Status of copper rockfish (*Sebastes caurinus*) along the Washigton US West coast in 2020

by
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Contents

List of Figures

List of Tables

1 Introduction

1.1 Basic Information

This assessment reports the status of copper rockfish (*Sebastes caurinus*) off the US West coast using data through 2020. Copper rockfish is a medium- to large-sized nearshore rockfish found from Mexico to Alaska. The core range is comparatively large, from northern Baja Mexico to the Gulf of Alaska, as well as in Puget Sound. They occur mostly on low relief or sand-rock interfaces. Copper rockfish have historically been a part of both commercial (mainly in the live-fish fishery) and recreational fisheries throughout its range.

1.2 Life History

Genetic work has revealed significant differences between Puget Sound and coastal stocks, but not among the coastal stocks (XXX Buonaccorsi et al. 2002). copper rockfish live at least 50 years (XX add reference XX) and have the highest vulnerability (V = 2.27) of any West Coast groundfish (XX add reference XX).

1.3 Ecosystem Considerations

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1.4 Historical and Current Fishery Information

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1.5 Summary of Management History and Performance

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1.6 Foreign Fisheries

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2 Data

A description of each data source is provided below (Figure 2).

2.1 Fishery-Dependent Data

(Ralston et al. 2010)

2.2 Fishery-Independent Data

There were no fishery-independent data sources available for copper rockfish off the Washington coast to be considered for this assessment.

2.3 Biological Data

2.3.1 Natural Mortality

Hamel (2015) developed a method for combining meta-analytic approaches relating the M rate to other life-history parameters such as longevity, size, growth rate, and reproductive effort to provide a prior on M. In that same issue of *ICES Journal of Marine Science*, Then et al. (2015) provided an updated data set of estimates of M and related life history parameters across a large number of fish species from which to develop an M estimator for fish species in general. They concluded by recommending M estimates be based on maximum age alone, based on an updated Hoenig non-linear least squares estimator $M = 4.899 A_{max}^{-0.916}$. The approach of basing M priors on maximum age alone was one that was already being used for West Coast rockfish assessments. However, in fitting the alternative model forms relating M to $A_{\max}$, Then et al. (2015) did not consistently apply their transformation. In particular, in real space, one would expect substantial heteroscedasticity in both the observation and process error associated with the observed relationship of M to $A_{\max}$. Therefore, it would be reasonable to fit all models under a log transformation. This was not done. Re-evaluating the data used in Then et al. (2015) by fitting the one-parameter $A_{\max}$ model under a log-log transformation (such that the slope is forced to be -1 in the transformed space Hamel (2015)), the point estimate for M is:

$$M = \frac{5.4}{A_{\max}}$$

The above is also the median of the prior. The prior is defined as a lognormal distribution with mean $ln(5.4/A_{\max})$ and SE = 0.438. Using a maximum age of 50, the point estimate and median of the prior is 0.108 per year The maximum age was selected based on available age data from all West Coast data sources and literature values. The oldest aged rockfish was 51 years with two observations, off the coast of Washington and Oregon in 2019. However, age data are subject to ageing error which could impact this estimate of longevity. The selection of 50 years was based on the range of other ages available with multiple observations of fish between 44 and 51 years of age and literature examining the longevity of `spp` (Love 1996).

2.3.2 Length-Weight Relationship

The length-weight relationship for copper rockfish was estimated outside the model using all coastwide biological data available from fishery-independent data sources (Figure 5). The estimated length-weight for female fish was 9.56e-06$L^{3.19}$ and males at 1.08e-05$L^{3.15}$ where L is length in cm (Figures 6).

2.3.3 Growth (Length-at-Age)

The length-at-age was estimated for male and female copper rockfish using data collected from fishery-dependent data sources off the coast of Oregon and Washington that were collected from 1998-2019 (Figure 7). Figure 8 shows the lengths and ages for all years by data source as well as predicted von Bertalanffy fits to the data. Females grow larger than males and sex-specific growth parameters were estimated at the following values:

$$\text{Females } L_\infty = 49.6 \text{ cm}; \; k = 0.152$$

$$\text{Males } L_\infty = 47.8 \text{ cm}; \; k = 0.182$$

These values were fixed within the base model for male and female copper rockfish.

2.3.4 Maturation and Fecundity

Maturity-at-length based on the work of Hannah (2014) which estimated the 50% size-at-maturity of 34.83 cm off the coast of Oregon with maturity asymptoting to 1.0 for larger fish (Figure 9).

The fecundity-at-length was based on research Dick et al. (2017). The fecundity relationship for copper rockfish was estimated equal to 3.362e-07$L^{3.68}$ in millions of eggs where L is length in cm. Fecundity-at-length is shown in Figure 10.

2.3.5 Sex Ratio

There was limited sex specific observations by length or age for all biological data sources (Figures 11 and 12). The sex ratio of young fish was assumed to be 1:1.

3 Assessment Model

3.1 Summary of Previous Assessments

Copper rockfish was last assesseed in 2013 (Cope et al. 2013). The stock was assessed using extended depletion-based stock reduction analysis (XDB-SRA) a data-moderate approach which incorporated catch and index data with prior on select parameters (natural mortality, stock status in a specified year, productivity, and the relative status of maximum productivity). Copper rockfish was assessed as two separated stocks, the area South of Pt. Conception off the California coast and the area North of Pt. Conception to the Washington Canada border. The 2013 assessment estimated the stock South of Pt. Conception at 75% of unfished spawning output North of Pt. Conception at 48% of unfished spawning output.

3.2 Model Structure and Assumptions

3.2.1 Modeling Platform and Structure

Stock Synthesis version 3.30.16 was used to estimate the parameters in the model. The R package r4ss, version XXX, along with R version 4.0.1 were used to investigate and plot model fits.

3.2.2 Model Parameters

Describe estimated vs. fixed parameters, priors

3.2.3 Key Assumptions and Structural Choices

3.3 Base Model Results

3.3.1 Parameter Estimates

3.3.2 Fits to the Data

3.3.3 Population Trajectory

3.3.4 Reference Points

3.4 Model Diagnostics

Describe all diagnostics

3.4.1 Convergence

3.4.2 Sensitivity Analyses

3.4.3 Retrospective Analysis

3.4.4 Likelihood Profiles

3.4.5 Unresolved Problems and Major Uncertainties

4 Management

4.1 Reference Points

4.2 Unresolved Problems and Major Uncertainties

4.3 Harvest Projections and Decision Tables

4.4 Evaluation of Scientific Uncertainty

4.5 Research and Data Needs

5 Acknowledgments

Here are all the mad props!

Merit McCrea, Gerry Richter, Louis Zimm, Daniel Platt

6 Tables

Table 1: Removals by fleet for all model years.

Year	Recreational (mt)	Commercial (mt)	Total Mortality
1935	0.02	0.00	0.02
1936	0.05	0.00	0.05
1937	0.08	0.00	0.08
1938	0.12	0.00	0.12
1939	0.15	0.00	0.15
1940	0.19	0.00	0.19
1941	0.22	0.00	0.22
1942	0.25	0.00	0.25
1943	0.29	0.00	0.29
1944	0.32	0.00	0.32
1945	0.36	0.00	0.36

Table 1: Removals by fleet for all model years. *(continued)*

Year	Recreational (mt)	Commercial (mt)	Total Mortality
1946	0.39	0.00	0.39
1947	0.42	0.00	0.42
1948	0.45	0.00	0.45
1949	0.49	0.00	0.49
1950	0.52	0.00	0.52
1951	0.56	0.00	0.56
1952	0.59	0.00	0.59
1953	0.62	0.00	0.62
1954	0.65	0.00	0.65
1955	0.69	0.00	0.69
1956	0.72	0.00	0.72
1957	0.75	0.00	0.75
1958	0.78	0.00	0.78
1959	0.82	0.00	0.82
1960	0.85	0.00	0.85
1961	0.88	0.00	0.88
1962	0.91	0.00	0.91
1963	0.94	0.00	0.94
1964	0.98	0.00	0.98
1965	1.01	0.00	1.01
1966	1.04	0.00	1.04
1967	1.07	0.00	1.07
1968	1.10	0.00	1.10
1969	1.13	0.00	1.13
1970	1.16	0.00	1.16
1971	1.19	0.00	1.19
1972	1.22	0.00	1.22
1973	1.25	0.00	1.25
1974	1.27	0.00	1.27
1975	1.30	0.00	1.30
1976	0.94	0.00	0.94
1977	0.58	0.00	0.58
1978	1.07	0.00	1.07
1979	1.42	0.00	1.42
1980	0.83	0.00	0.83
1981	1.85	0.00	1.85
1982	1.94	0.00	1.94
1983	1.18	0.00	1.18
1984	1.87	0.00	1.87
1985	1.61	0.20	1.80
1986	1.93	0.19	2.12
1987	2.31	0.93	3.25
1988	2.14	0.25	2.39
1989	2.15	0.00	2.15
1990	2.71	0.03	2.74

Table 1: Removals by fleet for all model years. *(continued)*

Year	Recreational (mt)	Commercial (mt)	Total Mortality
1991	1.94	0.00	1.94
1992	3.02	0.00	3.02
1993	2.18	0.01	2.19
1994	1.38	0.00	1.38
1995	1.67	0.00	1.67
1996	1.91	0.00	1.91
1997	1.83	0.00	1.83
1998	1.89	0.00	1.89
1999	1.94	0.00	1.94
2000	2.08	0.00	2.08
2001	2.18	0.00	2.18
2002	1.48	0.00	1.48
2003	1.86	0.00	1.86
2004	1.91	0.00	1.92
2005	5.58	0.00	5.58
2006	2.68	0.00	2.68
2007	2.75	0.00	2.75
2008	2.94	0.00	2.94
2009	2.74	0.00	2.74
2010	2.24	0.00	2.24
2011	2.90	0.00	2.90
2012	2.01	0.00	2.01
2013	3.01	0.00	3.01
2014	2.81	0.00	2.81
2015	1.58	0.00	1.58
2016	2.20	0.00	2.20
2017	1.50	0.01	1.51
2018	3.39	0.00	3.39
2019	4.55	0.00	4.55
2020	2.69	0.00	2.69

Table 2: Summary of the recreational length samples used in the stock assessment.

