1. Assessment of the Walleye Pollock Stock in the Gulf of Alaska

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The following documents are associated with this report and can be found at the associated links:

Appendix 1.A is available online here.

Executive Summary

Summary of Changes in Assessment Inputs

Changes to input data

1. Fishery: 2023 total catch was updated and catch at age added. 2024 catch was assumed to be 131,000 t, well below the TAC due a closure in the Central GOA.
2. Shelikof Strait acoustic survey: 2024 biomass index and age compositions.
3. NMFS bottom trawl survey: 2023 age compositions
4. Summer acoustic survey: 2023 age compositions
5. ADF&G crab/groundfish trawl survey: 2024 biomass index
6. The NMFS bottom trawl age compositions and weight at age were updated to include only survey tows west of 140W, bringing these data in line with the biomass index.

Changes in assessment methodology

Four alternative models were developed in 2024.

1. *Model 23a*: Data weights were revised this year. CVs for biomass indices and input sample sizes for age compositions for Shelikof Strait survey, NMFS bottom trawl survey, and summer acoustic survey were updated.
2. *Model 23b*: Extends model 23a to inncorporate an environmental covariate on catchability for the Shelikof Strait survey, based on Rogers *et al.* (2024).
3. *Model 23c*: The same as model 23b but the age 1 and 2 indices from the Shelikof Strait survey were removed from the model due to recent poor performance.
4. *Model 23d* **(author recommended)**: Extends model 23c to use the Dirichlet-multinomial likelihood in place of the multinomial for all age compositions.

A research model is presented in Appendix 1E, but not proposed as an alternative this year. This model incorporates a subset of the ESP data (Appendix 1A) into the assessment to explain variation in recruitment using a casual framework modeled via dynamic structural equation models (DSEM, Thorson *et al.* 2024).

Summary of Results

The following table shows key management quantities for the alternative models.

Model Version	2025 SSB (t)	B100	FOFL	FABC	OFL	ABC
23: 2024 data	259,437	534,000	0.308	0.261	186,778	161,183
23a: updated ISS CVs	245,952	529,000	0.309	0.262	180,218	155,540
23b: + Ecov q1 link	231,139	528,000	0.314	0.266	174,504	150,545
23c: - Shelikof 1 & 2s	238,824	529,000	0.316	0.267	205,536	177,035
23d: 2024 final	243,078	535,000	0.321	0.271	210,111	181,022

The base model (23d) projection of female spawning biomass in 2025 is 243,078 t, which is 45.4% of unfished spawning biomass (based on average post-1977 recruitment) and above B40% (214,000 t), thereby placing GOA pollock in sub-tier “a” of Tier 3. New surveys in 2024 include the winter Shelikof Strait acoustic survey and the ADF&G bottom trawl survey. These survey indices showed similar trends, with increases in the winter acoustic (12.0%) and ADF&G bottom trawl survey (17.3%) from 2023.

The risk matrix table recommended by the Scientific and Statistical Committee (SSC) was used to determine whether to recommend an ABC lower than the maximum permissible. The table is applied by evaluating the severity of four types of considerations that could be used to support a scientific recommendation to reduce the ABC from the maximum permissible. We identified some elevated concerns about the stock assessment, but none for population dynamics, environment/ecosystem, or fisheries performance categories. We therefore recommend no reduction from maximum permissible ABC.

The recommended 2025 ABC for pollock in the Gulf of Alaska west of 140° W lon. (W/C/WYK regions) is 181,022 t, which is an decrease of -22.2% from the 2024 ABC. The recommended 2026 ABC is 133,075 t. The OFL in 2025 is 210,111 t, and the OFL in 2026 if the ABC is taken in 2025 is 153,971 t. These calculations are based on a projected 2024 catch of 131,000 t and the ABC for years 2025 and 2026.

For pollock in southeast Alaska (Southeast Outside region, east of 140° W lon.), the ABC recommendation for both 2025 and 2026 is 9,749 t (see Appendix 1B) and the OFL recommendation for both 2025 and 2026 is 12,998 t. These recommendations are based on a Tier 5 assessment using the projected biomass in 2025 and 2026 from a random effects model fit to the 1990-2023 bottom trawl survey biomass estimates of the assessment area.

Status Summary for Gulf of Alaska Pollock in W/C/WYK Areas

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity/Status	2024	2025	2025*	2026*
M (natural mortality)	0.300	0.300	0.300	0.300
Tier	3a	3a	3a	3a
Projected total (age 3+) biomass (t)	1,154,403	1,430,029	1,269,931	1,005,310
Projected female spawning biomass (t)	274,141	227,091	243,078	196,028
$B_{100\%}$	505,000	505,000	535,000	535,000
$B_{40\%}$	202,000	202,000	214,000	214,000
$B_{35\%}$	177,000	177,000	187,000	187,000
F_{OFL}	0.307	0.307	0.321	0.321
maxF_{ABC}	0.260	0.260	0.271	0.271
F_{ABC}	0.260	0.260	0.271	0.271
OFL (t)	269,916	182,891	**210,111**	153,971
*max*ABC (t)	232,543	157,687	181,022	133,075
ABC (t)	232,543	157,687	**181,022**	133,075
	As determined *last* year for:		As determined *this* year for:	
Status	2023	2024	2024	2025
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projections are based on an estimated catch of 181,022 t for 2024 and estimates of 133,075 t and NA t used in place of maximum permissible ABC for 2025 and 2026.

Status Summary for Gulf of Alaska Pollock in the Southeast Outside Area

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity/Status	2024	2025	2025	2026
M (natural mortality)	0.30	0.30	0.30	0.30
Tier	5	5	5	5
Biomass (t)	43,328	43,328	43,328	43,328
F_{OFL}	0.30	0.30	0.30	0.30
maxF_{ABC}	0.23	0.23	0.23	0.23
F_{ABC}	0.23	0.23	0.23	0.23
OFL (t)	12,998	12,998	12,998	12,998
*max*ABC (t)	9,749	9,749	9,749	9,749
ABC (t)	9,749	9,749	9,749	9,749
	As determined *last* year for:		As determined *this* year for:	
Status	2023	2024	2024	2025
Overfishing	No	n/a	No	n/a

Area Allocation of Harvest

The following table shows the recommended ABC apportionment for 2025 and 2026. Please refer to Appendix 1D for information regarding how apportionment is calculated. Area 640 is not portioned by season.

Year	Area	Season A ABC (t)	Season B ABC (t)
2025	610	5,589	31,755
	620	63,267	18,998
	630	16,751	34,854
	640	5,282	
2026	610	4,109	23,344
	620	46,510	13,967
	630	12,314	25,622
	640	3,883	

Responses to SSC and Plan Team Comments

Responses to SSC and Plan Team Comments on Assessments in General

Responses to general issues are also found in the SAFE Introduction.

When there are time-varying biological and fishery parameters in the model, the SSC requests that a table be included in the SAFE that documents how reference points are calculated.

This is included in Table 1.26

Responses to SSC and Plan Team Comments Specific to this Assessment

Since fishery weight-at-age is so variable, the SSC is interested in seeing if TMB can help use these data directly in the model.

A WHAM version of the model presented in Correa *et al.* (2023) smooths weight at age (WAA) internally, but did not find a big impact so this was not prioritized. However, it is feasible in TMB, and likely advisable, to model WAA for the fishery and all surveys simultaneously, with annual, cohort, and age effects. This will be a priority research topic for 2025.

Check the recruitment that is set or estimated to be "1" in 2023. If there is no information due to lack of data for young pollock, perhaps recruitment in 2023 should be closer to mean recruitment.

Previously age 1 recruitments were informed by data from the Shelikof survey, which has age-1 and 2 indices in the assessment year. Those data were proposed to be removed from the model in 2024 (model 23c) and so the estimates will be mean recruitment.

Continue to investigate the estimates of recruitment variability and the extremely low recruitment estimates in recent years.

The extremely low recruitments were found to be driven entirely by the age-1 and 2 Shelikof indices which had unreasonably low estimates. Subsequent data were not able to counteract this signal and so excessively small cohort estimates persisted. As such, these data were removed from the model this year until a more appropriate way to include them can be found.

The SSC agrees with the GOA GPT to continue to present the 10-year standard used in AFSC assessments for retrospectives as it helps review bodies compare across assessments more readily.

Corrected in 2024.

The SSC notes that the ESR process has matured over several decades to effectively use ecosystem trends to inform annual specifications and encourages the use of trans-disciplinary approaches for linking ESR and ESPs to stock assessments in the future. The GOA pollock assessment was suggested as a potential case study, particularly in contrasting differences in the strength of 2018 vs. 2019 year classes.

A research model is presented in Appendix 1E that explores incorporating ESP data into the pollock stock assessment. This model embeds a dynamic structural equation model (DSEM) into the assessment, and uses complex causal relationships among eight ESP indicators to explain recruitment variation. Preliminary results are encouraging, with strong statistical evidence that this approach can substantially reduce unexplained recruitment variation and improve short-term projections like those used for management.

Introduction

Biology and Distribution

Walleye pollock (*Gadus chalcogrammus*; hereafter referred to as pollock) is a semi-pelagic schooling fish widely distributed in the North Pacific Ocean. Pollock in the central and western Gulf of Alaska (GOA) are managed as a single stock independently of pollock in the Bering Sea and Aleutian Islands. The separation of pollock in Alaskan waters into eastern Bering Sea and Gulf of Alaska stocks is supported by analysis of larval drift patterns from spawning locations (Bailey *et al.* 1997), genetic studies of allozyme frequencies (Grant and Utter 1980), mtDNA variability (Mulligan *et al.* 1992), and microsatellite allele variability (Bailey *et al.* 1997).

Stock Structure

The results of studies of stock structure within the Gulf of Alaska are equivocal. There is evidence from allozyme frequency and mtDNA that spawning populations in the northern part of the Gulf of Alaska (Prince William Sound and Middleton Island) may be genetically distinct from the Shelikof Strait spawning population (Olsen *et al.* 2002). However, significant variation in allozyme frequency was found between Prince William Sound samples in 1997 and 1998, indicating a lack of stability in genetic structure for this spawning population. Olsen *et al.* (2002) suggest that inter-annual genetic variation may be due to variable reproductive success, adult philopatry, source-sink population structure, or utilization of the same spawning areas by genetically distinct stocks with different spawning timing. There are important recent preliminary results from a genetic analysis of 617 walleye pollock from Japan, Bering Sea, Chukchi Sea, Aleutian Islands, Alaska Peninsula, and Gulf of Alaska using low-coverage whole genome sequencing. Results suggests there is a temporally stable stock structure with a latitudinal gradient, i.e., Bering Sea pollock are distinguishable from those in the Gulf of Alaska and Aleutian Islands (I. Spies, personal communication, 2021). An evaluation of stock structure for Gulf of Alaska pollock following the template developed by NPFMC stock structure working group was provided as an appendix to the 2012 assessment (Dorn *et al.* 2012). Available information supported the current approach of assessing and managing pollock in the eastern portion of the Gulf of Alaska (Southeast Outside) separately from pollock in the central and western portions of the Gulf of Alaska

(Central/Western/West Yakutat). The main part of this assessment deals only with the C/W/WYK stock, while results for a tier 5 assessment for southeast outside pollock are reported in Appendix 1B.

Fishery

The commercial fishery for walleye pollock in the Gulf of Alaska started as a foreign fishery in the early 1970s (Megrey 1989). Catches increased rapidly during the late 1970s and early 1980s (Table 1.1; Fig. 1.1). A large spawning aggregation was discovered in Shelikof Strait in 1981, and a fishery developed for which pollock roe was an important product. The domestic fishery for pollock developed rapidly in the Gulf of Alaska with only a short period of joint venture operations in the mid-1980s. The fishery was fully domestic by 1988.

Description of the Directed Fishery

Catch Patterns

The pollock target fishery in the Gulf of Alaska is entirely shore-based with approximately 96% of the catch taken with pelagic trawls. During winter, fishing effort targets pre-spawning aggregations in Shelikof Strait and near the Shumagin Islands (Figs. 1.2 and 1.3). Fishing in summer is less predictable, but typically occurs in deep-water troughs on the east side of Kodiak Island and along the Alaska Peninsula.

Bycatch and Discards

Incidental catch in the Gulf of Alaska directed pollock fishery is low. For tows classified as pollock targets in the Gulf of Alaska between 2019 and 2023, on average about 94.9% of the catch by weight of FMP species consisted of pollock (Table 1.2). Nominal pollock targets are defined by the dominance of pollock in the catch, and may include tows where other species were targeted, but pollock were caught instead. The most common managed species in the incidental catch are Pacific cod, Pacific ocean perch, arrowtooth flounder, sablefish, shallow-water flatfish, and flathead sole (Table 1.2). Sablefish incidental catch had trended upwards since 2018, but has fallen in the last few years. The most common recent non-target species are squid, miscellaneous fish, smelt, and grenadier (Table 1.2).

Bycatch estimates for prohibited species over the period 2019-2023 are given in Table 1.3. Chinook salmon are the most important prohibited species caught as bycatch in the pollock fishery. A sharp spike in Chinook salmon bycatch in 2010 led the Council to adopt management measures to reduce Chinook salmon bycatch, including a cap of 25,000 Chinook salmon bycatch in the directed pollock fishery. Estimated Chinook salmon bycatch since 2010 has been less than the peak in 2010 and was 18,433 in 2023. Final bycatch values are unavailable for 2024, but the Central GOA exceeded their PSC limit of Chinook salmon and was closed (for areas 620 and 634) on September 25, 2024. This was the first closure due to Chinook since the adoption of the managmeent measures in 2010.

Non-commercial catches

To comply with the Annual Catch Limit (ACL) requirements, estimates have been developed by the Alaska for non-commercial catches and removals from NMFS-managed stocks in Alaska (Table 1.4). Reported non-commercial catches primarily include catches associated with surveys and research projects. Small amounts of pollock catch are attributed to subsistence and bait for crab. It is important to note that there is unreported incidental catch of pollock in other fisheries in Alaska, such as the salmon fishery, which, based on anecdotal reports, may be substantial on occasion.

Management Measures

Since 1992, the Gulf of Alaska pollock Total Allowable Catch (TAC) has been apportioned spatially and temporally to reduce potential impacts on Steller sea lions. The details of the apportionment scheme have evolved over time, but the general objective is to allocate the TAC to management areas based on the distribution of surveyed biomass, and to establish three or four seasons between mid-January and fall during which some fraction of the TAC can be taken. The Steller Sea Lion Protection Measures implemented in 2001 established four seasons in the Central and Western GOA beginning January 20, March 10, August 25, and October 1, with 25% of the total TAC allocated to each season. Allocations to management areas 610, 620 and 630 are based on the seasonal biomass distribution as estimated by groundfish surveys. In addition, a harvest control rule was implemented that requires suspension of directed pollock fishing when spawning biomass declines below 20% of the reference unfished level.

Recently NMFS approved the final rule for Amendment 109 to GOA Fishery Management Plan developed by the North Pacific Fisheries Management Council. Amendment 109 combines pollock fishery A and B seasons into a single season (redesignated as the A season), and the C and D seasons into a single season (redesignated as the B season), and changes the annual start date of the redesignated pollock B season from August 25 to September 1. These changes were implemented beginning in 2021 and affect the seasonal allocation only in the Central and Western GOA.

Data

The data used in the assessment model consist of estimates of annual catch in tons, fishery age compositions, NMFS summer bottom trawl survey estimates of biomass and age and length compositions, acoustic survey estimates of biomass and age composition in Shelikof Strait, summer acoustic survey estimates of biomass and age and length composition, and ADF&G bottom trawl survey estimates of biomass and age composition (Figure 1.4). Binned length composition data are used in the model only when age composition estimates are unavailable. The following table specifies the data that were used in the GOA pollock assessment:

Source	**Data**	**Years**
Fishery	Total catch	1970-2024
Fishery	Age composition	1970-2023
Shelikof Strait acoustic survey	Biomass	1992-2024
Shelikof Strait acoustic survey	Age composition	1992-2024
Summer acoustic survey	Biomass	2013-2023, biennially
Summer acoustic survey	Age composition	2013-2023, biennially
NMFS bottom trawl survey	Area-swept biomass	1990-2023, biennially
NMFS bottom trawl survey	Age composition	1990-2023, biennially
ADF&G trawl survey	Delta-GLM index	1988-2024
ADF&G trawl survey	Age composition	2000-2022, biennially

Fishery

Catch

Total catch estimates were obtained from INPFC and ADF&G publications, and databases maintained at the Alaska Fisheries Science Center and the Alaska Regional Office. Foreign catches for 1963-1970 are reported in Forrester *et al.* (1978). During this period only Japanese vessels reported catch of pollock in the GOA, though there may have been some catches by Soviet Union vessels. Foreign catches 1971-1976 are reported by Forrester *et al.* (1983). During this period there are reported pollock catches for Japanese, Soviet Union, Polish, and South Korean vessels in the Gulf of Alaska. Foreign and joint venture catches for 1977-1988 are a blend of estimates from the NORPAC database maintained by the Alaska Fisheries Science Center. Domestic catches for 1970-1980 are reported in Rigby (1984). Domestic catches for 1981-1990 were obtained from PacFIN (Brad Stenberg, pers. comm. Feb 7, 2014). A discard ratio (discard/retained) of 13.5% was assumed for all domestic catches prior to 1991 based on the 1991-1992 average discard ratio. Estimated catch for 1991-2020 was obtained from the Catch Accounting System database maintained by the Alaska Regional Office. These estimates are derived from shoreside electronic logbooks and observer estimates of at-sea discards (Table 1.5). Catches include the state-managed pollock fishery in Prince William Sound (PWS). Since 1996, the pollock Guideline Harvest Level (GHL) of 2.5% for the PWS fishery has been deducted from the total Acceptable Biological Catch (ABC) by the NPFMC Gulf of Alaska Plan Team for management purposes (see SAFE introduction for further information). Non-commercial catches are reported in Table 1.4.

Age and Size Composition

Catch at age was re-estimated in the 2014 assessment for 1975-1999 from primary databases maintained at AFSC. A simple non-stratified estimator was used, which consisted of compiling a single age-length key for use in every year and then applying the annual length composition to that key. Use of an age-length key was considered necessary because observers used length-stratified sampling designs to collect otoliths prior to 1999 (Barbeaux *et al.* 2005). Estimates were made separately for the foreign/JV and domestic fisheries in 1987 when both fisheries were sampled. There were no major discrepancies between the re-estimated age composition and estimates that have built up gradually from assessment to assessment.

Estimates of fishery age composition from 2000 onwards were derived from at-sea and port sampling of the pollock catch for length and ageing structures (otoliths). The length composition and ageing data were obtained from the NORPAC database maintained at AFSC. Catch age composition was estimated using methods described by Kimura and Chikuni (1989). Age samples were used to construct age-length keys by sex and stratum. These keys were applied to sex and stratum specific length frequency data to estimate age composition, which were then weighted by the catch in numbers in each stratum to obtain an overall age composition. A background age-length key is used fill the gaps in age-length keys by sex and stratum. Sampling levels by stratum for 2000-2015 are documented in the assessments available online at http://www.afsc.noaa.gov/REFM/stocks/Historic_Assess.htm. Age and length samples from the 2023 fishery were stratified by half-year seasons and statistical area as follows:

Season	Type	Shumagin-610	Chirikof-620	Kodiak-630	W. Yakutat and PWS-640 and 649
1st half (A season)	No. ages	0	393	384	172
	No. lengths	0	3,881	1,173	509
	Catch (t)	74	57,348	8,335	10,135
2nd half (B season)	No. ages	397	237	393	0
	No. lengths	6,497	820	3,255	0
	Catch (t)	26,139	7,995	25,076	0

The dominant cohort in the 2024 expected age composition data was 2020 with 43%, followed by 2017 and 2018 with 12% and 17%, respectively. The 2012 cohort is in the plus group and only accounts for about 4% of expected catch this year. Fishery catch at age in 1975-2023 is presented in Table 1.6 (see also Fig. 1.5). Sample sizes for ages and lengths are given in Table 1.7.

Gulf of Alaska Bottom Trawl Survey

Trawl surveys have been conducted by Alaska Fisheries Science Center (AFSC) beginning in 1984 to assess the abundance of groundfish in the Gulf of Alaska (Tables 1.10 and 1.8). Following standard AFSC practice surveys prior to 1990 are excluded due to the difficulty in standardizing the surveys when Japanese vessels with different gear were used. Starting in 2001, the survey frequency was increased from once every three years to once every two years. The survey uses a stratified random design, with 49 strata based on depth, habitat, and statistical area (Szalay *et al.* 2010). Area-swept biomass estimates are obtained using mean CPUE (standardized for trawling distance and mean net width) and stratum area. The survey is conducted from chartered commercial bottom trawlers using standardized poly-Nor'eastern high opening bottom trawls rigged with roller gear. In a full three-boat survey, 800 tows are completed, but the recent average has been closer to 600 tows. On average, 72% of these tows contain pollock (Table 1.8). Recent years have dropped stations in deeper water which are unlikely to affect the index due to pollock typically being in shallower depths with on average 90.9% above 200 m and 99.6% above 300 m from 1984-2021.

Biomass Estimates

The time series of pollock biomass used in the assessment model is based on the surveyed area in the Gulf of Alaska west of 140° W long., obtained by adding the biomass estimates for the Shumagin-610, Chirikof-620, Kodiak-630 statistical areas, and the western portion of Yakutat-640 statistical area. Biomass estimates for the west Yakutat area were obtained by splitting strata and survey CPUE data at 140° W long. and re-estimating biomass for west Yakutat following Wakabayashi *et al.* (1985) and using the 'gapindex' R package (Oyafuso 2024). In 2001, when the eastern Gulf of Alaska was not surveyed, a random effects model was used to interpolate a value for west Yakutat for use in the assessment model. In 2024 the size composition, age-length key, age composition and weight at age estimates from 1990-2024 were also re-estimated to exclude pollock east of 140W, bringing them in line with the biomass estimates.

The Alaska Fisheries Science Center's (AFSC) Resource Assessment and Conservation Engineering (RACE) Division conducted the 18th comprehensive bottom trawl survey since 1984 during the summer of 2023 (Fig. 1.6). The 2023 gulfwide biomass estimate of pollock was 921,886 t, which is an increase of 74.3% from the 2021 estimate, which itself was a 72.2% increase from 2019, a sharp increase after the low in 2019. The biomass estimate for the portion of the Gulf of Alaska west of 140º W long. used in the assessment model is 887,602 t. The coefficient of variation (CV) of this estimate was 0.13, which is below the average of 0.197 for the entire time series.

Age Composition

Estimates of numbers at age from the bottom trawl survey are obtained from random otolith samples and length frequency samples (Table 1.8). Numbers at age are estimated by statistical area (Shumagin-610, Chirikof-620, Kodiak-630, Yakutat-640 and Southeastern-650) using a global age-length key calculated form specimen data west of 140W in each single year, and CPUE-weighted length frequency data by statistical area. The 2023 ages (Table 1.9) were added in 2024.

Shelikof Strait Acoustic Survey

Winter acoustic surveys to assess the biomass of pre-spawning aggregations of pollock in Shelikof Strait have been conducted annually since 1981 (except 1982, 1987, 1999, and 2011). Only surveys from 1992 and later are used in the stock assessment due to the higher uncertainty associated with the acoustic estimates produced with the Biosonics echosounder used prior to 1992. Additionally, raw survey data are not easily recoverable for the earlier acoustic surveys, so there is no way to verify (i.e., to reproduce) the estimates. In 2008, the noise-reduced R/V Oscar Dyson became the designated survey vessel for acoustic surveys in the Gulf of Alaska. Survey methods and results for 2024 are presented in a NMFS processed report (Levine and Jones in prep.).

Biomass Estimates

The 2024 biomass estimate for Shelikof Strait in 2024 for all fish is 289,973 t, which is a 12.0% percent increase from the 2023 estimate (Fig. 1.7, Table 1.10). This estimate accounts for escapement of fish from the midwater survey trawl used to sample echsign (i.e., trawl selectivity) via selectivity curves estimated from recapture nets attached to the survey trawl (Williams *et al.* 2011; Honkalehto *et al.* 2024). Winter 2024 pre-spawning pollock surveys were also conducted in the Shumagin Islands, Chirikof shelf break, and Pavlov Bay (Fig. 1.7. Further information about the surveys conducted in 2024 can be found in Levine and Jones (in prep.).

Age Composition

Estimates of numbers at age from the Shelikof Strait acoustic survey (Table 1.11, Fig. 1.8) were obtained using an age-length key compiled from random otolith samples and applied to weighted length frequency samples. Sample sizes for ages and lengths are given in Table 1.12. Estimates of age composition in Shelikof Strait in 2024 indicate reduced, but persistent dominance of the 2012 year class, and a mode of age 4-6 fish, indicating new year classes are starting to comprise the majority of the spawning and exploitable portion of the population.

Based on recommendations from the 2012 CIE review, an approach was developed to model the age-1 and age-2 pollock estimates separately from the Shelikof Strait acoustic survey biomass and age composition. These immature fish are not the main target of the pre-spawning survey, but age-1 and age-2 pollock are highly variable and occasionally are very abundant in winter acoustic surveys. By fitting them separately from the 3+ fish it is possible to utilize an error distribution that better reflects that variability. Indices are available for both the Shelikof Strait and Shumagin surveys, but a longer time series of net-selectivity corrected indices are available for Shelikof Strait. In addition, model comparisons in the 2018 assessment indicates that a slightly better fit could be obtained with only Shelikof Strait indices. The age-1 and age-2 pollock data provide an invaluable early source of information for recruitment as they are the only in-year age 1 estimates available for this stock.

However, in 2023 extremely low estimates of some cohorts were a major concern and discussion point in the 2023 SAFE (Monnahan *et al.* 2023). Explorations revealed that these issues were caused by unrealistically small observations of age 1 fish from Shelikof. While the cohorts appear small or very small, subsequent years of data were not able to counteract the signal in the age 1 fish. In 2024 another CIE review was done and this topic was explored in depth, and ended with a recommendation to either model the data differently or drop them from the model. So starting in 2024 with model 23c these indices are not fit in the model, and future research will identify a more appropriate way to incorporate these observations into the assessment.

Spawn timing and availability of pollock to the winter Shelikof survey

The Shelikof Strait winter acoustic survey is timed to correspond to the aggregation of pre-spawning pollock in Shelikof Strait. However, the timing of spawning has been found to vary from year to year, which may affect the availability of pollock to the survey. Variation in spawn timing is not random, but has been linked to thermal conditions in March and the age structure of the spawning stock (Rogers and Dougherty 2019); spawning tends to occur earlier when temperatures are warmer and when the spawning stock is older on average. Greater age diversity also results in a more protracted spawning period, presumably due to the presence of both early (old) and late (young) spawners, although this has not been verified in the field. A new approach to account for the timing of the survey relative to spawning was implemented in 2024 (model 23b) based on Rogers *et al.* (2024). The covariate used is the logit of proportion mature females greater than 30 cm from Shelikof. This covariate was slightly outperformed statistically by another in Rogers *et al.* (2024), but is easier to operationalize because covariate estimates are always available when a survey occurs. Following the approach used by the WHAM platform (Stock and Miller 2021) an expected covariate ($\hat{X}$) time-series was estimated with an AR(1) smoother by treating latent states as random effects in TMB and estimating a variance and correlation for that process. Observation errors on the covariate were assumed to be 0.02 to force $\hat{X}$ to be close to the observations. Future work could explore annually-varying observation errors derived from data, or estimating it. The expected catchability in year y is then calculated as

$$q_1(y) = exp\left(\mu + \beta\widehat{X_y} + z_y\right)$$

where z_y is a random walk component that was previously used but was disabled in 2024 (i.e., $z_y = 0$ for all y) per the recommendation of the SSC.

This covariate-linked model helps explain the misfit to high survey estimates from 2015-2019, which was a cause of concern and led to a reduction in the ABC in 2019.

Summer Acoustic Survey

Six complete acoustic surveys, in 2013, 2015, 2017, 2019, 2021 and 2023, have been conducted by AFSC on the R/V Oscar Dyson in the Gulf of Alaska during summer (Jones *et al.* in review, 2014, 2017, 2019; Levine and Jones in prep.; McGowan *et al.* in prep.). The area surveyed covers the Gulf of Alaska shelf and upper slope and associated bays and troughs, from a westward extent of 170° W, and extends to an eastward extent of 140° W. Prince William Sound was also surveyed in 2013, 2015, and 2019. The survey consists of widely-spaced parallel transects along the shelf, and more closely spaced transects in troughs, bays, and Shelikof Strait. Mid-water and bottom trawls are used to identify acoustic targets. The 2023 biomass estimate for summer acoustic survey is 740,417 t, which is a 71.7% percent increase from the 2021 estimate (Table 1.10). 2023 age compositions were added in 2024. Analysis of the 2023 survey was not complicated by the presence of age-0 pollock, which was a problem in previous summer acoustic surveys because age-0 pollock backscatter cannot be readily distinguished from age 1+ pollock (Jones *et al.* 2019).

In 2023 an issue with vessel noise was identified and required a minor change in the way the data were processed. The processing methods used in the survey assume that noise is negligible. However, in 2023 there was concern that this was no longer the case due to recent changes in vessel noise (sonar self-noise at 38 kHz at survey speed was ~10 dB or ten-fold higher than in 2022). The effects of noise are depth and density dependent and are difficult to predict. Signal-to-noise thresholding and noise correction (De Robertis and Higginbottom 2007) was used to exclude pollock backscatter from areas influenced by noise (i.e., all areas with a signal-to-noise threshold of <6 dB were removed from the estimate). This revised processing resulted in total pollock biomass that was 0.19% less than for uncorrected data, confirming that noise had only a minor impact on the biomass estimate. Further details can be found in McGowan *et al.* (in prep.).

Alaska Department of Fish and Game Crab/Groundfish Trawl Survey

The Alaska Department of Fish and Game (ADF&G) has conducted bottom trawl surveys of nearshore areas of the Gulf of Alaska since 1987 (depths from 10-160 m, median of 64 m in 2024; Fig. 1.9). Although these surveys are designed to monitor population trends of Tanner crab and red king crab, pollock and other fish are also sampled. Standardized survey methods using a 400-mesh eastern trawl were employed from 1987 to the present. The survey is designed to sample at fixed stations from mostly nearshore areas from Kodiak Island to Unimak Pass, and does not cover the entire shelf area (Fig. 1.9). The average number of tows completed during the survey is 352. On average, about 88% of these tows contained pollock. Details of the ADF&G trawl gear and sampling procedures are in Spalinger (2012).

The 2024 area-swept biomass estimate for pollock for the ADF&G crab/groundfish survey was 66,384 t, an increase of 17.2% from the 2023 biomass estimate (Table 1.10). The 2024 pollock estimate for this survey is approximately 74% of the long-term average.

Biomass Estimates

A delta GLM model was applied to the ADF&G tow by tow data for 1988-2024 to obtain standardized annual abundance indices. Data from all years were filtered to exclude missing latitude and longitudes and missing tows made in lower Shelikof Strait (between 154.7° W lon. and 156.7° W lon.) were excluded because these stations were sampled irregularly. The delta GLM model fit a separate model to the presence-absence observations and to the positive observations. A fixed effects model was used with the year, geographic area, and depth as factors. Strata were defined according to ADF&G district (Kodiak, Chignik, South Peninsula) and depth (<30 fm, 30-100 fm, >100 fm). Alternative depth strata were evaluated previously, and model results were found to be robust to different depth strata assumptions. The same model structure was used for both the presence-absence observations and the positive observations. The assumed likelihoods were binomial for presence-absence observations and gamma for the positive observations, after evaluation of several alternatives, including lognormal, gamma, and inverse Gaussian, and which is in line with recommendations for index standardization (Thorson *et al.* 2021). The model was fit using ‘brms’ package in R (Bürkner 2017, 2018), which fits Bayesian non-linear regression models using the modeling framework Stan (Stan Development Team 2020). Posterior samples were generated from six chains with 3000 iterations (1000 warmup) and thin rate of three. The analysis had a minimum effective sample size >1000 and largest Rhat<1.01 and thus passes standard convergence tests. Comparison of delta-GLM indices the area-swept estimates indicated similar trends (Fig. 1.10). Variances were based on MCMC sampling from the posterior distribution, and CVs for the annual index ranged from 0.10 to 0.17. These values likely understate the uncertainty of the indices with respect to population trends, since the area covered by the survey is a relatively small percentage of the GOA shelf area, and so the CVs are scaled up to have an average of 0.25.

Age Compositions

Ages were determined by age readers in the AFSC age and growth unit from samples of pollock otoliths collected during 2000- ADF&G surveys in even-numbered years (average sample size = 584; Table 1.13, Fig. 1.11). Comparison with fishery age composition shows that older fish (> age-8) are more common in the ADF&G crab/groundfish survey. This is consistent with the assessment model, which estimates a domed-shaped selectivity pattern for the fishery, but an asymptotic selectivity pattern for the ADF&G survey.

Data sets considered but not used

Egg production estimates of spawning biomass

Estimates of spawning biomass in Shelikof Strait based on egg production methods were produced during 1981-92 (Table 1.10). A complete description of the estimation process is given in Picquelle and Megrey (1993). Egg production estimates were discontinued in 1992 because the Shelikof Strait acoustic survey provided similar information. The egg production estimates are also not used in the assessment model because the surveys are no longer being conducted, and because the acoustic surveys in Shelikof Strait show a similar trend over the period when both were conducted.

Pre-1984 bottom trawl surveys

Considerable survey work was carried out in the Gulf of Alaska prior to the start of the NMFS triennial bottom trawl surveys in 1984. Between 1961 and the mid-1980s, the most common bottom trawl used for surveying was the 400-mesh eastern trawl. This trawl (or variants thereof) was used by IPHC for juvenile halibut surveys in the 1960s, 1970s, and early 1980s, and by NMFS for groundfish surveys in the 1970s. Szalay and Brown (2001) estimated a fishing power correction (FPC) for the ADF&G 400-mesh eastern trawl of 3.84 (SE = 1.26), indicating that 400-mesh eastern trawl CPUE for pollock would need to be multiplied by this factor to be comparable to the NMFS poly-Nor'eastern trawl.

In most cases, earlier surveys in the Gulf of Alaska were not designed to be comprehensive, with the general strategy being to cover the Gulf of Alaska west of Cape Spencer over a period of years, or to survey a large area to obtain an index for group of groundfish, i.e., flatfish or rockfish. For example, Ronholt *et al.* (1978) combined surveys for several years to obtain gulfwide estimates of pollock biomass for 1973-1976. There are several difficulties with such an approach, including the possibility of double-counting or missing a portion of the stock that happened to migrate between surveyed areas. Due to the difficulty in constructing a consistent time series, the historical survey estimates are no longer used in the assessment model.

Multi-year combined survey estimates indicate a large increase in pollock biomass in the Gulf of Alaska occurred between the early 1960s and the mid 1970s. Increases in pollock biomass between the 1960s and 1970s were also noted by Alton *et al.* (1987). In the 1961 survey, pollock were a relatively minor component of the groundfish community with a mean CPUE of 16 kg/hr (Ronholt *et al.* 1978). Arrowtooth flounder was the most common groundfish with a mean CPUE of 91 kg/hr. In the 1973-76 surveys, the CPUE of arrowtooth flounder was similar to the 1961 survey (83 kg/hr), but pollock CPUE had increased 20-fold to 321 kg/hr, and was by far the dominant groundfish species in the Gulf of Alaska. Mueter and Norcross (2002) also found that pollock was low in the relative abundance in 1960s, became the dominant species in Gulf of Alaska groundfish community in the 1970s, and subsequently declined in relative abundance.

Questions concerning the comparability of pollock CPUE data from historical trawl surveys with later surveys probably can never be fully resolved. However, because of the large magnitude of the change in CPUE between the surveys in the 1960s and the early 1970s using similar trawling gear, the conclusion that there was a large increase in pollock biomass seems robust. Early speculation about the rise of pollock in the Gulf of Alaska in the early 1970s implicated the large biomass removals of Pacific ocean perch, a potential competitor for euphausiid prey (Somerton 1979; Alton *et al.* 1987). Previous work has focused on role of climate change (Anderson and Piatt 1999; Bailey 2000). These earlier surveys suggest that population biomass in the 1960s, prior to large-scale commercial exploitation of the stock, may have been lower than at any time since then.

Qualitative Trends

To qualitatively assess recent trends in abundance, each survey time series was standardized by dividing the annual estimate by the average since 1990. Shelikof Strait acoustic survey estimates prior to 2008 were rescaled to be comparable to subsequent surveys conducted by the R/V Oscar Dyson. Although the indices are not directly comparable due to selectivity differences and the considerable variability in each survey time series, a fairly clear downward trend is evident to 2000, followed by a stable, though variable, trend to 2008, followed by a strong increase to 2013 (Fig. 1.12). From 2016 to 2019 there was a strong divergence among the trends, but the relative abundance came back into reasonable alignment from 2020-2024 with the exception of the large estimate of the NMFS bottom trawl survey in 2023.

Indices derived from fisheries catch data were also evaluated for trends in biological characteristics (Fig. 1.13). The percent of females in the catch shows some variability and generally is close to 50-50, but has been low since 2015. Evaluation of sex ratios by season indicated that this decrease was mostly due a low percentage of females during the A season prior to spawning. However the sex ratio during the B season was close to 50-50, suggesting the skewed sex in winter was related to spawning behavior, rather than an indication of a population characteristic. The mean age shows interannual variability due to strong year classes passing through the population, but there are no downward trends that would suggest excessive mortality rates. The percent of old fish in the catch (nominally defined as age 8 and older) is also highly variable due to variability in year class strength. The percent of old fish declined in 2015-2018 as the strong 2012 year class recruited to the fishery, but increased when the 2012 year class became age 8 in 2020. With large incoming cohorts and the decline of the 2012 cohort, the mean age has begun to decrease again. Under a constant F40% harvest rate, the mean percent of age 8 and older fish in the catch would be approximately 8%.

An annual index of catch at age diversity was computed using the Shannon-Wiener information index, H', defined as

$$H' = -\sum_{a} p_a \ln p_a$$

where p_a is the proportion at age and higher H' values correspond to higher diversity. Increases in fishing mortality would tend to reduce age diversity, but year class variability would also influence it. Age diversity was relatively stable during 1975-2015, but declined sharply to a low in 2016 and has been increasing since due to the dominance of the 2012 year class in the catch (Fig. 1.13). In 2021 the age diversity returned to near the long-term average and remains there through 2024.

The 2012 year class, which is both very strong, and which has experienced anomalous environmental conditions during the marine heatwave in the North Pacific during 2015-2017, has displayed unusual life history characteristics. These include early maturation, reduced growth, but apparently not reduced total mortality. It is unclear whether these changes are a result of density dependence or environmental forcing. Previous assessments examined this cohort in more depth, but its impact on the fishery is diminished and is not a focus here.

Analytical approach

General Model Structure

An age-structured model covering the period from 1970 to 2024 (55 years) was used to assess Gulf of Alaska pollock. The modeled population includes individuals from age 1 to age 10, with age 10 defined as a "plus" group, i.e., all individuals age 10 and older. Population dynamics were modeled using standard formulations for mortality and fishery catch (e.g., Fournier and Archibald 1982; Deriso *et al.* 1985; Hilborn and Walters 1992). Year- and age-specific fishing mortality was modeled as a product of a year effect, representing the full-selection fishing mortality, and an age effect, representing the selectivity of that age group to the fishery. The age effect was modeled using a double-logistic function with time-varying parameters (Dorn and Methot 1990; Sullivan *et al.* 1997). The model was fit to time series of catch biomass, survey indices of abundance, and estimates of age and length composition from the fishery and surveys. Details of the population dynamics and estimation equations are presented in Appendix 1C and model code can be found online at https://github.com/afsc-assessments/GOApollock.

Model parameters were estimated by maximizing the joint log likelihood of the data and penalties, viewed as a function of the parameters. Mean-unbiased log-normal likelihoods were used for survey biomass and total catch estimates, and multinomial likelihoods were used for age and length composition data. Model tuning for composition data was done by iterative re-weighting of input sample sizes using the Francis (2011) method. Variance estimates/assumptions for survey indices were not reweighted. The following table lists the likelihood components used in fitting the model. The linear form of the Dirichlet-multinomial was introduced in model 23d in 2024 (Thorson *et al.* 2017).

Likelihood component	Statistical model for error	Variance assumption
Fishery total catch (1970-2024)	Log-normal	CV = 0.05, 2024 catch is projected
Fishery age comp. (1975-2023)	Dirichlet-multinomial	Initial sample size: Determined from the harmonic mean of bootstrap distributions of input sample sizes
Shelikof acoustic survey biomass (1992-2024)	Log-normal	CV is taken from design-based estimator and whole series scaled to average 0.2
Shelikof acoustic survey age comp. (1992-2024)	Dirichlet-multinomial	Initial sample size = Double the number of tows (midwater + bottom trawl)
Shelikof acoustic survey age-1 and age-2 indices (1994-2024)	Log-normal	Currently disabled in the model due to poor performance.
Summer acoustic survey biomass (2013-2023)	Log-normal	CV is taken from design-based estimator and whole series scaled to average 0.25
Summer acoustic survey age comp. (2013-2021)	Dirichlet-multinomial	Initial sample size = Triple the number of tows (midwater + bottom trawl)
NMFS bottom trawl survey biom. (1990-2023)	Log-normal	Survey-specific CV from random-stratified design = 0.12-0.38
NMFS bottom trawl survey age comp. (1990-2021)	Dirichlet-multinomial	Initial sample size: Determined bootstrapping procedure in afscISS R package
ADF&G trawl survey index (1989-2023)	Log-normal	Survey-specific CV from delta GLM model rescaled so mean is 0.25=0.20-0.35
ADF&G survey age comp. (2000-2022)	Dirichlet-multinomial	Initial sample size = 45
Recruit process error (1970-2023)	Log-normal	Penalty of 1.3 (updated in 2022 model 19.1a)

Recruitment

Age composition in the first year is estimated with a single log deviation for recruitment abundance, which was then decremented by natural mortality to fill out the initial age vector. In previous versions of the model, a recruitment penalty of ($\sigma_R = 1.0$) was added only to recruitments for 1970-77, and in the last two years of the model and the rest were were estimated as free parameters. Starting in 2022 with model 19.1a the penalty was applied to all deviations, with a value of $\sigma_R = 1.3$ coming from an estimate of a state-space research version of the model. This change had a relatively small impact on the estimated recruits and management reference points.

Modeling fishery data

To accommodate changes in selectivity, we estimated year-specific parameters for the slope and the intercept parameter for the ascending logistic portion of selectivity curve (i.e., younger fish). Variation in these parameters was constrained using a random walk penalty.

Modeling survey data

Survey abundance was assumed to be proportional to total abundance as modified by the estimated survey selectivity pattern. Expected population numbers at age for the survey were based on the mid-date of the survey, assuming constant fishing and natural mortality throughout the year. Standard deviations in the log-normal likelihood were set equal to the sampling error CV (coefficient of variation) associated with each survey estimate of abundance (Kimura 1991).

Survey catchability coefficients can be fixed or freely estimated. The base model estimated the NMFS bottom trawl survey catchability, but used a log normal prior with a median of 0.85 and log standard deviation 0.1 based on expert judgment as a constraint on potential values (Fig. 1.14). Catchability coefficients for other surveys were estimated as free parameters. The age-1 and age-2 winter acoustic survey indices are numerical abundance estimates, and were modeled using independently estimated catchability coefficients (i.e., no selectivity is estimated).

