Status of Vermilion rockfish (*Sebastes miniatus*) along the US West - Oregon coast in 2021

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Executive Summary

Stock

This assessment reports the status of vermilion rockfish (*Sebastes miniatus*) off the US West - Oregon coast using data through xxxx.

Landings

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Data and Assessment

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Stock Biomass

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Recruitment

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Exploitation Status

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Reference Points

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Management Performance

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Unresolved Problems and Major Uncertainties

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Decision Table

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Research and Data Needs

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1 Introduction

1.1 Basic Information

This assessment reports the status of vermilion rockfish (*Sebastes miniatus*) off the US West - Oregon coast using data through xxxx.

1.2 Life History

Some descriptions of vermilion rockfish were observed prior to the separation of vermilion and sunset as a cryptic species pair by Hyde et al. in 2008 (**Hyde2008?**). Information pertaining solely to vermilion rockfish is used as much as possible.

Vermilion rockfish range from Prince William Sound, Alaska, to central Baja California at depths of 6 m to 436 m (**Love2002?**). However, they are most commonly found from central Oregon to Punta Baja, Mexico (**Hyde2009?**) at depths of 50 m to 150 m (**Hyde2009?**). Hyde and Vetter (**Hyde2009?**) describe vermilion rockfish as residents of shallower depths (<100 m) than sunset rockfish. Adult fish tend to cluster on high relief rocky outcrops (**Love2002?**) and kelp forests (**Hyde2009?**). North of Point Conception, some adults are shallower, living in caves and cracks (**Love2002?**). Vermilion rockfish have shown high site fidelity (**Hannah2011?** (only tagged 1 vermilion); **Lea1999?**), and low average larval dispersal distance (**Hyde2009?**). Lowe et al. (2009) [Lowe2009] suggested vermilion rockfish to have a lower site fidelity than previously believed, but they acknowledged that their observations of movements to different depths may have been due to the reality of a shallower species and a deeper species. Approximate lifespan for vermilion rockfish is 60 years, with females living longer and growing larger than their male counterparts. 50% are mature at 5 years and about 37 cm, with males probably maturing at shorter lengths than females (**Love2002?**). Vermilion rockfish are viviparous, and release 63,000 to 2,600,000 eggs per season. In southern California, vermilion rockfish larvae are released between July and March. In central and northern California, this release occurs in September, December, and April-June (**Love2002?**). Larval release in fall and winter is not common among other rockfish species. Hyde and Vetter (**Hyde2009?**) suggest that low larval dispersal may be due to weak poleward flow of nearshore waters corresponding with peak vermilion larval release. Young-of-the-year vermilion rockfish settle out of the plankton during two recruitment periods per year, first from February to April and a second from August to October, and settlement has been observed in May off southern California (**Love2002?**). Larvae measure about 4.3 mm. Both young-of-the-year vermilion and sunset rockfish are mottled brown with areas of black, and older juveniles turn a mottled orange or red color (**Love2012?**). Juvenile fish are found individually from 6 m to 36 m, living near sand and structures. After two months, juveniles travel deeper and live on low relief rocky outcrops and other structures (**Love2002?**). Adult vermilion rockfish predominantly eat smaller fish, though sometimes they pursue euphausiids and other various macroplankton (**Phillips1964?**). Love (**Love2002?**) noted their diet to include octopus, salps, shrimps, and pelagic red crabs.

1.3 Ecosystem Considerations

Replace text.

1.4 Historical and Current Fishery Information

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1.5 Summary of Management History and Performance

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2 Data

A description of each data source is provided below (Figure 1).

2.1 Fishery-Dependent Data

2.2 Fishery-Independent Data

2.2.1 AFSC Slope Survey

The AFSC Slope Survey (Slope Survey) operated during the months of October to November aboard the R/V *Miller Freeman*. Partial survey coverage of the US west coast occurred during the years 1988-1996 and complete coverage (north of 34°30'S) during the years 1997 and 1999-2001. Typically, only these four years that are seen as complete surveys are included in assessments.

2.2.2 AFSC/NWFSC West Coast Triennial Shelf Survey

The AFSC/NWFSC West Coast Triennial Shelf Survey (Triennial Survey) was first conducted by the Alaska Fisheries Science Center (AFSC) in 1977, and the survey continued until 2004 (Weinberg et al. 2002). Its basic design was a series of equally-spaced east-to-west transects across the continential shelf from which searches for tows in a specific depth range were initiated. The survey design changed slightly over time. In general, all of the surveys were conducted in the mid summer through early fall. The 1977 survey was conducted from early July through late September. The surveys from 1980 through 1989 were conducted from mid-July to late September. The 1992 survey was conducted from mid July through early October. The 1995 survey was conducted from early June through late August. The 1998 survey was conducted from early June through early August. Finally, the 2001 and 2004 surveys were conducted from May to July.