Year	All Fish	Sexed Fish	Unsexed Fish
1979	8	0	8
1981	4	0	4
1982	5	0	5
1983	3	0	3
1995	141	0	141
1996	221	0	221
1997	63	0	63
1998	202	46	156
1999	194	136	58
2000	26	26	0
2001	32	32	0
2002	83	61	22
2003	46	18	28
2004	244	201	43
2005	443	265	178
2006	169	96	73
2007	152	110	42
2008	91	71	20
2009	71	52	19
2010	57	38	19
2011	127	27	100
2012	81	37	44
2013	71	14	57
2014	136	130	6
2015	84	81	3
2016	179	155	24
2017	212	108	104
2018	315	188	127
2019	463	273	190
2020	59	58	1

Table 3: Summary of the recreational age samples. These ages were not directly used in the stock assessment.

Year	All Fish	Sexed Fish	Unsexed Fish
1998	46	46	0
1999	136	136	0
2000	26	26	0
2001	32	32	0
2002	19	19	0
2004	188	186	2
2005	225	225	0
2006	65	65	0
2007	86	86	0
2008	65	65	0
2009	35	35	0
2010	24	24	0
2011	27	26	1
2012	35	34	1
2013	8	8	0
2014	123	121	2
2015	74	71	3
2016	169	152	17
2017	101	99	2
2018	176	175	1
2019	274	272	2

Table 4: List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD).

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
NatM p 1 Fem GP 1	0.1080000	-2	(0.05, 0.4)	NA	NA	Log Norm (-2.2256, 0.48)
L at Amin Fem GP 1	15.7000000	-2	(3, 25)	NA	NA	None
L at Amax Fem GP 1	49.6000000	-2	(35, 60)	NA	NA	None
VonBert K Fem GP 1	0.1520000	-2	(0.03, 0.3)	NA	NA	None
CV young Fem GP 1	0.1000000	-2	(0.01, 0.3)	NA	NA	None
CV old Fem GP 1	0.1000000	-2	(0.01, 0.3)	NA	NA	None
Wtlen 1 Fem GP 1	0.0000096	-9	(0, 0.1)	NA	NA	None
Wtlen 2 Fem GP 1	3.1900000	-9	(2, 4)	NA	NA	None
Mat50Mat slope Fem GP 1	-0.6000000	-9	(-1, 0)	NA	NA	None
Eggs scalar Fem GP 1	0.0000003	-9	(-3, 3)	NA	NA	None
Eggs exp len Fem GP 1	3.6790000	-9	(-3, 3)	NA	NA	None
NatM p 1 Mal GP 1	0.1080000	-2	(0.05, 0.4)	NA	NA	Log Norm (-2.2256, 0.48)
L at Amin Mal GP 1	13.9000000	-2	(3, 25)	NA	NA	None
L at Amax Mal GP 1	47.8000000	-2	(35, 60)	NA	NA	None
VonBert K Mal GP 1	0.1820000	-2	(0.03, 0.3)	NA	NA	None
CV young Mal GP 1	0.1000000	-2	(0.01, 0.3)	NA	NA	None
CV old Mal GP 1	0.1000000	-2	(0.01, 0.3)	NA	NA	None
Wtlen 1 Mal GP 1	0.0000108	-9	(0, 0.1)	NA	NA	None
Wtlen 2 Mal GP 1	3.1500000	-9	(2, 4)	NA	NA	None
FracFemale GP 1	0.5000000	-9	(0.01, 0.99)	NA	NA	None
SR LN(R0)	1.5627300	1	(1, 20)	OK	0.150831	None
SR BH steep	0.7200000	-7	(0.22, 1)	NA	NA	Normal (0.72, 0.09)
SR sigmaR	0.9000000	-99	(0.15, 1)	NA	NA	None
SR regime	0.0000000	-99	(-2, 2)	NA	NA	None
SR autocorr	0.0000000	-99	(0, 0)	NA	NA	None
Early InitAge 1	-0.0184066	5	(-5, 5)	act	0.892105	dev (NA, NA)
Size DblN peak WA Recreational(1)	39.9812000	2	(15, 50)	OK	1.165670	None
Size DblN top logit WA Recreational(1)	-1.4692600	-2	(-7, 7)	NA	NA	None
Size DblN ascend se WA Recreational(1)	3.9245300	3	(-10, 10)	OK	0.167349	None

Table 4: List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD). *(continued)*

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Size DblN descend se WA Recreational(1)	6.0000000	-4	(-10, 10)	NA	NA	None
Size DblN start logit WA Recreational(1)	-20.0000000	-9	(-20, 30)	NA	NA	None
Size DblN end logit WA Recreational(1)	-9.2687300	3	(-10, 10)	OK	17.711800	None

Table 5: Time series of population estimates from the base model.

Year	Total Biomass (mt)	Spawning Output	Total Biomass 3 (mt)	Fraction Unfished	Age-0 Recruits	Total Catch (mt)	1-SPR	Exploitation Rate
1935	44.79	4.61	44.00	1.00	4.69	0.02	0.01	0.00
1936	44.77	4.61	43.99	1.00	4.68	0.05	0.02	0.00
1937	44.70	4.60	43.92	1.00	4.67	0.08	0.03	0.00
1938	44.59	4.59	43.82	1.00	4.66	0.12	0.04	0.00
1939	44.45	4.58	43.68	0.99	4.65	0.15	0.05	0.00
1940	44.27	4.56	43.50	0.99	4.64	0.19	0.06	0.00
1941	44.06	4.54	43.29	0.98	4.62	0.22	0.07	0.01
1942	43.82	4.52	43.05	0.98	4.61	0.25	0.08	0.01
1943	43.56	4.49	42.79	0.97	4.59	0.29	0.09	0.01
1944	43.26	4.45	42.50	0.97	4.57	0.32	0.10	0.01
1945	42.95	4.42	42.18	0.96	4.55	0.36	0.11	0.01
1946	42.61	4.38	41.85	0.95	4.53	0.39	0.12	0.01
1947	42.25	4.34	41.49	0.94	4.51	0.42	0.13	0.01
1948	41.87	4.30	41.12	0.93	4.49	0.45	0.14	0.01
1949	41.48	4.25	40.73	0.92	4.46	0.49	0.15	0.01
1950	41.06	4.21	40.32	0.91	4.44	0.52	0.16	0.01
1951	40.63	4.16	39.89	0.90	4.41	0.56	0.17	0.01
1952	40.18	4.11	39.45	0.89	4.38	0.59	0.18	0.01
1953	39.72	4.06	38.99	0.88	4.35	0.62	0.19	0.02
1954	39.24	4.01	38.52	0.87	4.32	0.65	0.20	0.02
1955	38.75	3.95	38.03	0.86	4.28	0.69	0.22	0.02
1956	38.24	3.89	37.53	0.84	4.25	0.72	0.23	0.02
1957	37.72	3.84	37.01	0.83	4.21	0.75	0.24	0.02
1958	37.19	3.78	36.48	0.82	4.17	0.78	0.25	0.02
1959	36.63	3.72	35.94	0.81	4.13	0.82	0.26	0.02
1960	36.07	3.65	35.38	0.79	4.09	0.85	0.27	0.02
1961	35.49	3.59	34.81	0.78	4.05	0.88	0.28	0.03
1962	34.90	3.53	34.22	0.76	4.01	0.91	0.29	0.03
1963	34.29	3.46	33.62	0.75	3.96	0.94	0.31	0.03
1964	33.67	3.39	33.01	0.74	3.93	0.98	0.32	0.03
1965	33.03	3.32	32.38	0.72	3.89	1.01	0.33	0.03
1966	32.39	3.25	31.74	0.70	3.86	1.04	0.34	0.03
1967	31.73	3.18	31.09	0.69	3.84	1.07	0.35	0.03
1968	31.07	3.10	30.43	0.67	3.83	1.10	0.37	0.04
1969	30.40	3.03	29.76	0.66	3.82	1.13	0.38	0.04
1970	29.73	2.95	29.09	0.64	3.82	1.16	0.39	0.04
1971	29.06	2.88	28.42	0.62	3.81	1.19	0.41	0.04
1972	28.39	2.80	27.75	0.61	3.80	1.22	0.42	0.04
1973	27.73	2.72	27.10	0.59	3.80	1.25	0.43	0.05
1974	27.08	2.65	26.45	0.57	3.72	1.27	0.45	0.05
1975	26.44	2.57	25.82	0.56	3.57	1.30	0.46	0.05
1976	25.81	2.50	25.20	0.54	3.57	0.94	0.38	0.04

Table 5: Time series of population estimates from the base model. *(continued)*

Year	Total Biomass (mt)	Spawning Output	Total Biomass 3 (mt)	Fraction Unfished	Age-0 Recruits	Total Catch (mt)	1-SPR	Exploitation Rate
1977	25.55	2.47	24.96	0.54	3.63	0.58	0.26	0.02
1978	25.67	2.48	25.07	0.54	3.81	1.07	0.41	0.04
1979	25.30	2.44	24.69	0.53	3.58	1.42	0.50	0.06
1980	24.59	2.36	23.97	0.51	3.24	0.83	0.36	0.03
1981	24.48	2.35	23.90	0.51	3.16	1.85	0.59	0.08
1982	23.34	2.23	22.81	0.48	3.04	1.94	0.61	0.08
1983	22.13	2.10	21.61	0.46	2.90	1.18	0.48	0.05
1984	21.66	2.06	21.16	0.45	2.76	1.87	0.62	0.09
1985	20.48	1.94	20.01	0.42	2.62	1.80	0.63	0.09
1986	19.36	1.83	18.91	0.40	2.52	2.12	0.69	0.11
1987	17.91	1.68	17.48	0.37	2.53	3.25	0.81	0.19
1988	15.36	1.42	14.94	0.31	2.79	2.39	0.78	0.16
1989	13.73	1.24	13.29	0.27	4.20	2.15	0.79	0.16
1990	12.46	1.09	11.92	0.24	4.09	2.74	0.86	0.23
1991	10.79	0.89	10.09	0.19	11.34	1.94	0.83	0.19
1992	10.42	0.77	9.39	0.17	3.24	3.02	0.92	0.32
1993	9.32	0.55	7.83	0.12	14.27	2.19	0.91	0.28
1994	9.75	0.45	8.68	0.10	1.51	1.38	0.85	0.16
1995	11.19	0.47	9.42	0.10	26.83	1.67	0.86	0.18
1996	13.52	0.54	12.02	0.12	1.90	1.91	0.84	0.16
1997	15.89	0.64	12.66	0.14	27.96	1.83	0.80	0.14
1998	19.50	0.80	17.90	0.17	2.35	1.89	0.76	0.11
1999	23.17	1.01	19.83	0.22	3.50	1.94	0.71	0.10
2000	26.68	1.30	26.20	0.28	19.79	2.08	0.66	0.08
2001	30.25	1.67	28.87	0.36	1.89	2.18	0.61	0.08
2002	33.20	2.10	30.82	0.45	2.20	1.48	0.45	0.05
2003	36.15	2.58	35.79	0.56	21.45	1.86	0.47	0.05
2004	38.79	2.95	37.48	0.64	2.23	1.92	0.45	0.05
2005	40.84	3.27	38.25	0.71	1.82	5.58	0.74	0.15
2006	38.80	3.18	38.45	0.69	1.57	2.68	0.55	0.07
2007	38.81	3.27	38.52	0.71	1.34	2.75	0.55	0.07
2008	38.02	3.36	37.77	0.73	1.30	2.94	0.57	0.08
2009	36.34	3.41	36.12	0.74	1.25	2.74	0.55	0.08
2010	34.23	3.40	34.01	0.74	1.41	2.24	0.51	0.07
2011	32.12	3.33	31.90	0.72	2.07	2.90	0.60	0.09
2012	29.04	3.09	28.77	0.67	2.44	2.01	0.53	0.07
2013	26.70	2.88	26.34	0.62	2.06	3.01	0.67	0.11
2014	23.32	2.51	22.94	0.54	1.84	2.81	0.70	0.12
2015	20.22	2.15	19.89	0.47	2.12	1.58	0.58	0.08
2016	18.48	1.94	18.16	0.42	2.71	2.20	0.71	0.12
2017	16.26	1.67	15.88	0.36	3.03	1.51	0.65	0.09
2018	14.94	1.49	14.47	0.32	3.67	3.39	0.86	0.23
2019	11.97	1.13	11.43	0.24	3.75	4.55	0.94	0.40

