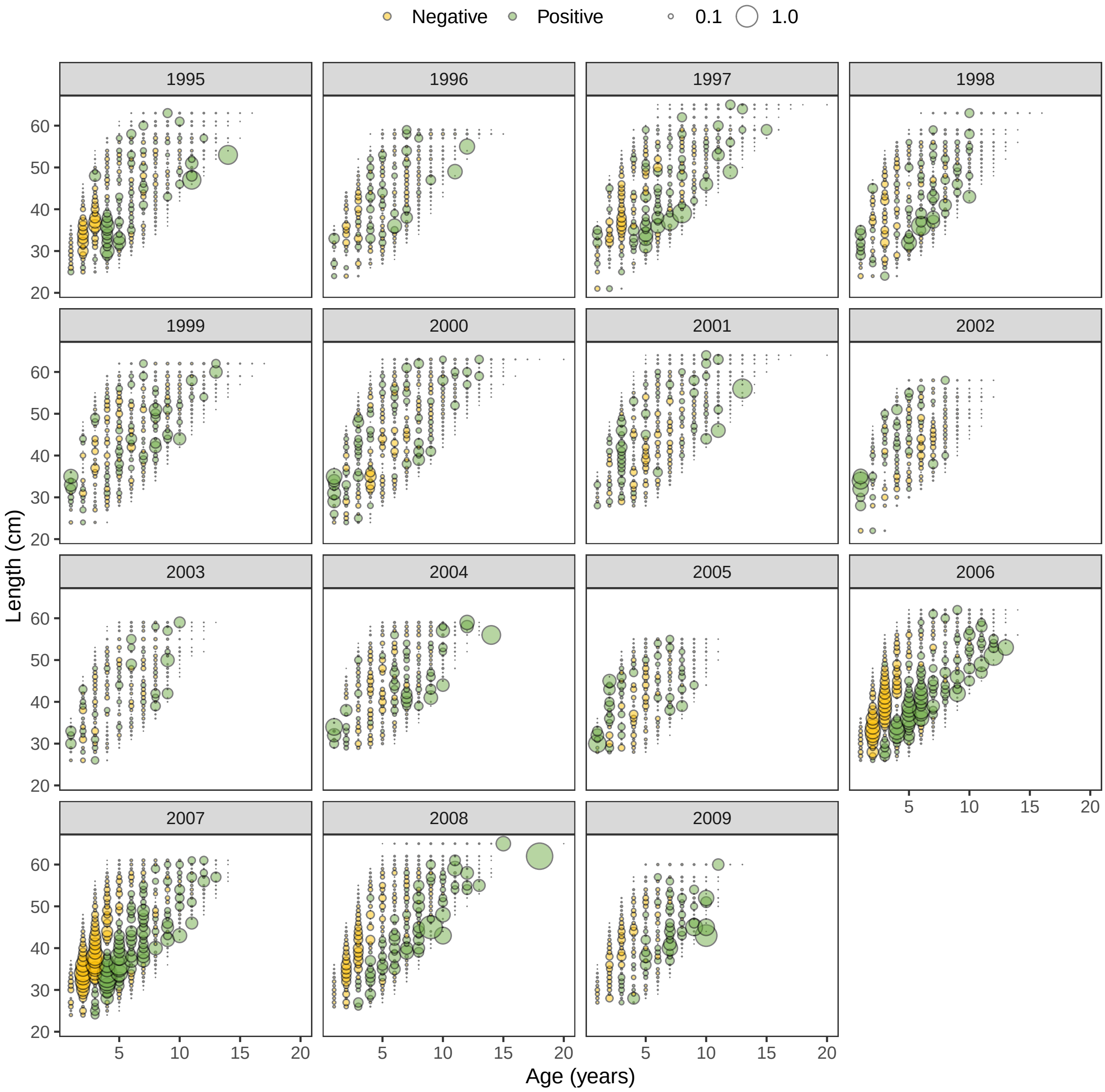

Figure C.37: Scenario 5: Pearson residuals for age-at-length compositions for the blue fishery for coral trout—circle size represents the magnitude of the Pearson residual

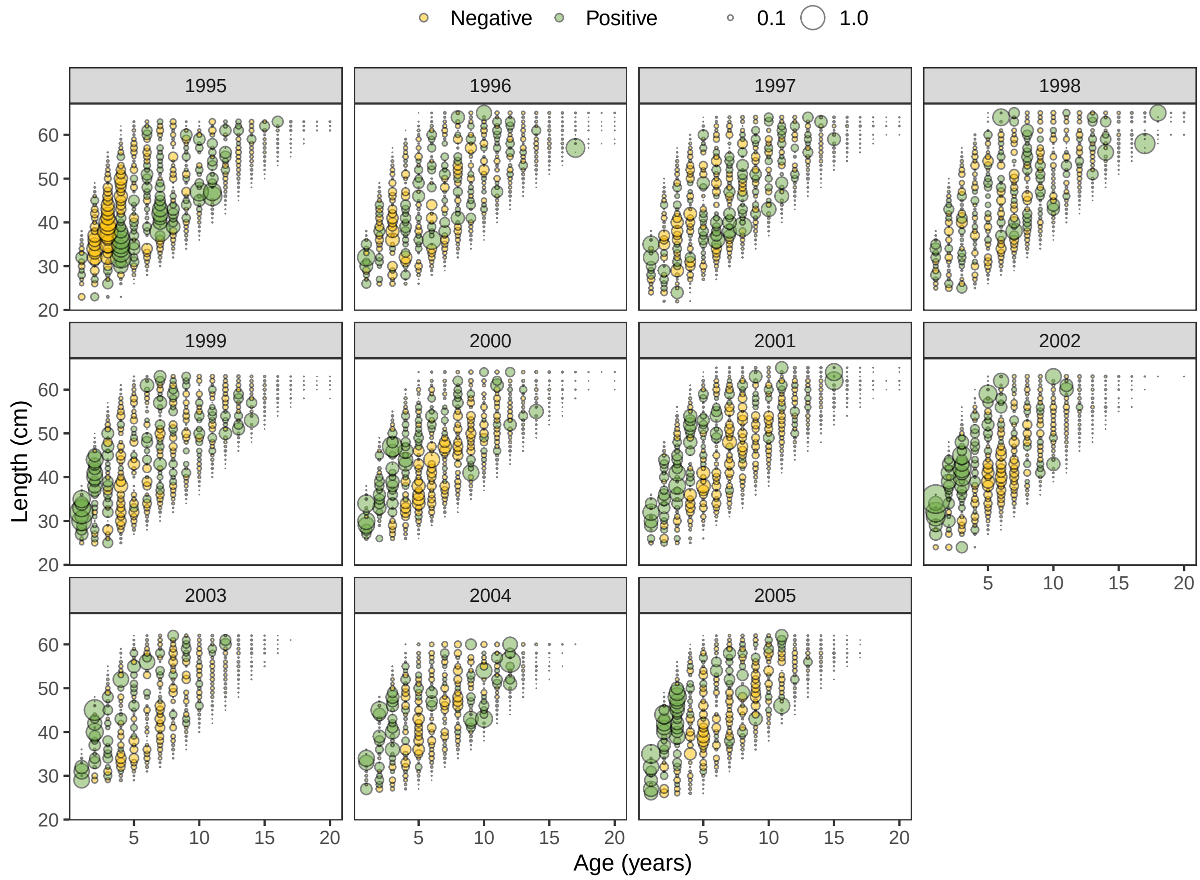

Figure C.38: Scenario 5: Pearson residuals for age-at-length compositions for the green fishery for coral troutr—circle size represents the magnitude of the Pearson residual