4. Assessment of the Shallow-water Flatfish Stock Complex in the Gulf of Alaska

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Executive Summary

Summary of Changes in Assessment Inputs

Changes in the input data

The random effects model was fit to the 1984 to 2021 NMFS summer bottom-trawl survey biomass for shallow-water flatfish (excluding rock sole) to estimate current biomass which was used to estimate ABC and OFL for 2022 and 2023. Tables of catch data were updated with catch extracted from the catch accounting system database by year (1993 to October 11, 2021), species, area and fishery.

Changes in assessment methodology

Changes were not made to the methodology. The random effects model was also used to estimate the percent of each species in the total biomass (determined using the random effects model summed over species) to estimate ABC by species. The random effects model was used to estimate the fraction of area-specific biomass to use for apportionment of the ABC.

Summary of Results

The total 2022 biomass estimate is 360,322 t an increase from the 2020 partial assessment estimate of 342,226 t. The survey biomass estimate for the shallow-water complex increased from 254,143 t in 2019 and 260,825 t in 2020 to 267,684 t in 2021. Survey biomass estimates for the shallow-water complex were higher in 2017 compared to 2015 for all species except yellowfin sole and butter sole. This was followed by a decline in 2019 for all species, except English sole, sand sole, and starry flounder. In 2021 the survey biomass estimates increased for all species except Alaska plaice (-53%), Butter sole (-28%), and yellowfin sole (-1%). The random effects model was used to estimate current biomass for estimating the OFL and ABC values.

The random effects model estimate for current (2021) biomass of shallow-water flatfish excluding rock sole was 1% lower than estimated biomass in 2020 and has been declining since 2017 (6% decline since 2017).

OFL and ABC values for 2022 and 2023 are lower in this assessment than the 2020 partial assessment mainly due to better accounting of growth of northern and southern rock sole and declining biomass and declining trends in survey biomass for the majority of shallow-water flatfish species. The current assessments recommended OFL and ABC values for 2022 are 63,895 t and 52,166 t compared to last year's assessment of 69,129 t and 56,409 t.

The recommended 2022 and 2023 shallow-water flatfish ABC and OFL levels with tier 3a estimates from projections run with the 2021 model for northern and southern rock sole (see Bryan, et al. 2021):

Stock/		**2021**				**2022**		**2023**	
Assemblage	**Area**	**OFL[1]**	**ABC[1]**	**TAC[1]**	**Catch[2]**	**OFL**	**ABC**	**OFL**	**ABC**
Shallow water flatfish	W	--	24,151	13,250	26	--	21,910	--	22,983
	C	--	28,082	28,082	1,591	--	26,083	--	27,361
	WYAK	--	2,808	2,808	<1	--	2,608	--	2,736
	SEO	--	1,123	1,123	<1	--	1,565	--	1,642
	Total	68,841	56,164	45,263			52,166		54,722

[1]As published in the Federal Register. [2]As of Oct. 1, 2021.

Note: Tables of ABCs, OFLs, and TACs published in the Federal Register are available for: 2021: https://alaskafisheries.noaa.gov/sites/default/files/17_18goatable1.pdf

The recommended shallow-water flatfish ABC and OFL levels are:

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2021	2022	2022	2023
M (natural mortality rate)[1]	0.2	0.2	0.2	0.2
Tier	3a and 5	3a and 5	3a and 5	3a and 5
Biomass (t)	339,593	342,226	360,322	372,674
F_{OFL}	*	*	*	*
$maxF_{ABC}$	*	*	*	*
F_{ABC}	*	*	*	*
OFL (t)	68,010	69,129	63,895	66,964
maxABC (t)	55,463	56,409	52,166	54,721
ABC (t)	55,463	56,409	52,166	54,721
Status	As determined *this* year for:			
	2019	2020	2020	2017
Overfishing	No	NA	No	NA

* See Tables 4.36 and 4.37 in Bryan, et al. 2021 for values by species. [1] Northern rock sole male M=0.232 in the central GOA and M=0.254 in the western GOA, southern rock sole male M= 0.253 in the central GOA and M=0.271 in the western GOA, all other M=0.2.

Area Apportionment

The recommended apportionments for the 2022 ABC are estimated using the random effects model estimates of biomass for the shallow water flatfish complex by management areas.