Haul depths ranged from 91-457 m during the 1977 survey with no hauls shallower than 91 m. Due to haul performance issues and truncated sampling with respect to depth, the data from 1977 were omitted from this analysis. The surveys in 1980, 1983, and 1986 covered the US West Coast south to 36.8°N latitude and a depth range of 55-366 m. The surveys in 1989 and 1992 covered the same depth range but extended the southern range to 34.5°N (near Point Conception). From 1995 through 2004, the surveys covered the depth range 55-500 m and surveyed south to 34.5°N. In 2004, the final year of the Triennial Survey series, the Northwest Fisheries Science Center (NWFSC) Fishery Resource and Monitoring division (FRAM) conducted the survey following similar protocols to earlier years.

2.2.3 NWFSC West Coast Groundfish Bottom Trawl Survey

The NWFSC West Coast Groundfish Bottom Trawl Survey (WCGBTS) is based on a random-grid design; covering the coastal waters from a depth of 55-1,280 m (Bradburn, Keller, and Horness 2011). This design generally uses four industry-chartered vessels per year assigned to a roughly equal number of randomly selected grid cells and divided into two 'passes' of the coast. Two vessels fish from north to south during each pass between late May to early October. This design therefore incorporates both vessel-to-vessel differences in catchability, as well as variance associated with selecting a relatively small number (approximately 700) of possible cells from a very large set of possible cells spread from the Mexican to the Canadian borders.

2.3 Biological Parameters

2.3.1 Growth (Length-at-Age)

The length-at-age was estimated for female and male vermilion rockfish using data from collections sampling the commerical and recreational fisheries off the coast of Oregon from years 2004-2020 (Table **??**. Figure 2 shows the lengths and ages for all years by sex and data source as well as predicted von Bertalanffy growth function (VBGF) fits to the data. Females grow larger than males and sex-specific growth parameters were estimated at the following values:

Females L_∞ = 57.2 cm; k = 0.146; t_0 = -0.65

$$\text{Males } L_\infty = 54.2 \text{ cm; } k = 0.18\text{; } t_0 = 0$$

The estimated VBGF parameters provided initial values for the estimation of growth in the model, as all age and length data are included in the model. The resultant growth curves estimated by the model are presented in Figure 3. Sensitivity to the treatment of growth parameters (fixed or estimated) are explored through sensitivity analyses.

2.3.2 Ageing Precision and Bias

Counting ages from ageing structures in long-lived temparate fishes is challenging. Ages derived from these structures can be hard to reproduce within and between readers (i.e., imprecision), and may not contain the true age (i.e., bias). Stock assessment outputs can be affected by bias and imprecision in ageing, thus it is important to quantify and integrate this source of variability when fitting age data in assessments. In Stock Synthesis, this is done by including ageing error matrices that include the mean age (row 1) and standard deviation in age (row 2). Ageing bias is implemented When the inputted mean age deviates from the expected middle age for any given age bin (e.g., 1.75 inputted versus 1.5 being the true age); ageing imprecision is given as the standard deviation for each age bin (row 2).

Ageing error matrices for commerical and recreational fisheries respectively were calculated using multiple reads within each reader (n = 181 for commercial; n = 237 for recreational). An additional ageing error matrix was constructed from the Committee of Age Reading Experts (CARE) otolith exchange, where an exchange of 43 individuals was done amonth ODFW, WDFW, SWFSC, and NWFSC. The ODFW internal reads were used in the reference model, with the CARE comparison explored in a sensitivity model run.

Estimation of ageing error matrices for each lab used the approach of Punt et al. (2008). The ageing error matrix offers a way to calculate both bias and imprecision in age reads. Reader 1, the primary reader of the ages used in the stock assessment, is always considered unbiased, but may be imprecise. Several model configurations are available for exploration based on either the functional form (e.g., constant CV, curvilinear standard deviation, or curvilinear CV) of the bias in reader 2 or in the precision of the readers. Model selection uses AIC corrected for small sample size (AICc), which converges to AIC when sample sizes are large. Bayesian Information Criterion (BIC) was also considered when selecting a final model.

The ODFW interlab comparison supported imprecision with a curvilinear standard deviation for the recretaional fishery, and a linear one for commercial. The CARE comparison was also linear, with a bit higher standard deviation (Table \ref{tab:age-error-models). The functional forms for each matrix are given in Figure 4.