A vessel comparison (VC) experiment was conducted in March 2007 during the Shelikof Strait acoustic survey. The VC experiment involved the R/V Miller Freeman (MF, the survey vessel used to conduct Shelikof Strait surveys since the mid-1980s), and the R/V Oscar Dyson (OD), a noise-reduced survey vessel designed to conduct surveys that have traditionally been done with the R/V Miller Freeman. The vessel comparison experiment was designed to collect data either with the two vessels running beside one another at a distance of 0.7 nmi, or with one vessel following nearly directly behind the other at a distance of about 1 nmi. The methods were similar to those used during the 2006 Bering Sea VC experiment (Robertis *et al.* 2008). Results indicate that the ratio of 38 kHz pollock backscatter from the R/V Oscar Dyson relative to the R/V Miller Freeman was significantly greater than one (1.13), as would be expected if the quieter OD reduced the avoidance response of the fish. Previously we included a likelihood component to incorporate this information in the assessment model, but dropped it because this survey was previously modeled with a random walk in catchability and now with a covariate, and a relatively small systematic change in catchability is inconsequential compared to other factors affecting catchability.

Ageing error

An ageing error conversion matrix is used in the assessment model to translate model population numbers at age to expected fishery and survey catch at age (Table 1.14). Dorn *et al.* (2003) estimated this matrix using an ageing error model fit to the observed percent reader agreement at ages 2 and 9. Mean percent agreement is close to 100% at age 1 and declines to 40% at age 10. Annual estimates of percent agreement are variable, but show no obvious trend; hence a single conversion matrix for all years in the assessment model was adopted. The model is based on a linear increase in the standard deviation of ageing error and the assumption that ageing error is normally distributed. The model predicts percent agreement by taking into account the probability that both readers are correct, both readers are off by one year in the same direction, and both readers are off by two years in the same direction (Methot 2000). The probability that both agree and were off by more than two years was considered negligible. A study evaluated pollock ageing criteria using radiometric methods and found them to be unbiased (Kastelle and Kimura 2006).

Length frequency data

The assessment model was fit to length frequency data from various sources by converting predicted age distributions (as modified by age-specific selectivity) to predicted length distributions using an age-length conversion matrix. This approach was used only when age composition estimates were unavailable, as occurs when the survey is the same as the assessment. Because seasonal differences in pollock length at age are large, particularly for the younger fish, several conversion matrices were used. For each matrix, unbiased length distributions at age were estimated for several years using age-length keys, and then averaged across years. A conversion matrix was estimated using 1992-1998 Shelikof Strait acoustic survey data and used for winter survey length frequency data. The following length bins were used: 5-16, 17-27, 28-35, 36-42, 43-50, 51-55, 56-70 (cm). Age data for the most recent survey is now routinely available so this option does not need to be invoked. A conversion matrix was estimated using second and third trimester fishery age and length data during the years (1989-1998), and was used when age composition data are unavailable for the summer bottom trawl survey, which is only for the most recent survey in the year that the survey is conducted. The following length bins were used: 5-24, 25-34, 35-41, 42-45, 46-50, 51-55, 56-70 (cm), so that the first four bins would capture most of the summer length distribution of the age-1, age-2, age-3 and age-4 fish, respectively. Bin definitions were different for the summer and the winter conversion matrices to account for the seasonal growth of the younger fish (ages 1-4).

Initial data weighting

Input sample sizes (ISS) for age compositions are the initial weights (number of fish) for a data set in a year. The ISS is then either tuned via the Francis approach to get effective sample size (ESS), or if using the Dirichlet-multinomial calculated by multiplying the ISS by the inverse logit of the log overdispersion parameter (often called θ). Because ISS serves as an upper limit for ESS with a Dirichlet-multinomial, it is important to get both the relative weights among years but also a reasonable estimate of absolute ESS. As θ goes to infinity the ESS converges to the ISS and can be reverted back to a multinomial.

Previous to 2024 ISS were generally considered constant among years, despite known variance in the quantity of information in the age data. So in 2024 a new approach was taken. For the fishery, previous assessments assumed an ISS of of 200 except when the age sample in a given year came from fewer than 200 hauls/deliveries, in which case the number of hauls/deliveries was used. This year, a bootstrap procedure was used in an external ALK sampler program developed at the AFSC (https://github.com/afsc-assessments/sampler). Each bootstrap replicate produces a "realized" sample size (RSS) for each year. 1000 replicates were done and the harmonic mean of the RSS was taken to get ISS. This procedure only works after 2000 due to database limitations. As such, the post-2000 ISS series was scaled to average 200 and the historical ISS values (before 2000) were unchanged. This procedure maintains the relative weight of fishery age compositions in these periods, but allows for interannual variability.

ISS for the Shelikof and summer acoustic age data was assumed to be twice to the number of hauls taken in that year (midwater + bottom). ISS for the NMFS BT survey come from a bootstrap procedure detailed in Hulson and Williams (2024). No change was made for the ADF&G survey, where ISS was assumed 45 in all years. ISS and ESS estimates are presented in the results section.

The CVs of the acoustic biomass indices were also updated in model 23a. For the two acoustic surveys, a 1-D geostastical estimate (Walline 2007) has been available (see e.g. Table 1.12 but had been deemed unrealistically small and values of 0.2 (Shelikof) and 0.25 (summer AT) were used for all years. Instead we assume the relative inter-annual CVs are correct and scaled the annual time series of CVs to average the historical values (0.2 and 0.25). This provides information on the relative difference in weights among years based on the survey data and published methods.

Parameters Estimated Outside the Assessment Model

Pollock life history characteristics, including natural mortality, weight at age, and maturity at age, were estimated independently outside the assessment model. These parameters are used in the model to estimate spawning and population biomass and obtain predictions of fishery catch and survey biomass. Pollock life history parameters include:

- Natural mortality (M)
- Proportion mature at age
- Weight at age and year by fishery and by survey

Natural mortality

Hollowed and Megrey (1990) estimated natural mortality (M) using a variety of methods including estimates based on: a) growth parameters (Alverson 1975; Pauly 1980), b) GSI (Gunderson and Dygert

1988), c) monitoring cohort abundance, and d) estimation in the assessment model. These methods produced estimates of natural mortality that ranged from 0.22 to 0.45. The maximum age observed was 22 years. Up until the 2014 assessment, natural mortality had been assumed to be 0.3 for all ages.

Hollowed *et al.* (2000) developed a model for Gulf of Alaska pollock that accounted for predation mortality. The model suggested that natural mortality declines from 0.8 at age 2 to 0.4 at age 5, and then remains relatively stable with increasing age. In addition, stock size was higher when predation mortality was included. In a simulation study, Clark (1999) evaluated the effect of an erroneous M on both estimated abundance and target harvest rates for a simple age-structured model. He found that "errors in estimated abundance and target harvest rate were always in the same direction, with the result that, in the short term, extremely high exploitation rates can be recommended (unintentionally) in cases where the natural mortality rate is overestimated and historical exploitation rates in the catch-at-age data are low." Clark (1999) proposed that the chance of this occurring could be reduced by using an estimate of natural mortality on the lower end of the credible range, which is the approach used in this assessment. In the 2014 assessment, several methods to estimate of the age-specific pattern of natural mortality were evaluated. Two general types of methods were used, both of which are external to the assessment model. The first type of method is based initially on theoretical life history or ecological relationships that are then evaluated using meta-analysis, resulting in an empirical equation that relates natural mortality to some more easily measured quantity such as length or weight. The second type of method is an age-structured statistical analysis using a multispecies model or single species model where predation is modeled. There are three examples of such models for pollock in Gulf of Alaska, a single species model with predation by Hollowed *et al.* (2000), and two multispecies models that included pollock by Kirk (2010, 2012). These models were published in the peer-reviewed literature, but likely did not receive the same level of scrutiny as stock assessment models. Although these models also estimate time-varying mortality, we averaged the total mortality (residual natural mortality plus predation mortality) for the last decade in the model to obtain a mean age-specific pattern (in some cases omitting the final year when estimates were much different than previous years). Use of the last decade was an attempt to use estimates with the strongest support from the data. Approaches for inclusion of time-varying natural mortality will be considered in future pollock assessments. The three theoretical/empirical methods used were the following:

Brodziak et al. (2011): Age-specific M is given by

$$M(a) = \begin{cases} M_c \dfrac{L_{mat}}{L(a)} & \text{for } a < a_{mat} \\ M_c & \text{for } a \geq a_{mat} \end{cases}$$

where L_{mat} is the length at maturity, $M_c = 0.30$ is the natural mortality at L_{mat}, $L(a)$ is the mean length at age for the summer bottom trawl survey for 1984-2013.

Lorenzen (1996): Age-specific M for ocean ecosystems is given by

$$M(a) = \bar{W_a}^{-0.305}$$

where $\bar{W_a}$ is the mean weight at age from the summer bottom trawl survey for 1984-2013.

Gislason et al. (2010): Age-specific M is given by

$$\ln(M) = 0.55 - 1.61\ln(L) + 1.44\ln(L_\infty) + \ln K$$

where $L_\infty = 65.2$ cm and $K = 0.30$ were estimated by fitting von Bertalanffy growth curves using the NLS routine in R using summer bottom trawl age data for 2005-2009 for sexes combined in the central and western Gulf of Alaska. Results were reasonably consistent and suggest use of a higher mortality rate for age classes younger than the age at maturity (Table 1.15 and Fig. 1.15). Somewhat surprisingly, the theoretical/empirical estimates were similar, on average, to predation model estimates. To obtain an age-specific natural mortality schedule for use in the stock assessment, we used an ensemble approach and averaged the results for all methods. Then we used the method recommended by Clay Porch in Brodziak *et al.* (2011) to rescale the age-specific values so that the average for range of ages equals a specified value. Age-specific values were rescaled so that a natural mortality for fish greater than or equal to age 5, the age at 50% maturity, was equal to 0.3, the value of natural mortality used in previous pollock assessments.

Maturity at age

Maturity stages for female pollock describe a continuous process of ovarian development between immature and post-spawning. For the purposes of estimating a maturity vector (the proportion of an age group that has been or will be reproductively active during the year) for stock assessment, all fish greater than or equal to a particular maturity stage are assumed to be mature, while those less than that stage are assumed to be immature. Maturity stages in which ovarian development had progressed to the point where ova were distinctly visible were assumed to be mature (i.e., stage 3 in the 5-stage pollock maturity scale). Maturity stages are qualitative rather than quantitative, so there is subjectivity in assigning stages, and a potential for different technicians to apply criteria differently (Neidetcher *et al.* 2014). Because the link between pre-spawning maturity stages and eventual reproductive activity later in the season is not well established, the division between mature and immature stages is problematic. Changes in the timing of spawning could also affect maturity at age estimates. Merati (1993) compared visual maturity stages with ovary histology and a blood assay for vitellogenin and found general consistency between the different approaches. Merati (1993) noted that ovaries classified as late developing stage (i.e., immature) may contain yolked eggs, but it was unclear whether these fish would have spawned later in the year. The average sample size of female pollock maturity stage data per year since 2000 from winter acoustic surveys in the Gulf of Alaska is 372 (Table 1.16). In 2019, a new approach was introduced to estimate maturity at age using specimen data from the Shelikof Strait acoustic survey. Maturity estimates from 2003 onwards were revised using this method. The approach uses local abundance to weight the maturity data collected in a haul. To estimate abundance, each acoustic survey distance unit (0.5 nmi of trackline) was assigned to a stratum representing nearest survey haul. Each haul's biological data was then used to scale the corresponding acoustic backscatter within that stratum into abundance. To generate abundance weights for specimen data taken for each haul location, the abundance estimates of adult pollock ($\geq$ 30 cm fork length) were summed for each haul-stratum. The 30 cm length threshold represents the length at which pollock are 5% mature in the entire Shelikof Strait historic survey data. Total adult pollock abundances in each stratum was scaled by dividing by the mean abundance per stratum (total abundance /number of haul-strata). Weights range from 0.05 to 6, as some hauls were placed in low-density regions while others sampled very dense aggregations. For each haul, the number of female pollock considered mature (prespawning, spawning, or spent) and immature (immature or developing) were computed for each age. The maturity ogive for maturity-at-age was estimated as a logistic regression using a weighted generalized linear model where the dependent variable was the binomial spawning state, the independent variable was the age, and data from each haul were weighted by the appropriate values as computed above. The length and age at 50% maturity was derived (L50%, A50%) from the ratio of the regression coefficients. The new maturity estimates had a relatively minor impact on assessment results, and usually reduced estimates of spawning biomass by about 2 percent. Estimates of maturity at age in 2022 from winter acoustic surveys using the new method are higher for younger fish, but lower for older fish, compared to 2021 and the long-term mean for all ages (Fig. 1.16 and 1.17). Inter-annual changes in maturity at age may reflect environmental conditions, pollock population biology, effect of strong year classes moving through the population, or simply ageing error. Because there did not appear to be an objective basis for excluding data, the 1983- 2024 average maturity at age was used in the assessment.

Logistic regression (McCullagh and Nelder 1983) was also used to estimate the age and length at 50% maturity at age for each year to evaluate long-term changes in maturation. Annual estimates of age at 50% maturity are highly variable and range from 2.6 years in 2017 to 6.1 years in 1991, with an average of 4.8 years (Fig. 1.18). The last few years has shown a decrease in the age at 50% mature, which is largely being driven by the maturation of the 2012 year class at younger ages than is typical, however the 2019 to 2024 estimates of age at 50% mature are near the long-term average. Length at 50% mature is less variable than the age at 50% mature, suggesting that at least some of the variability in the age at maturity can be attributed to changes in length at age. Changes in year-class dominance also likely affect estimates of maturity at length, as a similar pattern is seen as with maturity at age with the 2012 cohort. The average length at 50% mature for all years is approximately 43 cm.

Weight at age

Year-specific fishery weight-at-age estimates are used in the model to obtain expected catches in biomass. Where possible, year and survey-specific weight-at-age estimates are used to obtain expected survey biomass. For each data source, unbiased estimates of length at age were obtained using year-specific age-length keys. Bias-corrected parameters for the length-weight relationship, $W = aL^b$, were also estimated. Weights at age were estimated by multiplying length at age by the predicted weight based on the length-weight regressions. Weight at age for the fishery, the Shelikof Strait acoustic survey, and the NMFS bottom trawl survey and the summer acoustic survey are given in Tables 1.17, 1.18, and 1.19. Data from the Shelikof Strait acoustic survey indicates that there has been a substantial change in weight at age for older pollock (Fig. 1.19). For pollock greater than age 6, weight-at-age nearly doubled by 2012 compared to 1983-1990. However, weight at age trended strongly downward from 2012 to 2020, with a strong rebound in the last couple of years. Further analyses are needed to evaluate whether these changes are a density-dependent response to declining pollock abundance, or whether they are environmentally forced. Changes in weight-at-age have important implications for status determination and harvest control rules.

A random effects (RE) model for weight at age (Ianelli *et al.* 2016) was used to estimate of fishery weight at age in 2024 since age data were not available. The structural part of the model is an underlying von Bertalanffy growth curve. Year and cohort effects are estimated as random effects using the ADMB RE module. Further details are provided in Ianelli *et al.* (2016). Input data included fishery weight age for 1975-2023. The model also incorporates survey data by modeling an offset between fishery and survey weight at age. Weight at age for the Shelikof Strait acoustic survey (1981-2024) and the NMFS bottom trawl survey (1984-2023) were used. The model also requires input standard deviations for the weight at age data, which are not available for GOA pollock. In the 2016 assessment, a generalized variance function was developed using a quadratic curve to match the mean standard deviations at ages 3-10 for the eastern Bering Sea pollock data. The standard deviation at age one was assumed to be equal to the standard deviation at age 10. Survey weights at age were assumed to have standard deviations that were 1.5 times the fishery weights at age. A comparison of RE model estimates from last year of the 2023 fishery weight at age with the data now available indicate that the model overestimated weights slightly (Fig. 1.20). In this assessment, RE model estimates of weight at age are used for the fishery in 2024 and for yield projections and harvest recommendations.

Correa *et al.* (2023) details an exploratory and promising approach using a state-space model to estimate the WAA within the assessment model and this will be explored further in future years.

Parameters Estimated Inside the Assessment Model

A large number of parameters are estimated when using this modeling approach, though many are year-specific deviations in fishery selectivity coefficients. Parameters were estimated using Template Model Builder [TMB; Kristensen *et al.* (2016)], a modeling platform based strongly on AD Model Builder (Fournier *et al.* 2012) but which contains improved functionality for estimating non-linear hierarchical models. The model is determined to have converged when the maximum parameter gradient is less than a small constant (set to 1 x 10-6) and the Hessian matrix is invertible. Like AD Model Builder, TMB includes post-convergence routines to calculate standard errors (or likelihood profiles) for any quantity of interest, and has state of the art Bayesian integration capabilities (Monnahan and Kristensen 2018).

Priors are used for select parameters to stabilize optimization and integration, a practice recommended specifically for stock assessments (Monnahan 2024) and known as regularizing priors. This is needed because there are certain values of selectivity parameters that cannot be distinguished by data, such as when the slope at the inflection point goes to infinity (knife-edge) and there is thus a zero gradient of that parameter with respect to the log-likelihood surface. As such the following priors were used starting in 2024.

- The log of logistic and double-logistic slope parameters have a $N(-1,1.5)$ prior.
- The ascending logistic inflection age have a $N(0,3)$ prior.
- The descending logistic inflection age have a $N(10,3)$ prior.
- The log of the Dirichlet-multinomial θ parameters have a $N(0,2)$ prior.

These priors had a negligible impact on maximum likelihood estimates and uncertainty, but improve estimation substantially, particularly for MCMC. In the future regularizing priors will be developed for other fixed effect parameters.

A list of model parameters for the base model is shown below:

Population process modeled	Number of parameters	Estimation details
Mean recruitment	1	Estimated in log space
Recruitment deviations	Years 1970-2024 = 55	Estimated as log deviances from the log mean with all years constrained by random deviation process error of 1.3.
Natural mortality	Age-specific= 10	Not currently estimated in the model
Fishing mortality	Years 1970-2024 = 55	Estimated as log deviances from the log mean
Mean fishery selectivity	4	Slope parameters estimated on a log scale, intercept parameters on an arithmetic scale
Annual changes in fishery selectivity	2 * (No. years-1) = 110	Estimated as deviations from mean selectivity and constrained by random walk process error
Mean survey catchability	No. of surveys = 4	Catchabilities estimated on a log scale.
Annual changes in survey catchability	(No. years-1) = 54	Annual catchability for winter acoustic surveys and ADF&G surveys estimated as deviations from mean catchability and constrained by random walk process error
Covariate smoothing on catchability link for Shelikof survey	AR(1) process error and correlation, and effect size (3), as well as annual random effects (55)	The random effects are integrated out and not included in the total here.
Survey selectivity	8 (2 each for the Shelikof and summer acoustic surveys, and the NMFS and ADF&G BT surveys)	Slope parameters estimated on a log scale.
Overdispersion for Dirichlet-multinomial age composition	Fishery (1) and surveys (4)	Estimated in log space
Total	297 fixed effects (55 random effects)	

Results

Model selection and evaluation

Model selection

Prior to identifying a model for consideration, an analysis was conducted of the impact of each new data element on model results. Figure 1.21 shows the changes in estimated spawning biomass as the updated catch projections, catch at age, and surveys were added sequentially. This year, additions did not change the trend and scale of the stock as in the last few years.

Four new models were proposed this year, 23a, 23b, 23c, and 23d. Basic results are presented for the first three, and more detailed results for 23d which is the authors' recommended model. Model 23a which updates input sample sizes and biomass CVs had a minor impact on SSB and uncertainty relative to last year's model (23) with the 2024 data in it (Fig. 1.22). Model 23b estimated about 15% lower recent SSB, and about 15% higher SSB from 2000 to 2010, and overall decreased uncertainty. Dropping the age 1 and 2 indices (23c) had a minor impact and was very similar to 23b. Model 23d had the largest impact on estimates, with about a 20% reduction in the CV of SSB, due to the higher weight given to age composition data when using the Dirichlet-multinomial likelihood (Fig. 1.23).

Unreasonably low estimates of recruitment in recent years went away starting with model 23c and were similar for model 23d (Fig. 1.24).

Model evaluation

Model 23d had good statistical performance. Convergence was determined by successful inversion of the Hessian matrix and a maximum gradient component of less than 1e-4 (this value was 5.88e-8 for Model 23d). A jitter analysis revealed that the base model and all alternative models are insensitive to perturbations of parameter start values on the order of 10% (Fig. 1.25). All parameters were estimated within their pre-specified bounds. A self-test simulation, where 100 data sets were simulated from the the estimated model and refit also showed no concerns (Fig. 1.26). A likelihood profile over the catchability for the NMFS BT index serves as a proxy for scale, and shows limited information in the data sets to set this scale, a known issue with this stock (Fig. 1.27).

Parameter estimates and uncertainty are given in Table 1.20). Figure 1.28 shows the estimates of survey catchability, including for the Shelikof Strait acoustic survey which is driven by an environmental covariate. Catchability for the NMFS bottom trawl and summer acoustic surveys were similar (0.77 and 0.72 respectively).

The fit of model 23d to age composition data was evaluated using plots of observed and predicted age composition (Figs. 1.29, 1.30, 1.31, 1.32, and 1.33). One-step-ahead (OSA) residuals (Trijoulet *et al.* 2023) and aggregate fits are used to assess fits to composition data (Fig. 1.34). Model fits to fishery age composition data are adequate in most years, though the very strong 2012 year class shows up as a positive residual in 2016-2023 due to stronger than expected abundance in the age composition. Previous assessments had strong patterns of negative residuals for older ages, but it is clear now using OSA residuals that these were not real and instead an artifact of Pearson residuals being wrong. In contrast, the pattern of negative residuals for age 4 and positive for age 3 persists with OSA residuals, suggesting these are real. More complicated selectivity forms were able to eliminate this pattern (Appendix 1F of Monnahan *et al.* 2023), but these were not recommended due to their added complexity and minimal impact on management advice. The NMFS bottom trawl survey has relatively good residuals, even for the most recent years where there is a misfit in the index. The ADF&G compositions overall do not fit well, especially to the age 10 plus group. The two acoustic surveys had no apparent issues fitting to the data, although there are some large values. Overall there were no major issues in fitting the age composition data and the issues highlighted here are considered minor.

Model fits to survey biomass estimates are reasonably good for all surveys except the period 2015-2019 and now in 2023 with poor fits to the 2023 Shelikof winter acoustic survey and NMFS bottom trawl surveys (Fig. 1.35). The lack of fit in the NMFS bottom trawl survey from 2015 to 2023 is a major concern and discussed in the context of the risk table below. In addition, the model is unable to fit the extremely low values for the ADF&G survey in 2015-2017. The fit to the summer acoustic survey is reasonable even during the most recent period. The model shows good fits to both the 2021 Shelikof Strait acoustic survey and the 2021 NMFS bottom trawl, while the 2021 ADF&G bottom trawl and 2021 summer acoustic survey fits were reasonable.

Time series results

Parameter estimates and model output are presented in a series of tables and figures. Estimated survey and fishery selectivity for different periods are given in Table 1.21 (see also Figs. 1.36 and 1.37. Table 1.22 gives the estimated population numbers at age for the years 1970-2024. Table 1.23 gives the estimated time series of age 3+ population biomass, age-1 recruitment, status, and harvest rate (catch/3+ biomass) for 1977-2024 (see also Fig. 1.38). Table 1.24 gives coefficients of variation and 95% confidence intervals for age-1 recruitment and spawning stock biomass.

Stock size peaked in the early 1980s at approximately 103% of the proxy for unfished stock size (B100% = mean 1978- 2023 recruitment multiplied by the spawning biomass per recruit in the absence of fishing (SPR at F=0), see below for how this is calculated). In 2002, the stock dropped below B40% for the first time since the early 1980s, and reached a minimum in 2003 of 35% of unfished stock size. Over the years 2009-2013 stock size showed a strong upward trend, increasing from 49% to 83% of unfished stock size, but declined to 60% of unfished stock size in 2015. The spawning stock peaked in 2017 at 86% as the strong 2012 year class matured, and has declined subsequently to 56% in 2024. Figure 1.39 shows the historical pattern of exploitation of the stock both as a time series of SPR and fishing mortality compared to the current estimates of biomass and fishing mortality reference points. Except from the mid-1970s to mid-1980s fishing mortalities have generally been lower than the current OFL definition, and in nearly all years were lower than the FMSY proxy of F35%.

Retrospective analysis of base model

A retrospective analysis consists of dropping the data year-by-year from the current model, and provides an evaluation of the stability of the current model as new data are added. Figure 1.40 shows a retrospective plot with data sequentially removed back to 2017. The range of errors in the estimates of spawning biomass (if the current assessment is accepted as truth) is -32.1% to 2.3%, but usually the errors are much smaller (median absolute error is 16%). There was a relatively large negative retrospective pattern in the assessment in recent years (i.e., the model consistently underestimates SSB). The revised Mohn's ρ (Mohn 1999) across all ten peels for terminal spawning biomass is -0.159. This is not considered a significant ρ based on a bootstrapping analysis done in the 2022 assessment which found that by chance ρ would be between -0.21 and 0.29 (Bryan and Monnahan in prep), and is smaller than in recent years. Retrospective behavior of fishing mortality (F) and recruitment are also shown in Fig. 1.40 but not discussed here. Trends in estimates of cohort sizes is also given in Fig. 1.41, which are more stable compared to previous years due to the age 1 and 2 Shelikof indices being removed. The 2020 and 2021 cohorts are both estimated as smaller than originally thought.

Comparison of historical assessment results

A comparison of assessment results for the years 1999-2024 indicates the current estimated trend in spawning biomass for 1990-2024 is consistent with previous estimates (Table 1.25 and Fig. 1.42). All time series show a similar pattern of decreasing spawning biomass in the 1990s, a period of greater stability in 2000s, followed by an increase starting in 2008. The estimated 2024 age composition from the current assessment was very similar to the projected 2024 age composition from the 2023 assessment (Fig. 1.43). Generally, the two models agree except for the age 1 recruits, where the 2023 model assumed average recruitment, but the 2024 model has data from the Shelikof survey which showed a weak 2022 year class. This difference does not strongly affect the OFL and ABC for next year because these fish are not in the exploitable population.

Stock productivity

Recruitment of GOA pollock is more variable (CV = 1.3 over 1978-2023) than Eastern Bering Sea pollock (CV = 0.60). Other North Pacific groundfish stocks, such as sablefish and Pacific ocean perch, also have high recruitment variability. However, unlike sablefish and Pacific ocean perch, pollock have a short generation time (~8 years), so that large year classes do not persist in the population long enough to have a buffering effect on population variability. Because of these intrinsic population characteristics, the typical pattern of biomass variability for GOA pollock will be sharp increases due to strong recruitment, followed by periods of gradual decline until the next strong year class recruits to the population. GOA pollock is more likely to show this pattern than other groundfish stocks in the North Pacific due to the combination of a short generation time and high recruitment variability.

Since 1980, strong year classes have occurred periodically every four to six years (Fig. 1.38). Because of high recruitment variability, the mean relationship between spawning biomass and recruitment is difficult to estimate despite good contrast in spawning biomass. Strong and weak year classes have been produced at high and low level of spawning biomass. Spawner productivity is higher on average at low spawning biomass compared to high spawning biomass, indicating that survival of eggs to recruitment is density-dependent (Fig. 1.44). However, this pattern of density-dependent survival only emerges on a decadal scale, and could be confounded with environmental variability on the same temporal scale. The decadal trends in spawner productivity have produced the pattern of increase and decline in the GOA pollock population. The last two decades have been a period of relatively low spawner productivity, though there appears to be a recent increase.

Harvest Recommendations

Reference fishing mortality rates and spawning biomass levels

Since 1997, GOA pollock have been managed under Tier 3 of the NPFMC tier system. In Tier 3, reference mortality rates are based on spawning biomass per recruit (SPR), while biomass reference levels are estimated by multiplying the SPR by average recruitment. Estimates of the FSPR harvest rates were obtained using the life history characteristics of GOA pollock (Table 1.26). Spawning biomass reference levels were based on mean 1978-2023 age-1 recruitment (6.283 billion), which is -0.2% lower than the mean value in last year's assessment. Spawning was assumed to occur on March 15th, and a long-term average of maturity at age (1983- 2024) was used with mean spawning weight at age from the Shelikof Strait acoustic surveys in 2020-2024 to estimate current reproductive potential. Fishery weight at age was assumed to be the most recent estimate from the RE model. Pollock weight-at-age is highly variable, showing a sustained increase, followed by a steep decline until a sharp increase from 2020 to 2024 (Fig. 1.19). The factors causing this pattern are unclear, but are likely to involve both density-dependent factors and environmental forcing. The SPR at F=0 was estimated as 0.076 kg/recruit. FSPR rates depend on the selectivity pattern of the fishery. Selectivity has changed as the fishery evolved from a foreign fishery occurring along the shelf break to a domestic fishery on spawning aggregations and in nearshore waters. For SPR calculations, selectivity was based on the average for 2020 - 2023 to reflect current selectivity patterns. GOA pollock FSPR harvest rates are given below:

FSPR rate	Fishing mortality	Avg. Recr. (Million)	Total 3+ biomass (kt)	SSB (kt)	Catch (kt)	Harvest fraction
100.0%	0.000	6,279	1,844	535	0	0.0%
40.0%	0.271	6,279	1,095	214	232	21.2%
35.0%	0.321	6,279	1,027	187	253	24.6%

2025 acceptable biological catch (ABC)

The definitions of OFL and maximum permissible FABC under Amendment 56 provide a buffer between the overfishing level and the intended harvest rate, as required by NMFS national standard guidelines. Since estimates of stock biomass from assessment models are uncertain, the buffer between OFL and ABC provides a margin of safety so that assessment error will not result in the OFL being inadvertently exceeded. For GOA pollock, the maximum permissible FABC harvest rate (i.e., FABC/FOFL) is 84.4% of the OFL harvest rate. Projections for 2025 for the FOFL and the maximum permissible FABC are given in Table 1.27.

Risk Table and ABC Recommendation

The SSC in its December 2018 minutes recommended that all assessment authors use the risk table when determining whether to recommend an ABC lower than the maximum permissible. The Introduction to the Gulf of Alaska SAFE contains details on how the risk table is implemented.

Assessment considerations

Several important assessment considerations arose in 2023 which are revisited here in light of new data and models. In 2023 the new abundance indices had conflict, with two going up and two going down. The two surveys which cover the whole extent of the Gulf were both up more than 70% from three years ago, while the two with more limited spatial coverage were down from 2022. Not surprisingly the model was not able to fit these data points, and in particular the NMFS bottom trawl index has not fit well since 2015 (Fig. 1.35). Two surveys were completed in 2024. The Shelikof index was higher, but lower than predicted, similar to 2023. The ADF&G index was comparable to 2023. No new models were able to resolve this conflict, and it remains a concern.

The Shelikof abundance estimate is unexpectedly low and comprised predominantly of pollock greater than 40 cm, but also coincides with increased estimates of biomass in outlying areas, like the Chirikof shelf break, relative to recent years (Fig. 1.7). However, biomass estimates in the outlying areas are not abnormally high compared to historical surveys and the Shelikof estimate still constitutes the largest winter spawning area by far. This low Shelikof estimate is thus not well explained by spatial shifts. A mismatch between spawn timing and survey timing is another reasonable hypothesis, but inclusion of this covariate into model 23b did not resolve it. In the end, the fit is poor but not unprecedented with this stock, and the previous few years have fit very well. We therefore believe there is no reason for a substantial concern.

In contrast, the NMFS bottom trawl survey has fit poorly for the last 4 out of 5 biennial surveys. The expected trend is the opposite of the observed trend in some years. The consistency of this misfit is a larger concern, particularly because the prior on catchability for this index is an important contributor to estimating the scale of the stock. We therefore consider this an elevated stock assessment concern.

Previous assessments had significant retrospective patterns, but they were improved this year and not a concern.

Although there are poor model fits to some biomass indices, they do not equate to a major concern. We therefore assign level 1: normal for assessment considerations.

Population dynamics considerations

The large 2012 year class has had a strong impact on the recent pollock population, from a steep decline in age diversity (Fig. 1.13) to abnormal growth and maturation (but not mortality as previously suspected), which had led to an increase in concern. The estimated size of this cohort has increased substantially over the last few years, including a 9.2% and 9.9% increase in 2022 and 2023 with additional data, an increase of almost 10 billion fish from 2020 to 2023. For context, this increase alone would be considered a large cohort, and only magnifies the already large impact it has on the population dynamics over the last 10 years. However, the 2012 cohort, now in the 10+ age class, is no longer the predominant one in the fishery and three large ones (2017, 2018, and 2020) have already entered the fishery (Figs. 1.5 and 1.38), resulting in a return to normal age diversity and population dynamics (Fig. 1.13).

The 2023 assessment highlighted a new phenomenon of concern, specifically vanishingly small recent cohort estimates. This issue was identified and resolved in model 23c and thus is no longer a concern here.

Environmental/Ecosystem considerations

The most recent data available suggest an ecosystem risk Level 1 – Normal: "No apparent environmental/ecosystem concerns." This score is informed by ocean temperatures within optimal ranges for pollock life stages, average to above average prey abundance, reduced levels of competition, and moderate levels of predation. Appendix 1A (Shotwell and Dame 2024) provides a detailed look at environmental/ecosystem considerations specific to this stock within the ecosystem and socioeconomic profile (ESP). Broad-scale information on environmental and ecosystem considerations are provided by the Gulf of Alaska Ecosystem Status Report (Ferriss 2024). The text below summarizes ecosystem information related to GOA pollock provided from both the ESP and GOA ESR.

Environmental Processes: The 2023 ocean temperatures are all within known optimal ranges for pollock life history stages (Feb-May 150-300m: spawning 1-7°C, Mar-Apr 0-200m: egg 5-6°C, Apr-Jul surface: larva 3-7°C, as referenced in the ESP, Appendix 1A). The 2023/2024 El Niño event brought warmer surface temperatures to the GOA in the winter, but it was moderate and short-lived, resulting in approximately average surface temperatures by spring in the western GOA and continued warm surface waters through the spring in the eastern GOA. Despite warmer than average surface temperatures averaged across the western GOA shelf in January (5.1°C, satellite-derived; Lemagie and Callahan (2024)), NOAA's January acoustic survey in Shelikof Str. (key spawning habitat and time) observed cooler temperatures in the top 10m (3.2°C) and showed no evidence of warmth at depth (4°C at 100m; Jones *et al.* (2024)). Surface waters in the western GOA cooled to approximately average temperatures in March, and remained average through early spring and fall with warmer waters in the summer (Satellite: Lemagie and Callahan (2024); Appendix 1A: Callahan, Seward Line: Danielson and Hopcroft (2024)). The central GOA experienced no marine heatwave events this year, a decrease from last year (Appendix 1A: Barbeaux). The north/south component of the spring wind direction was toward the west during spring 2024 suggesting neutral retention in suitable larval habitat (Appendix 1A: Rogers). Upcoming 2025 winter and spring surface temperatures are predicted to be cooler than average, din alignment with weak La Nina condition (Lemagie and Bell 2024).

Prey: Zooplankton biomass, primary prey for adult and juvenile pollock, was average to above average on the GOA shelf in the spring and summer. Spring zooplankton biomass along the central GOA Seward Line included above average euphausiids, below average large copepods, and average small copepods (Hopcroft 2024). Planktivorous seabird reproductive success, an indicator of zooplankton availability and nutritional quality, was generally above average and increased from 2023 (Drummond and Renner 2024; Whelan 2024, Appendix 1A: Zador). Catches of YOY pollock in the summer beach seine survey was the highest on record (Kodiak beach seine survey, Appendix 1A: Laurel), suggesting productive feeding conditions in the nearshore for larval pollock. Adult and juvenile fish conditions were below average but slightly improved from 2023 (winter acoustic survey, Appendix 1A: Monnahan). GOA forage fish prey base was average to above average in 2024 (similar to 2023). Capelin continues to rebound in the GOA (Arimitsu *et al.* 2024; McGowan *et al.* 2024), and herring continue to have relatively elevated populations supported by the strong 2016 and 2020 year classes (Hebert and Dressel 2024). Forage species that are relatively lower in abundance include eulachon, sandlance, and juvenile salmon. The reproductive success of piscivorous, diving seabirds (with an overlapping prey base with juvenile sablefish), was generally above average across the GOA (Drummond and Renner 2024; Whelan 2024).

Predators and Competitors: Predation pressure from key groundfish species (arrowtooth flounder, Pacific cod, Pacific halibut, and potentially sablefish) is expected to be moderate. Pollock biomass consumed by predators in the multispecies model (Pacific cod, Pacific halibut, pollock, and arrowtooth flounder) remains low similar to 2023 (Appendix 1A: Adams). The sablefish population has had multiple large age classes, 2022 potentially being the most recent, potentially adding predation pressure to pollock prior to moving to adult slope habitat (Goethel *et al.* (2024); Appendix 1A). Western GOA Steller sea lions were not reassessed in 2023/2024 but remain lower than previous biomass peaks (K. Sweeney, 2022). Potential competitors include relatively low returns of pink salmon (Whitehouse 2023; Vulstek *et al.* 2024), a relatively large population of Pacific ocean perch (assessment, Hulson *et al.* (2023), Appendix 1A), and large year classes of juvenile sablefish (assessment, Goethel *et al.* (2024), Appendix 1A).

Fishery performance

Trends in effort-weighted fishery CPUE were examined in the ESP (Appendix 1A) for two seasons, the 2024 pre-spawning fishery (first trimester; A season) and the 2023 summer/fall fishery (third trimeseter; B season). Fishery CPUE is above (A) or close to (B) the long-term average, and is very consistent with the abundance trend of exploitable biomass from the assessment.

The fishery in the central Gulf (620 and 630) was closed on September 25, 2024 due to exceedence of king salmon bycatch. This is the first closure since it was put in place in 2010, and consequently about 50 kt of pollock TAC were left, reducing the expected catch in 2024. The estimated 2024 catch includes this closure, and thus is in the model. So while abnormal and noteworthy, the closure does not affect the risk of overfishing and thus is not considered in the risk table.

No concerns regarding fishery performance were identified and this element was given a score of 1.

Summary and ABC recommendation

Assessment-related considerations	*Population dynamics considerations*	*Ecosystem considerations*	*Fishery Performance considerations related to the health of the stock*
Level 1: Normal	Level 1: Normal	Level 1: Normal	Level 1: Normal

Given the overall lack of elevated scores in the risk table, the author's recommended ABC is based on the maximum permissible ABC, resulting in a 2025 ABC of 181,022 t, which is a -22.2% decrease from the 2024 ABC. The author's recommended 2026 ABC is 133,075 t. The OFL in 2025 is 210,111 t, and the OFL in 2026 if the 2025 ABC is taken in 2025 is 153,971 t.

To evaluate the probability that the stock will drop below the B20% threshold, we projected the stock forward for five years using the author's recommended fishing mortality schedule. This projection incorporates uncertainty in stock status, uncertainty in the estimate of B20%, and variability in future recruitment. We then sampled from the probability of future spawning biomass using Markov chain Monte Carlo (MCMC) using the no-U-turn sampler available in TMB (Monnahan and Kristensen 2018). Analysis of the posterior samples indicated convergence (ESS>400 and Rhat <1.01) and indicates that probability of the stock dropping below B20% will be negligible through 2029, conditional upon the model specified here.

Projections and Status Determination

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). For each scenario, the projections begin with the vector of 2024 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2025 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2024. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch after 2024 is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1,000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios support the alternative harvest strategies analyzed in the Alaska Groundfish Harvest Specifications Final Environmental Impact Statement. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2025, are as follow (maxF_{ABC} refers to the maximum permissible value of F_{ABC} under Amendment 56):

- Scenario 1: In all future years, F is set equal to $maxF_{ABC}$. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
- Scenario 2: In 2024 and 2025, F is set equal to a constant fraction of $maxF_{ABC}$, where this fraction is equal to the ratio of the realized catches in 2021- 2023 to the ABC recommended in the assessment for each of those years. For the remainder of the future years, maximum permissible ABC is used. (Rationale: In many fisheries the ABC is routinely not fully utilized, so assuming an average ratio catch to ABC will yield more realistic projections.)
- Scenario 3: In all future years, F is set equal to 50% of $maxF_{ABC}$. (Rationale: This scenario provides a likely lower bound on FABC that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
- Scenario 4: In all future years, F is set equal to the 2020-2024 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
- Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

- Scenario 6: In all future years, F is set equal to F_{OFL}. Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2024 or 2) above 1/2 of its MSY level in 2024 and above its MSY level in 2033 under this scenario, then the stock is not overfished.

- Scenario 7: In 2025 and 2026, F is set equal to max F_{ABC}, and in all subsequent years F is set equal to FOFL. Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) above its MSY level in 2026 or 2) above 1/2 of its MSY level in 2026 and expected to be above its MSY level in 2035 under this scenario, then the stock is not approaching an overfished condition.

Results from scenarios 1-7 are presented in Table 1.27. Mean spawning biomass is projected to decline to 2028 under full exploitation scenarios, but will stay stable under the F=0 and other low exploitation scenarios (Fig. 1.45). We project catches to decrease through 2027, and then increase slightly in 2028.

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

The catch estimate for the most recent complete year (2023) is 135,103 t, which is less than the 2023 OFL of 269,916 t. Therefore, the stock is not subject to overfishing. The fishing mortality that would have produced a catch in 2023 equal to the 2023 OFL is 0.205.

Scenarios 6 and 7 are used to make the MSFCMA's other required status determination as follows:

Under scenario 6, spawning biomass is estimated to be 301,897 t in 2024, which is above B35% (187,000 t). Therefore, GOA pollock is not currently overfished.

Under scenario 7, projected mean spawning biomass in 2026 is 196,028 t, which is above B35% (187,000 t). Therefore, GOA pollock is not approaching an overfished condition.

The recommended area apportionment to management areas in the central and western portions of the Gulf of Alaska (central/western/west Yakutat) are provided in Appendix 1D.

Data Gaps and Research Priorities

The following research priorities were identified based on previous CIE reviews and recent Plan Team and SSC discussions:

- Explore priors on catchability and the effect on the population scale and potentially how it relates to results from the predation mortality model.
- Estimate input variances for weight at age components in the WAA RE model.
- Continue to develop spatial GLMM models for survey indices and age composition of GOA pollock
- Evaluate pollock population dynamics in a multi-species context using the CEATTLE model.
- Explore implications of non-constant natural mortality on pollock assessment and management.

- Extend the maximum age to better account for dynamics for older fish, particularly in light of the large 2012 cohort.

Additional recommendations that could be done by other teams at the AFSC, but are unlikely to be specifically prioritized by the primary assessment author, include:

- Efforts to combine acoustic and bottom trawl information in a vertically integrated index, or similar approaches to better understand how gear availability varies over time and space (Monnahan *et al.* 2021).
- Efforts to improve understanding of changes of weight at age or and maturity at age, either via linkage to copepods/euphausiids or directly to the physical environment
- Efforts to better understand drivers of recruitment variability

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Tables

Table 1.1. Walleye pollock catch (t) in the Gulf of Alaska. The ABC is for the area west of 140W lon. (Western, Central and West Yakutat management areas) and includes the guideline harvest level for the state-managed fishery in Prince William Sound. Catches in the current year are incomplete and excluded.