	Western	Central	Yakutat	Southeast
Proportions this assessment	42%	50%	5%	3%
2022 ABC	21,910	26,083	2,608	1,565
2023 ABC	22,983	27,360	2,736	1,642

The history of biomass, OFL, ABC, TAC and catch for shallow-water flatfish is:

Species/Assemblage	Year	Biomass	OFL[1]	ABC[1]	TAC[1]	Catch
Shallow water flatfish	2007	278,369	62,418	51,450	19,972	8,359
	2008	268,611	74,364	60,989	22,256	8,851
	2009	256,552	74,364	60,989	22,256	8,391
	2010	250,540	67,768	56,242	20,062	5,824
	2011	247,848	67,768	56,242	20,062	3,991
	2012	241,427	55,943	45,802	37,029	4,010
	2013	232,788	55,680	45,484	37,077	5,507
	2014	222,518	50,007	40,805	33,679	4,729
	2015	210,980	54,207	44,205	35,381	3,341
	2016	204,809	54,520	44,364	36,763	3,798
	2017	202,419	54,583	44,512	36,843	2,557
	2018	200,497	67,240	54,688	42,732	2,751
	2019	199,201	68,309	55,587	43,217	2,858
	2020	199,600	68,010	55,463	44,864	4,348
	2021	203,679	68,841	56,164	45,263	1,594*

[1]As published in the Federal Register. [2]As of Oct. 11, 2021. * As of October 11, 2021.

Responses to SSC and Plan Team Comments on Assessments in General

SSC (Oct 2016): "The SSC reminds groundfish and crab stock assessment authors to follow their respective guidelines for SAFE preparation."

Authors' response: SAFE guidelines were followed.

Responses to SSC and Plan Team Comments Specific to this Assessment

There were no specific comments for this assessment from 2017-2020.

Introduction

The "flatfish" species complex previous to 1990 was managed as a group in the Gulf of Alaska and included the major flatfish species inhabiting the region with the exception of Pacific halibut (*Hippoglossus stenolepis*). The North Pacific Fishery Management Council divided the flatfish assemblage into four categories for management in 1990; "shallow flatfish" and "deep flatfish" (Table 4.1), flathead sole (*Hippoglossoides elassodon*) and arrowtooth flounder (*Atheresthes stomias*). This classification was made because of the significant difference in halibut bycatch rates in directed fisheries targeting on shallow-water and deep-water flatfish species. Arrowtooth flounder, because of its present high abundance and low commercial value, was separated from the group and managed under a separate acceptable biological catch (ABC). Flathead sole were likewise assigned a separate ABC since they overlap the depth distributions of the shallow-water and deep-water groups. In 1993 rex sole (*Glyptocephalus zachirus*) was split out of the deep-water management category because of concerns regarding the Pacific ocean perch bycatch in the rex sole target fishery.

The major species, which account for the majority of the current biomass for shallow-water flatfish are: northern rock sole (*Lepidopsetta polyxystra*), southern rock sole (*Pleuronectes bilineata*), butter sole (*Pleuronectes isolepis*), yellowfin sole (*Pleuronectes asper*), and starry flounder (*Platichthys stellatus*). For this assessment, biomass, fishing mortality rates, and ABC estimates are presented for each species and management category.

Beginning with the 1996 triennial trawl survey, rock sole was split into two species, northern rock sole and southern rock sole. Due to overlapping distributions, differential harvesting of the two species may occur, requiring separate management in the future.

This report describes flatfish catches taken from 1993 through October 11, 2021 and presents information on the status of flatfish stocks and their potential yield based a random effects model fit to Gulf of Alaska demersal trawl survey data through 2021 and population dynamics model estimates for Northern and Southern rock sole (Bryan, at al. 2021).

Fishery

Since the passage of the MFMCA in 1977, the fishery for flatfish in the Gulf of Alaska has undergone changes. Flatfish catch was primarily taken by foreign vessels targeting other species until 1981. With the cessation of foreign fishing in 1986, joint venture fishing began to account for the majority of the catch. In 1987, the gulf-wide flatfish catch increased with the joint venture fisheries accounting for nearly all of the increase. After 1988, only domestic fleets harvested flatfish.

The North Pacific Fishery Management Council (NPFMC) Central Gulf management area has produced the majority of the flatfish catch from the Gulf of Alaska (Table 4.2). Since 1988 the majority of the harvest has occurred on the continental shelf and slope east of Kodiak Island. Although arrowtooth flounder comprised about half the catch, the fishery primarily targeted on rock, rex and Dover sole.

Data

Fishery:

Shallow-water flatfish catch since 1993 has varied between 8,398 t and 2,035 t (1999) and peaked at 8,851 t in 2008 (Table 4.2). Catch has generally declined since 2009 from 8,391 t to 2,557 t in 2017 and increased to 4,348 t in 2020. Catch was 1,594 t in 2021 through October 11th.

Flatfish catch is currently reported for deep-water flatfish, shallow-water flatfish, arrowtooth flounder, flathead sole and rex sole by management area. This assessment includes shallow-water flatfish only. The catch by species in each year and area was extracted from the AKFIN database (Table 4.3, Figure 4.1). Most of the shallow-water flatfish catch (other than assigned to shallow-water flatfish fishery) comes from the Pacific cod fishery, followed by arrowtooth flounder and pollock bottom trawl and then flathead sole, rex sole, and rockfish fisheries (Tables 4.4 and 4.5 and Figure 4.2). Table 4.6 documents annual research catches (1977 to 2021) from NMFS longline and trawl surveys. Prohibited species catch and non-target species catch in the shallow water flatfish fishery are contained in Tables 4.7 and 4.8.