Table 5: Time series of population estimates from the base model. *(continued)*

Year	Total Biomass (mt)	Spawning Output	Total Biomass 3 (mt)	Fraction Unfished	Age-0 Recruits	Total Catch (mt)	1-SPR	Exploitation Rate
2020	8.20	0.66	7.58	0.14	3.19	2.69	0.93	0.35
2021	6.61	0.43	6.01	0.09	2.73	1.20	0.86	0.20
2022	6.65	0.39	6.14	0.08	2.62	1.11	0.85	0.18
2023	6.87	0.38	6.42	0.08	2.61	-0.03	0.00	0.00
2024	8.18	0.50	7.74	0.11	2.89	0.03	0.05	0.00
2025	9.46	0.64	9.01	0.14	3.16	0.16	0.22	0.02
2026	10.62	0.77	10.12	0.17	3.36	0.30	0.32	0.03
2027	11.63	0.89	11.09	0.19	3.51	0.42	0.37	0.04
2028	12.53	0.98	11.96	0.21	3.62	0.50	0.40	0.04
2029	13.35	1.06	12.76	0.23	3.71	0.57	0.42	0.04
2030	14.12	1.14	13.51	0.25	3.77	0.63	0.43	0.05
2031	14.85	1.20	14.23	0.26	3.83	0.68	0.44	0.05
2032	15.54	1.27	14.91	0.27	3.88	0.74	0.45	0.05

Table 6: Summary of reference points and management quantities, including estimates of the 95 percent intervals.

	Estimate	Lower Interval	Upper Interval
Unfished Spawning Output	4.61	3.25	5.97
Unfished Age 3+ Biomass (mt)	44.00	30.99	57.01
Unfished Recruitment (R0)	4.77	3.36	6.18
Spawning Output (2021)	0.43	-0.28	1.15
Fraction Unfished (2021)	0.09	-0.05	0.24
Reference Points Based SB40 Percent	NA	NA	NA
Proxy Spawning Output(SB40 Percent	1.84	1.30	2.39
SPR Resulting in SB40 Percent	0.46	0.46	0.46
Exploitation Rate Resulting in SB40 Percent	0.07	0.06	0.07
Yield with SPR Based On SB40 Percent (mt)	1.36	0.96	1.76
Reference Points Based on SPR Proxy for MSY	NA	NA	NA
Proxy Spawning Output (SPR50)	2.06	1.45	2.67
SPR50	50.00	NA	NA
Exploitation Rate Corresponding to SPR50	0.06	0.06	0.06
Yield with SPR50 at SB SPR (mt)	1.30	0.92	1.68
Reference Points Based on Estimated MSY Values	NA	NA	NA
Spawning Output at MSY (SB MSY)	1.22	0.87	1.57
SPR MSY	0.34	0.33	0.34
Exploitation Rate Corresponding to SPR MSY	0.10	0.10	0.10
MSY (mt)	1.47	1.04	1.90

Table 7: Projections of potential OFLs (mt), ABCs (mt), estimated spawning output and fraction unfished.

Year	Predicted OFL (mt)	ABC Catch (mt)	Age 3+ Biomass (mt)	Spawning Output	Fraction Unfished
2021	0.28	1.20	6.01	0.43	0.09
2022	0.28	1.11	6.14	0.39	0.08
2023	0.30	-0.03	6.42	0.38	0.08
2024	0.40	0.03	7.74	0.50	0.11
2025	0.50	0.16	9.01	0.64	0.14
2026	0.58	0.30	10.12	0.77	0.17
2027	0.65	0.42	11.09	0.89	0.19
2028	0.71	0.50	11.96	0.98	0.21
2029	0.75	0.57	12.76	1.06	0.23
2030	0.79	0.63	13.51	1.14	0.25
2031	0.83	0.68	14.23	1.20	0.26
2032	0.87	0.74	14.91	1.27	0.27

7 Figures

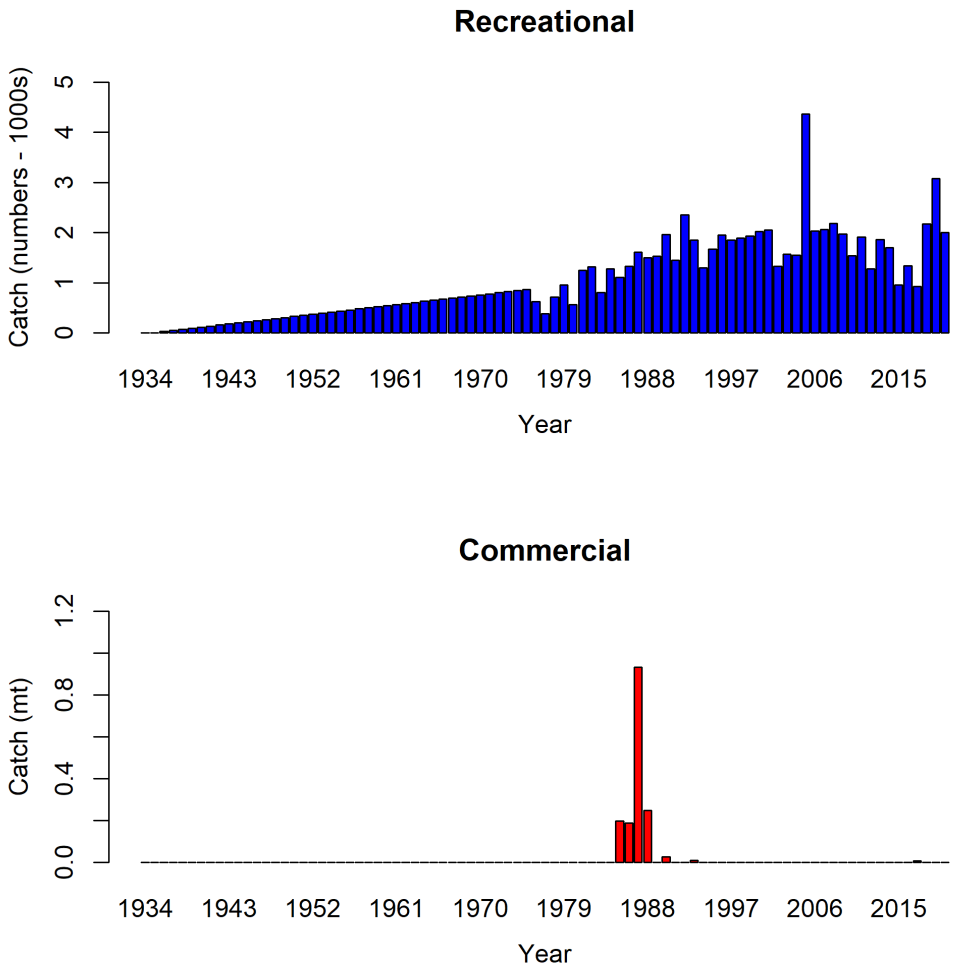

Figure 1: Catches by year for the recreational and commercial fleets in the model.

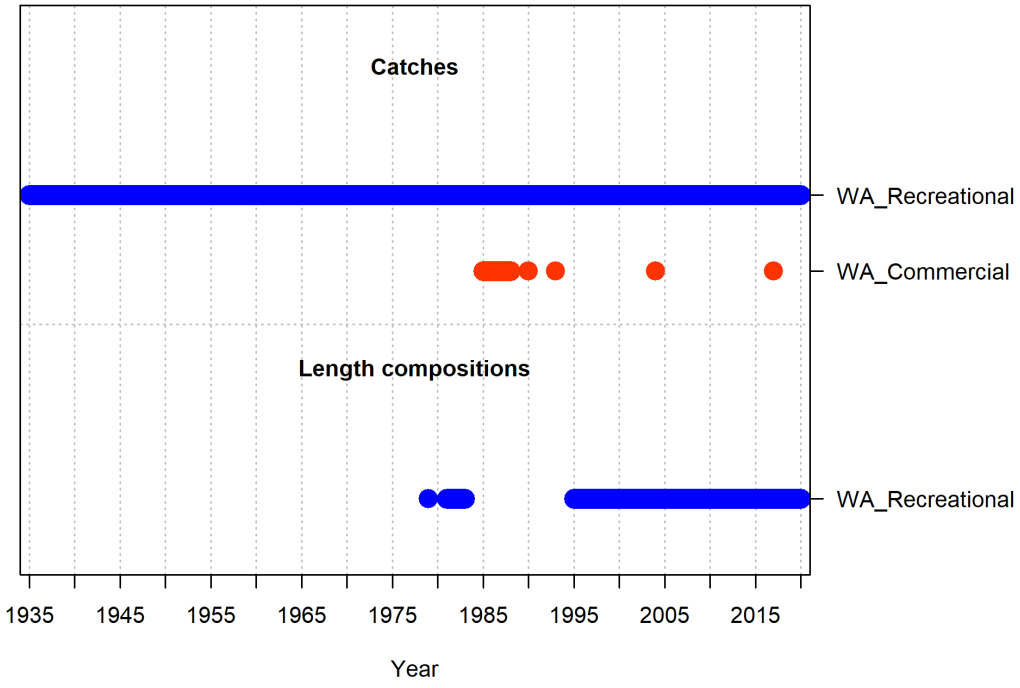

Figure 2: Summary of data sources used in the base model.