Year	Foreign	Joint Venture	Domestic	Total	ABC/TAC
1964	1,126			1,126	
1965	2,746			2,746	
1966	8,914			8,914	
1967	6,272			6,272	
1968	6,137			6,137	
1969	17,547			17,547	
1970	9,331		48	9,379	
1971	9,460		0	9,460	
1972	38,128		3	38,131	
1973	44,966		27	44,993	
1974	61,868		37	61,905	
1975	59,504		0	59,504	
1976	86,520		211	86,731	
1977	117,833		259	118,092	150,000
1978	94,223		1,184	95,408	168,800
1979	103,278	577	2,305	106,161	168,800
1980	112,996	1,136	1,026	115,158	168,800
1981	130,323	16,856	639	147,818	168,800
1982	92,612	73,918	2,515	169,045	168,800
1983	81,318	134,171	136	215,625	256,600
1984	99,259	207,104	1,177	307,541	416,600
1985	31,587	237,860	17,453	286,900	305,000
1986	114	62,591	24,205	86,910	116,000
1987		22,822	45,248	68,070	84,000
1988		152	63,239	63,391	93,000
1989			75,585	75,585	72,200
1990			88,269	88,269	73,400
1991			100,488	100,488	103,400
1992			90,858	90,858	87,400
1993			108,909	108,909	114,400
1994			107,335	107,335	109,300
1995			72,618	72,618	65,360
1996			51,263	51,263	54,810
1997			90,130	90,130	79,980
1998			125,460	125,460	124,730
1999			95,638	95,638	94,580
2000			73,080	73,080	94,960
2001			72,077	72,077	90,690
2002			51,934	51,934	53,490
2003			50,684	50,684	49,590
2004			63,844	63,844	65,660
2005			80,978	80,978	86,100
2006			71,976	71,976	81,300
2007			52,714	52,714	63,800
2008			52,584	52,584	53,590
2009			44,247	44,247	43,270
2010			76,748	76,748	77,150
2011			81,503	81,503	88,620
2012			103,954	103,954	108,440
2013			96,363	96,363	113,099
2014			142,640	142,640	167,657
2015			167,549	167,549	191,309
2016			177,129	177,129	254,310
2017			186,155	186,155	203,769
2018			158,070	158,070	161,492
2019			120,243	120,243	135,850
2020			107,471	107,471	108,494
2021			101,160	101,160	105,722
2022			132,698	132,698	129,754
2023			135,103	135,103	145,215
2024					185,971
Average (1977-2023)				110,374	125,917

Table 1.2. Incidental catch (t) of FMP species (upper table) and non-target species (bottom table) in the directed pollock fishery in the Gulf of Alaska. Species are in descending order according to the cumulative catch during the period. Incidental catch estimates include both retained and discarded catch.

Managed species/species group	2019	2020	2021	2022	2023
Pollock	117,649.7	105,934.9	98,857.6	130,704.9	132,642.1
Pacific Cod	811.3	1,039.3	2,914.6	3,475.9	3,978.5
Pacific Ocean Perch	1,083.5	1,131.0	778.6	2,248.1	2,197.5
Arrowtooth Flounder	2,019.6	2,417.1	810.8	771.0	769.6
Sablefish	409.2	794.7	57.7	85.4	77.3
GOA Shallow Water Flatfish	263.2	151.3	194.5	178.0	264.7
Flathead Sole	197.2	227.1	109.0	70.2	133.1
Shark	59.1	100.3	83.7	83.0	53.5
Shortraker Rockfish	8.4	29.5	30.8	121.6	140.2
GOA Skate, Big	66.5	78.3	53.4	64.6	60.6
GOA Rex Sole	89.7	100.4	51.5	15.8	61.6
Rougheye Rockfish	41.6	31.6	40.6	90.5	76.9
GOA Dusky Rockfish	16.4	24.6	37.5	47.4	44.7
Atka Mackerel	122.4	0.2	4.1	0.6	0.1
GOA Skate, Longnose	20.7	22.4	14.9	18.2	15.8
Sculpin	10.2	45.0			
GOA Deep Water Flatfish	12.7	12.1	0.9	0.2	17.5
Other Rockfish	4.6	0.2	1.4	18.4	0.2
BSAI Skate and GOA Skate, Other	3.5	4.1	3.5	3.8	4.2
Octopus	8.3	4.4	0.3	0.1	0.7
Northern Rockfish	7.2	0.9	1.9	1.2	0.7
GOA Thornyhead Rockfish	0.2	0.5	2.3	1.9	1.6
Percent non-pollock	0.0	0.1	0.0	0.1	0.1
Non target species/species group					
Squid	47.5	371.7	242.7	2,217.9	2,918.8
Misc fish	87.8	116.4	56.7	67.0	59.0
Smelt (Family Osmeridae)			240.5	93.2	52.0
Grenadier - Rattail Grenadier Unidentified	37.7	38.6	46.7	58.8	33.7
Other osmerids	47.0	7.0	87.6	1.4	11.1
Scypho jellies	121.4	5.5	9.8	3.4	13.6
Capelin	80.6	54.0			
Giant Grenadier	9.3	11.3	9.6	29.5	11.9
Sculpin			10.0	16.4	4.1
Eulachon	7.6	22.3			
Sea star	2.5	3.3	0.9	0.3	0.2
Bivalves	0.6				
Eelpouts		0.1		0.4	
Pacific Sand lance			0.1		0.1
urchins dollars cucumbers		0.0	0.1	0.0	
Hermit crab unidentified			0.0		

Table 1.3. Bycatch of prohibited species for the directed pollock fishery in the Gulf of Alaska. Herring and halibut bycatch is reported in metric tons, while crab and salmon are reported in number of fish.

Species/species group	2018	2019	2020	2021	2022
Bairdi Tanner Crab	41,889	19,010	1,833	757	1,164
Blue King Crab	0	0	0	0	0
Chinook Salmon	20,992	10,845	10,504	13,141	18,433
Golden (Brown) King Crab	0	2	0	0	0
Halibut	274	136	103	80	49
Herring	64	61	16	83	68
Non-Chinook Salmon	5,063	2,156	1,125	1,028	2,114
Opilio Tanner (Snow) Crab	0	0	0	0	0
Red King Crab	0	5	3	0	0

Table 1.4. Non-commercial catch (t) of pollock in the Gulf of Alaska by collection agency.

Year	ADF&G	IPHC	NMFS
1982	0.07	0.00	0.00
1986	0.06	0.00	0.00
1988	0.00	0.00	0.11
1989	0.00	0.00	0.23
1990	0.00	0.00	0.49
1991	0.09	0.00	0.49
1992	0.16	0.00	0.67
1993	0.17	0.00	0.57
1994	0.00	0.00	0.29
1995	0.00	0.00	0.44
1996	0.00	0.00	0.23
1997	0.17	0.00	0.41
1998	1.23	0.00	0.24
1999	4.66	0.00	0.13
2000	5.63	0.00	0.12
2001	1.54	0.00	0.02
2002	2.66	0.00	0.10
2003	3.72	0.00	0.14
2004	4.67	0.00	0.08
2005	8.97	0.00	0.09
2006	2.42	0.00	0.31
2007	3.05	0.00	0.63
2008	2.29	0.00	0.80
2009	3.62	0.00	3.22
2010	103.10	0.77	52.43
2011	104.67	0.25	44.40
2012	134.31	0.07	13.14
2013	91.70	0.55	2,337.70
2014	75.32	0.62	2,389.87
2015	35.39	0.40	62.94
2016	15.62	0.03	0.16
2017	30.45	0.06	105.97
2018	42.21	0.06	19.66
2019	31.41	0.06	76.14
2020	36.51	0.07	26.42
2021	41.61	0.19	70.32
2022	44.24	0.05	13.19
2023	39.18	0.29	104.92

Table 1.5. Estimated catch (retained and discarded) of walleye pollock (t) by management area in the Gulf of Alaska compiled by the Alaska Regional Office.

Year	Utilization	Shumagin 610	Chirikof 620	Kodiak 630	West Yakutat 640	Prince William Sound 649 (state waters)	Southeast and East Yakutat 650 & 659	Total	Percent discard
2012	Retained	27,352	44,779	25,125	2,380	2,624	0	102,261	
	Discarded	521	301	856	12	3	1	1,694	1.63%
	Total	27,873	45,080	25,981	2,392	2,627	1	103,954	
2013	Retained	7,644	52,692	28,169	2,933	2,622	0	94,062	
	Discarded	67	433	1,791	7	0	2	2,300	2.39%
	Total	7,711	53,125	29,960	2,940	2,623	2	96,362	
2014	Retained	13,228	82,611	41,791	1,314	2,368	0	141,312	
	Discarded	136	470	712	3	3	3	1,328	0.93%
	Total	13,364	83,081	42,503	1,317	2,371	3	142,640	
2015	Retained	28,679	80,950	51,973	248	4,455	0	166,305	
	Discarded	59	490	657	1	32	3	1,243	0.74%
	Total	28,739	81,439	52,630	250	4,487	3	167,548	
2016	Retained	61,019	46,810	64,281	121	3,893	0	176,123	
	Discarded	233	214	529	12	14	3	1,005	0.57%
	Total	61,252	47,024	64,810	133	3,907	3	177,128	
2017	Retained	49,246	80,855	52,338	39	1,881	0	184,359	
	Discarded	297	752	733	0	16	2	1,800	0.97%
	Total	49,542	81,607	53,071	40	1,897	2	186,158	
2018	Retained	30,580	79,024	39,325	4,054	3,086	0	156,069	
	Discarded	94	1,030	762	71	35	1	1,994	1.26%
	Total	30,675	80,054	40,087	4,125	3,122	1	158,063	
2019	Retained	21,723	63,610	24,259	6,424	2,959	0	118,976	
	Discarded	144	510	402	188	18	3	1,266	1.05%
	Total	21,868	64,120	24,661	6,612	2,977	3	120,242	
2020	Retained	18,988	55,074	25,407	5,152	2,309	0	106,931	
	Discarded	18	316	168	28	2	0	531	0.49%
	Total	19,005	55,391	25,575	5,180	2,311	0	107,462	
2021	Retained	17,663	52,075	22,825	5,115	2,136	0	99,814	
	Discarded	354	347	606	29	3	2	1,341	1.33%
	Total	18,017	52,422	23,431	5,144	2,139	2	101,155	
2022	Retained	23,282	69,048	30,007	6,402	2,801	0	131,539	
	Discarded	337	271	551	38	1	1	1,197	0.9%
	Total	23,618	69,318	30,557	6,440	2,802	1	132,736	
2023	Retained	25,995	64,784	32,902	6,830	3,252	0	133,763	
	Discarded	219	559	506	46	10	0	1,340	0.99%
	Total	26,214	65,343	33,408	6,876	3,262	0	135,103	
Average (2012-2023)		27,323	64,834	37,223	3,454	2,877	2	135,713	

Table 1.6. Catch at age (millions) of walleye pollock in the Gulf of Alaska.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1975	0.00	2.59	59.62	18.54	15.61	7.33	3.04	2.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	109.69
1976	0.00	1.66	20.16	108.26	35.11	14.62	3.23	2.50	1.72	0.21	0.00	0.00	0.00	0.00	0.00	187.47
1977	0.05	6.93	11.65	26.71	101.29	29.26	10.97	2.85	2.52	1.14	0.52	0.07	0.06	0.00	0.00	194.01
1978	0.31	10.87	34.64	24.38	24.27	47.04	13.58	5.77	2.15	1.32	0.57	0.05	0.04	0.01	0.00	164.99
1979	0.10	3.47	54.61	89.36	14.24	9.47	12.94	5.96	2.32	0.56	0.21	0.08	0.00	0.00	0.01	193.33
1980	0.49	9.84	27.85	58.42	42.16	13.92	10.76	9.79	4.95	1.32	0.69	0.24	0.09	0.03	0.00	180.55
1981	0.23	4.82	35.40	73.34	58.90	23.41	6.74	5.84	4.16	0.59	0.02	0.04	0.03	0.00	0.00	213.53
1982	0.04	9.52	41.68	92.53	72.56	42.91	10.94	1.71	1.10	0.70	0.05	0.03	0.02	0.00	0.00	273.80
1983	0.00	6.96	42.29	81.51	121.82	59.42	33.14	8.72	1.70	0.18	0.44	0.10	0.00	0.00	0.00	356.28
1984	0.71	5.28	62.46	66.85	81.92	122.05	43.96	14.94	4.95	0.43	0.06	0.12	0.10	0.00	0.00	403.84
1985	0.20	11.60	7.43	36.26	39.31	70.63	117.57	36.73	10.31	2.65	0.85	0.00	0.00	0.00	0.00	333.55
1986	1.00	6.05	14.67	8.80	19.45	8.27	9.01	10.90	4.35	0.74	0.00	0.00	0.00	0.00	0.00	83.26
1987	0.00	4.25	6.43	5.73	6.66	12.55	10.75	7.07	15.65	1.67	0.98	0.00	0.00	0.00	0.00	71.74
1988	0.85	8.86	12.71	19.21	16.11	10.63	5.93	2.72	0.40	5.83	0.48	0.11	0.06	0.00	0.00	83.91
1989	2.94	1.33	3.62	34.46	39.31	13.57	5.21	2.65	1.08	0.50	2.00	0.20	0.06	0.05	0.02	106.99
1990	0.00	1.15	1.45	2.14	12.43	39.17	13.99	7.93	1.91	1.70	0.11	1.08	0.03	0.10	0.19	83.37
1991	0.00	1.14	8.11	4.34	3.83	7.39	33.95	3.75	19.13	0.85	6.00	0.40	2.39	0.20	0.83	92.29
1992	0.11	1.56	3.31	21.09	22.47	11.82	8.56	17.75	5.44	6.10	1.13	2.26	0.39	0.47	0.40	102.86
1993	0.04	2.46	8.46	19.94	47.83	16.69	7.21	6.86	9.73	2.38	2.27	0.54	0.92	0.17	0.30	125.80
1994	0.06	0.88	4.16	7.60	33.41	29.84	12.00	5.28	4.72	6.10	1.29	1.17	0.25	0.07	0.06	106.90
1995	0.00	0.23	1.73	4.82	9.46	21.96	13.60	4.30	2.05	2.15	2.46	0.41	0.28	0.04	0.12	63.62
1996	0.00	0.80	1.95	1.44	4.09	5.64	10.91	11.66	3.82	1.84	0.72	1.97	0.34	0.40	0.20	45.76
1997	0.00	1.65	7.20	4.08	4.28	8.23	12.34	18.77	13.71	5.62	2.03	0.88	0.50	0.14	0.04	79.49
1998	0.56	0.19	19.38	33.10	14.54	8.58	9.75	11.36	16.51	12.01	4.33	0.91	0.59	0.16	0.12	132.08
1999	0.00	0.75	2.61	22.91	34.47	10.08	7.53	4.00	6.20	8.16	4.70	1.18	0.58	0.13	0.08	103.40
2000	0.08	0.98	2.84	3.47	14.65	24.63	6.24	5.05	2.30	1.24	3.00	1.52	0.30	0.14	0.04	66.48
2001	0.74	10.13	6.59	7.34	9.42	12.59	14.44	4.73	2.70	1.35	0.65	0.83	0.61	0.00	0.04	72.14
2002	0.16	12.31	20.72	6.76	4.47	8.75	5.37	6.06	1.33	0.82	0.43	0.30	0.33	0.22	0.13	68.16
2003	0.14	2.69	21.47	22.95	5.33	3.25	4.66	3.76	2.58	0.54	0.19	0.04	0.09	0.04	0.05	67.79
2004	0.85	6.28	11.91	31.84	25.09	5.98	2.43	2.63	0.77	0.22	0.25	0.00	0.00	0.00	0.00	88.24
2005	1.14	1.21	5.33	6.85	41.25	21.73	6.10	0.74	0.91	0.35	0.18	0.13	0.00	0.00	0.00	85.91
2006	2.20	7.79	4.16	2.75	5.97	27.38	12.80	2.45	0.83	0.46	0.23	0.10	0.07	0.03	0.00	67.22
2007	0.82	18.89	7.46	2.51	2.31	3.58	10.19	6.70	1.59	0.29	0.23	0.09	0.00	0.00	0.01	54.68
2008	0.32	6.29	21.94	6.76	2.15	1.16	2.27	5.60	2.84	0.87	0.36	0.21	0.06	0.04	0.02	50.89
2009	0.24	6.38	14.84	13.47	3.82	1.19	0.72	0.95	1.90	1.45	0.47	0.06	0.01	0.00	0.00	45.50
2010	0.01	5.29	23.35	21.32	18.14	3.68	1.11	0.73	0.92	1.02	0.64	0.05	0.06	0.01	0.00	76.31
2011	0.00	2.49	12.18	26.78	20.88	13.12	2.97	0.61	0.38	0.21	0.36	0.35	0.07	0.00	0.00	80.40
2012	0.03	0.66	4.64	13.49	29.83	21.43	8.94	1.95	0.43	0.18	0.23	0.16	0.04	0.07	0.08	82.15
2013	0.58	2.70	10.20	5.31	13.00	17.18	12.57	5.13	1.01	0.53	0.30	0.18	0.28	0.22	0.04	69.23
2014	0.07	9.95	6.37	29.79	11.52	14.22	20.78	16.67	6.56	1.95	0.70	0.01	0.27	0.00	0.01	118.90
2015	0.00	8.58	107.27	15.31	32.09	10.00	12.25	11.94	5.79	1.84	1.29	0.15	0.11	0.05	0.08	206.74
2016	0.00	1.33	15.97	272.64	11.17	10.72	2.42	1.13	0.47	0.19	0.00	0.15	0.00	0.00	0.00	316.19
2017	0.00	0.00	0.09	18.77	259.68	4.63	2.97	0.10	0.10	0.03	0.00	0.00	0.00	0.00	0.00	286.38
2018	1.11	3.13	0.17	0.79	35.52	160.14	7.28	1.55	0.23	0.10	0.00	0.00	0.00	0.00	0.00	210.03
2019	0.44	10.41	7.23	1.22	0.85	20.00	101.70	8.86	1.09	0.34	0.00	0.00	0.00	0.00	0.00	152.15
2020	0.20	13.41	56.07	7.94	1.29	1.88	19.81	48.93	5.27	0.78	0.09	0.00	0.05	0.00	0.00	155.73
2021	0.12	6.60	31.78	47.84	8.28	0.76	3.19	9.47	23.61	6.08	0.51	0.00	0.00	0.00	0.00	138.24
2022	0.03	5.95	13.61	51.88	49.82	6.57	1.44	3.00	9.14	15.67	3.91	1.12	0.33	0.00	0.00	162.47
2023	0.43	8.57	46.69	17.26	65.11	25.78	4.84	0.69	1.74	4.24	2.78	1.59	0.28	0.00	0.00	180.00

Table 1.7. Number of aged and measured fish in the Gulf of Alaska pollock fishery used to estimate fishery age composition.

Year	Aged Males	Aged Females	Aged Total	Lengthed Males	Lengthed Females	Lengthed Total
1989	882	892	1,774	6,454	6,456	12,910
1990	453	689	1,142	17,814	24,662	42,476
1991	1,146	1,322	2,468	23,946	39,467	63,413
1992	1,726	1,755	3,481	31,608	47,226	78,834
1993	926	949	1,875	28,035	31,306	59,341
1994	136	129	265	24,321	25,861	50,182
1995	499	544	1,043	10,591	10,869	21,460
1996	381	378	759	8,581	8,682	17,263
1997	496	486	982	8,750	8,808	17,558
1998	924	989	1,913	78,955	83,160	162,115
1999	980	1,115	2,095	16,304	17,964	34,268
2000	1,108	972	2,080	13,167	11,794	24,961
2001	1,063	1,025	2,088	13,731	13,552	27,283
2002	1,036	1,025	2,061	9,924	9,851	19,775
2003	1,091	1,119	2,210	8,375	8,220	16,595
2004	1,217	996	2,213	4,446	3,622	8,068
2005	1,065	968	2,033	6,837	6,005	12,842
2006	1,127	969	2,096	7,248	6,178	13,426
2007	998	1,064	2,062	4,504	5,064	9,568
2008	961	1,090	2,051	7,430	8,536	15,966
2009	1,011	1,034	2,045	9,913	9,447	19,360
2010	1,195	1,055	2,250	14,958	13,997	28,955
2011	1,197	1,025	2,222	9,625	11,023	20,648
2012	1,160	1,097	2,257	11,045	10,430	21,475
2013	683	774	1,457	3,565	4,084	7,649
2014	1,085	1,040	2,125	10,353	10,444	20,797
2015	1,048	1,069	2,117	21,104	23,144	44,248
2016	1,433	959	2,392	28,904	20,347	49,251
2017	1,245	925	2,170	18,627	15,007	33,634
2018	1,254	1,008	2,262	16,022	13,024	29,046
2019	1,175	936	2,111	13,989	11,875	25,864
2020	1,062	1,051	2,113	11,545	11,746	23,291
2021	1,003	919	1,922	6,430	6,435	12,865
2022	936	1,684	2,620	6,975	6,794	13,769
2023	955	1,646	2,601	6,812	6,960	13,772

Table 1.8. Survey sampling effort and biomass coefficients of variation (CV) for pollock in the NMFS bottom trawl survey west of 140W. The number of measured pollock is approximate due to subsample expansions in the database. The total number measured includes both sexed and unsexed fish.

Year	No. tows	No. of tows with pollock	Survey biomass CV	Aged Males	Aged Females	Aged Total	Lengthed Males	Lengthed Females	Lengthed 'Total
1990	607	478	0.12	503	560	1,065	4,253	5,076	9,655
1993	676	544	0.16	642	756	1,411	4,203	4,983	9,326
1996	674	569	0.15	440	485	928	3,561	3,891	7,849
1999	652	490	0.38	522	577	1,181	2,970	3,414	6,788
2001	489	302	0.30	383	504	897	1,926	2,120	4,203
2003	708	432	0.12	426	493	931	3,053	3,680	6,788
2005	715	426	0.15	399	509	921	2,535	3,028	5,985
2007	731	493	0.14	563	586	1,150	3,028	3,501	6,913
2009	722	487	0.15	606	749	1,360	3,841	4,333	8,489
2011	594	434	0.15	631	835	1,484	3,246	3,673	7,067
2013	496	400	0.21	704	725	1,439	2,941	3,308	6,325
2015	680	539	0.16	428	568	997	3,641	4,342	8,056
2017	467	369	0.44	340	393	738	1,354	1,618	3,191
2019	470	387	0.24	350	415	771	1,873	2,144	4,157
2021	450	362	0.17	500	589	1,089	2,760	3,273	6,100
2023	463	387	0.13	648	781	1,429	3,245	3,783	7,136

Table 1.9. Estimated number at age (millions) from the NMFS bottom trawl survey (top). Estimates are for the Western and Central Gulf of Alaska only (west of 140 degrees west), except for 1984 and 1987 which are not used in the model and are for regions 610-630. Estimated number at age (millions) from the summer acoustic survey (bottom).

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1984	38.7	15.7	74.5	158.8	194.7	271.2	85.9	37.4	13.6	2.4	0.5	0.3	0.2	0.0	0.0	893.8
1987	26.1	325.1	150.4	111.7	70.6	135.1	64.3	37.0	146.4	18.9	6.7	2.9	1.5	0.0	0.0	1,096.8
1990	73.5	254.8	47.8	41.7	202.6	233.6	69.2	105.3	25.6	37.0	5.8	24.3	6.0	0.7	1.1	1,129.1
1993	95.6	56.5	51.9	140.2	285.0	85.2	33.6	60.9	71.9	23.3	10.9	6.1	3.2	1.8	4.3	930.3
1996	245.1	159.5	23.3	26.5	52.8	64.8	183.1	89.0	47.6	24.7	12.1	16.7	7.4	10.1	3.1	966.1
1999	150.2	24.1	23.6	68.9	118.8	57.3	61.0	51.1	55.4	81.8	64.9	10.6	7.1	2.7	0.8	778.4
2001	415.6	114.1	34.0	33.7	25.2	33.2	37.6	8.5	5.2	0.6	4.5	2.5	1.3	0.0	0.2	716.2
2003	102.1	15.4	112.3	154.7	83.7	50.5	37.2	26.0	14.6	8.8	3.3	1.8	1.3	0.0	0.0	611.8
2005	278.6	39.4	35.7	27.2	91.6	94.0	49.1	20.9	10.6	10.2	5.3	0.6	1.0	0.0	0.0	664.2
2007	175.3	96.0	102.3	44.0	18.6	18.1	58.3	31.3	6.6	2.3	2.9	1.0	1.1	0.0	0.0	557.9
2009	236.8	86.9	105.1	147.3	111.1	26.3	15.9	25.5	54.7	30.3	10.1	7.2	2.8	1.6	0.0	861.7
2011	289.8	102.8	116.2	107.9	163.7	113.6	33.0	7.4	5.8	8.8	19.4	6.7	0.0	0.0	0.6	975.6
2013	789.0	65.1	53.2	58.2	84.6	152.7	162.3	118.4	26.3	5.5	2.4	2.5	3.9	3.1	0.9	1,528.3
2015	113.7	52.4	477.2	109.3	120.7	73.0	57.3	55.3	28.3	22.8	3.7	0.6	0.1	0.0	0.9	1,115.2
2017	181.3	4.8	6.5	28.8	302.4	29.2	18.0	4.7	0.4	0.2	0.8	0.0	0.0	0.1	0.0	577.2
2019	148.8	86.2	27.6	12.6	10.2	32.0	188.8	22.0	3.0	0.1	0.3	0.0	0.0	0.0	0.0	531.6
2021	421.3	146.6	180.5	249.1	62.4	12.3	8.9	38.1	70.3	8.6	1.4	0.0	0.0	0.0	0.0	1,199.3
2023	321.0	79.7	505.6	165.6	346.8	158.0	33.7	13.6	10.6	13.9	17.5	3.3	0.0	0.0	0.0	1,669.5

2013	7,793.4	90.6	366.7	57.0	72.0	106.5	83.9	38.2	10.8	4.5	2.0	2.1	0.6	1.1	0.2	8,629.5
2015	6.6	233.4	3,014.3	123.3	76.2	36.7	17.6	18.3	12.9	7.2	0.9	1.1	0.0	0.0	0.0	3,548.6
2017	717.3	0.8	1.0	118.6	1,702.4	88.2	12.7	1.4	0.0	0.7	0.4	0.0	0.0	0.0	0.0	2,643.4
2019	2,894.3	1,303.1	95.9	7.1	4.9	54.7	255.3	23.9	1.7	1.6	0.1	0.0	0.0	0.6	0.0	4,643.1
2019	2,894.3	1,303.1	95.9	7.1	4.9	54.7	255.3	23.9	1.7	1.6	0.1	0.0	0.0	0.6	0.0	4,643.1
2021	3,621.9	135.6	227.4	217.4	30.9	3.8	3.4	11.0	36.7	15.9	3.1	0.4	0.0	0.0	0.0	4,307.6
2023	563.1	93.3	584.2	109.7	253.7	129.4	19.1	1.2	3.0	7.9	8.4	1.2	0.0	0.0	0.0	1,774.2

Table 1.10. Biomass estimates (t) of walleye pollock from winter acoustic surveys in Shelikof Strait, summer gulfwide acoustic surveys, NMFS bottom trawl surveys (west of 140 W. long.), egg production surveys in Shelikof Strait, and ADF&G crab/groundfish trawl surveys.

Year	Shelikof Strait acoustic survey	Summer gulfwide acoustic survey	NMFS bottom trawl west of 140W	Shelikof Strait egg production	ADFG crab/groundfish survey
1981	2,785,755			1,788,908	
1982					
1983	2,278,172				
1984	1,757,168		726,229		
1985	1,175,823			768,419	
1986	585,755			375,907	
1987			737,900	484,455	
1988	301,709			504,418	
1989	290,461			433,894	214,434
1990	374,731		817,040	381,475	114,451
1991	380,331			370,000	
1992	713,429			616,000	127,359
1993	435,753		747,942		132,849
1994	492,593				103,420
1995	763,612				
1996	777,172		659,604		122,477
1997	583,017				93,728
1998	504,774				81,215
1999			601,969		53,587
2000	448,638				102,871
2001	432,749		220,141		86,967
2002	256,743				96,237
2003	317,269		394,333		66,989
2004	330,753				99,358
2005	356,117		354,209		79,089
2006	293,609				69,044
2007	180,881		278,541		76,674
2008	197,922				83,476
2009	257,422		662,557		145,438
2010	421,575				124,110
2011			660,207		100,839
2012	334,061				172,007
2013	807,838	884,049	947,877		102,406
2014	827,338				100,158
2015	847,970	1,606,171	707,774		42,277
2016	667,003				18,470
2017	1,465,229	1,318,396	288,943		21,855
2018	1,320,867				49,788
2019	1,281,083	580,543	257,604		50,960
2020	456,713				59,377
2021	526,974	431,148	494,743		64,813
2022	365,411				71,196
2023	258,829	740,417	887,602		56,611
2024	289,973				66,384

Table 1.11. Estimated number at age (millions) for the acoustic survey in Shelikof Strait. Estimates starting in 2008 account for net escapement.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1981	77.7	3,481.2	1,510.8	769.2	2,785.9	1,051.9	209.9	128.5	79.4	25.2	1.7	0.0	0.0	0.0	0.0	10,121.4
1983	1.2	901.8	380.2	1,296.8	1,170.8	698.1	598.8	131.5	14.5	11.6	3.9	1.7	0.0	0.0	0.0	5,210.9
1984	61.7	58.3	324.5	141.7	635.0	988.2	449.6	224.3	41.0	2.7	0.0	1.0	0.0	0.0	0.0	2,928.1
1985	2,091.7	544.4	122.7	314.8	180.5	347.2	439.3	166.7	42.7	5.6	1.8	1.3	0.0	0.0	0.0	4,258.7
1986	575.4	2,114.8	183.6	45.6	75.4	49.3	86.1	149.4	60.2	10.6	1.3	0.0	0.0	0.0	0.0	3,351.8
1988	17.4	109.9	694.3	322.1	77.6	17.0	5.7	5.6	4.0	9.0	1.8	1.8	0.2	0.0	0.0	1,266.4
1989	399.5	89.5	90.0	222.0	248.7	39.4	11.8	3.8	1.9	0.6	10.7	1.4	0.0	0.0	0.0	1,119.2
1990	49.1	1,210.2	71.7	63.4	115.9	180.1	46.3	22.4	8.2	8.2	0.9	3.1	1.5	0.8	0.2	1,782.1
1991	22.0	173.7	549.9	48.1	64.9	69.6	116.3	23.6	29.4	2.2	4.3	0.9	4.4	0.0	0.0	1,109.3
1992	228.0	33.7	73.5	188.1	368.0	84.1	85.0	171.2	32.7	56.4	2.3	14.7	0.9	0.3	0.0	1,338.8
1993	63.3	76.1	37.1	72.4	232.8	126.2	26.8	35.6	38.7	16.1	7.8	2.6	2.2	0.5	1.5	739.6
1994	186.0	35.8	49.3	31.7	155.0	83.6	42.5	27.2	44.4	48.5	14.8	6.6	1.1	2.3	0.6	729.5
1995	10,689.9	510.4	79.4	77.7	103.3	245.2	121.7	53.6	16.6	10.7	14.6	5.8	2.1	0.4	0.0	11,931.5
1996	56.1	3,307.2	118.9	25.1	54.0	71.0	201.0	118.5	39.8	13.0	11.3	5.3	2.5	0.0	0.4	4,024.4
1997	70.4	183.1	1,246.6	80.1	18.4	44.0	51.7	97.5	52.7	14.3	2.4	3.0	0.9	0.5	0.0	1,865.7
1998	395.5	88.5	125.6	474.4	136.1	14.2	31.9	36.3	74.1	25.9	14.3	6.9	0.3	0.6	0.6	1,425.0
2000	4,484.4	755.0	216.5	15.8	67.2	131.6	16.8	12.6	9.9	7.8	13.9	6.9	1.9	1.1	0.0	5,741.5
2001	288.9	4,103.9	351.7	61.0	41.6	23.0	34.6	13.1	6.2	2.7	1.2	1.9	0.7	0.5	0.2	4,931.3
2002	8.1	162.6	1,107.2	96.6	16.2	16.1	7.7	6.8	1.5	0.7	0.4	0.3	0.2	0.1	0.0	1,424.5
2003	51.2	89.6	207.7	802.5	56.6	7.7	4.1	1.6	1.5	0.9	0.3	0.0	0.1	0.0	0.0	1,223.6
2004	52.6	93.9	57.6	159.6	356.3	48.8	2.7	3.4	3.3	0.5	0.4	0.0	0.7	0.0	0.0	779.8
2005	1,626.1	157.5	55.5	34.6	172.7	162.4	36.0	3.6	2.4	0.0	0.8	0.0	0.0	0.0	0.0	2,251.7
2006	161.7	836.0	40.7	11.5	17.4	56.0	75.0	32.2	6.9	0.8	0.7	0.5	0.0	0.0	0.0	1,239.6
2007	53.5	231.7	174.9	29.7	10.1	17.3	34.4	20.9	1.5	1.0	0.7	0.0	0.0	0.0	0.0	575.7
2008	1,778.2	359.2	230.2	49.0	11.2	2.0	3.7	9.8	6.2	1.9	0.5	0.0	0.0	0.0	0.0	2,451.9
2009	814.1	1,127.2	105.8	95.8	57.8	9.5	2.7	0.8	4.7	5.6	1.3	0.2	0.0	0.0	0.0	2,225.5
2010	270.5	299.1	538.7	82.9	76.3	27.7	11.2	5.1	5.0	10.3	8.8	3.2	0.0	0.0	0.0	1,338.7
2012	193.8	842.3	43.3	76.6	94.7	45.9	28.9	4.4	1.1	0.3	0.1	0.5	0.0	0.0	0.0	1,332.0
2013	9,178.4	117.1	688.0	51.3	64.4	104.0	58.7	42.8	10.5	4.9	4.5	0.5	1.4	4.0	2.0	10,332.6
2014	1,590.8	3,492.9	17.4	279.9	82.8	57.7	98.5	54.6	25.6	17.6	7.3	0.7	2.3	0.0	0.7	5,728.9
2015	19.8	103.9	1,637.3	72.4	152.8	62.4	56.7	68.1	30.0	11.0	5.6	3.7	0.9	0.6	2.4	2,227.8
2016	0.0	1.8	78.2	1,451.8	43.4	33.5	15.5	3.6	7.4	1.7	0.0	0.0	0.0	0.0	0.0	1,636.9
2017	744.7	0.0	9.4	126.4	2,576.2	126.0	31.1	9.3	0.3	0.7	0.0	0.0	0.0	0.0	0.0	3,624.2
2018	1,819.6	142.6	1.6	9.9	166.4	1,803.9	86.1	46.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4,076.5
2019	7,361.2	1,671.7	155.5	6.1	6.6	261.7	1,127.5	53.9	11.1	9.0	0.1	0.1	0.0	0.0	0.0	10,664.4
2020	17.1	80.0	343.5	71.7	15.4	26.8	68.1	191.7	116.1	37.0	8.0	2.7	0.0	0.0	0.0	978.2
2021	7,730.1	36.7	94.2	150.7	55.4	7.3	12.5	64.0	133.9	63.4	14.3	2.2	0.0	0.0	0.0	8,364.7
2022	11.1	193.3	27.9	132.7	111.9	26.9	2.4	13.5	30.7	86.6	26.3	1.9	1.5	0.0	0.0	666.6
2023	0.1	1.4	8.1	41.6	106.8	34.7	5.6	1.2	3.6	23.5	46.5	10.0	4.2	0.4	0.5	288.1
2024	0.3	7.7	10.4	146.7	44.4	106.9	16.5	2.5	0.8	7.4	9.9	11.4	2.2	0.5	0.0	367.7

Table 1.12. Survey sampling effort and estimation uncertainty for pollock in the Shelikof Strait acoustic survey. Survey CVs based on a cluster sampling design are reported for 1981-91, while relative estimation error using a geostatistical method is reported starting in 1992.

Year	No. of midwater tows	No. of bottom trawl tows	Survey biomass CV	Aged Males	Aged Females	Aged Unsexed	Aged Total	Lengthed Males	Lengthed Females	Lengthed Unsexed	Lengthed Total
1981	38	13	0.12	1,921	1,815		3,736				
1983	40	0	0.16	1,642	1,103		2,745				
1984	45	0	0.18	1,739	1,622		3,361				
1985	57	0	0.14	1,055	1,187		2,242				
1986	39	0	0.22	642	618		1,260				
1987	27	0		557	643		1,200				
1988	26	0	0.17	537	464		1,001				
1989	21	0	0.10	582	545		1,127				
1990	28	13	0.17	1,034	1,181		2,215				
1991	16	2	0.35	468	567		1,035				
1992	17	8	0.04	784	765		1,549				
1993	22	2	0.05	583	624		1,207				
1994	44	9	0.05	553	632		1,185				
1995	22	3	0.05	599	575		1,174				
1996	30	8	0.04	724	775		1,499				
1997	16	14	0.04	682	853		1,535	5,380	6,104		11,484
1998	22	9	0.04	863	784		1,647	5,487	4,946		10,433
2000	31	0	0.05	422	363		785	6,007	5,196		11,203
2001	17	9	0.05	314	378		692	4,531	4,584		9,115
2002	18	1	0.07	278	326		604	2,876	2,871		5,747
2003	17	2	0.05	287	329		616	3,554	3,724		7,278
2004	13	2	0.09	492	440		932	3,838	2,552	91	6,481
2005	22	1	0.04	543	335		878	2,714	2,094		4,808
2006	17	2	0.04	295	487		782	2,527	3,026		5,553
2007	9	1	0.06	335	338		673	2,145	2,194		4,339
2008	10	2	0.06	171	248		419	1,641	1,675	163	3,479
2009	9	3	0.06	254	301	5	560	1,583	1,632	747	3,962
2010	13	2	0.03	286	244		530	2,590	2,358		4,948
2012	8	3	0.08	235	372	10	617	1,727	1,989	297	4,013
2013	29	5	0.05	376	386	26	788	2,198	2,436	171	4,805
2014	19	2	0.05	389	430	35	854	3,940	3,377	635	7,952
2015	20	0	0.04	354	372	29	755	4,552	4,227	176	8,955
2016	19	0	0.07	337	269		606	5,115	3,290		8,405
2017	16	1	0.04	241	314	58	613	2,501	2,781	515	5,797
2018	14	4	0.04	303	359	65	727	367	430	4,742	5,539
2019	19	7	0.07	378	413	100	891	929	977	5,693	7,599
2020	23	0	0.05	275	237	12	524	628	537	6,090	7,255
2021	24	0	0.03	253	260	90	603	575	658	7,581	8,814
2022	19	1	0.10	322	347	91	760	548	572	5,632	6,752
2023	16	0	0.05	259	312	2	573	358	408	3,767	4,533
2024	18	1	0.07	302	301	16	619	457	457	4,683	5,597

Table 1.13. Estimated proportions at age for the ADF&G crab/groundfish survey.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Sample size
2000	0.037	0.026	0.095	0.078	0.117	0.177	0.108	0.054	0.065	0.061	0.099	0.059	0.017	0.006	0.002	538
2002	0.009	0.074	0.184	0.193	0.149	0.117	0.106	0.071	0.045	0.019	0.015	0.009	0.004	0.004	0.002	538
2004	0.005	0.008	0.057	0.199	0.263	0.150	0.108	0.067	0.059	0.039	0.015	0.013	0.008	0.008	0.000	594
2006	0.005	0.042	0.112	0.083	0.147	0.301	0.166	0.059	0.036	0.029	0.012	0.003	0.002	0.000	0.003	591
2008	0.000	0.035	0.407	0.134	0.054	0.067	0.044	0.154	0.045	0.013	0.022	0.018	0.003	0.003	0.000	597
2010	0.002	0.044	0.140	0.265	0.260	0.084	0.056	0.019	0.038	0.029	0.036	0.014	0.007	0.003	0.003	585
2012	0.018	0.021	0.064	0.103	0.158	0.299	0.182	0.071	0.030	0.021	0.012	0.007	0.007	0.005	0.002	565
2014	0.000	0.019	0.054	0.160	0.135	0.144	0.159	0.194	0.083	0.022	0.015	0.008	0.003	0.003	0.000	592
2016	0.000	0.020	0.035	0.355	0.172	0.271	0.069	0.042	0.022	0.008	0.007	0.000	0.000	0.000	0.000	598
2018	0.000	0.065	0.023	0.022	0.101	0.593	0.136	0.047	0.005	0.007	0.002	0.000	0.000	0.000	0.000	597
2020	0.000	0.000	0.097	0.228	0.057	0.057	0.215	0.294	0.050	0.002	0.000	0.000	0.000	0.000	0.000	618
2022	0.000	0.007	0.143	0.287	0.216	0.093	0.047	0.056	0.049	0.076	0.017	0.008	0.000	0.000	0.002	593

Table 1.14. Ageing error transition matrix used in assessment model for GOA pollock. Relationship between true ages (rows) and observed ages (columns) determined by a normal distribution defined by a standard deviation (SD) and zero mean (unbiased reading).

True age	SD	1	2	3	4	5	6	7	8	9	10
1	0.182	0.997	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.227	0.014	0.972	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.272	0.000	0.033	0.934	0.033	0.000	0.000	0.000	0.000	0.000	0.000
4	0.317	0.000	0.000	0.057	0.886	0.057	0.000	0.000	0.000	0.000	0.000
5	0.361	0.000	0.000	0.000	0.083	0.834	0.083	0.000	0.000	0.000	0.000
6	0.406	0.000	0.000	0.000	0.000	0.109	0.782	0.109	0.000	0.000	0.000
7	0.451	0.000	0.000	0.000	0.000	0.000	0.133	0.732	0.133	0.000	0.000
8	0.496	0.000	0.000	0.000	0.000	0.000	0.001	0.155	0.687	0.155	0.001
9	0.541	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.175	0.645	0.177
10	0.585	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.191	0.804

Table 1.15. Estimates of natural mortality at age for GOA pollock using alternative methods. The rescaled average has mean natural mortality of 0.30 for ages greater than or equal to 5, the approximate age at maturity.

Age	Length (cm)	Weight (g)	Brodziak et al. 2010	Lorenzen 1996	Gislason et al. 2010	Hollowed et al. 2000	Van Kirk et al. 2010	Van Kirk et al. 2012	Average	Rescaled Avg.
1	15.27	26.5	0.97	1.36	2.62	0.86	2.31	2.00	1.69	1.39
2	27.38	166.7	0.54	0.78	1.02	0.76	1.01	0.95	0.84	0.69
3	36.78	406.4	0.40	0.59	0.64	0.58	0.58	0.73	0.59	0.48
4	44.94	752.4	0.33	0.49	0.46	0.49	0.37	0.57	0.45	0.37
5	49.24	966.0	0.30	0.45	0.40	0.41	0.36	0.53	0.41	0.34
6	52.55	1,154.2	0.30	0.43	0.36	0.38	0.28	0.47	0.37	0.30
7	55.06	1,273.5	0.30	0.42	0.33	0.38	0.30	0.46	0.36	0.30
8	57.40	1,421.7	0.30	0.40	0.31	0.38	0.29	0.43	0.35	0.29
9	60.25	1,624.8	0.30	0.39	0.29	0.39	0.29	0.42	0.35	0.28
10	61.11	1,599.6	0.30	0.39	0.28	0.39	0.33	0.40	0.35	0.29

Table 1.16. Proportion mature at age for female pollock based on maturity stage data collected during winter acoustic surveys in the GOA. Estimates from 2003 to the present are based on a GLM model using local abundance weighting.