The shallow-water flatfish catch in 2021 through October 11th was about 3% of the ABC (56,164 t) and about 4% of the TAC (45,263 t). In 2020 (the most recent full year of data), total catch was 8% of the ABC and 10% of the TAC. Retention of shallow water flatfish has been ~90% since 2000, although retention declined from 93.8% in 2016 to 80% in 2017. Retention increased to 92% in 2018, was 95% in 2020 and as of October 11th, 2021 is at 81% (Table 4.9).

Survey:

The principal source of information for evaluating the condition of flatfish stocks in the Gulf of Alaska is the bottom trawl survey conducted from 1984 to 2021 (Table 4.10 and Table 4.11). Flatfish biomass estimates from the 2001 to 2021 surveys by North Pacific Fishery Management Council (NPFMC)area and species are given in Tables 4.12a through 4.12i. The 2001 survey was conducted in the western and central portions of the Gulf of Alaska only. The 2001 survey biomass for the eastern Gulf of Alaska was approximated using the average of the 1999 to 2003 eastern Gulf of Alaska biomass estimates for all flatfish species and not included in this assessment.

Survey abundance estimates for the shallow-water complex were lower in 2021 compared to 2019 for all species except English sole and sand sole (Figure 4.3).

Length composition data from the triennial survey are shown in Figures 4.4 to 4.8. Aging of Gulf of Alaska flatfish species has been sporadic since the inception of the triennial surveys.

The distribution of survey sampling stations on the shelf and slope followed the methods developed for the shelf portion of the 1984 survey (Brown 1986). There was no sampling deeper than 500 meters during 1990 to 1996, and 2001 because of limited vessel time. The 500-1,000 m depths sampled in 1984 and 1987, 1999, 2007, 2009 and 2011 are generally outside the depth range of most shallow-water flatfish species. The 2003 and 2005 survey covered depths to 700 m.

Experimental evidence suggests that flatfish biomass estimates derived from the Noreastern trawl used in the survey may underestimate true biomass because the escapement occurs under the net (e.g., Weinberg et al., 2002).

Analytic Approach

The random effects model (Spencer, et al. 2013) was fit to the Gulf of Alaska bottom trawl survey biomass data for 1984-2021 to estimate current biomass for each of the tier 5 species within the SWF complex. The 2001 survey data were excluded because the eastern area was not surveyed. The random

effects model was also fit to total SWF survey biomass summed over the tier 5 species. The biomass estimates from the species-specific random effects models were adjusted so that the sum over species was equal to the result from the random effects model fit to total tier 5 species survey biomass. The adjusted biomass estimates were used to develop species-specific OFLs and ABCs and added to the management advice from the 2021 projection model for northern rock sole and southern rock sole (Bryan 2021) to provide a SWF complex OFL and ABC.

The apportionment by area was estimated by fitting the random effects model to the survey biomass summed for all species (including tier 3 rock sole) by area and estimating the percent biomass in 2021 by area.

The likelihood equation for the random effects model is,

$$\sum_{i=1}^{yrs}\left\{0.5\left(\log(2\pi\sigma_i^2)+\left(\frac{(\hat{B}_i-B_i)^2}{\sigma_i^2}\right)\right)\right\}+\sum_{t=2}^{yrs}\left\{0.5\left(\log(2\pi\sigma_p^2)+\left(\frac{(\hat{B}_t-\hat{B}_{t-1})^2}{\sigma_p^2}\right)\right)\right\}$$

where,

B_i is the log of observed biomass in year i,

$\widehat{B_t}$ is the model estimated log biomass in year t,

σ_i^2 is the variance of observed log biomass in year i,

σ_p^2 is the variance of the deviations in log survey biomass between years (i.e. process error variance), σ_p^2 was estimated as $e^{(2)}$, where is a parameter estimated in the random effects model and,

yrs is the number of years of survey biomass values.

Parameters Estimated Outside the Assessment Model

Natural mortality

Natural mortality rates for Gulf of Alaska flatfish species were estimated using the methods of Alverson and Carney (1975), Pauly (1980), and Hoenig (1983) in the 1988 assessment (Wilderbuer and Brown 1989). The estimates were different for each method and were not inconsistent with the value of 0.2, used in previous assessments (Wilderbuer and Brown 1989). A natural mortality value of 0.2 was used for all SWF flatfish excluding rock soles.

Growth

Table 15 contains growth estimates for Gulf of Alaska yellowfin sole. There are very few or no age-length samples for Alaska plaice, butter sole, English sole, sand sole, and starry flounder.

Parameters Estimated Inside the Assessment Model

Random Effects Model

There were 11 parameters estimated, one for each random effects model fitted. One parameter for the summed biomass (Table 4.13a), six parameters for the fit to biomass by species (Table 4.13b), and four parameters for the fit to the four areas summed over species (including rock sole) (Table 4.13a).

