Status of the Yellowtail Rockfish Stock off the U.S. West Coast North of 40°10′ in 2025

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Table of contents

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1. Executive summary

Stock

Yellowtail rockfish (*Sebastes flavidus*) is a midwater rockfish distributed mainly from Point Conception in California to the Gulf of Alaska, with the highest density around Washington state and British Columbia. Yellowtail rockfish are relatively fast-growing and short-lived for a rockfish species, with a maximum size around 55 cm reached around age 15, and few fish observed older than 40. They move farther offshore and northward as they grow older, and are found most consistently up to 250 m depth. There is a genetic break in the population at Cape Mendocino. This assessment is for the northern portion of the stock in U.S. waters, from 40°10′ N latitude (near Cape Mendocino) to the U.S.-Canada border.

Catches

Catches have averaged over 3,000 mt in recent years, and are mainly from a commercial trawl fishery (Table i, Figure i). Catches increased substantially with the rebuilding of other midwater rockfish species and coincident reopening of the midwater trawl fishery in 2017. Recreational catches are a minority of the landings, but have also increased in recent years as trips in both Washington and Oregon have moved farther offshore. Yellowtail rockfish is frequently caught as a bycatch species in the at-sea hake fishery, though this also represents a minority of catches.

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

Year	Commercial (mt)	At-Sea-Hake (mt)	Recreational (mt)	Total Catch (mt)
2015	1,845	86	49	1,980
2016	1,410	62	45	1,517
2017	2,713	278	62	3,053
2018	3,210	230	75	3,515
2019	3,295	317	80	3,692
2020	3,411	167	99	3,677
2021	2,761	82	91	2,934
2022	2,968	27	122	3,117
2023	2,918	268	175	3,360
2024	2,664	15	123	2,802

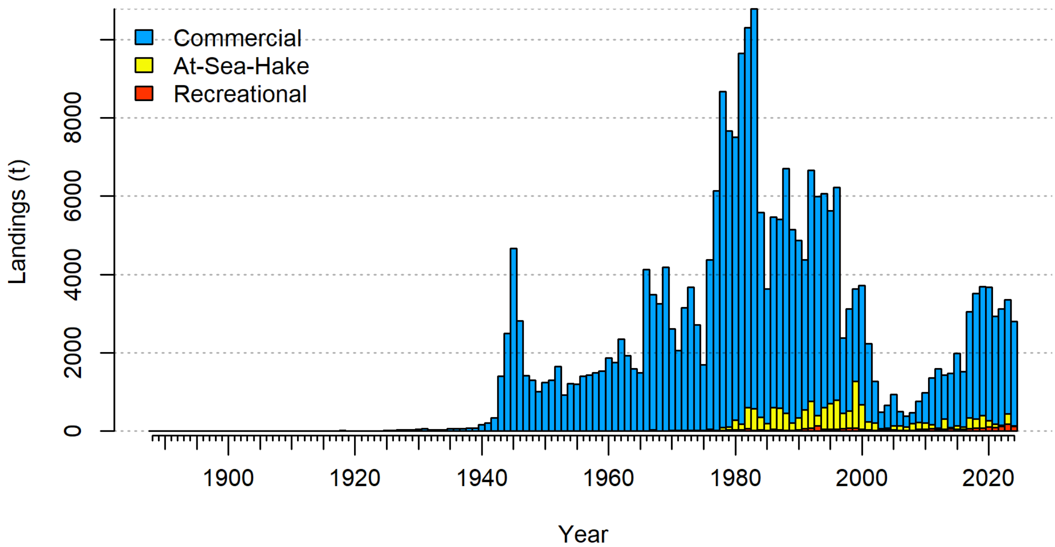

Figure i: Landings in metric tons (mt) by year for each fleet.

Data and assessment

The last assessment for the northern stock of yellowtail rockfish (defined identically) occurred in 2017. The current assessment builds off of that model. It includes catch, length, and age data from three fishery fleets (commercial shoreside, at-sea, recreational), age, length, and index data for one survey (Triennial), conditional age-at-length, length, and index data for one survey (West Coast Groundfish Bottom Trawl Survey). The assessment also includes two new fishery-independent indices: a combined hook and line survey from Oregon and Washington, which also includes associated length data, and a recruitment survey from Oregon. The assessment is relatively data-rich, but continued collection of all of these data sources is important for the continued ability to conduct assessments.

Stock spawning output and dynamics

The model estimates that the population was near the minimum stock size threshold throughout the 1980s and 1990s, but increased through the 2000s to mid 2010s (Figure ii, Figure iii). Since 2017 (coincident with the increase in catches), spawning output has been gradually declining, but is still well above the management target of 40% of unfished spawning depletion (Table ii).

Table ii: Estimated recent trend in spawning output (trillions of eggs) and the fraction of unfished spawning output and the 95 percent confidence intervals.

Year	Spawning output (trillions of eggs)	Lower Interval (mt)	Upper Interval (mt)	Fraction Unfished	Lower Interval	Upper Interval
2015	10.12	7.51	12.73	0.693	0.559	0.828
2016	10.08	7.48	12.69	0.691	0.560	0.822
2017	10.19	7.57	12.81	0.698	0.569	0.827
2018	10.13	7.48	12.79	0.694	0.565	0.823
2019	10.02	7.32	12.72	0.687	0.557	0.816
2020	9.86	7.12	12.61	0.676	0.545	0.807
2021	9.68	6.90	12.46	0.663	0.531	0.795
2022	9.59	6.77	12.41	0.657	0.524	0.790
2023	9.46	6.61	12.31	0.648	0.514	0.782
2024	9.27	6.39	12.15	0.635	0.499	0.771
2025	9.13	6.23	12.03	0.626	0.489	0.763

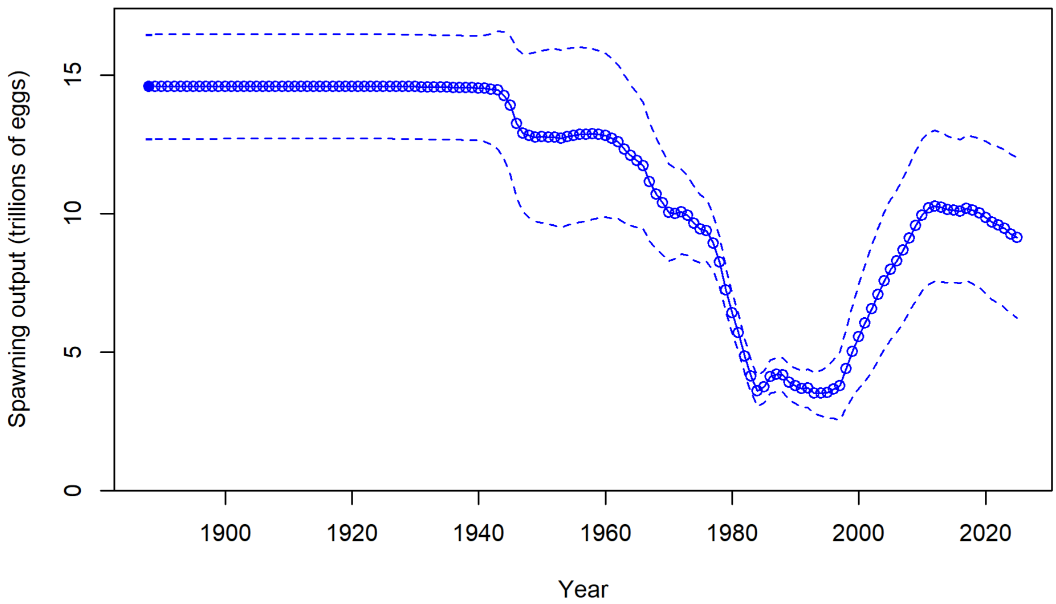

Figure ii: Estimated time series of spawning output (trillions of eggs) for the base model.

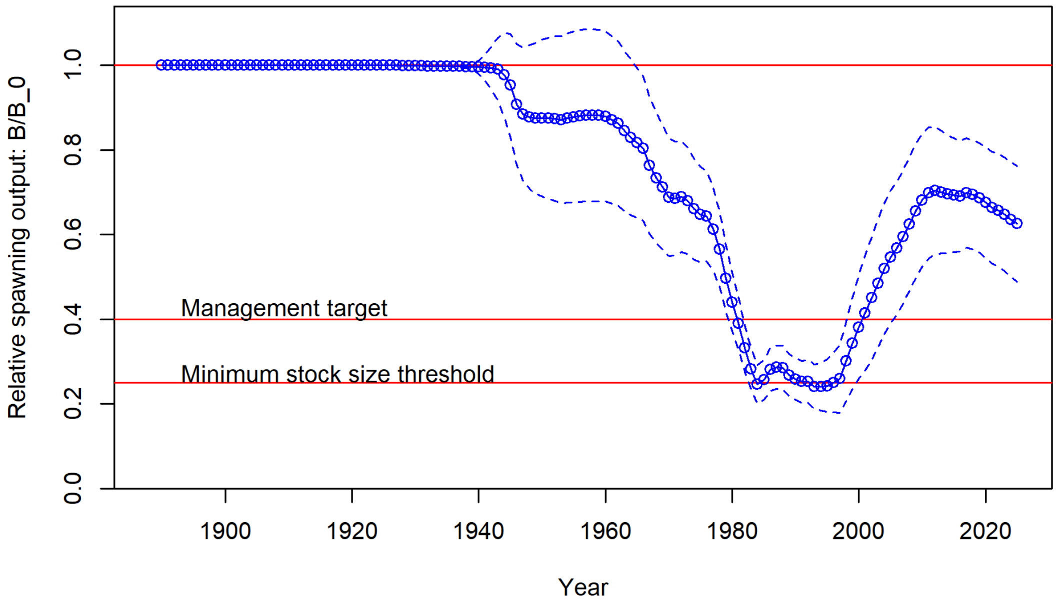

Figure iii: Estimated time series of fraction of unfished spawning output for the base model.

Recruitment

The estimated largest recruitment event throughout the time series was in 2008, which supported an increase in the population leading up to 2017 (Table iii, Figure iv). Recruitment is estimated to be relatively low in the later 2010s, but the model estimates that 2021 and 2023 may support large year classes in the future, with the estimates driven by the new recruitment index for both years.

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

Year	Recruitment (1,000s)	Lower Interval (1,000s)	Upper Interval (1,000s)	Recruitment Deviations	Lower Interval	Upper Interval
2015	22,756	12,148	42,629	-0.334	-0.844	0.175
2016	32,993	18,713	58,169	0.029	-0.396	0.454
2017	22,327	11,696	42,621	-0.374	-0.908	0.161
2018	20,164	10,034	40,521	-0.485	-1.083	0.114
2019	33,162	16,661	66,003	0.004	-0.594	0.601
2020	27,174	11,506	64,179	-0.203	-1.025	0.618
2021	46,846	21,338	102,848	0.333	-0.396	1.063
2022	30,012	12,899	69,827	-0.121	-0.925	0.684

2023	56,453	24,658	129,243	0.503	-0.281	1.286
2024	33,341	15,127	73,488	-0.031	-0.765	0.702

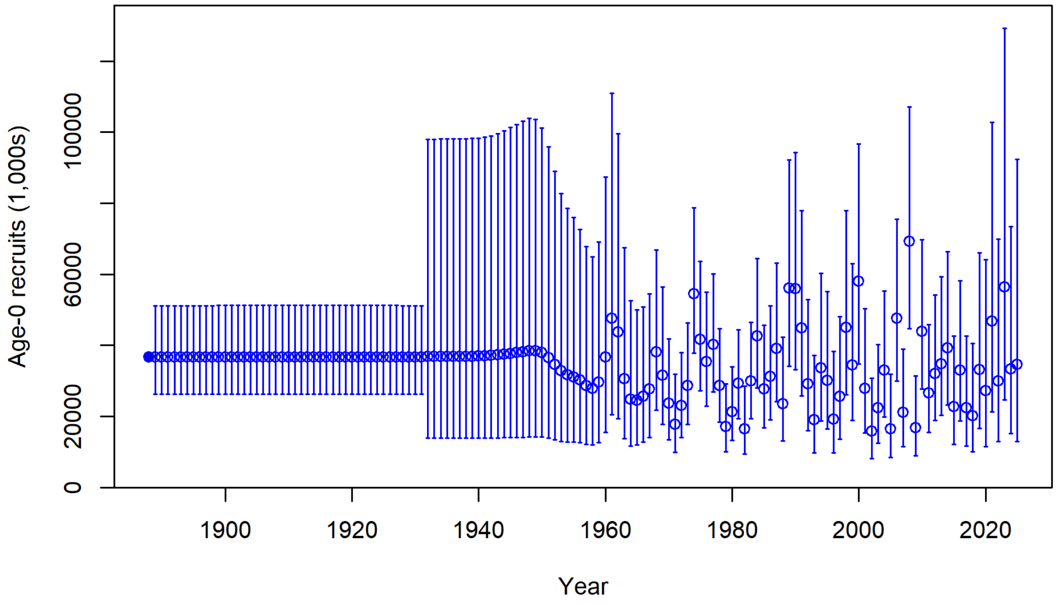

Figure iv: Estimated time series of age-0 recruits for the base model.

Exploitation status

Exploitation rates were above the management target of a fishing intensity that leads to a spawning potential ratio of 0.5 throughout the 1980s and 1990s. They decreased and were close to zero in the early 2000s due to restrictive trip limits. As with catches, exploitation rates increased substantially in 2017, have remained stable since then, and are still well below the management target (Table iv, Figure v).

Table iv: Estimated recent trend in relative fishing intensity (1-SPR)/(1-SPR50%), 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-SPR50%)	Lower Interval (SPR)	Upper Interval (SPR)	Exploitation Rate	Lower Interval (Rate)	Upper Interval (Rate)
2015	0.463	0.337	0.588	0.018	0.013	0.024
2016	0.369	0.265	0.473	0.014	0.010	0.018
2017	0.631	0.478	0.785	0.028	0.020	0.036

2018	0.700	0.536	0.864	0.032	0.023	0.042
2019	0.731	0.561	0.901	0.035	0.025	0.045
2020	0.737	0.563	0.911	0.035	0.025	0.046
2021	0.635	0.473	0.797	0.029	0.020	0.038
2022	0.669	0.500	0.838	0.032	0.022	0.041
2023	0.717	0.539	0.895	0.035	0.024	0.046
2024	0.638	0.469	0.807	0.030	0.020	0.039

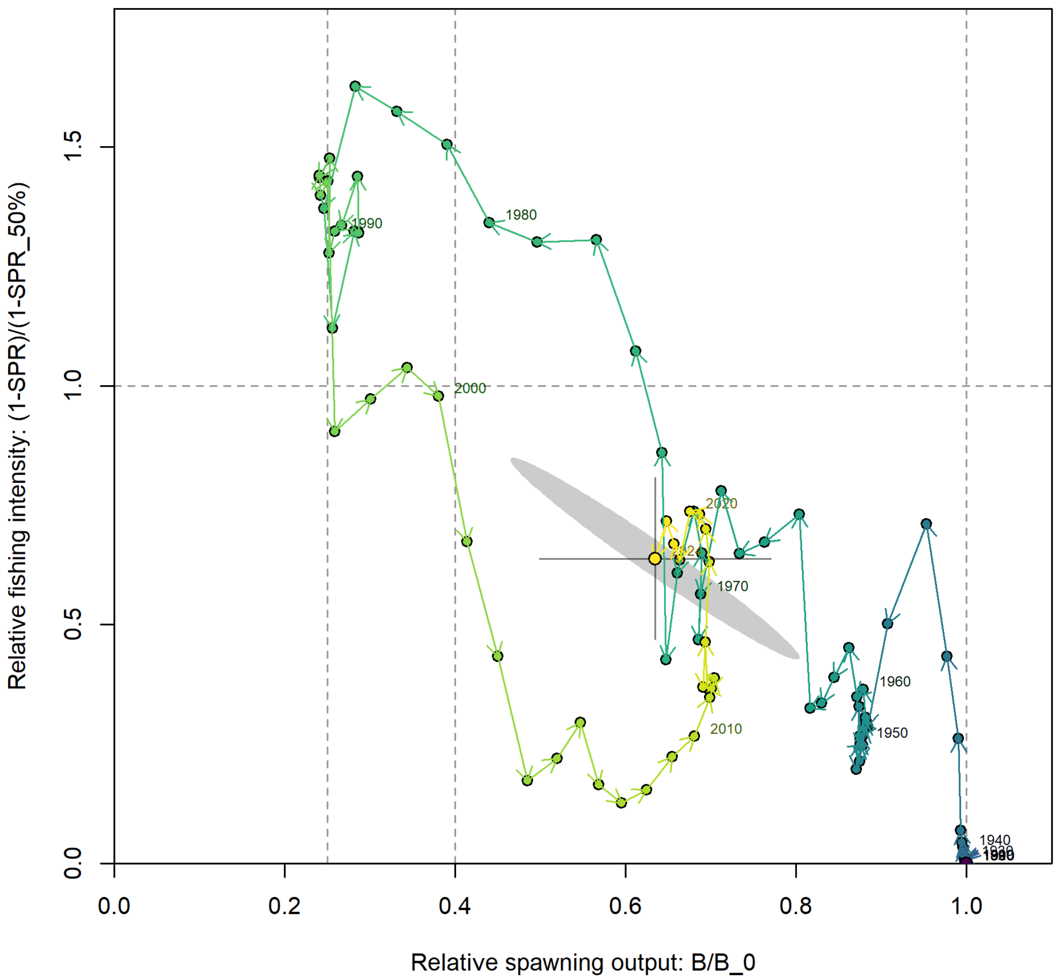

Figure v: Phase plot of fishing intensity versus fraction unfished. Each point represents the biomass ratio at the start of the year and the relative fishing intensity in that same year. Lines through the final point show 95% intervals based on the asymptotic uncertainty for each dimension. The shaded ellipse is a 95% region which accounts for the estimated correlation between the two quantities.

Ecosystem considerations

The assessment includes a sensitivity model with an oceanographic recruitment index. A number of ecosystem and environmental conditions were compiled by a team of ecosystem scientists at the NWFSC specific to the life history and distribution of northern yellowtail rockfish. These conditions included an evaluation of oceanographic conditions impacting recruitment, habitat change, prey availability, predator and competitor abundance, and climate vulnerability.

Reference points

A list of estimates of the current state of the population, as well as reference points based on 1) a target unfished spawning output of 40%, 2) a spawning potential ratio of 0.5, and 3) the model estimate of maximum sustainable yield, are all listed in Table v. SPR, or the spawning potential ratio, is the fraction of expected lifetime reproductive output under a given fishing intensity divided by unfished expected lifetime reproductive output.

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

Reference Point	Estimate	Lower Interval	Upper Interval
Unfished Spawning output (trillions of eggs)	14.6	12.7	16.5
Unfished Age 4+ Biomass (mt)	134,984	115,124	154,844
Unfished Recruitment (R0)	36,630	24,300	48,960
2025 Spawning output (trillions of eggs)	9	6	12
2025 Fraction Unfished	0.626	0.489	0.763
Reference Points Based SO40%	—	—	—
Proxy Spawning output (trillions of eggs) SO40%	6	5	7
SPR Resulting in SO40%	0.459	0.459	0.459
Exploitation Rate Resulting in SO40%	0.057	0.055	0.060
Yield with SPR Based On SO40% (mt)	4,570	3,730	5,410
Reference Points Based on SPR Proxy for MSY	—	—	—
Proxy Spawning output (trillions of eggs) (SPR50)	7	6	7
SPR50	0.500	—	—
Exploitation Rate Corresponding to SPR50	0.051	0.049	0.053
Yield with SPR50 at SO SPR (mt)	4,311	3,524	5,099
Reference Points Based on Estimated MSY Values	—	—	—
Spawning output (trillions of eggs) at MSY (SO MSY)	3	3	4
SPR MSY	0.309	0.304	0.313
Exploitation Rate Corresponding to SPR MSY	0.088	0.084	0.091
MSY (mt)	5,104	4,141	6,067

Management performance

Although catch increased substantially in 2017, it has still been well below the overfishing limit, allowable biological catch, and annual catch limit (Table vi). Attainment of the OFL has averaged around 50% since the increase in landings, and was even lower in prior years.

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

Year	OFL (mt)	ABC (mt)	ACL (mt)	Total dead catch (mt)
2015	7218	6590	6590	1980
2016	6949	6344	6344	1517
2017	6786	6196	6196	3053
2018	6574	6002	6002	3515
2019	6568	6279	6279	3692
2020	6261	5986	5986	3677
2021	6534	6050	6050	2934
2022	6324	5831	5831	3117
2023	6178	5666	5666	3360
2024	5795	5291	5291	2802

Unresolved problems and major uncertainties

The largest uncertainty in this model is the inability to fit a marked increase in the bottom trawl survey from 2014-2019. This coincides with an increase in catch-per-unit-effort from the midwater trawl fishery (which accounts for the majority of landings). The increase is likely due to the record 2008 year class, but the estimated size of the year class does not lead to a large enough increase to fit the survey index, and it is especially hard to fit the sudden decrease and then flattening of the index, given the estimated natural mortality rate and that catches were relatively stable from 2017-2024. The current assessment estimates that the stock is more depleted than it was in 2017, the time of the last assessment, which is likely the case. The magnitude of that difference is more uncertain.

Decision table and harvest projections

Projections of the overfishing limit, acceptable biological catch, and annual catch limit, all based on a P* of 0.45 and a log-space standard deviation of the overfishing limit of 0.5 are included in Table vii. Assumed catches for 2025 and 2026 for this projection were provided by the Groundfish Management Team, and catches from 2027 onward assume full attainment of the acceptable biological catch. Decision tables from the base model and low and high states of nature (axis of uncertainty is based on log of unfished recruitment) are in Table viii. The first set of projections in the decision table are based on full attainment of the ACL from the base model; the second set of projections assumes similar attainment to recent years (55%).

Table vii: Potential OFLs (mt), ABCs (mt), ACLs (mt), the buffer between the OFL and ABC, estimated spawning output (trillions of eggs), and fraction of unfished spawning output with adopted OFLs and ACLs and assumed catch for the first two years of the projection period.

Year	Adopted OFL (mt)	Adopted ACL (mt)	Assumed Catch (mt)	OFL (mt)	Buffer	ABC (mt)	ACL (mt)	Spawning output (trillions of eggs)	Fraction Unfished
2025	6,866	6,241	4,060	—	—	—	—	9.13	0.626
2026	6,662	6,023	4,066	—	—	—	—	8.77	0.601
2027	—	—	—	5,051	0.935	4,723	4,723	8.39	0.575
2028	—	—	—	4,882	0.930	4,540	4,540	7.95	0.545
2029	—	—	—	4,800	0.926	4,445	4,445	7.63	0.523
2030	—	—	—	4,794	0.922	4,421	4,421	7.43	0.509
2031	—	—	—	4,837	0.917	4,435	4,435	7.36	0.504
2032	—	—	—	4,892	0.913	4,467	4,467	7.39	0.506
2033	—	—	—	4,934	0.909	4,485	4,485	7.47	0.512
2034	—	—	—	4,952	0.904	4,476	4,476	7.55	0.517
2035	—	—	—	4,947	0.900	4,452	4,452	7.59	0.520
2036	—	—	—	4,926	0.896	4,414	4,414	7.59	0.520

Table viii: Decision table with 10-year projections. 'Mgmt' refers to the two management scenarios (A) the default harvest control rule $P^* = 0.45$ and sigma = 0.5, (B) Assuming an average ACL attainment of 55% (consistent with recent attainment) from 2027-2036. In each case the 2025 and 2026 catches are fixed at estimates provided by the GMT. The alternative states of nature ('Low', 'Base', and 'High' as discussed in the text) are provided in the columns, with Spawning Output ('Spawn', in trillions of eggs) and Fraction of unfished spawning output ('Frac') provided for each state.

Mgmt	Year	Catch	Low Spawn	Low Frac	Base Spawn	Base Frac	High Spawn	High Frac
A	2025	4060	7.75	0.539	9.13	0.626	10.38	0.693
	2026	4066	7.41	0.515	8.77	0.601	9.98	0.666
	2027	4723	7.06	0.490	8.39	0.575	9.57	0.639
	2028	4540	6.65	0.462	7.95	0.545	9.11	0.608
	2029	4445	6.33	0.440	7.63	0.523	8.76	0.585
	2030	4421	6.14	0.426	7.43	0.509	8.57	0.572
	2031	4435	6.06	0.421	7.36	0.504	8.51	0.568
	2032	4467	6.07	0.421	7.39	0.506	8.56	0.572
	2033	4485	6.12	0.425	7.47	0.512	8.66	0.578
	2034	4476	6.18	0.429	7.55	0.517	8.76	0.585
	2035	4452	6.21	0.431	7.59	0.520	8.81	0.588
	2036	4414	6.21	0.431	7.59	0.520	8.82	0.589
B	2025	4060	7.75	0.539	9.13	0.626	10.38	0.693
	2026	4066	7.41	0.515	8.77	0.601	9.98	0.666
	2027	2598	7.06	0.490	8.39	0.575	9.57	0.639
	2028	2497	6.95	0.483	8.26	0.566	9.41	0.628
	2029	2445	6.92	0.480	8.20	0.562	9.33	0.623
	2030	2431	6.97	0.484	8.25	0.565	9.37	0.626
	2031	2439	7.12	0.495	8.40	0.576	9.53	0.636
	2032	2457	7.35	0.510	8.64	0.592	9.77	0.652
	2033	2467	7.61	0.528	8.90	0.610	10.05	0.671
	2034	2462	7.86	0.546	9.16	0.628	10.32	0.689
	2035	2449	8.08	0.561	9.38	0.643	10.53	0.703
	2036	2428	8.25	0.573	9.54	0.654	10.68	0.713

Scientific uncertainty

The model estimate of the log-scale standard deviation of the overfishing limit (OFL) in 2025 is 0.186. This is less than the default SSC value of 0.5 for a category 1 assessment, so harvest projections assume an initial sigma of 0.5.

Research and data needs

The most important future research need is to better understand the catchability of the trawl survey and its drivers. This could help to resolve the mismatch between the survey index and composition data. Continued collection of age and other biological samples across gear types and fleets is also critical.

Risk table

Table ix: 'Risk Table' for northern yellowtail rockfish to document ecosystem and environmental factors potentially affecting stock productivity and uncertainty or other concerns arising from the stock assessment (see text). 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: unfavorable to neutral conditions for recruitment	• Catch reconstruction is reliable for a rockfish species, with some uncertainty in historical years when rockfish were not always sorted to species	• Well-informed sex-specific estimates of natural mortality, unfished recruitment, and growth
• Habitat: Neutral	• More age data than almost any other groundfish species. Covers shoreside, at-sea, and recreational sectors. Shoreside age data dating back to the 1970s.	• Steepness fixed at meta-analysis prior.
• Prey: Most available evidence suggests adequate forage for yellowtail in 2024 and recent years. Caveat: low krill in 2023 acoustic surveys.	• Age data are generally fit well with simple selectivity assumptions. Some mild issues with commercial (shoreside) length data.	• Good fits to abundant composition data with fairly simple selectivity assumptions and fleet structure
• Predators: no trend in abundance for 6 of 7 predators in the last 5 yrs	• Species-specific maturity and fecundity; maturity data collected over the last ~10 years	• Model generally misses an increase in the WCGBTS from 2014-2019. Non-stationary catchability seems more likely than an incorrect modeled population trajectory, given similar increases seen during this time for all midwater rockfish.
• Competitors: Some potential for hake competition for krill, but highly uncertain.	• Bottom trawl survey may not be reliable way to generate index for midwater rockfish	• Highly numerically stable model, MCMC posteriors are similar to assumption of asymptotic normality
	• New exploration of early life history and hook and line surveys	• Most sensitivity model runs are well within the asymptotic confidence interval of the base model
	• Generally a target species with most catch landed, only limited bycatch	
Level 2: neutral	Level 1	Level 1

To identify ecosystem and environmental processes impacting northern yellowtail rockfish we evaluated recent trends in environmental drivers, focusing on the years after main recruitment deviations are estimated (2019 - 2025). We considered trends in environmental drivers of yellowtail recruitment, habitat and distribution, prey, competitors and predators, and the climate vulnerability assessment (CVA) by McClure et al. (2023). We did not consider non-fisheries human activities as none were identified to be applicable to yellowtail. Overall we consider ecosystem and environmental conditions to be neutral (Level 2) with medium to high confidence based on agreement between a majority of indicators, robust but uncertain evidence, and no apparent concerns. We use this, plus information related to the stock assessment, to fill out the 'risk table' in Table ix, based on the framework outlined by the California Current Integrated Ecosystem Assessment (CCIEA) team (Golden et al. 2024).

1. Introduction

Yellowtail rockfish, *Sebastes flavidus*, occur off the West Coast of the United States from Baja California to the Aleutian Islands. yellowtail is a major commercial species, captured mostly in trawls from Central California to British Columbia (Love 2011). Because it is an aggregating midwater species it is usually caught in the commercial midwater trawl fishery. In Central California there is a large recreational fishery as well. The center of yellowtail rockfish abundance is from southern Oregon through British Columbia (Fraidenburg 1980). We briefly summarize yellowtail rockfish life history, fisheries, assessment and management here, but in-depth, extensive background information on yellowtail rockfish and other managed species is available in PFMC (2024).

Genetic evidence indicates that there are two stocks of yellowtail rockfish, with a genetic line at Cape Mendocino, California, roughly 40°10′ North Latitude (Hess et al. 2011). This study of 1013 fish from 21 sites along the West Coast from Mexico through Alaska examined two datasets, one of mitochondrial DNA, and one of nuclear DNA microsattelite loci. Findings in both datasets agreed, and also concur with the findings of Field and Ralston (2005) who looked at differences in recruitment trends related to physical forcing and coherence along the coast, and found the greatest differences among the U.S. and Canadian stocks to be defined by Cape Mendocino. Neither the genetic study nor the oceanographic studies definitively identify mechanisms of stock isolation; however, they suggest that a combination of physical forcing due to offshore advection and differences in available habitat across Cape Mendocino may together account for the differences observed.

The current assessment is for the northern stock only. A map showing the scope of the current assessment and depicting boundaries for the two west coast stocks is provided in Figure 6. The 2017 yellowtail rockfish assessment included the first full length and age integrated assessment model south of Cape Mendocino. However, it was withdrawn by the assessment team and has not been used in management.

1.1. Life history

Rockfish are in general long-lived and slow-growing; however, yellowtail rockfish have a high growth rate relative to other rockfish species, reaching a maximum size of about 55 cm in approximately 15 years (Tagart 1991). Yellowtail are reported to live at least 64 years (Love 2011), but no fish that old occur in data available for this assessment (the 95th percentile of age is 35 years for females and 45 years for males). The maximum age plausibly observed in the data is 60. There were additional data we considered to be outliers and possibly erroneous, including three fish in the commercial data reported to be 70, 99, and 101.

Yellowtail rockfish are among those that are fertilized internally and release live young. Spawning aggregations occur in the fall, and parturition in the winter and spring (January-May) (Eldridge et al. 1991). Young-of-the-year recruit to nearshore waters from April through August, migrating to deeper water in the fall. Preferred habitat is the midwater over reefs and boulder fields. Young-of-the-year yellowtail rockfish settle to nearshore areas, and are known to utilize kelp bed habitat (Love 2011). Laidig and Watters (2023) note that young yellowtail are found in kelp beds but also in slightly deeper waters seaward of kelp beds.

Yellowtail rockfish are extremely motile, and make rapid and frequent ascents and descents of 40 meters; they also exhibit strong homing tendencies (Love 2011). They are able to quickly release gas from their swim bladders, perhaps making them less susceptible to barotrauma than similar species (Eldridge et al. 1991).

1.2. Ecosystem considerations

A number of studies correlate environmental conditions to pelagic juvenile abundance and juvenile recruitment of rockfishes, including yellowtail rockfish. Year-class strength is particularly impacted during the early larval phase, and annual pelagic juvenile abundance is correlated with physical conditions, especially upwelling strength along the coast (e.g., Field and Ralston 2005; Laidig et al. 2007; Laidig 2010; Ralston and Stewart 2013). Rockfish in general are sensitive to the strength and timing of the upwelling cycle in the Eastern Pacific, which affects where pelagic juveniles settle, and impacts the availability of the zooplankton which the young require.

Yellowtail rockfish feed mainly on pelagic animals, but are opportunistic, occasionally eating benthic animals as well. Large juveniles and adults eat fish (small Pacific whiting, Pacific herring, smelt, anchovies, lanternfishes, and others), along with squid, krill, and other planktonic organisms. Wippel et al. (2017) summarized diet data for yellowtail rockfish based on 1069 stomachs collected from 1982 - 1999. Ranked from most to least common, the dominant prey were *euphasiids* (krill), juvenile hake, gelatinous zooplankton (predominantly salps and ctenophores) and herring. For juvenile yellowtail, the dominant prey taxa were *euphasiids* and mesozooplankton such as copepods.

Yellowtail rockfish are prey for Chinook salmon, lingcod, cormorants, pigeon guillemots and rhinoceros auklets (Love 2011). Based on Ecopath foodweb modeling, seven predators are identified as high sources of predation mortality: California sea lions, lingcod, porpoises, fur seals, harbor seals, sablefish, and skates (Koehn et al. 2016).

1.3. Fishery description

The rockfish fishery off the U.S. Pacific coast first developed off California in the late 19th century as a hook-and-line fishery (Love et al. 2002). The first record of yellowtail in a catch reconstruction is commercial catch in Washington in 1889; Oregon has a record shortly thereafter in 1892. Records for recreational fishing begin in 1928. The rockfish trawl fishery was established in the early 1940s, when the United States became involved in World War II and wartime shortage of red meat created an increased demand for other sources of protein (Harry and Morgan 1961; Alverson et al. 1964; Miller et al. 2014). During the early development period of the rockfish fishery there was little attention paid to quantifying the species composition of the landings. Although we know yellowtail rockfish were caught in the 1940s and 50s, we have limited quantitative knowledge of the proportion of their contribution to the total landings. In the early 1960s, coastal states began to report landings by species (Niska 1967; Tagart and Kimura 1982).

In 1977, the U.S. extended fisheries jurisdiction to 200 nautical miles offshore. Yellowtail rockfish off Oregon and Washington were an important target of the expanding fishery during this time. In the 1980s and 1990s, a directed midwater trawl fishery developed that targeted yellowtail rockfish, among several other rockfish species. New technology extended fishing operations into previously unfished areas and enabled vessels to follow widow rockfish concentrations throughout the year (Demory 1987; Quirollo 1987). As a midwater species, it has also commonly been caught as bycatch in the hake fishery.

Canary and widow rockfish, two common co-occurring species (Tagart 1988; Rogers and Pikitch 1992) were both declared overfished during the West Coast groundfish collapse around 2000. This substantially altered fishing opportunities for yellowtail rockfish. In order to achieve the necessary reduction in the catch of canary rockfish, widow rockfish, and other overfished species, stringent management measures were adopted that limited harvest of yellowtail rockfish.

Canary and widow rockfish were declared rebuilt in 2015 (Hicks and Wetzel 2015; Thorson and Wetzel 2015), and commercial and recreational yellowtail rockfish catch increased substantially beginning when those assessments were first used for harvest specifications in 2017. Today, the rebounding midwater trawl fishery for rockfish and the recreational groundfish fishery are dependent on yellowtail rockfish as a target species. However, the shoreside and at-sea hake sectors also encounter yellowtail rockfish, and are dependent on allocations of it in the event of "disaster tows" that inadvertently encounter large schools of yellowtail rockfish.

1.4. Management history

Yellowtail rockfish are currently managed with stock-specific harvest specifications north of 40°10′ N. latitude, and as part of the Southern Shelf rockfish complex south of 40°10′ N. latitude.

Prior to 1983, only market forces constrained the domestic trawl fishery for yellowtail rockfish. In 1983, U.S. managers imposed the first trip limit on landings from the *Sebastes* complex (a collection of rockfish species that included yellowtail rockfish) and set a target quota for the complex. By September 1983, harvest was approaching the quota in the Columbia and Vancouver areas. Managers responded by reducing trip limits and frequency. Thus began a tumultuous management history for *Sebastes* complex species and yellowtail rockfish, in particular (Tagart et al. 2000). The Pacific Fishery Management Council (PFMC) continued to use trip limit and frequency regulations in an attempt to spread the harvest throughout the calendar year, reduce bycatch in the directed fishery, and limit regulation-induced discard. In-season adjustments (usually reductions) to trip limits occurred often (Tagart et al. 2000). Increasing harvest rates and declining abundance of coastal groundfish species resulted in increasingly smaller trip limits.

A number of major management changes affecting yellowtail rockfish occurred in 2000. First, canary rockfish, a major co-occurring species, was determined to be overfished. In order to achieve the necessary reduction in the canary rockfish catch, the PFMC adopted stringent management measures that limited harvest of canary rockfish and their co-occurring species such as yellowtail rockfish. Second, shelf rockfish species could no longer be retained by vessels using bottom trawl footropes with a diameter greater than 8 inches. The use of small footrope gear increases the risk of gear loss in rocky areas. This restriction was intended to provide an incentive for fishers to avoid high-relief, rocky habitat, thus reducing the exposure of many depleted species to trawling. This reinforced reductions in landing limits for most shelf rockfish species. Third, the PFMC adopted a new partitioning of rockfish species. Yellowtail rockfish was assigned to the minor shelf rockfish group south of Cape Mendocino, and was managed as a single species in the North.

Since September 2002, trawl and non-trawl Rockfish Conservation Areas (RCAs, areas known to be critical habitat) have been closed to fishing. Alongside these closures, limits on landings were put in place that were designed so as to accommodate incidental bycatch only. These eliminated directed midwater fishing opportunities for yellowtail rockfish in non-tribal trawl fisheries and increased discard rates (which had historically been low). A somewhat greater opportunity to target yellowtail rockfish in the trawl fishery became available in 2011 under the trawl rationalization program. However, quotas for widow and canary rockfish generally constrained targeting of yellowtail rockfish.

This changed with the rebuilding declaration of both canary and widow rockfish, with increases in catch limits beginning in 2017. Additionally, new exempted fishing permits for midwater trawl gear occurred in 2017-2018 and a number of updates to regulations around trawl and non-trawl RCAs from 2019-2024 all further expanded opportunities to fish in abundant yellowtail rockfish habitat.

While recreational fisheries have caught yellowtail rockfish for many years, recent exempted fishing permits for Holloway longleader gear in Oregon and limited bag limits for black rockfish in Washington have pushed recreational fisheries farther offshore and increased the sizes and amount of yellowtail rockfish caught in the recreational sector.

1.5. Management performance

Over the past decade, catch has remained substantially below ACL (Table vi). Total catch (including landings and discards) doubled between 2016 and 2017 but still remained less than 50% of the annual catch limit (ACL). Total catch has remained well below the management limits and harvest specifications in recent years (Table vi)

1.6. Fisheries off Canada and Alaska

Yellowtail rockfish are a target species in Canada with catches between 4000-6000 mt since the late 1980s. It has the second largest single-species Total Allowable Catch (TAC) among rockfish species under quota management for the Canadian Pacific Coast. In Canada it is caught in similar amounts by bottom and midwater trawl gear. A 2015 stock assessment conducted by the Fisheries and Oceans Canada found the stock to be at 50% of unfished spawning biomass, in the "healthy" range (Canadian Science Advisory Secretariat 2015).

A new Canadian assessment was reviewed in October 2024 but has not yet been published. Like the current assessment, this model also used stock synthesis, but was purely age-based with an empirical weight-at-age matrix used instead of parametric growth. Management quantities were also based on posterior medians rather than maximum likelihood estimation (MLE) estimates. However, for purposes of comparison with the current base model, the MLE estimates from model files available online were used to compare results with the current base model. The time series of fraction of unfished spawning output is similar as are the recruitment deviations (Figure 72) suggesting that recruitment is linked between the two regions, which is not surprising given the lack of a biogeographic boundary. The 1990, 2000, and 2008 cohorts are some of the largest in both models (Figure 73).

The Alaska Fisheries Science Center assesses yellowtail rockfish as one of approximately 25 non-target rockfish species in the "Other rockfish" complex in the Gulf of Alaska. The complex is assessed biennially to coincide with the availability of new trawl survey biomass estimates in odd-numbered years. The last operational assessment was conducted in 2023 with an update in 2024. There was no evidence to suggest that overfishing is occurring for the complex. Total catch in 2023 was 1,079 t was lower than the Gulf-wide overfishing limit (OFL) and Acceptable Biological Catch (ABC) of 4,054 t and 3,774 t, respectively (Omari et al. 2023; Omari and Tribuzio 2024).

2. Data

A summary of available data by type and fleet is available in Figure 7.

2.1. Fishery-dependent data

Fishery-dependent data were split into three fleets: a shoreside commercial fleet ("commercial"), an at-sea hake commercial fleet ("at-sea"), and a recreational fleet ("recreational"). The vast majority of catches across all years has come from trawl gear in the shoreside commercial sector.

2.1.1. Landings

A summary of total removals are provided in Table 11 and Figure 8.

2.1.1.1. Commercial

Commercial landings ultimately came from a mix of Pacific Fisheries Information Network (PacFIN) and state reconstructions.

Washington Department of Fish and Wildlife (WDFW) provided a catch reconstruction from 1889 to 2000 (T. Tsou, WDFW, pers. comm.). The 2017 assessment used the same reconstruction (Stephens and Taylor 2017). The three main sources used in this reconstruction are from the U.S. Fish Commission Report (UFSC), Washington Bound Volumes, and Washington Statistical Bulletin. The historical species composition is based on the various historical reports and interviews of old-time fishermen and dockside samplers. The 1981 to 2000 landings are different from PacFIN records due to a revised approach for apportioning out unidentified rockfish ("URCK") in fish tickets to the species level. The revised approach relaxed the borrowing rules for missing data currently used in the WDFW species allocation algorithm (Tsou et al. 2015). Landings from 2001 to 2024 were downloaded from PacFIN (pulled March 10, 2025).

In Oregon, historical commercial landings from 1892 to 1986 were provided by Oregon Department of Fish and Wildlife (ODFW) (Karnowski et al. 2014). Landings from 1987 – 1999 were compiled from a combination of PacFIN and a separate ODFW reconstruction that delineated species-specific landings in the unspecified categories on PacFIN (e.g. URCK and POP1, Fish and Wildlife 2017). Yellowtail rockfish landings from this reconstruction were substituted for the URCK and POP1 landings available from PacFIN and added to PacFIN landings from other categories for a complete time series during this time period. Commercial landings from 2000 – 2024 are available on PacFIN.

California commercial landings came from the reconstruction in Ralston et al. (2010) and an additional reconstruction of catches off the coast of Oregon landed into California (J. Field, SWFSC, pers. comm.) during that time (1916-1968), CalCOM database for the California Cooperative Survey (CalCOM) (1969-1980), and PacFIN (1981-2024, pulled March 10, 2025). CalCOM and PacFIN data in California were filtered to include only the Eureka and Crescent City port area groups (equivalent to Humboldt and Del Norte counties) to approximate landings north of 40°10′ N. Lat. While Shelter Cove is in Humboldt county but south of 40°10′ N. Lat., and this approach assigns catch based on port of landing rather than geographic location of catch, this is the same approach used in the 2017 assessment. In conversations with California Department of Fish and Wildlife (CDFW), it was determined to be the best way to identify catches for the northern stock given the available data.

In the Ralston et al. (2010) reconstruction, the northernmost region (region 2) includes Crescent City, Eureka *and* Fort Bragg port area groups. Catch in the Crescent City and Eureka port area groups is estimated based on the fraction of catch in Crescent City and Eureka divided by catch in all of region 2 during the first five years of CalCOM (1969-1973). The vast majority (96%) of the catch is in the two northern port areas. All supplementary catches in the reconstruction of catches off the coast of Oregon, but landed into California are included.

Foreign commercial landings caught in U.S. waters that occurred prior to closure of the EEZ are not included in any state historical reconstruction. Estimates of these landings were added to domestic commercial catches for 1966-1976 (Rogers 2003). Note that these catches were missing from the 2017 assessment.

2.1.1.2. At-sea

At-sea catches from North Pacific Database Program (NORPAC) were provided by Vanessa Tuttle at Northwest Fisheries Science Center (NWFSC) on November 7, 2024 for the years 1976-2023, and on February 11, 2025 for 2024.

2.1.1.3. Recreational

Recreational landings came from a mix of Recreational Fishery Information Network (RecFIN), Marine Recreational Fisheries Statistics Survey (MRFSS), and state reconstructions. They are assumed to include both retained and released fish.

For Washington, historical catch estimates (1967-1970, 1972, 1973, and 1975-1989) and Washington Department of Fish and Wildlife Ocean Sampling Program (OSP) estimates (1990-2024) are available in RecFIN (pulled February 13, 2025). The historical catch estimates for 1971 and 1974 were not available in the historical report and were treated as the average of the two preceding and two following years. Historical data were filtered to marine catch areas 1-4. For OSP data, we used data in table CTE501 on RecFIN, filtering out catches from Canada and those east of the Sekiu River ("Sekiu River and Pillar Point" catch area).

Washington's historical recreational catches are only available in numbers. Unlike in the 2017 assessment, we converted these catches to weights before entering them into the model in order to facilitate a single recreational fleet. This seemed appropriate given that recreational catches across all three states represent a relatively small fraction of total fishing mortality (Figure 8). To do this, we calculated average length of samples collected prior to 1990 in the WA Sport Biodata. This included 48 samples from 1979, 1981, and 1982. The next available samples were in 1995. We used an unsexed length-weight relationship calculated from survey data.

For Oregon, a historical reconstruction provided numbers of fish from 1979-2000 (Whitman 2024), which were converted to biomass using biological samples from the MRFSS (A. Whitman, ODFW, pers. comm.). These landings in biomass were provided by ODFW. Recreational landings for Oregon from 2001-2024 are available from RecFIN.

California recreational catches came from Ralston et al. (2010) (1928-1980), as well as MRFSS (1981-2004) and California Recreational Fisheries Survey (CRFS) (2005-2024) estimates, both of which are available on RecFIN (downloaded November 12, 2024 and February 21, 2025, respectively). For CRFS, only catches in the Redwoods district were considered to be part of the northern stock. Ralston et al. (2010) and MRFSS aggregate catches into Northern and and Southern California. MRFSS excluded San Luis Obispo county from Northern California from 1980-1989 only. San Luis Obispo is included in Northern California in Ralston et al. (2010) and later years of MRFSS. Albin et al. (1993) estimated recreational catches in California by county from San Luis Obispo north from 1981-1986. We calculated 1) the ratio of catches in Albin et al. (1993) in Del Norte and Humboldt counties divided by the catch in *all* counties, 2) the ratio of catches in Albin et al. (1993) in Del Norte and Humboldt counties divided by the catch in all counties *except* San Luis Obispo, and 3) the ratio of total catch in CRFS in the Redwoods district divided by total catch in the Northern California sub-region from 2005-2010. Then, to calculate catches north of 40°10′ N. Lat., we multiplied total Northern California catches in Ralston et al. (2010) by ratio (1). From 1981-1989, we multiplied Northern California catches in MRFSS by ratio (2). From 1993-2004 we multiplied Northern California catches in MRFSS by a weighted average of ratios (1) and (3). Weights were the inverse of time to the last year in Albin et al. (1993) and the first year of CRFS. No MRFSS estimates are available from 1990-1992. For this time period, we interpolated between the average catches from 1987-1989 and 1993-1995.

2.1.2. Discards

Discards were added to landings for the shoreside commericial fleet. For the years prior to 2002 when the West Coast Groundfish Observer Program (WCGOP) program began, landings were multiplied by 1.0451 based on an estimated discard ratio of 4.51% (J. Wallace pers. comm.) in Pikitch et al. (1988). For 2002-2023, discard amounts in metric tons were taken from the Groundfish Expanded Mortality Multi-Year (GEMM) report. Because the GEMM report for 2024 mortality was not yet available, discards for 2024 were inadvertently left out of the base model. The mean discards over the period 2019-2023 were 5.3 mt per year and an exploration of the impact of adding these discards to the 2024 catches changed the fraction of unfished spawning output in 2025 by only 0.00005, but will be included in any future updates to the base model.

Explorations using the 2017 assessment model showed that the alternative discard treatments in the model had neglible impact on point estimates and uncertainty. Data exploration also indicated the sizes of discarded and retained fish were similar in years where discard composition data was available, so the consolidation of discards and landings seemed appropriate. The change simplifies the model by removing 13 estimated parameters. It also corrects an issue which led to overestimation of discard amounts in the 2017 assessment. Comparing discard estimates between the GEMM and the 2017 model revealed large discrepencies which were found to be related to differences between tribal and non-tribal discards. The discard rates estimated by WCGOP during the years 2004–2010 were estimated to be high (above 50% in some years), but only represent the non-tribal catch. During this same period, the tribal catch represented the majority of the commercial catch and the tribal fishery had full retention of yellowtail rockfish. Modeling retention appropriately would have required separating the tribal and non-tribal catch into separate fleets.

Historical recreational reconstructions do not include an estimate of discarded fish. Historical bag limits in the recreational fishery were generally liberal, and the assumption of full retention was deemed reasonable. Modern post-MRFSS recreational sampling programs incorporate estimates of discard mortality into total dead catch estimates, and these were used.

2.1.3. Biological data

Commercial biological samples were available from the three coastal states covering the years 1972–2024 (Table 12, Table 13, Figure 19, Figure 20, first row). There were 197,400 length samples, of which 49% were from Washington, 47% from Oregon, and 4% from California (Humboldt and Crescent City port area groups only). There were 161,697 age samples, of which 49% were from Washington, 48% were from Oregon, and 2% were from California. Because most commercial length and age data was sexed, unsexed commercial biological samples were excluded. Sensitivity to excluding unsexed lengths (where most of the unsexed data existed) was explored. Input sample size was calculated based on a combination of the number of trips and number of individuals (I. Stewart, pers. comm.):

$$N_{\text{input}} = \begin{cases} N_{\text{trips}} + 0.138 N_{\text{fish}}, & \frac{N_{\text{fish}}}{N_{\text{trips}}} < 44 \\ 7.06 N_{\text{trips}}, & \text{otherwise} \end{cases}$$

Any year with less than 100 length samples was excluded to avoid the influence of sparse data. Commercial composition data were filtered ("expanded") using the {pacfintools} package maintained at the NWFSC, where expansions weighted individual samples based on the trip-level and state-level catches.

At-sea biological samples were available from 1976–2024 (Table 14, Figure 19, Figure 20, second row). This includes 112,708 length samples across all years and 643 age samples from 2019 and 2023 (two recent years with particularly high yellowtail rockfish catches in the at-sea fishery). Virtually all data were sexed, so unsexed data were excluded. Input sample size was number of hauls ("tows").

Recreational biological samples were available from the three coastal states covering the years 1980–2024 (Table 15, Figure 19, Figure 20, third row). There were 64,637 length samples, of which 71% was from Oregon, 26% from Washington, and 3% from California (North of 40°10′). There were 9,205 age samples, 100% of which were from Washington. Recreational catches have been relatively evenly split between Oregon and Washington in recent years. If the recreational fleets in each state catch different segments of the population or there is localized depletion, the age and length data could provide different population signals since the length data is dominated by Oregon and the age data is dominated by Washington. However, ultimately we were able to fit both the length and age composition data and the sex ratio in the age data relatively well, and there were no major signs of conflict, so we did not explore this discrepancy in detail. Input sample size was number of fish.

2.1.4. Abundance indices

Two fishery-dependent abundance indices were developed: one from commercial observer data and one from recreational sampling data. While neither index is in the base model, sensitivity to their inclusion is explored, and the standardization procedure is described here.

2.1.4.1. Commercial observer and electronic monitoring index

Yellowtail rockfish are a midwater rockfish often found slightly above the seafloor in rocky untrawlable habitat, and therefore standard bottom trawl surveys may not effectively measure changes in relative abundance. The commercial fishery often catches them using midwater trawl gear. Catch share vessels in the trawl fishery have had 100% observer or electronic monitoring (EM) coverage since 2012. We generated a fishery-dependent observer index using data from WCGOP, filtered to trips that used midwater gear, caught yellowtail, widow, or canary rockfish (i.e., the main midwater rockfish species), and for which >50% of the catch was rockfish (i.e., not shoreside hake trips, where vessels may be actively avoiding rockfish). The data covered 2012-2023 and included 3,962 tows on 878 unique trips by 46 different vessels; 69.7% of tows contained yellowtail rockfish. Data from 2024 was not available by the data deadline. We used Species Distribution Models with Template Model Builder (`sdmTMB`) to fit a delta-lognormal model (Anderson et al. 2024) to the catch per unit effort (metric tons caught per hour towed). In addition to fixed effects for each year, we included a spline term for standardized depth, a cyclic spline for month (i.e., forces a smooth transition from December to January), a fixed effect for observer versus EM data, a random effect for vessel ID, and a fixed effect for whether the tow was conducted north or south of the mouth of the Columbia River. During the pre-assessment workshop, fishermen reported catches of yellowtail are consistently much higher north of the Columbia River, which is corroborated in the survey data (Figure 10). We did not fit a full spatiotemporal model because tow locations are non-random, which can lead to bias (Conn et al. 2017). The main purpose of this index was to explore whether fishery catch rates using midwater gear are similar to or different from a fishery-independent bottom trawl survey index; in general the temporal patterns appear quite similar (Figure 13). However, we did conduct a sensitivity to the inclusion of the index in the assessment model (Section 3.5.2).

2.1.4.2. Oregon ORBS Dockside Index (2001 - 2024)

Trip-level catch-per-unit-effort data from Oregon Department of Fish and Wildlife Oregon Recreational Boat Survey (ORBS) dockside sampling was obtained from ODFW. The travel time was subtracted from the hours fished. Travel time was stratified by boat type (charter and private) and was calculated as the inverse of boat type-specific speeds (13 mph for charter boat trips and 18 mph for private boat trips) multiplied by twice the distance between the port of origin and the reef that was fished. Catch-per-unit-effort (CPUE), expressed in terms of fish per angler-hour, was calculated by multiplying the number of anglers and the adjusted travel time. The database contains information on catch by species (number of retained fish), effort (angler hours), sample location (port where data were collected), date, bag limits and other relevant regulations, boat type (charter or private), and trip type (e.g., bottom associated fish).

The unfiltered data set contained 456,172 trips from 2001 - 2024. We filtered out trips with incorrect interview times and unreasonably long or short trips. Only bottomfish target trips were included. Further filters excluded temporal or spatial fishing closures and catches exceeding bag limits. Trips from several ports with extremely small sample sizes (<1% of total trips) and those that met criteria for irrational effort reporting (i.e., implausible values) or extreme catch rates were excluded as well. The final dataset included 137,502 trips, approximately 30% of the unfiltered sample size (Table 16).

We evaluated year, month, port, the open depths to fishing (all depths or inside 20/30/40 fm), boat type and the daily bag limit for yellowtail rockfish in the standardization model. Preliminary model explorations indicated that the daily bag limit covariate could not be combined with the open depth of the fishery due to changes in recreational fishing regulations over time. Prior to 2017, yellowtail rockfish were included in the general marine bag limit. However, in 2017, yellowtail rockfish were also included in a specialized longleader recreational bag limit where participants were required to be seaward of 40fm. As a result, the bag limits were binned into a binary variable for low (5 – 8 fish) and high (10 – 15 fish) bag limits during the 2001 – 2024 time period. Negative binomial models were fit in `sdmTMB` (Version 0.6.0) to the trip-level data (catch in numbers with a log offset for adjusted angler hours). Tweedie distributions were also explored for selected models but generally did not improve Q-Q plots. The final model selected by Akaike information criterion (AIC) includes year, month, port, open fishery depths, a flag for longleader trips, and the binned bag limit variable (Table 17). Diagnostics were acceptable (Figure 14). The index of abundance is shown in Figure 15. It was not used in the base model due to the availability of a fishery-independent hook and line survey that captures a similar segment of the population. While every attempt was made to standardize the index, it can be difficult to control for all management changes that impact CPUE in fishery-dependent indices.

2.2. Fishery-independent data

The model includes four sources of fishery-independent data: the Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey (WCGBTS), the Alaska Fisheries Science Center/Northwest Fisheries Science Center West Coast Triennial Shelf Survey (Triennial Survey), a combined Oregon-Washington hook and line survey, and an index from standard monitoring units for the recruitment of fishes (SMURFs) in Oregon.

2.2.1. West Coast groundfish bottom trawl survey

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

Yellowtail catches in the WCGBTS are highest in the northern part of the coast (north of 46° N. Lat.), with some of the largest hauls close to the U.S.–Canada border (Figure 10). Yellowtail occur in 13% of the hauls north of 40°10′ N. Lat. and 27% of the hauls north of 46° N. Lat. Within the 100–200 m depth range north of 46°, they occur in 55% of the hauls. Yellowtail are rarely found deeper than 250 m.

Geostatistical models of biomass density were fit to survey data from the WCGBTS using Template Model Builder (TMB) (Kristensen et al. 2016) via the R package `sdmTMB` (Anderson et al. 2022) as configured within the {indexwc} R package (Johnson et al. 2025a). Code to reproduce the analysis is available online. 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). Tweedie, delta-binomial, delta-gamma, and mixture distributions, which allow for extreme catch events, 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 yellowtail life history, and low AIC. Estimates of biomass from this best model were predicted using a grid based on available survey locations.

The index was estimated for the area north of 40°10′ N. Lat., but data from south of that point were included in the analysis to better inform densities near that boundary. The annual proportion north and south of that point (Cape Mendocino) was estimated to offset the influence of changes in abundance of the southern stock from the estimates for the north.

The data were truncated to depths less than 425 m prior to modeling given that there were zero positive encounters in depths deeper than 425 m. The prediction grid was also truncated to only include available survey locations in depths between 55–425 m to limit extrapolating beyond the data and edge effects.

The final model used a delta model with a lognormal 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. Annual proportion north and south of Cape Mendocino and pass were also included. Vessel-year effects, which were historically used for index standardization of this survey, were not included because the estimated variance for the random effect was close to zero. Vessel-year effects in WCGBTS index standardization 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 was included in the encounter probability but not the positive catch rate model. Spatial variation was approximated using 400 knots, where more knots led to non-estimable standard errors because the positive encounters are too sparse to support the dense spatiotemporal structure.

The index is relatively flat except for 2014-2019 where there is a sharp increase in estimated biomass (Figure 9).

2.2.2. West Coast triennial shelf survey

The Triennial Survey was first conducted by the Alaska Fisheries Science Center (AFSC) in 1977, and the survey continued until 2004 (Weinberg et al. 2002). Its basic design was a series of equally-spaced east-to-west transects across the continental shelf from which searches for tows in a specific depth range were initiated. The survey design changed slightly over time. In general, all of the surveys were conducted in the mid summer through early fall. The 1977 survey was conducted from early July through late September. The surveys from 1980 through 1989 were conducted from mid-July to late September. The 1992 survey was conducted from mid-July through early October. The 1995 survey was conducted from early June through late August. The 1998 survey was conducted from early June through early August. Finally, the 2001 and 2004 surveys were conducted from May to July. While the southern edge of the survey varied, the full latitudinal range of this assessment (40°10′ N. Lat. to the Canadian border) was consistently surveyed.

Due to haul performance issues and truncated sampling with respect to depth, the data from 1977 were omitted. The surveys from 1980 through 1992 covered a depth range of 55-366 m. From 1995 through 2004, the surveys covered the depth range 55-500 m. In 2004, the final year of the Triennial Survey series, the NWFSC Fishery Resource and Monitoring Division (FRAM) conducted the survey following similar protocols to earlier years.

