Status of the sablefish (*Anoplopoma fimbria*) off the U.S. West Coast in 2025

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Stock Assessment Summary

At the beginning of 2025, the population size of mature female fish (spawning output) is estimated to be 74,409 metric tons (mt), and overall stock status (i.e., relative spawning output compared to unfished) is estimated to be 33.9%. The total population (mature and immature fish) is estimated to be sharply increasing in recent years (nearly doubling in size since 2020) from multiple strong cohorts (e.g., recruitment) occurring in 2016, 2020, 2021, and 2023. The projected coastwide Overfishing Limit (OFL) and Acceptable Biological Catch (ABC) in 2027 are 14,935 mt and 13,965 mt, respectively. The projected coastwide OFL and ABC in 2028 are 16,240 mt and 15,103 mt, respectively.

This assessment includes all available data on catches (landings and discards), an updated index of abundance from the Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey (WCGBTS) from 2003–2024, all available fishery and survey ages deemed representative through 2024, and empirical weight-at-age data to empirically track changes in mean growth over time and space.

The 2025 assessment estimates the stock status of sablefish to be lower than what was projected by the 2023 assessment, with the population below the management limit of 40% and in the precautionary zone until 2027 when stock status is projected to be greater than 40%. The projected ABC in 2027 is more than double the 2024 removals but approximately 35% lower than the projected removals in 2025–2026. However, the overall scale of the population (SB_0) increased by 18% in this assessment compared to the 2023 assessment.

Why is this assessment different from the 2023 assessment?

This assessment includes five primary improvements and changes in the model relative to the 2023 update assessment. This includes two major data improvements: (1) the identification and use of additional historical ages collected from the commercial fishery between 1983–2000, primarily collected in Oregon, which led to the stock to be estimated to be more depleted during this historical period; and (2) the use of an improved and more transparent approach to estimate mortality of discarded fish by the commercial fishery based upon available data collected across fishery sectors. This new approach is considered to be more transparent to ensure that the landings and discard mortality used in the assessment are consistent with the values used by management in the Groundfish Expanded Multiyear Mortality Report. Several major model structure improvements were also made to better represent sablefish biological processes off the West Coast. The assessment model moved to a strict (3) data driven approach to estimate annual recruitments with greater flexibility in the model to estimate low and high recruitment years. The assessment model switched from estimating a static growth function for each sex to (4) the use of empirical weight-at-age data to account for variable growth by age, sex, year, and area across the West Coast. Additionally, (5) the shape of the selectivity function for the WCGBTS was updated based upon data from the survey. The survey was estimated to have some selectivity for age-0, full selectivity for age-1 fish, and lower than one selectivity, but constant, for all older ages. The WCGBTS is believed to consistently and representatively sample sablefish well, covering a large majority of their habitat off the West Coast. Many other data and model refinements were completed for this assessment.

Executive Summary

Stock Description

This assessment reports the status of the sablefish (*Anoplopoma fimbria*, or 'black cod') resource off the coast of the United States (U.S.) from southern California to the U.S.-Canadian border using data through 2024. The resource is modeled as a single stock, however sablefish do disperse to and from offshore sea mounts and along the coastal waters of the continental U.S., Mexico, Canada, and Alaska and across the Aleutian Islands to the western Pacific. Net changes in population size or structure due to movement across the assessment boundary are considered negligible, though alternative assumptions are explored using sensitivity model evaluations.

Catches

Removals for sablefish contains various historical domestic landings reconstructions, historical foreign fishery catch, commercial domestic landings, Pacific hake at-sea fishery catch estimates, and recreational landings data. Estimated discards are included for the domestic historical and current commercial landings using available information on discard rates with gear-specific discard mortality rates. The model includes six catch- or discard-based fishery fleets: trawl, hook-and-line, pot, trawl discards, hook-and-line discards, and pot discards. Total removals used in this assessment are shown by fleet in Table i and Figure i.

The earliest landings of sablefish off the U.S. West Coast used within in this assessment begin in 1890 with hook-and-line gear. The removals began to slowly increase starting in the 1910s and continued at a roughly constant level until the 1960s, where removals sharply increased due to the expansion of trawling and the use of pot gear (Figure i). After peaking in the late 1970s, catches slowly decreased until the 2000s when catches generally stabilized roughly between 4,000 and 7,000 metric tons (mt) until present (see Table i for the most recent ten years). The pattern of discarded sablefish across the time series was similar to catches, though on average discard fleets caught 2 percent of the catch fleets. Over the last 10 years, average annual catch was highest for the hook-and-line fleet (2,204 mt), followed by the trawl (1,706 mt) and pot (1,482 mt) fleets. Over the same period, average annual discards were similar for trawl and hook-and-line gear (80 and 86 mt, respectively) and was lowest for pot gear (51 mt).

Table i: Recent catches (mt) by fleet and total catch (mt) summed across fleets.

Year	Trawl	Hook-and-Line	Pot	Trawl Discard	Hook-and-Line Discard	Pot Discard	Total Catch
2015	1,511	2,358	1,315	4	75	38	5,302
2016	1,517	2,535	1,403	10	118	37	5,619
2017	1,827	2,416	1,427	19	69	18	5,777
2018	1,622	2,462	1,289	10	78	32	5,494
2019	1,711	2,275	1,464	42	100	44	5,635
2020	1,123	1,504	1,332	46	31	43	4,078
2021	1,709	1,886	1,328	80	99	20	5,122
2022	2,407	2,300	1,665	123	87	58	6,640
2023	1,838	2,270	1,935	120	106	116	6,385
2024	1,792	2,031	1,664	348	95	100	6,029

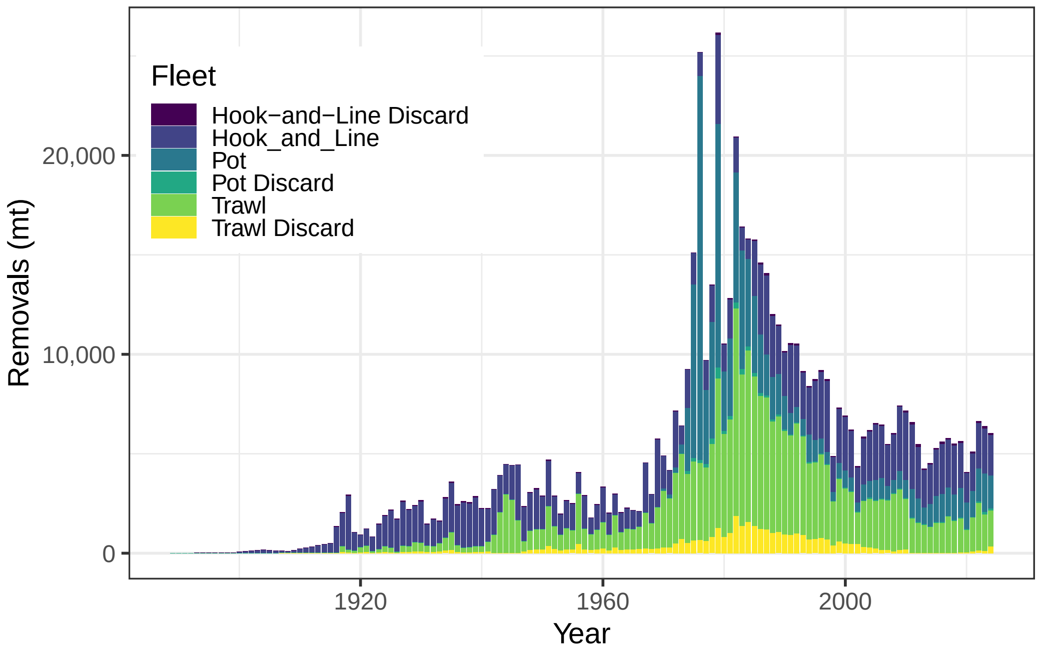

Figure i: Removals in metric tons (mt) by year for trawl, pot, and hook-and line gears.

Data and Assessments

The last benchmark stock assessment for sablefish took place in 2019 and was followed by update assessments in 2021 (Kapur et al. 2021) and 2023 (Johnson et al. 2023). Changes and additions between the 2023 update assessment and this assessment are listed in Section 3.3.3. This assessment used the most recent version of the Stock Synthesis modeling platform (3.30.24). Primary data sources include landings and age-composition data from the retained catch. Discarded sablefish and associated age-composition data (converted from length-compositions using a length-age key) are also used in this assessment. Weight-at-age data are used to empirically track changes in mean growth over time.

The relative index of abundance estimated from the National Marine Fisheries Service (NMFS) Northwest Fisheries Science Center (NWFSC) West Coast Groundfish Bottom Trawl Survey (WCGBTS), which includes depths from 55–1,280 m, represents the primary source of information on the stock's trend and was updated to include the most recent data, covering the period 2003–2024. This assessment also uses a relative index of abundance from the Alaska Fisheries Science Center/NWFSC Triennial Shelf Survey, split into early (1980–1992) and late (1995–2004) periods, and the NWFSC Slope Survey conducted from 1998–2002. Additionally, an environmentally-driven recruitment index was incorporated into the stock assessment to inform the most recent five years of recruitment.

The assessment is based upon a two-sex, age-structured model starting in 1890 and tracking annual changes in population dynamics up to an accumulated population age group of 70 years. Natural mortality (M) was estimated and assumed to be time invariant and equal between males and females. An empirical weight-at-age approach was implemented with sex-specific time-varying growth between 2003–2024 that was spatially integrated on an annual basis to represent coastwide trends in growth. Weight-at-age prior to 2003 was considered constant. Age data were grouped by individual age classes between 0–50, with 50 being used as a data plus group. Age-based selectivity was estimated as dome-shaped for each fleet and survey, and selectivity time blocks were used to allow for shifts in selectivity for each fishery fleet. Additionally, selectivity was mirrored (e.g., assumed to be the same) between the hook-and-line and pot fleets and sex-specific. Recruitment deviations were estimated from 1975 onwards with no restraint to sum to zero over the main estimation time period (1975–2023). Steepness (0.75), the standard deviation of recruitment variability (1.4), the functional maturity schedule, and the fecundity relationship were fixed inputs in the model. Fecundity was time-varying as the product of time-varying weight-at-age data and a spatially-integrated maturity schedule. The estimates of bias and uncertainty by age in age reading (e.g., ageing error) were updated for this assessment, and summary biomass was calculated for ages 3 plus.

The assessment was fit to data and prior information on natural mortality by minimizing the joint negative log-likelihood. The prior for M assumed a log-normal distribution with a median of 0.072 yr^{-1} and a standard error of 0.31. Age composition data was weighted by downsizing the input samples sizes for each data source following the Francis method. Twelve year projections were conducted that applied estimated M, the final year (i.e., time block) for fleet selectivity, a recent five year average weight-at-age (and similarly fecundity), and average recruitment. A suite of data and model structure sensitivities were conducted to examine the influence of individual data sources and base model robustness and stability. While base model results capture parametric uncertainty and sensitivity evaluations explore structural uncertainty, total uncertainty is underestimated in current stock size and status because this approach does not account for the interaction between them or all possible alternative model structures for sablefish population dynamics.

Stock Output and Dynamics

For the purposes of this assessment, female spawning biomass is assumed to be proportional to egg and larval production (i.e., spawning output) and the terms spawning biomass and spawning output are used interchangeably through the report. Spawning output is reported in metric tons (mt) throughout.

Overall, sablefish stock size and relative stock status have generally declined (at different rates) over time until a recent rapid increase due to several above average recruitment years (Table ii; Figure ii). Sablefish were exploited at relatively modest levels from the early 1900s to the mid-1970s, resulting in a gradual decline in spawning output from the equilibrium unfished level. Estimates of spawning output declined rapidly from the mid-1970s to the early 2000s as a result of higher than average harvest and modest recruitment. As annual harvest levels subsided to more moderate levels, spawning output generally leveled off from 2000–2017 in the range of 10 to 20 percent relative stock status (below the minimum stock size threshold; Figure iii). Since 2017, spawning output is estimated to have continually increased through 2025 to the highest spawning output size since 1989. This rapid increase in spawning output is due to several above average recruitment years since 2013. The summary biomass of fish age 3 and older has a steeper increase at the end of the time series from both the 2020 and 2021 strong cohorts. Although the relative trend in spawning output is robust to uncertainty in the leading model parameters, the productivity of the stock remains a key source of uncertainty due to confounding of natural mortality, absolute stock size, and productivity (e.g., steepness).

The estimate of 2025 female spawning output is 74,409 mt with 95 percent asymptotic confidence intervals from 59,331 to 89,486 mt (Table ii). The estimate of the 2025 stock status (i.e., the spawning output at the start 2025 divided by that at unfished equilibrium, B_0) is 33.9 percent (Table ii). However, the uncertainty covers 27.6 to 40.2 percent, partly due to remaining unknowns about the absolute size of recent, potentially large, recruitment events. The estimated trajectory of relative spawning output across the time series includes fishing the stock down to below the minimum stock stock size threshold and then rebounding to the precautionary zone after an extended period of reduced harvest (relative to time series maximums) and good recruitment (Figure iii) .

Table ii: Estimated recent trend in spawning output and the stock status and the 95 percent confidence intervals.

Year	Spawning output	Lower Interval (mt)	Upper Interval (mt)	Stock Status	Lower Interval	Upper Interval
2015	25,716	19,299	32,133	0.117	0.092	0.142
2016	27,092	20,372	33,813	0.123	0.097	0.150
2017	27,641	20,865	34,416	0.126	0.100	0.152
2018	31,646	24,074	39,218	0.144	0.115	0.174
2019	35,644	27,343	43,946	0.162	0.130	0.195
2020	40,716	31,457	49,976	0.186	0.149	0.223
2021	48,433	37,845	59,020	0.221	0.178	0.264
2022	53,073	41,765	64,381	0.242	0.196	0.288
2023	57,937	45,705	70,170	0.264	0.214	0.314
2024	61,505	48,701	74,308	0.280	0.227	0.333
2025	74,409	59,331	89,486	0.339	0.276	0.402

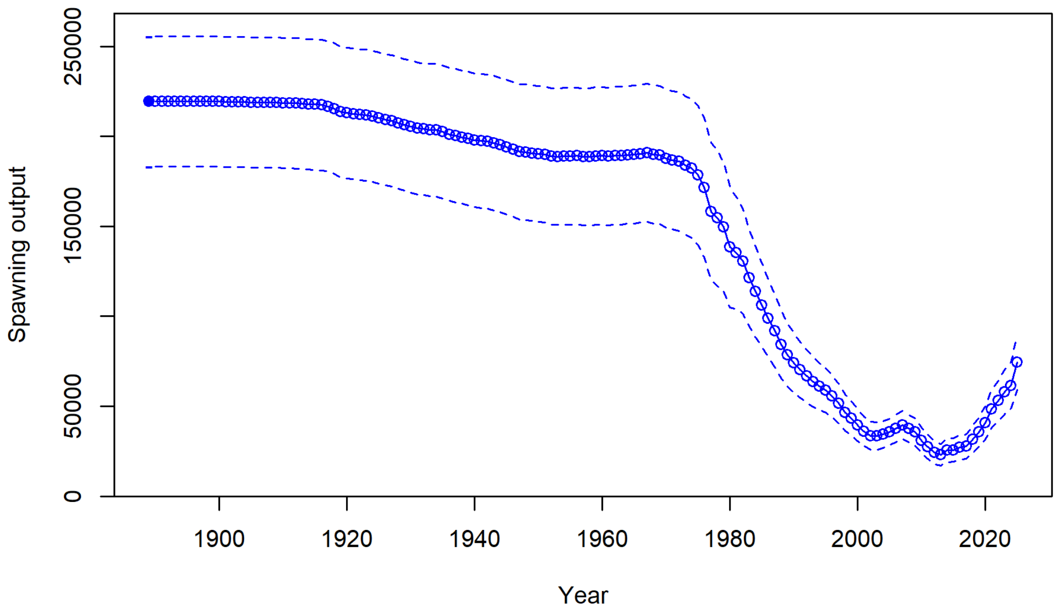

Figure ii: Estimated time series of spawning output for the base model.

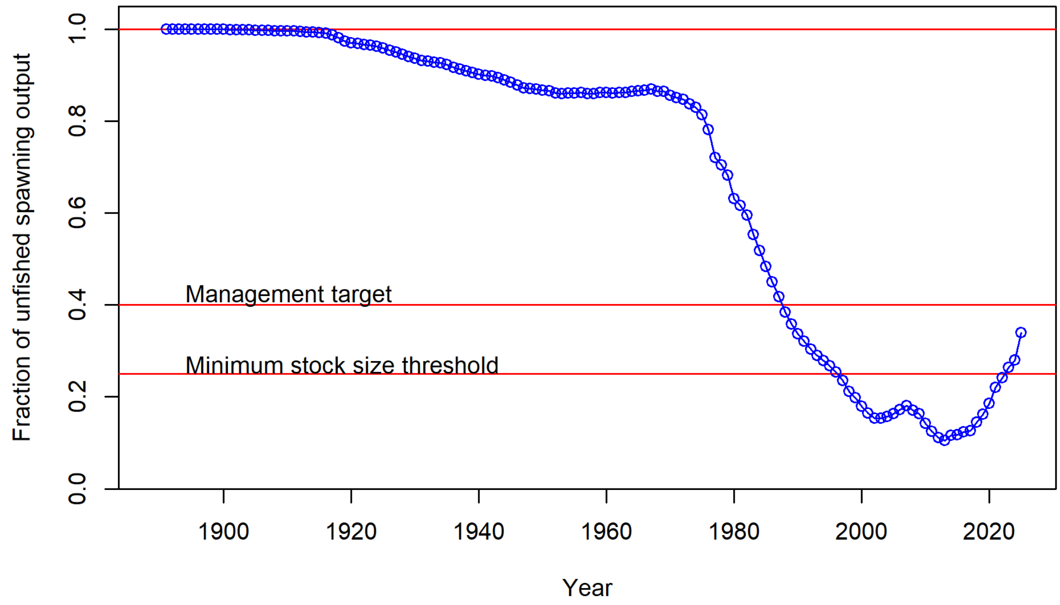

Figure iii: Estimated time series of relative spawning output (e.g., stock status) for the base model.

Recruitment

Sablefish recruitment is estimated to be quite variable with large amounts of uncertainty in individual recruitment events (Table iii; Figure iv). In general, sablefish has low to moderate recruitment (relative to the long-term average) with occasional large year classes (aligning with assumed high recruitment variability: 1.4). Initial model explorations found that there was limited information in the data to inform annual recruitment deviations prior to 1975, so recruitment deviations were not estimated prior to 1975 (Figure v).

Absolute recruitment was generally low during the 1980s–2000s when spawning output was decreasing reaching low levels by 2000. After that time, several average to well above average recruitment events occurred, including the highest four recruitment events in the time series falling between 2016–2023. Years with the highest recruitment deviations were estimated to have occurred in 2023, 2020, 2016, 2013, and 2021. The lowest annual recruitment deviations (e.g., negative deviations) were estimated to have occurred in 2005, 2007, 2009, 1996, and 1992. The estimated annual recruitment deviation in 2024 is uncertain, but estimated to be above average based upon data from the WCGBTS and the recruitment index. The series of large recruitment from 2013 onwards is a major contributor to the rapid increase in spawning output and, in particular, summary biomass (ages 3 plus) over the last 8–10 years.

Table iii: Estimated recent trend in recruitment (1,000s) and recruitment deviations and the 95 percent confidence intervals.

Year	Recruit-ment (1,000s)	Lower Interval (1,000s)	Upper Interval (1,000s)	Recruit-ment Deviations	Lower Interval	Upper Interval
2015	2,507	1,327	4,736	-0.911	-1.557	-0.264
2016	68,575	55,918	84,096	2.376	2.183	2.569
2017	2,855	1,353	6,020	-0.811	-1.575	-0.048
2018	9,106	6,610	12,544	0.294	-0.017	0.605
2019	22,505	17,267	29,332	1.155	0.900	1.409
2020	80,372	64,260	100,523	2.382	2.169	2.595
2021	59,662	46,157	77,119	2.030	1.780	2.280
2022	4,612	2,158	9,855	-0.556	-1.338	0.226
2023	93,874	63,700	138,343	2.434	2.046	2.823
2024	35,534	7,603	166,077	0.507	-1.296	2.310

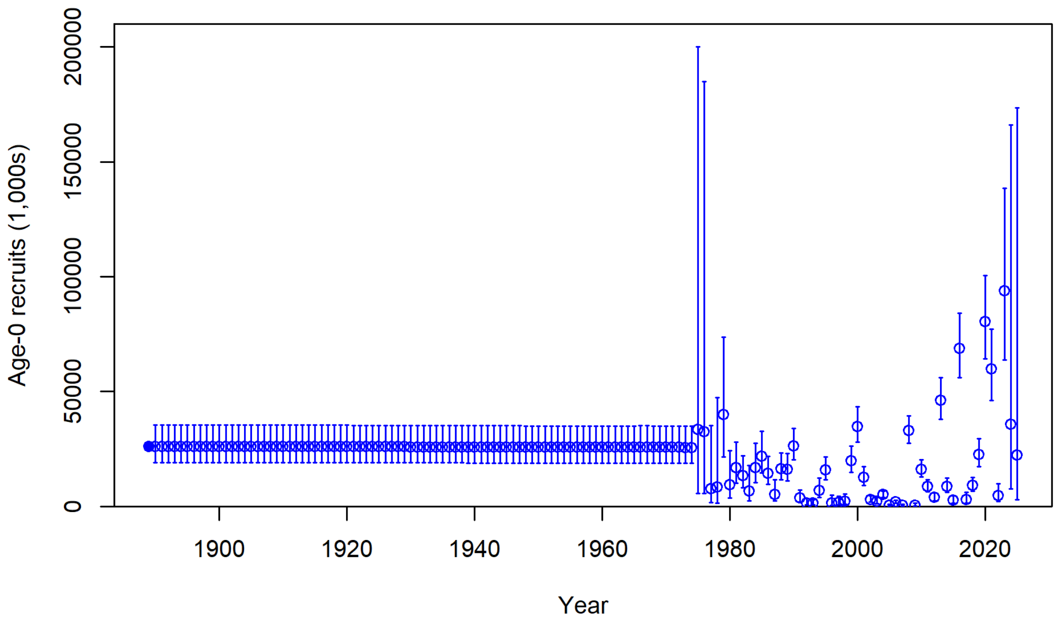

Figure iv: Estimated time series of age-0 recruits for the base model.

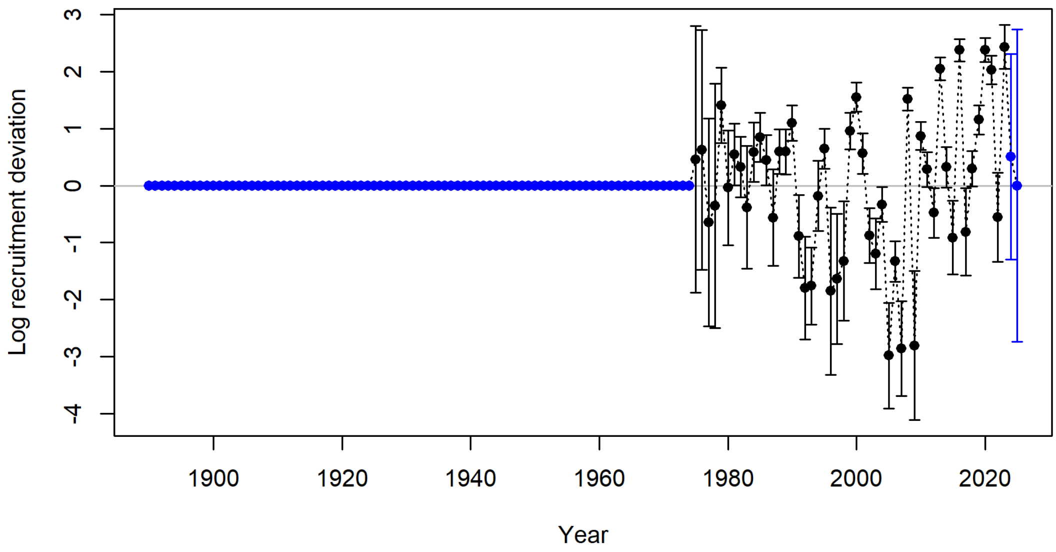

Figure v: Estimated time series of recruitment deviations for the base model.

Exploitation Status

The estimated relative fishing intensity on the stock was at or above the current management target of 1.0 from 1982 to 2018 (Table iv; Figure vi). Since that time, fishing intensity has been below 1.0, declining to 0.70 by 2024 with 95 percent asymptotic confidence intervals from 0.58 to 0.82. Here, fishing intensity is reported as a the ratio of one minus the spawning potential ratio to one minus the SPR target of 45 percent, or (1-SPR)/(1-$SPR_{45\%}$). The estimated exploitation rate (catch divided by biomass of fish of age-3 and above) for the most recent year was the lowest in the previous decade at 0.03 (Table iv). Exploitation rate has fallen faster than relative fishing intensity in recent years because recent large recruitments are already contributing to age 3 plus biomass (exploitation) but have not all yet reached the age of maturity (approximately 6 to 10 years) to contribute to spawning potential (relative fishing intensity).

Table iv: Estimated recent trend in relative fishing intensity (1-SPR)/(1-SPR45%), where SPR is the spawning potential ratio, and the exploitation rate, along with the 95 percent confidence intervals for both quantities.

Year	(1-SPR)/(1-SPR45%)	Lower Interval (SPR)	Upper Interval (SPR)	Exploitation Rate	Lower Interval (Rate)	Upper Interval (Rate)
2015	1.229	1.101	1.357	0.068	0.055	0.081
2016	1.228	1.097	1.359	0.052	0.043	0.062
2017	1.157	1.020	1.295	0.054	0.044	0.064
2018	1.005	0.866	1.143	0.052	0.043	0.062
2019	0.976	0.838	1.114	0.038	0.031	0.044
2020	0.710	0.584	0.835	0.027	0.022	0.032
2021	0.715	0.594	0.836	0.033	0.027	0.039
2022	0.857	0.728	0.986	0.042	0.035	0.050
2023	0.813	0.684	0.941	0.031	0.026	0.037
2024	0.701	0.581	0.820	0.027	0.022	0.032

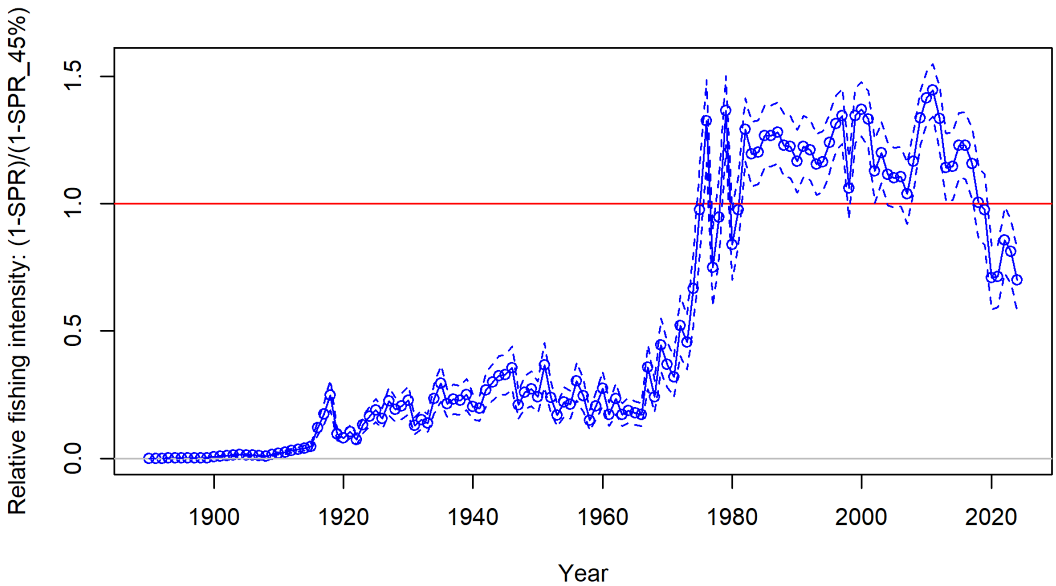

Figure vi: Estimated time series of fishing intensity for the base model.

Ecosysystem Consideration

The climate vulnerability analysis for the California Current (McClure et al. 2023a) suggests that processes affecting sablefish recruitment are sensitive to climatic and, therefore, oceanic drivers. Given the high climate vulnerability of sablefish, changes in their abundance, productivity, and spatial distribution are likely, and these changes are in turn likely to impact fishing fleets and communities because of the high value of this fishery. Strong coastwide recruitment appears to be associated with good recruitment north of Cape Mendocino (approximately 40° N. latitude), which itself is correlated with transport and temperature in the northern portion (40°–48° N. latitude) of the U.S. West Coast, specifically with the northern transport of yolk-sac larvae (Tolimieri et al. 2018). A subsequent analysis conducted for this assessment evaluated the relationship between a suite of environmental indicators derived from oceanographic models and sablefish recruitment found several predictors that explain variation around the stock–recruitment curve (see Section 2.3 and Appendix 9.2 for further details). These predictors were used to construct a recruitment index, which was used in the base model to provide additional information on the strength of recent recruitments (2020–2024). Other environmental considerations incorporated into the assessment model as input data directly include: the use of empirical weight-at-age data to account for latent environmental effects on spatiotemporal growth patterns; and the use of a spatially-integrated maturity schedule to account for latent environmental effects on latitudinal gradients in sablefish maturity.

Additional ecosystem and environmental considerations are explicit part of the risk table presented at the end of the executive summary (and in Section 4.5). The 2024-2025 California Current Ecosystem Status Report further describes the primary climate and ocean patterns that sablefish encounter, as well as changes in sablefish distribution, juvenile abundance indices, and trends in sablefish primary prey and predators. The occurrence of sablefish in the California Current has generally shifted northward over the past ten years. Recent observed environmental and biological conditions suggest that sablefish could be larger and closer to shore than during average conditions.

Reference Points

The Pacific Fishery Management Council (PFMC) groundfish Fishery Management Plan (FMP) includes a harvest control rule (HCR) based upon general species groups that determines the overfishing limit (OFL) and Acceptable Biological Catch (ABC). The target, threshold, and limit reference points for sablefish as defined by the FMP are 40, 25, and 10 percent levels of stock status, respectively. The OFL is determined by the target harvest rate based on an spawning potential ratio (SPR) rate of 45 percent ($SPR_{45\%}$). If the stock is above the management target of 40 percent, the ABC is equal to a fraction of the OFL based on time-varying scientific uncertainty (σ_y) and management risk tolerance (P^*). When the stock status is below the management target and above the management limit, the ABC is linearly reduced using the HCR to determine the annual catch limit (ACL). If the stock is below the management limit, 10 percent, the ACL is set to zero. Additionally, if the stock is estimated to be below the management threshold, 25 percent, in the year of the assessment, a rebuilding plan is required which can set the SPR to a fishing intensity lower than the target $SPR_{45\%}$.

The estimated 2025 spawning output relative to unfished of equilibrium spawning output is 33.9 percent, below the management target of 40 percent of unfished spawning output. The fishing intensity is estimated to be below the current management harvest rate limit ($SPR_{45\%}$) at the end of the time series but is estimated to have been above between the 1970s to the late-2010s (Figure vi). The interaction between the relative spawning output and the ratio of the estimated SPR to the management target ($SPR_{45\%}$) indicates that the stock is in the lower quadrant indicating that the overfishing is not occurring and that relative spawning output is below the management targets (Figure vii). The current estimate of stock status is larger than the maximum sustainable yield (MSY), below the SPR target and relative target biomass reference points (Figure viii).

Reference points were calculated using the estimated selectivities and catch distributions among fleets in the final year of the model, 2025 (Table v). The estimated sustainable total yield inclusive of both landings and discards was 11,126 mt according to $SPR_{45\%}$. The spawning output equivalent to 40 percent of unfished spawning output ($SB_{40\%}$) calculated using the SPR target, $SPR_{45\%}$, was 87,751 mt.

Table v: Summary of reference points and management quantities, including estimates of the 95 percent confidence intervals. SO is spawning output, SPR is the spawning potential ratio, and MSY is maximum sustainable yield.

Reference Point	Estimate	Lower Interval	Upper Interval
Unfished Spawning output	219,377	183,217	255,537
Unfished Age 3+ Biomass (mt)	458,861	375,411	542,311
Unfished Recruitment (R0)	25,981	17,926	34,036
2025 Spawning output	74,409	59,331	89,486
2025 Fraction Unfished	0.339	0.276	0.402
Reference Points Based SO40%	—	—	—
Proxy Spawning output SO40%	87,751	73,287	102,215
SPR Resulting in SO40%	0.450	0.450	0.450
Exploitation Rate Resulting in SO40%	0.046	0.042	0.049
Yield with SPR Based On SO40% (mt)	11,126	8,274	13,978
Reference Points Based on SPR Proxy for MSY	—	—	—
Proxy Spawning output (SPR45)	87,751	73,287	102,215
SPR45	0.450	—	—
Exploitation Rate Corresponding to SPR45	0.046	0.042	0.049
Yield with SPR45 at SO SPR (mt)	11,126	8,274	13,978
Reference Points Based on Estimated MSY Values	—	—	—
Spawning output at MSY (SO MSY)	47,863	40,183	55,543
SPR MSY	0.283	0.281	0.286
Exploitation Rate Corresponding to SPR MSY	0.079	0.073	0.085
MSY (mt)	12,705	9,423	15,986

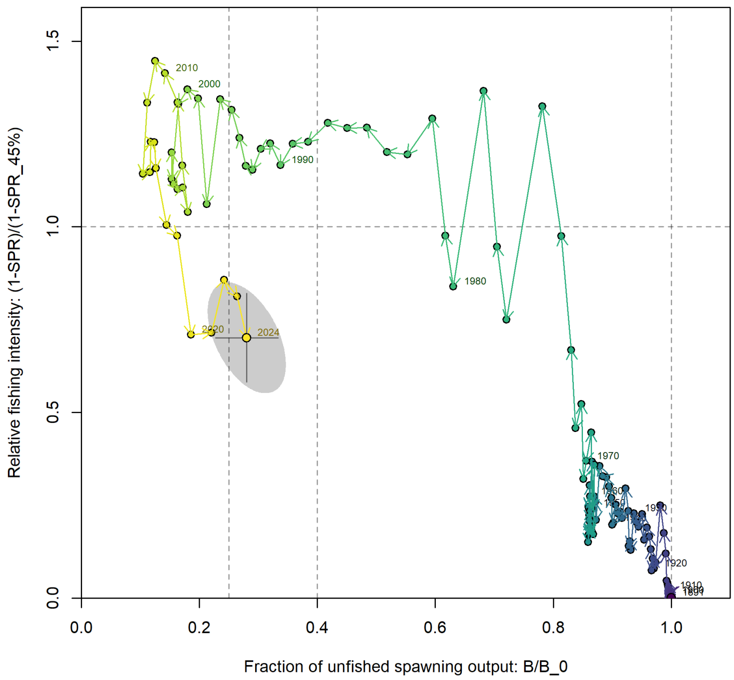

Figure vii: Phase plot of fishing intensity versus relative spawning output for the base model.

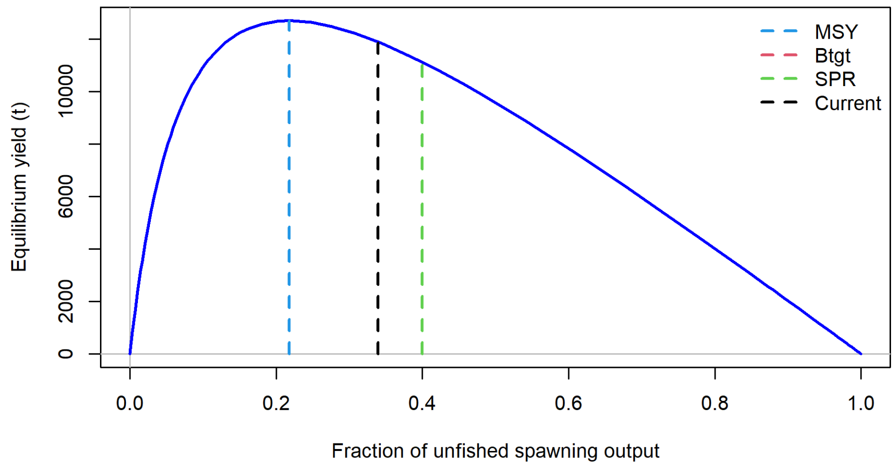

Figure viii: Estimated yield curve with reference points for the base model. The biomass target (Btgt) and the spawning potential ratio (SPR) target both are maximized at 0.40 fraction of unfished spawning output.

Management Performance

Sablefish management includes a rich history of seasons, size-limits, trip-limits, and a complex permit system. Sablefish is currently modeled as a coastwide stock with corresponding coastwide OFL and ABC. The coastwide ABC is then apportioned into two area-specific ACLs north and south of 36° N. latitude. This historical management line corresponds with a recent data-driven analysis of sablefish growth that suggests a difference in growth rates north and south of 36° N. latitude (Kapur et al. 2020). The coastwide OFL and ABC values and the area-based ACL are shown in Table vi.

For the 2019 assessment, the PFMC adopted a methodology to determine the area-based ACL using a five-year rolling average relative biomass estimate from the WCGBTS (November 2019 PFMC Meeting Decision Document). The relative biomass estimates represent the distribution of the sablefish population observed by the WCGBTS, not the entire population.

Table vi: Recent trend in the overfishing limits (OFL), the acceptable biological catches (ABCs), the annual catch limits (ACLs), and the total catch all in metric tons (mt).

Year	OFL (mt)	ABC (mt)	ACL North (mt)	ACL South (mt)	Catch (mt)
2015	7,857	7,173	4,793	1,719	5,302
2016	8,526	7,784	5,241	1,880	5,619
2017	8,050	7,350	5,252	1,864	5,777
2018	8,239	7,522	5,475	1,944	5,494
2019	8,489	7,750	5,606	1,990	5,635
2020	8,648	7,896	5,723	2,032	4,078
2021	9,402	8,791	6,892	1,899	5,122
2022	9,005	8,375	6,566	1,809	6,640
2023	11,577	10,825	8,486	2,338	6,385
2024	10,670	9,923	7,780	2,143	6,029

Evaluation of Scientific Uncertainty

The model estimated uncertainty around the 2025 spawning output for the model is $\sigma = 0.1$. The uncertainty around the OFL in 2025 is $\sigma = 0.12$ and the uncertainty around spawning output in 2025 is $\sigma = 0.1$. Each of these are likely underestimates of overall uncertainty due to the necessity to fix several key population dynamics parameters (e.g., steepness, recruitment variance) and also because there is no explicit incorporation of model structural uncertainty (although see the decision table for alternative states of nature).

Harvest Projections and Decision Tables

The projection of spawning output, stock status, and harvest limits were developed using the base model. The total catches in 2025 and 2026 were fixed at 19,114 and 19,082 mt, respectively, based on recommendations from the Groundfish Management Team (GMT) (Table vii). The ABC values were projected assuming a category 1 time-varying sigma with an initial value of 0.50 in 2027 and a management risk tolerance (P^*) of 0.45.

The catches during the projection period, 2027–2037 were set equal to the year-specific ABCs (Table viii). The spawning output and stock status increase during the projection due to the estimated large recruitments in 2020, 2021, and 2023 maturing and entering the spawning population, resulting in future OFLs and ABCs.

Two alternative catch streams based upon two options for P^*, 0.45 and 0.40, were created for the decision table (Table ix). Each alternative catch stream assumes a category 1 time varying sigma with an initial value of 0.50 in 2027. The axes of uncertainty in the decision table are based on the uncertainty around natural mortality. The low state of nature assumed a higher natural mortality of 0.095 yr^{-1} and the high state of nature assumed a lower natural mortality of 0.070 yr^{-1}. The low and high state of nature were run in a deterministic manner where they assumed the same parameter values, including annual recruitment deviations, as the base model except for natural mortality.

Table vii: Removal assumptions in metric tons (mt) provided by the Groundfish Management Team for 2025-2026 by fleet.

Year	Trawl	HKL	Pot	Trawl Discard	HKL Discard	Pot Discard	Total Catch
2025	5,768.1	6,387.8	6,098.2	381.8	253.3	224.9	19,114.1
2026	6,021.0	6,144.4	6,071.7	381.8	243.1	219.9	19,081.9

Table viii: Potential OFLs (mt), ABCs (mt), ACLs (mt), the buffer between the OFL and ABC, estimated spawning output,and stock status with adopted OFLs and ACLs and assumed catch for the first two years of the projection period (2025-2026). Projections were conducted assuming a category 1 time-varying sigma and a P* of 0.45.

Year	Adopted OFL (mt)	Adopted ACL (mt)	Assumed Catch (mt)	OFL (mt)	Buffer	ABC (mt)	ACL (mt)	Spawning output	Stock Status
2025	39,085	28,688	19,114	—	—	—	—	74,409	0.339
2026	37,310	27,238	19,082	—	—	—	—	80,877	0.369
2027	—	—	—	14,935	0.935	13,964	13,964	88,838	0.405
2028	—	—	—	16,240	0.930	15,103	15,103	98,185	0.448
2029	—	—	—	15,896	0.926	14,720	14,720	103,869	0.473
2030	—	—	—	15,287	0.922	14,094	14,094	107,603	0.490
2031	—	—	—	14,654	0.917	13,437	13,437	109,277	0.498
2032	—	—	—	13,970	0.913	12,755	12,755	107,167	0.489
2033	—	—	—	13,390	0.909	12,172	12,172	104,575	0.477
2034	—	—	—	12,997	0.904	11,749	11,749	103,162	0.470
2035	—	—	—	12,526	0.900	11,274	11,274	101,283	0.462
2036	—	—	—	12,186	0.896	10,918	10,918	99,821	0.455

Table ix: Decision table summary of 10 year projections beginning in 2027 for alternative states of nature based on an axis of uncertainty about natural mortality for the base model. Columns range over low, base, and high states of nature and rows range over different catch level assumptions. The base model estimated natural mortality of 0.088 yr^{-1} for females and males. The low state of nature assumee a natural mortality of 0.095 yr^{-1} and the high state of nature assumed a natural mortality of 0.070 yr^{-1} for both sexes. Catch in 2025 and 2026 were based upon removal assumptions provided by the GMT.

Alt. Option	Year	Catch	Low Spawning Output	Low Stock Status	Base Spawning Output	Base Stock Status	High Spawning Output	High Stock Status
P* 0.45	2025	19,114	45,746	0.237	74,409	0.339	136,165	0.436
	2026	19,082	49,979	0.259	80,877	0.369	145,453	0.466
	2027	13,964	54,904	0.285	88,838	0.405	157,818	0.506
	2028	15,103	61,586	0.319	98,185	0.448	171,209	0.548
	2029	14,720	65,692	0.341	103,869	0.473	179,879	0.576
	2030	14,094	68,210	0.354	107,603	0.490	186,364	0.597
	2031	13,437	69,067	0.358	109,277	0.498	190,326	0.610
	2032	12,755	67,342	0.349	107,167	0.489	188,697	0.604
	2033	12,172	65,405	0.339	104,575	0.477	186,051	0.596
	2034	11,749	64,381	0.334	103,162	0.470	185,006	0.593
	2035	11,273	63,290	0.328	101,283	0.462	182,588	0.585
	2036	10,918	62,613	0.325	99,821	0.455	180,530	0.578
P* 0.40	2025	19,114	45,746	0.237	74,409	0.339	136,165	0.436
	2026	19,082	49,979	0.259	80,877	0.369	145,453	0.466
	2027	13,039	54,904	0.285	88,838	0.405	157,818	0.506
	2028	14,084	62,010	0.322	98,644	0.450	171,704	0.550
	2029	13,713	66,625	0.346	104,874	0.478	180,953	0.580
	2030	13,115	69,703	0.362	109,201	0.498	188,061	0.602
	2031	12,500	71,125	0.369	111,469	0.508	192,658	0.617
	2032	11,842	69,855	0.362	109,844	0.501	191,566	0.614
	2033	11,275	68,315	0.354	107,677	0.491	189,412	0.607
	2034	10,880	67,688	0.351	106,688	0.486	188,863	0.605
	2035	10,407	66,935	0.347	105,159	0.479	186,863	0.599
	2036	10,045	66,586	0.345	104,029	0.474	185,201	0.593

Unresolved Problems and Major Uncertainties

The base model was developed with the goal of balancing parsimony with realism and fitting the data well. To achieve parsimony, some simplification of model structure was assumed which may have a moderate impact on the interpretation and fit to specific data sets. The base model was developed with a focus on stability which supports model development, interpretability, and future update assessments. This assessment estimates a sharp increase in young sablefish biomass and future data collected by the WCGBTS should be monitored potential changes in the population trajectories.

The estimated increase in young sablefish biomass is being driven by very large recruitment events occurring in recent years (e.g., 2020, 2021, and 2023). There have been multiple observations of the 2020 and 2021 year class and appear to be well estimated by the model. However, there is more uncertainty around the 2023 year class given the limited observations in the data by the the WCGBTS and the fishery fleets. The uncertainty around the strength of this year class will be resolved with future observations by the survey and the fishery.

The patterns observed in historical sablefish recruitment suggest that the stock trajectory, which is dominated by shifts in recruitment strength, is closely linked to productivity regimes in the California Current. Studies of oceanographic drivers of sablefish recruitment explain some portion of recruitment variability for sablefish, depending upon the oceanographic covariates evaluated. Uncertainty in future environmental conditions and changes in the timing, dynamics, and productivity of the California Current ecosystem via climate change or cycles similar to the historical period should be considered as a significant source of uncertainty in all projections of stock status. The ongoing WCGBTS is a fairly precise relative index of abundance over a broad demographic component of the stock but it does not survey the entire stock as sablefish reside in waters deeper than 1,280 m and to the north and south of the survey extent. Therefore, a portion of the stock is unobserved. This index has the potential to inform future stock assessments about the scale of the population relative to catches being removed; however, such information will require contrast in the observed survey trend.

Sablefish appear to have variable maturity-at-age latitudinally across the U.S. West Coast. Additionally, there appears to be variable growth spatially and temporally. This assessment attempts to account for these variations by using a empirical weight-at-age approach that accounts for space and time. In the available data, there were not clear trends across time but rather periods of above or below average growth. Future data should continue to be evaluated for potential trends in growth and maturity and whether those observed patterns vary from what was assumed in this assessment.

Research and Data Needs

Most of the research needs listed below entail investigations that need to take place outside of the routine assessment cycle and require additional resources to be completed.

1. Spatiotemporal distribution patterns with depth: There are patterns of age and sex ratios with depth which may indicate that the stock is more complex than currently modeled. Further research into the causes of these patterns as well as differences between seasons would help with understanding the stock characteristics

such that a more realistic model could be built if needed. This may also provide further insight into migration and help determine if there are localized populations.

2. Stock boundaries: A common question in stock assessments is whether or not the entire stock is being represented. Sablefish live deeper than the range of the fisheries and surveys off the U.S. West Coast. The assessment model attempts to account for out of area biomass through catchability coefficients and selectivity curves, but that portion of the stock is unknown and can only be conjectured. Research into abundance in deep areas would be useful to verify that the assessment adequately predicts the entire stock of sablefish. In addition, sablefish along the U.S. West Coast can move northward to Canada or Alaska management jurisdictions. Building on recent transboundary sablefish research (Kapur et al. 2024, Kapur et al. in press), investigations elucidating how variable movements (net emigration and immigration) are from year to year to better understand impacts on current management advice or, ultimately, incorporate these changes into stock assessment models.

3. Recruitment: Continued investigation and refinement of environmental covariates for recruitment on a stock-wide, northeast Pacific scale. Continued evaluations into the estimation of steepness (h) is warranted in future stock assessments

4. Stock trends: The WCGBTS is a critical data source in this assessment providing data about the age distribution of the stock, incoming recruitment with observations of age-0 fish, and an informative trend in biomass. Continuation of the annual WCGBTS will provide information on stock trends and incoming recruitments. A longer survey time series may improve the precision of estimates of absolute stock size and productivity into the future. This is particularly true now that the stock has had substantial contrast (declines and inclines) in stock biomass, catch, and recruitment dynamics.

5. Ageing: Age validation is needed to verify the level of age bias present in the data, if any. The assessment model now uses empirical weight-at-age data to track spatiotemporal variation in growth. The continuation of collecting representative otolith samples and fish weights from fishery-independent and fishery-dependent sources, and processing those samples for age determination, is required to continue including time-varying growth into the assessment model. Continued research and pilot applications using Fourier Transform Near-Infared Spectroscopy (FT-NIRS) methods for ageing, which includes an understanding of the potential benefits (e.g., increase age determination throughput and efficiency) and barriers (e.g., bias) specific to sablefish could help to achieve ongoing ageing goals given competing demands for available resources. In addition, there is an under-representation of ages from sablefish caught in fisheries off of California compared to other areas. Biological sampling designs should strive to be consistent across the stock domain.

6. Fish Weight: This assessment uses an empirical weight-at-age approach to account for spatially and time varying growth informed by data from the WCGBTS. Cur-

rently, fish weight information is not available coastwide commercial fisheries (e.g., information available in PacFIN). Collected and reporting fish weight information to port sampling coastwide would support the consideration of commercial fishery data to understand weight-at-age of sablefish for future assessments.

7. Temporal and spatial biology: Research on understanding the interactions between spatial patterns in sablefish growth, maturity, and natural mortality across space and time will provide important information for future assessments. Both growth and maturity show latitudinal trends across the stock domain. While the current assessment accounts for these trends in the pre-processing of the data provided to the assessment model, it does so in a limited way. While tracking spatiotemporal changes in natural mortality by sex or life-stage is difficult, often requiring data that is unavailable (e.g., extensive tagging data), there has been recent advances through the use of external ecosystem modeling approaches such as the Climate-Enhanced, Age-based model with Temperature-specific Trophic Linkages and Energetics (CEATTLE) that should be explored for sablefish.

Risk Table

Oceanographers and stock assessment scientists jointly constructed a risk table to identify the main ecosystem and environmental processes for sablefish that should be considered in conjunction with available data used in the stock assessment and the structural uncertainty embedded in the assessment (Table x). The group considered ecosystem and environmental indicators for sablefish recruitment, habitat, prey, predators, competitors, and the recent climate vulnerability assessment (McClure et al. 2023a). Overall, the group considered these conditions to generally be neutral (Level 2) when considering, among other things, unresolved uncertainty with linkages between trends in primary predators and competitors and a overall climate vulnerability score of moderate. Data inputs for sablefish were scored as favorable (Level 1) given confidence in historical catch reconstructions, a comprehensive and representative survey index of abundance (WCGBTS), well sampled age data beginning at age zero, an informative recruitment index, and information on time- (growth) and -spatially-varying (maturity) life history characteristics across the stock range. The ability for the stock assessment model to fit the data and capture key sources of structural uncertainty was also scored as favorable (Level 1). Despite the need to fix certain productivity parameters (e.g., steepness and recruitment variability) or simplify some assumptions (e.g., sex invariant M and no net loss from emigration or immigration), model complexity seemed to balance well potential bias and variance in a way that stabilized sablefish population dynamics across a wide breadth of alternative data and model structures (see Section 3.5.2 for sensitivity evaluations).

Table x: Risk table for sablefish to document ecosystem and environmental factors potentially affecting stock productivity and uncertainty or other concerns arising from the stock assessment. Level 1 is a favorable ranking, Level 2 neutral, and Level 3 unfavorable.

Ecosystem and Environmental Conditions	Assessment Data Inputs	Assessment Model Fits and Structural Uncertainty
• Recruitment: Recent strong recruitment is considered under the assessment data inputs. [Not Scored]	• Catch reconstructions (landings and discards) date back to the early 1900s for hook-and-line and trawl fisheries. Foreign landings records began in the 1960s. [Neutral]	• Age data generally fit well with realistic selectivity assumptions. Estimates of recent large cohorts were robust across sensitivity runs. The model estimates recent recruitments based on age data and the recruitment index. [Favorable]
• Habitat: The center of gravity for sablefish biomass has shifted approximately 2° northward in recent years. [Unknown]	• There is high confidence in the primary fishery-independent survey (WCGBTS). Sablefish also occur deeper than the survey samples. [Favorable]	• Natural mortality was estimated but assumed to be constant for all life stages and across time and space. Natural mortality was set to be equal by sex based upon similar model estimates. [Neutral]
• Prey: Increased euphausiid and juvenile hake biomass suggest adequate prey availability for sablefish in recent years. [Favorable]	• An informative but highly uncertain environmentally driven recruitment index was incorporated into the assessment for the most recent 5 years. [Neutral]	• Steepness was fixed (h = 0.75) given life history and management (reference point) objectives. Available data are not informative of absolute stock size or productivity at small stock sizes. [Neutral]
• Predators: Sablefish consumption (by California sea lions, sperm whales, porpoises, skates, and fur seals) is unlikely to have changed in recent years, but there have been long-term increases in the abundance of some groups like sea lions. [Neutral]	• Age data have been relatively well sampled. The WCGBTS provides coastwide age data and ages are available from the fishery for the last 40 years but lack coastwide sampling in recent years. Data to inform recent recruitment is well represented. There are known challenges and uncertainty in ageing. [Favorable]	• There is variation in maturity, growth, and potentially other biological processes across the latitudinal range that is partially captured in the model. [Neutral]
• Competition: There is potential for competition between sablefish and Pacific hake (e.g., for euphausiids). Changes in competitive interactions are highly uncertain given limited information about prey availability and spatiotemporal overlap with potential competitors. Recent large recruitments increase the likelihood of intraspecific, density-dependent, competition. [Unfavorable]	• Time-varying growth relies on empirical weight-at-age and is integrated across latitudes according to survey biomass. [Favorable]	• There is uncertainty with respect to biological stock boundaries, including movement across the Northeast Pacific. [Unfavorable]
	• Spatially explicit estimates of functional maturity account for latitudinal differences in productivity. [Favorable]	• Extensive sensitivity runs produced reasonable results and changes were generally similar relative to base model results. There were little to no retrospective patterns or other diagnostic issues. The model produces stable jitters and parameter estimates that did not considerably vary by data source or as a result of structural changes. [Favorable]
Level 2: neutral	Level 1: favorable	Level 1: favorable

1 Introduction

1.1 Stock Description

Sablefish (*Anoplopoma fimbria*, also known as black cod) are distributed in the northeastern Pacific Ocean from the southern tip of Baja California northward to the north-central Bering Sea and in the northwestern Pacific Ocean from Kamchatka southward to the northeastern coast of Japan (Hart 1973; Eschmeyer and Herald 1983). U.S. West Coast sablefish are modeled as a single stock. Thus, this stock assessment does not explicitly account for movement between offshore sea mounts (Shaw and Parks 1997; Morita et al. 2012; Hanselman et al. 2015), regions to the north or south of the U.S. West Coast, or to the western Pacific (Fujioka et al. 1988; Heifetz and Fujioka 1991; Hanselman et al. 2015). The area included in this assessment is shown in Figure 1.

Previous analyses suggest the existence of several stocks of sablefish in the eastern Pacific Ocean that are largely delineated by management boundaries (Schirripa (2007a); and earlier assessments), though more recent genetic analyses found that sablefish in the northeastern Pacific Ocean are a single panmictic population (Jasonowicz et al. 2017). Additional support for a panmictic population stems from tag recoveries that show sablefish move across international boundaries, including regions currently used for management (Kapur et al. in press; Hanselman et al. 2015; Sogard and Berkeley 2017). Despite generally similar movement estimates between the U.S. West Coast and British Columbia, a net change in demography may still be present due to differences in area-specific population sizes (Kapur et al. 2024). Analyses of length-at-age data have found spatial variation in von Bertalanffy growth parameters across the northeastern Pacific Ocean (McDevitt 1987a; Echave et al. 2012a; Head et al. 2014; Gertseva et al. 2017; Kapur et al. 2020). Geographic break points at approximately (1) 36° N. latitude between Point Conception and Monterey, California and (2) 50° N. latitude where the North Pacific Current bifurcates suggest zones of growth variation. However, increasing maximum body size and decreasing relative growth rates with increasing latitude do not indicate regions with separate populations.

Smaller sablefish are generally found in shallower waters, but the demographics appear to be fully mixed (adult and juvenile) near the shelf-slope break (i.e., 100–300 m). Beyond the shelf-slope break, the population is dominated by older individuals (Methot 1994a) and younger fish become increasingly rare. Fish in the deepest areas sampled tend to be the oldest but not the largest individuals, suggesting that age dictates depth-specific distributions. The interaction between environmental conditions and seasonal movements that produce an increase in age with depth are largely unknown. The stock is distributed beyond the greatest depths sampled by any of the surveys and beyond the deepest commercial fishing areas. Research in the deeper habitats occupied by sablefish is potentially difficult because they extend across the boundary of the exclusive economic zone and near sea mounts and ridges across the Pacific Ocean. The population of sablefish in the Puget Sound and Strait of Georgia is negligible compared to that in coastal U.S. waters. Therefore, connectivity among these areas and the open coast is likely of less importance to this stock assessment than movement along the coast.

1.2 Life History

Tolimieri et al. (2018) provide a thorough review of the literature on spawning and early life history of sablefish in the California Current. Briefly, sablefish off the U.S. West Coast spawn along the continental shelf-slope break in waters deeper than 300 m and exhibit a protracted spawning period from December through March, with peak activity in February (Guzmán et al. 2017). Spawning in deeper waters may result in reduced availability to the commercial fishery during the winter months. Pelagic juveniles are present in off-shore surface waters and settle to the benthos as age-0 recruits during the late summer and fall, with most newly settled fish observed at depths less than 250 m.

Sablefish mature between 5-11 years (Head et al. 2014). Female sablefish generally reach larger sizes than males. The sex-ratio tends to be skewed toward males at the oldest ages, implying higher fishing pressure on females or/and a lower natural mortality rate for males. The oldest sablefish observed off the West Coast as captured off Washington in 2006 and aged (with observation error) at 102 years.

Adult sablefish are fast-swimming and capable of feeding on a diverse array of prey species including fishes, cephalopods, and crustaceans (Low et al. 1976). The cohabitation of adult and juvenile sablefish may result in some cannibalism. The large changes in predator biomass could have a negative effect on juvenile survival and, therefore, stock productivity.

1.3 Ecosystem Considerations

The sablefish climate vulnerability analysis (CVA) suggests that processes affecting recruitment are sensitive to environmental drivers (McClure et al. 2023b). Climate-driven changes in the abundance, productivity, and spatial distribution of sablefish are likely and can have considerable impacts to fishing fleets and communities because of the high value of this fishery.

The sablefish stock has experienced latitudinal shifts in the center of the distribution of stock biomass within the California Current, which has affected fishing opportunities to individual ports (Selden et al. 2019). The population centroid shifted to the north from 1980 to 1992, to the south by 2013, and back to the north in recent years, illustrated by an increase in Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey (WCGBTS) biomass estimates.

Strong coast-wide recruitment appears to be associated with strong recruitment north of Cape Mendocino (~ 40° N. latitude). Strong recruitment is correlated with larval transport and temperature in the northern portion of the U.S. West Coast (40°–48° N. latitude) (Tolimieri et al. 2018). Variation around the stock-recruitment curve was negatively correlated with sea level north of Cape Mendocino, CA. The 2019 assessment of sablefish included a sea surface height index within the model to inform historical and recent recruitment (Haltuch et al. 2019). This assessment includes a revised recruitment index that accounts for several oceanographic and ecosystem variables that appear to be correlated with sablefish recruitment in recent years (see Section 2.3 for additional information).

Age-0 sablefish captured by the WCGBTS were most abundant in shelf and upper-slope waters around San Francisco Bay and from Cape Mendocino to the Columbia River. The abundance of age-0 recruits varied through time with peaks in recruitment in 2008, 2013, 2016, 2020, 2021, and 2023. Most strong recruitment years were associated with high recruitment north of Cape Mendocino. Recent modeling work suggests that strong age-0 recruitment is associated, in part, with the northward transport of yolk-sac larvae at depths between 1,000–1,200 m (Tolimieri et al. 2018), which may lead to greater spatiotemporal overlap between feeding larvae and copepod prey than when larval transport is not as well defined.

1.4 Fishery Description

Historical sablefish landings, beginning in 1890, have been reconstructed by the states (Washington, Oregon, and California) using a variety of sources. Generally, historical sablefish landings were more reliable than those for many other groundfish species because of consistent species-level identification. Although sablefish landings were recorded at the start of the 20th century, appreciable quantities were not landed until 1916–1919, with landings remaining below 5,000 mt through the late 1960s. Landings prior to 1960 were primarily harvested by hook-and-line gear.

Sablefish landings increased dramatically during the 1970s, first from a combination of foreign vessels (Lynde 1986; McDevitt 1987a), followed by an increase in the domestic fleet. Increases in catch correspond to the introduction of a pot fishery, followed by the trawl sector, with only minor increases in hook-and-line catches until the mid-1980s. Over 25,000 mt of sablefish were removed in 1976 and 1979 from U.S. West Coast waters. A rapid increase in domestic pot and trawl landings followed these peak removals, with slow declines from ~ 19,000 mt in 1982 to ~ 9,000 mt in 1990. This decline in domestic landings was likely due to a combination of declining stock size, reduced Asian-market strength, and stricter fishery regulations. Annual landings have remained below 6,500 mt over the past decade, with approximately 43 percent of removals from hook-and-line, 26 percent by pot, and 30 percent by trawl gear.

An individual fishing quota (IFQ) program was implemented off the U.S. West Coast in 2011. Sablefish are targeted by IFQ vessels using varying gear types. Gear switching within the IFQ fishery increased after the implementation of the program, leading to concerns about utilization of the trawl allocation for sablefish north of 36° N. latitude. The majority of landings by vessels participating in gear switching was sablefish. At the April 2024 meeting, the PFMC took final action to limit gear switching in years when sablefish ACL for the area north of 36° N. latitude is below 6,000 mt.

In 2024, the ex-vessel revenue of the sablefish fishery was estimated at 13.5 million USD, the lowest estimate since 2005 (pers. comm., E. Steiner, Northwest Fisheries Science Center (NWFSC)). Since 2005, the ex-vessel revenue peaked at 61.5 million U.S. dollars in 2011 and has generally declined since 2017.

1.5 Management History and Performance

From the early 1900s to the early 1980s, management of the sablefish fishery was the responsibility of individual coastal states (California, Oregon, and Washington). Since the adoption of the Groundfish FMP by the PFMC in 1982, responsibility has rested with the federal government and the PFMC. From 1977 to the mid-1980s, U.S. commercial fishermen took advantage of their newly protected fishing grounds (resulting from the enactment of the Magnuson-Stevens Fishery Conservation and Management Act in 1976), recording high catches of sablefish to meet the demands of flourishing exports (primarily to Asian countries) and domestic markets.

The first coastwide regulations off the U.S. West Coast for the sablefish fishery were implemented as trip limits in October 1982. This was followed by several management actions, including seasonal restrictions, size limits, trip limits, and a relatively complex permitting system. Beginning in 1983, additional trip limits were imposed on landings of sablefish less than 22 inches in length, which were generally considered incidental. Trawl and non-trawl allocations were implemented in 1987.

Beginning in the late-1980s, the fixed-gear sablefish fishery was managed as a 'derby' fishery, characterized by relatively short seasons. In 1991, the fully open season lasted seven weeks, from April 1 through May 23. In 1992, approximately 1,300 mt were landed under early season trip limits with the fully open season lasting from May 12 through May 26. In 1993, there was a 250 lbs. per day trip limit prior to the open season, which extended from May 12 through June 1. In 1994, the fully open season was restricted to May 15 through June 3. In 1995, the open season lasted one week, from August 3 to August 13. The open season spanned only six days in 1996, from September 1 to September 6. In 1997, nine days were set aside for the open season from August 25 to September 3, with a mop-up period from October 1 to October 15. More recently, the limited entry fixed gear sector has been managed primarily through the use of tiered cumulative limits (allocated on the basis of historical landings) for a 7-month season. The remaining open-access fishery and some limited-entry non-trawl vessels are allowed to make smaller landings that are subject to daily or weekly limits and 2-month cumulative caps.

In 2002 and 2003, the PFMC enacted Rockfish Conservation Areas (RCAs), which were closed to fishing for certain gear types to support rebuilding of overfished rockfish species in specific areas along the West Coast. The boundaries of the RCAs depended upon the fishing gear being used. At the start of 2024, restrictions for a considerable portion of RCAs were lifted for non-trawl commercial and recreational vessels targeting groundfishes.

Sablefish are harvested by the trawl fishery in association with a variety of other species that are distributed to domestic and foreign markets. Prior to 2011 (with the introduction of the IFQ), the trawl fishery was managed primarily through the use of trip limits. These evolved from simple per-trip limits in the 1980s to cumulative periodic (monthly or bi-monthly) limits by the mid-1990s. Since 2011, IFQ vessels have operated using allocated quota pounds, whereas vessels operating in limited entry and open access sector are still managed using trip limits that restrict landings per week and per two month periods. A list of select management changes since 2010 is provided in Section 9.1.

Currently, PFMC manages sablefish off the U.S. West using two areas, ACL north and south of 36° N. latitude. Management splits the coastwide ABC using the most recent 5-yr average of biomass estimates from the WCGBTS.

1.6 Fisheries off Canada and Alaska

Exploring regional trends in population dynamics can be a useful way to elicit patterns and gain insights, particularly for stocks such as sablefish that span multiple management jurisdictions. Landings data, population dynamics trends, and stock status determinations are available in the most recent sablefish stock assessments for British Columbia (DFO 2023) and Alaska (Goethel and Cheng 2024). Total landings of sablefish has changed considerably over time for all three stock assessments. Similar to the U.S. West Coast, sablefish fisheries in Alaska and British Columbia began in the late 1800s, with generally low catches until after World War II. Foreign fisheries began exploiting sablefish in in the Bering Sea during the late 1950s, with rapidly increasing catches through the 1980s. All three stock assessments showed a general decline in catch during the 1990s and 2000s, though there has been a slight increase in catch in recent years, especially in Alaska and British Columbia. For comparison, catch in 2021 was nearly 22,000 mt in Alaska, 2,400 mt in British Columbia, and 5,000 mt along the U.S. West Coast. Landings peaked during the 1970s at > 50,000 mt in Alaska, > 7,000 mt in British Columbia, and > 25,000 mt along the U.S. West Coast. The sablefish fishery off British Columbia primarily uses pots, with lower landings resulting from longlines and trawl gear. Historically, Alaskan landings have been much greater than those off the U.S. West Coast.

Spawning output in Alaska and British Columbia generally declined until the late 2010s, but are now rapidly increasing. The U.S. West Coast population generally declined from the 1970s to the early 2000s but was relatively stable through the late 2010s before increasing rapidly in recent years. There has been several strong recruitment events in all three stock assessments over the past 10 years. The three strongest recruitment events (all scaled to age-0) were similar in Alaska (2016, 2017, and 2019 cohorts), British Columbia (2015, 2016, and 2017), and along the U.S. West Coast (2016, 2020, and 2021).

Overall, stock status (i.e., depletion, relative spawning output, fraction unfished) is estimated at 67 percent of equilibrium spawning output in Alaska (in 2024), 54 percent in British Columbia (2022), and 33.9 percent in this assessment for the U.S. West Coast. Stock status in all three regions can be generalized to indicate that overfishing is not occurring and that the stocks are not overfished. The sablefish stock in Alaska and British Columbia has been above fishing-based reference levels and below biomass-based reference levels at one point or another during the time series (Figure 2). Recent strong recruitment events are driving the increase in spawning stock size over recent years for all three regions.

2 Data

A description of each data source used in this assessment (Figure 3) is provided below.

2.1 Fishery-Dependent data

2.1.1 Landings

Landings for sablefish comprise of various historical landings reconstructions, historical foreign fishery catch data, and commercial domestic landings data extracted from Pacific Fisheries Information Network (PacFIN) on February, 25, 2025. In addition, Pacific hake at-sea fishery catches (provided by Vanessa Tuttle, NWFSC, National Oceanic & Atmospheric Administration (NOAA)) and recreational landings were extracted from Recreational Fishery Information Network (RecFIN) on February 28, 2025. The landings used in this assessment are shown in Figure 4 and Table 1.

The assessment model uses fishery catch data aggregated by gear-type and catch-type (landed or discarded) to define six fishery fleets: 1) trawl, 2) hook-and-line, 3) pot, 4) trawl discards, 5) hook-and-line discards, and 6) pot discards. Landings for fleets 1–3 are described here, and discards for fleets 4–6 are described in Section 2.1.2. The trawl fleet includes mortality from the domestic historical (pre-1981 in California and Washington, pre-1987 in Oregon) and current landings available in PacFIN, estimated foreign trawl catch, and Pacific hake at-sea fishery total mortality estimates. The hook-and-line fleet includes mortality from the domestic historical (pre-1981 in California and Washington, pre-1987 in Oregon) and current landings available in PacFIN, estimated foreign hook-and-line total mortality, and recreational fisheries total mortality estimates. The pot fleet includes mortality from the domestic historical (pre-1981 in California and Washington, pre-1987 in Oregon) and current landings available in PacFIN and estimated foreign pot catch.

For the state of California, commercial landings between 1900 and 1931 were calculated following the approach used in the 2011 and 2019 sablefish assessments. Specifically, landings estimates from 1916–1931 were available from published California Department of Fish and Game Bulletins, 1908 to 1916 were based on Fisheries statistics of the U.S. published by the U.S. Fish Commission, and catches were extrapolated linearly from zero in 1900 to the value from the California Department of Fish and Game Bulletins in 1908. Landings for the period 1931–1968 relied on estimates from the recent reconstruction efforts by scientists at the Southwest Fisheries Science Center and California Department of Fish and Game (Ralston et al. 2010). This effort utilized newly available spatial information regarding groundfish landings back to 1931. This method is an improvement for sablefish, since it was identified as a separate market category. Landings between 1969–1977 were based on California fish tickets with a ratio estimator approach, and landings between 1978 to 1980 were pulled from the CALCOM database. Prior to 1969, the gear type associated with landings was not available so landings were allocated between trawl and hook-and-line gear based upon the proportions starting in 1969, with no landings assumed to be based on pot gear since the landings with pot gear were negligible (e.g., less than 0.5 mt in 1969 and 1970) until 1971. California commercial landings from 1981–2024 were extracted from PacFIN.

Oregon landings reconstructions cover 1927 through 1986 (Karnowski et al. 2014). Low et al. (1976) provided total landings from 1915 to 1926. No catch statistics were available prior to 1915, so a linear extrapolation from the 10 mt estimate for 1915 to 0 mt in 1891 was applied. Oregon landings from 1987 to 2024 were extracted from PacFIN.

Washington completed a historical landings reconstruction for the 2019 assessment of sablefish, which was used in this assessment as they represent the best scientific information available. The following information sources were included in the reconstruction: 1890 to 1908 from U.S. Fish Commission Bulletin; 1915 to 1952 from PMFC Bulletin 3, Appendix (page 130, using a conversion factor of 1.75 for dressed fish); 1953 to 1969 from the Washington Statistical Bulletin; and 1970 to 1980 from the Washington fish ticket database. Landings area assignments were based on Seattle market reports and Washington Statistical Bulletins. Gear type was based on PMFC Bulletin 3 (page 44, Table 2) and Washington Statistical Bulletins. Washington landings between 1981 to 2024 were extracted from PacFIN.

This assessment also included data on catch of sablefish by the Pacific hake at-sea fishery since 1978. The 2023 assessment of sablefish only included estimates going back to 1990. This assessment extends the at-sea catches to the first year of available catch data, 1978. Across most years, the catch of sablefish in the Pacific hake at-sea fishery is relatively low, particularly when compared to the magnitude of landings from other groundfish sectors contained in PacFIN. However, there have been select years where the catch of sablefish in this fishery has been higher than average. Catch was high between 1979 and 1982 ranging between 103 mt to 359 mt. In recent years, high catch in the Pacific hake at-sea fishery is likely driven by strong recruitment events with 153 mt and 117 mt of incidental catch in 2017 and 2018, respectively, and 306 mt and 161 mt in 2022 and 2023. The estimates provided from the At-Sea Hake Observer Program (ASHOP) included both discarded and retained catch of sablefish and were included in this assessment in the trawl fleet.

Foreign catches are included in gear-specific fleets. The foreign catch reconstructions were based on the records in the historical annotated landings (HAL) database (Lynde 1986). The catch by foreign vessels was very high in the late 1970s, relative to domestic fleets during that time. Previous assessments included the foreign catches in the corresponding landings gear fleet, which resulted in additional mortality being estimated (i.e., treated as if the estimates were landings not catches that accounted for total mortality). Lynde (1986) indicated that foreign catches account for both landings and discards, thus these estimates were treated as separate catch fleets for this assessment.

Recreational fishery landings were added to the hook-and-line landings fleet. Recreational landings of sablefish were historically low, with the average mortality < 3 mt per year between 2001 and 2022. However, recreational landings have sharply increased in recent years. For example, coastwide recreational mortality peaked at 34 mt in 2023 and was 29 mt in 2024.

A comparison between the total mortality from this assessment and the estimated total mortality from the previous assessment is shown in Figure 5.

2.1.2 Discards

This assessment included discard fleets for each gear type. Estimates of discard mortality were based on historical information (when available) and current discard practices by fleet. Discard mortality was estimated using PFMC adopted gear-specific discard mortality rates of 20 percent for fixed gear and 50 percent for trawl gear. The gear-specific discard moratlity rates were based upon literature and available fishery data (GMT Report 1, June 2017, Supplemental SSC Report, June 2017). Previous assessments of sablefish, since 2011 have assumed the same gear-specific discard mortality rates. The discard fleet mortality was calculated for the domestic commercial landings only (e.g., historical commercial reconstructions and landings in PacFIN). Sensitivities to the assumed discard mortality rates are presented in Section 3.5.2.

The calculated discard mortality used West Coast Groundfish Observer Program (WCGOP) gear-specific annual discard rates and discard mortality rates multiplied by the corresponding domestic landings in PacFIN (2002 to 2023). The discard mortality prior to 2002 for hook-and-line and pot gear was calculated using the average gear-specific discard rate between 2002 to 2010 and the discard mortality rate multiplied by the domestic year-specific landings from 1890 to 2001 (e.g., landings in PacFIN and the historical catch reconstructions). The discard mortality for trawl gear prior to 2002 was based on the average of discard rates observed in the Pikitch data (1985 to 1987) and the discard mortality rate multiplied by the domestic year-specific landings from 1890 to 2001. The discard mortality in 2024 was calculated by using the gear-specific discard rate for 2023. No discard mortality was assumed between 1942 and 1946 during World War II.

The estimation of the gear-specific annual discard rates for sablefish comes from multiple sources of data. A trawl discard study conducted from 1985 to 1987, referred to as the "Pikitch study", organized by Ellen Pikitch resulted in discard rates and length observations for various groundfish species including sablefish (Pikitch et al. 1988). The boundaries of the study were primarily within the Columbia International North Pacific Fishery Commission (INPFC) area off Oregon and Washington (Pikitch et al. 1988; Rogers and Pikitch 1992). Participation in the Pikitch study was voluntary and included vessels that used bottom, midwater, and shrimp trawl gear. Observers on commercial vessels collected the data, estimated the total weight of the catch by tow, and recorded the weight of species retained and discarded in the sample. Results from the Pikitch discard study were processed and provided by John Wallace (pers. comm., NWFSC, NOAA) as ratios of discard weight to total weight (discard and retained) of sablefish.

The second source for discard data is from WCGOP. This program is part of the NWFSC and has been recording discard observations starting in 2002. Since 2011, when the IFQ program was implemented, observer coverage rates increased to 100 percent for all the IFQ vessels in the program (i.e., through 2023) with lower discarding since the start of the IFQ program. Additionally, there are a number of other sectors (e.g., non-IFQ) in the groundfish fishery that catch sablefish with varying discarding practices that have less than 100 percent, sometimes well below, fishery observer coverage (see Somers et al. (2024) for observer coverage information).

Discard rates were obtained for both the IFQ (observed and electronic monitored vessels) and other sectors (e.g., open access, limited entry, etc. with less than 100 percent observer coverage) for sablefish. A single discard rate was calculated by weighting discard rates based on the commercial discards between the IFQ and other sectors and gears based on landings estimates from the Groundfish Expanded Mortality Multi-Year (GEMM) report. This approach to calculating weighted discard rates by gear across sectors is considered to be an improvement compared to approaches used in previous assessments for sablefish. The discard rates from both data sources by fleet based on gear type are shown in Table 3.

WCGOP collects biological data for observed discards from the commercial fishery. For sablefish, only length data were available from WCGOP. This assessment uses an empirical weight-at-age approach to account for time-varying changes in growth, requiring all composition data to be age-based (see Section 2.5.4 for details). A length-age key that accounts for the year and area of collection (north or south of 36° N. latitude) was used to estimate age from observed discard length. The `FSA` package in `R` was used to convert lengths to ages. The package calculates the probability that a fish is a particular age given its length. Data from the WCGBTS was used to inform the estimated length-age probabilities since this data source includes annual data with spatial locations (Figure 6). The estimated ages were expanded to the tow level and then aggregated annually for each gear type. The estimated ages were then used to inform the estimation of selectivity for each of the gear-specific discard fleets.

The number of samples, hauls, trips, and input sample sizes by gear are shown in Table 4 – Table 6. The aggregated discard ages by gear type are shown in Figure 8. Discard ages by gear and year are shown in Figure 9 – Figure 11. Generally, trawl fleets discard younger fish compared to the other gear types, with hook-and-line and pot gear discarding a wider range of ages.

2.1.3 Composition Data

Composition data for all states were extracted from the PacFIN Biological Data System. The weighting of commercial biological samples was conducted using the `R` package `pacfintool` developed and managed by scientists at the NWFSC. This package queries, filters, and expands fishery biological data based on the following steps:

1. Expand the sample weight of lengths or ages from the state recorded sub-sample, consisting of one or more baskets of fish, to the estimated total landings in that market category (or trip for ungraded samples). When sample weights were unavailable, sex-specific weight-length relationships were used to approximate the weight of the sample.

2. Sum the trip-expanded values within model-based gear fleets and state combinations. Data sampled from larger landings thus account for more weight in the sum to better reflect the total landings.

3. Expand the values to gear-specific landings, ensuring that data by state are expanded based upon the total landings within that state.

4. Calculate input sample sizes based upon the number of trips and samples.

The input sample sizes for each year and fleet in the model were calculated as:

$$\text{Input N} = N_{\text{trips}} + 0.138 * N_{\text{fish}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is } < 44$$

$$\text{Input N} = 7.06 * N_{\text{trips}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is } \geq 44$$

where N is the number of trips or fish sampled.

Commercial length data are available in PacFIN starting in 1974. Commercial age data are available starting in 1983 for trawl gear and 1986 for hook-and-line and pot gear (Table 7 – Table 9). This assessment incorporated only commercial age data to estimate the age distribution of removals by gear type. Initial investigation into the available age data identified a number of age samples that did not appear to be used in the 2019 assessment. Comparisons between the number of age samples by year for trawl and fixed gear (e.g., hook-and-line and pot combined based on the previous assessment) are shown in Table 10 – Table 11. Most of the omitted ages were from Oregon and were excluded because no ageing method was recorded or because samples were obtained from special projects. The Cooperative Ageing Program (CAP) confirmed that the method used to age sablefish has not changed throughout the time series. Given this, the ages without an ageing method denoted in PacFIN are likely break-and-burn reads and should be included in the assessment. In 2019, scientists at the NWFSC noticed that there were a number of data records in Oregon marked as “special samples” in early years of available data. After working with data experts at Oregon Department of Fish and Wildlife (ODFW), these data were identified as having been collected as random samples of market category fish and thus should be included in assessments (pers. comm., Ali Whitman, ODFW). The distribution of ages of these previously omitted ages is similar to other ages available in PacFIN (Figure 7).

The total number of ages, trips, and calculated input sample sizes are shown by year and gear type in Table 7, Table 8, and Table 9. Across all years, 28 percent, 50 percent, and 22 percent of all age data arise from California, Oregon, and Washington, respectively. By gear, 57 percent of available age data are from the trawl fleet, 32 percent from hook-and-line gear, and 11 percent from pot gear. The trawl fleet tends to catch younger fish compared to hook-and-line and pot gear (Figure 8). Age compositions from hook-and-line and pot gear are similar, with higher proportions of female fish compared to male fish. Age data by year from the trawl fleet are shown in Figure 12, hook-and-line in Figure 13, and pot in Figure 14.

2.2 Fishery-Independent Data

Historically, data from four research surveys have provided fishery-independent information about the abundance, distribution, and biological characteristics of sablefish. The longest time series of fishery-independent data arises from the WCGBTS survey, which began in 2003 and ends in 2024 for this assessment. This annual survey (excluding 2020 due to COVID-19) samples shelf and slope habitats off the U.S. West Coast, covering depths from 55 to 1,280 m (30 to 700 fathoms), and is considered the best source of information for sablefish population trends. This assessment also used data from two additional fishery-independent surveys: Northwest Fisheries Science Center Slope Survey (NWFSC Slope Survey) and the Alaska Fisheries Science Center/Northwest Fisheries Science Center West Coast Triennial Shelf Survey (Triennial Survey). Data from the Alaska Fisheries Science Center Slope Survey (AFSC Slope Survey) has been used in previous assessments of sablefish but was excluded in this assessment due to issues surrounding age data (see Section 2.4 for additional information).

The indices from each fishery-independent data source used in this assessment were standardized for comparison by rescaling the index by its mean (i.e., each index centered around 1.0), as shown in Figure 15.

2.2.1 NWFSC West Coast Groundfish Bottom Trawl Survey

The WCGBTS is based on a random-grid design that spans coastal waters from 55 to 1,280 m deep (Bradburn et al. 2011). This survey generally uses four industry-chartered vessels per year, each assigned to an approximately equal number of randomly selected grid cells that are divided into two 'passes' of the coast. Two vessels fish from north to south during each pass between late May to early October (i.e., except for 2019, which had one vessel per pass). This design therefore incorporates vessel-to-vessel differences in catchability and variance estimates associated with selecting a relatively small number of cells (approximately 700) from a very large set of possible cells that span from the US-Mexico border to the US-Canada border.

Sablefish are observed across the full range of latitudes (Figure 16) and depths (Figure 17) sampled by the WCGBTS. The sex ratio of positive tows is approximately 50:50 between depths of 55 to 400 m. More males are observed between 400 and 1,100 m, whereas more females are observed at the deepest depths (Figure 18). Generally, older sablefish are found at deeper depths and younger fish are more commonly observed from 55 to 500 m (Figure 19). The observed fraction of females is shown by age and year in Figure 20.

Geostatistical models of biomass density were fit to survey data using the R package Species Distribution Models with Template Model Builder (`sdmTMB`) developed by Anderson et al. (2022). These models can account for latent spatial factors with a constant spatial Gaussian random field and spatiotemporal deviations to evolve as a random walk Guassian random field (Thorson et al. 2015). Delta-lognormal and delta-Gamma distributions were investigated. Results are only shown for the distribution that led to the best model diagnostics (e.g., similar distributions of theoretical normal quantiles and model quantiles, high precision, lack of extreme predictions that are incompatible with life history traits, low Akaike information criterion (AIC)). Biomass from the best-fit model was predicted using a grid based on available survey locations. The `indexwc` and R package was used to conduct the analysis.

The best-fit model used a delta model with a Gamma distribution for the catch-rate component. A logit-link was used for encounter probability and a log-link for positive catch rates. The response variable was catch (mt) with an offset of area (km^2) to account for differences in effort. Fixed effects were estimated for each year and each survey pass. Vessel-year effects, which were historically used for index standardization of this survey, were excluded because the estimated variance for the random effect was close to zero. Vessel-year effects were more prominent when models did not include spatial effects and instead vessel-year terms accounted for the random selection of commercial vessels used during sampling (Helser et al. 2004; Thorson and Ward 2014). Spatial and spatiotemporal variation were included in both the encounter probability and positive catch rate models with anisotropy. Spatial variation was approximated using 500 knots.. The quantile-quantile (Q-Q) plot for the delta-Gamma model is shown in Figure 21. No spatial or spatiotemporal patterns were found in the Pearson residuals. The relative index of abundance for sablefish decreased to the lowest levels between 2008 and 2010, began to slowly increase between 2011 and 2019, sharply increased from 2021 to 2022, and remained high in 2023 and 2024 (Figure 22). The estimated proportion of biomass observed by the WCGBTS north and south of 36° N. latitude over the last five years of the survey are shown in Table 12.

Length and age samples are collected by the WCGBTS. The length data were not used in this assessment. The age data were processed into bins from 0 to 50 years of age by sex. Marginal age compositions were expanded to tow and strata levels (Table 13) using the `nwfscSurvey` R package. Input sample sizes for the marginal age compositions were calculated using a multiplier (e.g., 2.38) on the number of positive tows with age samples (Table 14) based on research by Stewart and Hamel (2014). The ages aggregated over all years are shown in Figure 8 and by year in Figure 23. The majority of unsexed fish are age 0, when sex cannot be reliably assigned. The mean age by year with 95 percent confidence intervals based on current sample sizes is shown in Figure 24. The data include observations of sablefish ranging from 0 to 91 years of age.

2.2.2 NWFSC Slope Survey

The NWFSC Slope Survey covered waters from 183 m to 1,280 m north of 34° 30′ N. latitude, which is near Point Conception, during the summers of 1999 to 2002. The survey sampled 80 fixed east-west transects, separated by 10′ latitude. Five stations in each transect were selected from two depth categories: shallow (183–549 m) and deep (550–1,280 m). There were a total of 400 possible stations to sample from each year, with 302–327 successful tows on average per year. The survey was conducted from mid-August to mid-October in 1998 but was somewhat earlier in 1999 and 2000 (late-June to late-September).

`sdmTMB` was used to estimate a spatial and spatiotemporal index for the NWFSC Slope Survey. The selected model used a delta model with a log-normal distribution for the catch-rate component. A logit-link was used for encounter probability and a log-link for positive catch. The response variable was catch (mt) with an offset of area (km^2) to account for differences in effort. Fixed effects were estimated for each year. No other covariates were modeled. Spatial and spatiotemporal variation were included in the encounter probability and the positive catch rate models with anisotropy. Spatial variation was approximated using 500 knots. Q-Q plot is shown in Figure 25. No spatial or spatiotemporal patterns were found in the Pearson residuals. The estimated index shows a relatively flat trajectory over the survey period, except for an increase in 2000 (Figure 26).

Length and age data were collected by the NWFSC Slope Survey. The length data were not used in this assessment and the age data were processed into bins from 0 to 50 years of age. Marginal age compositions were expanded to tow and strata levels (Table 15). Input sample sizes for the marginal age compositions were calculated using a multiplier (e.g., 2.38) by on the number of positive tows with age samples (Table 16) based on research by Stewart and Hamel (2014). The ages aggregated over all years are shown in Figure 8 and by year in Figure 27. The mean age by year with 95 percent confidence intervals based on current sample sizes is shown in Figure 28. The data include observations of sablefish ranging from 0 to 73 years of age.