Year	1	2	3	4	5	6	7	8	9	10+	Sample size
1983	0.000	0.000	0.165	0.798	0.960	0.974	0.983	0.943	1.000	1.000	1,333
1984	0.000	0.000	0.145	0.688	0.959	0.990	1.000	0.992	1.000	1.000	1,621
1985	0.000	0.015	0.051	0.424	0.520	0.929	0.992	0.992	1.000	1.000	1,183
1986	0.000	0.000	0.021	0.105	0.849	0.902	0.959	1.000	1.000	1.000	618
1987	0.000	0.000	0.012	0.106	0.340	0.769	0.885	0.950	0.991	1.000	638
1988	0.000	0.000	0.000	0.209	0.176	0.606	0.667	1.000	0.857	0.964	464
1989	0.000	0.000	0.000	0.297	0.442	0.710	0.919	1.000	1.000	1.000	796
1990	0.000	0.000	0.000	0.192	0.674	0.755	0.910	0.945	0.967	0.996	1,844
1991	0.000	0.000	0.000	0.111	0.082	0.567	0.802	0.864	0.978	1.000	628
1992	0.000	0.000	0.000	0.040	0.069	0.774	0.981	0.990	1.000	0.983	765
1993	0.000	0.000	0.016	0.120	0.465	0.429	0.804	0.968	1.000	0.985	624
1994	0.000	0.000	0.007	0.422	0.931	0.941	0.891	0.974	1.000	1.000	872
1995	0.000	0.000	0.000	0.153	0.716	0.967	0.978	0.921	0.917	0.977	805
1996	0.000	0.000	0.000	0.036	0.717	0.918	0.975	0.963	1.000	0.957	763
1997	0.000	0.000	0.000	0.241	0.760	1.000	1.000	0.996	1.000	1.000	843
1998	0.000	0.000	0.000	0.065	0.203	0.833	0.964	1.000	1.000	0.989	757
2000	0.000	0.000	0.012	0.125	0.632	0.780	0.579	0.846	1.000	0.923	356
2001	0.000	0.000	0.000	0.289	0.308	0.825	0.945	0.967	0.929	1.000	374
2002	0.000	0.000	0.026	0.259	0.750	0.933	0.974	1.000	1.000	1.000	499
2003	0.000	0.026	0.077	0.211	0.461	0.732	0.897	0.965	0.989	0.996	301
2004	0.000	0.081	0.221	0.480	0.749	0.906	0.969	0.990	0.997	0.999	444
2005	0.000	0.037	0.130	0.373	0.702	0.903	0.974	0.993	0.998	1.000	321
2006	0.000	0.004	0.023	0.124	0.466	0.842	0.970	0.995	0.999	1.000	476
2007	0.000	0.006	0.040	0.221	0.661	0.931	0.989	0.998	1.000	1.000	313
2008	0.000	0.001	0.009	0.060	0.321	0.779	0.963	0.995	0.999	1.000	240
2009	0.000	0.002	0.014	0.085	0.382	0.805	0.965	0.995	0.999	1.000	296
2010	0.000	0.003	0.033	0.265	0.791	0.976	0.998	1.000	1.000	1.000	314
2012	0.000	0.008	0.069	0.396	0.853	0.981	0.998	1.000	1.000	1.000	372
2013	0.000	0.000	0.009	0.210	0.884	0.995	1.000	1.000	1.000	1.000	622
2014	0.000	0.002	0.015	0.088	0.388	0.806	0.964	0.994	0.999	1.000	430
2015	0.000	0.018	0.087	0.323	0.706	0.924	0.984	0.997	0.999	1.000	372
2016	0.000	0.001	0.037	0.592	0.982	1.000	1.000	1.000	1.000	1.000	269
2017	0.000	0.232	0.594	0.877	0.972	0.994	0.999	1.000	1.000	1.000	423
2018	0.000	0.017	0.126	0.551	0.912	0.989	0.999	1.000	1.000	1.000	404
2019	0.000	0.002	0.019	0.159	0.644	0.946	0.994	0.999	1.000	1.000	551
2020	0.000	0.002	0.015	0.123	0.559	0.920	0.990	0.999	1.000	1.000	237
2021	0.000	0.047	0.132	0.319	0.591	0.816	0.932	0.977	0.992	0.997	228
2022	0.000	0.073	0.221	0.506	0.788	0.931	0.980	0.994	0.998	1.000	347
2023	0.001	0.015	0.151	0.670	0.959	0.996	1.000	1.000	1.000	1.000	573
2024	0.005	0.029	0.137	0.463	0.823	0.962	0.993	0.999	1.000	1.000	603
Average											
All years	0.000	0.015	0.065	0.294	0.629	0.868	0.944	0.980	0.990	0.994	
2013-2024	0.001	0.037	0.129	0.407	0.767	0.940	0.986	0.997	0.999	1.000	
2017-2024	0.001	0.052	0.174	0.458	0.781	0.944	0.986	0.996	0.999	1.000	

Table 1.17. Fishery weight at age (kg) for GOA pollock.

Year	1	2	3	4	5	6	7	8	9	10
1975	0.103	0.225	0.412	0.547	0.738	0.927	1.020	1.142	1.142	1.142
1976	0.103	0.237	0.325	0.426	0.493	0.567	0.825	0.864	0.810	0.843
1977	0.072	0.176	0.442	0.525	0.616	0.658	0.732	0.908	0.894	0.955
1978	0.100	0.140	0.322	0.574	0.616	0.685	0.742	0.842	0.896	0.929
1979	0.099	0.277	0.376	0.485	0.701	0.796	0.827	0.890	1.017	1.111
1980	0.091	0.188	0.487	0.559	0.635	0.774	0.885	0.932	0.957	1.032
1981	0.163	0.275	0.502	0.686	0.687	0.769	0.876	0.967	0.969	1.211
1982	0.072	0.297	0.416	0.582	0.691	0.665	0.730	0.951	0.991	1.051
1983	0.103	0.242	0.452	0.507	0.635	0.686	0.689	0.787	0.919	1.078
1984	0.134	0.334	0.539	0.724	0.746	0.815	0.854	0.895	0.993	1.129
1985	0.121	0.152	0.481	0.628	0.711	0.813	0.874	0.937	0.985	1.156
1986	0.078	0.153	0.464	0.717	0.791	0.892	0.902	0.951	1.010	1.073
1987	0.123	0.272	0.549	0.684	0.896	1.003	1.071	1.097	1.133	1.102
1988	0.160	0.152	0.433	0.532	0.806	0.997	1.165	1.331	1.395	1.410
1989	0.068	0.201	0.329	0.550	0.667	0.883	1.105	1.221	1.366	1.459
1990	0.123	0.137	0.248	0.536	0.867	0.980	1.135	1.377	1.627	1.763
1991	0.123	0.262	0.423	0.582	0.721	0.943	1.104	1.189	1.296	1.542
1992	0.121	0.238	0.375	0.566	0.621	0.807	1.060	1.179	1.188	1.417
1993	0.136	0.282	0.550	0.688	0.782	0.842	1.048	1.202	1.250	1.356
1994	0.141	0.193	0.471	0.743	0.872	1.000	1.080	1.230	1.325	1.433
1995	0.123	0.302	0.623	0.966	1.050	1.107	1.198	1.292	1.346	1.440
1996	0.123	0.249	0.355	0.670	1.010	1.102	1.179	1.238	1.284	1.410
1997	0.123	0.236	0.380	0.659	0.948	1.161	1.233	1.274	1.297	1.358
1998	0.097	0.248	0.472	0.571	0.817	0.983	1.219	1.325	1.360	1.409
1999	0.123	0.323	0.533	0.704	0.757	0.914	1.049	1.196	1.313	1.378
2000	0.157	0.312	0.434	0.773	0.991	0.998	1.202	1.271	1.456	1.663
2001	0.108	0.292	0.442	0.701	1.003	1.208	1.286	1.473	1.540	1.724
2002	0.145	0.316	0.480	0.615	0.898	1.050	1.146	1.263	1.363	1.522
2003	0.136	0.369	0.546	0.507	0.715	1.049	1.242	1.430	1.511	1.700
2004	0.112	0.259	0.507	0.720	0.677	0.896	1.123	1.262	1.337	1.747
2005	0.127	0.275	0.446	0.790	1.005	0.977	0.921	1.305	1.385	1.485
2006	0.129	0.260	0.566	0.974	1.229	1.242	1.243	1.358	1.424	1.653
2007	0.127	0.345	0.469	0.885	1.195	1.385	1.547	1.634	1.749	1.940
2008	0.143	0.309	0.649	0.856	1.495	1.637	1.894	1.896	1.855	2.204
2009	0.205	0.235	0.566	0.960	1.249	1.835	2.002	2.151	2.187	2.208
2010	0.133	0.327	0.573	0.972	1.267	1.483	1.674	2.036	2.329	2.191
2011	0.141	0.473	0.593	0.833	1.107	1.275	1.409	1.632	1.999	1.913
2012	0.194	0.294	0.793	0.982	1.145	1.425	1.600	1.869	2.051	2.237
2013	0.140	0.561	0.685	1.141	1.323	1.467	1.641	1.801	1.913	2.167
2014	0.104	0.245	0.749	0.865	1.092	1.362	1.482	1.632	1.720	1.826
2015	0.141	0.349	0.502	0.860	0.993	1.141	1.393	1.527	1.650	1.783
2016	0.141	0.402	0.473	0.534	0.705	0.825	1.035	1.171	1.169	1.179
2017	0.141	0.402	0.615	0.606	0.644	0.805	0.890	0.967	1.025	1.403
2018	0.098	0.372	0.479	0.593	0.726	0.769	0.825	1.003	1.004	1.135
2019	0.111	0.300	0.522	0.624	0.815	0.816	0.838	0.869	1.071	1.022
2020	0.202	0.310	0.423	0.616	0.796	0.944	0.942	0.954	0.943	0.948
2021	0.107	0.368	0.530	0.612	0.734	1.054	0.965	1.008	1.015	1.044
2022	0.114	0.321	0.609	0.699	0.779	0.973	0.919	1.143	1.077	1.094
2023	0.121	0.385	0.550	0.744	0.759	0.893	0.966	1.265	1.244	1.230

Table 1.18. Weight at age (kg) of pollock in the winter acoustic survey.

Year	1	2	3	4	5	6	7	8	9	10
1992	0.011	0.086	0.211	0.321	0.392	0.811	1.087	1.132	1.106	1.304
1993	0.010	0.082	0.304	0.469	0.583	0.714	1.054	1.197	1.189	1.332
1994	0.010	0.090	0.284	0.639	0.817	0.899	1.120	1.238	1.444	1.431
1995	0.011	0.091	0.295	0.526	0.804	0.898	0.949	1.034	1.147	1.352
1996	0.011	0.055	0.206	0.469	0.923	1.031	1.052	1.115	1.217	1.374
1997	0.010	0.079	0.157	0.347	0.716	1.200	1.179	1.231	1.279	1.424
1998	0.011	0.089	0.225	0.322	0.386	0.864	1.217	1.295	1.282	1.362
2000	0.013	0.084	0.279	0.570	0.810	0.811	1.010	1.319	1.490	1.551
2001	0.009	0.052	0.172	0.416	0.641	1.061	1.166	1.379	1.339	1.739
2002	0.012	0.082	0.148	0.300	0.714	0.984	1.190	1.241	1.535	1.765
2003	0.012	0.091	0.207	0.277	0.436	0.906	1.220	1.280	1.722	1.584
2004	0.010	0.085	0.246	0.486	0.502	0.749	1.341	1.338	1.446	1.311
2005	0.011	0.084	0.305	0.548	0.767	0.734	0.798	1.169	1.205	1.837
2006	0.009	0.066	0.262	0.429	0.828	1.124	1.163	1.327	1.493	1.884
2007	0.011	0.063	0.222	0.446	0.841	1.248	1.378	1.439	1.789	1.896
2008	0.014	0.099	0.267	0.484	0.795	1.373	1.890	1.869	1.882	2.014
2009	0.011	0.078	0.262	0.522	0.734	1.070	1.658	2.014	2.103	2.067
2010	0.010	0.079	0.239	0.673	1.093	1.287	1.828	2.090	2.291	2.227
2012	0.013	0.079	0.272	0.653	0.928	1.335	1.485	1.554	1.930	1.939
2013	0.009	0.127	0.347	0.626	1.157	1.371	1.600	1.772	1.849	2.262
2014	0.012	0.058	0.304	0.594	0.712	1.294	1.336	1.531	1.572	1.666
2015	0.013	0.094	0.200	0.542	0.880	1.055	1.430	1.498	1.594	1.654
2016	0.013	0.133	0.303	0.390	0.557	0.751	0.860	1.120	1.115	1.178
2017	0.011	0.133	0.345	0.451	0.505	0.578	0.912	0.951	1.383	1.339
2018	0.008	0.089	0.181	0.516	0.539	0.609	0.679	0.892	1.383	1.339
2019	0.008	0.061	0.221	0.493	0.637	0.701	0.736	0.789	0.879	1.044
2020	0.015	0.072	0.172	0.311	0.480	0.711	0.808	0.806	0.800	0.848
2021	0.009	0.191	0.321	0.494	0.682	0.856	0.876	1.019	1.054	1.059
2022	0.009	0.051	0.369	0.548	0.611	0.867	0.845	1.177	1.047	1.133
2023	0.009	0.189	0.348	0.646	0.722	0.884	1.180	1.250	1.283	1.276
2024	0.014	0.128	0.444	0.634	0.818	0.852	1.042	1.460	0.822	1.351

Table 1.19. Weight at age (kg) of pollock in the summer NMFS bottom trawl survey (top) and NMFS summer acoustic survey (bottom).

Year	1	2	3	4	5	6	7	8	9	10
1990	0.052	0.169	0.303	0.566	0.775	0.901	1.106	1.128	1.272	1.472
1993	0.043	0.168	0.466	0.682	0.786	0.942	1.087	1.302	1.354	1.391
1996	0.029	0.094	0.304	0.669	0.934	0.998	1.089	1.190	1.265	1.441
1999	0.027	0.143	0.365	0.592	0.698	0.787	0.874	1.073	1.217	1.292
2001	0.031	0.106	0.405	0.701	0.928	1.075	1.205	1.423	1.284	1.491
2003	0.054	0.131	0.455	0.580	0.735	0.930	1.141	1.144	1.381	1.522
2005	0.026	0.179	0.384	0.635	0.832	0.905	0.983	1.214	1.259	1.485
2007	0.022	0.136	0.308	0.588	0.996	1.231	1.410	1.472	1.780	1.761
2009	0.024	0.216	0.460	0.845	1.051	1.416	1.646	1.841	1.951	2.006
2011	0.031	0.243	0.430	0.712	1.021	1.342	1.515	1.656	1.967	2.034
2013	0.020	0.215	0.452	0.913	1.130	1.324	1.482	1.569	1.638	2.044
2015	0.034	0.177	0.362	0.604	0.861	1.063	1.273	1.374	1.426	1.521
2017	0.033	0.183	0.501	0.567	0.640	0.768	0.950	1.116	1.107	1.298
2019	0.042	0.140	0.377	0.628	0.700	0.736	0.825	0.867	1.110	1.251
2021	0.036	0.215	0.455	0.585	0.796	1.009	0.955	1.092	1.052	1.058
2023	0.032	0.248	0.422	0.644	0.741	0.876	1.014	1.110	1.333	1.206

Year	1	2	3	4	5	6	7	8	9	10
2013	0.028	0.235	0.498	0.812	1.128	1.257	1.364	1.443	1.465	1.783
2015	0.046	0.237	0.395	0.584	0.765	1.004	1.199	1.282	1.319	1.421
2017	0.035	0.374	0.393	0.614	0.681	0.794	1.028	1.251	1.829	1.154
2019	0.038	0.140	0.330	0.557	0.647	0.741	0.779	0.809	0.984	1.188
2021	0.026	0.217	0.408	0.556	0.713	0.971	0.926	0.990	0.978	0.980
2023	0.068	0.282	0.457	0.612	0.743	0.815	0.875	1.107	1.100	1.085

Table 1.20. Estimated fixed effects and standard errors (SE) from the final model.

Parameter	Type	Name	Estimate	SE
Mean log age 1 recruitment (billions)	Recruitment	mean_log_recruit	1.323	0.186
Descending slope of fishery selectivity	Selectivity	log_slp2_fsh_mean	0.685	0.279
Descending inflection point of fishery selectivity	Selectivity	inf2_fsh_mean	9.635	0.128
Descending slope of Shelikof selectivity	Selectivity	log_slp2_srv1	0.922	0.605
Descending inflection point of Shelikof selectivity	Selectivity	inf2_srv1	10.180	0.248
Ascending slope of NMFS BT selectivity	Selectivity	log_slp1_srv2	-0.389	0.099
Ascending inflection point of NMFS BT selectivity	Selectivity	inf1_srv2	3.871	0.297
Ascending slope of ADF&G selectivity	Selectivity	log_slp1_srv3	0.544	0.100
Ascending inflection point of ADF&G selectivity	Selectivity	inf1_srv3	4.166	0.208
Ascending slope of summer AT selectivity	Selectivity	log_slp2_srv6	0.069	0.265
Ascending inflection point of summer AT selectivity	Selectivity	inf2_srv6	8.276	0.560
Catchability for Shelikof (mean)	Catchability	log_q1_mean	-0.688	0.079
Catchability for NMFS BT	Catchability	log_q2_mean	-0.258	0.092
Catchability for summer AT	Catchability	log_q6	-0.333	0.127
AR(1) correlation for maturity covariate	Catchability	transf_rho	0.457	0.171
AR(1) standard deviation for maturity covariate	Catchability	log_Ecov_sd	-0.021	0.131
Effect of maturity on log-catchability for Shelikof	Catchability	Ecov_beta	0.325	0.033
Dirichlet-multinomial overdispersion for fishery	Overdispersion	log_DM_pars	-0.017	0.167
Dirichlet-multinomial overdispersion for Shelikof	Overdispersion	log_DM_pars	-0.141	0.187
Dirichlet-multinomial overdispersion for NMFS BT	Overdispersion	log_DM_pars	-0.045	0.226
Dirichlet-multinomial overdispersion for ADF&G	Overdispersion	log_DM_pars	0.560	0.352
Dirichlet-multinomial overdispersion for summer AT	Overdispersion	log_DM_pars	1.171	1.085

Table 1.21. Estimated selectivity at age for GOA pollock fisheries and surveys. The fisheries and surveys were modeled using double logistic selectivity functions. Acoustic survey catchablity at age 1 and age 2 are estimated separately.

Age	Foreign (1970-81)	Foreign and JV (1982-1988)	Domestic (1989-2000)	Domestic (2001-2014)	Recent domestic (2018-2023)	Shelikof acoustic survey	Summer acoustic survey	Bottom trawl survey	ADF&G bottom trawl
1	0.001	0.004	0.002	0.010	0.004	0.301	1.000	0.127	0.004
2	0.012	0.028	0.013	0.067	0.041	0.340	0.999	0.223	0.023
3	0.126	0.170	0.074	0.329	0.292	1.000	0.997	0.362	0.118
4	0.625	0.588	0.316	0.766	0.803	1.000	0.990	0.530	0.429
5	0.954	0.910	0.733	0.962	0.980	1.000	0.971	0.693	0.808
6	1.000	0.991	0.953	0.999	1.002	1.000	0.920	0.822	0.959
7	1.000	1.000	1.000	1.000	1.000	1.000	0.797	0.907	0.993
8	0.968	0.970	0.977	0.969	0.968	0.996	0.574	0.957	0.999
9	0.784	0.785	0.792	0.784	0.784	0.951	0.315	0.985	1.000
10	0.328	0.329	0.332	0.329	0.328	0.611	0.136	1.000	1.000

Table 1.22. Total estimated abundance at age (millions) of GOA pollock from the age-structured assessment model

Year	1	2	3	4	5	6	7	8	9	10
1970	1,543	384	238	164	117	87	64	48	36	108
1971	3,362	384	193	147	111	81	62	46	35	107
1972	3,673	837	193	119	99	77	58	45	33	105
1973	11,130	915	419	117	75	61	49	37	29	97
1974	2,352	2,772	458	253	71	44	37	30	23	86
1975	2,399	586	1,385	273	146	39	24	21	17	73
1976	9,412	597	293	837	167	87	24	15	13	62
1977	12,709	2,344	299	175	489	93	50	14	9	51
1978	15,150	3,165	1,171	178	99	257	50	27	7	39
1979	26,634	3,772	1,582	697	102	53	143	28	15	31
1980	13,789	6,632	1,886	948	414	58	32	84	17	31
1981	7,803	3,434	3,320	1,146	594	250	36	20	53	33
1982	7,867	1,943	1,719	2,023	732	371	161	23	13	59
1983	6,064	1,959	972	1,042	1,295	467	244	106	16	52
1984	5,542	1,509	978	583	651	804	300	157	69	47
1985	17,428	1,379	752	580	352	385	490	183	97	78
1986	4,562	4,337	688	450	351	201	223	283	107	114
1987	2,350	1,136	2,170	420	297	232	137	152	195	159
1988	5,292	585	569	1,331	281	200	162	95	107	257
1989	12,281	1,318	293	349	894	191	140	113	68	266
1990	7,835	3,058	660	180	234	599	132	97	79	243
1991	2,910	1,951	1,532	406	121	156	410	90	67	233
1992	2,155	725	978	943	273	80	104	270	60	213
1993	1,533	537	363	601	631	179	53	68	180	194
1994	1,765	382	269	222	398	409	118	35	45	263
1995	6,986	439	191	165	147	258	270	77	23	220
1996	3,199	1,740	220	117	110	98	176	183	53	176
1997	1,518	797	872	136	79	74	68	121	127	166
1998	1,693	378	399	533	89	50	47	42	76	201
1999	2,305	421	189	241	333	50	27	25	23	180
2000	7,474	574	211	115	153	195	29	15	14	137
2001	7,549	1,861	287	129	74	95	120	18	10	106
2002	1,134	1,879	929	173	81	46	59	75	11	81
2003	1,131	282	936	558	111	52	30	39	50	66

Year	1	2	3	4	5	6	7	8	9	10
2004	970	281	140	562	361	72	35	20	27	83
2005	2,367	241	139	83	358	234	49	24	14	79
2006	6,551	588	120	82	52	226	152	32	16	66
2007	6,055	1,629	292	70	51	33	148	100	21	58
2008	6,880	1,506	809	173	45	34	22	101	69	57
2009	3,536	1,712	751	485	112	30	23	15	70	91
2010	1,661	880	855	454	321	76	21	16	11	118
2011	5,315	413	439	513	295	213	53	15	11	94
2012	758	1,323	207	264	331	194	145	36	10	77
2013	47,373	189	662	125	169	213	130	97	24	63
2014	1,799	11,798	95	403	81	109	143	87	66	62
2015	332	448	5,908	57	249	48	67	87	54	87
2016	357	83	224	3,565	35	144	28	40	53	95
2017	1,772	89	41	136	2,242	22	94	19	26	104
2018	8,633	441	44	25	85	1,393	14	60	12	92
2019	7,496	2,149	220	27	15	52	885	9	39	74
2020	1,999	1,866	1,072	130	16	9	33	559	6	78
2021	8,601	497	928	627	79	10	6	21	360	60
2022	763	2,141	248	549	385	49	6	4	14	286
2023	1,840	190	1,066	146	324	225	30	4	2	209
2024	3,760	458	94	620	85	188	135	18	2	147
Average	6,170	1,526	763	463	288	181	115	73	49	117

Table 1.23. Estimates of population biomass, recruitment, and harvest of GOA pollock from the age-structured assessment model. The harvest rate is the catch in biomass divided by the total biomass of age 3+ fish at the start of the year.

	2024 assessment						2023 assessment			
Year	3+ total biomass (kt)	SSB (kt)	% of SB100	Age 1 recruits (millions)	Catch (t)	Harvest rate	3+ total biomass (kt)	SSB (kt)	Age 1 recruits (millions)	Harvest rate
1977	830	161	30%	12,709	118,092	14%	743	138	11,931	16%
1978	1,075	149	28%	15,150	95,408	9%	968	126	14,244	10%
1979	1,493	159	30%	26,634	106,161	7%	1,362	135	25,554	8%
1980	1,980	217	41%	13,789	115,158	6%	1,821	189	12,958	6%
1981	3,039	235	44%	7,803	147,818	5%	2,847	209	7,264	5%
1982	3,175	375	70%	7,867	169,045	5%	2,968	340	7,307	6%
1983	2,903	514	96%	6,064	215,625	7%	2,703	471	5,056	8%
1984	2,602	569	106%	5,542	307,541	12%	2,405	520	6,125	13%
1985	2,163	524	98%	17,428	286,900	13%	1,947	472	15,187	15%
1986	1,791	483	90%	4,562	86,910	5%	1,648	428	4,265	5%
1987	2,237	455	85%	2,350	68,070	3%	2,007	402	1,885	3%
1988	2,110	459	86%	5,292	63,391	3%	1,899	407	4,792	3%
1989	1,888	478	89%	12,281	75,585	4%	1,682	425	11,548	4%
1990	1,735	495	92%	7,835	88,269	5%	1,547	436	8,685	6%
1991	2,061	491	92%	2,910	100,488	5%	1,859	430	3,461	5%
1992	2,076	449	84%	2,155	90,858	4%	1,949	393	2,475	5%
1993	1,903	476	89%	1,533	108,909	6%	1,847	426	1,827	6%
1994	1,595	542	101%	1,765	107,335	7%	1,571	502	1,833	7%
1995	1,293	439	82%	6,986	72,618	6%	1,292	420	6,803	6%
1996	1,077	395	74%	3,199	51,263	5%	1,093	389	3,311	5%
1997	1,095	345	65%	1,518	90,130	8%	1,109	346	1,563	8%
1998	1,048	267	50%	1,693	125,460	12%	1,070	270	1,474	12%
1999	794	249	47%	2,305	95,638	12%	804	253	1,784	12%
2000	719	237	44%	7,474	73,080	10%	717	241	6,438	10%
2001	717	224	42%	7,549	72,077	10%	686	226	7,229	11%
2002	925	192	36%	1,134	51,934	6%	861	191	1,076	6%
2003	1,126	185	35%	1,131	50,684	5%	1,085	177	825	5%
2004	971	212	40%	970	63,844	7%	911	194	792	7%
2005	827	258	48%	2,367	80,978	10%	765	235	1,896	11%
2006	736	283	53%	6,551	71,976	10%	655	253	6,429	11%
2007	720	259	48%	6,055	52,714	7%	614	225	6,387	9%
2008	963	265	50%	6,880	52,584	5%	865	226	7,668	6%
2009	1,302	265	50%	3,536	44,247	3%	1,255	227	3,586	4%
2010	1,494	355	66%	1,661	76,748	5%	1,495	317	1,491	5%
2011	1,458	399	75%	5,315	81,503	6%	1,445	377	5,557	6%
2012	1,370	414	77%	758	103,954	8%	1,364	407	1,164	8%
2013	1,400	445	83%	47,373	96,363	7%	1,399	445	48,590	7%
2014	1,091	344	64%	1,799	142,640	13%	1,122	349	3,709	13%
2015	2,851	323	60%	332	167,549	6%	2,964	331	94	6%
2016	2,625	345	65%	357	177,129	7%	3,048	358	13	6%
2017	1,823	461	86%	1,772	186,155	10%	2,279	485	2,504	8%
2018	1,342	443	83%	8,633	158,070	12%	1,586	476	9,644	10%
2019	1,022	355	66%	7,496	120,243	12%	1,200	388	8,060	10%
2020	1,120	262	49%	1,999	107,471	10%	1,351	292	311	8%
2021	1,332	283	53%	8,601	101,160	8%	1,500	320	10,430	7%
2022	1,117	286	53%	763	132,698	12%	1,154	323	60	11%
2023	1,270	308	58%	1,840	135,103	11%	1,430	342	1	9%
2024	1,005	302	56%	3,760	131,000	13%				

Table 1.24. Uncertainty of estimates of recruitment and spawning biomass of GOA pollock from the age-structured assessment model.

	Age-1 Recruits (millions)				Spawning biomass (kt)			
Year	Estimate	CV	Lower 95% CI	Upper 95% CI	Estimate	CV	Lower 95% CI	Upper 95% CI
1970	1,543	0.22	1,006	2,367	158	0.22	103	243
1971	3,362	0.36	1,692	6,681	152	0.23	98	235
1972	3,673	0.31	2,014	6,699	141	0.23	90	222
1973	11,130	0.14	8,452	14,656	123	0.25	76	199
1974	2,352	0.26	1,434	3,857	112	0.23	71	176
1975	2,399	0.24	1,511	3,808	116	0.19	80	169
1976	9,412	0.16	6,869	12,895	146	0.16	108	198
1977	12,709	0.16	9,346	17,283	161	0.16	118	220
1978	15,150	0.16	11,171	20,546	149	0.18	104	212
1979	26,634	0.13	20,600	34,435	159	0.18	111	226
1980	13,789	0.16	10,070	18,880	217	0.17	156	301
1981	7,803	0.20	5,334	11,416	235	0.15	174	317
1982	7,867	0.20	5,370	11,525	375	0.14	286	491
1983	6,064	0.26	3,644	10,090	514	0.13	398	665
1984	5,542	0.27	3,283	9,354	569	0.14	436	743
1985	17,428	0.12	13,718	22,141	524	0.15	392	699
1986	4,562	0.23	2,949	7,056	483	0.16	356	655
1987	2,350	0.26	1,418	3,894	455	0.15	340	608
1988	5,292	0.16	3,854	7,267	459	0.14	352	600
1989	12,281	0.10	10,086	14,953	478	0.12	382	599
1990	7,835	0.12	6,232	9,850	495	0.11	400	612
1991	2,910	0.18	2,057	4,115	491	0.11	398	605
1992	2,155	0.17	1,547	3,000	449	0.10	368	548
1993	1,533	0.19	1,052	2,235	476	0.09	397	571
1994	1,765	0.19	1,226	2,540	542	0.09	456	644
1995	6,986	0.09	5,823	8,380	439	0.09	368	522
1996	3,199	0.13	2,486	4,116	395	0.09	332	471
1997	1,518	0.18	1,065	2,164	345	0.09	289	413
1998	1,693	0.16	1,251	2,291	267	0.10	221	323
1999	2,305	0.14	1,757	3,025	249	0.10	205	304
2000	7,474	0.10	6,203	9,007	237	0.10	194	291
2001	7,549	0.09	6,322	9,015	224	0.11	180	278
2002	1,134	0.20	765	1,680	192	0.11	154	241
2003	1,131	0.17	817	1,566	185	0.11	149	230
2004	970	0.20	661	1,424	212	0.10	176	257
2005	2,367	0.15	1,779	3,148	258	0.10	213	312
2006	6,551	0.11	5,332	8,047	283	0.10	232	345
2007	6,055	0.11	4,881	7,513	259	0.11	209	319
2008	6,880	0.10	5,612	8,435	265	0.11	214	329
2009	3,536	0.13	2,742	4,559	265	0.11	216	326
2010	1,661	0.19	1,148	2,402	355	0.10	294	428
2011	5,315	0.11	4,311	6,552	399	0.09	333	478
2012	758	0.37	373	1,544	414	0.09	346	495
2013	47,373	0.06	41,874	53,593	445	0.10	369	536
2014	1,799	0.27	1,070	3,026	344	0.10	283	417
2015	332	0.36	168	655	323	0.10	264	394
2016	357	0.34	186	686	345	0.08	293	407
2017	1,772	0.15	1,331	2,360	461	0.08	393	541
2018	8,633	0.10	7,152	10,420	443	0.09	373	526
2019	7,496	0.10	6,113	9,193	355	0.10	294	429
2020	1,999	0.23	1,274	3,136	262	0.11	212	323
2021	8,601	0.14	6,574	11,253	283	0.11	229	350
2022	763	0.40	360	1,617	286	0.10	233	351
2023	1,840	0.23	1,177	2,876	308	0.11	249	380
2024	3,760	1.31	528	26,776	302	0.12	241	379

Table 1.25. Methods used to assess GOA pollock. The basis for catch recommendation in 1977-1989 is the presumptive method by which the ABC was determined (based on the assessment and SSC minutes). The basis for catch recommendation given after 1989 is the method used by the Plan Team to derive the ABC recommendation given in the SAFE summary chapter.

Year	Assessment Method	Catch recommendation basis	B40% (t)
1977-81	Survey biomass, CPUE trends, M=0.4	MSY = 0.4 * M * Bzero	
1982	CAGEAN	MSY = 0.4 * M * Bzero	
1983	CAGEAN	Mean annual surplus production	
1984	Projection of survey numbers at age	Stabilize biomass trend	
1985	CAGEAN, projection of survey numbers at age, CPUE trends	Stabilize biomass trend	
1986	CAGEAN, projection of survey numbers at age	Stabilize biomass trend	
1987	CAGEAN, projection of survey numbers at age	Stabilize biomass trend	
1988	CAGEAN, projection of survey numbers at age	10% of exploitable biomass	
1989	Stock synthesis	10% of exploitable biomass	
1990	Stock synthesis, reduce M to 0.3	10% of exploitable biomass	
1991	Stock synthesis, assume trawl survey catchability = 1	FMSY from an assumed SR curve	
1992	Stock synthesis	Max[-Pr(SB<Threshold)+Yld]	
1993	Stock synthesis	Pr(SB>B20)=0.95	
1994	Stock synthesis	Pr(SB>B20)=0.95	
1995	Stock synthesis	Max[-Pr(SB<Threshold)+Yld]	
1996	Stock synthesis	Amend. 44 Tier 3	289,689
1997	Stock synthesis	Amend. 44 Tier 3	267,600
1998	Stock synthesis	Amend. 44 Tier 3	240,000
1999	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	247,000
2000	AD Model Builder	Amend. 56 Tier 3	250,000
2001	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	245,000
2002	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	240,000
2003	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	248,000
2004	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC), and stairstep approach for projected ABC increase)	229,000
2005	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	224,000
2006	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	220,000
2007	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	221,000
2008	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	237,000
2009	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	248,000
2010	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	276,000
2011	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	271,000
2012	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	297,000
2013	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	290,000
2014	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	312,000
2015	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	300,000
2016	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	267,000
2017	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	238,000
2018	AD Model Builder	Amend. 56 Tier 3 (with ABC < maxABC)	221,000
2019	AD Model Builder	Amend. 56 Tier 3 (with 12,055 t reduction from maxABC)	194,000
2020	AD Model Builder	Amend. 56 Tier 3	177,000
2021	AD Model Builder	Amend. 56 Tier 3	172,000
2022	AD Model Builder	Amend. 56 Tier 3	188,000
2023	Template Model Builder	Amend. 56 Tier 3	202,000
2024	Template Model Builder	Amend. 56 Tier 3	214,000

Table 1.26. GOA pollock life history and fishery characteristics used to estimate spawning biomass per recruit (FSPR) harvest rates. Spawning weight at age (WAA, kg) is based on an average from the Shelikof Strait acoustic survey conducted in March. Population weight at age is based on an average for the last three bottom trawl survey conducted in June to August. Proportion mature females is the average from winter acoustic survey specimen data.

Age	Natural mortality	Fishery selectivity (Avg. 2020-2023)	Spawning WAA (Avg. 2020-2024)	Population WAA (Avg. 2019, 2021, 2023)	Fishery WAA (Est. 2024 from RE model)	Proportion mature females (Avg. 1983-2024)
1	1.39	0.005	0.011	0.037	0.173	0.000
2	0.69	0.043	0.126	0.201	0.396	0.015
3	0.48	0.303	0.331	0.418	0.740	0.065
4	0.37	0.809	0.527	0.619	0.908	0.294
5	0.34	0.979	0.663	0.746	1.093	0.629
6	0.30	1.000	0.834	0.874	1.114	0.868
7	0.30	0.998	0.950	0.931	1.174	0.944
8	0.29	0.966	1.142	1.023	1.278	0.980
9	0.28	0.782	1.001	1.165	1.360	0.990
10+	0.29	0.328	1.133	1.172	1.397	0.994

Table 1.27. Projections of GOA pollock spawning biomass, full recruitment fishing mortality, and catch for 2024 - 2037 under different harvest policies (columns). For these projections, fishery weight at age was assumed to be equal to the estimated weight at age in 2024 for the RE model. All projections begin with initial age composition in 2024 using the base run model with a projected 2024 catch of 131,000 t. The values for B100%, B40%, and B35% are 535,000 t, 214,000 t, 187,000 t, respectively

Spawning biomass (t)							
Year	Max FABC	Author's recommended F	Average F	F75%	F=0	FOFL	Max FABC for two years, then FOFL
2025	243,078	243,078	247,195	251,424	254,681	241,013	243,078
2026	196,028	196,028	214,470	236,060	254,047	187,518	196,028
2027	165,926	165,926	187,781	219,692	248,215	156,495	165,926
2028	172,542	172,542	194,025	235,278	274,214	162,704	171,532
2029	185,112	185,112	206,681	254,517	300,999	174,962	179,486
2030	204,877	204,877	231,875	291,932	351,820	192,384	194,675
2031	217,191	217,191	251,242	322,453	394,934	202,064	203,148
2032	224,917	224,917	265,674	347,564	432,912	207,448	207,958
2033	228,574	228,574	274,691	365,081	461,384	209,374	209,673
2034	230,485	230,485	280,324	377,895	483,842	209,966	210,146
2035	231,951	231,951	284,370	387,218	500,577	210,673	210,781
2036	231,444	231,444	285,706	392,325	511,228	209,756	209,821
2037	230,602	230,602	286,063	395,432	518,583	208,721	208,759
2038	229,873	229,873	285,832	396,590	522,311	208,136	208,158

Fishing mortality							
Year	Max FABC	Author's recommended F	Average F	F75%	F=0	FOFL	Max FABC for two years, then FOFL
2025	0.27	0.27	0.17	0.07	0.00	0.32	0.27
2026	0.25	0.25	0.17	0.07	0.00	0.28	0.25
2027	0.21	0.21	0.17	0.07	0.00	0.23	0.21
2028	0.22	0.22	0.17	0.07	0.00	0.24	0.25
2029	0.22	0.22	0.17	0.07	0.00	0.25	0.26
2030	0.23	0.23	0.17	0.07	0.00	0.26	0.26
2031	0.23	0.23	0.17	0.07	0.00	0.26	0.26
2032	0.23	0.23	0.17	0.07	0.00	0.26	0.26
2033	0.23	0.23	0.17	0.07	0.00	0.26	0.26
2034	0.23	0.23	0.17	0.07	0.00	0.26	0.26
2035	0.23	0.23	0.17	0.07	0.00	0.26	0.26
2036	0.23	0.23	0.17	0.07	0.00	0.26	0.26
2037	0.23	0.23	0.17	0.07	0.00	0.26	0.26
2038	0.23	0.23	0.17	0.07	0.00	0.26	0.26

Catch (t)							
Year	Max FABC	Author's recommended F	Average F	F75%	F=0	FOFL	Max FABC for two years, then FOFL
2025	181,022	181,022	120,297	53,965	0	210,111	181,022
2026	133,075	133,075	102,456	49,047	0	143,776	133,075
2027	119,181	119,181	108,884	53,379	0	127,130	119,181
2028	152,171	152,171	129,667	64,089	0	163,455	176,766
2029	185,854	185,854	148,194	74,100	0	202,777	208,179
2030	206,851	206,851	160,167	80,843	0	226,353	227,975
2031	218,978	218,978	171,358	87,976	0	238,596	238,982
2032	225,567	225,567	178,045	92,612	0	244,877	244,878
2033	225,875	225,875	180,311	94,624	0	244,910	244,870
2034	224,761	224,761	180,549	95,151	0	242,721	242,719
2035	225,315	225,315	180,597	95,471	0	242,748	242,759
2036	221,653	221,653	178,799	94,873	0	238,411	238,423
2037	221,218	221,218	178,077	94,556	0	237,528	237,537
2038	222,145	222,145	178,480	94,759	0	238,852	238,857

Figures

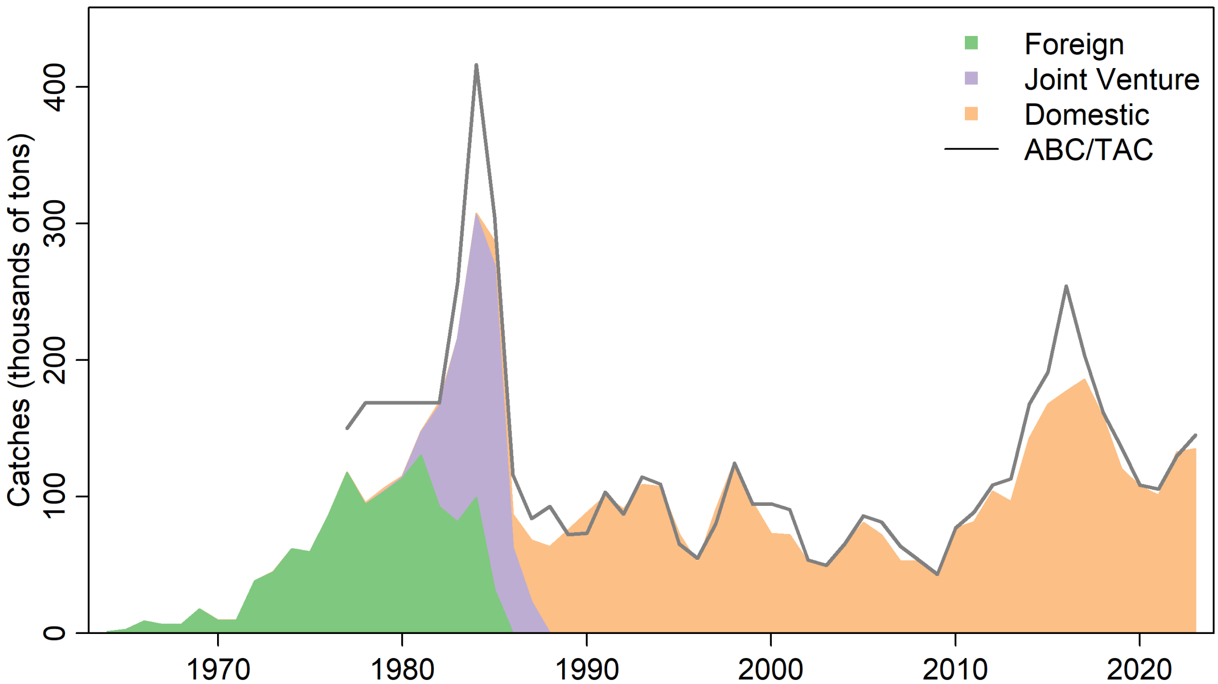

Figure 1.1. Overview of historical catches by source compared to the ABC/TAC

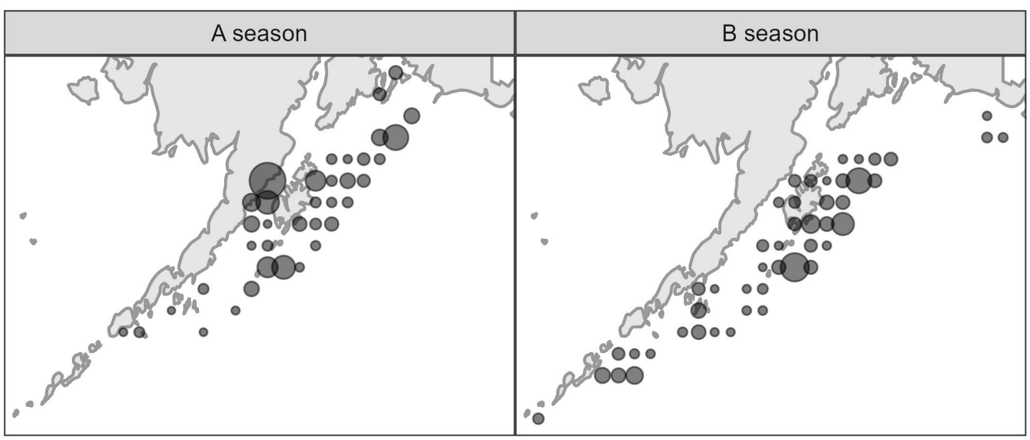

Figure 1.2. Distribution of pollock catch in the 2023 fishery shown for 1/2 degree latitude by 1 degree longitude blocks by season in the Gulf of Alaska as determined by fishery observer-recorded haul retrieval locations. Blocks with less than 1.0 t of pollock catch are not shown. The area of the circle is proportional to the catch.