The data processessing and index standardization followed a similar procedure to the WCGBTS, including the depth truncation, the distributional assumptions, and the number of knots. No pass covariate was included due to differences in survey design.

Because yellowtail are rarely found deeper than 366 m and are not known to undertake seasonal migrations, we included the Triennial Survey as a single time series following the assumption used in the 2017 assessment (Figure 9).

2.2.3. Combined Oregon-Washington hook and line survey

The Marine Reserves program at ODFW and the WDFW Coastal Marine Fish Science Unit execute standardized hook and line (or "rod and reel") surveys that collect drift-level catch and biological data in rocky reef habitats on Washington's nearshore waters and at four marine reserve sites that span Oregon's coastline. Both are loosely modeled after the California Cooperative Fisheries Research Program (CCFRP) survey. The WDFW rod and reel survey was assessed in a methodology review with the PFMC Scientific and Statistical Committee (SSC) (Pacific Fishery Management Council 2022a, 2022b), and both the ODFW and WDFW hook and line surveys have separately been used in previous assessments, including most recently the 2023 black rockfish assessments for Washington (Cope et al. 2023a) and Oregon (Cope et al. 2023b). Given the similarities in the survey protocols, these surveys were combined to produce a single index that spans the northern yellowtail rockfish stock assessment area.

The WDFW survey includes fixed standardized stations within three regional marine catch areas (i.e., MCA 2, MCA 3, and MCA 4) sampled with three replicate 8-minute drifts at each station. Details about the sample frame, site selection, and survey methodology of the WDFW survey can be found in the Groundfish Subcommittee of the SSC Visual-Hydroacoustic Survey Methodology Review and Hook-and-Line Survey Workshop (Pacific Fishery Management Council 2022a). The ODFW survey includes both marine reserves and nearby comparison areas. Comparison areas are pre-selected areas with similar bathymetry and habitat characteristics as the reserve areas, but are open to fishing. Each reserve has at least one comparison area, but several have more than one. The index modeling procedure considered treatment (inside vs. outside a reserve) as a covariate. A 500-meter square grid overlaid on the area defines the ODFW sampling units or cells. Cells are randomly selected within a marine reserve or comparison area for each sampling event. The cells are considered analogous to stations in the WDFW survey. Unlike the WDFW survey, three replicate 15-minute drifts are executed in each cell. Data are aggregated to the cell-day level for ODFW data and to the station level for the WDFW data, and subsequently counts of fish per cell/station-day are used as the catch metric for CPUE. Sampling occurs in the spring and late summer/fall seasons for both surveys, but given the focus of the WDFW survey on semi-pelagic rockfish species in the spring, both data sets were subset to spring months only (March – June). This also alleviated differences in gear types between the two surveys. Throughout the history of these surveys, different gear types have been explored. Generally, the gear types mirror recreational fishing gear. Gears from each survey were categorized in several ways to evaluate as a potential covariate in the index development. Primary gear types include diamond jigs, shrimp flies, mooching jigs and other jig or combination configurations with various sizes of attached weights. There were no significant differences in the length distributions of the yellowtail rockfish encountered between the two surveys, despite the minor differences in gear (Figure 11). Finally, a covariate for ODFW data was created to evaluate regional spatial differences on a scale similar to the marine catch area-level in the WDFW survey. The two northern reserve areas (Cape Falcon and Cascade Head; "S5") were combined into a single region, with Cape Perpetua (S6) and Redfish Rocks (S7) as separate Oregon regions. Each marine catch area in Washington was considered a single region (N2 – 4). Years with limited observations were removed (2009 and 2020). The final dataset contained 1,972 observations (Table 18).

Index standardization used `sdmTMB` with a negative binomial model to fit the yellowtail catch in numbers, applying a log effort offset for angler hours. Covariates evaluated include year, month, region, treatment (reserve or comparison area), a binned average drift depth, and multiple different gear categorizations. These included two different categorizations (n = 5 or n = 3) and a binomial covariate based on whether or not shrimp flies were used. None of these gear covariates were ultimately included. Some variations were not found to be significant factors based on AIC model selection, and others had strata-specific sample sizes that were too limited for models to converge. Marine reserve treatment was also not found to be a significant factor influencing CPUE in model selection, and was similarly excluded.

Two full model series were considered: one including all potential covariates with a regional covariate, and one with a survey (or state) covariate substituted for region. The best fit model according to AIC included year, region, drift depth (binned), and month. However, the Q-Q plot for this model was not ideal, so a second model series with survey was developed. In this second series, the best fit model according to AIC included year, survey, drift depth (binned), and month (Table 19). Acceptable diagnostics were achieved when this model was fitted via MLE using the `sdmTMB` R package (Version 0.6.0) Figure 12. The final index of abundance is shown in Figure 9.

2.2.4. Standard monitoring units for the recruitment of fishes

ODFW and Oregon State University (OSU) have collaborated on young-of-the-year (YOY) fish and environmental monitoring in and around Oregon Marine Reserves using standard monitoring units for the recruitment of fishes (SMRUF) devices. SMURFs are standardized sampling units that collect newly-settled juvenile fishes. Data were provided for two regions on the Oregon coast near the Otter Rock Marine Reserve (central) and the Redfish Rocks Marine Reserve (southern). Both regions have a site inside of the reserve and a comparison site outside of the reserve, and have sampled from 2011 to the present. These are monitored regularly (approximately every 2 weeks) during the settlement season (April - September) and YOY are collected for genetic identification and measured. Settlement rate of YOY yellowtail rockfish was provided by OSU for each site within each region. Daily mean temperature data for three depth strata (1m, 7.5m, and 15m) for each site within each region was provided by the ODFW Marine Reserve Ecological Monitoring team.

Local temperature likely impacts settlement rates. Oceanographic sampling by the ODFW Marine Reserve Ecological Monitoring team has not been done simultaneously in both reserves at each mooring site at all depths due to a lack of equipment. However, for time periods when there was matched data, temperature was highly correlated across depths (Pearson's correlation coefficient > 0.90) and between sites within each region (Pearson's correlation coefficients >0.98). In order to calculate an index of daily water column temperature that was continuous enough to be combined with settlement rate data, temperature data was standardized within year and depth. Standardizing within year means that the temperature is measuring *intra*-annual temperature variability that could impact catchability on a given collection date, and not *inter*-annual temperature variability that could impact YOY survival. For periods with multiple observations, the mean was taken in order to generate a single continuous temperature time series. Mean SMURF deployment lasted 15.5 days. In order to summarize temperature in an ecologically meaningful way relative to the SMURF sampling design, a 16-day rolling mean of temperature and cumulative degree days over 16-day periods were calculated. These data were matched with settlement rate data such that the mean temperature or the cumulative degree days during the 16-day period that the SMURF was deployed was used.

Covariates that were evaluated included year, month, region (Redfish Rocks or Otter Rock), temperature, and treatment (within marine reserve or nearby comparison site). Preliminary model runs indicated a consistent lack of convergence. Additional filters were applied including limiting the data to 2014 - 2024 and to the peak months of settlement for yellowtail (May - July). Temperature covariates explored were all binned into quantiles, depending on the range of the specific tempature covariate. Month was not included in models that included temperature, as both covariates were used to describe seasonal variation in settlement rate. Marine reserve treatment was not a significant covariate in this model, which was expected; the presence of a reserve would not be anticipated to impact juvenile settlement rates. Models were fit to the settlement rate data (YOY fish per day) using the `sdmTMB` R package (Version 0.6.0) (Anderson et al. 2024). Both negative binomial and tweedie distributions were evaluated. The model that was selected was based on fit (Table 20) and expert opinion from OSU and ODFW staff. The final model contained year, region, and temperature summarized as cumulative degree days 16-days prior to SMURF recovery using a negative binomial distribution. Acceptable model convergence and other diagnostic criteria for the final index were achieved (Figure 16). The index of YOY abundance are shown in figures 9 and 18.

2.2.5. Rockfish recruitment and ecosystem assessment survey

The Fishery Ecology Division of the Southwest Fishery Science Center has conducted a standardized pelagic juvenile trawl survey (the Rockfish Recruitment and Ecosystem Assessment Survey, RREAS) during May-June every year since 1983 (Ralston et al. 2013; Sakuma et al. 2016; Field et al. 2021). A primary purpose of the survey is to estimate the abundance of pelagic juvenile rockfishes (*Sebastes spp.*) and to develop indices of year-class strength for use in groundfish stock assessments on the U. S. West Coast. This is possible because the survey samples young-of-the-year rockfish when they are ~100 days old, an ontogenetic stage that occurs after year-class strength is thought to establish, but well before cohorts recruit to commercial and recreational fisheries. This survey has encountered tremendous interannual variability in the abundance of the species that are routinely indexed, as well as high apparent synchrony in abundance among the ten most frequently encountered species (Ralston et al. 2013; Schroeder et al. 2019). Past assessments have used data from this survey to provide indices of year-class strength (as relative age-0 abundance), including assessments for canary rockfish (Lagnseth et al. 2023), blue/deacon rockfish (Dick et al. 2017b) widow rockfish (Adams et al. 2019), Bocaccio (He et al. 2015), shortbelly rockfish (Field et al. 2007) and Chilipepper Rockfish (Field et al. 2015).

Historically, the survey was conducted between 30°30′ and 38°20′ N. Lat. (the 'core area' from approximately Carmel to just north of Point Reyes, CA), but starting in 2004 the spatial coverage expanded to cover from the U.S./Mexico border to Cape Mendocino. Additionally, since 2001, data are available from comparable surveys conducted by the Pacific Whiting Conservation Cooperative (2001-2009) and the Northwest Fisheries Science Center "Pre-recruit" survey (2011-2022) for waters off of Oregon and Washington (Field et al. 2021). As the core area index seems to have failed to capture the magnitude of the 1999 year class for most stocks, the recommendations from the juvenile rockfish survey workshop held in 2005 were to use only the coastwide data (since 2001) for juvenile indices rather than the longer-term 'core area' indices.

We considered data from the RREAS survey for northern yellowtail from 2001 to 2024, the period for which we have coastwide coverage. On account of the COVID-19 pandemic, sampling in 2020 was very limited and restricted to the historical core area. Catch per tow was adjusted to a common age of 100 days to account for interannual differences in age structure (Ralston et al. 2013), as has been done for prior assessment indices using this dataset.

Since catch (and sampling) varied over space and time, we modeled catch using a spatial GLM with the package `sdmTMB` (Anderson et al. 2024). The 100-day standardized catch-per-tow was modeled as a function of fixed year effects along with Julian date (GAM smoother with k=4) to account for seasonality, a spatial random field, and independent identically distributed spatiotemporal random fields. We fit the model using 3 different error structures: tweedie, delta-lognormal, and delta-gamma. Dharma quantile residuals suggested that tweedie distribution was the best, so this is the model we proceeded with. The tweedie model also best reproduced the observed proportion of zeros in the data based on simulations from the fitted model. The Julian date effect increased linearly through the sampling season, which may indicate the peak of the distribution was not sampled.

We explored a coastwide index of recruitment from RREAS data. An index was developed with only data north of 40°10′ N. Lat., but was too sparse to provide a meaningful time series. Ultimately, the coastwide index was not included in the base model, but a sensitivity to its inclusion is described in Section 3.5.2. The use of a coastwide index for an assessment of a stock north of Cape Mendocino was carefully considered. In addition to the sparsity of the northern index, yellowtail appear to migrate north throughout their lives (Figure 17 c). Yellowtail are densest in RREAS in Central California, in small fish in the WCGBTS in Oregon, and in total biomass in the WCGBTS in Washington. However, given the genetic separation at Cape Mendocino, it is unclear how to determine which coastwide RREAS samples are most predictive of recruitment of the northern stock. The coastwide RREAS index was ultimately not included in the base model because it seemed uncorrelated with recruitment for year-classes that are well-informed by composition data. The survey missed major recruitment events, and saw high densities of yellowtail rockfish in years with unremarkable recruitment. Yellowtail rockfish observations have been well above the long-term average in RREAS since 2021, so inclusion of the index would have major impacts on forecasts of biomass, but given the historical performance of the survey for northern yellowtail rockfish recruitment, its reliability was considered too uncertain for inclusion in the base model, particularly considering the availability other data sources.

The juvenile rockfish index (not species-specific) from RREAS for the northern California Current Ecosystem (Gasbarro et al. 2025) is in our comparison of juvenile abundance datasets (Figure 18), but this index was only considered for comparative purposes and was not considered for the assessment model or sensitivity runs based on recommendations from the juvenile rockfish survey workshop.

2.2.6. Biological data

Length and age data were available from the WCGBTS and Triennial Survey (Table 21, Table 22, Figure 19, Figure 20, last two rows). There were 17,329 length observations in the WCGBTS data set, of which only 22 were unsexed, so the unsexed samples were excluded. There were 14,275 lengths in the Triennial Survey, none of which were unsexed. Composition data were processed using the {nwfscSurvey} R package, which weights samples for marginal distributions by biomass at the tow and stratum level (Wetzel et al. 2025a). Data were separated into two strata: samples shallower and deeper than 183 m. This is consistent with the stratification for the WCGBTS sampling design. Triennial Survey composition data are based on the same stratification scheme (though it is unrelated to the survey design). Ages from the WCGBTS were conditioned on length while the age data from the Triennial Survey were processed as marginal distributions. For the conditional age-at-length data, the number of fish within each length bin within each sex is used as the input sample size. The input sample sizes for the marginal distributions are based on the formula of Stewart and Hamel (2014) as Input $\mathrm{N}_y = 2.43 * N_{tow}$ where the scalar was estimated for a group of 17 shelf rockfish, including yellowtail rockfish. Unsexed length compositions from the combined Oregon-Washington hook and line survey are included without any expansions, using number of fish as the input sample size. Length compositions were filtered to reflect those included in the final filtered CPUE index (n = 1,658 fish, Figure 19, fourth row).

Surveys collect data in a standardized way with recorded locations that can be helpful for exploring empirical patterns in species biology that may inform modeling practices. There is a slight pattern where length-at-age in the WCGBTS decreased around 2014 (Figure 17 b), coincident with the increase in CPUE (Figure 9). Length-at-age appears fairly consistent along the coast within the model area (Figure 17 a), though average age increases north along the coast (Figure 17 c).

2.3. Ageing error

The age composition data was based on age estimates provided by two labs, WDFW and the Cooperative Ageing Project (CAP) under the Pacific States Marine Fisheries Commission. There were a total of 6,339 otoliths with multiple age readings, 4,402 aged by WDFW readers only, 1,716 by CAP readers only, and 221 aged by readers from both labs.

A series of models estimating ageing error were explored to estimate variability in age estimates as a function of age and to test for differences between labs and among readers. This analysis was conducted using the {AgeingError} software package (Punt et al. 2025) which is based on Punt et al. (2008). The estimated differences between the two labs was negligible; the labs differed by an average of 0.6%, or less than 0.25 years for a 40-year-old fish. Similarly, the estimated CV of the age reads was similar between labs: 0.0615 for the WDFW lab and 0.0595 for the CAP lab. The differences among readers within labs were likewise small. Therefore, the most parsimonious model was chosen, which was to treat all readers equally and estimate a single CV parameter relating ageing uncertainty to age. The estimated CV was 0.0606 which corresponds to a standard deviation of 1.2 years for a 20-year old fish and 2.4 years at age 40. This estimate is similar to the results of the ageing uncertainty estimation in the 2017 assessment and indicates that ageing is more precise than for many other west coast groundfish. The relatively precise ageing is corraborated by one of the age reader's comments that yellowtail rockfish are extremely easy to age (B. Kamikawa, pers. comm.).

2.4. Biological parameters

2.4.1. Natural mortality

The model freely estimates natural mortality. However, a lognormal prior based on maximum age is applied (Hamel and Cope 2022). The maximum age used for the prior is 43 years, which is the 99.9th percentile of the 161,828 ages available in PacFIN. Because so much age data is available, use of the absolute maximum age observed is subject to influence from outliers. There were 131 samples in PacFIN between ages 43 and 60 with roughly exponentially decreasing frequency-at-age, and one extreme outlier aged at 77 years. Half of these 132 oldest ages were from samples prior to 1984. The maximum age of 43 is associated with a median natural mortality rate of 0.126 yr^{-1}.

An unusual phenomenon in yellowtail rockfish data is an increasingly male-skewed sex ratio at older ages. This is shared with several other rockfish species, including black rockfish, which is closely related to yellowtail, and canary rockfish. All data sources for this assessment (commercial, recreational, and survey data) show this pattern; however, below age 20, the recreational fleet has a female-skewed sex ratio, while the trawl gears have a sex ratio that is more evenly balanced (Figure 17 d). Over the years, assessments for all three species have explored whether this pattern is due to differences between the sexes in selectivity, mortality, or some combination. It appears females tend to die at younger ages even in aquarium settings, supporting that the phenomenon is at least in part due to natural mortality (L. Rasmuson, ODFW, pers. comm.).

2.4.2. Weight-at-length

Sex-specific weight-at-length was estimated using a log-transformed linear regression and then bias corrected to predict mean weight-at-length rather than median weight-at-length; however, the curves for the two sexes are very similar (Figure 21). Initial data exploration indicated that some years tended to have consistently negative or positive residuals to this single regression equation (i.e., fish condition varies across time). A time-varying weight length relationship is explored in Section 3.5.2. At present, time-varying biology can bias reference point calculations in the stock synthesis modeling platform (R. Methot, pers. comm.), so this was not considered a good choice for a base model. The time-invariant weight length relationship used was $W = 1.38743 \times 10^{-5} L^{3.02201}$ for females and $W = 1.18399 \times 10^{-5} L^{3.06734}$ for males.

2.4.3. Maturity

We used a total of 232 individual histological samples of aged female yellowtail rockfish to estimate maturity for the assessment. These samples were all collected north of 40.167° N. Lat. The 232 samples were collected over the period 2016—2023, though more samples were collected earlier in these years (n = 111 in 2016, 52 in 2017, 31 in 2018, 17 in 2021, 9 in 2022, 13 in 2023). Previous assessments of yellowtail rockfish estimated length-based maturity (L50 = 42.49 cm in 2017 assessment); however, we switched to an age-based model for the current assessment. For many species, energy is reallocated toward maturation from growth, and as a result growth rates slow during the juvenile to adult transition period. Thus, length at 50% maturity will represent a range of ages, providing a less accurate understanding of the spawning population. We treated maturity as a binomial response, and considered a variety of models with temporal and spatial covariates, using a logit link and generalized linear mixed model framework, implemented using the R package `sdmTMB` (Anderson et al. 2024). Briefly, we considered models that included (1) temporal year effects (either estimated as a random walk intercept, or smooth term), (2) spatial random fields (using a mesh cutoff distance of 50km), and (3) spatially varying coefficients of age, following the model adopted by Grandin et al. (2024). Models that converged were compared by examining QQ plots, AUC metrics, and AIC scores. Likely because of the uneven temporal distribution of sampling, and general sparsity, we did not find support for including temporal or spatial effects, and decided on the simpler null model (equivalent to a logistic regression). For the age-based model, we estimated an intercept of -6.70 (SE = 0.99) and slope of 0.67 (SE = 0.10), equivalent to an A50 of 10.0 years (Figure 22). For a more direct comparison to the previous assessment, we used these same 232 samples to fit an equivalent length-based model, which resulted in an estimated L50 = 42.5 cm, essentially identical to the value used in 2017.

2.4.4. Fecundity

Fecundity is based on Dick et al. (2017a) and is unchanged from the 2017 assessment. The relationship for spawning output for an individual is 1.1185×10^{-11}*length$^{4.59}$.

2.5. Environmental and ecosystem data

2.5.1. Oceanographic index

Over the past several years, progress has been made in understanding how oceanographic conditions drive recruitment of groundfish species in the California Current Ecosystem across life stages for petrale sole, sablefish and Pacific hake. Recent increases in staff capacity supported by the Climate, Ecosystem, and Fisheries Initiative provided the ability to build on these previous lines of research and examine the relationship between northern yellowtail rockfish recruitment and oceanographic drivers based on model output from Global Ocean Physics Reanalysis (GLORYS) from Copernicus Marine Environment Monitoring Service (CMEMS) and Regional Ocean Modeling System (ROMS) model for the California Current Ecosystem (Neveu et al. 2016). The results suggest that GLORYS output may allow for better model precision and near-term forecasting than ROMS. This approach builds on previous research (Tolimieri et al. 2018; Haltuch et al. 2020; Vestfals et al. 2023) and assessments (Berger et al. 2023; Taylor et al. 2023; Grandin et al. 2024) by applying similar techniques to establish oceanographic relationships and develop an oceanographic index based on a conceptual life history model for yellowtail rockfish (Darby et al. In Prep). GLORYS also provides a temporally robust time series and is not susceptible to discontinuities identified in the 2023 petrale sole assessment (Taylor et al. 2023). Appendix A of this report describes the most recent efforts in developing a new environmental index of northern yellowtail rockfish recruitment based on GLORYS products. The final selected oceanographic model included the date of spring transition from the Coastal Upwelling Transport Index, degree days (which represents temperature exposure) during egg fertilization and development, longshore transport during the pelagic juvenile lifestage, and El Niño conditions during the pelagic juvenile lifestage. The oceanographic model was fit using the recruitment deviations (1994 - 2019) from the base model and used to predict log-recruitment deviations for the next five years, 2020 - 2024, using oceanographic conditions. The index is not included in the base model, but sensitivity to including the final five years (predicted log-recruitment deviations only) is explored in Section 3.5.2.

2.6. Data sources evaluated, but not used in the assessment model

2.6.1. Washington recreational dockside catch-per-unit-effort

WDFW gathers data on catch and effort in the state's coastal recreational fisheries. This dockside interview data was initially considered a fishery-dependent index of abundance in the assessment. However, a combination of different factors, including changes in management measures (e.g., bag limit changes) and the lack of finer-scale measures of effort available, warrants further consideration to address potential shifts in fishing behavior and necessitates further evaluation of whether the data could provide a reliable signal on abundance to be used in future assessments.

2.6.2. Olympic Coast National Marine Sanctuary dive survey

Data from young-of-the-year dive surveys conducted between 2015 and 2024 from waters within the Olympic Coast National Marine Sanctuary (OCNMS) were provided by Nick Tolimieri and Ole Shelton (NWFSC). These data were first considered for use in stocks assessment in Cope et al. (2023a). The survey uses SCUBA and belt transects to estimate rockfish abundance, where yellowtail rockfish are identified as a black-yellowtail rockfish (BYT) complex based on coarsely binned (2-5 cm) length compositions. Detailed description of survey methods and aims are found in Tolimieri et al. (2023). The YOY survey is interpreted as an index of age-0 abundance, though admittedly a rough one as it combines yellowtail rockfish and black rockfish because they are visually indistinguishable at the surveyed size and age. For the purposes of this assessment, these data are compared to other indices of YOY and recruitment trends to consider shared patterns in variability and whether the trends in these data are consistent with the trends in the overall assessment and across other early life history indices (Figure 18)

2.6.3. Juvenile abundance index considerations

One of the challenges of stock assessment for yellowtail rockfish is that they are not well represented in survey data until they are 6-7 years old, which makes forecasts used for setting catch limits subject to substantial uncertainty due to the uknown strength of many year classes that contribute to spawning output. In order to address this challenge we considered five indices of age-0 abundance or recruitment based on YOY surveys and oceanographic information (Figure 18). To prioritize which dataset would be most informative, we considered the benefits and drawbacks of the sampling design and data availability of each dataset (Table 23). Multiple indices showed some degree of synchrony. The northern YOY rockfish index, oceanographic index, and SMURF index all captured an increase in abundance from 2019 - 2021, followed by low abundance in 2022, and an increase in abundance in 2023 although the magnitude of abundance in 2023 varied across data sources.

We prioritized the SMURF index in the base model based on an assessment of the benefits and drawbacks of each potential dataset (Table 23) and considered the oceanographic index and yellowtail RREAS index as sensitivity runs (Section 3.5.2). Both the OCNMS nearshore survey and the northern YOY rockfish index are estimates of abundance that are not specific to yellowtail rockfish, and we felt the three age-0/recruitment indices we did consider were higher quality given their specificity (Table 23). The RREAS coastwide index did not seem to capture the low juvenile abundance identified across indices in 2022. In addition it estimated an increase in abundance between 2023 and 2024 where the oceanographic and SMURF indices estimated a decline (Figure 18). Similarly, the oceanographic index was higher than other indices in 2018 (Figure 76 and Figure 18).

3. Assessment model

3.1. History of modeling approaches

Figure 65 shows the timeseries of age 4+ biomass for yellowtail rockfish across past assessments. Early studies of yellowtail rockfish on the U.S. West Coast north of 40°10′ N. latitude (Cape Mendocino, northern California) began in the 1980s with observational surveys. Statistical assessments of yellowtail rockfish were conducted in 1982 (Tagart 1982), 1988 (Tagart 1988), 1996 (Tagart et al. 1997), and 1997 (Tagart et al. 1997) to determine harvest specifications for the stock. These early assessments employed a variety of statistical methods. For example, the 1997 assessment used cohort analysis and dynamic pool modeling.

The yellowtail rockfish assessment in 2000 (Tagart et al. 2000) was the first that estimated stock status, with an estimated depletion of 60.5% at the start of 2000. Lai et al. (Lai et al. 2003) updated the 2000 assessment and estimated that stock depletion was 46% at the start of 2003. A second assessment update was prepared in 2005 (Wallace and Lai 2005) with an estimated depletion of 55% at the start of 2005. The 2000 assessment and updates were age-structured assessments conducted using AD Model Builder as the software platform for nonlinear optimization (Fournier et al. 2012).

A data-moderate assessment of yellowtail rockfish north of 40°10′ N. latitude was conducted in 2013 (Cope et al. 2013). The data-moderate approach included only catch and indices of abundance with no age or length composition data included.

The most recent assessment was conducted in 2017 (Stephens and Taylor 2017) which returned to the benchmark approach and included age and length composition data and modeled discards through a parametric retention function fit to discard length compositions and discard rates. In the same year the first assessment for the stock of yellowtail rockfish south of 40°10′ N. Lat. was attempted, but the data were not adequate to provide reliable estimates and the assessment was withdrawn having been found to be too uncertain for management (Stephens and Taylor 2017).

3.2. Response to most recent STAR panel and SSC recommendations

- Additional investigations that better quantify the male-skewed sex ratio at older ages, and evaluate potential mechanisms for the observed discontinuities, should be pursued.
  - We have run a number of sensitivities involving different parameterizations of natural mortality and selectivity and included data plots that further explore this dynamic, as well.

- The draft northern yellowtail assessment models included indices of relative abundance based on fishery-dependent time series, including a trawl logbook CPUE index and an index of abundance based on yellowtail bycatch in the at-sea Pacific whiting fishery. During the STAR panel, these were removed from the final base model. However, as the indices were influential with respect to model results, greater exploration of the potential for these data to inform a relative abundance index, particularly for the trawl logbook cpue data, would benefit future assessment efforts.
  - As the 2017 review found, historical logbook data is extremely difficult to standardize in a reliable way. However, we have explored data from the current WCGOP program as an alternative fishery-dependent index from the trawl sector, covering a later subset of years.
- Consideration of alternative survey methods (e.g, acoustic surveys, midwater trawl surveys) and/or the means to account for changes in catchability that may be associated with environmental factors, could improve the ability of survey indices to track stock abundance.
  - We have included a new hook and line index in the assessment. However, this remains a key research priority, made even more clear by the inability of the model to fit the peak and rapid decline in the trawl survey index since the 2017 assessment. This issue cannot be addressed via assessment modeling, and needs targeted research between assessment cycles.
- Combined US/Canadian transboundary assessment.
  - This remains an important research priority.
- Common documentation of data streams and sources to support fishery independent and fishery dependent indices and compositional data could reduce the burden on assessment analysts to provide details about each data source, and allow reviewers a robust source of information on the most important, common data sources for any given stock assessment cycle.
  - The stock assessment program at NWFSC has made great strides in improving data processing since 2017 through a number of standardized R packages for commercial and survey data. This assessment gratefully utilized these tools.

3.3. Model structure and assumptions

3.3.1. Model changes from the last assessment

The following bullets list major changes from the 2017 benchmark assessment (Stephens and Taylor 2017):

- Reanalyzed and extended all relevant data sources through 2024.
- Early data exploration indicated that commercial fishery composition data was likely entered as "raw" in 2017, which is not the default approach recommended by the PFMC groundfish assessment accepted practices document. That is, each individual sample was equally weighted, rather than weighting samples based on catch amounts at the trip and state level. This assessment uses the NWFSC R package {pacfintools} (Wetzel et al. 2025b) to summarize age and length composition data from the commercial fishery.
- Added combined hook and line index as a CPUE index in units of number of fish.
- Added SMURF index as an index of recruitment.
- Esimated commercial discards from the GEMM report were added to landings rather than modeled separately through a parametric retention.
- Updated ageing error as described in Section 2.3.
- Used a single recreational fleet instead of separating Washington from Oregon and California north of 40°10′ N. Lat. Most Washington recreational catch data is now available in biomass on RecFIN. This facilitated combining recreational catches across all three states into a single model fleet with catch supplied in biomass. Different catch reporting units was the main reason listed for separating the recreational fleets in 2017.
- Added foreign trawl catches from 1966-1976 to the commercial fleet.
- Recreational fishery selectivity is modeled as sex-specific, with different descending limbs for males and females and males having an overall lower likelihood of being selected. This greatly improved fits to recreational length and age composition data.
- Added additional selectivity blocks for 1) recreational selectivity beginning in 2017, when trips in both Oregon (longleader gear) and Washington (avoiding black rockfish) were reported to get deeper and 2) the at-sea hake fishery beginning in 2015. The at-sea hake fishery is highly mobile and moves around to wherever hake are densest and bycatch species can be avoided. It has been occurring farther south in recent years.
- The fishery-dependent indices included as sensitivities in 2017 were not reproduced or extended.
- The maximum age in the data bins increased from 25 to 30 to better match observed data.

3.3.2. Modeling platform and structure

The stock assessment is conducted in Stock Synthesis version 3.30.23.1 compiled December 5, 2024 (available online). The model is sex-specific and includes three fishery fleets (commercial, at-sea hake, recreational) and 4 surveys (an Oregon-Washington combined hook and line survey, the Triennial Survey, the WCGBTS, and the SMURF index). There is a single model area from 40°10′ N. Lat. to the Canadian border. The model begins in 1889, which is the earliest year of the commercial catch reconstruction. The population was assumed to be unfished and at an equilibrium age structure at this point. The first length composition data included in the model is in 1972. Early recruitment deviations are estimated from 1932 to 1961 to better match the age structure at the start of the composition data. The model configuration is summarized in Table 24.

3.3.3. Model parameters

The base model had 140 estimated parameters (tallied by type in Table 25). Due to the richness of age composition data, most life history parameters were estimable. Natural mortality and growth are both estimated separately for males and females with shared parameters for length at age 2 and CV of length-at-age for young fish. Separate values for small fish were not estimable, nor was the four-parameter Richards growth curve. Male values were estimated as an offset of female values. A prior was placed on female natural mortality, but the data overwhelmed it (Figure 27, Figure 68 and discussed in Section 3.5.4). Unfished recruitment is estimated. Steepness of the stock-recruit relationship was kept fixed at 0.718, matching the 2017 assessment. This is a more precise value than the 0.72 specified in the PFMC Terms of Reference for rockfish assessments and Accepted Practices Guidelines, but explorations of the difference showed negligible impact of this difference (e.g. 0.001 units of relative spawning output). When estimated, steepness goes to 1.0. The standard deviation of log-recruitment deviations is 0.5, similar to the value used in 2017. Reevaluating the tuning of this parameter indicated no changes were necessary (Methot and Taylor 2011). Recruitment deviations during the "main" period (from 1962 to 2018) were forced to sum to zero. Relaxing this assumption led to no visible changes in the model, and the constraint allows for clearer interpretation of management reference points.

Length, age, and age-at-length composition data weights were tuned using the Francis method (Francis 2011, Table 27). All selectivity was assumed to be length-based and used a double-normal functional form. We explored age-based selectivity, but due to sexual dimorphism, fitting the composition data well would have required a more complex formulation with additional estimated parameters. Selectivity was estimated to be sex-specific and dome-shaped for the recreational fleet with three base parameters (ascending and descending limbs and length at peak selectivity) and two sex-specific parameters (descending limb and scaling factor for males) being estimated. Selectivity for the hook and line survey was also dome-shaped, but male parameters were not well-estimated, likely because the the length composition data is not sex-specific, so selectivity was shared for the two sexes. All other fleets had a single shared asymptotic selectivity for both sexes. Early explorations into dome-shaped selectivity for fleets using predominantly trawl gear indicated that the descending limbs were estimated at the far right side of the length distribution such that few fish were actually observed or expected to exist in the range of the descending limbs. Sex-specific selectivity for fleets using trawl gear did not visibly improve fits to composition data, so were not considered for the base model, though a sensitivity is shown. The length at peak selectivity consistently hit the upper bound for the triennial and at-sea hake fleets, so was fixed at 55 cm, near the maximum data length bin.

Selectivity was constant across time for all but the recreational and at-sea hake fleets. Recreational selectivity is estimated across three time periods: model start to 2003, 2004 to 2016 when depth restrictions were in place to prevent catch of overfished rockfish, and 2017 to 2024 to account for the growing longleader fleet in Oregon and avoidance of black rockfish in Washington, both of which led to recreational trips occurring farther offshore and catching larger fish. The sex-specific parameters were assumed to be constant. The at-sea hake fleet has estimates of selectivity across two time periods: the start to 2014 and 2015 to 2024. While no particular management change warranted this block, the at-sea hake fleet is highly mobile from year to year and does not target yellowtail, so changes in selectivity across time are likely. Length compositions became smaller than expected around the time of the block, particularly for females, a misfit that was not seen across other fleets. The hake fishery has occurred farther south in recent years, where yellowtail do tend to be younger, and therefore smaller (Figure 17 c). Due to the smaller sized fish in recent years, the length at peak selectivity *was* estimable for the later period for the at-sea hake fleet.

3.3.4. Key assumptions and structural choices

Modeling choices were made to seek balance between model realism and parsimony. See Section 3.3.3 for further details on these choices and alternatives considered.

3.3.5. Bridging analysis

Reanalyzing catch data led to an increase in population scale due to the addition of a large amount of foreign landings in the 1960s and 1970s (Figure 23). Reanalyzing the triennial and WCGBTS indices led to a small increase in scale and a decrease in the maximum spawning output around 2012. Updating the biology (length-weight and maturity relationships) led to an increase in scale, mainly due to the change to age-based maturity. Changing the treatment of discards led to minimal changes. The relative spawning output in 2017 is similar across all models incorporating these changes.

Reanalyzing composition data led to more significant changes, particularly with the reanalysis of age data (Figure 24). Deeper investigation indicated that treatment of commercial composition data in 2017 differed from standard practices for a data-rich stock such as yellowtail rockfish; it did not weight samples by catch at the trip or state level, and instead appears to have entered data "raw." The current model *does* weight samples using the NWFSC R package {pacfintools}. Expanding commercial age data in particular leads to a lower population scale and lower terminal relative spawning output compared to the 2017 base model and the model from the first set of bridging steps. Finally, extending all data sources to 2024 leads to a different perception of the population peak around 2012. Rather than peaking and steeply declining, the population is relatively stable from around 2010-2015, and declines only in years since the last assessment. The additional eight years of data leads to much higher estimates of the 2006-2008 recruitment deviations, where the 2008 year class is now estimated as the largest year class on record. After reanalyzing and extending all data sources, the estimate of unfished spawning output is nearly identical to the estimate from the 2017 model. However, spawning output in 2017 is estimated slightly lower, leading to a slightly lower relative spawning output, but well within the estimated uncertainty from the 2017 model. Spawning output in the 1980s and 1990s in the model with extended data is estimated to be near the lower limit of the confidence interval from the 2017 model.

The modeling update that led to the largest change in the estimated population trajectory was changing the recreational blocking, which included the addition of a new block in 2017 and led to a decrease in the population beginning around 2012 (Figure 25). Rather than attribute the additional large fish in the recreational composition data to changes in the population, the model now attributes them to selectivity changes. The updated block improved the likelihood by 20 units and estimated only two additional parameters. (The ascending limb parameter is assumed to be shared across time.) Sex-specific recreational selectivity substantially improved fits to both age and length data from the recreational fleet, but did not lead to major changes in model outputs. (Improvements were so great the model needed to be retuned to upweight recreational data, but as a result likelihoods are not comparable.) The block in hake selectivity, combined hook and line index, SMURF index, and various other updates (updating the natural mortality prior and aging error, minor corrections to input data) all had limited impacts on the estimate of the population trajectory. The terminal depletion and spawning estimates from the 2017 assessment are well within the estimated confidence intervals for 2017 in the current model, and the estimates of terminal depletion and spawning output in 2017 from the current model are well within the estimated confidence intervals in the 2017 model. The additional data and modeling changes have also narrowed the uncertainty in population scale (i.e., unfished spawning output).

3.4. Base model results

3.4.1. Parameter estimates

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 26.

Exploratory MCMC runs indicated that posterior distributions largely matched these asymptotic distributions, but took much longer to produce. The parameter where the posterior distribution diverged the most from the maximum likelihood was the descending slope of the recent recreational selectivity, where the MLE corresponded to a gently declining selectivity. The posterior mode matched the MLE, but a large fraction of the posterior samples were from higher values corresponding to asymptotic selectivity.

Selectivity curves by length and age indicate that all trawl-based gears have fairly similar selectivities (Figures 30, 31), whereas hook and line gears select smaller fish. Selectivity of males in the recreational fleet is lower than it is for females, consistent with the high percent females observed in that fleet until around age 20 (Figure 17 d). Time-varying selectivity for the at-sea hake and recreational fleets is in Figure 32.

The estimates of recruitment and spawning output indicate a weak stock-recruit relationship over the observed range of spawning output (Figure 26).

The estimated length-age relationship is in Figure 28, and the relationship between growth (estimated internally), maturity (estimated externally) and weight (estimated externally) is in Figure 29.

3.4.2. Fits to the data

The model fits all indices reasonably well with the exception of the WCGBTS index which has a group of large observations (4 out of the 6 years in 2014-2019) which are not fit well (Figure 33). The challenge of fitting these points is discussed in Section 3.6. The Triennial Survey shows changes among the years 1995, 1998, 2001, and 2004 which are too large to represent reasonable population dynamics and are also not fit will by the model. The fit to the SMURF index is achieved through estimates of recruitment deviations during the period covered (2014–2024), but the penalty on deviations away from zero associated with the sigmaR parameter leads to less good fits to the low observation in 2015 and the high observations in 2021 and 2023.

Fits to length composition data are generally good (Figure 34). The model does estimate a more left-skewed distribution of female lengths in the commercial fleet than is observed. The hook and line survey has more fish observed at peak length and fewer samples in the right tail than expected. The WCGBTS has a more peaked distribution for males than expected by the model. Across time, fits are poorest for the commercial fleet early in the time series when data are more sparse, and from 2009 to 2015 when the average length observed was higher than the model estimate (Figures 35, 36). The STAT was not aware of management changes covering this period in particular that could explain this misfit. However, fits to length data in recent years are better. The length distribution for males in the WCGBTS in 2024 was more steeply peaked than the predicted value, a more extreme example of the pattern observed when aggregated across years (Figures 35, 41). Fits to length data across time for other fleets were generally not notable (Figures 35, 37–40).

Fits to marginal age data were also generally good, though somewhat noisier for the at-sea hake and triennial fleets (Figure 42). The male commercial age distribution is slightly more left skewed than expected, and the distribution for females is slightly more right-skewed than expected. The recreational fleet observes more females from around ages 10-20 than expected. Across time, fits to the 1997 recreational age data were quite poor, and observations were much older than expected; this was true to a lesser extent in 2014, as well (Figures 43, 49). The 1997 ages came from around 100 individuals, and WDFW staff could not identify any reason these samples would not be representative of the population, so they were retained in the model. Otherwise there were no particularly notable patterns (Figures 43, 47–50).

Fits to conditional age-at-length data are harder to evaluate, but generally seem acceptable (Figures 44–46). There is possibly an increase in positive residuals for older age-at-length and negative residuals for younger age-at-length in recent years that would be consistent with the observed patterns of decreasing length-at-age in the data (Figure 17 b). This appears more notable for males than females. Fits to the marginal age distributions not present in the likelihood (figure in r4ss appendix) and mean age over time (Figure 51) showed no concerning patterns.

3.4.3. Population trajectory

The estimated population trajectory indicates the population declined slowly with the initial onset of fishing, and then declined steeply with the onset of the midwater trawl fishery around 1980 and was near the minimum stock size threshold throughout the 1980s and 90s; it then increased beginning around 2000, peaked around 2012, and has been declining in recent years, but is currently estimated to be well above the management target (Table 28, Figures 52, 53, 56, 57, 59). Recruitment is estimated to be highest in 2008 (Figures 54, 55). This strong year class (and, to a lesser extent, the 2006 and

2010 year classes) was apparent across all sources of composition data, and was also supported by increases in the combined hook and line and bottom trawl surveys as those year classes became selected. Recruitment is estimated to be low throughout the late 2010s; however, the SMURF index suggests large year classes from 2021 and 2023 may be entering the population.

3.5. Model diagnostics

3.5.1. Convergence

The maximum parameter gradient was 1.2×10^{-4} and the jitter analysis showed that 95 out of 100 model runs with jittered initial values converged to the same model estimate. Those that did not converge to the same model estimate converged to worse likelihoods. Exploratory MCMC runs indicated that posterior distributions largely matched these asymptotic distributions.

3.5.2. Sensitivity analyses

We conducted a number of model runs exploring sensitivity of the model to decisions regarding data and model structure. They are briefly described below:

- Index sensitivities
  - Remove all indices (Triennial, WCGBTS, SMURF, combined hook and line)
  - Remove SMURF index
  - Add WCGOP index
  - Add oceanographic index (included as index of recruitment deviations, only include years not present in training data: 2020-2024, fix catchability at one, since only other "data" to inform estimate of catchability during the years the index is included is the prior pulling recruitment deviations to zero)
  - Add ORBS index (no added SE)
  - Add ORBS index (with added SE)
  - Add RREAS index (included as index of absolute recruitment)

  - Upweight WCGBTS index (fix SE of log of index to 0.05)

- Modeling sensitivities

  - Estimate natural mortality for all males and females through age 9, and estimate natural mortality for females aged 10 and older (based on age at 50% maturity of 10 years)
  - No sex selectivity for the recreational fleet
  - Estimate sex selectivity for all trawl fleets (ascending limb and scale)
  - Estimate shared natural mortality for males and females
  - Time-varying weight-length relationship for years with WCGBTS data
  - Hybrid F method (an alternative approach to internal calculations of fishing mortality which treats F as a continuous rate rather than using Pope's approximation)
  - Estimate a density-dependent parameter for WCGBTS catchability

- Composition data sensitivities

  - McAllister & Ianelli data weighting
  - Remove all lengths from fishery data (selectivity remains length-based and uses the growth curve estimated from survey data and age compositions from fishery fleets)
  - Add unsexed commercial lengths

A figure summarizing various key management quantities across all sensitivity models is included in Figure 60.

3.5.2.1. Indices

Model sensitivity to index data is in Figure 61 and Table 29.

The ORBS index suggests a higher unfished population scale and lower terminal year depletion below the management target. Unfished recruitment is actually lower, but natural mortality is also lower, and the growth curves differ (lower L_∞, higher K, more similar growth for males and females in model with ORBS index). Overall these differences result in a higher unfished spawning output, similar terminal year spawning output, and therefore lower terminal year relative spawning output. However, the input standard errors on the ORBS index are lower than for any of the fishery-independent indices, which is likely unrealistic. When the model is given the freedom to downweight the index by estimating an additional standard error, the model trajectory is very similar to the base model.

Removing all indices results in a higher unfished recruitment, higher natural mortality, and similar unfished spawning output compared to the base model. (That unfished recruitment and natural mortality change in concert both with the addition of the ORBS index and removal of all indices is not surprising. The base model hessian estimates a correlation between log(R0) and female natural mortality of 0.92.) Upweighting the WCGBTS by forcing the standard error of the log of the index to be 0.05 (compared to an average input value of 0.32 in the base model) has the opposite effect of removing all indices (lower unfished recruitment, lower natural mortality, slightly higher unfished spawning output). Upweighting the WCGBTS also suggests that the peak in the combined hook and line index is slightly inconsistent with the peak in the WCGBTS index, and occurs approximately two years later than expected, given the selectivities estimated from the composition data associated with the two surveys. Notably, the run with the upweighted WCGBTS index has a problematic pattern in the early recruitment deviations, all of which are below zero, suggesting parameter estimates may be biased. Fits to the high survey values between 2014-2019 are still poor, though the population does have a more pronounced peak during those years.

All other sensitivities to index data led to only minor changes during the estimation period. However, choice of recruitment index does influence the population forecast, particularly beginning around 2030. Including the RREAS index results in the highest absolute and relative spawning output during the forecast because the survey has been well above average since 2021. The SMURF index (base model), has the next highest forecast due to high observations in 2021 and 2023. A model with no recruitment index (no SMURF) is third highest. The model with the oceanographic index has the lowest forecast, though is only slightly lower than a model with no recruitment index. While the oceanographic index indicates higher recruitment in 2021 than in surrounding years, it predicts that the recruitment deviation is close to zero in 2021, and below average in all other years. The models with the RREAS and SMURF indices estimate that recruitment was well above average either for 2021-2024 (RREAS), or in 2021 and 2023 (SMURF). The RREAS index was not included in the base model because it did not appear correlated to recruitment for well-estimated year classes, and predicted high recruitment in years with not particularly notable year classes, while missing the large year classes in 2008 and 2010. The SMURF index is not long enough to compare to recruitment in any well-estimated years. (Exploratory 15-year retrospectives indicated year class strength stabilizes around age 10.) While the oceanographic index can be estimated as far back as 1994, recruitment deviation estimates through 2019 were used to train the regression model, so comparing the index to recruitment estimates prior to 2020 would be circular.

3.5.2.2. Modeling

Sensitivity to modeling assumptions is in Figure 62 and Table 30.

A breakpoint natural mortality near the age at maturity and a shared natural mortality between males and females resulted in similar model results, with lower unfished recruitment, higher unfished spawning output, lower terminal year spawning output, and a relative terminal year spawning output below the management target. The likelihood for breakpoint natural mortality is 56 units worse than the base model with a similar number of parameters. The likelihood for a model with shared natural mortality is 59 likelihood units worse with one less parameter.

The model with time-varying length-weight does not lead to changes in spawning output because spawning output is modeled as a function of length, not weight, but the time series of summary biomass does vary from the base model. Unfished summary biomass is lower than the base model and summary biomass also has more high-frequency variability during WCGBTS years when the length-weight relationship is changing.

The model with non-linear density-dependent catchability for the WCGBTS improves the survey likelihood by about four units, worsens the age likelihood by about one unit, and improves the length likelihood by less than one unit. While the WCGBTS index fit is slightly better, the model still misses the overall pattern, indicating time-invariant density-dependent catchability alone cannot explain the conflict between composition and index data.

No other modeling sensitivities led to notable changes in population trajectories. However, we do note that estimating two sex-specific selectivity parameters for the recreational fleet improved the likelihood by 18 units. Estimating sex-specific selectivity for all fleets with sex data improves the likelihood by an additional 28 units. However, this involves estimating 12 additional parameters, many of which seemed poorly estimated during earlier explorations.

An additional modeling sensitivity (not shown in the figure and table) explored the use of a Lorenzen natural mortality relationship (Lorenzen 1996) with age. This resulted in much higher estimates of M up to about age 5, but the impact on the model results was small because these ages are mostly immature and are rarely selected, so higher M at young ages is confounded with the estimated unfished equilibrium recruitment. The fit to the age composition data was worse with the Lorenzen M but there was little change in the likelihood for other data types, including the fit to the WCGBTS index.

3.5.2.3. Composition data

Sensitivity to use and treatment of composition data is in Figure 63 and Table 31.

The McAllister & Ianelli data weight method leads to a higher unfished recruitment, higher natural mortality, and higher somatic growth rate. This results in a higher unfished spawning output, much higher population peak in the 2000s, and a higher terminal year spawning output and relative spawning output. The lowpoint of the population in the 1980s and 1990s is also estimated to be larger.

Removing fishery lengths leads to a higher unfished spawning output, but similar terminal year spawning output, so a lower relative spawning output. Unfished recruitment is fairly similar but natural mortality is lower and the somatic growth rate is higher.

3.5.3. Retrospective analysis

The retrospective analysis showed little change in the population trajectory (Figure 64).

Age 4+ abundance is used to compare among historical assessments (Figure 65) due to different assumptions about maturity and fecundity that make spawning output and fraction of unfished spawning output difficult to compare. Similar patterns of decline throughout the 1970s and 1980s are estimated among all previous among assessments although there were differences in estimated scale. The models conducted in 2005 and more recently have all estimated increases in the 2000s, but the timing of when the increase began has differed among assessments. The differences in age 4+ biomass between this assessment and that from 2017 are a low scale in the current assessment and a later recent peak in biomass (2019 rather than 2005).

3.5.4. Likelihood profiles

Likelihood profiles were conducted over the parameters controlling unfished equilibrium recruitment ($\log(R_0)$), female natural mortality (M), and stock-recruit steepness (h) as shown in Figure 66 to Figure 71.

The profile over $\log(R_0)$ shows relatively consistent support for similar values with some minor differences among data types and fleets (Figure 66). In particular, the age data are fit better with higher $\log(R_0)$ and the index data are fit better at a slightly lower value. The length compositions are less informative about this parameter. Among the age compositions, the commercial comps are the most influential. Among the indices, the

WCGBTS is better fit at lower $\log(R_0)$ and the Triennial Survey is best fit at moderate values.

The spawning output at initial equilibrium is relatively insensitive to the changes in $\log(R_0)$ while the final spawning output is more strongly correlated with that parameter (Figure 67). Therefore, at low $\log(R_0)$, the stock is estimated to be at a small fraction of unfished. However, the change in likelihood at those values is large, indicating that the low $\log(R_0)$ values are not supported by the data.

There is somewhat conflicting information about M among data types and fleets (Figure 68). The age and length data support a higher M while the indices and recruitment penalties support a lower M. The likelihood contribution of the M prior is small compared to the other data sources. The profile includes a model with female $M = 0.125$, which is similar to the median of the prior ($M = 0.126$). The difference in negative-log-likelihood between the estimated $M = 0.157$ and the $M = 0.125$ model was 6.56 units of log-likelihood compared to the prior likelihood contribution of 0.24 in the base model, indicating signficant support in the data for the higher M value. There was a step in the profile in which the male M (calculated as an offset from female M) was equal to the median of the prior (when rounded to 3 significant digits). The corresponding female M was 0.145, which is relatively close to the base model estimate, with only 0.82 units of negative-log-likelihood difference from the base model.

At low M values, the final spawning output decreases while the initial equilibrium remains stable, leading to a smaller fraction of unfished (Figure 69). However, the change in likelihood at those values is large, indicating that low M is not supported by the data.

All data sources with the exception of the commercial length comps support a high steepness value, but the difference in likelihood is small (Figure 70). There are only 1 units of improvement in negative log-likelihood when changing steepness from the $h = 0.718$ fixed in the base model and the $h = 1.0$ in the profile. A steepness of one was deemed implausible for the population.

At low steepness values, the initial spawning output increases and the final spawning output decreases, leading to a smaller fraction of unfished (Figure 71). However, the change in likelihood at those values is large, indicating that low steepness is not supported by the data.

3.6. Unresolved problems and major uncertainties

The composition data regularly include 30+ year-old fish, and support a medium-lived population. The likelihood profiles indicate the survey likelihood is maximized at a lower natural mortality than the estimated value. However, the WCGBTS index doubles and then halves again over a period of approximately five years, and the model is not able to fit this dynamic. Intuitively, a higher natural mortality could make the population more dynamic, so it is unclear why the survey likelihood is maximized at a lower natural mortality. The doubling could come from the large 2008 and, to a lesser extent, 2010 year classes, but the estimated recruitment deviation is not large enough to support the magnitude of the increase observed in the survey (and in observer catch rates on midwater trawl vessels). In addition, it is difficult for a population with relatively constant catches since 2017 and with individuals that regularly survive to 30+ years to have adult biomass decrease by approximately one-half over only two years (2019-2021). While changes in natural mortality could be possible, ocean conditions were relatively positive during those years (Harvey et al. 2022) and changes in natural mortality more often impact younger individuals. The large 2008 year class becomes less apparent in age-composition data in different years for the commercial fleet and the WCGBTS, and the mechanism for this "blurring" is unclear (several hypotheses: movement and selectivity changes, natural mortality, fishing mortality, increasing ageing error as the year class ages, some combination). Overall, we were unable to find a reliable mechanistic way to simultaneously fit the survey and composition data; the candidate base model fits the composition data at the expense of the survey index. All data sources and the candidate base model indicate the population is at a more depleted state than it was in 2017 and than the 2017 assessment estimated the population was in 2017 (two distinct quantities). The magnitude of the change is less clear.

4. Management

4.1. Reference points

Reference points based on the biomass target of 40% of unfished spawning output, the spawners-per-recruit (SPR) target of 0.5, and the internal model estimate of maximum sustainable yield are shown in Table v and Figure 58.

4.2. Harvest projections and decision tables

Harvest projections for the candidate base model assuming a P* of 0.45, sigma = 0.5, and the time-varying buffer are in Table 32. After exploration of alternative axes of uncertainty during the review panel, the chosen axis of uncertainty was the parameter for unfished recruitment on a log scale: $\log(R_0)$.

The range of values was based on the following guidance in the terms of reference:

> One method bases uncertainty in management quantities for the decision table on the asymptotic standard deviation for the OFL in the final year of the model from the base model. Specifically, the current year spawning biomass for the high and low states of nature are given by the base model mean plus or minus 1.15 standard deviations (i.e., the 12.5th and 87.5th percentiles). A search across fixed values of lnR0 are then used to attain the current year spawning biomass values for the high and low states of nature.

The asymptotic standard deviation for the 2025 OFL from the base model was 0.186 and the point estimate of the 2025 OFL was 5440 mt. The associated 12.5th and 87.5th percentiles were 4392 mt and 6739 mt. Model runs from the likelihood profiles for $\log(R_0)$ which had OFL values which best matched these two values had $\log(R_0) = 10.25$ and 10.75 relative to a base model estimate of 10.51.

The Groundfish Management Team provided assumed catches for 2025 and 2026. These are based on a combination of the GEMM report, Shorebased Individual Fishing Quota (IFQ) projections, 2025-2026 Harvest Specifications set asides, and the PacFIN Groundfish Species Scorecard for 2024 Yellowtail Rockfish North of 40° 10' N. Lat. Table 34 lists out sector-specific catch assumptions and how those map onto modeled fleets.

4.3. Evaluation of scientific uncertainty

The model estimate of the coefficient of variation of the overfishing limit (OFL) in 2025 is 0.186. This is less than the default SSC value of 0.5 for a category 1 assessment, so harvest projections assume an initial sigma of 0.5.

4.3.1. Risk table

Below is a risk table for northern yellowtail rockfish to document 1) ecosystem and environmental factors, 2) stock assessment data inputs, and 3) assessment model fits and structural factors that could potentially affect stock productivity and/or uncertainty arising from the stock assessment (see text). Level 1 is favorable/less uncertain, Level 2 neutral, and Level 3 unfavorable/more uncertain

Ecosystem and environmental conditions	Assessment data inputs	Assessment model fits and structural uncertainty
• Recruitment: unfavorable to neutral conditions for recruitment	• Catch reconstruction is reliable for a rockfish species, with some uncertainty in historical years when rockfish were not always sorted to species	• Well-informed sex-specific estimates of natural mortality, unfished recruitment, and growth
• Habitat: Neutral	• More age data than almost any other groundfish species. Covers shoreside, at-sea, and recreational sectors. Shoreside age data dating back to the 1970s.	• Steepness fixed at meta-analysis prior.
• Prey: Most available evidence suggests adequate forage for yellowtail in 2024 and recent years. Caveat: low krill in 2023 acoustic surveys.	• Age data are generally fit well with simple selectivity assumptions. Some mild issues with commercial (shoreside) length data.	• Good fits to abundant composition data with fairly simple selectivity assumptions and fleet structure
• Predators: no trend in abundance for 6 of 7 predators in the last 5 yrs	• Species-specific maturity and fecundity; maturity data collected over the last ~10 years	• Model generally misses an increase in the WCGBTS from 2014-2019. Non-stationary catchability seems more likely than an incorrect modeled population trajectory, given similar increases seen during this time for all midwater rockfish.
• Competitors: Some potential for hake competition for krill, but highly uncertain.	• Bottom trawl survey may not be reliable way to generate index for midwater rockfish	• Highly numerically stable model, MCMC posteriors are similar to assumption of asymptotic normality
	• New exploration of early life history and hook and line surveys	• Most sensitivity model runs are well within the asymptotic confidence interval of the base model
	• Generally a target species with most catch landed, only limited bycatch	
Level 2: neutral	Level 1	Level 1

4.3.1.1. Ecosystem and environmental conditions

To identify ecosystem and environmental processes impacting northern yellowtail rockfish we evaluated recent trends in environmental drivers, focusing on the years after main recruitment deviations are estimated (2019 - 2025). We considered trends in environmental drivers of yellowtail rockfish recruitment, habitat and distribution, prey, competitors and predators, and the climate vulnerability assessment (CVA) by McClure et al. (2023). We did not consider non-fisheries human activities as none were identified to be applicable to yellowtail rockfish. Overall we consider ecosystem and environmental conditions to be neutral (Level 2) with medium to high confidence based on agreement between a majority of indicators, robust but uncertain evidence, and no apparent concerns. We use this, plus information related to the stock assessment, to fill out the 'risk table' in Table ix, based on the framework outlined by the California Current Integrated Ecosystem Assessment (CCIEA) team (Golden et al. 2024). The ecosystem and environmental conditions discussed here were contributed by Megan Feddern, Isaac Kaplan, Nick Tolimieri, Chris Harvey and Jameal Samhouri.

4.3.1.1.1. Recruitment

La Niña conditions persisted from 2020 - 2022 but were followed by a strong El Niño in 2023 - 24, which caused warmer than average ocean temperatures that were particularly pronounced during the pelagic juvenile lifestage and which are negatively associated with yellowtail rockfish recruitment. Spring transition was substantially earlier than optimal for northern yellowtail rockfish in 2020 and later than optimal in 2022, but close to optimal in 2021, 2023 and 2024 based on the relationships described in Appendix A. Temperature exposure during egg incubation was above average in 2021 and 2023, indicating poor conditions, but average in 2024. Since 2019, longshore transport has been substantially above average during the pelagic juvenile lifestage indicating poor conditions for recruitment.

The Washington nearshore rockfish survey in OCNMS (Cope et al. 2023a; Tolimieri et al. 2023), which was updated through 2024 for this assessment, indicated an increase in the black-yellowtail rockfish species complex from 2019 - 2021, low abundance in 2022 - 2023, and an increase in 2024. Similar patterns were observed based on the northern YOY rockfish index from the RREAS survey (Gasbarro et al. 2025), with a more optimistic outlook of abundance in 2023. The coastwide RREAS index for yellowtail rockfish also indicated a strong YOY class in 2024 (Field et al. 2021; Santora et al. 2021), but had less interannual variability from 2021 - 2023 (Figure 18). The collective evidence across oceanographic indices of recruitment and indices of juvenile abundance indicates recruitment was average or below the long-term average over the last 5 years with the exception of 2021.

Overall, based on the collective evidence recruitment is characterized as neutral to unfavorable conditions with robust evidence.