2.2.3 AFSC/NWFSC West Coast Triennial Shelf Survey

The Triennial Survey was conducted every three years from 1977 to 2004 (Weinberg et al. 2002). The survey consisted of a series of equally-spaced east-to-west transects across the continental shelf from which searches for tows in a specific depth range were initiated. The survey design changed slightly over time but was generally conducted from mid-summer to 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. The 2001 and 2004 surveys were conducted from May to July. The sampling protocol for biological data collection varied through time, with more limited sampling in earlier years.

The Triennial Survey was conducted by the Alaska Fisheries Science Center (AFSC) from 1977–2001, with the NWFSC Fishery Resource and Monitoring Division (FRAM) Division conducting the survey in 2004, the final year, following similar protocols to earlier years. Haul depths ranged from 91 to 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, data from 1977 were omitted from this assessment. The surveys in 1980, 1983, and 1986 covered the U.S. West Coast south to 36° 8′ N. latitude and included a depth range of 55 to 366 m. The surveys in 1989 and 1992 covered the same depth range but extended the southern range to 34° 50′ N. latitude (near Point Conception, California). From 1995 through 2004, the surveys covered a depth range 55 to 500 m and surveyed south to 34° 50′ N. latitude.

In general, the Triennial Survey were conducted in the mid-summer through early-fall. The surveys from 1980 through 1989 ran from mid-July to late-September; the 1992 survey spanned from mid-July through early-October; the 1995 survey was conducted from early-June to late-August; the 1998 survey ran from early-June through early-August; and the 2001 and 2004 surveys were conducted from May through July. Due to changes in survey timing, the Triennial Survey data is frequently split into an early (1980–1992) and late (1995–2004) time series for most groundfish assesments. This assessment opted to split the early (1980–1992) and late (1995–2004) periods from this survey into two separate fleets to enable the modeling of changes in selectivity and separate data weighting between the early and late period. The previous assessment modeled this survey as a single fleet with a shift in catchability (q) between the early and late period with the same data weighting applied to the age data from both periods.

`sdmTMB` was used to estimate indices of abundance for the early and late periods of the Triennial Survey. The selected model for both the early and late periods used a delta model with a Gamma distribution for the catch-rate component. A logit-link was used for encounter probability and a log-link for positive catch rates. The response variable was catch (mt) with an offset of area (km^2) to account for differences in effort. Fixed effects were estimated for each year. No other covariates were modeled. Spatial and spatiotemporal variation were included in the positive catch rate model but not the encounter probability model. Anisotropy was included in the model and spatial variation was approximated using 500 knots. Q-Q plots for each survey period are shown in Figure 29 and Figure 30. No spatial or spatiotemporal patterns were found in the Pearson residuals. The estimated index shows a relatively flat trajectory over the period from 1980 to 1989 with an increase in 1992 (Figure 31). The late period of the Triennial Survey had a flat trend from 1995 to 1998 and showed an increase in 2001 and 2004 (Figure 32).

Length and age data were collected by the Triennial Survey. The length data were not used in this assessment and the age data were processed into bins from 0 to 50 years of age. Marginal age compositions were expanded to tow and strata levels for each survey period based upon the change in sampling depth and latitude (Table 17 and Table 18). Input sample sizes for the marginal age compositions were calculated using a multiplier (e.g., 2.38) by on the number of positive tows with age samples (Table 19 and Table 20) based on research by Stewart and Hamel (2014). During the early Triennial Survey, the number of tows where age data were available was limited. The age data from 1986 were not used in the base model because they represented only one out of 372 positive tows that year (Table 19). In the late period of the Triennial Survey, the number of tows with age data increased relative to the early period but were still limited compared to the total number of positive tows by year (except in 2004). The age data from 1998 and 2001 were excluded from the base model because they were not representative (Figure 33). The location of age data by year compared to the location of tows with lengths sampled are shown in Figure 34.

The ages aggregated over all years are shown in Figure 8 and by year for the early years Figure 35 and late year Figure 36. The mean age by year with 95 percent confidence intervals based on current sample sizes is shown in Figure 37 and Figure 38. During the early period of the Triennial Survey, a range of ages from 0 to 21 years were observed, with the majority of ages from 1 to 4 years of age. During the late period of the Triennial Survey, a range of ages from 0 to 36 years were observed, with the majority of ages from 1 to 6 years of age.

2.3 Environmental/Ecosystem Indicator Data

Linear models were used to examine relationships between recruitment deviations in log-space from the 2023 assessment of sablefish and predictors from the Global Ocean Reanalysis and Simulations (GLORYS) model output. The period from 1993 to 2019 was used as training data, leaving 2020 to 2024 data as out-of-sample predictions for use in the 2025 base model. All combinations of the GLORYS predictors, excluding correlated variables from the same model, were fit. The total number of predictors in any model was limited to three (just over 8 data points per predictor). Model selection was carried out using the `dredge` function in the `MuMIn` package in `R` (Bartoń 2023; R Core Team 2023). Candidate models were evaluated based on their ΔAICc and number of predictors.

Five models had ΔAICc values ≤ 2.0 (Table 21). All models included cross-shelf transport during pelagic juvenile (CSTpjuv) and benthic juvenile (CSTbjuv) stages. Model 3 was identified as the best-fit because it had the fewest predictors (2). These two predictors were in all of the top five models. The best-fit model explained 37 percent of the variation in recruitment deviations from 1993 to 2022 ($r^2 = 0.37$, Table 21). The remaining four models included the mean temperature during spawning (Tspawn), degree days during the female preconditioning stage (DDpre), cross-shelf transport during egg stage (CSTegg), or cross-shelf transport during yolk stage (CSTyolk) as predictors. These results suggest that additional terms may help explain variance in different years, but that CSTpjuv and CSTbjuv provide a consistent basis for prediction. Including an additional factor like Tpre may increase the explained variance by ~ 10 percent ($r^2 = 0.47$).

For all models, recruitment was negatively correlated with CSTpjuv. This suggests that processes like upwelling may be important for producing feeding conditions conducive to survival. CSTbjuv was positively correlated with recruitment, suggesting that onshore transport during the shift to benthic habitat leads to better recruitment. Both the Regional Ocean Modeling System (ROMS) analysis and the results here suggest that colder waters during the female preconditioning stage (negative correlation with DDpre, here model 2) are associated with higher recruitment (Figure 39).

The recruitment index with uncertainty is shown in Figure 40. See Section 9.2 for additional details.

2.4 Additional Data Considered

2.4.1 AFSC Slope Survey

The AFSC Slope Survey operated from October to November aboard the R/V Miller Freeman. Partial survey coverage occurred from 1988 to 1996 and complete coverage (north of 34° 30′ N. latitude) took place in 1997 and from 1999 to 2001.

The number of tows, positive tows, tows with age data, and total number of ages are shown in Table 22. The AFSC Slope Survey had an unusually high rate (~ 98 percent) of positive tows for sablefish, particularly compared to the NWFSC Slope Survey (~ 86 percent), which was conducted across similar years and depths. This high rate of positive tows prevented use of the delta-model given that nearly all tows were positive for sablefish. A Tweedie distribution was used to estimate the index of abundance shown in Figure 41.

During investigations of the age data from the AFSC Slope Survey, it was determined that aged sablefish were not representative of the lengths observed (i.e., fish identified for otolith collection were not selected randomly from all fish caught; Figure 42). This issue was also identified in the most recent assessment of Dover sole (Wetzel and Berger 2021). Given concerns about the data collected by the AFSC Slope Survey for sablefish and the fact that there was a comparable survey during these years, the index and associated age data from the AFSC Slope Survey were excluded from the base model.

2.4.2 Fournier Transform Near Infrared Spectroscopy Age Data

Scientists at the NWFSC and at the CAP laboratory have been working on developing age estimates using Fournier Transform Near Infrared Spectroscopy (FT-NIRS) combined with Neural Net (NN) models. The approach takes a spectral scan of an otolith, the spectral scan information is then passed through a NN model with varying covariates to predict an age. A total of 11,722 otoliths collected by the WCGBTS from 2015 to 2024 have been scanned using FT-NIRS. The NN model predicts age as a function of otolith weight, fish weight, depth, latitude, sex, and month. All predicted ages have a corresponding traditional age that is included in this assessment. Otoliths collected from the commercial fishery between 2018 and 2024 were also scanned, with none of these otoliths having an existing age from traditional ageing methods. The NN model was trained on age data from the WCGBTS between 2017 and 2022. The NN model was then used to predict ages from 2015, 2016, 2023, and 2024. The NN model predicted ages from the WCGBTS in 2015 and 2016 that appeared to align with traditional age estimates. However, the same model performed less well when used to predict ages from 2023 and 2024.

The work on FT-NIRS is ongoing at the NWFSC in collaboration with other NMFS science centers and best practices are still evolving. Given the ongoing nature of this work and the challenges identified in predicting ages from 2023 and 2024, FT-NIRS ages were not used in the assessment at this time. Continued research and pilot applications using FT-NIRS methods for ageing, which includes an understanding of the potential benefits (e.g., increase ageing efficiency) and barriers (e.g., bias) specific to sablefish could help to achieve ongoing ageing goals given competing demands for available resources.

As the methodology develops, future assessments for sablefish should evaluate NN model-predicted ages.

2.4.3 Enhanced Data Collection Program (EDCP) Discard Rates

The Enhanced Data Collection Project (EDCP) estimated a discard rate of 0.40 for select trawl vessels off Oregon in 1997. However, discard estimates from this study were not representative of the entire fleet. Thus, EDCP data were excluded from this assessment.

2.5 Biological Data

2.5.1 Natural Mortality

The current method for developing a prior on natural mortality (M) for West Coast groundfish stock assessments is based on Hamel and Cope (2022). This method combines meta-analytic approaches that relate M to other life-history traits such as longevity, size, growth, and reproductive effort. This approach modifies work by Then et al. (2015), which synthesized life history traits for several fish species to develop a generalized M estimator. Then et al. (2015) recommended M based on maximum age using an updated Hoenig nonlinear least squares estimator $M = 4.899A_{\text{max}}^{-0.916}$. Hamel and Cope (2022) re-evaluated the data used by 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 (Hamel and Cope 2022). The point estimate and median of the prior for M is:

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

where A_{max} is the maximum age. The prior is defined as a log-normal distribution with mean $ln(5.4/A_{\text{max}})$ and standard error $= 0.31$.

The maximum age for sablefish was selected based on available age data from all West Coast data sources. The oldest sablefish was captured by the commercial fishery in 2006 and estimated to be 102 years (not accounting for potential ageing error). Examining all aged fish from commercial and survey data, a maximum age of 75 was selected for both sexes. Across all data sources, there were limited estimates older than 75 years. In data from the WCGBTS an age of 75 years of age corresponds to approximately the 99.9 percentile of all ages. There is a higher frequency of older males compared to females observed in the data, though females grow to larger sizes and generally have higher fishery selectivity that may bias the sex-ratio of older individuals. Using a maximum age of 75, the median of the prior was 0.072 yr^{-1} with a standard error of 0.31.

2.5.2 Sex Ratio

The sex ratio observed showed some patterns by depth, with an approximate 50:50 ratio from 55 to 400 m. There were slightly more males from 500 to 1,100 m and a higher proportion females at the deepest depths (Figure 18). The sex ratio varied by age in the WCGBTS data, with a 50:50 ratio at younger ages and a higher ratio of males at age 10 plus (Figure 20). A reduction in the number of females compared to males for these older ages could be due to greater fishing pressure for females, which are generally larger-at-age. It could also be due to sex-specific differences in natural mortality. This assessment assumed the same M for both sexes but also explored sex-specific estimates.

2.5.3 Growth

Range-wide investigations of sablefish suggest that growth varies across the northeastern Pacific, with a generally increasing cline in length-at-age with latitude (McDevitt 1987b; Echave et al. 2012b; Gertseva et al. 2017; Kapur et al. 2020). A break point in growth has been identified at $\sim 50^{\circ}$ N. latitude (at the northern end of Vancouver Island, Canada), where female asymptotic length is > 70 cm to the north and < 66 cm to the south (Kapur et al. 2020). A second break point was identified at 36° N. latitude (approximately Monterey, California), where asymptotic length to the south is 60 cm for females and 55 cm for males (Kapur et al. 2020).

Female sablefish generally grow to larger sizes than males. The size at age for the oldest sablefish is highly variable, leading to considerable uncertainty in maximum size. For example, the 95th quantile of all lengths from the WCGBTS is from 55 to 77 cm for females and from 51 to 67 cm for males. As found by Kapur et al. (2020), splitting data from the WCGBTS north and south of 36° N. latitude results in smaller length-at-age to the south (Figure 43). Examining von Bertanlaffy growth parameters by latitude support a shift in growth rates north and south of 38° N. latitude (Figure 44).

The review of the 2019 assessment noted that a time-invariant growth curve resulted in periods of misfit to conditional-age-at-length data from the WCGBTS, suggesting that growth may vary by year and age. The review panel recommended that future assessments explore an empirical weight-at-age approach to account for time-varying growth. This assessment uses an empirical weight-at-age approach in the base model.

2.5.4 Weight-at-Age

A matrix of empirically derived weight-at-age data is used in the current assessment model to translate numbers-at-age to biomass-at-age in each year. Annual weight-at-age data was modeled from biological samples from the WCGBTS between 2003 and 2024. Weight-at-age from fishery samples were excluded because weight is not reported for samples in California and only available for very limited samples in Washington. Samples are shown by year, sex, and age in Table 23, with the age 25 column reflecting the total for fish 25 years and older.

Following a similar approach used for Pacific hake (Grandin et al. 2024), a generalized linear mixed model (GLMM) with a log-normal distribution has been used to model weight-at-age data external to the assessment. Weight was thought to relate to a smoothed effect of age between ages 0 to 30; random effects for cohort and year; and fixed effect by sex and area (e.g., north and south of 36° N. latitude). Unsexed fish older than age 0 were removed from the data. Unsexed fish of age 0 were randomly assigned a sex with a binomial process by year. Weights from fish ages 30 and older were pooled, thus the oldest fish are assumed to have the same weight-at-age. The 30 year plus group was based on weight-at-age data and the growth curve. Estimated parameters from the model were weighted by collection area and used to predict sex-specific weight-at-age for 0 to 30 year old fish from 2003 to 2019 and 2021 to 2024. The year-, sex-, and age-specific means were used as inputs for the assessment model (Figure 45, Figure 46, and Figure 47).

The biomass at the start of a given year is based on weight-at-age from the same mid-year when samples were collected by the WCGBTS. A similar approach was used by the Pacific hake assessment, given that samples at the beginning of the year are limited. Prior to 2003, weight-at-age inputs are assumed to be equal to the mean of all available years for each respective age (2003 to 2019 and 2021 to 2024). Sex-specific weight-at-age for 2020 was assumed to be equal to the mean of 2019 and 2021. Weight-at-age used for the projection period were based on age-specific means from the most recent five years in the data (2020 to 2024).

The use of empirical weight-at-age data is a convenient method to capture the variability in both the weight-at-length relationship within and among years as well as the variability in length-at-age data, without requiring parametric models to represent growth relationships. The empirical weight-at-age method requires the assumption that observed values are not biased by strong selectivity at length or weight and that the spatial and temporal patterns of the data sources provide a representative view of the underlying population. Simulations show that, in general, using empirical weight-at-age data when many observations are available results in more accurate estimates of spawning biomass than modeling growth (Kuriyama et al. 2016).

2.5.5 Maturity and Fecundity

New maturity reads and analyses were available for this assessment. A total of 695 sablefish maturity samples were collected by the WCGBTS in 2010, 2015, 2018, 2021, and

2022 (Table 24). Ovarian tissue samples were histologically evaluated for physiological maturity markers (i.e., presence of vitellogenin and post ovulatory follicles), and then determined to be either functionally mature (i.e., potential spawners in a given year) or immature. Estimates of maturity-at-age or maturity-at-length were evaluated north and south of 36° N. latitude. Of the samples processed, sablefish begin to mature as early as age 4 in the north and 5 in the south. Generally, sablefish tend to mature at younger ages in the north compared to the south (Figure 48).

Following similar approaches in recent Pacific hake assessments (Grandin et al. 2024), maturity was estimated using spatial models and age or length as the predictor variable. A total of 10 spatial and spatiotemporal models were considered but data limitations required that only models with spatial effects or spatially varying coefficients (e.g., no fixed year effects of spatiotemporal fields) were considered. Day of year was omitted from the models and results given little support for such an effect. A spatial field and spatially varying effect of length (spatial varying ~ length scaled or spatial varying ~ age scaled), which are analogous to a spatial intercept and spatial slope, were included. These components allow maturation rates to vary spatially but assume relatively constant rates through time.

Maturity as a function of age shows a strong spatial gradient, with lower age-at-50% (a_{50}) estimates in the north compared to the south. Maturity as a function of length shows a weaker spatial gradient, with more patchiness (e.g., several estimates of above average length-at-50% (l_{50}) off southern California). For each of the models, estimates of a_{50} and l_{50} were generated in two ways: coastwide and spatially split north and south of 36° N. latitude. The model estimated a_{50} for sablefish in the north between 5 and 6 years of age. In contrast, the model estimated a_{50} for sablefish in the south was between 10 and 11 years of age. A coastwide maturity curve was estimated by weighting the spatially split curves by biomass estimates from the WCGBTS. The biomass weighted coastwide maturity curve was more similar to the maturity estimated for the northern area due to more biomass being estimated in the north compared to the southern area. The assessment uses the biomass weighted maturity curve (spatial, Figure 49).

Available data suggest that sablefish are determinate spawners (i.e., total oocytes at the beginning of the spawning season is equivalent to total annual spawning output) that advance batches of oocytes at discrete times for release (Hunter et al. 1989; Macewicz and Hunter 1994). The total number of oocytes at the beginning of the spawning season appears to be linearly proportional to weight (Hunter et al. 1989), suggesting that spawning output for a mature female is also proportional to weight. This assumption has been used in previous sablefish stock assessments and is retained here in the absence of new information. Skipped spawning for sablefish is not a significant process and is accounted for in the functional maturity used in this assessment. To date, it is uncertain what environmental effects or other factors that could cause fecundity to vary non-linearly with weight and to induce skipped spawning in sablefish.

The product of the maturity-at-age and the fecundity-at-age (e.g., equal to weight) is show in Figure 50.

2.5.6 Ageing Precision and Bias

Observed sablefish ages are derived from visually counting rings on otoliths using break-and-burn methods. These counts can be large because sablefish are long-lived and error-prone because the repeatability of individual age estimates is imperfect, especially for older fish. Age-reading staff have indicated that sablefish can be difficult to age. The observed age can differ, sometimes substantially, from the true age of a fish (i.e., "reading error"). Ageing error can be decomposed into the difference between true age and average-read age (bias) and variability around that average read age (precision).

The majority of aged sablefish used in the assessment were aged by the CAP. Within-lab ageing error was estimated for CAP. Break-and-burn double reads of more than 12,000 otoliths were provided by the CAP lab (unpublished data). An ageing error estimate was made based on the double reads using a computational tool specifically developed for estimating ageing error (Punt et al. 2008). The R package AgeingError (release 2.1.0.) was used for input and output diagnostics.

Ageing error analyses were run exploring ageing bias and linear or curve-linear error with age. One reader was selected as unbiased and age estimates from all other readers where grouped into a second reader vector. The linear model with no bias in age estimation was selected as the final model (Figure 51). A comparison of age reads are shown in Figure 52.

3 Assessment

3.1 History of Modeling Approaches

The first sablefish stock assessment was completed in 1984 (Francis 1984), followed by frequent assessments since then (Francis 1985; McDevitt 1987b; Methot and Hightower 1988, 1989, 1990; Methot 1992, 1994b; Crone et al. 1997; Methot et al. 1998; Schirripa and Methot 2001; Schirripa 2002, 2007b; Schirripa and Colbert 2005; Stewart et al. 2011; Johnson et al. 2016, 2023; Haltuch et al. 2019; Kapur et al. 2021). Previous assessments have largely drawn similar conclusions regarding historical trends, with assessments estimating a rapid decline in the population size and status in the 1970s and 1980s due to high fishing pressure. Previous assessments have estimated a wide range of unfished spawning output levels between 100,000 mt up to approximately 250,000 mt, indicating a high level of uncertainty regarding the absolute scale of the sablefish population off the West Coast.

The 1984 assessment examined catch-per-unit-effort (CPUE) data from the 1979 to 1983 National Marine Fisheries Service (NMFS) pot survey (Francis 1984). Subsequent stock assessments were age-structured of varying complexity. The 1985 age-structured assessment utilized a simulation model to examine maximum sustainable yield (MSY) by incorporating estimates of M, average weight-at-age, recruitment, and relative age-specific catchability. The model relied on NMFS trawl and pot surveys as well as parameter estimates generated from independent research. The 1987 sablefish assessment extended the NMFS survey time-series and primarily consisted of a modified yield-per-recruitment analysis focusing on the minimum size limit (22 inches) implemented in 1983.

In 1988, a catch-at-age analysis using an early version of the Stock Synthesis modeling framework, which is the basis for all subsequent assessments, was implemented (Methot and Hightower 1988). This model included two fleets, fixed gear and trawl, and two years of fishery biological data. NMFS trawl and pot surveys provided indices of abundance, and estimates of exploitation rate were based on tag-recapture information generated from a tagging study that began in 1971. The 1989 sablefish stock assessment followed a similar approach, though revisions in the age-determination criteria for sablefish caused an increase in the observed proportion of old fish and a decrease in the estimate of M from 0.15 to 0.09 yr^{-1}. The 1990 assessment (Methot and Hightower 1990) explicitly modeled stock structure with a northern population (U.S. Vancouver and Columbia INPFC areas) and a southern population (Eureka, Monterey, and Conception INPFC areas). Including spatial structure was motivated by differences in growth rates and the hypothesis of low migration rates. The spatial models facilitated comparisons between and among areas with signals in the raw data.

In 1992, the assessment reverted to a single stock area, excluding the Conception INPFC area (Methot 1992). Data from the Triennial Survey were used to extrapolate survey estimates to the entire assessment area (Monterey through U.S. Vancouver INPFC areas). Analysis focused on exploring the trade-off in fitting the trawl-survey biomass and the trend from the pot survey. The depth stratified age- and length-composition data suggested that movement of sablefish into deep water was more closely related to their age than size. The 1994 assessment (Methot 1994b) was similar to the 1992 analysis, but the survey was used as an absolute measure of biomass after extrapolation to the coast-wide level. The 1997 assessment (Crone et al. 1997) added CPUE data and noted difficulties fitting all indices well. The 1998 assessment (Methot et al. 1998) focused on the inclusion and exclusion of the pot survey index and the use of commercial logbook CPUE.

The 2001 assessment (Schirripa and Methot 2001) focused on evaluating the sensitivity of the results to the treatment of the survey data and trade-offs among pot survey and logbook indices of abundance. This assessment was the first to introduce the possibility that sablefish recruitment may be linked to environmental factors. The 2002 assessment (Schirripa 2002) was an update to Schirripa and Methot (2001) and focused mainly on newly available data from existing sources. It was the first assessment to detect the strong 1999 and 2000 cohorts in the 2001 data, following many years of below average recruitment. A significant relationship between recruitment and sea level was identified.

Several important changes were made to the assessment of sablefish in 2005 (Schirripa and Colbert 2005). Landings and the modeled time-period were extended back to the year 1900. Separate selectivity curves were implemented for the trawl surveys, and years with limited geographic coverage in the Triennial Survey were eliminated. Discard data from the relatively new observer program were included and discard mortality was investigated. Sea level was used as an explicit offset in the population dynamics to expected recruitment.

The 2007 assessment (Schirripa 2007b) included newly available data and changed the treatment of the sea level index of recruitment within the stock assessment model to be a survey index of recruitment with observation error, rather than an explicit offset in the population dynamics to expected recruitment. The assessment made the explicit assumption that catchability for the WCGBTS was equal to 0.56, which was modeled by using only the shelf region. Uncertainty was investigated and reported primarily through alternate values for catchability.

The 2011 stock assessment (Stewart et al. 2011) reduced the number of parameters used to model fishery dynamics. Historical management actions were condensed to those that had a strong influence on fishery behavior (e.g., sorting and retention, selectivity, or both). Previously fixed leading parameters, M and trawl survey catchability, were estimated or used analytical solutions. Changes led to increased, more realistic, estimates of uncertainty around stock size estimates. Repeated testing of the correlation between sea level and recruitment continued to find a significant relationship that explained approximately 35 percent of the variability in recruitment deviations. The sea-level data was used from 1970 forward, a period with length- and age-composition data, and was not retained in the base model because the index provided a recruitment signal largely consistent with that provided by the composition data. Finally, the large number of deviations about annual growth and annual selectivity curves estimated in the 2007 model were reduced, with the net effect that uncertainty was increased. The sensitivity of model results to M, equilibrium recruitment, and steepness (h), which was estimated prior to 2011, was investigated via likelihood profiles. The 2011 assessment estimated the stock to be within the management precautionary zone (e.g., above 25 percent and below 40 percent) at 34 percent. The 2015 stock assessment (Johnson et al. 2016) was an update to the 2011 stock assessment, maintaining the same model structure and focused on adding the new data and updating data weights used in the model, resulting in an estimated stock status of 35 percent.

In 2019, a new benchmark stock assessment for sablefish was conducted that evaluated the model structure used in previous assessments and incorporated a new environmental index to inform estimates of recruitment (Haltuch et al. 2019). The 2019 assessment continued to model discarding and retention similar to previous assessments, but simplified the fleet structure to two commercial fleets: trawl and a fixed gear fleet that combined pot and hook-and-line gears. Selectivity continued to be parameterized as age-based, but the 2019 assessment opted to model selectivity for all fleets using a double-normal parameterization, moving away from using spline-based parameterization used in the previous assessment for the fishery fleets. Dome-shaped selectivity was used for all fishery and survey fleets, similar to the 2011 assessment. The assessment estimated the stock status to be just below the management target (e.g., 40 percent) at 39 percent. In 2021 and 2023, update assessments were conducted that focused on adding new data while retaining the 2019 model structure (Kapur et al. 2021; Johnson et al. 2023). The 2021 update assessment updated all data and estimated a stock status of 58 percent (Kapur et al. 2021). Finally, the 2023 update assessment was considered a "limited" update where only recent catches and new WCGBTS survey data were added. The 2023 limited update assessment estimated very strong recent recruitments at the end of the times (e.g., 2020 and 2021), driving the stock up with an estimated stock status of 63 percent.

3.2 Most Recent Stock Assessment Review Panel Recommendations

The Stock Assessment Review (STAR) Panel report from the 2019 benchmark assessment made the following suggestions:

Short Term

Recommendation: To understand whether regional differences in growth, and associated size or age composition, are behind the strong tensions observed in age and length composition data, future assessment models should evaluate having separate fixed gear fleets north and south of 36° N (as discussed in unresolved problems and major uncertainties). The potential merits of other regional differences in fleet structure could also be explored.

Response: The Stock Assessment Team (STAT) explored using regional based fleets, however, there are limited age data available south of 36° N. latitude which prevented further exploration of this approach. The STAT attempted to account for time-varying and regional differences in growth by using an empirical weight-at-age approach, where annual coastwide weight-at-age data was a biomass weighted average of weight-at-age north and south of 36° N. latitude.

Recommendation: Future assessments should consider the use of empirical weights-at-age. One approach would be to begin with the WCGBT data and use it to fit (outside model) a smoother outside the model (see Jim Ianelli for code that uses a random effects model to estimate weights using empirical data by cohort and year). This would avoids confounding weight at age with growth estimates (e.g., Lee et al. 2019, Whitten et al. 2013), should allow the model to run faster, and should enable the model to better accommodate variability in growth (in both age and over time). Another advantage is that somatic body masses are based on actual measurements instead of model estimates which predicts mean length and then converts length to mass via a fixed set of length-weight parameters

Response: The STAT agreed with this recommendation and is now using an empirical weight-at-age approach in this assessment.

Recommendation: Consider (and potentially adopt) length based selectivity for the WCGBTS, as selectivity bias could lead to observed age zero fish not being a good representation of mean length at age 0 (which could affect estimates of growth). Figure 13 shows some summary results of this issue, including the lack of apparent growth of age 0 sablefish during the period of the survey. A related issue is that specifying the size at age 0.5 (or 1.5), as well as the CV, should be in common by sex. Dimorphic growth presumably occurs at older ages. Future assessments should consider configuring "offsets" for sex differences in the growth. The rationale for this change is that differences between sexes at such young ages seem unlikely and re-configuring the model in this way will reduce the number of parameters needed.

Response: This assessment retained age-based selectivity for the WCGBTS in order to incorporate an empirical weight-at-age approach. The weight-at-age was informed using data from the WCGBTS and should better capture the variation in size-at-age across time.

Recommendation: Examine age-specific selectivity that is fixed at a "plus group" age (or have a reasonable rationale as to why selectivity might be changing over those ages).

Response: The selectivities for all fleets in the model estimated a fixed selectivity for older ages.

Recommendation: Provide estimates of retention external to the model and evaluate if the approach of doing it within the model (and then fixing the values because of discard length composition data affecting model results other than the shape of the retention curve).

Response: This assessment moved to a discard fleet approach because there were concerns about model stability with retention being estimated within the model. The discard totals were estimated external to the model and the selectivity for the discard fleets were estimated using estimated discard ages.

Recommendation: Reconsider spline or some other non-parametric selectivity forms, as there are unexpected behaviors observed in estimating double normal selectivities for the fixed gear fishery. The requirement (apparently) to have to fix the "P6" parameter related to old sablefish selectivity and some other interactions seems unusual, and several of the convergence issues were related to selectivity parameters for some gear types/surveys. The 2015 model used a different form for selectivity and the document provided little justification to choose one over the other. "Fewer parameters" is a poor reason if performance overall is so much worse. The convergence problems did seem to be largely resolved after the STAT fixed the CV of young ages.

Response: The STAT explored splines for fishery and survey fleets in the model, but were not found to improve the fits to the data compared to double-normal selectivity given other fleet structure refinements.

Recommendation: The CAAL plots suggest that in the early years of the WCGBTS the residuals of the biggest fish were generally "young" and in the more recent years the pattern of observed and predicted were more consistent. This could be due to changes in growth and/or size (or age) based selectivity/availability changes and should be investigated.

Response: The STAT agrees that there appeared to be periods where the conditional-age-at-length residuals were generally positive or negative. The empirical weight-at-age approach explicitly accounts for potential time-varying growth by year.

Recommendation: Developing diagnostics that better evaluate sex ratio observations against model predictions would be useful, especially given some of the differences observed in the fisheries selectivities estimates and in sex specific natural mortality configurations compared to combined sexes natural mortality.

Response: The `r4ss` package now includes improved sex ratio figures. Additionally, the sex ratio of observed ages for all fishing and survey fleets were evaluated to determine whether sex-specific selectivity was occurring. The hook-and-line and pot gear have greater selectivity for females compared to males which could lead to changes in sex ratios of selected fish over time. The STAT did not find clear evidence for differing natural mortality rates by sex, and thus a single natural mortality was used for both sexes.

Recommendation: Reducing the number of ages should be considered, as the plus group information and dynamics beyond some ages are unlikely to change (as shown in Figure 14).

Response: The STAT agrees that the data plus group of age-50 may be larger than necessary. A sensitivity was conducted that truncated the data plus group at age 35 that shows very minor changes in the estimated stock scale but similar estimates of stock status.

Recommendation: Continuing to evaluate the use of sea level and/or other environmental indicators as drivers of both historic and future recruitments is strongly encouraged, and future assessments should strive to clearly convey how such data explicitly relate to recruitment as well as to convey the logic and presumed mechanisms behind the relationship.

Response: The assessment opted to use a recruitment index that covered the last five years of the model given that there are significant survey and fishery data to inform recruitment estimation for earlier years. Additionally, preliminary research conducted by Dr. Kiva Oken NWFSC determined that including longer time series of recruitment indices may bias estimates of stock size and recommended that recruitment indices be isolated to periods where there is little to no information about recruitment from other data sources in the model.

Medium and Long Term

Recommendation: The panel had concerns about the large amount of data and the challenges faced doing things such as estimating natural mortality and the CVs on growth and other factors. However, the core growth parameters were generally stable, and convergence problems are not atypical when natural mortality is difficult to estimate and selectivity patterns are all dome-shaped. The panel notes that it is worth reflecting on whether a somewhat different modeling approach would work better (in the longer term). The nature of the issues in the data may be stretching the capacity of the analytical framework and software to do what needs to be done.

Response: The STAT agrees that estimating growth, natural mortality, selectivity, and retention with this assessment can (and did) lead to an unstable model (e.g., variable or uninformed estimates across sensitivities, and/or an inability to invert the hessian). To address these issues, this assessment made significant efforts to simplify the model structure and to improve paramaterization of key processes.

Recommendation: The STAT provided very helpful updates on ongoing efforts to evaluate life history characteristics, movement patterns and management approaches throughout the range of sablefish in the Northeast Pacific. The STAR Panel agrees with the STAT that ongoing and future work, such as efforts to develop a trans-boundary stock assessment and management framework, be pursued. This is based on strong indications that current stock boundaries are likely to be inappropriate, and that a trans-boundary assessment would likely improve the ability to estimate the scale of the population.

Response: This STAT agrees that work should continue to evaluate coherence of sablefish across the Northeast Pacific, including net changes in biomass due to emigration and immigration across assessment boundaries. Recent research by Kapur et al. (in press) presents estimates of trans-boundary exchange for Northeast Pacific sablefish, which forms the basis for a sensitivity evaluation in this assessment.

Recommendation: As the WCGBTS is highly informative in the model, maintaining full coastwide survey effort is essential. However, currently the survey does not include a large fraction of the habitat south of 36° N, the cowcod conservation areas. Despite a lack of data in this large area, catch is allocated north and south of 36° N based on the estimated fraction of sablefish in these areas, and this fraction, in turn, is based on an extrapolation of survey catch rates outside the CCAs to those inside. As fish within the CCAs are only subject to fishing pressure if and when they move, and movement rates are variable, this concentration of effort outside of the CCAs could potentially lead to localized depletion, which in turn could bias the signal in fishery (and potentially survey) age and length composition from the fished areas. It would be beneficial to have survey data from within the CCAs to inform the survey, and to allow for some evaluation of whether and how population structure may vary inside and outside of the CCAs. There could be some potential for local depletion elsewhere as well, given the concentration of trawl effort off of Oregon and Washington and the decline in fishing effort and catches of both trawl and fished gear in California north of 36° N.

Response: The STAT attempted to evaluate the proportion of trawlable habitat south of 34° 47′ N. latitude but did not have time to complete this analysis. The STAT notes that a spatiotemporal model is currently used to estimated the index of abundance for the WCGBTS, which can incorporate spatial and temporal information to smooth estimates across sampled and unsampled areas. However, composition data are limited in some areas, and if consistent differences exist in sablefish abundance, size, or age in unsampled compared to sampled areas, then even spatiotemporal models will not be able to accurately account for spatial heterogeneity in the biological data. Starting in 2024,the WCGBTS is now sampling within the CCA which may provide additional information to understand potential difference in sablefish abundance, size, or age inside and outside the CCA.

Recommendation: For the WCGBTS, evaluate cohort total mortality (Z) for consistency and as a check with model values. Comparing the survey estimate numbers at age over time (e.g., relative abundance at age 2 in year y compared to abundance at age 3 in year $y+1$).

Response: The STAT did not have sufficient time to address this recommendation and agrees that a future STAT should work to understand cohort mortality.

Recommendation: Better estimates of aging error, bias and continued efforts to improve on age validation remain high research priorities.

Response: This assessment incorporated an updated ageing error estimate of uncertainty and bias using Template Model Builder, which can account for random effects. The STAT agrees that future work should be done to improve age validation to improve our understanding of age-structure in the sablefish population off the U.S. West Coast.

3.3 Model Structure and Assumptions

3.3.1 Modeling Platform and Structure

This assessment was conducted using Stock Synthesis version 3.30.24 developed by Dr. Richard Methot at the NOAA, NWFSC (Methot and Wetzel 2013). This most recent version was used because it included improvements and corrections to older model versions. The previous assessment of sablefish used an earlier version of Stock Synthesis (3.30.21). Model bridging was performed between both versions of Stock Synthesis and discussed below. The `R` package `r4ss`, version 1.51.0, along with `R` version 4.4.1 were used to investigate and plot model fits.

3.3.2 Model Selection and Evaluation

The base assessment model was developed to balance parsimony and realism to ultimately achieve a robust and stable model structure. The goal was to estimate stock size, stock status, and related reference points (e.g., spawning output trajectory) for the population off the West Coast of the U.S. The model contains many assumptions to achieve parsimony and uses many different sources of data to estimate reality. A series of investigative model runs were done to achieve the base model.

3.3.3 Model Changes from the Last Assessment

A number of data and modeling changes were made in this assessment relative to the previous benchmark assessment (Haltuch et al. 2019):

- All available data were reprocessed and extended through 2024.
- Hook-and-line and pot gear were split into separate fleets whereas the previous assessment combined these data into a single fixed gear fleet.
- The index and age data from the AFSC Slope Survey were not included in the base model due to issues with the age data.
- The Triennial Survey was split into two separate survey fleets, each with indices and estimates of catchability and selectivity. The early period ranged from 1980–1992 and the late period 1995–2004. The previous assessment split the survey with a change in catchability and selected selectivity parameters between the early and late period. Splitting this survey into two separate fleets allowed for period-specific estimation of selectivity and separate data weighting. Additionally, select years of age data were excluded due to concerns that they were not representative due to limited spatial coverage across tows.
- This assessment incorporated a new shorter environmental index to inform the estimates of recruitment. The previous assessment used an environmental index based upon sea surface height from 1925–2018. The new environmental index were based on a GLORYS model informed by a number of environmental covariates that ranged from 2020–2024. This newer index approach was selected since the estimation of historical recruitments should be well informed by data and that recruitment near the end of the model period can be the most uncertain due to limited observations.
- An new evaluation of ageing error was conducted and the assumed bias and uncertainty were updated.
- This assessment incorporates new research on maturity moving from maturity-at-length to maturity-at-age. The coastwide maturity-at-age vector was estimated using a spatial modeling approach that supported the development of a biomass-weighted maturity curve to better account for variation in maturity-at-age by area north and south of 36° N. latitude.
- Empirical weight-at-age was used in this assessment to account for time-varying growth by age, sex, and year.
- The prior assumed for M was updated based upon new research.
- M continues to be estimated, but is estimated to be equal between female and males.
- Steepness (h) continues to be fixed at an assumed value. However, due the lack of research on sablefish productivity and resiliency, h is fixed at 0.75 in this assessment to align with the proxy reference points used for management of the stock off the U.S. West Coast. The previous assessment fixed h at 0.70.
- This assessment opted to model removals via discard fleets for each gear type. The discard fleet approach was considered to be more transparent, allowing separate selectivity for retained and discarded fish, and improved model stability.
- This assessment simplified the modeling of changing selectivity (e.g., blocks) due to management changes where possible.
- Annual recruitment deviations were estimated starting in 1975 with recruitment

between 1890–1974 assumed to be equal to be equal to the stock-recruitment curve.
- Recruitment deviations were estimated as simple deviations (recruitment deviation option two in Stock Synthesis) rather than a deviation vector with a sum to zero constraint (option one in Stock Synthesis).

3.3.4 Key Assumptions and Structural Choices

The specifications of the assessment are listed in Table 25. The model is a two-sex, age-structured model starting in 1890 with an accumulated population age group at 70 years. *M* was estimated and assumed to be time invariant and equal between males and females. An empirical weight-at-age approach was implemented with sex-specific time-varying growth between 2003–2024. The ages in the population were tracked by 1 year intervals between 0–70 years of age and the age data were grouped by age between 0–50 with 50 being used as data plus group. Summary biomass was calculated for ages 3 plus. The sablefish population off the U.S. West Coast was modeled as a single area with only one season per year and coastwide time-varying growth pattern by sex via the weight-at-age approach.

Selectivity was age-based and modeled by fleet (retained/total removals and discard fleets) with time blocks on selectivity to allow for shifts in selectivity for each fishery fleet. The selectivity between hook-and-line and pot gears were mirrored (e.g., data combined to estimate selectivity for both gear types) due to similarity in the composition of retained age data between the gears. The trawl fleet and each of the discard fleets (trawl, hook-and-line, and pot) estimated fleet-specific selectivities. The mirrored hook-and-line and pot fleets also allowed for sex-specific selectivity with females having a higher selectivity by these gears compared to males. The trawl, hook-and-line, and pot gears had time blocks between 1890–2001 and 2002–2024 to account for the implementation of the RCAs that eliminated fishing in select depth ranges across the coast. It is important to note that many RCAs were opened for groundfish fishing in 2024, but with only one year of data, an additional time block starting in 2024 was not included in the base model. Future updates to this model should explore adding a time block starting in 2024 to determine if there were changes in selectivity arising from the opening of RCAs. The trawl and hook-and-line discard fleets assumed three time blocks: 1890–2010, 2011–2018, and 2019–2024 to account for implementation of the IFQ system in 2011 and the change by management to credit quota accounts in the IFQ fishery for discarded sablefish that were assumed to have survived based upon discard mortality rates which led to changes in discarding practices. The pot discard fleet assumed two time blocks: 1890–2010 and 2011–2024, with early model development determining that an additional block for 2019–2024 had little to no impact on the model fits to the age data for this fleet.

The specification of when to estimate recruitment deviations is an assumption that influences not only the estimate of model uncertainty around stock scale and status during that period but also the fits to composition data. Extensive model explorations were conducted to determine the appropriate range of years to estimate recruitment deviations. This assessment opted to not include recruitment deviations early in the model period, when data were not available, and begun estimation in 1975 based upon when the estimates appeared to be informed by data. The earliest age-composition data began in 1983. The estimates of recruitment deviations from 1975–2023 were considered within the "main period" and 2024 as the "late period" within Stock Synthesis. A bias adjustment was applied between 1974–2024 and no bias adjustment was applied during the projection period (i.e., 2025–2036). Methot and Taylor (2011) summarize the reasoning behind varying levels of bias adjustment based on the information available to estimate the recruitment deviations. The standard deviation of recruitment variability was assumed to be 1.4 based on the estimated variation in recruitment from the base model.

The following distributions were assumed for fitting data: survey indices were log-normal; the environmental index was normal, and the age-composition data followed a multinomial error structure.

3.3.5 Estimated and Fixed Parameters

There were 99 estimated parameters in the base model. These included one parameter for R_0 parameterized in log-space, one parameter for M, two parameters for extra variability for the late Triennial and NWFSC slope survey indices, one parameter for catchability for the recruitment index, 32 parameters for age-based selectivity and time blocking of the fishery and the survey fleets, 50 recruitment deviations, and 12 projected recruitment deviations (Table 26).

Fixed parameters in the model were as follows. Steepness was fixed at 0.75. Maturity-at-age was fixed in the model and fecundity was assumed equal to body weight. Sex-specific empirical weight-at-age by year was estimated external to the model to account for growth variation by year, area, sex, and age. The standard deviation of recruitment deviates was fixed at 1.4, the same value assumed in the last assessment.

Specific selectivity parameters were estimated for all fishery and survey fleets in the model. All fleets were allowed to estimate dome-shaped selectivity. The selectivity between the hook-and-line and pot fleets were assumed equal (e.g., mirrored) and incorporated sex-specific selectivity with females being more selected compared to males. The trawl fleet, all three discard fleets, and survey fleets assumed equal selectivity for females and males. The decision about whether to mirror selectivity among fleets and whether to allow for sex-specific selectivity was based upon explorations of the data and model testing. The recruitment index was modeled as a recruitment deviation survey within Stock Synthesis which assumes the index is representative of age-0 fish.

3.3.6 Priors

A prior was used for M in the base model. The base model estimated M with a prior distribution based on the Hamel and Cope (2022) meta-analytic approach with an assumed maximum age of 75 years for both males and females. The prior assumed a log-normal distribution for M. The log-normal prior has a median of 0.072 yr^{-1} and a standard error of 0.31. The prior was assumed the same for each sex during early model development with the base model estimating a single M for both sexes.

The treatment of h has varied across recent assessment given the lack of research about sablefish productivity and resiliency. The assessment conducted in 2007 estimated $h = 0.43$, the 2011 assessment fixed h at 0.60 based upon He et al. (2006), and the 2019 assessment assumed a fixed value of 0.70. This assessment opted to fix h at 0.75. A sensitivity was done where h was estimated with a prior using a beta distribution with mean of 0.75 and standard error of 0.15 (see Section 3.5.2). A value of 0.75 was selected and based upon the range of values that appeared to be supported based upon data and current understanding about life history. Additionally, a value of 0.75 aligns with PFMC adopted reference points for sablefish.

3.3.7 Data Weighting

Age data from each fishery and survey fleet were fit and appropriately weighted within the model. Age data started with a sample size determined from the equation listed in Section 2.1.3 for fishing fleets in the model. Input sample sizes for survey age data were calculated according to the method described in Section 2.2.1.

The base model was weighted using the Francis method, which was based on equation TA1.8 in Francis (Francis 2011). Sensitivities were performed examining the difference between the McAllister Ianelli (McAllister and Ianelli 1997) method (Harmonic Mean weighting) and the Francis data weighting. The weights applied to the age data by fleet for the base model are shown Table 27.

Extra variability parameters were estimated and added to the input variance for the indices of abundance for two surveys in the model: 1) the late Triennial Survey (1995–2004) and 2) the NWFSC Slope Survey. Estimating additional variance for the early Triennial Survey (1980–1992) was explored but not found to be necessary. The WCGBTS is considered to sample sablefish off the U.S. West Coast well and no additional variance was estimated to ensure that the model fit this index. Estimating additional variance for the WCGBTS was explored during model development resulting in the model estimating ~0.10 added variance. The overall stock trajectory was similar across the time series between the model with and without added variance for the WCGBTS, but the overall fit to the index was poorer when added variance was allowed which led to it not being included in the base model.

3.3.8 Bridging Analysis

An extensive bridging analysis was conducted to detail the transition from the previous assessment to the base model. The bridging analysis is presented in three sections: 1) updating the version of Stock Synthesis used, 2) data updating and minor model structure changes, 3) major model structure changes. Updating the version of Stock Synthesis did not result in changes to estimated parameters or derived spawning output (Figure 53).

Extensive changes to the data and the model structure were targeted to improve model stability (i.e., estimating informed parameters towards balancing bias and variance), which made it challenging to develop a single, simple and transparent bridging process. The data bridging process, where data were reprocessed and updated through 2024, was conducted in an additive fashion. However, many of the model structure changes were often not made in a completely linear fashion during development of the base model. In the bridging presented, changes were grouped for clarity, particularly within the major model structure bridging section, and may not be presented in the order that they were originally decided during modeling development. This non-linear model development and the needed linear bridging has led to some steps in the bridging process to show larger changes in model estimates compared to what was observed when these model structure or parameter changes were decided. Given this, it is recommended to consider both the bridging and the sensitivities for the base model in tandem (see Section 3.5.2 for base model sensitivities).

The order of data updating and minor model structure changes were:

1. Remove the sea surface height environmental index.

2. Update landings for trawl and fixed gears from 1890–2022 and add new landings 2023–2024.

3. Reprocess fishery ages from 1983 – 2022 and add new ages from 2023–2024.

4. Reprocess fishery discard rates for trawl and fixed gears from 2002–2021 and add 2022.

5. Reprocess fishery discard lengths and mean body weights for trawl and fixed gears from 2002–2021 and add 2022.

6. Split landings, discard, and age data from the fixed gear fleet into two separate fleets: hook-and-line and pot gears.

7. Revise and fix selectivity and retention blocks based upon data and extend through 2024.

8. Reprocess indices of abundance and age composition data from the Triennial Survey, AFSC Slope Survey, and NWFSC Slope Survey.

9. Reprocess and extend the index of abundance, length compositions, and conditional-age-at-length data from the WCGBTS.

10. Update maturity from maturity-at-length to maturity-at-age based upon new research.

11. Update the M prior for female and males with a median of 0.072 yr^{-1} and a standard error of 0.31. Continue to estimate sex-specific M.

12. Update the ageing error bias and uncertainty using available double-read information through 2024.

Removing the sea surface height environmental index and updating and extending landings had limited impact on the estimated summary biomass and stock status (Figure 54 and Figure 55). Reprocessing and extending the fishery ages reduced the overall scale of summary biomass and reduced the stock status across all model years. Data and model explorations determined that the change in estimates from the 2023 assessment was due to inclusion of additional historical ages (i.e., 1983—2010) that were not included in previous assessments. The distribution of previously excluded and all the ages used in this assessment were similar (Figure 7) indicating that the change in model estimates were due larger sample sizes rather than changes in the age distribution. Table 11 compares the number of ages by year and gear group between this assessment and the 2019 assessment. The revised age data primarily was collected in Oregon and was excluded due to the lack of information about the ageing method (e.g., break and burn, surface read, etc.) or were marked as special samples in the ODFW database. After conversations with staff at ODFW and CAP, it was determined that the ageing methodology has been generally consistent across time for sablefish and that these samples were likely determined via break-and-burn methods, consistent with current methodology. It further was determined that records marked as special samples in early years of PacFIN data were randomly collected market samples similar to current sampling programs and that these data should be included in the assessment.

Reprocessing and extending the fishery discard rates resulted in a reduced estimate of spawning output and stock status across the time series compared to the previous model (e.g., +fishery ages model, Figure 54 and Figure 55). The methodology used for determining discard rates was improved for this assessment compared to previous assessments, which resulted in modest increases in the discard rates primarily for the fixed gear fleet (e.g., hook-and-line and pot, see Section 2.1.2 for additional information). Reprocessing and extending the mean discard weights and length compositions resulted in only minor changes to model estimates.

Splitting hook-and-line and pot gear landings, discard, and age composition data into separate fleets resulted in generally small decreases to the estimated spawning output and stock status. During the process of splitting out hook-and-line and pot gear fleets, some issues were identified with the time blocks applied to the fishery selectivity and retention parameters resulting in some time-varying parameters being estimated in the absence of data (age or discard length compositions). Hence, blocks were simplified accordingly to ensure data were available to inform estimates. Finally, the blocks were extended through 2024. These fixes resulted in an increase estimated stock size and stock status compared to the previous model (e.g., Split Fixed Gear, Figure 54 and Figure 55). Reprocessing historical survey based on current best practices resulted in only minor changes in model estimates. Reprocessing and extending the index of abundance, length compositions, and conditional-age-at-length data from the WCGBTS slightly reduced estimated stock size across the time series but had limited impact on the estimated stock status. Adding the new maturity-at-age changed the scale of stock size across the time series but did not change the stock status (Figure 56 and Figure 57). The final two revisions in the data bridging section, updating the prior for M (i.e., continuing to estimate M) and the ageing error bias and uncertainty resulted in only minor changes to model estimates.

In summary, across the data bridging, including all available age data had the largest impact on model estimates. The new discard rates that incorporated an improved methodology to calculate gear-specific discarding across fishery sectors resulted in the next most influential change to model estimates.

This assessment made a number of structural changes to the model. The order of major structural and data changes were:

1. Move to start of the main period for estimated annual recruitment deviations in 1975 from 1925 (used in the previous assessment) to align with the period of available data to inform estimates of recruitment and start estimating recruitment deviations at the start of the model (1890) rather than before the first years in the model.

2. Estimate annual recruitment deviations starting in 1975 (e.g., no annual recruitment deviations between 1890–1974).

3. Remove the index of abundance and age composition data from the AFSC Slope Survey.

4. Split out foreign catches from the domestic trawl, hook-and-line, and pot fleets and replace discard lengths with the estimated discard ages. The model has six fishery fleets: three domestic fleets that estimate age-based selectivity and retention, and three foreign fleets that mirror the age-based selectivity for the corresponding domestic fleet by gear.

5. Split the Triennial Survey survey into two separate survey fleets in the model and remove select years of non-representative age composition data in the early and late periods.

6. Revise fixed and estimated selectivity parameters for the WCGBTS to better fit the age composition data.

7. Switch to a discard fleet approach where discard mortality is estimated outside the model and included as separate fleets. The model now has six fishery fleets: three removal fleets and three discard fleets by gear type.

8. Include empirical weight-at-age and remove parameters estimating growth.

9. Estimate a single M for both females and males.

10. Update the assumed h from 0.70 to 0.75.

11. Add new recruitment index and estimate annual recruitment deviations as simple deviations.

The 2019 assessment introduced a sea surface height index to inform the estimation of annual recruitment and the model structure of that assessment defined the main period of recruitment to range from 1925–2018. In Stock Synthesis, a user defines three recruitment periods: early, main, and late. The general guidance for defining recruitment periods is that the main period should be years when annual recruitment deviations are well informed by the data (e.g., lower uncertainty intervals). Additionally, the 2019 assessment opted to model annual recruitment deviations with the constraint that the vector of main period deviations sum to zero (e.g. option 1 in Stock Synthesis). During early model explorations it was determined that the decision to start the main period in 1925 combined with the sum to zero constraint had a non-trivial impact on the overall model estimates. Adjusting the main period for recruitment deviation estimation from 1925 to 1975, when annual recruitment deviations were well informed by the data, increased the estimated stock size between 1890–2000 (Figure 58) and led to a more depleted population at the end of the time series (Figure 59). Additionally, during the early period of the time series there was a notable drop in the stock size by 1960 and then a sharp increase in stock size peaking in the mid-1970s that was not due to catches, but mostly due to recruitment deviations. The annual recruitment deviations from the

the ageing error model, which retains the 2019 parameterization for early and main period for deviations, were generally more positive and less negative compared to the models that adjusted the period for main deviations (Figure 60). This difference in the estimation of the annual recruitment deviations is likely not driven by data but rather the sum to zero constraint across the extended main recruitment estimation period. In order to simplify the model and to only estimate data driven trends in the time series, early recruitment deviations were not estimated in the base model. Sensitivities to this decision are presented in Section 3.5.2.

Figure 61 and Figure 62 show the impact of models that remove data from the AFSC Slope Survey, split out foreign catches (i.e., selectivity mirrored to domestic gear specific fleets) and estimate age-based selectivity and retention, and split the Triennial Survey and remove select years of age data. There was limited impact on the model estimates from removing the AFSC Slope Survey data and splitting out the foreign catches and moving to age-based retention. Splitting the Triennial Survey and removing select years of age composition data reduced the estimate of summary biomass across the time series, but had only a minimal impact to the estimated stock status.

The next steps in the bridging process revised the selectivity for the WCGBTS and changed the model structure to a discard fleet approach (Figure 63 and Figure 64). Optimizing the estimated and fixed parameters for the WCGBTS decreased the estimate of summary biomass and resulted in a more depleted population compared to the previous model in the structure bridging (e.g., split Triennial Survey). The parameterization for this survey in the previous assessment assumed a steep dome-shaped selectivity with a plateau in selectivity around ~ 0.45 for ages 10 and older (see Figure 53 in Haltuch et al. (2019)). During model explorations for this assessment, all parameters from this survey were estimated to provide flexibility for the selectivity shape to change based upon the data and, subsequently, parameters were fixed at the estimates as necessary (e.g., parameters at inconsequential bounds or containing large uncertainty). During this exploration the data supported a steep increase in selectivity between age-0 and age-1, maximum selectivity at age-1, and only a limited dome with a plateau of selectivity for age 3 and older around ~ 0.8. The WCGBTS samples much of the depth range for sablefish (sampling between 55–1,280 m), and the survey is believed to be representative and informative of the sablefish population off the West Coast. The resulting selectivity shape was more in line with *a priori* expectations for this survey. Removing the estimation of retention and adding discard fleets marginally increased the estimate of summary biomass at the start of the time series and marginally decreased it at the end of the times series when compared to the previous bridging model (Figure 63).

The final bridging steps included adding time-varying growth through the use of empirical weight-at-age data, assuming a single M value for both sexes, updating the fixed h value to 0.75, and adding the recruitment index with the simple deviation approach used in Stock Synthesis (Figure 65 and Figure 66). Estimates of stock size and stock status were relatively similar across models. Switching to an empirical weight-at-age approach slightly increased the estimate of stock size across the time series. Revising the assumption around h reduced the estimates of stock size at the start of the time series. The estimated stock status was similar across these models.

In summary, across all the model structure bridging steps, revising the treatment of recruitment deviations (i.e., changing the defined main period) and the selectivity for the WCGBTS had the largest impact on model estimates. Both of these changes were considered improvements to the model structure by improving the fits to data while aligning with modeling best practices. A comparison of the base model to the 2023 model, and earlier assessments, is provided in Section 3.6.

3.4 Modeling Results

Parameters were estimated using maximum likelihood estimation and uncertainty is based on the assumption of asymptotic multivariate normality of the maximum likelihood estimate, where the variance-covariance matrix is the inverse of the hessian matrix. A list of fixed and estimated parameters in the model and asymptotic standard error estimates for estimated parameters is available in Table 28. The negative log likelihood components by data type are shown in Table 29. Estimates of derived reference points and approximate 95 percent asymptotic confidence intervals are shown in Table 30. Estimates of stock size and other key population metrics over time are shown in Table 31.

3.4.1 Parameter Estimates

The M for both females and males was estimated as a single parameter. M was estimated to be 0.088 yr^{-1} using a prior with a median of 0.072 yr^{-1} and a standard error of 0.31 (Table 28 and Figure 67). Sensitivities to the treatment of M are shown in Section 3.5.2.

Age-based selectivity curves were estimated for the fishery and survey fleets using the double-normal selectivity parameterization in Stock Synthesis. The selectivity curves for the hook-and-line and pot gears were sex-specific while all other fishery and survey fleets were parameterized to have a single selectivity curve for both sexes. The estimated selectivity curves are shown in Figure 68 and Figure 69. The selectivity for the trawl, hook-and-line, and pot gears (recall the pot and hook-and-line gears were mirrored) were estimated to be dome-shaped with each fleet estimating small changes in selectivity between 1890–2001 and 2002–2024. The dome in the trawl selectivity between 2002–2024 shifts rightward, increasing peak selectivity for older fish compared to 1890–2001. The selectivity was assumed to be equal for the hook-and-line and pot gears with higher selectivity for females compared to males. The selectivity for hook-and-line and pot gears peaked at older ages and had lower selectivity at the oldest ages when compared to trawl gear selectivity.

Three selectivity periods were estimated for the trawl and hook-and-line discard fleets: 1890–2010, 2011–2018, and 2019–2024 (Figure 68). The selectivity for the trawl discard fleet was estimated to be sharply domed with discarding peaking for young fish followed by a rapid decline to a lower level of discarding for older fish in each time period. The hook-and-line discard fleet estimated dome-shape selectivity to peak between 3–5 years of age depending upon the time block. The selectivity for the pot discard fleet has time blocks between 1890–2010 and 2011–2024 that show a peak occurring between 3–6 years of age, but with a higher frequency of discarding older fish compared to the hook-and-line discard fleet.

The estimated selectivity for the separate early and late periods of the Triennial Survey were domed with the survey primarily selecting only young fish (Figure 69). The early period of the Triennial Survey, 1980–1992, sampled depths ranging form 55–366 m and was estimated to have full selectivity for ages 1 to 3, limited selectivity for age 4, and very low selectivity for older ages (e.g., 0.005). The late period of the Triennial Survey, 1995–2004, extended the sampling out to depths of 500 m. The estimated selectivity for the late period peaked at age 2 and then declined from ages 3 to 6 before settling at a low selectivity for older ages (e.g., 0.02). The estimated selectivity for the NWFSC Slope Survey was estimated to be slightly domed, peaking at age 4 and then declining slightly around age 5 and 6 before plateauing to a constant level for older ages (Figure 69). The selectivity curve for the WCGBTS was similar to the selectivity for NWFSC Slope Survey, with the survey having limited selectivity for age-0 fish but then quickly peaking at age 1 before decreasing slightly by age 2 to a constant plateau for older ages (Figure 69). The selectivity of age-0 fish, the steep increase, limited width at the peak, and the steep decrease in selectivity for the WCGBTS led to issues with parameters being estimated at parameter bounds requiring many of the selectivity parameters to be fixed. Future update and benchmark assessments for sablefish should evaluate if fixed parameters need to be revised based upon new data in order to retain the best fit to the survey data.

Catchability for each of the surveys was analytically derived by comparing observed to expected vulnerable biomass across all years for each survey. The catchability for the early and periods of the Triennial Survey was 1.02 and 2.77, respectively (Table 28). The catchability for the NWFSC Slope Survey was 0.51 and was 1.05 for the WCGBTS. It is important to note that the interpretation of catchability for surveys with dome-shaped selectivity is challenging, particularly for the Triennial Survey, since the catchability is based upon only the fully selected ages. The catchability for the recruitment index was an estimated parameter (i.e., compared to the other surveys where catchability was analytically calculated and not a parameter) and estimated at 0.24, but its interpretation is not as intuitive as it is for abundance indices.

Process error was added directly to each years input standard deviation for the late period of the Triennial Survey and NWFSC Slope Survey as additional survey variability. The added standard deviation for each of these surveys was 0.08 and 0.14, respectively (Table 28). No additional survey variability was needed to fit the trend in the early period of the Triennial Survey. No additional survey variability was estimated for the WCGBTS, because this survey is largely considered an effective sampling tool for sablefish and identified as a key data source that the model needed to fit.

The time series of estimated recruitments and annual recruitment deviations are shown in Figure 70 and Figure 71. Initial model explorations found that there was limited information in the data to inform annual recruitment deviations prior to 1975, often leading to a source of model instability. Thus, deviations for years prior to 1975 were not estimated in the base model and the estimated deviations from 1975–2024 were estimated as simple deviations. The sum of the recruitment deviations from 1975–2023 was 0.42 with the estimates being similar to sensitivities where the deviations were forced to sum to zero (see Section 3.5.2). A bias adjustment was applied based upon Methot and Taylor (2011) and is shown Figure 72.

Estimated recruitment deviations during years with the majority of the age data (i.e., after 1990) have relatively low uncertainty intervals indicating support in the data for strong or poor recruitment years. The estimated annual recruitment deviation in 2024 is uncertain, but estimated to be above average based upon age 0 data from the WCGBTS and the recruitment index. Years with the highest recruitment deviations were estimated to have occurred in 2023, 2020, 2016, 2013, and 2021. The lowest annual recruitment deviations (e.g., negative deviations) were estimated to have occurred in 2005, 2007, 2009, 1996, and 1992.

3.4.2 Model Fits

The fit to the survey indices are shown in Figure 73 – Figure 76. The model fit the early period for the Triennial Survey well. The late period for the Triennial Survey had an increasing trend in the index that the model generally fit, although additional survey variability was estimated in order to fit the 1998 and 2001 data points. The model fit the trend in the NWFSC Slope Survey index between 1999–2001, but estimated a higher vulnerable biomass in 1998 and then lower in 2002 relative to the index. The model fit the trend in the WCGBTS index for most years, but the model trend for the 2019 (above) and 2022 (below) data points was outside the uncertainty interval. The fit to the recruitment index generally followed the trend in the annual data points (Figure 77).

Fits to the age data are shown based on the proportions of age observed across all years and the Pearson residuals-at-age for all fleets. Age composition aggregated fits by fleet are reasonably well fit and are shown in Figure 78. The residuals for the trawl fleet did not show clear patterns or periods of misfit by sex (Figure 79), however, there appeared to be some pattern of observations being greater than the model expectations that move through the age distribution across years likely due to strong recruitments. The model fits the general trend in the mean ages for sexed fish, particularly between 2014 onward (Figure 80). Similar to the trawl data, there was some patterns in the residuals for the hook-and-line data that move through the age classes across years, but aside from that, there were no other clear patterns of misfit for the hook-and-line data (Figure 81). Extensive explorations in blocking of selectivity parameters were done in attempt to reduce the residual pattern across ages in the final block, 2019–2024, but a better fit to the data was not found. The residual pattern in this period is more prominent for females, likely due to the higher selectivity for females compared to males in this fishery. The pattern in mean age of the hook-and-line data was generally fit by the model, with the model estimating subtle decreases and increases in the mean age that aligns with the trend in the data (Figure 82). There was a slight pattern in the residuals for pot gear between 1986–1990 with greater observations compared to model expectations, but this is also the period when the age data were the most limited for this fleet (Table 9 and Figure 83). The mean ages across years for the pot fleet has large confidence intervals with the model generally fitting the trend for most years except for the increase in the mean age between the late 1980s and early 1990s (Figure 84).

The aggregated age compositions for the discard fleets were generally well fit (Figure 78). The majority of discard ages from the trawl discard fleet were young fish. There is a large residual in the trawl discard ages in 2022 at the youngest ages, likely due to the large 2020 and 2021 cohort (Figure 85). The model fit the decline in the mean ages between 2008 and 2009 in the trawl discard fleet (Figure 86). The majority of trawl fishing and discarding since 2011 is from IFQ vessels, where discarding has been low and generally of young, small fish as observed in the data. There are no clear patterns of residuals in the hook-and-line discards (Figure 87) and pot discards (Figure 89). The mean age from the hook-and-line discard fleet was older on average compared to the trawl discard fleet. The predicted fit was within the uncertainty interval for all years for both the hook-and-line and pot discard fleets, but the model did not closely track the mean age across years (Figure 88 and Figure 90).

For the Triennial Survey, in 1983 and 1989 there was slight over-fitting for females and under-fitting of males and a general good fit in 1992 (Figure 91). The model fit the mean age for 1983, 1986, and 1992, though it was generally flat over the survey period (Figure 92). For the late period of the Triennial Survey, the largest residuals indicated that there were more older ages observed than expected in 1995 compared to 2004 (Figure 93). The base model predicted a drop in mean age for this survey between 1995 and 2004 which matched the trend for mean age in the data (Figure 94). The model fit the age data from the NWFSC Slope Survey with no clear patter in residuals across years (Figure 95). The model predicted a larger drop in the mean age between 2001 and 2002 which was not observed in the data from this survey (Figure 96).

The aggregated age composition for female and male fish for the WCGBTS were fit well by the model (Figure 78). There was no clear residual patterns in the fit to the WCGBTS age data (Figure 97). The largest residuals were for unsexed fish at age-0 since the majority of unsexed data for this survey are from fish too small to reliably sex. The model generally under predicted the mean age of the sexed fish between 2006–2016 (Figure 98). The mean age in the sexed fish has declined in recent years, likely due to multiple years of strong recruitments (e.g., 2016, 2020, 2021, and 2023).

3.4.3 Population Trajectory

The predicted spawning output is given in Table 31 and plotted in Figure 99. The predicted spawning output time series shows a slow decline in spawning output from 1890–1980 and a rapid decline from 1981–2000 from the fishery ramping up with large removals starting in the mid-1970s. Since 2001, spawning output remained at lower levels until approximately 2017 before a sharp increase started in 2018. The recent increase in spawning output is being driven by the the strong 2016 cohort and the proportion of mature fish from the strong 2020 cohort. The summary biomass of fish age 3 and older has an even steeper increase at the end of the time series from both the 2020 and 2021 strong cohorts (Figure 100). The estimated total biomass follows a similar trend as the summary biomass but with even a more dramatic increase at the end of the time series, again, due to recent strong cohorts (Figure 101). Stock status (or relative spawning output) is estimated to have declined below the management target in 1988 and continued to decline until 2013 (Table 31 and Figure 102). Since 2014, stock status has steadily increased due to the 2008 cohort and has continued to increase from additional strong recruitments. The stock status in 2025 is estimated to be 33.9 percent, currently below the management target but projected to surpass the management target in 2027 (Table 31).

The stock-recruit curve resulting from a value of steepness fixed at 0.75 is shown in Figure 103 with estimated recruitments also shown. Steepness was not estimated in this model, but a likelihood profile across steepness values is shown in Section 3.5.3. Dynamic estimates of spawning output with and without fishing is shown in Figure 104.

3.5 Model Diagnostics

3.5.1 Convergence

Proper convergence was determined by starting the minimization process from dispersed values of the maximum likelihood estimates to determine if the model found a better minimum. Starting parameters were jittered using the jitter function with Stock Synthesis, using jitter input of 0.05. This was repeated 100 times with one of the 100 runs returning to the base model likelihood. A better, lower negative log-likelihood, model fit was not found. In the jittering analysis models with similar log-likelihood values (difference < 0.50 units) were often found with little difference in overall derived quantities of stock size and status indicating a relatively flat likelihood surface around the maximum likelihood estimate. Additionally, jitters using a smaller jitter value yielded an increased frequency of runs returning to the base model with no models finding a better fit to the data. Through the jittering done as explained and likelihood profiles, we are confident that the base model as presented represents the best fit to the data given the assumptions made. There were no difficulties in inverting the Hessian for model with discard fleets to obtain estimates of variability, although much of the early model investigation was done without attempting to estimate a Hessian.

3.5.2 Sensitivity Analyses

Sensitivity analyses were conducted to investigate influence of data inputs and structural uncertainty of the base model by investigating how changes to the model affected the estimated values and derived quantities. These include several key underlying structural model assumptions that were identified in previous assessments and STAR panels, have persisted across recent assessments, or arose during the model bridging steps presented in this assessment (see Section 3.3.8). Many additional sensitivity runs were conducted while developing and testing the 2025 base model. Here we focus on the main sensitivities, relative to the base model, which are as follows:

1. Remove the index and age composition data from the WCGBTS,
2. Remove the index and age composition data from the Triennial Survey,
3. Remove the index and age composition data from the the NWFSC Slope Survey,
4. Remove the environmental-based recruitment index,
5. Remove empirical weight-at-age data for calculating time-varying growth and instead estimate time-invariant growth within the assessment model,
6. Estimate sex-specific natural mortality (M),
7. Fix M at the sex-invariant value used in the assessment of sablefish in Alaska,
8. Fix M at a sex-invariant value that is adjusted upwards to offset potential net emigration to Canada,

9. Fix M at sex-specific values used in the 2019 U.S. West Coast assessment of sablefish,

10. Estimate the steepness (h) parameter of the stock-recruitment function,

11. Impose a restriction that recruitment deviations in the main recruitment period must sum to zero,

12. Estimate early (1890–1974) recruitment deviations with the sum to zero constraint imposed for the main period,

13. Switch from the Francis method to the McAllister-Ianelli harmonic mean method for weighting age composition data,

14. Force the estimation of asymptotic selectivity for WCGBTS and NWFSC Slope Survey,

15. Remove the updated ageing error vector and apply the vector used in the 2019 stock assessment,

16. Increase the assumed discard mortality to 100% for all fleets,

17. Increase the assumed discard mortality to 75% for the trawl fleet and 60% for the hook-and-line and pot fleets,

18. Double catches for all fleets prior to 1969,

19. Fix all model parameters at estimated values and increase the strength of annual recruitment deviations from 2016-2023 by 10% in log space (i.e., more positive and more negative deviations), and

20. Fix all model parameters at estimated values and decrease the strength of annual recruitment deviations from 2016-2023 by 10% in log space (i.e., less positive and less negative deviations).

Most of the sensitivities resulted in a similar trajectory of the population dynamics as the base model (Table 32 – Table 35; Figure 105 – Figure 114), with the largest deviations occurring in the sensitivities related to M and the estimation of early (1890–1974) recruitment deviations.

All sensitivity models matched the base model in terms of the stock trend increasing rapidly from a time series low in the early 2010s. This is in part due to the well above average estimates of recruitment given the stock size (i.e., positive recruitment deviations) in 2013, 2016, 2020, 2021, and 2023. All sensitivity models indicate that stock status at the beginning of 2025 is estimated to be at or below $SB_{40\%}$, with the majority of runs aligning with the base model stock status of 33.9 percent. The overall scale of the population was generally robust to alternative sensitivity runs, with the exception of model runs exploring various alternative assumptions about M.

Results from the base model were generally robust to the removal of survey data (index and age compositions), with the important exception of the removal of the WCGBTS. Current stock size and status estimates were reduced by approximately 15 percent when WCGBTS data were removed (Figure 105 – Figure 106), considerably lowering estimates of recent recruitment (Figure 107). Furthermore, the stock trend levels off in recent years when ignoring recent WCGBTS data (Figure 108), suggesting that these data are particularly influential on recent stock trends. Overall, the WCGBTS is the most important source of fishery-independent information in this assessment because of its longevity under a rigorous and spatially comprehensive survey design and direct application to recent stock trends.

The sensitivity of the base model to how growth is incorporated into the the stock assessment model provides contrast between two fundamentally different ways of tracking changes in biomass among survivors from year to year. For reasons outlined in Section 2.5.4, growth in the base model uses empirical weight-at-age information to directly calculate average changes in biomass due to growth for each sex, age, and year combination. Alternatively, and similar to what was done in previous sablefish assessments, growth can be estimated within the model itself (see Table 34) using length frequency and conditional-age-at-length data from the WCGBTS. While stock status was similar between models (Figure 109), the sensitivity model that estimated growth internally indicated a slightly lower population scale (Figure 110) and generally minor changes to recruitment deviation estimates (leading to less recruitment variability, especially in recent years; Figure 111). Recruitment estimates for 2024 were the most sensitive, where the direction of the deviation switched from positive (base model) to negative (sensitivity model).

The largest changes relative to the base model were from different natural mortality (M) specifications. Across sensitivities, M deviated from the base model estimate of 0.088 yr^{-1}, ranging from a low of 0.068 yr^{-1} (2019 stock assessment estimate for males) to 0.132 yr^{-1} (increase in M to account for potential net emigration to Canadian waters; Table 34). In general, higher values of M led to considerable increases in population scale and stock status, whereas lower values reduced population scale and stock status (Figure 109 – Figure 110). The range of estimates for 2025 stock status were from 26.1 to 40.0 percent, compared to 33.9 percent for the base model. Recruitment patterns were relatively insensitive to M, but the absolute size of recruitment deviations scaled with M (Figure 111). In other words, higher relative values of M translated to higher relative recruitment deviations for any given year.

In addition to growth and mortality, assumptions about sablefish recruitment also influence the underlying biological processes used in an assessment model. Sensitivity models that estimated the parameter for the steepness (h) of the stock-recruitment function and constrained the recruitment deviations to sum to zero during the main recruitment period (1975–2023) resulted in little change in model results (Figure 112 – Figure 114). This is because estimated h (0.797) was similar to the fixed value in the base model (0.75; Table 35), and the sum of main period recruitment deviations in the base model was already close to zero (0.42). While estimating early period (1890–1974) recruitment deviations did not appreciably change stock scale or status, it did alter the size and trend in recruitment deviations and the general stock trajectory prior to 1980 (Figure 112 – Figure 114).

Many other data and model structure sensitivities were explored during the development and testing of the 2025 base model. In particular, changing the data weighting approach for age composition data from the Francis method to the McAllister-Ianelli method and changing the functional form of selectivity to be asymptotic (logistic) for NWFSC surveys had almost no impact on stock size and stock status (Table 33; Figure 115 – Figure 116). McAllister-Ianelli data weights led to moderately different recruitment deviations, though difference were well within the range of uncertainty for the base model (Figure 117). Ignoring recent age structure double read data and associated updates to ageing error analyses (i.e., use ageing error information from the 2019 stock assessment) lowered population scale, including the alteration of recruitment estimates, but did not impact relative stock status (Figure 115 – Figure 117). Increasing discard mortality and doubling pre-1969 catch for all fleets had negligible effect on current stock status and only minor impacts on overall stock size (Table 36; Figure 118 – Figure 119).

Sensitivity explorations also examined how recent recruitment strength impacted management quantities in the forecast period. In this case, sensitivity models were run with all model parameters fixed at the base model maximum likelihood estimates, with the only changes being from the specified adjustments to recent recruitment deviations. Specifically, the strength of recent (2016-2023) recruitment deviations were either increased or decreased by 10% in log-space, so the real change in recruitment strength was non-linear given the transformation. During the forecast period, catches in 2025 and 2026 were based on GMT recommendations (see Section 4.3). The catches from 2027 to 2036 were set equal to the year-specific ABCs. The ABC values were projected using a category 1 time-varying sigma with an initial value of 0.50 in 2027 and a management risk tolerance (P$*$) of 0.45. The strength of recent recruitment considerably alters the trajectory and status of the stock during the forecast period (Figure 118 – Figure 121), although in all cases the stock continues to increase through 2030. The OFL values change by 20 to 30% relative to the base model when recruitment deviations are increased or decreased by 10% (Table 37).

3.5.3 Likelihood Profiles

Likelihood profiles were used to elucidate conflicting information among various data sources, to determine how asymmetric the likelihood surfaces surrounding point estimates may be, and to provide an additional evaluation of how precisely parameters are being estimated. Likelihood profiles were completed for three key model parameters: unexploited (unfished) equilibrium recruitment in log-space (R_0), natural mortality (M), and steepness (h). For a single parameter, an increase in negative log-likelihood of more than two units is considered a definitively worse model and of more than seven units a comparatively implausible model.

Unexploited equilibrium recruitment (R_0) was found to be supported by the data across a range from 9.9-10.4, values which led to a broad range of stock sizes (Figure 122–Figure 124). The range of values explored led to large differences in overall scale of the spawning population (Figure 123), but relatively small differences in estimates of current stock status (Figure 124). The largest differences in stock status arose from the 1920s to the 1970s, where there is little information on recruitment during a period with fishing.

Natural mortality (M) profiles were conducted on the female M parameter only since the base model does not specify sex-specific M (i.e., equivalent results for male M). In general, M was moderately informed across a range of values spanning from about 0.080 to 0.095 yr^{-1} (Figure 125), compared to 0.088 yr^{-1} for the base model. Across this range, assessment results varied considerably among these values in the absolute scale of spawning output (Figure 126). Differences were also apparent on resulting stock status estimates, particularly as it pertains to how fast the population declines early in the time series (Figure 127). While abundance index data had little information content for estimating M, age data from the trawl fishery and the WCGBTS were the most influential (Figure 125).

In the base model, steepness (h) is fixed at 0.75, making it an important profile to evaluate as its uncertainty is not explicitly included in the base-model results. In 2019, h was fixed at 0.70. This assessment found no support in any data source for estimating h over a broad range of explored values (Figure 128). Structural uncertainty from unknown h was well within the parametric uncertainty (95 percent asymptotic intervals) of the base model for both spawning stock size and stock status (Figure 129 and Figure 130, respectively), suggesting that results are relatively insensitive to alternative values of h.

3.5.4 Retrospective Analysis

A retrospective analysis was conducted by running the base model with data removed iteratively from 1 to 10 years. The Mohn's rho for each run was calculated based upon

Hurtado-Ferro et al. (2015) which compares the estiamtes from the base model and the retrospective run for the final data year. All retrospective model runs fall well within the uncertainty estimates from the base model and contain very low values for Mohn's rho (Figure 131–Figure 132), suggesting no concerns of a retrospective pattern for key derived management quantities. Similarly, there was little evidence of a retrospective pattern in the estimation of recruitment deviations (Figure 133). Generally, recruitment is fairly well determined (as defined by the directionality and size of the deviation) by age 2 to 3. This is consistent with sablefish being well sampled by the WCGBTS and fisheries at young ages. In a few cases, cohort strength changed direction (i.e., recruitment below average or above average given the stock size) with a new year or two of data (e.g., 2018 and 2022 year classes; see Figure 133).

3.6 Historical Analysis

The estimated spawning output and stock status across stock assessments since 2005 is shown in Figure 134 and Figure 135. The estimate of unfished stock size from the base model is higher than other previous assessments, except for the 2005 assessment. The base model estimated a decline in stock size during the early 1970s through the mid 2000s, similar to all other previous assessments. However, the extent of that decline is greater in the base model compared to previous assessments. At the end of the time series, the base model estimates an increase in spawning output and stock status similar to the 2021 and 2023 assessments, however, from differing levels compared to these assessments.

4 Management

4.1 Reference Points

The PFMC groundfish FMP includes a HCR based upon general species groups that determines the OFL and ABC. The target, threshold, and limit reference points for sablefish as defined by the FMP are 40, 25, and 10 percent levels of stock status, respectively. The OFL is determined by the target harvest rate based on an SPR rate of 45 percent ($SPR_{45\%}$). If the stock is above the management target of 40 percent, the ABC is equal to a fraction of the OFL based on time-varying scientific uncertainty (σ_y) and management risk tolerance (P^*). When the stock status is below the management target and above the management limit, the ABC is linearly reduced using the HCR to determine the ACL. If the stock is below the management limit, 10 percent, the ACL is set to zero. Additionally, if the stock is estimated to be below the management threshold, 25 percent, in the year of the assessment, a rebuilding plan is required which can set the SPR to a fishing intensity lower than the target $SPR_{45\%}$.

The derived stock status in 2025 is 33.9 percent, below the management target of 40 percent. The fishing intensity is estimated to be below the current management harvest rate limit ($SPR_{45\%}$) at the end of the time series but is estimated to have been above it between the 1970s to the late-2010s (Figure 136). The interaction between the stock status and the ratio of the estimated SPR to the management target ($SPR_{45\%}$) indicates that the stock is in the lower quadrant indicating that the overfishing is not occurring and that stock status is below the management target (Figure 137). The current estimate of stock status is larger than the MSY, below the SPR target and stock status reference points (Figure 138) based on h of 0.75.

Reference points were calculated using the estimated selectivities and catch distributions among fleets in the final year of the model, 2025 (Table 30). The estimated sustainable total yield inclusive of both landings and discards was 11,126 mt according to $SPR_{45\%}$. The spawning output equivalent to 40 percent of unfished spawning output ($SB_{40\%}$) calculated using the SPR target, ($SPR_{45\%}$), was 87,751 mt.

4.2 Evaluation of Scientific Uncertainty

The model estimated uncertainty around the 2025 spawning output for the model is $\sigma =$ 0.1. The uncertainty around the OFL in 2025 is $\sigma = 0.12$ and the uncertainty around spawning output in 2025 is $\sigma = 0.1$. Each of these are likely underestimates of overall uncertainty due to the necessity to fix several key population dynamics parameters (e.g., steepness, recruitment variance) and also because there is no explicit incorporation of model structural uncertainty (although see the decision table for alternative states of nature).

4.3 Harvest Projections and Decision Tables

The projection of spawning ouput, stock status, and harvest limits were developed using the base model. The total catches in 2025 and 2026 were fixed at 19,114 and 19,082 mt, respectively, based on recommendations from the GMT (Table 38). The ABC values were projected assuming a category 1 time-varying sigma with an initial value of 0.50 in 2027 and a management risk tolerance (P^*) of 0.45.

The catches during the projection period, 2027–2037 were set equal to the year-specific ABCs (Table 39). The stock size and status increase during the projection due to the estimated large recruitments in 2020 and 2021 maturing and entering the spawning population, resulting in future OFLs and ABCs.

Two alternative catch streams based upon two options for P^*, 0.45 and 0.40, were created for the decision table (Table 40). Each alternative catch stream assumes a category 1 time varying sigma with an initial value of 0.50 in 2027. The axes of uncertainty in the decision table are based on the uncertainty around natural mortality. The low state of nature assumed a higher natural mortality of 0.095 yr^{-1} and the high state of nature assumed a lower natural mortality of 0.070 yr^{-1}. The low and high state of nature were run in a deterministic manner where they assumed the same parameter values, including annual recruitment deviations, as the base model except for natural mortality.

4.4 Regional Management Considerations

Sablefish is currently modeled as a coastwide stock with a corresponding coastwide OFL and ABC. The coastwide ABC is then apportioned into two area-specific ACLs north and south of 36° N. latitude. This historical management line corresponds with a recent data-driven analysis of sablefish growth that suggests a difference in growth rates north and south of 36° N. latitude (Kapur et al. 2020). The coastwide OFL and ABC values and the area-based ACL are shown in Table 2.

For the 2019 assessment, the PFMC adopted a methodology to determine the area-based ACL using a five-year rolling average biomass estimate by area from the WCGBTS (November 2019 PFMC Meeting Decision Document). Estimates presented are based on the relative distribution of the sablefish population observed by the survey, not the entire population. The estimated proportion of the 2018–2024 observed biomass by the WCGBTS is shown in Table 12.

4.5 Risk Table

Oceanographers and stock assessment scientists jointly constructed a risk table to identify the main ecosystem and environmental processes for sablefish that should be considered in conjunction with available data used in the stock assessment and the structural uncertainty embedded in the assessment (Table 41). The group considered ecosystem and environmental indicators for sablefish recruitment, habitat, prey, predators, competitors, and the recent climate vulnerability assessment (McClure et al. 2023a). Overall, the group considered these conditions to generally be neutral (Level 2) when considering, among other things, unresolved uncertainty with linkages between trends in primary predators and competitors and a overall climate vulnerability score of moderate. Data inputs for sablefish were scored as favorable (Level 1) given confidence in historical catch reconstructions, a comprehensive and representative survey index of abundance (WCGBTS), well sampled age data beginning at age zero, an informative recruitment index, and information on time- (growth) and -spatially-varying (maturity) life history characteristics across the stock range. The ability for the stock assessment model to fit the data and capture key sources of structural uncertainty was also scored as favorable (Level 1). Despite the need to fix certain productivity parameters (e.g., steepness and recruitment variability) or simplify some assumptions (e.g., sex invariant M and no net loss from emigration or immigration), model complexity seemed to balance well potential bias and variance in a way that stabilized sablefish population dynamics across a wide breadth of alternative data and model structures (see Section 3.5.2 for sensitivity evaluations).

To understand the impact of ecosystem and environmental conditions on sablefish, we evaluated recent trends in drivers of recruitment, predators, and prey, along with context from the climate vulnerability assessment (CVA) in McClure et al. (2023a). We did not consider habitat or non-fisheries human activities (such as offshore wind development) during this evaluation. In considering predators and prey effects here, we focus on recent trends over the last five years; we assume that long term trends are implicitly represented in the stock assessment and do not represent notable changes that warrant inclusion in the risk table.

4.5.1 Recruitment

Environmental drivers of recruitment for sablefish have received attention in the literature and prior stock assessments (Schirripa and Colbert 2006; Schirripa et al. 2009; Tolimieri et al. 2018; Haltuch et al. 2019; Johnson et al. 2023; Tolimieri and Haltuch 2023). Prior assessments have examined or included sea-level in the northern portion of the West Coast as an environmental index of recruitment in the stock assessment model (Haltuch et al. 2019; Johnson et al. 2023). More recent work examining the utility of output from the GLORYS model suggests that cross-shelf transport during the pelagic larval and benthic juvenile stages is a good predictor of sablefish recruitment (see Section 9.2).