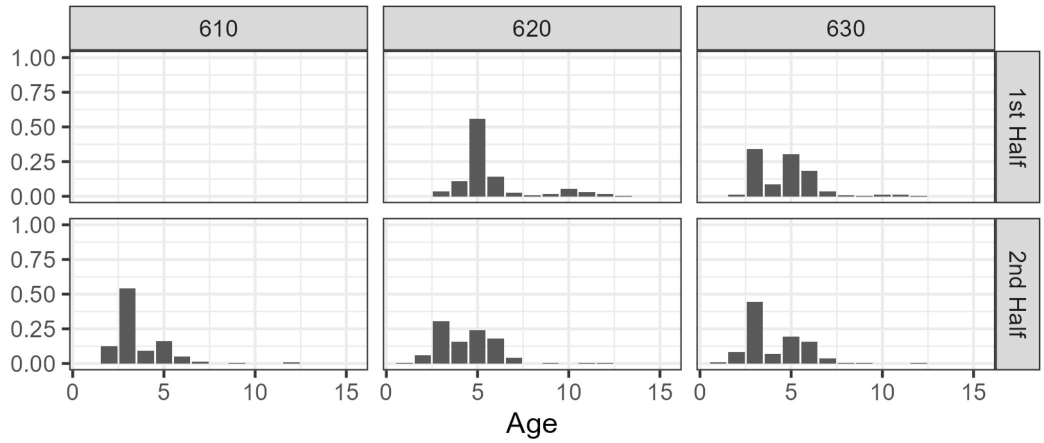

Figure 1.3. Distribution of pollock catch at age in the 2023 separated by season and area.

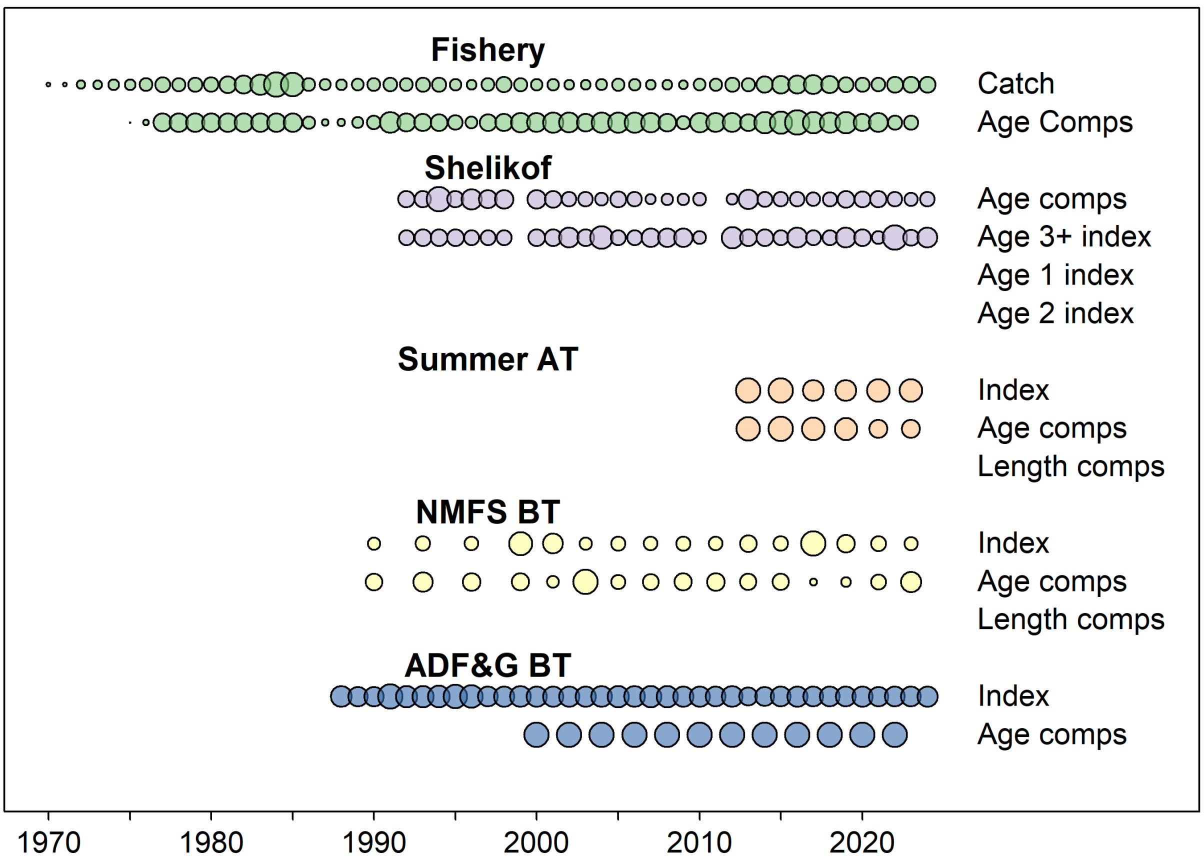

Figure 1.4. Overview of data sources and their relative weights. Circle sizes are relative to catches or data information for surveys within a row. Length compositions are only used in years without age compositions.

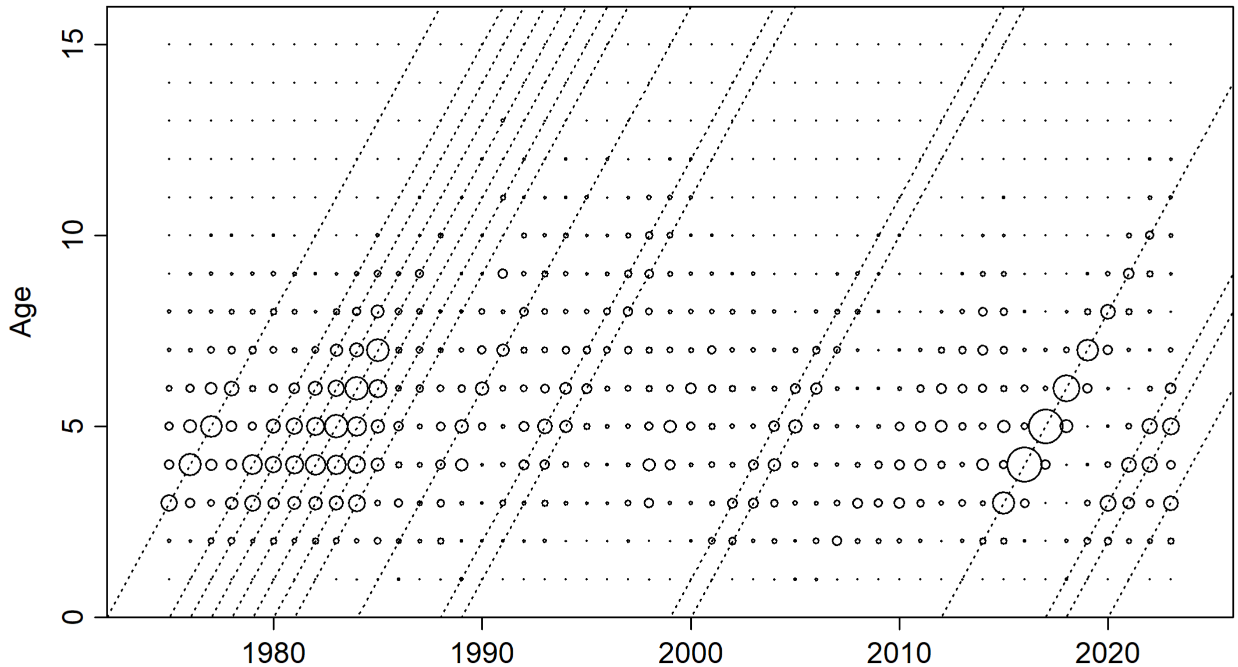

Figure 1.5. GOA pollock fishery age composition (1975- 2023).The area of the circle is proportional to the catch. Diagonal lines show strong year classes.

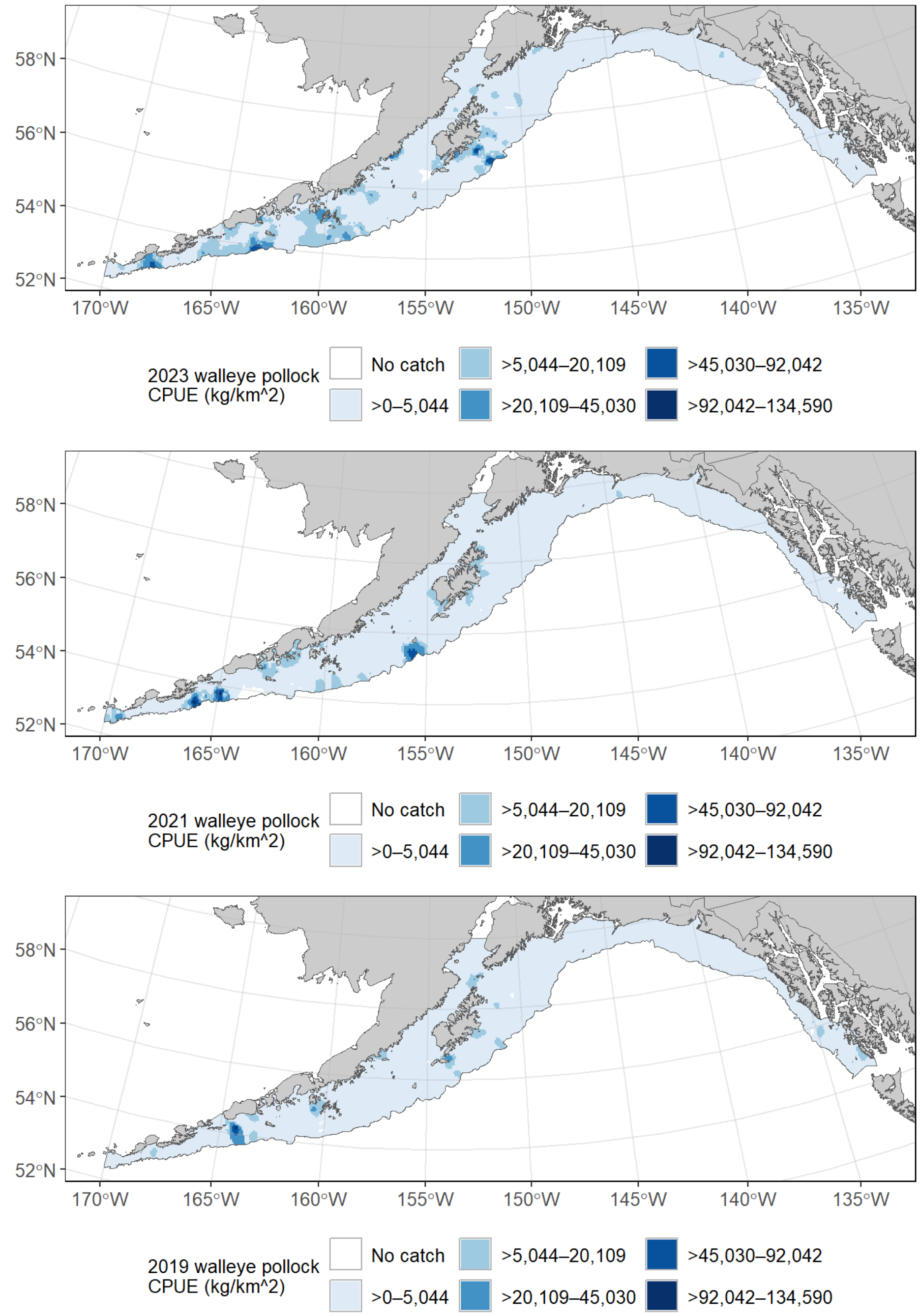

Figure 1.6. Pollock catch per unit effort (CPUE) for the last three NMFS bottom trawl survey in the Gulf of Alaska. Used with permission from the Design-Based Production Data (NOAA Fisheries Alaska Fisheries Science Center, Groundfish Assessment Program, 2024). Accessed through the Alaska Fisheries Information Network https://github.com/MattCallahan-NOAA/gapproductssynopsis/

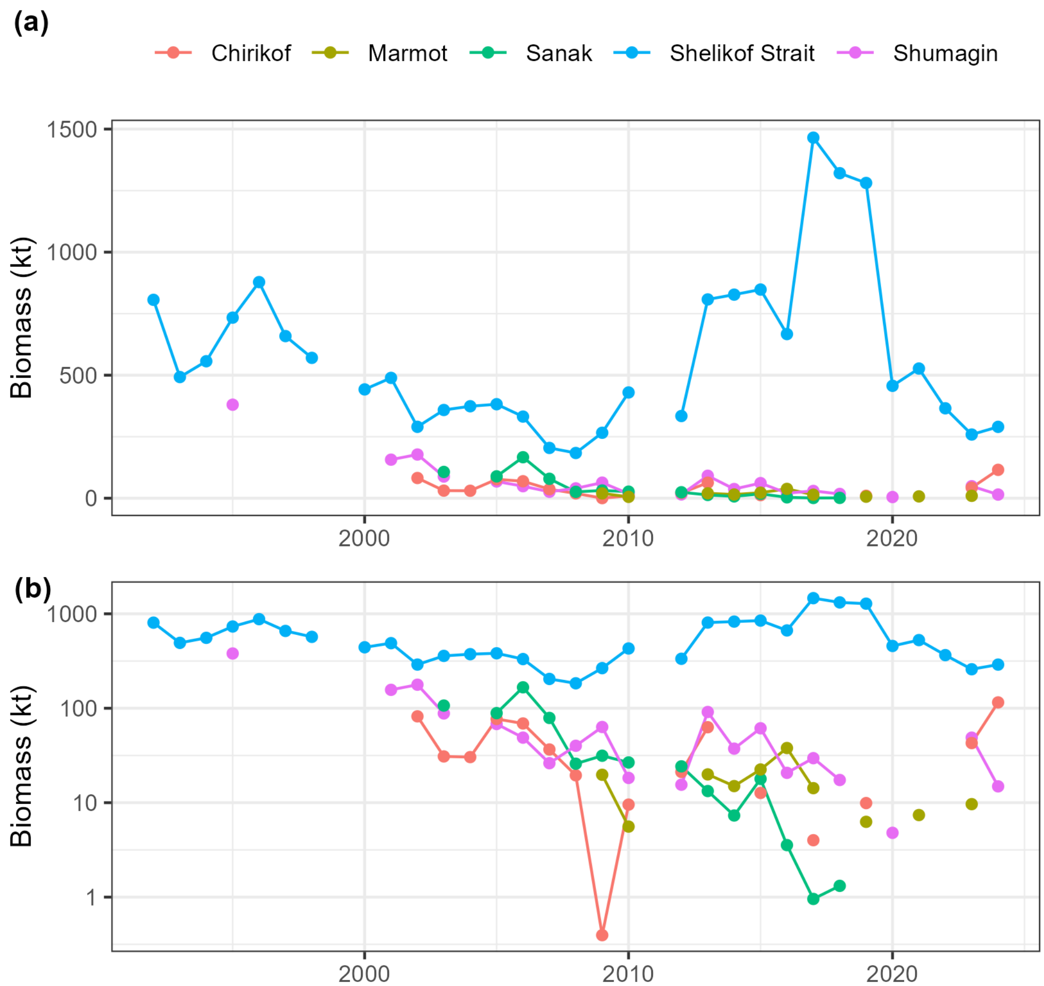

Figure 1.7. Biomass (age 1+) trends from winter acoustic surveys of pre-spawning aggregations of pollock in the GOA. Panel (a) shows estiamtes in natural space to highlight absolute scale and (b) in log space to better see trends across all areas.

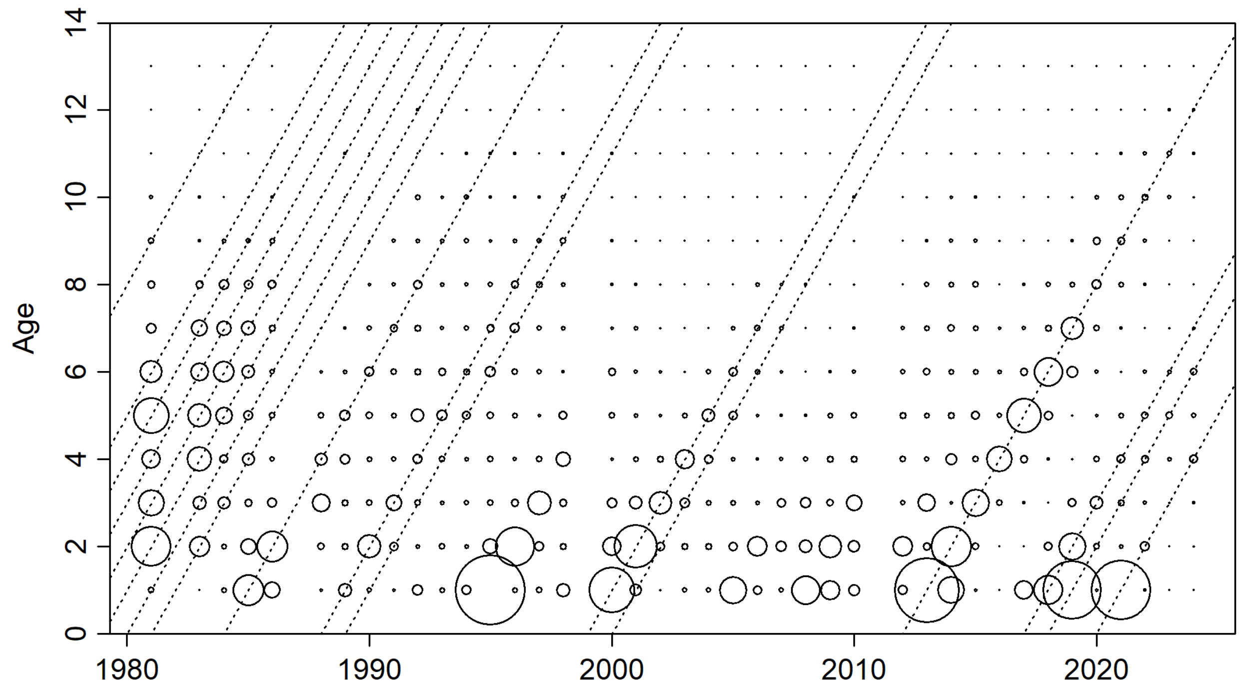

Figure 1.8. Estimated abundance at age in the Shelikof Strait acoustic survey (1981-2024 except 1982, 1987, 1999, and 2011). The area of the circle is proportional to the estimated abundance.

Figure 1.9. Tow locations for the 2024 ADF&G crab/groundfish trawl survey.

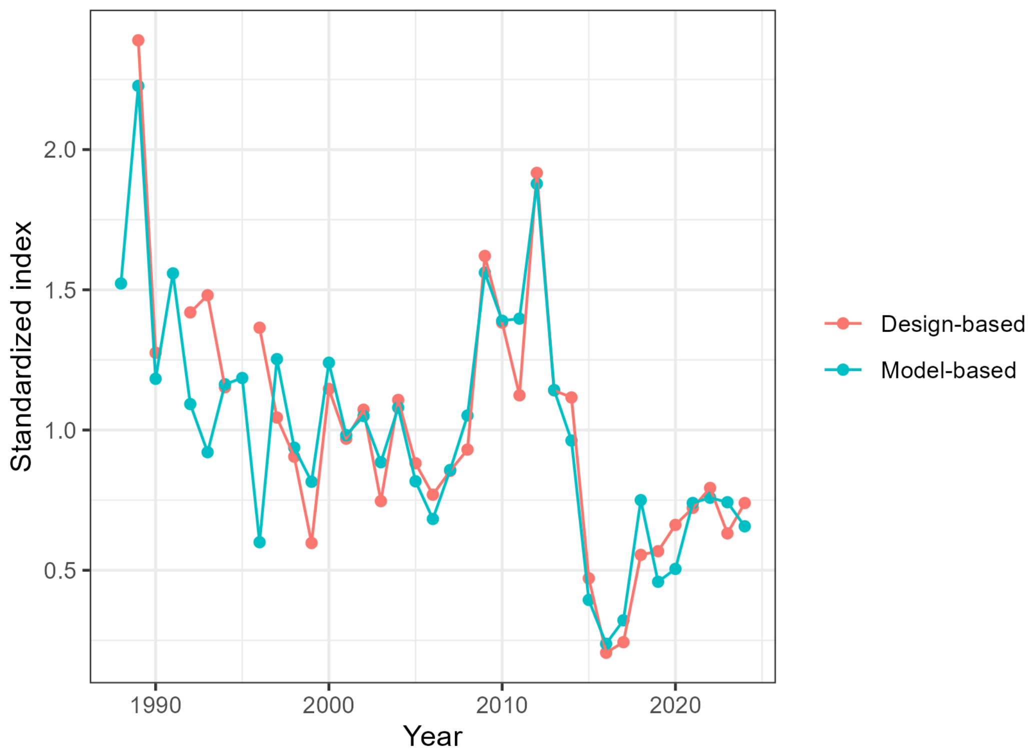

Figure 1.10. Comparison of ADF&G crab/groundfish trawl area-swept indices with year indices for a delta GLM model with a gamma error assumption for the positive observations. Both time series have been scaled by their mean.

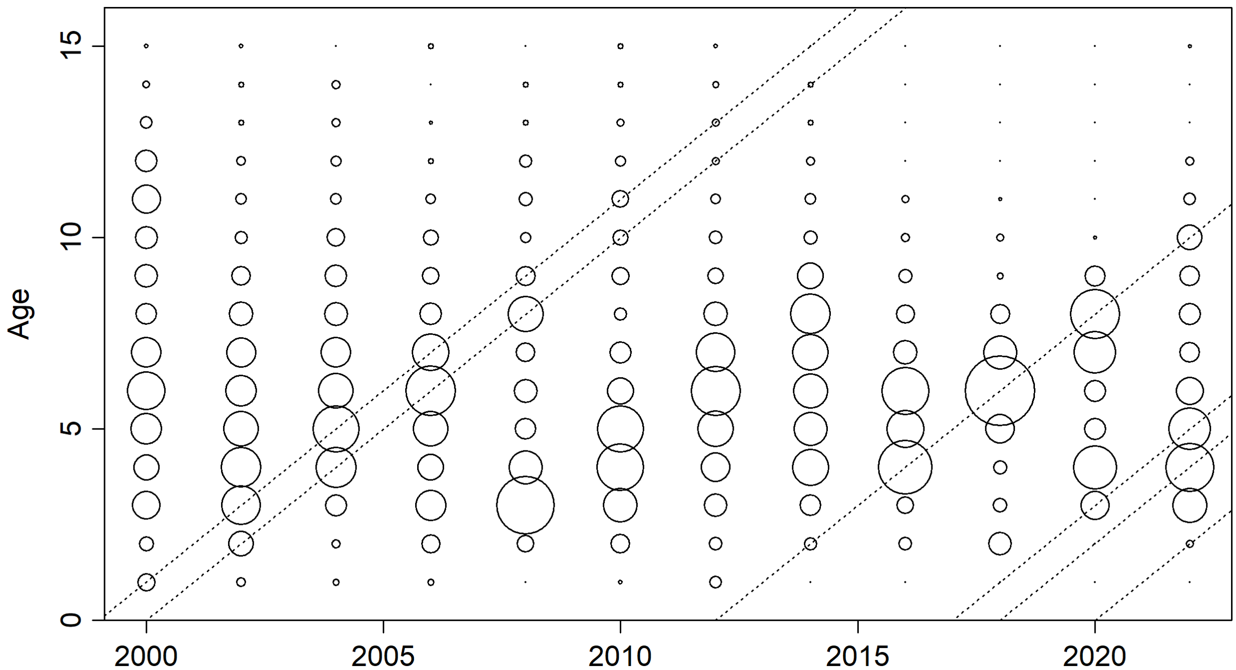

Figure 1.11. Estimated proportions at age in the ADF&G crab/groundfish survey (2000-2022). The area of the circle is proportional to the estimated abundance.

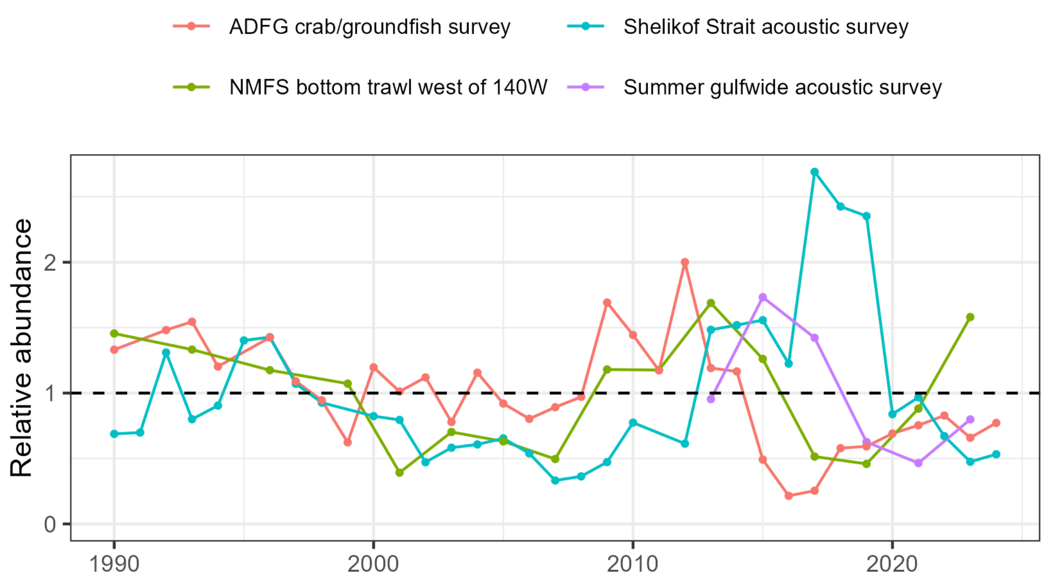

Figure 1.12. Relative trends in pollock biomass since 1990 for the Shelikof Strait acoustic survey, the NMFS bottom trawl survey, and the ADF&G crab/groundfish trawl survey. Each survey biomass estimate is standardized to the average since 1990. Shelikof Strait acoustic surveys prior to 2008 were re-scaled to be comparable to the surveys conducted from 2008 onwards by the R/V Oscar Dyson.

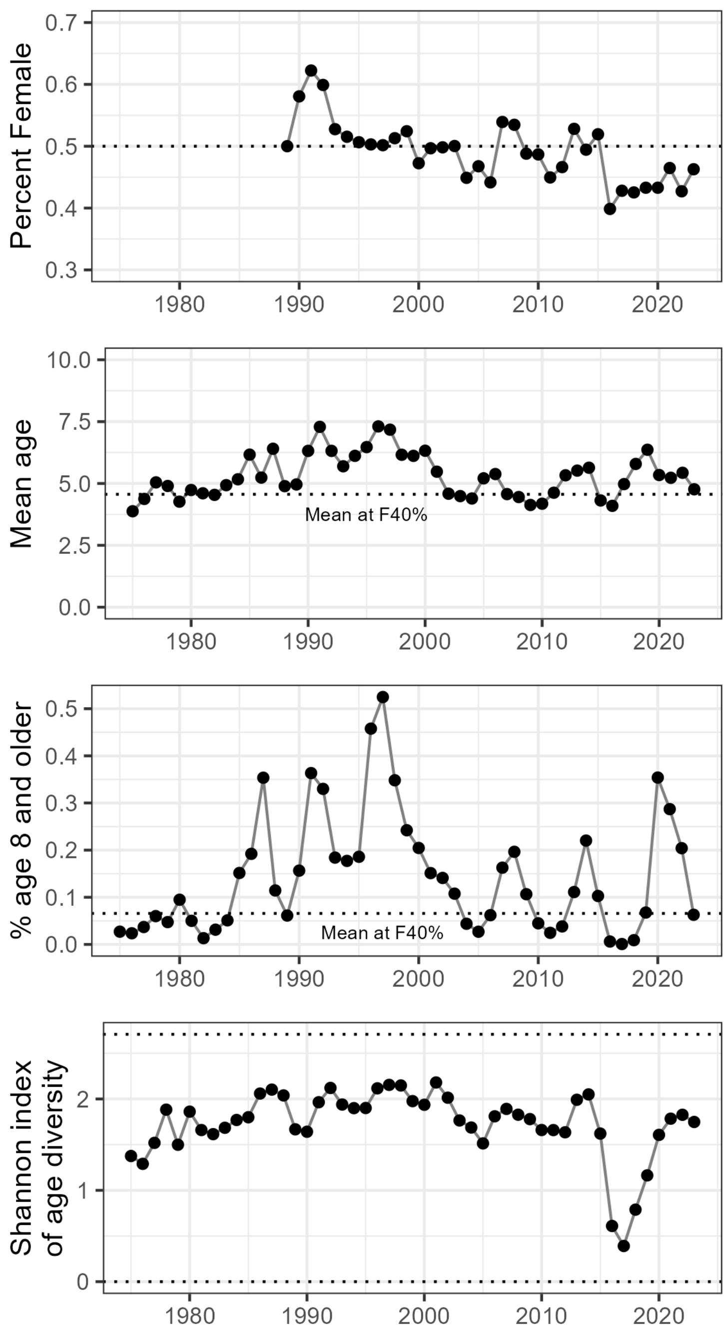

Figure 1.13. GOA pollock fishery catch characteristics.

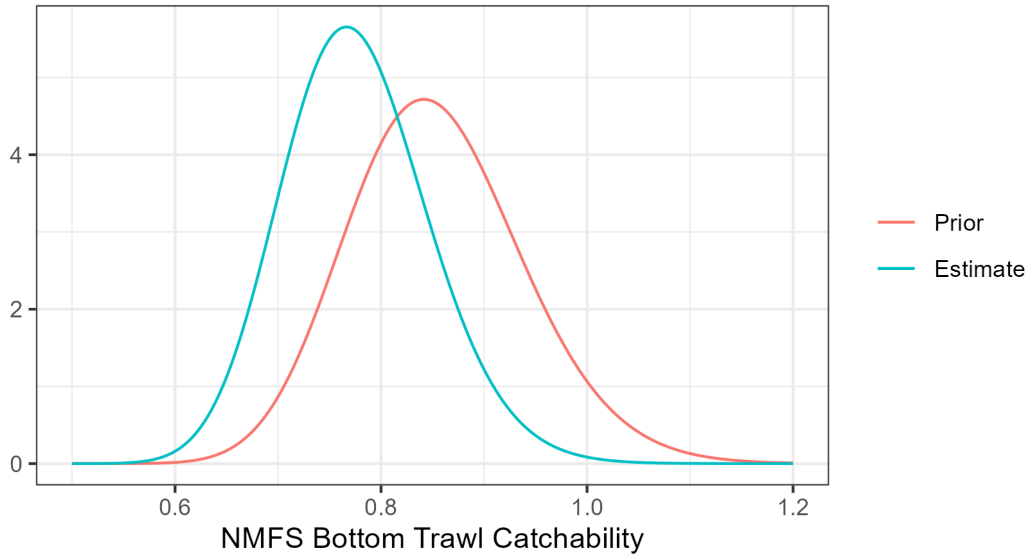

Figure 1.14. Prior on bottom trawl catchability used in the base model, and the estimate and uncertainty from the base model.

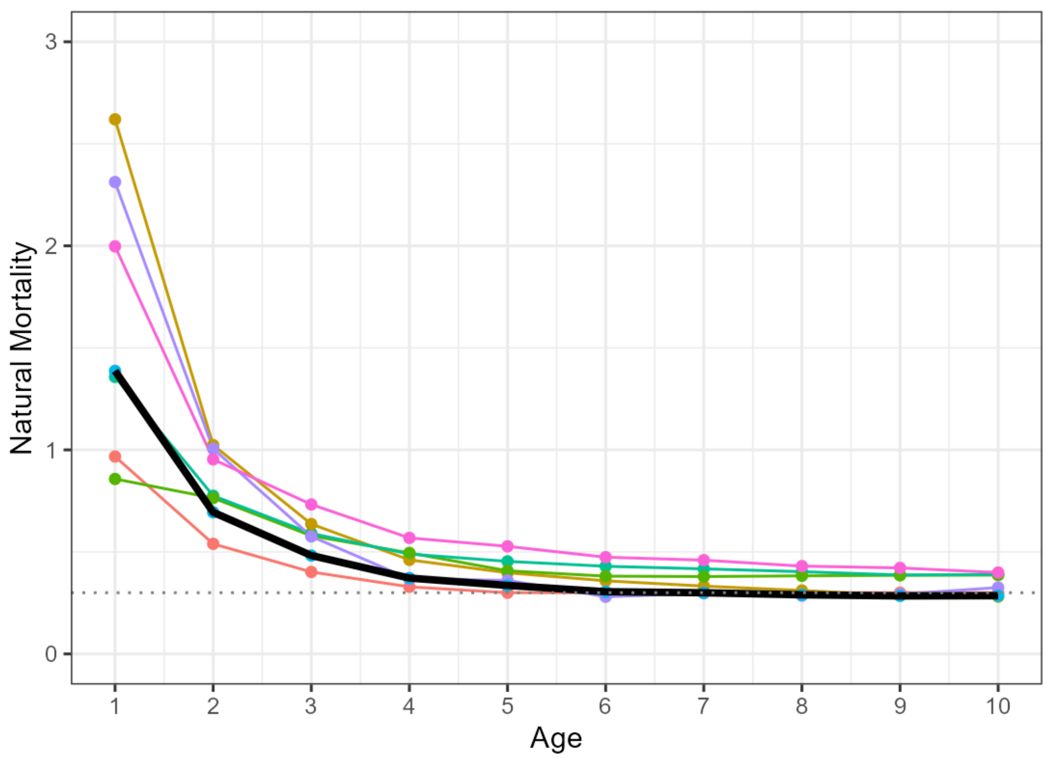

Figure 1.15. Alternative estimates of age-specific natural mortality. The scaled average was used in the stock assessment model. See table 1.15 for more information

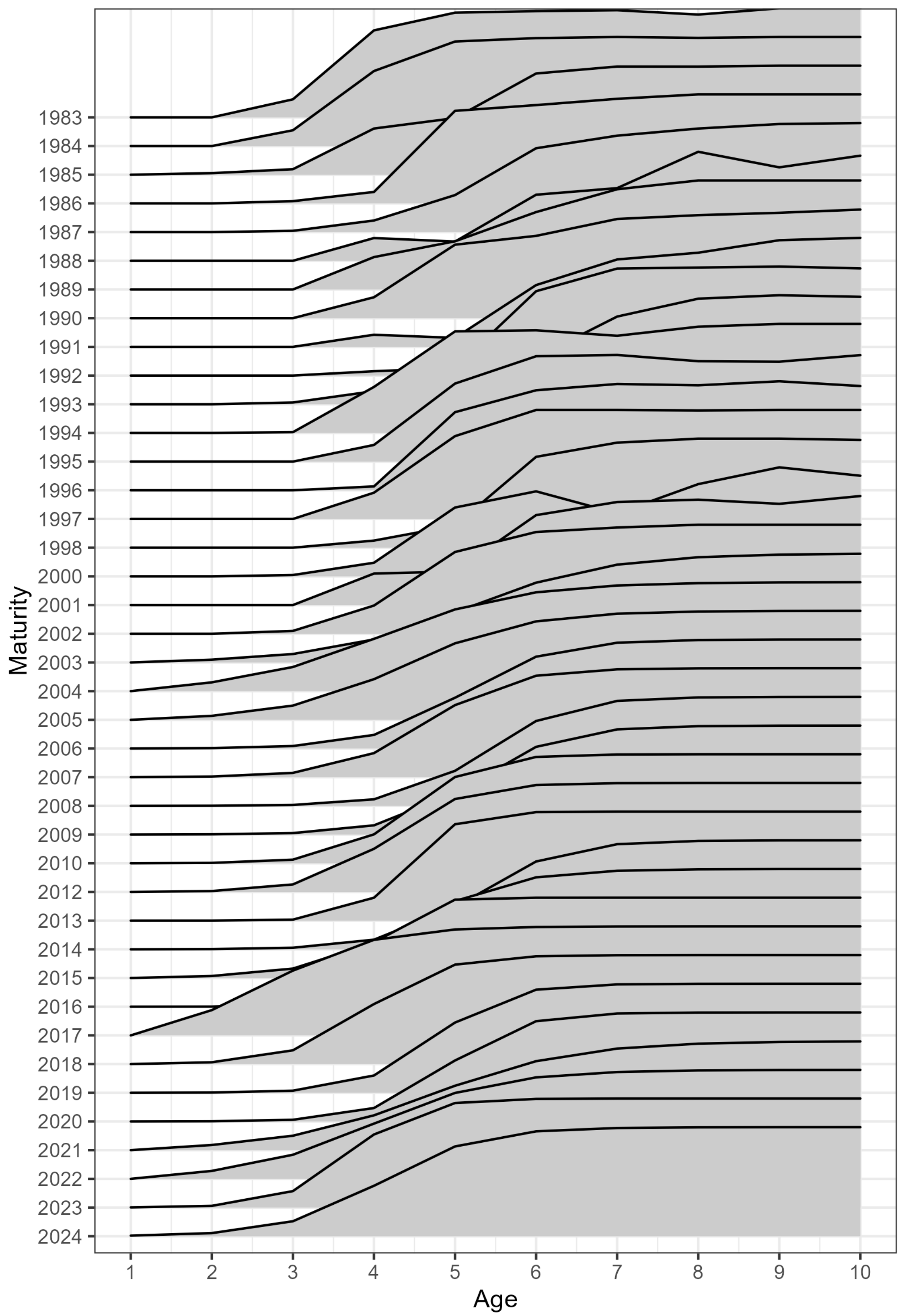

Figure 1.16. Estimates of the proportion mature at age from weighted visual maturity data collected on winter acoustic surveys in the Gulf of Alaska for all years. Maturity for age-1 fish is assumed to be zero.

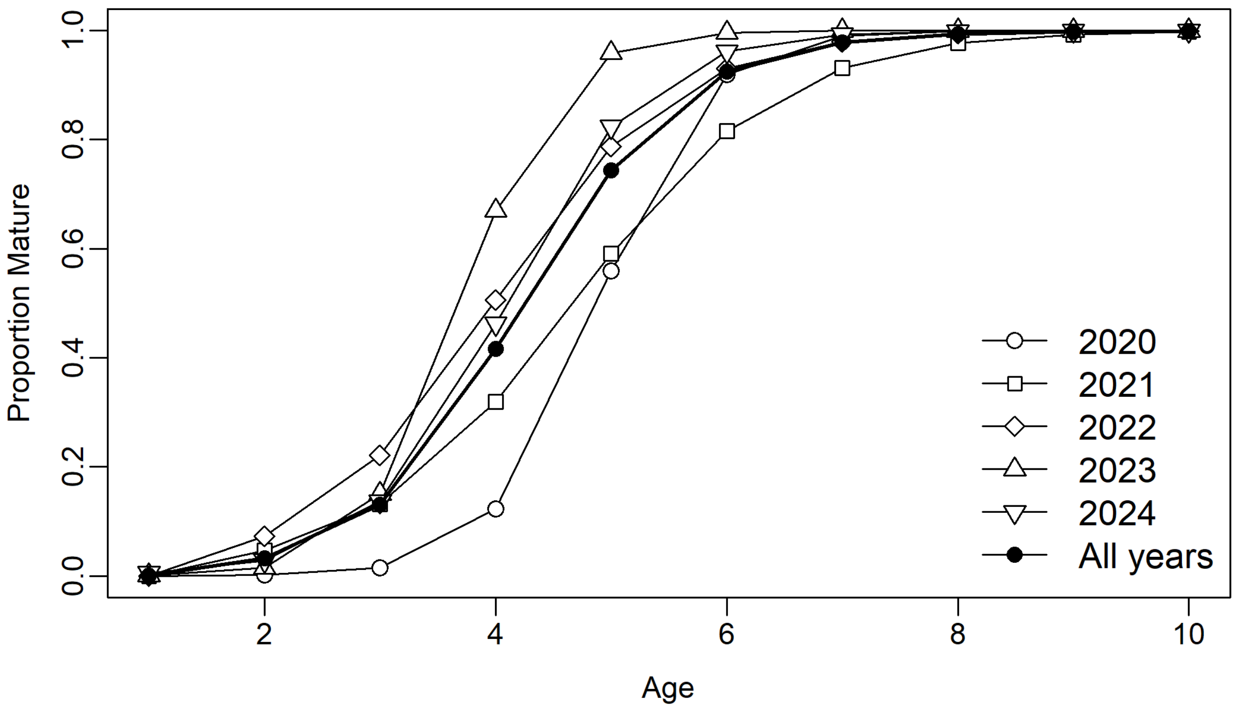

Figure 1.17. Estimates of the proportion mature at age from weighted visual maturity data collected during 2020-2024 winter acoustic surveys in the Gulf of Alaska and long-term average proportion mature at age (1983-2024). Maturity for age-1 fish is assumed to be zero.

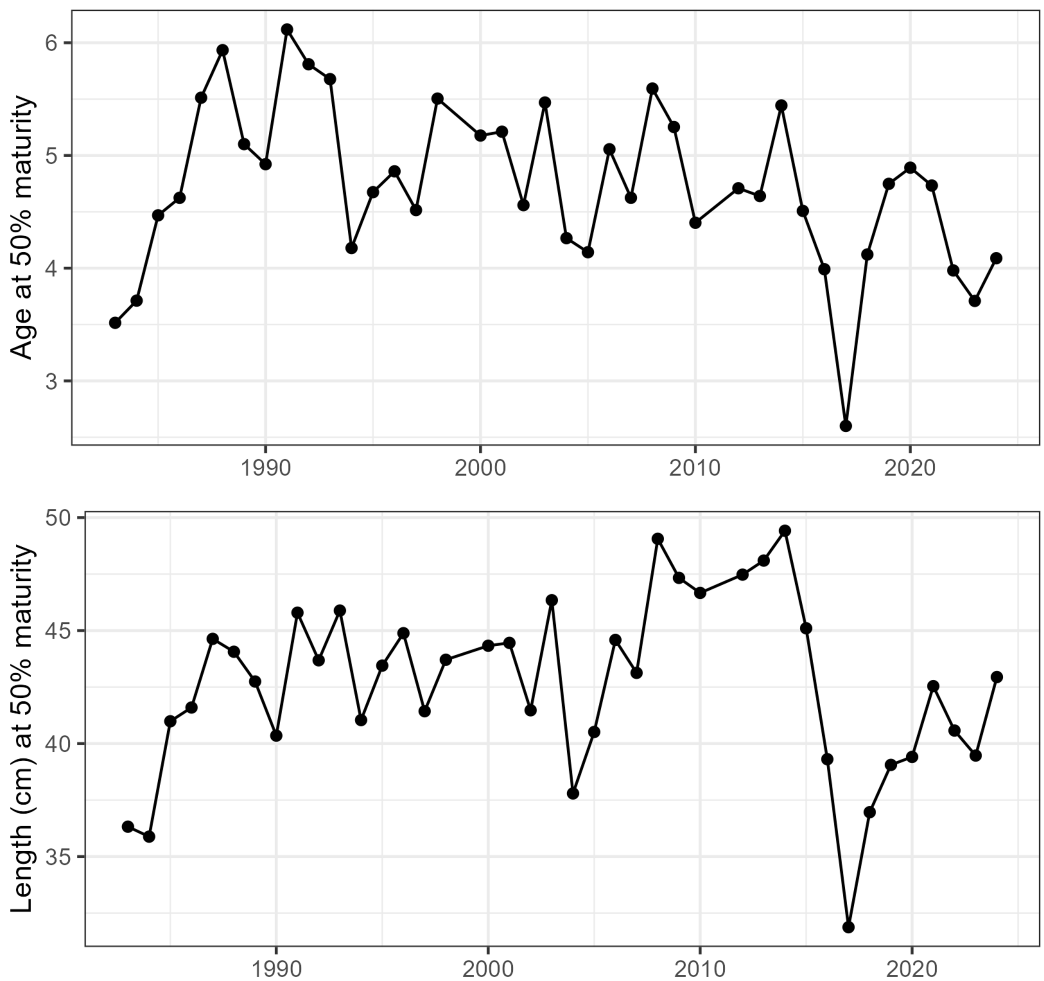

Figure 1.18. Age at 50% mature (top) and length at 50% mature (bottom) from annual logistic regressions for female pollock from winter acoustic survey data in the Gulf of Alaska. Estimates since 2003 are weighted by local abundance.