4.3.1.1.2. Distribution and habitat

Young of the year yellowtail rockfish settle to nearshore areas and are known to utilize kelp bed habitat. Giant and bull kelp abundance based on the Kelp Watch Report Card remain close to the historical average in Washington (Bell 2023). However, Oregon bull kelp cover is low, and is estimated to be at only 39% of historical levels, and over the last five years cover has been at only 19% of historical levels. Kelp abundance in California regions is also low relative to the historical mean. Tolimieri et al. (2020) and Taylor et al. (2023) used spatio-temporal models to examine the distribution and abundance of groundfish along the West Coast. We considered updated spatio-temporal models for young (less than 4.5 years) and adult yellowtail rockfish, separately. These models indicate no changes in distribution. Collectively, habitat and distribution information indicate neutral to somewhat unfavorable conditions due to low kelp cover in Oregon.

4.3.1.1.3. Prey

Overall, most available evidence suggests adequate forage for yellowtail rockfish in 2024 and recent years and is characterized as neutral to favorable. The CCIEA RREAS euphausiid (krill) indicator shows an increasing trend in the central Central California Current over the last five years, including 2024 (Leising et al. (2025); see Figure I.2). RREAS data for 42 - 46 degrees N indicates no strong trend over the last five years, and krill abundance and size from the Trinidad Head Line were near average for most of 2024. Herring abundance sampled by JSOES in the Northern California Current has been stable in recent years, although the 2023 acoustic survey estimates of coastwide herring abundance suggest a decline from 2019 levels (Stierhoff et al. 2024). Production of juvenile hake was estimated in the stock assessment to be above average in 2020 and 2021, though there is high uncertainty in the stock assessment estimates of recruitment for more recent years (Johnson et al. 2025b). Copepods are found in diets of juvenile yellowtail rockfish, and sampling at the Newport Hydrographic Line (Leising et al. (2025); see Figure 3.1) suggested average feeding conditions over the last 5 years, with improvements once El Niño conditions waned in early 2024. We note that the coastwide krill abundance index, derived from acoustic data, was not available in 2024, but the 2023 values for this index were the 2nd lowest since the beginning of sampling in 2007.

4.3.1.1.4. Predators and competitors

Predators that impose the largest amounts of predation mortality on yellowtail rockfish were identified from Ecopath food web modeling. The Ecopath models of Field et al. (2006) and Koehn et al. (2016) were recently revised (C. Best-Otubu, P.Y. Hernvann, N. Lezama Ochoa, I. Kaplan). The highest sources of predation mortality on yellowtail rockfish, from greatest to least, derive from seven predators: California sea lions, lingcod, porpoises, fur seals, harbor seals, sablefish and skates. Based on changes in abundance over the last 5 years, six of the seven main predators are unlikely to drive any changes in predation over the last 5 years (Gertseva et al. 2019; Taylor et al. 2019, 2021; Caretta et al. 2024). One predator, sablefish, may have imposed some increased predation pressure on the ecosystem (Johnson et al. 2023), but the linkage to yellowtail rockfish specifically is very uncertain. Similarly, we considered hake as a potential competitor for krill, however the lack of evidence of krill being a limiting prey source for yellowtail rockfish and lack of direct evidence of competition makes this link highly uncertain. Overall, we scored predation and competition effects as neutral, with some uncertainty.

4.3.1.1.5. Climate vulnerability assessment

McClure et al. (2023) found that yellowtail rockfish had a climate vulnerability of moderate/high and an overall climate exposure of high, due largely to potential impacts from ocean acidification on prey (ranked very high) and mean sea surface temperature (ranked high). We consider the effects of temperature and prey availability 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.

4.4. Regional management considerations

Currently yellowtail rockfish is managed with distinct harvest specifications north and south of 40°10′ N. latitude. This assessment aligns with the entire northern stock and therefore does not provide a recommended method for allocating harvests at a finer regional scale. Current genetic, oceanographic, and life history evidence indicates a single break in the population around Cape Mendocino, near 40°10′ N. latitude.

4.5. Research and data needs

4.5.1. Response to recommendations in previous assessment

- A problem common to assessments of all stocks caught in the midwater is the lack of a targeting survey
    - This is still an outstanding issue. This assessment explores inclusion of a new hook and line survey.

- Research to determine whether old females of a variety of rockfish species actually have a mortality rate different than that of younger females. Assessments variously treat the discrepancies seen in sex ratios of older fish as either mortality-related or due unavailability to the fishery (e.g., ontogenetic movement offshore, or to rockier habitats). As these assumptions impact model outcomes very differently, resolving this issue would greatly improve confidence in the assessments.
  - This assessment includes a number of sensitivities related to this, as well as deeper exploration of data patterns outside of the assessment model to support modeling choices.
- A hindrance to analysis of the commercial fishery is the inability to distinguish between midwater and trawl gear, particularly in data from the 1980s-1990s. Reliable recording of gear type will ensure that this does not continue to be problematic for future assessments.
  - In years where midwater and bottom trawl gear are differentiated in PacFIN, exploratory data analysis indicated there is essentially no difference in the age and size compositions of fish caught. Thus, combining midwater and bottom trawl gear into a single model fleet seemed appropriate, and there is no need to reconstruct the historical ratio of catches between the two gears. We agree they should continue to be differentiated in ongoing sampling programs.
- A commercial index in the North. This is by far the largest segment of the fishery, and the introduction of the trawl rationalization program should mean that an index can be developed for the current fishery when the next full assessment is performed.
  - This was explored as a sensitivity
- Further investigation into an index for the commercial logbook dataset from earlier periods.
  - This was not done. A new fishery-independent hook and line index and a number of indices of recruitment were explored instead.
- Further analysis of growth patterns along the Northern coast. The previous full assessment subdivided the Northern stock based on research showing differential growth along the coast, and although data for the assessment is no longer available along the INPFC areas used in that analysis, there may be some evidence of growth variability that would be useful to include in a future assessment.
  - While growth may be different above and below Cape Mendocino, we found no evidence for spatial variability in size-at-age in the area north of $40^{\circ}10'$ N. Lat.

4.5.2. New recommendations

While all of the following recommendations would improve the assessment, they are listed roughly in order of importance:

1. Explore catchability and selectivity of the bottom trawl survey using existing data streams. No new midwater surveys have begun in the last eight years, and the likelihood of new surveys in future years is low, so recommending new surveys is an unproductive recommendation, and other options should be explored. The STAT understands that the WCGBTS has collected echosounder data over the years which has not been analyzed to date. Analyzing this data and exploring the relationship between acoustic data and sampled biomass from the bottom trawl gear will help understand potential variability in catchability. Identifying drivers of bottom trawl catchability (e.g., environmental drivers, density-dependence and/or schooling behavior) would be useful for all midwater species, not just yellowtail rockfish (e.g., canary and widow rockfish). More sophisticated comparisons between CPUE in the catch share commercial midwater trawl sector and the bottom trawl survey could also be fruitful.

2. This assessment explored a number of new sources of data to provide and index of early life history survival years before yellowtail rockfish recruit to more traditional forms of population sampling. Ultimately, we chose to include the SMURF index in the base model. However, future research could more formally validate these indices and potentially use ensemble modeling to facilitate the inclusion of multiple different data sources on early life history into a single index in the model. A transition to a modeling framework that permits modeling of random effects (e.g., WHAM) may help facilitate this effort.

3. Age data is the only source of sex-specific recreational composition data, and it provided important information about selectivity of the fleet and patterns of sex ratio by age. Continued collection of recreational age data from Washington and new collections from Oregon should be prioritized, and could support a transition to an empirical weight-at-age model in the future.

4. The oceanographic index is an externally estimated regression trained on estimated recruitment deviations from a near-to-final base model. Therefore, using the index to predict recruitment deviations in years that it was trained on is circular and ill-advised. We only included the oceanographic index for years *not* included in the training data, but this meant that the years for which the index *was* included in the sensitivity model had no other data informing recruitment that could help estimate the scaling factor for the index (i.e., catchability). We fixed catchability at one in the sensitivity, since in theory the index should predict absolute recruitment deviations, but this is a strong assumption. A process that uses raw oceanographic

data directly in the assessment, instead of predictions from a regression on historical recruitment deviations, could avoid this. As above, such an exercise is likely easier in an assessment platform that permits estimation of random effects (e.g., WHAM).

5. The biological population extends into British Columbia, but no data from Canada is included in this model. Better understanding of transboundary population dynamics would improve management.

6. The combined hook and line survey catches smaller, and presumably younger fish, than the trawl surveys and fishing fleets, so can provide leading information about incoming year class strength. However, the fits to the length data are not very good. The recreational length composition data have a similarly shaped distribution, and adding sex-specific selectivity greatly improved the fit to recreational data. However, sex-specific selectivity was not estimable for the hook and line survey, likely because there is no sex data. Collecting sex and age data from the hook and line survey could allow for better estimation of selectivity and a more informative survey.

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7. Tables

7.1. Data

7.1.1. Fishery-dependent data

Table 11: Total removals (mt) of yellowtail rockfish for the commercial (Com.), foreign (For.), at-sea hake (ASHOP), and recreational (Rec.) fleets used in the assessment model. Foreign catches are included in the commercial fleet.

X	Year	Com. WA	Com. OR	Com. CA	Com. Discards	For.	ComTotal	ASHOP	Rec. WA	Rec. OR	Rec. CA
1	1889	0.1	0.0	0.0	0.0	0	0.1	0.0	0.0	0.0	0.0
2	1890	0.1	0.0	0.0	0.0	0	0.1	0.0	0.0	0.0	0.0
3	1891	0.2	0.0	0.0	0.0	0	0.3	0.0	0.0	0.0	0.0
4	1892	0.3	2.1	0.0	0.1	0	2.5	0.0	0.0	0.0	0.0
5	1893	0.0	2.1	0.0	0.1	0	2.2	0.0	0.0	0.0	0.0
6	1894	0.0	2.1	0.0	0.1	0	2.2	0.0	0.0	0.0	0.0
7	1895	0.0	0.5	0.0	0.0	0	0.6	0.0	0.0	0.0	0.0
8	1896	0.0	0.1	0.0	0.0	0	0.1	0.0	0.0	0.0	0.0
9	1897	0.0	0.1	0.0	0.0	0	0.1	0.0	0.0	0.0	0.0
10	1898	0.0	0.1	0.0	0.0	0	0.1	0.0	0.0	0.0	0.0
11	1899	0.1	0.1	0.0	0.0	0	0.2	0.0	0.0	0.0	0.0
12	1900	0.0	0.2	0.0	0.0	0	0.2	0.0	0.0	0.0	0.0
13	1901	0.0	0.2	0.0	0.0	0	0.2	0.0	0.0	0.0	0.0
14	1902	0.0	0.3	0.0	0.0	0	0.3	0.0	0.0	0.0	0.0
15	1903	0.0	0.3	0.0	0.0	0	0.3	0.0	0.0	0.0	0.0
16	1904	0.3	0.4	0.0	0.0	0	0.7	0.0	0.0	0.0	0.0
17	1905	0.0	0.4	0.0	0.0	0	0.5	0.0	0.0	0.0	0.0
18	1906	0.0	0.5	0.0	0.0	0	0.5	0.0	0.0	0.0	0.0
19	1907	0.0	0.5	0.0	0.0	0	0.6	0.0	0.0	0.0	0.0
20	1908	0.2	0.6	0.0	0.0	0	0.8	0.0	0.0	0.0	0.0
21	1909	0.0	0.6	0.0	0.0	0	0.7	0.0	0.0	0.0	0.0
22	1910	0.0	0.7	0.0	0.0	0	0.7	0.0	0.0	0.0	0.0
23	1911	0.0	0.7	0.0	0.0	0	0.8	0.0	0.0	0.0	0.0
24	1912	0.0	0.8	0.0	0.0	0	0.8	0.0	0.0	0.0	0.0
25	1913	0.0	0.8	0.0	0.0	0	0.9	0.0	0.0	0.0	0.0
26	1914	0.0	0.9	0.0	0.0	0	0.9	0.0	0.0	0.0	0.0
27	1915	0.1	0.9	0.0	0.0	0	1.1	0.0	0.0	0.0	0.0
28	1916	0.0	1.0	2.5	0.2	0	3.7	0.0	0.0	0.0	0.0
29	1917	0.0	1.1	5.0	0.3	0	6.3	0.0	0.0	0.0	0.0
30	1918	2.7	1.1	11.6	0.7	0	16.1	0.0	0.0	0.0	0.0
31	1919	0.9	1.2	2.7	0.2	0	4.9	0.0	0.0	0.0	0.0
32	1920	0.7	1.2	3.6	0.3	0	5.8	0.0	0.0	0.0	0.0
33	1921	0.7	1.3	5.4	0.3	0	7.7	0.0	0.0	0.0	0.0

34	1922	0.3	1.3	4.1	0.3	0	6.0	0.0	0.0	0.0	0.0
35	1923	0.4	1.4	1.3	0.1	0	3.3	0.0	0.0	0.0	0.0
36	1924	1.1	1.4	3.6	0.3	0	6.4	0.0	0.0	0.0	0.0
37	1925	1.4	1.5	11.8	0.7	0	15.3	0.0	0.0	0.0	0.0
38	1926	2.4	1.5	11.6	0.7	0	16.2	0.0	0.0	0.0	0.0
39	1927	3.2	1.6	22.1	1.2	0	28.0	0.0	0.0	0.0	0.0
40	1928	2.8	2.6	19.0	1.1	0	25.6	0.0	0.0	0.0	0.1
41	1929	2.2	9.1	20.9	1.5	0	33.7	0.0	0.0	0.0	0.2
42	1930	3.1	12.5	30.3	2.1	0	47.9	0.0	0.0	0.0	0.2
43	1931	2.9	7.1	43.8	2.4	0	56.3	0.0	0.0	0.0	0.3
44	1932	1.1	1.8	33.0	1.6	0	37.6	0.0	0.0	0.0	0.3
45	1933	1.2	2.9	29.1	1.5	0	34.7	0.0	0.0	0.0	0.4
46	1934	3.7	3.1	24.9	1.4	0	33.2	0.0	0.0	0.0	0.5
47	1935	7.5	2.0	41.6	2.3	0	53.4	0.0	0.0	0.0	0.5
48	1936	3.6	10.1	37.4	2.3	0	53.4	0.0	0.0	0.0	0.6
49	1937	2.4	23.0	30.5	2.5	0	58.4	0.0	0.0	0.0	0.7
50	1938	5.4	22.9	39.6	3.1	0	71.0	0.0	0.0	0.0	0.7
51	1939	8.0	28.5	41.6	3.5	0	81.7	0.0	0.0	0.0	0.6
52	1940	11.6	119.0	19.7	6.8	0	157.1	0.0	0.0	0.0	0.9
53	1941	14.8	159.2	27.6	9.1	0	210.7	0.0	0.0	0.0	0.8
54	1942	19.6	282.7	22.6	14.7	0	339.6	0.0	0.0	0.0	0.4
55	1943	375.7	924.1	38.3	60.3	0	1398.5	0.0	0.0	0.0	0.4
56	1944	615.4	1572.6	194.7	107.5	0	2490.1	0.0	0.0	0.0	0.3
57	1945	1570.6	2420.2	470.0	201.2	0	4662.1	0.0	0.0	0.0	0.5
58	1946	703.9	1507.1	477.7	121.3	0	2809.9	0.0	0.0	0.0	0.8
59	1947	327.6	916.8	109.9	61.1	0	1415.4	0.0	0.0	0.0	0.6
60	1948	415.9	627.0	200.7	56.1	0	1299.7	0.0	0.0	0.0	1.2
61	1949	348.8	541.1	79.8	43.7	0	1013.3	0.0	0.0	0.0	1.6
62	1950	564.5	581.1	43.1	53.6	0	1242.4	0.0	0.0	0.0	2.0
63	1951	620.2	512.9	108.2	56.0	0	1297.2	0.0	0.0	0.0	2.2
64	1952	956.7	537.3	81.4	71.1	0	1646.4	0.0	0.0	0.0	2.0
65	1953	384.9	444.6	56.4	40.0	0	925.8	0.0	0.0	0.0	1.7
66	1954	550.5	530.7	74.3	52.1	0	1207.6	0.0	0.0	0.0	2.1
67	1955	562.4	568.1	18.4	51.8	0	1200.8	0.0	0.0	0.0	2.5
68	1956	561.5	755.2	20.9	60.3	0	1397.9	0.0	0.0	0.0	2.8
69	1957	340.7	996.7	34.2	61.9	0	1433.5	0.0	0.0	0.0	2.4
70	1958	620.3	752.0	49.9	64.1	0	1486.3	0.0	0.0	0.0	4.1
71	1959	605.4	824.6	29.2	65.8	0	1524.9	0.0	0.0	0.0	3.8

72	1960	686.4	1075.8	18.8	80.3	0	1861.3	0.0	0.0	0.0	2.8
73	1961	684.0	977.5	14.1	75.6	0	1751.1	0.0	0.0	0.0	2.1
74	1962	1103.6	1131.4	12.0	101.3	0	2348.3	0.0	0.0	0.0	2.4
75	1963	845.8	960.8	32.7	83.0	0	1922.3	0.0	0.0	0.0	1.7
76	1964	788.4	687.7	38.0	68.3	0	1582.3	0.0	0.0	0.0	1.3
77	1965	721.6	675.1	32.1	64.4	0	1493.3	0.0	0.0	0.0	2.1
78	1966	263.2	818.9	15.5	177.8	2845	4120.3	0.0	0.0	0.0	2.3
79	1967	482.1	835.2	30.0	149.0	1956	3452.4	0.0	36.2	0.0	2.3
80	1968	913.6	981.8	30.3	140.4	1187	3253.1	0.0	2.2	0.0	2.5
81	1969	1775.0	1378.6	58.9	180.3	786	4178.9	0.0	2.1	0.0	3.1
82	1970	866.4	521.8	60.7	111.8	1031	2591.7	0.0	13.0	0.0	3.5
83	1971	750.8	674.2	92.2	88.0	434	2039.2	0.0	11.7	0.0	2.7
84	1972	1063.0	1113.7	99.8	135.0	716	3127.5	0.0	12.1	0.0	3.6
85	1973	1558.2	1071.8	85.8	157.2	770	3643.0	0.0	19.8	0.0	4.7
86	1974	1031.2	780.2	109.9	116.1	654	2691.5	0.0	14.6	0.0	5.0
87	1975	587.1	707.5	86.9	72.3	222	1675.8	0.0	11.2	0.0	5.0
88	1976	2446.7	1338.8	111.6	186.4	235	4318.5	29.5	15.4	0.0	6.0
89	1977	4228.2	1513.1	111.1	263.9	0	6116.3	7.4	7.2	0.0	5.3
90	1978	5691.0	2221.5	297.2	370.3	0	8580.0	75.4	11.9	0.0	4.8
91	1979	5101.4	2061.9	67.5	326.1	0	7556.9	82.0	3.9	18.6	5.1
92	1980	3826.7	3048.5	37.5	311.8	0	7224.5	255.4	2.8	22.7	4.3
93	1981	5325.9	3633.5	94.4	408.3	0	9462.1	152.6	3.9	15.7	9.2
94	1982	5993.4	2960.2	331.4	418.8	0	9703.8	551.2	1.7	24.7	27.4
95	1983	5812.9	3857.1	105.3	440.9	0	10216.1	548.4	2.7	0.0	13.8
96	1984	2574.5	2071.7	357.7	225.7	0	5229.6	312.0	3.3	28.3	6.6
97	1985	1550.5	1613.9	120.2	148.1	0	3432.7	174.2	4.8	7.5	5.9
98	1986	2229.1	2163.1	268.9	210.2	0	4871.3	560.1	8.7	27.7	4.8
99	1987	1990.4	2484.0	141.6	208.2	0	4824.2	541.4	7.7	24.8	5.8
100	1988	3231.7	2613.8	144.7	270.2	0	6260.4	423.4	6.9	12.5	4.2
101	1989	1814.4	2551.0	354.0	212.8	0	4932.3	184.6	6.3	9.5	6.2
102	1990	1725.6	2147.3	466.4	195.7	0	4535.1	295.1	15.2	16.3	4.3
103	1991	1192.4	2066.7	405.8	165.3	0	3830.2	480.0	33.4	29.8	3.1
104	1992	1418.3	3998.1	231.9	254.7	0	5903.1	694.8	35.3	32.1	2.0
105	1993	2162.2	3090.7	102.3	241.5	0	5596.7	273.4	46.4	79.8	1.3
106	1994	1908.7	3215.4	104.6	235.8	0	5464.6	560.4	20.2	22.7	0.7
107	1995	1482.7	3113.7	115.9	212.5	0	4924.7	646.8	16.2	35.5	0.6
108	1996	1451.5	3599.3	153.2	234.7	0	5438.6	746.2	22.1	20.8	1.6
109	1997	476.6	1271.2	89.6	82.9	0	1920.3	396.3	26.8	21.6	6.6

110	1998	617.1	1744.2	132.6	112.5	0	2606.3	438.1	44.3	31.2	1.8
111	1999	563.6	1624.2	60.9	101.4	0	2350.1	1198.6	16.8	56.3	3.1
112	2000	877.6	2012.2	21.0	131.3	0	3042.1	635.3	19.1	20.6	2.1
113	2001	756.3	1101.8	41.2	85.7	0	1985.1	213.4	12.6	15.3	0.8
114	2002	659.9	350.2	16.0	35.6	0	1061.7	189.9	3.5	19.6	0.4
115	2003	358.1	55.2	1.1	3.1	0	417.5	36.6	11.7	15.1	0.3
116	2004	467.3	97.8	3.7	8.6	0	577.5	47.6	18.2	11.3	0.2
117	2005	651.0	103.0	0.8	40.7	0	795.5	112.2	15.8	12.5	0.2
118	2006	280.3	77.4	0.8	5.2	0	363.6	108.7	10.2	8.3	0.2
119	2007	220.3	57.0	1.4	7.9	0	286.5	78.7	14.7	6.8	0.5
120	2008	262.4	14.0	1.7	1.1	0	279.3	175.0	14.4	5.6	0.2
121	2009	506.2	32.4	0.6	10.6	0	549.7	176.2	29.3	10.2	1.0
122	2010	664.6	88.9	0.2	16.6	0	770.2	150.1	44.3	8.3	0.3
123	2011	601.1	594.6	0.3	1.3	0	1197.2	101.2	53.4	11.6	0.5
124	2012	924.2	593.7	0.3	2.0	0	1520.2	43.0	18.8	13.8	0.7
125	2013	538.9	577.6	0.8	0.4	0	1117.7	269.0	23.5	16.1	0.6
126	2014	442.0	927.9	0.7	0.8	0	1371.4	42.0	42.7	11.4	0.3
127	2015	528.4	1310.0	4.3	2.2	0	1844.8	86.4	26.3	22.1	0.6
128	2016	417.2	988.8	1.3	2.9	0	1410.1	62.3	36.7	7.7	0.2
129	2017	789.7	1908.6	4.0	10.6	0	2713.0	278.1	47.4	14.0	0.5
130	2018	1015.4	2170.4	11.0	13.3	0	3210.1	229.9	38.2	35.6	1.0
131	2019	1064.2	2214.1	11.2	5.5	0	3295.0	316.9	48.6	30.4	1.3
132	2020	1128.7	2264.3	14.0	3.8	0	3410.8	166.9	60.1	38.4	0.6
133	2021	983.8	1745.7	28.1	3.2	0	2760.9	82.4	61.9	27.9	1.1
134	2022	917.8	2020.9	19.2	10.2	0	2968.0	27.4	68.9	51.7	1.2
135	2023	893.5	1999.5	20.7	3.8	0	2917.6	267.6	88.9	82.9	3.1
136	2024	633.0	2003.8	27.1	0.0	0	0.0	14.5	60.8	61.4	1.0

Table 12: Summary of the number of length samples and trips for California (CA), Oregon (OR), and Washington (WA) commercial fishery.

Year	N Lengths (CA)	N Trips (CA)	N Lengths (OR)	N Trips (OR)	N Lengths (WA)	N Trips (WA)	N Input
1972	0	0	611	8	785	4	14.120
1972	0	0	611	8	785	4	84.720
1973	0	0	150	2	492	3	7.060
1973	0	0	150	2	492	3	35.300
1974	0	0	167	2	349	2	28.240
1975	0	0	0	0	458	3	21.180
1976	0	0	500	5	2774	14	134.140
1977	0	0	1049	11	778	3	98.840
1978	132	21	484	6	1876	9	254.160
1979	41	11	1100	11	1599	16	268.280
1980	62	22	798	8	3700	37	473.020
1981	61	14	1007	10	3900	39	444.780
1982	184	48	1800	18	3496	35	713.060
1983	278	55	299	3	2366	25	489.134
1984	704	47	1298	13	3200	33	656.580
1985	261	22	2652	26	3500	35	585.980
1986	181	24	1747	17	2992	30	501.260
1987	145	17	1891	37	2046	40	656.316
1988	37	7	1670	34	1650	33	522.440
1989	230	17	2055	42	1650	33	635.030
1990	192	16	1802	36	1874	38	623.784
1991	265	12	1296	39	1999	38	580.280
1992	213	12	2490	71	1700	34	96.312
1992	213	12	2490	71	1700	34	724.614
1993	92	5	2022	54	1800	36	36.322
1993	92	5	2022	54	1800	36	635.132
1994	140	6	2641	70	3562	53	120.566
1994	140	6	2641	70	3562	53	910.740
1995	248	8	2242	61	3505	54	43.944
1995	248	8	2242	61	3505	54	868.380
1996	326	13	2259	57	3148	48	77.920
1996	326	13	2259	57	3148	48	833.080
1997	94	4	4092	110	2490	43	46.772
1997	94	4	4092	110	2490	43	1078.288
1998	156	6	3235	85	2104	45	74.894
1998	156	6	3235	85	2104	45	894.310
1999	190	7	3577	99	2194	47	39.356
1999	190	7	3577	99	2194	47	975.618
2000	71	3	3002	90	2282	46	877.990
2001	177	7	2832	91	1995	40	828.552
2002	96	6	1536	45	1660	35	540.296
2003	37	2	701	21	1626	42	391.232
2004	64	4	1341	36	1692	43	510.386
2005	66	5	916	25	1173	31	358.390
2006	93	11	1236	35	899	22	375.464
2007	101	9	1189	70	1610	43	168.546
2007	101	9	1189	70	1610	43	522.200
2008	41	8	584	39	1499	27	55.334
2008	41	8	584	39	1499	27	367.112
2009	19	2	855	67	942	21	89.762
2009	19	2	855	67	942	21	340.608
2010	2	1	1618	83	880	18	91.780
2010	2	1	1618	83	880	18	447.000
2011	58	3	1816	115	980	20	73.962

2011	58	3	1816	115	980	20	531.852
2012	41	7	1914	107	1531	28	132.158
2012	41	7	1914	107	1531	28	623.068
2013	12	5	1263	111	975	15	87.586
2013	12	5	1263	111	975	15	441.500
2014	111	5	1893	167	1158	16	59.432
2014	111	5	1893	167	1158	16	624.356
2015	117	6	2391	148	1058	22	135.054
2015	117	6	2391	148	1058	22	668.108
2016	145	8	3141	150	1371	30	49.812
2016	145	8	3141	150	1371	30	830.666
2017	267	14	3037	185	2470	70	30.422
2017	267	14	3037	185	2470	70	1065.812
2018	276	16	2948	194	1651	70	952.750
2019	277	17	2782	199	1146	72	868.290
2020	168	12	1926	122	549	24	522.734
2021	632	32	1815	130	1157	45	704.352
2022	184	15	2442	174	1467	61	814.834
2023	302	22	2143	141	1410	57	751.990
2024	471	21	2053	129	1864	58	813.544

Table 13: Summary of the number of age samples and trips for for California (CA), Oregon (OR), and Washington (WA) commercial fishery.

Year	N Ages (CA)	N Trips (CA)	N Ages (OR)	N Trips (OR)	N Ages (WA)	N Trips (WA)	N Input
1972	0	0	557	8	0	0	56.480
1973	0	0	98	1	0	0	7.060
1974	0	0	163	2	122	1	21.180
1975	0	0	0	0	305	3	21.180
1976	0	0	99	1	1279	14	105.900
1977	0	0	1030	11	296	3	98.840
1978	0	0	373	5	599	6	77.660
1979	0	0	787	8	1560	16	169.440
1980	61	21	793	8	3627	37	465.960
1981	61	14	988	10	3741	38	437.720
1982	162	45	1580	16	3331	34	670.700
1983	234	47	294	3	2350	25	472.164
1984	685	46	1192	12	3192	33	642.460
1985	260	21	2187	22	3498	35	550.680
1986	164	19	1381	15	2985	30	451.840
1987	97	16	1891	37	2092	40	656.040
1988	36	5	1670	34	1645	33	508.320
1989	229	17	2053	42	1643	33	633.650
1990	187	16	1792	36	1871	38	621.300
1991	265	12	1289	39	1843	37	556.786
1992	150	9	2424	69	1696	34	701.260
1993	0	0	1981	53	1798	36	610.502
1994	139	5	2637	70	1747	34	733.174
1995	90	4	2203	60	1900	38	680.634
1996	244	8	2161	55	1644	33	654.762
1997	76	4	3735	103	1772	36	913.454
1998	47	4	2263	59	2092	42	712.476
1999	82	5	3382	93	2179	45	921.734
2000	25	2	2860	84	2249	46	840.492
2001	177	7	2749	85	1994	40	810.960
2002	68	3	1508	42	1651	34	524.326
2003	0	0	584	16	1620	42	362.152
2004	32	3	1328	33	1665	39	492.450
2005	66	5	832	24	1169	31	345.246
2006	93	11	1207	31	747	21	345.486
2007	0	0	473	27	1396	35	319.922
2008	41	8	574	35	1076	27	303.358
2009	4	1	638	46	940	21	286.316
2010	2	1	1080	50	829	18	332.718
2011	26	2	1007	70	811	19	345.472
2012	28	6	1335	79	1279	27	476.596
2013	12	5	1097	97	749	15	373.404
2014	110	5	1825	161	712	15	546.286
2015	56	3	2156	138	900	21	591.456
2016	0	0	2197	128	1184	30	624.578
2017	0	0	2462	155	1574	56	767.968
2018	0	0	2079	156	1144	62	662.774
2019	0	0	1810	160	1014	65	614.712
2020	0	0	1411	99	495	22	384.028
2021	0	0	1325	108	945	43	464.260
2022	0	0	1877	140	867	56	574.672
2023	0	0	1553	103	812	53	482.370
2024	0	0	1232	85	857	41	414.282

Table 14: Summary of the number of age and length samples and trips for the at-sea hake fishery

Year	Lengths (n tows)	Lengths (n fish)	Ages (n tows)	Ages (n fish)
1976	18	206	0	0
1978	15	277	0	0
1979	2	5	0	0
1980	88	3111	0	0
1982	9	177	0	0
1985	3	43	0	0
1989	5	14	0	0
1992	237	4641	0	0
1993	176	2435	0	0
1994	375	5024	0	0
1995	179	2568	0	0
1996	297	4127	0	0
1997	388	5201	0	0
1998	417	2898	0	0
1999	558	5532	0	0
2000	443	3847	0	0
2001	323	1573	0	0
2002	148	832	0	0
2003	327	2134	0	0
2004	483	2864	0	0
2005	536	5094	0	0
2006	536	5808	0	0
2007	718	5557	0	0
2008	620	4731	0	0
2009	404	3571	0	0
2010	645	5709	0	0
2011	622	4809	0	0
2012	234	1482	0	0
2013	205	1844	0	0
2014	137	1314	0	0
2015	129	1646	0	0
2016	481	4213	0	0
2017	781	8299	0	0
2018	409	4330	0	0
2019	344	3899	326	326
2020	84	922	0	0
2021	44	235	0	0
2022	17	97	0	0
2023	187	1286	185	317
2024	56	353	0	0

Table 15: Sample sizes for age and length samples from the recreational fishery.

Year	Washington ages	Washington	Oregon	California
1980	0	90	0	12
1981	0	26	0	2
1982	0	16	0	20
1983	0	3	0	25
1984	0	9	0	33
1985	0	11	0	76
1986	0	0	0	45
1987	0	14	0	6
1989	0	0	0	4
1993	0	0	384	20
1994	0	0	592	47
1995	0	13	557	10
1996	0	6	284	18
1997	100	137	262	34
1998	0	112	476	5
1999	0	5	688	0
2000	0	2	435	1
2001	0	2	787	9
2002	0	195	1639	1
2003	0	800	1550	6
2004	0	675	1233	26
2005	0	869	1754	29
2006	18	362	1498	29
2007	0	313	1583	77
2008	0	189	1896	37
2009	2	464	2525	69
2010	14	218	2318	49
2011	15	391	2264	45
2012	0	228	2673	125
2013	0	348	2121	114
2014	527	680	1822	57
2015	593	683	1869	53
2016	832	928	800	24
2017	1144	1317	1227	74
2018	637	903	2556	116
2019	1299	1798	2787	103
2020	881	891	129	0
2021	685	826	1827	74
2022	610	669	1825	52
2023	1239	1534	1675	144
2024	609	1279	1868	56

Table 16: Summary of trips from ORBS dockside sampling from ODFW.

year	tripsWithTarget	tripsWOTarget	totalTrips	percentpos
2001	448	3324	3772	0.12
2002	548	3266	3814	0.14
2003	626	3536	4162	0.15

2004	510	2825	3335	0.15
2005	639	5831	6470	0.10
2006	592	6046	6638	0.09
2007	449	4177	4626	0.10
2008	497	4840	5337	0.09
2009	648	4654	5302	0.12
2010	894	4996	5890	0.15
2011	837	4389	5226	0.16
2012	912	4171	5083	0.18
2013	1019	5814	6833	0.15
2014	956	4608	5564	0.17
2015	979	6954	7933	0.12
2016	474	6180	6654	0.07
2017	623	6436	7059	0.09
2018	623	6143	6766	0.09
2019	711	5244	5955	0.12
2020	772	5961	6733	0.11
2021	570	4925	5495	0.10
2022	569	5606	6175	0.09
2023	845	5533	6378	0.13
2024	690	5612	6302	0.11

Table 17: Model selection for top ten covariate combinations considered for the ORBS index.

Boattype	Gf_opendepth	Lltrip	Month	Port	Tgt.bag_bin	Year	Effort.Offset	Df	Log.Likelihood	AICc	Delta
Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	49	-66518.8	133135.6	0.0
Incl.	Incl.	Incl.	Incl.	Incl.	-	Incl.	Incl.	48	-66562.4	133220.9	85.3
Incl.	-	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	46	-66584.9	133261.8	126.2
Incl.	-	Incl.	Incl.	Incl.	-	Incl.	Incl.	45	-66643.9	133377.8	242.2
Incl.	Incl.	Incl.	-	Incl.	Incl.	Incl.	Incl.	38	-66728.7	133533.4	397.8
Incl.	Incl.	Incl.	-	Incl.	-	Incl.	Incl.	37	-66749.3	133572.6	437.0
-	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	48	-66912.9	133921.9	786.3
-	Incl.	Incl.	Incl.	Incl.	-	Incl.	Incl.	47	-66957.8	134009.6	874.0
-	-	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	45	-66965.6	134021.2	885.7
Incl.	-	Incl.	-	Incl.	Incl.	Incl.	Incl.	35	-67003.3	134076.6	941.0

7.1.2. Fishery-independent data

Table 18: Summary of percent positive by number of trips for the combined OR-WA hook and line survey.

year	tripsWithTarget	tripsWOTarget	totalTrips	percentpos
2010	22	53	75	0.29
2011	10	55	65	0.15
2012	30	62	92	0.33
2013	34	108	142	0.24
2014	33	85	118	0.28
2015	24	270	294	0.08
2016	10	91	101	0.10
2017	4	48	52	0.08
2018	9	143	152	0.06
2019	37	180	217	0.17
2021	30	91	121	0.25
2022	19	95	114	0.17
2023	40	159	199	0.20
2024	56	174	230	0.24

Table 19: Summary of model selection for the combined OR-WA hook and line survey.

Depth_bin	Gear_bi	Month	Survey	Year	Effort.Offset	Df	Log.Likelihood	AICc	Delta
Included	-	Included	Included	Included	Included	21	-1545.9	3134.3	0.0
Included	+	Included	Included	Included	Included	22	-1545.6	3135.7	1.4
Included	+	Included	-	Included	Included	21	-1569.1	3180.6	46.2
Included	-	Included	-	Included	Included	20	-1571.8	3184.0	49.6
Included	-	-	Included	Included	Included	18	-1587.5	3211.3	77.0
Included	+	-	Included	Included	Included	19	-1587.2	3212.8	78.5
Included	+	-	-	Included	Included	18	-1598.0	3232.4	98.0
Included	-	-	-	Included	Included	17	-1603.4	3241.1	106.8
-	-	Included	Included	Included	Included	19	-1653.6	3345.7	211.3
-	+	Included	Included	Included	Included	20	-1653.4	3347.2	212.9
-	-	Included	-	Included	Included	18	-1669.2	3374.8	240.5
-	+	Included	-	Included	Included	19	-1669.0	3376.3	242.0
-	-	-	Included	Included	Included	16	-1680.8	3393.8	259.5
-	+	-	Included	Included	Included	17	-1680.7	3395.8	261.4
-	+	-	-	Included	Included	16	-1689.2	3410.8	276.4
-	-	-	-	Included	Included	15	-1691.1	3412.4	278.1

Table 20: Model selection for covariate combinations considered for the SMURF YOY index.

Region	Temp_bin	Year	Effort.Offset	Df	Log.Likelihood	AICc	Delta
Incl.	Incl.	Incl.	Incl.	16	-914.2	1861.2	0.0
Incl.	NA	Incl.	Incl.	12	-919.4	1863.3	2.1
NA	Incl.	Incl.	Incl.	15	-923.0	1876.8	15.6
NA	NA	Incl.	Incl.	11	-942.3	1907.0	45.8

Table 21: Sample sizes for the age and length compositions from the WCGBTS. The ages are treated as conditioned on length and use the number of fish (within each length bin) as the input sample size.

Year	N. ages	N. tows	N. lengths	Input N.
2003	258	32	737	77
2004	141	21	524	51
2005	315	41	875	99
2006	149	30	366	72
2007	265	43	946	104
2008	300	31	619	75
2009	261	35	307	85
2010	462	43	1089	104
2011	467	46	786	111
2012	333	40	886	97
2013	149	20	379	48
2014	573	49	1357	119
2015	539	57	818	138
2016	568	78	2256	189
2017	NA	68	1751	165
2018	NA	59	856	143
2019	NA	31	538	75
2021	309	32	395	77
2022	261	35	417	85
2023	398	62	714	150
2024	425	45	691	109

Table 22: Sample sizes for the marginal age and length compositions from the Triennial survey.

Year	N. tows with ages	N. ages	Input N. for ages	N. tows with lengths	N. lengths	Input N. for lengths
1980	12	651	29	19	955	46
1983	16	1291	38	50	2617	121
1986	22	1216	53	38	2805	92
1989	8	291	19	40	1337	97
1992	9	309	21	44	1137	106
1995	33	304	80	44	700	106
1998	73	1042	177	94	2664	228
2001	40	483	97	43	651	104
2004	53	452	128	53	1409	128

Table 23: Comparison of potential age-0 abundance and recruitment indices by data source.

Recruitment / Age-0 abundance index	Benefits	Drawbacks
Oceanographic Index	• Includes oceanographic conditions identified by literature and expert opinion • Potential to use forecasts in future assessments	• Indirect observation of recruitment • Index development procedures make balancing model convergence and potential bias challenging • Good practices for including recruitment deviation indices in stock synthesis models are not yet established
OCNMS Nearshore Rockfish	• Direct observations of YOY in region where juveniles are highly abundant	• Identified as a complex with Black Rockfish, which make up most observations • Limited temporal scope throughout the settlement season • Data only available since 2015
SMURF Juvenile Survey	• Direct observations of YOY settlement rate in region where juveniles are highly abundant • Identified at the species level • Repeat sampling throughout the settlement season • Environmentally informed such that settlement rate is associated with temperature exposure • Collaboratively developed with agency and university partners	• Limited spatial scope • Data only available since 2014
Yellowtail RREAS Coastwide	• Long time series since 2001	• Less synchronous with other juvenile indices • Variable sampling effort/spatial domain focused south of stock • Poorly correlated with well-informed estimates of recruitment
Northern YOY Rockfish	• Synchrony with other indices	• Not taxonomically specific to yellowtail rockfish

7.2. Model results

Table 24: Specifications and structure of the model.

Section	Configuration

Maximum age	40
Sexes	Females, males
Population bins	1-65 cm by 1 cm bins
Summary biomass (mt) age	4+
Number of areas	1
Number of seasons	1
Number of growth patterns	1
Start year	1889
End year	2024
Data length bins	20-56 cm by 2 cm bins
Data age bins	1-30 by 1 year

Table 25: Estimated parameters in the model.

Type	Count
Natural Mortality (M)	2
Growth mean	5
Growth variability	3
Stock-recruit	1
Rec. dev. time series	93
Rec. dev. forecast	12
Index	4
Size selectivity	14
Size selectivity time-variation	6

Table 26: 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	0.157	2	(0.02, 0.25)	ok	0.00937	lognormal(0.126, 0.310)
L_at_Amin_Fem_GP_1	14	3	(1, 25)	ok	0.626	none
L_at_Amax_Fem_GP_1	52.9	2	(35, 70)	ok	0.189	none
VonBert_K_Fem_GP_1	0.143	3	(0.1, 0.4)	ok	0.00354	none
CV_young_Fem_GP_1	0.113	5	(0.03, 0.16)	ok	0.0123	none
CV_old_Fem_GP_1	0.0406	5	(0.03, 0.16)	ok	0.0027	none
Wtlen_1_Fem_GP_1	1.39e-05	-50	(0, 3)	fixed		none
Wtlen_2_Fem_GP_1	3.02	-50	(2, 4)	fixed		none
Mat50%_Fem_GP_1	10	-50	(1, 30)	fixed		none
Mat_slope_Fem_GP_1	-0.67	-50	(-2, 1)	fixed		none
Eggs_scalar_Fem_GP_1	1.12e-11	-50	(0, 6)	fixed		none
Eggs_exp_len_Fem_GP_1	4.59	-50	(2, 7)	fixed		none
NatM_uniform_Mal_GP_1	-0.143	2	(-3, 3)	ok	0.0126	none
L_at_Amin_Mal_GP_1	0	-2	(-1, 1)	fixed		none
L_at_Amax_Mal_GP_1	-0.14	2	(-1, 1)	ok	0.00496	none
VonBert_K_Mal_GP_1	0.351	3	(-1, 1)	ok	0.0217	none
CV_young_Mal_GP_1	0	-5	(-1, 1)	fixed		none
CV_old_Mal_GP_1	0.279	5	(-1, 1)	ok	0.0693	none
Wtlen_1_Mal_GP_1	1.18e-05	-50	(0, 3)	fixed		none
Wtlen_2_Mal_GP_1	3.07	-50	(2, 4)	fixed		none
CohortGrowDev	1	-50	(0, 2)	fixed		none
FracFemale_GP_1	0.5	-99	(0.001, 1)	fixed		none
SR_LN(R0)	10.5	1	(5, 20)	ok	0.172	none
SR_BH_steep	0.718	-6	(0.2, 1)	fixed		none
SR_sigmaR	0.5	-6	(0.4, 1.2)	fixed		none
SR_regime	0	-50	(-5, 5)	fixed		none
SR_autocorr	0	-50	(0, 2)	fixed		none
Early_RecrDev_1932	0.0059	5	(-6, 6)	dev	0.501	normal(0.00, 0.50)
Early_RecrDev_1933	0.00625	5	(-6, 6)	dev	0.501	normal(0.00, 0.50)
Early_RecrDev_1934	0.00654	5	(-6, 6)	dev	0.501	normal(0.00, 0.50)
Early_RecrDev_1935	0.00673	5	(-6, 6)	dev	0.501	normal(0.00, 0.50)
Early_RecrDev_1936	0.00681	5	(-6, 6)	dev	0.501	normal(0.00, 0.50)
Early_RecrDev_1937	0.00682	5	(-6, 6)	dev	0.501	normal(0.00, 0.50)

Early_RecrDev_1938	0.00687	5	(-6, 6)	dev	0.501	normal(0.00, 0.50)
Early_RecrDev_1939	0.0071	5	(-6, 6)	dev	0.501	normal(0.00, 0.50)
Early_RecrDev_1940	0.00779	5	(-6, 6)	dev	0.501	normal(0.00, 0.50)
Early_RecrDev_1941	0.00929	5	(-6, 6)	dev	0.501	normal(0.00, 0.50)
Early_RecrDev_1942	0.0122	5	(-6, 6)	dev	0.501	normal(0.00, 0.50)
Early_RecrDev_1943	0.0171	5	(-6, 6)	dev	0.502	normal(0.00, 0.50)
Early_RecrDev_1944	0.0243	5	(-6, 6)	dev	0.503	normal(0.00, 0.50)
Early_RecrDev_1945	0.0332	5	(-6, 6)	dev	0.504	normal(0.00, 0.50)
Early_RecrDev_1946	0.043	5	(-6, 6)	dev	0.506	normal(0.00, 0.50)
Early_RecrDev_1947	0.0532	5	(-6, 6)	dev	0.506	normal(0.00, 0.50)
Early_RecrDev_1948	0.0617	5	(-6, 6)	dev	0.506	normal(0.00, 0.50)
Early_RecrDev_1949	0.0622	5	(-6, 6)	dev	0.504	normal(0.00, 0.50)
Early_RecrDev_1950	0.0466	5	(-6, 6)	dev	0.498	normal(0.00, 0.50)
Early_RecrDev_1951	0.0106	5	(-6, 6)	dev	0.488	normal(0.00, 0.50)
Early_RecrDev_1952	-0.0393	5	(-6, 6)	dev	0.476	normal(0.00, 0.50)
Early_RecrDev_1953	-0.0879	5	(-6, 6)	dev	0.464	normal(0.00, 0.50)
Early_RecrDev_1954	-0.12	5	(-6, 6)	dev	0.454	normal(0.00, 0.50)
Early_RecrDev_1955	-0.133	5	(-6, 6)	dev	0.446	normal(0.00, 0.50)
Early_RecrDev_1956	-0.158	5	(-6, 6)	dev	0.437	normal(0.00, 0.50)
Early_RecrDev_1957	-0.206	5	(-6, 6)	dev	0.427	normal(0.00, 0.50)
Early_RecrDev_1958	-0.234	5	(-6, 6)	dev	0.42	normal(0.00, 0.50)
Early_RecrDev_1959	-0.168	5	(-6, 6)	dev	0.423	normal(0.00, 0.50)
Early_RecrDev_1960	0.0542	5	(-6, 6)	dev	0.436	normal(0.00, 0.50)
Early_RecrDev_1961	0.318	5	(-6, 6)	dev	0.432	normal(0.00, 0.50)
Main_RecrDev_1962	0.24	2	(-6, 6)	dev	0.407	normal(0.00, 0.50)
Main_RecrDev_1963	-0.115	2	(-6, 6)	dev	0.393	normal(0.00, 0.50)
Main_RecrDev_1964	-0.315	2	(-6, 6)	dev	0.368	normal(0.00, 0.50)
Main_RecrDev_1965	-0.322	2	(-6, 6)	dev	0.35	normal(0.00, 0.50)
Main_RecrDev_1966	-0.275	2	(-6, 6)	dev	0.337	normal(0.00, 0.50)
Main_RecrDev_1967	-0.183	2	(-6, 6)	dev	0.33	normal(0.00, 0.50)
Main_RecrDev_1968	0.146	2	(-6, 6)	dev	0.271	normal(0.00, 0.50)
Main_RecrDev_1969	-0.0342	2	(-6, 6)	dev	0.279	normal(0.00, 0.50)
Main_RecrDev_1970	-0.314	2	(-6, 6)	dev	0.273	normal(0.00, 0.50)
Main_RecrDev_1971	-0.596	2	(-6, 6)	dev	0.279	normal(0.00, 0.50)
Main_RecrDev_1972	-0.332	2	(-6, 6)	dev	0.232	normal(0.00, 0.50)
Main_RecrDev_1973	-0.108	2	(-6, 6)	dev	0.218	normal(0.00, 0.50)
Main_RecrDev_1974	0.542	2	(-6, 6)	dev	0.152	normal(0.00, 0.50)
Main_RecrDev_1975	0.278	2	(-6, 6)	dev	0.182	normal(0.00, 0.50)

Main_RecrDev_1976	0.119	2	(-6, 6)	dev	0.187	normal(0.00, 0.50)
Main_RecrDev_1977	0.252	2	(-6, 6)	dev	0.16	normal(0.00, 0.50)
Main_RecrDev_1978	-0.0743	2	(-6, 6)	dev	0.186	normal(0.00, 0.50)
Main_RecrDev_1979	-0.565	2	(-6, 6)	dev	0.234	normal(0.00, 0.50)
Main_RecrDev_1980	-0.33	2	(-6, 6)	dev	0.196	normal(0.00, 0.50)
Main_RecrDev_1981	0.0185	2	(-6, 6)	dev	0.156	normal(0.00, 0.50)
Main_RecrDev_1982	-0.528	2	(-6, 6)	dev	0.239	normal(0.00, 0.50)
Main_RecrDev_1983	0.117	2	(-6, 6)	dev	0.16	normal(0.00, 0.50)
Main_RecrDev_1984	0.505	2	(-6, 6)	dev	0.13	normal(0.00, 0.50)
Main_RecrDev_1985	0.061	2	(-6, 6)	dev	0.186	normal(0.00, 0.50)
Main_RecrDev_1986	0.157	2	(-6, 6)	dev	0.169	normal(0.00, 0.50)
Main_RecrDev_1987	0.376	2	(-6, 6)	dev	0.143	normal(0.00, 0.50)
Main_RecrDev_1988	-0.13	2	(-6, 6)	dev	0.219	normal(0.00, 0.50)
Main_RecrDev_1989	0.758	2	(-6, 6)	dev	0.129	normal(0.00, 0.50)
Main_RecrDev_1990	0.764	2	(-6, 6)	dev	0.143	normal(0.00, 0.50)
Main_RecrDev_1991	0.55	2	(-6, 6)	dev	0.164	normal(0.00, 0.50)
Main_RecrDev_1992	0.117	2	(-6, 6)	dev	0.203	normal(0.00, 0.50)
Main_RecrDev_1993	-0.293	2	(-6, 6)	dev	0.258	normal(0.00, 0.50)
Main_RecrDev_1994	0.276	2	(-6, 6)	dev	0.185	normal(0.00, 0.50)
Main_RecrDev_1995	0.164	2	(-6, 6)	dev	0.206	normal(0.00, 0.50)
Main_RecrDev_1996	-0.296	2	(-6, 6)	dev	0.273	normal(0.00, 0.50)
Main_RecrDev_1997	-0.0175	2	(-6, 6)	dev	0.23	normal(0.00, 0.50)
Main_RecrDev_1998	0.507	2	(-6, 6)	dev	0.166	normal(0.00, 0.50)
Main_RecrDev_1999	0.205	2	(-6, 6)	dev	0.218	normal(0.00, 0.50)
Main_RecrDev_2000	0.705	2	(-6, 6)	dev	0.142	normal(0.00, 0.50)
Main_RecrDev_2001	-0.048	2	(-6, 6)	dev	0.219	normal(0.00, 0.50)
Main_RecrDev_2002	-0.628	2	(-6, 6)	dev	0.273	normal(0.00, 0.50)
Main_RecrDev_2003	-0.298	2	(-6, 6)	dev	0.22	normal(0.00, 0.50)
Main_RecrDev_2004	0.0824	2	(-6, 6)	dev	0.167	normal(0.00, 0.50)
Main_RecrDev_2005	-0.627	2	(-6, 6)	dev	0.277	normal(0.00, 0.50)
Main_RecrDev_2006	0.431	2	(-6, 6)	dev	0.128	normal(0.00, 0.50)
Main_RecrDev_2007	-0.385	2	(-6, 6)	dev	0.243	normal(0.00, 0.50)
Main_RecrDev_2008	0.792	2	(-6, 6)	dev	0.105	normal(0.00, 0.50)
Main_RecrDev_2009	-0.635	2	(-6, 6)	dev	0.261	normal(0.00, 0.50)
Main_RecrDev_2010	0.325	2	(-6, 6)	dev	0.135	normal(0.00, 0.50)
Main_RecrDev_2011	-0.179	2	(-6, 6)	dev	0.2	normal(0.00, 0.50)
Main_RecrDev_2012	0.00461	2	(-6, 6)	dev	0.187	normal(0.00, 0.50)
Main_RecrDev_2013	0.0882	2	(-6, 6)	dev	0.193	normal(0.00, 0.50)

Main_RecrDev_2014	0.211	2	(-6, 6)	dev	0.185	normal(0.00, 0.50)
Main_RecrDev_2015	-0.334	2	(-6, 6)	dev	0.26	normal(0.00, 0.50)
Main_RecrDev_2016	0.0287	2	(-6, 6)	dev	0.217	normal(0.00, 0.50)
Main_RecrDev_2017	-0.374	2	(-6, 6)	dev	0.273	normal(0.00, 0.50)
Main_RecrDev_2018	-0.485	2	(-6, 6)	dev	0.305	normal(0.00, 0.50)
Late_RecrDev_2019	0.00381	5	(-6, 6)	dev	0.305	normal(0.00, 0.50)
Late_RecrDev_2020	-0.203	5	(-6, 6)	dev	0.419	normal(0.00, 0.50)
Late_RecrDev_2021	0.333	5	(-6, 6)	dev	0.372	normal(0.00, 0.50)
Late_RecrDev_2022	-0.121	5	(-6, 6)	dev	0.41	normal(0.00, 0.50)
Late_RecrDev_2023	0.503	5	(-6, 6)	dev	0.4	normal(0.00, 0.50)
Late_RecrDev_2024	-0.0313	5	(-6, 6)	dev	0.374	normal(0.00, 0.50)
ForeRecr_2025	0	5	(-6, 6)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2026	0	5	(-6, 6)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2027	0	5	(-6, 6)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2028	0	5	(-6, 6)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2029	0	5	(-6, 6)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2030	0	5	(-6, 6)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2031	0	5	(-6, 6)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2032	0	5	(-6, 6)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2033	0	5	(-6, 6)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2034	0	5	(-6, 6)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2035	0	5	(-6, 6)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2036	0	5	(-6, 6)	dev	0.5	normal(0.00, 0.50)
LnQ_base_H&L_survey(4)	-16.4	2	(-30, 15)	ok	0.23	none
Q_extraSD_H&L_survey(4)	0	-99	(0, 0.5)	fixed		none
LnQ_base_Triennial(5)	-0.864	2	(-30, 15)	ok	0.151	none
Q_extraSD_Triennial(5)	0	-99	(0, 0.5)	fixed		none
LnQ_base_WCGBTS(6)	-1.11	2	(-30, 15)	ok	0.173	none
Q_extraSD_WCGBTS(6)	0	-99	(0, 0.5)	fixed		none
LnQ_base_SMURF(7)	-12.8	2	(-30, 15)	ok	0.306	none
Q_extraSD_SMURF(7)	0	-99	(0, 0.5)	fixed		none
Size_DblN_peak_Commercial(1)	47.1	1	(20, 55)	ok	0.537	none
Size_DblN_top_logit_Commercial(1)	70	-4	(-20, 70)	fixed		none
Size_DblN_ascend_se_Commercial(1)	4.01	3	(-5, 20)	ok	0.0828	none
Size_DblN_descend_se_Commercial(1)	70	-4	(-5, 70)	fixed		none
Size_DblN_start_logit_Commercial(1)	-999	-99	(-1000, 25)	fixed		none
Size_DblN_end_logit_Commercial(1)	-999	-99	(-1000, 25)	fixed		none
SzSel_Male_Peak_Commercial(1)	0	-99	(-10, 10)	fixed		none

SzSel_Male_Ascend_Commercial(1)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Descend_Commercial(1)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Final_Commercial(1)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Scale_Commercial(1)	1	-99	(0, 2)	fixed		none
Size_DblN_peak_At-Sea-Hake(2)	55	-99	(20, 55)	fixed		none
Size_DblN_top_logit_At-Sea-Hake(2)	70	-4	(-20, 70)	fixed		none
Size_DblN_ascend_se_At-Sea-Hake(2)	4.33	3	(-5, 20)	ok	0.0386	none
Size_DblN_descend_se_At-Sea-Hake(2)	70	-4	(-5, 70)	fixed		none
Size_DblN_start_logit_At-Sea-Hake(2)	-999	-99	(-1000, 25)	fixed		none
Size_DblN_end_logit_At-Sea-Hake(2)	-999	-99	(-1000, 25)	fixed		none
SzSel_Male_Peak_At-Sea-Hake(2)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Ascend_At-Sea-Hake(2)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Descend_At-Sea-Hake(2)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Final_At-Sea-Hake(2)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Scale_At-Sea-Hake(2)	1	-99	(0, 2)	fixed		none
Size_DblN_peak_Recreational(3)	30.9	6	(20, 55)	ok	0.817	none
Size_DblN_top_logit_Recreational(3)	-20	-4	(-20, 70)	fixed		none
Size_DblN_ascend_se_Recreational(3)	3.14	6	(-5, 20)	ok	0.176	none
Size_DblN_descend_se_Recreational(3)	7.68	4	(-5, 20)	ok	0.942	none
Size_DblN_start_logit_Recreational(3)	-999	-99	(-1000, 25)	fixed		none
Size_DblN_end_logit_Recreational(3)	-999	-99	(-1000, 25)	fixed		none
SzSel_Male_Peak_Recreational(3)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Ascend_Recreational(3)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Descend_Recreational(3)	-2.18	6	(-10, 10)	ok	0.48	none
SzSel_Male_Final_Recreational(3)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Scale_Recreational(3)	0.71	6	(0, 2)	ok	0.113	none
Size_DblN_peak_H&L_survey(4)	28.5	6	(20, 55)	ok	1.65	none
Size_DblN_top_logit_H&L_survey(4)	-20	-4	(-20, 70)	fixed		none
Size_DblN_ascend_se_H&L_survey(4)	3.46	6	(-5, 20)	ok	0.509	none
Size_DblN_descend_se_H&L_survey(4)	4.76	4	(-5, 20)	ok	0.355	none
Size_DblN_start_logit_H&L_survey(4)	-999	-99	(-1000, 25)	fixed		none
Size_DblN_end_logit_H&L_survey(4)	-999	-99	(-1000, 25)	fixed		none
SzSel_Male_Peak_H&L_survey(4)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Ascend_H&L_survey(4)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Descend_H&L_survey(4)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Final_H&L_survey(4)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Scale_H&L_survey(4)	1	-99	(0, 2)	fixed		none
Size_DblN_peak_Triennial(5)	55	-1	(20, 55)	fixed		none

Size_DblN_top_logit_Triennial(5)	70	-4	(-20, 70)	fixed		none
Size_DblN_ascend_se_Triennial(5)	5.09	3	(-5, 20)	ok	0.111	none
Size_DblN_descend_se_Triennial(5)	70	-4	(-5, 70)	fixed		none
Size_DblN_start_logit_Triennial(5)	-999	-99	(-1000, 25)	fixed		none
Size_DblN_end_logit_Triennial(5)	-999	-99	(-1000, 25)	fixed		none
SzSel_Male_Peak_Triennial(5)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Ascend_Triennial(5)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Descend_Triennial(5)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Final_Triennial(5)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Scale_Triennial(5)	1	-99	(0, 2)	fixed		none
Size_DblN_peak_WCGBTS(6)	48.1	1	(20, 55)	ok	1.84	none
Size_DblN_top_logit_WCGBTS(6)	70	-4	(-20, 70)	fixed		none
Size_DblN_ascend_se_WCGBTS(6)	4.32	3	(-5, 20)	ok	0.31	none
Size_DblN_descend_se_WCGBTS(6)	70	-4	(-5, 70)	fixed		none
Size_DblN_start_logit_WCGBTS(6)	-999	-99	(-1000, 25)	fixed		none
Size_DblN_end_logit_WCGBTS(6)	-999	-99	(-1000, 25)	fixed		none
SzSel_Male_Peak_WCGBTS(6)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Ascend_WCGBTS(6)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Descend_WCGBTS(6)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Final_WCGBTS(6)	0	-99	(-10, 10)	fixed		none
SzSel_Male_Scale_WCGBTS(6)	1	-99	(0, 2)	fixed		none
Size_DblN_peak_At-Sea-Hake(2)_BLK2repl_2015	47.8	6	(20, 55)	ok	0.844	none
Size_DblN_ascend_se_At-Sea-Hake(2)_BLK2repl_2015	3.55	6	(-5, 20)	ok	0.205	none
Size_DblN_peak_Recreational(3)_BLK1repl_2004	32.4	6	(20, 55)	ok	0.564	none
Size_DblN_peak_Recreational(3)_BLK1repl_2017	35.1	6	(20, 55)	ok	0.704	none
Size_DblN_descend_se_Recreational(3)_BLK1repl_2004	5.76	6	(-5, 20)	ok	0.228	none
Size_DblN_descend_se_Recreational(3)_BLK1repl_2017	9.51	6	(-5, 20)	ok	3.71	none

Table 27: Data weightings applied to compositions according to the `Francis` method. `Obs.` refers to the number of unique composition vectors included in the likelihood. `N input` and `N adj.` refer to the sample sizes of those vectors before and after being adjusted by the the weights. `CAAL` is conditional age-at-length data.