A species distribution model (`sdmTMB`, delta-lognormal, spatial and spatiotemporal autocorrelation, scaled depth as a quadratic variable) used the WCGBTS data to estimate the distribution and abundance of sablefish juveniles (29 cm total length, usually age-0 but may include age-1 fishes in years following high recruitment). Prior to 2014, juveniles were more frequent and more abundant south of Cape Mendocino. However, from 2014–2019 (during the strong marine heatwave years) juveniles were more abundant in the north. From 2019 juvenile abundance has been relatively evenly distributed across the West Coast.

Data from the WCGBTS and predictions from the northern sea-level index and the GLORYS index indicate good recruitment (juvenile abundance) conditions in recent years (with the exception of 2022) with some exceptionally high recruitment years. Data and projections for 2025 are not available. Upon a comprehensive risk table examination, recruiment was not explicitly incorporated into the overall rating for ecosystem and environmental conditions because of the explicit inclusion of the recruitment index in the assessment model.

4.5.2 Distribution and Habitat Considerations

The distribution of sablefish biomass was examined using data from the WCGBTS and species distribution modeling using `sdmTMB`. The delta-lognormal model included spatial and spatiotemporal autoregression including scaled depth as a smoothed parameter (3 knots). The center of gravity of sablefish biomass has shifted north by approximately 2° N. since 2013 to 41° 5′ N. latitude in 2024 but only by approximately 1° N. since the start of the WCGBTS in 2003. As a result, sablefish have become more available to northern ports, especially Astoria. The shift north coincides with stronger recruitment (juvenile abundance) north of Cape Mendocino concurrent with the large marine heatwave of the 2014–2016 period.

4.5.3 Predators and Prey and Trophic Overlap with Competitors

We did not see evidence for recent changes in potential predation on sablefish. California sea lions, sperm whales, porpoises, skates, and fur seals were estimated to account for 97 percent of predation mortality on sablefish (Ecopath food web model, Field et al. (2006), Koehn et al. (2016), recently revised by C. Best-Otubu, P.Y. Hernvann, N. Lezama Ochoa, I. Kaplan, with 2006 as the base year for calculation of food web interactions and mass balance). While California sea lions have shown substantial recovery since the 1970s

(Carretta et al. 2022), the population appears to have stabilized around 2010. More recently, the 2023 sea lion pup cohort (see California Current Ecosystem Status Report Figure N.1) exhibited low growth rate. Assessments for sperm whales (Carretta et al. 2022) and Dall's porpoises (Carretta et al. 2022) do not suggest strong abundance trends for 1991–2018 and do not provide more recent data. Assessments for big skate (Taylor et al. 2019) and longnose skate (Gertseva et al. 2019) estimated stable population sizes for both species through 2019. Fur seal populations also have recovered from low levels, but the stock assessment report includes population estimates only to 2013.

Available evidence suggests average or adequate prey availability. Common prey items for adult sablefish are: deep small rockfish (including longspine thornyhead), Pacific hake, Pacific herring, cephalopods, deposit feeders (including amphipods, isopods, small crustacea), deep demersal fish (grenadier, eelpout), and carrion (Wippel et al. 2017). Juvenile diets include: small planktivorous fish, euphausiids, gelatinous zooplankton, and deposit feeders (Wippel et al. 2017).

Euphausiid abundance appears to be stable or slightly increasing in Central California over the last five years (RREAS survey, see California Current Ecosystem Status Report Figure I.2) with variable abundance in Northern waters between 42°-46° N. latitude but with no strong trend and the mean of the last five years near the long term average (data from B. Wells, NOAA SWFSC Pers. Comm.). While, krill length and biomass indices from the Trinidad Head survey line were near average for most of 2024 (see California Current Ecosystem Status Report Figure 3.2), the coastwide krill abundance index, derived from acoustic data was 2nd lowest in 2023 (no 2024 data available) since the beginning of sampling in 2007 (see California Current Ecosystem Status Report Figure 3.3). Production of fledgling Cassin's auklet, which feeds on krill, was near average at Southeast Farallon Island suggesting typical feeding conditions (see California Current Ecosystem Status Report Figure M.2).

Production of juvenile Pacific hake was in above average in 2020 and 2021 (Johnson et al. 2025). Though there is high uncertainty in the stock assessment estimates of recruitment for more recent years (Johnson et al. 2025), field surveys provide evidence of continued good Pacific hake recruitment in recent years (see California Current Ecosystem Status Report Figure I2). Herring abundance sampled by JSOES in the Northern California Current has been stable in recent years, though the 2023 acoustic survey estimates of coastwide herring abundance suggest a decline from 2019 levels (Stierhoff et al. 2024). The longspine thornyhead stock was estimated to be at healthy levels of abundance in 2013 (Stephens and Taylor 2013), but we cannot infer the recent (approximately 2021–2025) status of the stock.

4.5.3.1 Trophic Overlap

Euphausiids are a substantial component of the sablefish diet. Potential competitors for euphausiids were identified from the Ecopath food web model described above. Carnivorous zooplankton, mesopelagic fish, adult Pacific hake, large jellyfish, other cephalopods, sardine, and juvenile Pacific hake are estimated to account for 75 percent of total predation mortality on euphausiids, with adult and juvenile Pacific hake together accounting for 16 percent of predation on euphausiids. There is substantial uncertainty in these estimates, especially because of high uncertainty regarding abundances of these invertebrates and mesopelagic fish. In comparison, sablefish account for less than 1 percent (0.1 percent) of predation mortality on euphausiids. Though we cannot quantitatively determine that euphausiid abundance is limiting for sablefish, there is some potential for competition by Pacific hake and sablefish for prey (euphausiids), given 1) some spatial overlap of sablefish and Pacific hake on the outer continental shelf near the shelf break, and 2) based on the 2025 assessment of Pacific hake, Pacific hake total biomass in 2025 is 72 percent higher in 2025 than in 2006, which was the base year for the Ecopath calculations. In contrast, though lonspine thornyhead appear common in sablefish diets, there appears to be less competition for longspine thornyhead by other predators: 84 percent of the predation pressure on longspine thornyhead is estimated in the Ecopath model to derive from sablefish.

4.5.4 Climate Vulnerability Assessment Rank

McClure et al. (2023a) found that sablefish had a climate vulnerability of moderate, based on consideration of both exposure and sensitivity. Climate exposure was high, due largely to potential impacts on these species (and many others) from ocean acidification and mean sea surface temperature. These exposure metrics in the CVA represent expected change between a historical period (1955–2005) and a future period (2006–2055). Biological sensitivity was ranked moderate, due to slow population growth rate and early life history survival and settlement requirements. Relevant to these Risk Tables and recent trends, the overall context from the rapid, expert-opinion CVA for this species suggests particular attention should be paid to any recent changes in ocean acidification (related to potential effects on prey such as zooplankton) or in environmental conditions relevant to early life history and recruitment. We consider the effects of prey availability and recruitment to be well informed in other sections of this risk table and the assessment, and as a result the CVA ranking was not included in our final scoring of the ecosystem and environmental considerations.

4.6 Unresolved Problems and Major Uncertainties

The base model was developed with the goal of balancing parsimony with realism and fitting the data well. To achieve parsimony, some simplification of model structure was assumed which may have a moderate impact on the interpretation and fit to specific data sets. The base model was developed with a focus on stability which supports model development, interpretability, and future update assessments. This assessment estimates a sharp increase in young sablefish biomass and future data collected by the WCGBTS should be monitored potential changes in the population trajectories.

The estimated increase in young sablefish biomass is being driven by very large recruitment events occurring in recent years (e.g., 2020, 2021, and 2023). There have been multiple observations of the 2020 and 2021 year class and appear to be well estimated by the model. However, there is more uncertainty around the 2023 year class given the limited observations in the data by the the WCGBTS and the fishery fleets. The uncertainty around the strength of this year class will be resolved with future observations by the survey and the fishery.

The patterns observed in historical sablefish recruitment suggest that the stock trajectory, which is dominated by shifts in recruitment strength, is closely linked to productivity regimes in the California Current. Studies of oceanographic drivers of sablefish recruitment explain some portion of recruitment variability for sablefish, depending upon the oceanographic covariates evaluated. Uncertainty in future environmental conditions and changes in the timing, dynamics, and productivity of the California Current ecosystem via climate change or cycles similar to the historical period should be considered as a significant source of uncertainty in all projections of stock status. The ongoing WCGBTS is a fairly precise relative index of abundance over a broad demographic component of the stock but it does not survey the entire stock as sablefish reside in waters deeper than 1,280 m and to the north and south of the survey extent. Therefore, a portion of the stock is unobserved. This index has the potential to inform future stock assessments about the scale of the population relative to catches being removed; however, such information will require contrast in the observed survey trend.

Sablefish appear to have variable maturity-at-age latitudinally across the U.S. West Coast. Additionally, there appears to be variable growth spatially and temporally. This assessment attempts to account for these variations by using a empirical weight-at-age approach that accounts for space and time. In the available data, there were not clear trends across time but rather periods of above or below average growth. Future data should continue to be evaluated for potential trends in growth and maturity and whether those observed patterns vary from what was assumed in this assessment.

4.7 Research and Data Needs

Most of the research needs listed below entail investigations that need to take place outside of the routine assessment cycle and require additional resources to be completed.

1. Spatiotemporal distribution patterns with depth: There are patterns of age and sex ratios with depth which may indicate that the stock is more complex than currently modeled. Further research into the causes of these patterns as well as differences between seasons would help with understanding the stock characteristics such that a more realistic model could be built if needed. This may also provide further insight into migration and help determine if there are localized populations.

2. Stock boundaries: A common question in stock assessments is whether or not the entire stock is being represented. Sablefish live deeper than the range of the fisheries and surveys off the U.S. West Coast. The assessment model attempts to account for out of area biomass through catchability coefficients and selectivity curves, but that portion of the stock is unknown and can only be conjectured. Research into abundance in deep areas would be useful to verify that the assessment adequately predicts the entire stock of sablefish. In addition, sablefish along the U.S. West Coast can move northward to Canada or Alaska management jurisdictions. Building on recent transboundary sablefish research (Kapur et al. 2024, Kapur et al. in press), investigations elucidating how variable movements (net emigration and immigration) are from year to year to better understand impacts on current management advice or, ultimately, incorporate these changes into stock assessment models.

3. Recruitment: Continued investigation and refinement of environmental covariates for recruitment on a stock-wide, northeast Pacific scale. Continued evaluations into the estimation of steepness (h) is warranted in future stock assessments

4. Stock trends: The WCGBTS is a critical data source in this assessment providing data about the age distribution of the stock, incoming recruitment with observations of age-0 fish, and an informative trend in biomass. Continuation of the annual WCGBTS will provide information on stock trends and incoming recruitments. A longer survey time series may improve the precision of estimates of absolute stock size and productivity into the future. This is particularly true now that the stock has had substantial contrast (declines and inclines) in stock biomass, catch, and recruitment dynamics.

5. Ageing: Age validation is needed to verify the level of age bias present in the data, if any. The assessment model now uses empirical weight-at-age data to track spatiotemporal variation in growth. The continuation of collecting representative otolith samples and fish weights from fishery-independent and fishery-dependent sources, and processing those samples for age determination, is required to continue including time-varying growth into the assessment model. Continued research and pilot applications using Fourier Transform Near-Infared Spectroscopy (FT-NIRS) methods for ageing, which includes an understanding of the potential benefits (e.g., increase age determination throughput and efficiency) and barriers (e.g., bias) specific to sablefish could help to achieve ongoing ageing goals given competing

demands for available resources. In addition, there is an under-representation of ages from sablefish caught in fisheries off of California compared to other areas. Biological sampling designs should strive to be consistent across the stock domain.

6. Fish Weight: This assessment uses an empirical weight-at-age approach to account for spatially and time varying growth informed by data from the WCGBTS. Currently, fish weight information is not available coastwide commercial fisheries (e.g., information available in PacFIN). Collected and reporting fish weight information to port sampling coastwide would support the consideration of commercial fishery data to understand weight-at-age of sablefish for future assessments.

7. Temporal and spatial biology: Research on understanding the interactions between spatial patterns in sablefish growth, maturity, and natural mortality across space and time will provide important information for future assessments. Both growth and maturity show latitudinal trends across the stock domain. While the current assessment accounts for these trends in the pre-processing of the data provided to the assessment model, it does so in a limited way. While tracking spatiotemporal changes in natural mortality by sex or life-stage is difficult, often requiring data that is unavailable (e.g., extensive tagging data), there has been recent advances through the use of external ecosystem modeling approaches such as the Climate-Enhanced, Age-based model with Temperature-specific Trophic Linkages and Energetics (CEATTLE) that should be explored for sablefish.

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7 Tables

7.1 Data

Table 1: Removals in metric tons (mt) by year for each fleet.

Year	Trawl	Hook-and-Line	Pot	Trawl Discard	Hook-and-Line Discard	Pot Discard	Total Catch
1890	0	2	0	0	0	0	2
1891	0	6	0	0	0	0	6
1892	0	7	0	0	0	0	7
1893	0	11	0	0	0	0	11
1894	0	15	0	0	0	0	15
1895	0	18	0	0	0	0	18
1896	0	21	0	0	1	0	22
1897	0	23	0	0	1	0	24
1898	0	26	0	0	1	0	27
1899	0	28	0	0	1	0	29
1900	0	78	0	0	2	0	80
1901	1	93	0	0	2	0	96
1902	3	111	0	0	3	0	117
1903	4	132	0	1	3	0	140
1904	6	158	0	1	4	0	169
1905	7	141	0	1	4	0	153
1906	8	123	0	2	3	0	136
1907	10	105	0	2	3	0	120
1908	11	88	0	2	2	0	103
1909	12	143	0	2	4	0	161
1910	14	198	0	2	5	0	219
1911	15	253	0	3	6	0	277
1912	16	308	0	3	8	0	335
1913	18	363	0	3	9	0	393
1914	19	418	0	3	11	0	451
1915	20	472	0	4	12	0	508
1916	26	1,288	0	5	33	0	1,352
1917	286	1,695	0	52	43	0	2,076
1918	157	2,684	0	29	69	0	2,939
1919	105	919	0	19	23	0	1,066
1920	246	627	0	45	16	0	934
1921	322	846	0	58	22	0	1,248
1922	85	711	0	15	18	0	829
1923	169	1,259	0	31	32	0	1,491
1924	294	1,535	0	53	39	0	1,921
1925	227	1,869	0	41	48	0	2,185
1926	55	1,639	0	10	42	0	1,746
1927	312	2,206	0	57	56	0	2,631
1928	289	1,821	0	52	47	0	2,209
1929	468	1,815	0	85	46	0	2,414
1930	446	2,097	0	81	54	0	2,678
1931	324	1,073	0	59	27	0	1,483
1932	297	1,351	0	54	35	0	1,737
1933	420	1,102	0	76	28	0	1,626
1934	668	1,971	0	121	50	0	2,810
1935	884	2,499	0	161	64	0	3,608
1936	330	2,022	0	60	52	0	2,464

Table 1: Removals in metric tons (mt) by year for each fleet. *(continued)*

Year	Trawl	Hook-and-Line	Pot	Trawl Discard	Hook-and-Line Discard	Pot Discard	Total Catch
1937	227	2,301	0	41	59	0	2,628
1938	253	2,222	0	46	57	0	2,578
1939	291	2,453	0	53	63	0	2,860
1940	298	1,882	0	54	48	0	2,282
1941	484	1,656	0	88	42	0	2,270
1942	923	2,306	0	0	0	0	3,229
1943	2,064	1,858	0	0	0	0	3,922
1944	2,973	1,512	0	0	0	0	4,485
1945	2,687	1,731	0	0	0	0	4,418
1946	1,656	2,799	0	0	0	0	4,455
1947	511	1,722	0	93	44	0	2,370
1948	948	1,907	0	172	49	0	3,076
1949	1,011	2,015	0	184	52	0	3,262
1950	1,021	1,643	0	185	42	0	2,891
1951	2,008	2,278	0	365	58	0	4,709
1952	1,158	1,493	0	210	38	0	2,899
1953	791	1,027	0	144	26	0	1,988
1954	1,065	1,376	0	193	35	0	2,669
1955	969	1,341	0	176	34	0	2,520
1956	2,533	1,043	0	460	27	0	4,063
1957	1,036	1,659	0	188	42	0	2,925
1958	816	802	0	148	21	0	1,787
1959	1,002	1,260	0	182	32	0	2,476
1960	1,317	1,755	0	239	45	0	3,356
1961	782	1,082	0	142	28	0	2,034
1962	1,625	1,032	0	295	26	0	2,978
1963	899	979	0	163	25	0	2,066
1964	1,036	1,030	0	188	26	0	2,280
1965	1,021	935	0	185	24	0	2,165
1966	1,134	770	0	206	19	0	2,129
1967	1,804	2,488	0	238	21	0	4,551
1968	1,306	1,447	0	198	18	0	2,969
1969	2,068	3,396	15	245	25	1	5,750
1970	2,841	1,653	114	289	17	5	4,919
1971	2,480	1,227	181	276	14	8	4,186
1972	3,539	2,810	273	496	28	12	7,158
1973	4,276	945	452	719	8	20	6,420
1974	3,479	1,947	3,177	515	8	131	9,257
1975	3,971	1,593	8,743	641	10	160	15,118
1976	3,894	1,201	19,304	651	11	136	25,197
1977	3,700	1,510	3,724	608	16	155	9,713
1978	4,712	1,849	5,845	802	32	255	13,495
1979	7,512	4,487	12,249	1,273	106	534	26,161
1980	5,196	1,371	2,991	817	32	130	10,537
1981	5,717	1,975	3,897	1,009	50	170	12,818
1982	10,444	1,775	6,511	1,879	45	284	20,938
1983	7,631	1,163	5,955	1,369	30	260	16,408
1984	8,635	1,002	4,401	1,565	26	192	15,821
1985	7,527	2,762	3,870	1,362	71	169	15,761
1986	6,702	3,533	2,946	1,212	90	129	14,612
1987	6,640	3,973	2,077	1,190	102	91	14,073
1988	5,629	3,068	2,133	1,007	78	93	12,008
1989	5,817	2,431	2,047	1,055	62	89	11,501
1990	5,214	2,205	1,664	944	56	73	10,156
1991	5,014	3,450	1,064	906	88	46	10,568

Table 1: Removals in metric tons (mt) by year for each fleet. *(continued)*

Year	Trawl	Hook-and-Line	Pot	Trawl Discard	Hook-and-Line Discard	Pot Discard	Total Catch
1992	5,526	3,098	798	993	79	35	10,529
1993	4,969	2,338	847	901	60	37	9,152
1994	3,833	2,376	1,370	696	61	60	8,396
1995	3,870	2,992	1,065	701	76	46	8,750
1996	4,211	3,362	750	764	86	33	9,206
1997	3,773	3,587	584	685	92	25	8,746
1998	2,212	1,759	448	396	45	20	4,880
1999	3,169	2,720	755	575	70	33	7,322
2000	2,764	2,715	852	493	69	37	6,930
2001	2,624	2,363	673	473	60	29	6,222
2002	1,600	1,754	472	453	62	30	4,371
2003	2,332	2,313	799	300	76	23	5,843
2004	2,448	2,525	815	295	54	53	6,190
2005	2,420	2,809	996	225	63	28	6,541
2006	2,545	2,606	1,053	156	61	38	6,459
2007	2,498	2,065	687	149	43	35	5,477
2008	2,898	2,303	675	79	69	27	6,051
2009	3,062	3,272	864	154	49	36	7,437
2010	2,553	3,387	905	186	98	34	7,163
2011	1,736	3,243	1,448	3	112	42	6,584
2012	1,532	2,606	1,167	3	128	33	5,469
2013	1,424	1,877	846	3	62	28	4,240
2014	1,323	2,011	1,108	8	51	22	4,523
2015	1,511	2,358	1,315	4	75	38	5,301
2016	1,517	2,535	1,403	10	118	37	5,620
2017	1,827	2,416	1,427	19	69	18	5,776
2018	1,622	2,462	1,289	10	78	32	5,493
2019	1,711	2,275	1,464	42	100	44	5,636
2020	1,123	1,504	1,332	46	31	43	4,079
2021	1,709	1,886	1,328	80	99	20	5,122
2022	2,407	2,300	1,665	123	87	58	6,640
2023	1,838	2,270	1,935	120	106	116	6,385
2024	1,792	2,031	1,664	348	95	100	6,030

Table 2: Recent trend in the overfishing limits (OFL), the acceptable biological catches (ABCs), the annual catch limits (ACLs), and the total catch all in metric tons (mt).

Year	OFL (mt)	ABC (mt)	ACL North (mt)	ACL South (mt)	Catch (mt)
2015	7,857	7,173	4,793	1,719	5,302
2016	8,526	7,784	5,241	1,880	5,619
2017	8,050	7,350	5,252	1,864	5,777
2018	8,239	7,522	5,475	1,944	5,494
2019	8,489	7,750	5,606	1,990	5,635
2020	8,648	7,896	5,723	2,032	4,078
2021	9,402	8,791	6,892	1,899	5,122
2022	9,005	8,375	6,566	1,809	6,640
2023	11,577	10,825	8,486	2,338	6,385
2024	10,670	9,923	7,780	2,143	6,029

Table 3: Observed discard rates by gear based upon West Coast Groundfish Observer Program (2002-2023) and Pikitch (1985-1987) data.

Year	Trawl Discard Rate	Hook-and-Line Discard Rate	Pot Discard Rate
1985	0.373	-	-
1986	0.364	-	-
1987	0.353	-	-
2002	0.575	0.177	0.315
2003	0.260	0.164	0.146
2004	0.243	0.107	0.326
2005	0.187	0.113	0.141
2006	0.123	0.117	0.182
2007	0.119	0.105	0.255
2008	0.055	0.149	0.203
2009	0.101	0.074	0.206
2010	0.146	0.144	0.188
2011	0.004	0.173	0.143
2012	0.004	0.246	0.140
2013	0.004	0.165	0.165
2014	0.012	0.127	0.099
2015	0.006	0.159	0.144
2016	0.013	0.233	0.131
2017	0.023	0.142	0.065
2018	0.013	0.158	0.126
2019	0.051	0.220	0.148
2020	0.083	0.102	0.160
2021	0.097	0.262	0.077
2022	0.117	0.189	0.173
2023	0.143	0.233	0.299

Table 4: Number of fish, hauls, trips, and calculated input sample size (N) for discard ages from the trawl fleet.

Year	Samples	Hauls	Trips	Input N
2004	7	5	5	6
2005	15	5	2	4
2006	1,127	279	169	325
2007	1,011	265	161	301
2008	1,066	290	164	311
2009	2,125	529	295	588
2010	1,729	363	197	436
2011	669	186	123	215
2012	479	155	119	185
2013	698	200	149	245
2014	1,396	320	209	402
2015	947	252	157	288
2016	990	249	149	286
2017	1,294	321	189	368
2018	653	188	127	217
2019	1,904	444	231	494
2020	2,164	489	268	567
2021	2,846	603	317	710
2022	3,324	699	367	826
2023	3,226	671	346	791

Table 5: Number of fish, hauls, trips, and calculated input sample size (N) for discard ages from the hook-and-line fleet.

Year	Samples	Hauls	Trips	Input N
2005	2	2	1	1
2006	441	110	36	97
2007	1,041	224	74	218
2008	1,288	295	80	258
2009	404	127	55	111
2010	2,923	613	170	573
2011	2,229	489	131	439
2012	3,032	475	121	539
2013	1,185	220	52	216
2014	793	179	64	173
2015	2,736	499	120	498
2016	2,261	439	106	418
2017	1,919	397	104	369
2018	2,789	557	114	499
2019	2,783	568	100	484
2020	422	92	34	92
2021	1,259	251	64	238
2022	1,525	314	60	270
2023	1,948	387	67	336

Table 6: Number of fish, hauls, trips, and calculated input sample size (N) for discard ages from the pot fleet.

Year	Samples	Hauls	Trips	Input N
2006	703	147	33	130
2007	632	124	48	135
2008	1,070	238	32	180
2009	419	86	43	101
2010	1,223	277	61	230
2011	1,230	215	59	229
2012	1,162	265	45	205
2013	439	66	29	90
2014	1,263	183	26	184
2015	1,925	377	82	348
2016	2,800	568	88	474
2017	605	127	59	142
2018	1,944	400	69	337
2019	2,690	544	61	431
2020	2,342	497	41	289
2021	1,233	265	33	203
2022	2,057	414	44	311
2023	4,922	988	95	671

Table 7: Number of sampled trips, age samples, and calculated input sample size (N) by year for the trawl fleet.

Year	Trips	Samples	Input N
1983	1	35	5.8
1986	163	1,434	360.9
1987	157	2,530	506.1
1988	94	1,467	296.4
1989	83	1,241	254.3
1990	81	1,139	238.2
1991	61	1,788	307.7
1992	19	694	114.8
1993	37	818	149.9
1994	33	658	123.8
1995	26	444	87.3
1996	48	1,017	188.3
1997	92	1,906	355.0
1998	30	587	111.0
1999	36	774	142.8
2000	77	1,591	296.6
2001	92	1,528	302.9
2002	49	1,047	193.5
2003	32	734	133.3
2004	36	825	149.8
2005	58	1,176	220.3
2006	77	1,509	285.2
2007	83	1,604	304.4
2008	9	161	31.2
2009	39	951	170.2
2010	40	955	171.8
2011	30	777	137.2
2012	5	72	14.9
2013	36	870	156.1
2014	55	909	180.4
2015	67	727	167.3
2016	56	372	107.3
2017	70	646	159.1
2018	103	1,018	243.5
2019	45	875	165.8
2020	79	1,207	245.6
2021	77	471	142.0
2022	114	744	216.7
2023	86	326	131.0
2024	91	513	161.8

Table 8: Number of sampled trips, age samples, and calculated input sample size (N) by year for the hook-and-line fleet.

Year	Trips	Samples	Input N
1986	32	234	64.3
1987	71	870	191.1
1988	22	208	50.7
1989	7	55	14.6
1990	9	101	22.9
1991	10	262	46.2
1993	2	48	8.6
1994	4	84	15.6
1995	11	198	38.3
1996	27	539	101.4
1997	47	968	180.6
1998	17	291	57.2
1999	38	757	142.5
2000	32	516	103.2
2001	51	596	133.2
2002	26	423	84.4
2003	15	270	52.3
2004	11	148	31.4
2005	44	710	142.0
2006	33	769	139.1
2007	83	1,475	286.6
2008	8	398	56.5
2009	42	941	171.9
2010	44	901	168.3
2011	34	665	125.8
2012	81	914	207.1
2013	31	907	156.2
2014	1	45	7.1
2015	76	422	134.2
2016	115	321	159.3
2017	89	630	175.9
2018	101	1,170	262.5
2019	36	1,118	190.3
2020	55	733	156.2
2021	92	438	152.4
2022	99	600	181.8
2023	101	434	160.9
2024	103	617	188.1

Table 9: Number of sampled trips, age samples, and calculated input sample size (N) by year for the pot fleet.

Year	Trips	Samples	Input N
1986	20	139	39.2
1987	33	221	63.5
1988	7	86	18.9
1989	25	229	56.6
1990	10	79	20.9
1991	14	309	56.6
1993	6	122	22.8
1994	4	84	15.6
1995	7	120	23.6
1996	17	323	61.6
1997	29	601	111.9
1999	16	303	57.8
2000	14	264	50.4
2001	13	194	39.8
2002	11	165	33.8
2003	10	176	34.3
2004	6	94	19.0
2005	10	162	32.4
2006	5	84	16.6
2007	16	390	69.8
2008	2	51	9.0
2009	16	410	72.6
2010	12	300	53.4
2011	11	272	48.5
2012	4	58	12.0
2013	10	245	43.8
2015	30	232	62.0
2016	39	217	68.9
2017	25	314	68.3
2018	31	197	58.2
2019	1	2	1.3
2020	15	190	39.5
2021	20	128	37.7
2022	28	261	64.0
2023	50	336	96.4
2024	27	204	55.2

Table 10: Change in the number of age samples by year for the trawl fleet between this assessment and the 2019 assessment.

Year	Fishery	Ages (2019)	Ages (2025)	Difference
1983	Trawl	0	35	35
1984	Trawl	0	0	0
1985	Trawl	0	0	0
1986	Trawl	0	1,434	1,434
1987	Trawl	2,454	2,530	76
1988	Trawl	1,452	1,467	15
1989	Trawl	1,241	1,241	0
1990	Trawl	1,138	1,139	1
1991	Trawl	1,689	1,788	99
1992	Trawl	586	694	108
1993	Trawl	802	818	16
1994	Trawl	648	658	10
1995	Trawl	444	444	0
1996	Trawl	986	1,017	31
1997	Trawl	1,836	1,906	70
1998	Trawl	537	587	50
1999	Trawl	699	774	75
2000	Trawl	1,430	1,591	161
2001	Trawl	1,308	1,528	220
2002	Trawl	627	1,047	420
2003	Trawl	684	734	50
2004	Trawl	825	825	0
2005	Trawl	1,175	1,176	1
2006	Trawl	1,509	1,509	0
2007	Trawl	1,567	1,604	37
2008	Trawl	160	161	1
2009	Trawl	918	951	33
2010	Trawl	865	955	90
2011	Trawl	776	777	1
2012	Trawl	71	72	1
2013	Trawl	858	870	12
2014	Trawl	851	909	58
2015	Trawl	0	727	727
2016	Trawl	274	372	98
2017	Trawl	508	646	138
2018	Trawl	210	1,018	808

Table 11: Change in the number of age samples by year for the fixed fleet (hook-and-line and pot gears combined) between this assessment and the 2019 assessment.

Year	Fishery	Ages (2019)	Ages (2025)	Difference
1986	Fixed	36	373	337
1987	Fixed	1,091	1,091	0
1988	Fixed	294	294	0
1989	Fixed	284	284	0
1990	Fixed	180	180	0
1991	Fixed	571	571	0
1992	Fixed	0	0	0
1993	Fixed	170	170	0
1994	Fixed	168	168	0
1995	Fixed	318	318	0
1996	Fixed	811	862	51
1997	Fixed	1,569	1,569	0
1998	Fixed	289	291	2
1999	Fixed	1,060	1,060	0
2000	Fixed	778	780	2
2001	Fixed	789	790	1
2002	Fixed	587	588	1
2003	Fixed	446	446	0
2004	Fixed	242	242	0
2005	Fixed	871	872	1
2006	Fixed	848	853	5
2007	Fixed	1,863	1,865	2
2008	Fixed	449	449	0
2009	Fixed	1,351	1,351	0
2010	Fixed	1,201	1,201	0
2011	Fixed	937	937	0
2012	Fixed	967	972	5
2013	Fixed	1,151	1,152	1
2014	Fixed	45	45	0
2015	Fixed	0	654	654
2016	Fixed	536	538	2
2017	Fixed	944	944	0
2018	Fixed	542	1,367	825

Table 12: Estimated percentage of sablefish biomass estimated north and south of 36° N. latitude based on the NWFSC West Coast Groundfish Bottom Trawl Survey data over the last five years.

Year	N. 36 Latitude	S. 36 Latitude
2019	79.1%	20.9%
2021	82.2%	17.8%
2022	81.3%	18.7%
2023	81.1%	18.9%
2024	83.7%	16.3%
Average	81.5%	18.5%

Table 13: Design-based stratification by depth and latitude used to expand composition data for the NWFSC West Coast Groundfish Bottom Trawl Survey.

Depth (m)	Latitude	Area (km2)
55-183	32-34.5	5,812
183-549	32-34.5	9,955
549-900	32-34.5	15,684
900-1280	32-34.5	15,789
55-183	34.5-40.5	10,688
183-549	34.5-40.5	6,952
549-900	34.5-40.5	7,801
900-1280	34.5-40.5	8,059
55-183	40.5-45	11,255
183-549	40.5-45	6,211
549-900	40.5-45	5,264
900-1280	40.5-45	5,304
55-183	45-49	11,787
183-549	45-49	5,829
549-900	45-49	4,024
900-1280	45-49	3,955

Table 14: Number of tows, positive tows for sablefish, the proportion positive, and the number of age samples by year from the NWFSC West Coast Groundfish Bottom Trawl Survey.

Year	Tows	Positive Tows	Prop. Positive	Sampled Tows	Aged
2003	542	422	0.779	383	1,389
2004	470	330	0.702	277	1,086
2005	641	448	0.699	416	1,577
2006	638	399	0.625	369	1,363
2007	687	429	0.624	396	1,259
2008	680	420	0.618	368	1,190
2009	680	419	0.616	383	1,181
2010	713	456	0.640	420	1,270
2011	695	456	0.656	425	1,193
2012	695	428	0.616	395	1,091
2013	468	307	0.656	285	992
2014	678	460	0.678	429	1,196
2015	666	420	0.631	401	1,197
2016	692	439	0.634	426	1,213
2017	705	458	0.650	441	1,214
2018	701	434	0.619	430	1,478
2019	348	226	0.649	223	874
2021	684	520	0.760	518	2,169
2022	634	464	0.732	463	1,656
2023	661	483	0.731	481	1,720
2024	657	477	0.726	444	1,197

Table 15: Design-based stratification by depth and latitude used to expand composition data for the NWFSC Slope Survey.

Depth (m)	Latitude	Area (km2)
183-549	34.5-40.5	6,952
549-900	34.5-40.5	7,801
900-1280	34.5-40.5	8,059
183-549	40.5-45	6,211
549-900	40.5-45	5,264
900-1280	40.5-45	5,304
183-549	45-49	5,829
549-900	45-49	4,024
900-1280	45-49	3,955

Table 16: Number of tows, positive tows for samples, proportion of positive tows, and age samples by year from the NWFSC Slope Survey.

Year	Tows	Positive Tows	Prop. Positive	Sampled Tows	Aged
1998	301	200	0.664	115	673
1999	324	293	0.904	127	469
2000	329	299	0.909	150	752
2001	334	306	0.916	135	617
2002	426	383	0.899	196	1,631

Table 17: Design-based stratification by depth and latitude used to expand composition data for the Triennial Survey between 1980-1992.

Depth (m)	Latitude	Area (km2)
55-183	36-40.5	9,177
183-350	36-40.5	1,544
55-183	40.5-45	11,255
183-350	40.5-45	3,041
55-183	45-49	11,787
183-350	45-49	3,025

Table 18: Design-based stratification by depth and latitude used to expand composition data for the Triennial Survey between 1995-2004.

Depth (m)	Latitude	Area (km2)
55-183	36-40.5	9,177
183-350	36-40.5	1,544
55-183	40.5-45	11,255
183-350	40.5-45	3,041
55-183	45-49	11,787
183-350	45-49	3,025

Table 19: Number of tows, positive tows for samples, proportion of positive tows, and age samples by year from the Triennial Survey (1980-1992).

Year	Tows	Positive Tows	Prop. Positive	Sampled Tows	Aged
1980	301	186	0.618	0	0
1983	479	337	0.704	20	915
1986	483	372	0.770	1	68
1989	440	314	0.714	22	490
1992	421	284	0.675	47	550

Table 20: Number of tows, positive tows for samples, proportion of positive tows, and age samples by year from the Triennial Survey (1995-2004).

Year	Tows	Positive Tows	Prop. Positive	Sampled Tows	Aged
1995	441	338	0.766	78	363
1998	468	268	0.573	79	432
2001	466	371	0.796	122	435
2004	383	296	0.773	239	490

Table 21: Results of model fitting showing estimated coefficients for models with delta AIC </= 2.0. CST = cross-shelf transport, DD = degree days, T = temperature, yolk = yolksack stage, pjuv = pelagic juvenile, and bjuv = benthic juvenile stage.

Model	Intercept	CSTbjuv	CSTegg	CSTpjuv	CSTyolk	DDpre	Tspawn	R2	df	AICc	delta
Model 1	13.07	224.27		-210.56			-2.27	0.47	5	89.34	0.00
Model 2	4.54	236.72		-187.78		-1.81		0.45	5	90.13	0.78
Model 3	-0.76	206.49		-180.33				0.37	4	90.97	1.63
Model 4	-1.35	195.45	132.36	-192.35				0.43	5	91.06	1.72
Model 5	-1.28	238.12		-228.60	142.66			0.43	5	91.17	1.83

Table 22: Number of tows, positive tows for samples, proportion of positive tows, and age samples by year from the AFSC Slope Survey.

Year	Tows	Positive Tows	Prop. Positive	Sampled Tows	Aged
1997	182	176	0.967	153	1,485
1999	199	193	0.970	160	492
2000	207	206	0.995	198	1,665
2001	207	206	0.995	126	484

Table 23: Number of ages by sex and year used to estimate the empirical weight-at-age. A plus group of age 25 is shown with all available ages 25 and older combined.

		Number of Ages																								
Year	Sex	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+
2003	F	17	73	57	207	137	31	17	14	19	9	6	4	5	9	2	0	6	4	1	4	3	3	1	1	2	32
2003	M	28	69	49	159	149	28	28	11	11	13	3	4	6	6	8	3	4	2	6	2	3	10	4	3	2	81
2004	F	56	19	27	54	105	67	32	8	7	7	5	1	1	4	4	1	5	2	4	2	4	2	2	3	2	25
2004	M	57	21	43	55	100	52	15	8	9	11	3	3	1	5	6	3	2	5	5	4	4	7	4	1	6	63
2005	F	1	118	41	103	97	130	52	29	6	4	8	5	11	6	8	12	4	8	6	5	7	8	4	4	3	47
2005	M	3	105	41	104	132	130	57	23	12	12	21	12	12	8	8	10	8	6	13	8	7	2	9	8	14	75
2006	F	1	6	39	31	65	78	109	71	26	12	9	6	11	7	7	3	8	10	7	9	7	7	5	5	3	62
2006	M	3	4	51	25	48	92	117	56	22	24	21	21	8	11	6	7	5	10	5	11	6	9	13	7	5	148
2007	F	1	28	5	62	27	46	65	99	63	18	13	14	6	6	7	7	3	5	9	6	3	5	5	10	4	58
2007	M	0	14	5	64	23	57	67	106	51	33	13	11	11	7	4	4	8	6	4	5	3	12	7	8	2	143
2008	F	74	3	26	4	19	16	42	61	87	35	22	18	13	6	5	5	4	5	9	5	10	3	3	8	4	59
2008	M	79	4	16	5	17	9	51	69	80	46	32	21	10	8	7	3	11	8	7	12	4	6	3	7	5	113
2009	F	11	167	9	10	7	23	12	17	18	54	37	19	9	4	6	4	5	2	6	2	1	9	1	2	1	69
2009	M	13	167	11	10	6	23	16	30	39	57	58	26	14	7	10	13	7	3	4	6	7	7	2	5	3	124
2010	F	38	11	201	22	9	7	19	18	21	24	38	16	10	8	4	2	5	4	3	1	2	4	1	7	5	57
2010	M	53	15	256	30	3	4	14	23	12	30	43	40	16	7	4	7	8	3	5	4	4	7	4	3	8	116
2011	F	20	112	24	169	19	8	13	18	15	20	13	23	12	13	6	4	3	2	5	3	5	5	2	1	3	45
2011	M	31	85	41	135	18	7	16	14	25	20	22	25	21	12	6	7	9	3	5	6	3	5	5	9	2	86
2012	F	21	47	78	43	113	27	10	5	7	7	3	15	26	15	9	6	7	6	3	1	2	4	3	5	4	56
2012	M	15	46	101	35	82	23	13	5	9	8	12	17	27	19	11	13	9	4	3	1	3	2	5	4	2	89
2013	F	30	20	35	73	57	80	16	6	7	6	4	11	11	17	12	6	4	6	2	5	4	0	2	4	1	42
2013	M	41	13	34	93	38	64	21	8	6	7	11	12	21	23	17	11	2	8	6	0	9	3	2	4	2	70
2014	F	15	176	15	42	50	50	56	24	14	5	7	6	6	4	7	5	7	7	4	6	2	5	5	1	2	39
2014	M	19	164	24	19	60	31	61	34	20	11	7	6	11	8	8	12	15	18	3	5	1	5	4	1	2	78
2015	F	5	49	170	62	32	53	31	34	11	4	3	7	7	6	5	13	5	6	6	2	5	2	3	1	2	61
2015	M	12	45	171	36	24	54	33	38	21	12	5	4	6	8	2	5	10	9	9	3	4	2	5	2	1	83
2016	F	34	14	52	160	48	41	41	37	23	17	5	4	9	2	10	9	11	8	6	4	0	2	3	1	3	41
2016	M	57	24	55	141	40	25	35	23	33	18	3	6	6	8	12	13	10	8	11	9	4	4	3	2	4	62
2017	F	7	124	33	61	101	39	27	27	24	8	12	5	5	5	3	5	8	9	10	5	0	8	2	5	1	43
2017	M	7	113	24	66	104	34	28	25	26	29	17	9	10	6	5	13	8	5	6	4	7	2	5	3	4	65
2018	F	14	26	168	46	67	99	49	49	38	22	24	6	8	3	4	4	8	9	7	7	9	7	3	1	2	46
2018	M	11	26	175	34	55	92	48	42	27	30	26	12	9	7	10	10	7	7	6	7	7	7	5	5	0	80
2019	F	18	45	7	103	26	18	73	18	19	13	10	11	3	3	4	1	2	2	3	4	5	4	2	2	0	20
2019	M	26	36	11	101	27	32	56	22	14	15	10	12	4	4	7	4	7	2	7	9	6	2	1	2	1	38
2021	F	114	241	72	34	22	169	57	47	41	34	29	32	24	16	19	11	13	5	5	2	7	6	8	11	5	68
2021	M	124	226	66	32	42	139	40	32	43	31	42	32	37	26	10	11	10	6	6	4	3	11	11	8	3	74
2022	F	9	165	197	64	18	14	100	22	18	18	15	14	23	18	14	12	6	3	6	3	4	2	3	4	4	41
2022	M	18	188	191	56	25	19	83	24	20	27	22	21	17	14	9	6	9	5	7	6	7	7	3	4	6	57
2023	F	68	19	183	192	42	29	34	89	19	16	20	15	23	23	15	15	9	8	5	2	4	8	4	6	4	32
2023	M	87	17	173	146	40	14	37	69	24	23	15	23	16	16	15	14	9	8	9	7	5	3	5	4	5	45
2024	F	11	95	11	127	108	33	23	21	47	11	15	10	12	8	11	9	6	5	3	5	1	1	0	3	3	15
2024	M	26	91	18	93	99	19	17	20	52	13	7	13	19	10	9	10	11	5	6	2	2	4	4	5	4	42

Table 24: Maturity samples collected by the NWFSC West Coast Groundfish Bottom Trawl Survey by year and area where north and south of 36° N. latitude.

Year	Samples-North	Samples-South
2010	207	78
2015	108	38
2018	63	25
2021	28	18
2022	90	40

7.2 Assessment and Modeling

Table 25: Specifications and structure of the model.

Section	Configuration
Maximum model age	70
Sexes	Females, males
Population bins	0-70 age bins
Summary biomass (mt) age	3+
Number of areas	1
Number of seasons	1
Number of growth patterns	Time-varying 2003-2024
Start year	1890
End year	2024
Data length bins	-
Data age bins	0-50 by 1 year

Table 26: Estimated parameters in the model.

Type	Count
Natural Mortality (M)	1
M time-variation	0
Growth mean	0
Growth variability	0
Growth time-variation	0
Stock-recruit	1
Stock-recruit variation	0
Rec. dev. time series	50
Rec. dev. initial age	0
Rec. dev. forecast	12
Index	3
Index time-variation	0
Size selectivity	0
Size selectivity time-variation	0
Retention	0
Retention time-variation	0
Age selectivity	27
Age selectivity time-variation	5

Table 27: Data weights from the base model. The data weights for both periods of the Triennial Survey are capped at 1.0 to avoid upweighting these data beyond the number of total samples.

Fleet	Data Weight
Trawl	0.194
Hook-and-Line	0.319
Pot	0.126
Trawl Discard	0.329
Hook-and-Line Discard	0.071
Pot Discard	0.077
Early Triennial	1.000
Late Triennial	1.000
NWFSC Slope	0.123
WCGBTS	0.053

Table 28: Parameter estimates, estimation phase, parameter bounds, estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model.

Label	Value	Phase	Bounds	Status	SD	Prior
NatM_uniform_Fem_GP_1	0.0878	2	(0.04, 0.13)	ok	0.00461	lognormal(0.072, 0.310)
SR_LN(R0)	10.2	1	(8, 12)	ok	0.158	none
SR_BH_steep	0.75	-7	(0.2, 1)	fixed	0	beta(0.750, 0.150)
SR_sigmaR	1.4	-50	(0.2, 1.5)	fixed	0	none
SR_regime	0	-50	(-1, 1)	fixed	0	none
SR_autocorr	0	-50	(-1, 1)	fixed	0	none
Early_RecrDev_1974	0	NA	(NA, NA)	fixed	0	normal(0.00, 1.40)
Main_RecrDev_1975	0.459	2	(-4, 4)	dev	1.19	normal(0.00, 1.40)
Main_RecrDev_1976	0.623	2	(-4, 4)	dev	1.07	normal(0.00, 1.40)
Main_RecrDev_1977	-0.646	2	(-4, 4)	dev	0.932	normal(0.00, 1.40)
Main_RecrDev_1978	-0.352	2	(-4, 4)	dev	1.09	normal(0.00, 1.40)
Main_RecrDev_1979	1.41	2	(-4, 4)	dev	0.338	normal(0.00, 1.40)
Main_RecrDev_1980	-0.035	2	(-4, 4)	dev	0.513	normal(0.00, 1.40)
Main_RecrDev_1981	0.55	2	(-4, 4)	dev	0.276	normal(0.00, 1.40)
Main_RecrDev_1982	0.326	2	(-4, 4)	dev	0.271	normal(0.00, 1.40)
Main_RecrDev_1983	-0.38	2	(-4, 4)	dev	0.552	normal(0.00, 1.40)
Main_RecrDev_1984	0.586	2	(-4, 4)	dev	0.265	normal(0.00, 1.40)
Main_RecrDev_1985	0.849	2	(-4, 4)	dev	0.221	normal(0.00, 1.40)
Main_RecrDev_1986	0.446	2	(-4, 4)	dev	0.226	normal(0.00, 1.40)
Main_RecrDev_1987	-0.563	2	(-4, 4)	dev	0.431	normal(0.00, 1.40)
Main_RecrDev_1988	0.599	2	(-4, 4)	dev	0.199	normal(0.00, 1.40)
Main_RecrDev_1989	0.594	2	(-4, 4)	dev	0.203	normal(0.00, 1.40)
Main_RecrDev_1990	1.1	2	(-4, 4)	dev	0.158	normal(0.00, 1.40)
Main_RecrDev_1991	-0.887	2	(-4, 4)	dev	0.371	normal(0.00, 1.40)
Main_RecrDev_1992	-1.8	2	(-4, 4)	dev	0.46	normal(0.00, 1.40)
Main_RecrDev_1993	-1.76	2	(-4, 4)	dev	0.346	normal(0.00, 1.40)
Main_RecrDev_1994	-0.182	2	(-4, 4)	dev	0.314	normal(0.00, 1.40)
Main_RecrDev_1995	0.647	2	(-4, 4)	dev	0.181	normal(0.00, 1.40)
Main_RecrDev_1996	-1.85	2	(-4, 4)	dev	0.751	normal(0.00, 1.40)
Main_RecrDev_1997	-1.64	2	(-4, 4)	dev	0.583	normal(0.00, 1.40)
Main_RecrDev_1998	-1.32	2	(-4, 4)	dev	0.532	normal(0.00, 1.40)
Main_RecrDev_1999	0.957	2	(-4, 4)	dev	0.166	normal(0.00, 1.40)
Main_RecrDev_2000	1.55	2	(-4, 4)	dev	0.132	normal(0.00, 1.40)
Main_RecrDev_2001	0.563	2	(-4, 4)	dev	0.179	normal(0.00, 1.40)
Main_RecrDev_2002	-0.873	2	(-4, 4)	dev	0.244	normal(0.00, 1.40)

Table 28: Parameter estimates, estimation phase, parameter bounds, estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model. *(continued)*

Label	Value	Phase	Bounds	Status	SD	Prior
Main_RecrDev_2003	-1.19	2	(-4, 4)	dev	0.317	normal(0.00, 1.40)
Main_RecrDev_2004	-0.331	2	(-4, 4)	dev	0.157	normal(0.00, 1.40)
Main_RecrDev_2005	-2.98	2	(-4, 4)	dev	0.475	normal(0.00, 1.40)
Main_RecrDev_2006	-1.33	2	(-4, 4)	dev	0.182	normal(0.00, 1.40)
Main_RecrDev_2007	-2.86	2	(-4, 4)	dev	0.425	normal(0.00, 1.40)
Main_RecrDev_2008	1.52	2	(-4, 4)	dev	0.103	normal(0.00, 1.40)
Main_RecrDev_2009	-2.8	2	(-4, 4)	dev	0.666	normal(0.00, 1.40)
Main_RecrDev_2010	0.871	2	(-4, 4)	dev	0.126	normal(0.00, 1.40)
Main_RecrDev_2011	0.283	2	(-4, 4)	dev	0.156	normal(0.00, 1.40)
Main_RecrDev_2012	-0.48	2	(-4, 4)	dev	0.221	normal(0.00, 1.40)
Main_RecrDev_2013	2.05	2	(-4, 4)	dev	0.102	normal(0.00, 1.40)
Main_RecrDev_2014	0.324	2	(-4, 4)	dev	0.182	normal(0.00, 1.40)
Main_RecrDev_2015	-0.911	2	(-4, 4)	dev	0.33	normal(0.00, 1.40)
Main_RecrDev_2016	2.38	2	(-4, 4)	dev	0.0985	normal(0.00, 1.40)
Main_RecrDev_2017	-0.811	2	(-4, 4)	dev	0.39	normal(0.00, 1.40)
Main_RecrDev_2018	0.294	2	(-4, 4)	dev	0.159	normal(0.00, 1.40)
Main_RecrDev_2019	1.15	2	(-4, 4)	dev	0.13	normal(0.00, 1.40)
Main_RecrDev_2020	2.38	2	(-4, 4)	dev	0.109	normal(0.00, 1.40)
Main_RecrDev_2021	2.03	2	(-4, 4)	dev	0.128	normal(0.00, 1.40)
Main_RecrDev_2022	-0.556	2	(-4, 4)	dev	0.399	normal(0.00, 1.40)
Main_RecrDev_2023	2.43	2	(-4, 4)	dev	0.198	normal(0.00, 1.40)
Late_RecrDev_2024	0.507	3	(-4, 4)	dev	0.92	normal(0.00, 1.40)
ForeRecr_2025	0	3	(-4, 4)	dev	1.4	normal(0.00, 1.40)
ForeRecr_2026	0	3	(-4, 4)	dev	1.4	normal(0.00, 1.40)
ForeRecr_2027	0	3	(-4, 4)	dev	1.4	normal(0.00, 1.40)
ForeRecr_2028	0	3	(-4, 4)	dev	1.4	normal(0.00, 1.40)
ForeRecr_2029	0	3	(-4, 4)	dev	1.4	normal(0.00, 1.40)
ForeRecr_2030	0	3	(-4, 4)	dev	1.4	normal(0.00, 1.40)
ForeRecr_2031	0	3	(-4, 4)	dev	1.4	normal(0.00, 1.40)
ForeRecr_2032	0	3	(-4, 4)	dev	1.4	normal(0.00, 1.40)
ForeRecr_2033	0	3	(-4, 4)	dev	1.4	normal(0.00, 1.40)
ForeRecr_2034	0	3	(-4, 4)	dev	1.4	normal(0.00, 1.40)
ForeRecr_2035	0	3	(-4, 4)	dev	1.4	normal(0.00, 1.40)
ForeRecr_2036	0	3	(-4, 4)	dev	1.4	normal(0.00, 1.40)
LnQ_base_Triennial_Early(7)	0.0226	-1	(-15, 15)	fixed	0	none
Q_extraSD_Triennial_Early(7)	0.001	-2	(0.001, 0.5)	fixed	0	none

Table 28: Parameter estimates, estimation phase, parameter bounds, estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model. *(continued)*

Label	Value	Phase	Bounds	Status	SD	Prior
LnQ_base_Triennial_Late(8)	1.02	-1	(-15, 15)	fixed	0	none
Q_extraSD_Triennial_Late(8)	0.0838	1	(0.001, 0.75)	ok	0.0768	none
LnQ_base_NWFSC_Slope(9)	-0.674	-1	(-15, 15)	fixed	0	none
Q_extraSD_NWFSC_Slope(9)	0.144	2	(0.001, 0.75)	ok	0.0761	none
LnQ_base_WCGBTS(10)	0.0485	-1	(-15, 15)	fixed	0	none
Q_extraSD_WCGBTS(10)	1e-04	-2	(1e-04, 0.3)	fixed	0	none
Q_base_Recruitment_Index(11)	0.237	1	(0, 10)	ok	0.296	none
Q_offset_Recruitment_Index(11)	0	-1	(-15, 15)	fixed	0	none
Age_DblN_peak_Trawl(1)	3.6	3	(0.01, 10)	ok	0.215	none
Age_DblN_top_logit_Trawl(1)	-1.77	5	(-10, 10)	ok	0.0229	none
Age_DblN_ascend_se_Trawl(1)	0.9	4	(-10, 10)	ok	0.242	none
Age_DblN_descend_se_Trawl(1)	-10	-5	(-10, 10)	fixed	0	none
Age_DblN_start_logit_Trawl(1)	-10	-4	(-10, 10)	fixed	0	none
Age_DblN_end_logit_Trawl(1)	0.547	5	(-10, 10)	ok	0.251	none
Age_DblN_peak_Hook_and_Line(2)	5.3	3	(0.01, 20)	ok	0.242	none
Age_DblN_top_logit_Hook_and_Line(2)	-4	-4	(-5, 5)	fixed	0	none
Age_DblN_ascend_se_Hook_and_Line(2)	0.885	5	(-10, 10)	ok	0.213	none
Age_DblN_descend_se_Hook_and_Line(2)	4.06	5	(-10, 10)	ok	0.431	none
Age_DblN_start_logit_Hook_and_Line(2)	-5	-4	(-10, 10)	fixed	0	none
Age_DblN_end_logit_Hook_and_Line(2)	-1.35	5	(-10, 10)	ok	0.337	none
AgeSel_2Male_Peak_Hook_and_Line	-0.211	3	(-20, 20)	ok	0.172	none
AgeSel_2Male_Ascend_Hook_and_Line	0	-4	(-5, 5)	fixed	0	none
AgeSel_2Male_Descend_Hook_and_Line	0	-4	(-10, 10)	fixed	0	none
AgeSel_2Male_Final_Hook_and_Line	-0.654	4	(-20, 10)	ok	0.351	none
AgeSel_2Male_Scale_Hook_and_Line	0.278	3	(0.01, 1)	ok	0.0229	none
Age_DblN_peak_Trawl_Discard(4)	0.206	-4	(0.01, 20)	fixed	0	none
Age_DblN_top_logit_Trawl_Discard(4)	-3.74	-4	(-10, 10)	fixed	0	none
Age_DblN_ascend_se_Trawl_Discard(4)	10	-5	(-10, 10)	fixed	0	none
Age_DblN_descend_se_Trawl_Discard(4)	-2.75	5	(-10, 10)	ok	0.156	none
Age_DblN_start_logit_Trawl_Discard(4)	-3.31	-4	(-10, 10)	fixed	0	none
Age_DblN_end_logit_Trawl_Discard(4)	-1.92	4	(-10, 10)	ok	0.0873	none
Age_DblN_peak_Hook_and_Line_Discard(5)	4.5	3	(0.01, 20)	ok	0.374	none
Age_DblN_top_logit_Hook_and_Line_Discard(5)	-5.95	-4	(-10, 10)	fixed	0	none
Age_DblN_ascend_se_Hook_and_Line_Discard(5)	1.09	4	(-10, 10)	ok	0.255	none
Age_DblN_descend_se_Hook_and_Line_Discard(5)	-7.82	-5	(-10, 10)	fixed	0	none
Age_DblN_start_logit_Hook_and_Line_Discard(5)	-5	-4	(-10, 10)	fixed	0	none

Table 28: Parameter estimates, estimation phase, parameter bounds, estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model. *(continued)*

Label	Value	Phase	Bounds	Status	SD	Prior
Age_DblN_end_logit_Hook_and_Line_Discard(5)	0.519	4	(-10, 10)	ok	0.405	none
Age_DblN_peak_Pot_Discard(6)	2.73	3	(0.01, 20)	ok	0.394	none
Age_DblN_top_logit_Pot_Discard(6)	-3.23	-4	(-10, 10)	fixed	0	none
Age_DblN_ascend_se_Pot_Discard(6)	-0.627	4	(-10, 10)	ok	1.07	none
Age_DblN_descend_se_Pot_Discard(6)	-5.5	-5	(-10, 10)	fixed	0	none
Age_DblN_start_logit_Pot_Discard(6)	-5	-4	(-10, 10)	fixed	0	none
Age_DblN_end_logit_Pot_Discard(6)	2.45	4	(-10, 10)	ok	1.87	none
Age_DblN_peak_Triennial_Early(7)	0.581	-4	(0.01, 12)	fixed	0	none
Age_DblN_top_logit_Triennial_Early(7)	-3.35	4	(-10, 10)	ok	0.0205	none
Age_DblN_ascend_se_Triennial_Early(7)	-9.72	-4	(-10, 10)	fixed	0	none
Age_DblN_descend_se_Triennial_Early(7)	-8.65	-4	(-10, 10)	fixed	0	none
Age_DblN_start_logit_Triennial_Early(7)	-5	-4	(-10, 5)	fixed	0	none
Age_DblN_end_logit_Triennial_Early(7)	-5.32	4	(-10, 10)	ok	1.58	none
Age_DblN_peak_Triennial_Late(8)	1.05	3	(0.01, 12)	ok	0.034	none
Age_DblN_top_logit_Triennial_Late(8)	-10	-4	(-10, 10)	fixed	0	none
Age_DblN_ascend_se_Triennial_Late(8)	-9.72	-4	(-10, 10)	fixed	0	none
Age_DblN_descend_se_Triennial_Late(8)	1.37	4	(-10, 10)	ok	0.16	none
Age_DblN_start_logit_Triennial_Late(8)	-5	-4	(-10, 5)	fixed	0	none
Age_DblN_end_logit_Triennial_Late(8)	-3.71	4	(-10, 10)	ok	0.271	none
Age_DblN_peak_NWFSC_Slope(9)	3.73	-4	(0.01, 15)	fixed	0	none
Age_DblN_top_logit_NWFSC_Slope(9)	-5.68	-4	(-10, 10)	fixed	0	none
Age_DblN_ascend_se_NWFSC_Slope(9)	1.55	4	(-10, 10)	ok	0.373	none
Age_DblN_descend_se_NWFSC_Slope(9)	-6.94	-4	(-10, 10)	fixed	0	none
Age_DblN_start_logit_NWFSC_Slope(9)	-4.72	-4	(-10, 10)	fixed	0	none
Age_DblN_end_logit_NWFSC_Slope(9)	1.24	4	(-10, 10)	ok	1.08	none
Age_DblN_peak_WCGBTS(10)	0.25	-4	(0.01, 10)	fixed	0	none
Age_DblN_top_logit_WCGBTS(10)	-10	-4	(-10, 10)	fixed	0	none
Age_DblN_ascend_se_WCGBTS(10)	4.34	-4	(-10, 10)	fixed	0	none
Age_DblN_descend_se_WCGBTS(10)	-9.9	-4	(-10, 10)	fixed	0	none
Age_DblN_start_logit_WCGBTS(10)	-2.75	-4	(-10, 5)	fixed	0	none
Age_DblN_end_logit_WCGBTS(10)	1.39	4	(-10, 10)	ok	0.444	none
minage@sel=1_Recruitment_Index(11)	0	-99	(0, 10)	fixed	0	none
maxage@sel=1_Recruitment_Index(11)	0	-99	(0, 10)	fixed	0	none
Age_DblN_peak_Trawl(1)_BLK3repl_1890	1.12	6	(0.01, 20)	ok	0.0257	none
Age_DblN_ascend_se_Trawl(1)_BLK3repl_1890	-7.27	-4	(-10, 10)	fixed	0	none
Age_DblN_peak_Hook_and_Line(2)_BLK3repl_1890	4.54	6	(1, 20)	ok	0.257	none

Table 28: Parameter estimates, estimation phase, parameter bounds, estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model. *(continued)*

Label	Value	Phase	Bounds	Status	SD	Prior
Age_DblN_peak_Trawl_Discard(4)_BLK1repl_1890	0.407	6	(0.01, 20)	ok	0.0142	none
Age_DblN_peak_Trawl_Discard(4)_BLK1repl_2011	0.0911	-6	(0.01, 20)	fixed	0	none
Age_DblN_descend_se_Trawl_Discard(4)_BLK2repl_-1890	-10	-7	(-10, 10)	fixed	0	none
Age_DblN_peak_Hook_and_Line_Discard(5)_-BLK1repl_1890	2.11	-6	(1, 20)	fixed	0	none
Age_DblN_peak_Hook_and_Line_Discard(5)_-BLK1repl_2011	3.79	7	(1, 20)	ok	0.137	none
Age_DblN_peak_Pot_Discard(6)_BLK2repl_1890	2.09	6	(1, 20)	ok	0.326	none

Table 29: Likelihood components by source.

Label	Total
TOTAL	1,335.8
Catch	0.0
Equil catch	0.0
Survey	-43.5
Length comp	0.0
Age comp	1,341.5
Recruitment	37.5
InitEQ Regime	0.0
Forecast Recruitment	0.1
Parm priors	0.2
Parm devs	0.0
Crash Pen	0.0

Table 30: Summary of reference points and management quantities, including estimates of the 95 percent confidence intervals. SO is spawning output, SPR is the spawning potential ratio, and MSY is maximum sustainable yield.

Reference Point	Estimate	Lower Interval	Upper Interval
Unfished Spawning output	219,377	183,217	255,537
Unfished Age 3+ Biomass (mt)	458,861	375,411	542,311
Unfished Recruitment (R0)	25,981	17,926	34,036
2025 Spawning output	74,409	59,331	89,486
2025 Fraction Unfished	0.339	0.276	0.402
Reference Points Based SO40%	—	—	—
Proxy Spawning output SO40%	87,751	73,287	102,215
SPR Resulting in SO40%	0.450	0.450	0.450
Exploitation Rate Resulting in SO40%	0.046	0.042	0.049
Yield with SPR Based On SO40% (mt)	11,126	8,274	13,978
Reference Points Based on SPR Proxy for MSY	—	—	—
Proxy Spawning output (SPR45)	87,751	73,287	102,215
SPR45	0.450	—	—
Exploitation Rate Corresponding to SPR45	0.046	0.042	0.049
Yield with SPR45 at SO SPR (mt)	11,126	8,274	13,978
Reference Points Based on Estimated MSY Values	—	—	—
Spawning output at MSY (SO MSY)	47,863	40,183	55,543
SPR MSY	0.283	0.281	0.286
Exploitation Rate Corresponding to SPR MSY	0.079	0.073	0.085
MSY (mt)	12,705	9,423	15,986

Table 31: Time series of population estimates from the base model.

Year	Total Biomass (mt)	Spawning Output (mt)	Total Biomass 3+ (mt)	Stock Status	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_-45%)	Exploitation Rate
1890	489,494	219,377	458,861	1.000	25,981	2	0.000	0.000
1891	489,491	219,357	458,859	1.000	25,980	6	0.001	0.000
1892	489,485	219,353	458,853	1.000	25,980	7	0.001	0.000
1893	489,478	219,348	458,846	1.000	25,980	11	0.001	0.000
1894	489,467	219,341	458,835	1.000	25,980	15	0.001	0.000
1895	489,453	219,331	458,821	1.000	25,980	19	0.002	0.000
1896	489,436	219,319	458,804	1.000	25,980	21	0.002	0.000
1897	489,417	219,305	458,786	1.000	25,980	24	0.002	0.000
1898	489,397	219,291	458,765	1.000	25,980	26	0.002	0.000
1899	489,375	219,275	458,744	1.000	25,980	29	0.003	0.000
1900	489,352	219,257	458,721	0.999	25,980	80	0.007	0.000
1901	489,278	219,208	458,648	0.999	25,979	97	0.009	0.000
1902	489,191	219,148	458,561	0.999	25,978	117	0.011	0.000
1903	489,089	219,075	458,459	0.999	25,978	140	0.013	0.000
1904	488,967	218,989	458,339	0.998	25,977	169	0.015	0.000
1905	488,823	218,887	458,196	0.998	25,976	152	0.014	0.000
1906	488,704	218,799	458,077	0.997	25,975	136	0.012	0.000
1907	488,608	218,725	457,982	0.997	25,974	119	0.011	0.000
1908	488,534	218,668	457,909	0.997	25,974	103	0.009	0.000
1909	488,481	218,626	457,857	0.997	25,973	161	0.014	0.000
1910	488,373	218,552	457,751	0.996	25,972	219	0.020	0.000
1911	488,213	218,443	457,591	0.996	25,971	277	0.025	0.001
1912	488,002	218,299	457,381	0.995	25,970	335	0.030	0.001
1913	487,743	218,119	457,124	0.994	25,968	393	0.035	0.001
1914	487,440	217,906	456,823	0.993	25,966	451	0.041	0.001
1915	487,094	217,661	456,480	0.992	25,964	508	0.046	0.001
1916	486,709	217,385	456,098	0.991	25,961	1,352	0.120	0.003
1917	485,492	216,573	454,887	0.987	25,953	2,077	0.175	0.005
1918	483,592	215,353	453,005	0.982	25,940	2,938	0.249	0.006
1919	480,912	213,548	450,335	0.973	25,922	1,067	0.095	0.002
1920	480,258	212,951	449,692	0.971	25,916	934	0.080	0.002
1921	479,790	212,546	449,243	0.969	25,911	1,248	0.106	0.003
1922	479,038	212,029	448,501	0.967	25,906	829	0.074	0.002
1923	478,758	211,772	448,217	0.965	25,903	1,491	0.131	0.003
1924	477,832	211,150	447,300	0.962	25,897	1,921	0.165	0.004
1925	476,515	210,300	445,995	0.959	25,888	2,186	0.189	0.005
1926	474,999	209,281	444,487	0.954	25,877	1,746	0.157	0.004
1927	474,018	208,526	443,509	0.951	25,868	2,632	0.225	0.006
1928	472,201	207,306	441,717	0.945	25,855	2,209	0.192	0.005
1929	470,906	206,387	440,432	0.941	25,845	2,415	0.205	0.005
1930	469,470	205,430	439,017	0.936	25,834	2,677	0.228	0.006
1931	467,845	204,348	437,404	0.931	25,822	1,483	0.129	0.003
1932	467,519	204,046	437,083	0.930	25,819	1,737	0.152	0.004
1933	466,975	203,640	436,548	0.928	25,814	1,627	0.139	0.004
1934	466,581	203,386	436,163	0.927	25,812	2,811	0.234	0.006
1935	465,011	202,477	434,611	0.923	25,801	3,607	0.295	0.008
1936	462,699	201,124	432,318	0.917	25,786	2,464	0.216	0.006
1937	461,671	200,368	431,281	0.913	25,777	2,628	0.232	0.006
1938	460,560	199,521	430,180	0.909	25,767	2,578	0.228	0.006
1939	459,578	198,758	429,210	0.906	25,758	2,859	0.251	0.007
1940	458,377	197,880	428,022	0.902	25,748	2,282	0.203	0.005

Table 31: Time series of population estimates from the base model. *(continued)*

Year	Total Biomass (mt)	Spawning Output (mt)	Total Biomass 3+ (mt)	Stock Status	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_-45%)	Exploita-tion Rate
1941	457,830	197,423	427,485	0.900	25,742	2,270	0.197	0.005
1942	457,329	197,080	427,001	0.898	25,738	3,229	0.269	0.008
1943	455,900	196,220	425,563	0.894	25,728	3,923	0.300	0.009
1944	453,835	195,164	423,511	0.890	25,715	4,484	0.325	0.011
1945	451,294	193,952	420,987	0.884	25,700	4,417	0.328	0.010
1946	448,948	192,753	418,656	0.879	25,685	4,455	0.356	0.011
1947	446,705	191,355	416,428	0.872	25,667	2,370	0.209	0.006
1948	446,708	191,141	416,462	0.871	25,665	3,075	0.259	0.007
1949	446,018	190,669	415,804	0.869	25,659	3,261	0.273	0.008
1950	445,176	190,158	414,971	0.867	25,652	2,891	0.242	0.007
1951	444,752	189,930	414,553	0.866	25,649	4,709	0.367	0.011
1952	442,473	188,826	412,325	0.861	25,635	2,899	0.240	0.007
1953	442,132	188,650	411,956	0.860	25,633	1,988	0.169	0.005
1954	442,769	188,989	412,584	0.861	25,637	2,670	0.222	0.006
1955	442,718	189,006	412,544	0.862	25,637	2,521	0.211	0.006
1956	442,839	189,116	412,658	0.862	25,639	4,062	0.304	0.010
1957	441,345	188,655	411,231	0.860	25,633	2,926	0.245	0.007
1958	441,086	188,525	410,913	0.859	25,631	1,787	0.150	0.004
1959	442,026	189,056	411,843	0.862	25,638	2,477	0.207	0.006
1960	442,248	189,211	412,071	0.862	25,640	3,356	0.274	0.008
1961	441,566	188,889	411,400	0.861	25,636	2,033	0.173	0.005
1962	442,270	189,271	412,080	0.863	25,641	2,979	0.235	0.007
1963	441,976	189,283	411,822	0.863	25,641	2,066	0.173	0.005
1964	442,634	189,691	412,445	0.865	25,646	2,281	0.188	0.006
1965	443,049	189,995	412,863	0.866	25,650	2,165	0.178	0.005
1966	443,567	190,361	413,374	0.868	25,655	2,130	0.172	0.005
1967	444,093	190,772	413,900	0.870	25,660	4,552	0.359	0.011
1968	442,128	189,755	411,945	0.865	25,647	2,969	0.242	0.007
1969	441,846	189,592	411,654	0.864	25,645	5,750	0.446	0.014
1970	438,759	187,804	408,595	0.856	25,622	4,918	0.369	0.012
1971	436,627	186,687	406,488	0.851	25,607	4,186	0.320	0.010
1972	435,338	185,991	405,215	0.848	25,598	7,158	0.522	0.018
1973	431,069	183,721	401,019	0.837	25,567	6,421	0.457	0.016
1974	427,669	182,140	397,690	0.830	25,546	9,258	0.667	0.023
1975	422,649	178,570	391,573	0.814	33,441	15,118	0.974	0.039
1976	413,747	171,448	379,886	0.782	32,500	25,196	1.324	0.066
1977	393,825	158,112	358,597	0.721	7,500	9,714	0.750	0.027
1978	385,690	154,572	360,339	0.705	8,319	13,494	0.946	0.037
1979	372,270	149,657	358,728	0.682	39,912	26,162	1.366	0.073
1980	346,597	138,368	324,922	0.631	9,337	10,538	0.839	0.032
1981	337,722	135,301	305,841	0.617	16,714	12,819	0.975	0.042
1982	322,929	130,483	308,720	0.595	13,291	20,938	1.291	0.068
1983	299,761	121,267	283,176	0.553	6,497	16,407	1.195	0.058
1984	280,030	113,630	266,712	0.518	16,901	15,819	1.201	0.059
1985	261,243	106,216	247,743	0.484	21,776	15,761	1.267	0.064
1986	246,587	98,863	225,612	0.451	14,382	14,611	1.266	0.065
1987	232,947	91,718	212,821	0.418	5,177	14,072	1.279	0.066
1988	218,396	84,344	204,946	0.384	16,292	12,008	1.229	0.059
1989	207,303	78,668	195,641	0.359	15,982	11,501	1.223	0.059
1990	200,202	74,032	180,135	0.337	26,211	10,156	1.166	0.056
1991	194,203	70,296	173,554	0.320	3,549	10,569	1.224	0.061
1992	186,549	66,711	168,059	0.304	1,409	10,529	1.210	0.063

Table 31: Time series of population estimates from the base model. *(continued)*

Year	Total Biomass (mt)	Spawning Output (mt)	Total Biomass 3+ (mt)	Stock Status	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_-45%)	Exploitation Rate
1993	174,623	63,647	171,605	0.290	1,446	9,153	1.154	0.053
1994	161,817	61,103	159,412	0.279	6,953	8,396	1.164	0.053
1995	150,809	58,788	145,098	0.268	15,782	8,751	1.239	0.060
1996	140,606	55,828	130,055	0.254	1,280	9,206	1.314	0.071
1997	129,852	51,548	119,053	0.235	1,544	8,747	1.344	0.073
1998	117,546	46,577	115,859	0.212	2,064	4,878	1.061	0.042
1999	111,375	43,420	106,881	0.198	19,743	7,322	1.346	0.069
2000	108,911	39,483	95,399	0.180	34,748	6,931	1.370	0.073
2001	112,281	36,056	84,791	0.164	12,503	6,223	1.331	0.073
2002	117,232	33,602	89,502	0.153	2,901	4,371	1.128	0.049
2003	128,427	33,565	117,359	0.153	2,102	5,844	1.200	0.050
2004	128,777	34,337	124,772	0.157	5,026	6,190	1.115	0.050
2005	121,416	35,754	117,668	0.163	359	6,542	1.101	0.056
2006	112,465	37,611	108,392	0.171	1,914	6,459	1.105	0.060
2007	105,364	39,511	104,314	0.180	420	5,477	1.039	0.053
2008	96,902	37,552	91,215	0.171	32,938	6,051	1.165	0.066
2009	96,259	35,764	83,780	0.163	430	7,436	1.335	0.089
2010	93,848	31,094	70,824	0.142	16,108	7,163	1.414	0.101
2011	92,537	27,373	85,103	0.125	8,492	6,584	1.446	0.077
2012	91,014	24,406	77,089	0.111	3,769	5,468	1.334	0.071
2013	91,633	22,914	78,897	0.104	46,000	4,240	1.142	0.054
2014	106,832	25,446	84,808	0.116	8,575	4,523	1.147	0.053
2015	111,900	25,716	77,798	0.117	2,507	5,302	1.229	0.068
2016	124,332	27,092	107,756	0.123	68,575	5,619	1.228	0.052
2017	133,458	27,641	106,126	0.126	2,855	5,777	1.157	0.054
2018	152,403	31,646	104,654	0.144	9,106	5,494	1.005	0.052
2019	158,189	35,644	150,179	0.162	22,505	5,635	0.976	0.038
2020	173,770	40,716	149,954	0.186	80,372	4,078	0.710	0.027
2021	205,184	48,433	155,169	0.221	59,662	5,122	0.715	0.033
2022	224,890	53,073	157,146	0.242	4,612	6,640	0.857	0.042
2023	248,668	57,937	203,171	0.264	93,874	6,385	0.813	0.031
2024	264,202	61,505	225,668	0.280	35,534	6,029	0.701	0.027
2025	318,750	74,409	246,677	0.339	22,352	19,114	1.212	0.077
2026	323,765	80,877	291,609	0.369	22,736	19,082	1.181	0.065
2027	326,504	88,838	302,163	0.405	23,146	13,965	0.971	0.046
2028	330,290	98,185	305,496	0.448	23,558	15,103	0.967	0.049
2029	323,626	103,869	298,409	0.473	23,777	14,720	0.965	0.049
2030	317,118	107,603	291,558	0.490	23,911	14,095	0.962	0.048
2031	312,024	109,277	286,277	0.498	23,968	13,437	0.959	0.047
2032	304,225	107,167	278,386	0.489	23,896	12,755	0.957	0.046
2033	298,333	104,575	272,495	0.477	23,803	12,172	0.954	0.045
2034	295,654	103,162	269,899	0.470	23,751	11,749	0.951	0.044
2035	292,126	101,283	266,454	0.462	23,680	11,274	0.948	0.042
2036	289,647	99,821	264,038	0.455	23,623	10,918	0.946	0.041

Table 32: Maximum likelihood estimates for select parameters, derived quantities, reference points, and negative log likelihoods for the base model and alternative sensitivity runs representing the removal of index and age composition data from the NWFSC West Coast Groundfish Bottom Trawl Survey (WCGBTS), the Trienniel Survey, or the NWFSC Slope Survey. Additionally, estimates for the removal of the environmental-based recruitment index are shown.

Metric	Base Model	Remove WCGBTS	Remove Triennial	Remove NWFSC Slope	Remove Recruitment Index
Total Likelihood	1,335.77	1,129.35	1,255.43	1,301.42	1,334.52
Survey Likelihood	-43.512	-18.433	-29.627	-37.536	-44.774
Length Likelihood	0	0	0	0	0
Age Likelihood	1,341.49	1,112.8	1,249.06	1,301.55	1,341.53
Recruitment Likelihood	37.52	34.616	35.734	37.142	37.518
Forecast Recruitment Likelihood	0.066	0.002	0.063	0.068	0.046
Parameter Priors Likelihood	0.204	0.364	0.204	0.196	0.203
log(R0)	10.165	10.281	10.184	10.136	10.164
SB Virgin	219,377	221,153	223,569	214,295	219,237
SB 2025	74,408.8	62,678.3	73,849	73,166	74,392.1
Fraction Unfished 2025	0.339	0.283	0.33	0.341	0.339
Total Yield - SPR 45	11,126.2	12,047.1	11,330.3	10,841.3	11,114.5
Steepness	0.75	0.75	0.75	0.75	0.75
Natural Mortality - Female	0.088	0.094	0.088	0.087	0.088
Natural Mortality - Male	0.088	0.094	0.088	0.087	0.088

Table 33: Maximum likelihood estimates for select parameters, derived quantities, reference points, and negative log likelihoods for the base model and alternative sensitivity runs representing the use of the McAllister-Ianelli harmonic mean method for weighting composition data, the specifiation of asymptotic selectivity for all NWFSC Surveys, and using the ageing error vector applied in the 2019 stock assessment.

Metric	Base Model	McAllister-Ianelli Data Weighting	NWFSC Survey Asymptotic Selectivity	Ageing Error 2019 Assessment
Total Likelihood	1,335.77	1,142.42	1,339.29	1,480.56
Survey Likelihood	-43.512	-46.895	-45.657	-44.434
Length Likelihood	0	0	0	0
Age Likelihood	1,341.49	1,153.4	1,347.05	1,479.05
Recruitment Likelihood	37.52	35.793	37.59	45.797
Forecast Recruitment Likelihood	0.066	0.002	0.08	0.004
Parameter Priors Likelihood	0.204	0.12	0.235	0.14
log(R0)	10.165	10.074	10.198	10.051
SB Virgin	219,377	215,771	221,526	206,673
SB 2025	74,408.8	72,862.5	74,872.2	70,571.6
Fraction Unfished 2025	0.339	0.338	0.338	0.341
Total Yield - SPR 45	11,126.2	10,445.1	11,413.9	10,114.8
Steepness	0.75	0.75	0.75	0.75
Natural Mortality - Female	0.088	0.084	0.089	0.085
Length at Amin - Female	25.182	25.182	25.182	25.182
Length at Amax - Female	60.718	60.718	60.718	60.718
Von Bert. k - Female	0.343	0.343	0.343	0.343
CV young - Female	—	—	—	—
CV old - Female	—	—	—	—
Natural Mortality - Male	0	0	0	0
Length at Amin - Male	26.646	26.646	26.646	26.646
Length at Amax - Male	56.059	56.059	56.059	56.059
Von Bert. k - Male	0.351	0.351	0.351	0.351
CV young - Male	—	—	—	—
CV old - Male	—	—	—	—

Table 34: Maximum likelihood estimates for select parameters, derived quantities, reference points, and negative log likelihoods for the base model and alternative sensitivity runs representing the estimation of growth (rather than using an empircal weight-at-age approach for growth as in the base model), the estimation of sex-specific natural mortality (M), and fixing M at the value used in the assessment of sablefish in Alaska, adjusted upwards to offset potential net emigration to Canada, or set to sex-specific values used in the 2019 U.S. West coast assessment of sablefish.

Metric	Base Model	Estimate Growth	M Sex-Specific	M Alaska Assessment	M Adjust For Migration	M Fix 2019 Assessment
Total Likelihood	1,335.77	1,863.72	1,335.92	1,350.18	1,371.66	1,352.8
Survey Likelihood	-43.512	-34.249	-43.341	-44.228	-43.697	-40.399
Length Likelihood	0	52.72	0	0	0	0
Age Likelihood	1,341.49	1,809.41	1,341.26	1,353.48	1,370.03	1,353.94
Recruitment Likelihood	37.52	35.669	37.508	39.747	43.431	39.106
Forecast Recruitment Likelihood	0.066	0.04	0.065	0.017	0.002	0.112
Parameter Priors Likelihood	0.204	0.131	0.424	1.166	1.891	0.038
log(R0)	10.165	10.097	10.179	11.032	11.687	9.655
SB Virgin	219,377	196,419	219,117	336,221	499,783	165,666
SB 2025	74,408.8	64,051.6	74,951.1	98,394.6	130,466	66,302.6
Fraction Unfished 2025	0.339	0.326	0.342	0.293	0.261	0.4
Total Yield - SPR 45	11,126.2	10,370.5	11,260.7	22,649.5	39,689.7	7,513.39
Steepness	0.75	0.75	0.75	0.75	0.75	0.75
Natural Mortality - Female	0.088	0.084	0.089	0.114	0.132	0.076
Length at Amin - Female	—	25.139	—	—	—	—
Length at Amax - Female	—	61.07	—	—	—	—
Von Bert. k - Female	—	0.338	—	—	—	—
CV young - Female	—	0.099	—	—	—	—
CV old - Female	—	0.088	—	—	—	—
Natural Mortality - Male	0.088	0.084	0.088	0.114	0.132	0.068
Length at Amin - Male	—	26.527	—	—	—	—
Length at Amax - Male	—	56.157	—	—	—	—
Von Bert. k - Male	—	0.351	—	—	—	—
CV young - Male	—	0.086	—	—	—	—
CV old - Male	—	0.073	—	—	—	—

Table 35: Maximum likelihood estimates for select parameters, derived quantities, reference points, and negative log likelihoods for the base model and alternative sensitivity runs representing the estimaton of steepness (h), imposing the restriction that recruitment deviations in the main recruitment period must sum to zero, and estimating early (1890-1974) recruitment deviations with the sum to zero constraint imposed.

Metric	Base Model	Estimate Steepness	RecDevs Sum To Zero	Estimate Early RecDevs (Sum 0)
Total Likelihood	1,335.77	1,335.72	1,335.78	1,329.43
Survey Likelihood	-43.512	-43.512	-43.532	-43.373
Length Likelihood	0	0	0	0
Age Likelihood	1,341.49	1,341.53	1,341.47	1,331.58
Recruitment Likelihood	37.52	37.525	37.557	41.044
Forecast Recruitment Likelihood	0.066	0.062	0.065	0.07
Parameter Priors Likelihood	0.204	0.112	0.211	0.114
log(R0)	10.165	10.144	10.177	10.094
SB Virgin	219,377	216,706	220,703	221,301
SB 2025	74,408.8	74,101.1	74,585	71,435.4
Fraction Unfished 2025	0.339	0.342	0.338	0.323
Total Yield - SPR 45	11,126.2	11,269.6	11,233.5	10,645.6
Steepness	0.75	0.797	0.75	0.75
Natural Mortality - Female	0.088	0.087	0.088	0.084
Natural Mortality - Male	0.088	0.087	0.088	0.084

Table 36: Maximum likelihood estimates for select parameters, derived quantities, reference points, and negative log likelihoods for the base model and alternative sensitivity runs where discard mortality was increased to 100% for all fleets, discard mortality was increased to 75% for the trawl fishery and 60% for both hook-and-line and pot fisheries, and the pre-1969 catch was doubled.

Metric	Base Model	100% Discard Mortality	75% TWL & 60% HKL/Pot Discard Mortality	Double Pre-1969 Catch
Total Likelihood	1,335.77	1,336.52	1,336.13	1,334.29
Survey Likelihood	-43.512	-43.576	-43.548	-43.436
Length Likelihood	0	0	0	0
Age Likelihood	1,341.49	1,342.48	1,341.96	1,340
Recruitment Likelihood	37.52	37.373	37.464	37.495
Forecast Recruitment Likelihood	0.066	0.063	0.064	0.067
Parameter Priors Likelihood	0.204	0.186	0.195	0.162
log(R0)	10.165	10.211	10.191	10.14
SB Virgin	219,377	232,950	226,783	221,431
SB 2025	74,408.8	75,465.5	75,191.2	73,070.6
Fraction Unfished 2025	0.339	0.324	0.332	0.33
Total Yield - SPR 45	11,126.2	11,718.9	11,461.9	10,981.8
Steepness	0.75	0.75	0.75	0.75
Natural Mortality - Female	0.088	0.087	0.087	0.086
Length at Amin - Female	25.182	25.182	25.182	25.182
Length at Amax - Female	60.718	60.718	60.718	60.718
Von Bert. k - Female	0.343	0.343	0.343	0.343
CV young - Female	—	—	—	—
CV old - Female	—	—	—	—
Natural Mortality - Male	0	0	0	0
Length at Amin - Male	26.646	26.646	26.646	26.646
Length at Amax - Male	56.059	56.059	56.059	56.059
Von Bert. k - Male	0.351	0.351	0.351	0.351
CV young - Male	—	—	—	—
CV old - Male	—	—	—	—

Table 37: Maximum likelihood estimates for the base model and select derived quantities for the base model and alternative sensitivity runs that either increase or decrease the strength of recent (2016-2023) recruitment deviations by 10% in log-space. Sensitivity models were run with all model parameters fixed at the base model maximum likelihood estimates, with the only changes being from the specified adjustments to recent recruitment deviations. Forecast catches in 2025 and 2026 were based on GMT recommendations. The catches from 2027 to 2036 were set equal to the year-specific ABCs. The ABC values were projected using a category 1 time-varying sigma with an initial value of 0.50 in 2027 and a management risk tolerance (P∗) of 0.45.

Metric	Base Model	Increase Recent Recruitment Strength (10%)	Decrease Recent Recruitment Strength (10%)
OFL 2025	13,584.1	16,720.9	11,126.8
OFL 2027	14,935.3	19,107.5	11,696.5
OFL 2029	15,896.1	20,350.5	12,448.1
OFL 2031	14,653.7	18,517.4	11,620.7
Spawning Biomass 2025	74,408.8	89,012.1	62,880.6
Spawning Biomass 2027	88,838.3	112,857	70,018.7
Spawning Biomass 2029	103,869	135,905	79,241.3
Spawning Biomass 2030	109,277	144,315	82,703.3
Summary (age 3+) Biomass 2025	57,937.2	66,301.6	51,309.9
Summary (age 3+) Biomass 2027	74,408.8	89,012.1	62,880.6
Summary (age 3+) Biomass 2029	88,838.3	112,857	70,018.7
Summary (age 3+) Biomass 2030	103,869	135,905	79,241.3
Fraction Unfished 2025	0.339	0.406	0.287
Fraction Unfished 2027	0.405	0.514	0.319
Fraction Unfished 2029	0.473	0.62	0.361
Fraction Unfished 2031	0.498	0.658	0.377

Table 38: Removal assumptions in metric tons (mt) provided by the Groundfish Management Team for 2025-2026 by fleet. Removal assumptions were used to project OFLs (mt) and ABCs (mt) for 2027-2036.