Results

The total current biomass estimate is 360,322 t increased from 342,226 t for 2022 from last year's assessment (executive summary table). This is due to the majority of species experiencing declines in biomass (Figure 4.3).

The fits to total biomass (excluding rock sole) from the random effects model smooth the data fitting higher than the 2013, 2015, 2019, and 2021 observed survey biomass, and lower than the 2017 biomass (Figure 4.10). The fits to the species-specific survey biomass are shown in Figure 4.3. Survey and estimated biomass declined in 2021 for all species, except English sole and sand sole. English sole estimated biomass increased by 21% and sand sole increased by 6%. Alaska plaice declined by 19%, butter sole declined by 3%, starry flounder declined by 4%, and yellowfin sole declined by 3%.

The fits to biomass by area were used to apportion the ABC (Figures 4.9 and 4.10). Apportionment by area was estimated at 42% Western, 50% Central, 5% Yakutat and 3% Southeast (Table 4.13a and 4.9 and 4.10). The trends in biomass over time in the western and central areas that contain most of the biomass are similar (Figure 4.10). Biomass in the western area increased more rapidly in the 1990s than in the Central area and both peaked in 2007. This was followed by a rapid decline in the Central area between 2011 and 2015. This decline was more gradual in the Western area. Figures 4.3 shows the random effects model fits to individual species survey biomass for the estimation of biomass, OFL and ABC by species.

Parameter estimates from the random effects model fits are shown in Tables 4.13a and 4.13b. The process variance ranged between 0.006 and 0.14 for the model fits to the area-specific data (Table 4.13a). The process variance for the fit to total biomass (excluding rock sole, 98,205 t) was 0.0041 which results in a smoother fit to the data than higher process variances. The parameter estimated in the random effects model (λ) was -2.754 with a standard error of 0.0494 (Table 4.13b). Process variances for the species-specific random model fits varied between 0.01 and 0.27.

Risk Table

The shallow water flatfish management complex in the GOA consists of eight species: southern rock sole (*Lepidopsetta bilineata*), northern rock sole (*Lepidopsetta polyxystra*), yellowfin sole (*Limanda aspera*), starry flounder (*Platichthys stellatus*), butter sole (*Isopsetta isolepis*), English sole (*Parophrys vetulus*), Alaska plaice (*Pleuronectes quadrituberculatus*), and sand sole (*Psettichthys melanostictus*). In this risk table we focus on northern and southern rock sole, and butter sole, as the most abundant species of commercial importance, and yellowfin sole as a more vulnerable stock.

Assessment related considerations

Northern and southern rock sole are assessed as tier 3 species with an age-structured catch-at-age model, which relies on data from the GOA biennial bottom trawl trawl survey (biomass, length composition, and conditional age-at-length. The remainder of the shallow water flatfish species are assessed with the random effects model that relies solely on the biennial bottom trawl surveys in the GOA.

The northern rock sole model fit to the bottom trawl biomass exhibits a pattern of autocorrelation indicating potential non-stationarity. Additionally this assessment exhibits a strong retrospective pattern. Both issues require further investigation in the future.

We propose a level 2 designation for the assessment category in the risk table.

Population dynamic considerations

The two larger populations and tier 3 species, northern and southern rock sole, in the shallow water flatfish species complex are relatively lightly exploited and are exhibiting relatively stable or experiencing increasing trends in biomass. English sole and sand sole are also exhibiting increasing trends, while butter sole and starry flounder have been declining since 2009. Yellowfin sole biomass has been steadily declining since 1996. Yellowfin sole catch was highest between 1996 and 2000 corresponding to the decreasing trend early in the time series, but has remained quite low since 2001. Although yellowfin sole is experiencing light exploitation, biomass has declined by ~ 65% since 1996. Biomass in 1996 was estimated to be 73,179 t and in 2021 biomass is 25,460 t.

Given the relatively light exploitation of this species complex, we propose a level 1 designation for this category in the risk table.

Environmental/ecosystem considerations

We scored this category as level 1 (normal concern) for shallow water flatfish given moderate thermal conditions for adults and moderate to below average thermal conditions for larvae, mixed/unknown trends in abundance of prey, predators, and competitors, and a lack of a mechanistic understanding for the direct and indirect effects of environmental change on the survival and productivity of most shallow water flatfish. A trend to watch is the declining catch of GOA yellowfin sole, and whether there is a relationship to warming temperatures (e.g., distribution shift or physiological effects).

Northern and southern rock sole are demersal except for a pelagic larval phase. Yellowfin sole and butter sole have pelagic egg and larval phases, but are otherwise demersal. Northern rock sole are found in western and central Gulf of Alaska waters shallower than 40m in the summer, and deeper waters (down to 150m) in the winter (Abookire & Norcross, 1998). Temperature affects spawn timing, size-at hatch, timing of metamorphosis, and northern rock sole larval growth, which has a carry-over effect to first year growth and recruitment (Hurst et al. 2010). Winter-spring spawning temperatures positively relate to size-at-hatch (Fedewa et al. 2016). Southern rock sole spawn in the summer and can be found 50-100 m, returning to deeper waters in the winter. Butter sole spawn in nearshore areas in the winter and spring.