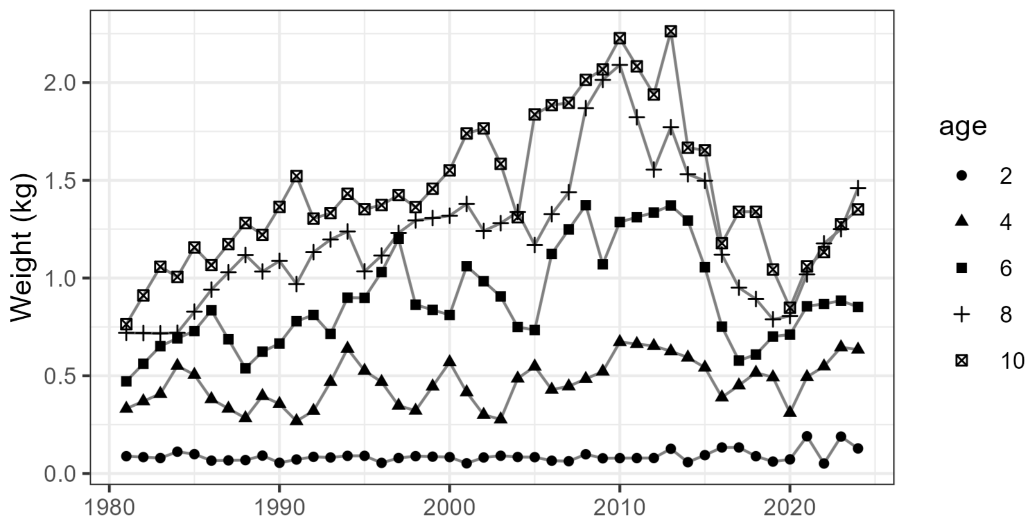

Figure 1.19. Estimated weight at age of GOA pollock (ages 2, 4, 6, 8, and 10) from Shelikof Strait acoustic surveys used in the assessment model. In 1999 and 2011, when the acoustic survey was not conducted, weights-at-age were interpolated from surveys in adjacent years.

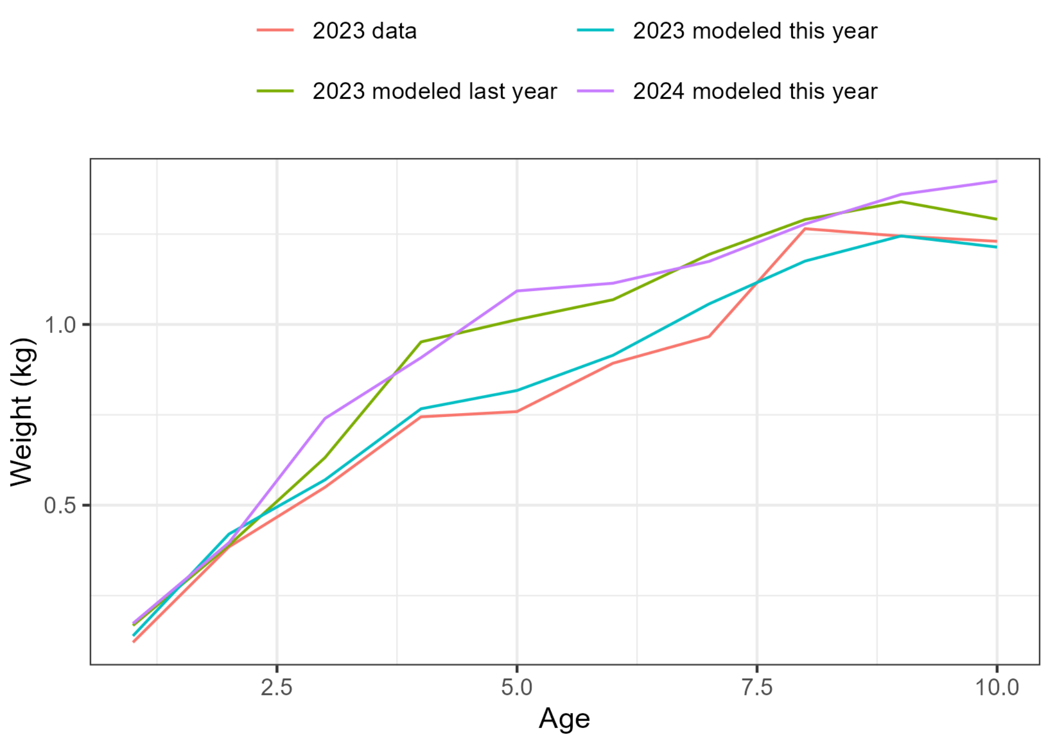

Figure 1.20. Comparison of fishery weight at age for 2023 with estimates from the random effects model last year and this year' assessment (top panel). Random effects model estimates for 2024 used in the assessment model and for yield projections (bottom panel).

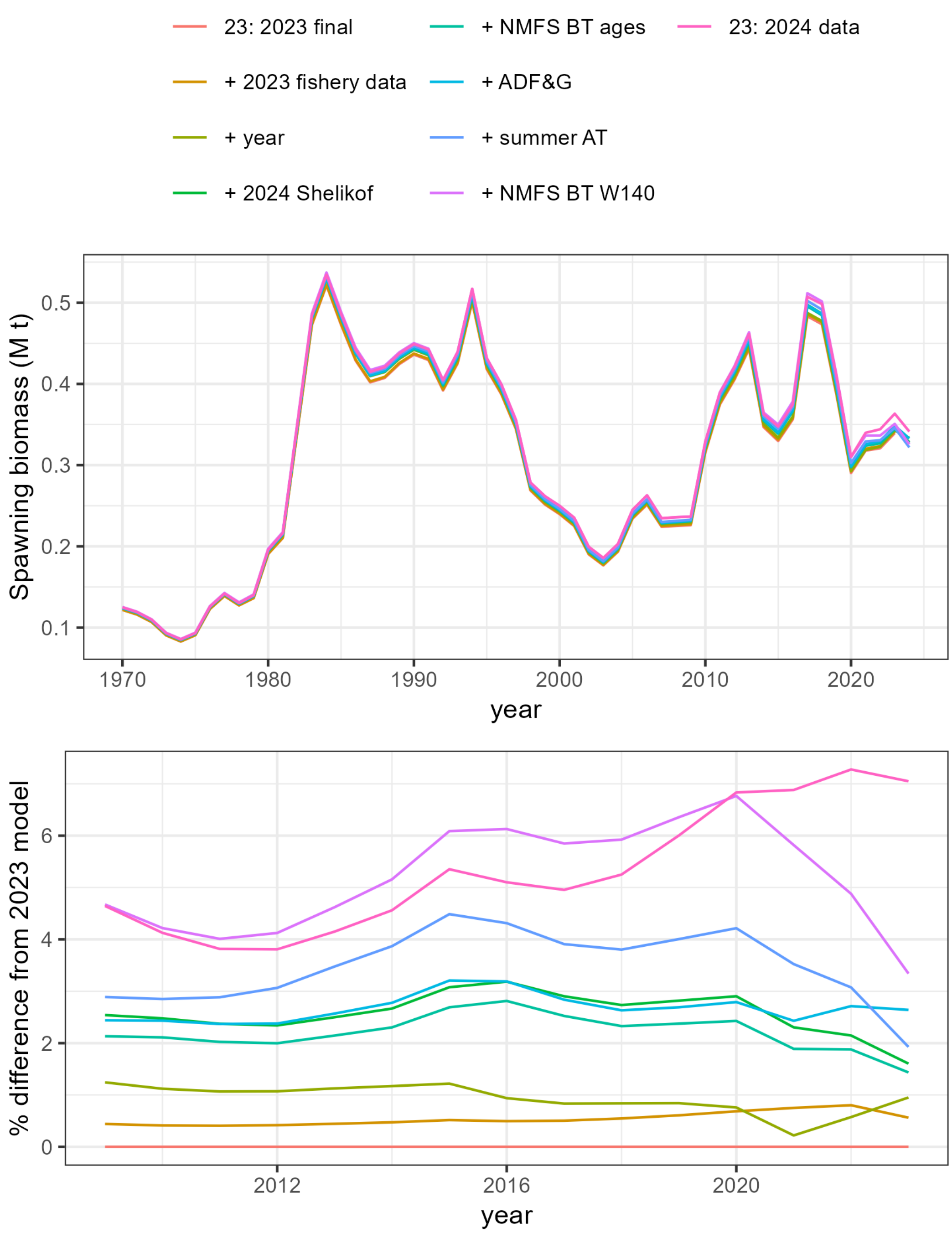

Figure 1.21. Changes in estimated spawning biomass as new data were added successively to last year's base model, ordered by row in the legend at the top. The lower panel shows recent years relative to last year's model.

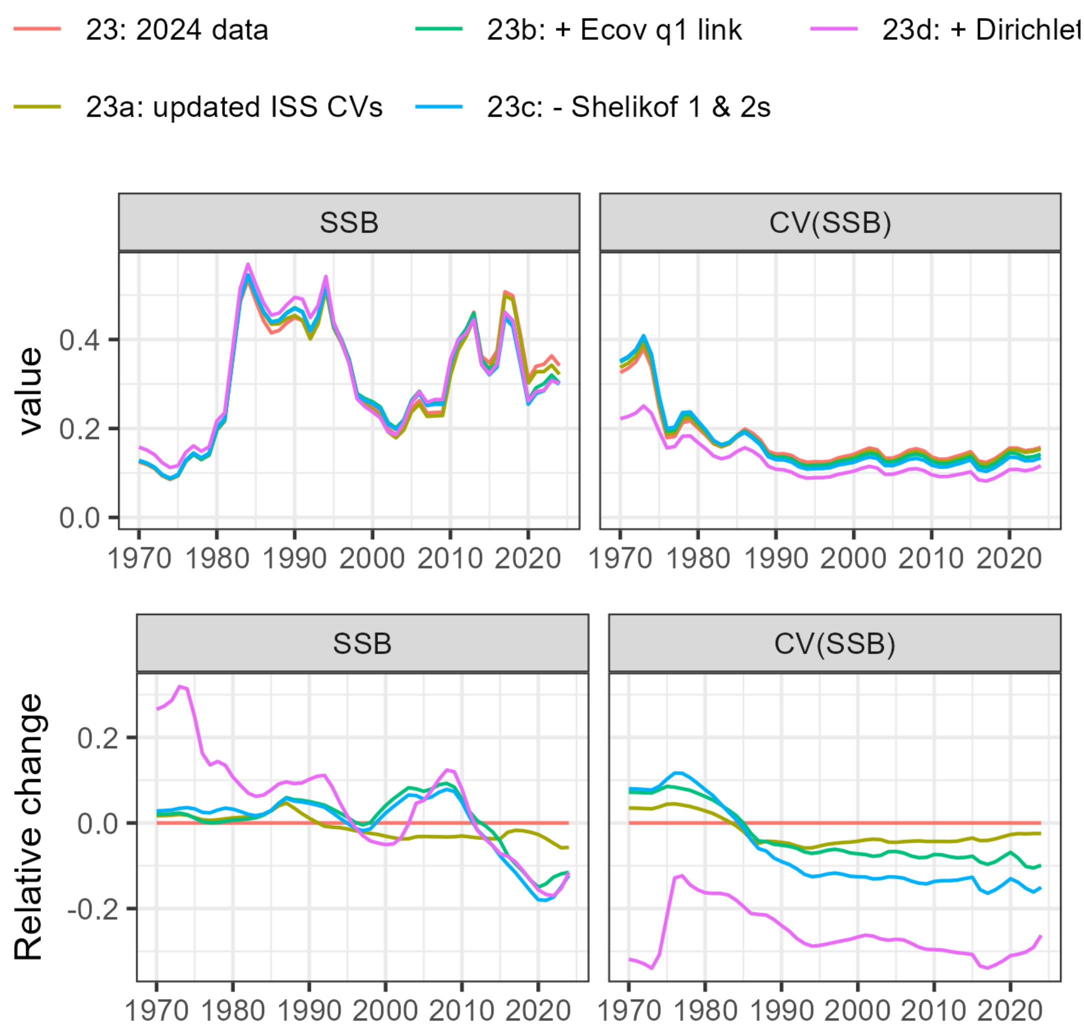

Figure 1.22. Changes in estimated spawning biomass and uncertainty for proposed models. The top panel shows SSB and the CV of SSB, while the bottom shows change relative to last year's model with this year's data. Note that models are cumulative in the order they appear in the legend.

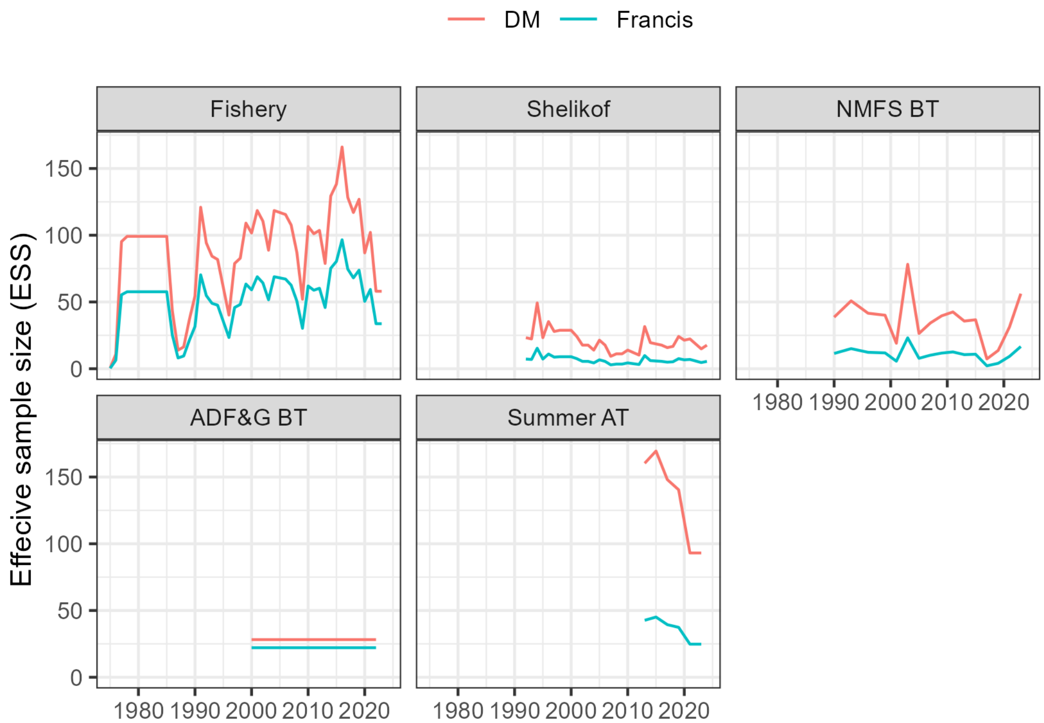

Figure 1.23. Effective sample sizes for models 23c and 23d. The former uses Francis tuning and the latter is calculated from the Dirichlet-multinomial (DM) estimates of dispersion. Annual differences in input sample size were introduced in model 23a.

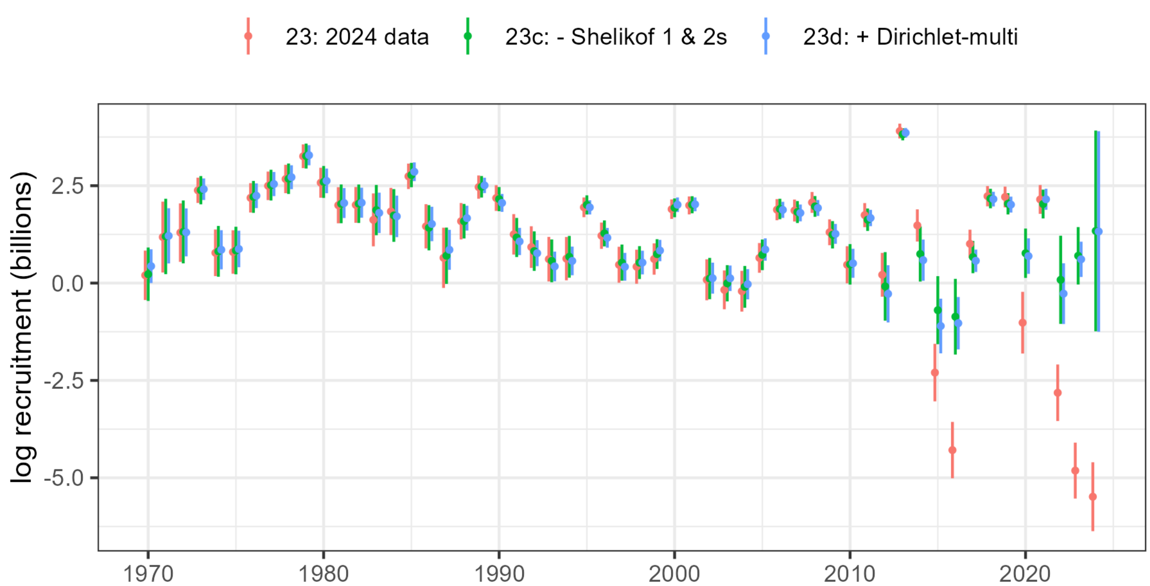

Figure 1.24. Estimates of recruitment in log space among select alternative models.

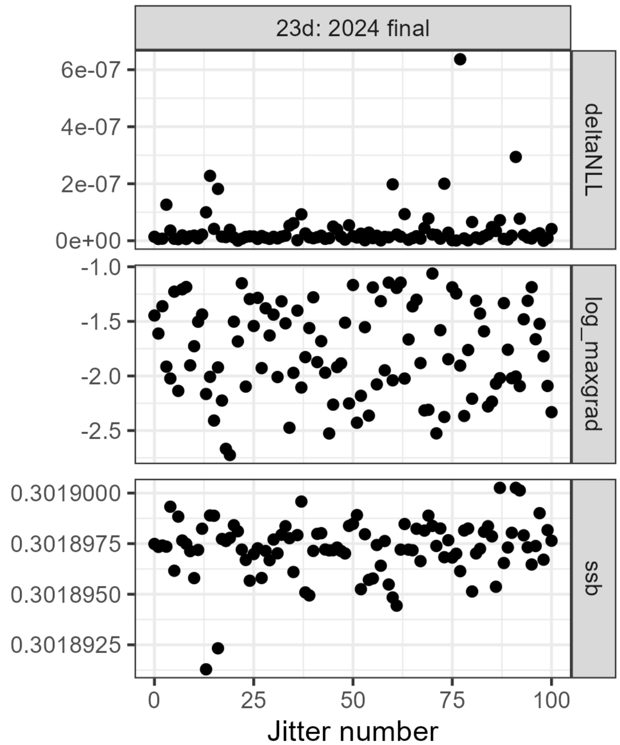

Figure 1.25. Results of a jitter analysis where the model was restarted 100 times from parameters randomly perturbed 10% from the MLE. The change in marginal negative log likelihood (deltaNLL), log of maximum gradient, and terminal SSB are shown in rows.

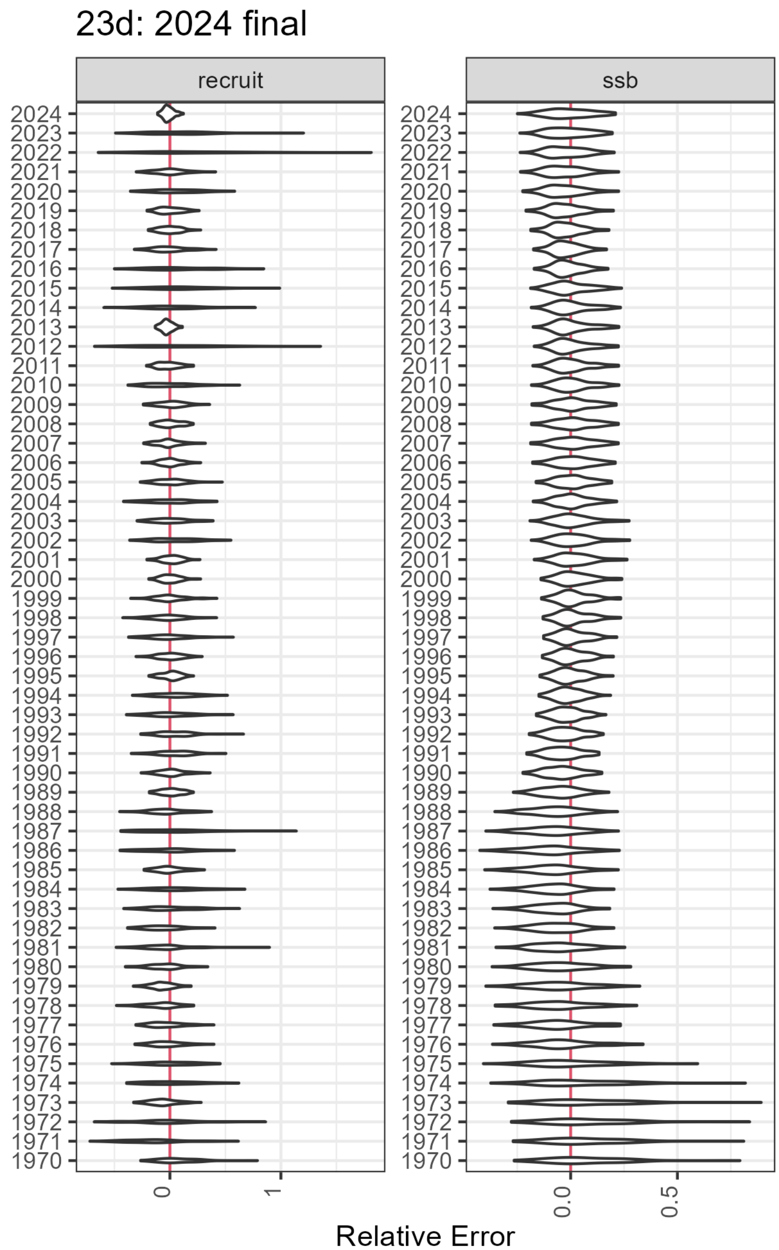

Figure 1.26. Results of a self-test analysis where the model is refit to 100 simulated data sets. Relative error for the timeseries of recruitment and spawning biomass are shown.

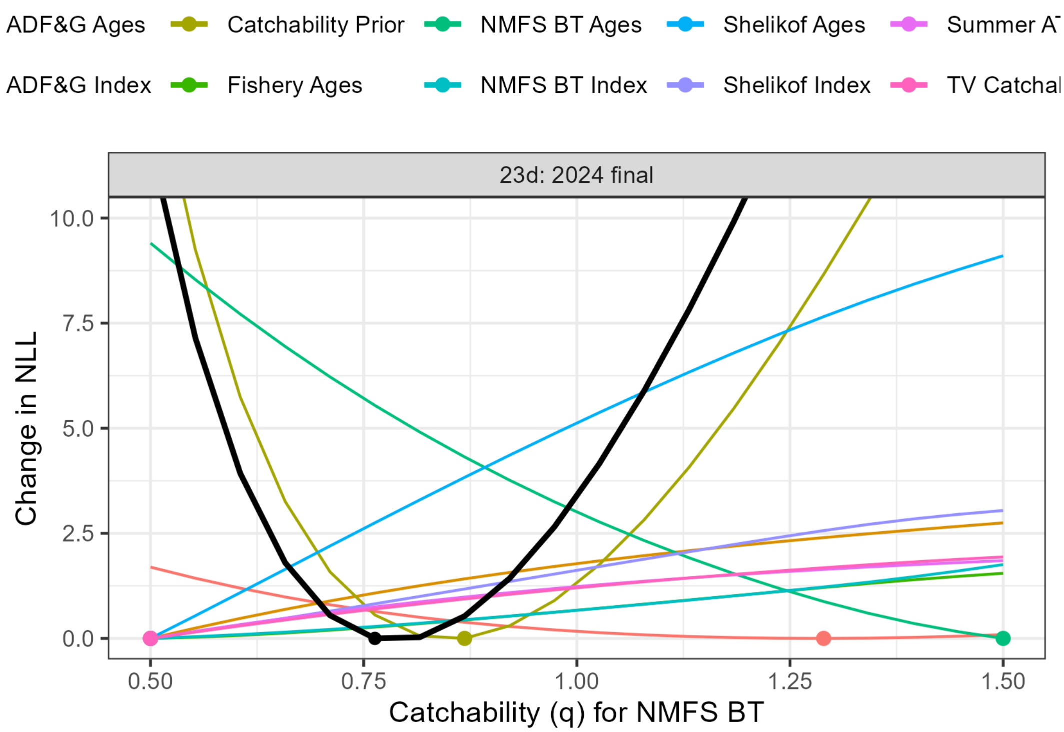

Figure 1.27. Profile likelihood on catchability for the NMFS BT biomass index, which includes a prior. The thick black line shows the total and colors individual components, each with their minimum shown as a point.

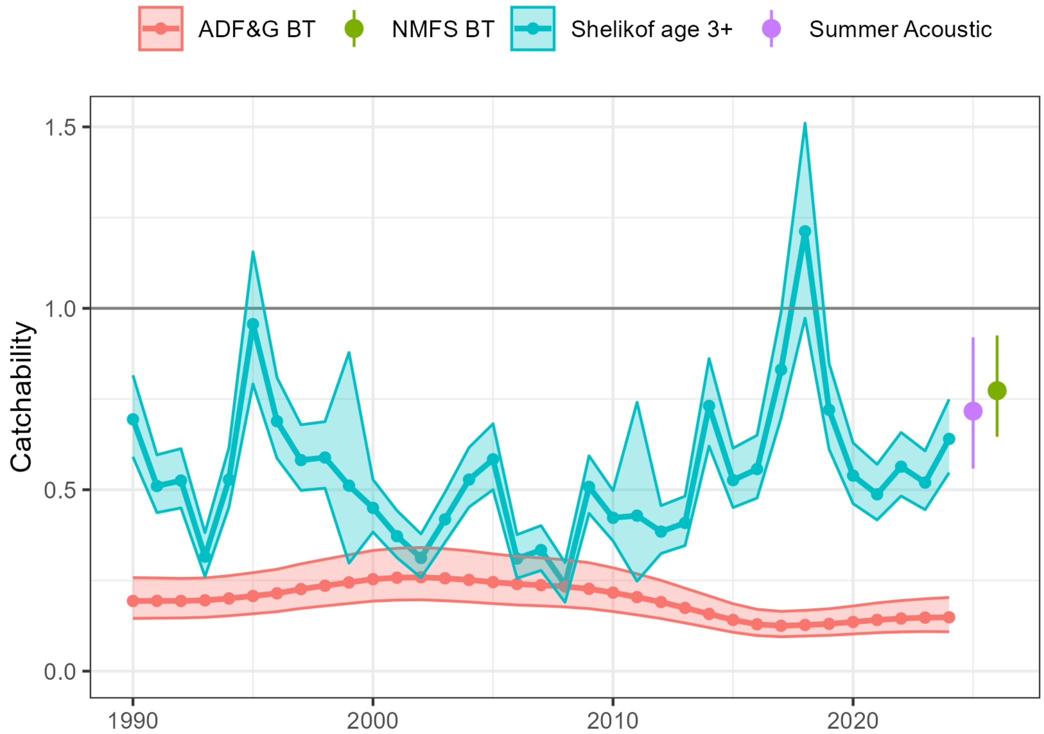

Figure 1.28. Covariate-linked catchability for the Shelikof Strait acoustic survey, a time-varying estimate for the ADF&G crab/groundfish trawl survey, and constant catchability for the NMFS bottom trawl, and the summer NMFS acoustic survey, for the final model. Ribbons and lines represent the 95% CI

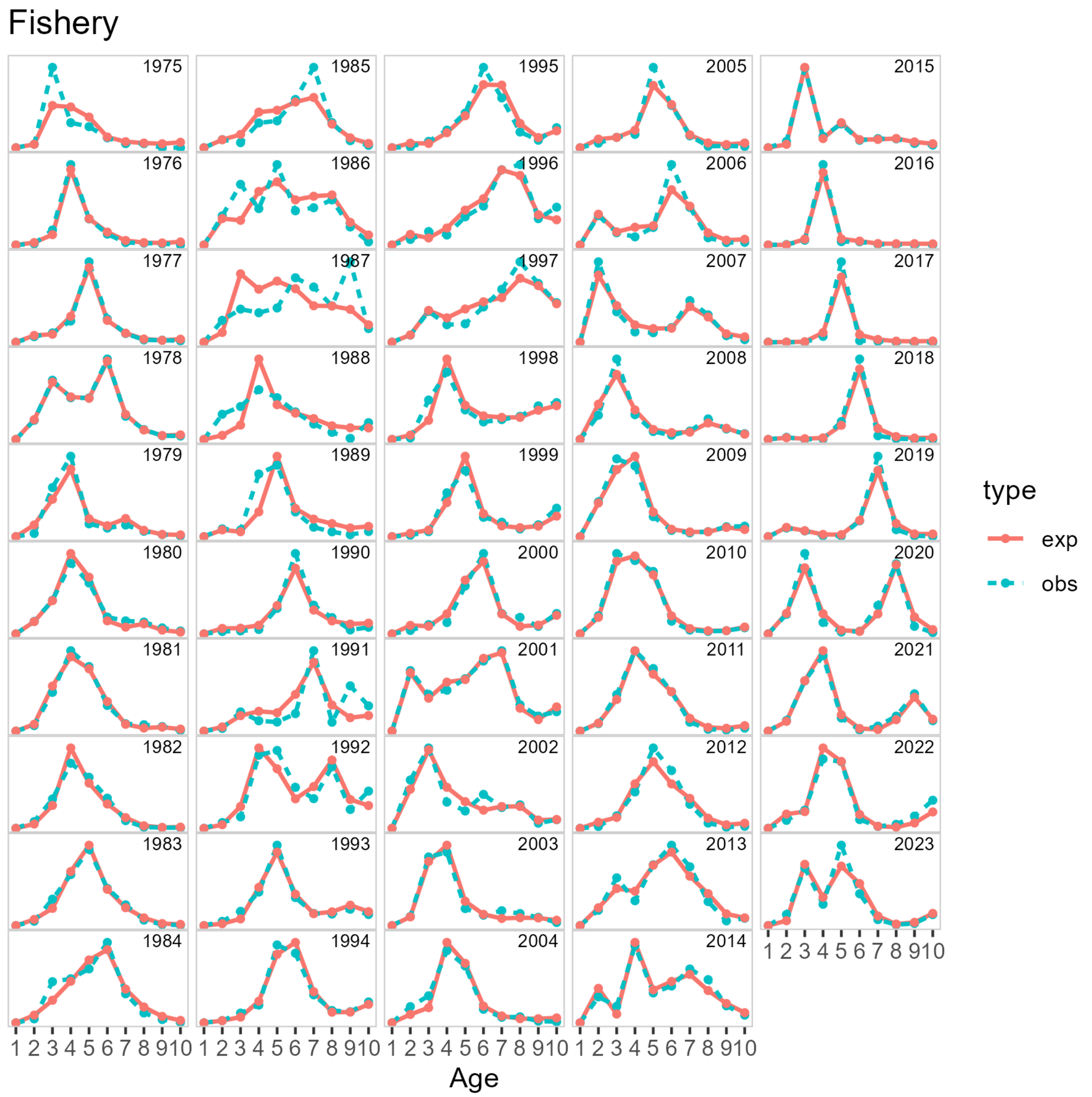

Figure 1.29. Observed and predicted fishery age composition for GOA pollock from the base model. Dashed blue lines are observations and solid red lines are model expectations.

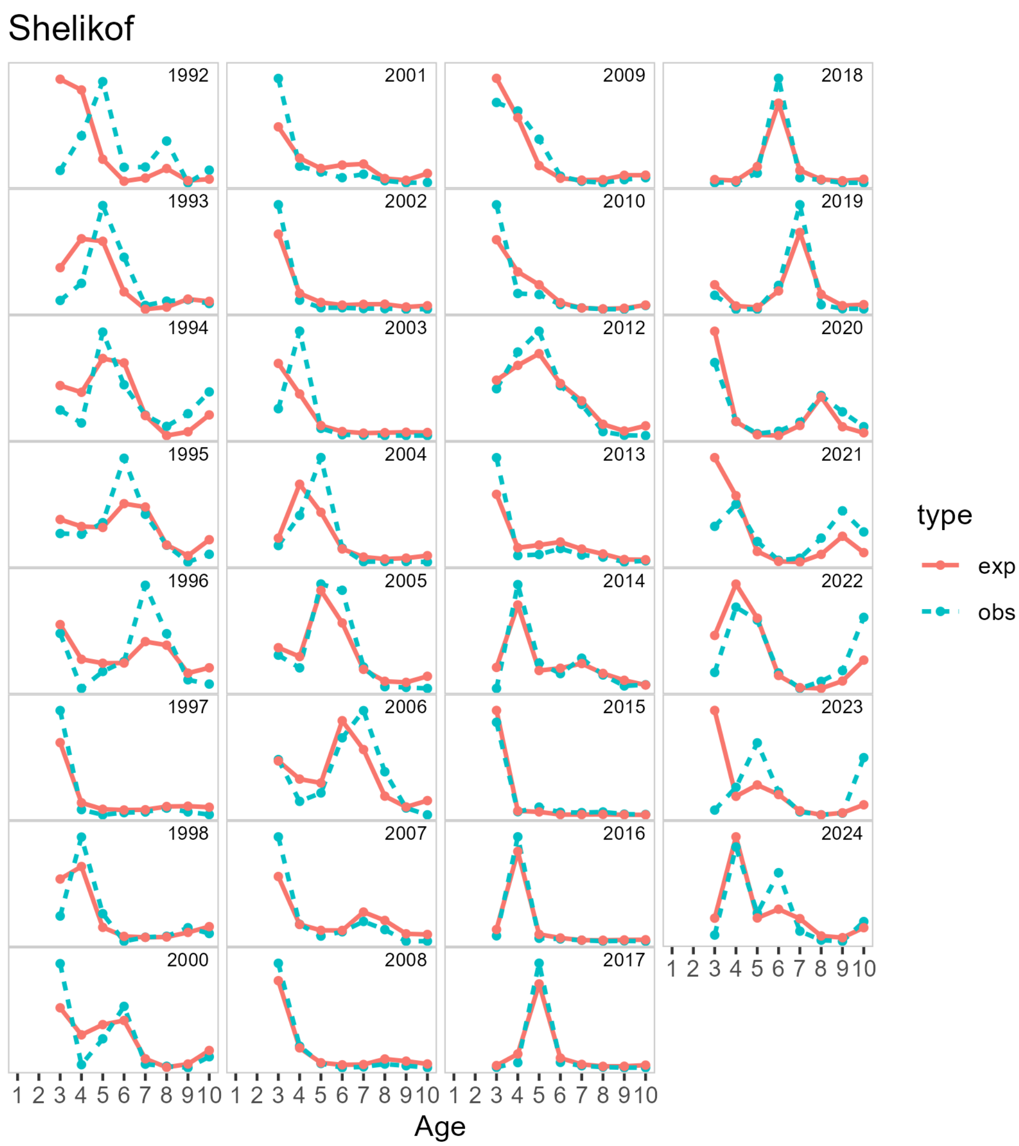

Figure 1.30. Observed and predicted Shelikof Strait acoustic survey age composition for GOA pollock from the base model. Dashed blue lines are observations and solid red lines are model expectations. Age 1 and 2 fish are modeled separately and excluded.

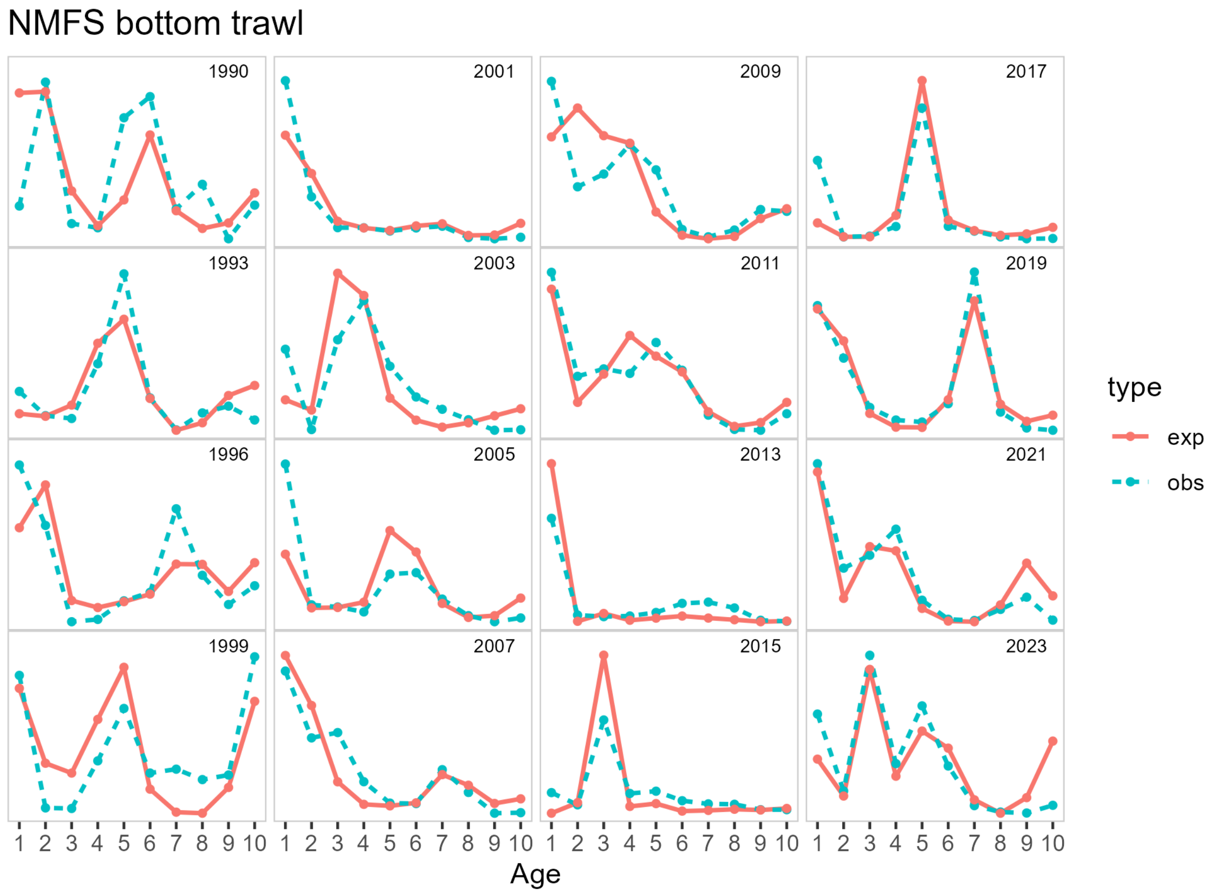

Figure 1.31. Observed and predicted NMFS bottom trawl age composition for GOA pollock from the base model (top). Dashed blue lines are observations and solid red lines are model expectations.

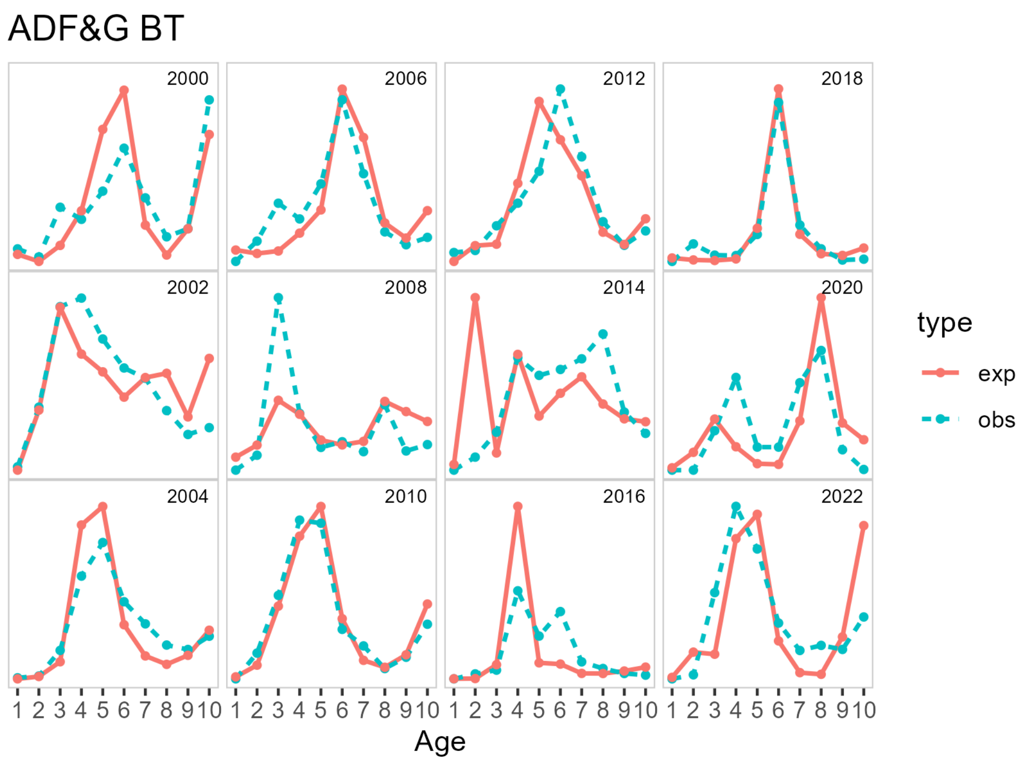

Figure 1.32. Observed and predicted ADF&G bottom trawl age composition for GOA pollock from the base model (top). Dashed blue lines are observations and solid red lines are model expectations.

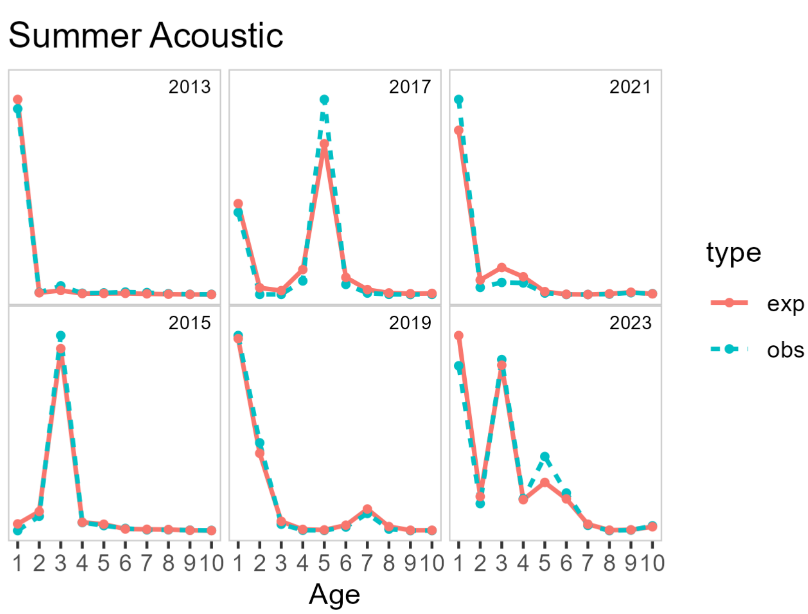

Figure 1.33. Observed and predicted summer acoustic trawl age composition for GOA pollock from the base model (top). Dashed blue lines are observations and solid red lines are model expectations.