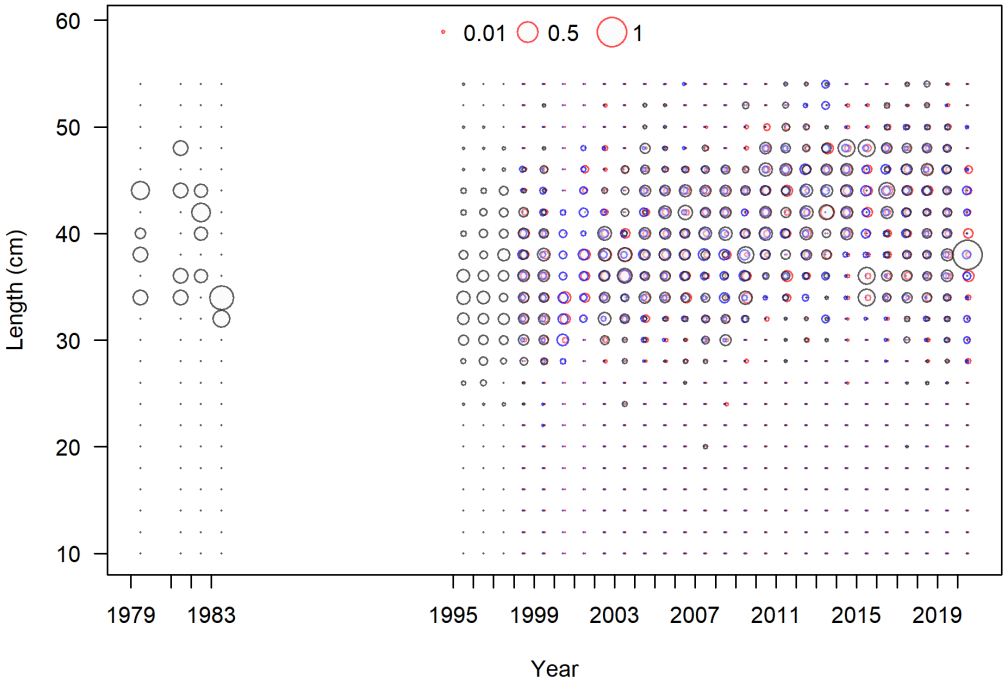

Figure 3: Length composition data from the recreational fleet.

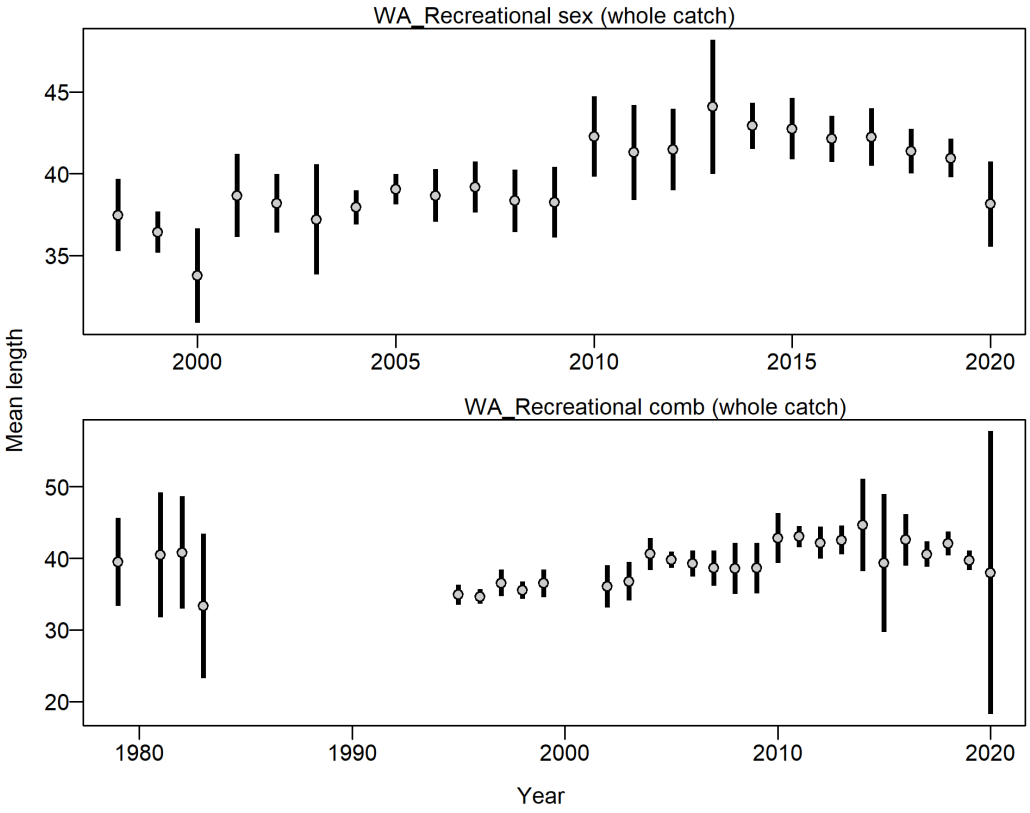

Figure 4: Mean length for recreational fleet with 95 percent confidence intervals.

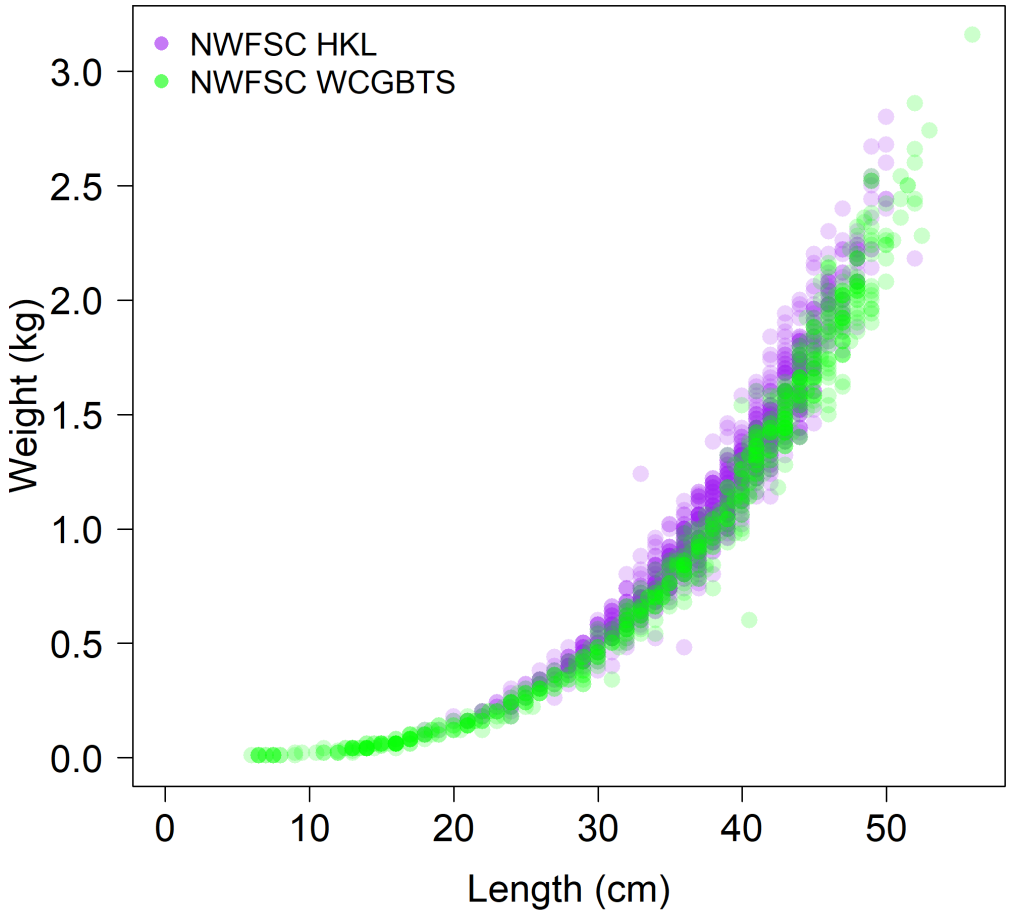

Figure 5: Comparison of the length-at-weight data from the NWFSC Hook and Line and the NWFSC WCGBT surveys.

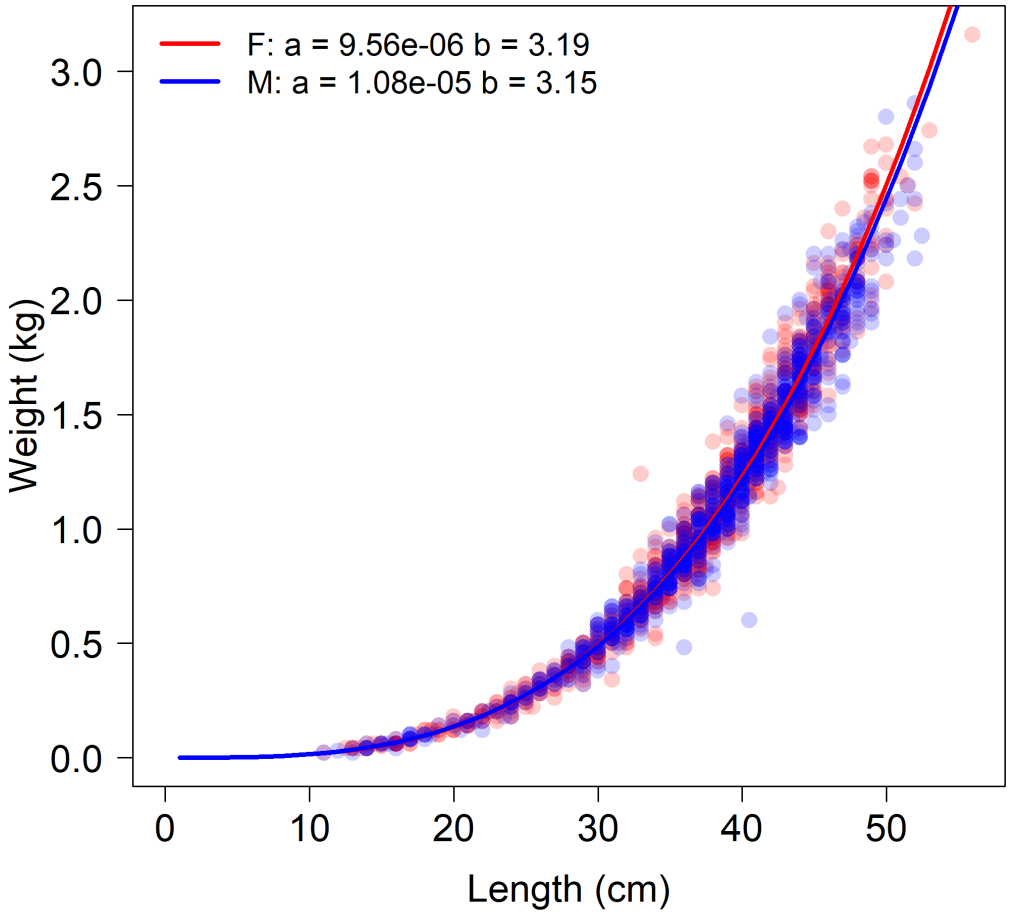

Figure 6: Survey length-at-weight data with sex specific estimated fits.