2.3.3 Natural Mortality

Natural mortality was not directly measured, so life-history based empirical relationships were used. The Natural Mortality Tool (NMT; https://github.com/shcaba/Natural-Mortality-

Tool), a Shiny-based graphical user interface allowing for the application of a variety of natural mortality estimators based on measures such as longevity, size, age and growth, and maturity, was used to obtain estimates of natural mortality. The NMT currently provides 22 options, including the Hamel (2015) method, which is a corrected form of the Then et al. (2015) functional regression model and is a commonly applied method for west coast groundfish. The NMT also allows for the construction of a natural mortality prior weighted across methods by the user.

We assumed the age of 54 years to represent the practical longevity (i.e., 90% of the commonly seen maximum age of 60) for both females and males, though the absolute oldest age in OR was >60 years. In the larger biomass, higher sampled area of California, ages 80+ were even encountered. Empirical M estimators using the von Bertalanffy growth parameters were also considered, but they produced unreasonably high estimates (2-3 times higher than the longevity estimates). This is likely explained by the fact that while vermilion rockfish have protracted longevity at L_∞. Additionally, the FishLife (**thorson_predicting_2017?**) estimate was included, though, given the source of FishLife data is FishBase, there is a good chance the estimates of M are also from methods using longevity, though the actual source of longevity in FishLife was unknown. The final composite M distributionn (Figure 7) are based on 4 empirical estimators, and result in a median value of 0.1. We assume a lognormal distribution with a standard deviation of 0.438 (Hamel (2015)) for the purposes of the prior used to estimate M. This creates a wide prior to allow the data in the model to also influence the final estimated value of M.We also explore sensitivity to these assumptions of natural mortality through likelihood profiling.

2.3.4 Maturation and Fecundity

Maturity-at-length is based on the work of Hannah and Kautzi (2012) which estimated the 50 percent size-at-maturity of 39.4 cm off Oregon, though the slope of the maturity curve was not provided. Looking at the data provided in the reference, and length at 95% maturity was assumed at 48cm, resulting in a slope of -0.34. Maturity was assumed to stay asymptotic for larger fish (Figure 5) as no functional maturity estimate was availale (Head, Cope, and Wulfing 2020).

The fecundity-at-length was based on research by Dick et al.(2017). The fecundity relationship for vermilion rockfish was estimated equal to Fec=4.32e-07$L^{3.55}$ in millions of eggs where L is length in cm. Fecundity-at-length is shown in Figure 6.

2.3.5 Length-Weight Relationship

The length(cm)-weight(kg) relationship for vermilion rockfish was estimated outside the model using all coastwide biological data available from fishery-independent data sources. The estimated length-weight relationship for female fish was W=2.60642e-05$L^{2.93}$ and males at W=3.7636e-05$L^{2.83}$ (Figures **??**).

2.3.6 Sex Ratio

No information on the sex ratio at birth was available so it was assumed to be 50:50.

2.3.7 Steepness

The Thorson-Dorn rockfish prior (developed for use West Coast rockfish assessments) conducted by James Thorson (personal communication, NWFSC, NOAA) and reviewed and endorsed by the Scientific and Statistical Committee (SSC) in 2017, has been a primary source of information on steepness for rockfishes. This approach, however, was subsequently rejected for future analysis in 2019 when the new meta-analysis resulted in a mean value of approximately 0.95. In the absense of a new method for generating a prior for steepness the default approach reverts to the previously endorsed method, the 2017 prior for steepness (h; beta distribution with μ=0.72 and σ=0.15) is retained.

2.4 Environmental and Ecosystem Data

3 Assessment Model

3.1 Summary of Previous Assessments and Reviews

3.1.1 History of Modeling Approaches (not required for an update assessment)

3.1.2 Most Recent STAR Panel and SSC Recommendations (not required for an update assessment)

3.1.3 Response to Groundfish Subcommittee Requests (not required in draft)

3.2 Model Structure and Assumptions

3.2.1 Model Changes from the Last Assessment (not required for an update assessment)

3.2.2 Modeling Platform and Structure

General model specifications (e.g., executable version, model structure, definition of fleets and areas)

3.2.3 Model Parameters

Describe estimated vs. fixed parameters, priors

3.2.4 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

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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!

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7 Tables

Table 1: Catches (mt) by fleet for all years and total catches (mt) summed by year.