Type	Fleet	Francis	Obs.	Mean N input	Mean N adj.	Sum N adj.
Length	Commercial	0.056	53	575.5	32.5	1720.4
Length	At-Sea-Hake	0.166	40	292.0	48.6	1943.0
Length	Recreational	0.020	41	1576.5	31.6	1293.6
Length	H&L_survey	0.052	14	112.0	5.8	81.3
Length	Triennial	0.076	9	114.0	8.6	77.7
Length	WCGBTS	0.096	21	103.3	9.9	207.5
Age	Commercial	0.239	53	480.0	114.6	6073.1
Age	At-Sea-Hake	0.130	2	255.5	33.2	66.4
Age	Recreational	0.018	15	613.5	11.2	167.8
Age	Triennial	0.137	9	66.8	9.1	82.1
CAAL	WCGBTS	0.140	520	15.0	2.1	1089.6

Table 28: Time series of population estimates from the base model.

Year	Total Biomass (mt)	Spawning output (trillions of eggs)	Total Biomass 4+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_-50%)	Exploitation Rate
1889	139024	14.60	134984	1.000	36654	0	0.000	0.000
1890	139024	14.60	134984	1.000	36654	0	0.000	0.000
1891	139025	14.60	134983	1.000	36654	0	0.000	0.000
1892	139026	14.60	134983	1.000	36654	2	0.001	0.000
1893	139027	14.59	134984	1.000	36654	2	0.000	0.000
1894	139030	14.59	134986	1.000	36654	2	0.000	0.000
1895	139033	14.59	134990	1.000	36654	1	0.000	0.000
1896	139039	14.59	134996	1.000	36654	0	0.000	0.000
1897	139045	14.59	135002	1.000	36654	0	0.000	0.000
1898	139052	14.59	135008	1.000	36654	0	0.000	0.000
1899	139058	14.60	135015	1.000	36654	0	0.000	0.000
1900	139064	14.60	135021	1.000	36654	0	0.000	0.000
1901	139069	14.60	135026	1.000	36655	0	0.000	0.000
1902	139075	14.60	135031	1.000	36655	0	0.000	0.000
1903	139079	14.60	135036	1.000	36655	0	0.000	0.000
1904	139083	14.60	135040	1.000	36655	1	0.000	0.000
1905	139087	14.60	135044	1.000	36655	0	0.000	0.000
1906	139090	14.60	135047	1.000	36656	1	0.000	0.000
1907	139093	14.60	135050	1.000	36656	1	0.000	0.000
1908	139096	14.60	135053	1.000	36656	1	0.000	0.000
1909	139098	14.60	135055	1.000	36656	1	0.000	0.000
1910	139100	14.60	135057	1.000	36656	1	0.000	0.000
1911	139102	14.60	135059	1.000	36656	1	0.000	0.000
1912	139104	14.60	135061	1.000	36656	1	0.000	0.000
1913	139105	14.60	135062	1.001	36656	1	0.000	0.000
1914	139107	14.60	135063	1.001	36656	1	0.000	0.000

Table 28: Time series of population estimates from the base model. *(continued)*

Year	Total Biomass (mt)	Spawning output (trillions of eggs)	Total Biomass 4+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_-50%)	Exploita-tion Rate
1915	139108	14.60	135064	1.001	36656	1	0.000	0.000
1916	139109	14.60	135065	1.001	36656	4	0.001	0.000
1917	139107	14.60	135064	1.001	36656	6	0.001	0.000
1918	139103	14.60	135060	1.000	36656	16	0.003	0.000
1919	139091	14.60	135047	1.000	36656	5	0.001	0.000
1920	139090	14.60	135046	1.000	36655	6	0.001	0.000
1921	139088	14.60	135045	1.000	36655	8	0.002	0.000
1922	139085	14.60	135042	1.000	36655	6	0.001	0.000
1923	139084	14.60	135040	1.000	36655	3	0.001	0.000
1924	139085	14.60	135042	1.000	36655	6	0.001	0.000
1925	139083	14.60	135040	1.000	36655	15	0.003	0.000
1926	139074	14.60	135030	1.000	36655	16	0.003	0.000
1927	139064	14.59	135021	1.000	36654	28	0.006	0.000
1928	139045	14.59	135001	1.000	36654	26	0.005	0.000
1929	139029	14.59	134986	1.000	36653	34	0.007	0.000
1930	139008	14.58	134965	0.999	36652	48	0.010	0.000
1931	138976	14.58	134933	0.999	36650	57	0.012	0.000
1932	138939	14.57	134896	0.998	36866	38	0.008	0.000
1933	138924	14.57	134880	0.998	36878	35	0.007	0.000
1934	138919	14.57	134869	0.998	36888	34	0.007	0.000
1935	138927	14.56	134860	0.998	36894	54	0.011	0.000
1936	138928	14.56	134860	0.998	36896	54	0.011	0.000
1937	138943	14.56	134874	0.997	36896	59	0.012	0.000
1938	138964	14.55	134895	0.997	36896	72	0.015	0.001
1939	138984	14.55	134914	0.997	36904	82	0.017	0.001
1940	139001	14.54	134931	0.996	36927	158	0.032	0.001
1941	138955	14.52	134885	0.995	36979	211	0.043	0.002
1942	138871	14.50	134800	0.994	37081	340	0.069	0.003
1943	138686	14.46	134610	0.991	37255	1399	0.261	0.010
1944	137558	14.26	133474	0.977	37472	2490	0.433	0.019
1945	135556	13.91	131458	0.953	37712	4663	0.710	0.035
1946	131788	13.25	127669	0.908	37890	2811	0.501	0.022
1947	130139	12.91	125996	0.885	38176	1416	0.286	0.011
1948	130010	12.82	125842	0.878	38473	1301	0.267	0.010
1949	130092	12.77	125901	0.875	38476	1015	0.213	0.008
1950	130524	12.78	126302	0.876	37884	1244	0.256	0.010
1951	130793	12.77	126552	0.875	36484	1299	0.266	0.010
1952	131043	12.76	126828	0.874	34561	1648	0.328	0.013
1953	130944	12.71	126826	0.871	32772	927	0.196	0.007
1954	131411	12.78	127466	0.876	31640	1210	0.249	0.009
1955	131365	12.81	127623	0.878	31089	1203	0.247	0.009
1956	131024	12.85	127453	0.881	30203	1401	0.282	0.011
1957	130173	12.87	126708	0.882	28683	1436	0.288	0.011
1958	128980	12.87	125591	0.882	27774	1490	0.298	0.012
1959	127437	12.86	124165	0.881	29549	1529	0.305	0.012
1960	125593	12.83	122452	0.879	36744	1864	0.364	0.015
1961	123301	12.72	120134	0.871	47613	1753	0.349	0.015
1962	121303	12.59	117726	0.863	43810	2351	0.451	0.020
1963	119354	12.33	114930	0.845	30515	1924	0.389	0.017
1964	118605	12.11	113561	0.830	24820	1584	0.336	0.014
1965	118645	11.92	114322	0.817	24502	1495	0.325	0.013
1966	118740	11.73	115581	0.804	25542	4123	0.731	0.036

Table 28: Time series of population estimates from the base model. *(continued)*

Year	Total Biomass (mt)	Spawning output (trillions of eggs)	Total Biomass 4+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_-50%)	Exploitation Rate
1967	116043	11.14	113311	0.764	27713	3491	0.672	0.031
1968	113658	10.71	110906	0.734	38145	3258	0.649	0.029
1969	111268	10.40	108317	0.712	31608	4184	0.780	0.039
1970	108083	10.04	104686	0.688	23695	2608	0.564	0.025
1971	106605	10.01	102676	0.686	17788	2054	0.468	0.020
1972	105613	10.07	102443	0.690	23093	3143	0.650	0.031
1973	103308	9.93	100879	0.680	28694	3667	0.737	0.036
1974	100262	9.65	98077	0.661	54563	2711	0.608	0.028
1975	98193	9.45	95306	0.648	41588	1692	0.426	0.018
1976	97735	9.39	93708	0.643	35429	4369	0.860	0.047
1977	95723	8.93	90205	0.612	40188	6136	1.073	0.068
1978	93101	8.26	88710	0.566	28650	8672	1.305	0.098
1979	89063	7.24	85046	0.496	17157	7667	1.301	0.090
1980	86604	6.43	82648	0.440	21232	7510	1.341	0.091
1981	84265	5.70	81497	0.390	29363	9643	1.505	0.118
1982	79609	4.84	77527	0.332	16384	10309	1.575	0.133
1983	74149	4.13	71583	0.283	29990	10781	1.627	0.151
1984	68085	3.59	65240	0.246	42551	5580	1.371	0.086
1985	66811	3.74	64447	0.256	27617	3625	1.120	0.056
1986	67505	4.10	63824	0.281	31198	5473	1.324	0.086
1987	66758	4.19	62583	0.287	39009	5404	1.320	0.086
1988	66434	4.17	63217	0.286	23496	6707	1.438	0.106
1989	65316	3.90	61675	0.267	56088	5139	1.336	0.083
1990	66062	3.77	62144	0.259	55905	4866	1.324	0.078
1991	67749	3.68	63984	0.252	44850	4377	1.278	0.068
1992	70900	3.69	64780	0.253	29095	6667	1.477	0.103
1993	72772	3.51	67090	0.240	19033	5997	1.436	0.089
1994	75497	3.51	71172	0.240	33607	6069	1.440	0.085
1995	77659	3.54	74734	0.242	30101	5624	1.399	0.075
1996	79476	3.66	76871	0.251	19201	6229	1.428	0.081
1997	79942	3.78	76419	0.259	25602	2372	0.904	0.031
1998	83019	4.40	80056	0.301	45050	3122	0.972	0.039
1999	84481	5.01	82028	0.344	34393	3625	1.038	0.044
2000	85135	5.56	81666	0.381	58012	3719	0.978	0.046
2001	85810	6.04	81099	0.414	27810	2227	0.673	0.027
2002	88386	6.57	83903	0.450	15829	1275	0.433	0.015
2003	92062	7.08	86816	0.485	22326	481	0.172	0.006
2004	95968	7.58	93297	0.519	33047	655	0.220	0.007
2005	98813	7.98	96776	0.547	16393	936	0.295	0.010
2006	100548	8.30	97787	0.569	47531	491	0.164	0.005
2007	101965	8.68	98754	0.595	21162	387	0.126	0.004
2008	103125	9.12	100334	0.625	69192	475	0.153	0.005
2009	104183	9.56	99635	0.655	16720	766	0.223	0.008
2010	105484	9.94	101700	0.681	43889	973	0.266	0.010
2011	107003	10.20	101117	0.699	26602	1364	0.347	0.013
2012	108367	10.28	105636	0.704	31998	1597	0.388	0.015
2013	109503	10.23	105255	0.701	34766	1427	0.366	0.014
2014	110627	10.16	107483	0.696	39273	1468	0.366	0.014
2015	111540	10.12	107887	0.693	22756	1980	0.463	0.018
2016	111875	10.08	107966	0.691	32993	1517	0.369	0.014
2017	112426	10.19	108635	0.698	22327	3053	0.631	0.028
2018	111232	10.13	108411	0.694	20164	3515	0.700	0.032

Table 28: Time series of population estimates from the base model. *(continued)*

Year	Total Biomass (mt)	Spawning output (trillions of eggs)	Total Biomass 4+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_-50%)	Exploitation Rate
2019	109263	10.02	106019	0.687	33162	3692	0.731	0.035
2020	106735	9.86	104280	0.676	27174	3677	0.737	0.035
2021	104023	9.68	101362	0.663	46846	2934	0.635	0.029
2022	102076	9.59	98529	0.657	30012	3117	0.669	0.032
2023	100377	9.46	96760	0.648	56453	3360	0.717	0.035
2024	99102	9.27	94401	0.635	33341	2802	0.638	0.030
2025	99256	9.13	95116	0.626	34652	4060	0.838	0.043
2026	98997	8.77	93596	0.601	34445	4066	0.860	0.043
2027	99231	8.39	95507	0.575	34214	4723	0.962	0.049
2028	99067	7.95	95254	0.545	33924	4540	0.959	0.048
2029	99140	7.63	95351	0.523	33689	4445	0.956	0.047
2030	99234	7.43	95472	0.509	33541	4421	0.954	0.046
2031	99215	7.36	95482	0.504	33487	4435	0.951	0.046
2032	99026	7.39	95315	0.506	33510	4467	0.948	0.047
2033	98662	7.47	94964	0.512	33570	4485	0.946	0.047
2034	98167	7.55	94472	0.517	33628	4476	0.943	0.047
2035	97608	7.59	93909	0.520	33661	4452	0.940	0.047
2036	97035	7.59	93330	0.520	33664	4414	0.938	0.047

Table 29: Differences in negative log-likelihood, estimates of key parameters, and estimates of derived quantities between the base model and several alternative models (columns). See main text for details on each sensitivity analysis. Red values indicate negative log-likelihoods that were lower (fit better to that component) than the base model.

Label	Base	No indices	- SMURF index	+ WC-GOP index	+ Oceano-graphic index	+ ORBS index	+ ORBS w/added SE	+ RREAS index	Decrease WCG-BTS CV
Diff. in likelihood from base model									
Total	0	-17.64	-7.46	-4.33	-2.61	608.72	-10.14	119.96	743.05
Index	0	NA	-5.329	-4.333	-2.07	52.5	-11.732	95.258	662.982
Length comp	0	-2.267	-0.878	0.116	-0.181	241.752	3.011	-1.914	18.365
Age comp	0	-3.11	-0.368	-0.074	-0.165	306.512	-1.499	15.84	55.401
Recruitment	0	1.978	-0.16	-0.037	0.001	7.709	0.099	5.955	6.282
Parm priors	0	0.29	0	0.001	0	0.232	0.009	-0.055	-0.051
Estimates of key parameters									
Recruitment unfished millions	36.63	50.379	37.093	36.436	36.431	13.884	36.689	34.382	13.668
log(R0)	10.509	10.827	10.521	10.503	10.503	9.538	10.51	10.445	9.523
M Female	0.157	0.174	0.157	0.157	0.157	0.093	0.157	0.153	0.104
M Male	0.136	0.151	0.136	0.136	0.136	0.082	0.137	0.132	0.09
L at Amax Female	52.9	53	52.9	52.9	52.9	52.1	53	52.9	52.9
L at Amax Male	47.866	47.956	47.866	47.866	47.866	47.142	47.956	47.866	47.866
Estimates of derived quantities									
Unfished age 4+ bio 1000 mt	134.984	149.322	136.73	134.15	134.222	127.099	134.093	133.621	110.65
B0 trillions of eggs	14.595	14.783	14.779	14.505	14.514	19.274	14.453	14.748	15.719
B2025 trillions of eggs	9.13	10.101	9.42	8.975	8.999	6.158	8.938	9.81	3.866
Fraction unfished 2025	0.626	0.683	0.637	0.619	0.62	0.32	0.618	0.665	0.246
Fishing intensity 2024	0.638	0.541	0.624	0.645	0.644	1.195	0.647	0.617	1.315
Catchability for WCGBTS	0.329	NA	0.324	0.332	0.331	0.446	0.329	0.328	0.603

Table 30: Differences in negative log-likelihood, estimates of key parameters, and estimates of derived quantities between the base model and several alternative models (columns). See main text for details on each sensitivity analysis. Red values indicate negative log-likelihoods that were lower (fit better to that component) than the base model.

Label	Base	Break-point M	No sex selectivity	Sex selectivity all fleets	Single M	Time-vary weight-length	Hybrid F method	Nonlinear WCG-BTS Q
Diff. in likelihood from base model								
Total	0	56.94	18.18	-27.36	59.74	0.48	-5.95	-3.15
Index	0	-0.001	-0.167	0.208	0.39	0.437	-0.518	-3.764
Length comp	0	23.471	13.671	-1.208	25.002	0.023	-0.637	-0.58
Age comp	0	31.691	4.531	-26.549	33.642	0.053	-4.124	1.307
Recruitment	0	0.752	0.161	0.178	0.905	-0.027	-0.628	-0.092
Parm priors	0	1.052	-0.016	0.025	-0.17	-0.003	-0.049	-0.013
Estimates of key parameters								
Recruitment unfished millions	36.63	11.339	36.613	36.152	18.35	36.483	33.699	35.907
log(R0)	10.509	9.336	10.508	10.496	9.817	10.505	10.425	10.489
M Female	0.157	0.059	0.156	0.158	0.112	0.156	0.153	0.156
M Male	0.136	0.059	0.136	0.132	0.112	0.136	0.132	0.135
M (old) Female	NA	0.115	NA	NA	NA	NA	NA	NA
L at Amax Female	52.9	52.7	53	52.9	52.8	52.9	53	52.9
L at Amax Male	47.866	47.685	47.956	47.866	47.775	47.866	47.956	47.866
Estimates of derived quantities								
Unfished age 4+ bio 1000 mt	134.984	113.567	135.92	136.122	115.239	134.36	130.335	133.99
B0 trillions of eggs	14.595	17.495	14.916	14.037	17.429	14.597	14.327	14.556
B2025 trillions of eggs	9.13	6.597	9.499	8.314	6.168	9.127	8.618	9.012
Fraction unfished 2025	0.626	0.377	0.637	0.592	0.354	0.625	0.601	0.619
Fishing intensity 2024	0.638	1.027	0.625	0.684	1.073	0.645	0.675	0.647
Catchability for WCGBTS	0.329	0.475	0.32	0.344	0.51	0.329	0.36	0

Table 31: Differences in negative log-likelihood, estimates of key parameters, and estimates of derived quantities between the base model and several alternative models (columns). See main text for details on each sensitivity analysis. Red values indicate negative log-likelihoods that were lower (fit better to that component) than the base model.

Label	Base	McAllister-Ianelli	- Fishery lengths	+ Unsexed commercial lengths	Raw commercial comps
Diff. in likelihood from base model					
Total	0	1260.87	-288.524	37.96	-55.92
Index	0	7.13	-1.588	0.253	1.067
Length comp	0	533.677	-240.8	35.889	-23.632
Age comp	0	712.662	-46.207	1.615	-32.402
Recruitment	0	6.683	0.215	0.166	-0.966
Parm priors	0	0.46	-0.116	0.034	-0.025
Estimates of key parameters					
Recruitment unfished millions	36.63	60.869	32.267	38.002	37.835
log(R0)	10.509	11.017	10.382	10.545	10.541
M Female	0.157	0.182	0.148	0.159	0.155
M Male	0.136	0.158	0.13	0.138	0.135
L at Amax Female	52.9	52.5	53.9	53	52.9
L at Amax Male	47.866	47.504	44.13	47.956	47.866
Estimates of derived quantities					
Unfished age 4+ bio 1000 mt	134.984	158.684	130.528	135.955	141.703
B0 trillions of eggs	14.595	15.535	15.606	14.528	15.588
B2025 trillions of eggs	9.13	12.005	8.664	9.194	9.966
Fraction unfished 2025	0.626	0.773	0.555	0.633	0.639
Fishing intensity 2024	0.638	0.45	0.738	0.628	0.619
Catchability for WCGBTS	0.329	0.231	0.413	0.325	0.312

7.3. Management

Table 32: Potential OFLs (mt), ABCs (mt), ACLs (mt), the buffer between the OFL and ABC, estimated spawning output (trillions of eggs), and fraction of unfished spawning output with adopted OFLs and ACLs and assumed catch for the first two years of the projection period.

Year	Adopted OFL (mt)	Adopted ACL (mt)	Assumed Catch (mt)	OFL (mt)	Buffer	ABC (mt)	ACL (mt)	Spawning output (trillions of eggs)	Fraction Unfished
2025	6,866	6,241	4,060	—	—	—	—	9.13	0.626
2026	6,662	6,023	4,066	—	—	—	—	8.77	0.601
2027	—	—	—	5,051	0.935	4,723	4,723	8.39	0.575
2028	—	—	—	4,882	0.930	4,540	4,540	7.95	0.545
2029	—	—	—	4,800	0.926	4,445	4,445	7.63	0.523
2030	—	—	—	4,794	0.922	4,421	4,421	7.43	0.509
2031	—	—	—	4,837	0.917	4,435	4,435	7.36	0.504
2032	—	—	—	4,892	0.913	4,467	4,467	7.39	0.506
2033	—	—	—	4,934	0.909	4,485	4,485	7.47	0.512
2034	—	—	—	4,952	0.904	4,476	4,476	7.55	0.517
2035	—	—	—	4,947	0.900	4,452	4,452	7.59	0.520
2036	—	—	—	4,926	0.896	4,414	4,414	7.59	0.520

Table 33: Decision table with 10-year projections. 'Mgmt' refers to the two management scenarios (A) the default harvest control rule $P^* = 0.45$ and sigma = 0.5, (B) Assuming an average ACL attainment of 55% (consistent with recent attainment) from 2027-2036. In each case the 2025 and 2026 catches are fixed at estimates provided by the GMT. The alternative states of nature ('Low', 'Base', and 'High' as discussed in the text) are provided in the columns, with Spawning Output ('Spawn', in trillions of eggs) and Fraction of unfished spawning output ('Frac') provided for each state.

Mgmt	Year	Catch	Low Spawn	Low Frac	Base Spawn	Base Frac	High Spawn	High Frac
A	2025	4060	7.75	0.539	9.13	0.626	10.38	0.693
	2026	4066	7.41	0.515	8.77	0.601	9.98	0.666
	2027	4723	7.06	0.490	8.39	0.575	9.57	0.639
	2028	4540	6.65	0.462	7.95	0.545	9.11	0.608
	2029	4445	6.33	0.440	7.63	0.523	8.76	0.585
	2030	4421	6.14	0.426	7.43	0.509	8.57	0.572
	2031	4435	6.06	0.421	7.36	0.504	8.51	0.568
	2032	4467	6.07	0.421	7.39	0.506	8.56	0.572
	2033	4485	6.12	0.425	7.47	0.512	8.66	0.578
	2034	4476	6.18	0.429	7.55	0.517	8.76	0.585
	2035	4452	6.21	0.431	7.59	0.520	8.81	0.588
	2036	4414	6.21	0.431	7.59	0.520	8.82	0.589
B	2025	4060	7.75	0.539	9.13	0.626	10.38	0.693
	2026	4066	7.41	0.515	8.77	0.601	9.98	0.666
	2027	2598	7.06	0.490	8.39	0.575	9.57	0.639
	2028	2497	6.95	0.483	8.26	0.566	9.41	0.628
	2029	2445	6.92	0.480	8.20	0.562	9.33	0.623
	2030	2431	6.97	0.484	8.25	0.565	9.37	0.626
	2031	2439	7.12	0.495	8.40	0.576	9.53	0.636
	2032	2457	7.35	0.510	8.64	0.592	9.77	0.652
	2033	2467	7.61	0.528	8.90	0.610	10.05	0.671
	2034	2462	7.86	0.546	9.16	0.628	10.32	0.689
	2035	2449	8.08	0.561	9.38	0.643	10.53	0.703
	2036	2428	8.25	0.573	9.54	0.654	10.68	0.713

Table 34: Catch projections for yellowtail rockfish north of 40°10' N. Lat. in 2025-2026 with detailed sector breakdown for each fleet used within the stock assessment. CP is catcher processor, MSCV is mother ship catcher vessel, and IFQ is individual fishing quota. All units are in metric tons.

	At-sea hake	Commercial				Recreational		
Catch Projection Year	CP & MSCV	IFQ	Tribal Shoreside	Incidental	Non-Trawl Commercial	WA Rec.	OR Rec.	CA Rec.
2025	360	3112	350	23	12	100	100	3.1
2026	360	3018	450	23	12	100	100	3.1

8. Figures

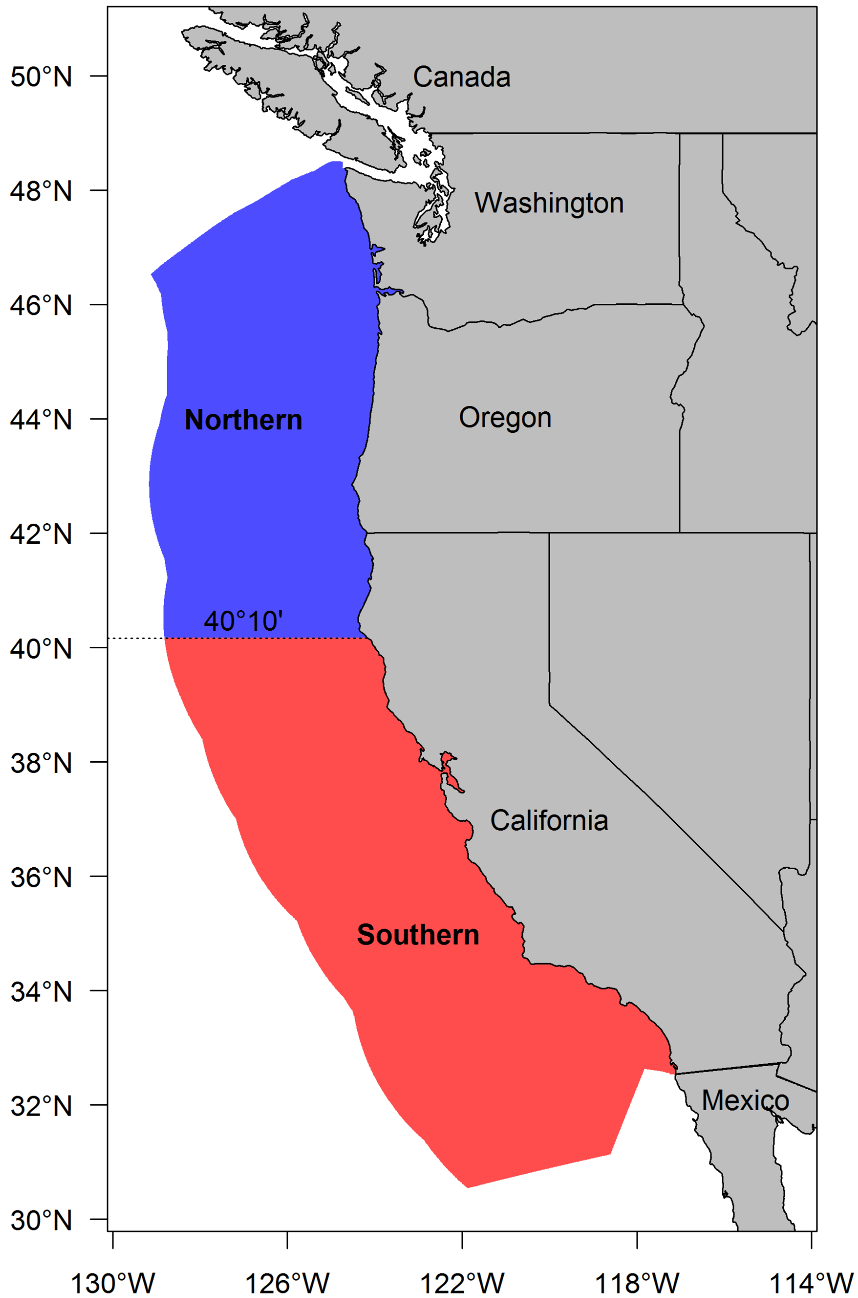

Figure 6: Map depicting the two genetic stocks of yellowtail rockfish within the U.S. West Coast Exclusive Economic Zone.

8.1. Data

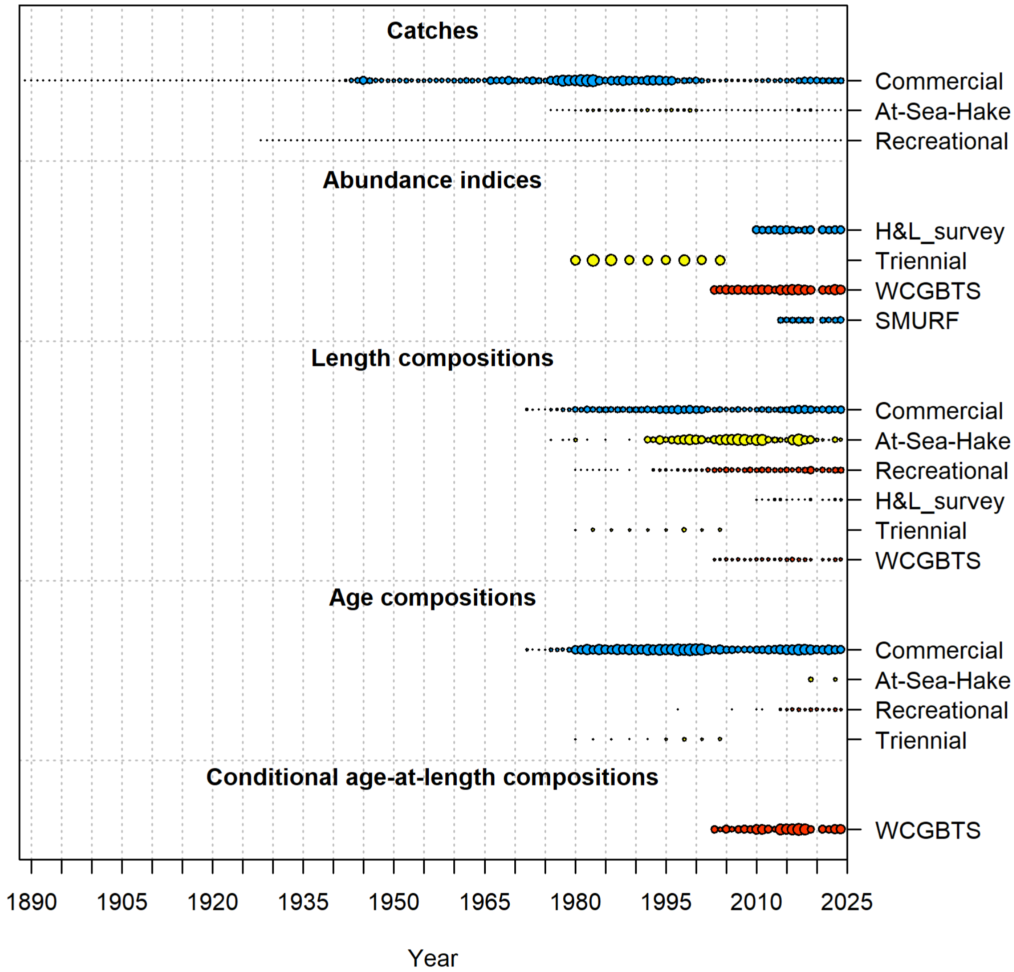

Figure 7: Data presence by year for each fleet, where circle area is relative within a data type. Circles are proportional to total catch for catches; to precision for indices, discards, and mean body weight observations; and to total sample size for compositions and mean weight- or length-at-age observations. Observations excluded from the likelihood have equal size for all years.

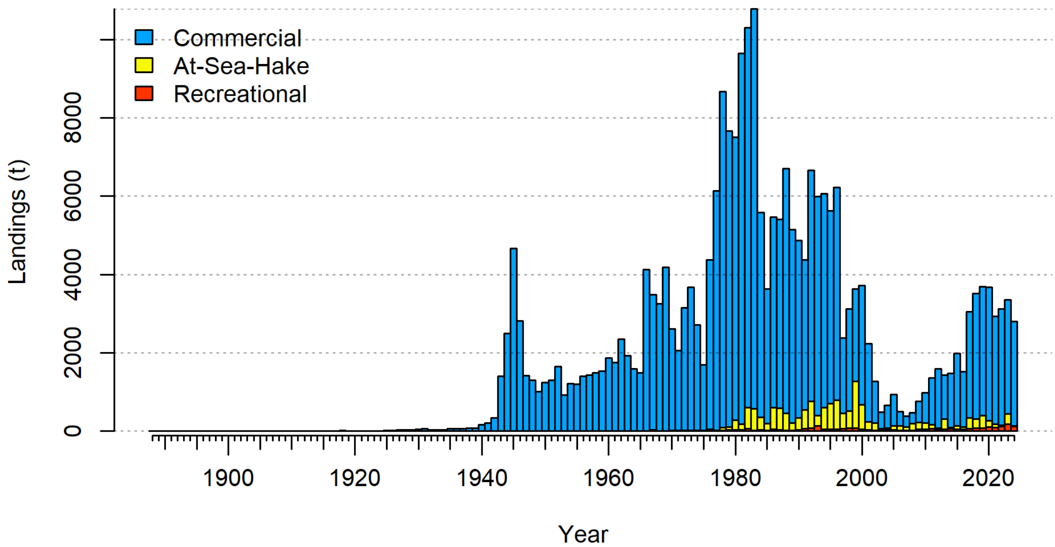

Figure 8: Total catch (mt) by fleet (including discards) used in the base model.

8.1.1. Indices

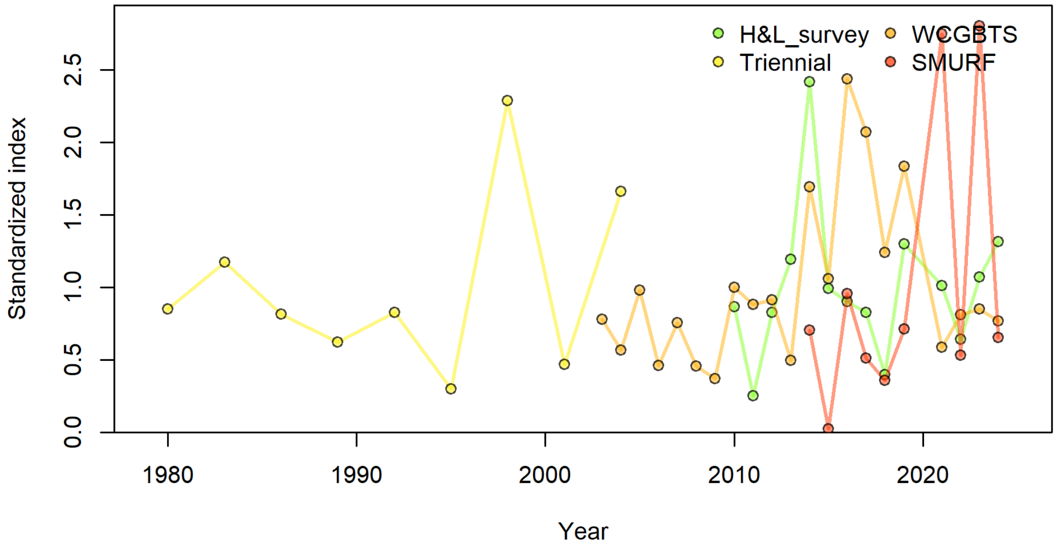

Figure 9: Indices used in the model, each of which is scaled to have mean 1.0.

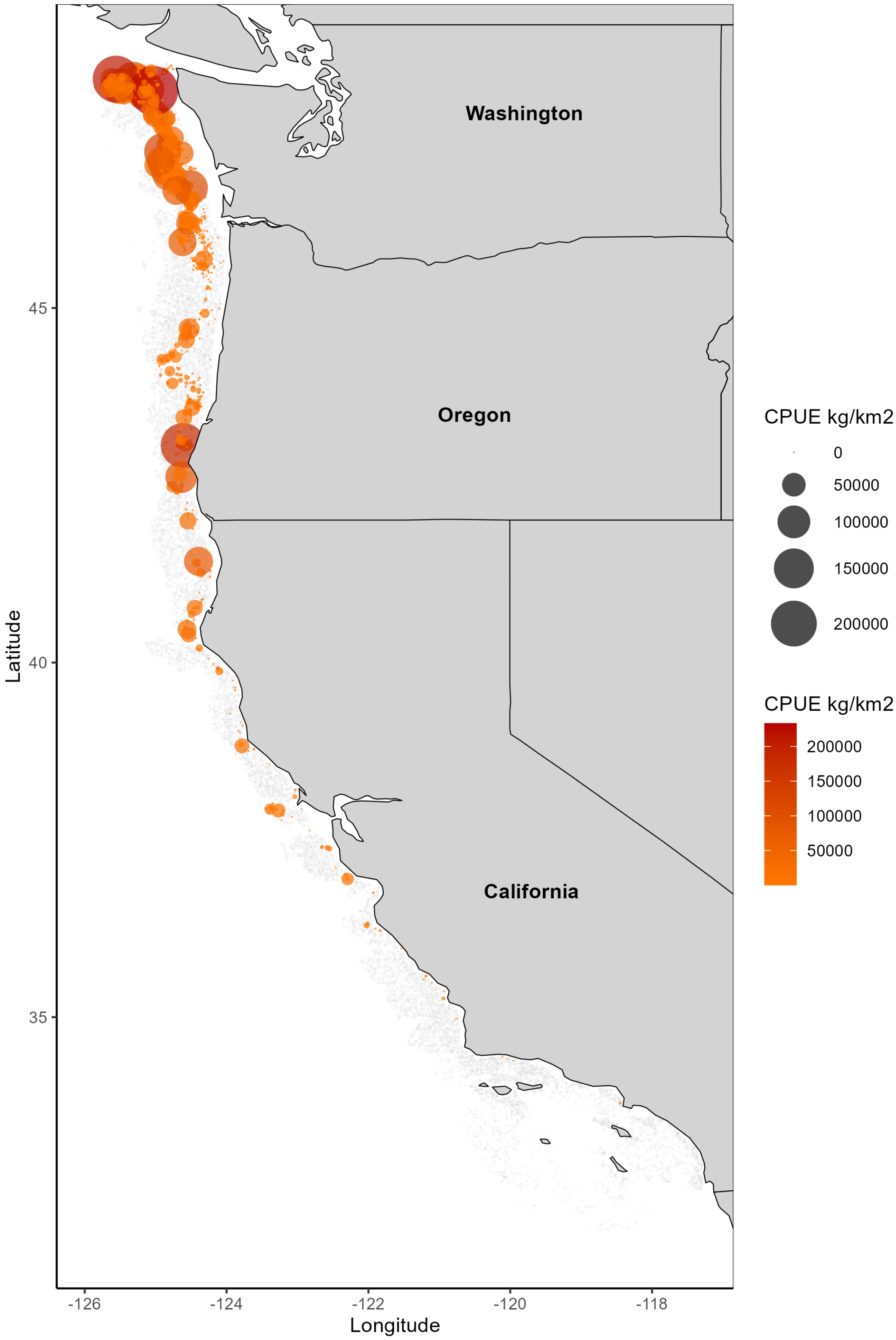

Figure 10: Distribution of catch in the WCGBTS.

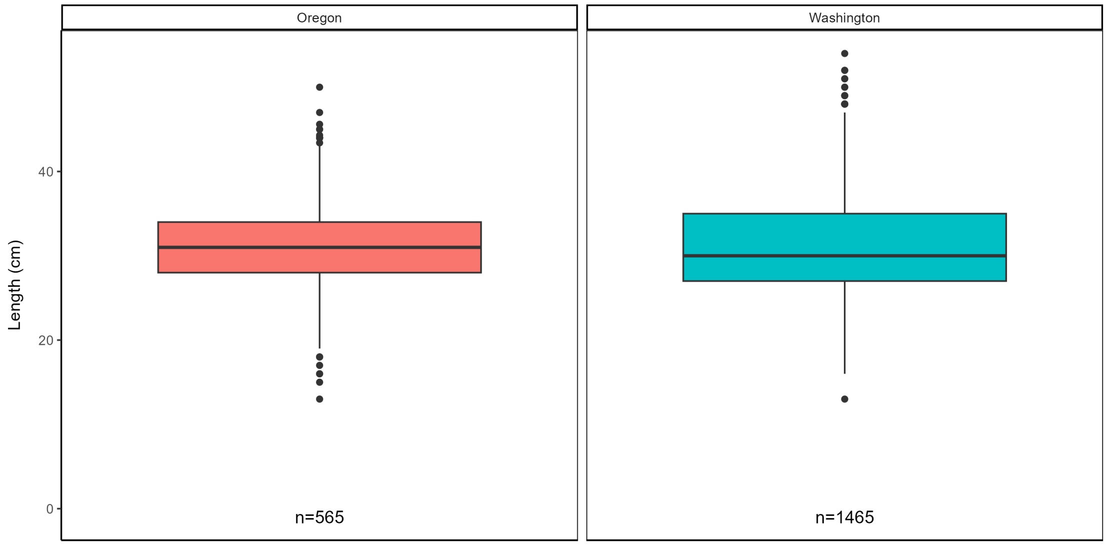

Figure 11: Comparison of lengths (cm) of fish caught in the Oregon and Washington hook and line surveys.

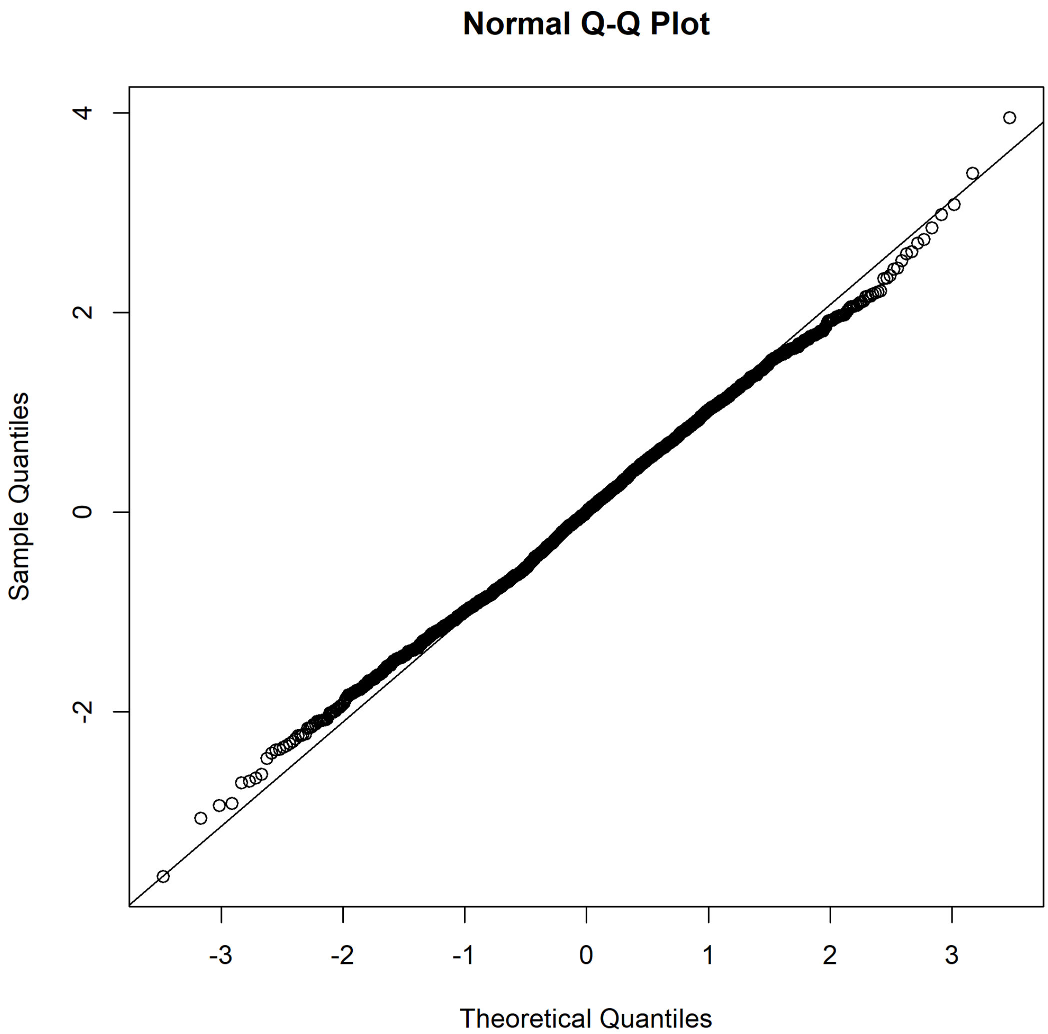

Figure 12: Q-Q plot diagnostics for the combined Oregon and Washington hook and line surveys.

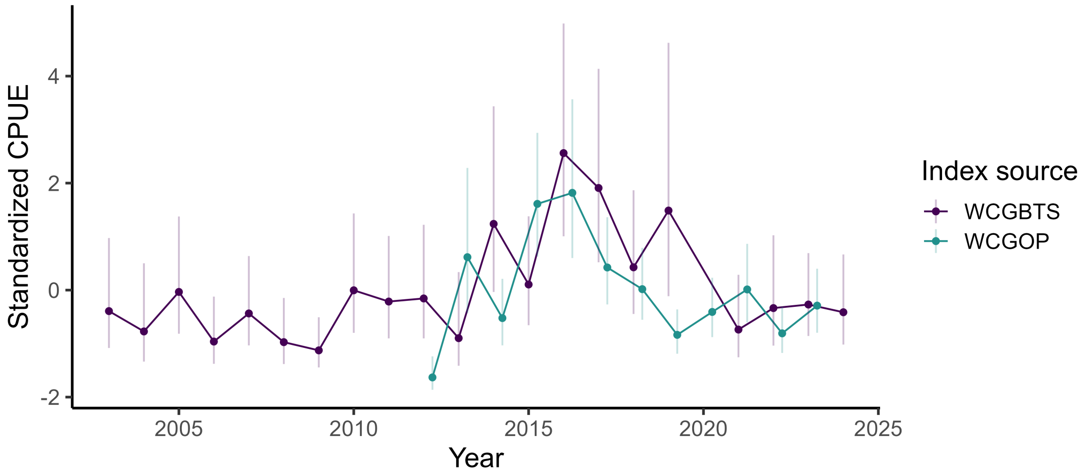

Figure 13: Time series of the observer program (WCGOP) index overlaid with the bottom trawl survey (WCGBTS) index, standardized to be on the same scale.

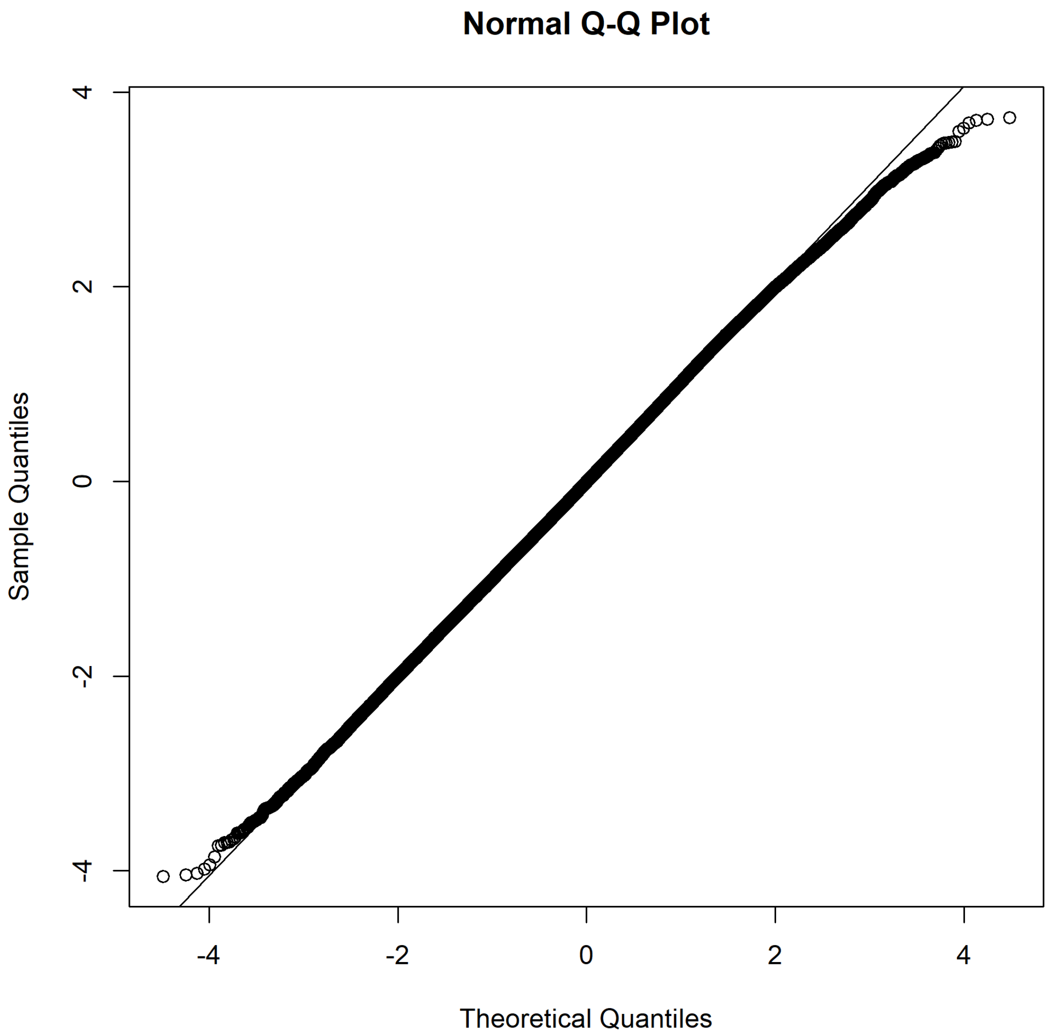

Figure 14: Q-Q plot diagnostics for ORBS index.

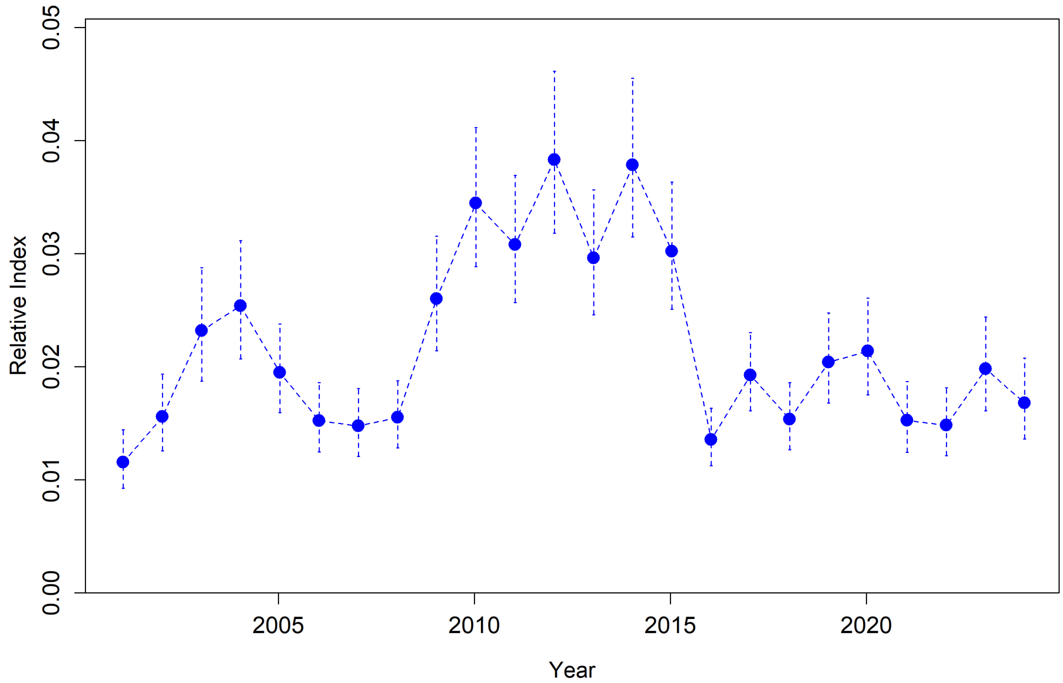

Figure 15: Time series of the relative index of abundance from ORBS dockside sampling from ODFW.

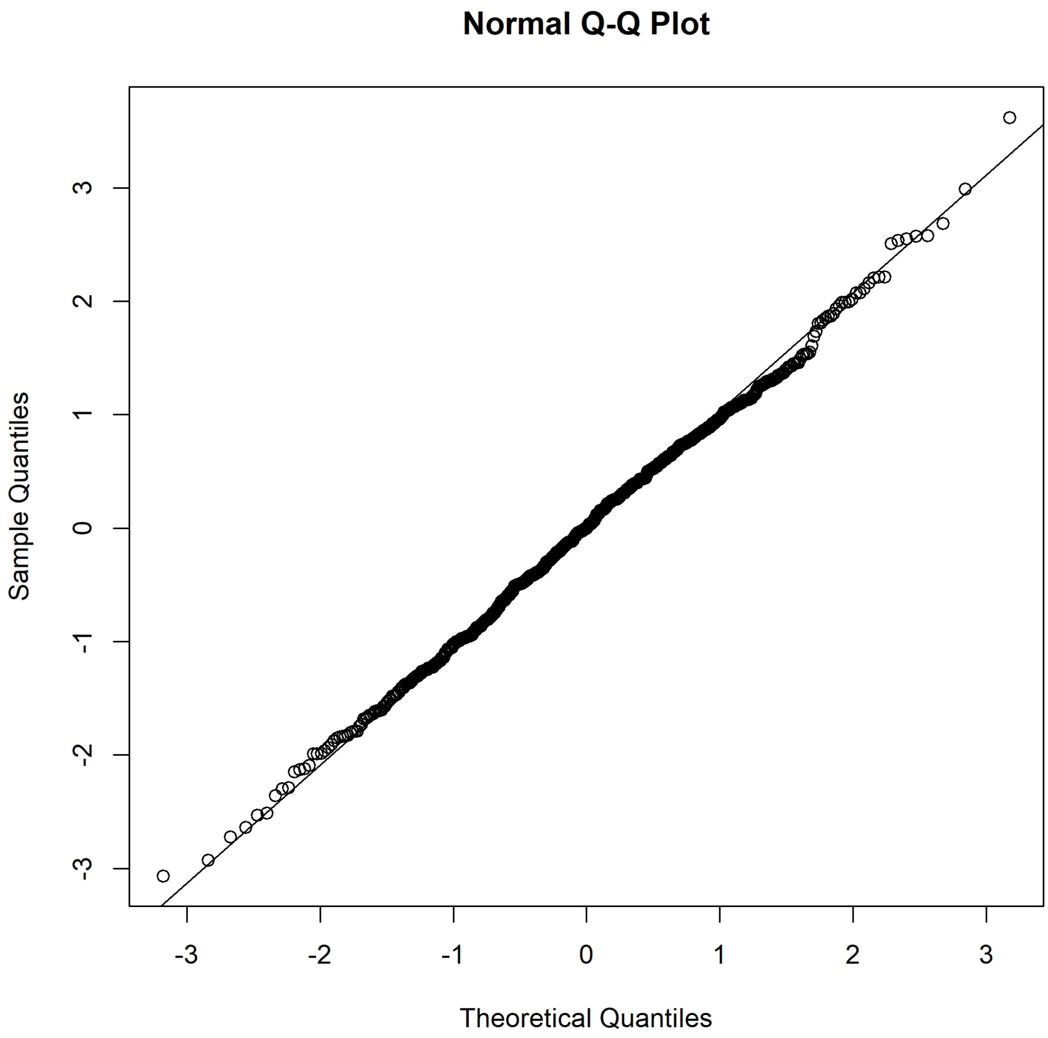

Figure 16: Q-Q plot diagnostics for SMURF YOY index.

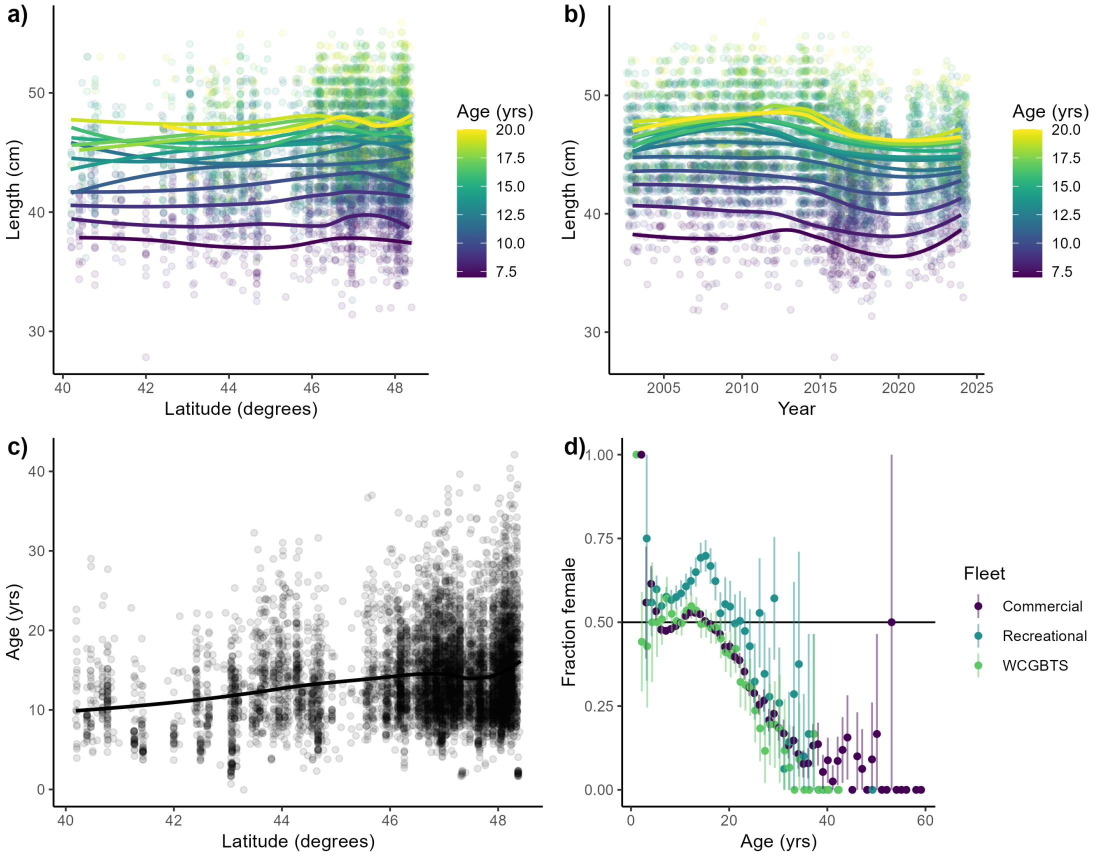

Figure 17: Plots of biological patterns in the data. Smoothed lines are loess smoothers. Data in panels (a)-(c) are from the WCGBTS, and points in those panels are jittered to avoid overplotting. Ranges in panel (d) are 95% confidence intervals, and the horizontal line is at 0.5.