It is reasonable to expect that the 2021, and predicted 2022 average deeper ocean temperatures, would provide good spawning habitat and the average to cooler surface temperatures contribute to good pelagic conditions for shallow water flatfish during a time when they are growing to a size that promotes over winter survival. However, relatively low abundance of age-0 northern and southern rock sole were observed in the EcoFOCI spring survey (Deary, 2021), potentially reflecting poor larval feeding conditions. Low abundance of larval northern rock sole, along with larval walleye pollock and Pacific cod, have been observed in previous years that had warmer ocean temperatures and average to late phytoplankton bloom timing (e.g., 2019, 2016). While 2021 was not characterized as a ‘warm year’, the WGOA spring surface temperatures were above average and WGOA bloom timing was average with relatively low chlorophyll-a abundance (Watson 2021). Ocean temperatures at the surface and at depth on the shelf were around the long-term average in 2021 (i.e., not a marine heatwave year, Watson 2021; AFSC Bottom Trawl Survey, Laman 2021; AFSC EcoFOCI survey, Rogers 2021; Seward Line Survey, Danielson 2021). Although the western GOA started the year with warmer surface waters (satellite data; Watson 2021) and there was above average warmth (5.2°C) at 200m depth along the outer edge of the shelf during the summer (AFSC Longline Survey; Siwicke 2021), 2021 is not considered a marine heatwave year. Numerous temperature time series showed signs of cooling from previous surveys (returning to average from recent marine heatwave years 2014-2016, 2019) at the surface and at depth and 2022 surface temperatures are predicted to continue cooling, in alignment with La Niña conditions and a negative Pacific Decadal Oscillation.

Larval northern and southern rock sole, and yellowfin sole larvae, eat plankton and algae, and early juveniles eat zooplankton. The diet of late juvenile and adult rock sole includes bivalves, worms, amphipods, mollusks, and crustaceans. Adult yellowfin sole eat bivalves, polychaetes, amphipods and echiurids. Feeding for rock sole and yellowfin sole occurs primarily in the spring and summer, and diminishes when they overwinter in deeper waters along the shelf-margin. Adult butter sole feed on marine worms, young herring, shrimp and sand dollars. Planktivorous foraging conditions were moderate and regionally variable across the GOA in 2021. Southern rock sole body condition continues a negative trend (lower weight at a given length) since 2015 with positive condition (improved from 2019) in EGOA and negative condition in the WGOA which is considered the edge of it's range (Bottom Trawl Survey, O'Leary 2021). The western GOA had lower spring biomass of large copepods and approximately average biomass of smaller copepods was around Kodiak, characteristics of previous warm, less productive years (e.g., 2019). Planktivorous seabird reproductive success, an indicator of zooplankton availability and nutritional quality, was below average just north of Kodiak (E. Amatuli Island; Drummond 2021). Around the eastern edge of WGOA (Seward Line, Middleton Island) the biomass of large copepods was average to above-average (Seward Line Survey, Hopcroft 2021) and planktivorous seabirds had better reproductive success (Middleton Island, Hatch 2021), indicating improved forage conditions. The eastern GOA inside waters of Icy Strait, northern southeast Alaska, had higher than average large copepods and euphausiids (AFSC SECM Survey, Icy Strait, Fergusson 2021), however planktivorous seabirds had mixed reproductive success. Shrimp have been increasing around Chirikof, Yakutat, and southeastern GOA regions, but declining around Kodiak over the past 5 years (AFSC Bottom Trawl Survey, Laman 2021). Little is known about the status of bivalves, polychaetes, and the other prey groups.

There is no cause to suspect increased predation or competition on larval or adult shallow water flatfish. Northern rock sole overlap in distribution and diets with Pacific halibut, yellowfin sole, and English sole (Hurst et al. 2007). In the eastern Bering Sea, Wilderbuer et al. (1992) found primary competitors of yellowfin sole were Alaska plaice, rock sole, starfish, crabs, and to a lesser extent, eelpouts. Predators of rock sole include sharks, marine mammals, and large fish, including rock sole that eat larval and juvenile rock sole, Pacific halibut, Pacific cod, walleye pollock, and yellowfin sole. Predators of yellowfin sole include Pacific cod, skates, and Pacific halibut. In general, apex fish predators in the GOA are at relatively low abundances (including cod and arrowtooth flounder, although sablefish are abundant) (Whitehouse 2021).