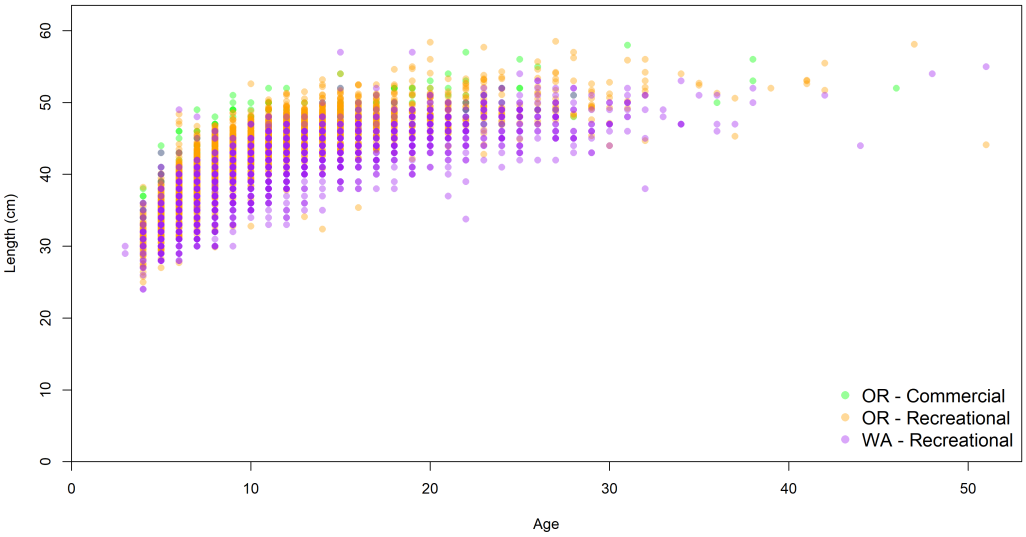

Figure 7: Observed length-at-age by data source.

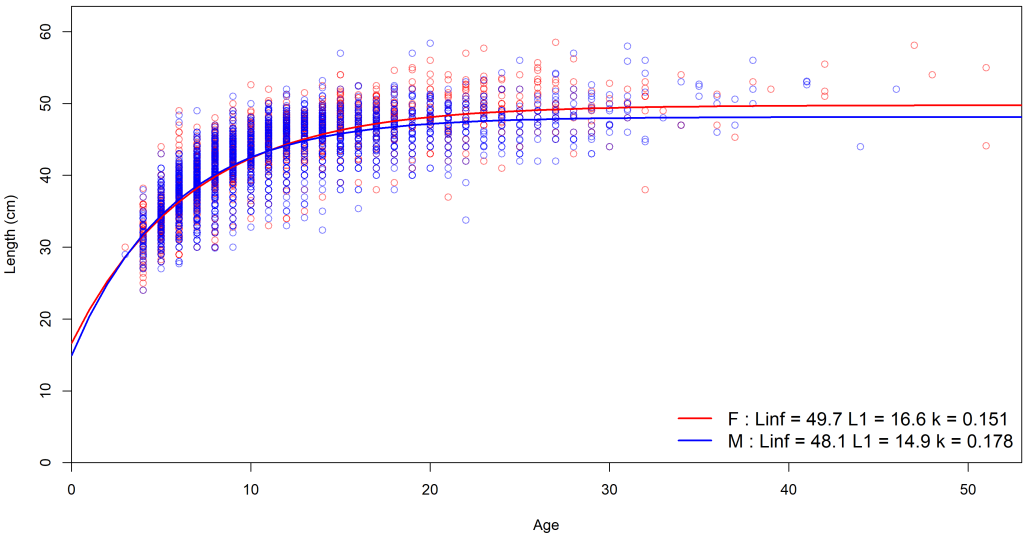

Figure 8: Length-at-age data from the with sex specific estimated growth.

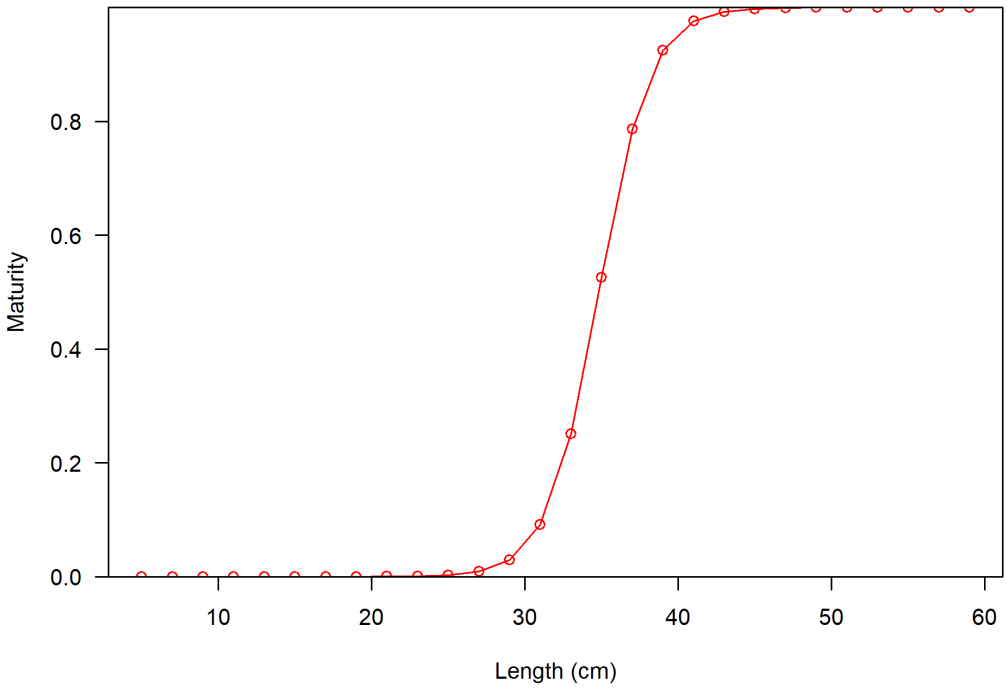

Figure 9: Maturity as a function of length.

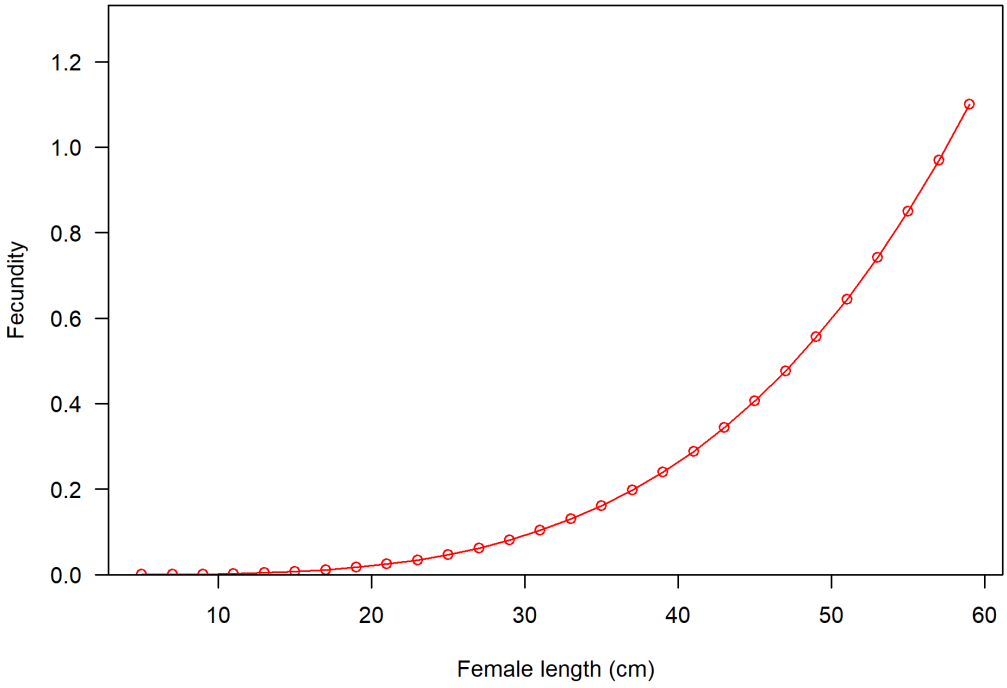

Figure 10: Fecundity as a function of length.