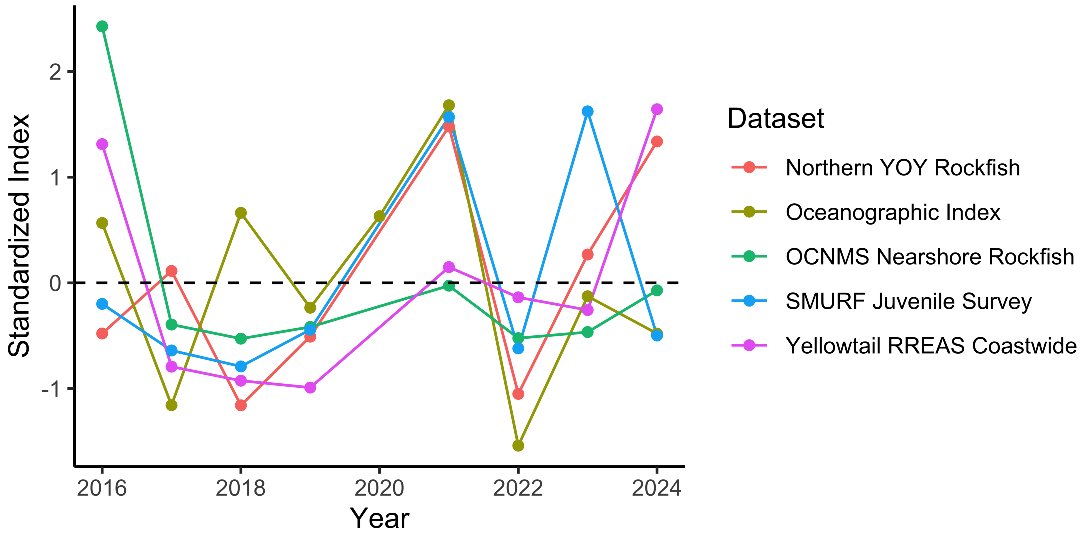

Figure 18: Indices of recruitment and age-0 abundance standardized by subtracting the mean and dividing by the standard deviation for the 2016 - 2024 time period.

8.1.2. Composition data

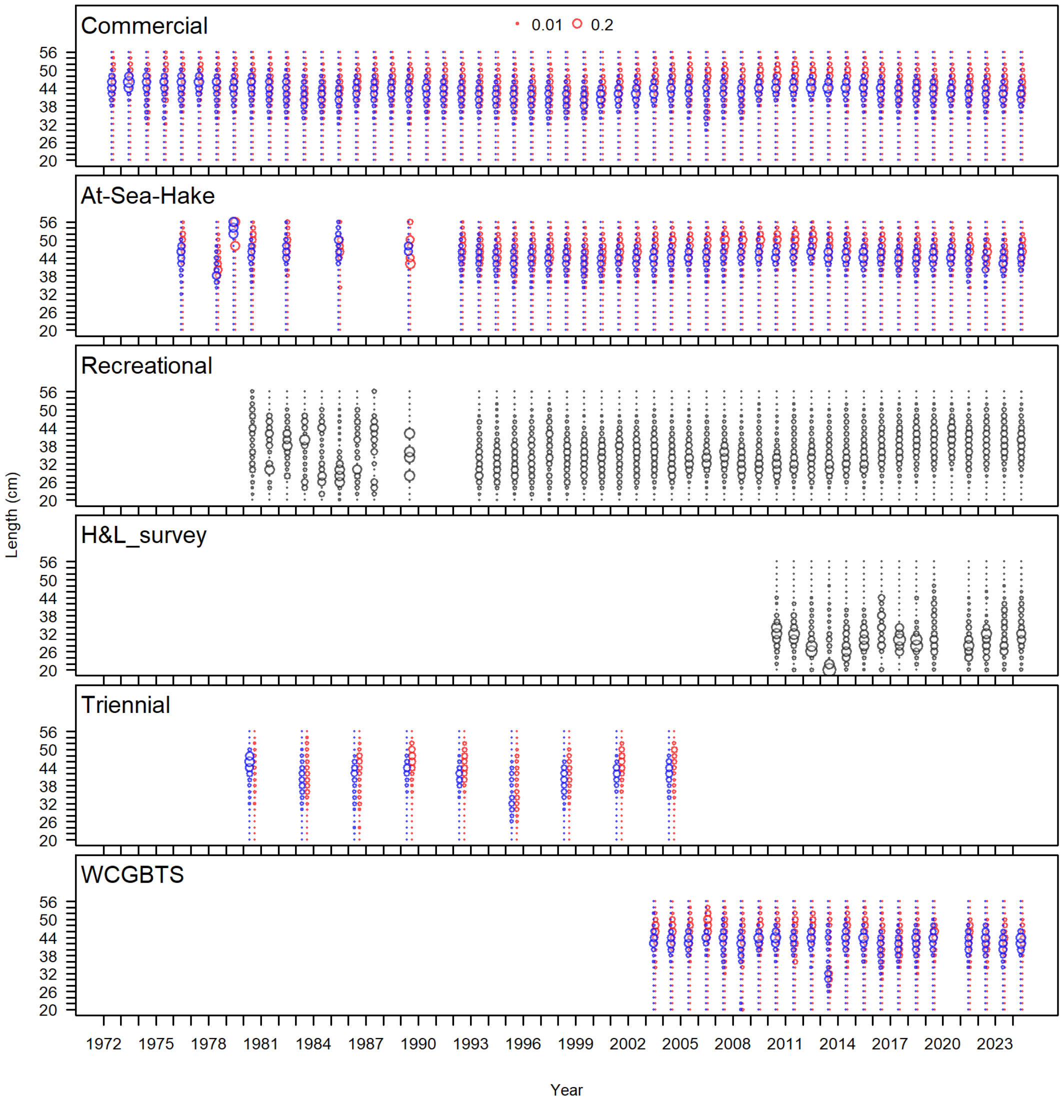

Figure 19: Length composition data for all fleets (red female, blue male, grey unsexed).

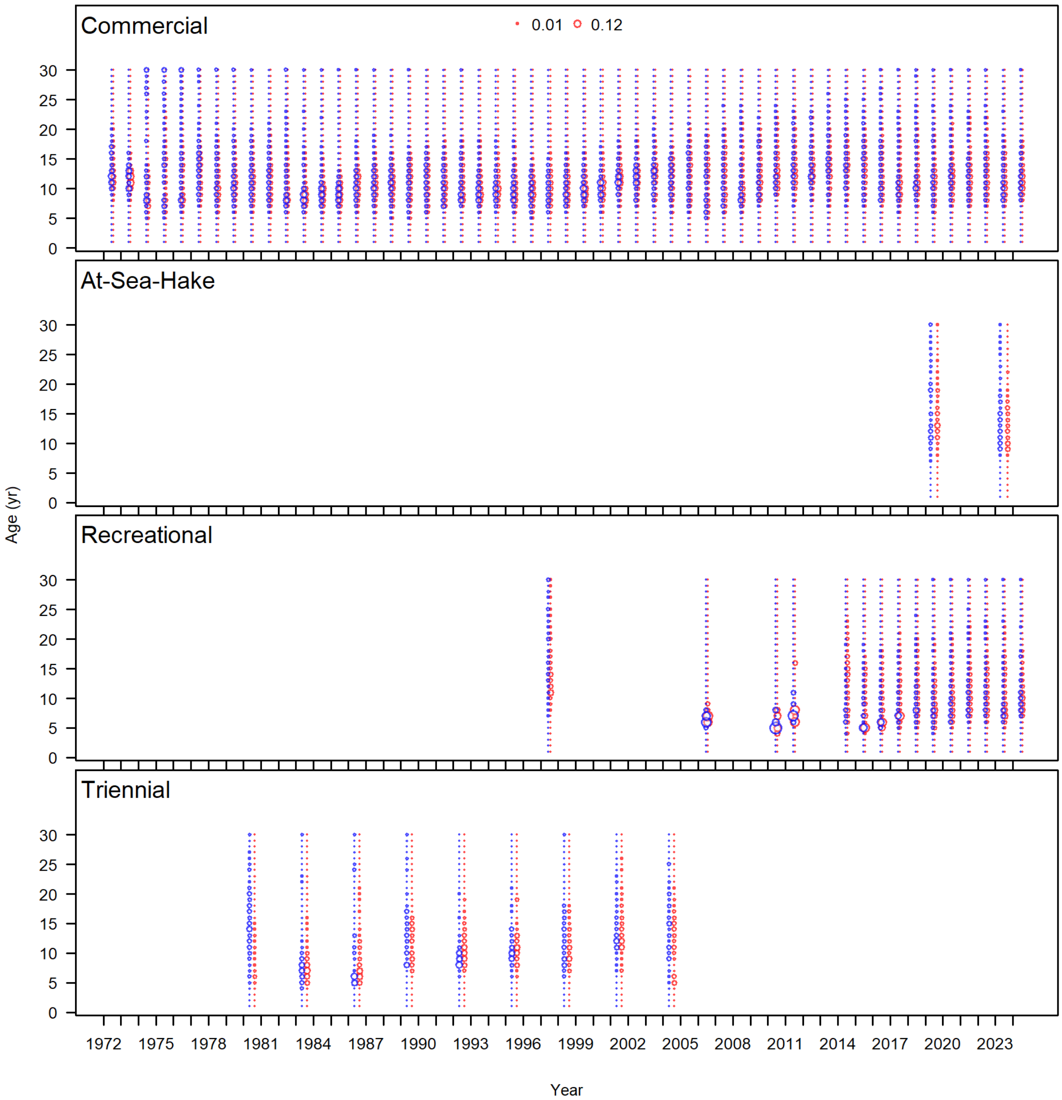

Figure 20: Marginal age composition data for all fleets (red female, blue male, grey unsexed). The WCGBTS ages are not included as they are conditioned on length.

8.1.3. Biological data

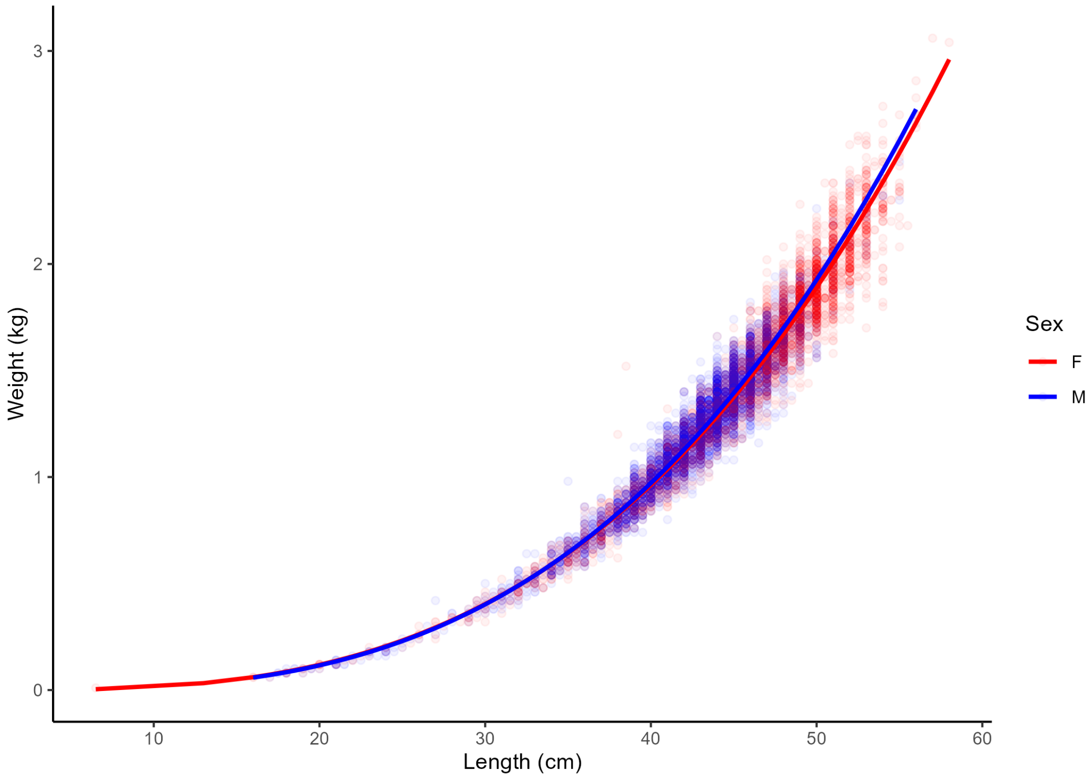

Figure 21: Length-weight relationship with fitted data

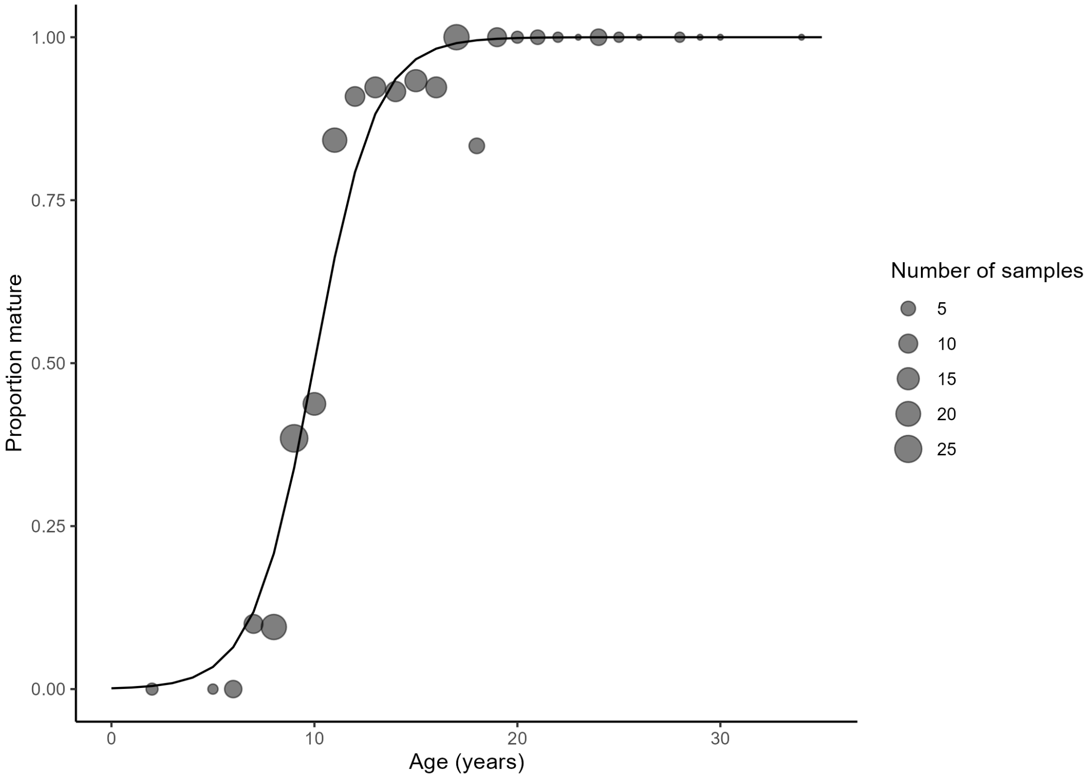

Figure 22: Maturity curve with fitted data.

8.2. Model

8.2.1. Bridging

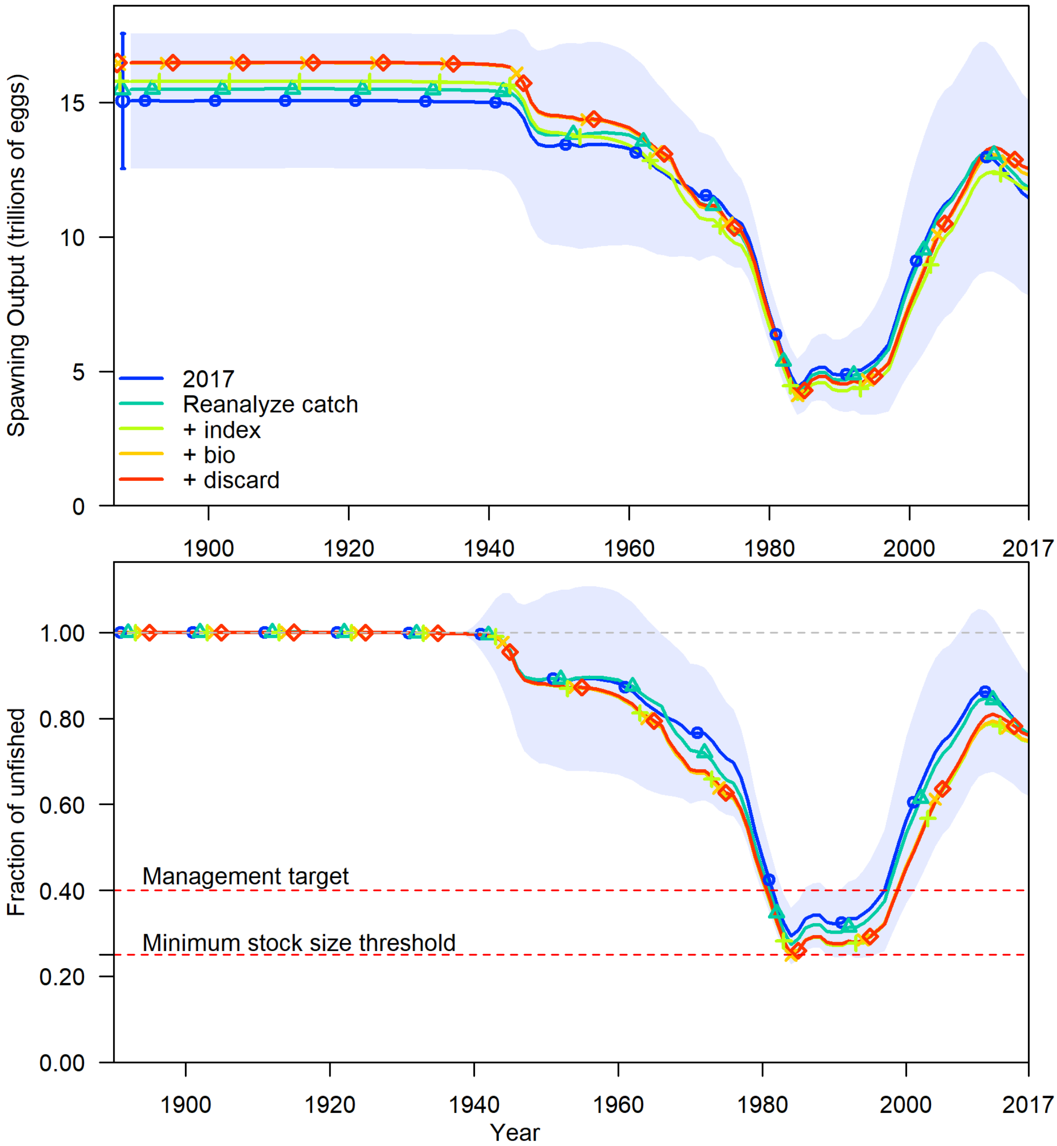

Figure 23: Spawning output (trillions of eggs, top), and relative spawning output (bottom) from first steps in model bridging. Catches from recreational fleets are combined when catch is updated. Uncertainty is only shown for the 2017 model.

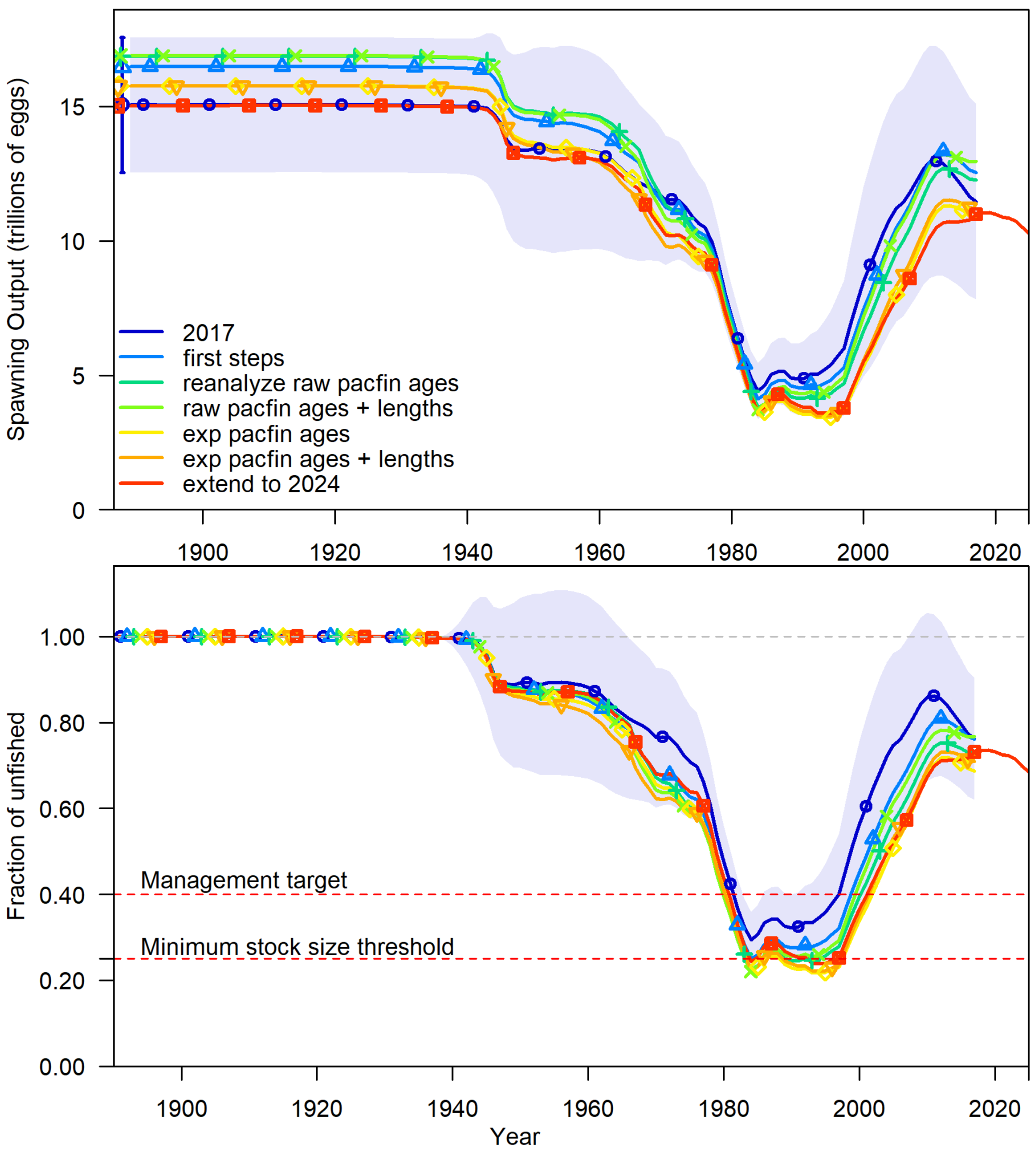

Figure 24: Spawning output (trillions of eggs, top), and relative spawning output (bottom) from second steps (updating composition data) in model bridging. “Exp” is expanded PacFIN data. Composition data from recreational fleets are combined as length and age data are renanalyzed. Every model run includes two rounds of Francis tuning of composition data. Bias adjustment ramp is updated when data are extended. Uncertainty is only shown for the 2017 model.

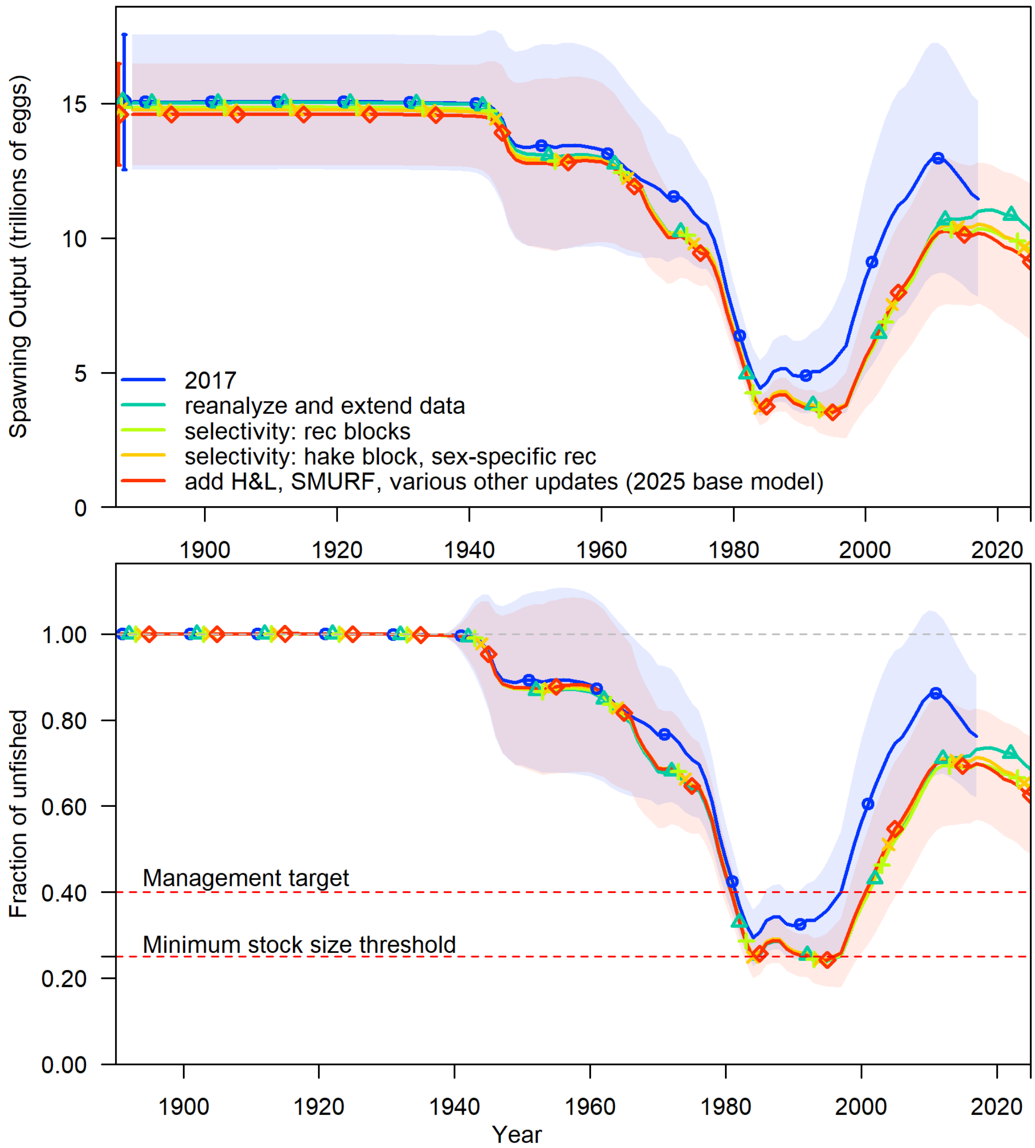

Figure 25: Spawning output (trillions of eggs, top), and relative spawning output (bottom) from third steps (model changes) in model bridging. Uncertainty is shown for the 2017 model and the final bridging step (the 2025 base model).

8.2.2. Biology

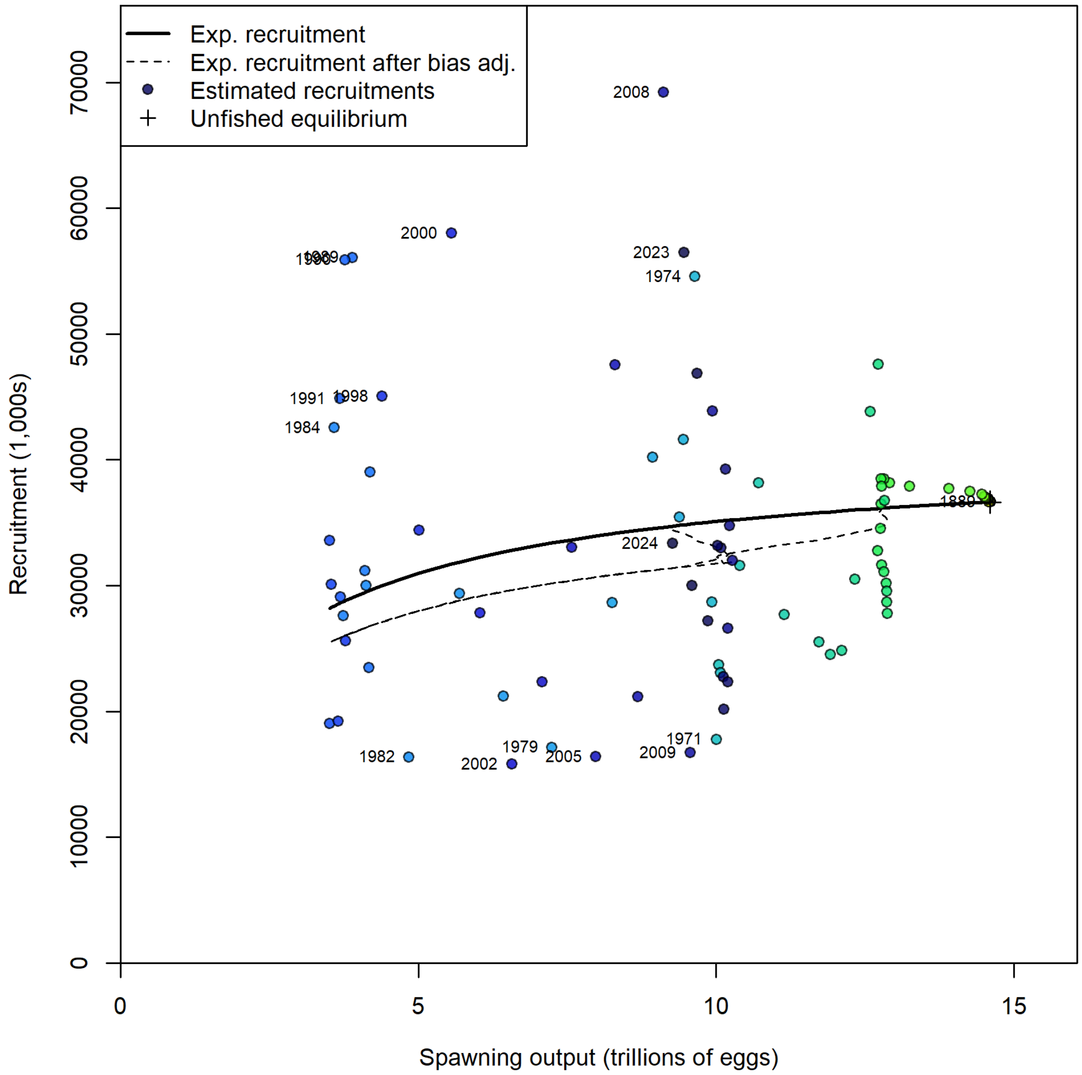

Figure 26: Stock-recruit curve with labels on first, last, and years with (log) deviations > 0.5. Point colors indicate year, with warmer colors indicating earlier years and cooler colors in showing later years.

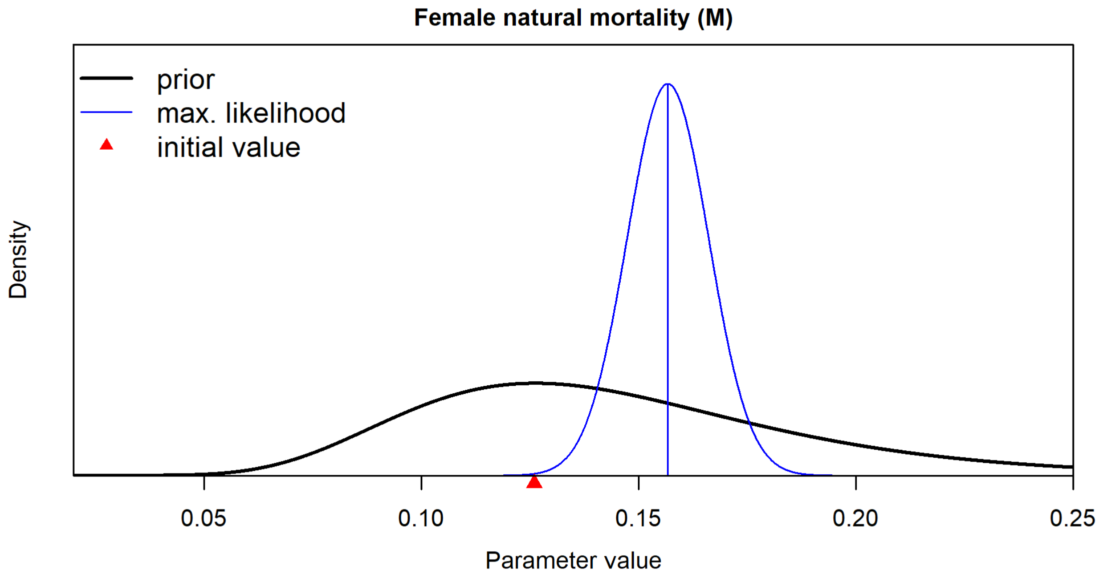

Figure 27: Prior distributions and parameter estimates for female natural mortality. Black lines show prior distributions, blue lines show maximum likelihood estimate and associated uncertainty. Male natural mortality is represented as an offset from females and does have an associated prior distribution.

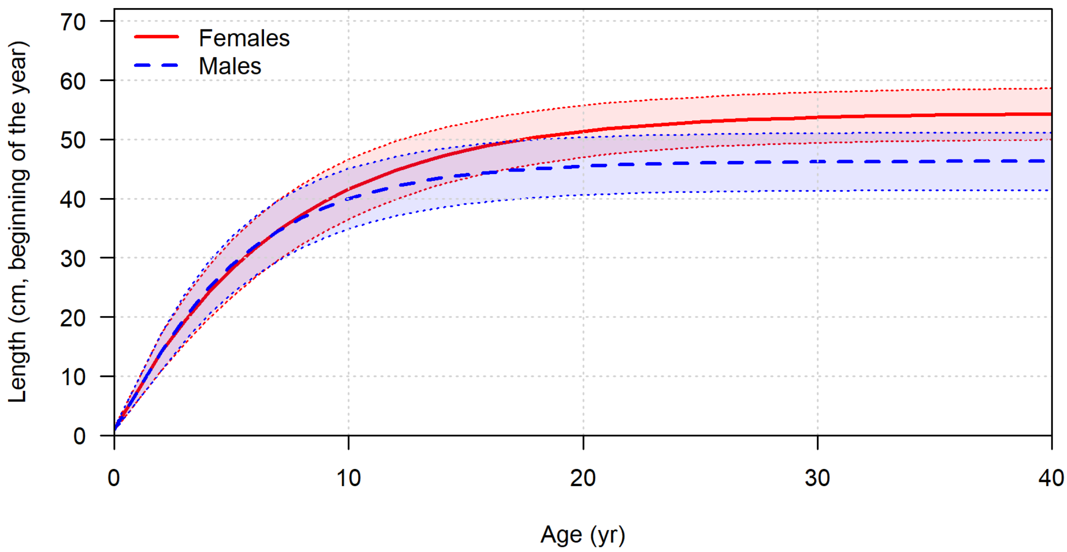

Figure 28: Model estimated length-at-age in the beginning of the year. Shaded area indicates 95 percent distribution of length-at-age around the estimated growth curve.

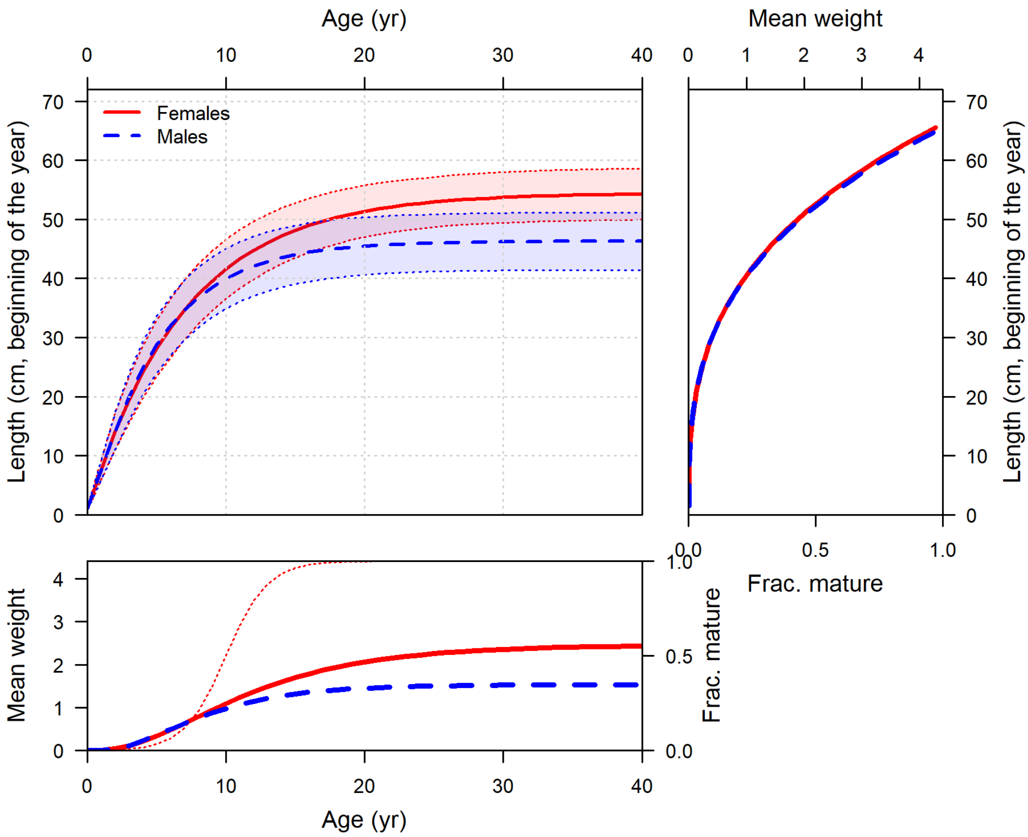

Figure 29: Relationship between growth, maturity, and weight. Length at age is in the top-left panel with weight (thick lines) and maturity (thin lines) shown in top-right and lower-left panels.

8.2.3. Selectivity

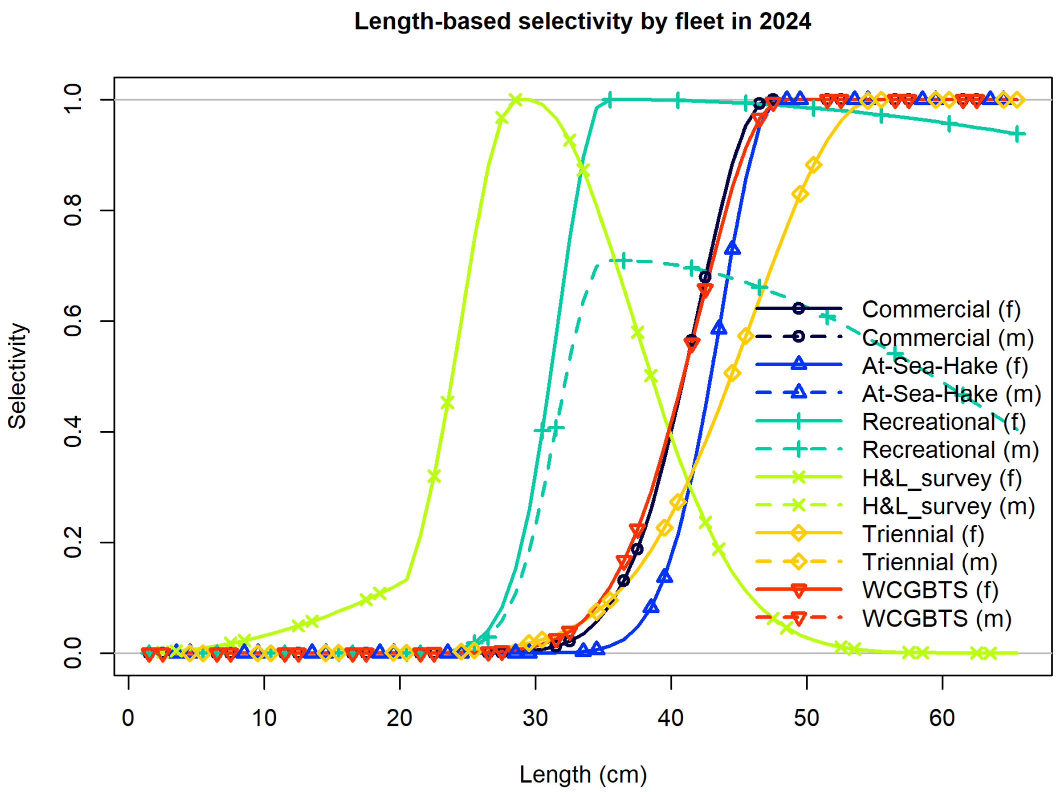

Figure 30: Ending-year selectivity at length for multiple fleets. Solid lines are female selectivity, dashed are male. The SMURF fleet is not shown because the recruitment index bypasses the selectivity dynamics in SS3.

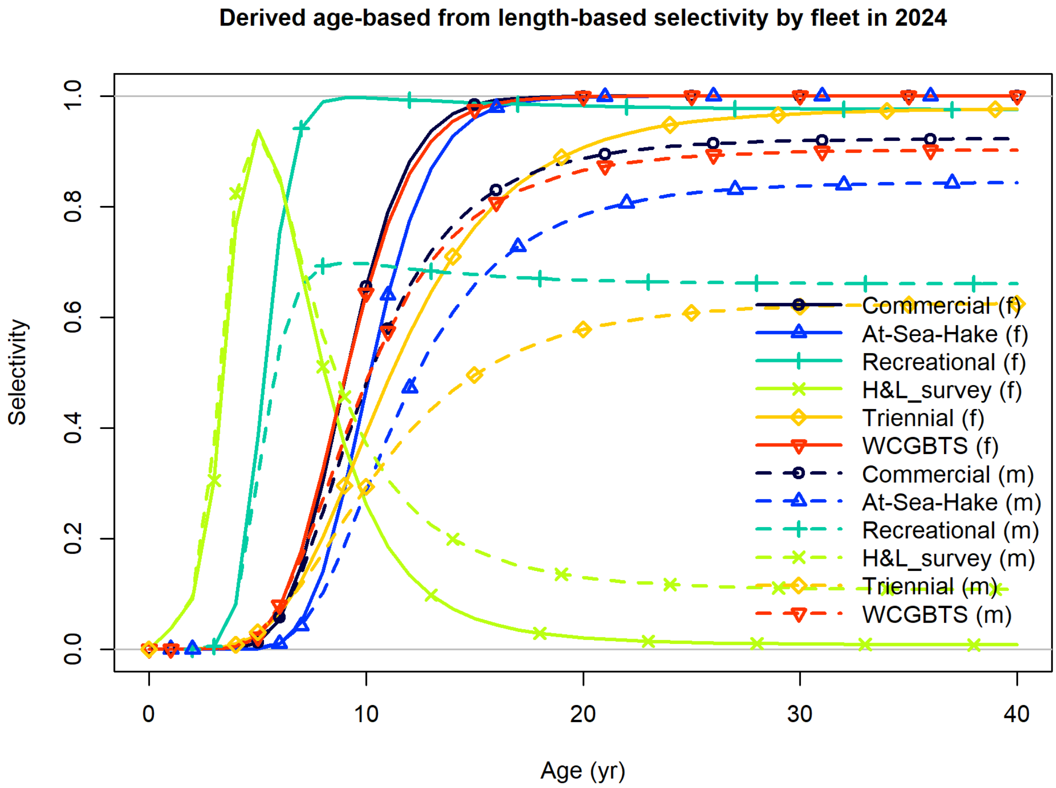

Figure 31: Ending-year selectivity at age derived from selectivity at length (solid female, dashed male). The SMURF fleet is not shown because the recruitment index bypasses the selectivity dynamics in SS3.

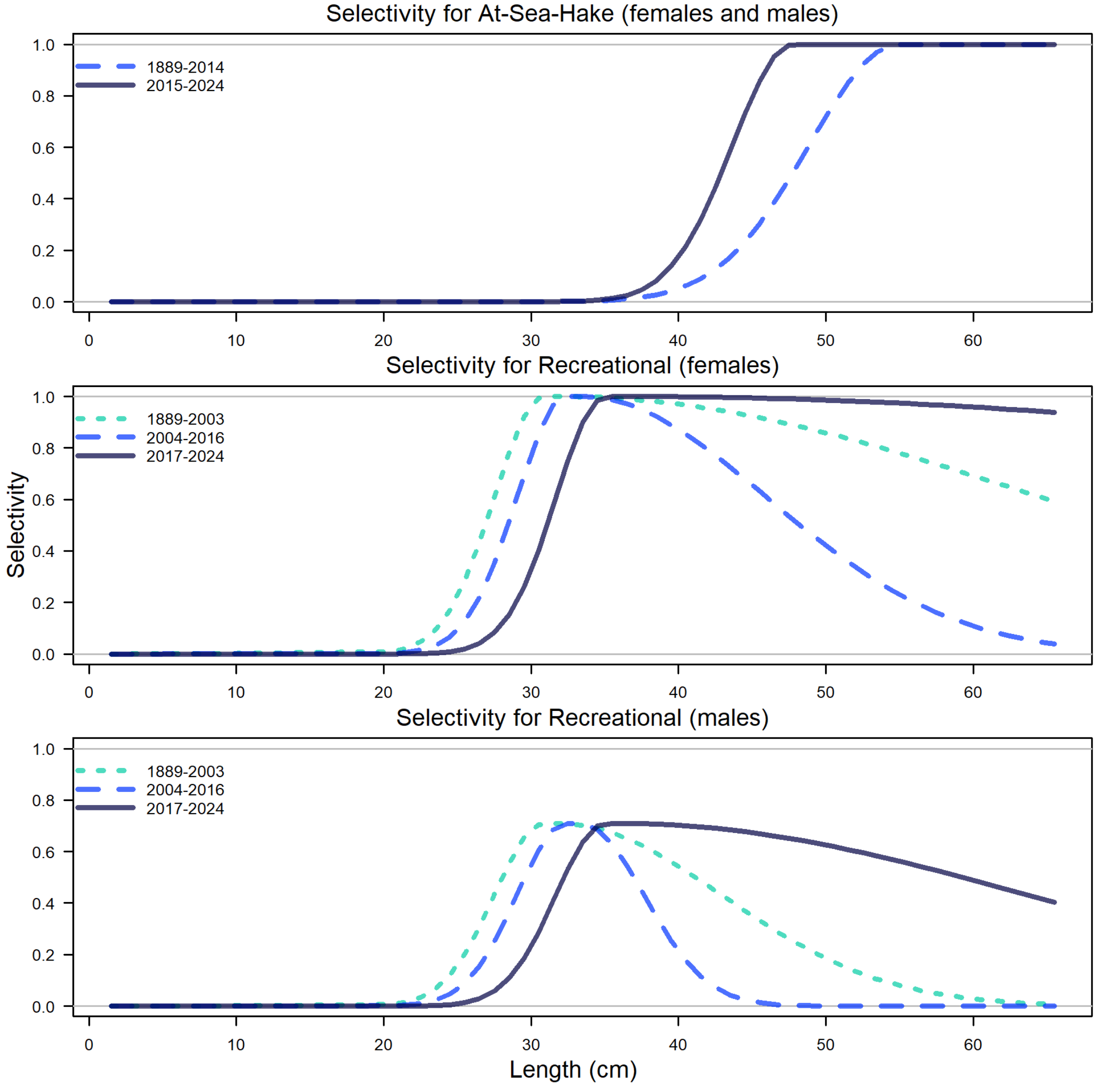

Figure 32: Selectivity by time period for those fleets with time-varying selectivity.

8.2.4. Fits to data

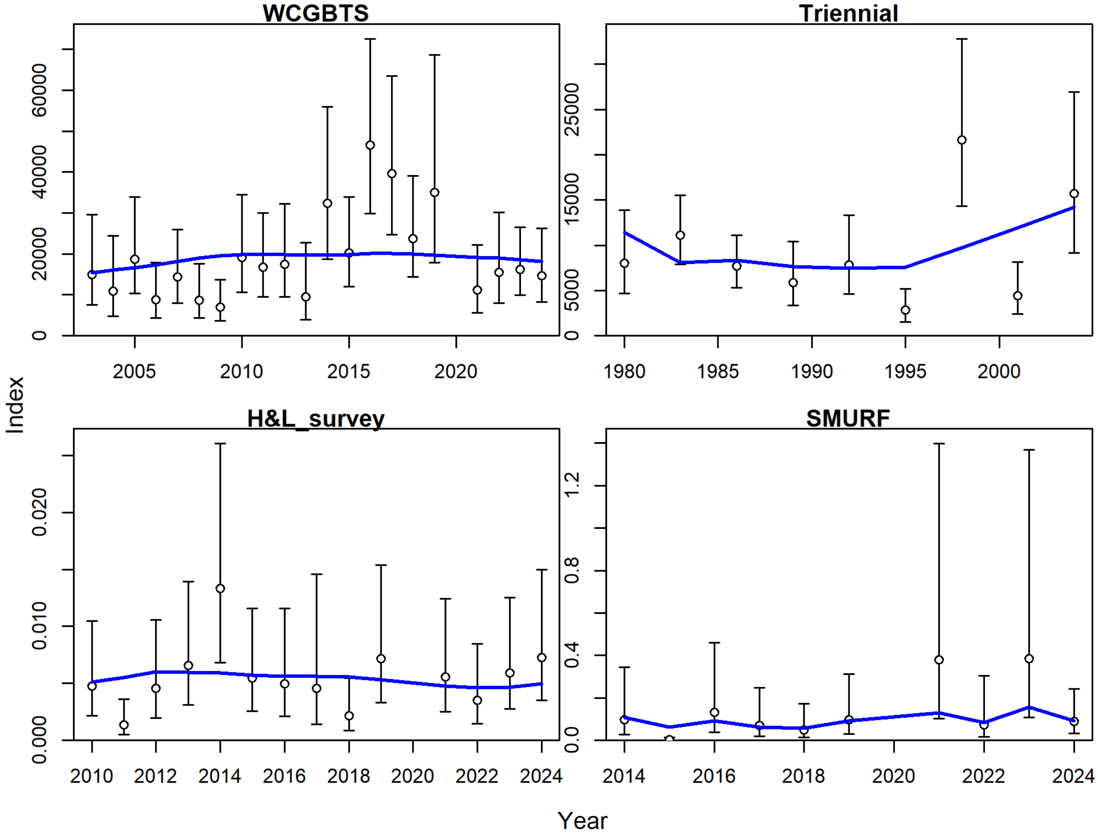

Figure 33: Fit to all indices used in the model. Blue line is expected value, black circles are point estimates and whiskers show 95% intervals based on input uncertainty. No extra standard error was estimated for any of the indices.

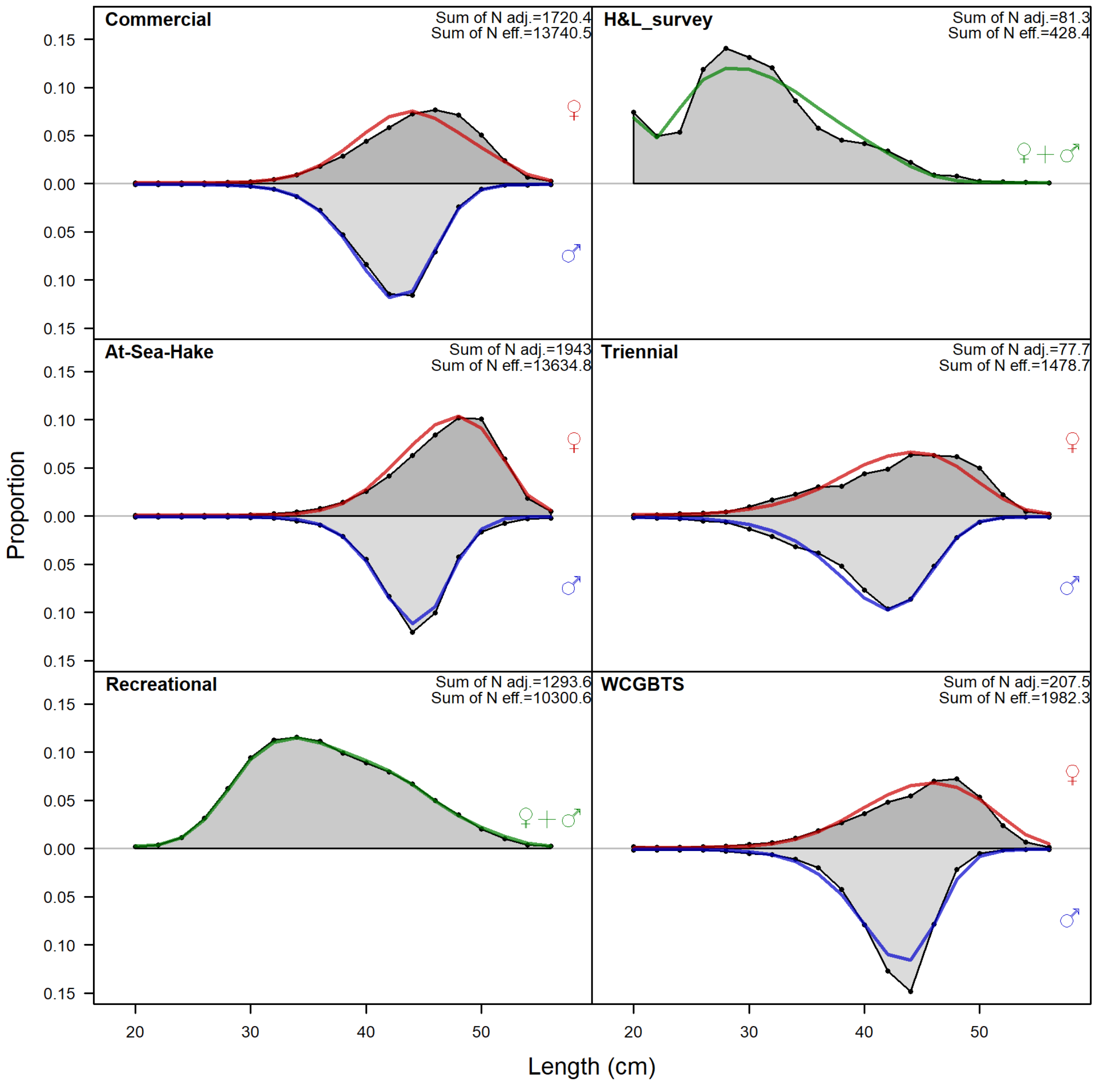

Figure 34: Length composition aggregated across years by fleet with the model with estimated fit to the data by sex (red female, blue male, green unsexed).

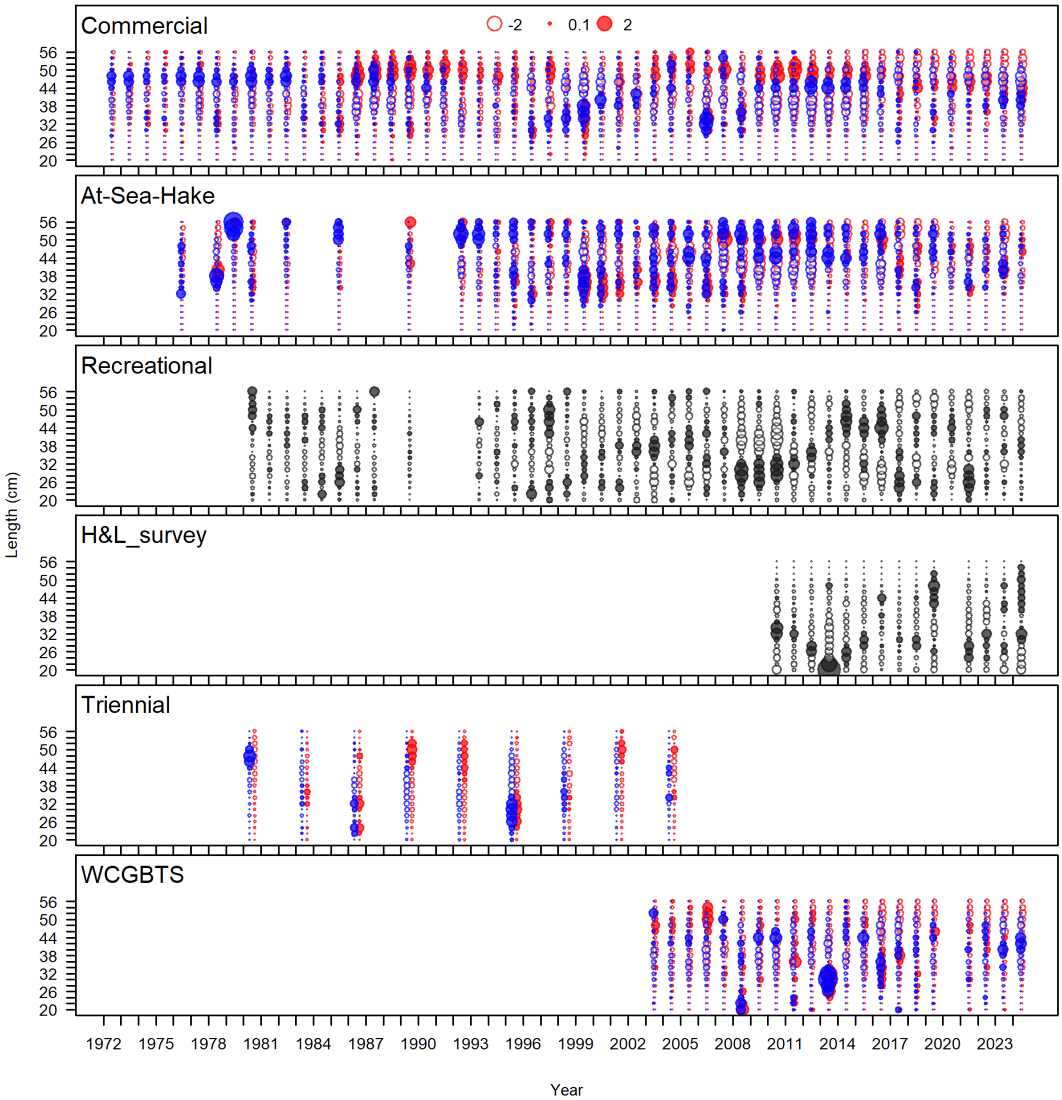

Figure 35: Pearson residuals for fit to length composition data for all fleets (red female, blue male, grey unsexed). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

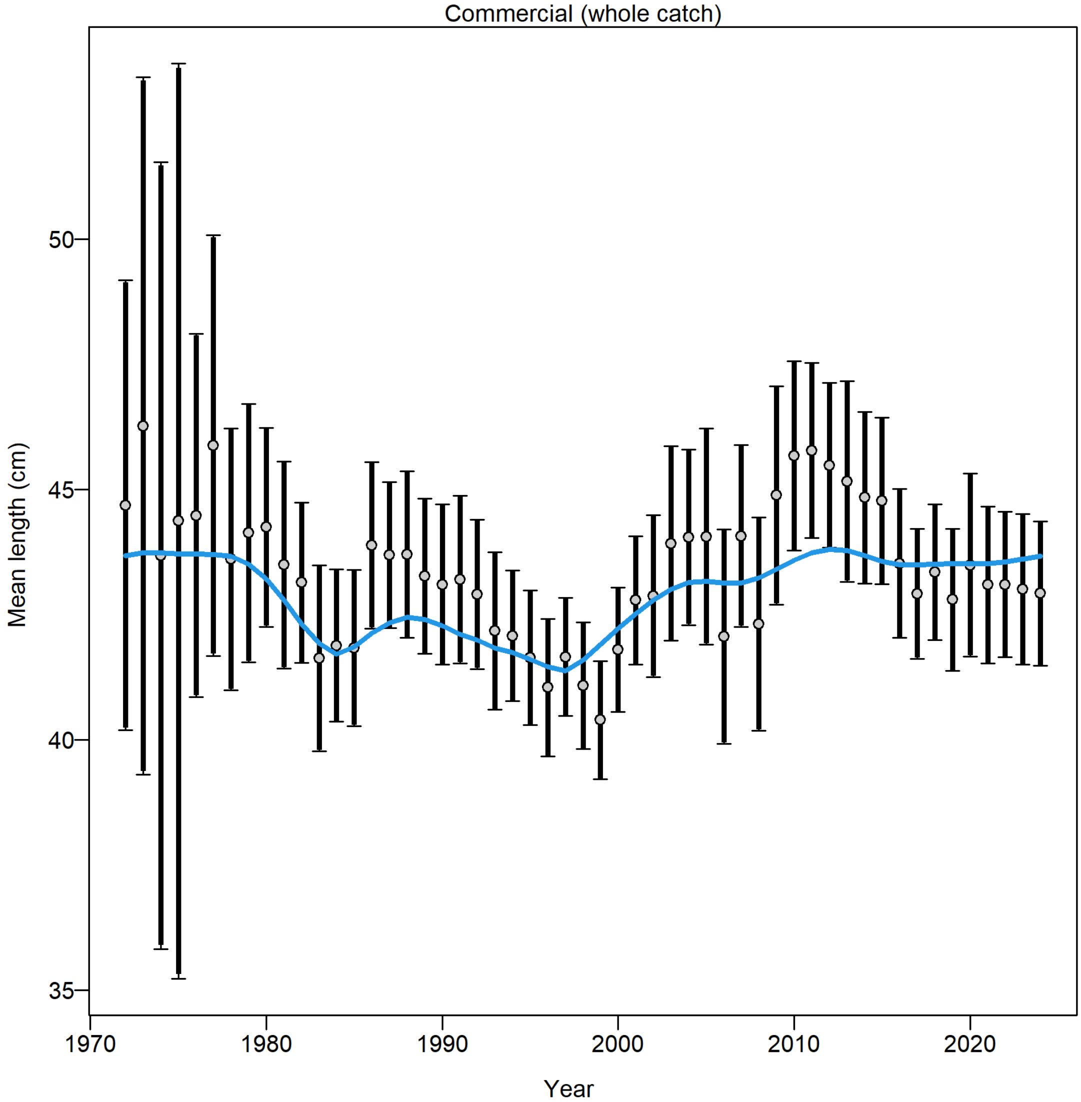

Figure 36: Mean length (cm) for Commercial with 95% confidence intervals based on adjusted input sample sizes. The blue line is the model expectation.