Year	Trawl	Hook-and-Line	Pot	Trawl Discard	Hook-and-Line Discard	Pot Discard	Total Catch
2025	5,768.1	6,387.8	6,098.2	381.8	253.3	224.9	19,114.1
2026	6,021.0	6,144.4	6,071.7	381.8	243.1	219.9	19,081.9

Table 39: Potential OFLs (mt), ABCs (mt), ACLs (mt), the buffer between the OFL and ABC, estimated spawning output,and stock status with adopted OFLs and ACLs and assumed catch for the first two years of the projection period (2025-2026). Projections were conducted assuming a category 1 time-varying sigma of 0.50 and a P* of 0.45.

Year	Adopted OFL (mt)	Adopted ACL (mt)	Assumed Catch (mt)	OFL (mt)	Buffer	ABC (mt)	ACL (mt)	Spawning output	Fraction Unfished
2025	39,085	28,688	19,114	—	—	—	—	74,409	0.339
2026	37,310	27,238	19,082	—	—	—	—	80,877	0.369
2027	—	—	—	14,935	0.935	13,964	13,964	88,838	0.405
2028	—	—	—	16,240	0.930	15,103	15,103	98,185	0.448
2029	—	—	—	15,896	0.926	14,720	14,720	103,869	0.473
2030	—	—	—	15,287	0.922	14,094	14,094	107,603	0.490
2031	—	—	—	14,654	0.917	13,437	13,437	109,277	0.498
2032	—	—	—	13,970	0.913	12,755	12,755	107,167	0.489
2033	—	—	—	13,390	0.909	12,172	12,172	104,575	0.477
2034	—	—	—	12,997	0.904	11,749	11,749	103,162	0.470
2035	—	—	—	12,526	0.900	11,274	11,274	101,283	0.462
2036	—	—	—	12,186	0.896	10,918	10,918	99,821	0.455

Table 40: Decision table summary of 10 year projections beginning in 2027 for alternative states of nature based on an axis of uncertainty about natural mortality for the base model. Columns range over low, base, and high states of nature and rows range over different catch level assumptions. The base model estimated natural mortality of 0.088 yr^{-1} for females and males. The low state of nature assumee a natural mortality of 0.095 yr^{-1} and the high state of nature assumed a natural mortality of 0.070 yr^{-1} for both sexes. Catch in 2025 and 2026 were based upon removal assumptions provided by the GMT.

Alt. Option	Year	Catch	Low Spawning Output	Low Stock Status	Base Spawning Output	Base Stock Status	High Spawning Output	High Stock Status
P* 0.45	2025	19,114	45,746	0.237	74,409	0.339	136,165	0.436
	2026	19,082	49,979	0.259	80,877	0.369	145,453	0.466
	2027	13,964	54,904	0.285	88,838	0.405	157,818	0.506
	2028	15,103	61,586	0.319	98,185	0.448	171,209	0.548
	2029	14,720	65,692	0.341	103,869	0.473	179,879	0.576
	2030	14,094	68,210	0.354	107,603	0.490	186,364	0.597
	2031	13,437	69,067	0.358	109,277	0.498	190,326	0.610
	2032	12,755	67,342	0.349	107,167	0.489	188,697	0.604
	2033	12,172	65,405	0.339	104,575	0.477	186,051	0.596
	2034	11,749	64,381	0.334	103,162	0.470	185,006	0.593
	2035	11,273	63,290	0.328	101,283	0.462	182,588	0.585
	2036	10,918	62,613	0.325	99,821	0.455	180,530	0.578
P* 0.40	2025	19,114	45,746	0.237	74,409	0.339	136,165	0.436
	2026	19,082	49,979	0.259	80,877	0.369	145,453	0.466
	2027	13,039	54,904	0.285	88,838	0.405	157,818	0.506
	2028	14,084	62,010	0.322	98,644	0.450	171,704	0.550
	2029	13,713	66,625	0.346	104,874	0.478	180,953	0.580
	2030	13,115	69,703	0.362	109,201	0.498	188,061	0.602
	2031	12,500	71,125	0.369	111,469	0.508	192,658	0.617
	2032	11,842	69,855	0.362	109,844	0.501	191,566	0.614
	2033	11,275	68,315	0.354	107,677	0.491	189,412	0.607
	2034	10,880	67,688	0.351	106,688	0.486	188,863	0.605
	2035	10,407	66,935	0.347	105,159	0.479	186,863	0.599
	2036	10,045	66,586	0.345	104,029	0.474	185,201	0.593

Table 41: Risk table for sablefish to document ecosystem and environmental factors potentially affecting stock productivity and uncertainty or other concerns arising from the stock assessment. Level 1 is a favorable ranking, Level 2 neutral, and Level 3 unfavorable.

Ecosystem and Environmental Conditions	Assessment Data Inputs	Assessment Model Fits and Structural Uncertainty
• Recruitment: Recent strong recruitment is considered under the assessment data inputs. [Not Scored]	• Catch reconstructions (landings and discards) date back to the early 1900s for hook-and-line and trawl fisheries. Foreign landings records began in the 1960s. [Neutral]	• Age data generally fit well with realistic selectivity assumptions. Estimates of recent large cohorts were robust across sensitivity runs. The model estimates recent recruitments based on age data and the recruitment index. [Favorable]
• Habitat: The center of gravity for sablefish biomass has shifted approximately 2° northward in recent years. [Unknown]	• There is high confidence in the primary fishery-independent survey (WCGBTS). Sablefish also occur deeper than the survey samples. [Favorable]	• Natural mortality was estimated but assumed to be constant for all life stages and across time and space. Natural mortality was set to be equal by sex based upon similar model estimates. [Neutral]
• Prey: Increased euphausiid and juvenile hake biomass suggest adequate prey availability for sablefish in recent years. [Favorable]	• An informative but highly uncertain environmentally driven recruitment index was incorporated into the assessment for the most recent 5 years. [Neutral]	• Steepness was fixed (h = 0.75) given life history and management (reference point) objectives. Available data are not informative of absolute stock size or productivity at small stock sizes. [Neutral]
• Predators: Sablefish consumption (by California sea lions, sperm whales, porpoises, skates, and fur seals) is unlikely to have changed in recent years, but there have been long-term increases in the abundance of some groups like sea lions. [Neutral]	• Age data have been relatively well sampled. The WCGBTS provides coastwide age data and ages are available from the fishery for the last 40 years but lack coastwide sampling in recent years. Data to inform recent recruitment is well represented. There are known challenges and uncertainty in ageing. [Favorable]	• There is variation in maturity, growth, and potentially other biological processes across the latitudinal range that is partially captured in the model. [Neutral]
• Competition: There is potential for competition between sablefish and Pacific hake (e.g., for euphausiids). Changes in competitive interactions are highly uncertain given limited information about prey availability and spatiotemporal overlap with potential competitors. Recent large recruitments increase the likelihood of intraspecific, density-dependent, competition. [Unfavorable]	• Time-varying growth relies on empirical weight-at-age and is integrated across latitudes according to survey biomass. [Favorable]	• There is uncertainty with respect to biological stock boundaries, including movement across the Northeast Pacific. [Unfavorable]
	• Spatially explicit estimates of functional maturity account for latitudinal differences in productivity. [Favorable]	• Extensive sensitivity runs produced reasonable results and changes were generally similar relative to base model results. There were little to no retrospective patterns or other diagnostic issues. The model produces stable jitters and parameter estimates that did not considerably vary by data source or as a result of structural changes. [Favorable]
Level 2: neutral	Level 1: favorable	Level 1: favorable

8 Figures

8.1 Assessment Area

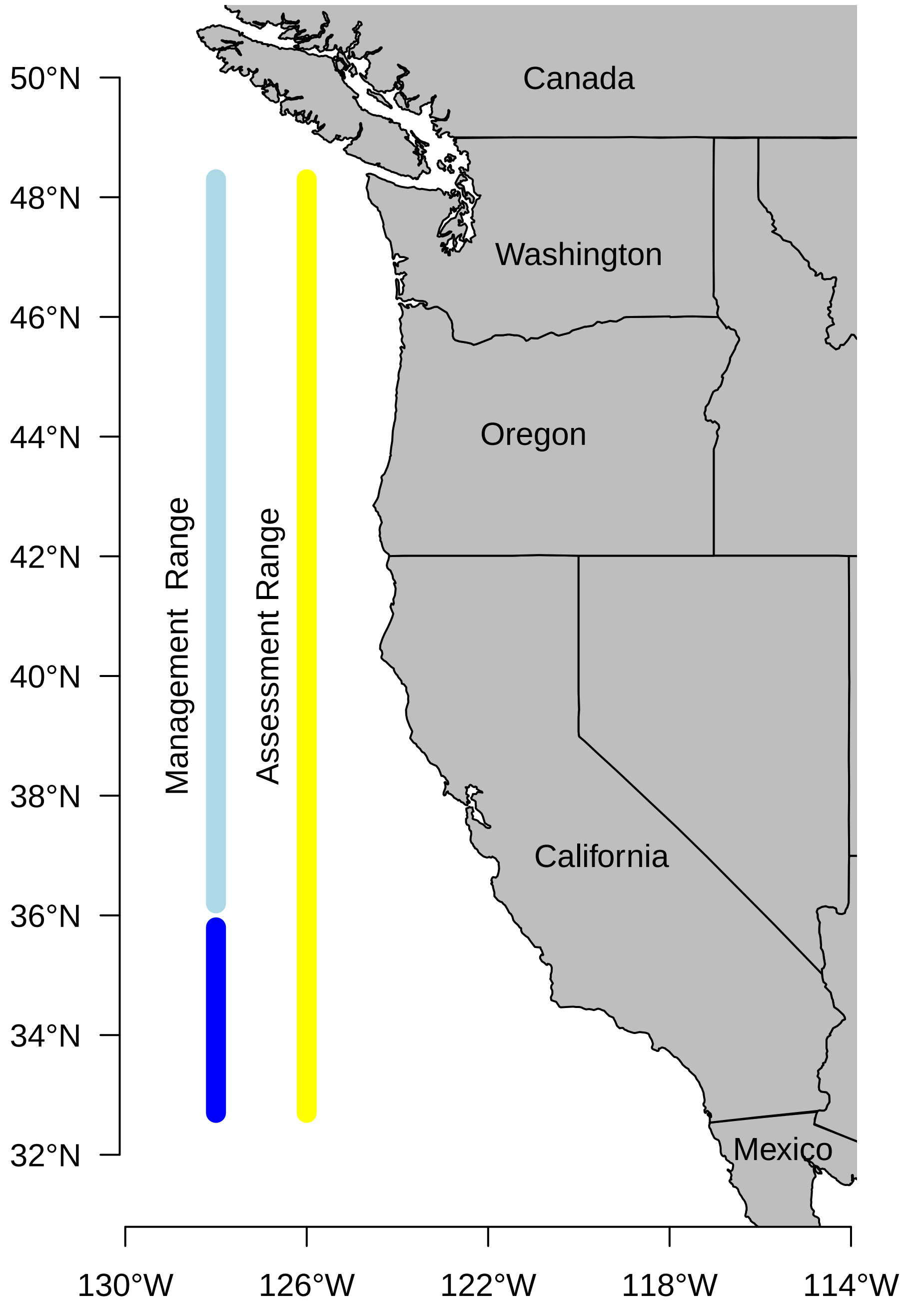

Figure 1: Map of the assessment area and management areas for sablefish off the U.S. West Coast.

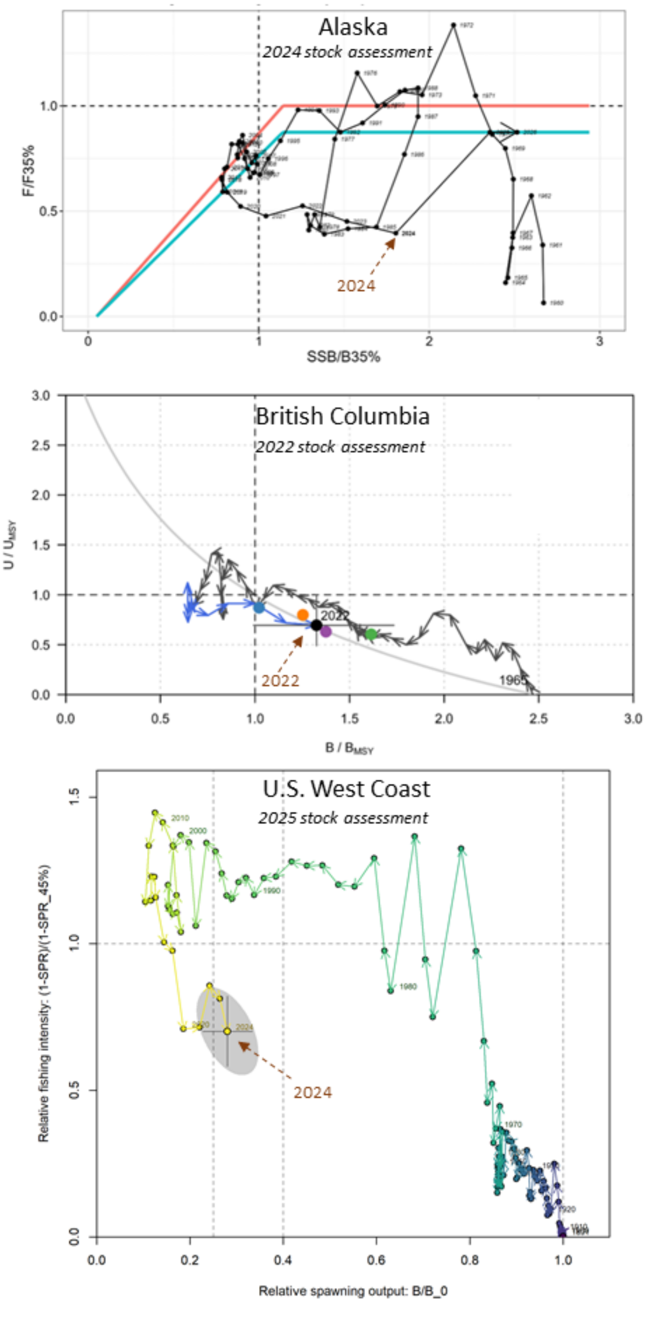

Figure 2: Time series of sablefish biomass-based and fishing-based estimates of status in Alaska, British Columbia, and along the U.S. West Coast from the most recent stock assessments. The arrow indicates estimates for the current year of the stock assessment. Vertical and horizontal axes differ by area due to region-dependent reference point use and specifications.

8.2 Data

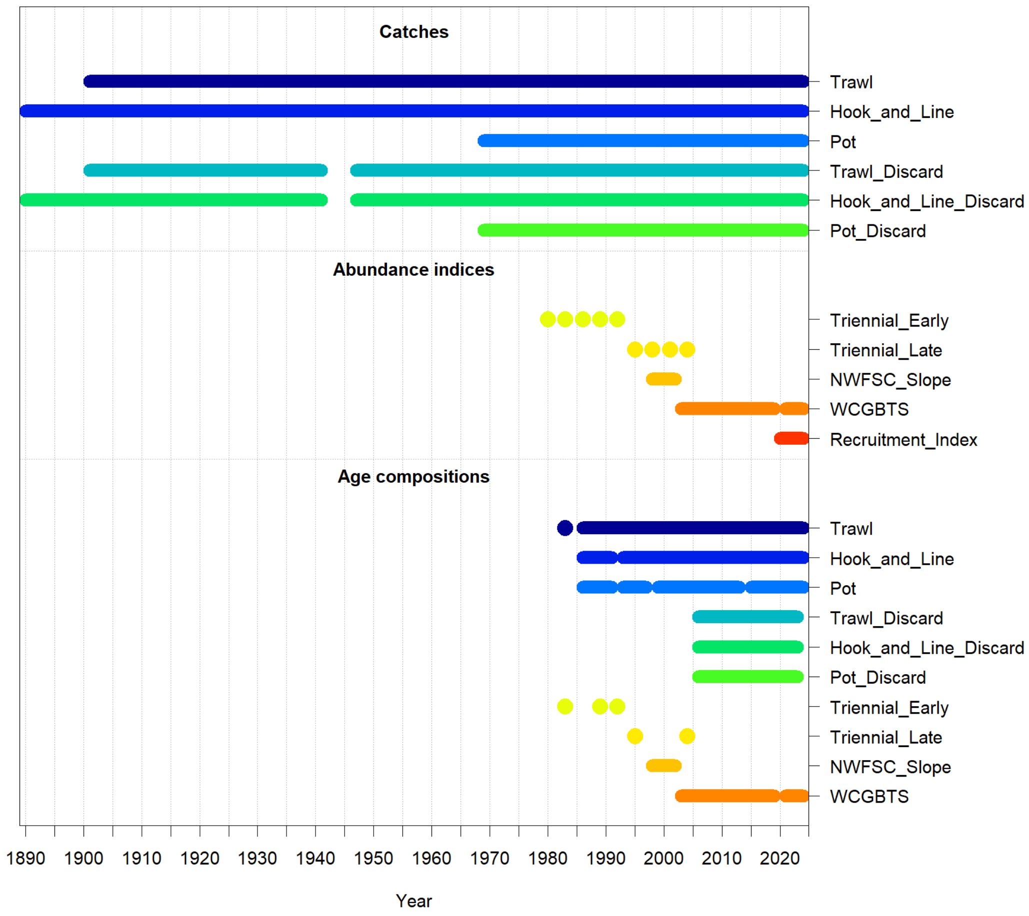

Figure 3: Data used in the base model.

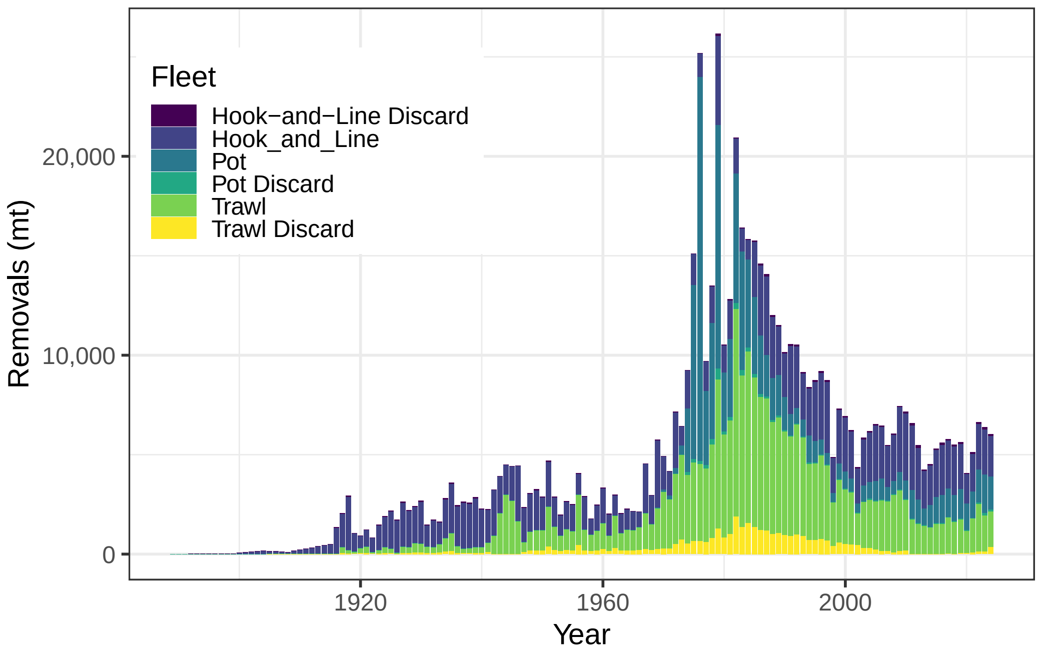

Figure 4: Removals in metric tons (mt) by year for trawl, pot, and hook-and line gears.

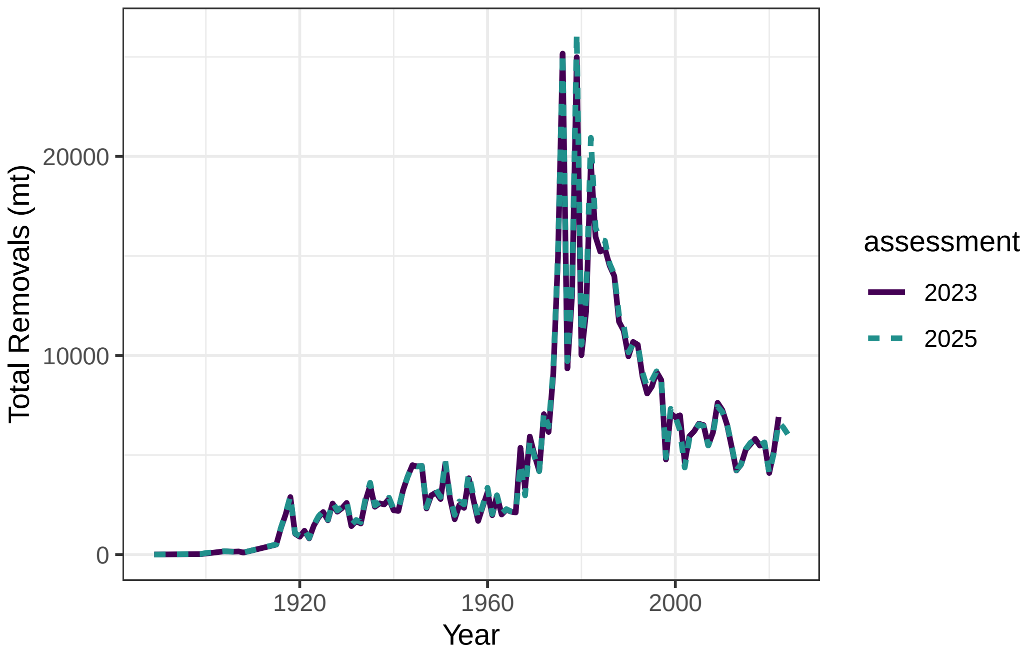

Figure 5: Comparison of the total removals in metric tons (mt) by year between this assessment and the 2023 assessment.

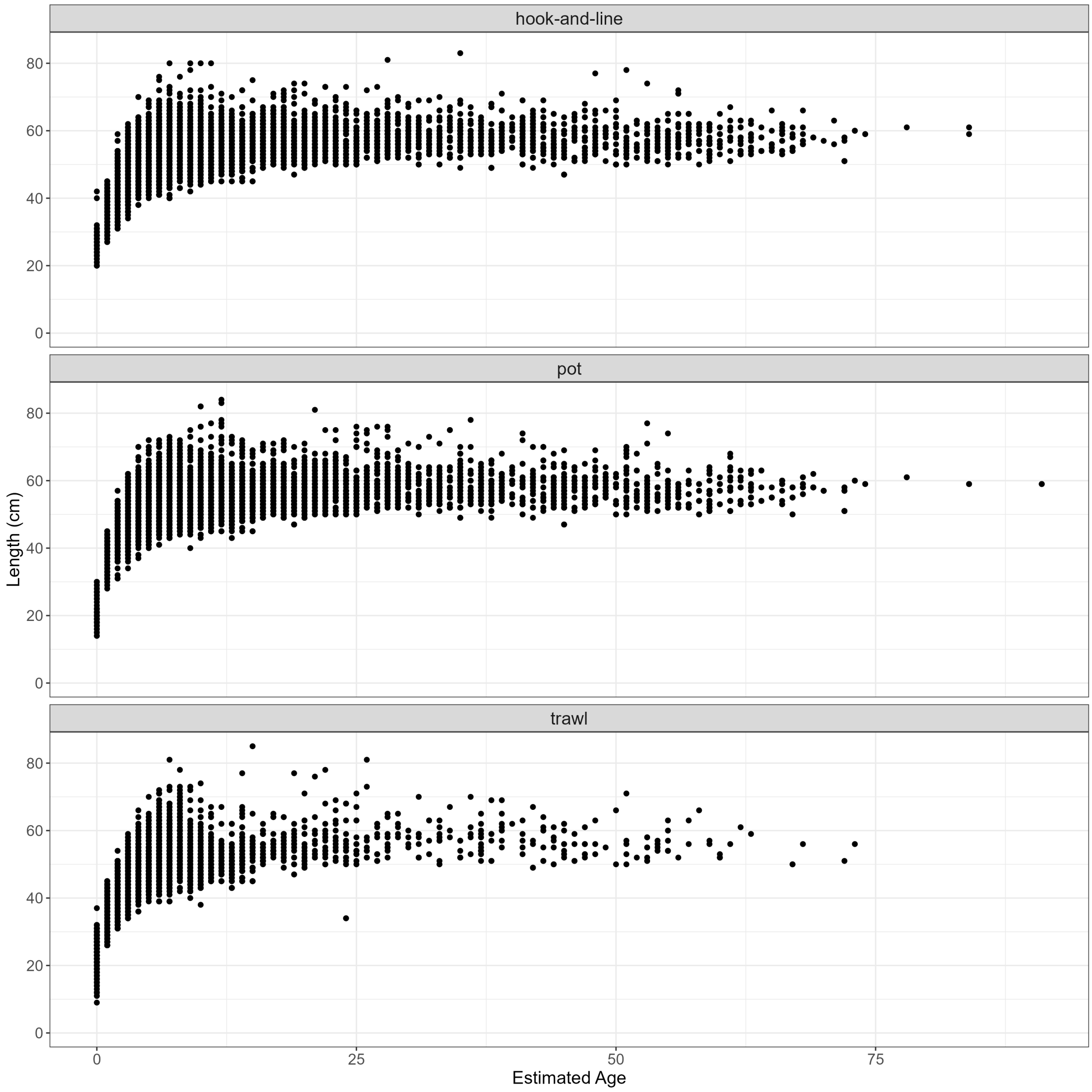

Figure 6: Comparison of estimated discard age by length for each gear type.

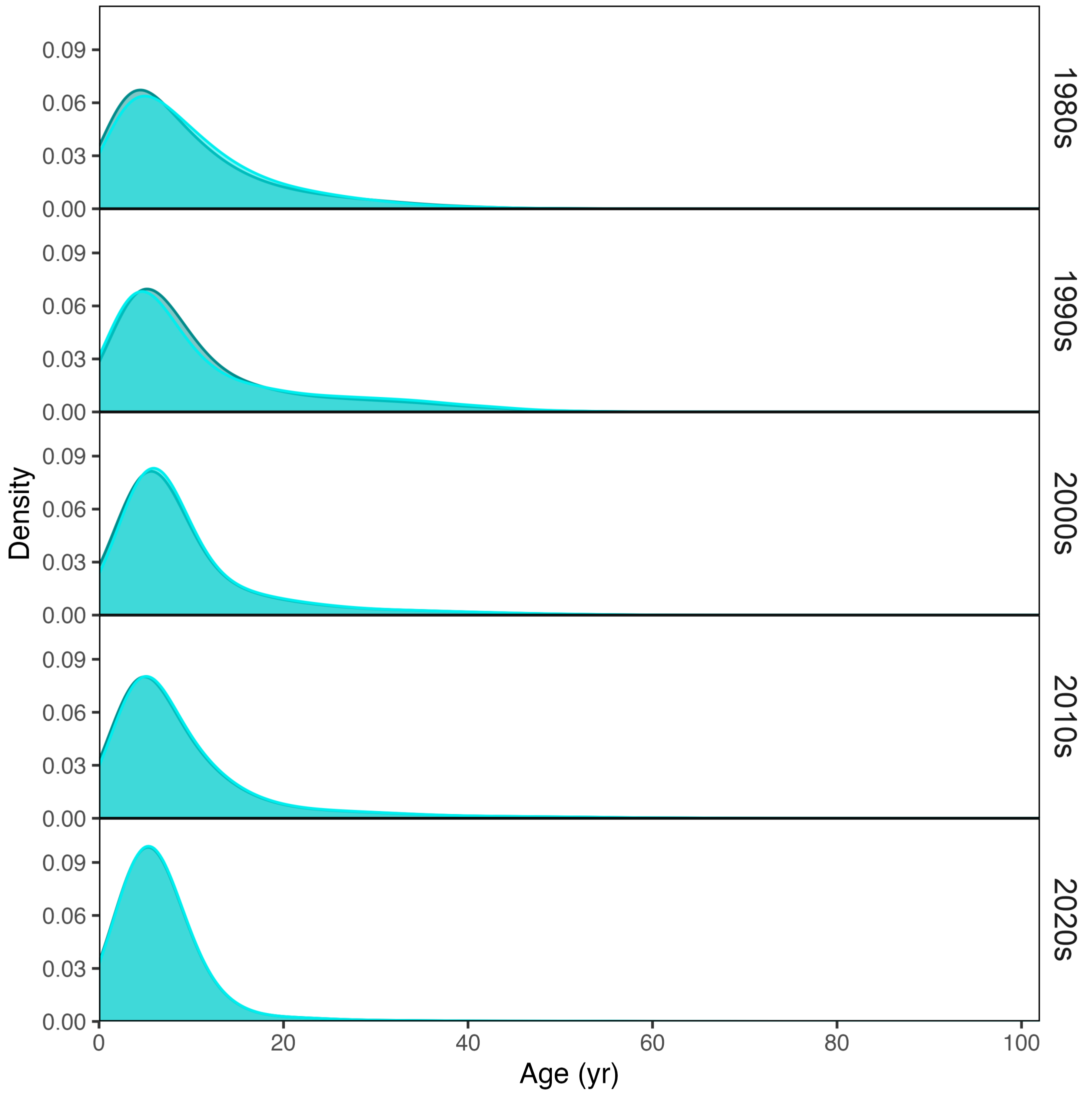

Figure 7: Distribution of ages before (dark color) and after (light color) removing samples without an ageing method assigned and those collected as part of special projects by decade.

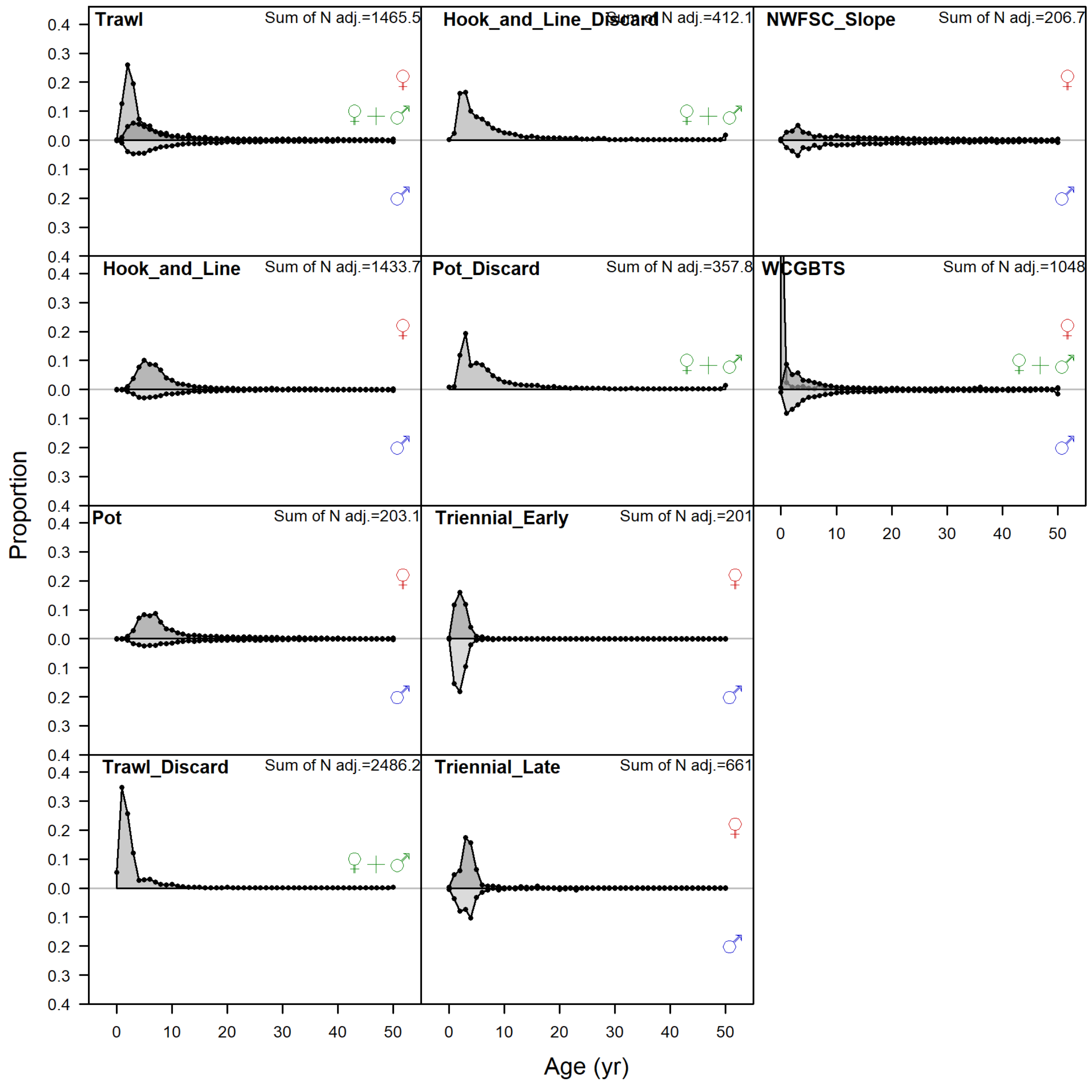

Figure 8: Aggregated ages across all years by fleet.

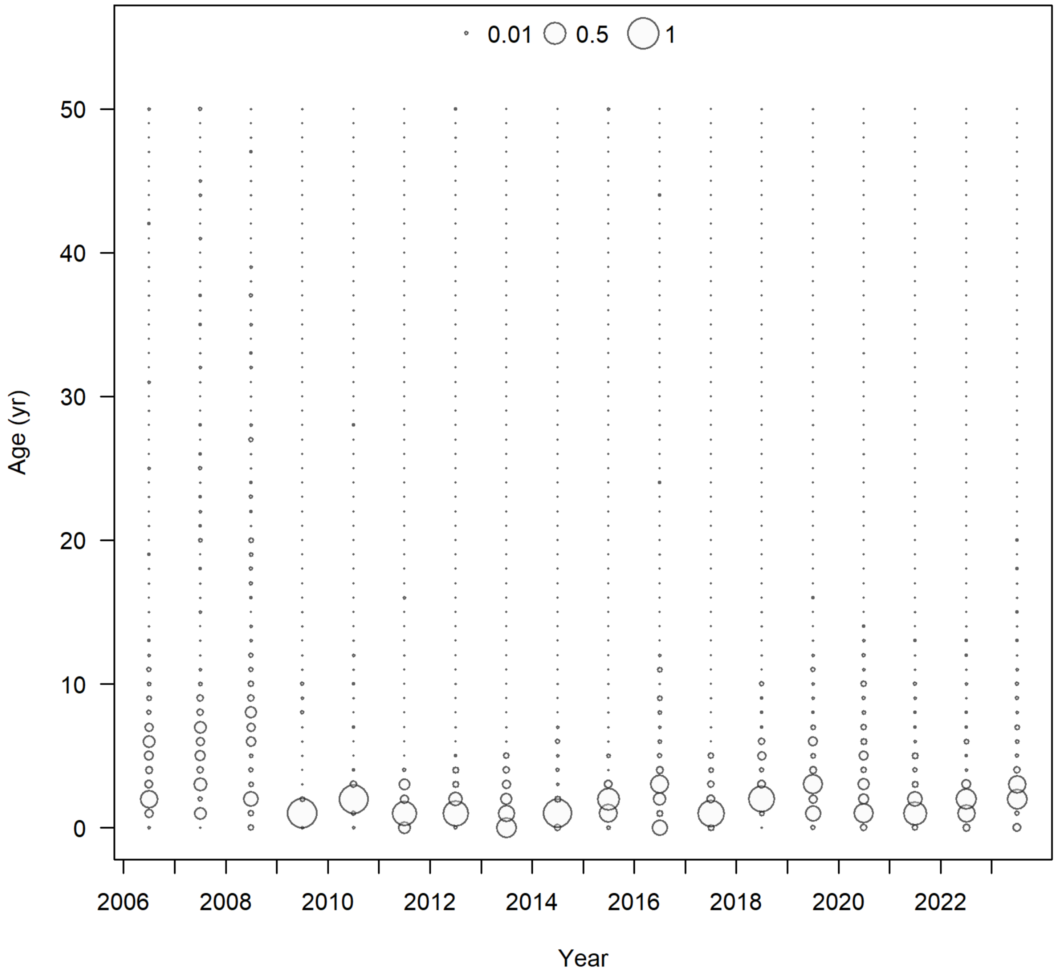

Figure 9: Ages by year for the trawl discard fleet. All ages are unsexed.

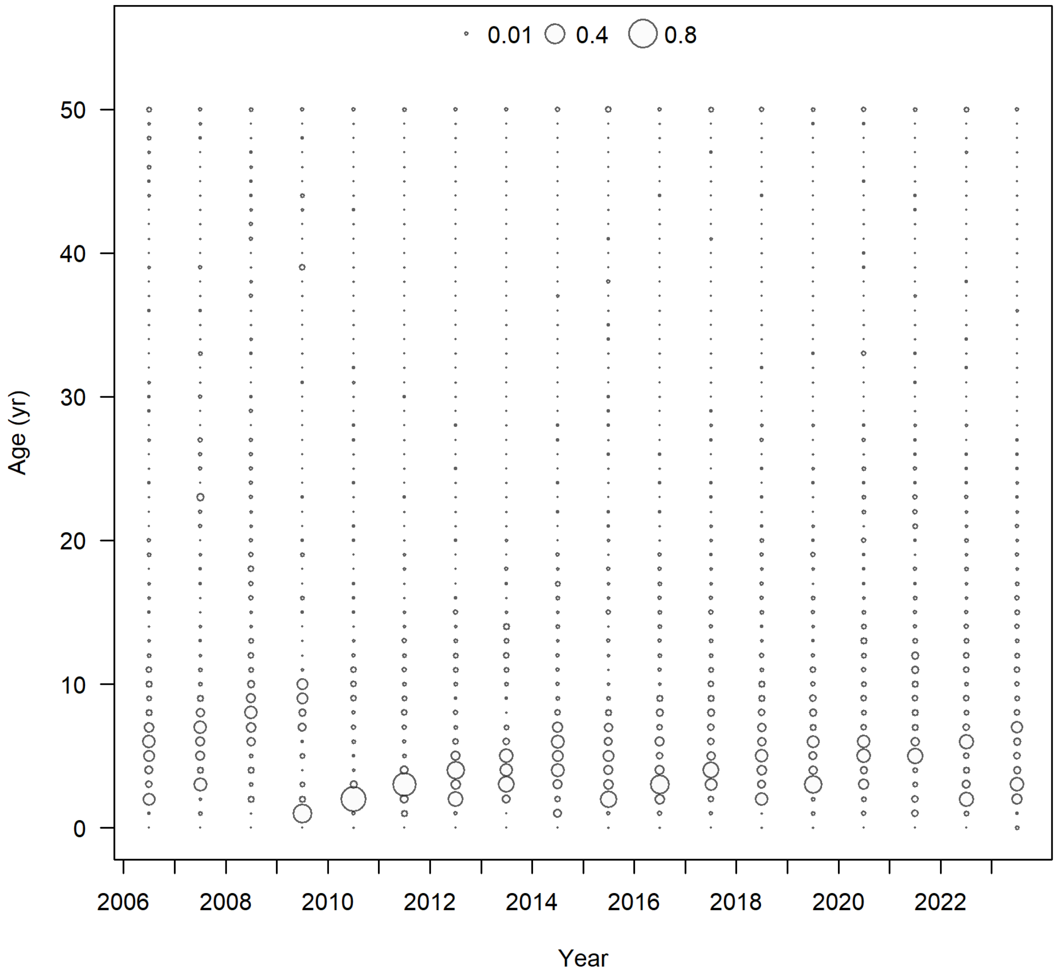

Figure 10: Ages by year for the hook-and-line discard fleet. All ages are unsexed.

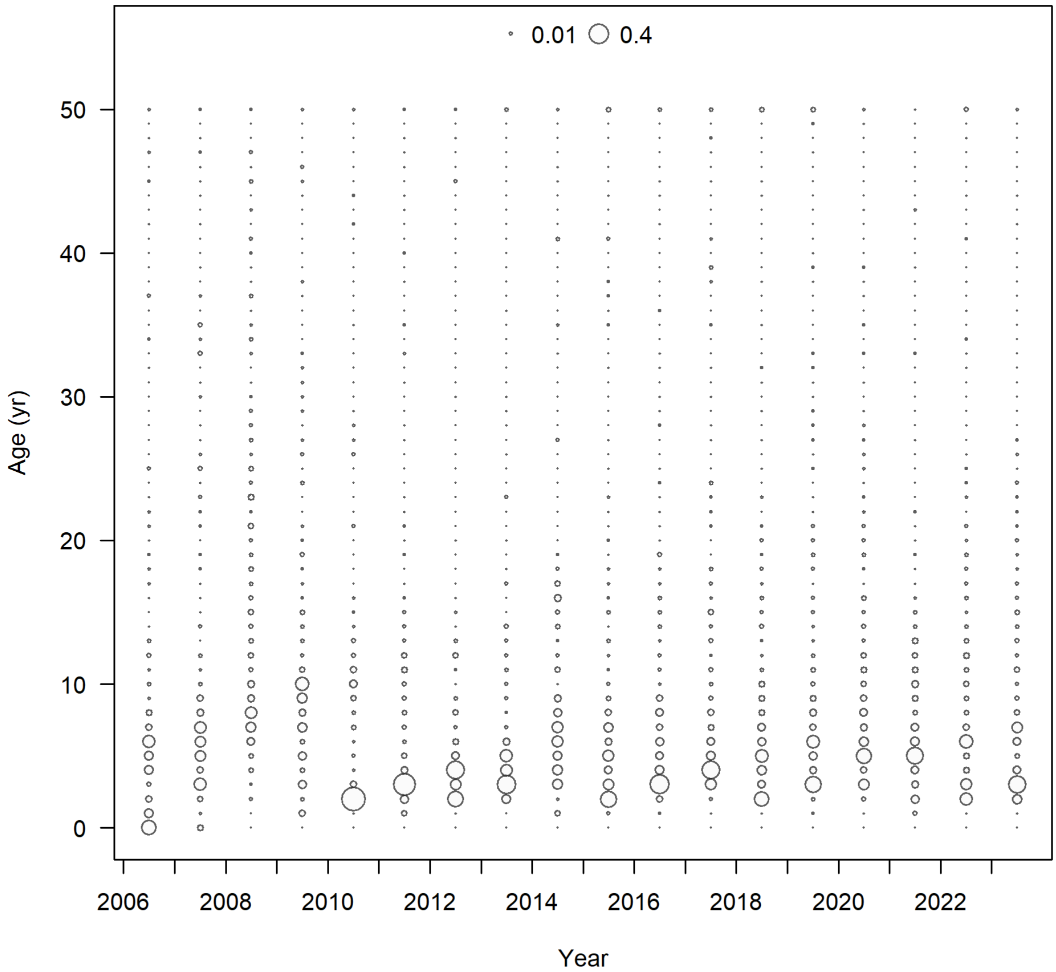

Figure 11: Ages by year for the pot discard fleet. All ages are unsexed.

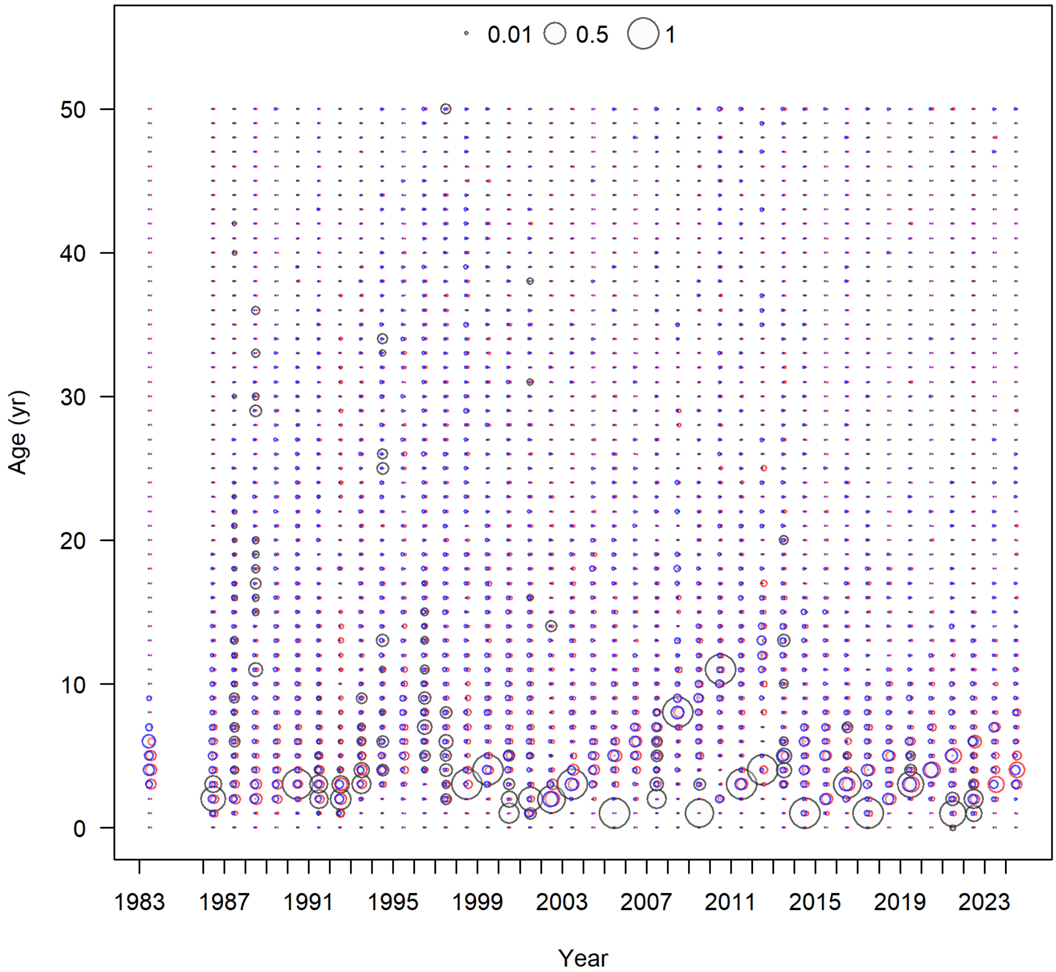

Figure 12: Age composition by year and sex for the trawl fleet. Females are shown in red, males in blue, and unsexed fish in grey.

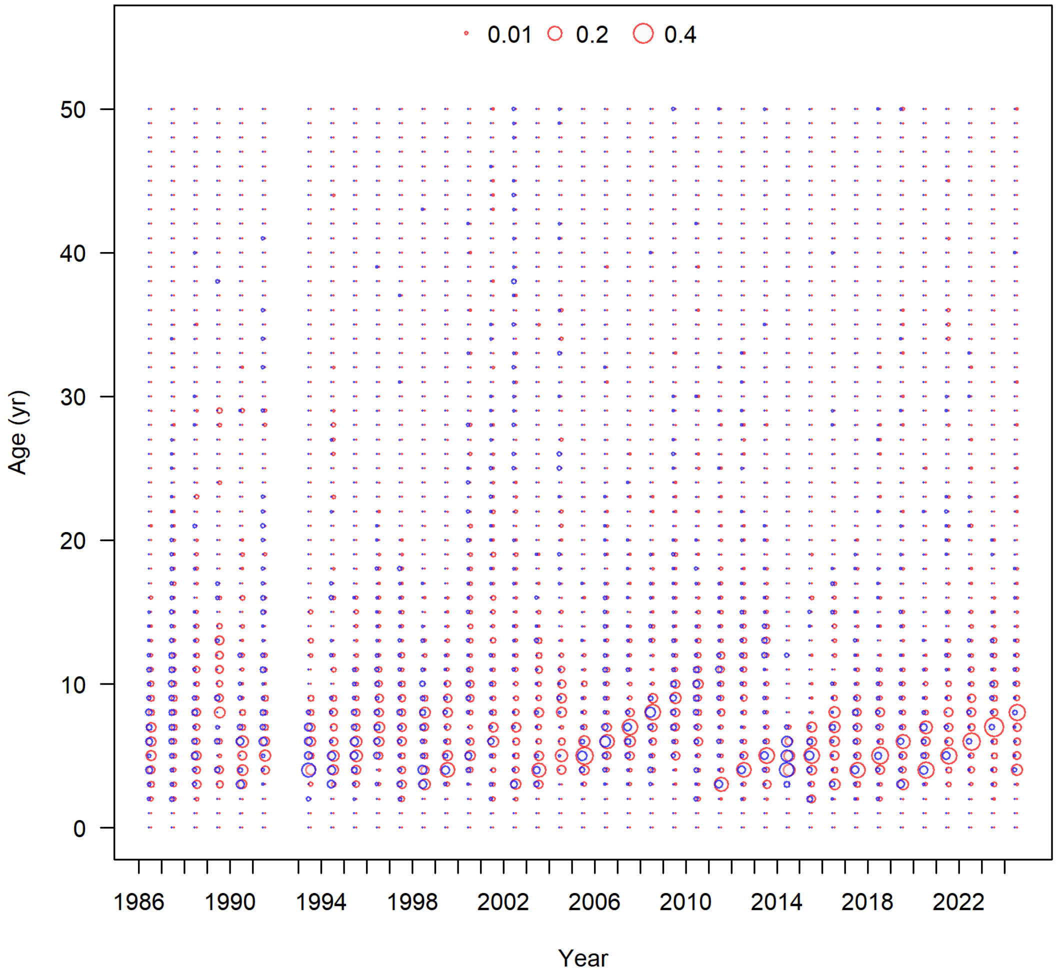

Figure 13: Age composition by year and sex for the hook-and-line fleet. Females are shown in red and males in blue.

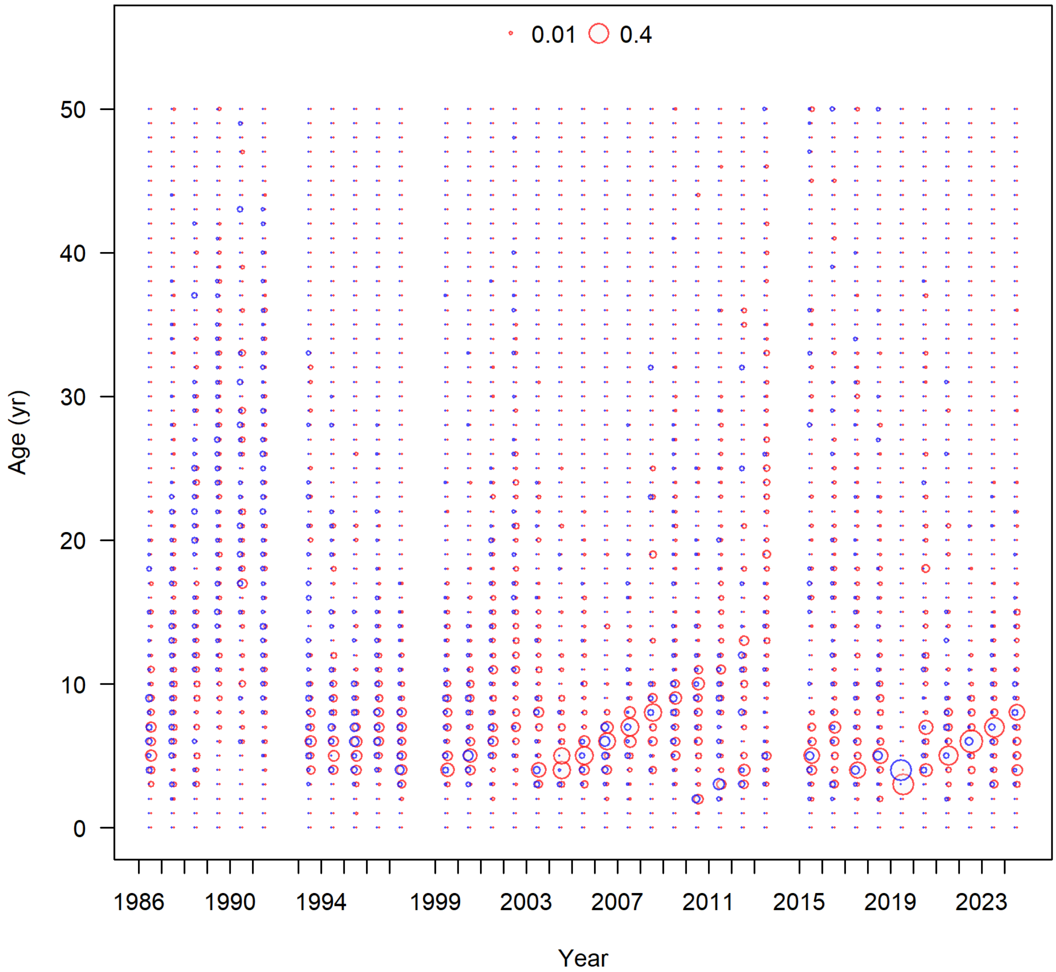

Figure 14: Age composition by year and sex for the pot fleet. Females are shown in red and males in blue.

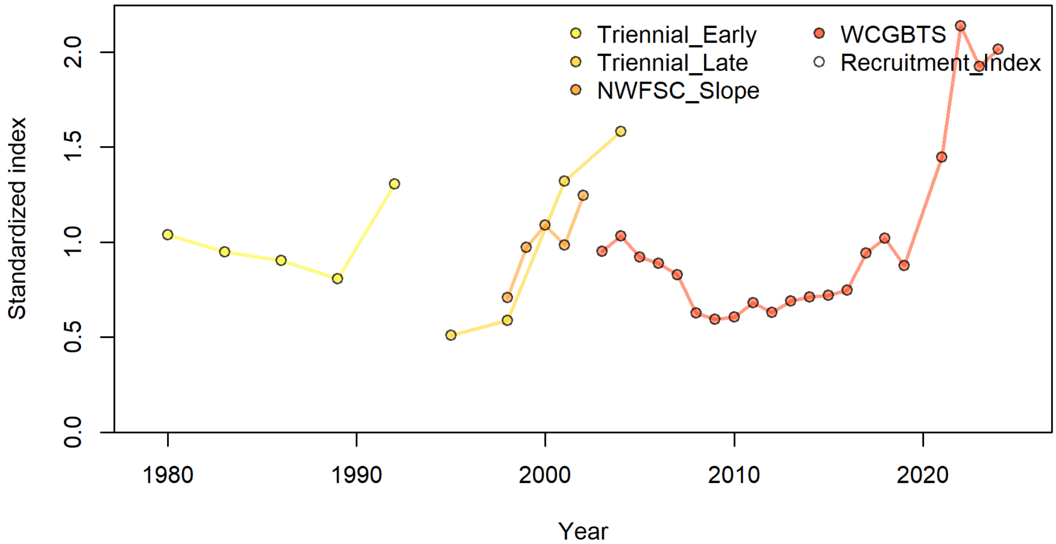

Figure 15: Relative indices of abundance used in the base model standardized and overlaid. Each index is rescaled to have mean observation = 1.0.

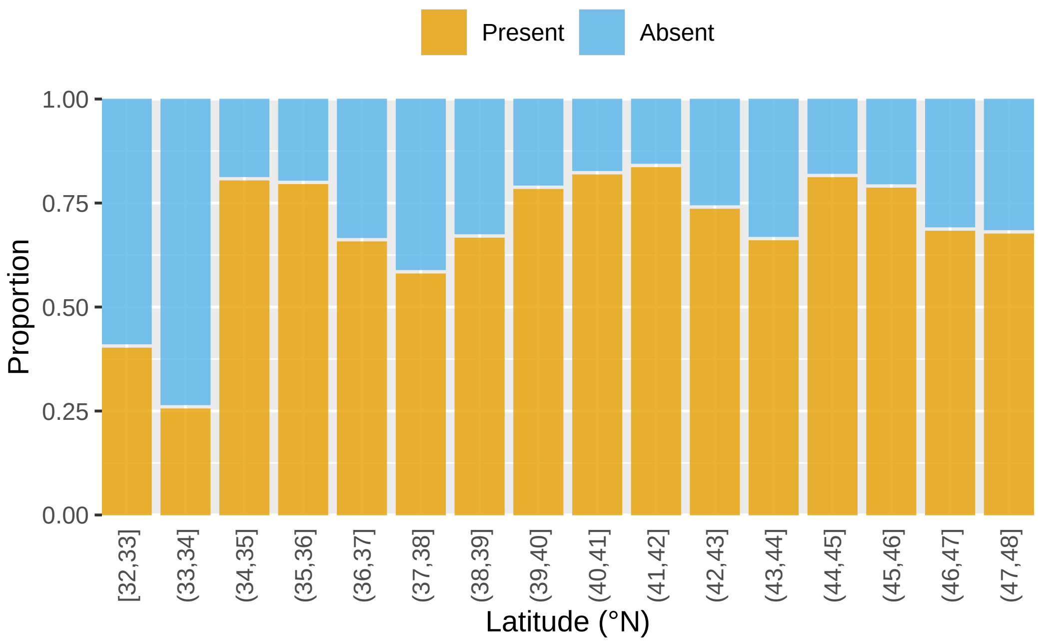

Figure 16: Proportion of tows where sablefish was present or absent across all years by latitude for the NWFSC West Coast Groundfish Bottom Trawl Survey.

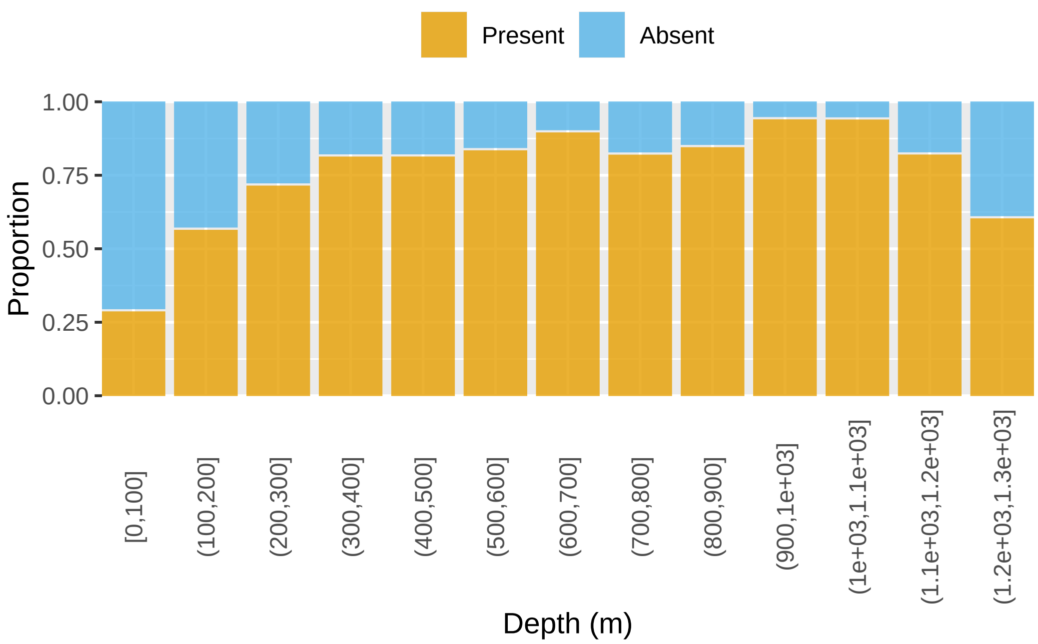

Figure 17: Proportion of tows where sablefish was present or absent across all years by depth (m) for the NWFSC West Coast Groundfish Bottom Trawl Survey.

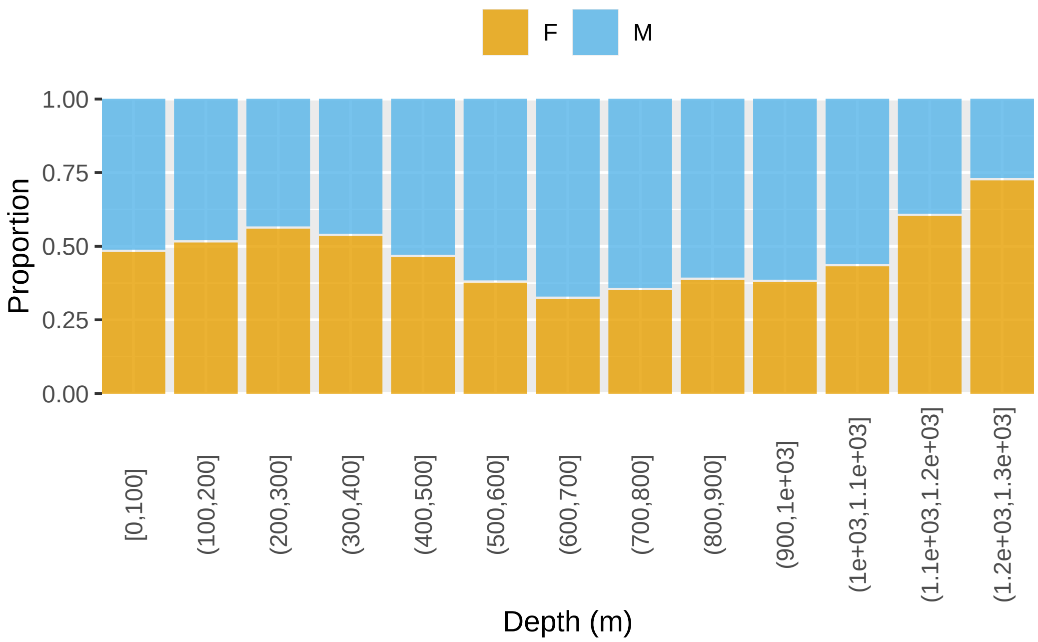

Figure 18: Sex ratio across all years by depth (m) for the NWFSC West Coast Groundfish Bottom Trawl Survey.

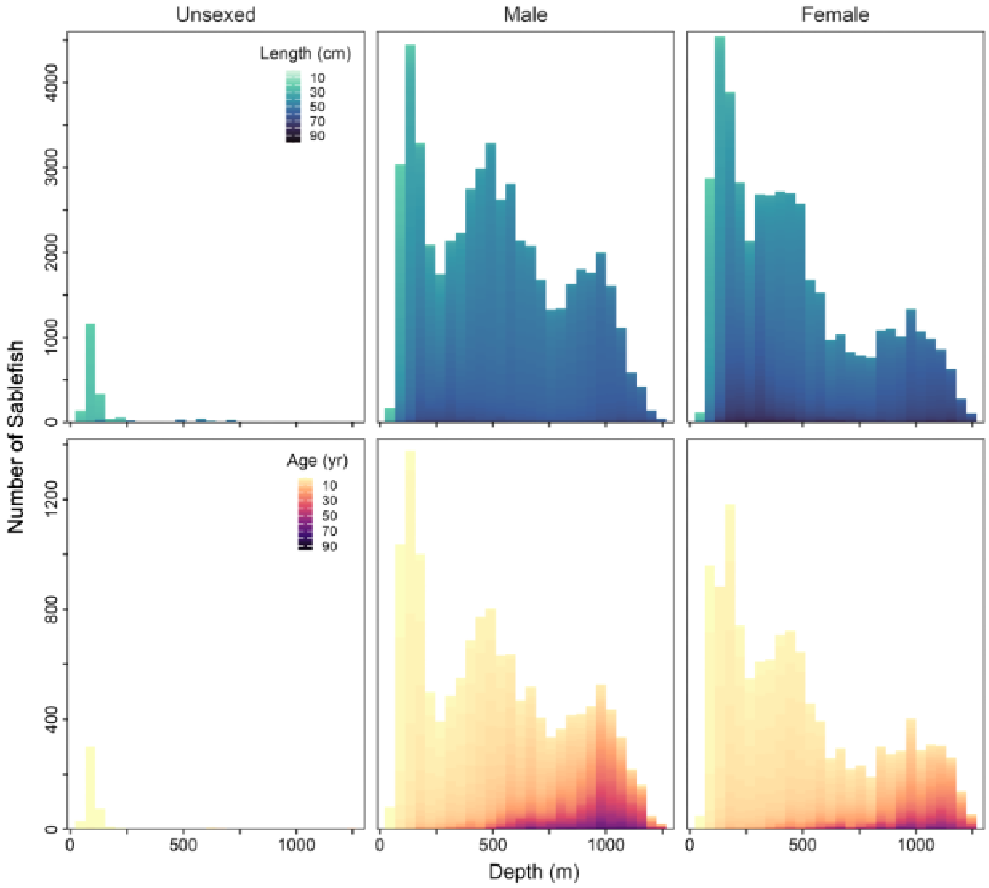

Figure 19: Length (top; cm) and age (bottom; yr) compositions for sablefish collected by the NWFSC West Coast Groundfish Bottom Trawl Survey between 2003 and 2024 by sex and depth (m). Lighter colors represent smaller or younger individuals and darker colors represent larger or older individuals.

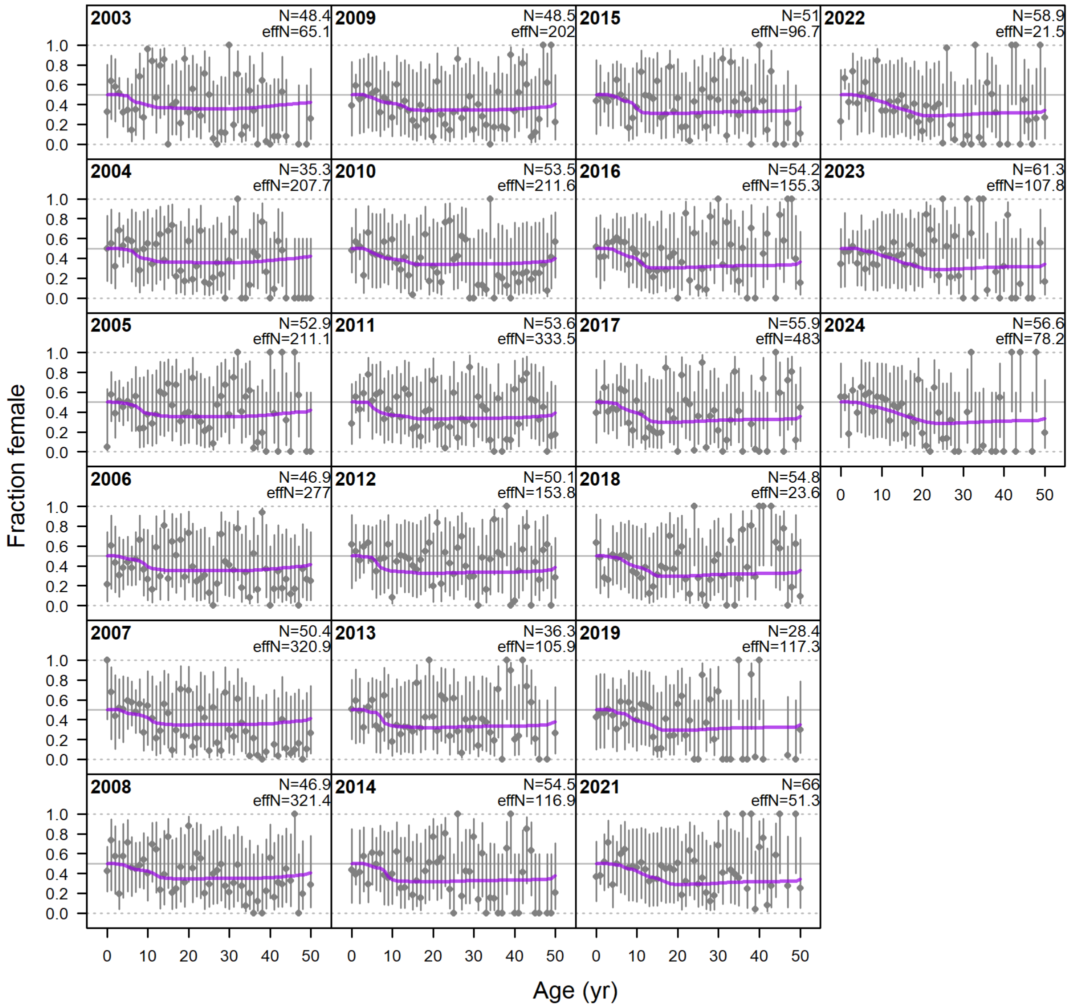

Figure 20: Observed fraction female by age in the NWFSC West Coast Groundfish Bottom Trawl Survey by year.

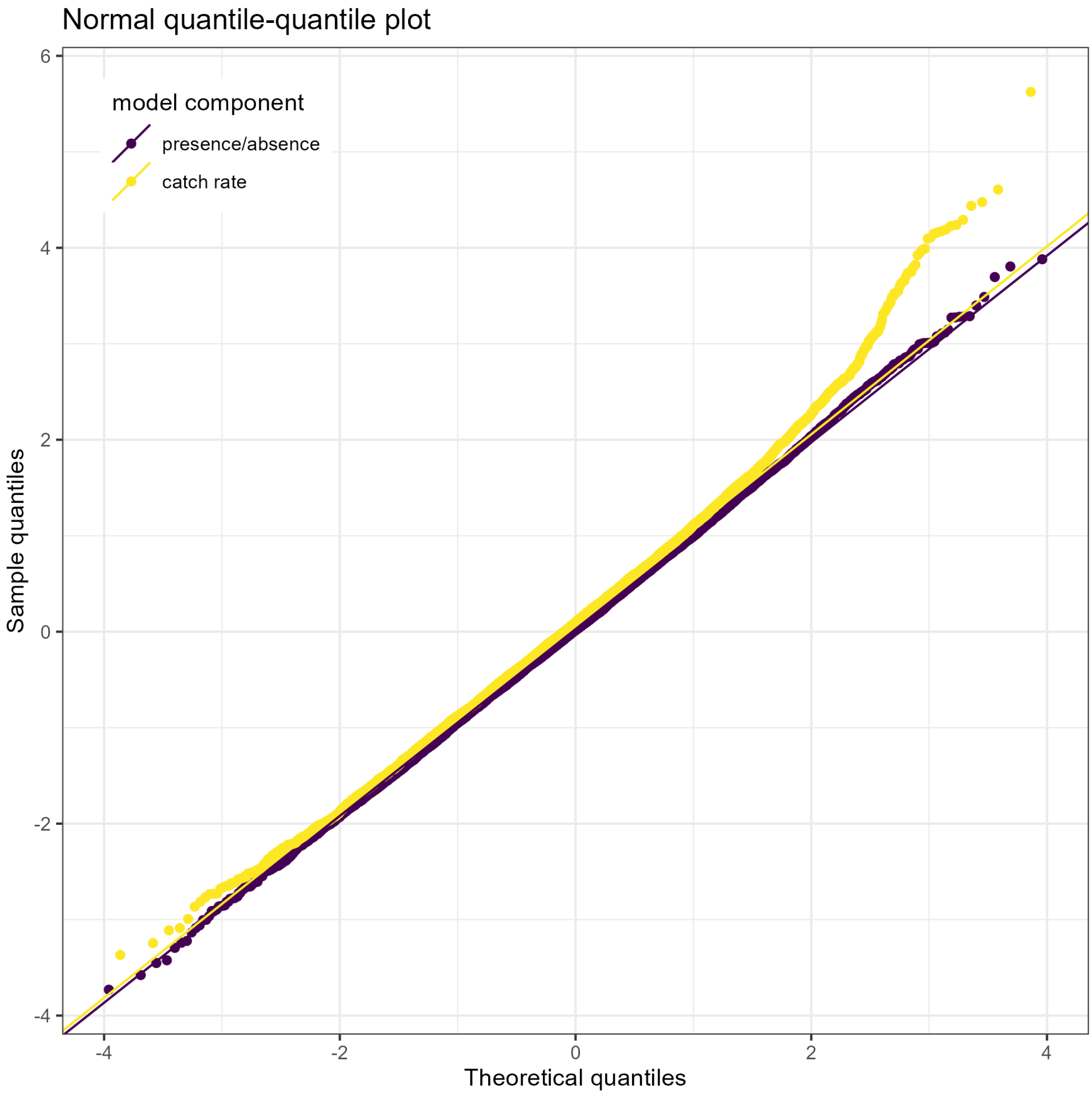

Figure 21: QQ plot for the NWFSC West Coast Groundfish Bottom Trawl Survey.

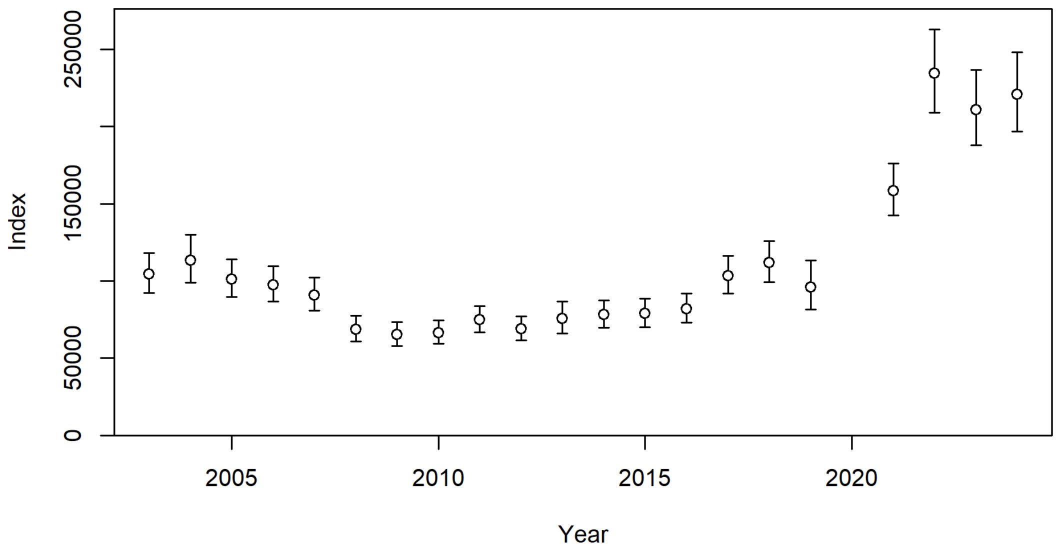

Figure 22: Relative index of abundance for the NWFSC West Coast Groundfish Bottom Trawl Survey.

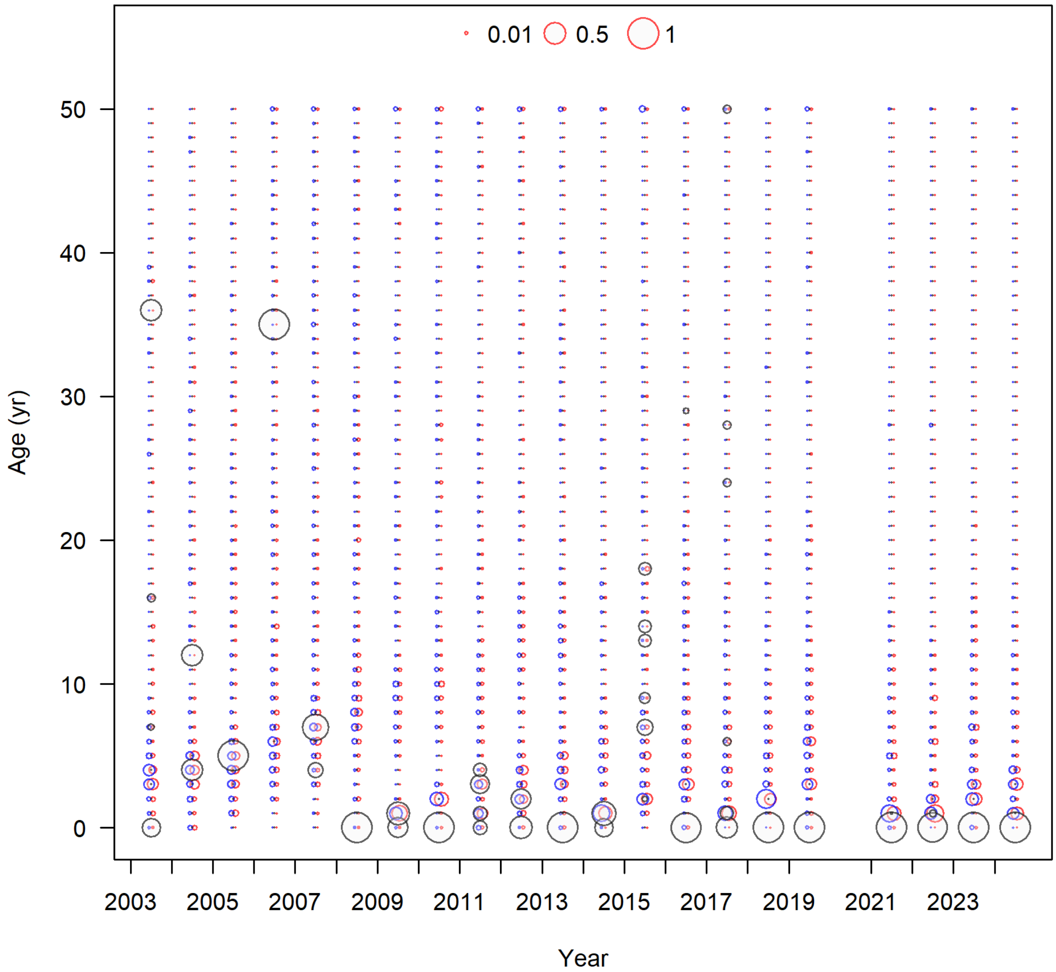

Figure 23: Age composition data by year from the NWFSC West Coast Groundfish Bottom Trawl Survey. Females are shown in red, males in blue, and unsexed fish in grey.

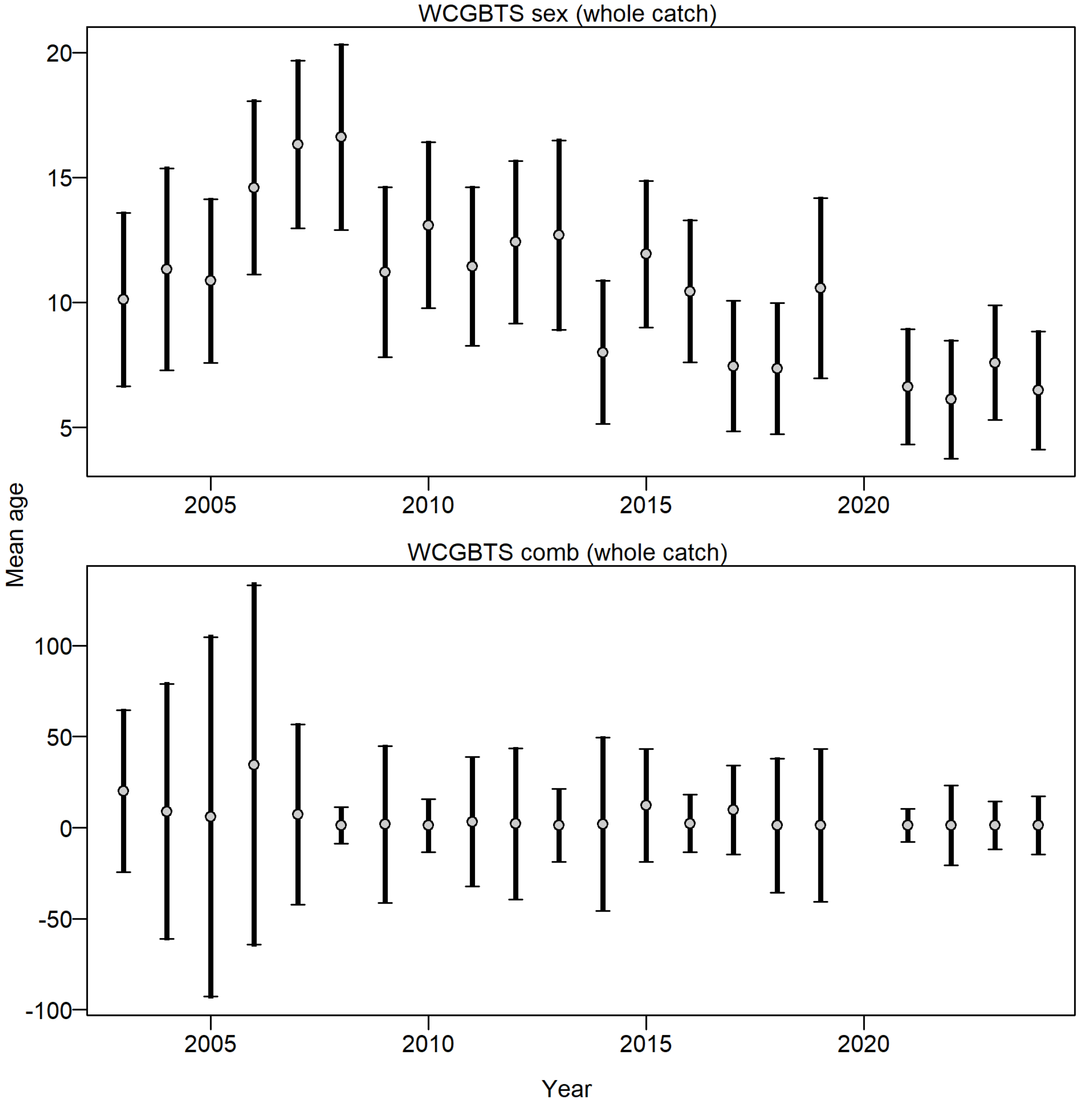

Figure 24: Mean age for NWFSC West Coast Groundfish Bottom Trawl Survey with 95 percent confidence intervals based on current sample sizes. The top panel is sexed ages only and the bottom panel includes both sexed and unsexed ages.

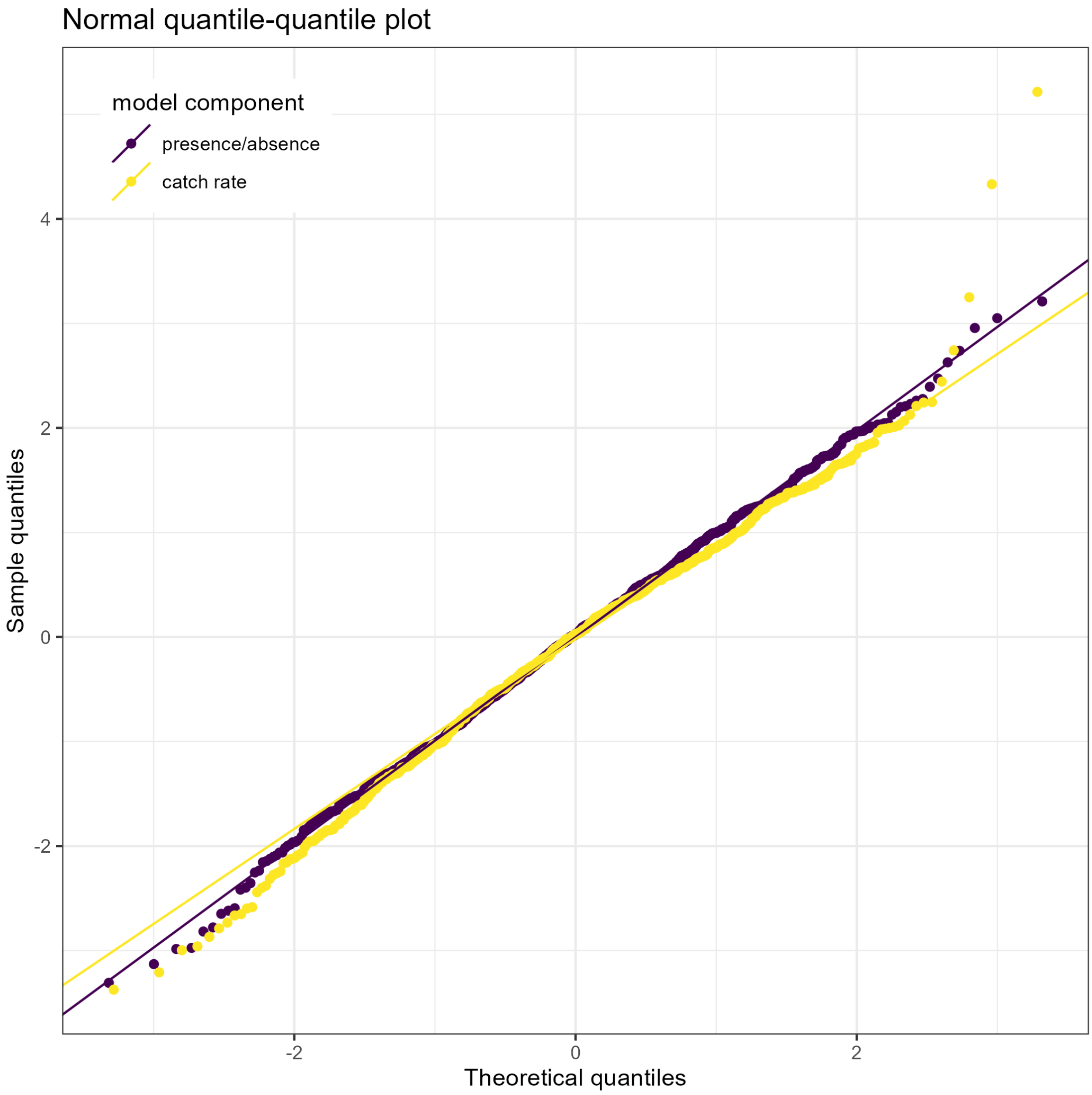

Figure 25: QQ plot for the NWFSC Slope Survey.

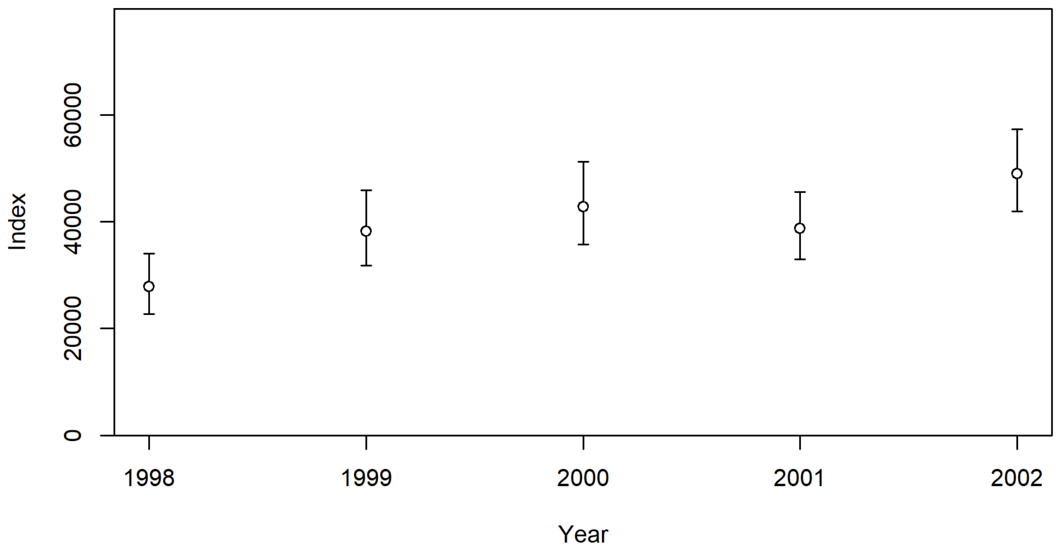

Figure 26: Relative index of abundance for the NWFSC Slope Survey.