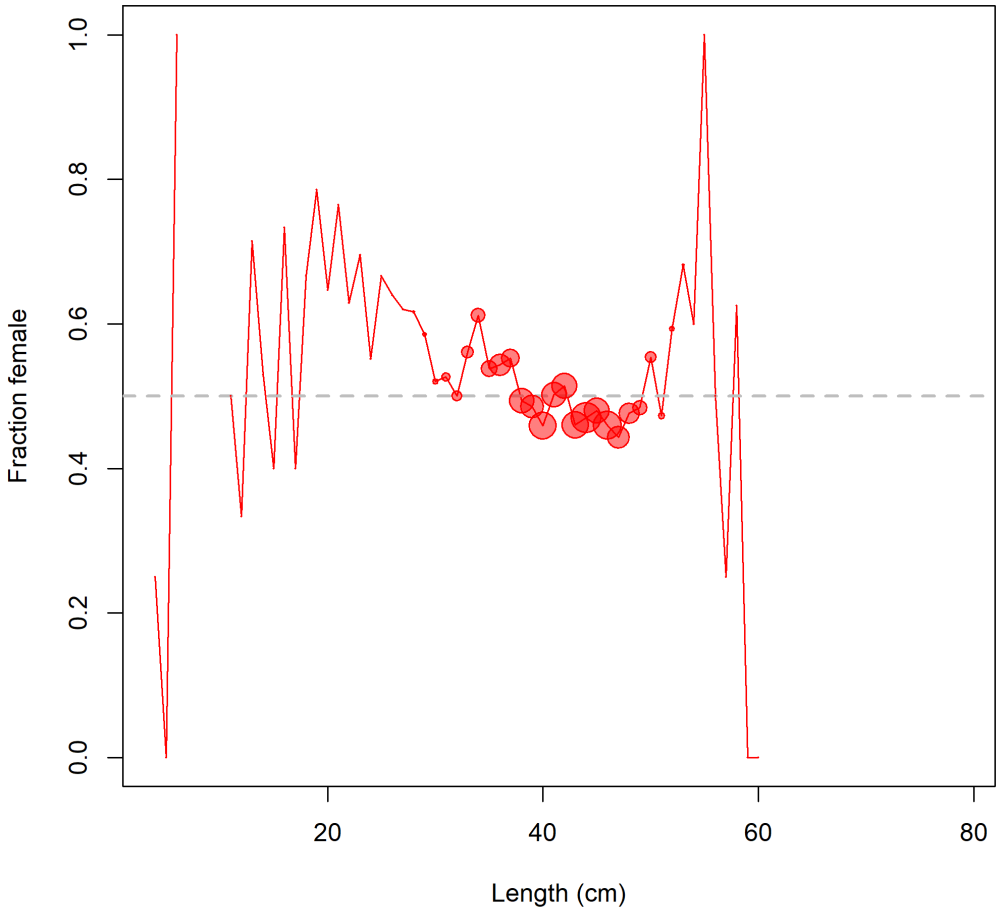

Figure 11: Fraction female by length across all available data sources.

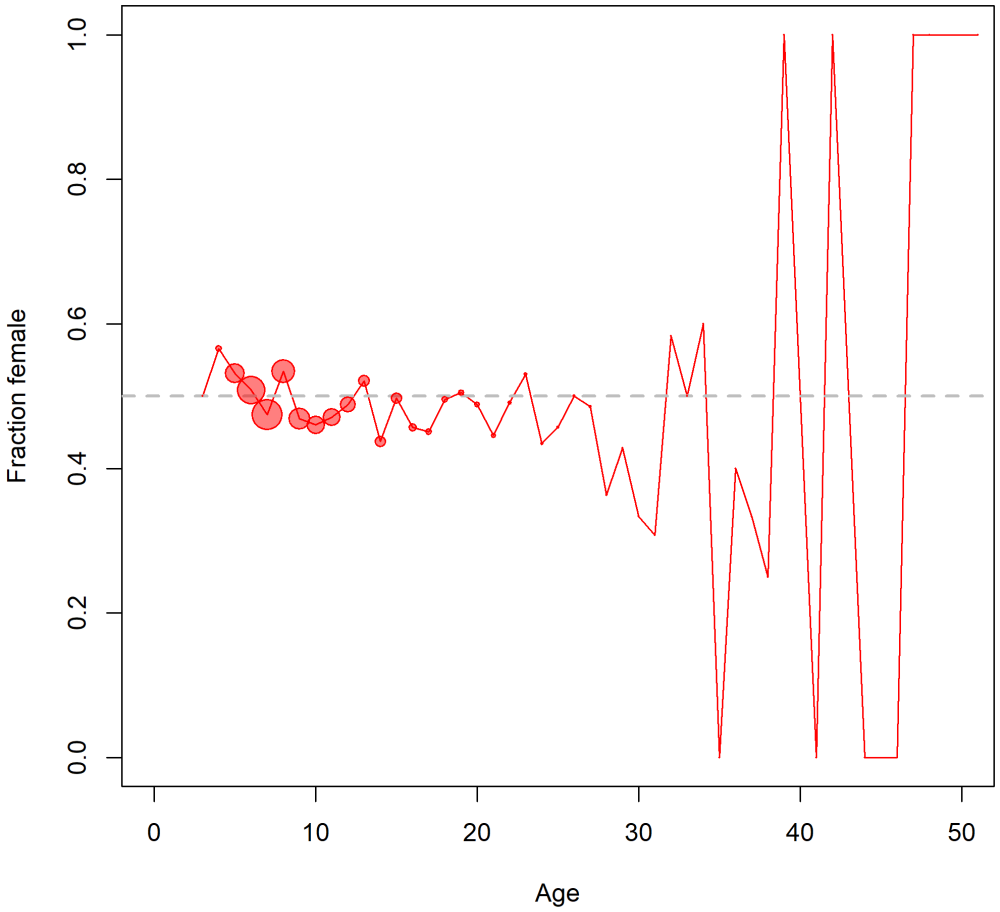

Figure 12: Fraction female by age across all available data sources.

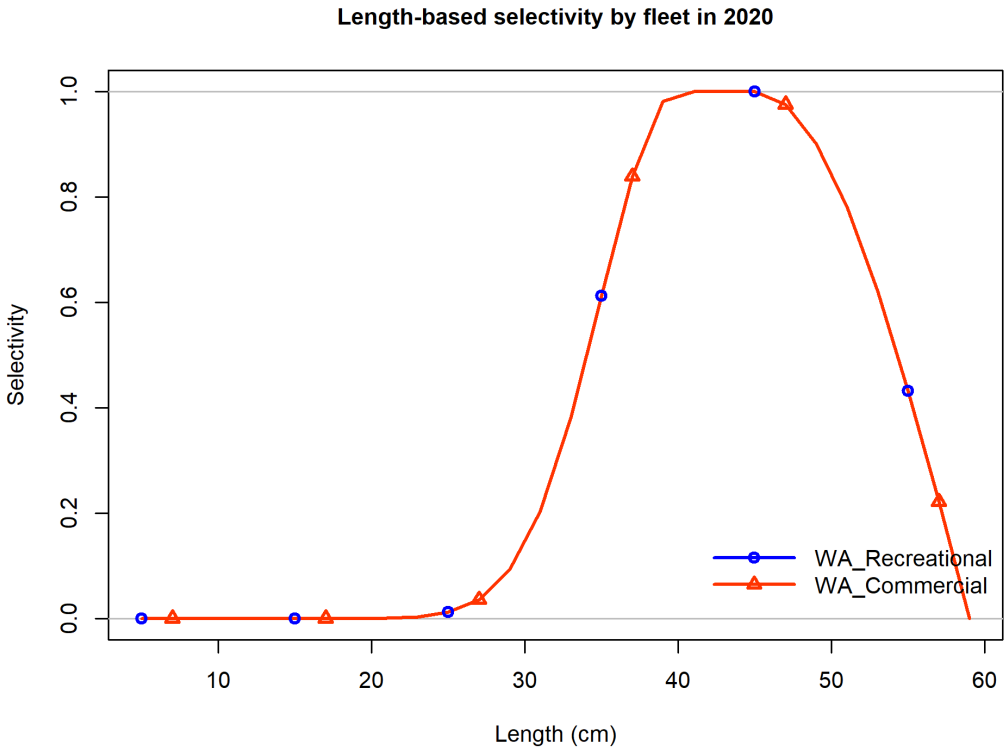

Figure 13: Selectivity at length by fleet.

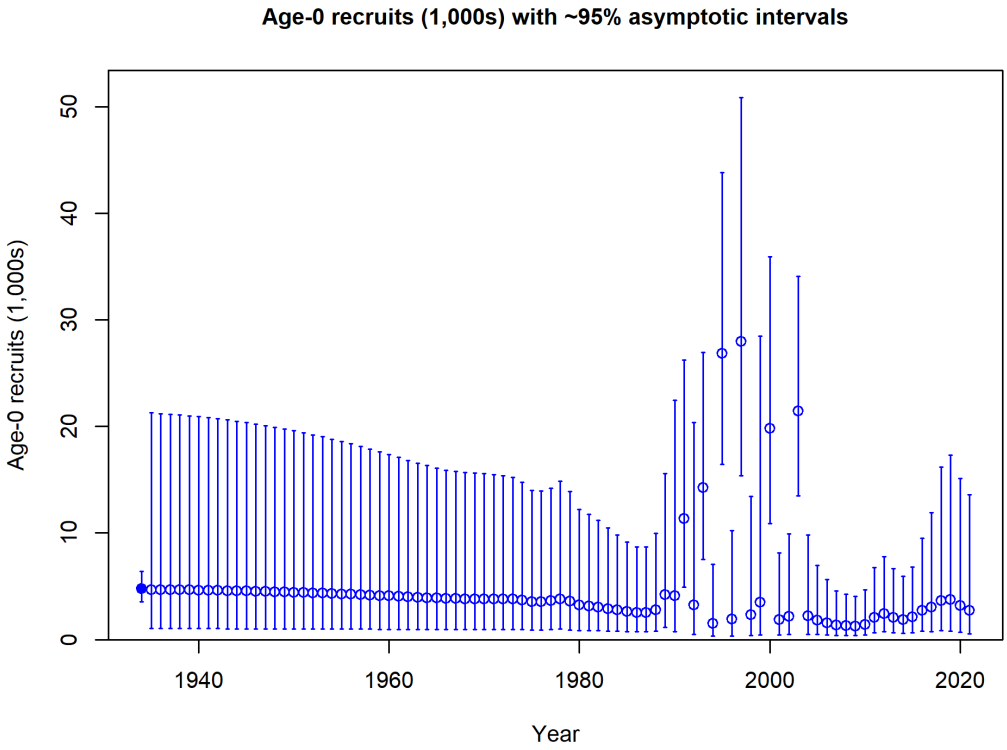

Figure 14: Estimated time series of age-0 recruits (1000s).