Fishery performance considerations

We note that the fishery has consistently only captured a small fraction of the ABC (~9% on average since 2007) and primarily caught in the central GOA. On average 97% of rock sole are caught in the central GOA, where ~38% of northern rock sole survey biomass is observed and ~56% of southern rock sole survey biomass is observed. Overall this complex is lightly exploited and incidentally captured, but given the overlapping distributions of all species could put weaker stocks at risk. Given the relatively light exploitation of this species complex, we propose a level 1 designation for this category in the risk table.

Summary and ABC recommendations

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ ecosystem considerations*	*Fishery Performance considerations*
Level 2	Level 1	Level 1	Level 1

Harvest Recommendations

ABCs for all shallow water flatfish species other than northern and southern rock sole were calculated using F_{ABC}= 0.75 M and F_{OFL} = M (tier 5), since maturity information are not available. Natural mortality was assumed to be 0.2 for yellowfin sole, butter sole, starry flounder, English sole, Alaska plaice, and sand sole.

The flatfish complex ABCs for the 2022 and 2023 fishing seasons were calculated using the F_{ABC} fishing mortality rate, and the random effects model estimate of current biomass for each species over all areas except rock sole ABCs which are estimated from an age-structured assessment model (Bryan et al. 2021).

The 2022 ABC for shallow-water flatfish declined to 52,166 t from 56,409 t, which was estimated in 2020 by conducting a partial assessment. The estimated 2023 ABC was estimated at 54,721 t.

Due to the overlapping distributions of flatfish species, especially in the shallow-water group, it may be difficult to target a species within an arbitrary management group without impacting other flatfish species in that group or other species which were "split-out" and managed separately. Given the present management strategy used by the North Pacific Fishery Management Council for Gulf of Alaska flatfish, some species may be subjected to higher fishing mortalities than that resulting from the recommended ABCs. The ongoing efforts by the observer program to improve species identification will help monitor these fisheries in the event that species compositions change.

Under tiers 4 through 6 projections of harvest scenarios equivalent to tier 1 through 3 stocks are not possible. No projections were done for the shallow-water flatfish complex.

Ecosystem Considerations

Ecosystem Effects on the Stock

Flatfish consume a variety of benthic organisms (Table 4.16; Livingston and Goiney 1983, Yang 1990). Larval rock sole eat plankton and algae and early juveniles eat zooplankton. The diet of late juvenile and adults includes bivalves, worms, amphipods, mollusks, and crustaceans. (https://www.fisheries.noaa.gov/species/rock-sole). Yellowfin sole larvae and early juveniles eat plankton and algae. The diet of late juveniles and adults eat bivalves, worms, amphipods, mullusks, krill, shrimp, brittle stars, sculpins, and other crustaceans (https://www.fisheries.noaa.gov/species/yellowfin-sole). Yellowfin sole adults feed on bivalves, polychaetes, amphipods and echiurids during the summer, on nearshore, sandy substrates. Adult feeding diminishes in the winter as they migrate to deeper waters along the shelf margin. Other flatfishes consume mostly polychaetes, crustaceans and mollusks. Butter sole diet includes marine worms, young herring, shrimp and sand dollars (Hart 1973).

Predators of the species that make up the shallow water flatfish complex are likely similar, but data are limited. Predators of rock sole include sharks, marine mammals, and large fish, including rock sole that eat larval and juvenile rock sole, Pacific halibut, and Pacific cod (https://www.fisheries.noaa.gov/species/rock-sole) (Yang and Nelson 2000). Predators of juvenile yellowfin sole include Pacific cod and halibut, and skates (https://www.fisheries.noaa.gov/species/yellowfin-sole). In the eastern Bering Sea, Wilderbuer et al. (1992) found primary predators of yellowfin sole were Pacific cod, walleye pollock, plain sculpin, and marine mammals, and to a lesser extent Pacific halibut and seabirds.

Fishery Effects on the Ecosystem

Non-target and prohibited species catch in the directed GOA shallow-water flatfish fishery are shown in Tables 4.8 and 4.9. In recent years the 3 highest non-target catch was from state managed rockfish, sea stars and miscellaneous fish. Prohibited species catch is mostly Bairdi Tanner crab, followed by non-Chinook salmon, halibut, and Chinook salmon.

Data Gaps and Research Priorities

More aging data are needed to improve estimates of natural mortality for Tier 5 species.

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Tables

Table 4.1. Flatfish constituents of the NPFMC Gulf of Alaska shallow-water management category.

Common name	**Genus and Species**
Northern rock sole	*Lepidopsetta polyxystra*
Southern rock sole	*Pleuronectes bilineata*
Yellowfin sole	*Pleuronectes asper*
Starry flounder	*Platichthys stellatus*
Butter sole	*Pleuronectes isolepis*
English sole	*Pleuronectes vetulus*
Alaska plaice	*Pleuronectes quadrituberculatus*
Sand sole	*Psettichthys melanostictus*

Table 4.2. Gulf of Alaska shallow water flatfish catch, 1993 to October 8, 2021, by North Pacific Fishery Management Council regulatory area and harvest specifications. Western Gulf (WG), Central Gulf (CG), Southeast (SE), West Yakutat (WY).