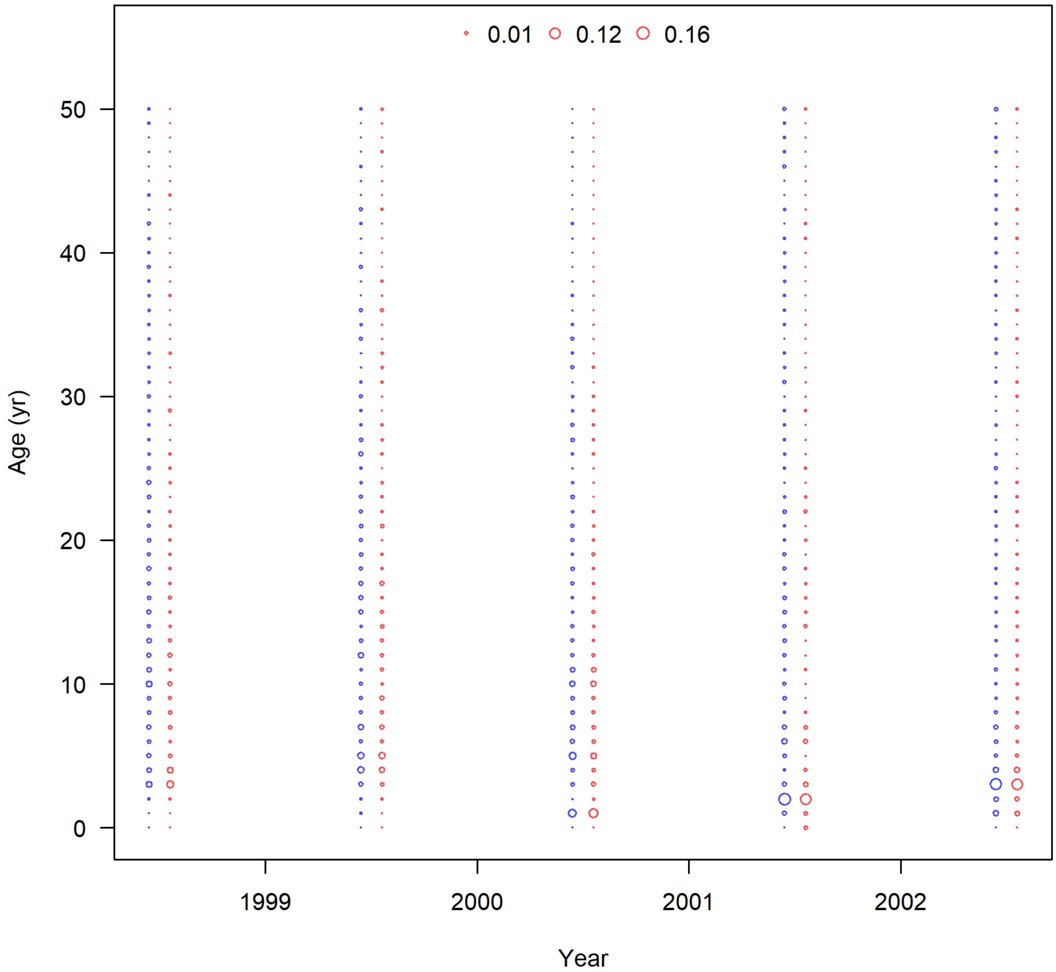

Figure 27: Age compositions by year from the NWFSC Slope Survey. Females are shown in red, males in blue, and unsexed fish in grey.

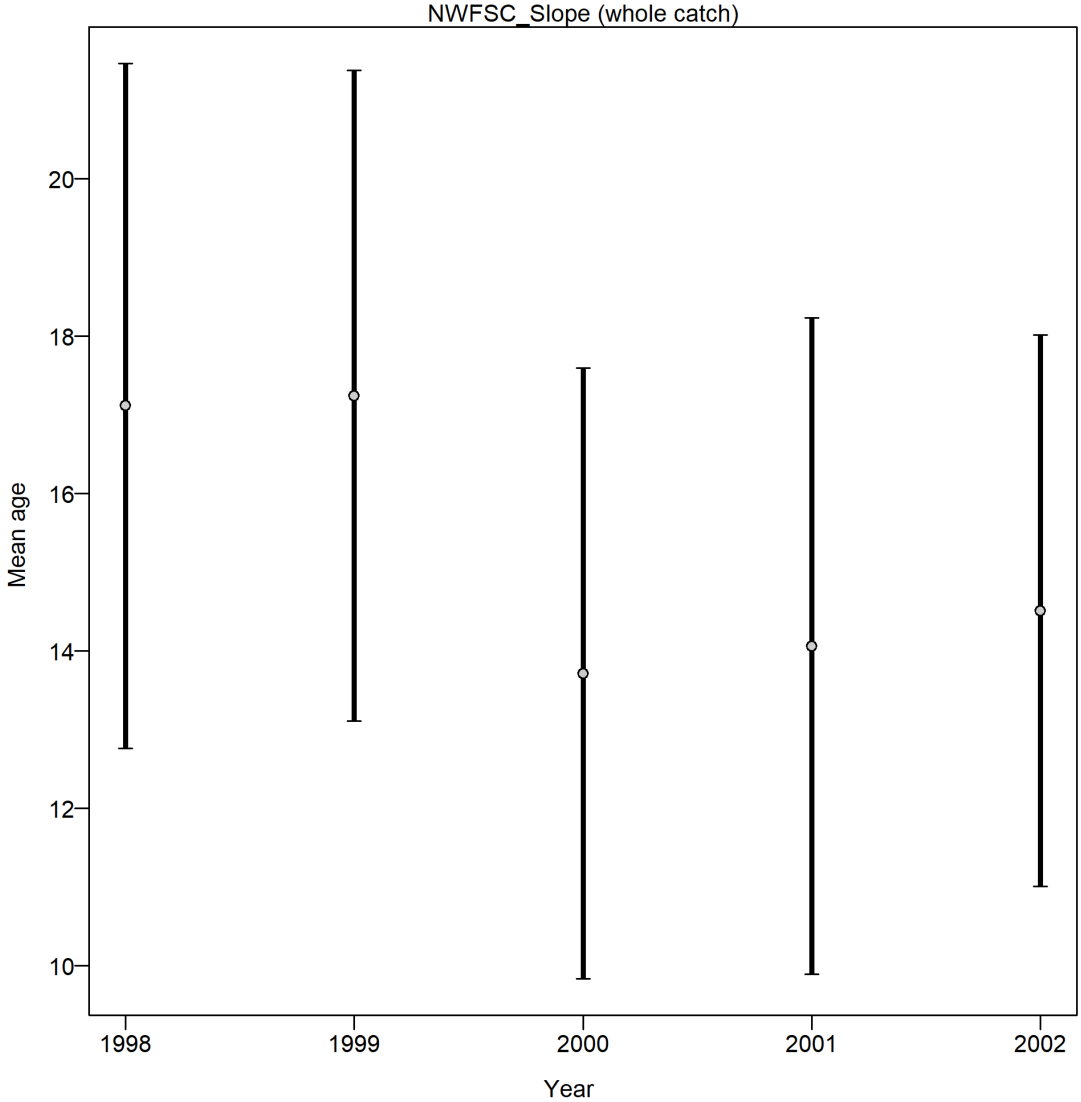

Figure 28: Mean age for NWFSC Slope Survey with 95 percent confidence intervals based on current sample sizes.

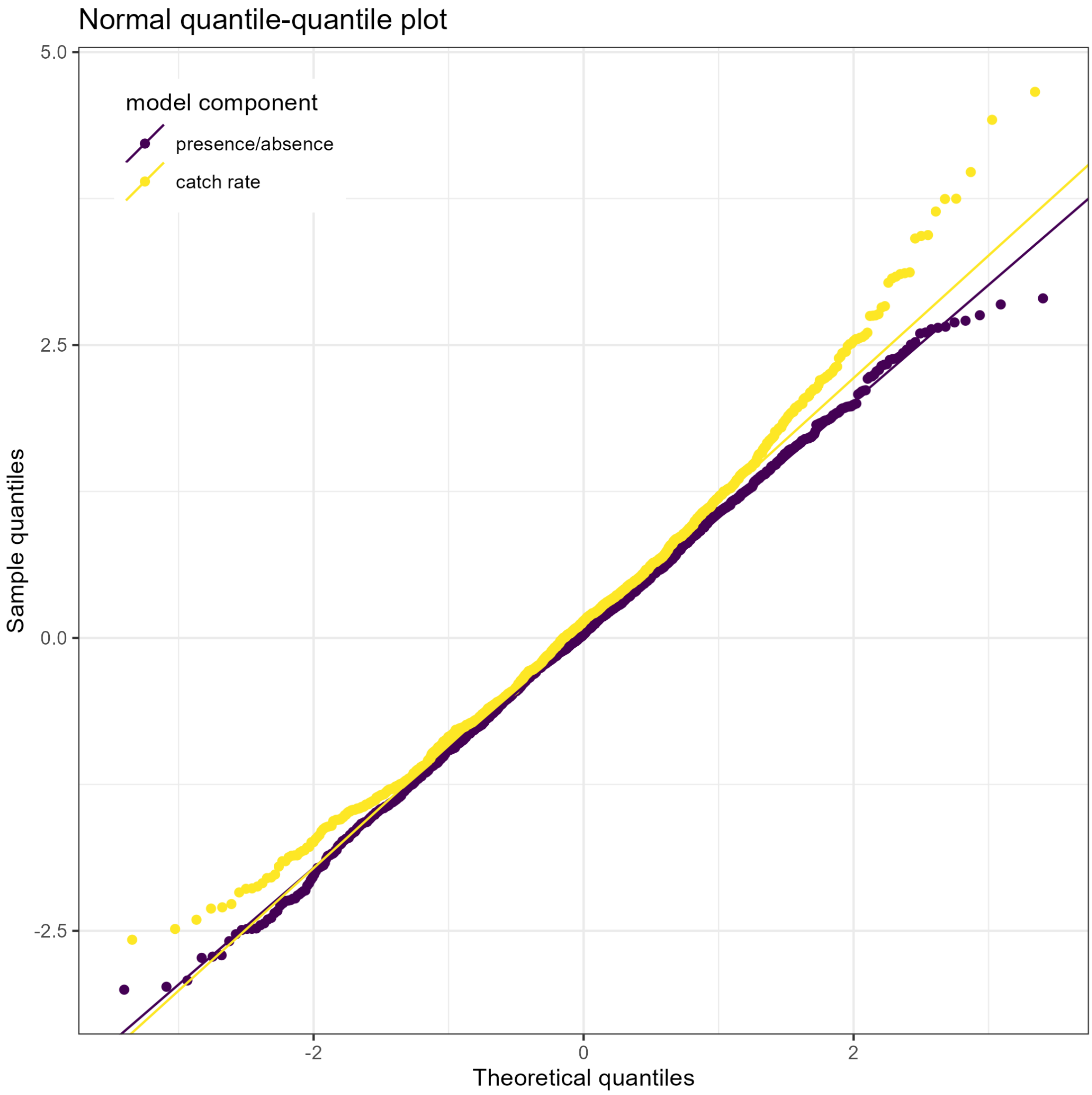

Figure 29: QQ plot for the Triennial Survey for the early period, 1980-1992.

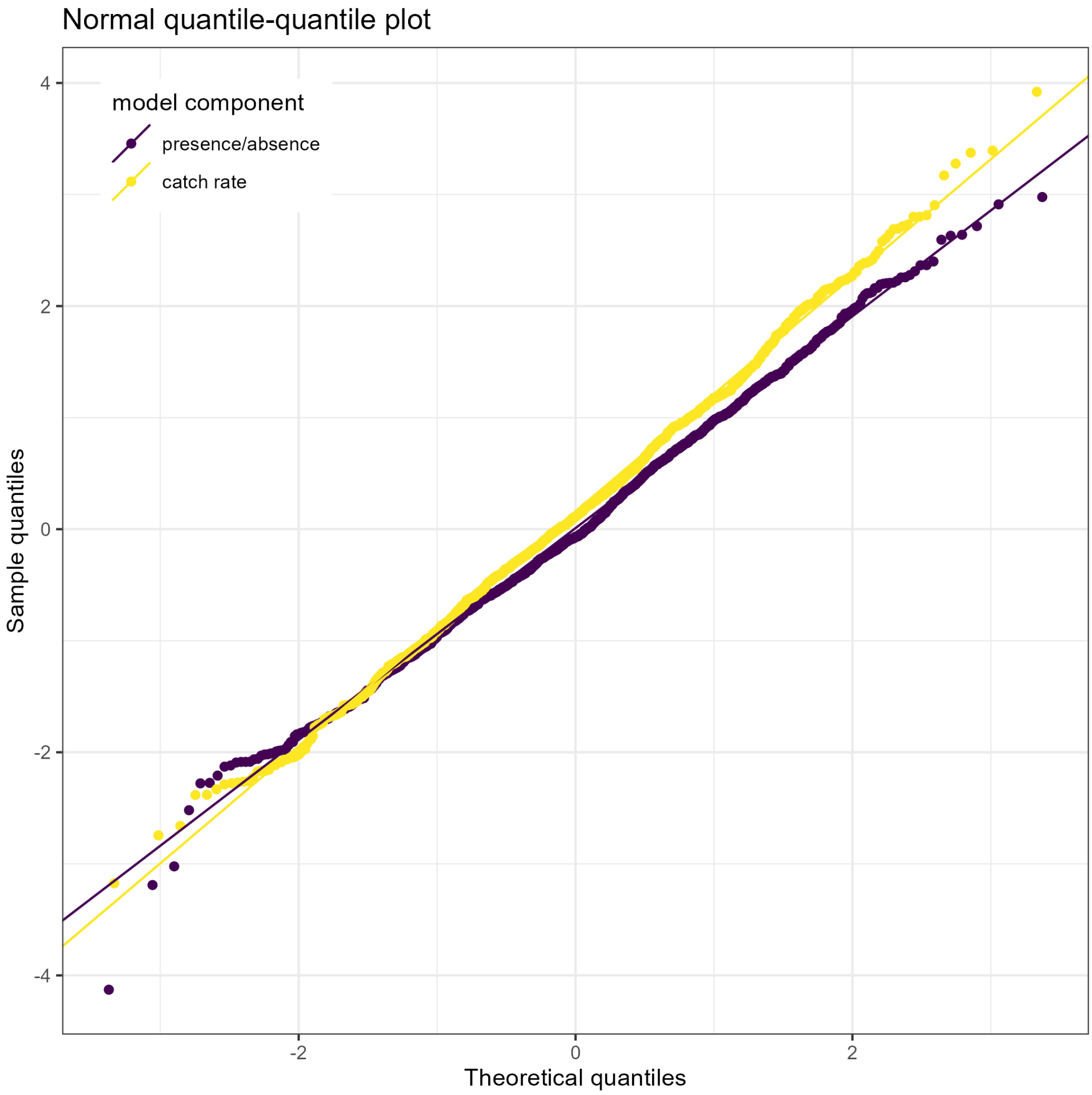

Figure 30: QQ plot for the Triennial Survey for the late period, 1995-2004.

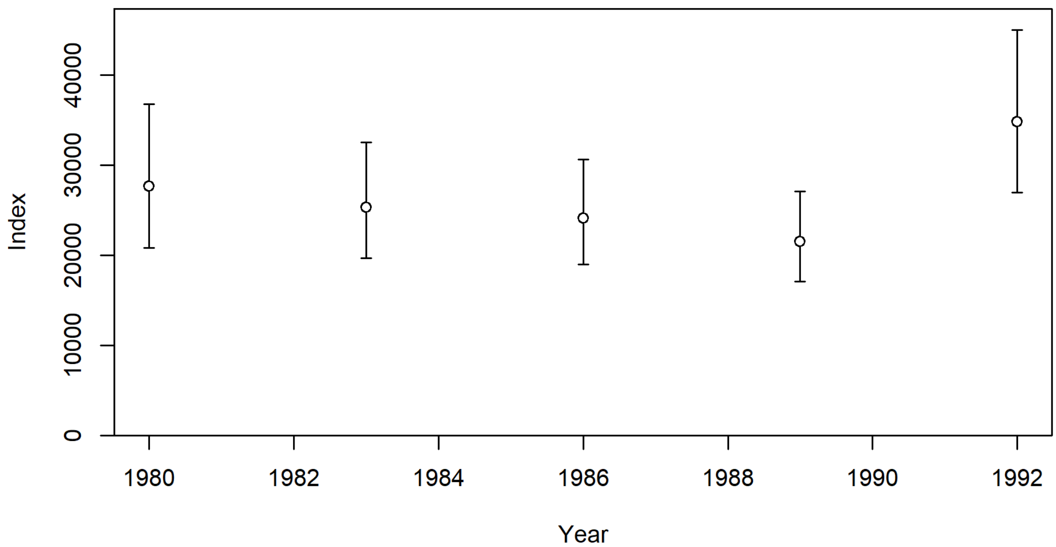

Figure 31: Relative index of abundance for the Triennial Survey for the early period, 1980-1992.

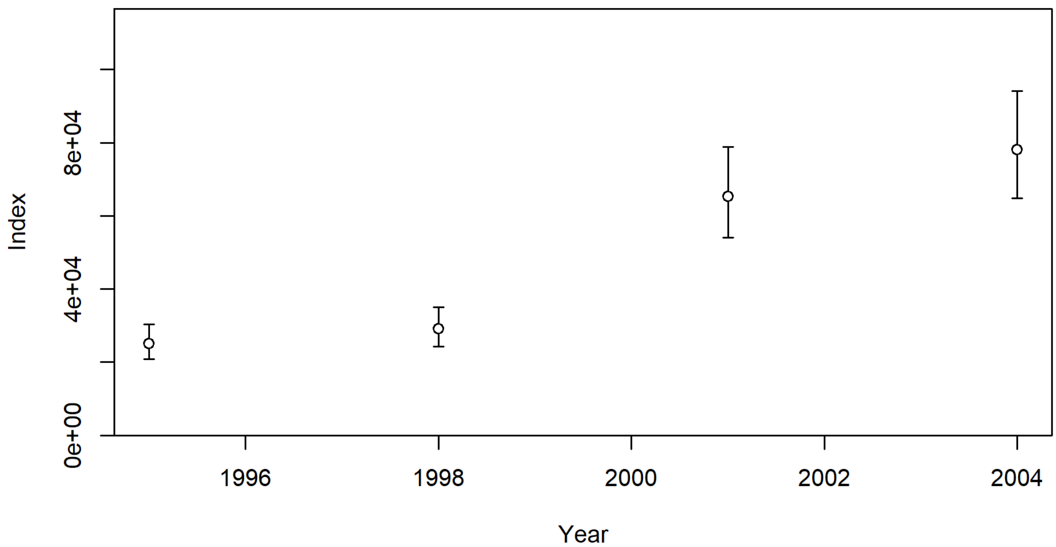

Figure 32: Relative index of abundance for the Triennial Survey for the late period, 1995-2004.

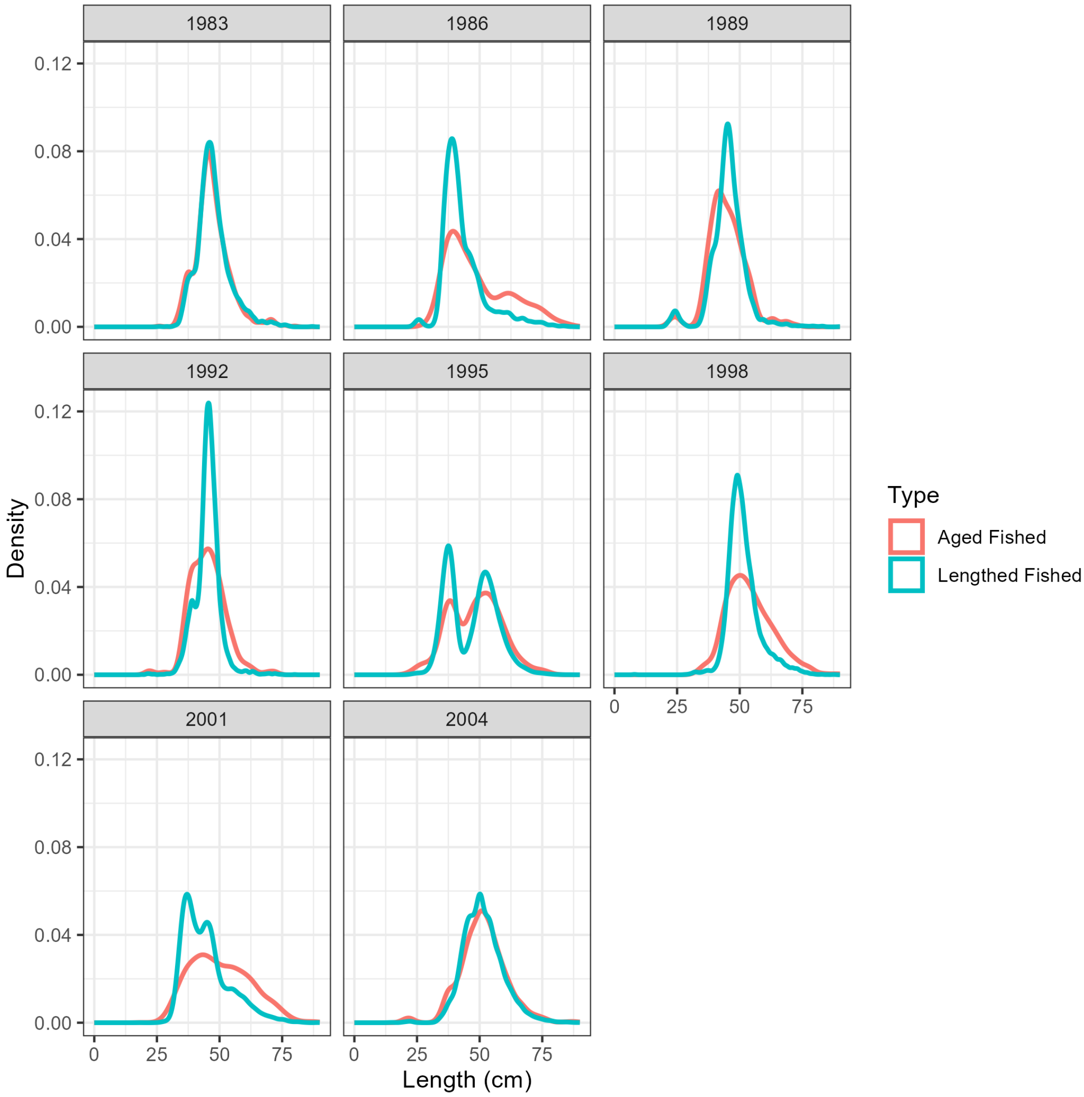

Figure 33: Comparison by year of the distribution from all length data to the lengths from fish with ages collected by the Triennial Survey.

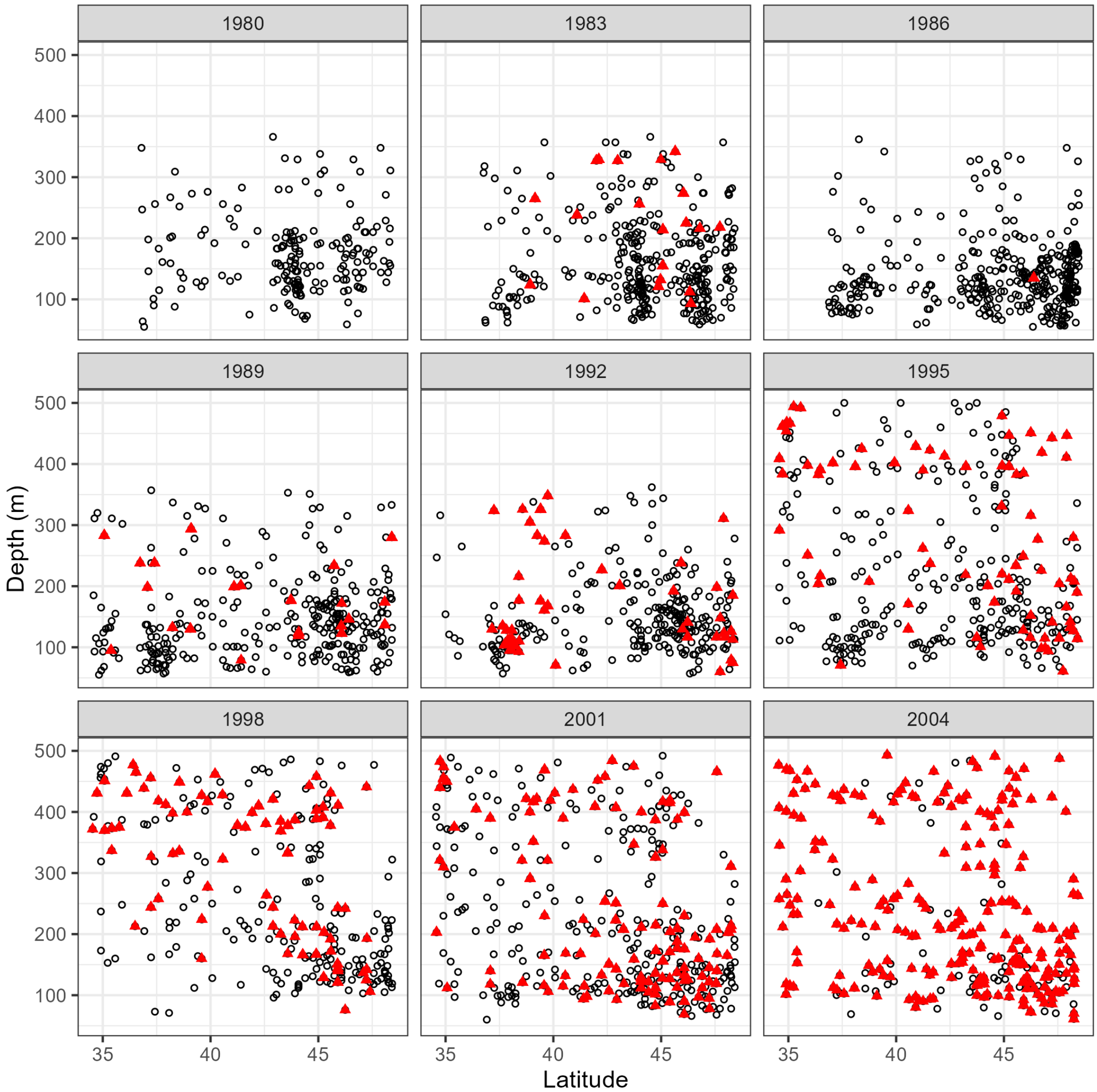

Figure 34: Tow location by latitude and year where lengths were sampled (black open circles) compared to location of available age data (red filled triangles) from the Triennial Survey.

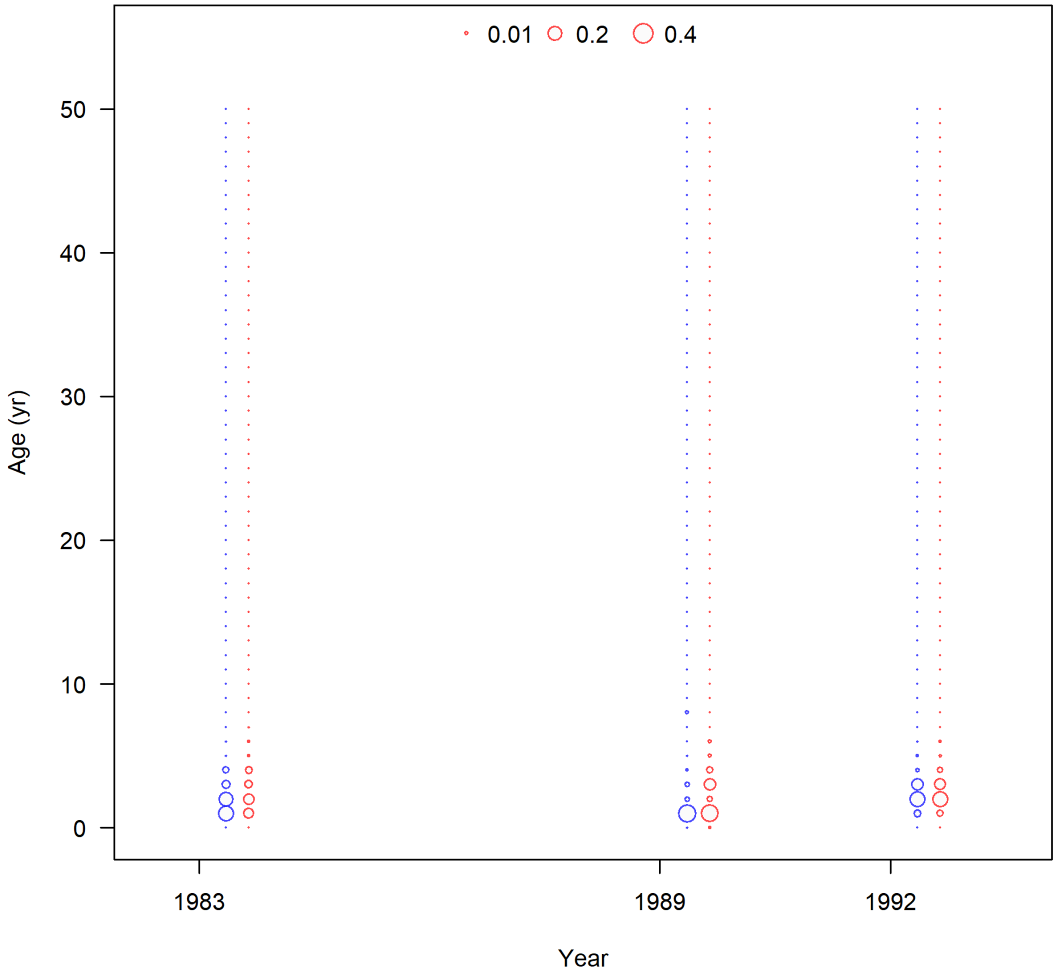

Figure 35: Age compositon by year from the early Triennial Survey. Females are shown in red and males in blue.

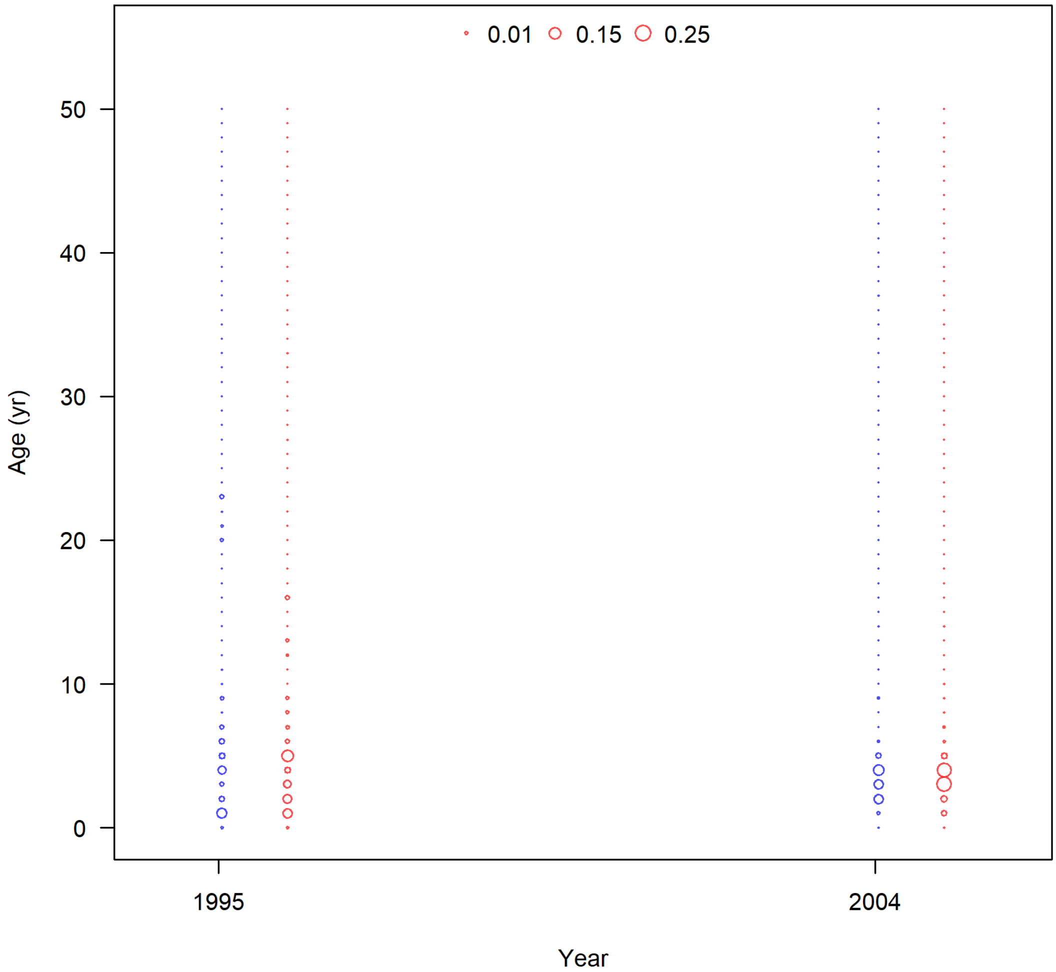

Figure 36: Age compositon by year from the late Triennial Survey. Females are shown in red and males in blue

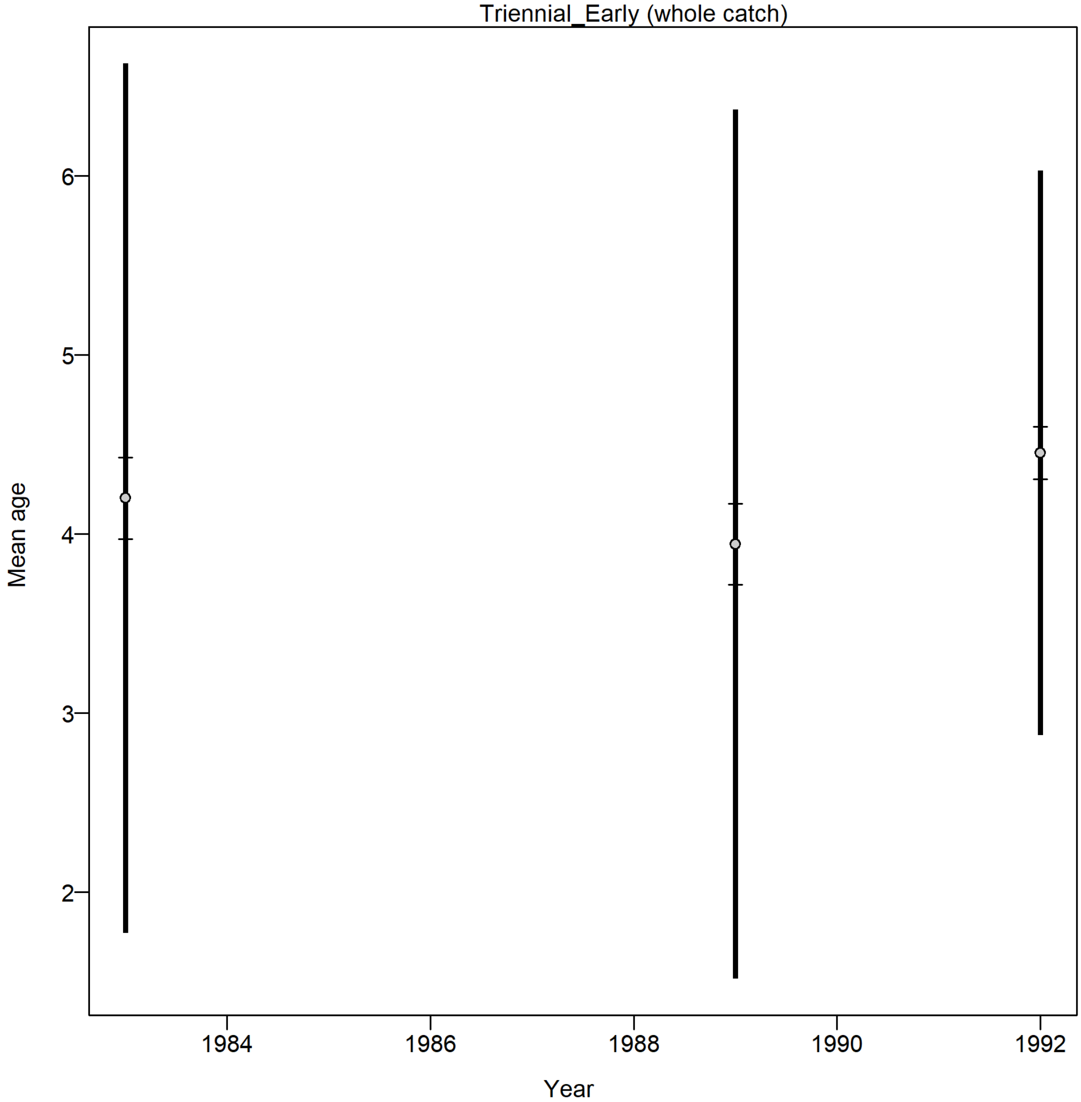

Figure 37: Mean age for early period of Triennial Survey with 95 percent confidence intervals based on current sample sizes.

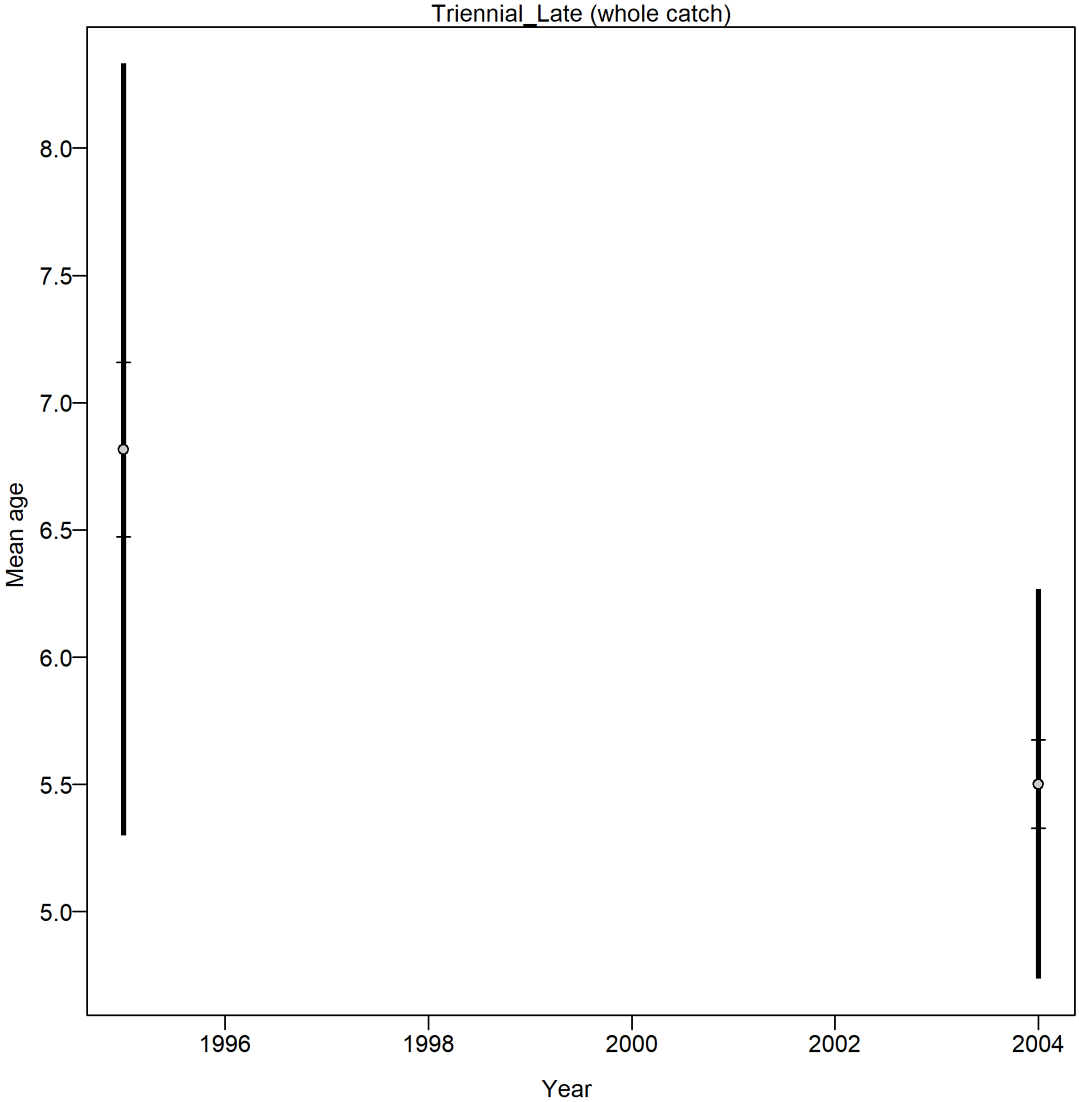

Figure 38: Mean age for late period of Triennial Survey with 95 percent confidence intervals based on current sample sizes.

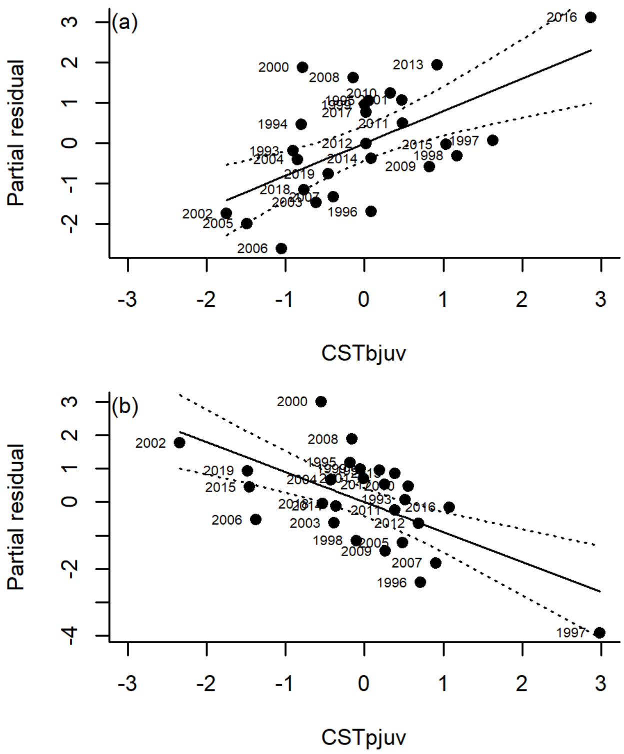

Figure 39: Partial residual plots of GLORYS predictors. CST = cross-shelf transport, T = temperature, spawn = spaning stage, pjuv = pelagic juvenile, and bjuv = benthic juvenile stage.

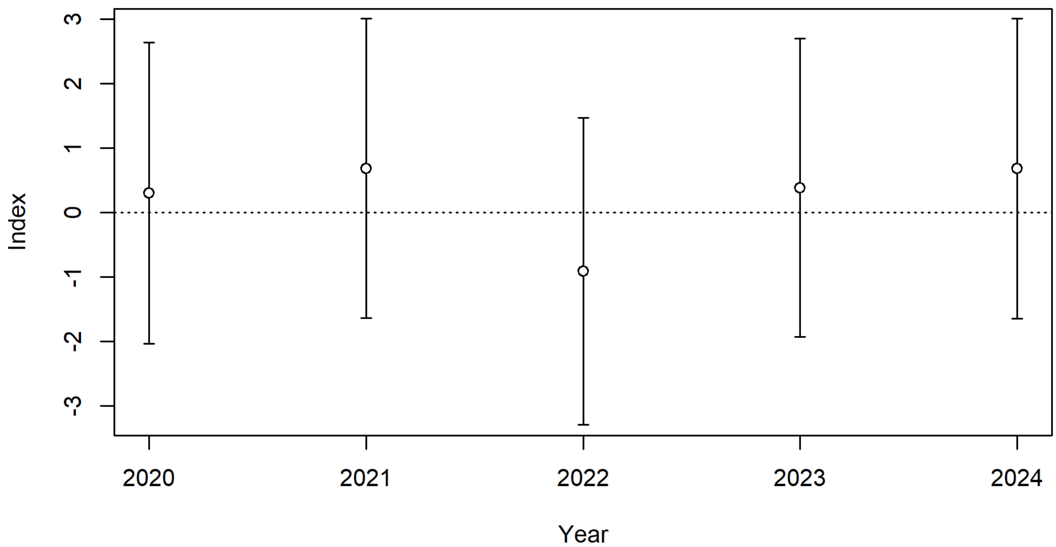

Figure 40: Recruitment deviation index.

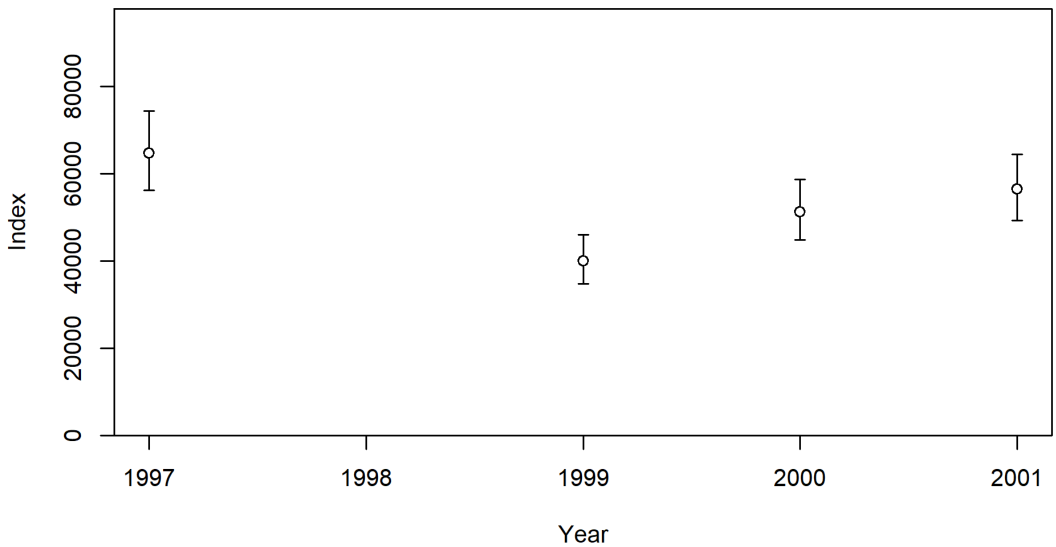

Figure 41: Relative index of abundance for the AFSC Slope Survey.

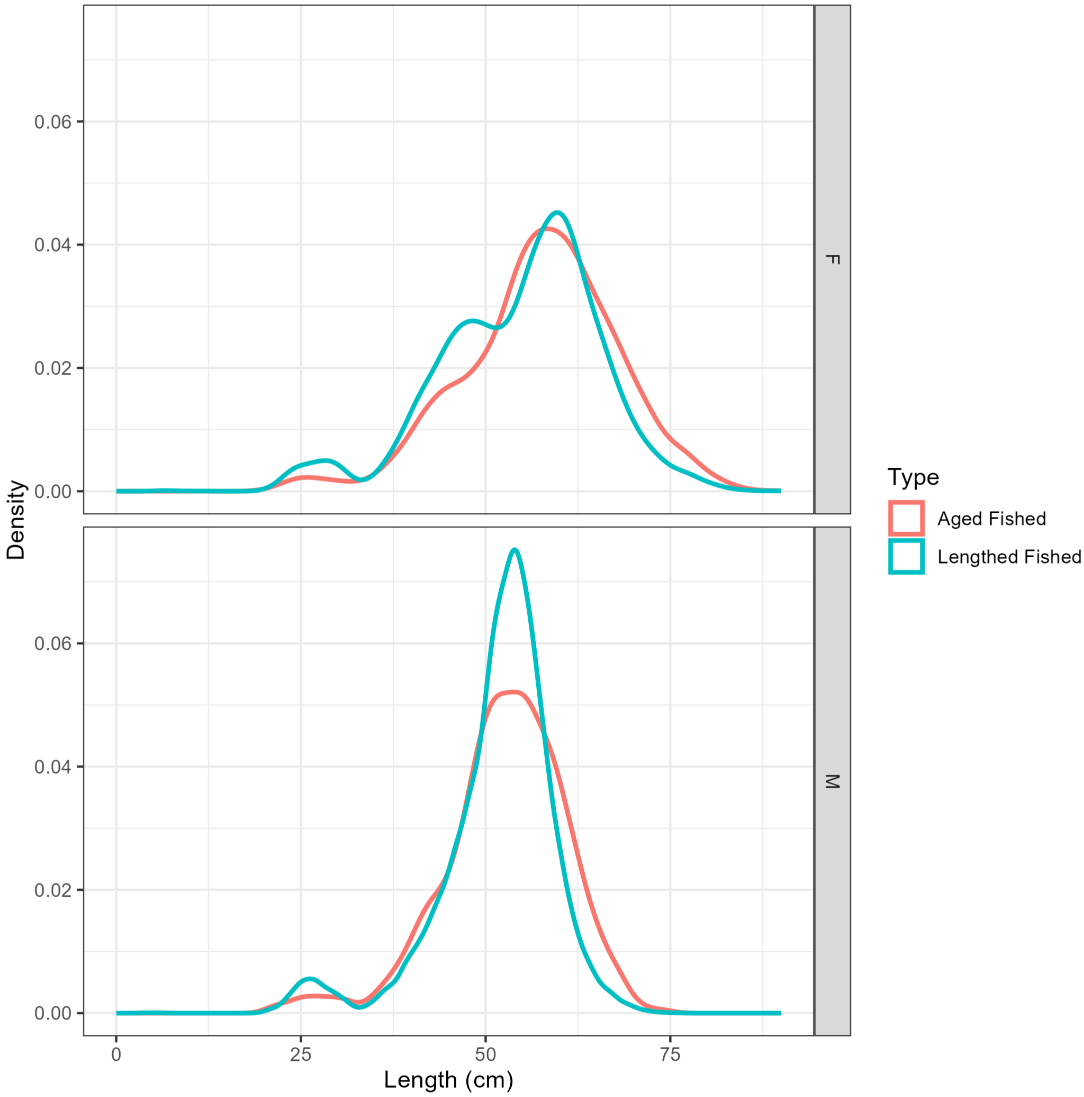

Figure 42: Comparison of the distribution from all length data to the lengths from fish with ages collected by the AFSC Slope Survey.

8.3 Biology

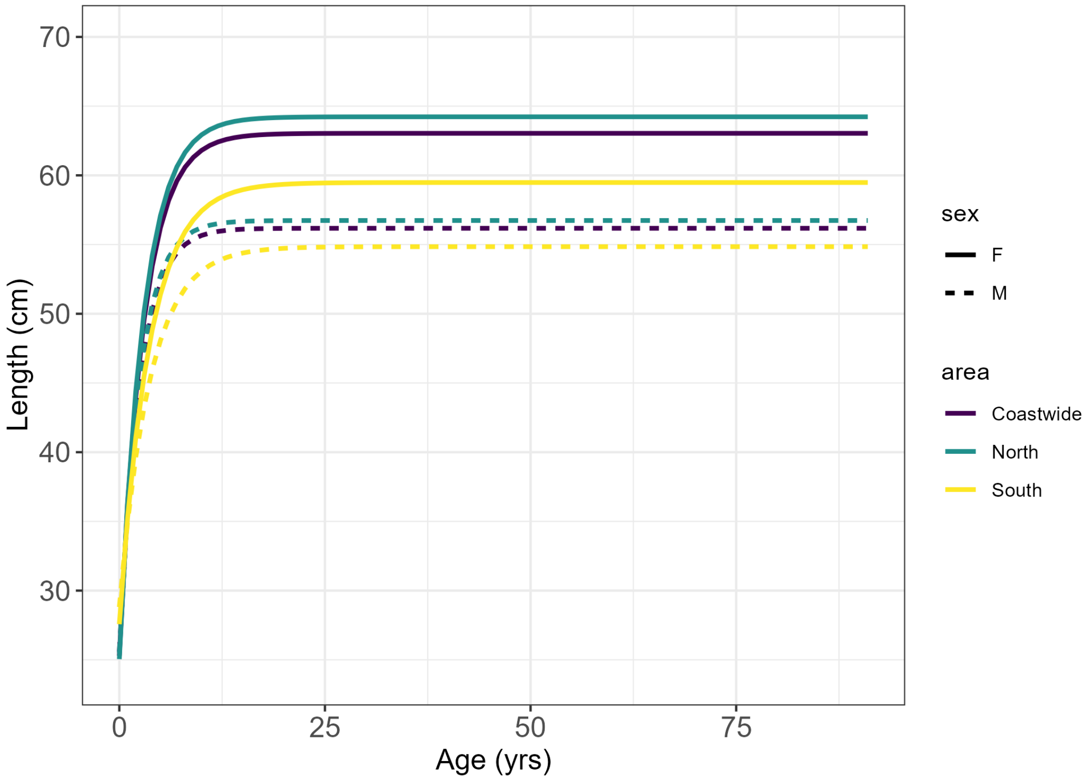

Figure 43: Estimated length-at-age coastwide and by area for females (solid lines) and males (dashed lines) north and south of 36° N. latitude.

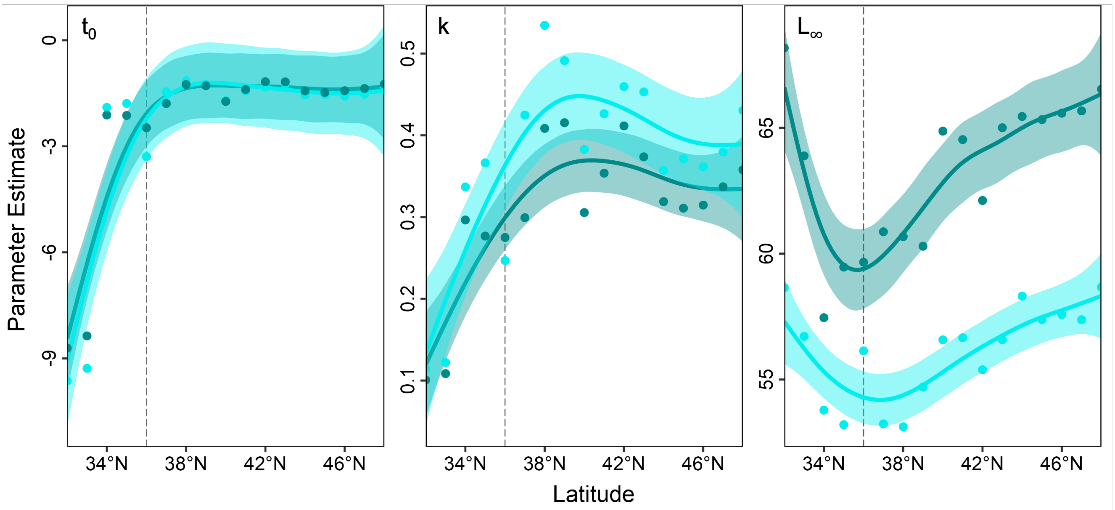

Figure 44: Latitudinal variation in sex-specific von Bertalanffy growth parameters (t_0: length at age 0, k: growth coefficient, L∞: asymptotic length). Dashed horizontal line denotes 36° N. latitude. Predicted using the NWFSC West Coast Groundfish Bottom Trawl Survey data between 2003 and 2024. The darker color represents females and the lighter color represents males.

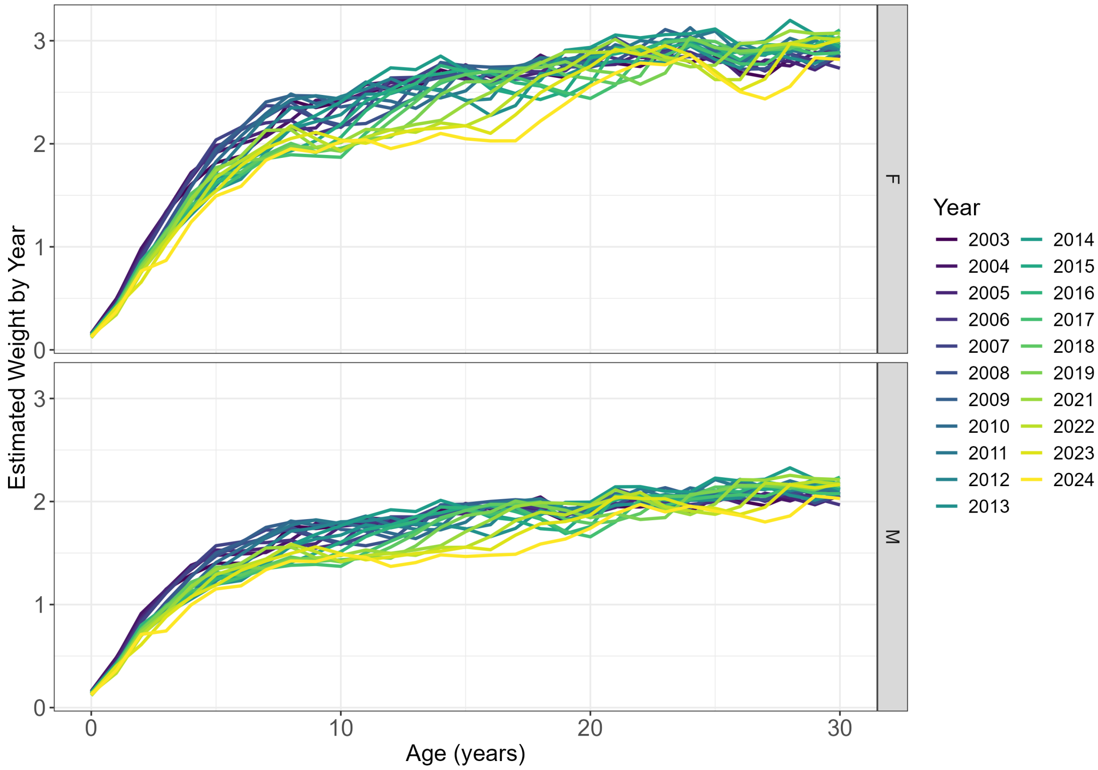

Figure 45: Estimated weight-at-age by year and sex.

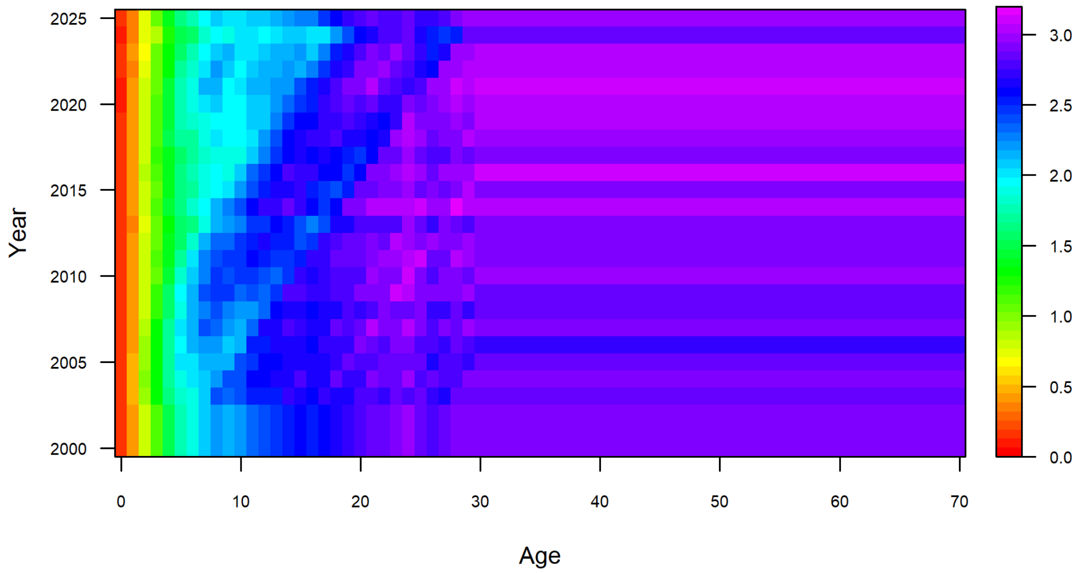

Figure 46: Female weight-at-age by year.

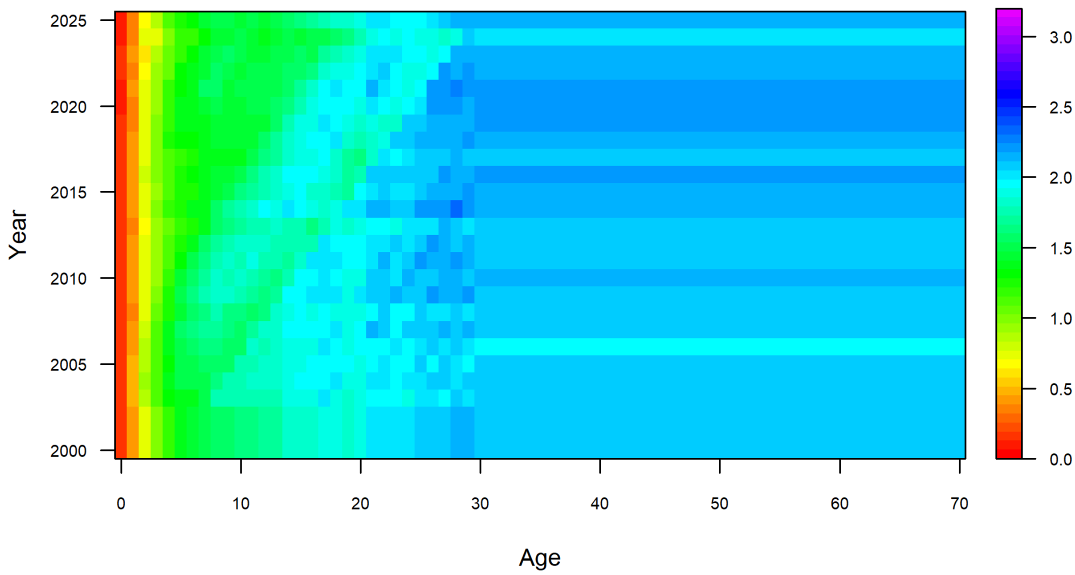

Figure 47: Male weight-at-age by year.

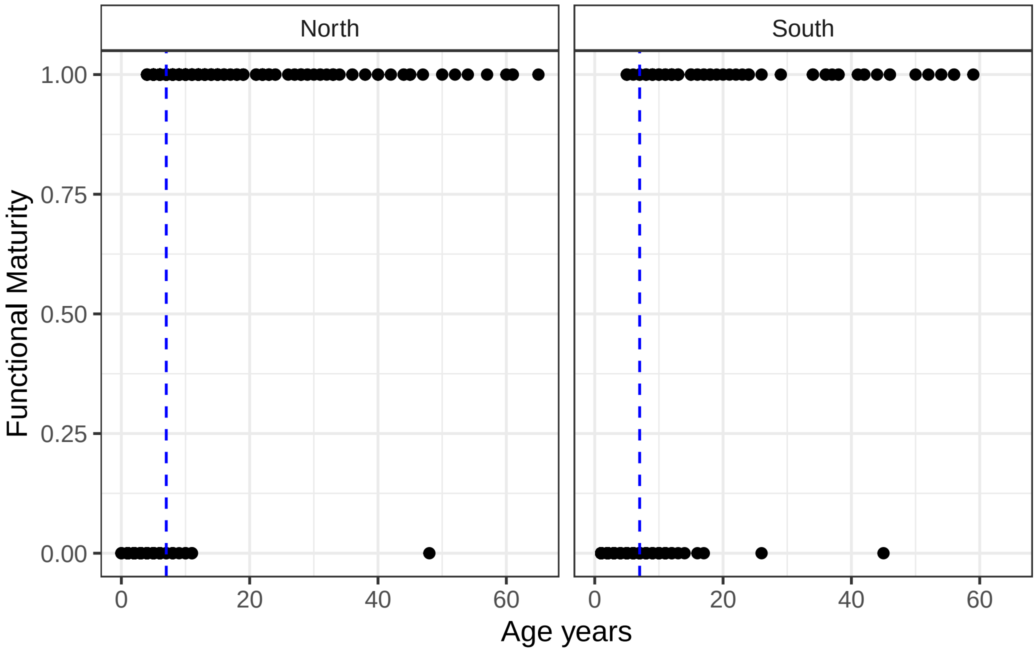

Figure 48: Samples by age that were determined to be functionally mature and immature north and south of 36° N. latitude. Immature fish have a functional maturity of 0 and mature fish have a functional maturity of 1. Blue vertical dashed line at age 7.

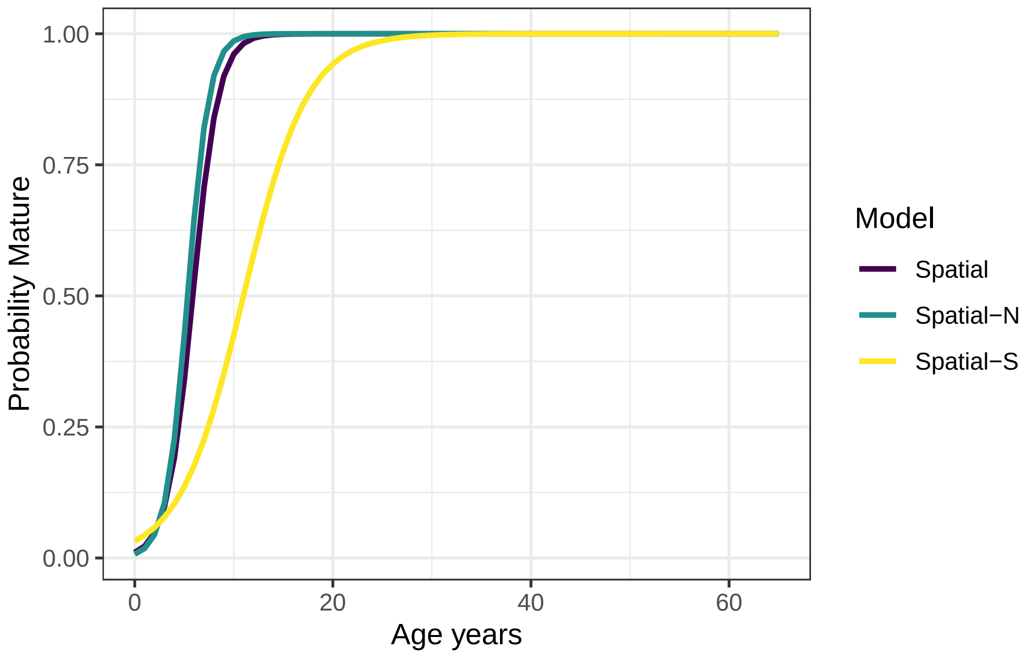

Figure 49: Estimated maturity-at-age by area and the biomass weighted coastwide (Spatial) maturity curve and north (Spatial-N) and south (Spatial-S) of 36° N. latitude.

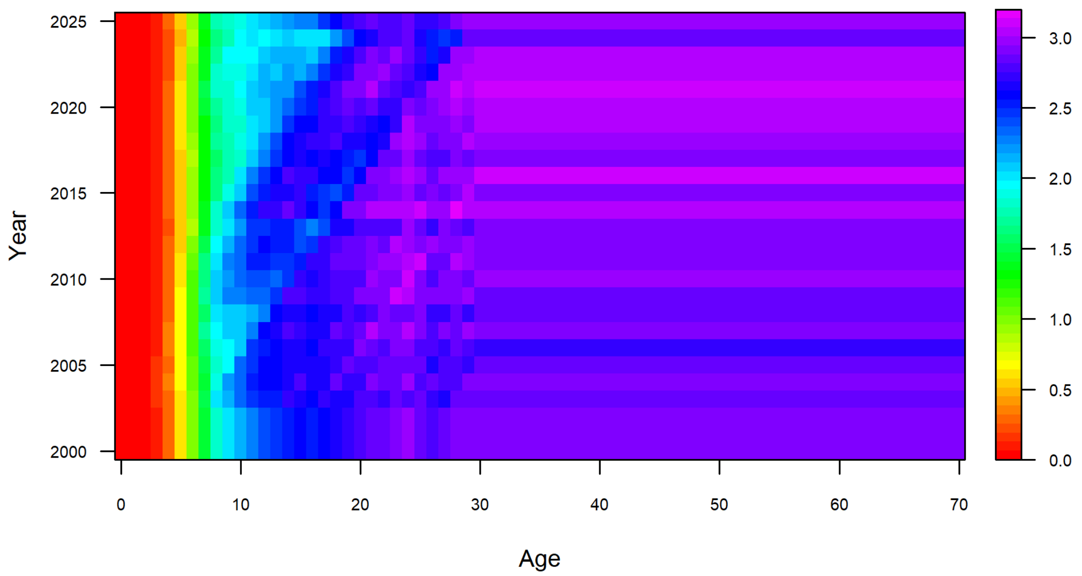

Figure 50: Spawning output at age based upon maturity and fecundity.

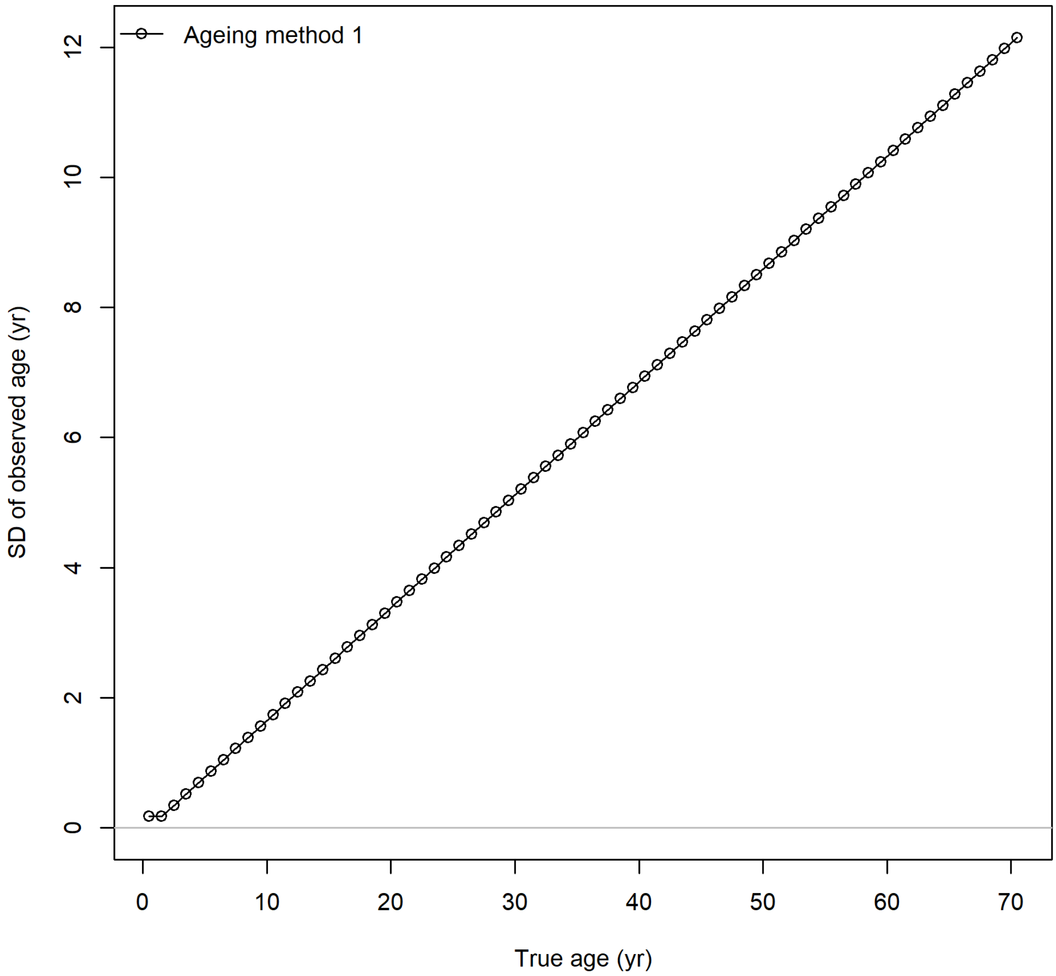

Figure 51: Comparison of ageing imprecision, standard deviation by observed age, used in the base model (blue line - Ageing method 1) and from the 2019 model (red line - Ageing method 2).

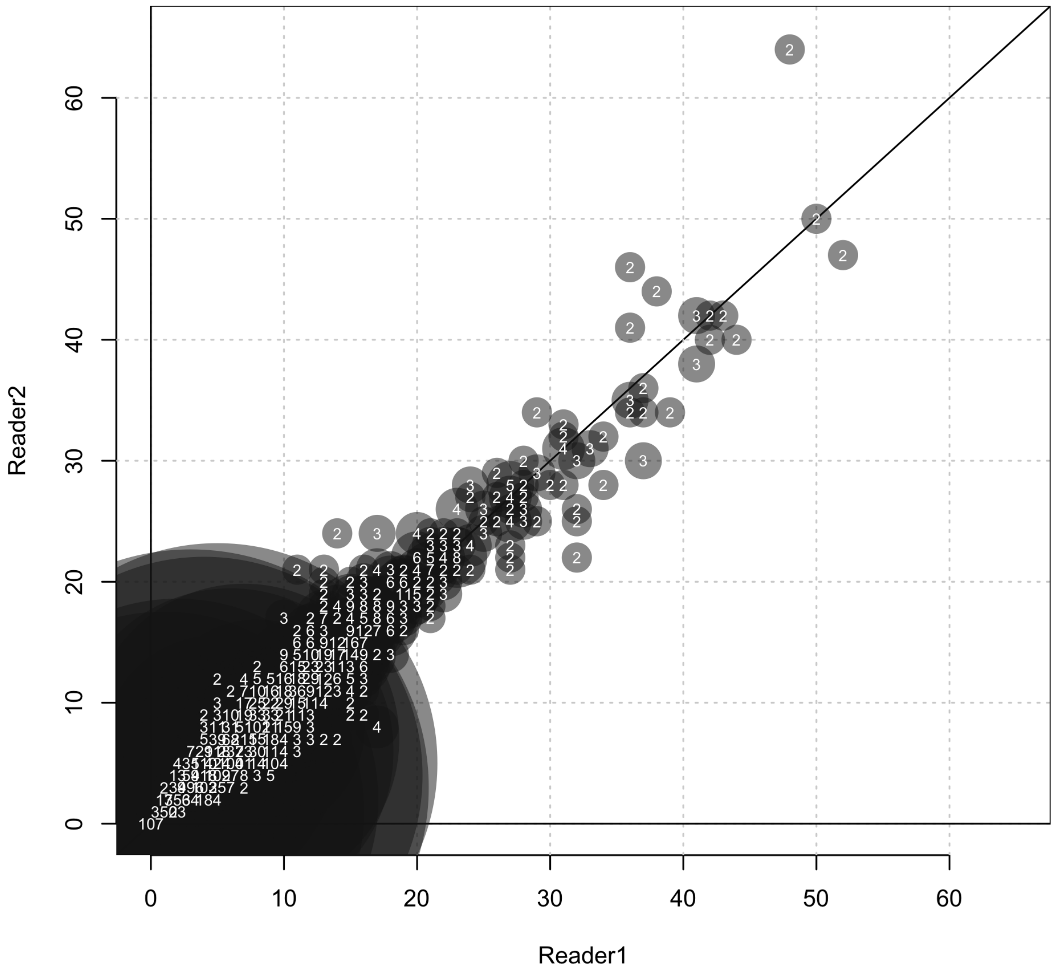

Figure 52: Comparison of age reads between reader 1 and reader 2 where reader 1 was assumed to be unbiased. The size of the bubbles is based on the number of age read groups between readers with larger bubbles for higher age read combinations.

8.4 Model Bridging

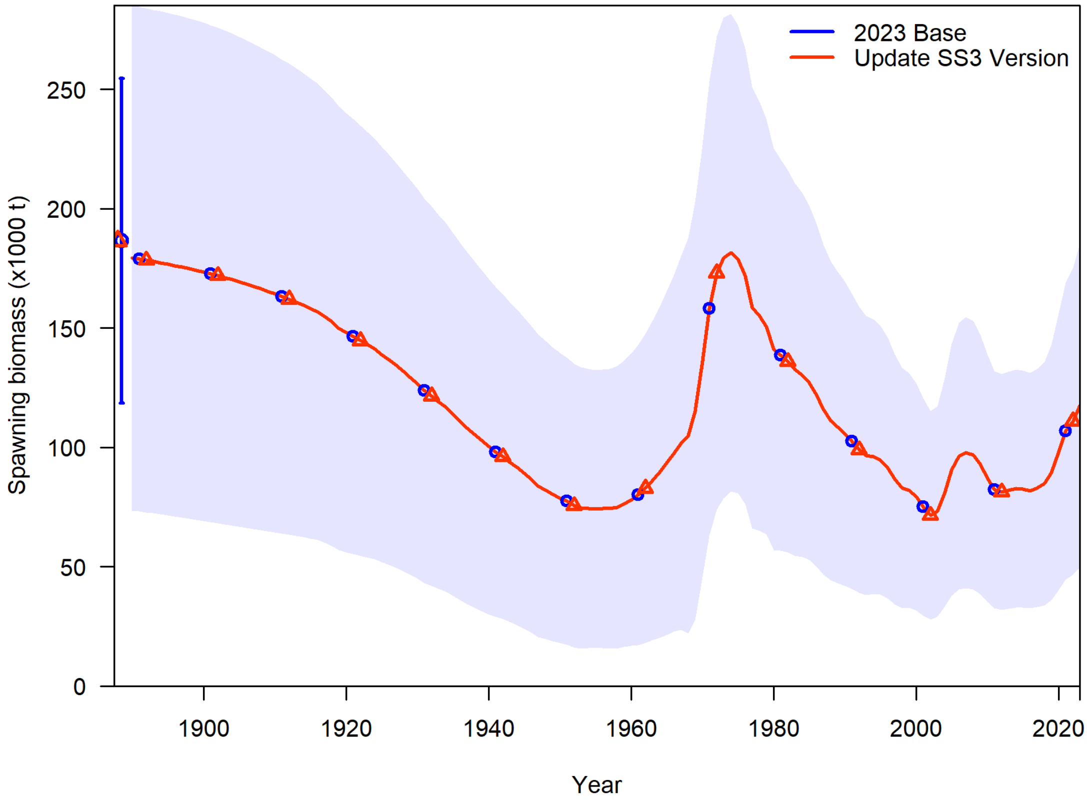

Figure 53: Comparison of estimated spawning output (e.g., spawning biomass) between Stock Synthesis executable versions.

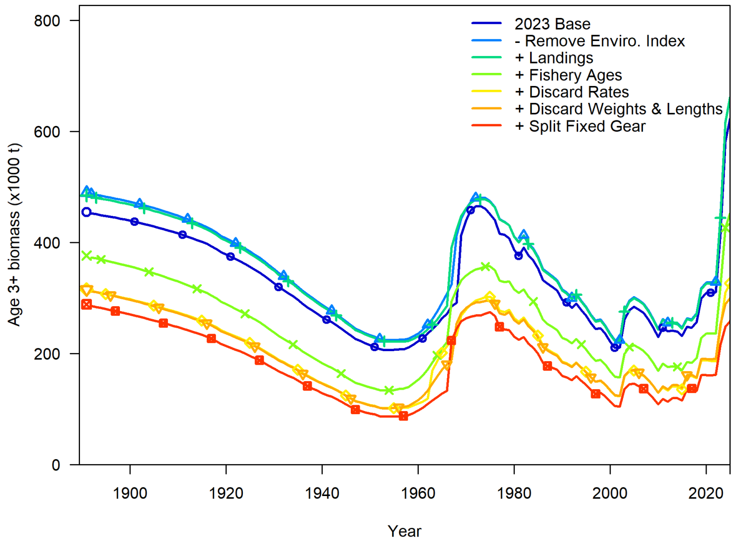

Figure 54: Comparison of estimated summary biomass for ages 3+ when adding new data.

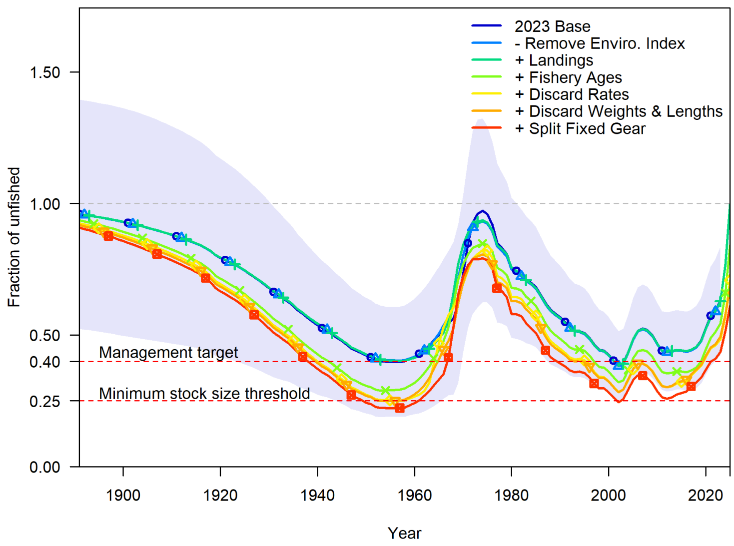

Figure 55: Comparison of estimated fraction unfished (i.e., stock status) when adding new data.

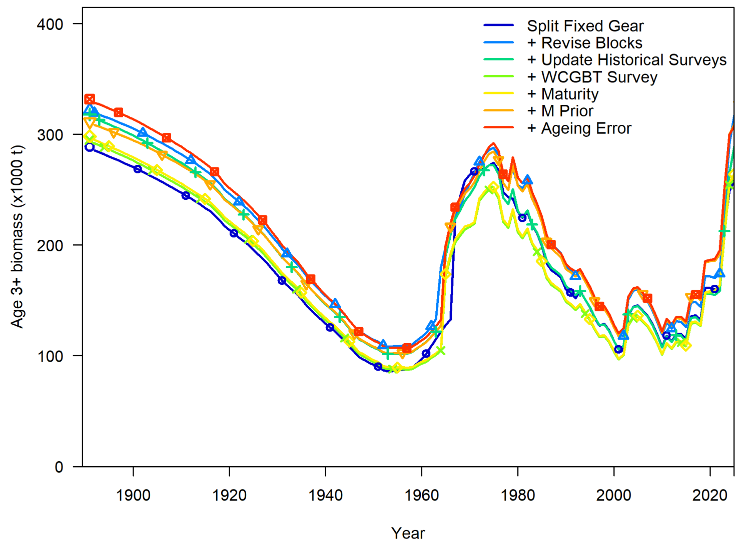

Figure 56: Comparison of estimated summary biomass for ages 3+ when adding new data.

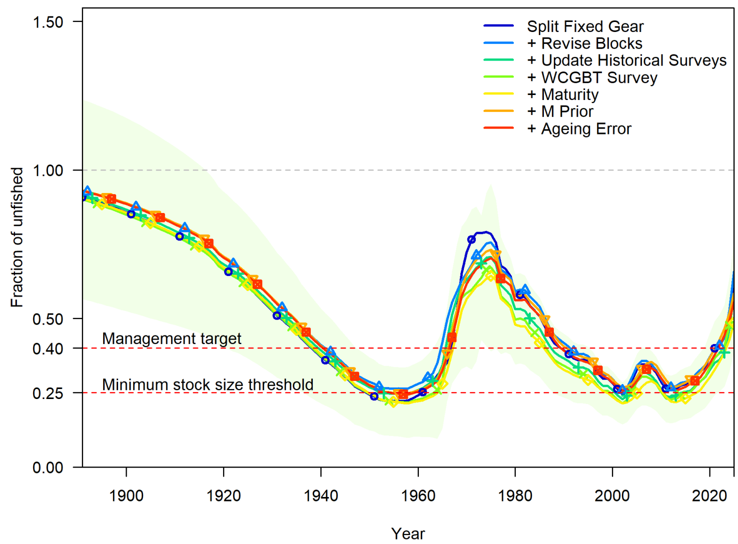

Figure 57: Comparison of estimated fraction unfished (i.e., stock status) when adding new data.

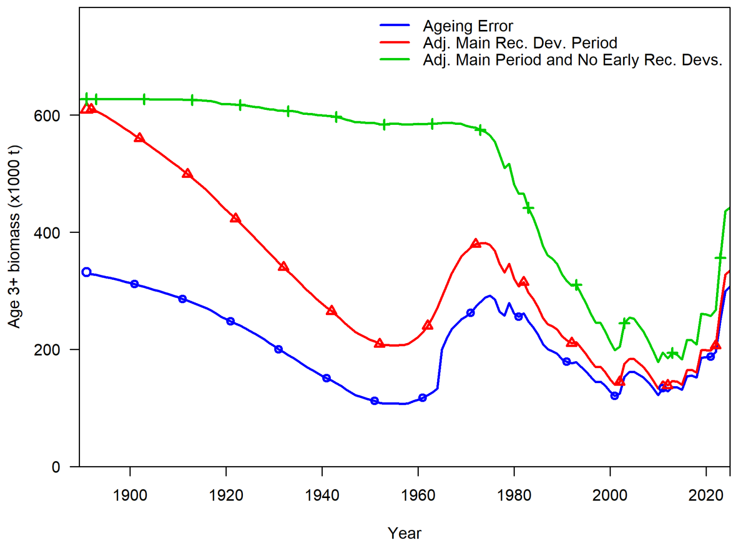

Figure 58: Comparison of estimated summary biomass for ages 3+ when the estimation of annual recruitment deviations is revised.