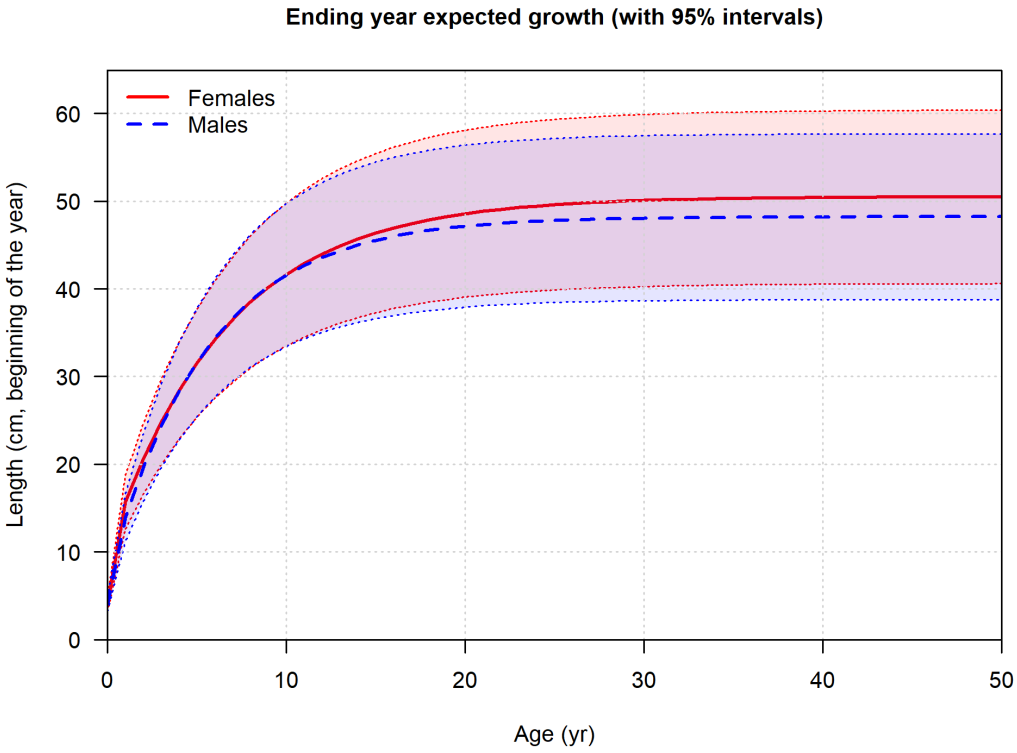

Figure 15: Length at age in the beginning of the year in the ending year of the model.

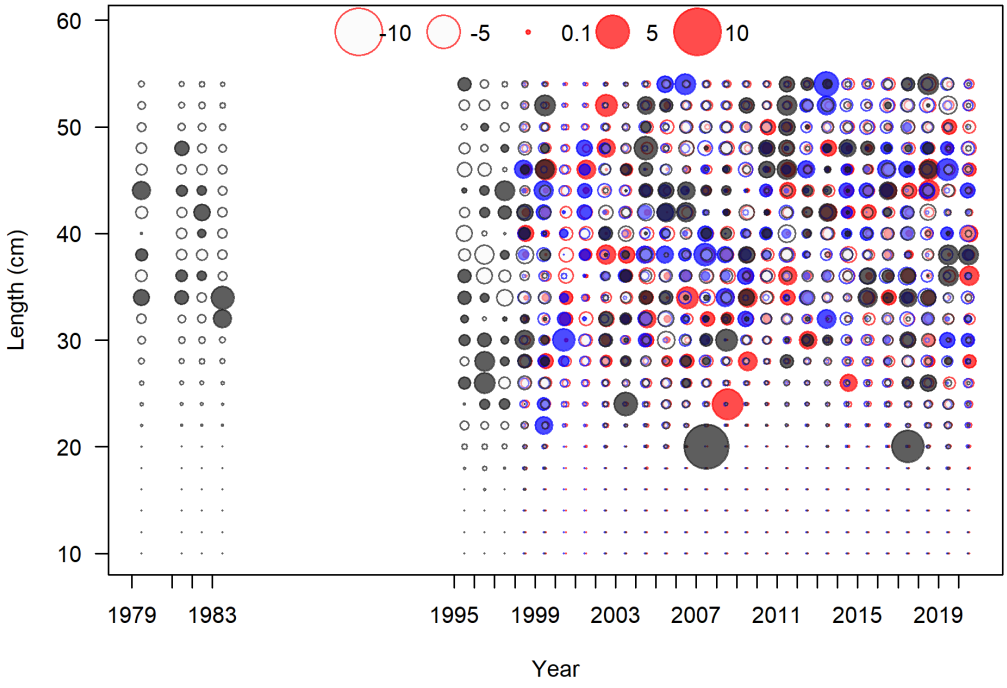

Figure 16: Pearson residuals for recreational fleet. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

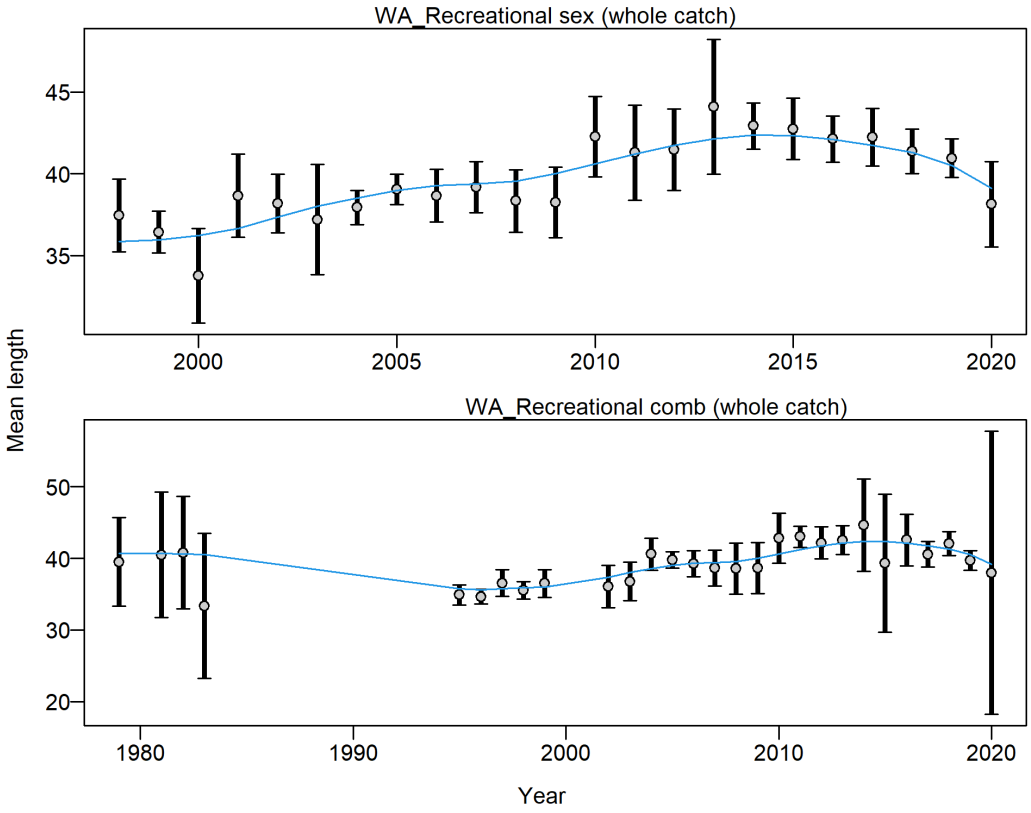

Figure 17: Mean length for recreational with 95 percent confidence intervals based on current samples sizes.

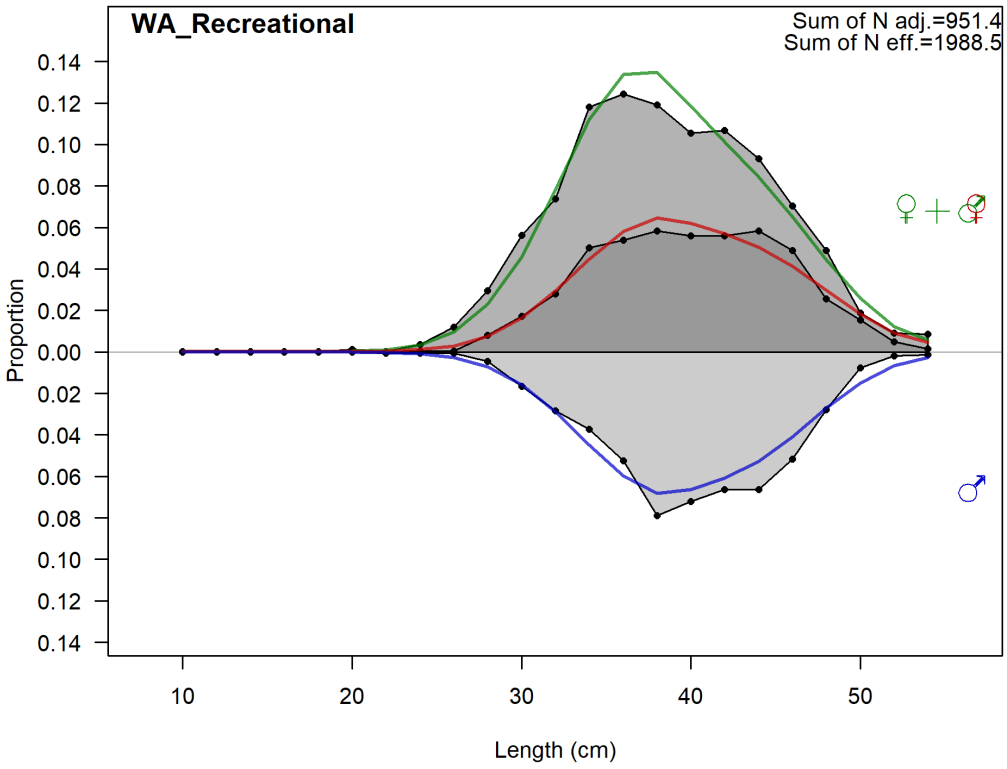

Figure 18: Aggregated length comps over all years.

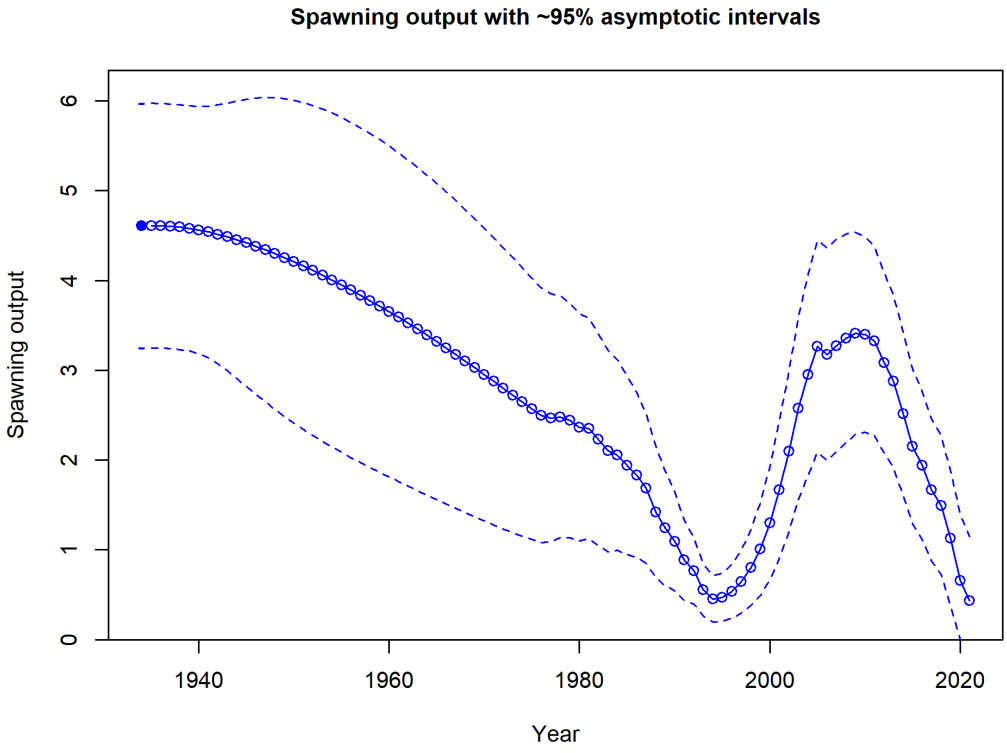

Figure 19: Estimated time series of spawning output.