Year	Commercial	Recreational	Total Catch
1892	0.00	0.00	0.00
1893	0.00	0.00	0.00
1894	0.00	0.00	0.00
1895	0.00	0.00	0.00
1896	0.00	0.00	0.00
1897	0.00	0.00	0.00
1898	0.00	0.00	0.00
1899	0.00	0.00	0.00
1900	0.00	0.00	0.00
1901	0.00	0.00	0.00
1902	0.00	0.00	0.00
1903	0.00	0.00	0.00
1904	0.00	0.00	0.00
1905	0.00	0.00	0.00
1906	0.00	0.00	0.00
1907	0.00	0.00	0.00
1908	0.00	0.00	0.00
1909	0.00	0.00	0.00
1910	0.00	0.00	0.00
1911	0.00	0.00	0.00
1912	0.00	0.00	0.00
1913	0.00	0.00	0.00
1914	0.00	0.00	0.00
1915	0.00	0.00	0.00
1916	0.00	0.00	0.00
1917	0.00	0.00	0.00
1918	0.00	0.00	0.00
1919	0.00	0.00	0.00
1920	0.00	0.00	0.00
1921	0.00	0.00	0.00
1922	0.00	0.00	0.00
1923	0.00	0.00	0.00
1924	0.00	0.00	0.00
1925	0.00	0.00	0.00
1926	0.00	0.00	0.00
1927	0.00	0.00	0.00
1928	0.00	0.00	0.00
1929	0.32	0.00	0.32
1930	0.58	0.00	0.58
1931	0.28	0.00	0.28
1932	0.00	0.00	0.00
1933	0.06	0.00	0.06
1934	0.09	0.00	0.09
1935	0.00	0.00	0.00
1936	0.33	0.00	0.33

Table 1: Catches (mt) by fleet for all years and total catches (mt) summed by year. *(continued)*

Year	Commercial	Recreational	Total Catch
1937	1.08	0.00	1.08
1938	1.26	0.00	1.26
1939	1.52	0.00	1.52
1940	1.81	0.00	1.81
1941	1.21	0.00	1.21
1942	1.46	0.00	1.46
1943	1.65	0.00	1.65
1944	2.28	0.00	2.28
1945	2.57	0.00	2.57
1946	2.78	0.00	2.78
1947	0.92	0.00	0.92
1948	1.87	0.00	1.87
1949	2.00	0.00	2.00
1950	0.72	0.00	0.72
1951	0.65	0.00	0.65
1952	1.29	0.00	1.29
1953	0.44	0.00	0.44
1954	0.29	0.00	0.29
1955	0.83	0.00	0.83
1956	0.41	0.00	0.41
1957	0.87	0.00	0.87
1958	0.09	0.00	0.09
1959	0.27	0.00	0.27
1960	0.35	0.00	0.35
1961	0.65	0.00	0.65
1962	0.36	0.00	0.36
1963	0.63	0.00	0.63
1964	0.36	0.00	0.36
1965	1.82	0.00	1.82
1966	1.14	0.00	1.14
1967	3.26	0.00	3.26
1968	3.10	0.00	3.10
1969	6.04	0.00	6.04
1970	2.83	0.00	2.83
1971	6.42	0.00	6.42
1972	8.31	0.00	8.31
1973	9.02	0.00	9.02
1974	11.53	0.00	11.53
1975	5.97	0.00	5.97
1976	7.98	0.00	7.98
1977	11.21	0.00	11.21
1978	11.75	0.00	11.75
1979	7.70	0.30	8.00
1980	8.16	0.48	8.64
1981	4.37	1.66	6.03

Table 1: Catches (mt) by fleet for all years and total catches (mt) summed by year. *(continued)*

Year	Commercial	Recreational	Total Catch
1982	4.94	2.02	6.96
1983	6.03	0.85	6.88
1984	5.60	1.52	7.12
1985	8.53	0.64	9.17
1986	10.38	3.18	13.56
1987	9.63	0.12	9.75
1988	10.11	1.26	11.37
1989	9.98	6.26	16.23
1990	10.87	5.20	16.07
1991	3.60	2.36	5.96
1992	4.30	5.05	9.35
1993	13.90	13.00	26.90
1994	4.07	4.66	8.72
1995	1.78	2.26	4.04
1996	5.41	2.35	7.76
1997	4.55	4.04	8.59
1998	4.71	6.40	11.11
1999	1.44	1.57	3.01
2000	2.99	2.59	5.58
2001	4.80	3.24	8.04
2002	2.08	3.21	5.28
2003	2.20	4.21	6.41
2004	1.76	3.50	5.26
2005	1.68	6.07	7.74
2006	2.42	5.42	7.85
2007	2.06	6.85	8.91
2008	3.99	5.66	9.64
2009	4.08	3.98	8.06
2010	1.64	4.78	6.42
2011	2.95	6.10	9.05
2012	2.79	9.15	11.94
2013	3.42	6.30	9.73
2014	2.28	3.95	6.23
2015	1.47	4.65	6.12
2016	2.02	3.69	5.71
2017	3.26	8.80	12.06
2018	3.09	9.20	12.29
2019	3.86	9.25	13.11
2020	3.05	8.24	11.29