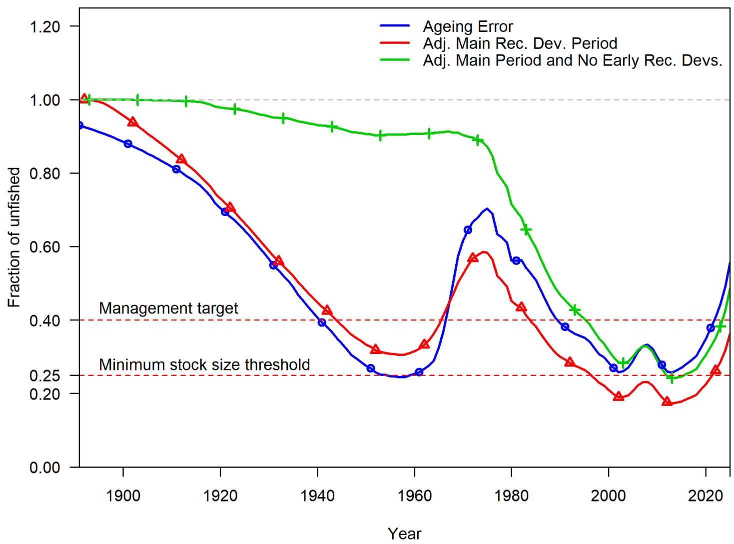

Figure 59: Comparison of estimated fraction unfished (i.e., stock status) when the estimation of annual recruitment deviations is revised.

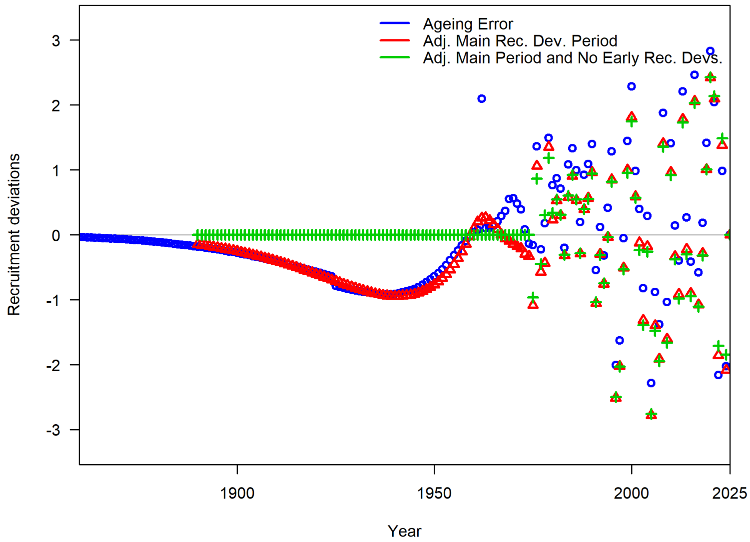

Figure 60: Comparison of estimated annual recruitment deviations when the estimation of annual recruitment deviations is revised.

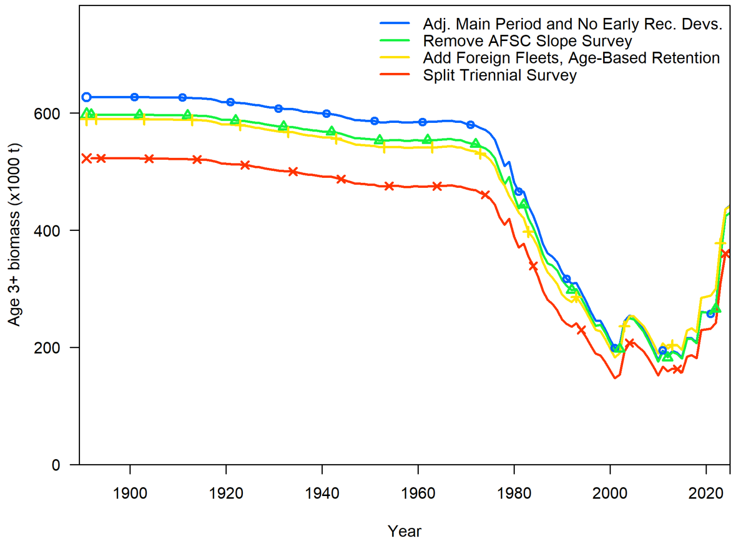

Figure 61: Comparison of estimated summary biomass for ages 3+ when the model structure is revised.

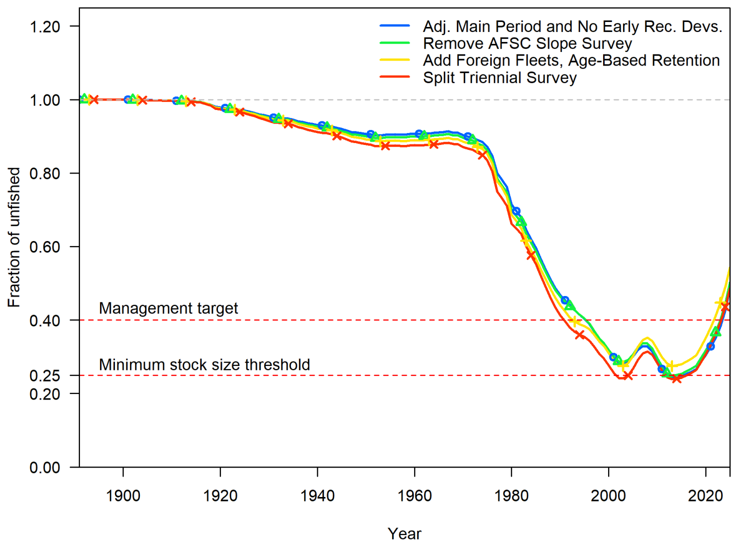

Figure 62: Comparison of estimated fraction unfished (i.e., stock status) when the model structure is revised.

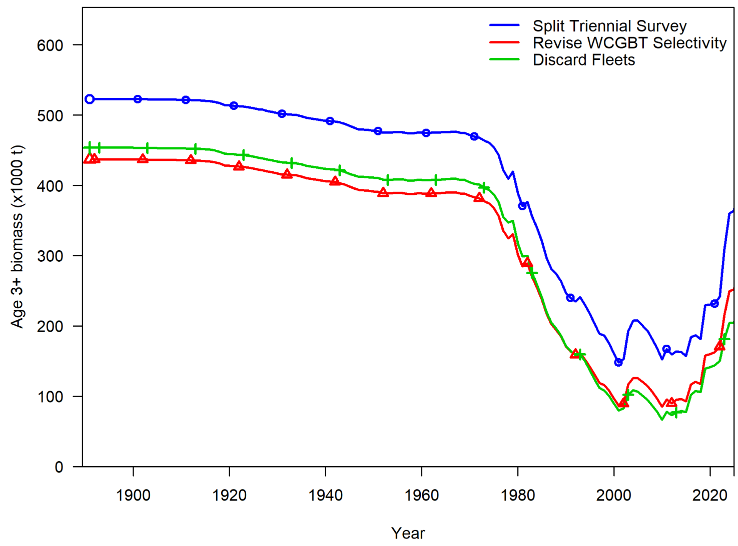

Figure 63: Comparison of estimated summary biomass for ages 3+ when the model structure is revised.

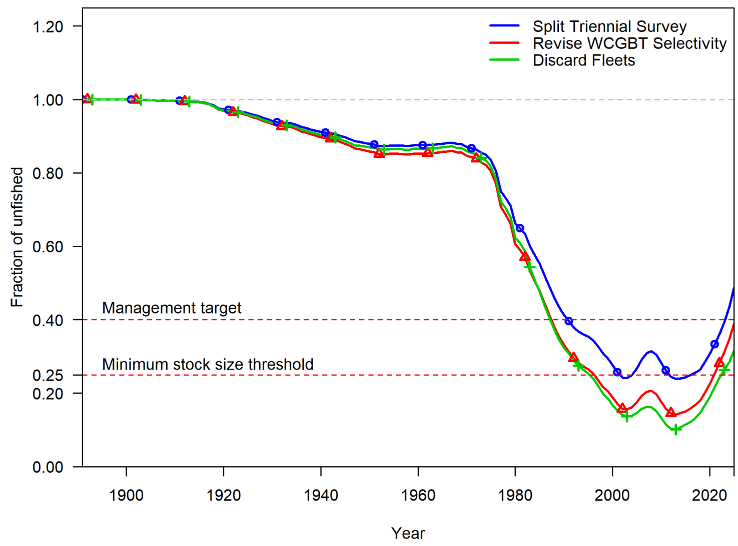

Figure 64: Comparison of estimated fraction unfished (i.e., stock status) when the model structure is revised.

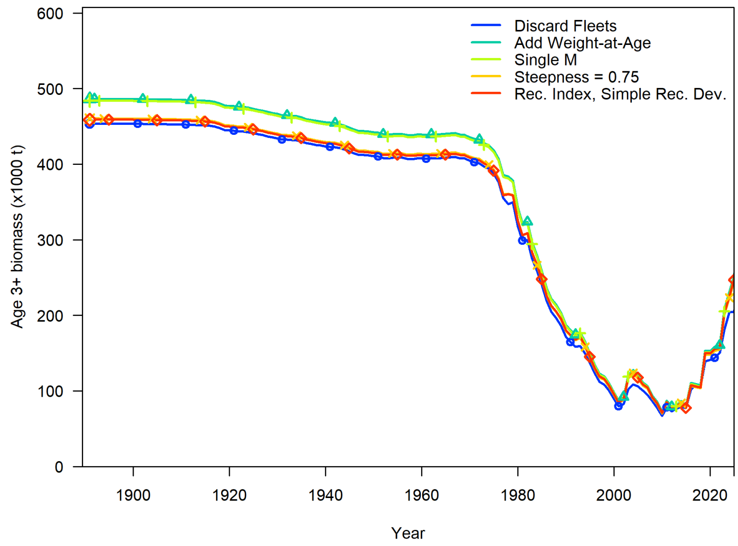

Figure 65: Comparison of estimated summary biomass for ages 3+ when the model structure is revised.

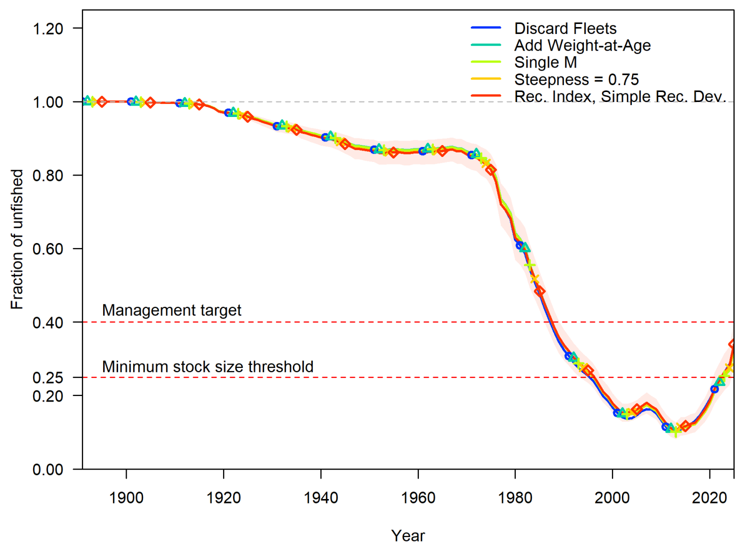

Figure 66: Comparison of estimated fraction unfished (e.g., stock status) when the model structure is revised.

8.5 Paramters

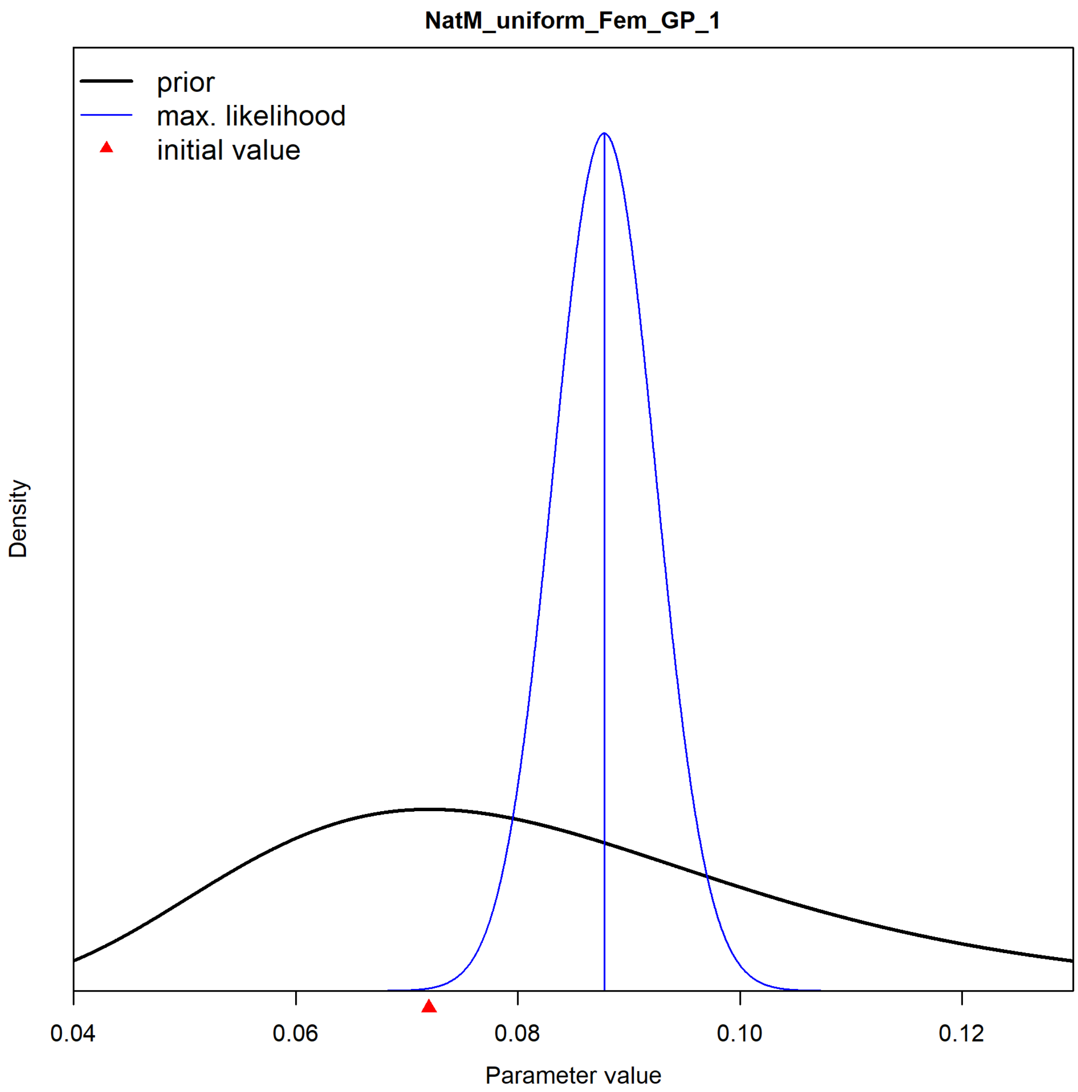

Figure 67: Prior distributions and parameter estimates for natural mortality. Black lines show prior distributions, blue lines show maximum likelihood estimate and associated uncertainty.

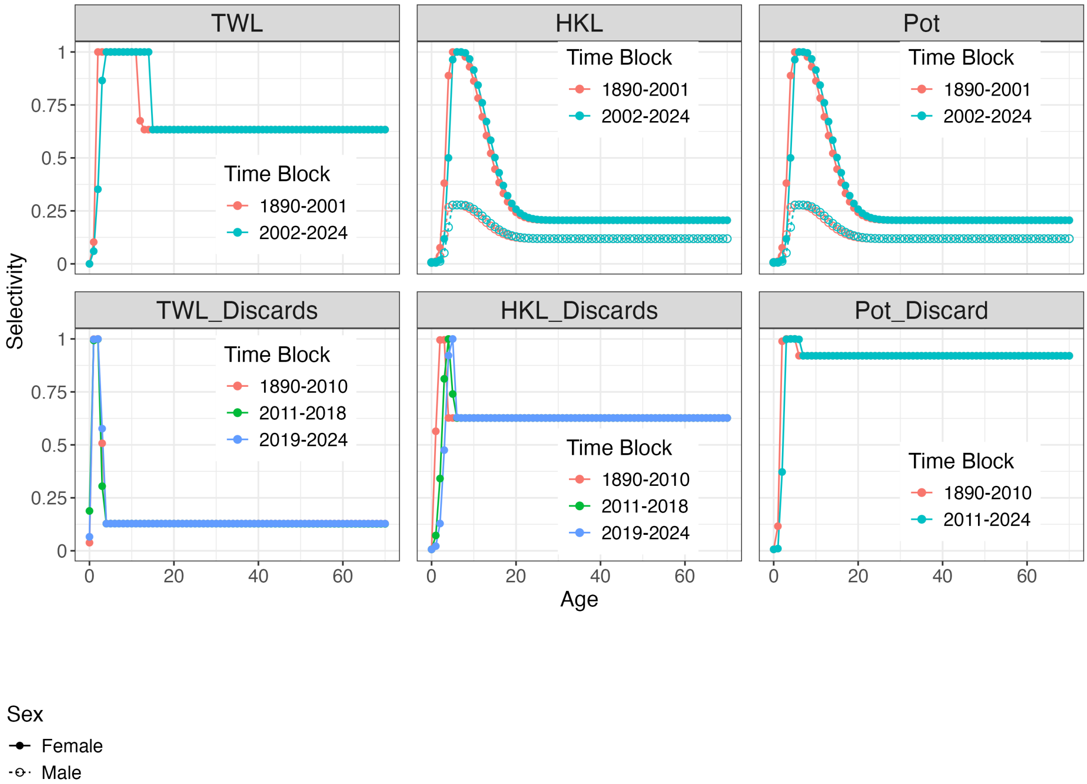

Figure 68: Selectivity curves for each fishery fleet in the base model.

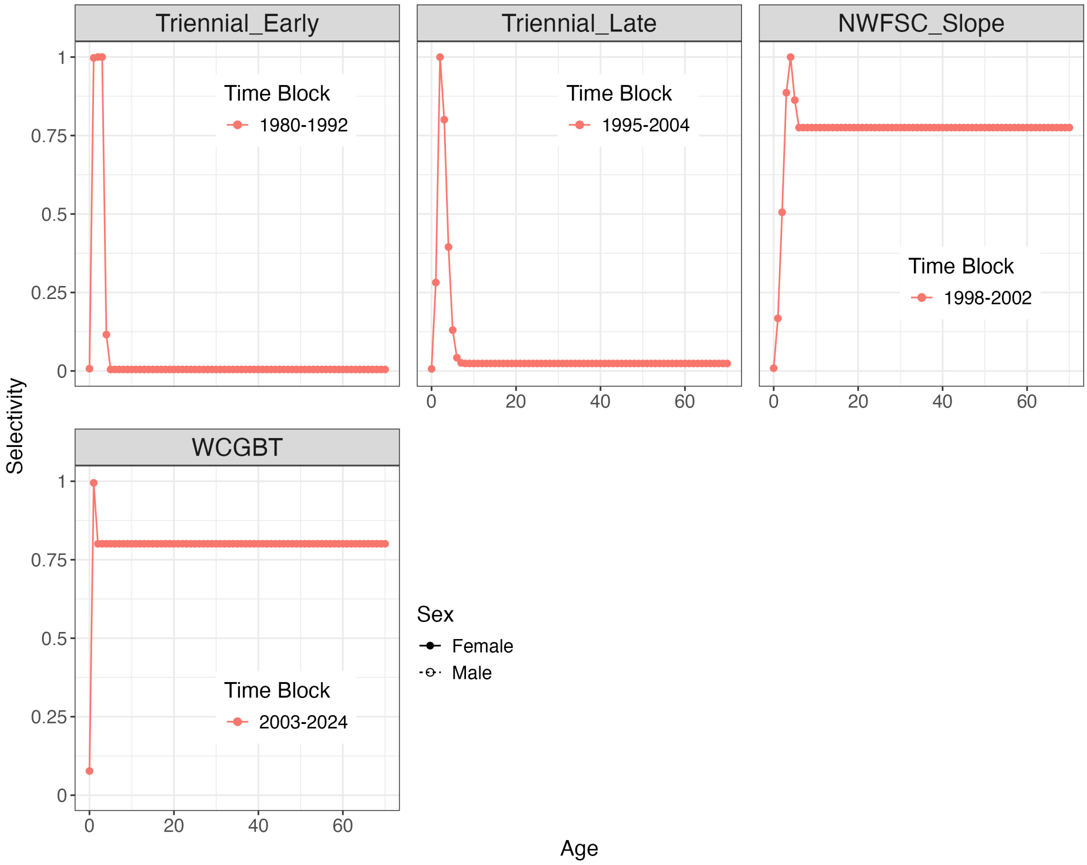

Figure 69: Selectivity curves for each survey in the base model.

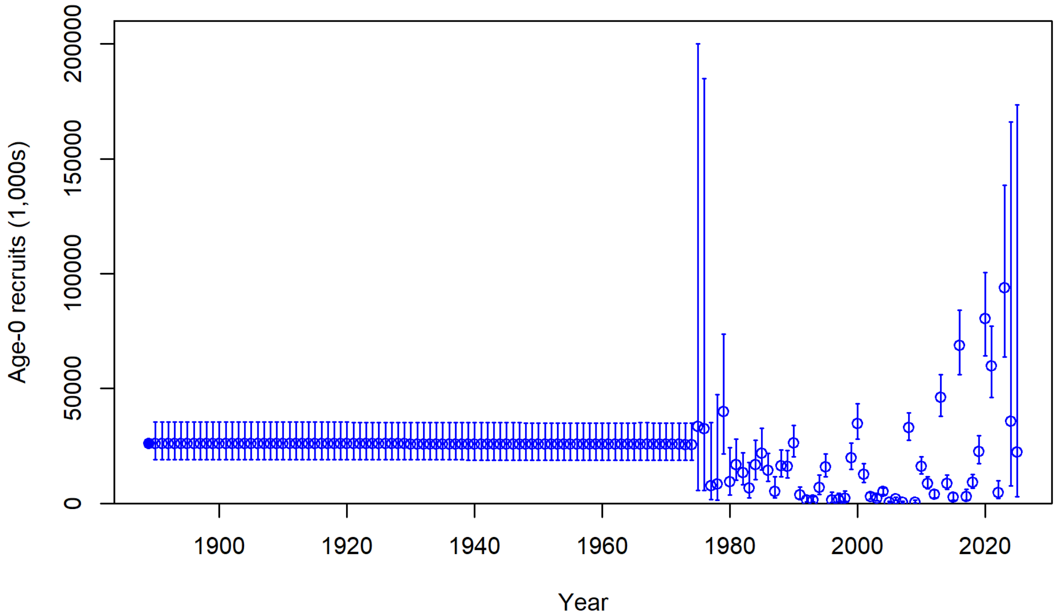

Figure 70: Estimated time series of age-0 recruits in 1,000s of fish for the base model.

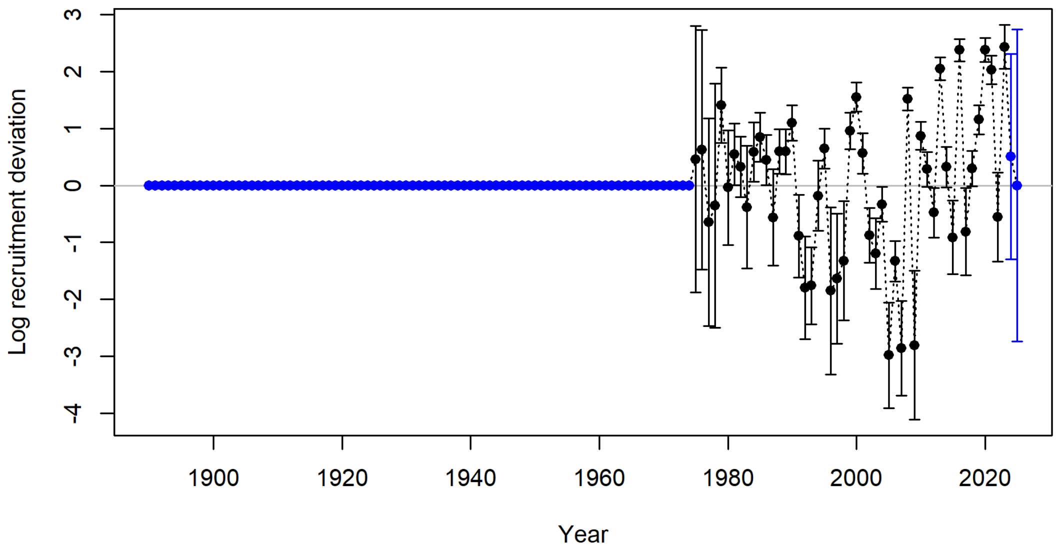

Figure 71: Estimated time series of recruitment deviations in log-space for the base model.

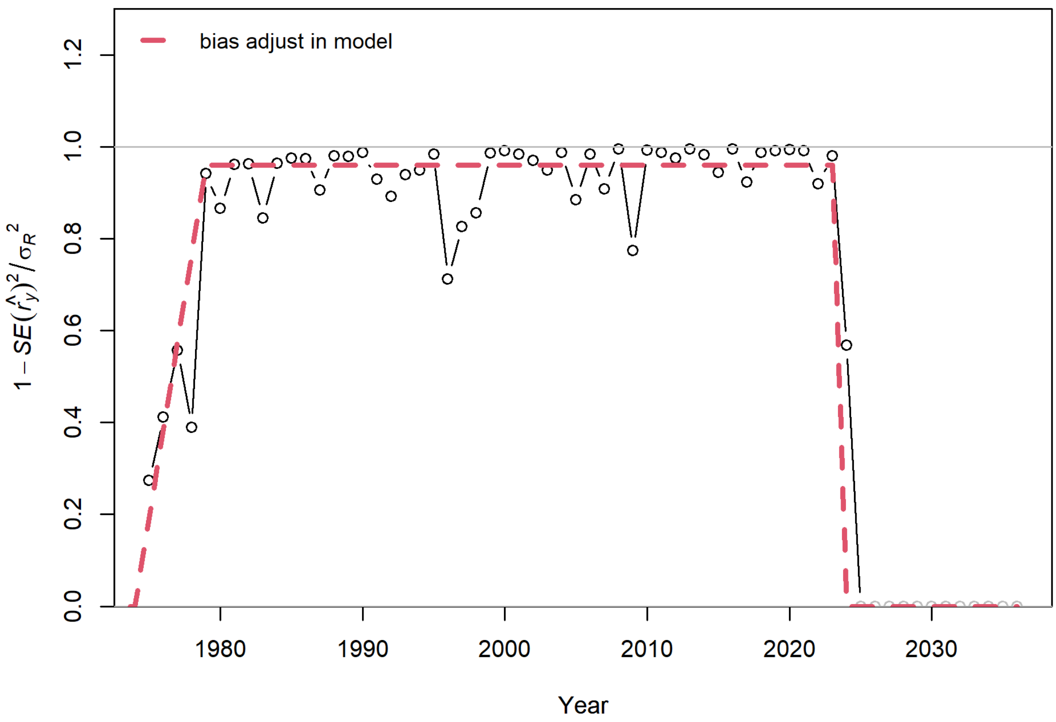

Figure 72: Bias adjustment applied to the recruitment deviations (red line). Points are transformed variances relative to the assumed variance of recruitment.

8.6 Fits to Data

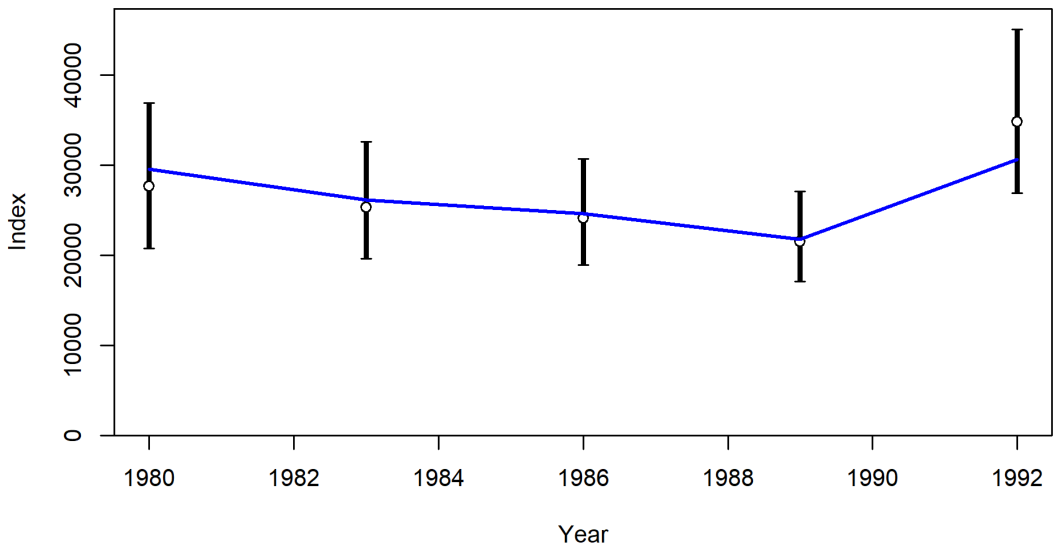

Figure 73: Fit to index data for the early Triennial Survey (1980-1992).

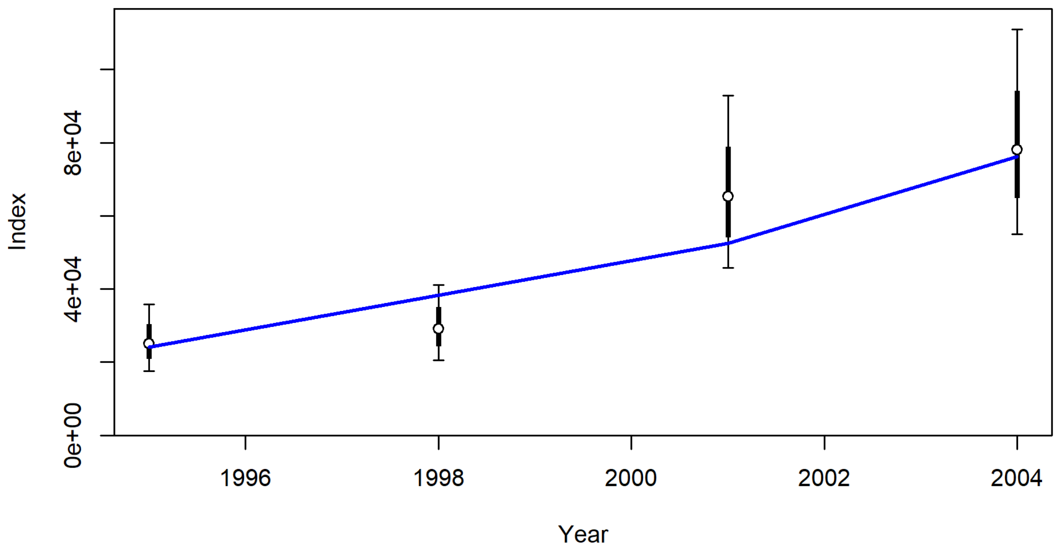

Figure 74: Fit to index data for the late Triennial Survey (1995-2004).

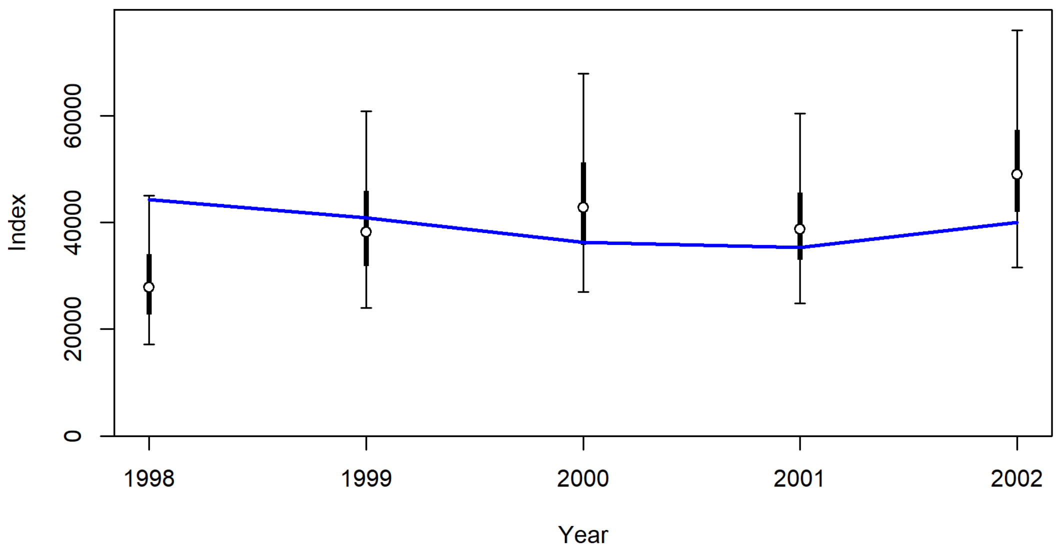

Figure 75: Fit to index data for the NWFSC Slope Survey.

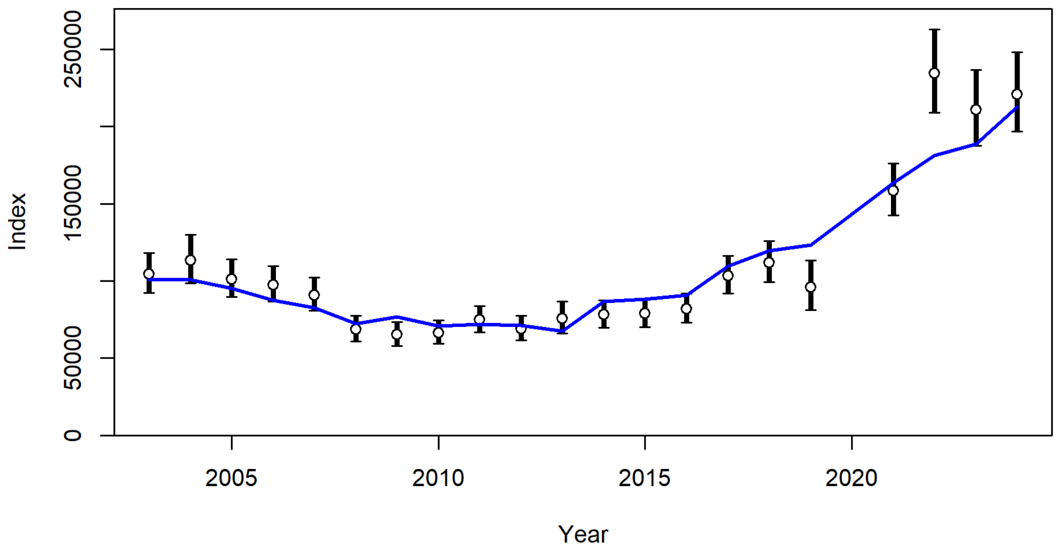

Figure 76: Fit to index data for the NWFSC West Coast Groundfish Bottom Trawl Survey.

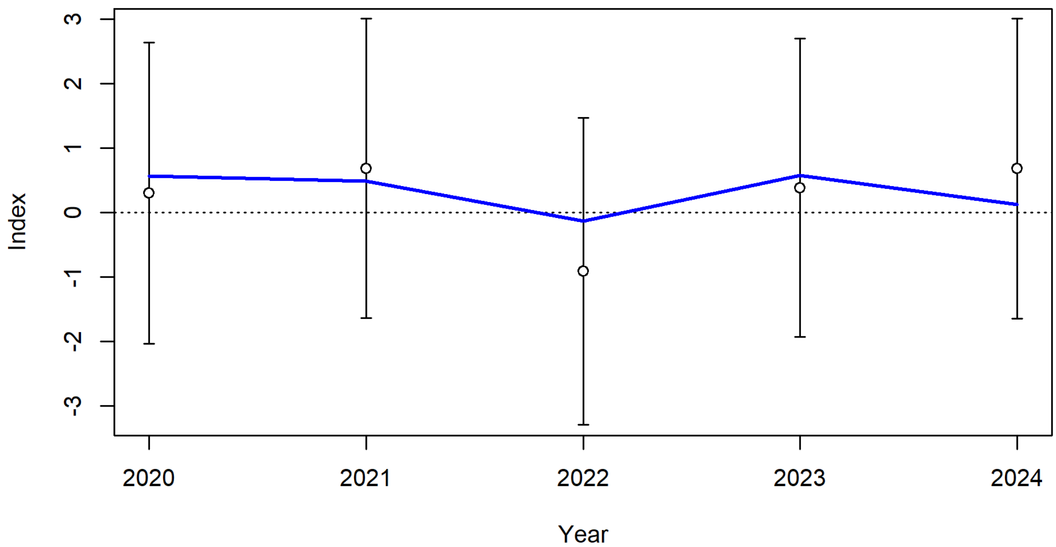

Figure 77: Fit to index data for the recuitment index.

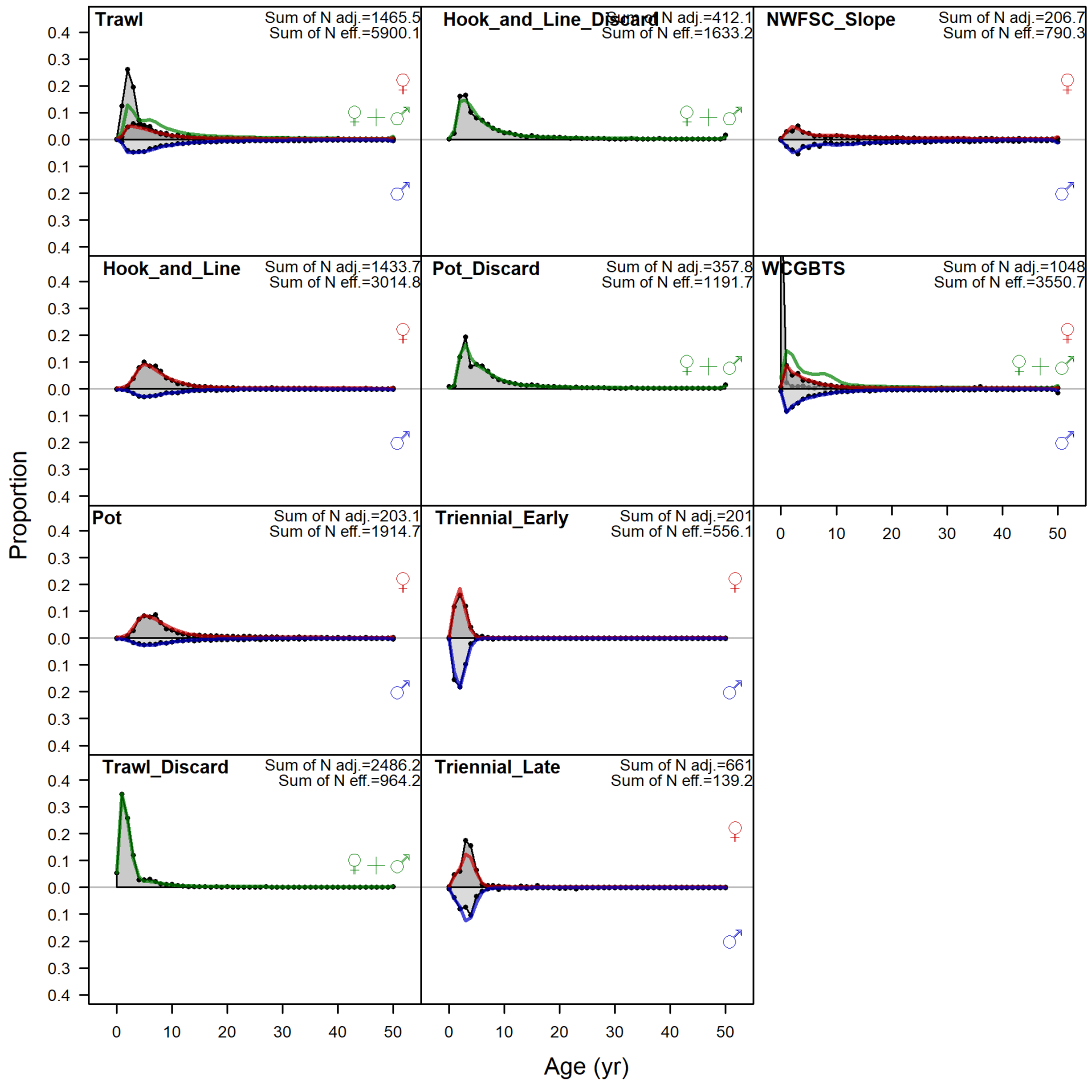

Figure 78: Aggregated fit to the age composition data across all years by fleet.

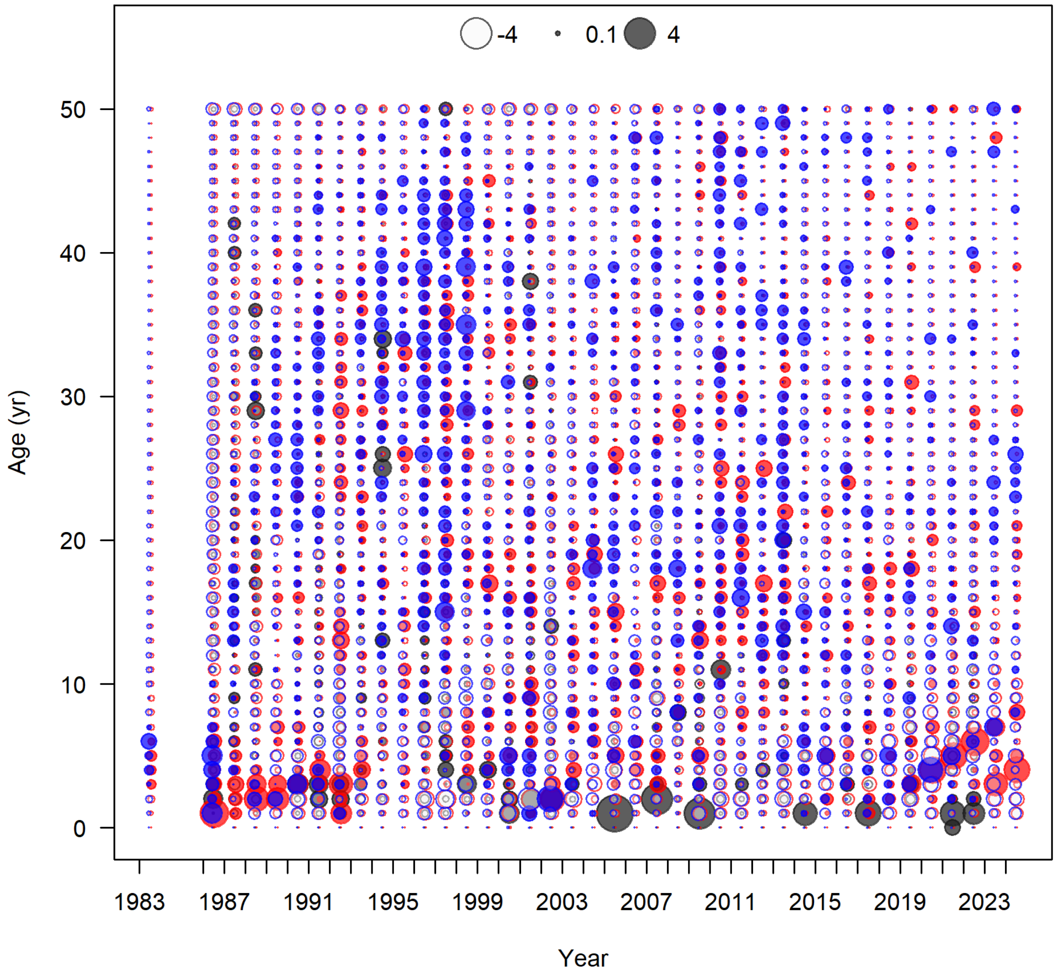

Figure 79: Pearsons residuals to age composition data from the trawl fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

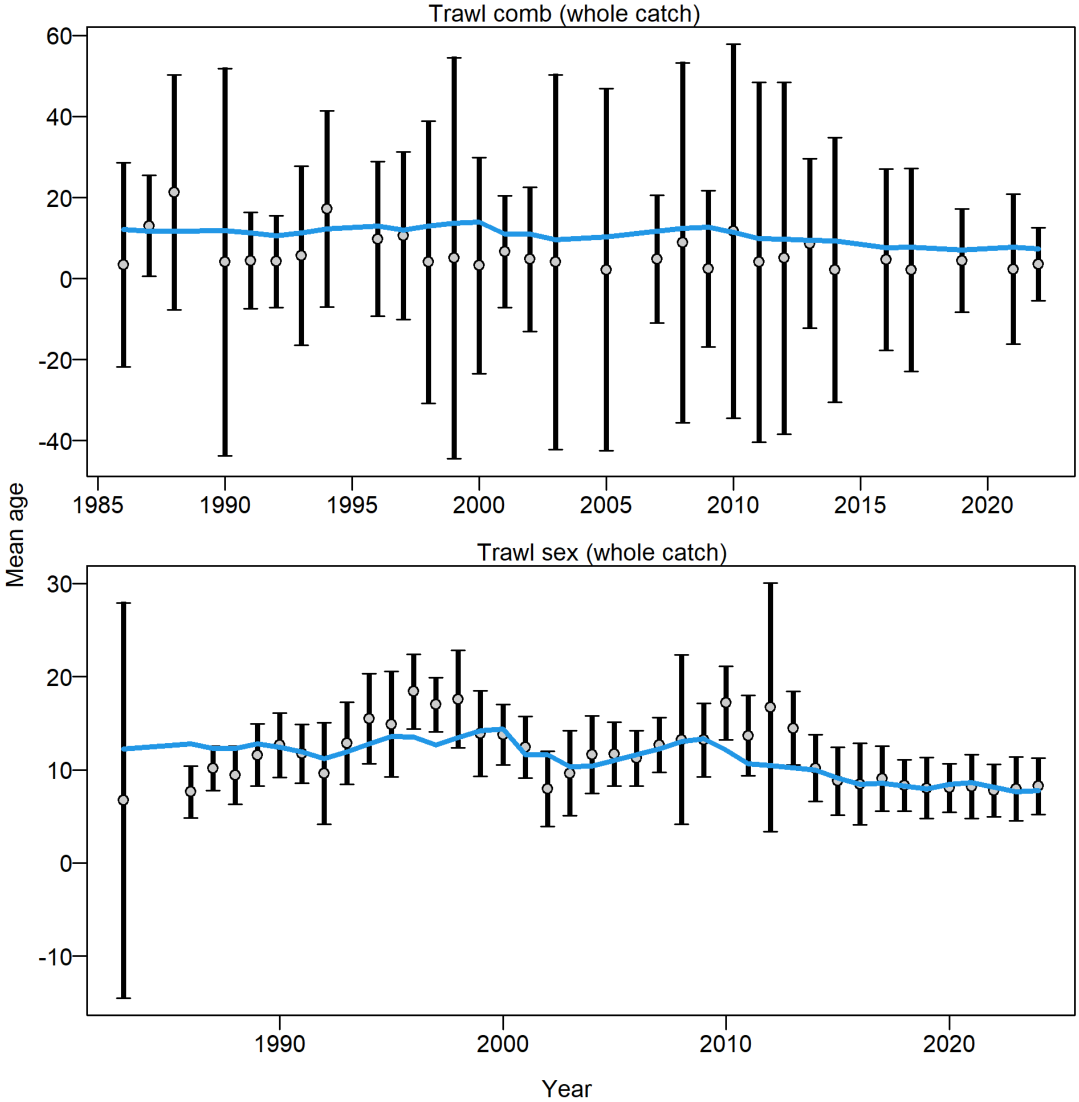

Figure 80: Mean age by year with confidence intervals for sexed and unsexed ages from the trawl fleet. The top panel is sexed ages and the bottom panel includes both sexed and unsexed ages.

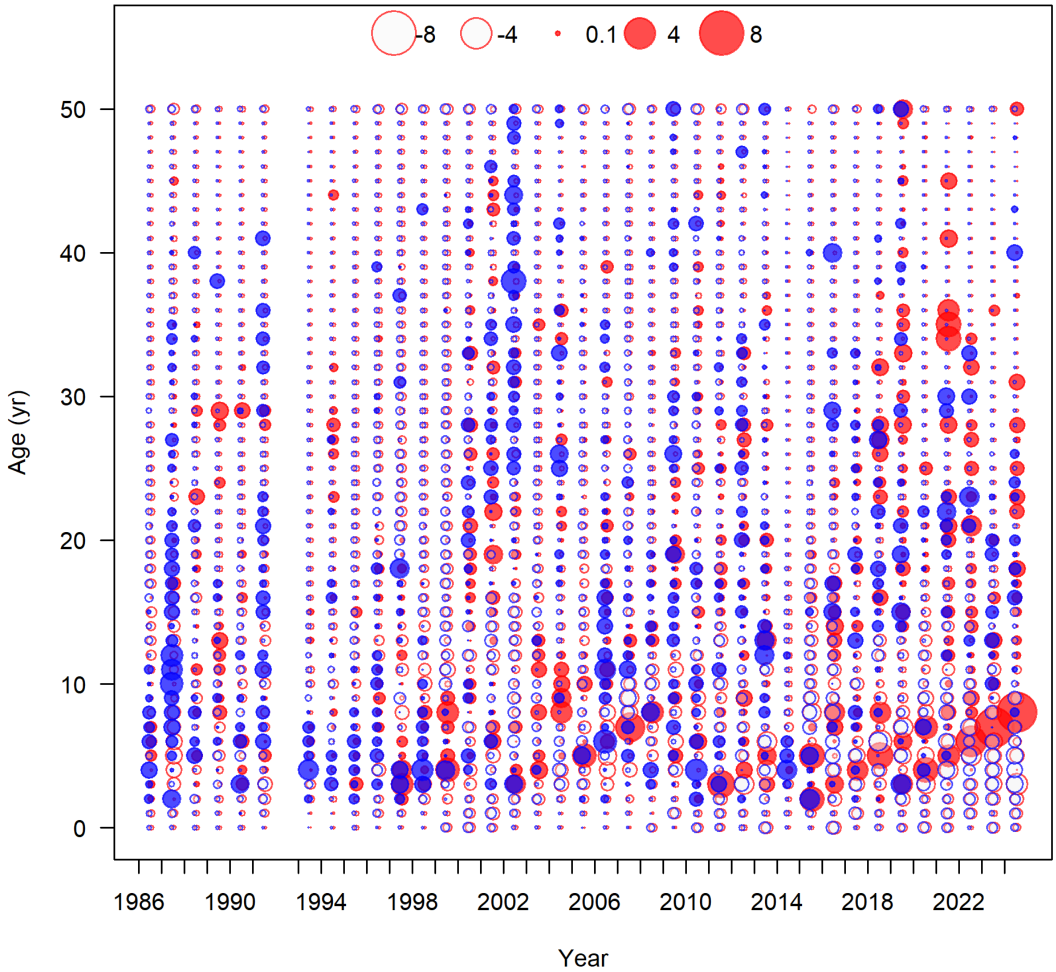

Figure 81: Pearsons residuals to age composition data from the hook-and-line fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

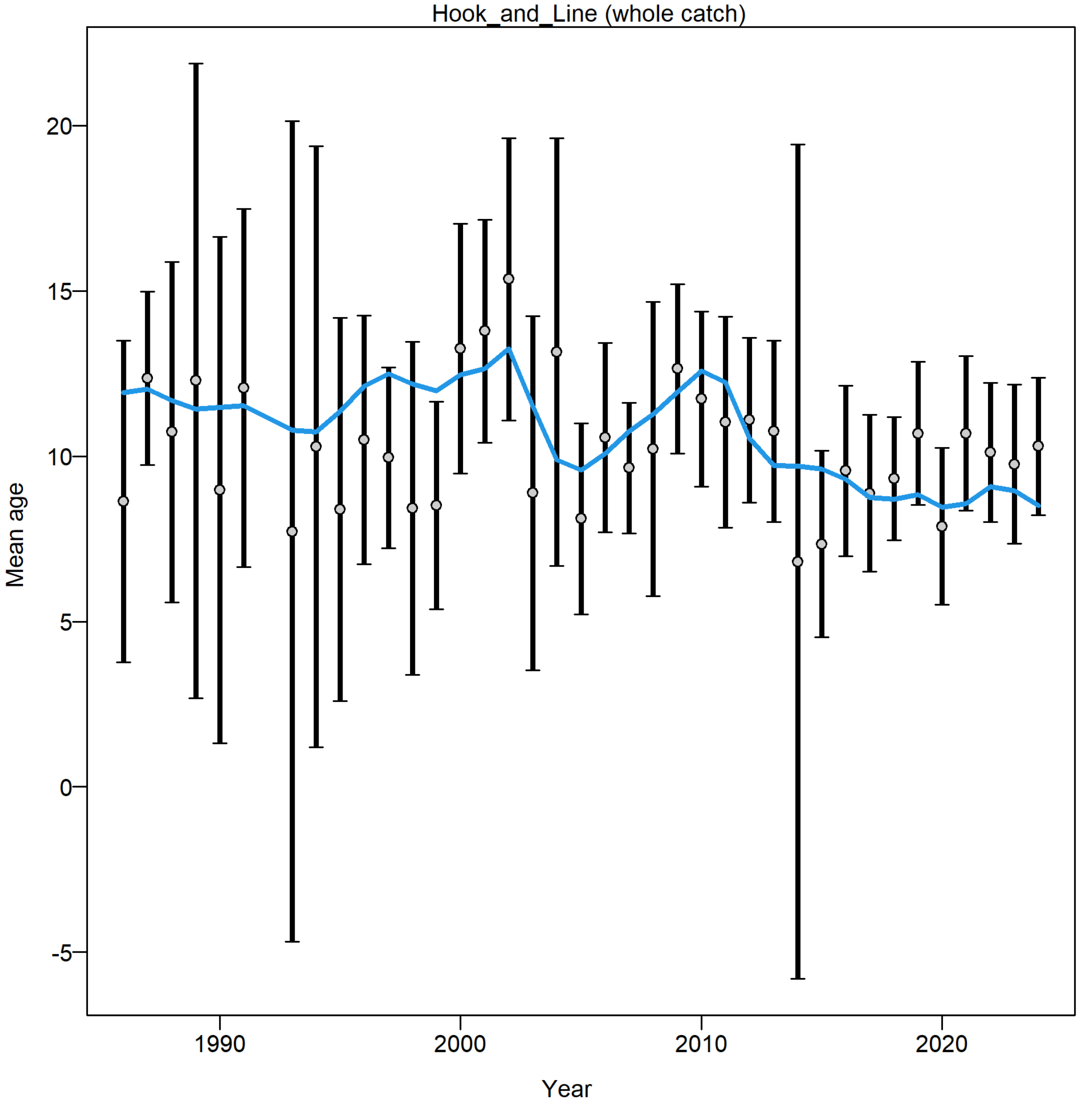

Figure 82: Mean age by year with confidence intervals for sexed and unsexed ages from the hook-and-line fleet.

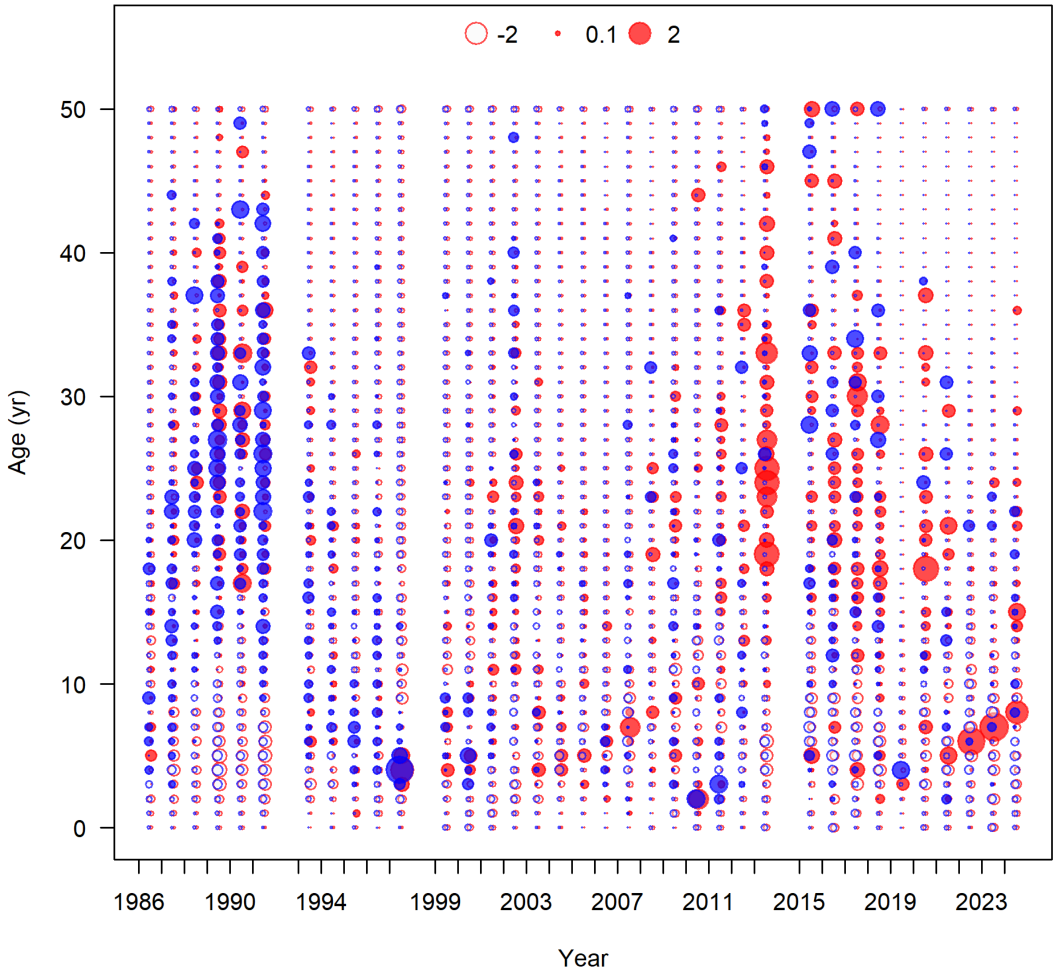

Figure 83: Pearsons residuals to age composition data from the pot fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

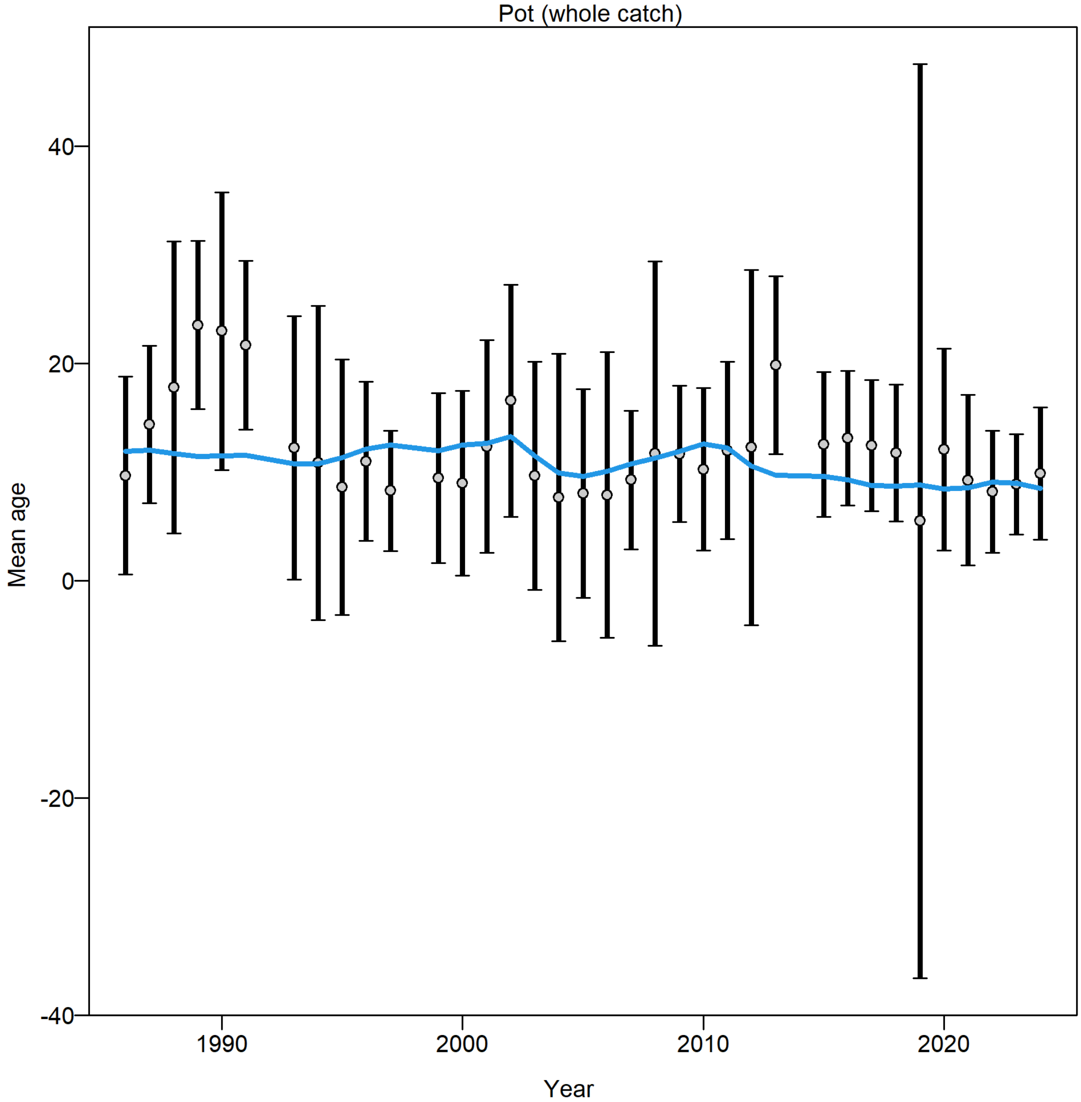

Figure 84: Mean age by year with confidence intervals for sexed and unsexed ages from the pot fleet.

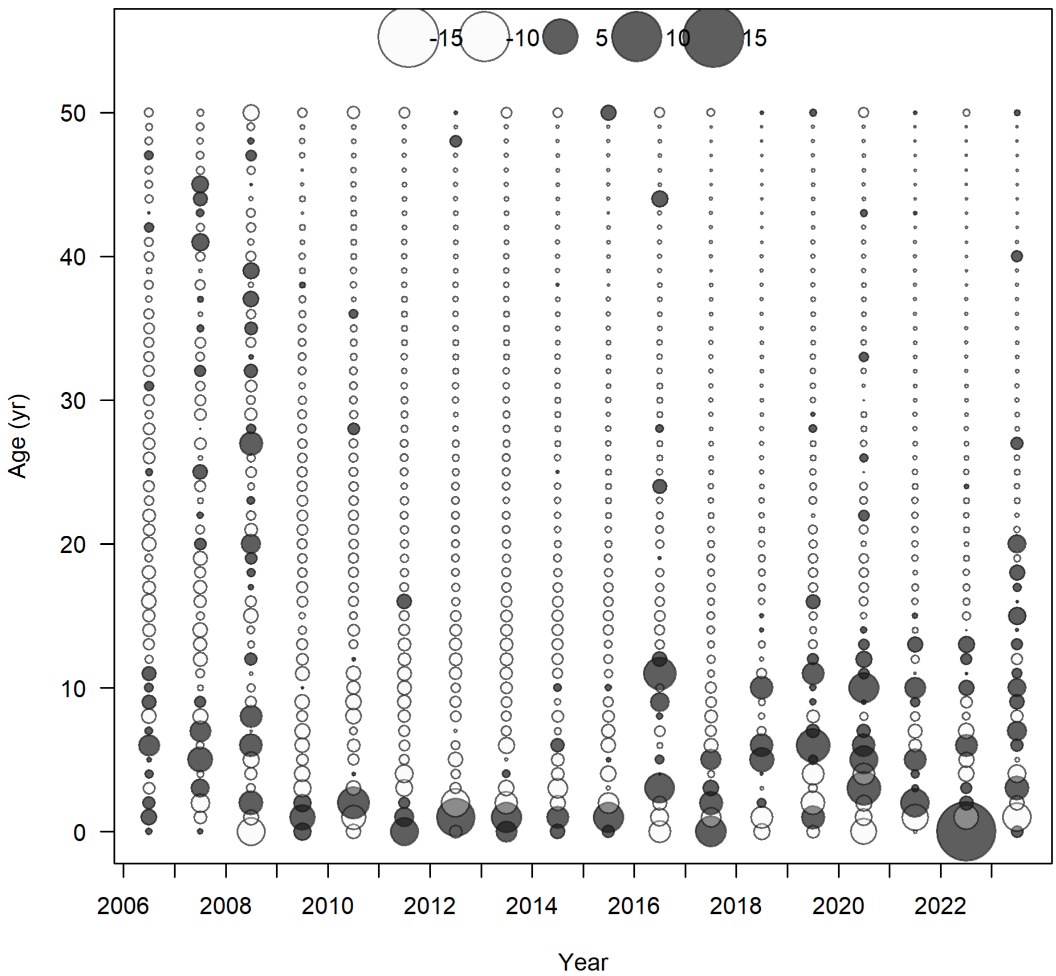

Figure 85: Pearsons residuals to age composition data from the trawl discard fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

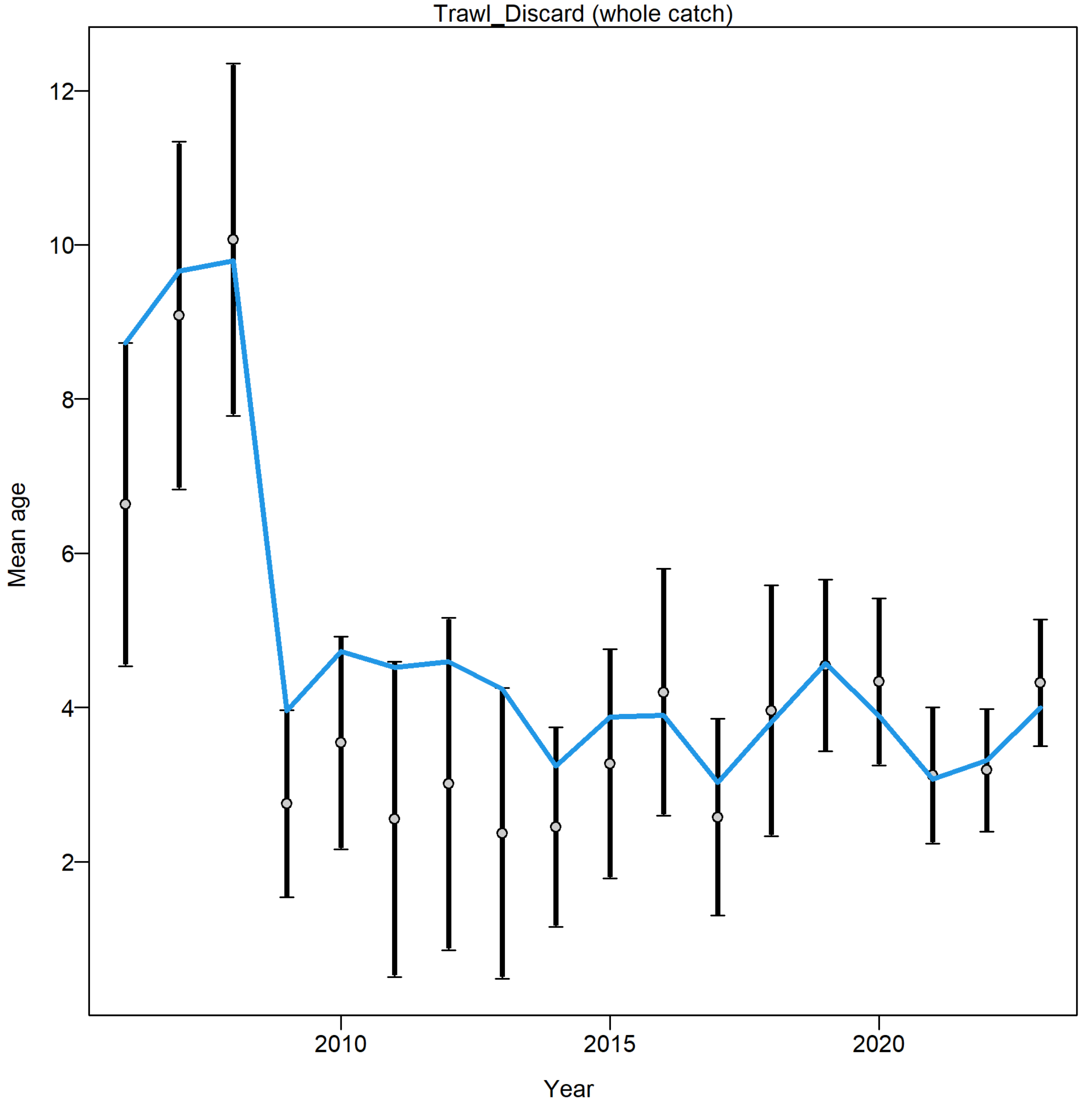

Figure 86: Mean age by year with confidence intervals for sexed and unsexed ages from the trawl discard fleet.

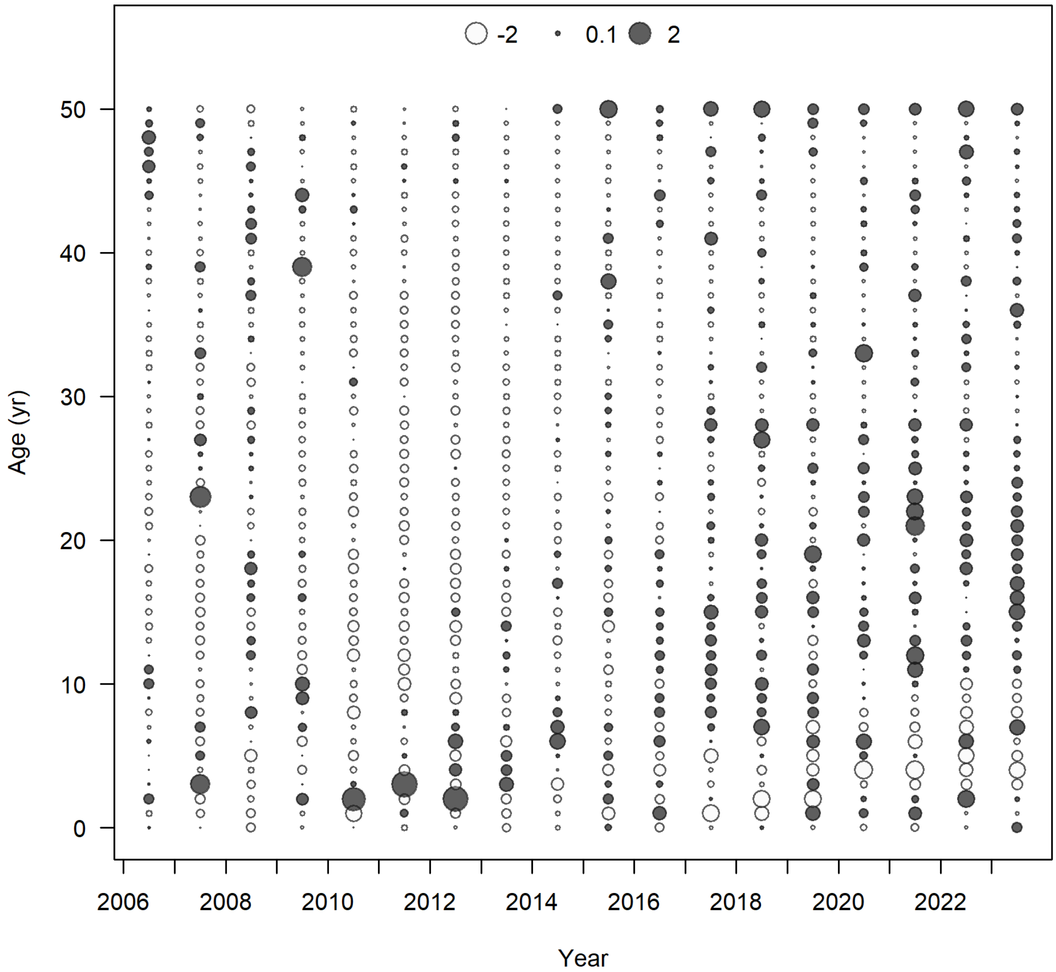

Figure 87: Pearsons residuals to age composition data from the hook-and-line discard fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

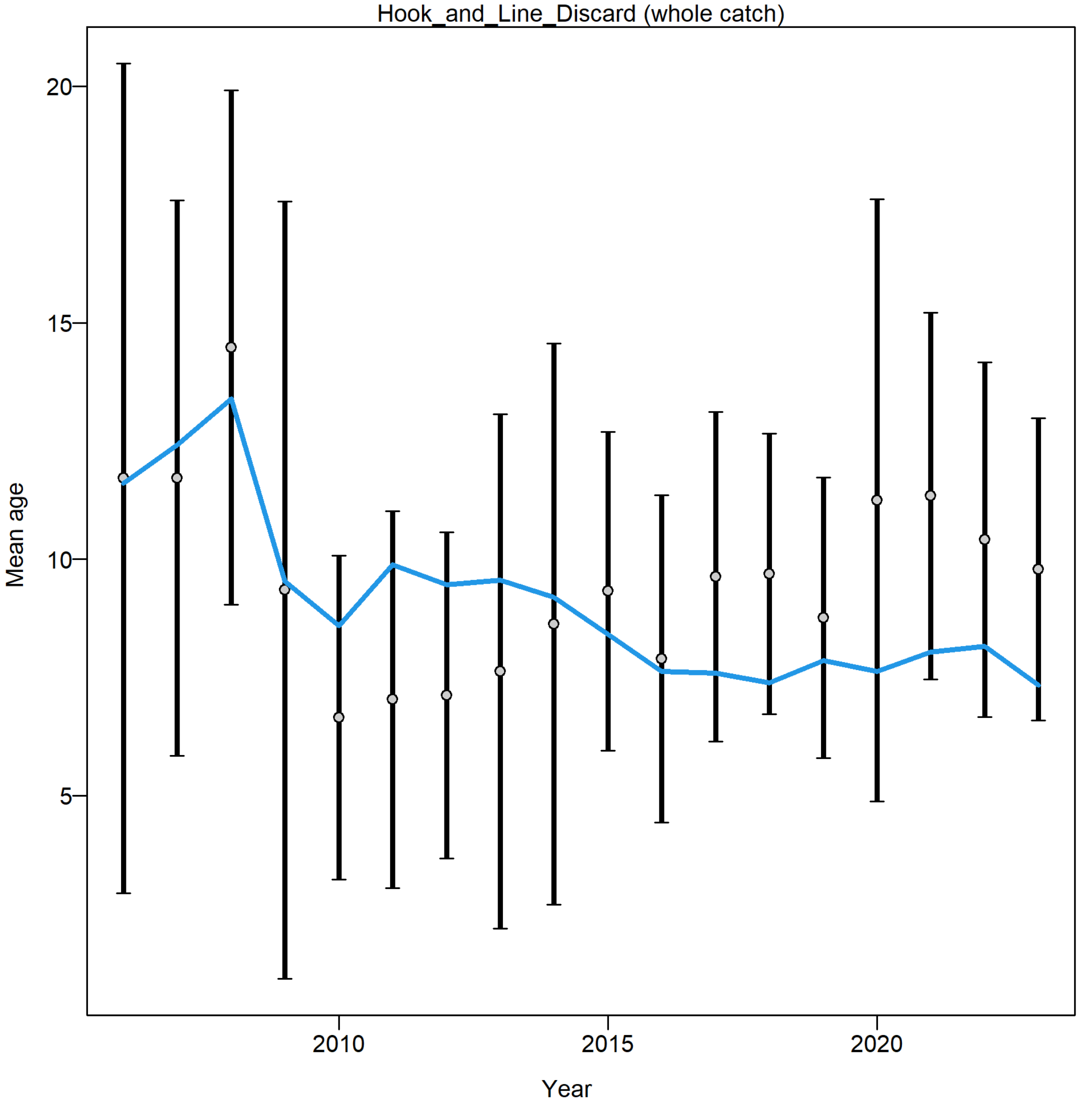

Figure 88: Mean age by year with confidence intervals for sexed and unsexed ages from the hook-and-line discard fleet.

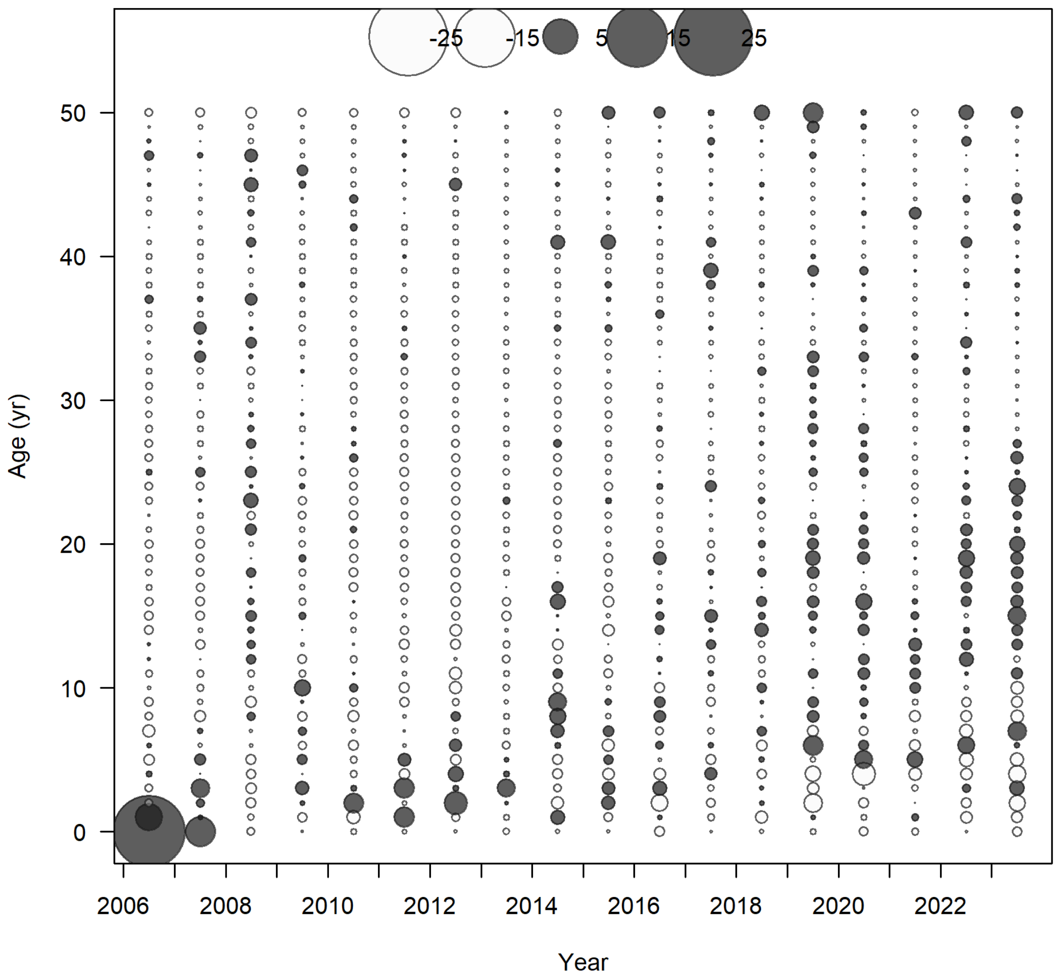

Figure 89: Pearsons residuals to age composition data from the pot discard fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

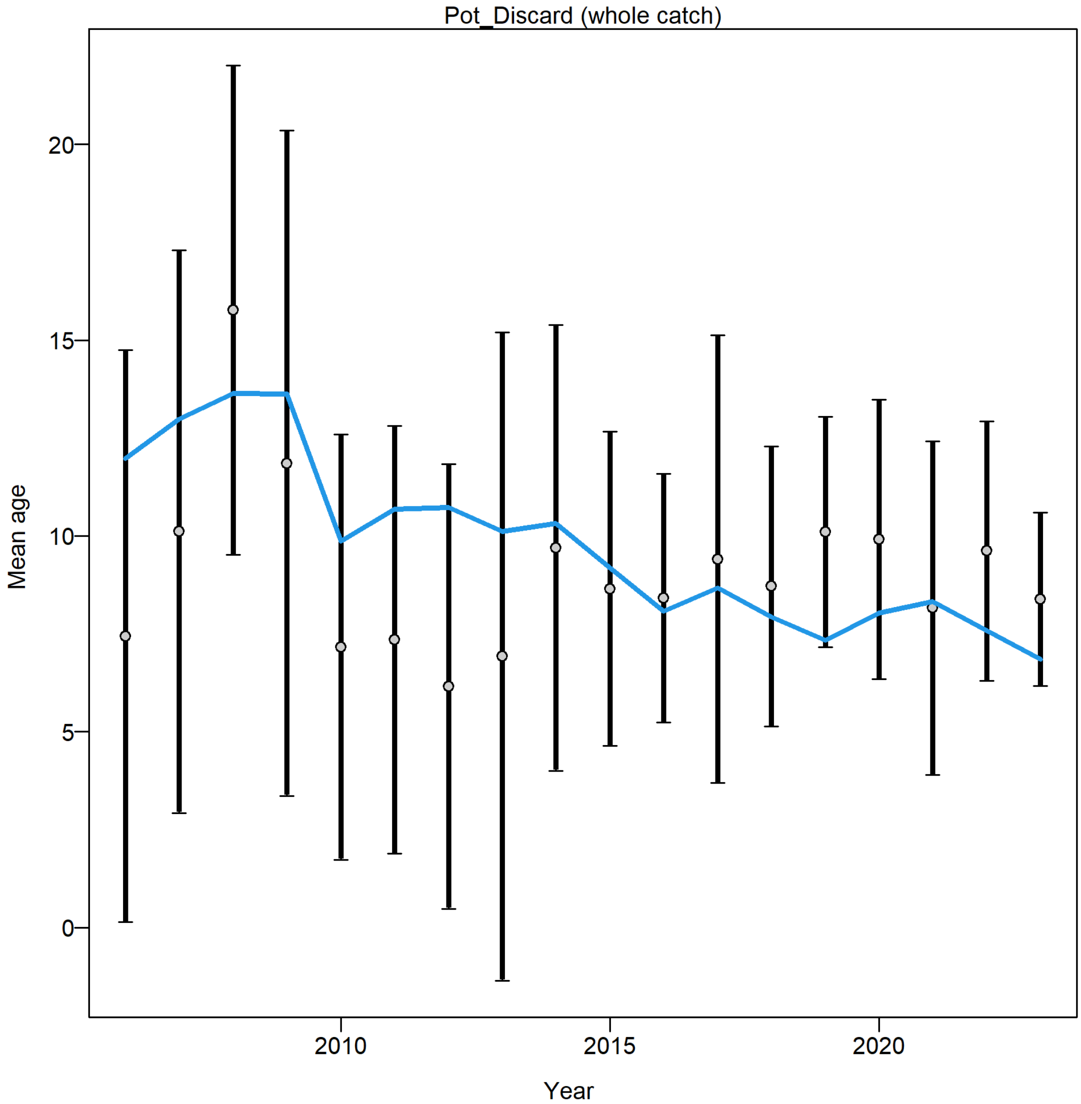

Figure 90: Mean age by year with confidence intervals for sexed and unsexed ages from the pot discard fleet.

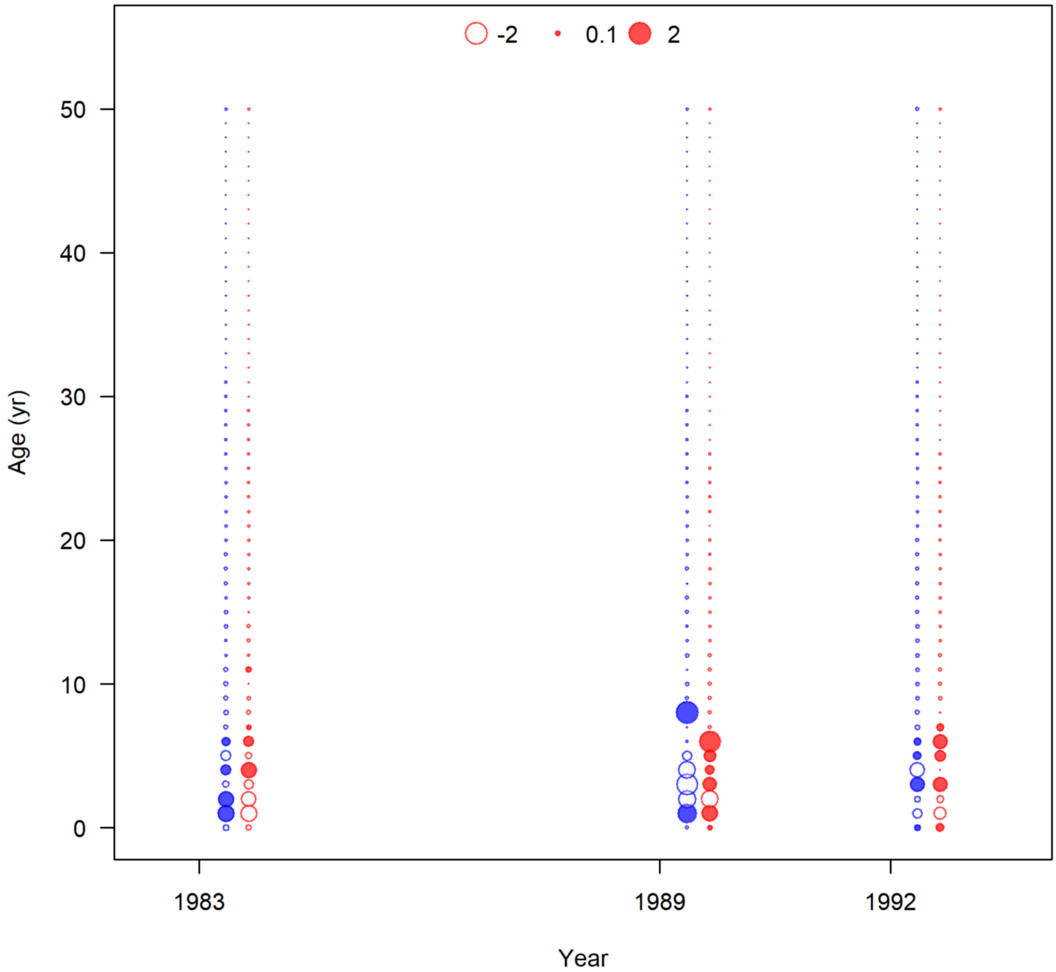

Figure 91: Pearsons residuals to age composition data from the Triennial Survey (1980-1992). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

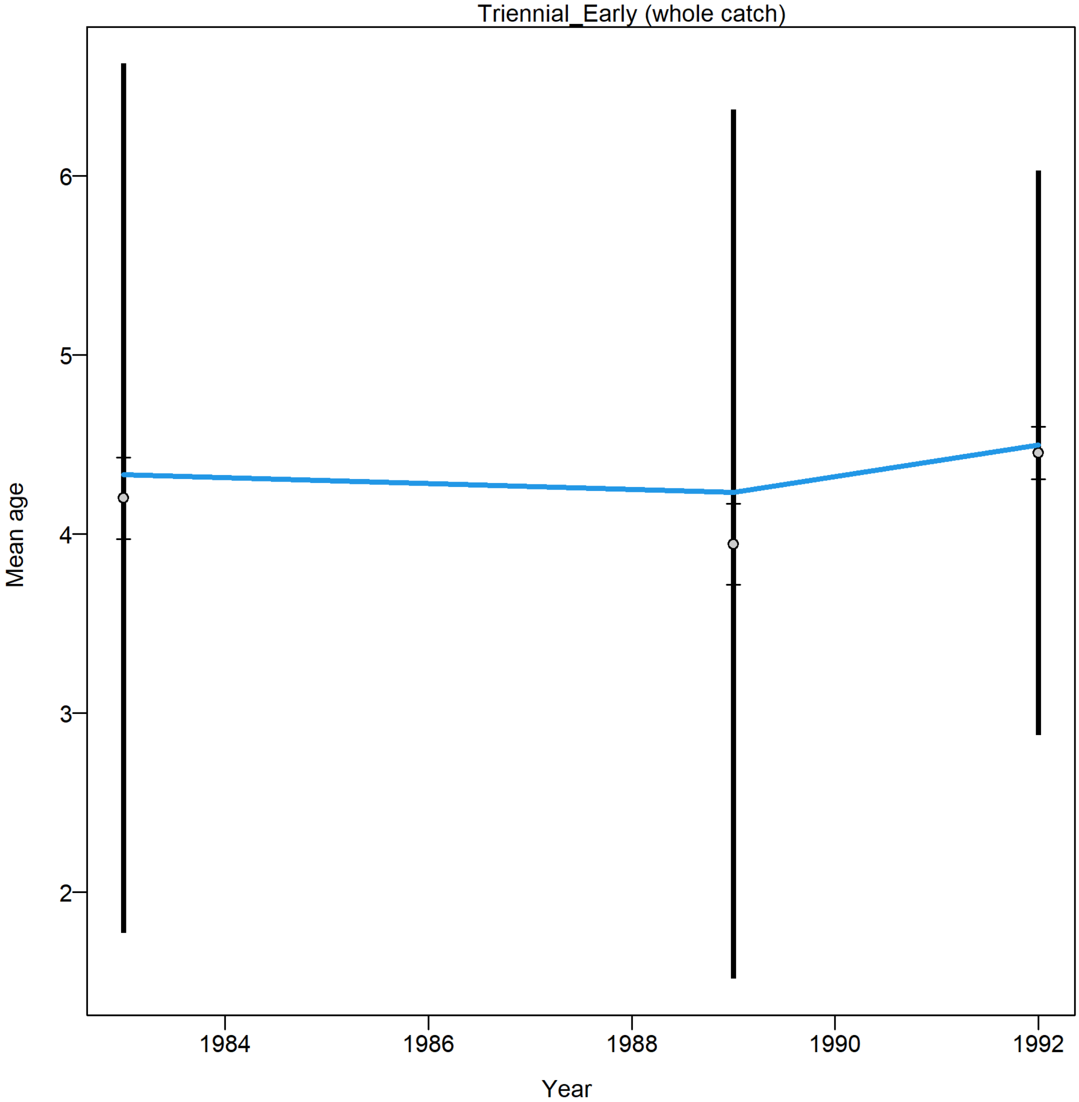

Figure 92: Mean age by year with confidence intervals for sexed and unsexed ages from the Triennial Survey (1980-1992).