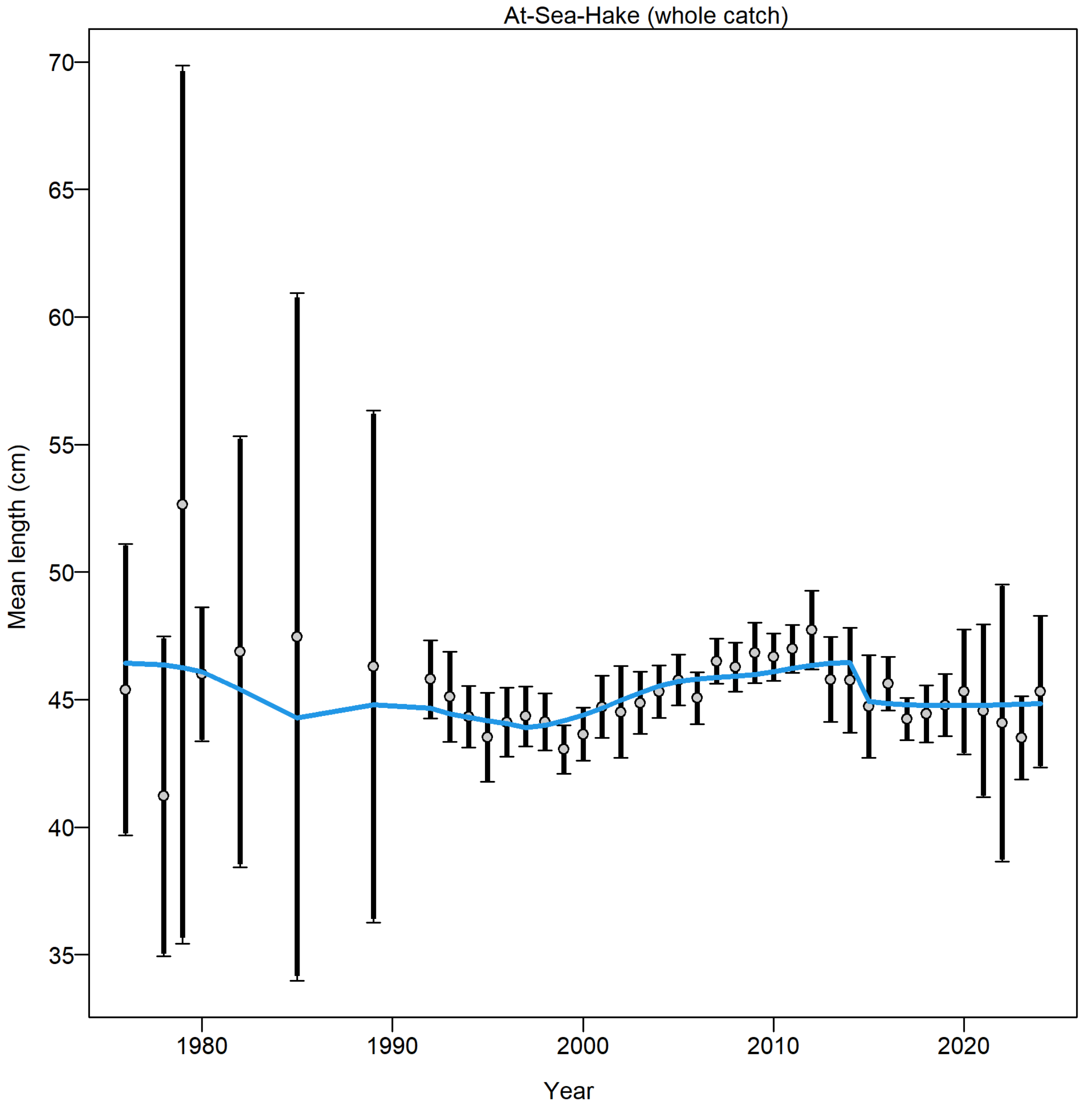

Figure 37: Mean length (cm) for At-Sea Hake with 95% confidence intervals based on adjusted input sample sizes. The blue line is the model expectation.

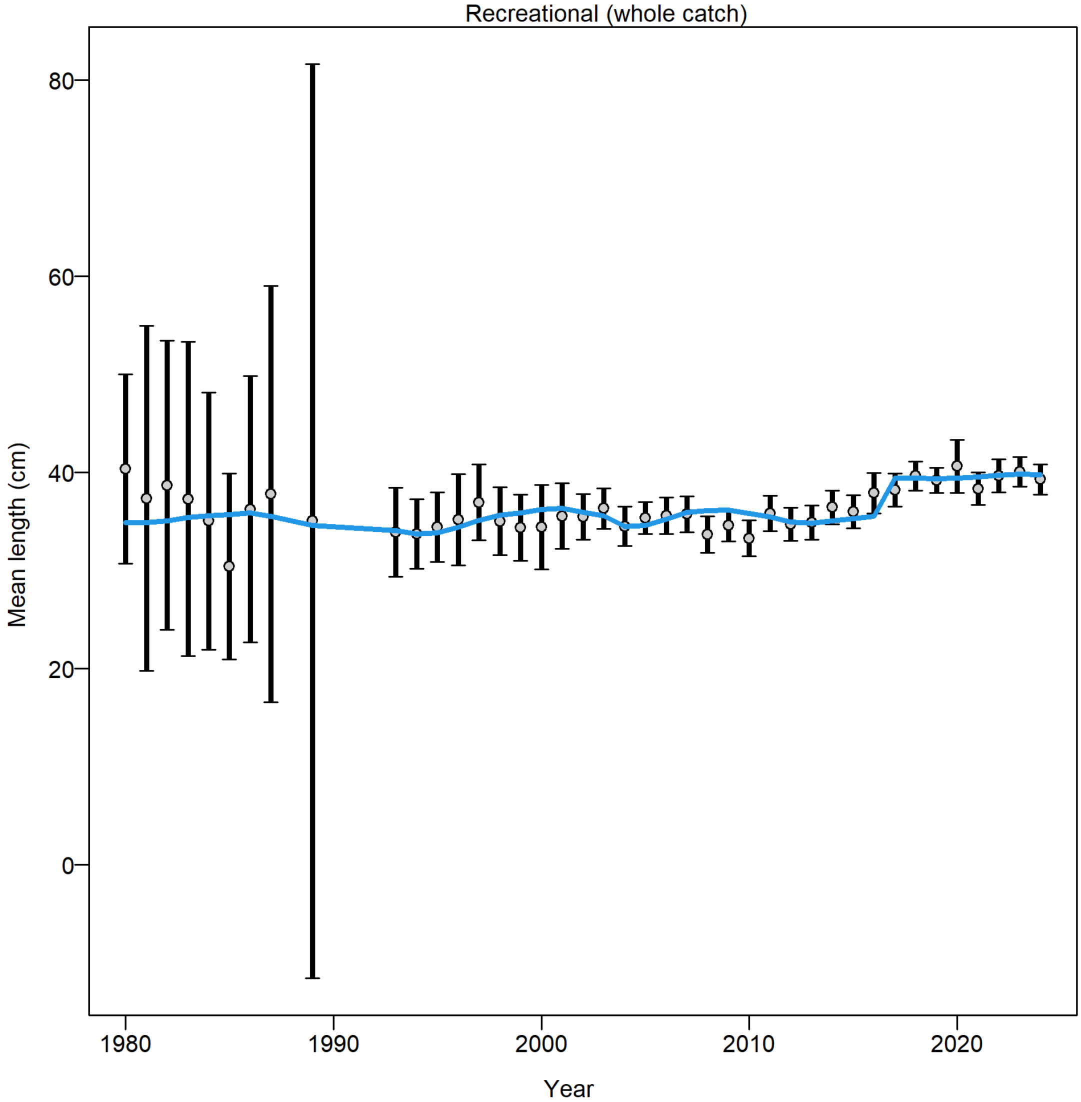

Figure 38: Mean length (cm) for the Recreational fleet with 95% confidence intervals based on adjusted input sample sizes. The blue line is the model expectation.

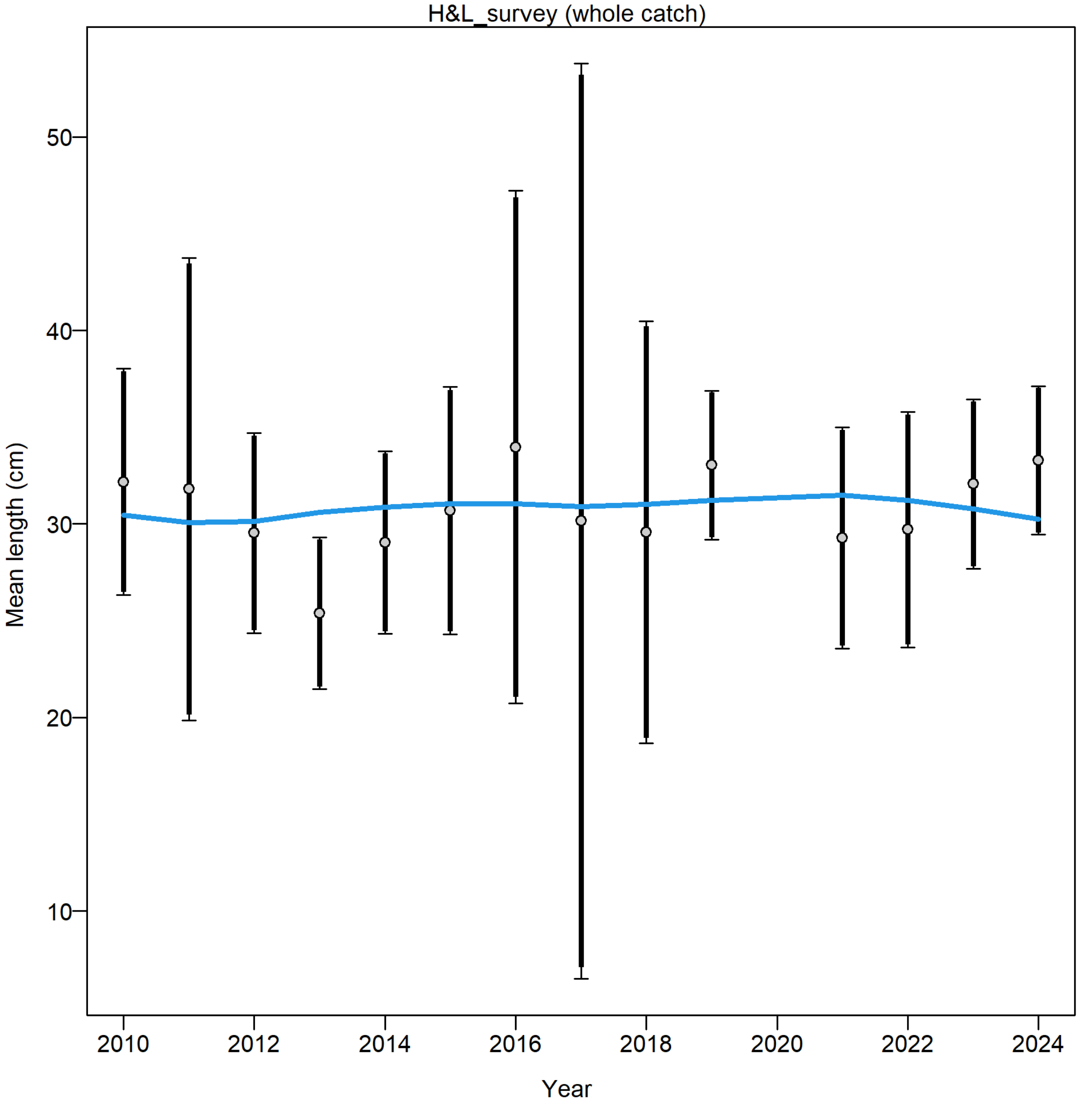

Figure 39: Mean length (cm) for the Hook and Line Survey with 95% confidence intervals based on adjusted input sample sizes. The blue line is the model expectation.

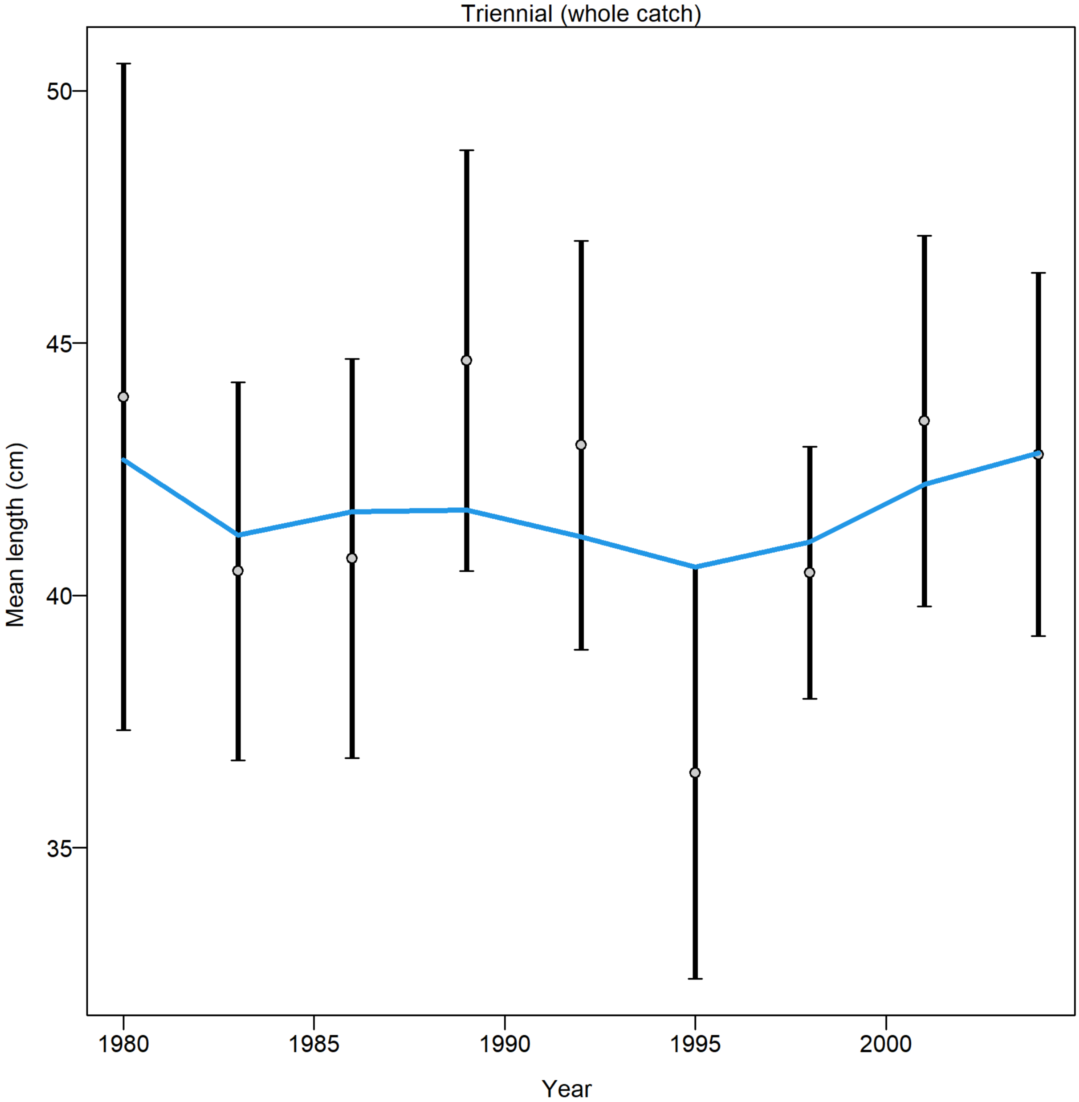

Figure 40: Mean length (cm) for the Triennial Survey with 95% confidence intervals based on adjusted input sample sizes. The blue line is the model expectation.

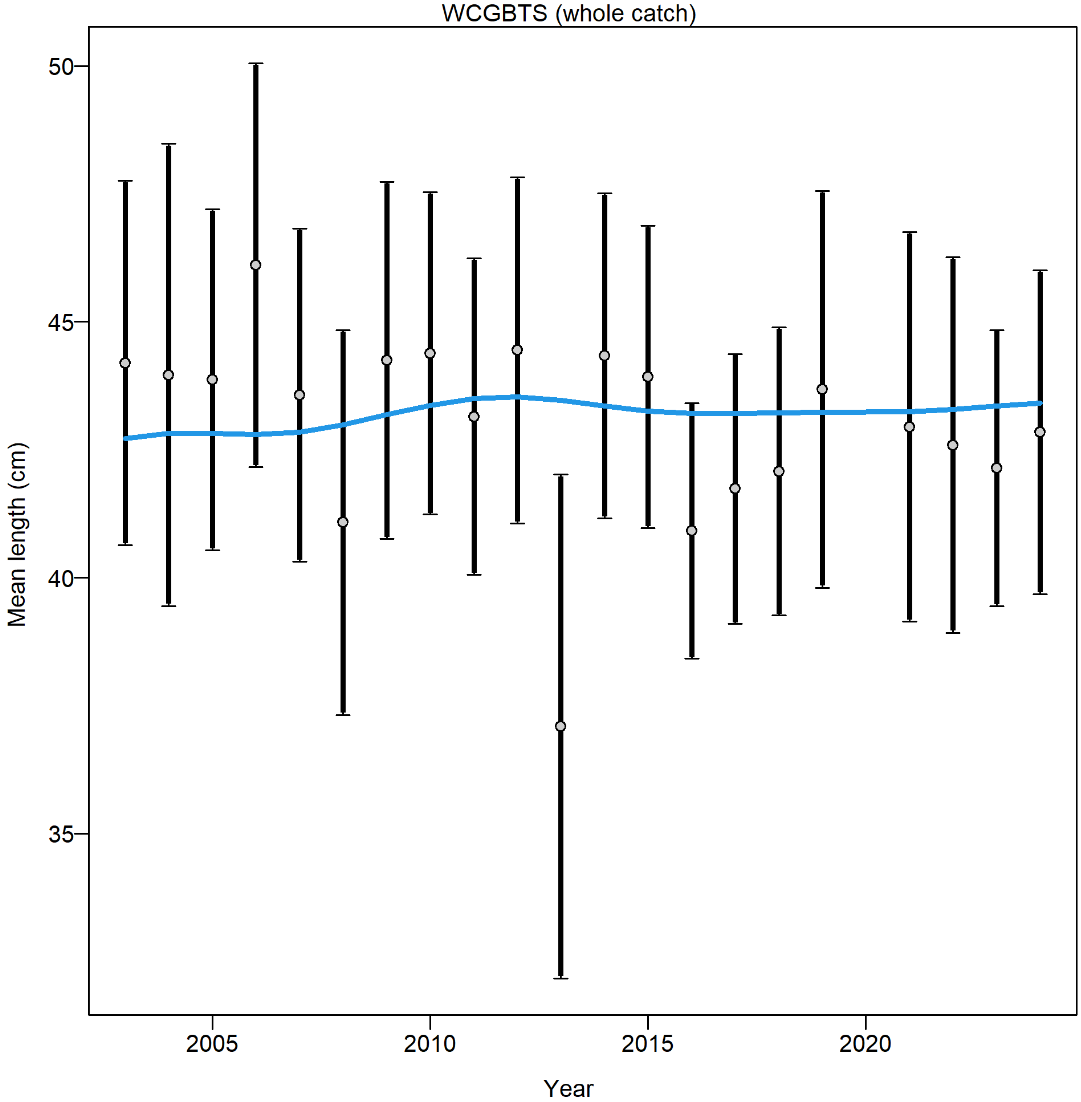

Figure 41: Mean length (cm) for the WCGBTS with 95% confidence intervals based on adjusted input sample sizes. The blue line is the model expectation.

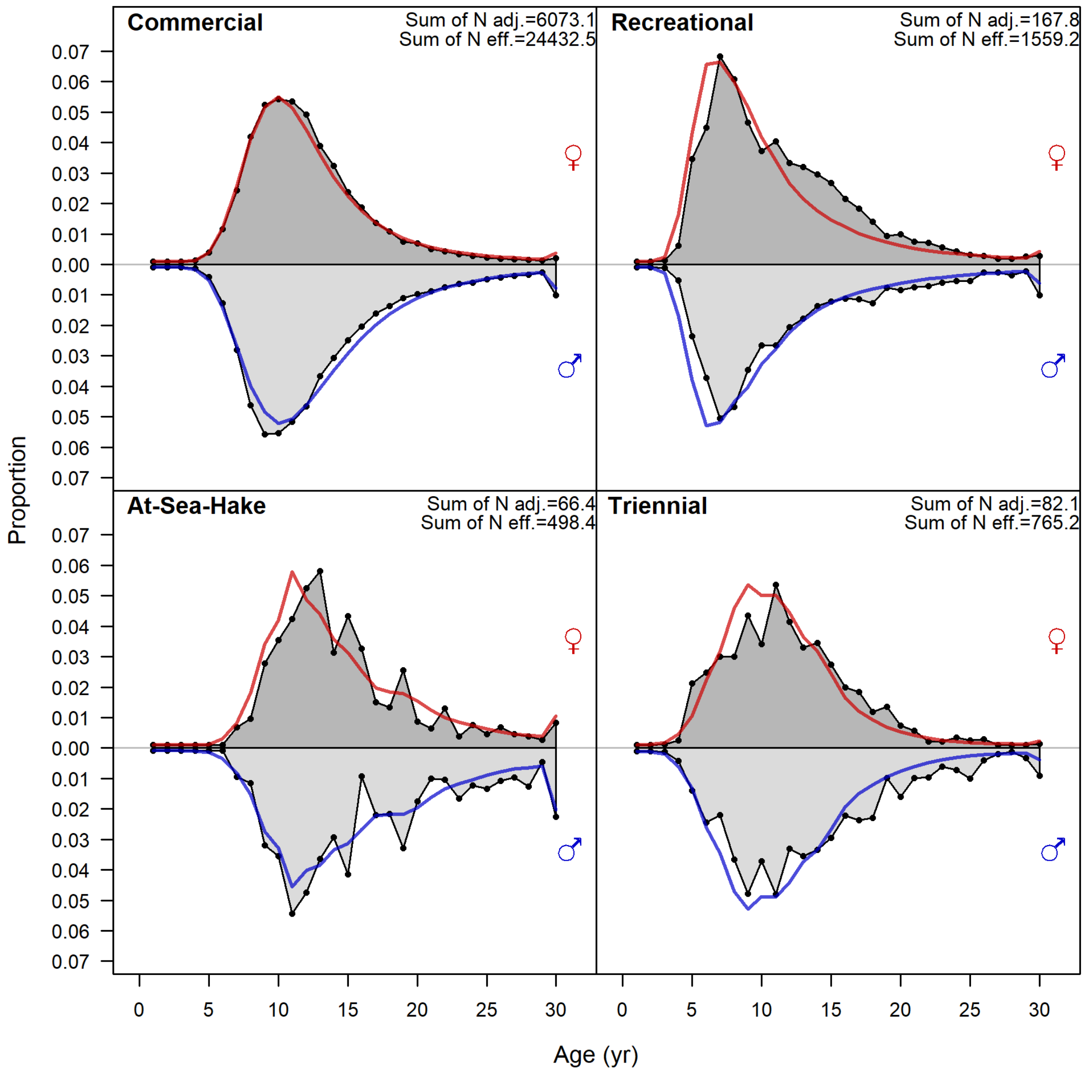

Figure 42: Marginal age compositions aggregated across years by fleet with the model with estimated fit to the data by sex (red female, blue male, green unsexed). The WCGBTS ages are not included as they are conditioned on length.

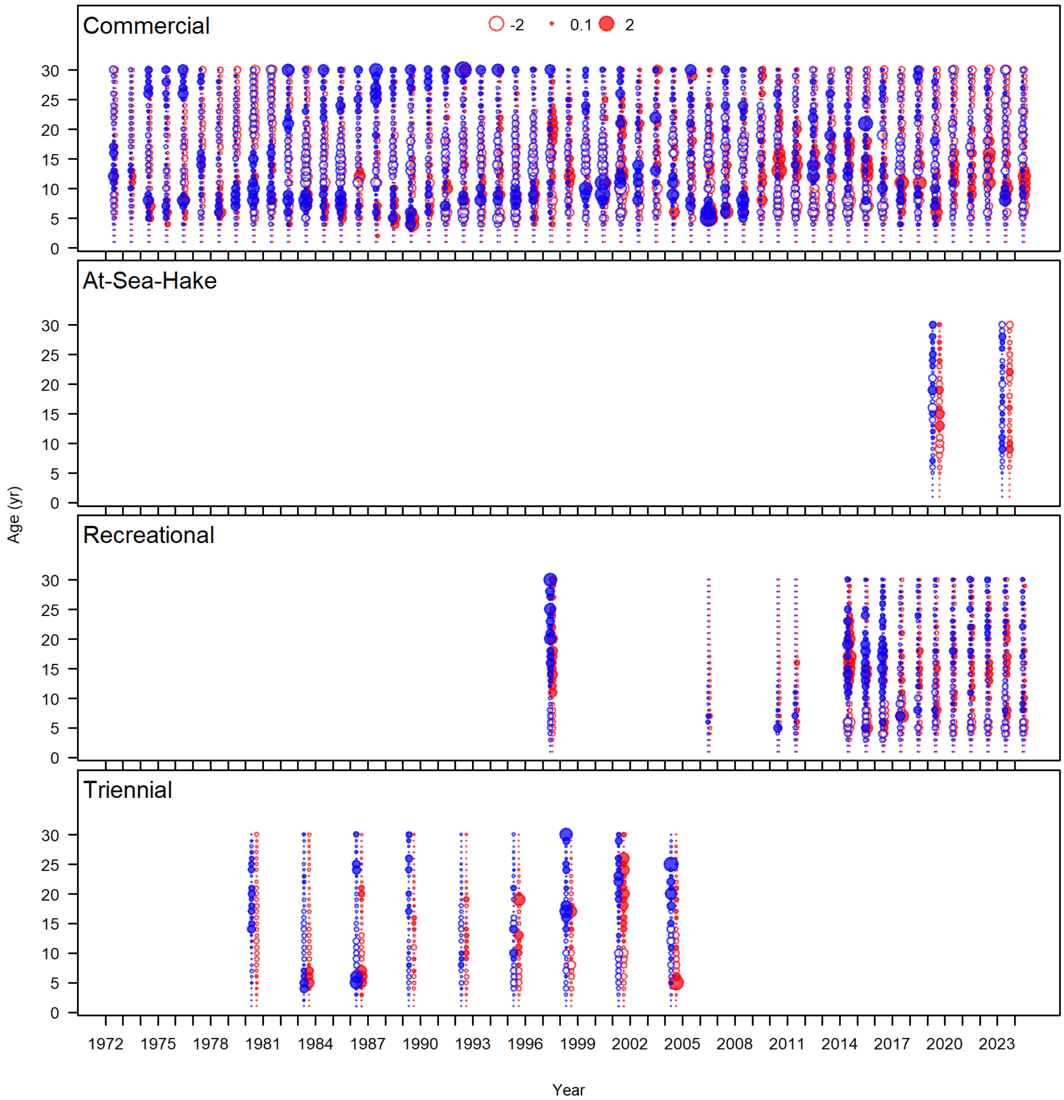

Figure 43: Residuals for fit to marginal age composition data for all fleets (red female, blue male, grey unsexed). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). The WCGBTS ages are not included as they are conditioned on length.

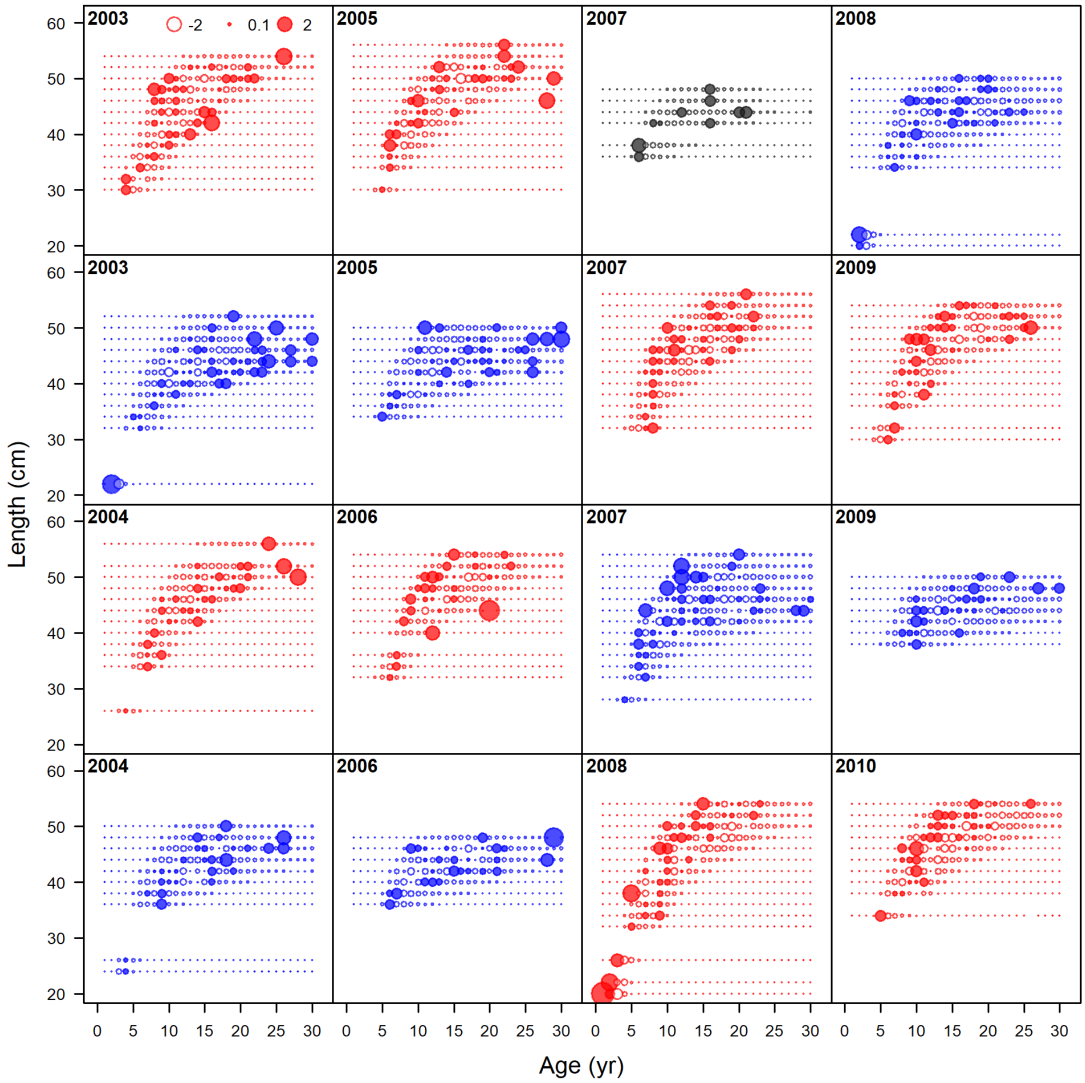

Figure 44: Residuals (page 1 of 3) for fit to conditional-age-at-length data for the WCGBTS (red female, blue male, grey unsexed). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). The WCGBTS ages are not included as they are conditioned on length.

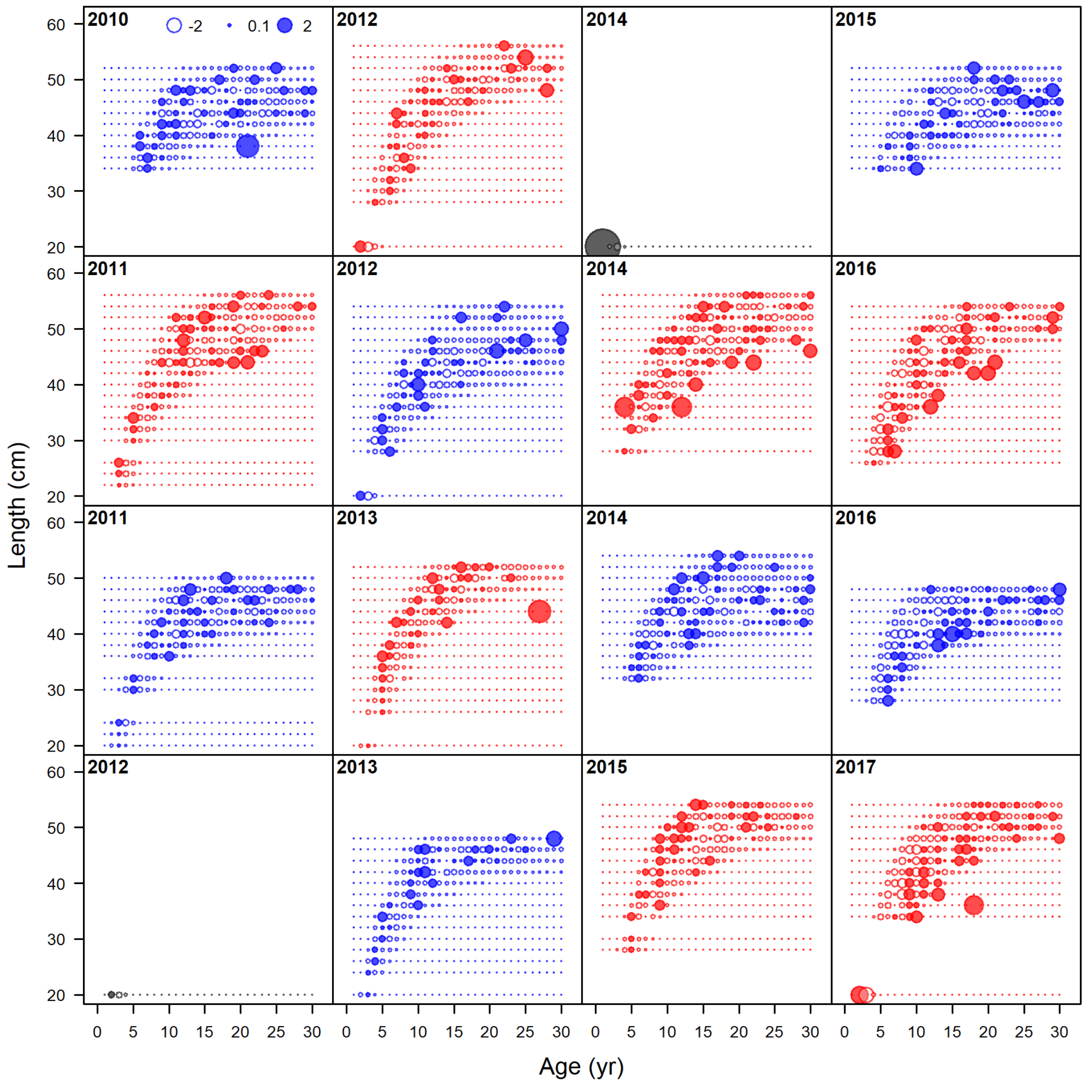

Figure 45: Residuals (page 2 of 3) for fit to conditional-age-at-length data for the WCGBTS (red female, blue male, grey unsexed). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). The WCGBTS ages are not included as they are conditioned on length.

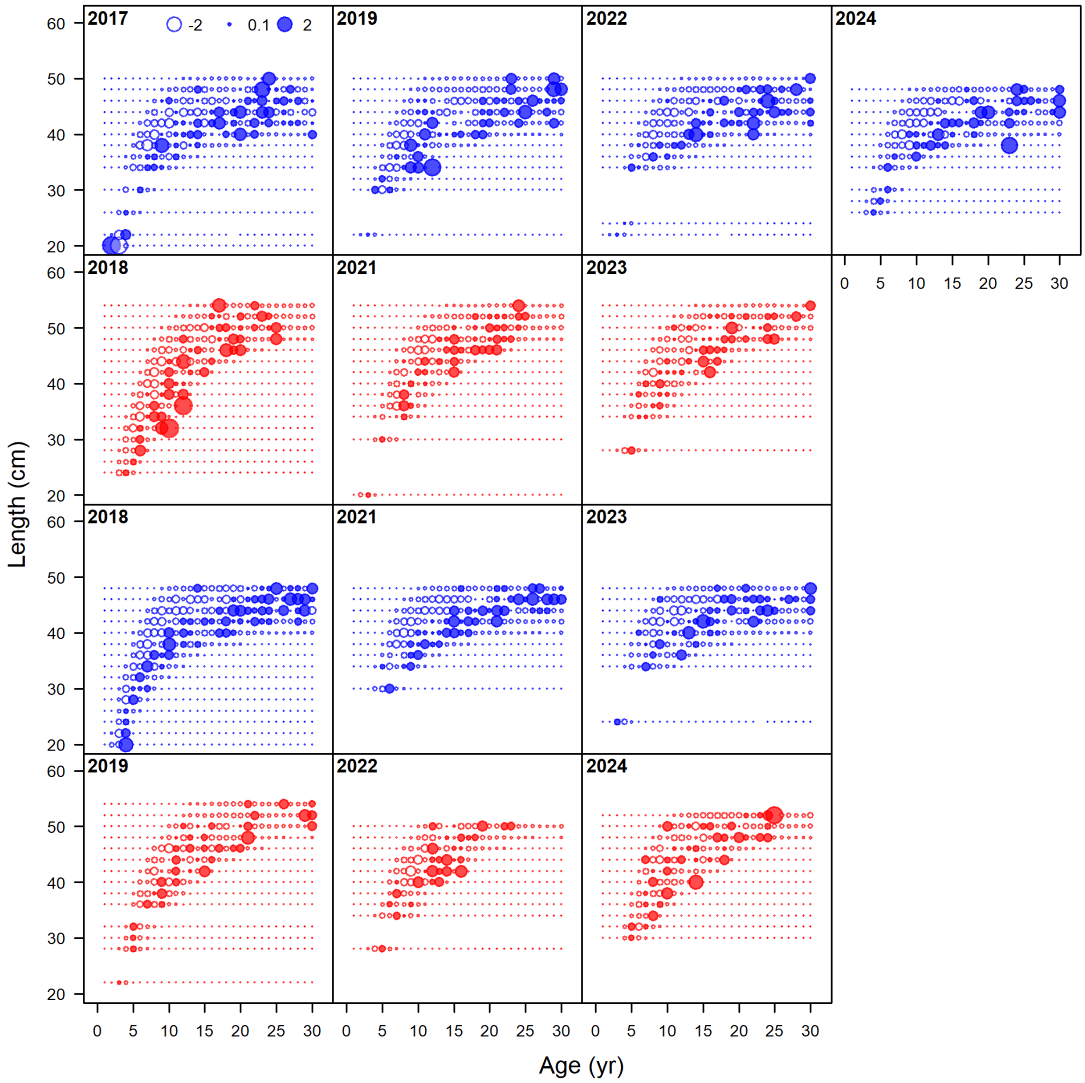

Figure 46: Residuals (page 3 of 3) for fit to conditional-age-at-length data for the WCG-BTS (red female, blue male, grey unsexed). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). The WCGBTS ages are not included as they are conditioned on length.

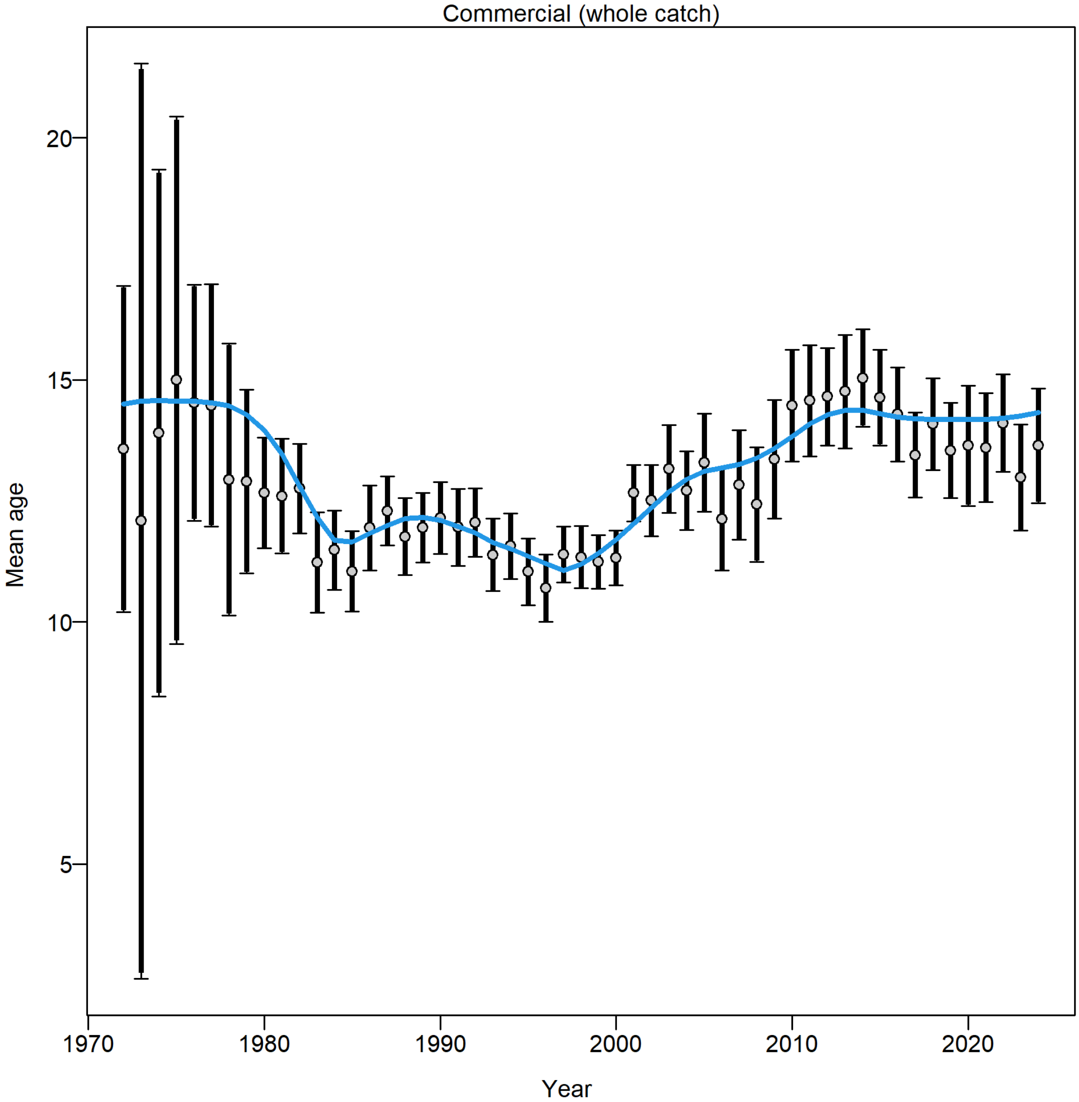

Figure 47: Mean age for Commercial with 95% confidence intervals based on adjusted input sample sizes. The blue line is the model expectation.

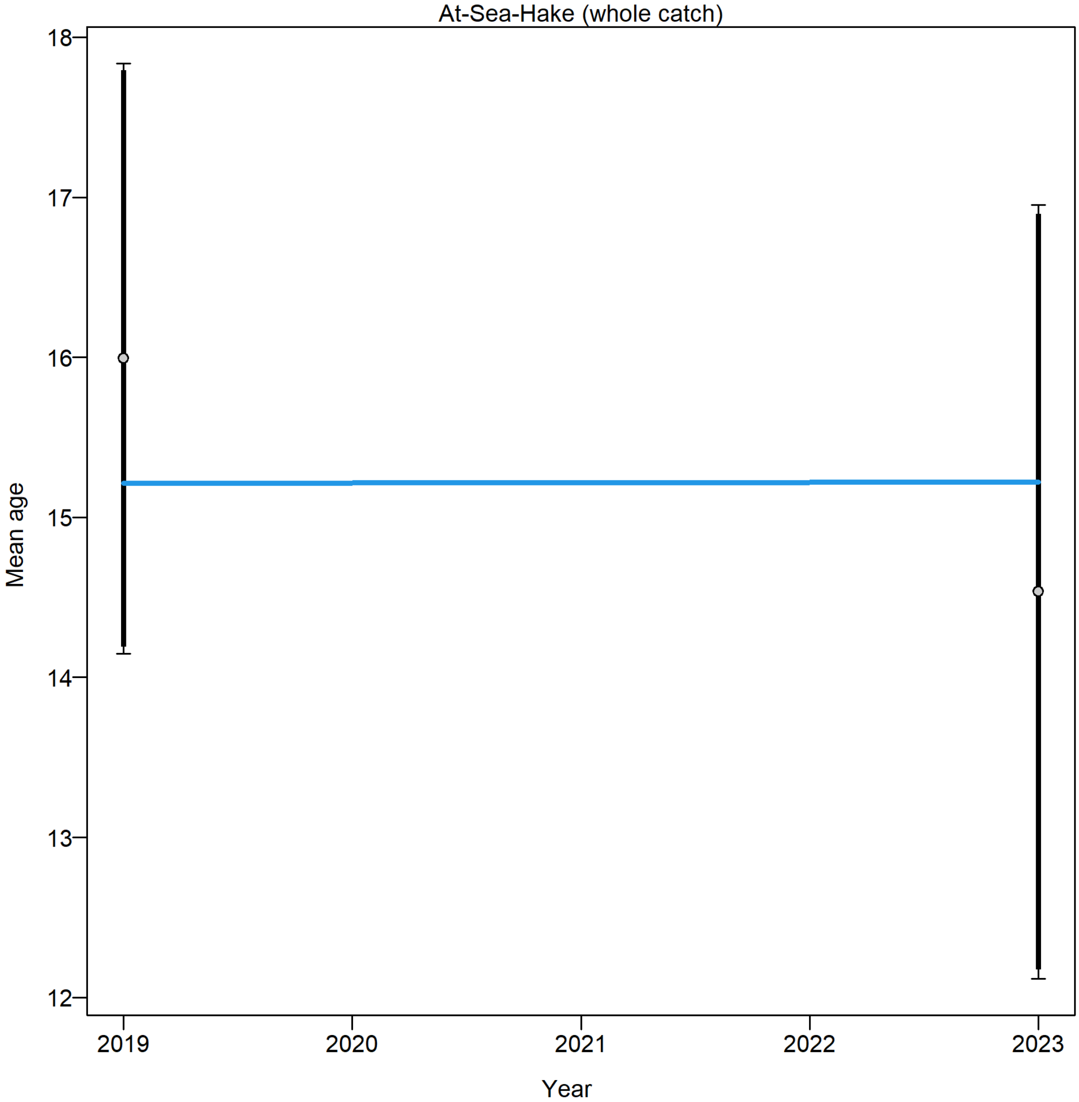

Figure 48: Mean age for At-Sea Hake with 95% confidence intervals based on adjusted input sample sizes. The blue line is the model expectation.

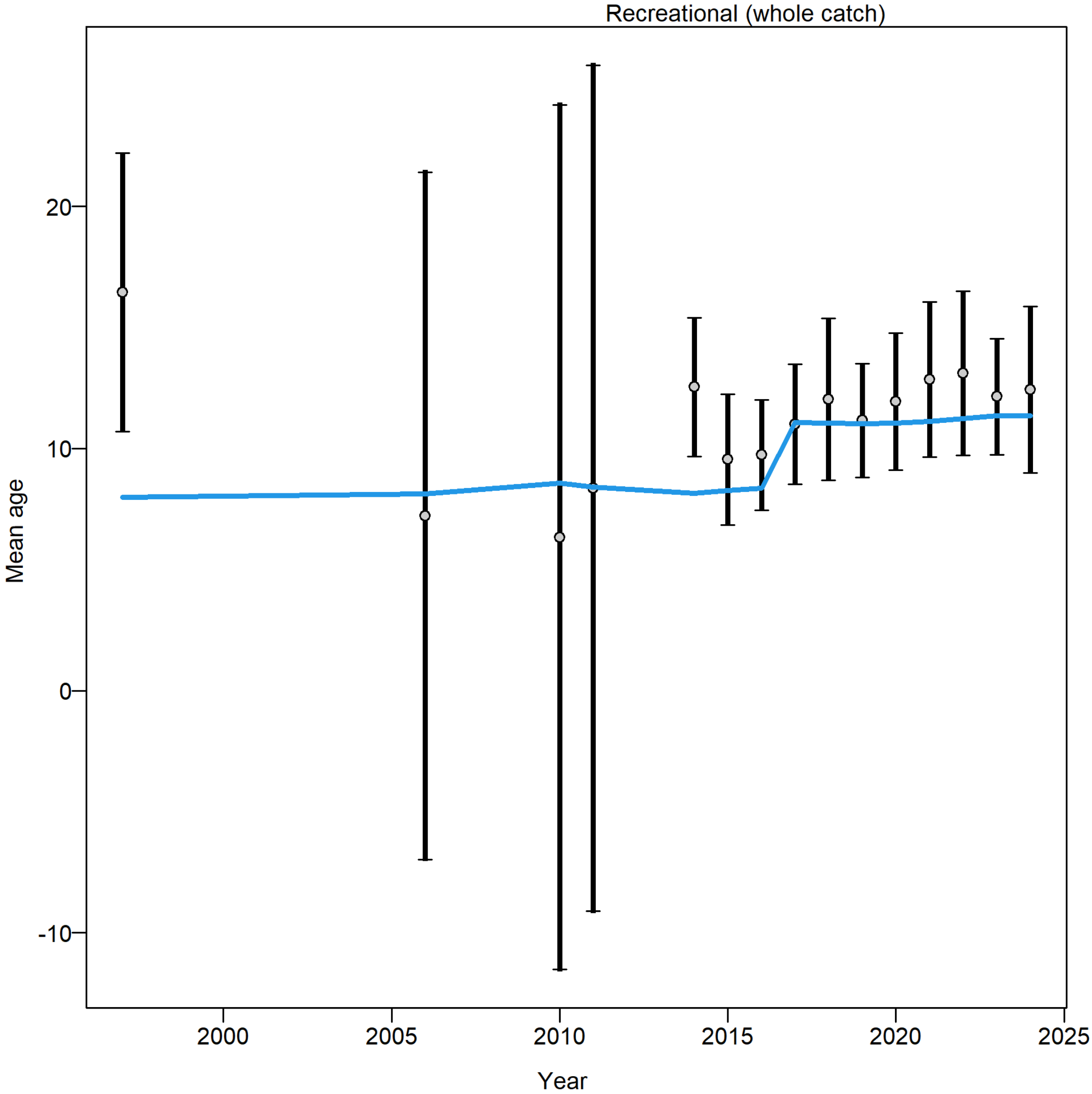

Figure 49: Mean age for the Recreational fleet with 95% confidence intervals based on adjusted input sample sizes. The blue line is the model expectation.

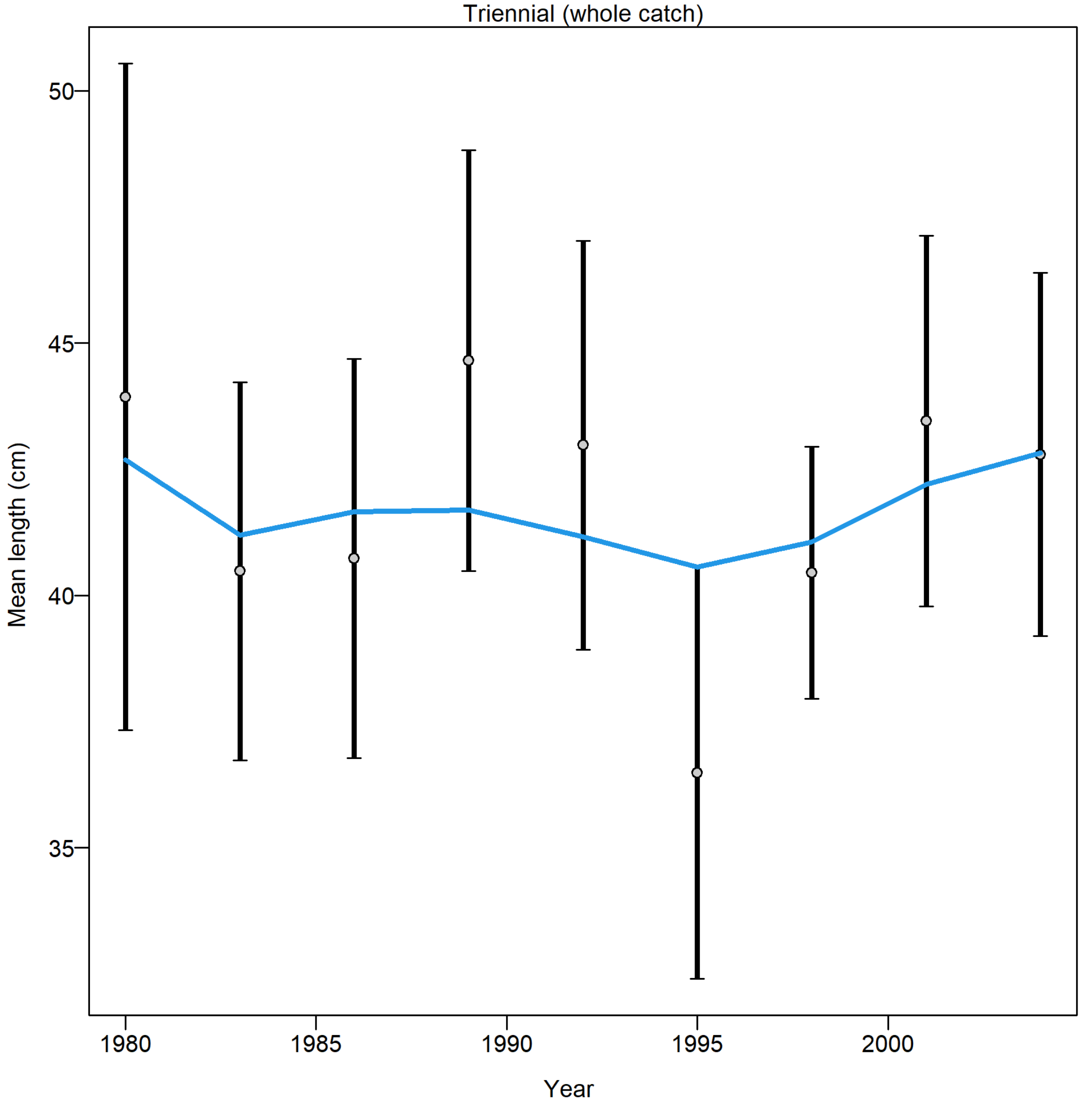

Figure 50: Mean age for the Triennial Survey with 95% confidence intervals based on adjusted input sample sizes. The blue line is the model expectation.