Table 2: Ageing error models and resultant model selection (AICc) values for 9 models of bias and precision explored for each lab used in the vermilion rockfish assessments. Gray bars indicate the chosen model. Model codes: 0= unbiased; 1 = Constant CV; 2 = Curvilinear SD; 3= Curvilinear CV

Model	Bias	Precision	Bias	Precision	AICc	ΔAICc	BIC	ΔBIC
1	0	1	0	1	0	26	0	25
2	0	2	0	2	0	4	0	4
3	**0**	**3**	**0**	**3**	**0**	**0**	**0**	**0**
4	0	1	1	1	0	16	0	16
5	0	2	1	2	0	15	0	16
6	0	3	1	3	0	15	0	16
7	0	1	2	1	0	24	0	25
8	0	2	2	2	0	24	0	26
9	0	3	2	3	0	28	0	30

Model	Bias	Precision	Bias	Precision	AICc	ΔAICc	BIC	ΔBIC
1	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**
2	0	2	0	2	0	4	0	6
3	0	3	0	3	0	4	0	6
4	0	1	1	1	0	0	0	3
5	0	2	1	2	0	4	0	8
6	0	3	1	3	0	8	0	12
7	0	1	2	1	0	39	0	42
8	0	2	2	2	0	10	0	14
9	0	3	2	3	0	9	0	14

Table 4: Ageing error models and resultant model selection (AICc) values for 9 models of bias and precision explored for each lab used in the vermilion rockfish assessments. Gray bars indicate the chosen model. Model codes: 0= unbiased; 1 = Constant CV; 2 = Curvilinear SD; 3= Curvilinear CV *(continued)*

Model	Bias	Precision	Bias	Precision	AICc	ΔAICc	BIC	ΔBIC
1	0	1	0	1	0	73	0	64
2	0	2	0	2	0	61	0	54
3	0	3	0	3	0	57	0	50
4	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**0**
5	0	2	1	2	0	17	0	18
6	0	3	1	3	0	7	0	8
7	0	1	2	1	0	1	0	3
8	0	2	2	2	0	13	0	16
9	0	3	2	3	0	10	0	13