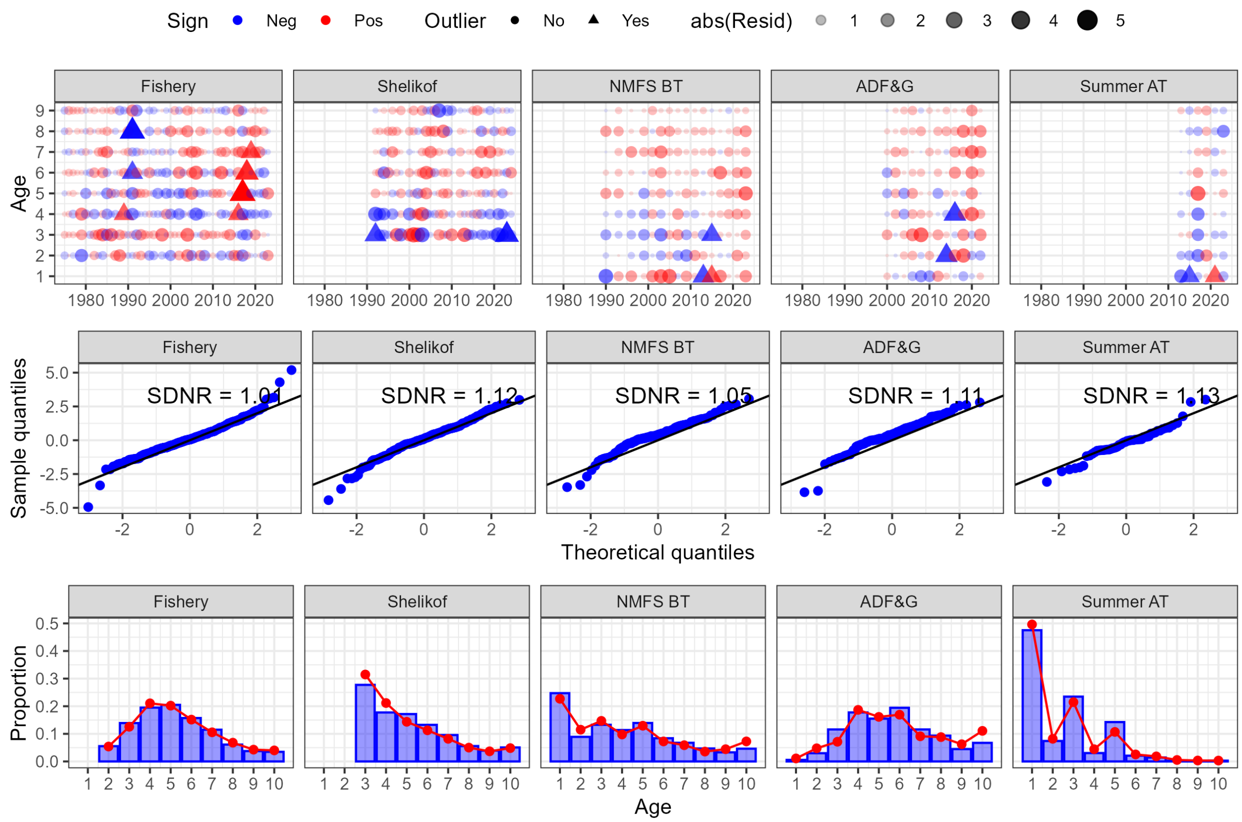

Figure 1.34. One-step-ahead (OSA) residuals for age composition data. These residuals will be distributed iid standard normal, within and among years, under a correctly specified model and assuming that the last bin fits perfectly. When the absolute residuals are larger than 3 or there are clear correlations or other patterns across ages/years, then the assumption is likely violated and interpreted as model misfit. Bubble plots can be used to detect temporal misfit, QQ plots and SDNR for non-normality or other statistical issues, and aggregate fits consistent misfit by age.

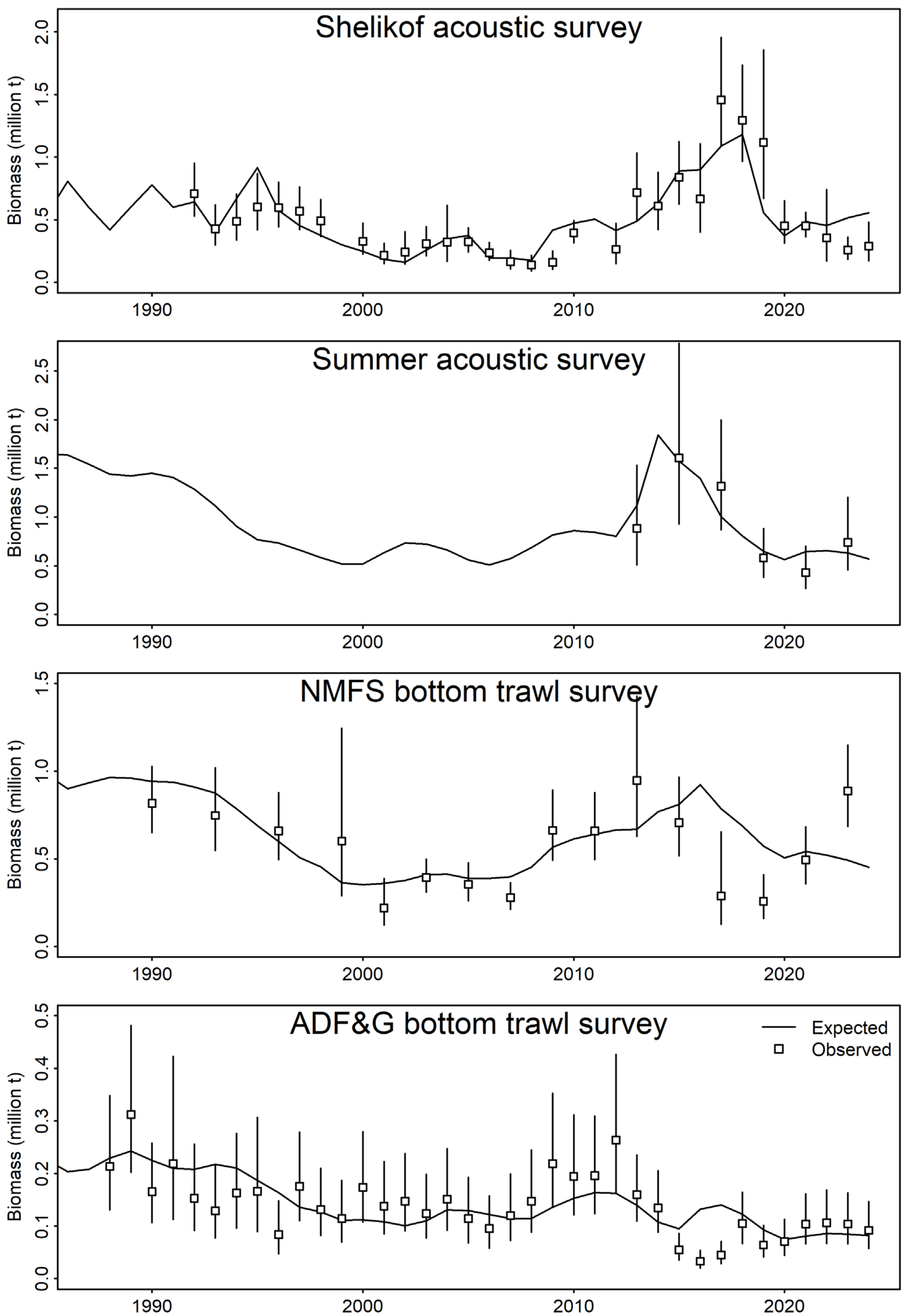

Figure 1.35. Model predicted (line) and observed survey biomass (points and 95% confidence intervals) for the four surveys. The winter Shelikof survey (top panel) is only for ages 3+.

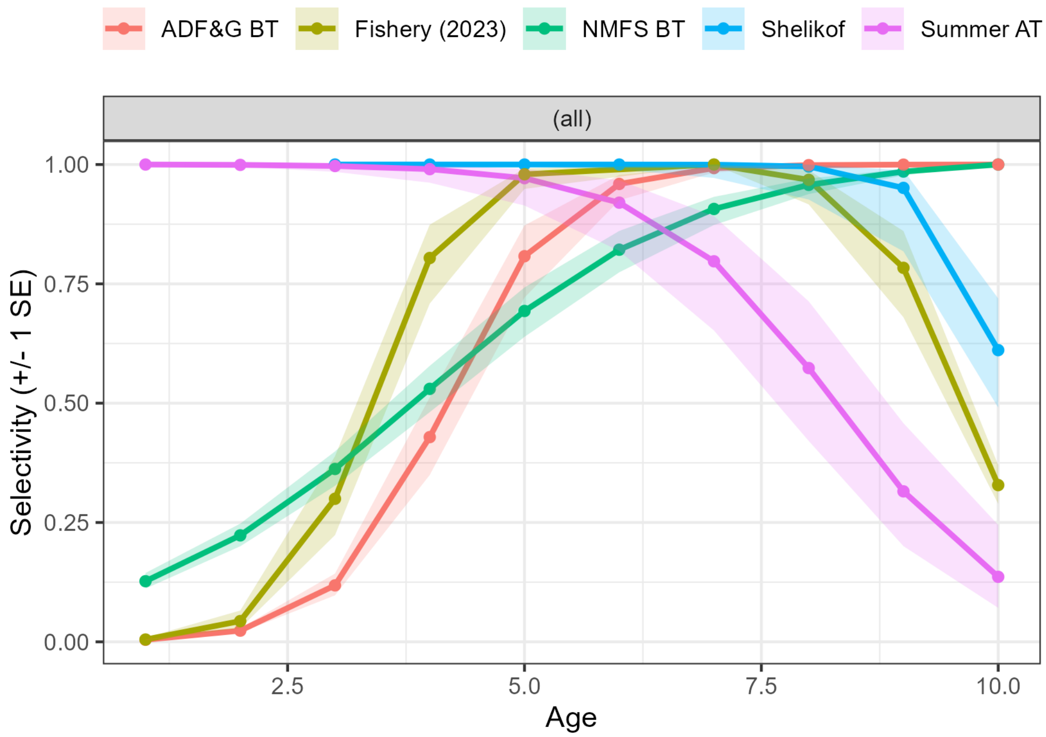

Figure 1.36. Estimated selectivity at age (lines) and uncertainty (+/- 1 SE; ribbons) for the fishery and surveys. Uncertainty calculations are done in logit space then converted and hence are asymmetric.

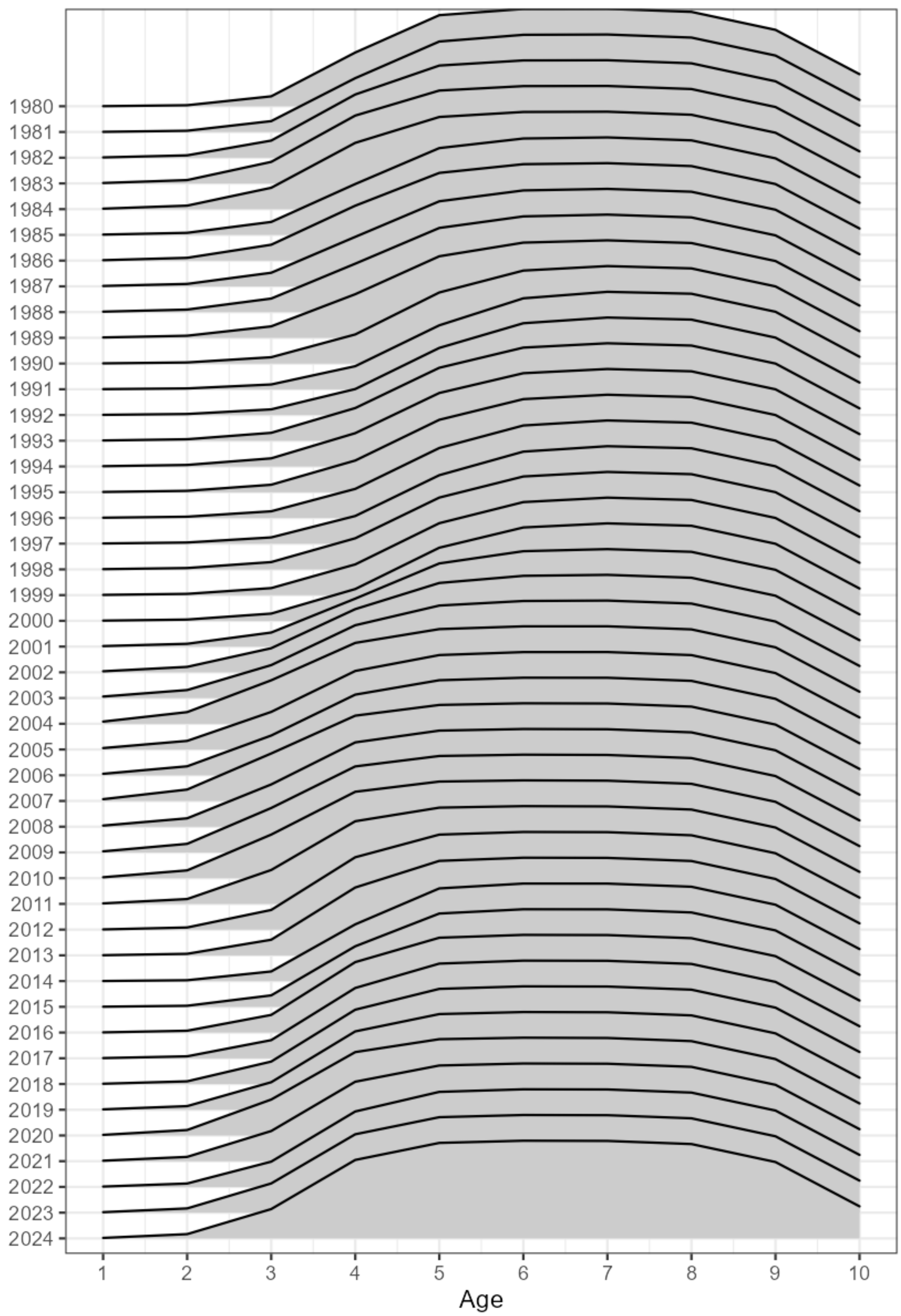

Figure 1.37. Estimates of time-varying double-logistic fishery selectivity for GOA pollock for the base model. The selectivity is scaled so the maximum in each year is 1.0.

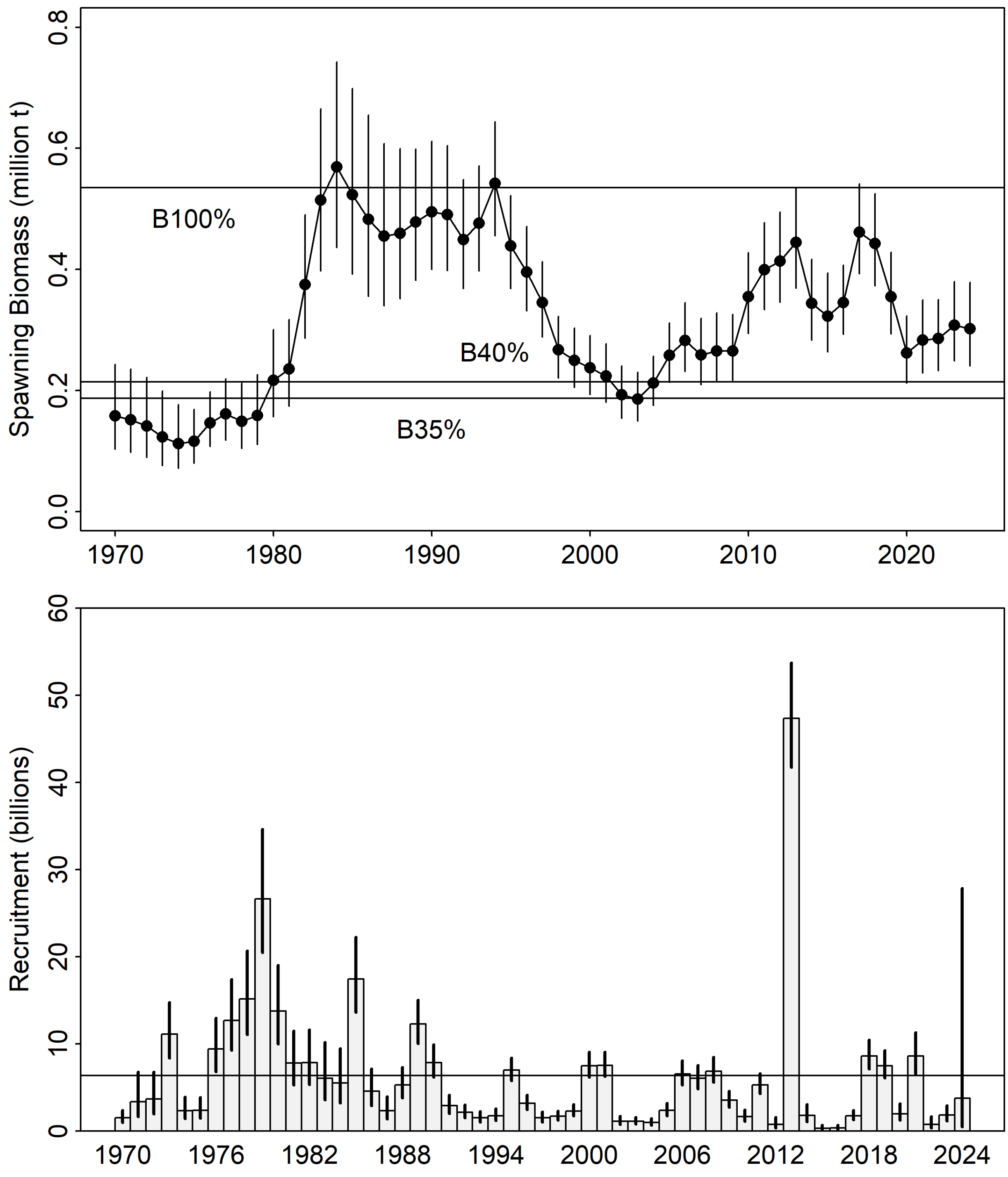

Figure 1.38. Estimated time series of GOA pollock spawning biomass (top) and age 1 recruitment (bottom) for the base model, with horizontal line at the average from 1978-2023. Vertical bars represent two standard deviations. The B35% and B40% lines represent the current estimate of these benchmarks.

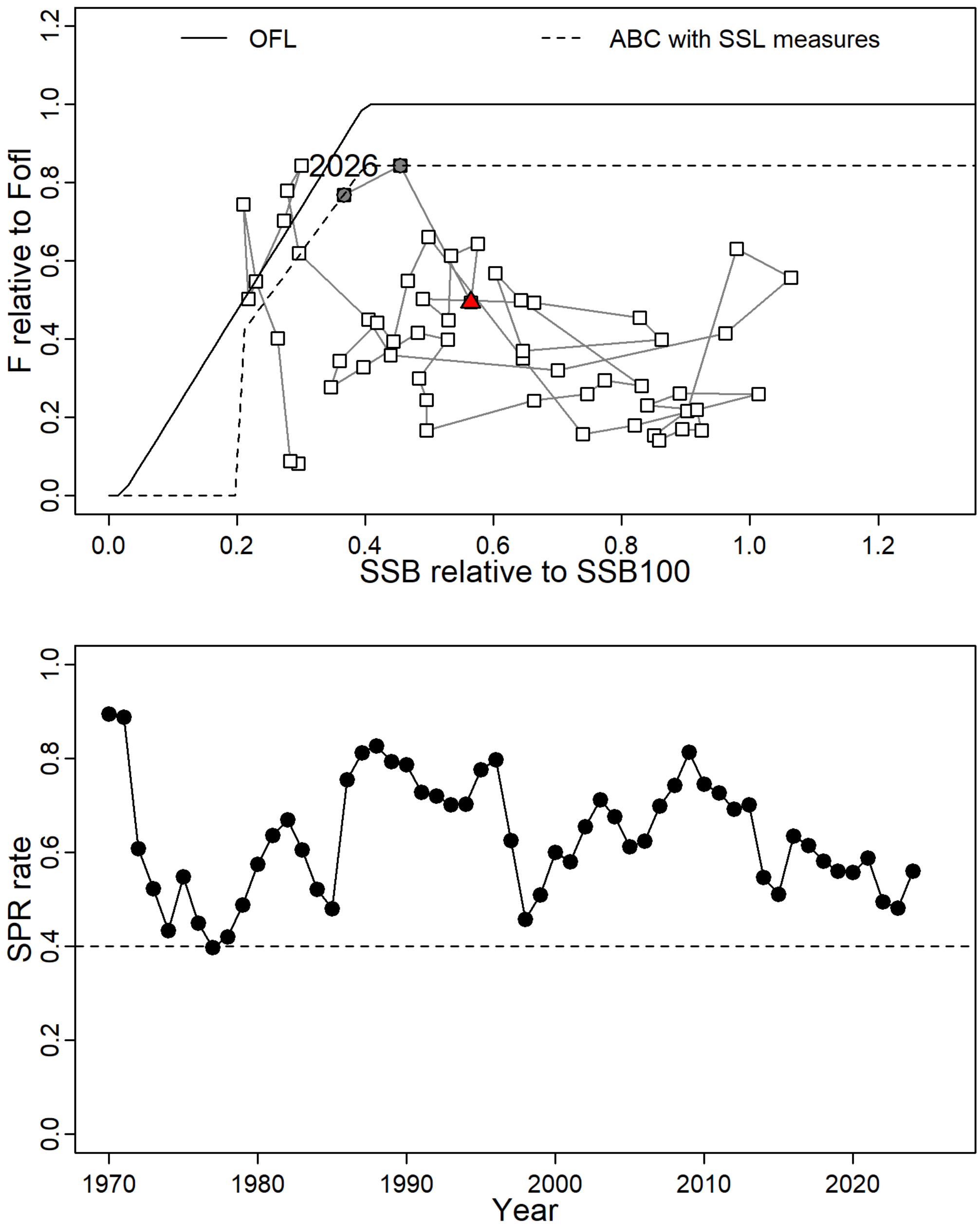

Figure 1.39. Annual fishing mortality as measured in percentage of unfished spawning biomass per recruit (top). GOA pollock spawning biomass relative to the unfished level and fishing mortality relative to FMSY (bottom). The ratio of fishing mortality to FMSY is calculated using the estimated selectivity pattern in that year. Estimates of B100% spawning biomass are based on current estimates of maturity at age, weight at age, and mean recruitment. Because these estimates change as new data become available, this figure can only be used in a general way to evaluate management performance relative to biomass and fishing mortality reference levels.

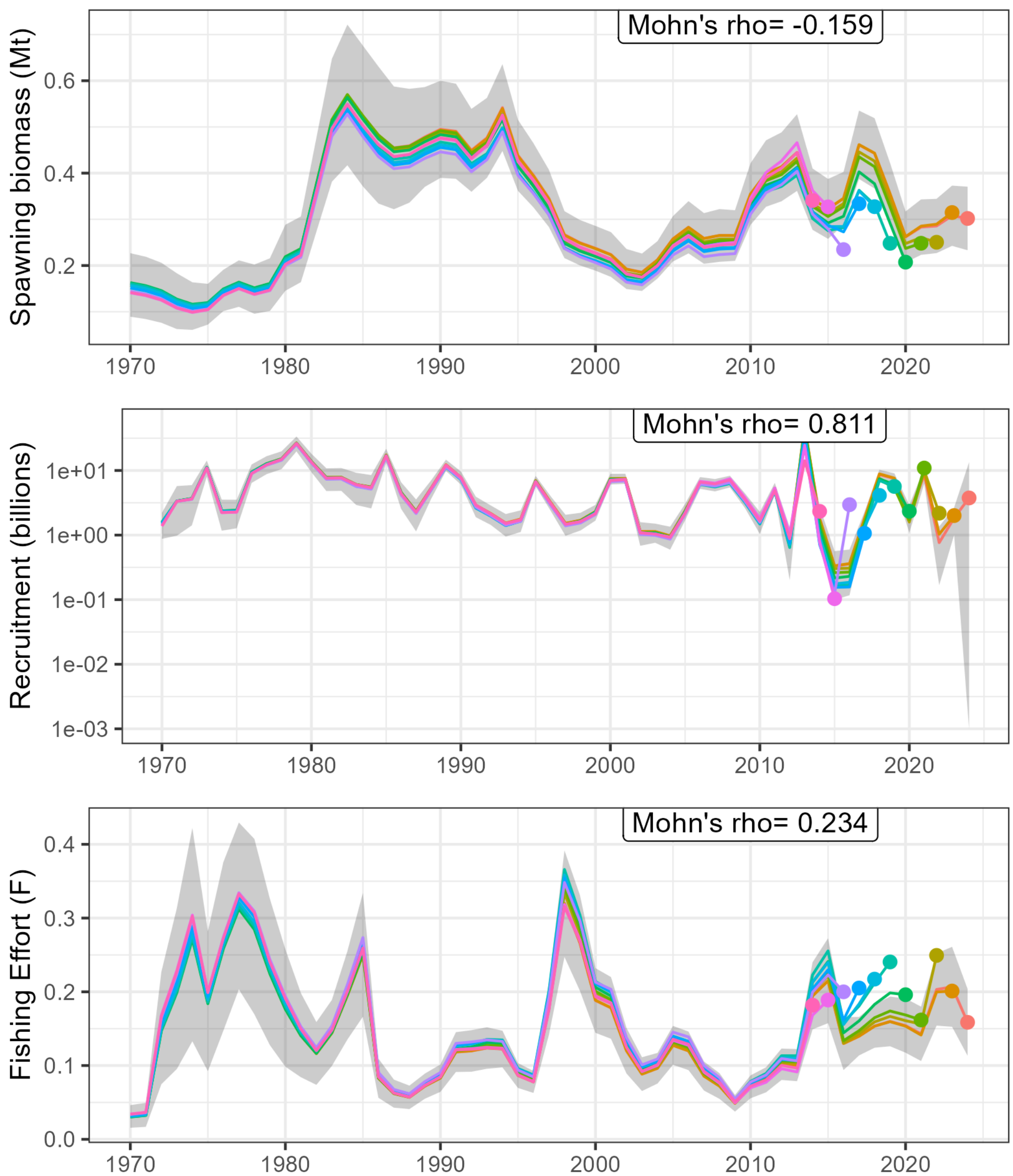

Figure 1.40. Retrospective plot of spawning biomass, recruitment, and fishing effort for models using 10 peels for the 2024 base model.

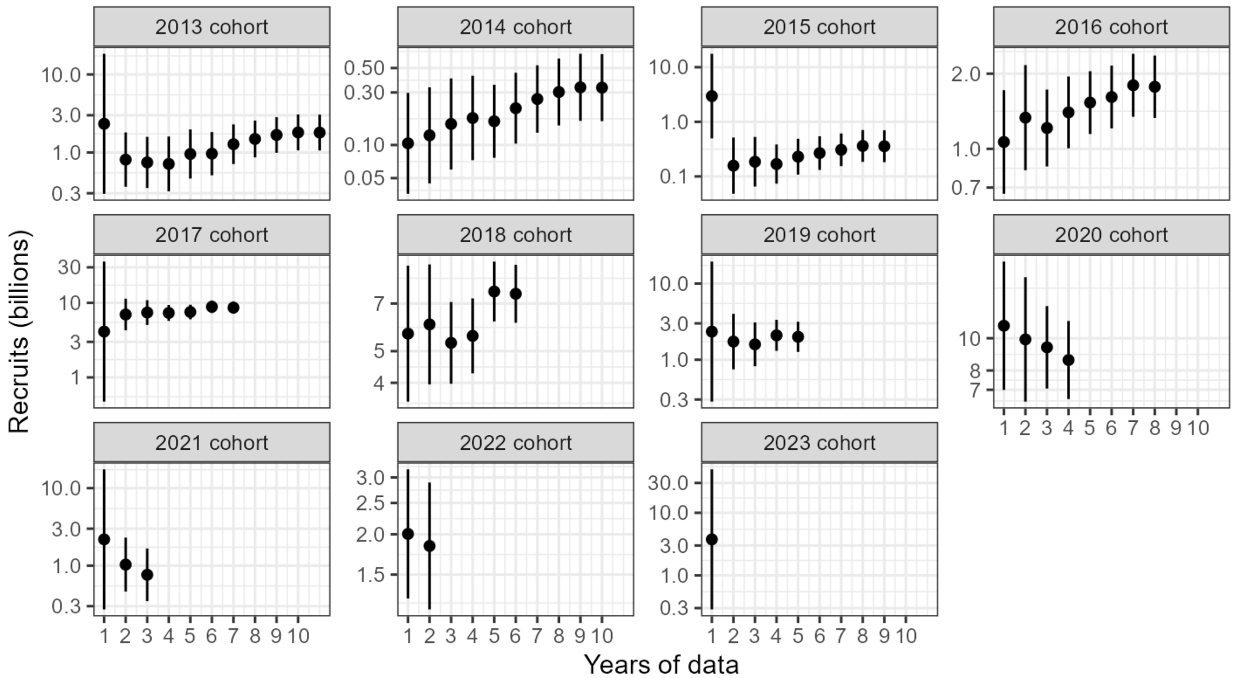

Figure 1.41. Estimates of cohort size (points) and uncertainty (95% confidence intervals) as years of data are added to the model from the retrospective analysis

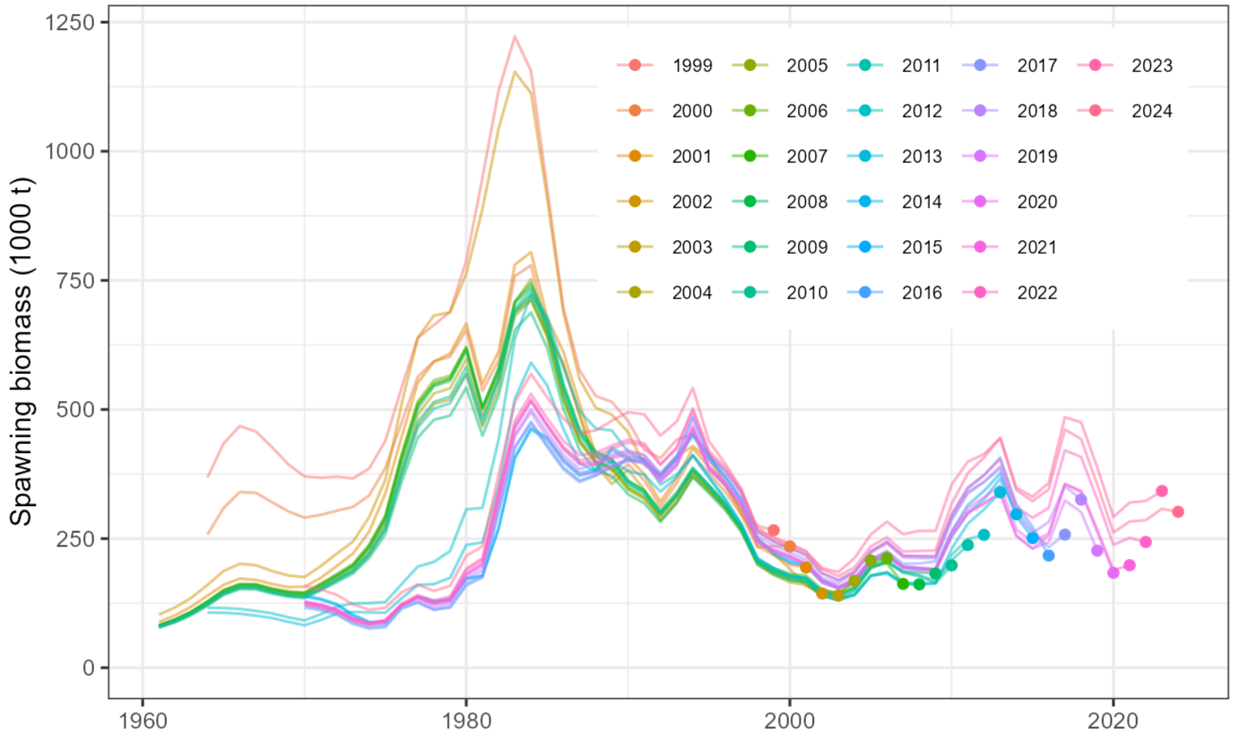

Figure 1.42. Estimated female spawning biomass for historical stock assessments conducted between 1999-2024. Lines reprsent the estimate in the assessment year and point is the terminal estimate in that year.

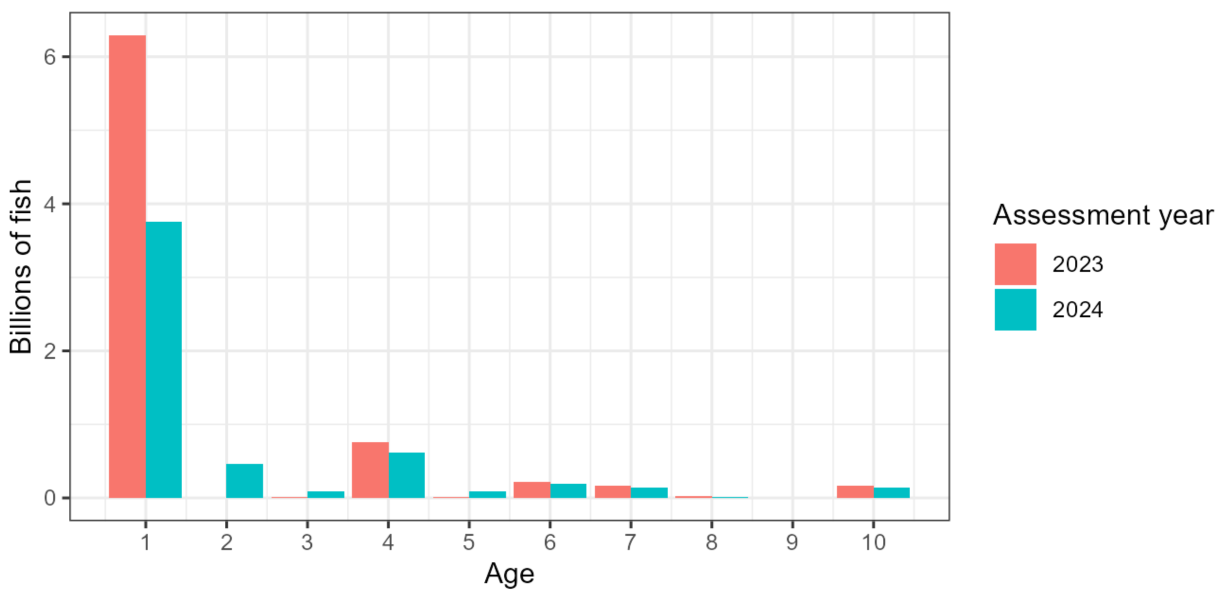

Figure 1.43. The estimated age composition in 2024 from the 2023 and 2024 assessments. The age-1 recruits have no information in the 2023 assessment and so are the average and hence not comparable

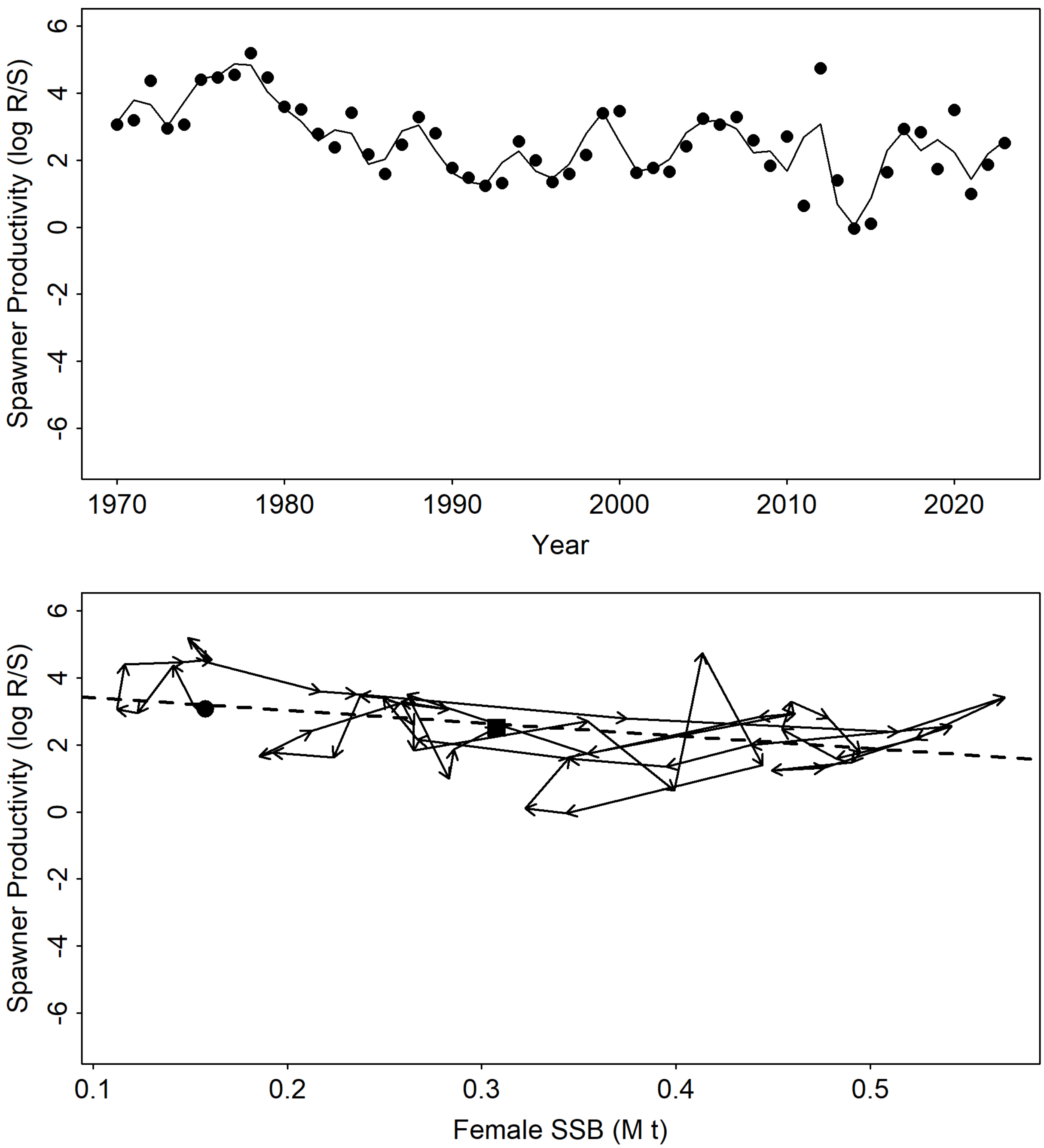

Figure 1.44. GOA pollock spawner productivity, log(R/S) with a five-year running average (top). Spawner productivity in relation to female spawning biomass (bottom). The Ricker stock-recruit curve is linear in a plot of spawner productivity against spawning biomass.

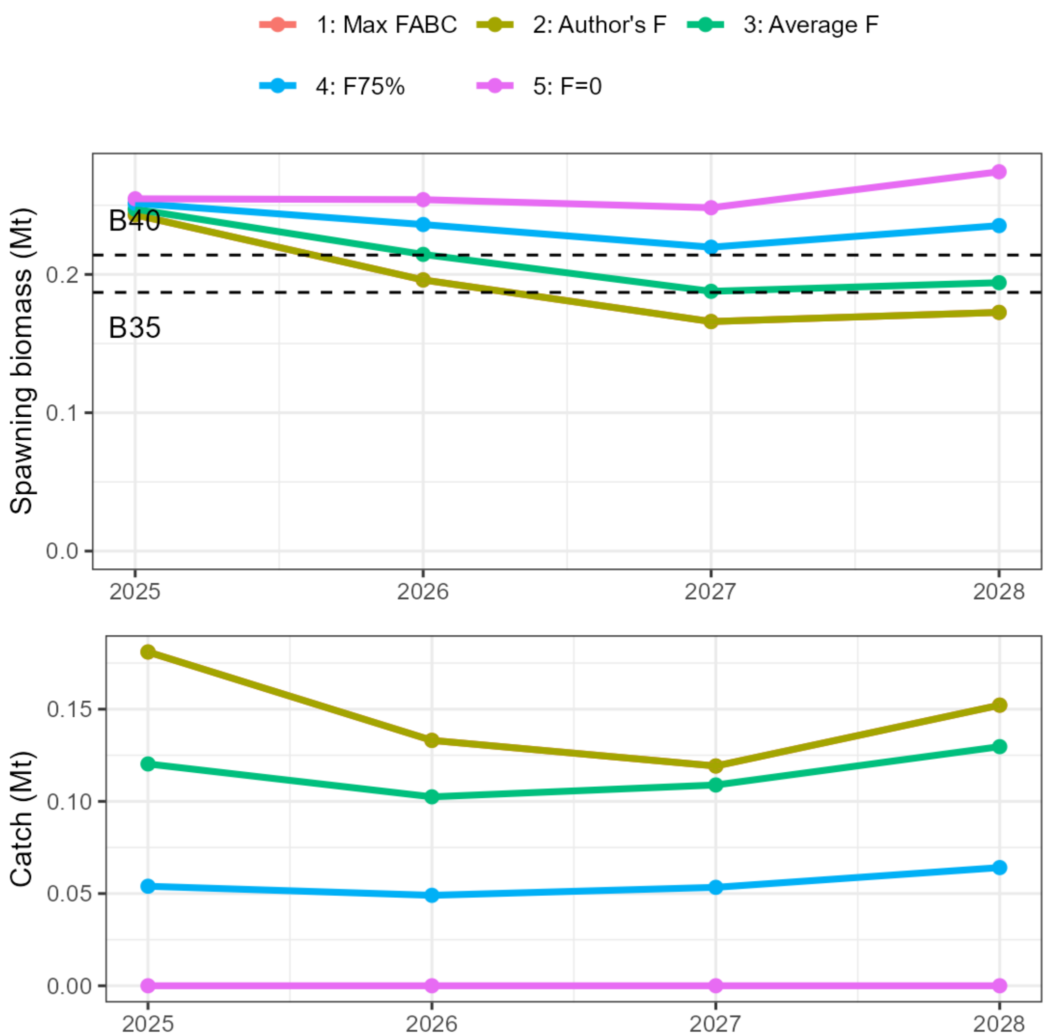

Figure 1.45. Projected mean spawning biomass and catches in 2022-2026 under different harvest rates.

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Appendix 1A. Ecosystem and Socioeconomic Profile of the Walleye Pollock stock in the Gulf of Alaska - Report Card

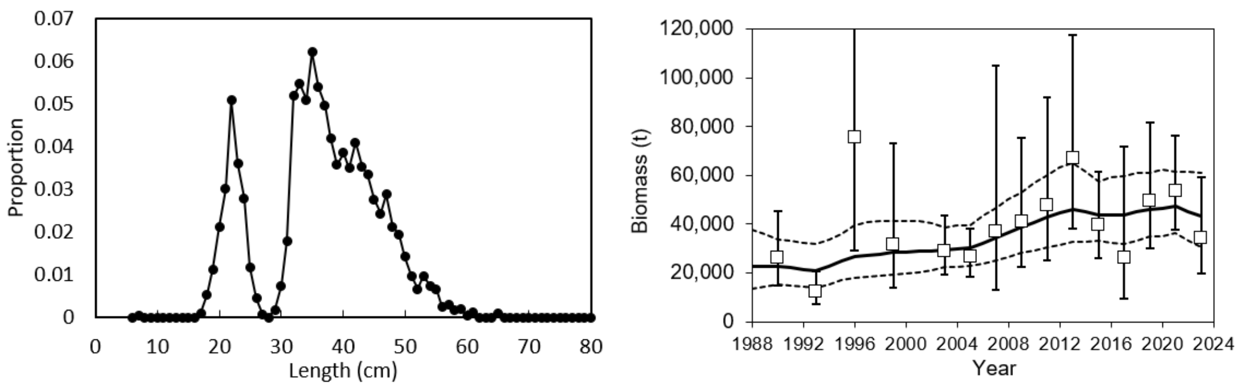
Appendix 1.A is available at this external link.