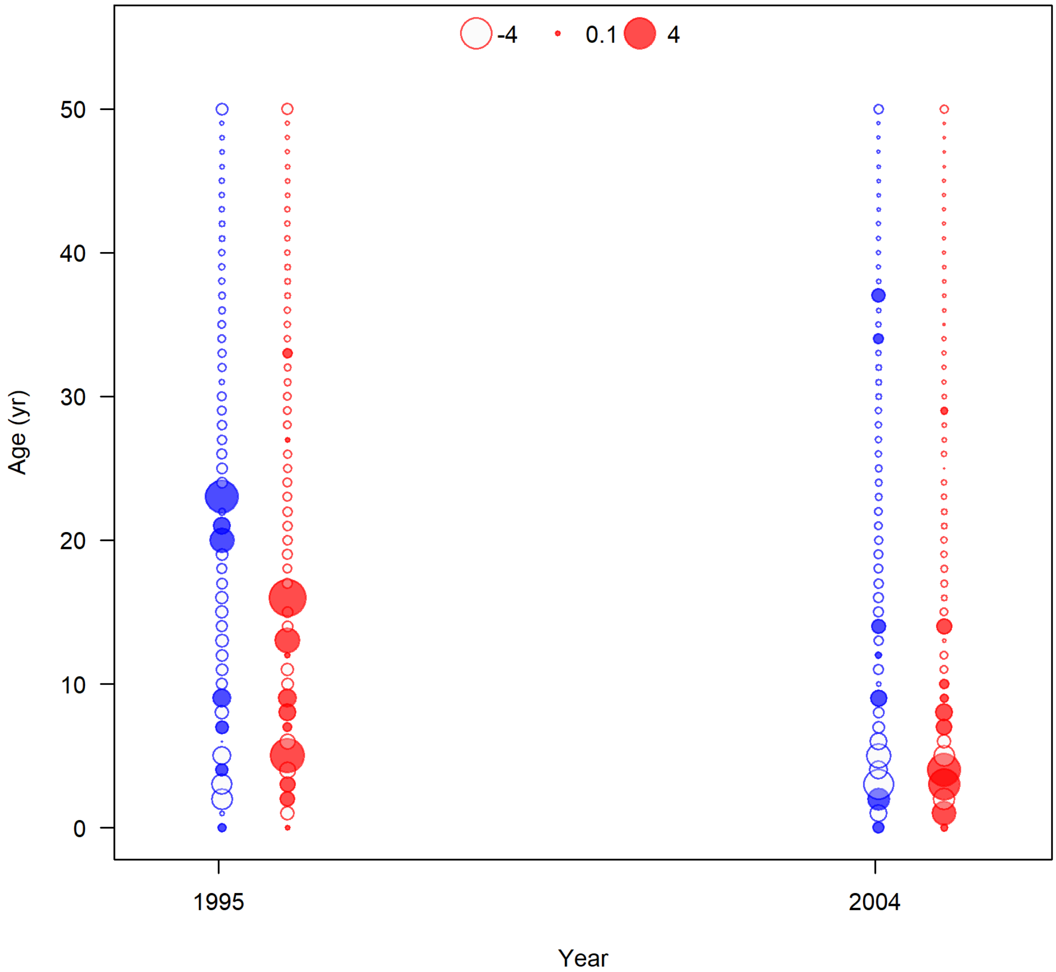

Figure 93: Pearsons residuals to age composition data from the Triennial Survey (1995-2004). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

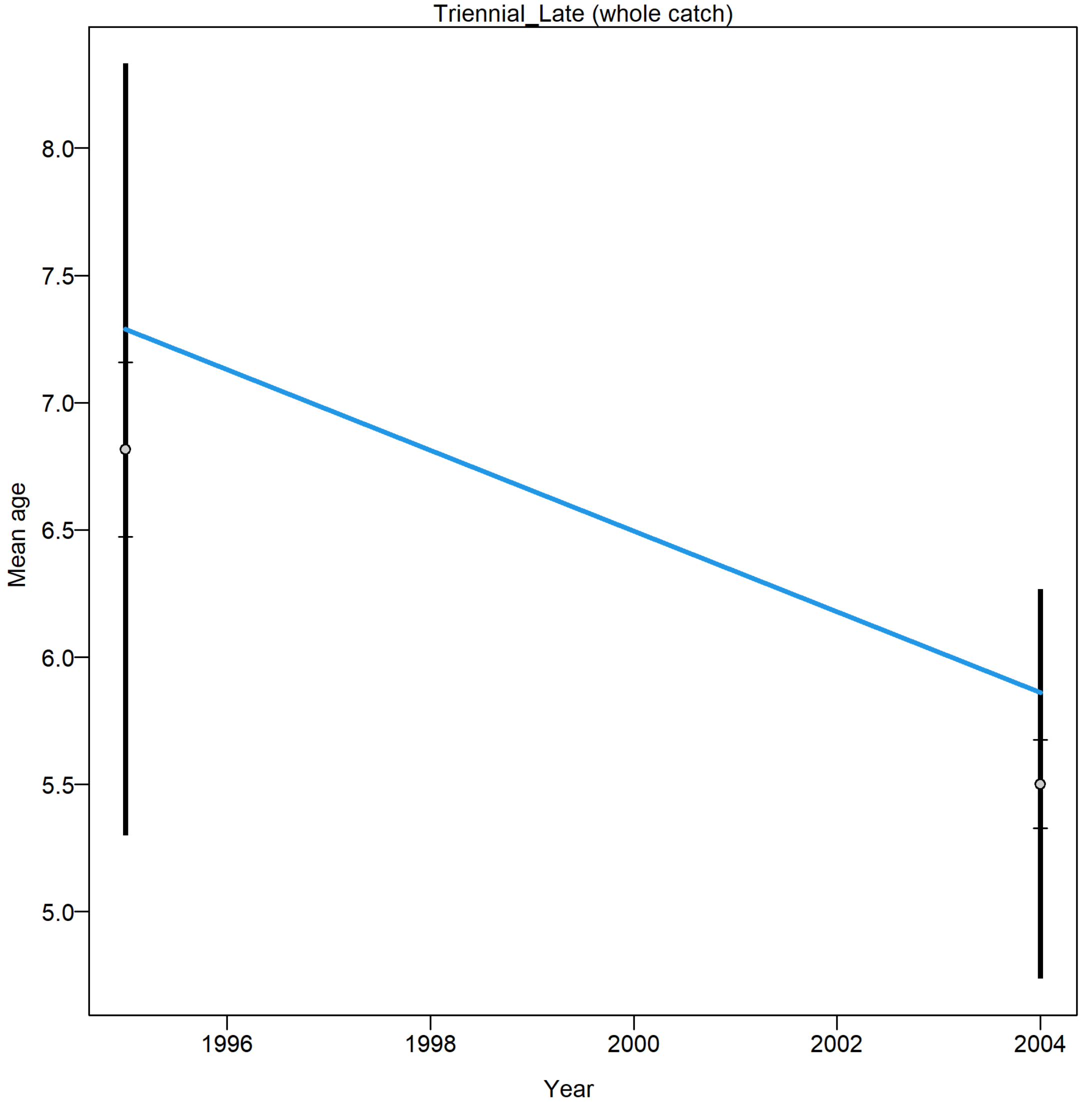

Figure 94: Mean age by year with confidence intervals for sexed and unsexed ages from the Triennial Survey (1995-2004).

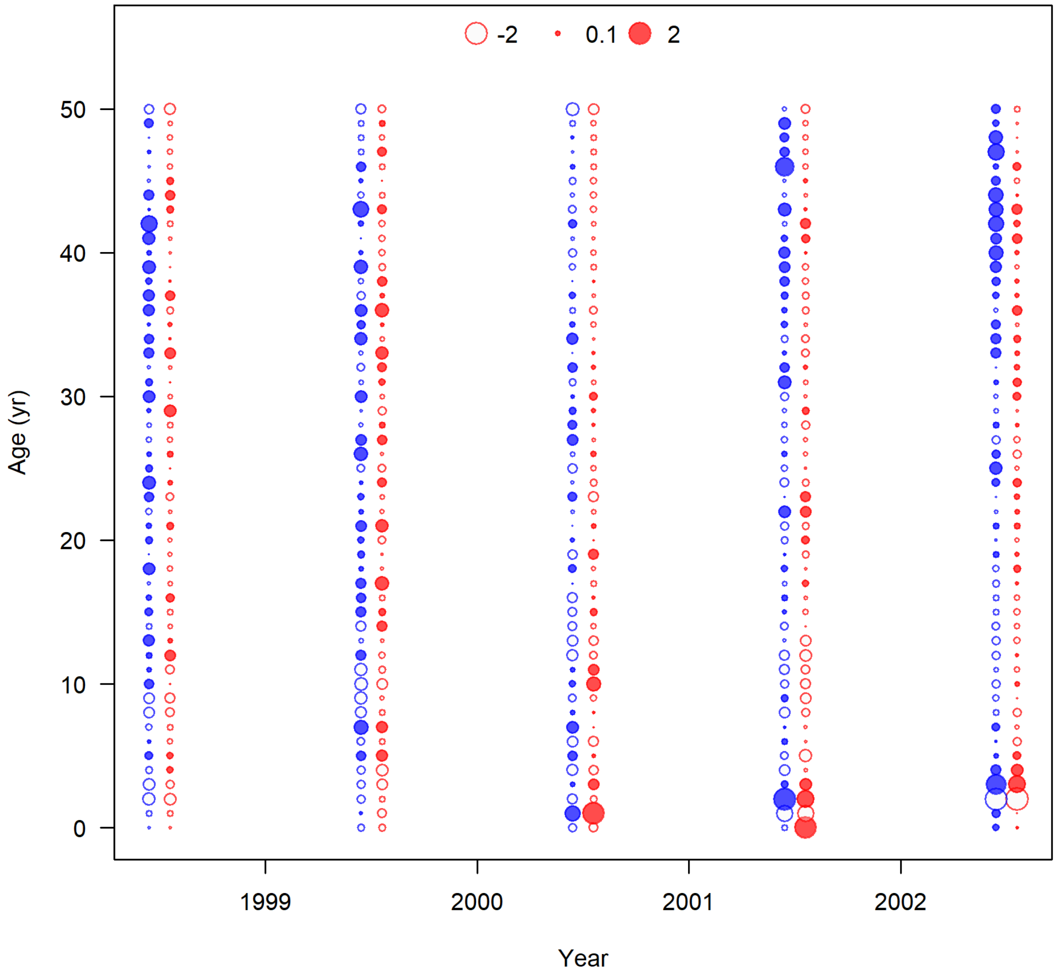

Figure 95: Pearsons residuals to age composition data from the NWFSC Slope Survey. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

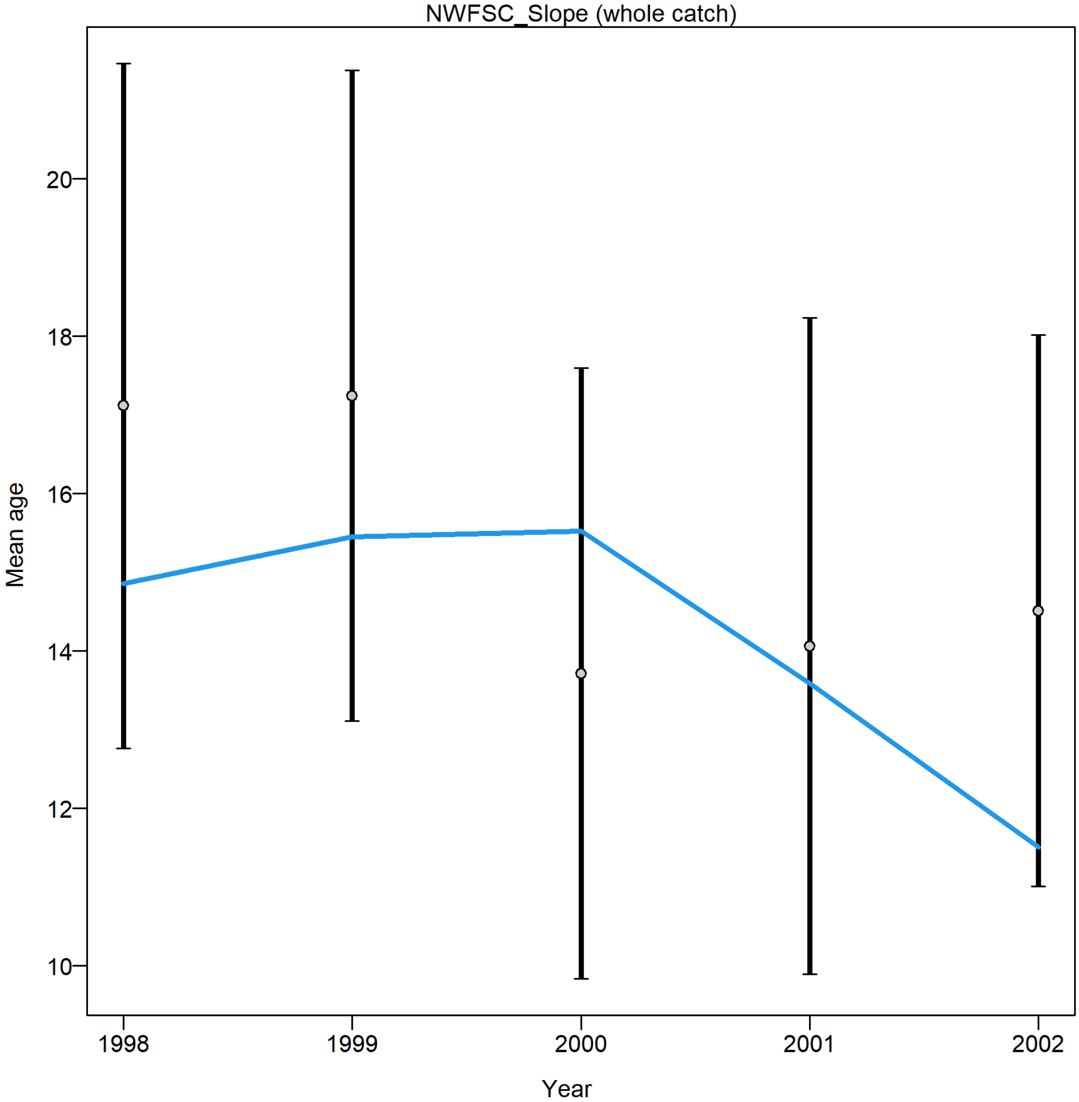

Figure 96: Mean age by year with confidence intervals for sexed and unsexed ages from the NWFSC Slope Survey.

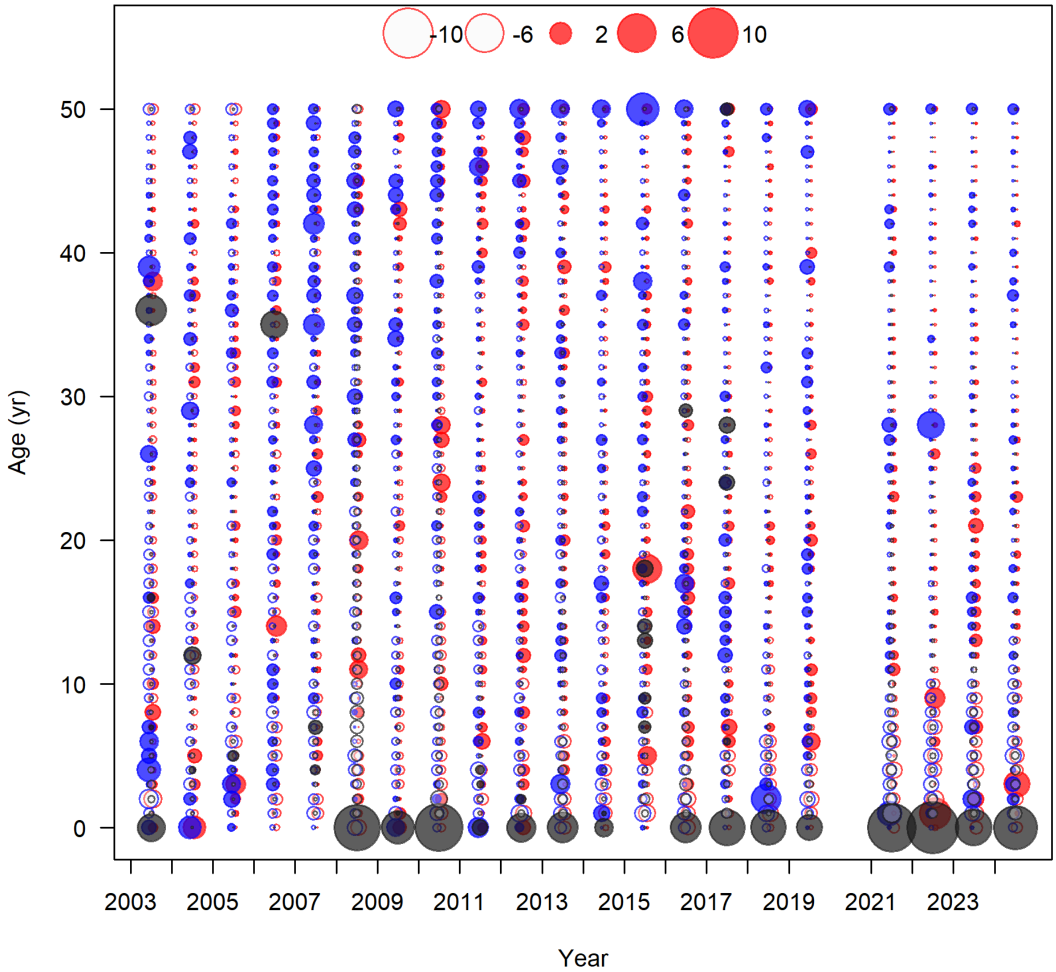

Figure 97: Pearsons residuals to age composition data from the NWFSC West Coast Groundfish Bottom Trawl Survey. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

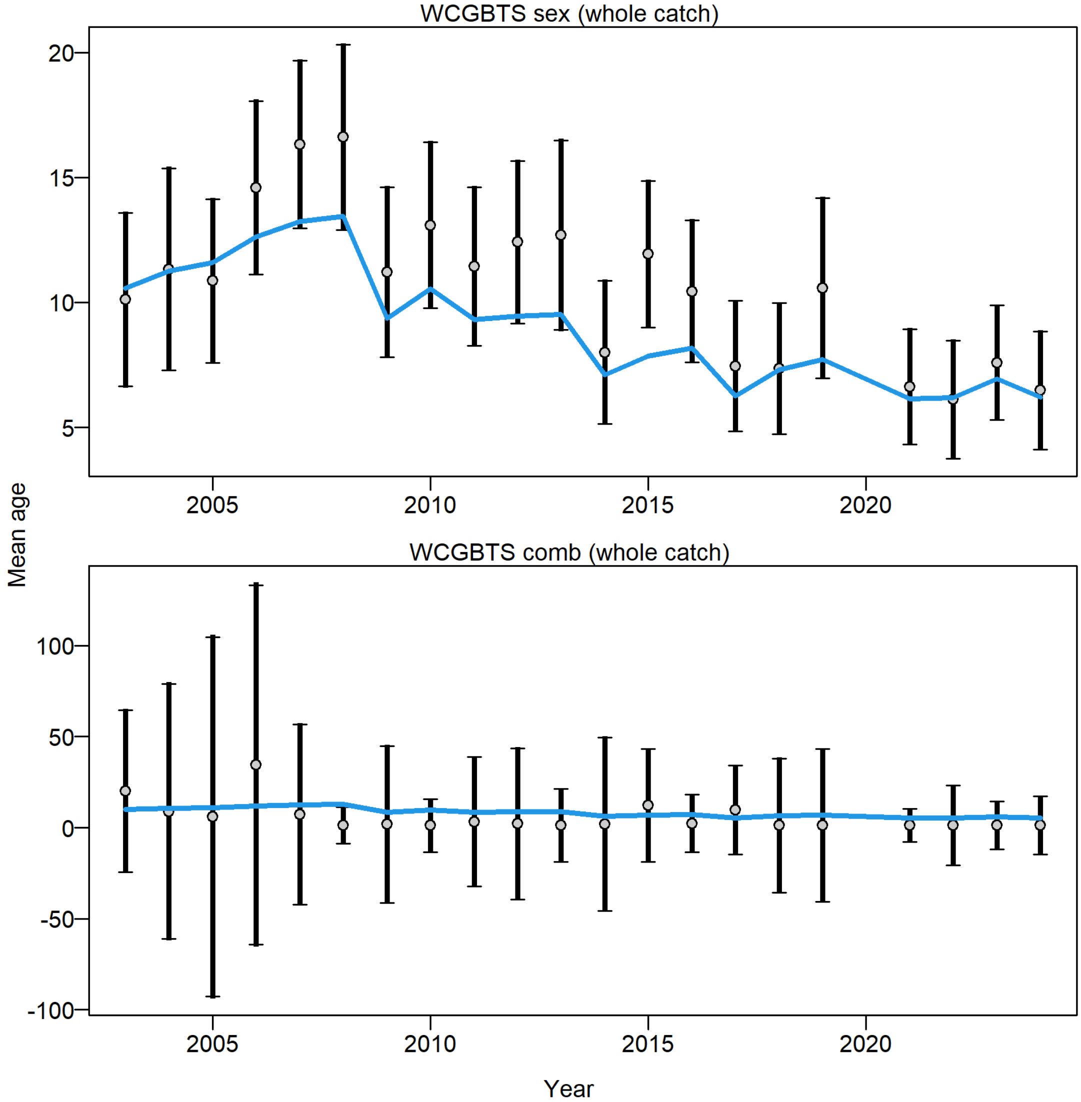

Figure 98: Mean age by year with confidence intervals for sexed and unsexed ages from the NWFSC West Coast Groundfish Bottom Trawl Survey. The top panel is sexed ages and the bottom panel includes both sexed and unsexed ages.

8.7 Time-series

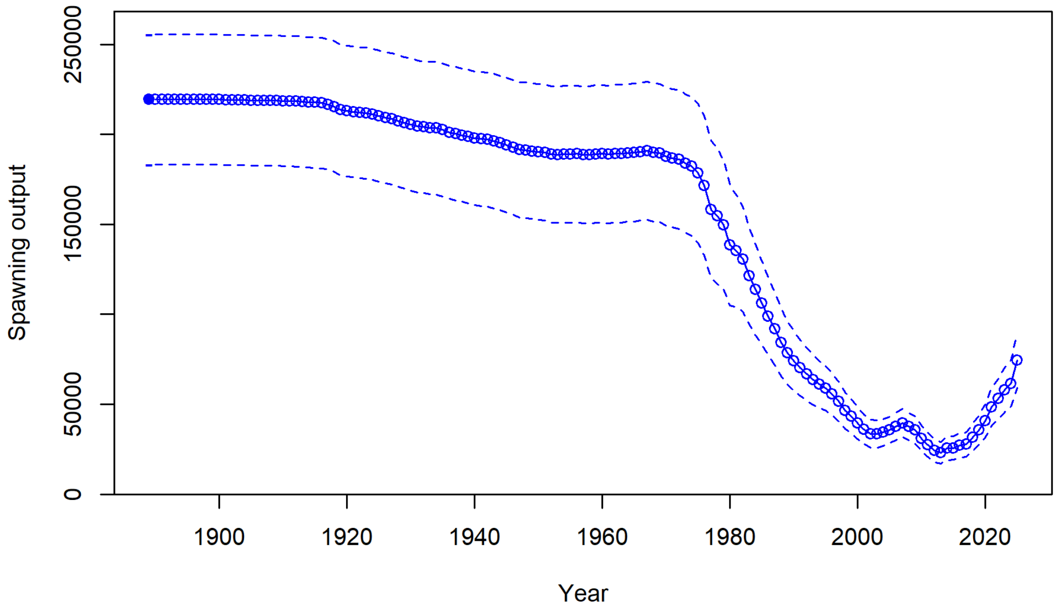

Figure 99: Estimated time series of spawning output for the base model.

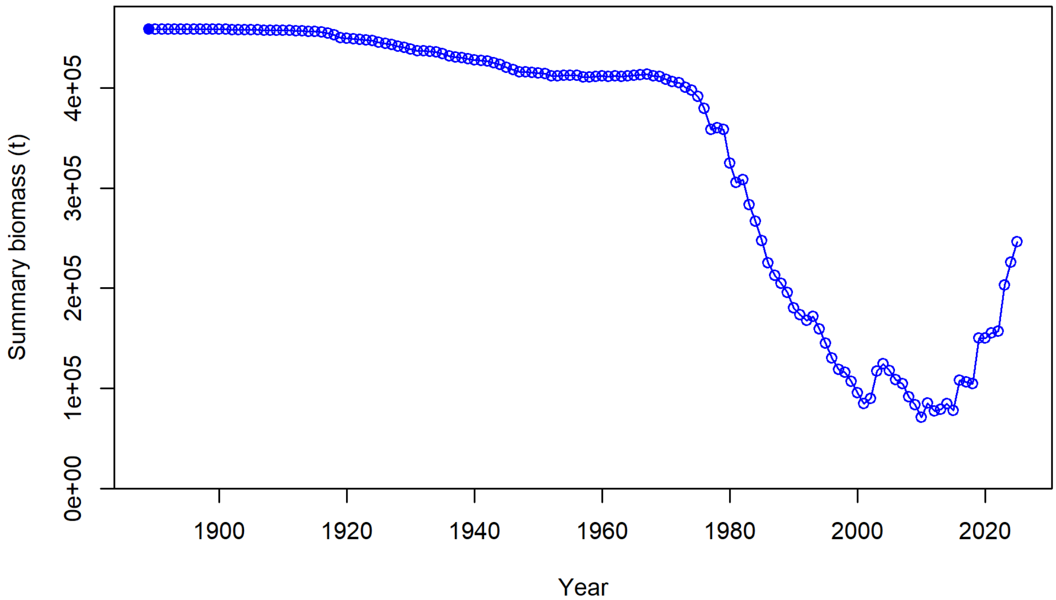

Figure 100: Estimated time series of summary biomass for age 3 and older for the base model.

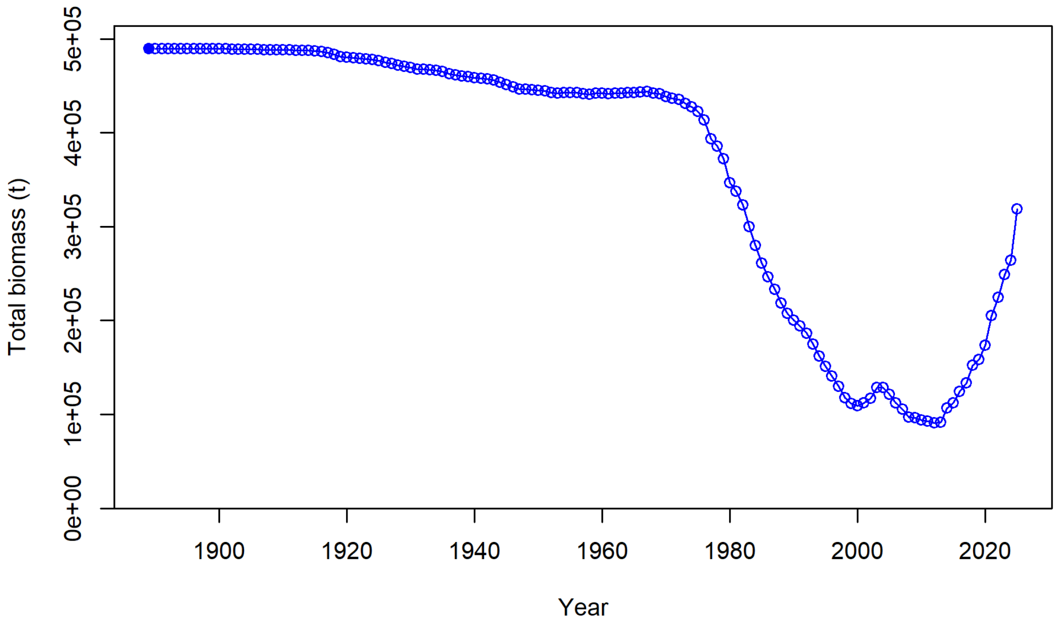

Figure 101: Estimated time series of total biomass for the base model.

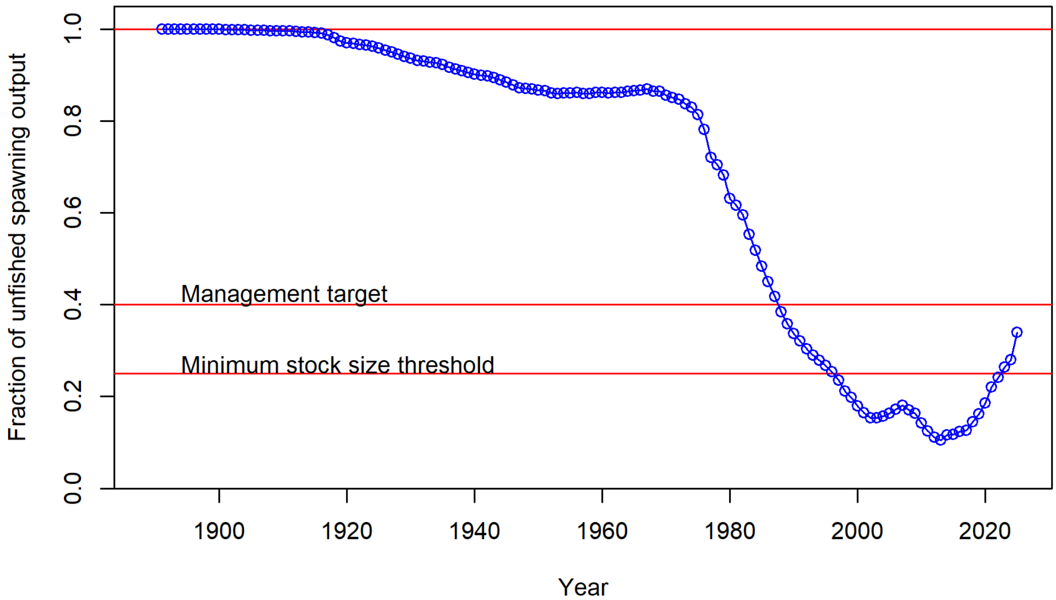

Figure 102: Estimated time series of relative spawning output (i.e., stock status) for the base model.

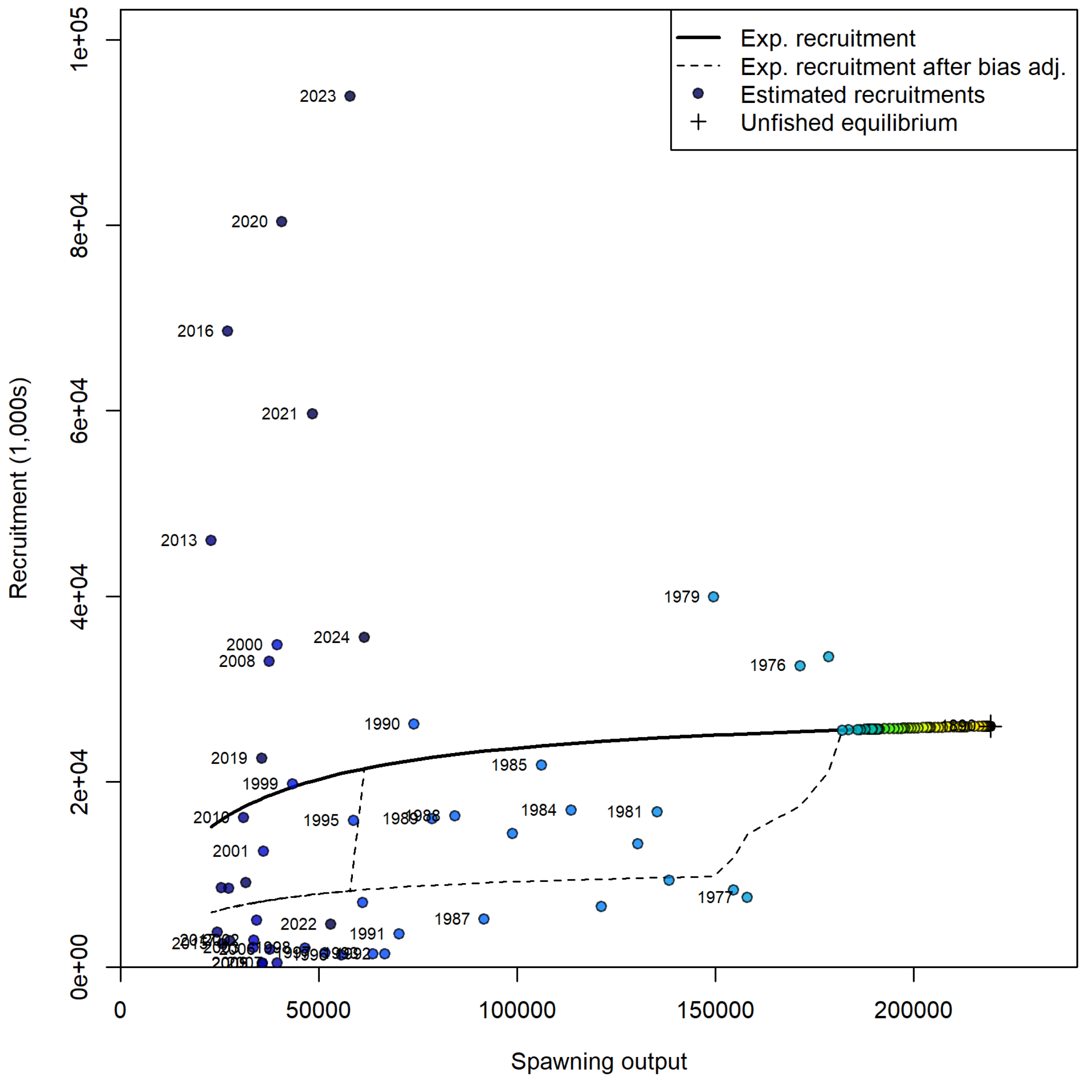

Figure 103: Stock-recruit curve with labels on first, last, and years with (log) deviations > 0.5. Point colors indicate year, with warmer colors indicating earlier years and cooler colors in showing later years.

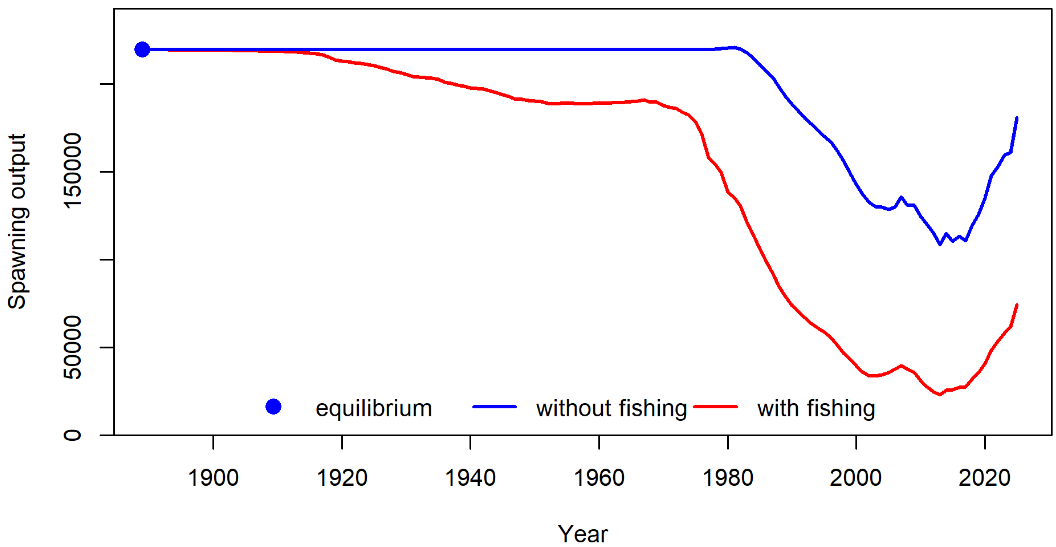

Figure 104: The lower line shows the time series of estimated spawning output in the presence of fishing mortality. The upper line shows the time series that could occur under the same dynamics (including deviations in recruitment), but without fishing. The point at the left represents the unfished equilibrium.

8.8 Sensitivity Analyses

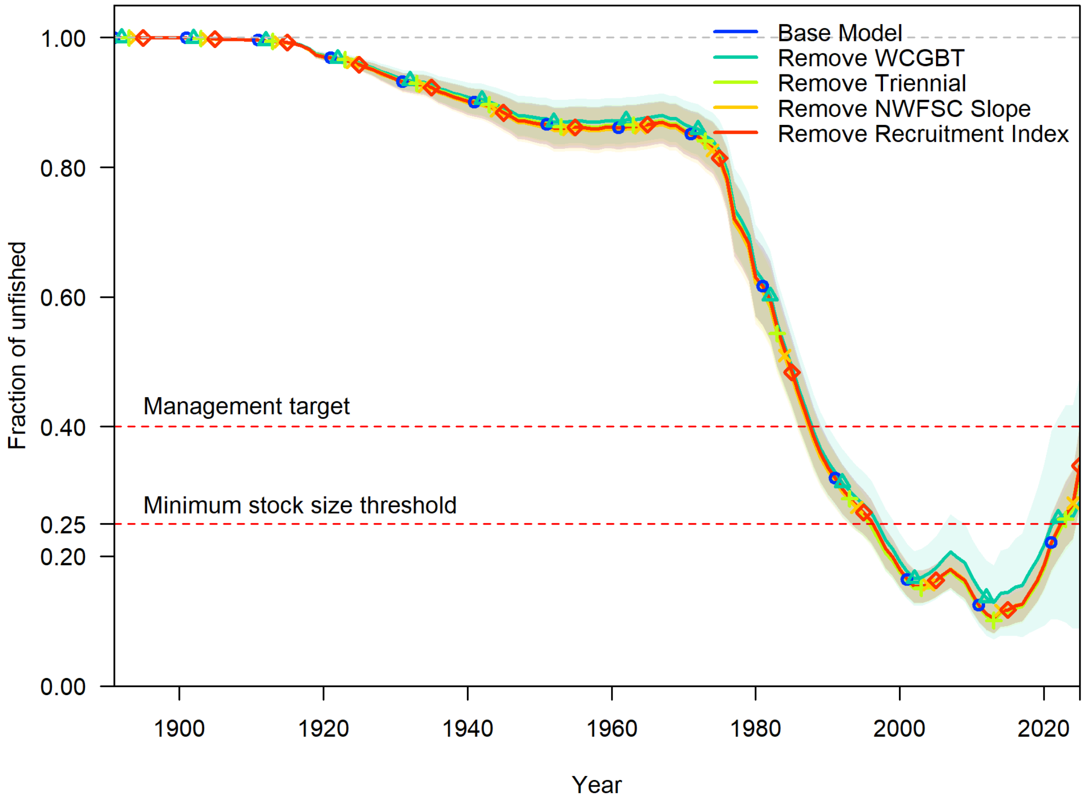

Figure 105: Maximum likelihood estimates of fraction of unfished (i.e., stock status) for the base model and alternative sensitivity runs representing the removal of index and age composition data from the West Coast Groundfish Bottom Trawl Survey (WCGBT), the Trienniel Survey, or the Northwest Fisheries Science Center Slope Survey. Additionally, estimates for the removal of the environmental-based recruitment index are shown. Shaded regions represent asymptotic 95 percent confidence intervals.

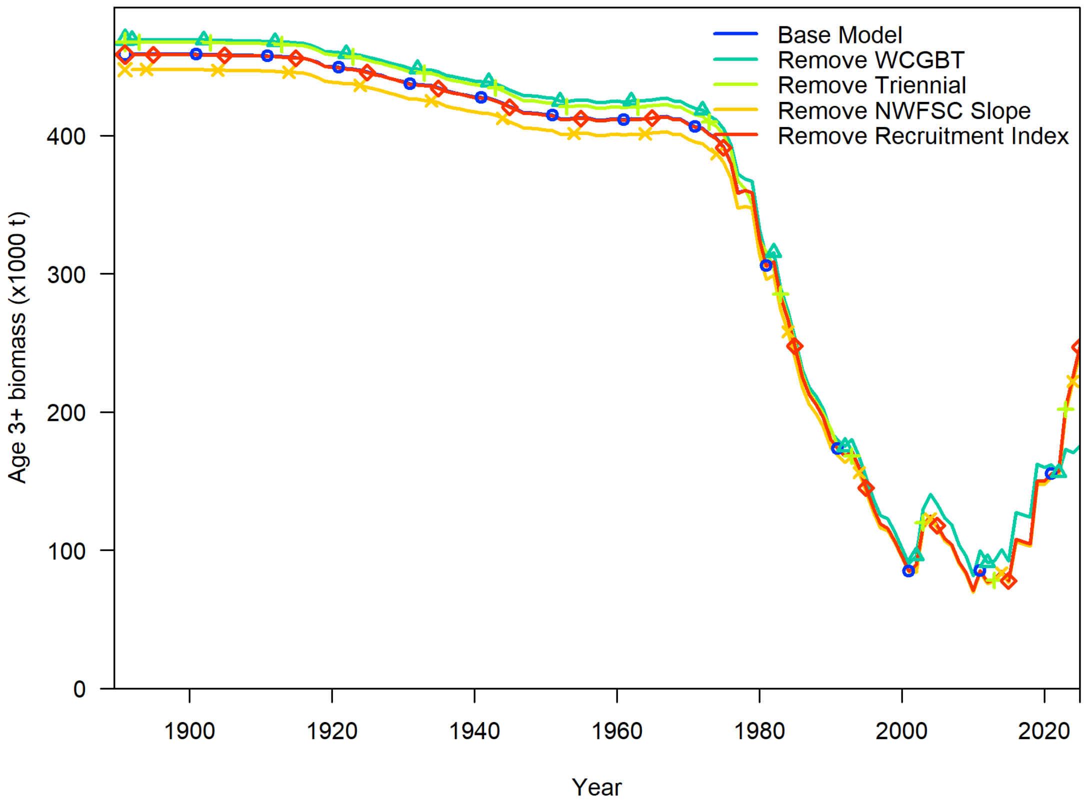

Figure 106: Maximum likelihood estimates of summary biomass (age 3 and older) for the base model and alternative sensitivity runs representing the removal of index and age composition data from the West Coast Groundfish Bottom Trawl Survey (WCGBT), the Trienniel Survey, or the Northwest Fisheries Science Center Slope Survey. Additionally, estimates for the removal of the environmental-based recruitment index are shown.

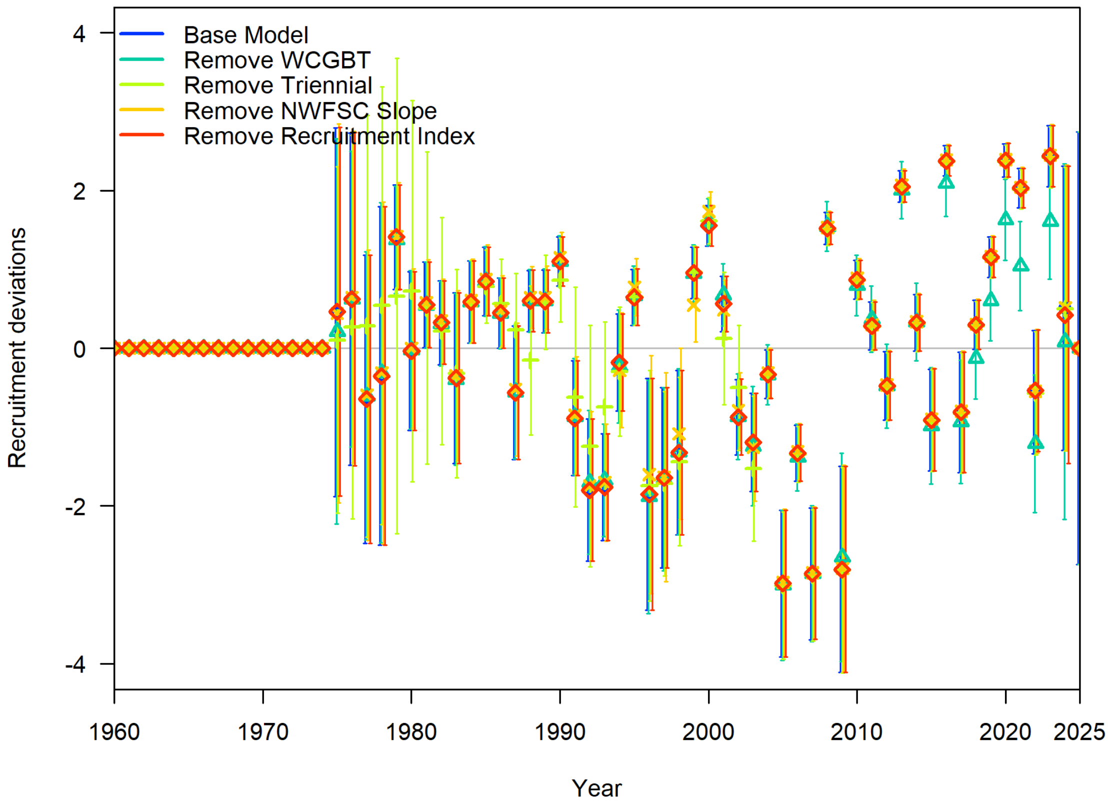

Figure 107: Maximum likelihood estimates of recruitment deviations from 1960-2025 for the base model and alternative sensitivity runs representing the removal of index and age composition data from the West Coast Groundfish Bottom Trawl Survey (WCGBT), the Trienniel Survey, or the Northwest Fisheries Science Center Slope Survey. Additionally, estimates for the removal of the environmental-based recruitment index are shown. Bars represent asymptotic 95 percent confidence intervals.

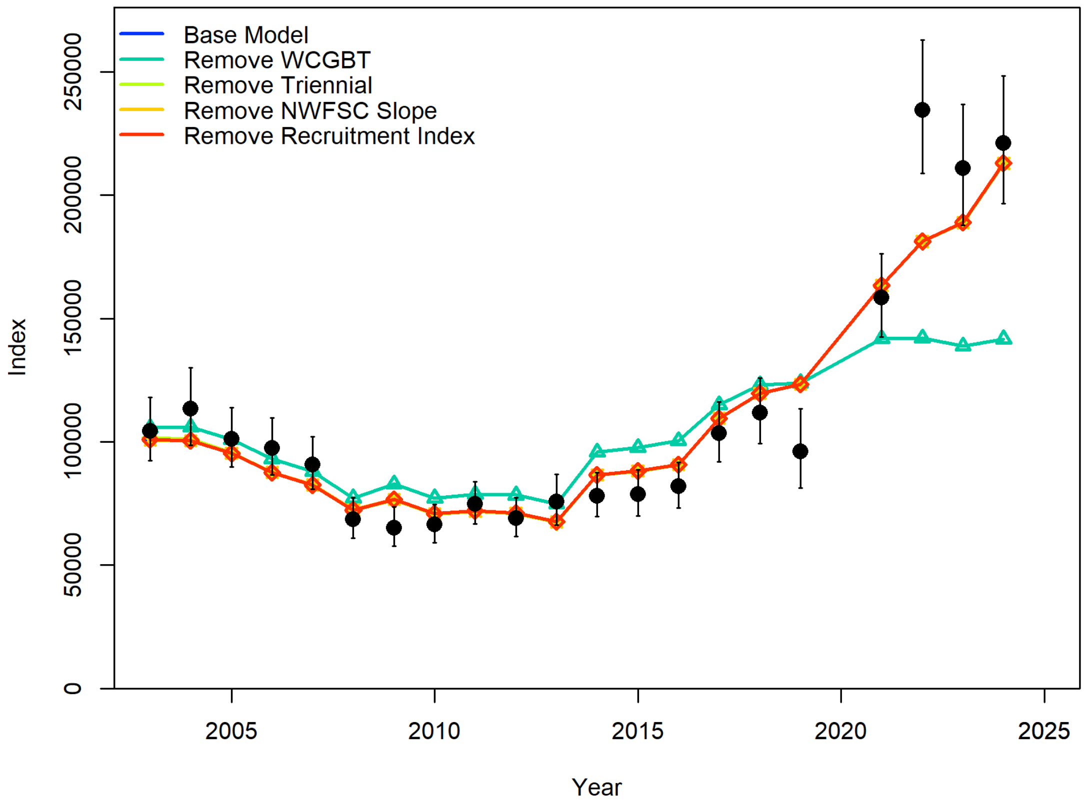

Figure 108: Maximum likelihood estimates of the fit to the NWFSC West Coast Groundfish Bottom Trawl Survey (WCGBTS) time series for the base model and alternative sensitivity runs representing the removal of index and age composition data from the West Coast Groundfish Bottom Trawl Survey (WCGBTS), the Trienniel Survey, or the NWFSC Slope Survey. Additionally, estimates for the removal of the environmental-based recruitment index are shown. The black dots with error bars represent the input index data points with associated uncertainty, whereas colors reprsent the estimated values for each year and model. Note that the results for all models are nearly identical, except for the Remove WCBGTS run.

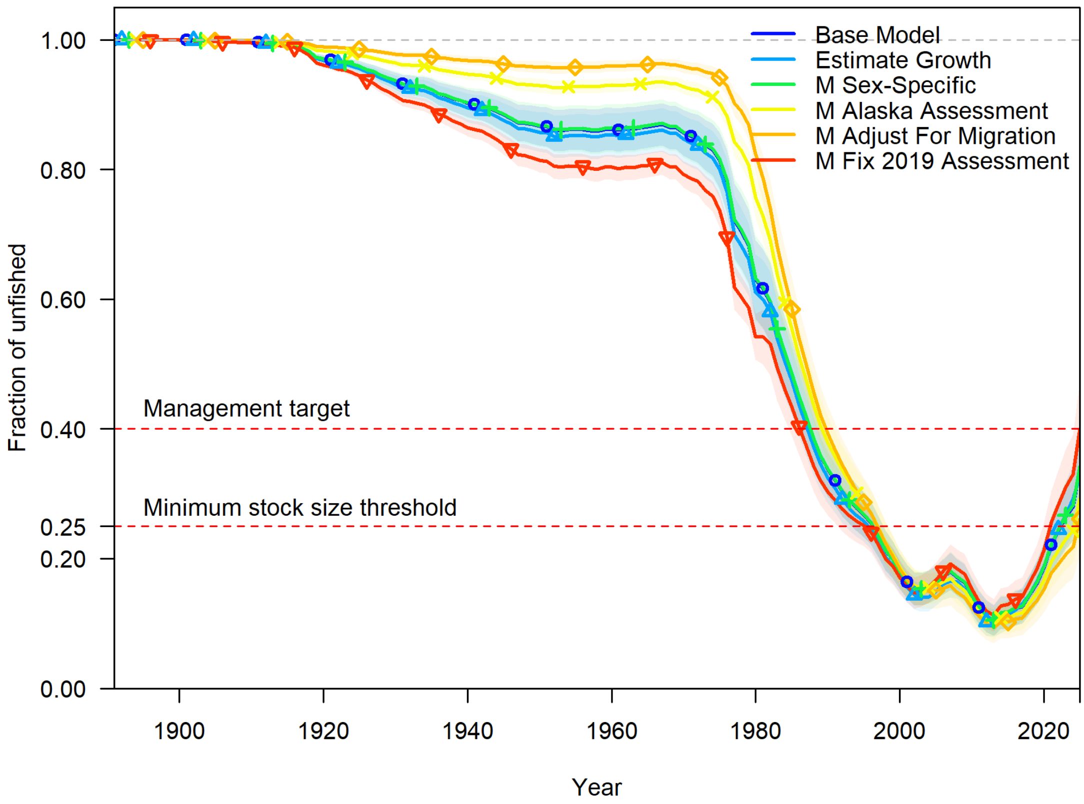

Figure 109: Maximum likelihood estimates of fraction of unfished (i.e., stock status) for the base model and alternative sensitivity runs representing the estimation of growth (rather than using an empircal weight-at-age approach for growth as in the base model), the estimation of sex-specific natural mortality (M), and fixing M at the value used in the assessment of sablefish in Alaska, adjusted upwards to offset potential net emigration to Canada, or set to sex-specific values used in the 2019 U.S. West Coast assessment of sablefish. Shaded regions represent asymptotic 95 percent confidence intervals.

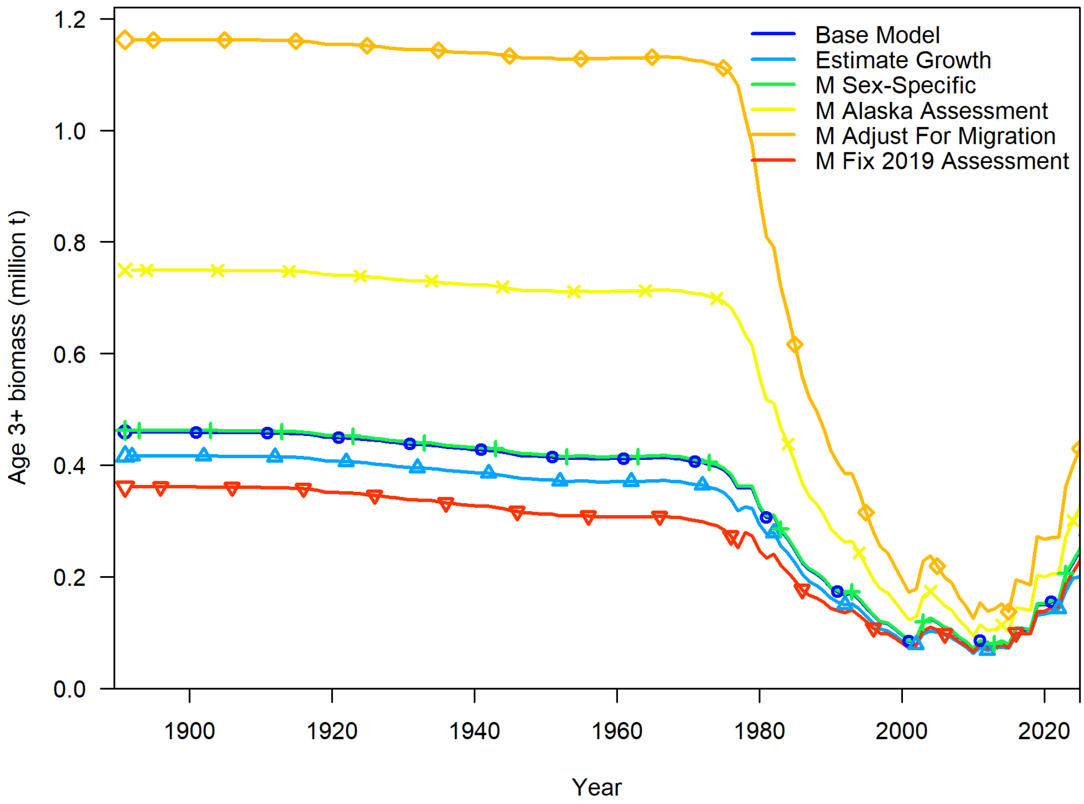

Figure 110: Maximum likelihood estimates of summary biomass (age 3 and older) for the base model and alternative sensitivity runs representing the estimation of growth (rather than using an empircal weight-at-age approach for growth as in the base model), the estimation of sex-specific natural mortality (M), and fixing M at the value used in the assessment of sablefish in Alaska, adjusted upwards to offset potential net emigration to Canada, or set to sex-specific values used in the 2019 U.S. West Coast assessment of sablefish.

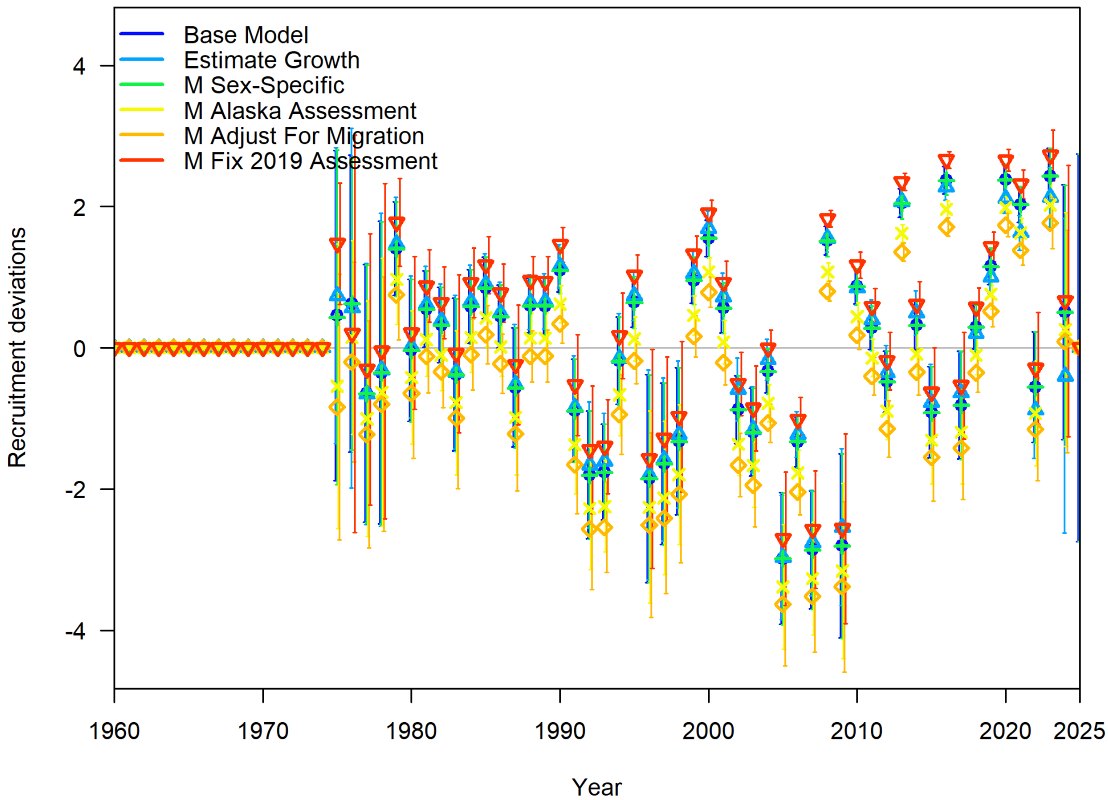

Figure 111: Maximum likelihood estimates of recruitment deviations from 1960-2025 for the base model and alternative sensitivity runs representing the estimation of growth (rather than using an empirical weight-at-age approach for growth as in the base model), the estimation of sex-specific natural mortality (M), and fixing M at the value used in the assessment of sablefish in Alaska, adjusted upwards to offset potential net emigration to Canada, or set to sex-specific values used in the 2019 U.S. West Coast assessment of sablefish. Bars represent asymptotic 95 percent confidence intervals.

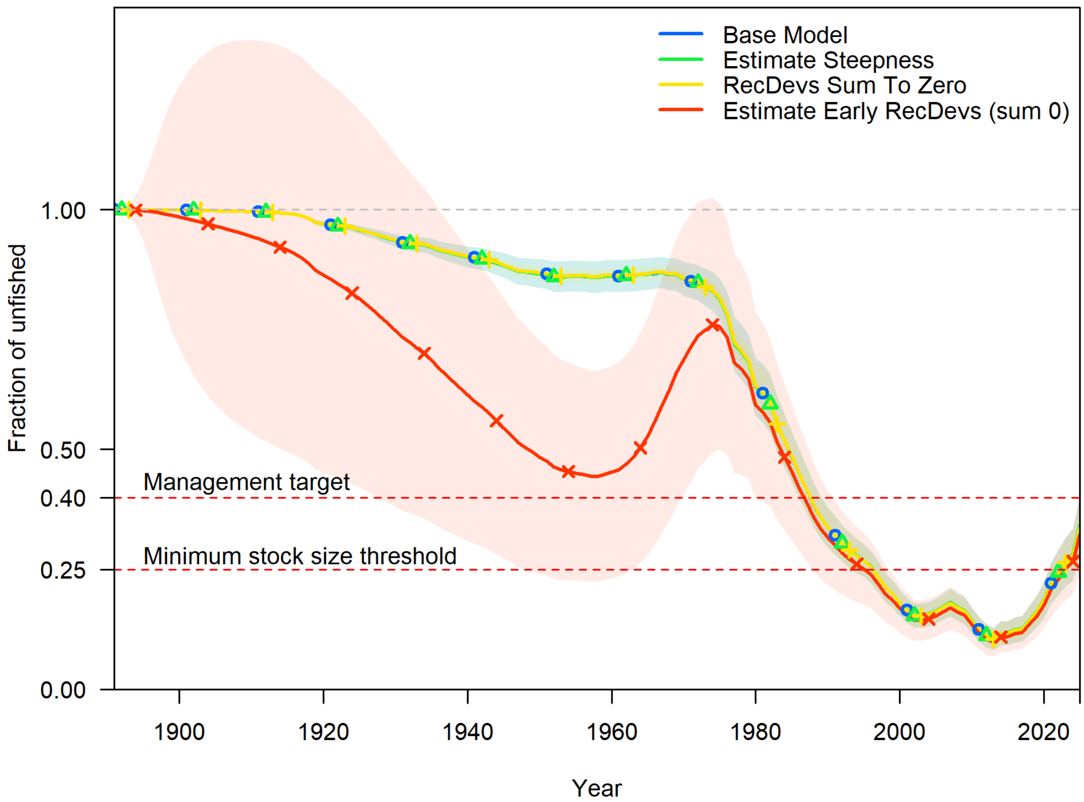

Figure 112: Maximum likelihood estimates of fraction of unfished (i.e., stock status) for the base model and alternative sensitivity runs representing the estimaton of steepness (h), imposing the restriction that recruitment deviations in the main recruitment period must sum to zero, and estimating early (1890-1974) recruitment deviations with the sum to zero constraint imposed. Shaded regions represent asymptotic 95 percent confidence intervals.

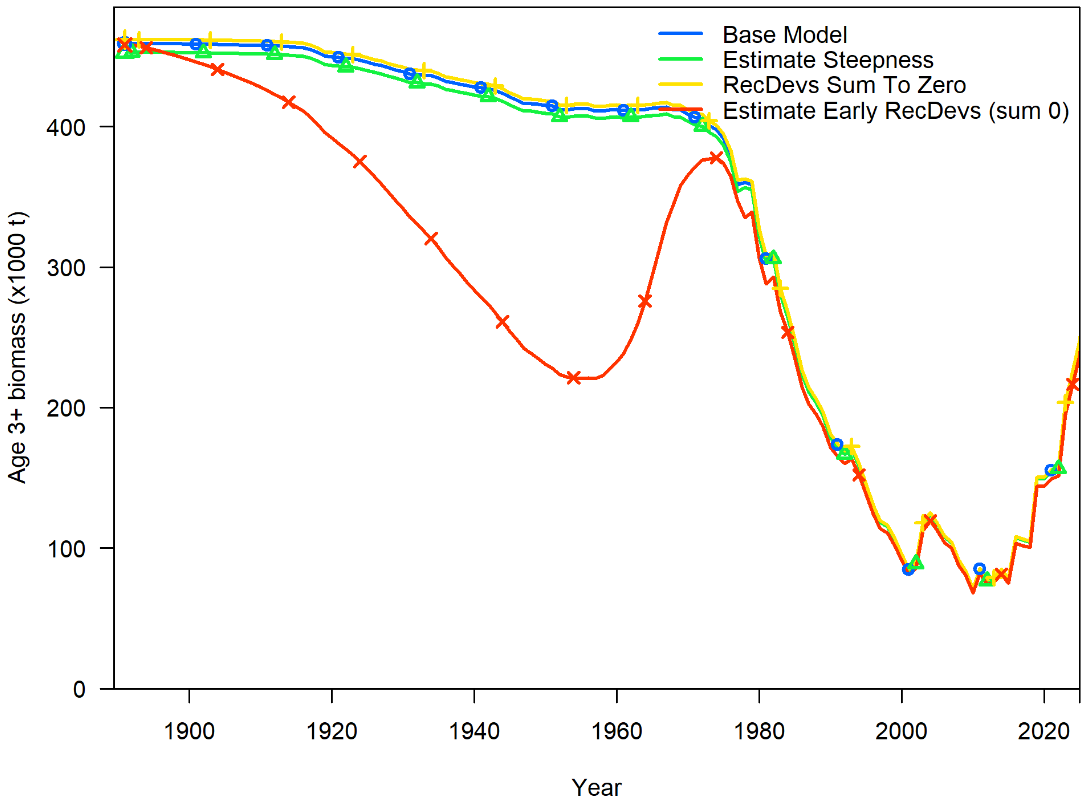

Figure 113: Maximum likelihood estimates of summary biomass (age 3 and older) for the base model and alternative sensitivity runs representing the estimaton of steepness (h), imposing the restriction that recruitment deviations in the main recruitment period must sum to zero, and estimating early (1890-1974) recruitment deviations with the sum to zero constraint imposed.

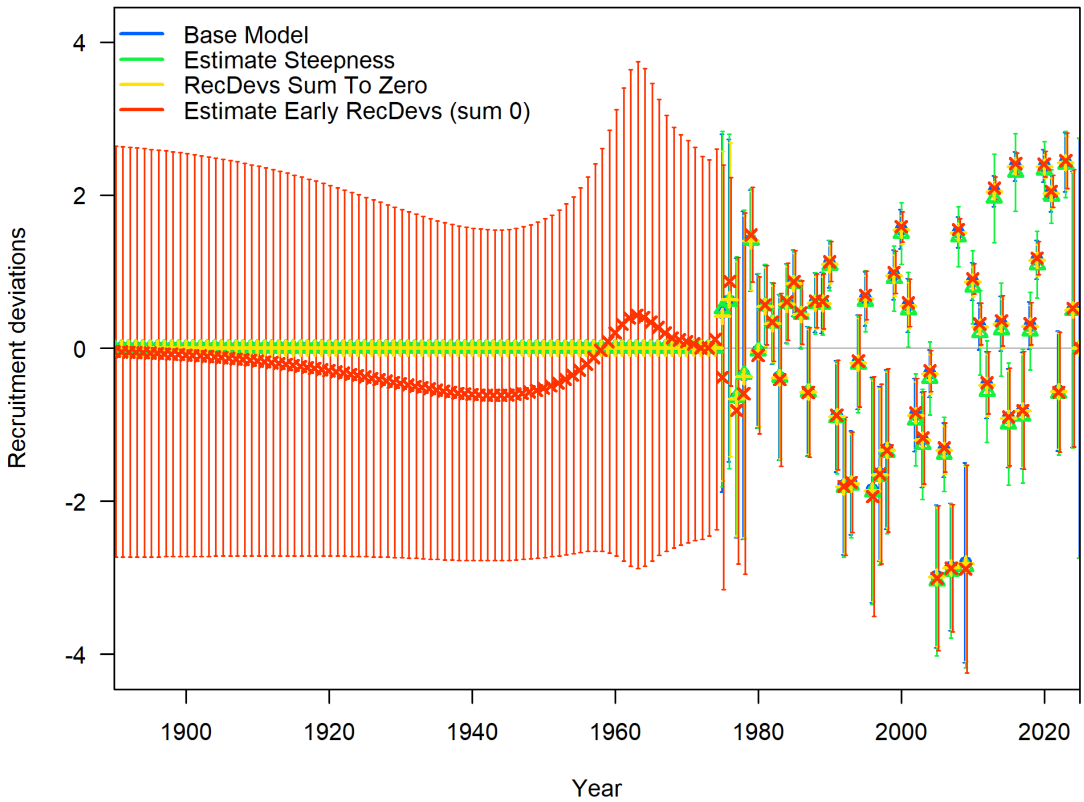

Figure 114: Maximum likelihood estimates of recruitment deviations for the base model and alternative sensitivity runs representing the estimaton of steepness (h), imposing the restriction that recruitment deviations in the main recruitment period must sum to zero, and estimating early (1890-1974) recruitment deviations with the sum to zero constraint imposed. Bars represent asymptotic 95 percent confidence intervals.

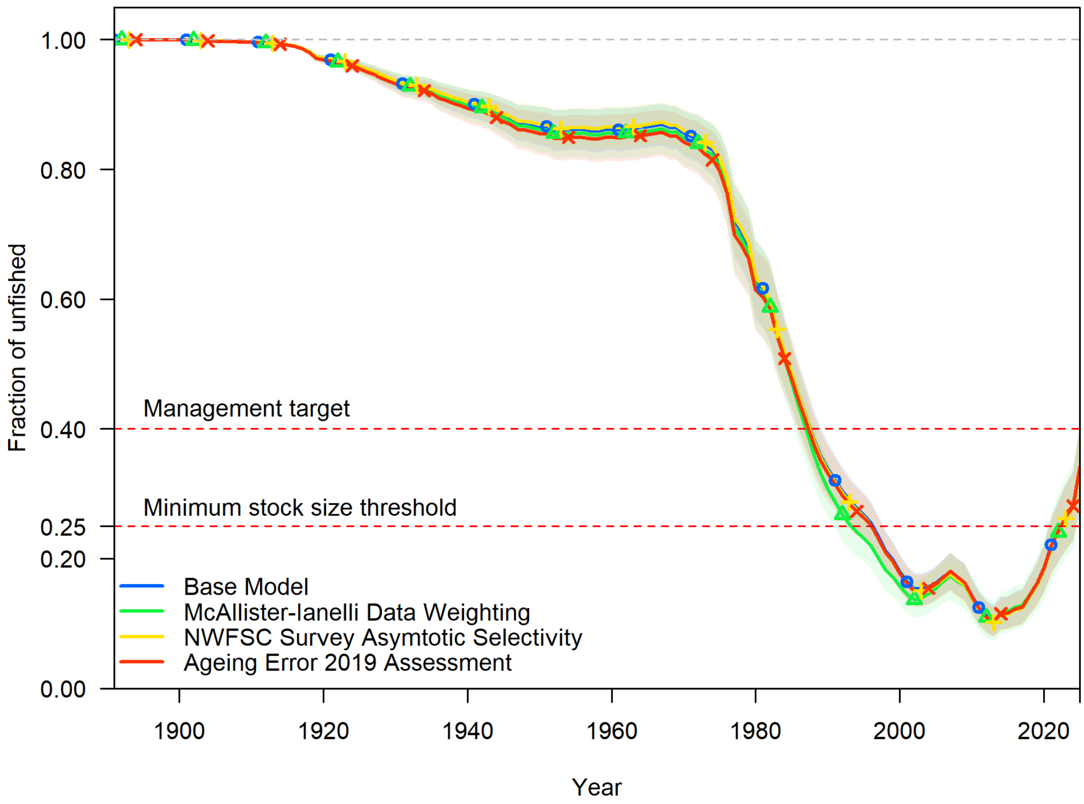

Figure 115: Maximum likelihood estimates of fraction of unfished (i.e., stock status) for the base model and alternative sensitivity runs representing the use of the McAllister-Ianelli harmonic mean method for weighting composition data, the specification of asymptotic selectivity for NWFSC Surveys, and using the ageing error vector applied in the 2019 stock assessment. Shaded regions represent asymptotic 95 percent confidence intervals.

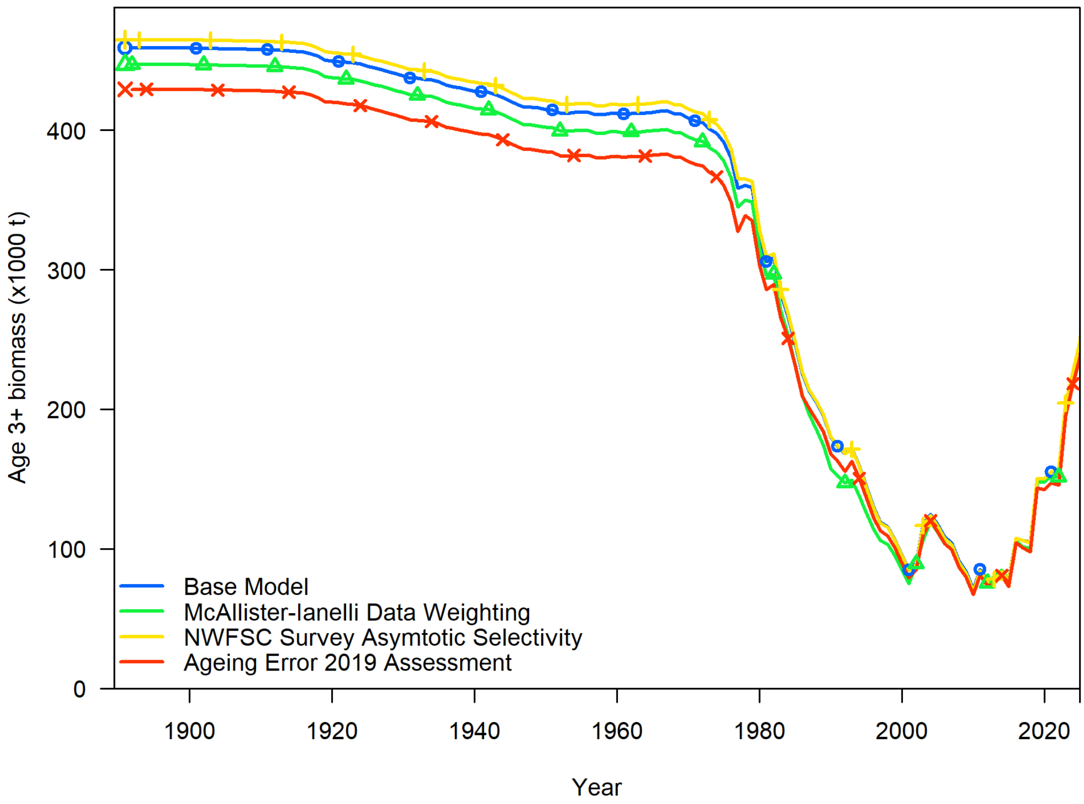

Figure 116: Maximum likelihood estimates of summary biomass (age 3 and older) for the base model and alternative sensitivity runs representing the use of the McAllister-Ianelli harmonic mean method for weighting composition data, the specification of asymptotic selectivity for NWFSC Surveys, and using the ageing error vector applied in the 2019 stock assessment.

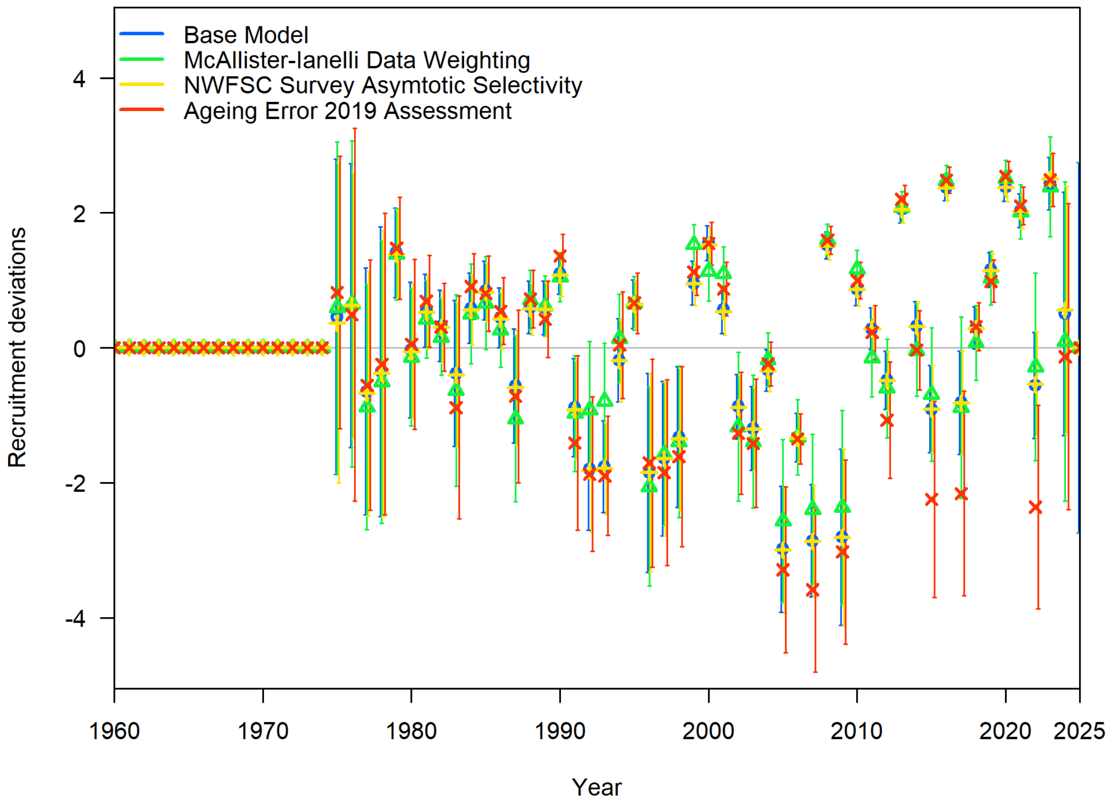

Figure 117: Maximum likelihood estimates of recruitment deviations from 1960-2025 for the base model and alternative sensitivity runs representing the use of the McAllister-Ianelli harmonic mean method for weighting composition data, the specification of asymptotic selectivity for NWFSC Surveys, and using the ageing error vector applied in the 2019 stock assessment. Bars represent asymptotic 95 percent confidence intervals.

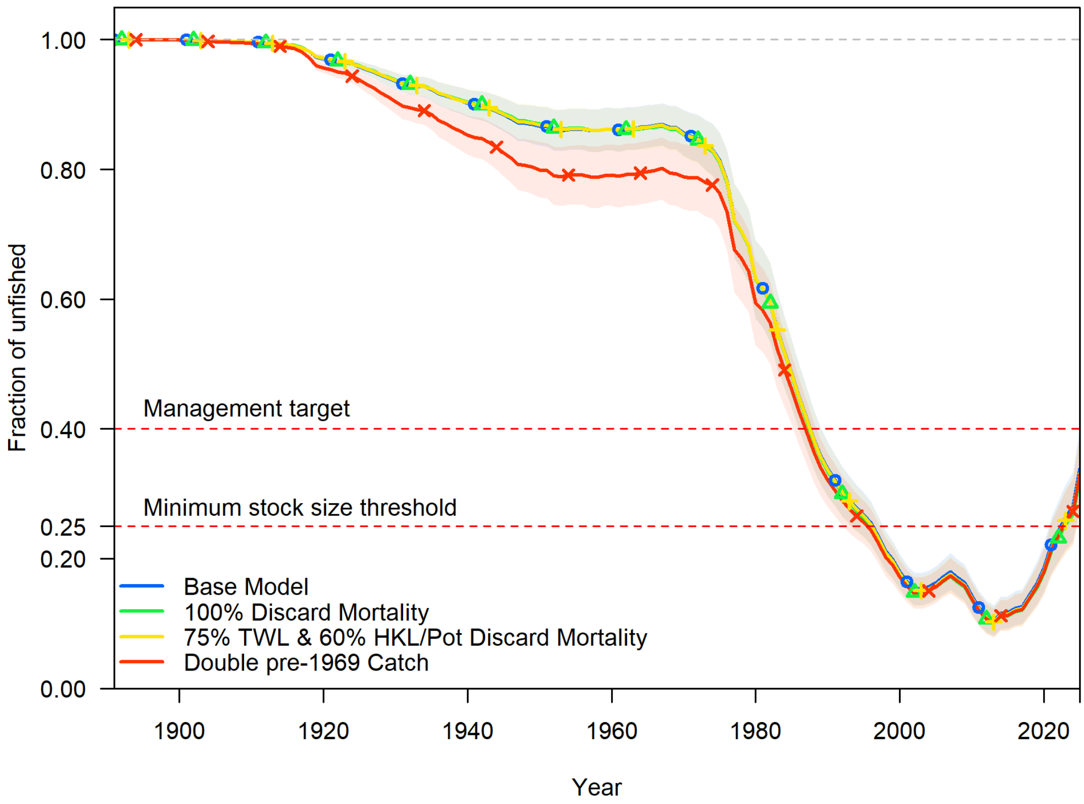

Figure 118: Maximum likelihood estimates of fraction of unfished (i.e., stock status) for the base model and alternative sensitivity runs where discard mortality was increased to 100% for all fleets, discard mortality was increased to 75% for the trawl fishery and 60% for both hook-and-line and pot fisheries, and the pre-1969 catch was doubled. Shaded regions represent asymptotic 95 percent confidence intervals.

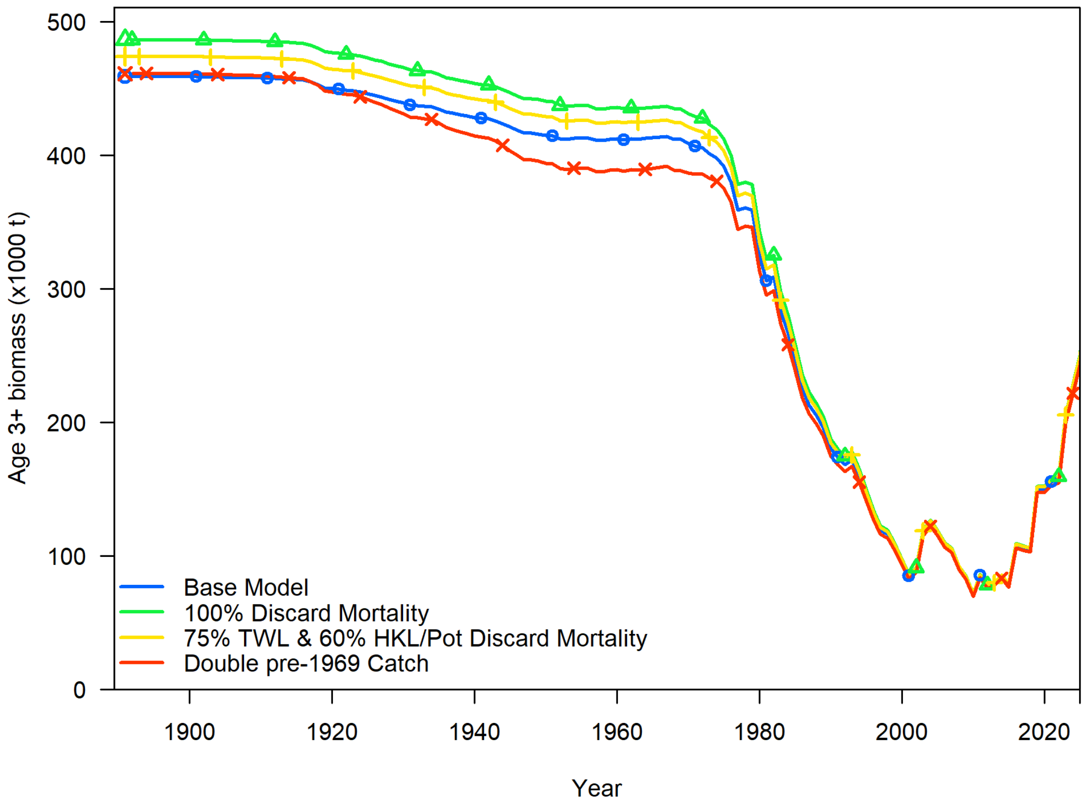

Figure 119: Maximum likelihood estimates of summary biomass (age 3 and older) for the base model and alternative sensitivity runs where discard mortality was increased to 100% for all fleets, discard mortality was increased to 75% for the trawl fishery and 60% for both hook-and-line and pot fisheries, and the pre-1969 catch was doubled.