8 Figures

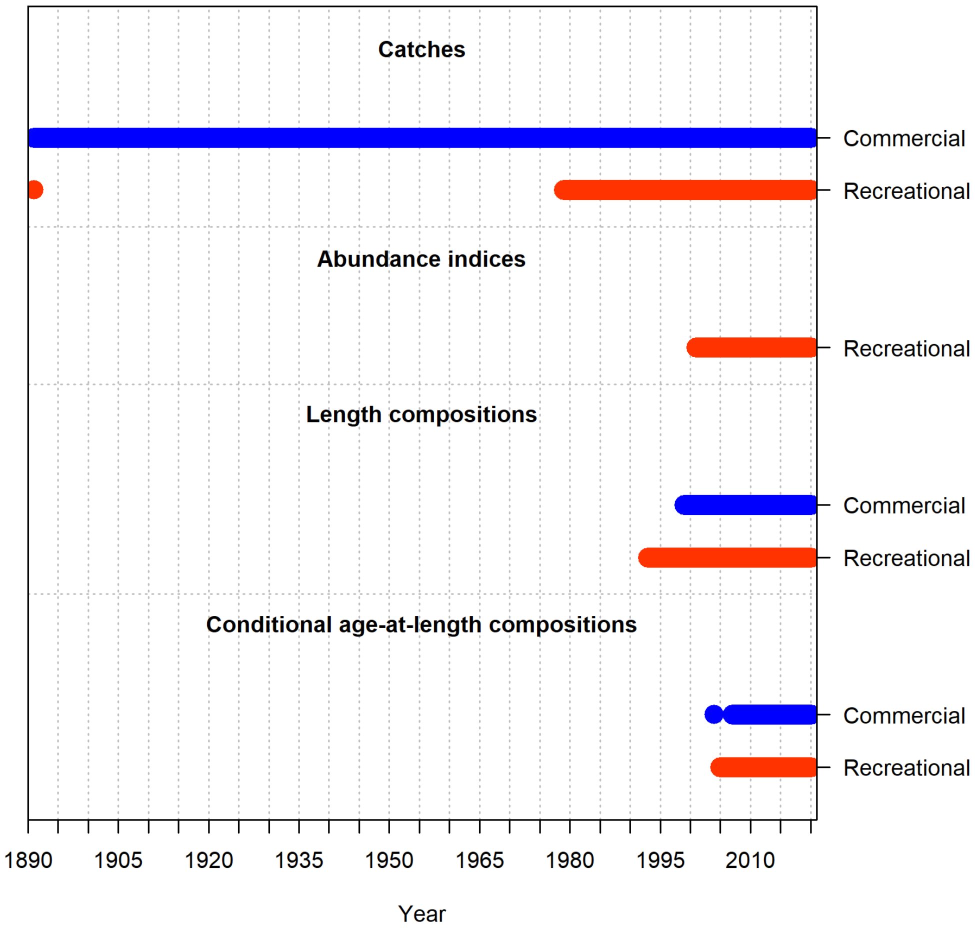

Figure 1: Summary of data sources used in the base model.

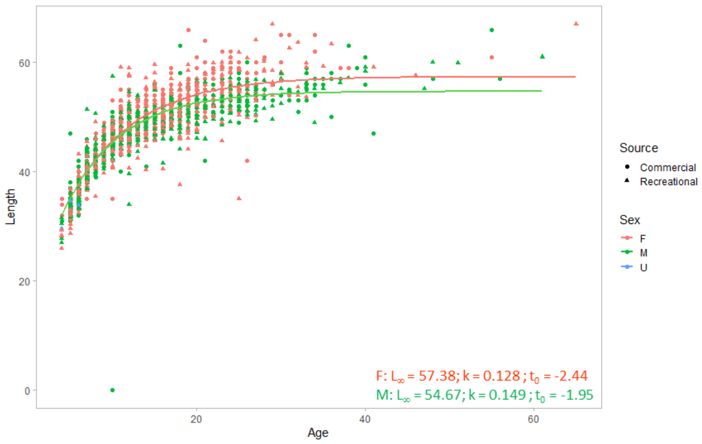

Figure 2: Observed length-at-age by data source and sex. Lines indicate fits to the von Bertalanffy growth equation, with parameter estimates provided in the bottom right corner of the figure.

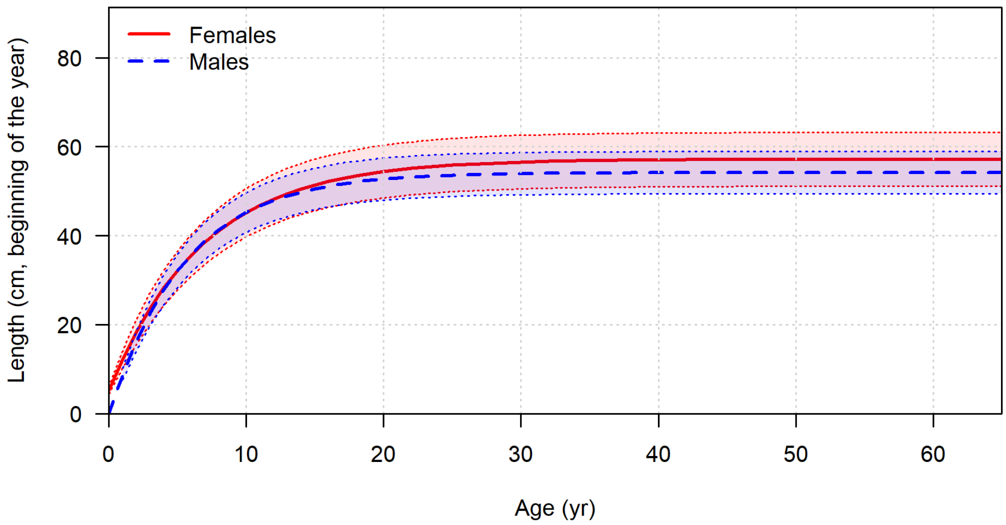

Figure 3: Length at age in the beginning of the year in the ending year of the model.