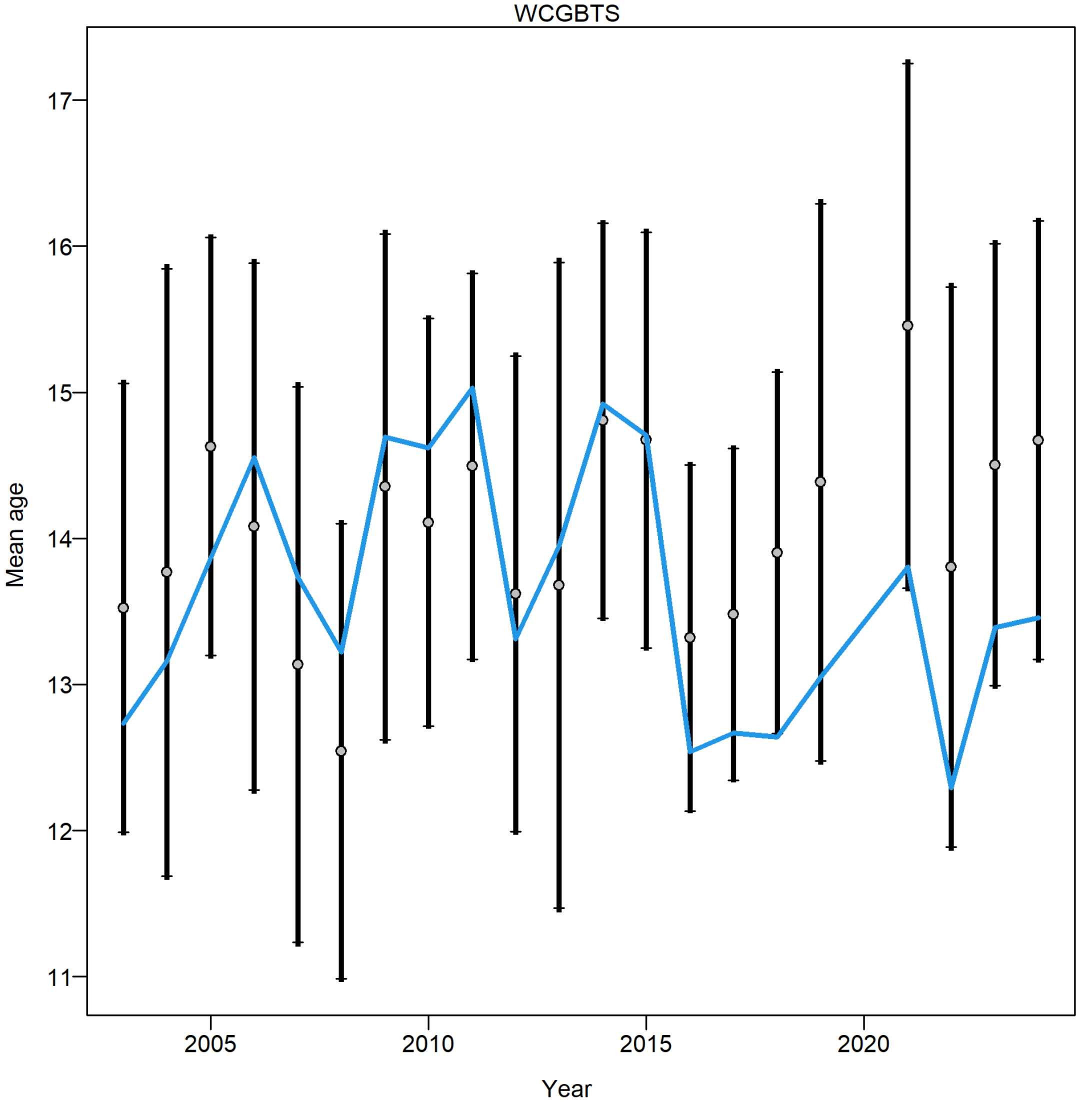

Figure 51: Mean age from conditional data (aggregated across length bins) for the WCGBTS with 95% confidence intervals based on adjusted input sample sizes. The blue line is the model expectation.

8.2.5. Time series

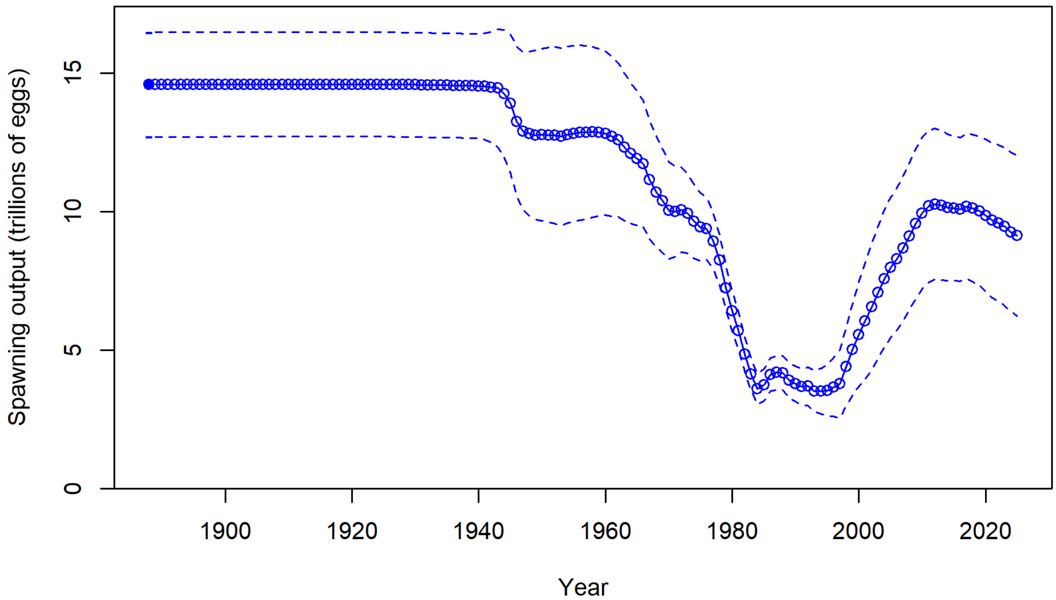

Figure 52: Estimated time series of spawning output for the base model.

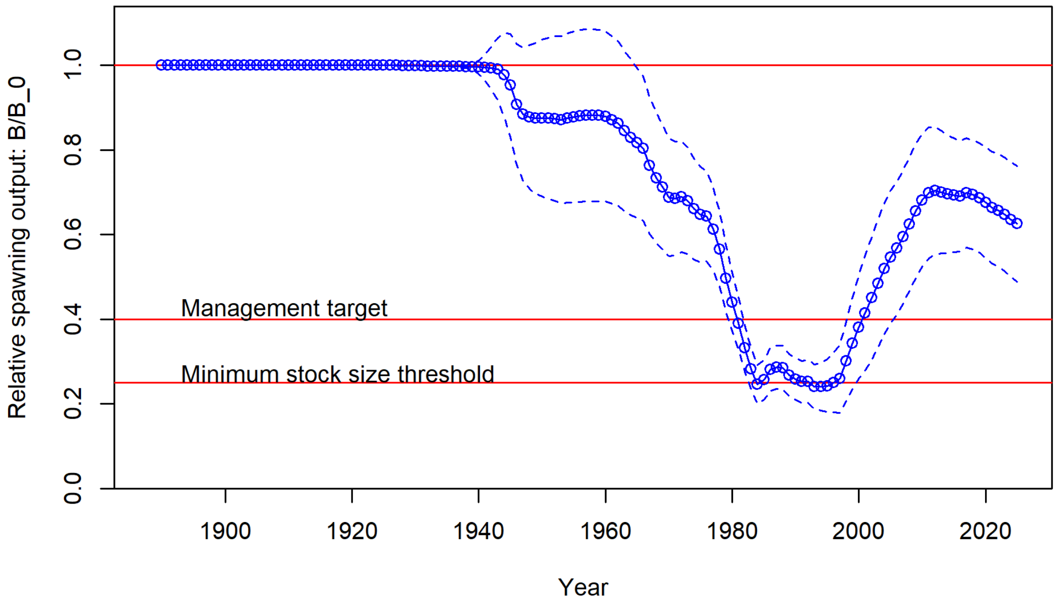

Figure 53: Estimated time series of fraction of unfished spawning output for the base model.

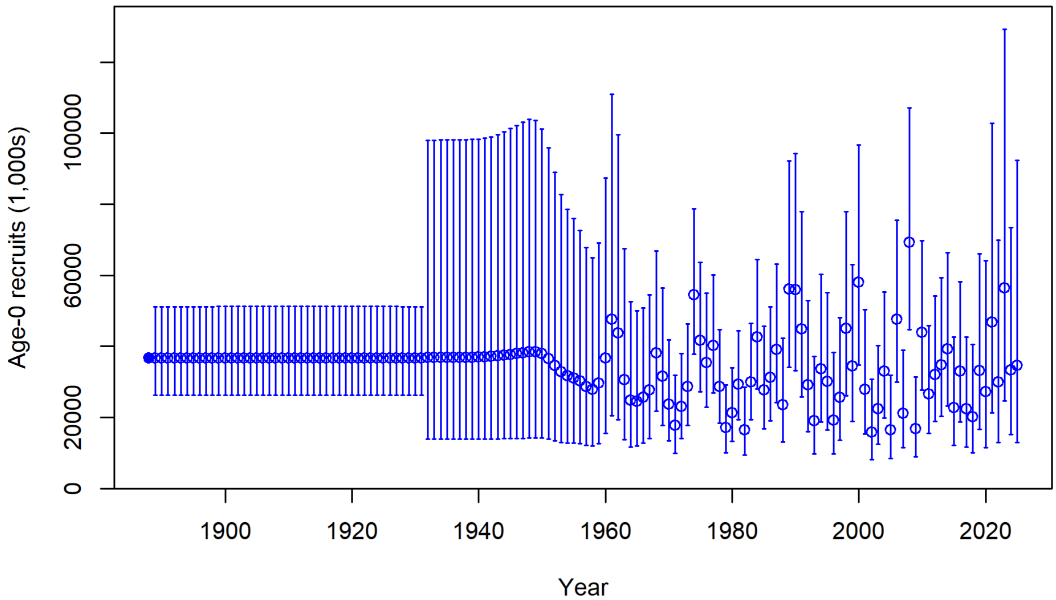

Figure 54: Estimated time series of age-0 recruits for the base model.

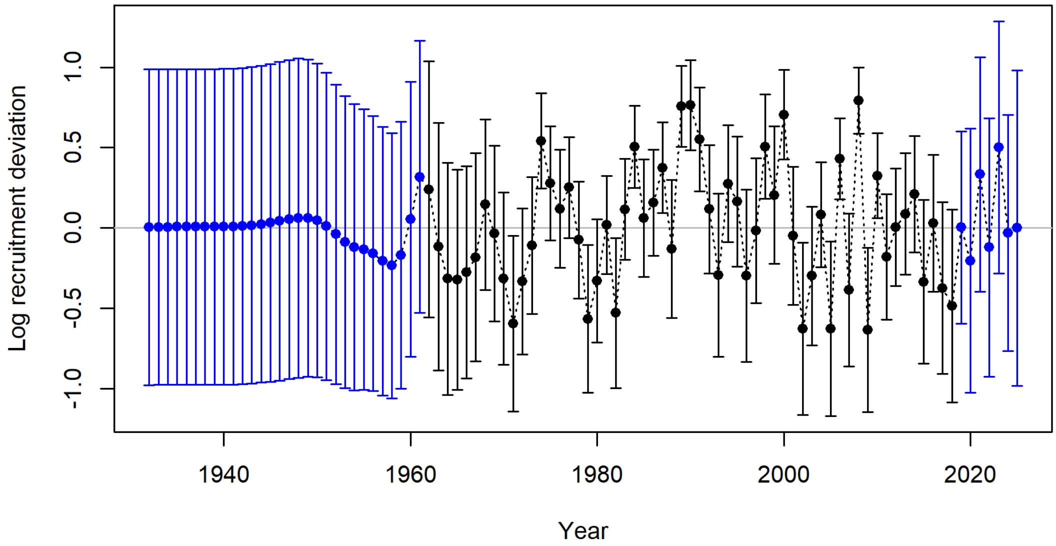

Figure 55: Estimated time series of recruitment deviations for the base model.

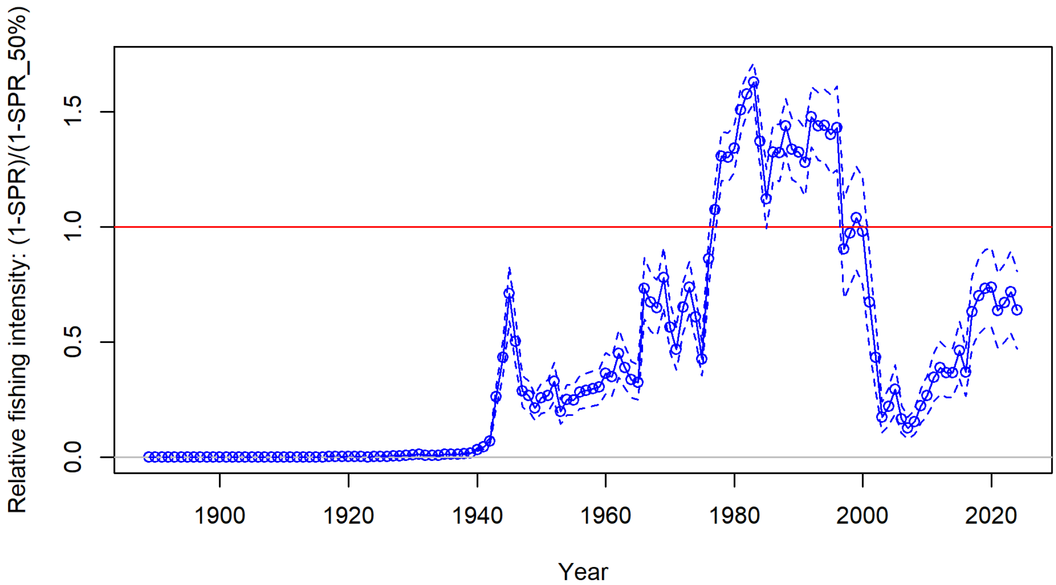

Figure 56: Estimated time series of fishing intensity for the base model.

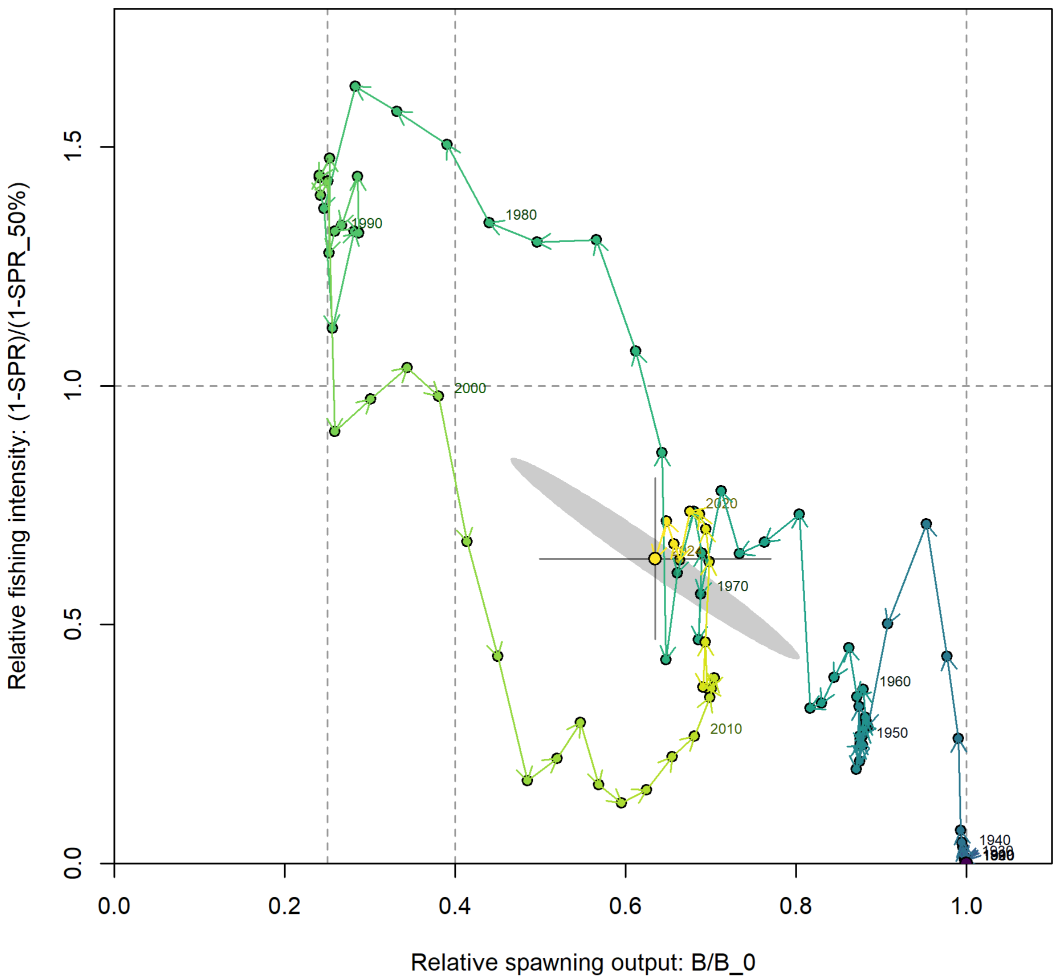

Figure 57: Phase plot of fishing intensity versus fraction unfished. Each point represents the biomass ratio at the start of the year and the relative fishing intensity in that same year. Lines through the final point show 95% intervals based on the asymptotic uncertainty for each dimension. The shaded ellipse is a 95% region which accounts for the estimated correlation between the two quantities.

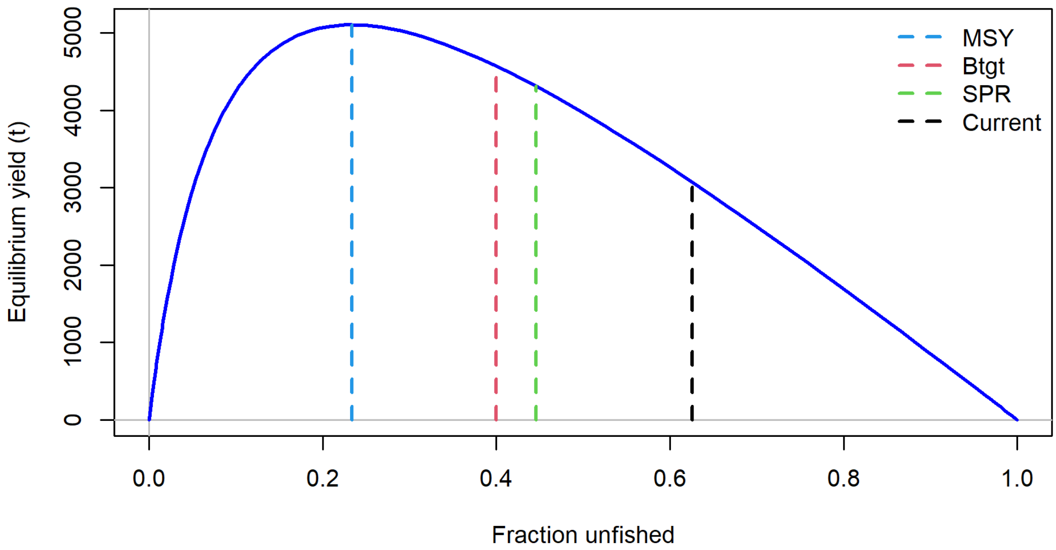

Figure 58: Estimated yield curve with reference points for the base model.

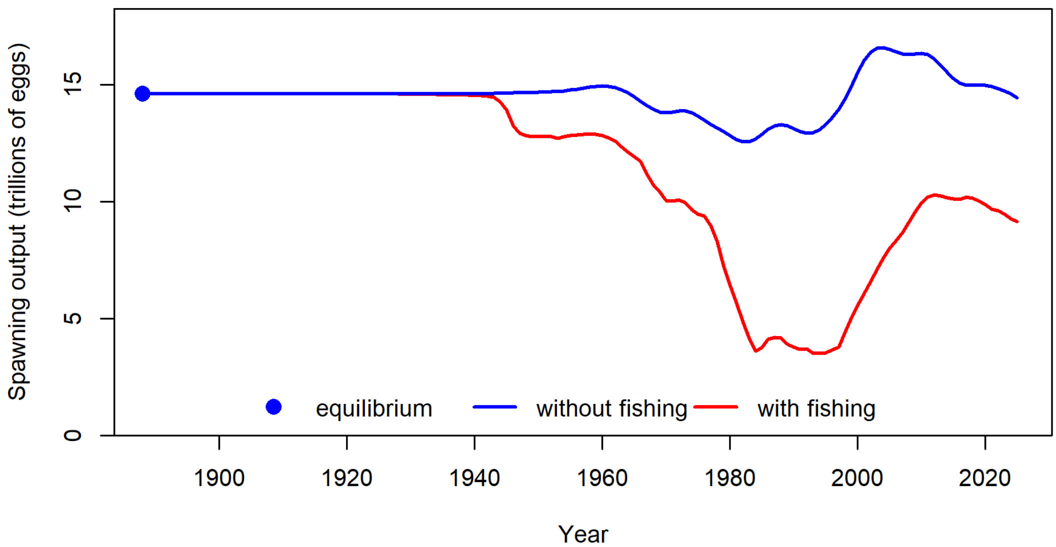

Figure 59: Dynamic B0 plot. The lower line shows the time series of estimated spawning output in the presence of fishing mortality. The upper line shows the time series that could occur under the same dynamics (including deviations in recruitment), but without fishing. The point at the left represents the unfished equilibrium.

8.3. Model diagnostics

8.3.1. Sensitivity analyses

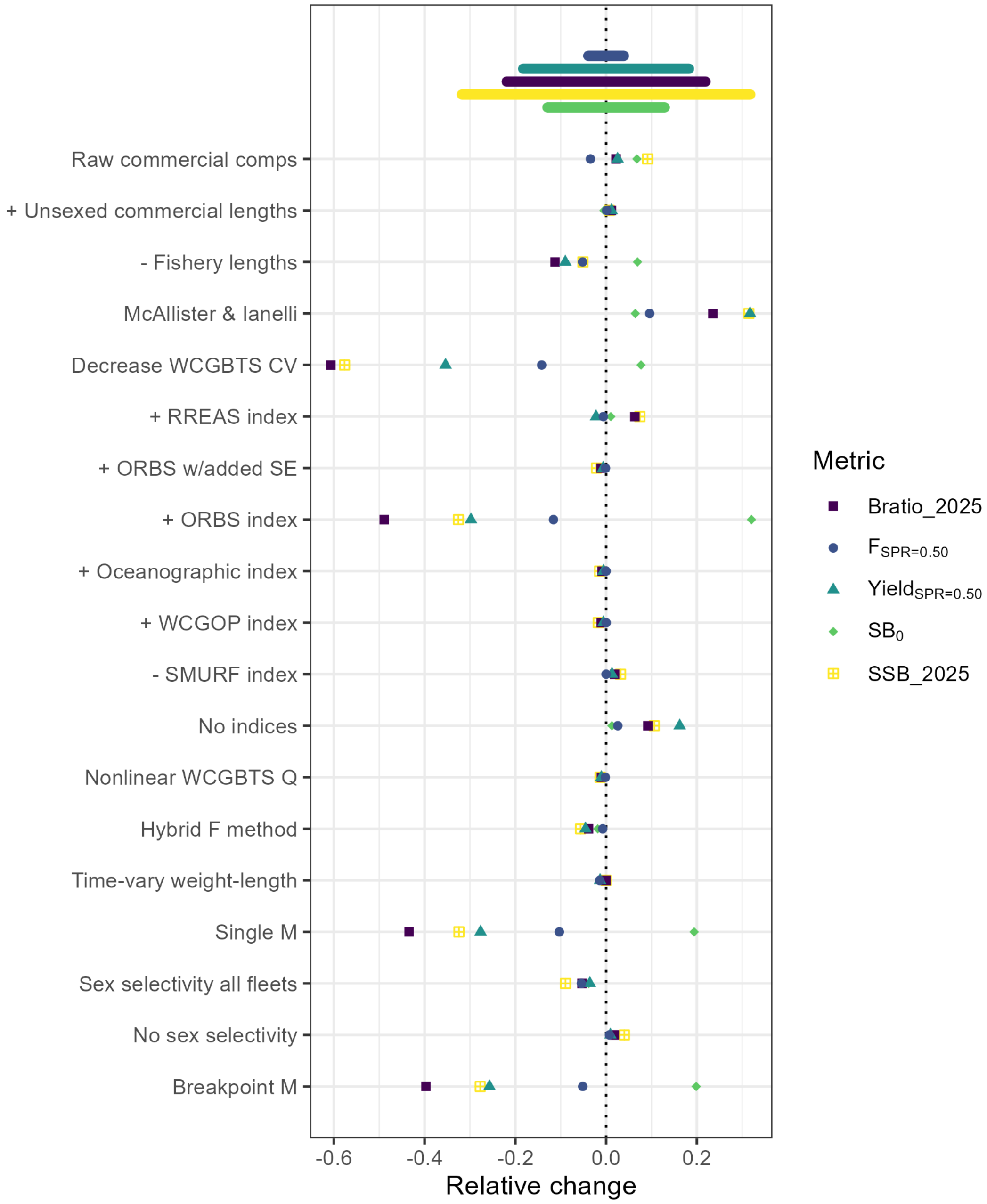

Figure 60: Comparison of various management quantities across all sensitivities. Metrics are terminal year relative spawning output, fishing mortality rate at SPR = 0.5, yield at SPR = 0.5, unfished spawning output, and terminal year spawning output. Bars at the top of the figure represent 95% confidence intervals for the metrics in the base model. See legend for which metric each color represents.

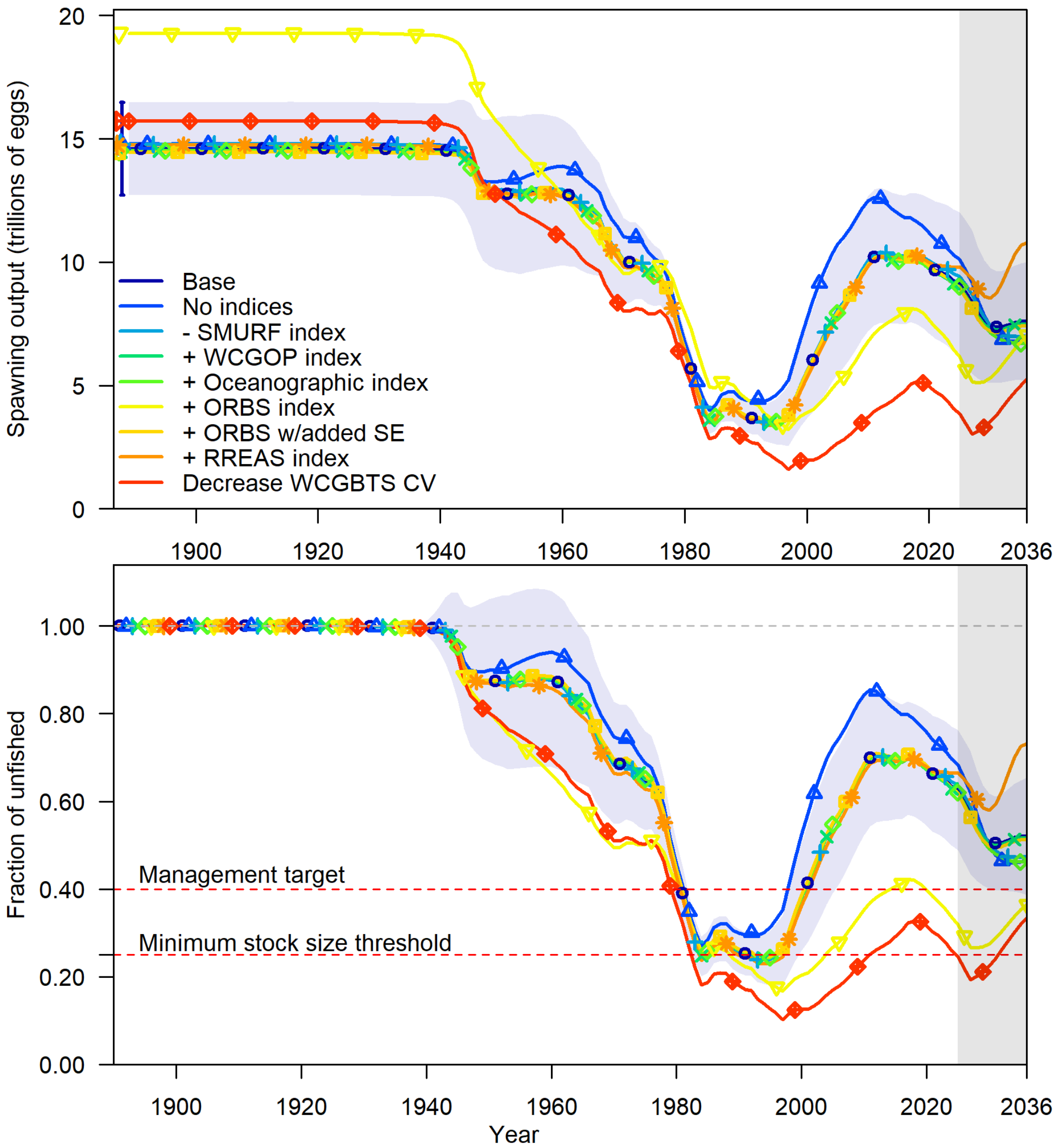

Figure 61: Spawning output (trillions of eggs, top), and relative spawning output (bottom) for index sensitivities.

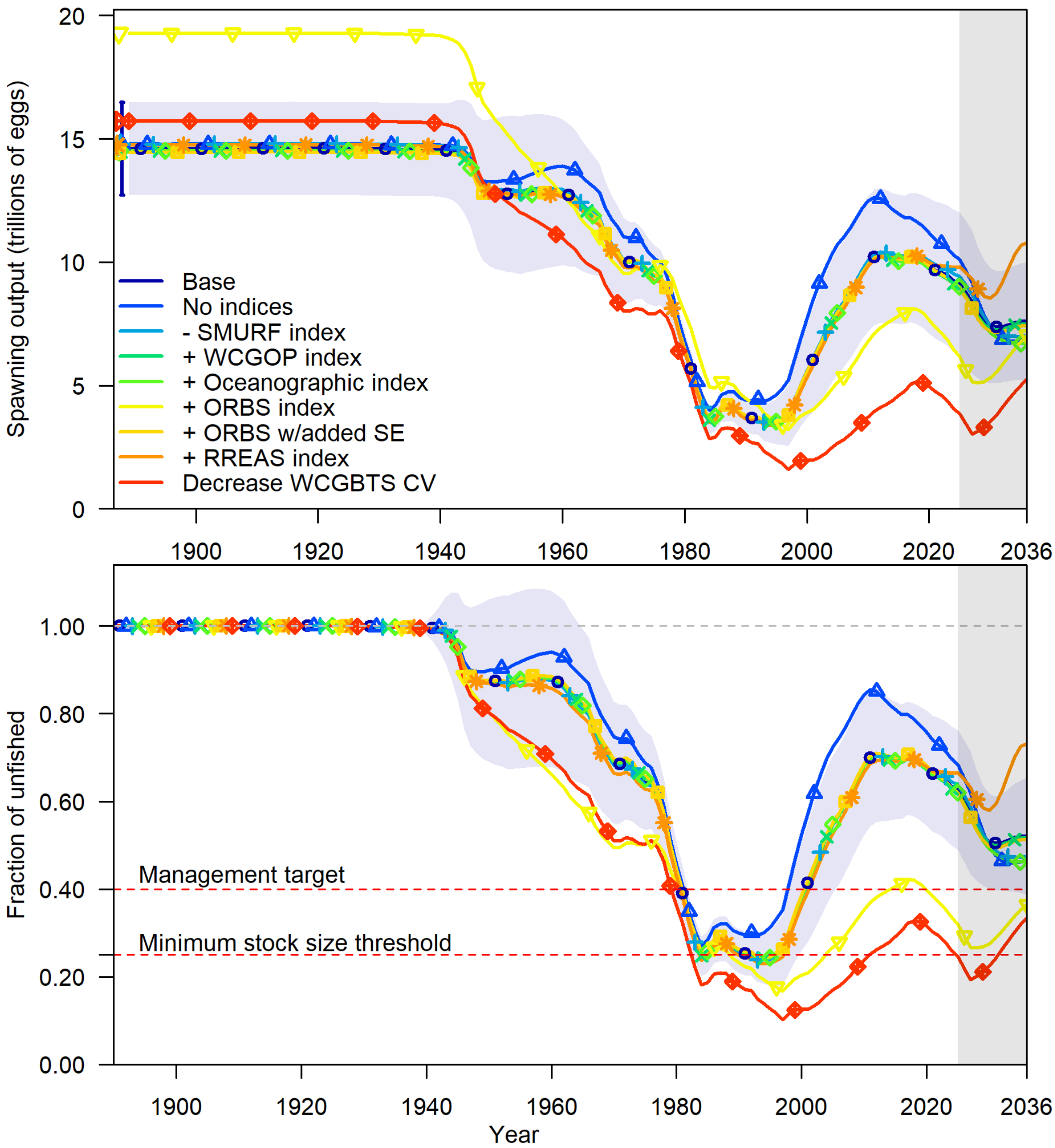

Figure 62: Spawning output (trillions of eggs, top), and relative spawning output (bottom) for modeling sensitivities.

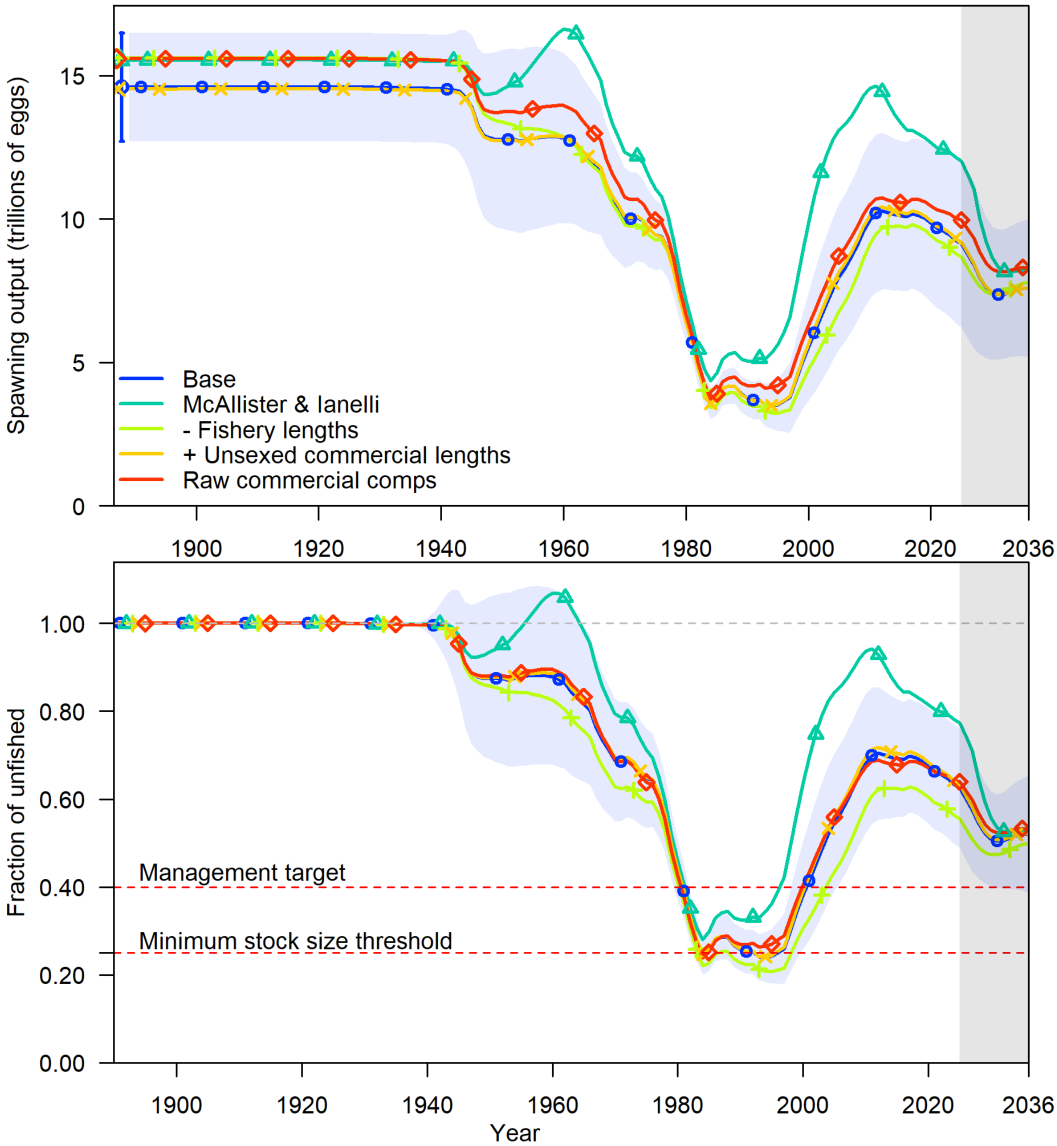

Figure 63: Spawning output (trillions of eggs, top), and relative spawning output (bottom) for composition data sensitivities

8.3.2. Retrospectives and likelihood profiles

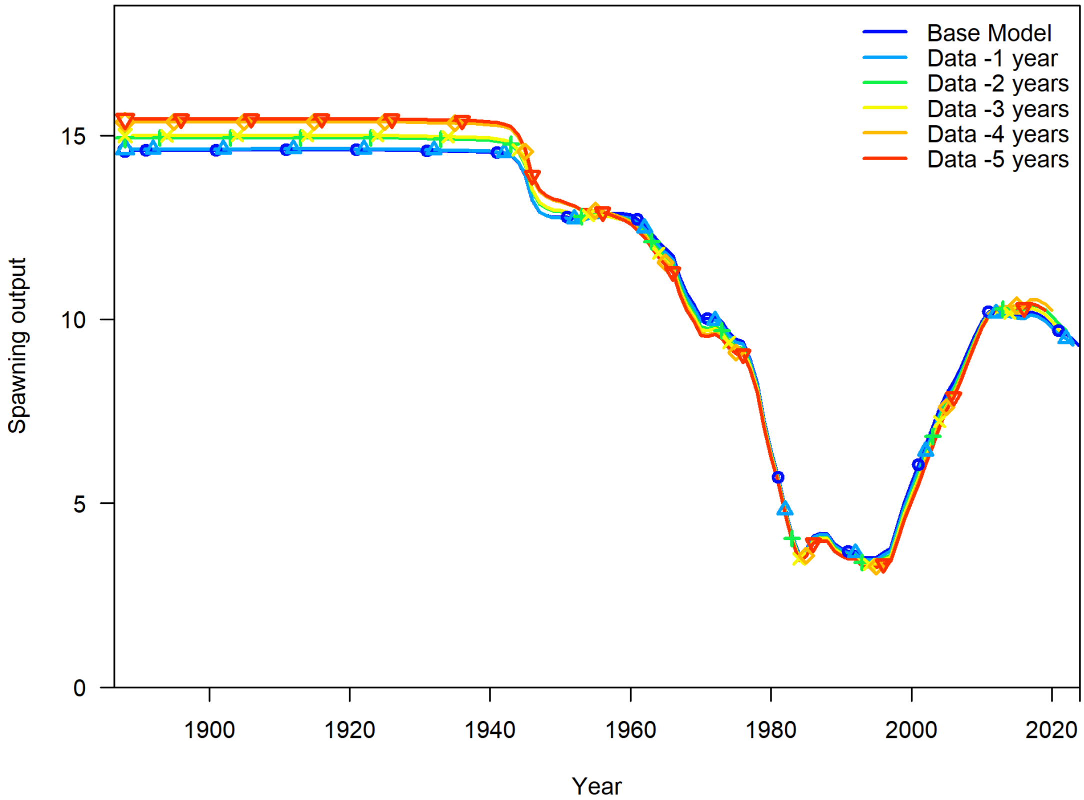

Figure 64: Change in the estimate of spawning output when the most recent 5 years of data area removed sequentially.

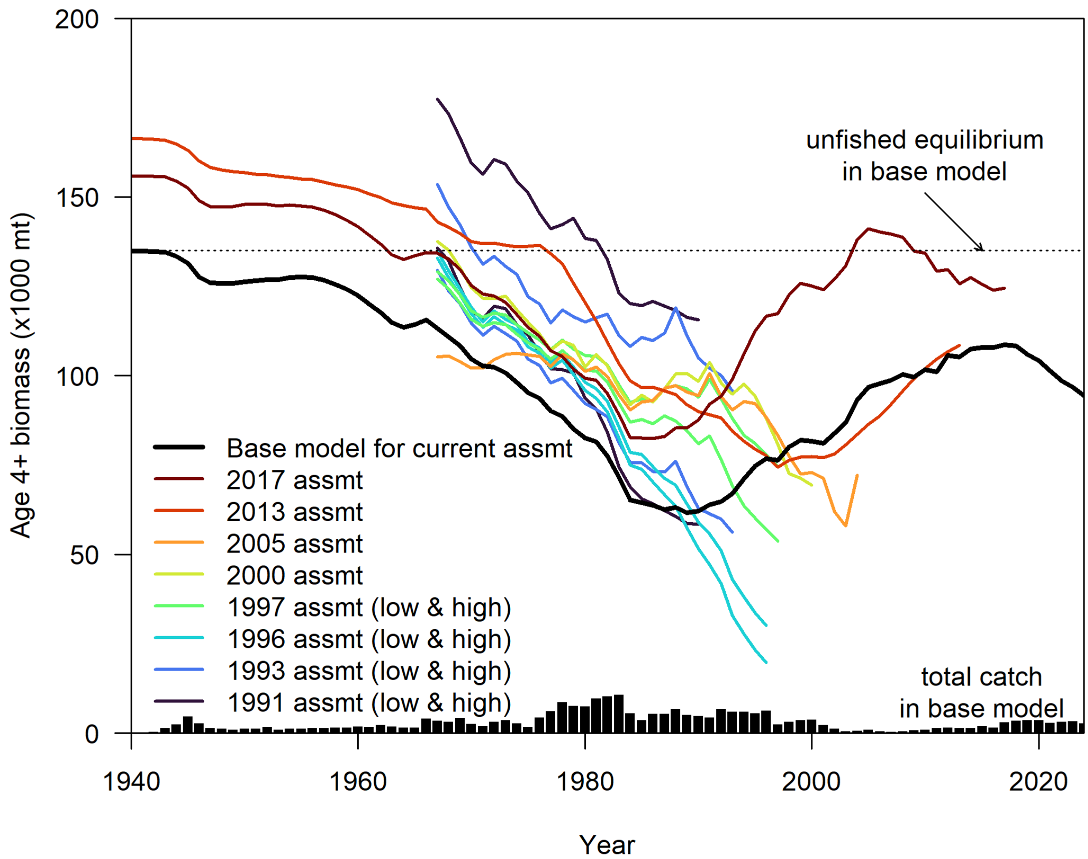

Figure 65: Comparison of time series of age 4+ biomass for yellowtail rockfish across past assessments. Previous assessments were focused only on the area north of 40°10' N. Lat., but some also included a small area within Canada. The 2013 assessment used the data-moderate approach and the line represents the posterior median of a Sampling Importance Resampling approach.

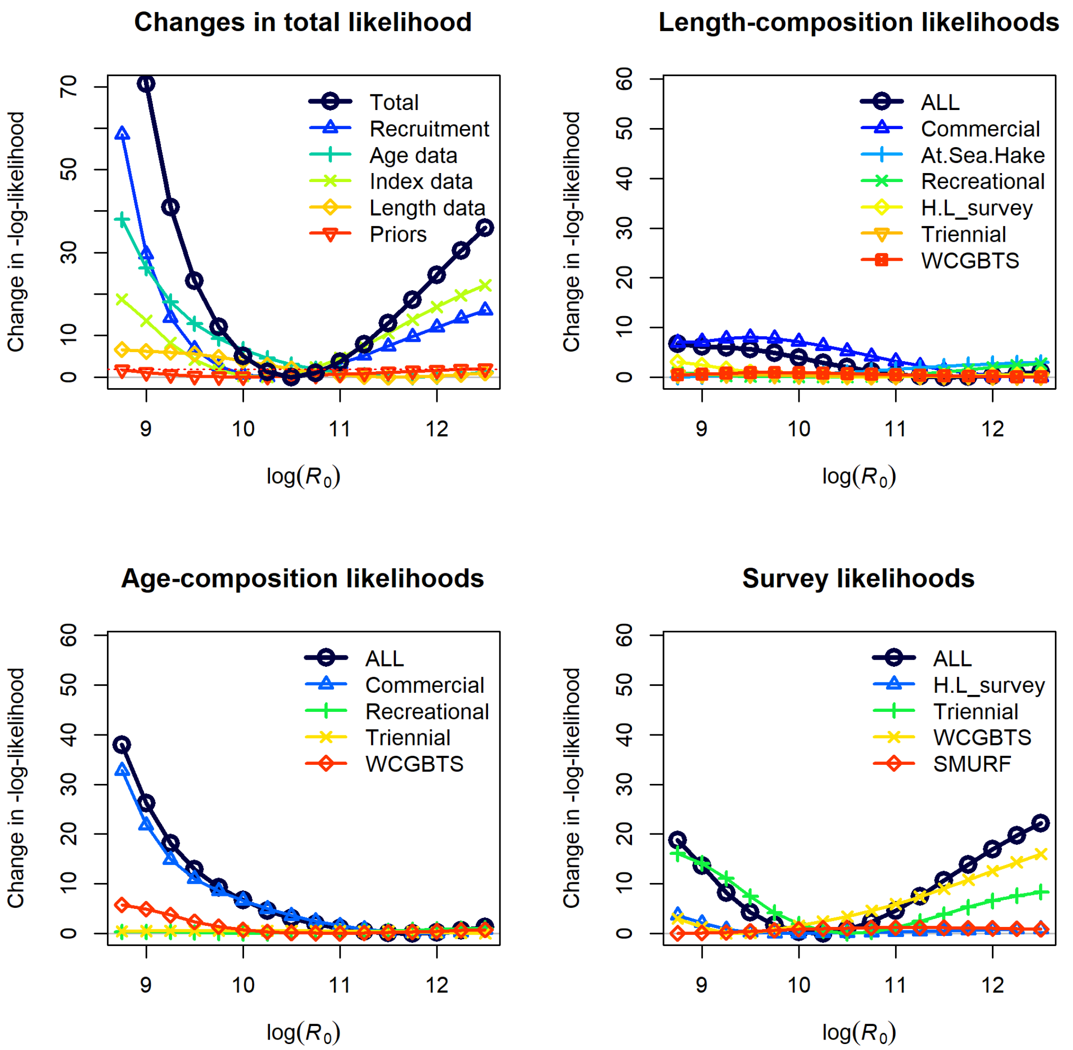

Figure 66: Change in the negative log-likelihood across a range of log(R0) values.

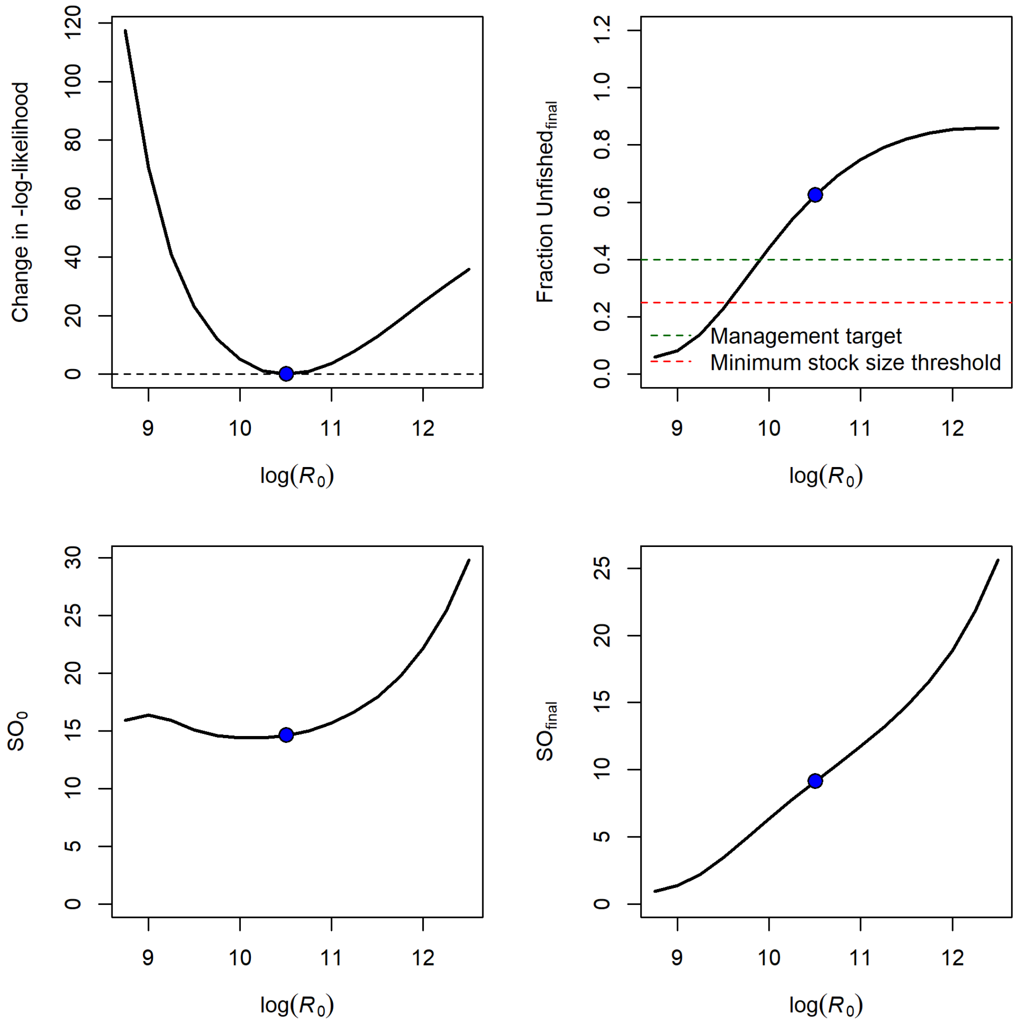

Figure 67: Change in quantities of interest related to spawning output across a range of log(R0) values: fraction of unfished spawning output in 2025 (top-right), spawning output in 2025 (bottom-right), and unfished equilibrium spawning output (bottom-left). These are shown along with the change in total negative log-likelihood (top-left, matches previous figure).

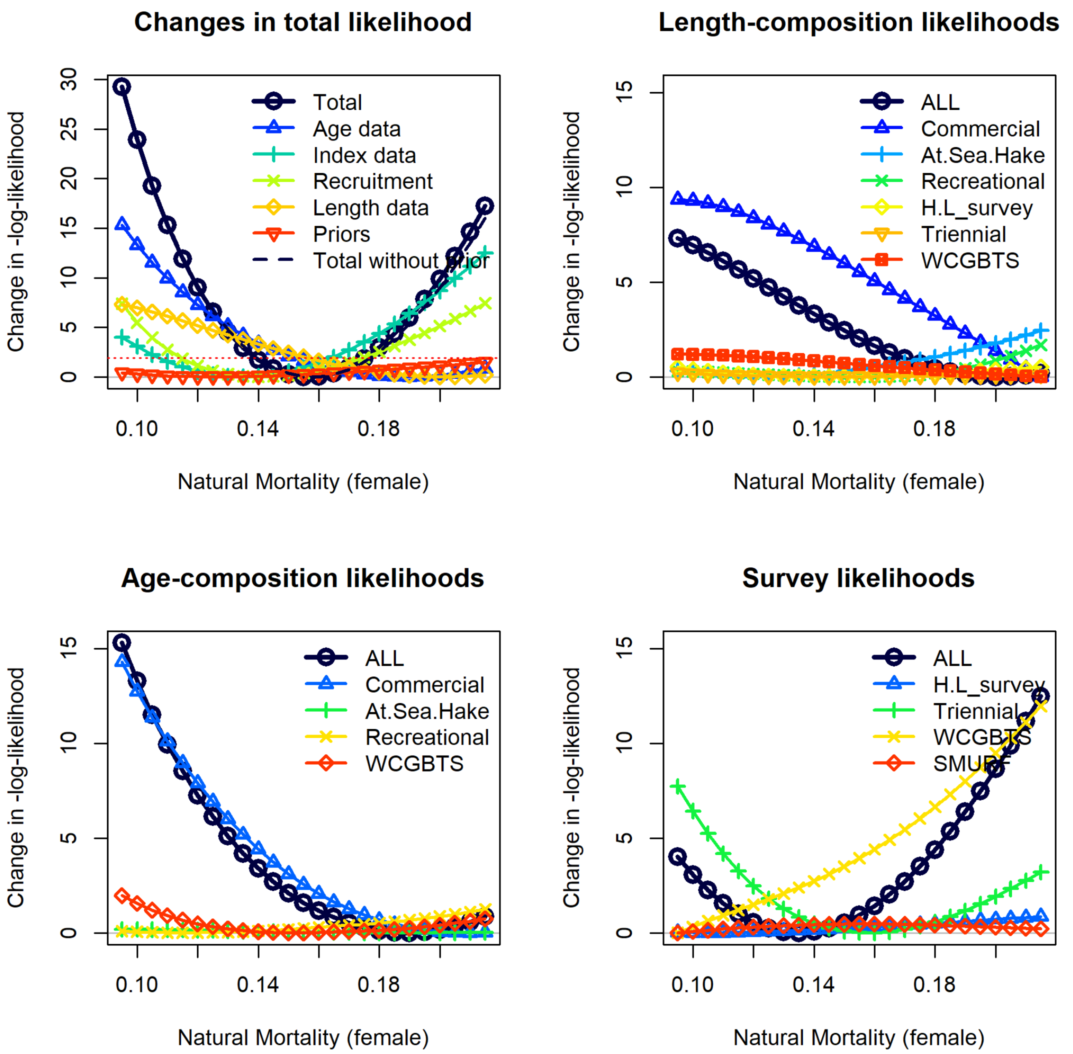

Figure 68: Change in the negative log-likelihood across a range of female natural mortality (M) values.

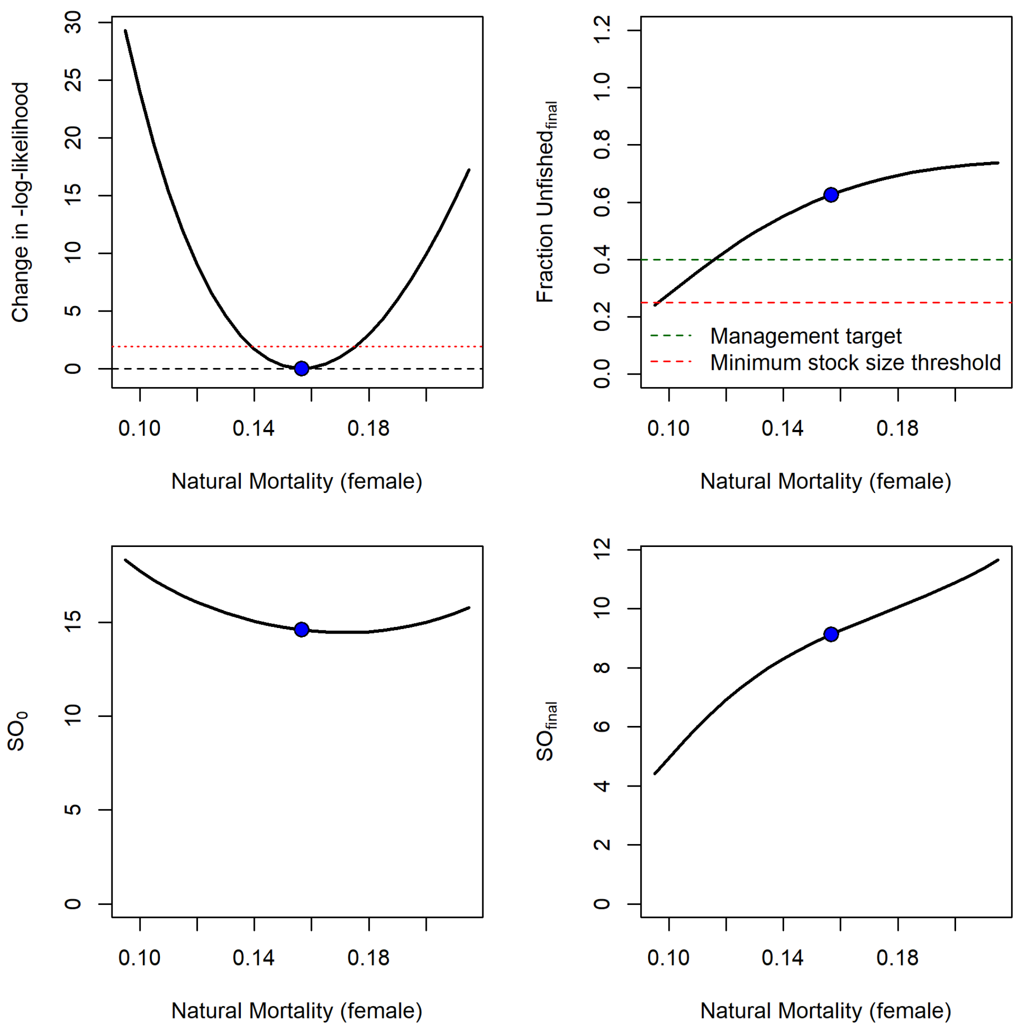

Figure 69: Change in quantities of interest related to spawning output across a range of female natural mortality (M) values: fraction of unfished spawning output in 2025 (top-right), spawning output in 2025 (bottom-right), and unfished equilibrium spawning output (bottom-left). These are shown along with the change in total negative log-likelihood (top-left, matches previous figure).

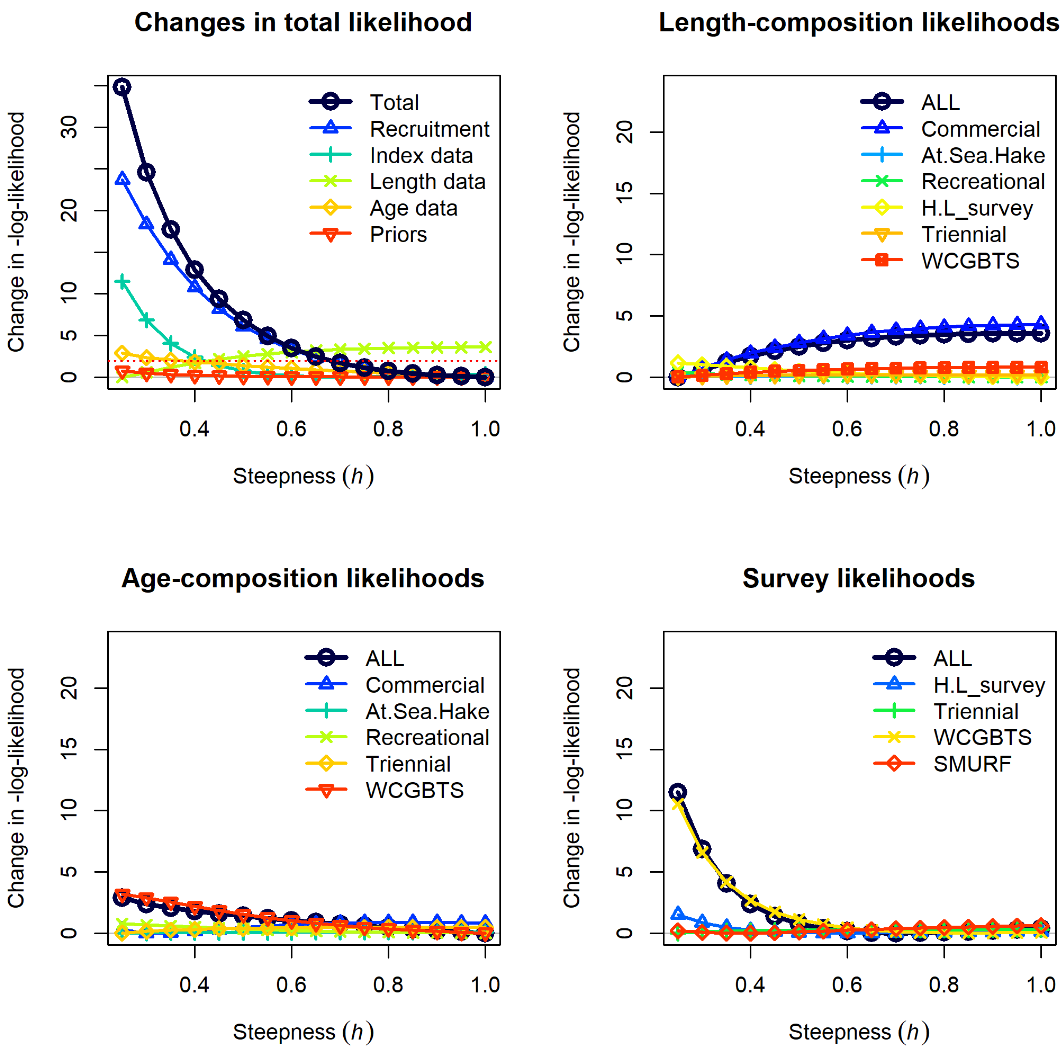

Figure 70: Change in the negative log-likelihood across a range of steepness (h) values.