	Area							
Year	WG	CG	SE	WY	Total	OFL	ABC	TAC
1993	125	8,398		0	8,523	70,860	50,480	16,240
1994	50	3,327		3	3,379	44,670	34,420	18,630
1995	55	4,297		1	4,353	60,262	28,790	18,630
1996	105	7,869		17	7,990	60,262	28,790	18,630
1997	56	6,405		36	6,496	59,540	43,150	18,630
1998	51	2,792	52	1	2,896	59,540	43,150	18,630
1999	97	1,935	2	0	2,035	59,540	43,150	18,770
2000	390	5,978		44	6,412	45,330	37,860	19,400
2001	78	5,399		0	5,478	45,330	37,860	19,400
2002	106	6,376		2	6,485	61,810	49,550	20,420
2003	132	4,192	0		4,324	61,810	49,340	21,620
2004	101	2,795		1	2,897	63,840	52,070	20,740
2005	84	4,554			4,638	63,840	52,070	20,740
2006	100	7,078	0	0	7,178	62,418	51,450	19,972
2007	63	8,296	0		8,359	62,418	51,450	19,972
2008	61	8,790			8,851	74,364	60,989	22,256
2009	77	8,314		0	8,391	74,364	60,989	22,256
2010	83	5,741	0	1	5,824	67,768	56,242	20,062
2011	122	3,869	0	0	3,991	67,768	56,242	20,062
2012	152	3,858	0	0	4,010	61,681	50,683	37,029
2013	153	5,354	0	0	5,507	55,680	45,484	37,077
2014	245	4,483	0	1	4,729	50,007	40,805	33,679
2015	274	3,067	0	0	3,341	54,207	44,205	35,381
2016	147	3,650	0	0	3,798	54,520	44,364	36,763
2017	270	2,287	0	0	2,557	54,583	44,514	36,843
2018	55	2,695	1	1	2,751	67,240	54,688	42,732
2019	72	2,785	0	0	2,858	68,309	55,587	43,217
2020	16	4,333	0	0	4,348	68,010	55,463	44,864
2021	19	1,575	0	0	1,594	68,841	56,164	45,263

Table 4.3. Catch (t) by species in the shallow-water flatfish group and by area for 1993 to October 11, 2021. Western Gulf (WG), Central Gulf (CG), Southeast (SE), West Yakutat (WY).

Rock sole			Area		
Year	WG	CG	SE	WY	Grand Total
1993	123	7989		0	8112
1994	44	2962		2	3008
1995	47	3875		1	3923
1996	72	6523		0	6595
1997	26	5406		34	5467
1998	40	2440	51	1	2532
1999	64	1699	2	0	1765
2000	341	5001		44	5387
2001	76	4696		0	4772
2002	102	5460		2	5564
2003	128	3426	0		3555
2004	83	2133		1	2217
2005	82	4049			4131
2006	52	5712	0	0	5763
2007	59	6668	0		6727
2008	58	7211			7269
2009	75	6464		0	6539
2010	80	3490	0	0	3571
2011	120	3118		0	3238
2012	123	2800	0	0	2923
2013	130	4070	0	0	4200
2014	199	3444	0	1	3644
2015	224	2639	0	0	2863
2016	130	3037	0	0	3167
2017	262	1855	0	0	2117
2018	43	2063	0	1	2106
2019	66	2106	0	0	2172
2020	15	3160	0	0	3175
2021	15	1115	0	0	1130

Table 4.3. continued.

Alaska plaice	Area				
Year	WG	CG	SE	WY	Grand Total
1993	0	1			1
1994		5			5
1995	0	26			26
1996	0	66			66
1997		69			69
1998	0	10			10
1999	1	0			1
2000	3	0			4
2001	1	1			2
2002		1			1
2003	1	15			16
2004	3	5			8
2005		3			3
2006		1			1
2007	0	6			6
2008	0	3			3
2009	0	8			8
2010	0	22			23
2011	1	9			10
2012	0	7			7
2013	4	13			17
2014	1	4			5
2015	0	2			2
2016	0	3			3
2017	0	4			4
2018	2	7			9
2019	0	4			4
2020		4			4
2021		1			1

Table 4.3. continued.