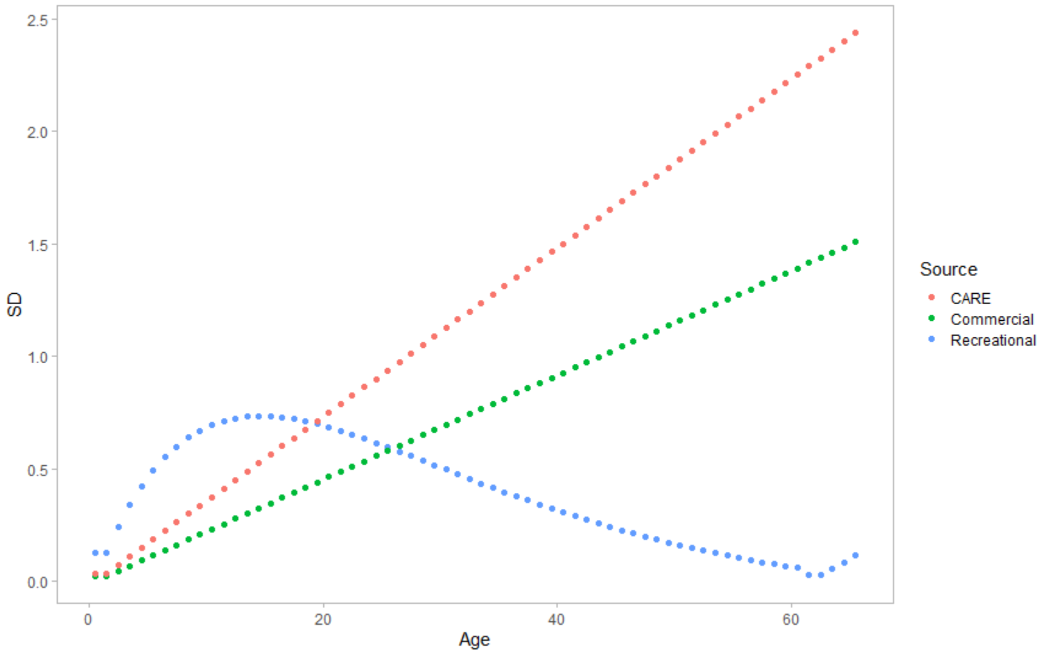

Figure 4: Agein error matrix (age by standard deviation) values by source. The commercial and recreational matrices are based on inter-reader comparisons.

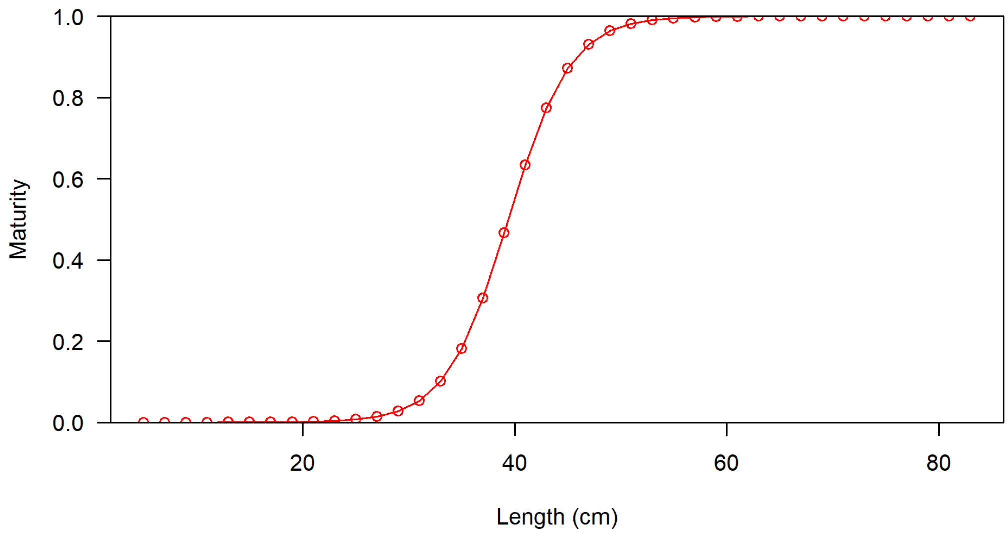

Figure 5: Maturity as a function of length.