Appendix 1B. Southeast Alaska pollock assessment

Bottom trawl surveys indicate a substantial reduction in pollock abundance east of 140° W. lon. Stock structure in this area is poorly understood. Bailey et al. (1999) suggest that pollock metapopulation structure in southeast Alaska is characterized by numerous fiord populations. In the 2023 NMFS bottom trawl survey, higher pollock CPUE in southeast Alaska occurred primarily from Baranof Island south to Dixon Entrance, where the shelf is broader. Pollock length composition in the 2023 bottom trawl survey showed a dominant mode at 20 cm about from 30 to 60 cm (Fig. A.1). Juveniles in this area are unlikely to influence the population dynamics of pollock in the central and western Gulf of Alaska. Ocean currents are generally northward in this area, suggesting that juvenile settlement is a result of spawning further south. Spawning aggregations of pollock have been reported from the northern part of Dixon Entrance (Saunders et al. 1988).

Historically, there has been little directed fishing for pollock in Southeast Alaska (Fritz 1993). Pollock catch in the Southeast and East Yakutat statistical areas has averaged about 2 t since 2012 (Table 1.4). The ban on trawling east of 140° W. lon. prevents the development of a trawl fishery for pollock in Southeast Alaska, though recently there has been interest in directed pollock fishing using other gear types, such as purse seine.

Biomass in Southeast Alaska was estimated by splitting survey strata and CPUE data in the Yakutat statistical area at 140° W. lon. and combining the strata east of the line with comparable strata in the Southeastern statistical area. Surveys since 1996 had the most complete coverage of shallow strata in southeast Alaska, and indicate that stock size is approximately 25-75,000 t (Appendix Fig. B.1). There is a gradual increase in biomass since 2005, but confidence intervals are large. A random effects model was fit to the 1990-2023 bottom trawl survey biomass estimates in southeast Alaska. We recommend placing southeast Alaska pollock in Tier 5 of the NPFMC tier system, and basing the ABC and OFL on natural mortality (0.3) and the biomass estimate from the random effects model (43,328 t). Since there was no new index in 2024 the previous model results are carried over. **The model results in a 2025 ABC of 9,749 t (43,328 t * 0.75 M), and a 2025 OFL of 12,998 t (43,328 t * M). The same ABC and OFL are recommended for 2026.**



Appendix figure 1B.1. Pollock length composition in 2023 (left) and biomass trend in southeast Alaska from a random effects model fit to NMFS bottom trawl surveys in 1990-2023 (right). Error bars indicate plus and minus two standard deviations. The solid line is the biomass trend from the random effects model, while dotted lines indicate the 95% confidence interval.

Appendix 1C. GOA pollock stock assessment model

Population dynamics

The age-structured model for pollock describes the relationships between population numbers by age and year. The modeled population includes individuals from age 1 to age 10, with age 10 defined as a "plus" group, i.e., all individuals age 10 and older. The Baranov (1918) catch equations are assumed, so that

$$c_{ij} = N_{ij} \frac{F_{ij}}{Z_{ij}} [1 - \exp(-Z_{ij})]$$

$$Z_{ij} = \sum_k F_{ij} + M_j$$

$$N_{i+1\,j+1} = N_{ij} \exp(-Z_{ij})$$

except for the plus group, where

$$N_{i+1,10} = N_{i,9} \exp(-Z_{i,9}) + N_{i,10} \exp(-Z_{i,10})$$

where N_{ij} is the population abundance at the start of year i for age j fish, F_{ij} = fishing mortality rate in year i for age j fish, and c_{ij} = catch in year i for age j fish. The natural mortality rate, M_j, is age-specific, but does not vary by year (at least for now).

Fishing mortality is modeled as a product of year-specific and age-specific factors (Doubleday 1976)

$$F_{ij} = s_j f_i$$

where s_j is age-specific selectivity, and f_i is the annual fishing mortality rate. To ensure that the selectivities are well determined, we require that $\max(s_j) = 1$. Following previous assessments, a scaled double-logistic function (Dorn and Methot 1990) was used to model age-specific selectivity,

$$s'_j = \left(\frac{1}{1 + \exp[-\beta_1 (j - \alpha_1)]} \right) \left(1 - \frac{1}{1 + \exp[-\beta_2 (j - \alpha_2)]} \right)$$

$$s_j = s'_j / \max(s'_j)$$

where α_1 = inflection age, β_1 = slope at the inflection age for the ascending logistic part of the equation, and α_2 , β_2 = the inflection age and slope for the descending logistic part.

Measurement error

Model parameters were estimated by maximum likelihood (Fournier and Archibald 1982, Kimura 1989, 1990, 1991). Fishery observations consist of the total annual catch in tons, C_i, and the proportions at age in the catch, p_{ij}. Predicted values from the model are obtained from

$$\hat{C}_i = \sum_j w_{ij}\, c_{ij}$$

$$\hat{p}_{ij} = c_{ij} / \sum_j c_{ij}$$

where w_{ij} is the weight at age j in year i . Year-specific weights at age are used when available.

Log-normal measurement error in total catch and multinomial sampling error in the proportions at age give a log-likelihood of

$$\log L_k = -\sum_i [\log(C_i) - \log(\hat{C}_i)]^2 / 2\sigma_i^2 + \sum_i m_i \sum_j p_{ij} \log(\hat{p}_{ij} / p_{ij})$$

where σ_i is standard deviation of the logarithm of total catch (~ CV of total catch) and m_i is the size of the age sample. In the multinomial part of the likelihood, the expected proportions at age have been divided by the observed proportion at age, so that a perfect fit to the data for a year gives a log likelihood value of zero (Fournier and Archibald 1982). This formulation of the likelihood allows considerable flexibility to give different weights (i.e. emphasis) to each estimate of annual catch and age composition. Expressing these weights explicitly as CVs (for the total catch estimates), and sample sizes (for the proportions at age) assists in making reasonable assumptions about appropriate weights for estimates whose variances are not routinely calculated.

Survey observations consist of a total biomass estimate, B_i, and survey proportions at age π_{ij}. Predicted values from the model are obtained from

$$\hat{B}_i = q \sum_j w_{ij} s_j N_{ij} \exp[\phi_i Z_{ij}]$$

where q = survey catchability, w_{ij} is the survey weight at age *j* in year *i* (if available), s_j = selectivity at age for the survey, and ϕ_i = fraction of the year to the mid-point of the survey. Although there are multiple surveys for GOA pollock, a subscript to index a particular survey has been suppressed in the above and subsequent equations in the interest of clarity. Survey selectivity was modeled using either a double-logistic function of the same form used for fishery selectivity, or simpler variant, such as single logistic function. The expected proportions at age in the survey in the *i*th year are given by

$$\hat{\pi}_{ij} = s_j N_{ij} \exp[\phi_i Z_{ij}] / \sum_j s_j N_{ij} \exp[\phi_i Z_{ij}]$$

Log-normal errors in total biomass and multinomial sampling error in the proportions at age give a log-likelihood for survey *k* of

$$\log L_k = -\sum_i [\log(B_i) - \log(\hat{B}_i) + \sigma^2/2]^2 / 2\sigma_i^2 + \sum_i m_i \sum_j \pi_{ij} \log(\hat{\pi}_{ij} / \pi_{ij})$$

where σ_i is the standard deviation of the logarithm of total biomass (~ CV of the total biomass) and m_i is the size of the age sample from the survey.

Process error

Process error refers to random changes in parameter values from one year to the next. Annual variation in recruitment and fishing mortality can be considered types of process error (Schnute and Richards 1995). In the pollock model, these annual recruitment and fishing mortality parameters are generally estimated as free parameters, with no additional error constraints. We use process error to describe changes in fisheries selectivity over time. To model temporal variation in a parameter γ, the year-specific value of the parameter is given by

$$\gamma_i = \bar{\gamma} + \delta_i$$

where $\bar{\gamma}$ is the mean value (on either a log scale or an arithmetic scale), and δ_i is an annual deviation subject to the constraint $\sum \delta_i = 0$. For a random walk where annual *changes* are normally distributed, the log-likelihood is

$$\log L_{Proc.\,Err.} = -\sum \frac{(\delta_i - \delta_{i+1})^2}{2\sigma_i^2}$$

where σ_i is the standard deviation of the annual change in the parameter. We use a process error model for the two parameters for the ascending portion of the fishery double-logistic curve. Variation in the intercept selectivity parameter is modeled using a random walk on an arithmetic scale, while variation in the slope parameter is modeled using a log-scale random walk. We also use a process error model for catchability for the Shelikof Strait acoustic survey and the ADFG bottom trawl survey to account for changes in the proportion of the stock surveyed.

The total log likelihood is the sum of the likelihood components for each fishery and survey, plus a term for process error,

$$\text{Log}\, L = \sum_k \text{Log}\, L_k + \sum_p \text{Log}\, L_{Proc.\,Err.}\,.$$

Appendix 1D. Seasonal distribution and apportionment of pollock among management areas in the Gulf of Alaska

Since 1992, the GOA pollock TAC has been apportioned between management areas based on the distribution of biomass in groundfish surveys. Steller sea lion protection measures that were implemented in 2001 require apportionment of pollock TAC based on the seasonal distribution of biomass. Both single species and ecosystem considerations provide rationale for apportioning the TAC. From an ecosystem perspective, apportioning the TAC will spatially distribute the effects of fishing on other pollock consumers, such as Steller sea lions, potentially reducing the overall intensity of any adverse effects. Apportioning the TAC also ensures that no smaller component of the stock experiences higher mortality than any other. Although sub-stock units of pollock have not been identified in the Gulf of Alaska, managing the fishery so as to preserve the existing spatial structure could be regarded as a precautionary approach. Protection of sub-stock units would be most important during spawning season, when they would be separated spatially.

Recently NMFS approved the final rule for Amendment 109 to GOA Fishery Management Plan developed by the North Pacific Fisheries Management Council. Amendment 109 combines pollock fishery A and B seasons into a single season (redesignated as the A season), and the C and D seasons into a single season (redesignated as the B season), and changes the annual start date of the redesignated pollock B season from August 25 to September 1. The TAC is still allocated 50% to a pre-spawning season (new A season) and 50% to a late summer season (new B season). These changes will be implemented beginning in 2021 and affect the seasonal allocation only in the Central and Western GOA. Our approach to implementing this regulation change is to use the same methodology as was used previously to apportion the TAC into the A, B, C, and D seasons, and then to aggregate the A and B seasons allocation to form the allocation for the new A season, and similarly to aggregate the C and D season allocations into the new B season. This approach ensures that there is no net redistribution between management areas due to the new season structure.

Pollock in the GOA undergo an annual migration between summer foraging habitats and winter spawning grounds. Since surveying effort has been concentrated during the summer months, and prior to spawning in late winter, the dynamics and timing of this migration are not well understood. Regional biomass estimates are highly variable, indicating either large sampling variability, large interannual changes in distribution, or, more likely, both. There is a comprehensive survey of the Gulf of Alaska in summer, but surveying during winter has historically focused on the Shelikof Strait spawning grounds. Recently there has been expanded acoustic surveying effort outside of Shelikof Strait in winter, but there have been only infrequent attempts to survey all or most of the known spawning areas in the GOA.

Winter apportionment

An annual acoustic survey on pre-spawning aggregations in Shelikof Strait has been conducted since 1981. Since 2000, additional spawning areas have been surveyed multiple times, including Sanak Gully, the Shumagin Islands, the shelf break near Chirikof Island, and Marmot Bay. Although none of these spawning grounds are as important as Shelikof Strait, especially from a historical perspective, in some years the aggregate biomass surveyed outside Shelikof Strait has been comparable to that within Shelikof Strait.

As in previous assessments, a “composite” approach was used to estimate the percent of the total stock in each management area. The estimated 2+ biomass for each survey was divided by the total 2+ biomass of pollock estimated by the assessment model in that year and then split into management areas for surveys that crossed management boundaries. The percent for each survey was added together to form a composite biomass distribution, which was then rescaled so that it summed to 100%. Model estimates of

2+ biomass at spawning took into account the total mortality between the start of the year and spawning, and used mean weight at age from Shelikof Strait surveys.

We used the four most recent surveys at each spawning area, and used a rule that a minimum of three surveys was necessary to include an area. This criterion is intended to provide estimates that reflect recent biomass distribution while at the same time providing some stability in the estimates. The biomass in these secondary spawning areas tends to be highly variable from one year to the next. Areas meeting this criterion were Shelikof Strait, the shelf break near Chirikof Island, the Shumagin area, Sanak Gully, Morzhovoi Bay, Pavlof Bay, and Marmot Bay. While the spawning aggregations found in the Kenai Bays, and in Prince William Sound are likely important, additional surveys are needed to confirm stability of spawning in these areas before including them in the apportionment calculations. There are also several potentially difficult issues that would need to dealt with, for example, whether including biomass in the Kenai Bays would lead increased harvests on the east side of Kodiak, both of which are in area 630. In addition, the fishery inside Prince William Sound (area 649) is managed by the State of Alaska, and state management objectives for Prince William Sound would need to be considered.

The sum of the percent biomass for all surveys combined was 40.33% which may reflect sampling variability, or interannual variation in spawning location. After rescaling, the resulting average biomass distribution was 6.53%, 80.95%, and 12.52% in areas 610, 620, and 630 (Appendix table 1D.1). In comparison to last year, the percentage in area 610 is 0.3 percentage points lower, 5.9 percentage points higher in area 620, and 5.6 percentage points lower in area 630.

A1-season apportionment between areas 620 and 630

In 2002, based on evaluation of fishing patterns which suggested that the migration to spawning areas was not complete by January 20, the Gulf of Alaska plan team recommended an alternative apportionment scheme for areas 620 and 630 based on the average of the summer and winter distributions in area 630. This approach was not used for area 610 because fishing patterns during the A1 season suggested that most of the fish captured in area 610 would eventually spawn in area 610. The resulting A1 season apportionment is: 610, 6.5%; 620, 66.9%; 630, 26.6%. Under the new season structure, 25% of the TAC allocated in this way, and 25% is allocated based on the winter survey-estimated distribution in the previous section to comprise the new A season allocation.

Summer distribution

Several allocation options were presented to the plan team in 2017 to account for the variability and lack of consistency in the bottom trawl and the acoustic surveys. The option that was recommended and adopted by the plan team was a 3-survey weighted average of the sum of the acoustic and bottom trawl biomass estimates for each area. The weighted average gave weights of 1.0, 0.5, and 0.25 to 2017, 2015, and 2013, respectively. Updating this approach using 2023, 2021, and 2019 surveys gave the resulting apportionment is 610, 36.0%; 620, 21.5%; 630, 39.5%; 640, 3.0%.

Apportionment for area 640

The apportionment for area 640, which is not managed by season, is based on the estimated summer distribution of the biomass. The percentage (3.0%) of the TAC in area 640 is subtracted from the TAC before allocating the remaining TAC by season and region. The overall allocation by season and area is given in Appendix table 1D.2.

Appendix table 1D.1. Estimates of percent pollock in areas 610-630 during winter EIT surveys in the GOA. The biomass of age-1 fish is excluded from the acoustic survey biomass estimates.

Survey	*Year*	*Estimated age 2+ spawning biomass (t)*	*Survey age 2+ biomass estimate (t)*	*Percent*	*Area 610*	*Area 620*	*Area 630*
Shelikof	2021	1,117,261	457,659	41.0%	0.0%	97.1%	2.9%
Shelikof	2022	1,015,868	365,307	36.0%	0.0%	97.7%	2.3%
Shelikof	2023	1,116,045	258,829	23.2%	0.0%	98.3%	1.7%
Shelikof	2024	986,437	289,968	29.4%	0.0%	95.4%	4.6%
Shelikof			Average	32.4%	0.0%	97.1%	2.9%
			% of total biomass		0.0%	31.4%	0.9%
Chirikof	2017	1,369,421	2,485	0.2%	0.0%	26.3%	73.7%
Chirikof	2019	911,619	9,907	1.1%	0.0%	0.4%	99.6%
Chirikof	2023	1,116,045	42,804	3.8%	0.0%	36.4%	63.6%
Chirikof	2024	986,437	115,349	11.7%	0.0%	22.1%	77.9%
Chirikof			Average	4.2%	0.0%	21.3%	78.7%
			% of total biomass		0.0%	0.9%	3.3%
Marmot	2018	1,052,555	12,905	1.2%	0.0%	0.0%	100.0%
Marmot	2019	911,619	5,407	0.6%	0.0%	0.0%	100.0%
Marmot	2021	1,117,261	6,128	0.5%	0.0%	0.0%	100.0%
Marmot	2023	1,116,045	9,653	0.9%	0.0%	0.0%	100.0%
Marmot			Average	0.8%	0.0%	0.0%	100.0%
			% of total biomass		0.0%	0.0%	0.8%
Shumagin	2018	1,052,555	7,777	0.7%	95.0%	5.0%	0.0%
Shumagin	2020	830,869	4,637	0.6%	47.4%	52.6%	0.0%
Shumagin	2023	1,116,045	48,820	4.4%	96.9%	3.1%	0.0%
Shumagin	2024	986,437	14,294	1.4%	93.4%	6.6%	0.0%
Shumagin			Average	1.8%	83.2%	16.8%	0.0%
			% of total biomass		1.5%	0.3%	0.0%
Sanak	2015	1,778,260	17,905	1.0%	100.0%	0.0%	0.0%
Sanak	2016	1,667,681	3,571	0.2%	100.0%	0.0%	0.0%
Sanak	2017	1,369,421	831	0.1%	100.0%	0.0%	0.0%
Sanak	2018	1,052,555		0.0%	100.0%	0.0%	0.0%
Sanak			Average	0.3%	100.0%	0.0%	0.0%
			% of total biomass		0.3%	0.0%	0.0%
Mozhovoi	2016	1,667,681	11,459	0.7%	100.0%	0.0%	0.0%
Mozhovoi	2017	1,369,421	3,924	0.3%	100.0%	0.0%	0.0%
Mozhovoi	2018	1,052,555	3,759	0.4%	100.0%	0.0%	0.0%
Mozhovoi	2023	1,116,045	4,028	0.4%	100.0%	0.0%	0.0%
Mozhovoi			Average	0.4%	100.0%	0.0%	0.0%
			% of total biomass		0.4%	0.0%	0.0%
Pavlof	2017	1,369,421	2,092	0.2%	100.0%	0.0%	0.0%
Pavlof	2018	1,052,555	4,413	0.4%	100.0%	0.0%	0.0%
Pavlof	2023	1,116,045	5,529	0.5%	100.0%	0.0%	0.0%
Pavlof	2024	986,437	5,570	0.6%	100.0%	0.0%	0.0%
Pavlof			Average	0.4%	100.0%	0.0%	0.0%
			% of total biomass		0.4%	0.0%	0.0%
Total				40.32%	2.63%	32.64%	5.05%
Rescaled total				100.00%	6.53%	80.95%	12.52%

Appendix table 1D.2. Summer acoustic and NMFS bottom trawl biomass estimates of walleye pollock by management area. The weighted average for allocation gives weights of 1.0, 0.5, and 0.25 to 2023, 2021, and 2019, respectively.

		Summer acoustic estimates		
		Biomass (t)		
Year	*Area 610*	*Area 620*	*Area 630*	*Area 640*
2019	119,502	201,711	207,058	43,204
2021	78,468	131,625	197,118	23,937
2023	121,402	152,672	454,642	11,701
		Percent		
	Area 610	*Area 620*	*Area 630*	*Area 640*
2019	20.9%	35.3%	36.2%	7.6%
2021	18.2%	30.5%	45.7%	5.6%
2023	16.4%	20.6%	61.4%	1.6%
		Bottom trawl estimates		
		Biomass (t)		
Year	*Area 610*	*Area 620*	*Area 630*	*Area 640*
2019	119,312	36,450	90,921	10,921
2021	252,827	113,737	108,813	19,367
2023	480,242	159,889	225,582	21,889
		Percent		
	Area 610	*Area 620*	*Area 630*	*Area 640*
2019	46.3%	14.1%	35.3%	4.2%
2021	51.1%	23.0%	22.0%	3.9%
2023	54.1%	18.0%	25.4%	2.5%

Options for allocation

Option 5: Weighted average of acoustic plus bottom trawl biomass (2017-2023)

	Area 610	*Area 620*	*Area 630*	*Area 640*
	472,568	282,732	518,677	39,299
	35.98%	21.53%	39.49%	2.99%

Appendix table 1D.3. Calculation of 2025 Seasonal and Area TAC Allowances for the W/C/WYK region. Small differences in totals may occur between this table and other sources due to rounding.

Proposed 2025 ABC for W/C/WYK (t): 181,022

Winter biomass distribution			
Area	610	620	630
Percent	6.5%	81.0%	12.5%

Summer biomass distribution				
Area	610	620	630	640
Percent	36.0%	21.5%	39.5%	3.0%

1) Deduct the Prince William Sound State Guideline Harvest Level.

PWS percent	2.5%	GHL (t)	4,526
Federal percent	97.5%	Federal ABC	176,496

2) Use summer biomass distribution for the 640 allowance:

640 percent	3.0%	640 ABC (t)	5,282
610-630 percent	97.0%	610-630 ABC (t)	171,215

3) Calculate seasonal apportionments of ABC for the A1, A2, B1, and B2 seasons for areas 610-630

ABC (t)	Percent	ABC (t)
A1 season	25%	42,804
A2 season	25%	42,804
B1 & B2 seasons	50%	85,607

4) For the A1 season, the ABC allocation in 630 is based on an average of winter and summer distributions. For the A2 season, the allocation of ABC is based on the winter biomass distribution.

	A1 season		A2 season	
Area	Percent	ABC (t)	Percent	ABC (t)
610	6.5%	2,795	6.5%	2,795
620	66.9%	28,617	81.0%	34,651
630	26.6%	11,393	12.5%	5,358

5) For the B1 and B2 seasons, the allocation is based on the summer biomass distribution.

	B1 & B2 season	
Area	Percent	ABC (t)
610	37.1%	31,755
620	22.2%	18,998
630	40.7%	34,854

6) For the A and B seasons, add A1 and A2, and B1 and B2. Area 640 catch is not portioned by season.

	ABC (t)		Percent	
Area	Season A	Season B	Season A	Season B
610	5,589	31,755	3.2%	18.0%
620	63,267	18,998	35.8%	10.8%
630	16,751	34,854	9.5%	19.7%
640	5,282		3.0%	

Appendix 1E. Using causal relationships among ESP indicators to explain variation in recruitment

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Abstract
The development of climate-linked fisheries stock assessments is a high priority for the AFSC, NPFMC and NMFS. Here, we hypothesize that a new statistical framework, dynamic structural equation models (DSEM), can provide an improved framework to implement them because it allows for authors to directly incorporate expert system knowledge and existing data sets into assessments via causal relationships. To test this hypothesis, we built a research model by integrating DSEM into the GOA pollock assessment, and used recruitment as an example by linking a curated set of stock-specific indicators from the Ecosystem and Socioeconomic Profile (ESP) to log-recruitment deviations. Initial results are very promising: it was able to outperform the operational assessment from 2023 (model 23) in several important metrics such as 71% reduction in unexplained recruitment variance, improved marginal AIC (18 units), and better 1-year projections of recruitment. Research is ongoing on this case study, but early indications suggest this DSEM-linked model may be a useful framework for incorporating climate and ecosystem changes into stock assessments in Alaska. We anticipate proposing this model for operational use for review by the PT and SSC in 2025, and to explore applying it to other population processes of pollock, and processes in other AFSC stocks in the coming years.

Introduction
There is ongoing interest in linking stock assessments to climate conditions, so that the impact of short term (heatwaves) or decadal trends can be explored (Holsman et al. 2020). This is often accomplished by including covariates that are associated with time-varying processes such as recruitment (du Pontavice et al. 2022) or growth (Lee et al. 2017). This is relevant to the NPFMC, as noted by the SSC in 2023 that the "*... ESR* [ecosystem status report] *process has matured over several decades to effectively use ecosystem trends to inform annual specifications and encourages the use of trans-disciplinary approaches for linking ESR and ESPs to stock assessments in the future. The GOA pollock assessment was suggested as a potential case study, particularly in contrasting differences in the strength of 2018 vs. 2019 year classes.*"

However, stock assessment scientists often have many potential covariates from which to choose. In many cases, multiple covariates are proxies for a single hypothesized climate driver (e.g., inshore and offshore young-of-year condition as proxies for forage availability and subsequent survival). These multiple covariates will then be collinear, and collinearity will degrade the ability to estimate the strength of relationship when using a standard regression framework. To address collinearity, assessment scientists must often choose a single covariate from the suite of potential indicators, and this presents a dilemma when choosing between covariates with a direct mechanistic linkage (e.g., biological measurements of early life history) and covariates with a long time-series length (e.g., physical measurements of ocean conditions).

As an alternative, a dynamic structural equation model (DSEM; Thorson et al. 2024) allows the analyst to incorporate scientific and stakeholder input about how covariates are related to one-another, as well as to stock dynamics. This directly models the collinearity, and can mitigate the impact of collinearity (chapter 7 of Thorson and Kristensen 2024).

Here, we provide the first (to our knowledge) example of incorporating multiple ecosystem linkages in a stock-assessment model while accounting for the relationship among covariates. We incorporate stock-specific indicators created for the Ecosystem and Socioeconomic Profile (ESP; Shotwell et al. 2023a) of GOA pollock, and estimate linkages between climate indices (temperature and springtime wind), early life indicators (condition, larval, and juvenile densities), and assessment estimates of cohort strength.

Methods

Our overall approach required two key steps. The first was to hypothesize a set of alternative causal maps which are conceptual models with underlying statistical assumptions about how environmental and ecosystem indicators from the ESP relate causally to each other (with lags as necessary) and to pollock recruitment. A causal link of A to B (written A -> B) asserts that a change in A will cause a change in B, which is different from them being correlated, and could be caused by some unknown factor impacting both simultaneously. We worked closely with AFSC scientists with expertise in GOA oceanography, biology, ecology, and pollock recruitment to develop a handful of plausible causal maps, but only one is presented here for clarity (Fig. 1E.1, Table 1E.1). Since the indicators have missing data we assumed an AR(1) process on each, with an assumed observation CV of 0.1. As in the assessment, recruitment (billions of age 1 pollock on January 1) was assumed to be independent and identically distributed (iid) normal with an estimated variance term σ_R^2, but an AR(1) or other process could also be used.

Table 1E.1. Indicator variables (covariates) used in the DSEM model. All variables come from the 2023 ESP (Shotwell et al. 2023b). See Fig. 1E.1 for how they relate.

Variable name	Description
Spring SST	Spring (April-May) daily sea surface temperatures (SST) for the western and central (combined) GOA from the NOAA Coral Reef Watch Program (contact: M. Callahan). Proposed sign of the relationship to recruitment is negative.
Wind	Mean springtime (April-May) north/south surface wind strength from the National Data Buoy Center for site B-AMAA2 located in the NE Kodiak Archipelago (contact: L. Rogers). Proposed sign of the relationship to recruitment is negative.
Euphausiids	Summer euphausiid abundance from the AFSC acoustic survey for the Kodiak core survey area (contact: P. Ressler). Proposed sign of the relationship to recruitment is positive.
Fall adult condition	Fall pollock condition for adults from the pollock fishery sampled by observers (contact: C. Monnahan). Proposed sign of the relationship to recruitment is positive.
Larvae	Spring pollock larvae catch-per-unit-of-effort (CPUE) from the EcoFOCI spring survey (contact: L. Rogers). Proposed sign of the relationship to recruitment is positive.
Offshore YOY	Summer young-of-the-year (YOY) pollock catch-per-unit-of-effort (CPUE) from the EcoFOCI summer survey (contact: L. Rogers). Proposed sign of the relationship to recruitment is positive.
Nearshore YOY	Summer pollock catch-per-unit-of-effort (CPUE) of young-of-the-year (YOY) from the AFSC beach seine survey in the Kodiak region (contact: B. Laurel and M. Litzow). Proposed sign of the relationship to recruitment is positive.
YOY Condition	Summer pollock condition for young-of-the-year (YOY) from EcoFOCI summer survey (contact: L. Rogers). Proposed sign of the relationship to recruitment is positive.

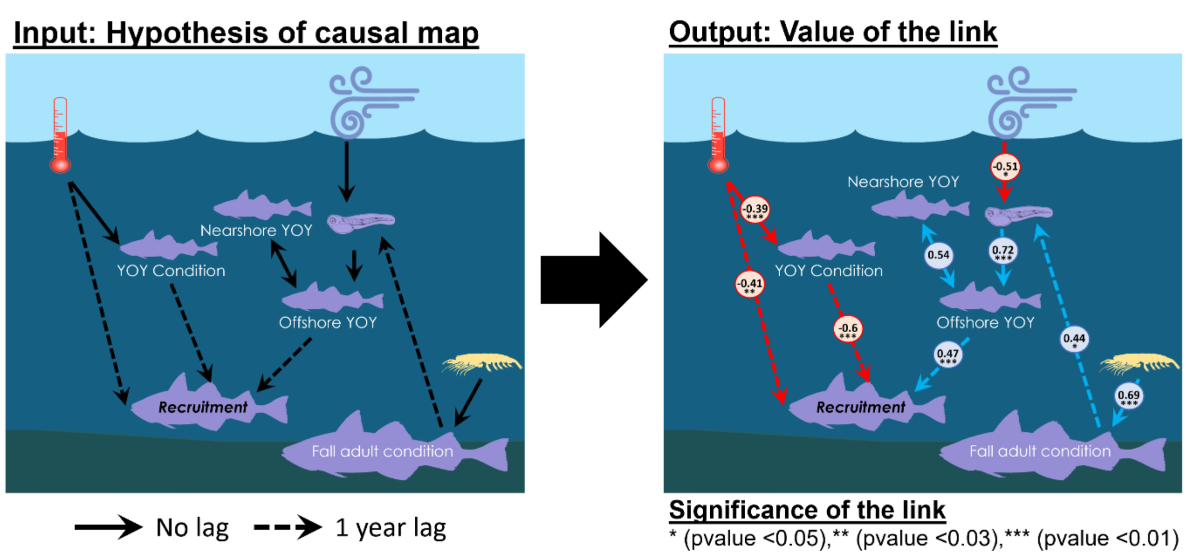

Figure 1E.1. The assumed causal map (left) and the estimated effect sizes and their statistical significance using standard Wald tests. Recruitment represents deviations from mean recruitment in log space.

The second step was to integrate DSEM into the operational stock assessment from 2023 (model 23), but without age-1 and age-2 Shelikof indices (which were giving erroneous recruitment estimates; model 23b). The joint model estimates the DSEM parameters which are the latent states (random effects) of the covariates, AR(1) variances and correlations, and effect sizes (betas) of the causal relationships. The DSEM are estimated simultaneously with the typical stock assessment parameters (F, selectivity, catchability, etc.). By setting the three betas causing recruitment (Spring SST, YOY condition, and Offshore YOY; Fig. 1E.1) to zero and turning off estimation, the model is unaffected by the causal map and reverts back to iid recruitment (model 23). We refer to this as the "R_iid" model and it is statistically comparable to the "R_DSEM" model because the data sets are identical.

Once a joint model is fitted the parameter estimates can be examined for the strength and significance of the causal relationships assumed in the causal map (Fig. 1E.1). Positive effects mean that an increase in one variable will cause an increase in its dependents, and negative effects the opposite. We also calculated a "total effect" of each covariate on recruitment by multiplying effect sizes along the full path(s) between them, noting that this effect will vary by lag. Large total effects imply changes in that covariate will have a large influence on recruitment, and thus allows for quantifying a relative importance of the drivers of pollock recruitment.

We validate the R_DSEM model using three metrics: reduction in recruitment variance, marginal AIC, and predictive performance (skill testing). In both the R_iid and R_DSEM versions of the model the recruitment variability ($V = \sigma_R^2$) is estimated, and we compute the reduction in recruitment variation as $(V_{DSEM} - V_{iid})/V_{iid}$. The bigger the reduction, the more recruitment variation is explained using the causal map. We calculated the change in AIC between the two models using marginal AIC (Burnham and Anderson 2002), i.e., counting only the fixed effects as parameters because the random effects (latent covariates, including recruitment) are integrated out via Template Model Builder's Laplace approximation (Kristensen et al. 2016). The performance of marginal AIC for hierarchical stock assessments is not well understood but has been used in other contexts (du Pontavice et al. 2022, Rogers et al. 2024).

Finally, we used a projection module in the assessment which assumes fishing under F_{ABC} as calculated in 2023, and modified by the standard Tier 3 harvest control rule for GOA pollock. Short-term projections (3 years) of recruitment were then made for 10 data peels. Projected recruitment using the R_iid model is always average recruitment, while information about future recruitment in the R_DSEM model comes from two sources. First, many important indicators (e.g., Offshore YOY; Table 1E.1) have lags of a year and so data from last year are available this year and are predictive of recruitment this year. Second, even without lags each indicator is assumed AR(1) and so will revert to an estimated mean without data, and the rate of this version depends on the properties of the estimated AR(1) properties and the terminal latent state. We used this projection module to compare predictive performance by computing the root mean square error (RMSE) using the recruitment from the full model (no peels) as the truth for each peel, and then averaging across all peels. A smaller average RMSE indicates better projection capabilities and would imply improved projections for management. Since recruitment is not precisely estimated until at least one year of data is available, we did not use peel 1 in our analysis.

Results

The DSEM-linked model had 325 fixed effects and 627 random effects for the latent covariate states, and ran in about 2 minutes with good convergence diagnostics (small gradient, invertible Hessian). The estimated covariate values were slightly different between the model versions, particularly in years with data, although there are some differences early in the time series (Fig. 1E.2). The resulting effect sizes were mostly significant and matched our expectation of the sign (Fig. 1E.1, Table 1E.1).

The three metrics for model validation all showed a meaningful improvement by using the DSEM module. The model estimated a σ_R of 1.0 and 0.54 for the R_iid and R_DSEM models, respectively, which is a reduction of 71% in unexplained recruitment variation. The marginal AIC was reduced by 18 by incorporating the causal links to recruitment into the model. When averaging over 4 or 8 peels, the RMSE for the 1-year projection of recruitment in R_DSEM was improved by 23% and 13%, respectively, when compared to the R_iid model.

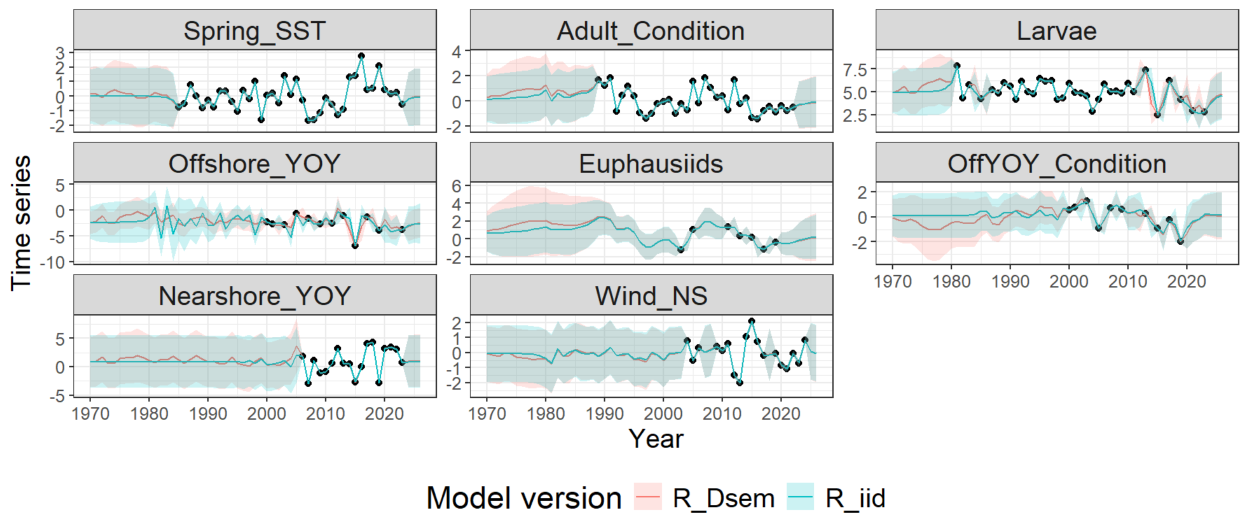

Figure 1E.2. The estimated covariates (ESP indicators) between the two models, shown as means (lines) and 95% confidence intervals (ribbons). The data are shown as black points. Most variables are scaled to have a mean of zero and variance of one. See Table 1 for details on the variables.

Estimates of recruitment and uncertainty were also quite similar, except for 2016 and the projection period where the R_DSEM model was slower to return to the mean (Fig. 1E.3).

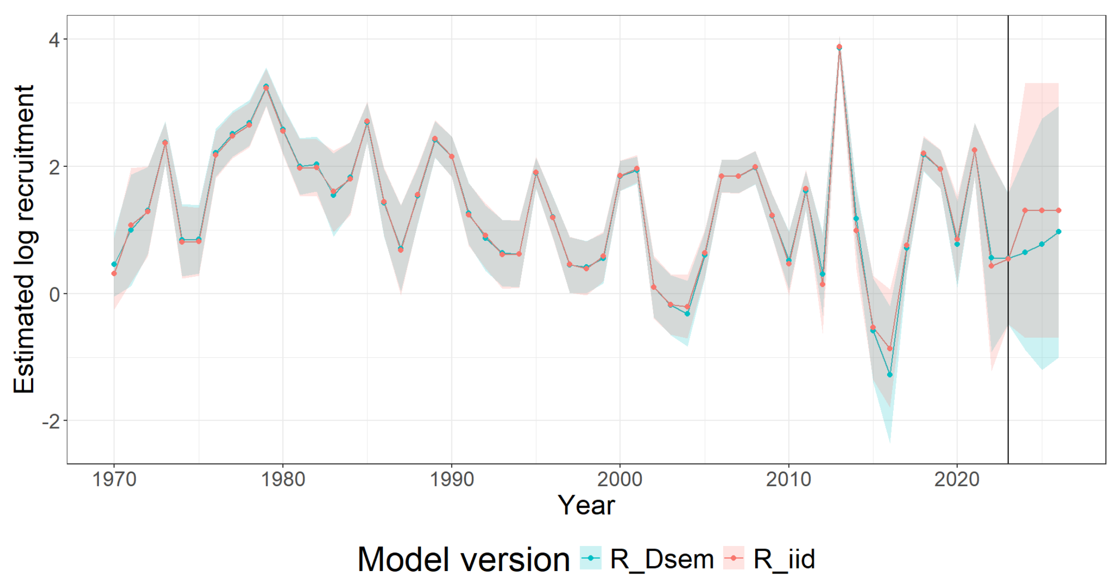

Figure 1E.3. Estimates of log recruitment (billions) between the two models (colors), shown as means (lines) and 95% confidence intervals (ribbons). The vertical line denotes the projection period.

The total effect varied by covariate, with offshore YOY and larvae being the strongest positive effects, particularly for lag 1, and offshore YOY condition the strongest negative effects for both lags 1 and 2 (Fig. 1E.4), which is counter to the initial expectation for reasons yet to be determined.

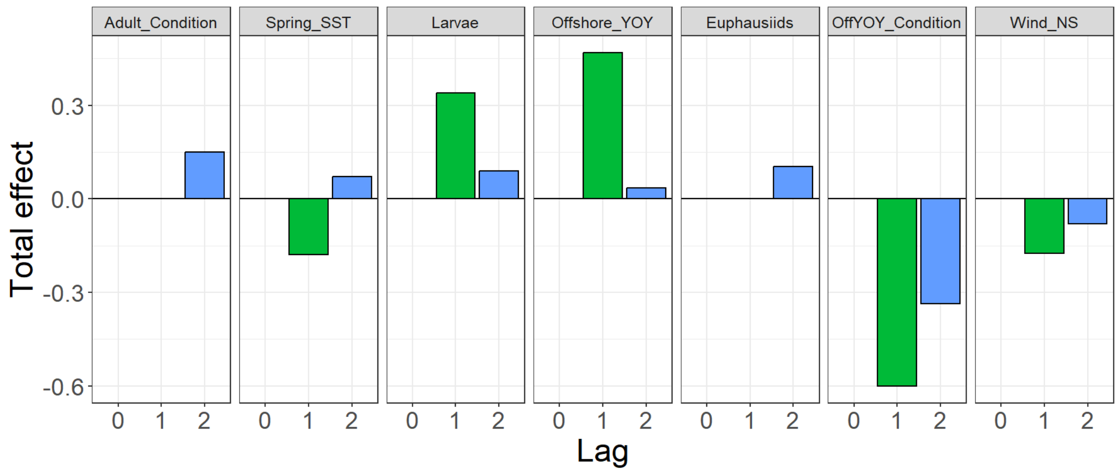

Figure 1E.4. Estimates of the total effect of a covariate (panel) on recruitment at lags 1 and 2.

Discussion

This research model investigates the performance of a new type of flexible, climate-linked stock assessment which allows for complex causal relations of measured indicators with key population processes. We tested it by linking ESP indicators to recruitment and found very clear statistical evidence that this approach can improve our understanding of pollock recruitment drivers. Specifically, the model was able to substantially reduce the amount of unexplained recruitment variance and outperform standard R_iid models in terms of projecting recruitment, and had overwhelmingly improved marginal AIC values. Taken together, we believe these results indicate that there is valuable information about recruitment in the ESP data, and that incorporating them into the operational model could lead to better management outcomes for GOA pollock.

More generally, adoption of this causal framework has several important aspects that are relevant to operational management of Alaskan groundfish. First, the author is able to leverage existing expertise on how the system works, specifically how physical characteristics affect primary production, and how primary production affects secondary production. The DSEM method also uses the ESP and ESR data in a quantitative way and helps mitigate the issue of correlated covariates by directly modeling their relationship, instead of picking one or the other covariate to use. There is no current method to formally incorporate this expertise and data in AFSC stock assessment, and consequently this information is underutilized in guiding fisheries management. Once a causal map is built, vetted, validated and estimated, the resulting links can be used to quantify important drivers of productivity (e.g., total effects), but also run counterfactual experiments to explore potential reactions to changing climate (by perturbing variables). As such they not only can improve management outcomes, but can also be used to understand why recruitment varies and the implications of climate and ecosystem change.

More research and experimentation are needed to identify appropriate approaches to build map and validate these causal maps. The model presented here is still in progress, and we plan to continue to refine the approach, publish it in 2025, and present it as an alternative to the Plan Team and SSC in 2025. Our focus was on recruitment, but this approach could be used for any time-varying process (growth, mortality, catchability, etc.) in an assessment. We plan to investigate pathways to applying DSEM to a broader set of AFSC groundfish assessments in the coming years. Two potential options are to incorporate it into WHAM (Stock and Miller 2021) or RCEATTLE (Adams et al. 2022), both of which already have AFSC assessments bridged and are in TMB (Kristensen et al. 2016) which is a requirement to fit DSEM models.

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