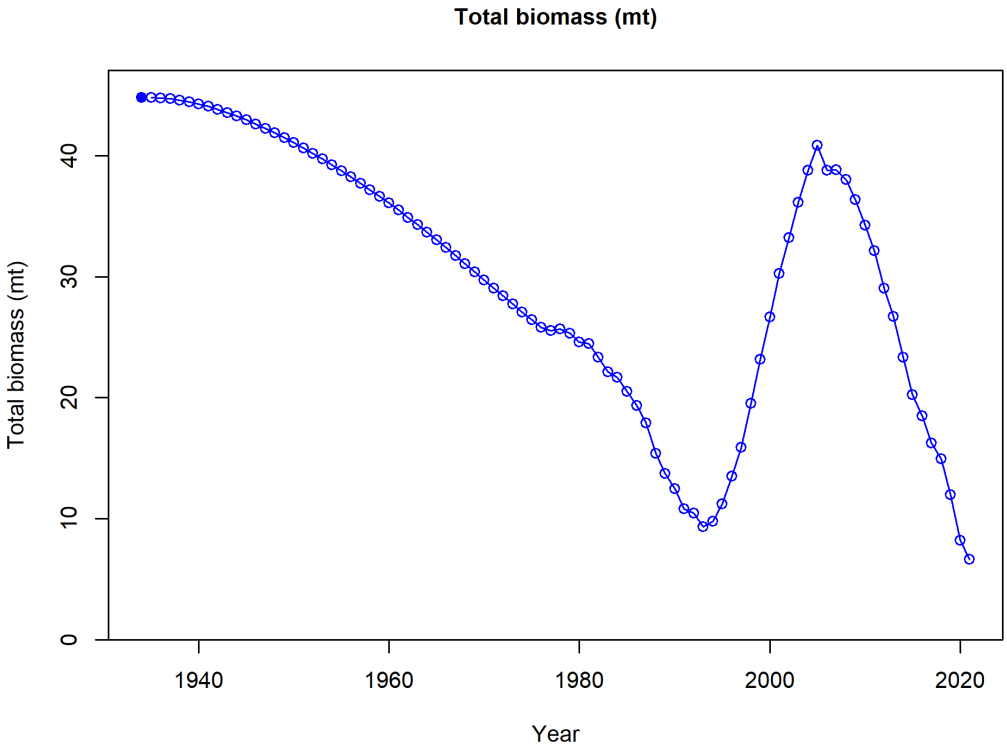

Figure 20: Estimated time series of total biomass.

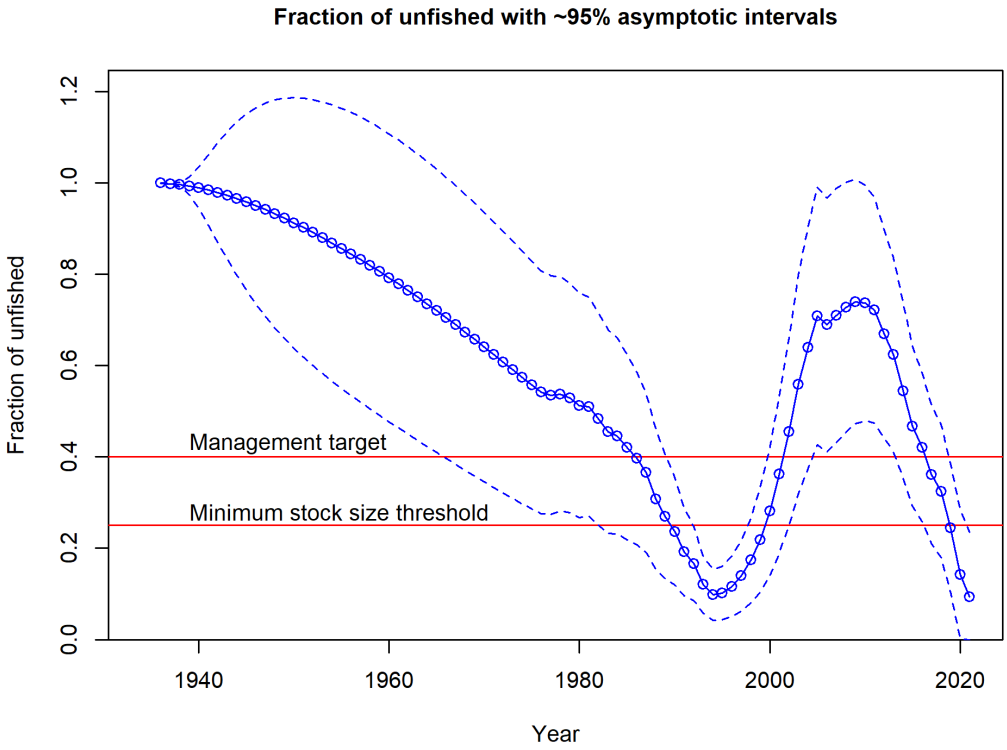

Figure 21: Estimated time series of fraction of unfished spawning output.

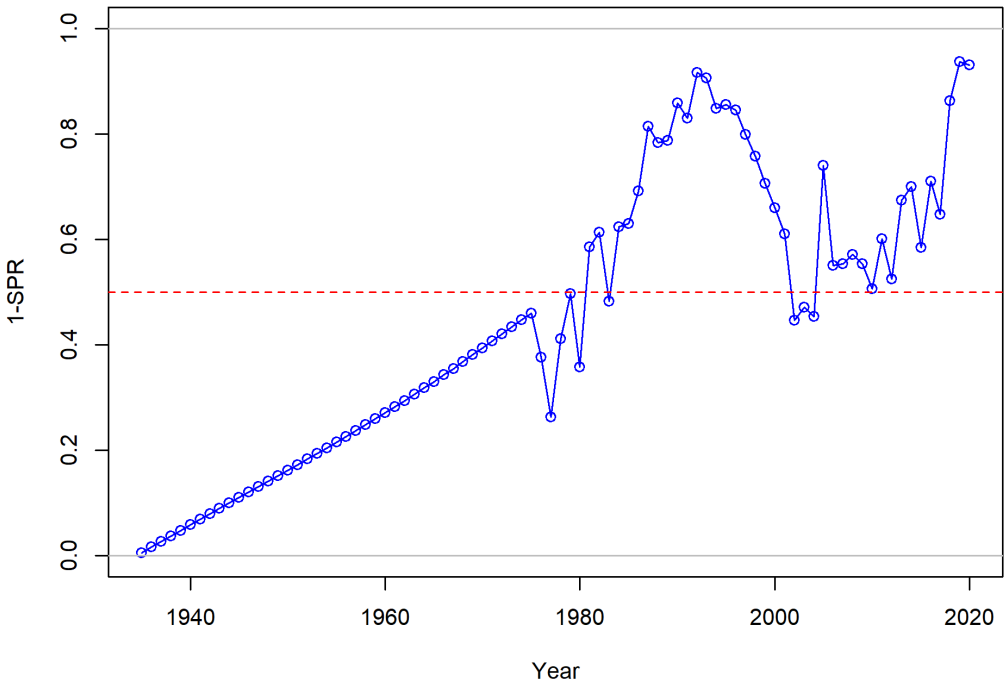

Figure 22: Estimated 1 - relative spawning ratio (SPR) by year.

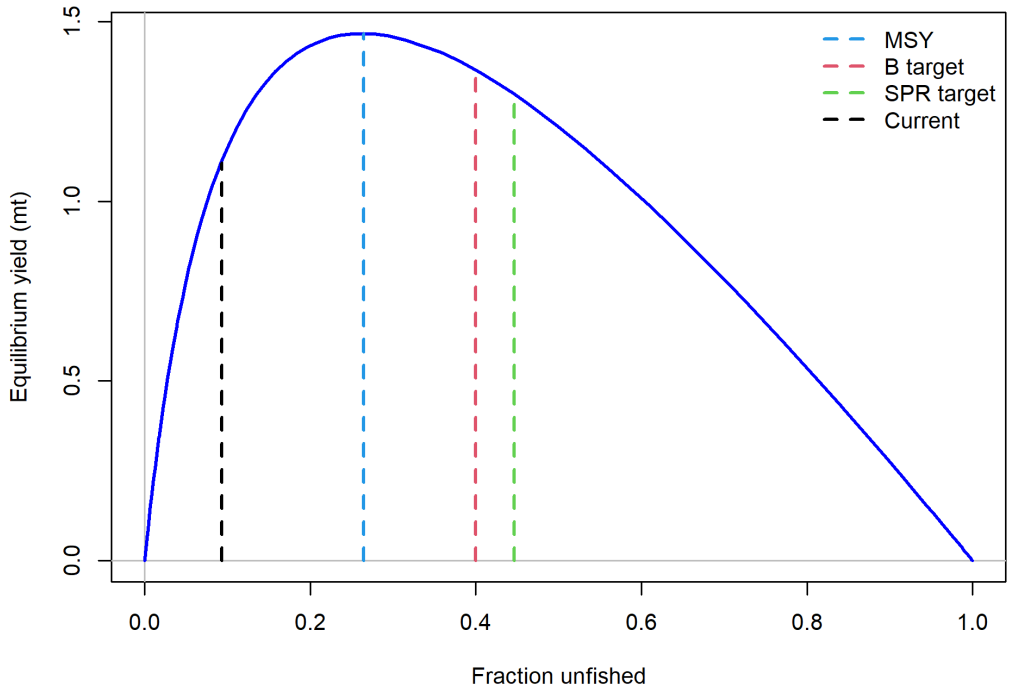

Figure 23: Equilibrium yield curve for the base case model. Values are based on the 2020 fishery selectivity and with steepness fixed at 0.72.

8 References

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