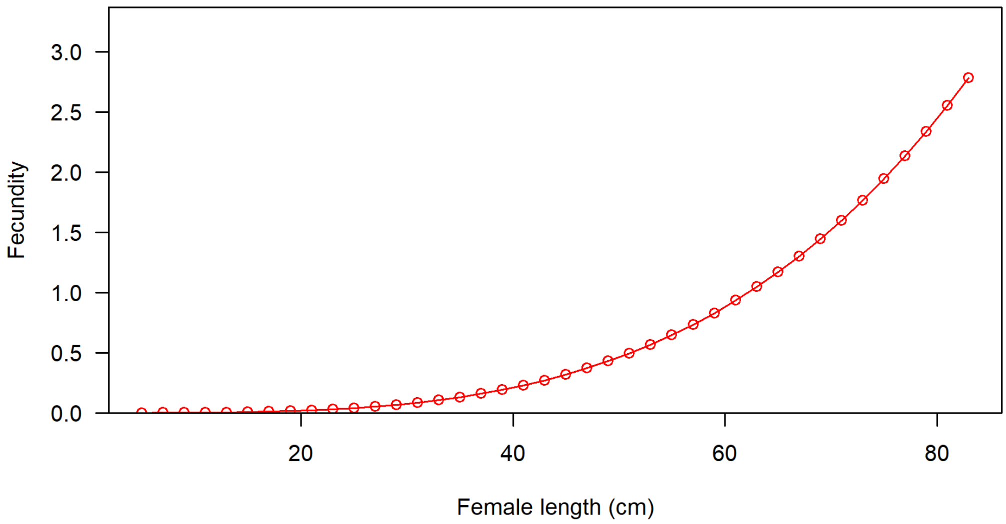

Figure 6: Fecundity as a function of length.

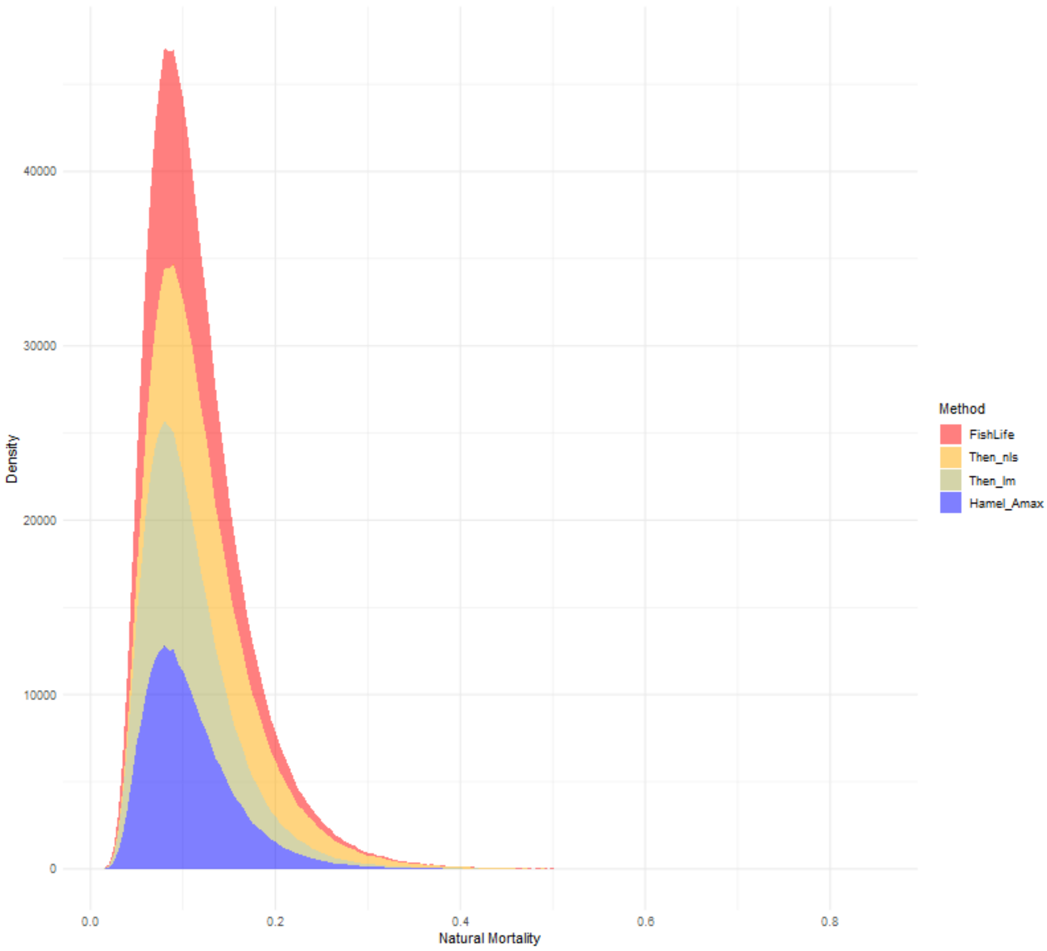

Figure 7: Composite natural mortality distriubtion for *S.hopkinsi* using four longevity estimators each with a SD = 0.2 presuming a lognomral error distibution.