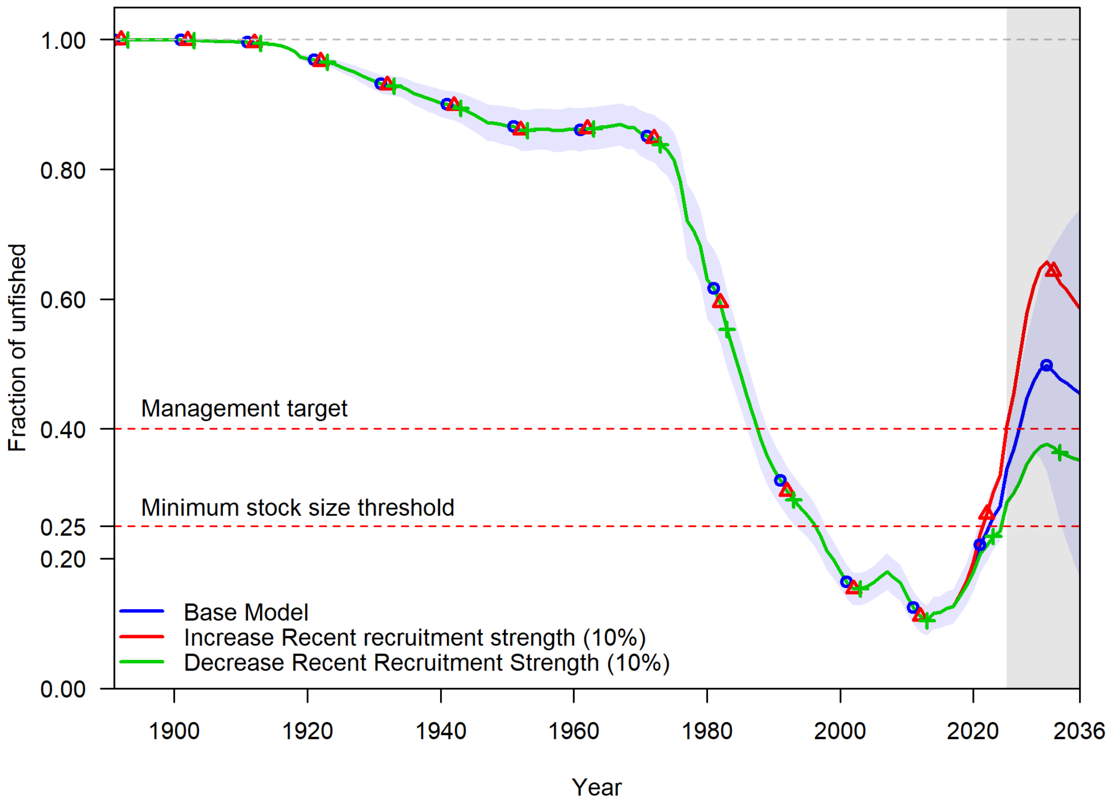

Figure 120: Maximum likelihood estimates of fraction of unfished (i.e., stock status) for the base model and alternative sensitivity runs that either increase or decrease the strength of recent (2016-2023) recruitment deviations by 10% in log-space. Sensitivity models were run with all model parameters fixed at the base model maximum likelihood estimates, with the only changes being from the specified adjustments to recent recruitment deviations. Forecast catches in 2025 and 2026 were based on GMT recommendations. The catches from 2027 to 2036 were set equal to the year-specific ABCs. The shaded regions represents the asymptotic 95 percent confidence interval for the base model.

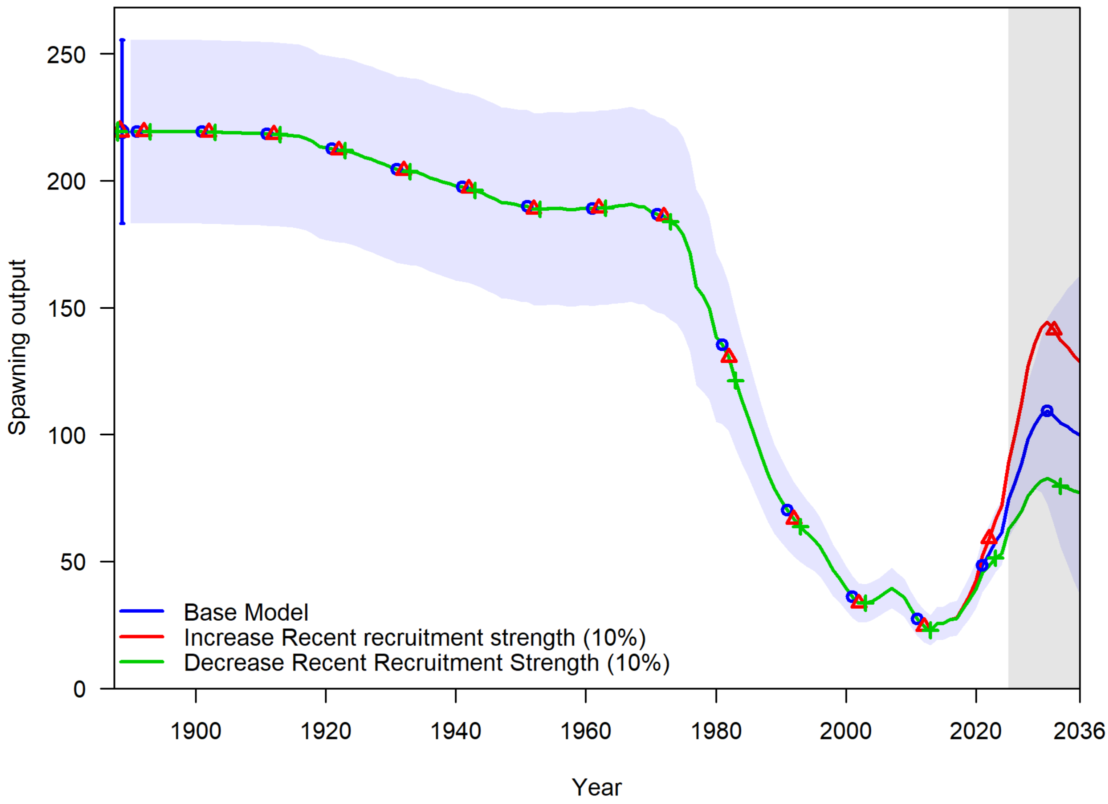

Figure 121: Maximum likelihood estimates of spawning biomass for the base model and alternative sensitivity runs that either increase or decrease the strength of recent (2016-2023) recruitment deviations by 10% in log-space. Sensitivity models were run with all model parameters fixed at the base model maximum likelihood estimates, with the only changes being from the specified adjustments to recent recruitment deviations. Forecast catches in 2025 and 2026 were based on GMT recommendations. The catches from 2027 to 2036 were set equal to the year-specific ABCs. The shaded regions represents the asymptotic 95 percent confidence interval for the base model.

8.9 Likelihood Profiles

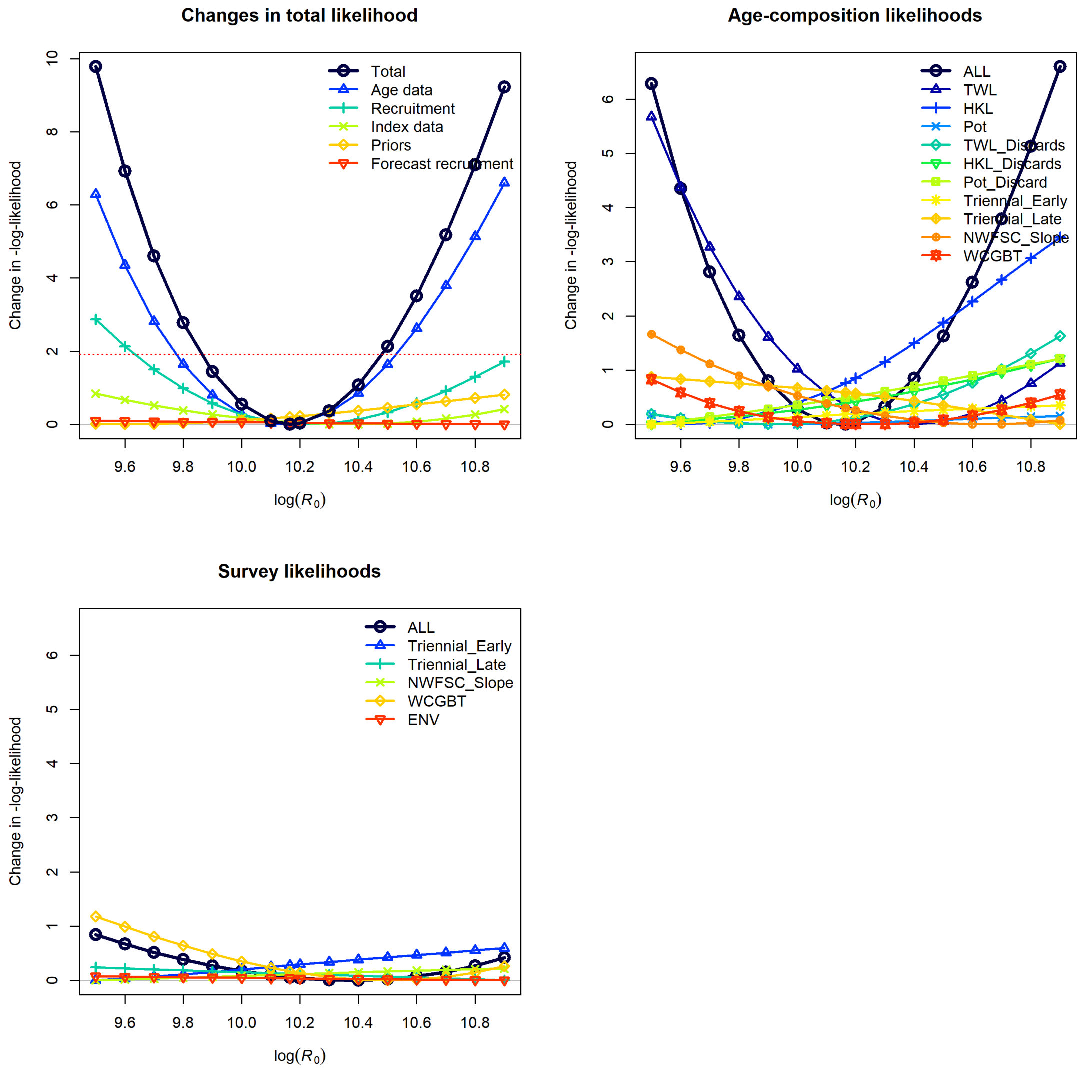

Figure 122: Change in the negative log-likelihood across a range of log(R_0) values.

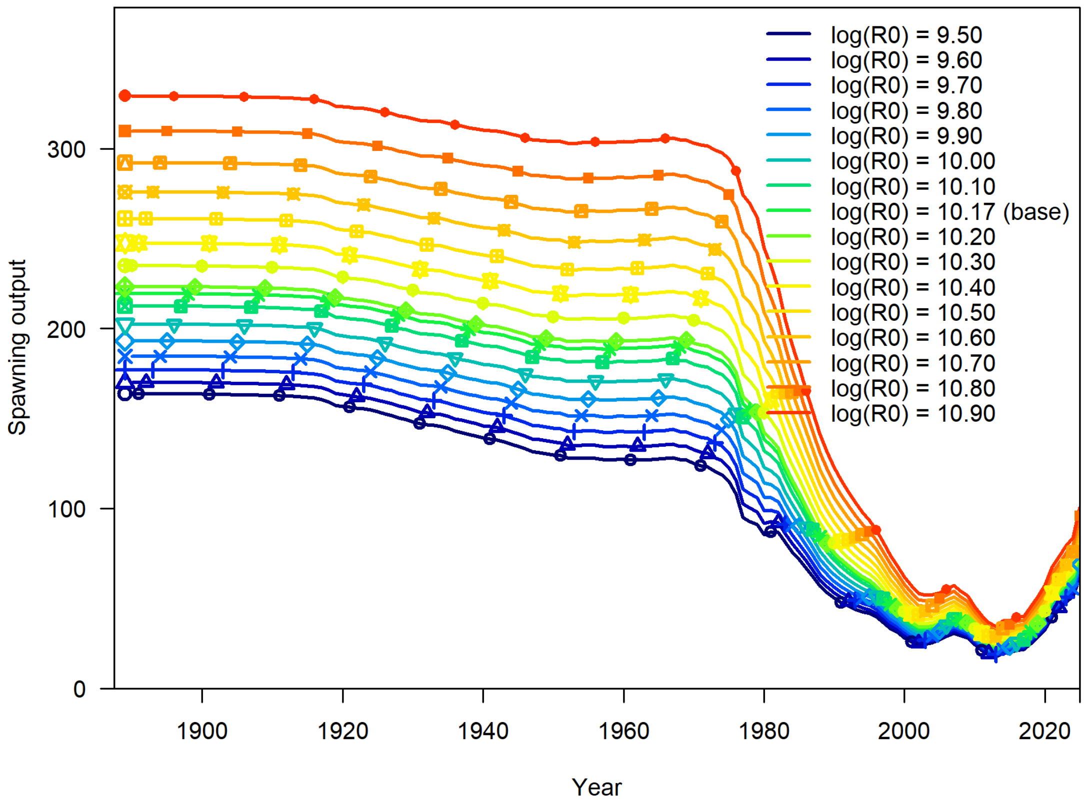

Figure 123: Change in the spawning output across a range of $\log(R_0)$ values.

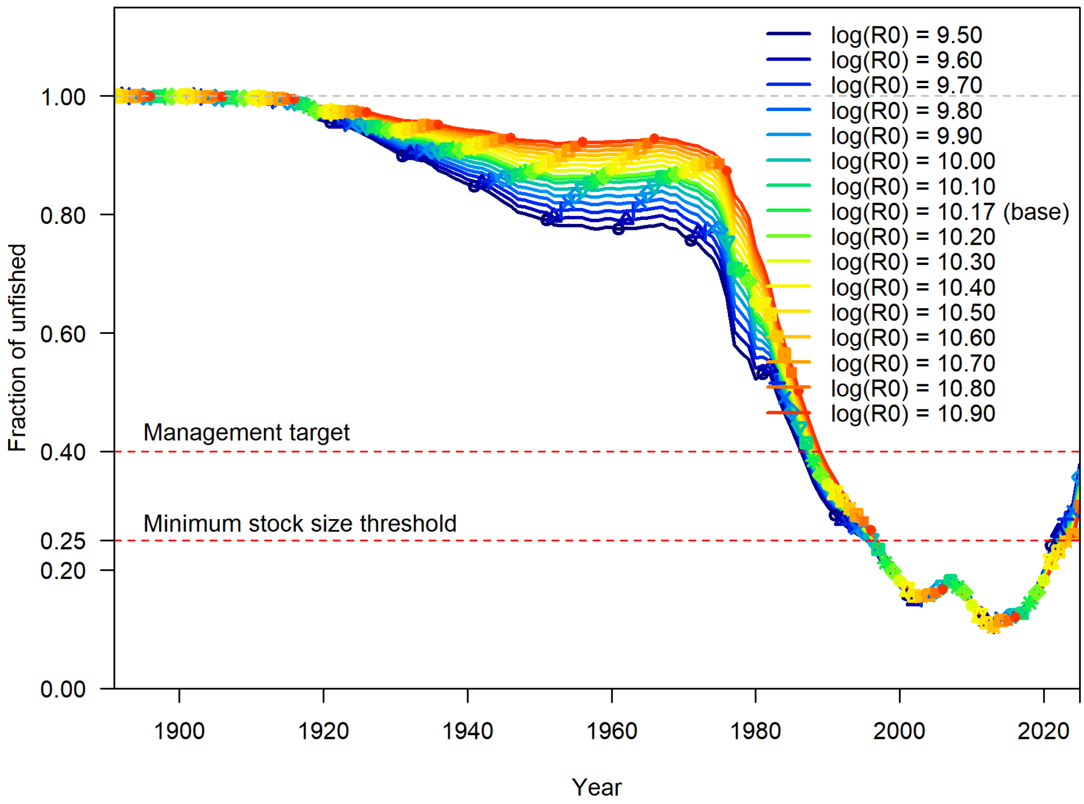

Figure 124: Change in the fraction of unfished (i.e., stock status) across a range of $\log(R_0)$ values.

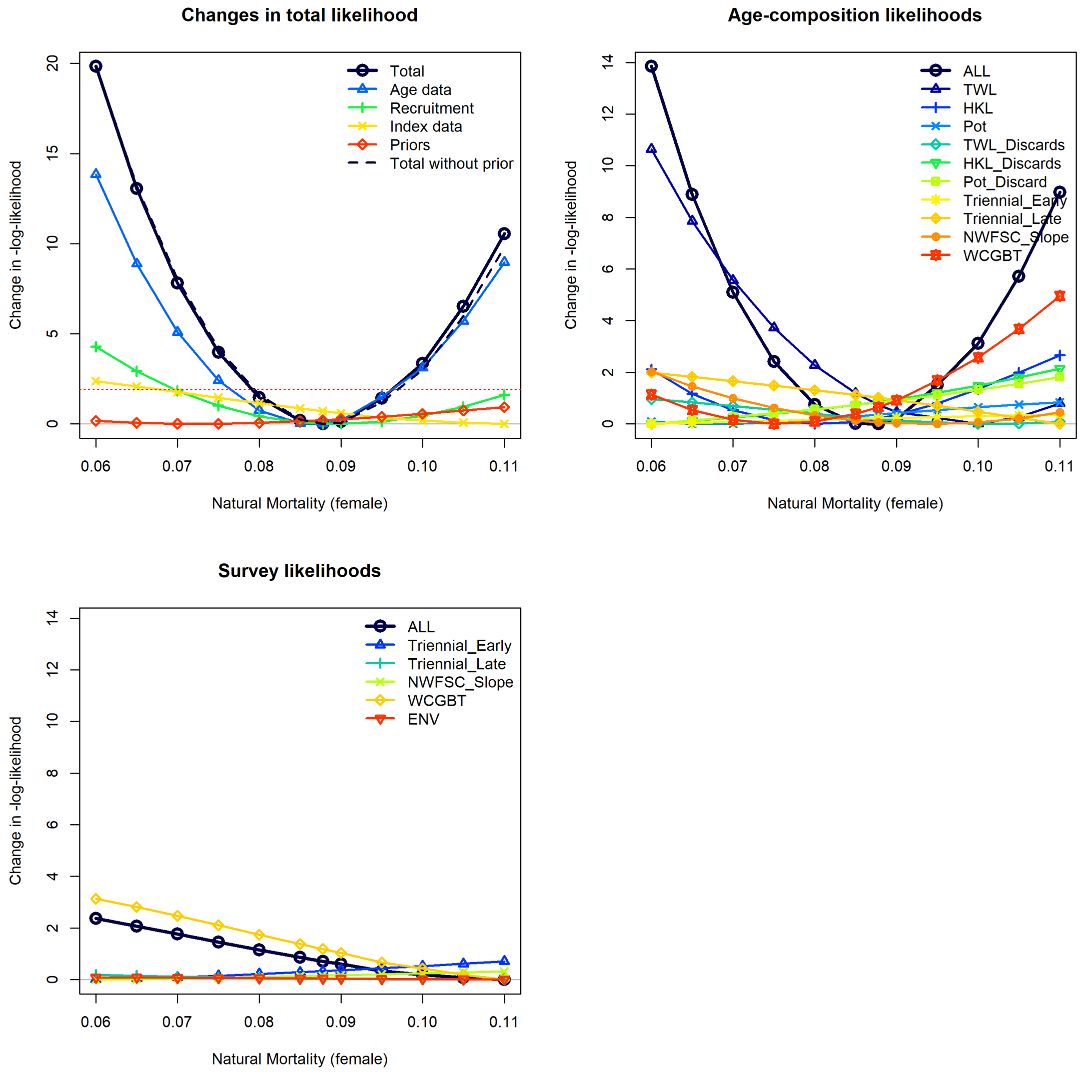

Figure 125: Change in the negative log-likelihood across a range of natural mortality (M) values. Only female M is shown, because M is sex-invariant in the base model.

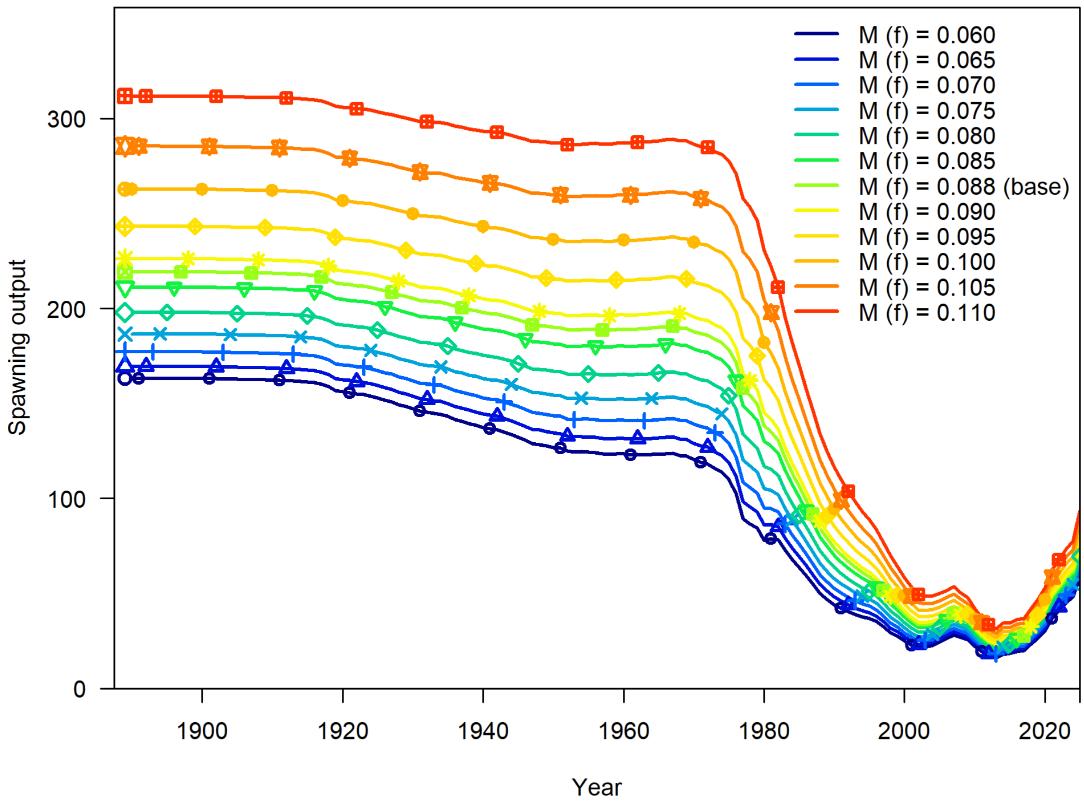

Figure 126: Change in the spawning output across a range of natural mortality (M) values. Only female M is shown, because M is sex-invariant in the base model.

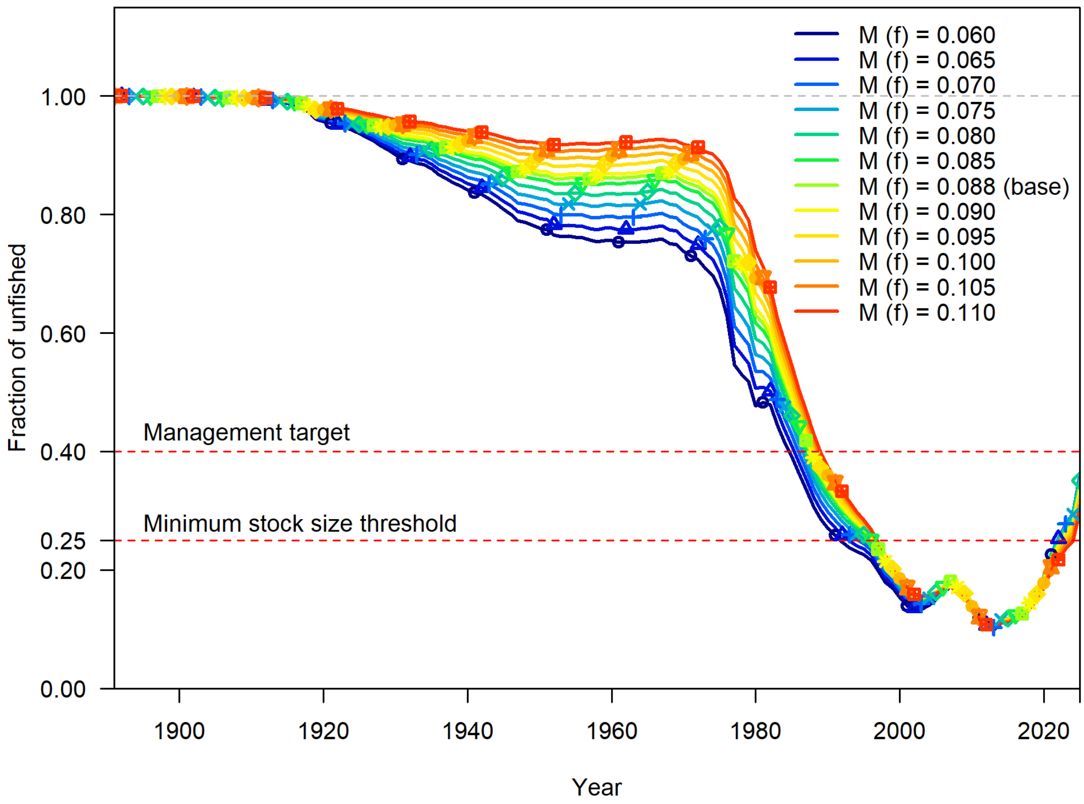

Figure 127: Change in the fraction of unfished (i.e., stock status) across a range of natural mortality (M) values. Only female M is shown, because M is sex-invariant in the base model.

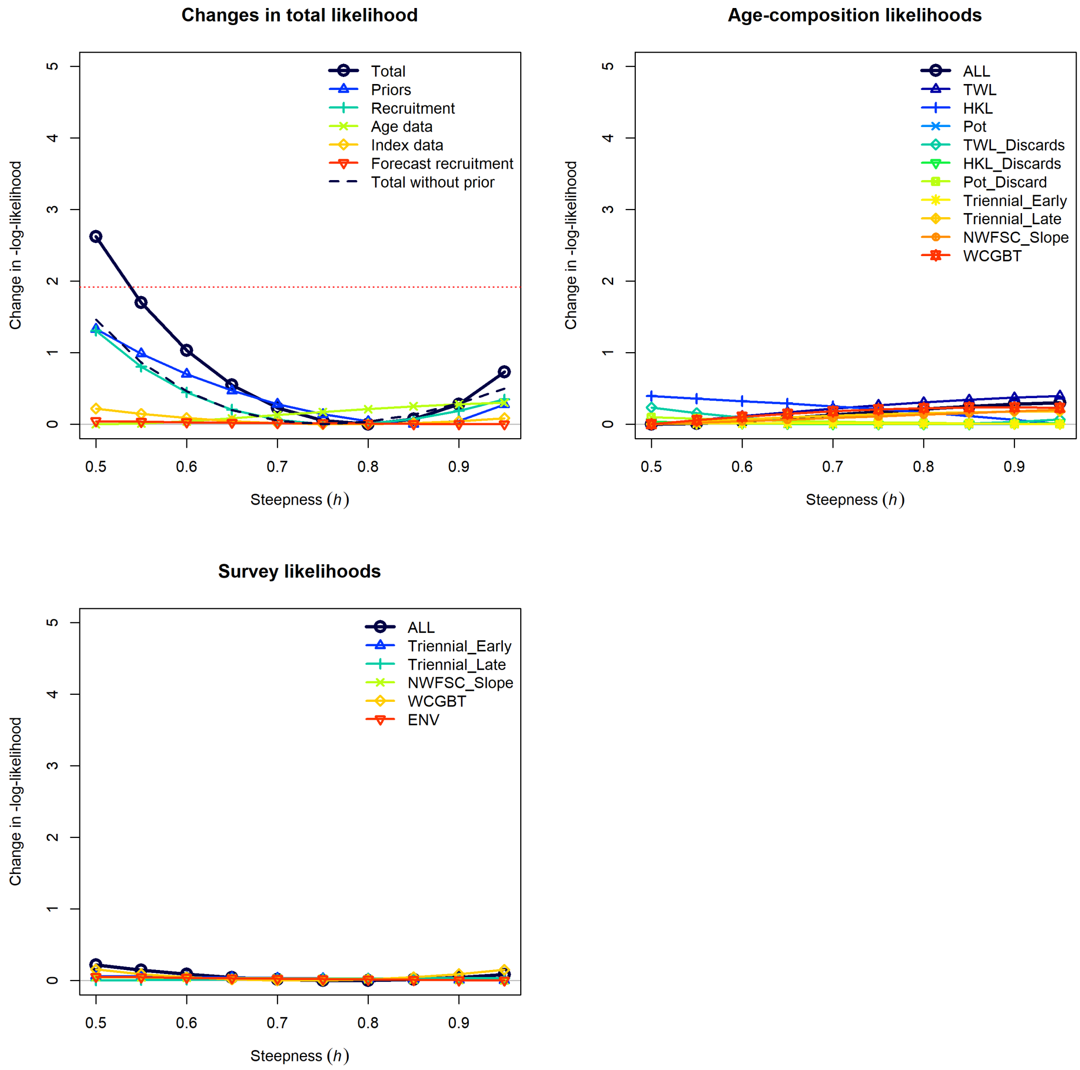

Figure 128: Change in the negative log-likelihood across a range of steepness (h) values.

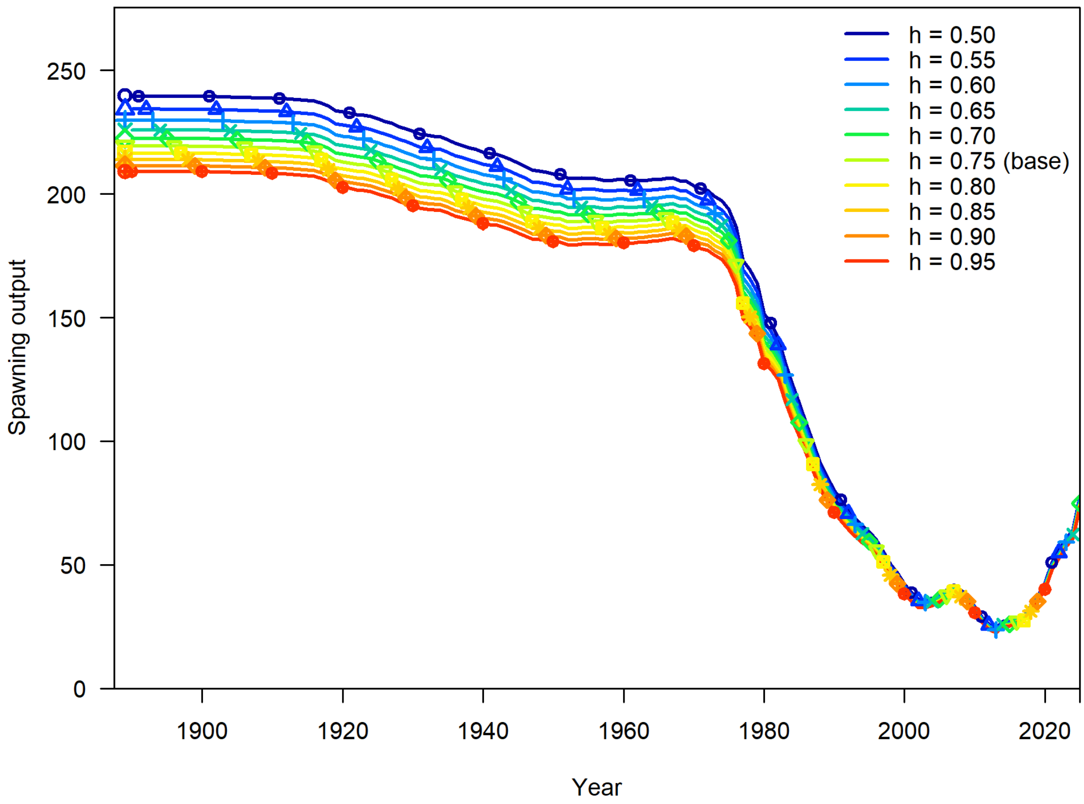

Figure 129: Change in the spawning output across a range of steepness (h) values.

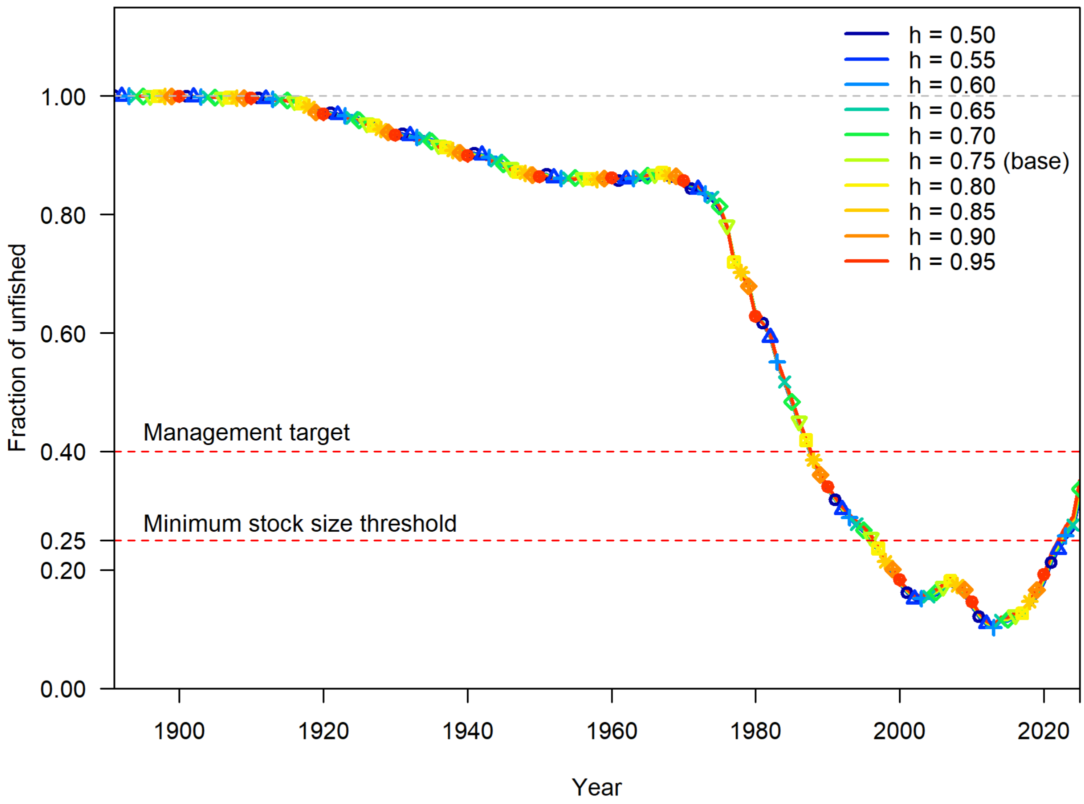

Figure 130: Change in the fraction of unfished (i.e., stock status) across a range of steepness (h) values.

8.10 Retrospecitve Analysis

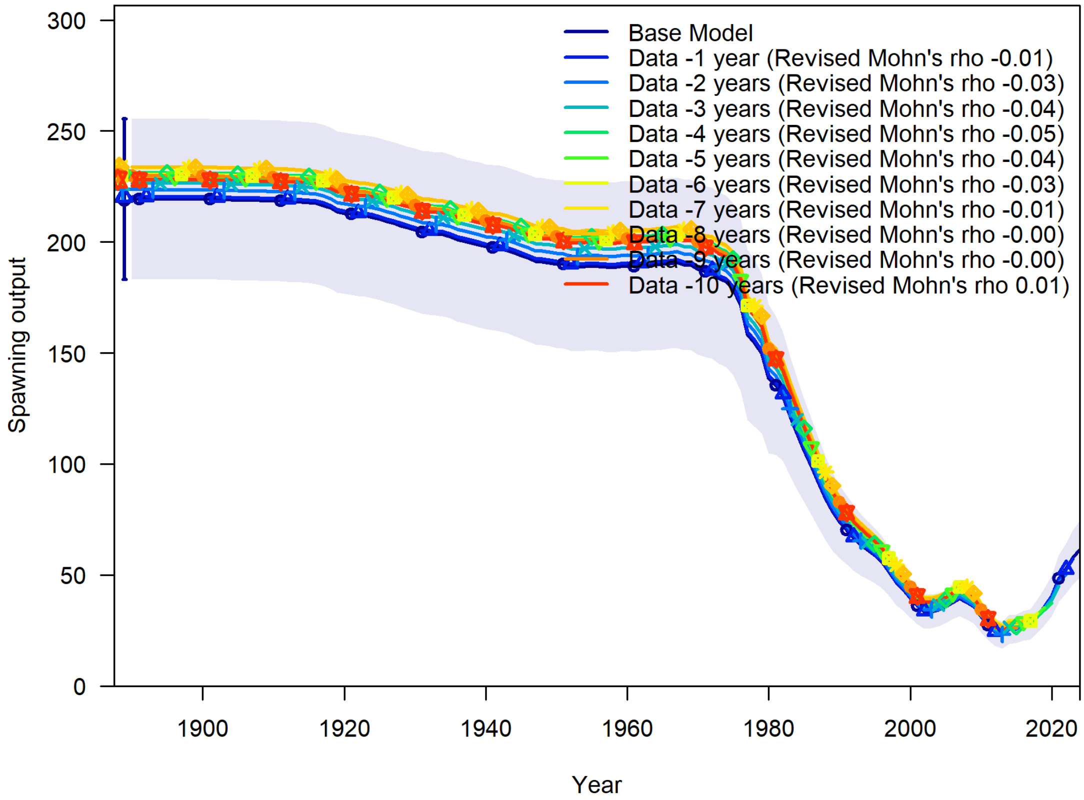

Figure 131: Change in the estimate of spawning output when the most recent 10 years of data are removed sequentially.

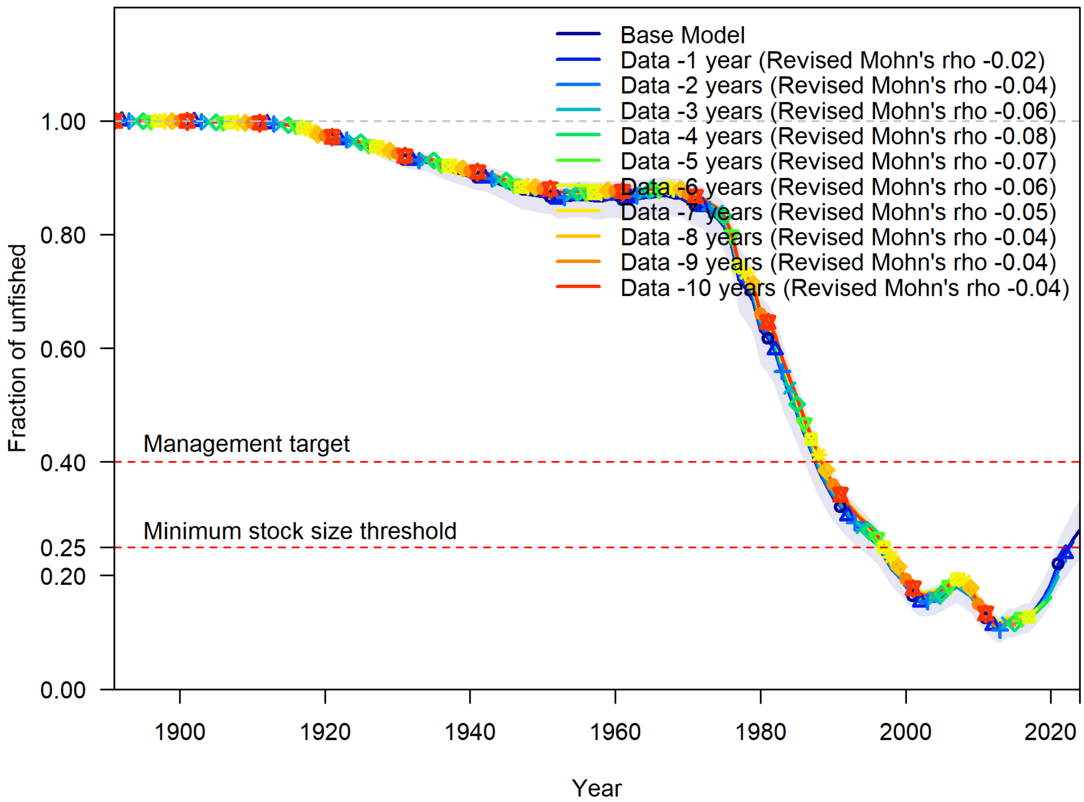

Figure 132: Change in the estimate of fraction unfished (i.e., stock status) when the most recent 10 years of data are removed sequentially.

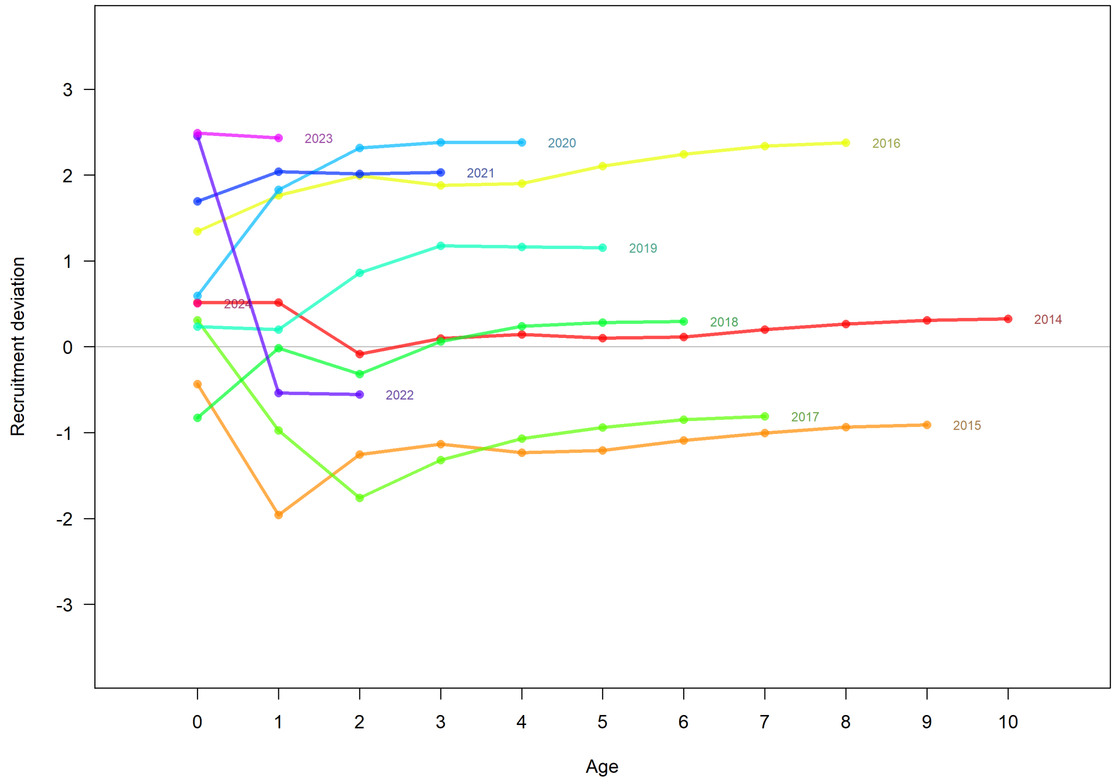

Figure 133: Change in the estimate annual recruitment deviations when the most recent 10 years of data are removed sequentially.

8.11 Historical Analysis

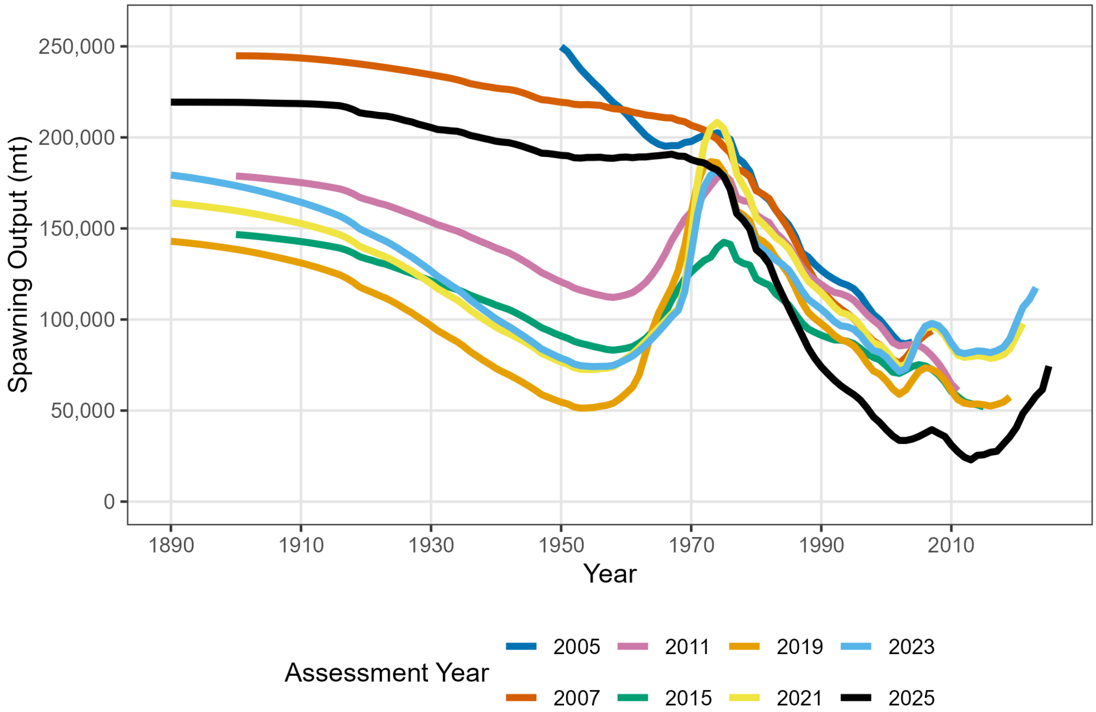

Figure 134: Spawning ouptut (mt) trajectories from the base model and historical assessments for sablefish.

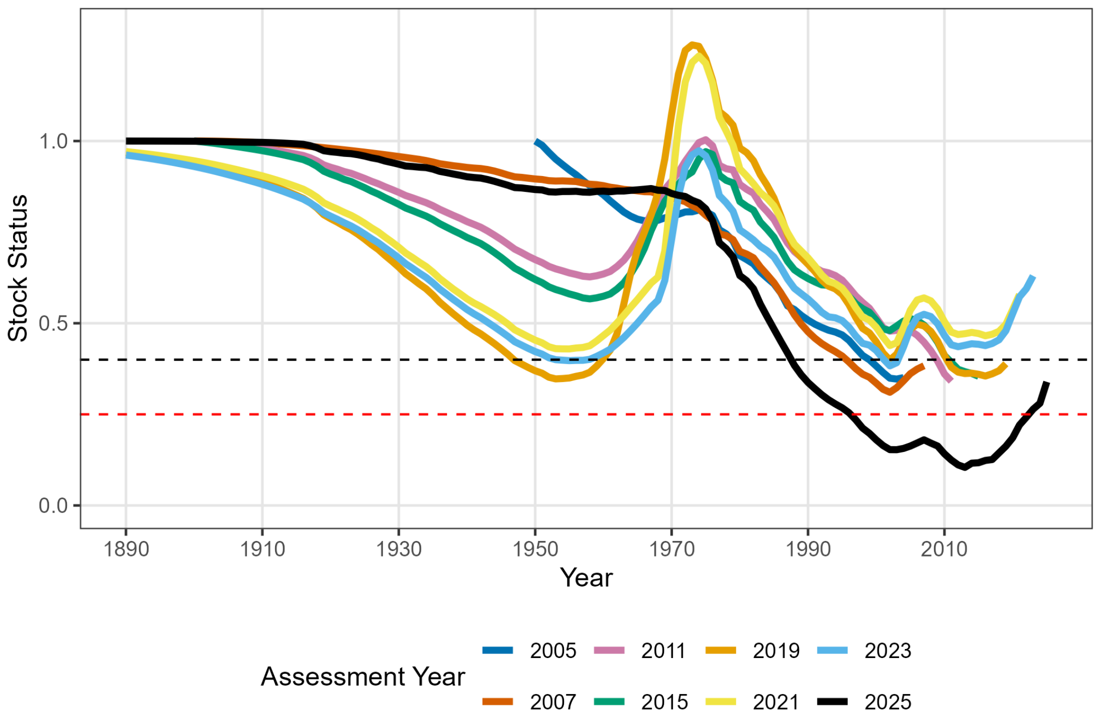

Figure 135: Stock status trajectories from the base model and historical assessments for sablefish.

8.12 Management

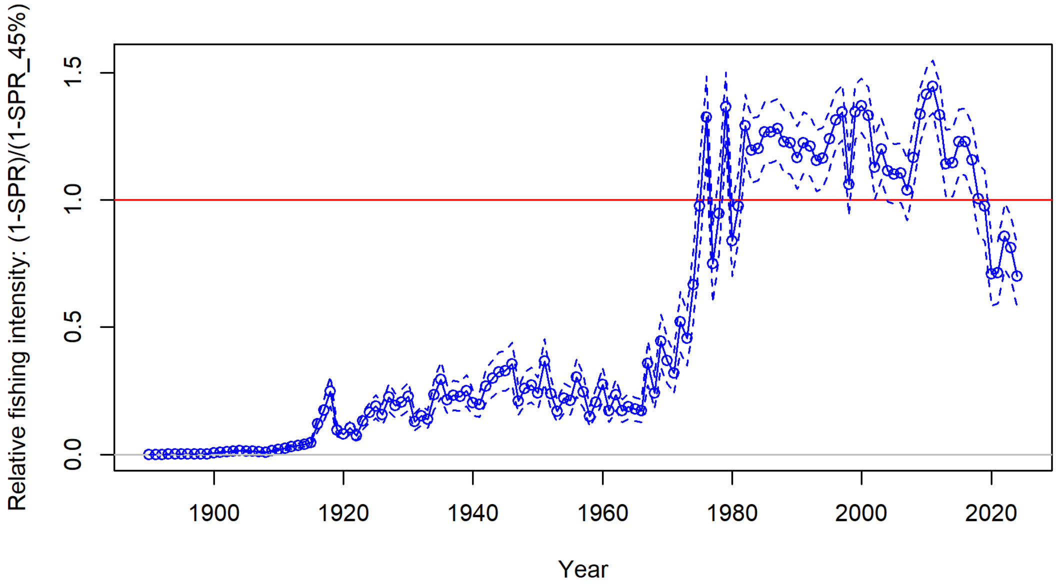

Figure 136: Estimated time series of fishing intensity for the base model.

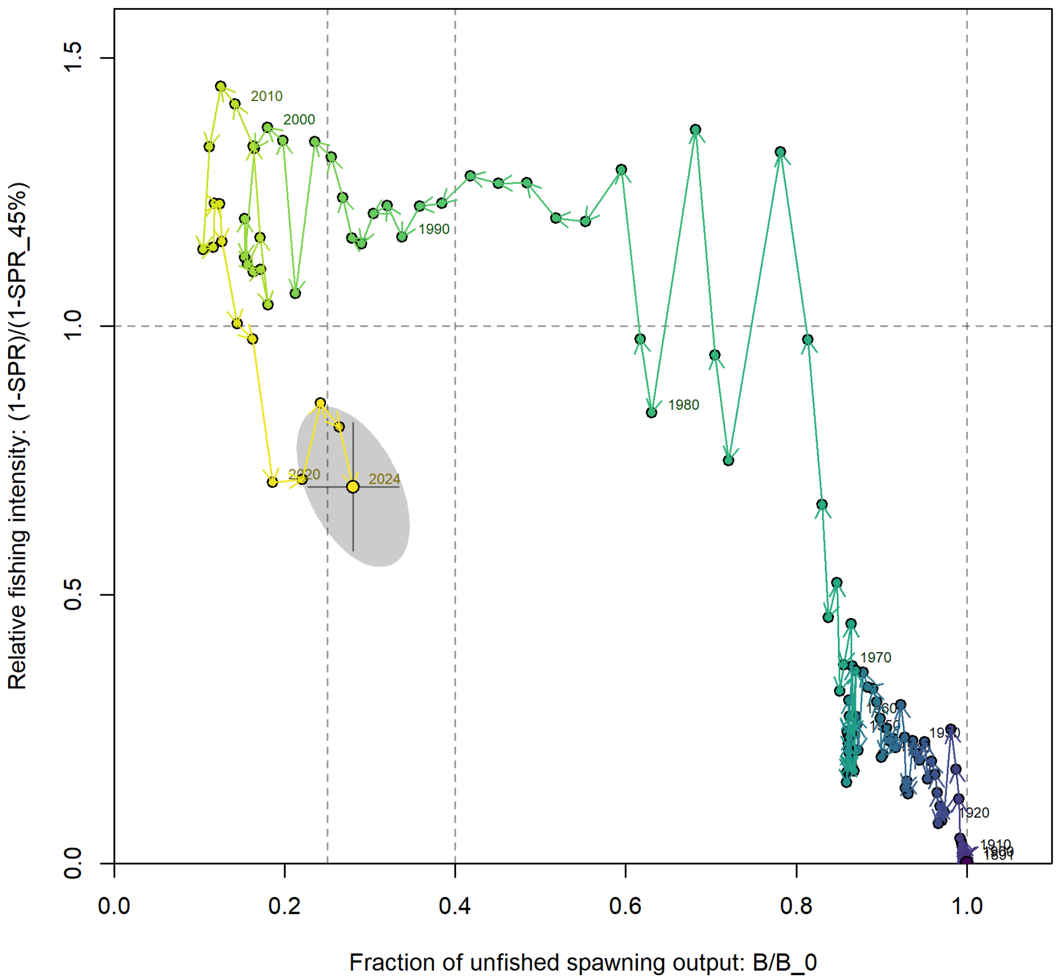

Figure 137: Phase plot of fishing intensity versus relative spawning output (i.e., stock status) for the base model.

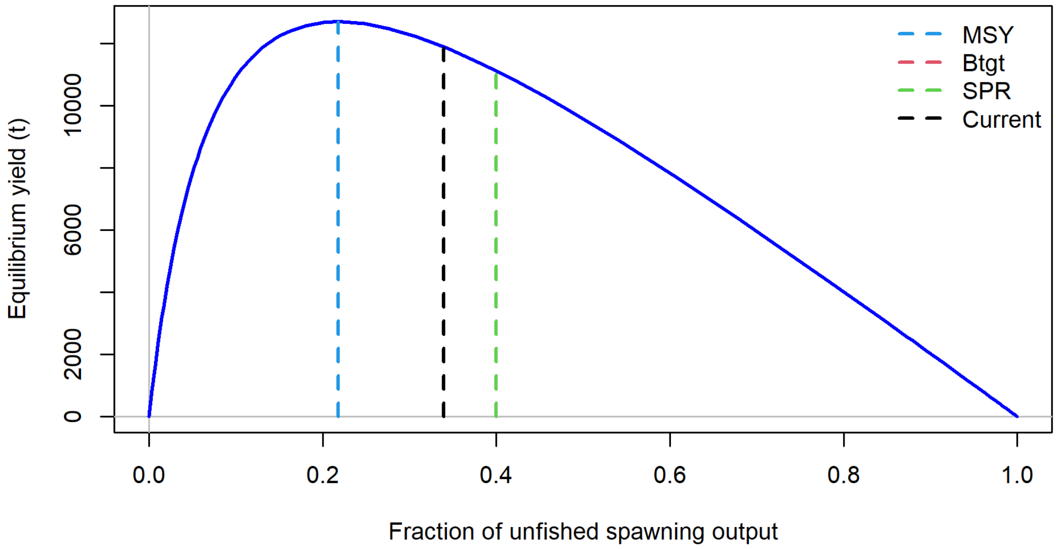

Figure 138: Estimated yield curve with reference points for the base model. The biomass target (Btgt) and the spawning potential ratio (SPR) target both are maximized at 0.40 fraction of unfished spawning output.

9 Appendices

9.1 Select Management History

The GMT provided a list of select management actions for sablefish since 2010:

- 2010: Limited Entry North sablefish and south daily trip limits removed (max Limited Entry North mortality in 2010 and 2011 right after the removal).
  - Limited Entry North trip limits were lowered in subsequent years because of lower overall harvest limits but removing the daily limit appeared to increase mortality at least right after the change.
  - Limited Entry South trip limits were not lowered to the same degree and mortality remained high for several years after the daily limit was removed, but has since been declining largely due to loss of infrastructure in the south.
  - Discard rate did not appear to change notably for sablefish north or south after the daily limit was removed.
- 2015: Sablefish trip limits closed in Period 6 because sector exceeded catch share.
- 2020: Trawl RCAs off Oregon and California removed.
- 2021: Open Access south sablefish daily trip limit removed.
- 2020 & 2021: Emergency rules to extend season to Nov. 15 and Dec. 31, respectively.
- 2023: Open Access north sablefish daily trip limit removed.
- 2023+: Primary sablefish season permanently extended to Dec. 31.

In 2020, there was a severe impact to the fixed gear sector targeting sablefish with low participation and subsequent years; sablefish prices have been very low since ~2019 and exacerbated by COVID-19.

9.2 Recruitment Index

The sablefish stock-recruitment curve relationship is weak suggesting that environmental drivers are important for determining annual reproductive success and recruitment (Tolimieri et al. 2018). Environmental drivers of recruitment for sablefish have received substantial attention with a focus on sea surface height (SSH) (Schirripa and Colbert 2006; Schirripa et al. 2009; Tolimieri and Haltuch 2023), although some studies have focused more closely on hypothesis-driven selection of oceanic drivers (Tolimieri et al. 2018). Modeling work using output from a Regional Ocean Modeling System (ROMS) suggests that strong recruitment is associated with (i) colder conditions during the spawner preconditioning period, (ii) warmer water temperatures during the egg stage, (iii) stronger cross-shelf transport to near-shore nursery habitats during the egg stage,

(iv) stronger long-shore transport to the north during the yolk-sac stage, and (v) cold surface water temperatures during the larval stage (Tolimieri et al. 2018). However, discontinuities in ROMS output following model upgrades 2010/2011 has motivated looking at alternate oceanographic models.

Here, we evaluate using output from the GLORYS oceanographic model (described further below) for predicting variation in natural log of recruitment deviations from the sablefish stock assessment.

9.2.1 Conceptual life-history model

The conceptual life-history model was developed by Tolimieri et al. (2018). The the conceptual model is summarized here (Table 42). All predictors were derived from the GLORYS data (see below).

Table 42: Summary of oceanographic conditions influencing sablefish life history. Abbreviations: DD = degree days,T = temperature, MLD = mixed-layer depth, LST = longshore transport, CST = crossshelf transport, pre = female precondition period prior to spawning, egg = egg stage, larv = larval stage, pjuv = pelagic juveniles, ben = benthic juveniles

Life-history stage	Time period	Depth	Longitudinal extent	Hypothesis	Covariates	Stage
Preconditioning	Jun - Dec (Yr 0)	50-1200 m	50-1200 m isobath	(H2) Higher temperature increases food demand resulting in lower egg production, egg quality, or probability of spawning resulting in lower recruitment	Degree days	DDpre
Spawning	Dec (Yr 0)-Mar (Yr 1)	300-500 m	300-500 m isobath	(H3) Temperature acts as a spawning cue with fish less likely to spawn at high temperature resulting in lower recruitment	Mean temperature	Tspawn
				(H4) As H3 but degree days not mean temperature	Degree days	DDspawn
Eggs	Jan-Apr	300-825 m	Inshore limit: 500 m bottom depth; Seaward to 170 nmi	(H5) Eggs are buoyant so Mixed Layer Depth may limit how far they rise in the water column affecting later transport	Mixed layer depth (m)	MLDegg
				(H6) Transport to settlement habitat affects recruitment	Net long-shore transport	LSTegg
				(H7) Transport to settlement habitat affects recruitment	Net cross-shelf transport	CSTegg
				(H8 Growth/Predation hypothesis: growth rate is faster in warm water leading to reduced time vulnerable to predators	Degree days	DDegg
Yolk-sac larvae	Feb-May	1000-1200 m	1000 m to 170 nmi	(H9) Transport to settlement habitat affects recruitment	Net long-shore transport	LSTyolk
				(H10) Transport to settlement habitat affects recruitment	Net cross-shelf transport	CSTyolk
				(H11) Growth/Predation hypothesis: growth rate is faster in warm water leading to reduced time vulnerable to predators	Degree days	DDyolk
Larvae (feeding)	Feb-May	Surface waters	0-150 nautical nmi	(H12) Transport to settlement habitat affects recruitment	Net long-shore transport	LSTlarv
				(H13) Transport to settlement habitat affects recruitment	Net cross-shelf transport	CSTlarv
				(H14) Growth/Predation hypothesis	Degree days	DDlarv

Pelagic juveniles	Apr-Nov	Surface waters	0-150 nautical nmi	(H15 Transport to settlement habitat affects recruitment	Net long-shore transport	LSTpjuv
				(H16) Transport to settlement habitat affects recruitment	Net cross-shelf transport	CSTpjuv
				(H17) Growth/Predation hypothesis	Degree days	DDjpuv
Benthic Juveniles (Age-0)	Aug-Nov	0 - 250 m	0-250 m isobath	(H18) Transport to settlement habitat affects recruitment	Net long-shore transport	LSTbjuv
				(H19) Transport to settlement habitat affects recruitment	Net cross-shelf transport	CSTbjuv

9.2.2 Oceanographic time series

We used oceanographic model products produced by Copernicus Marine Environment Monitoring Service (CMEMS) (https://marine.copernicus.eu/) and Mercator Ocean International (MOI) (https://www.mercator-ocean.eu/) to test if this modelling framework could be used to produce an environmental index of sablefish recruitment.

We combined two CMEMS products from the Global Ocean Reanalysis (GLORYS) model (GLORYS12V1:GLOBAL_MULTIYEAR_PHY_001_030, https://doi.org/10.48670/moi-00021) (Fernandez and Lellouche 2018; Drevillon et al. 2022)–a global ocean eddy-resolving (1/12° horizontal resolution, 50 vertical levels) reanalysis covering the altimetry (1993 onward). The products included: (1) the reanalysis (1993-01-01 to 2020-10-31; files: cmems_mod_glo_phy_my_0.083deg_P1D-m for daily data, and cmems_mod_glo_phy_my_0.083deg_P1M-m for monthly data), and (2) the interim product (2020-11-01 to 2025-01-01; files: cmems_mod_glo_phy_myint_0.083deg_P1D-m, cmems_mod_glo_phy_myint_0.083deg_P1M-m, for daily and monthly data respectively). For bottom depth, we obtained static data from: cmems_mod_glo_phy_my_0.083deg_static.

Overall the GLORYS analysis followed Tolimieri et al. (2018) and Haltuch et al. (2020). More specifically, data for water column temperature, bottom temperature, and mixed-layer depth were downloaded as daily values. For transport variables, monthly means were used to reduce processing time. We included oceanographic variables for 40–48° N. latitude and processed as follows for each life-history-stage:

1. Subsetted data by bottom depth, mixed-layer depth, and distance from shore as relevant (Table 42).

2. Calculated the daily average across the depth and latitude frames.

3. Subsetted #2 by the relevant monthly/seasonal time periods.

4. Calculated the annual average for 1993-2024 for each potential predictor.

Overall, the combined GLORYS time series did not show obvious break points from 2020 to 2021 (Figure 139).

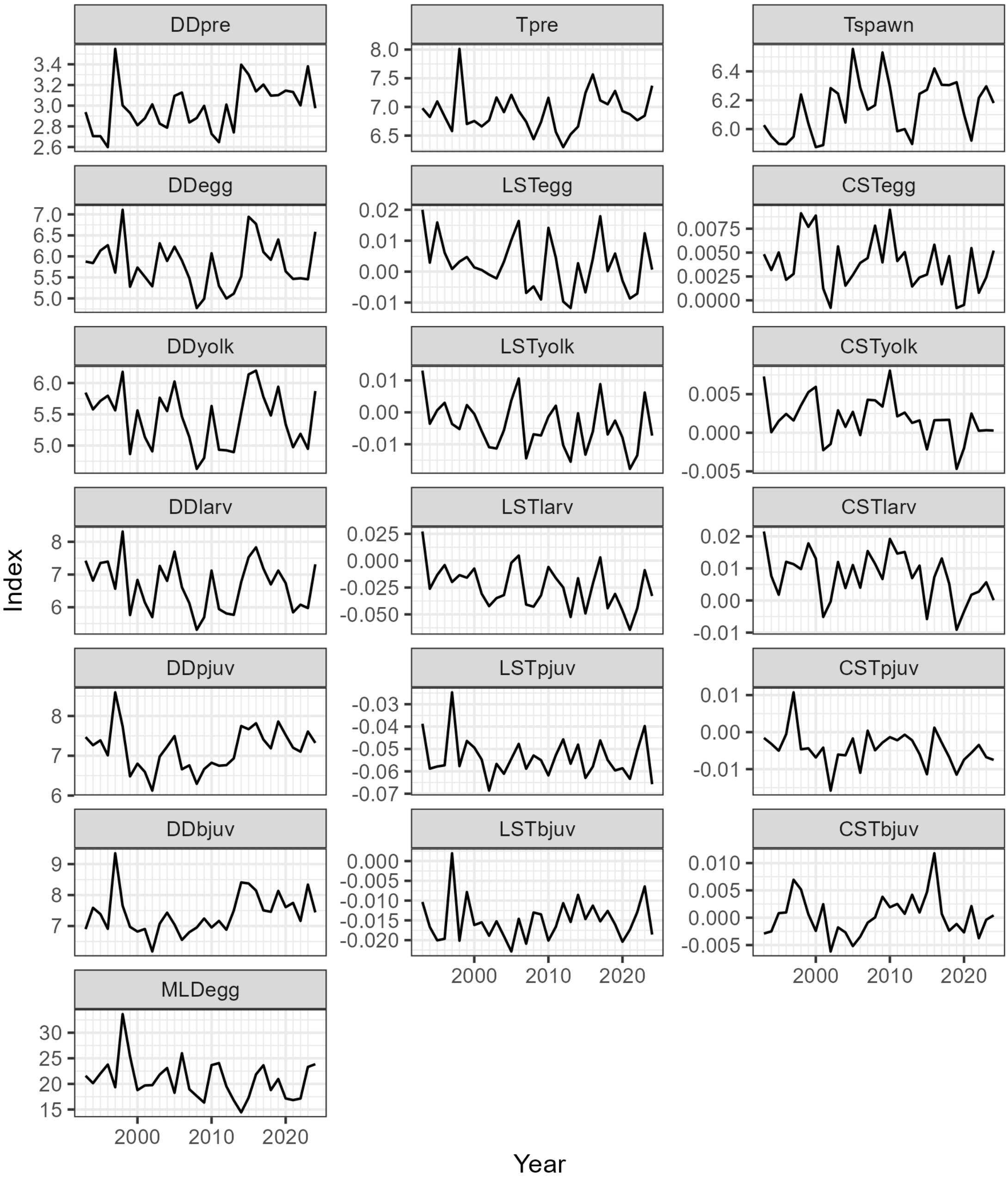

Figure 139: Transport and temperatures times series from the GLORYS models. DD = degree days, T = temperature, MLD = mixed-layer depth, LST = longshore transport, CST = cross-shelf transport, pre = female precondition period prior to spawning, egg = egg stage, larv = larval stage, pjuv = pelagic juveniles, bjuv = benthic juveniles.

9.2.2.1 Correlations among variables

GLORYS predictors were pre-screened for correlations among variables and non-linear relationships with sablefish recruitment deviations. Correlated predictors ($r \geq 0.75$, Figure 140) were excluded from the same model.

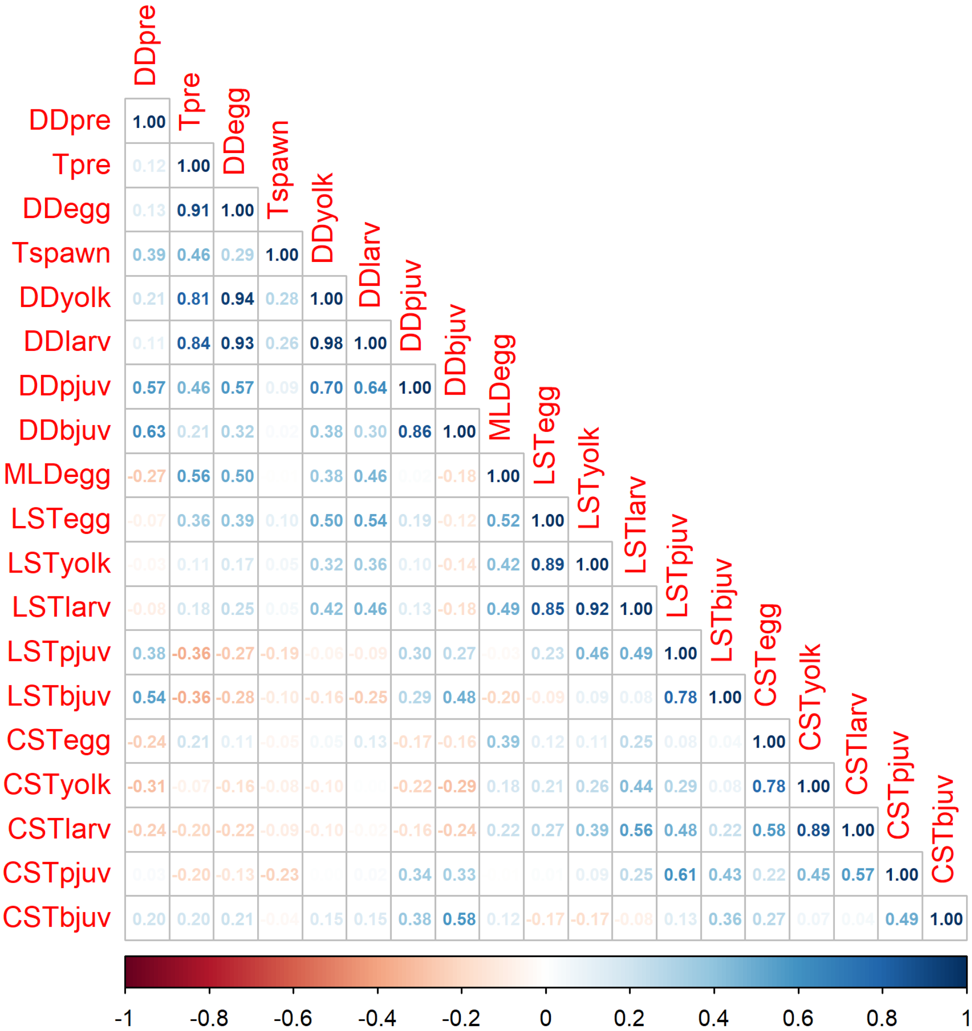

Figure 140: Correlations between GLORYS time series. DD = degree days, T = temperature, MLD = mixed-layer depth, LST = longshore transport, CST = cross-shelf transport, pre = female precondition period prior to spawning, egg = egg stage, larv = larval stage, pjuv = pelagic juveniles, bjuv = benthic juveniles.

9.2.2.2 Non-linear relationships

Non-linearity for individual terms was evaluated by comparing the linear model to a model including both the linear and quadratic forms of the predictor. If the AICc of the quadratic form was lower, we included the quadratic form as a potential predictor as well, but required that the linear term appear in models that included the quadratic from.

9.2.3 Index development

9.2.3.1 Methods

We used linear models to examine relationships between ln(recruitment deviations) from the 2023 sablefish stock assessment and predictors from the GLOYRS model output. We used 1993-2019 as training data, leaving 2020-2024 as out-of-sample for use in the sensitivity analyses. We fit all combinations of the GLORYS predictors, excluding correlated variables from the same model, and limiting the the total number of predictors in any model to three (just over 8 data points per predictor). Model selection was carried out using the 'dredge' function in the MuMIn package in R (Bartoń 2023; R Core Team 2023). Candidate models were evaluated based on their ΔAICc and number of predictors.

Table 43: Results of model fitting showing estimated coefficients for models with delta AIC </= 2.0. CST = cross-shelf transport, DD = degree days, T = temperature, yolk = yolksack stage, pjuv = pelagic juvenile, and bjuv = benthic juvenile stage.

Model	Intercept	CSTbjuv	CSTegg	CSTpjuv	CSTyolk	DDpre	Tspawn	R2	df	AICc	delta
Model 1	13.07	224.27		-210.56			-2.27	0.47	5	89.34	0.00
Model 2	4.54	236.72		-187.78		-1.81		0.45	5	90.13	0.78
Model 3	-0.76	206.49		-180.33				0.37	4	90.97	1.63
Model 4	-1.35	195.45	132.36	-192.35				0.43	5	91.06	1.72
Model 5	-1.28	238.12		-228.60	142.66			0.43	5	91.17	1.83

9.2.3.2 Results

Five models had ΔAICc values ≤ 2.0 (Table 43). All models included cross-shelf transport during pelagic juvenile (CSTpjuv), and benthic juvenile (CSTbjuv) stages. Model 3 was chosen as the best-fit because it had the fewest predictors (2), and these two predictors were in all top-five models providing consistency. The best-fit model explained 37% of the variation in recruitment deviations from 1993-2022 ($r^2 = 0.37$, Table 43, Figure 141). The model tracked the data well with most recruitment deviations falling with $\pm$ 1.0 s.e. of the recruitment index (Figure 141).

The remaining four models included either Tspawn, DDpre, CSTegg, or CSTyolk as predictors. These results suggest that different additional terms might help explain variance in different years, but that CSTpjuv and CSTbjuv provide a consistent basis for prediction. Including an additional factor like Tpre would increase the explained variance by ~ 10% points ($r^2 = 0.47$).

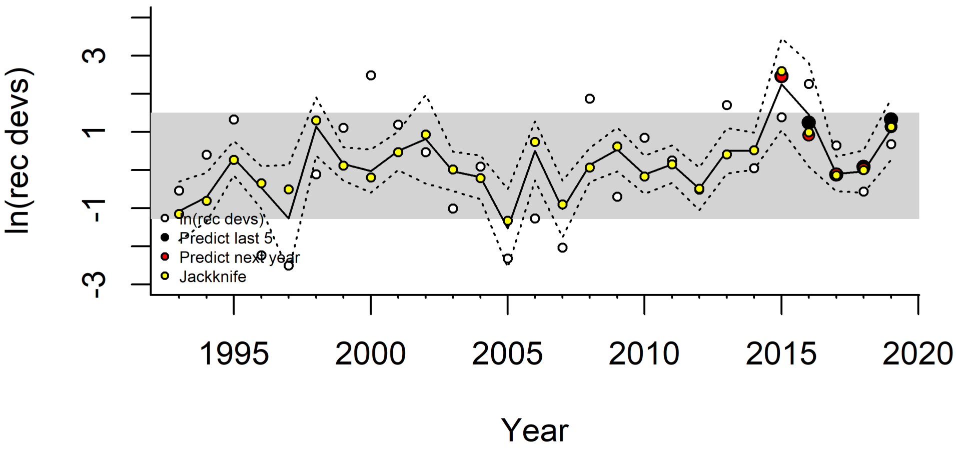

Figure 141: Model fit to the training data (ln recruitment deviations from the stock assessment model for 1993-2019) and model testing results. Black line is the model prediction ± 1.0 s.e (dotted lines). Open (white) points are the ln recruitment deviations. Yellow points are from jackknife analysis leaving out one year and refitting the model, and red points fit the best-fit model to 1993-2014 then predict 2015-2019.

For all models recruitment was negatively correlated with CSTpjuv suggesting that processes like upwelling may be important for producing feeding conditions conducive to survival. CSTbjuv was positively correlated with recruitment, which may indicate that onshore transport during the shift to benthic habitat leads to better recruitment. Both the ROMS analysis and the results here suggest that colder water during the female preconditioning stage (negative correlation with DDpre, here model 2) results in higher recruitment.

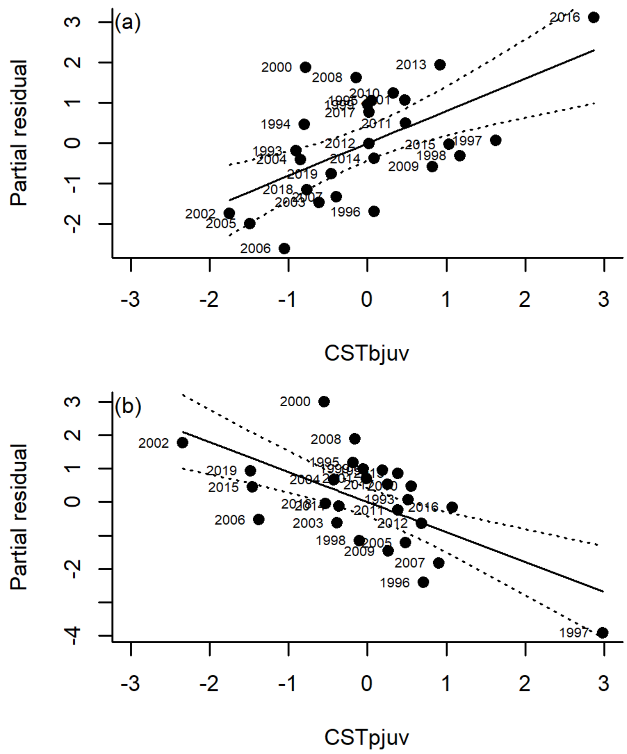

Figure 142: Partial residual plots of GLORYS predictors. CST = cross-shelf transport, T = temperature, spawn = spaning stage, pjuv = pelagic juvenile, and bjuv = benthic juvenile stage.

9.2.3.3 Model testing

Model diagnostics were examined and testing was carried out to determine how stable the best-fit model was to both individual years and the precision of the estimates of recruitment deviations. Testing followed Tolimieri et al. (2018) and Haltuch et al. (2020), but only a subset of test results is shown here:

1. Jackknife analysis on the best-fit model was used to determine the impact of individual years on the model fit.

2. Refit the best-fit model using data for 1993-2014and then predict 2015-2019.

3. Refit the best-fit model for 1993-2014 and predict 2015. Repeat stepping forward one year at a time.

4. Individual years were jackknifed and then the entire model selection process was

rerun to determine the impact of individual years on the selection of the predictors in the best-fit model.

Residual plots showed some deviation from the 1:1 line for the best-fit model (Figure 143).

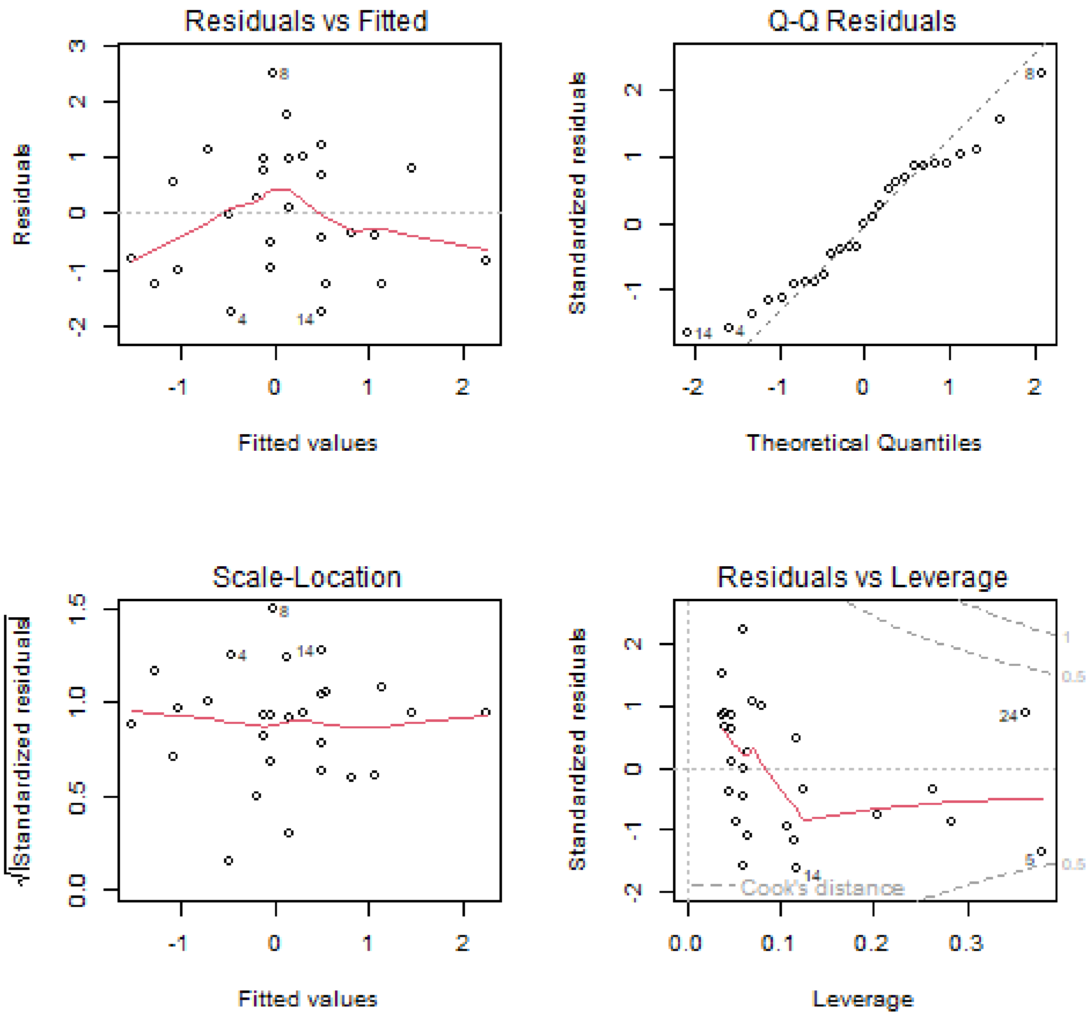

Figure 143: Diagnostics plots from the best-fit model.

Jackknife testing (excluding an individual year and refitting the best-fit model) showed stable results with little change in the r^2 value (Figure 141 and Figure 144). Fitting the best-fit model to 1993-2014 and predicting 2015-2019 produced similar results to the best-fit model (Figure 141), as did predicting ahead one year at a time from 2015 on.

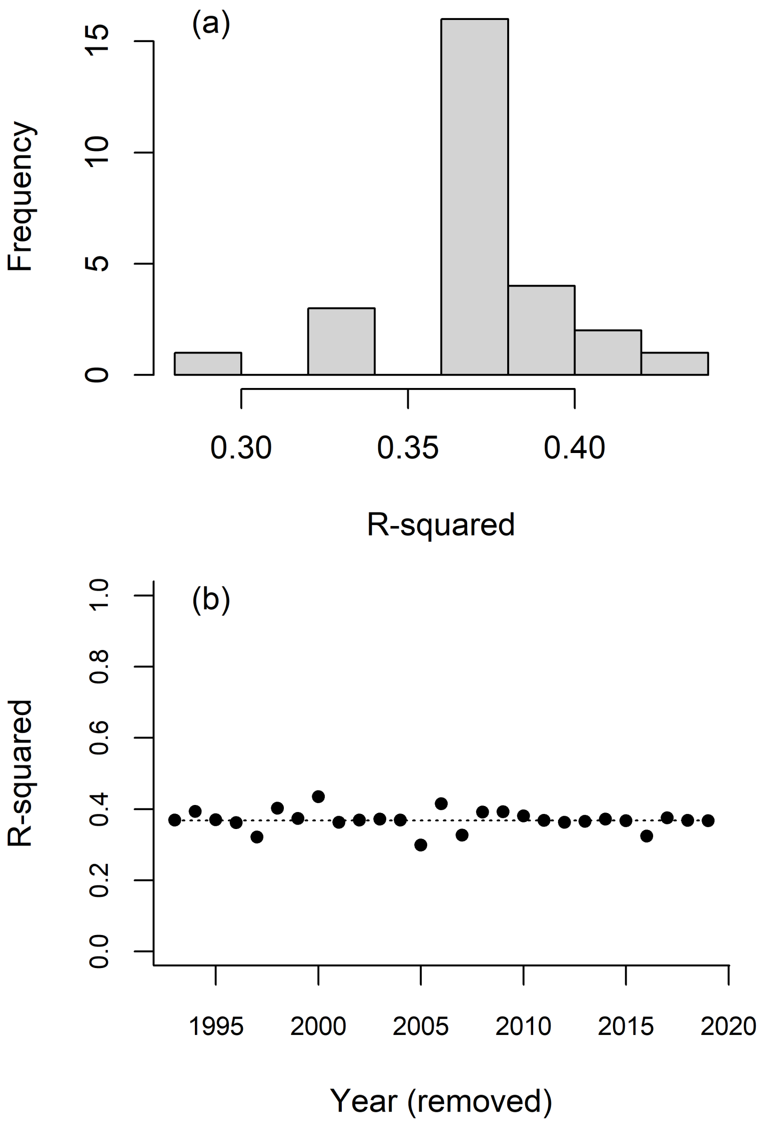

Figure 144: Results of jackknife analysis indicating changes in the r^2 when individual years were excluded from the best-fit model.

Jackknifing individual years and re-running the entire model selection produced stable model selection. CSTbjuv occurred in 28 of the 30 models (where each model leave out one year); CSTpjuv was in 29 models; and Tspawn was in 27 models. DDegg, CSTegg, and CSTlarv each occurred in one model year.

9.2.3.4 Forward prediction

GLORYS data were available through 2024, so we used the results of the index fitting above to predict ln recruitment deviations from 2020 - 2024 (Figure 145). The model predicted average recruitment in 2020 and above average recruitment in 2021, 2023, and 2024. The model picked up low recruitment in 2022, consistent with the recruitment deviations from the 2023 assessment but under predicted high recruitment in 2020, and 2021; thus the predictions were conservative.

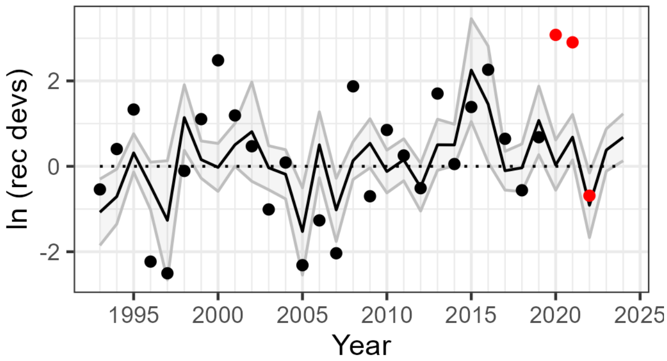

Figure 145: Predicted recruitment deviations through 2024. Lines are the GLORYS index (predicted recruitment through 2024) with standard error. The points are the ln recruitment deviations from the 2023 assessment. Black points indicate training data used in the initial model fitting. Red points are out-of-sample data.