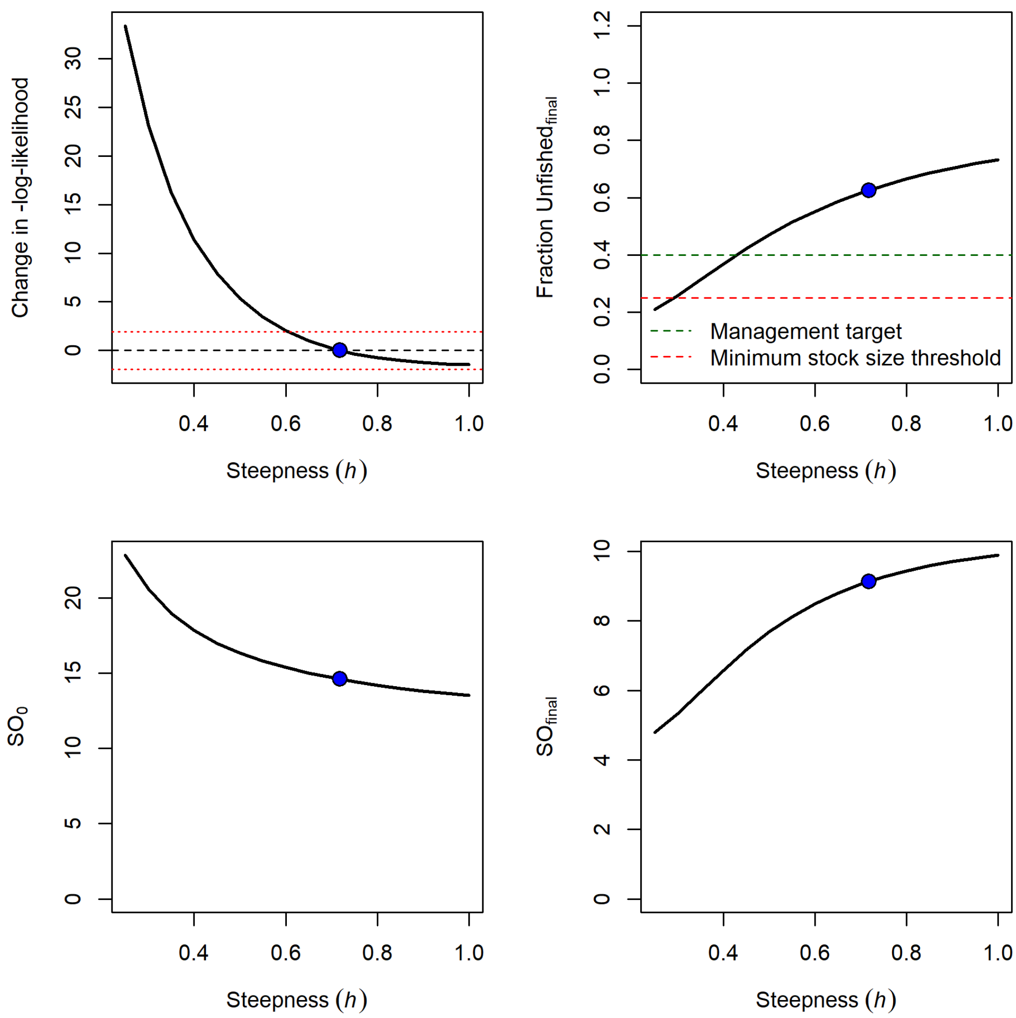

Figure 71: Change in quantities of interest related to spawning output across a range of steepness (h) values: fraction of unfished spawning output in 2025 (top-right), spawning output in 2025 (bottom-right), and unfished equilibrium spawning output (bottom-left). These are shown along with the change in total negative log-likelihood (top-left, matches previous figure).

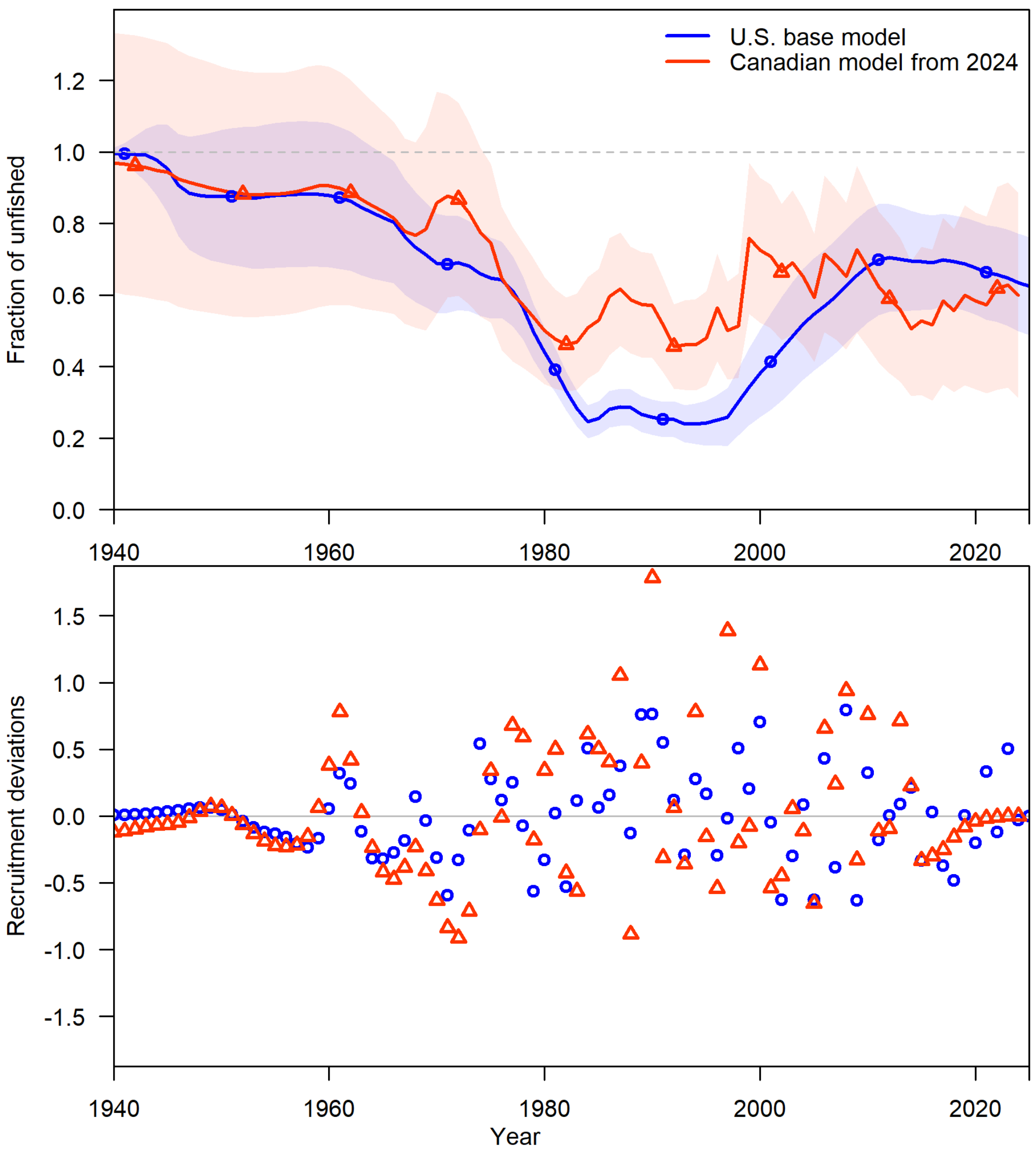

Figure 72: Time series of fraction of unfished spawning output (top) and recruitment deviations (bottom) for the current base model and the 2024 Canadian stock assessment. The Canadian model estimates are based on MLE estimates and associated uncertainty rather than the posterior distributions used in the production assessment. The Canadian model used the empirical weight-at-age approach with different empirical weight-at-age values by year, which contributes to the higher inter-annual variability in the spawning output.

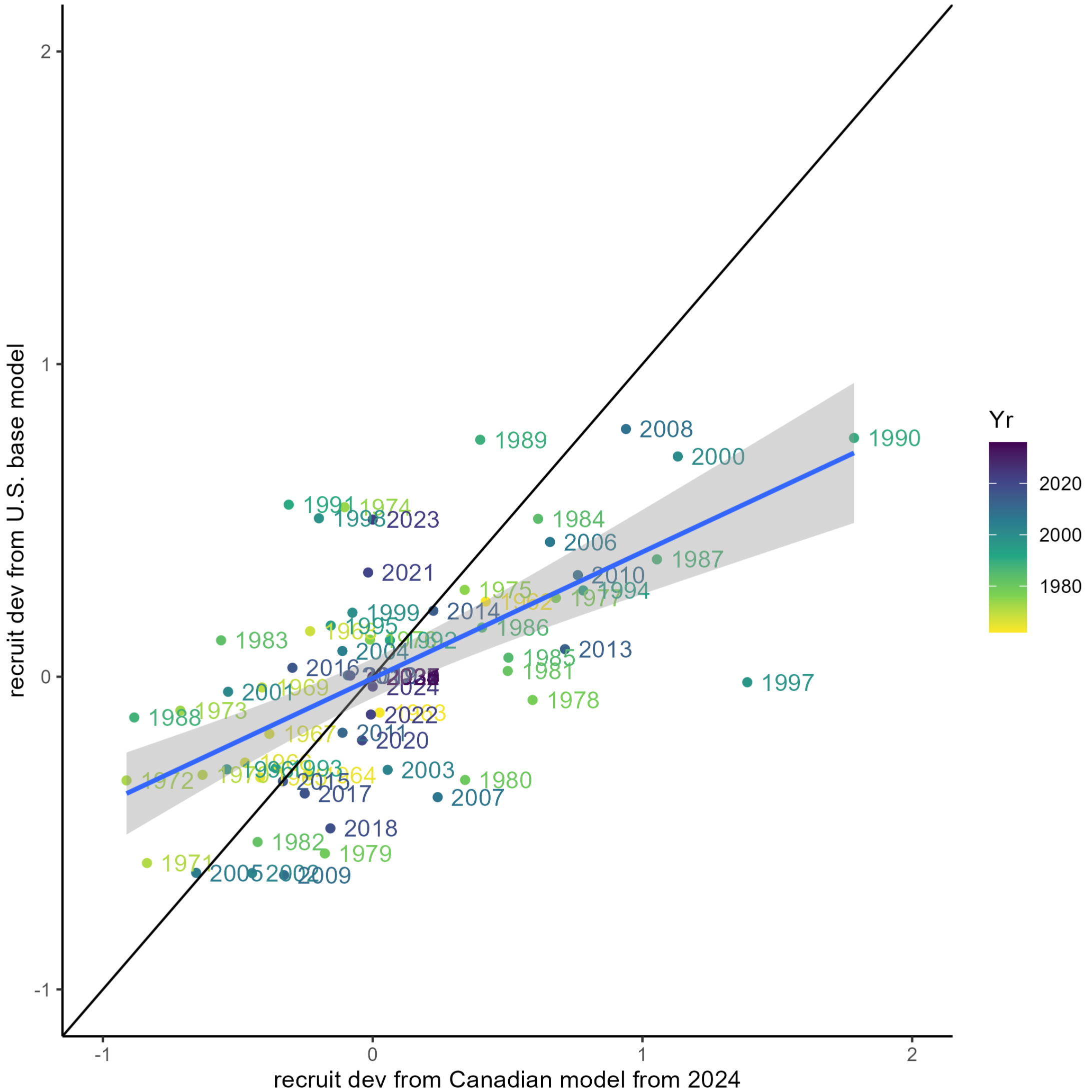

Figure 73: Recruitment deviations from the current base model and the 2024 Canadian stock assessment. The Canadian model estimates are based on MLE estimates rather than the posterior distributions used in the production assessment. The black line represents the 1-to-1 relationship while the blue line and gray interval show the results of a linear model fit to the estimates.

A. Appendix: oceanographic index

Contributed by: Megan Feddern and Nick Tolimieri

The correlation between groundfish recruitment strength and environmental conditions in the California Current has been the topic of extensive research (Tolimieri et al. 2018; Haltuch et al. 2020; Vestfals et al. 2023). For recent assessments the environmental-recruitment relationship has been modeled as an index of recruitment deviations (Johnson et al. 2023; Taylor et al. 2023). This allows for error in the environmental time series, as well as for tuning of the uncertainty so that forecast uncertainty is consistent with the degree of correspondence observed within the time-series and ensures the appropriate degree of recruitment variability for the deviations themselves (Schirripa 2007).

A process for evaluating oceanographic drivers of groundfish recruitment has been established for sablefish (Tolimieri et al. 2018; Johnson et al. 2023), petrale sole (Haltuch et al. 2020; Taylor et al. 2023), and Pacific hake (Vestfals et al. 2023; Grandin et al. 2024). This process involves first, the development of a conceptual life history model which links hypothesized oceanographic conditions with specific lifestages that influence recruitment based on established literature and expert opinion. These oceanographic conditions are then characterized using ocean model products (e.g. Regional Ocean Modeling System [ROMS] or Global Ocean Reanalysis and Simulation [GLORYS]) during the appropriate season and spatial domain to align with each species life history. The oceanographic conditions that are most important for recruitment are then identified through a model selection process and used to develop an index.

A team of ecosystem and stock assessment scientists at NWFSC identified northern yellowtail rockfish as a species that is suitable for evaluation of an oceanographic index. Northern yellowtail rockfish have extensive age composition data but are not well sampled in the NMFS Bottom Trawl Survey until they reach seven years old. As a result, main recruitment deviations are well informed but late recruitment deviations, which start in 2019, have very little information and would benefit from an index to inform recent recruitment and the forecast period. It was also identified that the methods applied in previous studies and assessments could be improved upon by:

1) Modeling flexible non-linear relationships between recruitment deviations and oceanographic conditions using Generalized Additive Models
2) Using GLORYS-based environmental times series when available to avoid temporal discontinuities of ROMS identified in the 2023 petrale sole stock assessment (Taylor et al. 2023)
3) Evaluate predictive capacity of oceanographic models in addition to model fit

A.1. Conceptual life history model

A literature-based, conceptual life-history model for northern yellowtail rockfish was developed that included seven lifestages from preconditioning through benthic recruitment (Table 35) (Darby et al. In Prep). To summarize the methods of Darby et al. (In Prep), each life-history stage that could contribute to the size of each yellowtail rockfish year class was identified, starting with female condition prior to the start of the spawning season (Table 35). Typically, larger, older mothers invest more resources into larval quality, promoting larval survival and contributing significantly to recruitment (Beyer et al. 2015). Nutritional stores in these females, which are gained during the summer upwelling season, are activated for ovarian development during the late fall and winter (MacFarlane et al. 1993). Therefore, the summer through the winter prior to spawning (July – March) may be important for female preconditioning. Copulation (spawning) occurs from August to October in the same year, with fertilization of the eggs occurring approximately 30 days after copulation (November – December). Rockfish carry developing embryos enclosed in egg envelopes for most of gestation but the larvae hatch several days prior to parturition (Macfarlane and Bowers 1995). Parturition occurs from January to April with a peak in February of the following year. Birth of live larvae takes place at depths shallower than 180 meters (Stephens and Taylor 2017). Larvae are often distributed below the surface in the mixed portion of the water column between 20 and 70 meters (Petersen et al. 2010). Pelagic juveniles recruit to nearshore waters throughout the summer months before migrating to deeper waters (up to ~550 meters deep) in the fall where their preferred habitat is the midwater over reefs and boulder fields (Stephens and Taylor 2017). The timing of reproduction corresponds to the larval lifestage aligning with upwelling-induced food production (Barnett et al. 2015). The importance of this phenological alignment between lifestage and recruitment was illustrated in 2005 when a long delay in the spring transition to upwelling-favorable conditions contributed to large-scale recruitment failures that were observed in many marine species (Barth et al. 2007).

Twenty-seven a priori hypotheses (specific to life-stage, time of year, and depth distribution) for oceanographic covariates (Figure 74) that may drive variation in northern Yellowtail rockfish recruitment were developed. For each hypothesis, the time and depth range for the potential predictor were specified, for example, mixed layer depth between February and March at 0 – 90 m depth may affect where larvae are distributed in the water column (Table 35). In some cases, the literature suggested multiple (or overlapping) time periods or depth ranges over which environmental or biological variables might influence recruitment. When this occurred, the broader time periods and depth ranges were included in our analyses to reduce the number of predictors considered. The resulting testable hypotheses fall into four general categories (Table 35): temperature, transport, upwelling indices, and basin-scale processes (i.e., El Niño Southern Oscillation).

A.2. Oceanographic time series

For each hypothesized relationship between northern yellowtail rockfish recruitment and physical oceanographic parameters, a time series was derived from Copernicus Marine Environment Monitoring Service [CMEMS] Global Ocean Reanalysis products (Cabanes et al. 2010). These models provide a higher global ocean eddy permitting resolution (1/4°) reanalysis system, with the objective of describing the mean and time-varying state of ocean circulation over the past several decades. This approach produces a comprehensive record of how ocean properties, such as temperature and mixed layer depth, are changing over time (Cabanes et al. 2010).

We followed the same methods for accessing CMEMS products as the 2023 Petrale Sole stock assessment (Taylor et al. 2023). Briefly, we combined two CMEMS products: the Global Ocean Reanalysis and Simulation (GLORYS12V1:GLOBAL_MULTIYEAR_PHY_001_030, https://doi.org/10.48670/moi-000211) (Fernandez and Lellouche 2018; Drevillon et al. 2022) and the Copernicus Marine global analysis and forecast (CMGAF, GLOBAL_ANALYSISFORECAST_PHY_001_024; https://doi.org/10.48670/moi-00016) (Le Galloudec et al. 2022). The data are served by the Copernicus Marine Service (https://marine.copernicus.eu/). When downloaded the data covered: GLORYS: 1993-01-01 to 2020-11-01 and CMGAF: 2020-11-01 to 2025-01-01. Note both the reanalysis and the analysis and forecast walk forward in time. For the CMGAF, time series are updated at regular intervals beginning with a daily forecast and hindcast simulation, and a weekly 'hindcast-best analysis' with data assimilation through -15 days (Le Galloudec et al. 2022). We use "GLORYS" throughout to refer to the combined data set.

Overall the GLORYS analysis followed Tolimieri et al. (2018) and Haltuch et al. (2020); modified for the life history of Yellowtail rockfish. More specifically, data for water column temperature and bottom temperature were downloaded as daily values for 40-48 °N and processed as follows for each life-history-stage predictor:

1) Subsetted data by depth (Table 35)
2) Calculated the daily average
3) Subsetted #2 by the relevant time periods (Tolimieri et al. 2018)
4) Calculated the annual average (or sum for degree days) for 1993-2024 for that potential predictor

For transport variables and mixed-layer depth, monthly means from the GLORYS models were used to reduce processing time but followed the same overall process as as above. All output data for each physical oceanographic parameter was either summed or averaged over the appropriate period (as defined in Table 35) over a 31 year period, 1994 - 2024 and standardized by subtracting the mean and dividing by the standard deviation such that the standardized time series had a mean of 0 and standard deviation of 1.

For upwelling variables we used two ecologically important characterizations of upwelling conditions. The Coastal Upwelling Transport Index (CUTI) provides estimates of vertical transport near the coast (i.e., upwelling/downwelling). It was developed as a more accurate alternative to the previously available 'Bakun Index' (Jacox et al. 2018). The Biologically Effective Upwelling Transport Index (BEUTI) provides estimates of vertical nitrate flux near the coast (i.e., the amount of nitrate upwelled/downwelled), which may be more relevant than upwelling strength when considering some biological responses (Jacox et al. 2018). CUTI and BEUTI are calculated from ocean state estimates and surface wind forcing obtained from historical reanalyses of the CCS produced using the ROMS with 4-dimensional variational data assimilation described by Jacox et al. (2018). CUTI and BEUTI have not been developed for the 1994 - 2024 time period from GLORYS so ROMS was used as an alternative. Notably, the ROMS data from which CUTI and BEUTI are calculated is consistent across the 2010/2011 time period and these datasets do not have the major sensitivities reported in Taylor et al. (2023) (Mike Jacox, NOAA SWFSC, personal communication, November 1 2024), which were particularly apparent for temperature and mixed layer depth.

Spring transition index (STI; date at which the minimum value of cumulative upwelling is achieved thus representing the onset of the upwelling season) and total upwelling magnitude (TUMI; measures the total intensity of coastal upwelling over the entire length of the upwelling season) are two important characterizations of upwelling phenology (Bograd et al. 2009) that have been linked to rockfish recruitment (Barnett et al. 2015). Therefore, we used used both STI and TUMI calculated from CUTI (CutiSTI, CutiTUMI) and BEUTI (BeutiSTI, BeutiTUMI) following the methods of Bograd et al. (2009) and which we updated through 2024.

Climate indices are designed to represent large-scale environmental patterns and often explain a higher proportion of ecological variance than a single local predictor (Hallett et al. 2004). We considered two climate indices for their influence on yellowtail rockfish recruitment, the Oceanic Niño Index and the Pacific Decadal Oscillation. The Oceanic Niño Index (ONI) describes the equatorial El Niño Southern Oscillation (ENSO). An ONI above 0.5°C indicates El Niño conditions, which often lead to lower primary production, weaker upwelling, poleward transport of equatorial waters and species, and more southerly storm tracks in the CCE. An ONI below -0.5°C means La Niña conditions, which influence atmospheric pressure conditions that lead to upwelling-favorable winds that drive productivity in the California Current Ecosystem (Leising et al. 2025). The Oceanic Niño Index data are from the NOAA Climate Prediction Center https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php.

The Pacific Decadal Oscillation (PDO) describes North Pacific sea surface temperature (SSTa) anomalies that may persist for many years. Positive PDOs are associated with warmer SSTa and lower productivity in the California Current Ecosystem, while negative PDOs indicate cooler SSTa and are associated with higher productivity. There is evidence that the ecological meaning of the PDO has been changing through time

(Litzow et al. 2018; Malick 2020) particularly in the Gulf of Alaska and in relation to Pacific salmon. However the evidence of nonstationary (i.e., time-varying relationships) between the PDO and local physical conditions in the CCS are less conclusive, with relatively stable relationships between the PDO and regional sea surface height, temperature, bifurcation index, and sea level pressure (SLP) through time (Litzow et al. 2018). Recent research has shown that PDO has not changed in pattern or strength, and a pattern of pan-basin warming now overwhelms SSTa changes, producing periods that diverge from what is expected from classic PDO expression (Cluett et al. In Review). Altogether, this indicates that the PDO may still be an important climate index for non-salmon species in the CCS as the PDO still represents basin-scale patterns in SSTa warranting its inclusion, but any interpretations of PDO relationships should consider the pan-basin warming pattern which has been the dominant expression of SSTa since 2014 (Cluett et al. In Review). PDO data included here are from N. Mantua, NMFS/SWFSC, and are served on the CCIEA ERDDAP server https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_PDO.html.

A.3. Index development

Generalized Additive Models (GAM) were used to fit the relationship between oceanographic conditions and recruitment deviations of the base model. GAMs offer a potential improvement over linear models used for oceanographic indices in previous stock assessments by providing additional flexibility for the shape of the relationship between recruitment and oceanographic conditions by fitting non-linear smoothed terms. In order to ensure that the relationship between driver (oceanographic time series) and response variables (recruitment deviations) were ecologically realistic, each smoothed term was only allowed to have up to three knots (k = 3). As such, the relationship could represent linear, threshold, or dome-shaped relationships, but relationships were not permitted to be more "wiggly" than a parabola.

Physical ocean conditions are often correlated due to shared atmospheric forcing, interrelated physics driving variability, and a high degree of both spatial and temporal autocorrelation. As such, many conditions identified in the conceptual life history model are described by highly or moderately correlated time series. In order to prevent multicollinearity and overfitting of the oceanographic index correlations between each individual time series were evaluated (Figure 75). Only time series with a Pearson's correlation coefficient of less than 0.3 (weak correlation) were considered for inclusion in the same model. Up to four oceanographic conditions were included in a single model and all possible combinations of oceanographic conditions were tested for a total of 660 models.

There is a tradeoff between using model fit and predictive capacity when evaluating the performance of environmental-ecological relationships. Models that have a good fit to the entirety of the time period do not necessarily have strong predictive capacity for a specified time period compared to other models. As a result, selecting a model that has a good fit to the data may not have good out of sample predictive capacity. Similarly, a model that fits the data well during the early time period may not fit or predict a more recent time period. This is especially important when considering nonstationarity of environmental conditions (Litzow et al. 2018) and the associated implications for ecological relationships; not all relationships hold up through time (Myers 1998). In addition, the benefit of including an oceanographic index of recruitment particularly for northern yellowtail rockfish is that it is most useful for recent years when recruitment deviations are only weakly informed by age composition data or unable to be estimated. Models that perform well based on classic information criteria such as AIC should therefore be assessed for their predictive performance as well.

Predictive capacity is typically evaluated by cross validation. Here we evaluate model predictive capacity in addition to classically employed model selection techniques AIC, R^2, and deviance explained, specifically, we evaluate Leave-One-Out Cross Validation (LOO-CV) and Leave-Future-Out Cross Validation (LFO-CV). LOO-CV iteratively leaves out one year of data at a time and the model is fit, omitting a given year. The fitted model is then used to predict that year of data (here we are predicting ln(recruitment deviations) for each year). This process is repeated for each year of data for the full time series and each model predicted value is compared to the observed value. Model performance can be evaluated by calculating the Root Mean Square Error (RMSE) from the observed and predicted values. LOO-CV is typically useful for not selecting models prone to leverage years or models with short-term correlations between a driver and response variable, but equally weights the predictive capacity for recent compared to earlier observations.

LFO-CV uses a training dataset to fit the model while omitting the last 5 - 10 years of data. The performance of the model is then evaluated by predicting one year ahead for each year of the omitted data, and seeing how well the predicted values compare to the observed values. However, selecting a model exclusively based on five years of recent data can be prone to selecting a model with shorter-term relationships between recruitment deviations and oceanographic conditions that may not offer robust predictions through time. This is particularly relevant when evaluating models that are fit to short time series or using a large number of candidate models. It can also select models that may be highly sensitive to leverage years. Therefore, the model selected in this process may be highly sensitive to which years are in training and prediction time periods.

To balance these competing priorities for model selection, we evaluated the models using a suite of selection criteria and critically evaluated diagnostics for the highest ranked models. The following criteria were used to compare models based on model selection criteria:

1) LOO-CV using the full model time period, 1994 - 2019

2) LFO-CV with 1994 - 2013 as the training period and 2014 - 2018 as the prediction period
3) AIC, deviance explained, and R^2 for the 1994 - 2019 period
4) Relative improvement of mean RMSE compared to a null model that represents predictive performance of the stock-recruitment relationship alone for 1994 - 2019

Model diagnostics and testing followed a similar evaluation to Tolimieri et al. (2018) and Haltuch et al. (2020), but only a subset of test results are shown here. Model 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. Diagnostics were evaluated for the best performing models based on LOO-CV and LFO-CV. Tests included:

1) Individual years were iteratively removed, the model was fit to the remaining data and then used to predict the omitted observations. These predicted observations were compared to model predictions using the full 1994 - 2019 time period to fit the model
2) Individual years were iteratively removed and the model fit (R^2) was re-evaluated
3) Visual inspection of model fits, with particular attention to the last 5 years of main recruitment deviations

For the final selected model, residual plots were visually inspected.

A.4. Model comparison and selection

No models had a ΔAIC<2 (Model 1, Table 36) and this model was also the highest ranked model based on LOO-CV, had the highest R^2 of 0.53, and explained 65% of the deviance, the highest of any of the candidate models (Table 36). Model 1 included four predictors of recruitment deviations, CutiSTI, DDegg, LSTpjuv, and ONIpjuv (see Table 35 for all abbreviations) each of which were identified to be significant predictors of recruitment deviations ($p < 0.1$; Table 37). Of the highest ranked models based on LOO-CV, CutiSTI and ONIpjuv were both included in all models. During development of the SMURF index it was noted by OSU collaborators that upwelling conditions would be a valuable inclusion for oceanographically informed indices of juvenile abundance (Kirsten Grorud-Colvert, OSU, personal communication, February 20 2025). At the 2025 northern yellowtail rockfish pre-assessment workshop, participants noted observations of El Niño events impacting the stock and suggested consideration for its inclusion in the stock assessment.

The highest ranked model based on LFO-CV included three predictors of recruitment deviations, CutiTUMI, DDpjuv, and MLDpjuv (Table 36, Model 6). Despite the model's strong performance predicting 2014 - 2018 using a 1994 - 2013 training period, the model only explained 28% of the deviance for the 1994 - 2019 time period with an R^2 of 0.18 (Table 36, Model 6). Out of sample prediction for 2008 was significantly different than model prediction fit to the entire time series (Figure 76) and substantially influenced model fits (Figure 77 a & b). Overall, model fits of model 6 were more sensitive to individual years compared to model 1 (Figure 77). No years were identified as being highly influential to the model based on Cook's distance (<1 for all years).

Model 6 predicted recruitment deviations well when they were close to the stock-recruitment curve (when ln(recruitment deviations) are equal to 0) but did not capture deviation trends above and below the stock-recruitment curve well; 40% of the main recruitment deviations were not within the prediction interval of model 6, including multiple years in the last 5 years (Figure 75 A, 2014, 2017, 2018) compared to model 1 (Figure 75 B, 16% and 2018). When compared to a null model, the null model had a 13% improvement in RMSE compared to model 6 for the 1994 - 2019 period. In contrast, model 1 had a 27% improvement in RMSE over the null model.

Based on the collective weight of evidence from model selection criteria and model diagnostics, model 1 was considered the best model. Residual plots showed reasonable residuals (Figure 78) and thus model 1 used as the oceanographic index of recruitment for northern yellowtail rockfish.

A.5. Oceanographic index

The selected model included the spring transition index from the Coastal Upwelling Transport Index (CutiSTI), degree days during egg fertilization (DDegg), along-shore transport during the pelagic juvenile lifestage (LSTpjuv), and the Oceanic Niño Index during the pelagic lifestage (ONIpjuv). Yellowtail rockfish recruitment was positively correlated with CutiSTI at low values and negatively correlated with CutiSTI at high values indicating average timing of the spring transition, occurring around March 23rd, is optimal for yellowtail recruitment (Figure 80). The shape of the relationship was similar with long-shore transport, where optimal conditions for recruitment occurred when transport was slightly above average values. The relationship was highly uncertain at values that were more than 1 sd above the mean; this is likely because a period of exceptionally high LSTpjuv began in 2019 and continued through 2024. DDegg indicated a threshold relationship, where there was a strong negative relationship until the mean, when the relationship levels off and is mostly flat. This indicates that for degree days during egg fertilization, the mean is a critical point for declines in recruitment in response to temperature expose of eggs. Finally, we find the relationship between ONIpjuv and recruitment is negative at all values (linearly negative), although the relationship is uncertain and may be weaker at 1 sd above the mean. El Niño conditions negatively impact yellowtail rockfish recruitment when they occur during the pelagic juvenile phase. Overall, the shapes of the relationships identified from GAM models are ecologically realistic and align with the hypothesized relationships identified from the literature (Table 35).

We note that the oceanographic index substantially overestimates recruitment in 2018, a year that was estimated to have low recruitment rates across juvenile abundance data (Figure 18). Increased recruitment between 2019 - 2021 and low recruitment in 2022 is supported by estimates of late recruitment deviations and other sources of young-of-year data, indicating that the oceanographic index is capturing important dynamics of recruitment and juvenile abundance.

A.6. Figures

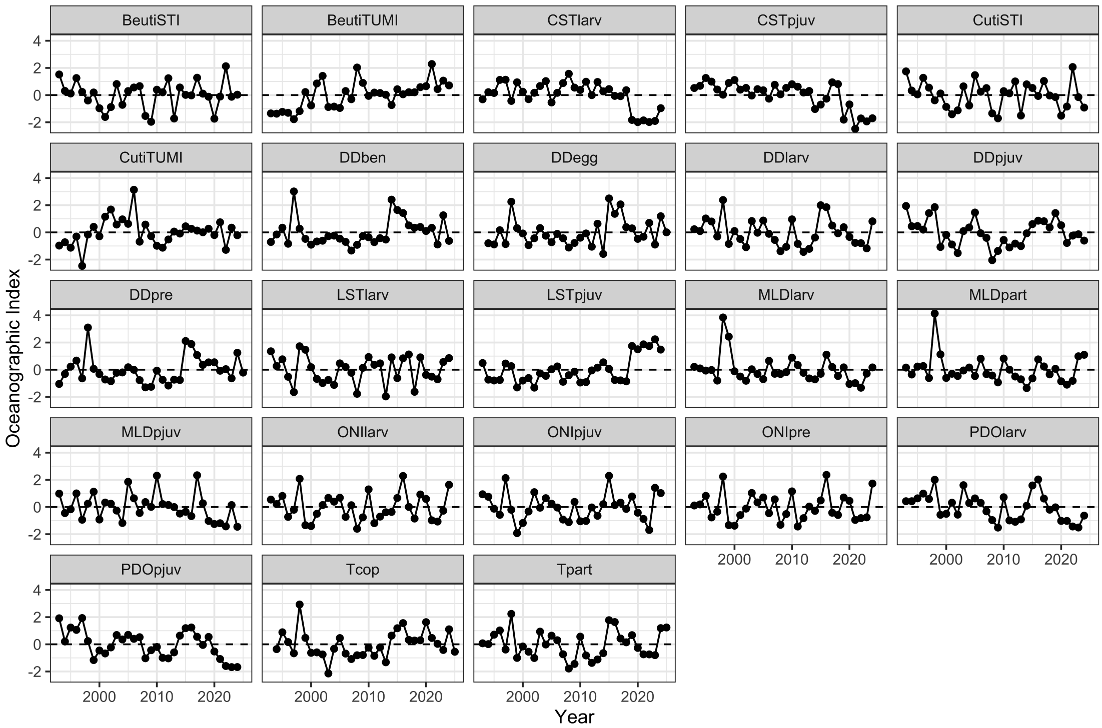

Figure 74: Transport and temperatures times series from the GLORYS models. DD = degree days,T = temperature, MLD = mixed-layer depth, LST = longshore transport, CST = crossshelf transport, Beuti = Biologically Effective Upwelling Transport Index, Cuti = Coastal Upwelling Transport Index, STI= Spring Transition Index, TUMI = Total Upwelling Magnitude Index, pre = female precondition period prior to spawning, egg = egg stage, larv = larval stage, pjuv = pelagic juveniles, ben = benthic juveniles.

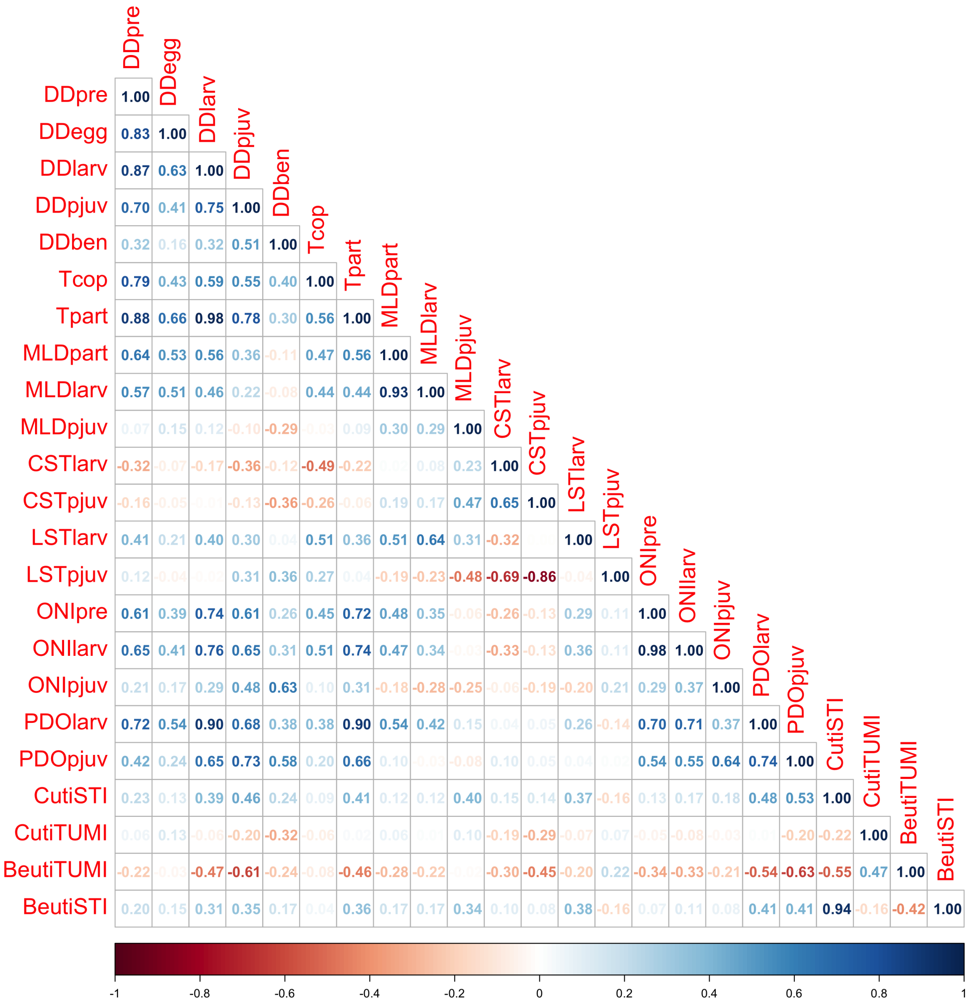

Figure 75: Correlations between oceanographic time series. DD = degree days,T = temperature, MLD = mixed-layer depth, LST = longshore transport, CST = crossshelf transport, Beuti = Biologically Effective Upwelling Transport Index, Cuti = Coastal Upwelling Transport Index, STI= Spring Transition Index, TUMI = Total Upwelling Magnitude Index, pre = female precondition period prior to spawning, egg = egg stage, larv = larval stage, pjuv = pelagic juveniles, ben = benthic juveniles.

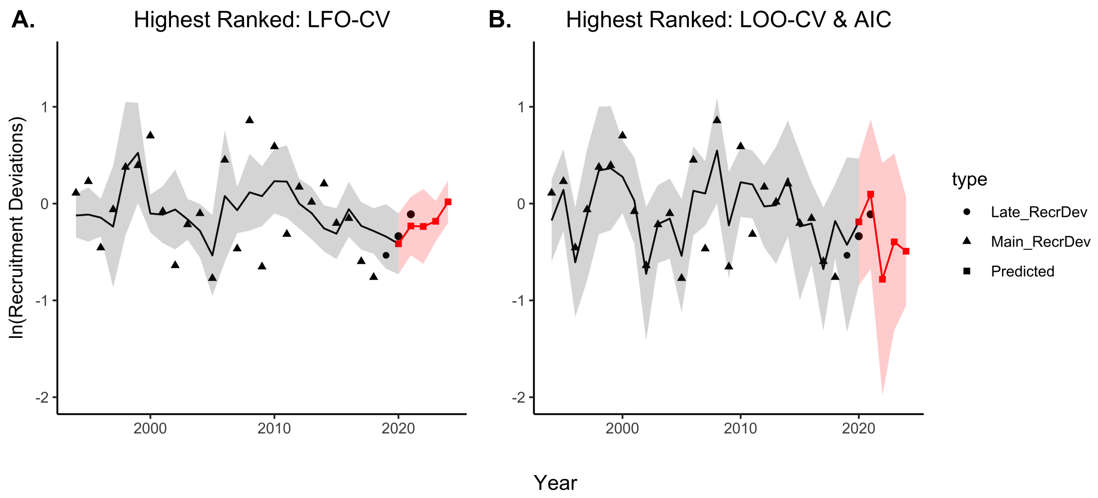

Figure 76: Model fit to the data for a) the highest ranked model based on LFO-CV (Model 6) and b) the highest ranked model based on LOO-CV (Model 1). The black line is the model prediction with the prediction interval shaded for the model fitting period 1994 - 2019. Red line is the 5-year out of sample model prediction and the prediction interval shaded from 2020 - 2024. Squares indicate main recruitment deviations (most age classes observed) and circles represent late recruitment deviations (age classes not fully observed) and squares represent out of sample predictions of the model.

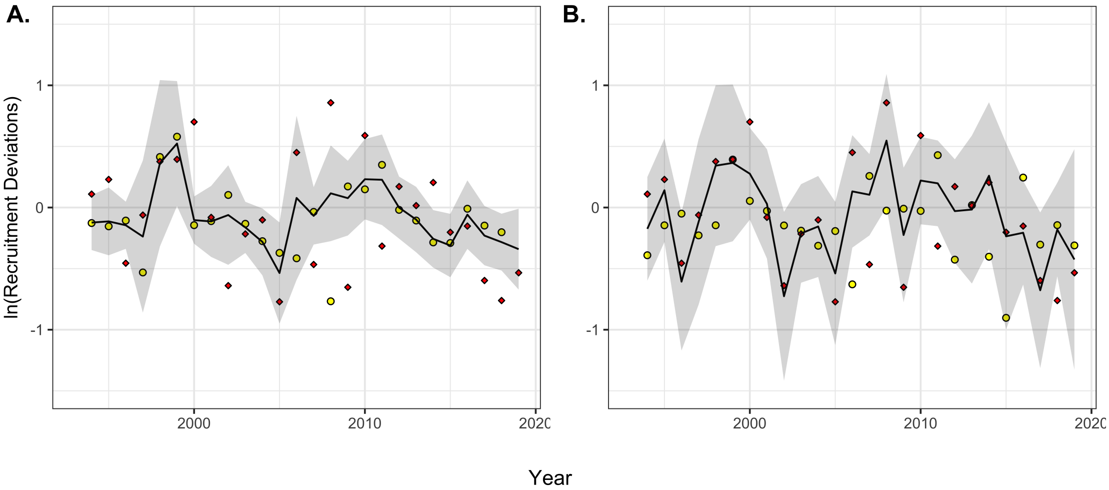

Figure 77: Jackknife analysis for a) the highest ranked model based on LFO-CV (Model 6) and b) the highest ranked model based on LOO-CV (Model 1). The black line is the model prediction with the prediction intervals shaded. Yellow points are from jackknife analysis leaving out one year and refitting the model. Interpretation: how close yellow points are to the line indicate how different the model prediction is when a given year is removed, whether a yellow point is included in the shaded area indicates whether the out of sample prediction for that year is significantly different than the prediction for that year using the 1994 - 2019 time period.

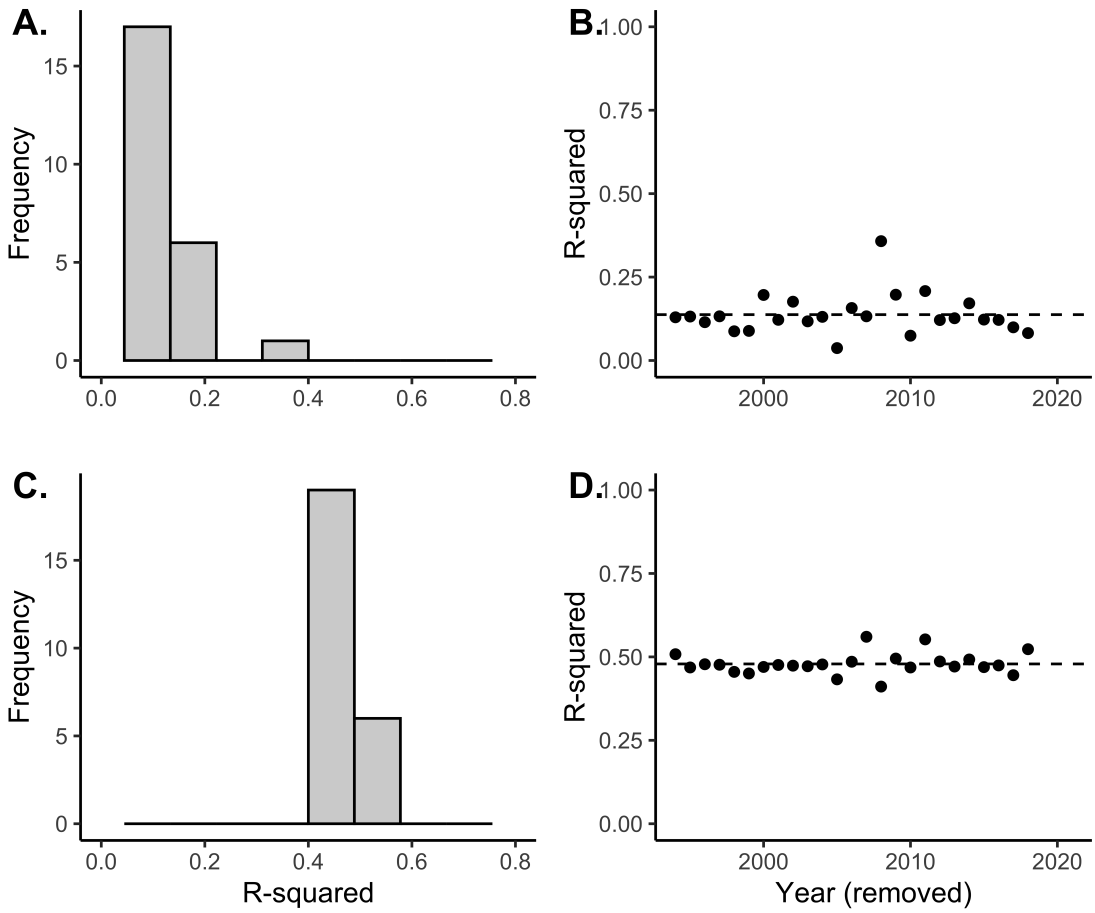

Figure 78: Results of jackknife analysis for the highest ranked model based on LFO-CV (a and b; Model 6) and the highest ranked model based on LOO-CV (c and d; Model 1). A and c indicate the distribution of r^2 values when a single year and omitted and b and c illustrate how much the r^2 value changes when an individual year is excluded from the models.

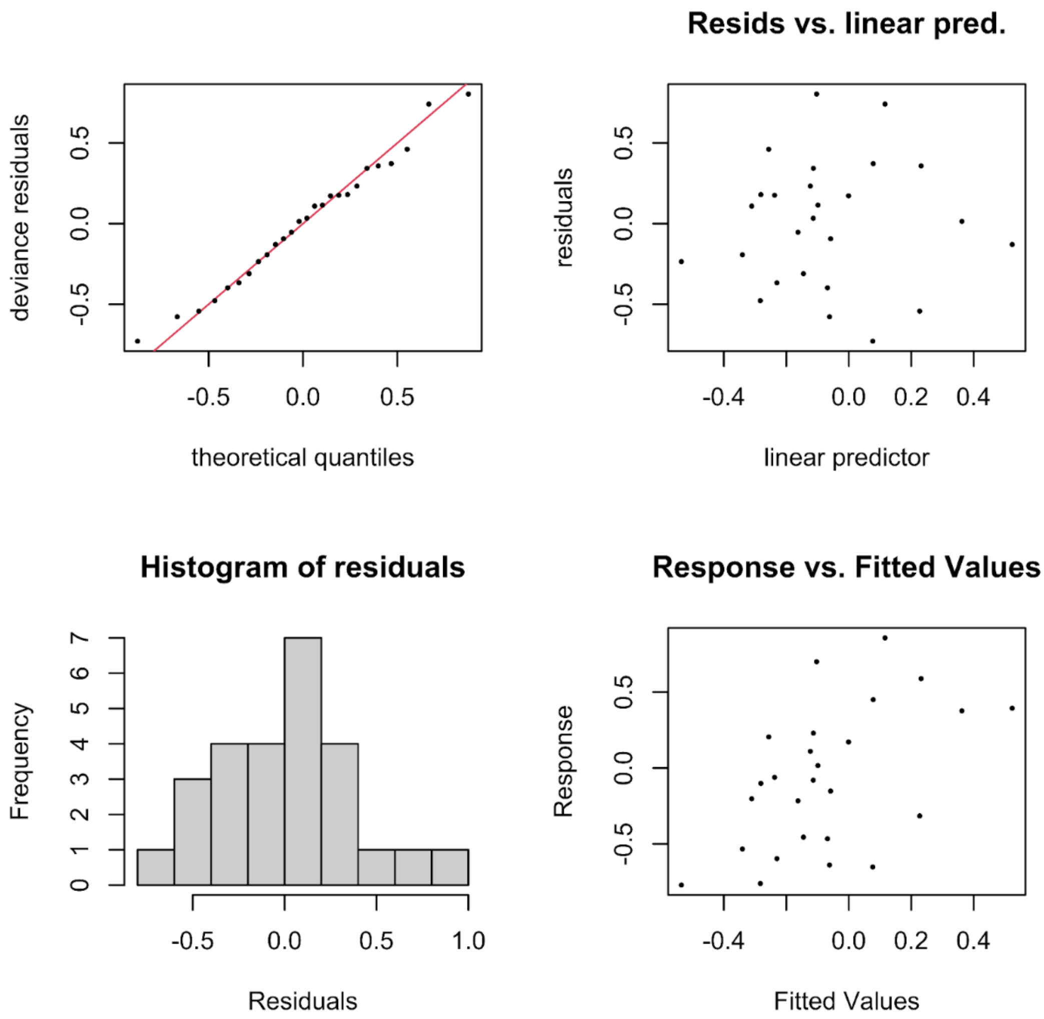

Figure 79: Residual plots showed reasonable residuals for the best-fit model although there were some minor deviation from the 1:1 line. (note: looks better with unexpanded rec devs).

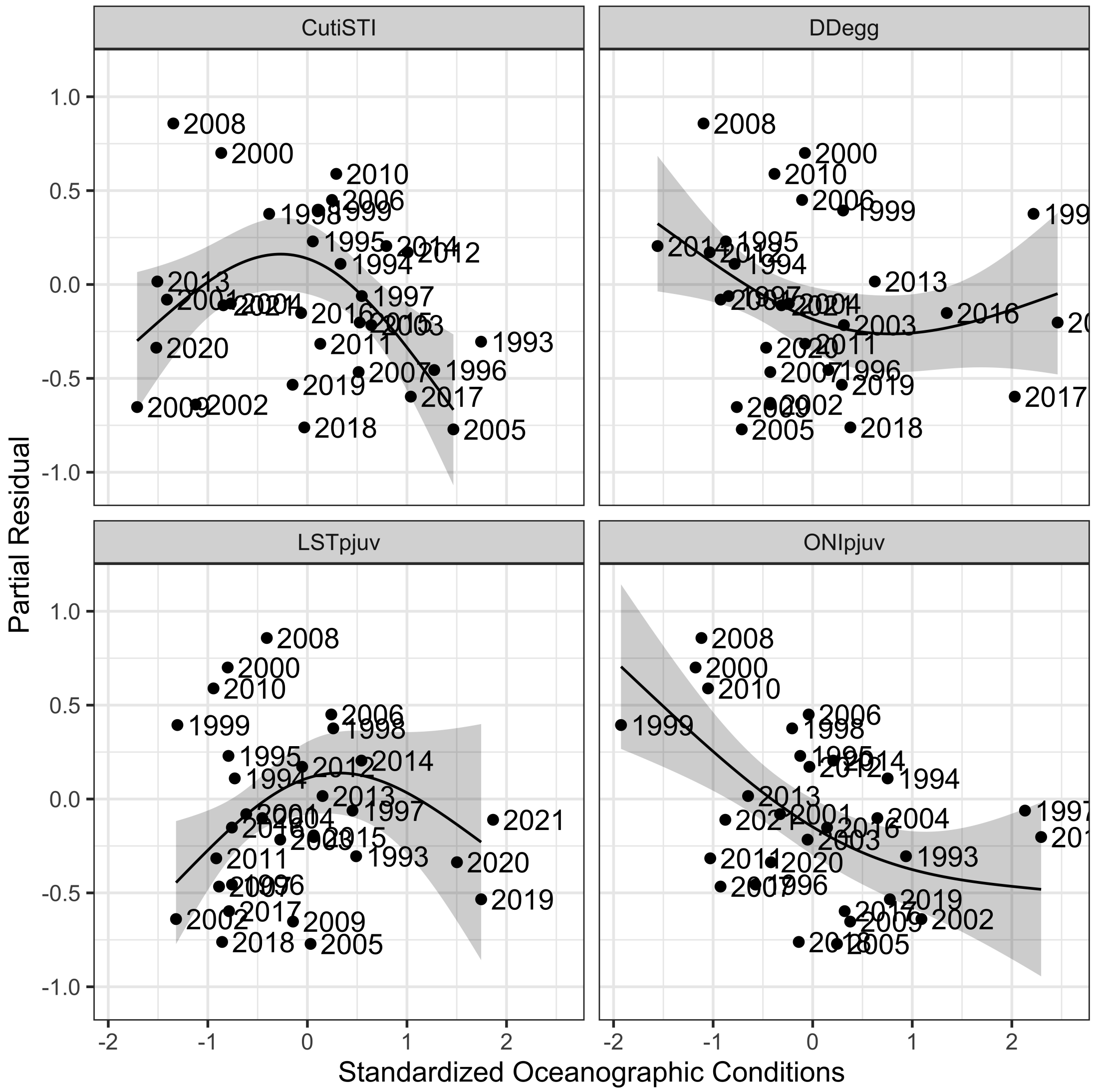

Figure 80: Partial residual plots of oceanographic predictors of recruitment. LST = along-shelf transport, DD = degree days, ONI = Oceanic Nino Index, Cuti = Coastal Upwelling Transport Index, STI= Spring Transition Index, T = temperature, pjuv = pelagic juvenile, and egg = egg stage.

Table 35: Summary of oceanographic conditions influencing yellowtail rockfish life history. Abbreviations: DD = degree days,T = temperature, MLD = mixed-layer depth, LST = longshore transport, CST = crossshelf transport, Beuti = Biologically Effective Upwelling Transport Index, Cuti = Coastal Upwelling Transport Index, STI= Spring Transition Index, TUMI = Total Upwelling Magnitude Index, 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	Hypothesis	Stage	Covariates	Data Source
Preconditioning	Jul (Year 0) – Mar (Year 1)	90 – 180 m	(H1) Higher temperature (degree days) increases food demand, resulting in lower egg production, ultimately resulting in lower recruitment	DDpre	Degree days	GLORYS
			(H2) El Niño/ La Niña cause shifts in temperature and precipitation which lead to changes in recruitment success	ONIpre	Ocean Niño Index	Leising et al. (2024)
Copulation	Aug – Oct	90 – 180 m	(H3) Temperature may act as a spawning cue for initiation of copulation	Tcop	Temperature	GLORYS
Egg fertilization	Nov – Dec	90 – 180 m	(H4) Higher temperature (degree days) affects delayed fertilization and development of the embryo.	DDegg	Degree days	GLORYS
Parturition	Jan – Apr (peak in Feb)	0 – 180 m	(H5) Temperature may act as a cue for birth of live larvae	Tpart	Temperature	GLORYS
			(H6) Location of mixed layer depth may limit where in the water column females give birth	MLDpart	Location of mixed layer depth	GLORYS

Larvae	Feb – Mar	0 – 90 m	(H7) Growth/predation hypothesis: Growth rate is faster in warmer water, leading to reduced time vulnerable to predators	DDlarv	Degree days	GLORYS
			(H8) Cross-shelf transport to settlement habitat affects recruitment	CSTlarv	Net cross-shelf transport	GLORYS
			(H9) Long-shore transport to settlement habitat affects recruitment	LSTlarv	Net long-shore transport	GLORYS
			(H10) Location of mixed layer depth may limit where they are able to move in the water column, affecting transport and recruitment	MLDlarv	Location of mixed layer depth	GLORYS
			(H11) El Niño/La Niña cause shifts in temperature and precipitation which lead to changes in recruitment success	ONIlarv	Ocean Niño Index	Leising et al. (2024)
			(H12) Changes in wind speed and direction impact upwelling/downwelling processes, ultimately impacting recruitment	PDOlarv	Pacific Decadal Oscillation	Leising et al. (2024)
Pelagic juvenile	Apr – Aug	30 – 130 m	(H13) Growth/predation hypothesis: Growth rate is faster in warmer water, leading to reduced time vulnerable to predators	DDpjuv	Degree days	GLORYS
			(H14) Cross-shelf transport to settlement habitat affects recruitment	CSTpjuv	Net cross-shelf transport	GLORYS
			(H16) Long-shore transport to settlement habitat affects recruitment	LSTpjuv	Net long-shore transport	GLORYS

			(H17) Location of mixed layer depth may limit where they are able to move in the water column, affecting transport and recruitment	MLDpjuv	Location of mixed layer depth	GLORYS
			(H18) El Niño/ La Niña cause shifts in temperature and precipitation which lead to changes in recruitment success	ONIpjuv	Ocean Niño Index	Leising et al. (2024)
			(H19) Changes in wind speed and direction impact upwelling/downwelling processes, ultimately impacting recruitment	PDOpjuv	Pacific Decadal Oscillation	Leising et al. (2024)
			(H20) Coastal upwelling impacts nutrient and food availability the timing of which contributes to growth and survival	CutiSTI	Coastal Upwelling Transport Index	Jorgensen et al. (2024)
			(H21) Coastal upwelling impacts nutrient and food availability the amount of which contributes to growth and survival	CutiTUMI	Coastal Upwelling Transport Index	Jorgensen et al. (2024)
			(H22) Nitrate is essential for primary productivity, the timing of which impacts presence of phytoplankton available as a food source	BeutiSTI	Biologically Effective Upwelling Index	Jorgensen et al. (2024)
			(H23) Nitrate is essential for primary productivity, the amount of which impacts presence of phytoplankton available as a food source	BeutiTUMI	Biologically Effective Upwelling Index	Jorgensen et al. (2024)
Benthic juvenile	Sept – Dec	180 – 549 m	(H24) Growth/predation hypothesis: Growth rate is faster in warmer water, leading to reduced time vulnerable to predators	DDben	Degree days	GLORYS

Table 36: Results of model selection showing the top 5 ranked models based on LOO-CV. Model 6 is the highest ranked model based on LFO-CV. The null model had an RMSE of 0.46.

Model	Rank (LOO)	Covariate 1	Covariate 2	Covariate 3	Covariate 4	ΔAIC	R-squared	Deviance Explained	RMSE (LFO-CV) 5 Year	RMSE (LOO-CV)
Model 1	1	CutiSTI	DDegg	LSTpjuv	ONIpjuv	0.00	0.53	0.65	0.59	0.33
Model 2	2	CutiSTI	-	LSTpjuv	ONIpjuv	4.47	0.43	0.54	0.71	0.37
Model 3	3	CutiSTI	DDpre	LSTpjuv	ONIpjuv	6.10	0.41	0.55	0.71	0.38
Model 4	4	CutiSTI	DDegg	CSTlarv	ONIpjuv	6.50	0.39	0.52	0.38	0.38
Model 5	5	CutiSTI	LSTpjuv	CutiTUMI	ONIpjuv	6.40	0.40	0.55	0.71	0.39
Model 6	240	CutiTUMI	DDpjuv	MLDpjuv	-	35.00	0.18	0.28	0.35	0.52

Table 37: Coefficients for best-fit model (Model 1).

Smooth	edf	Ref.df	F	p.value.
s(CutiSTI)	1.93	1.99	4.76	0.019**
s(DDegg)	1.71	1.91	2.31	0.100*
s(LSTpjuv)	1.79	1.95	3.43	0.078*
s(ONIpjuv)	1.72	1.92	8.51	0.0054**
Covariate	Estimate	SE	t value	Pr(>|t|)
Intercept	-0.78	0.063	-1.15	0.27