Starry flounder	Area				
Year	WG	CG	SE	WY	Grand Total
1993		80			80
1994		52		0	52
1995	0	134			135
1996	0	806		0	806
1997		401		0	402
1998	0	148	1		150
1999	1	86			87
2000	3	265			268
2001	0	86			86
2002		110			110
2003	0	139			139
2004	0	114		0	114
2005		111			111
2006		265			265
2007	0	154			154
2008	0	130			130
2009	0	115			115
2010	0	158			158
2011	0	112			112
2012	1	207			208
2013	0	135	0	0	135
2014	35	136			171
2015	45	93			138
2016	2	69			72
2017	3	211		0	214
2018	0	82	0	0	82
2019	0	107	0	0	107
2020	0	73			73
2021	0	36	0	0	36

Table 4.3. continued

Butter sole	Area				
Year	WG	CG	SE	WY	Grand Total
1993		250			250
1994	2	227			229
1995	0	177			177
1996	30	380			410
1997	27	425			452
1998	10	168			178
1999	2	146			148
2000	21	695			716
2001	1	598			599
2002	2	779		0	781
2003	1	607			608
2004	7	532			539
2005	0	378			379
2006	0	1084			1084
2007		1431			1431
2008	0	1419			1419
2009		1698			1698
2010	0	2034		0	2035
2011	0	601			601
2012	14	818	0	0	831
2013	1	1078			1079
2014	0	834		0	834
2015	0	291			291
2016	0	501	0	0	502
2017	1	163			164
2018	3	416			419
2019	0	295	0		296
2020	0	595	0	0	595
2021	0	237			237

Table 4.3. continued.

English sole	Area				
Year	WG	CG	SE	WY	Grand Total
1993	0	6			6
1994	0	8		0	8
1995	0	16		0	16
1996	0	12		17	29
1997	1	21		1	22
1998	0	10		0	11
1999	6	1		0	7
2000	2	11			13
2001	0	6			6
2002		13			13
2003	0	2			2
2004	0	6		0	6
2005	0	2			2
2006	48	10			58
2007	3	22			26
2008	2	23			26
2009	1	27			28
2010	2	35		0	37
2011	1	27	0		29
2012	14	25			40
2013	17	52		0	69
2014	5	62	0	0	67
2015	3	38		0	41
2016	13	36	0	0	49
2017	2	53		0	55
2018	5	124			129
2019	5	262	0	0	267
2020	1	479	0	0	480
2021	3	138			141

Table 4.3. continued.

Sand sole	Area				
Year	WG	CG	SE	WY	Grand Total
1993	1				1
1994		15		0	15
1995	0	10			10
1996	2	5			6
1997	2	41			43
1998		1			1
1999		1			1
2000	1	5			6
2001	0	13		0	13
2002	2	12			13
2003		3			3
2004		4			4
2005		3			3
2006		5			5
2007		3			3
2008		3			3
2009	0	2			2
2010		1			1
2011		1			1
2012	0	1			1
2013		4			4
2014		2			2
2015	0	2			2
2016	0	0		0	0
2017		1			1
2018		1			1
2019		11			11
2020		17			17
2021		45			45

Table 4.3. continued.

Yellowfin sole			Area		
Year	WG	CG	SE	WY	Grand Total
1993	1	71		0	72
1994	4	58			61
1995	7	59			66
1996	1	77			79
1997	0	42			42
1998	0	15			15
1999	24	2			26
2000	18	1			18
2002	1	2			2
2003	0	0			0
2004	8				8
2005	1	9			10
2006	0	0	0		1
2007	0	11			11
2008	1	0			1
2009	1				1
2010	0	0			0
2011	0	0			0
2012	0	0			0
2013	1	2	0		2
2014	5	1	0	0	6
2015	2	2	0	0	4
2016	2	3			6
2017	1	1		0	2
2018	3	2	0	0	5
2019	1	0	0	0	1
2020	0	3			3
2021	0	3	0	0	3

Table 4.4. Shallow-water flatfish catch (t) by year and fishery from 1993 to October 8, 2021. See table 4.5 for full fishery names abbreviated in column headings.

Year	AF	AM	DWF	FS	Ha	OS	PC	PB	PM	RS	RF	SFh	SWF
1993	97		357			59	652	1,459	108		4		5,787
1994	82	22	251	151		1	487	148	18	29	21	0	2,170
1995	273		158	20			1,206	32	4	32	247		2,381
1996	175	0	218	90		0	1,133	94	2	19	316	6	5,936
1997	150		293	105		39	2,347	40	5	54	47	0	3,416
1998	1		94	122		10	1,215	23	2	19	49	0	1,361
1999	17		21			54	1,070	14	2	10	29		817
2000	573		82	6		1	740	56	6	36	327		4,585
2001	58		17	125			1,632	165	1	4	366	0	3,110
2002	169		20	156			458	18	3	42	117	0	5,501
2003	87		11	110	0	190	477	20	5	31	57	0	3,334
2004	269		47	40	0	23	648	6	3	10	92		1,759
2005	100		2	2	0	0	305	3	1	8	52		4,162
2006	536		2	29			266	438	1	40	20	0	5,846
2007	348			26			870	121	1	10	21	0	6,962
2008	364			41	0		905	228	2	12	59	0	7,240
2009	228			95	0	0	211	15	2	45	51	0	7,744
2010	472		4	130	0		661	75	294	31	47	0	4,110
2011	780	0	4	78	0	10	936	259	36	11	47	1	1,829
2012	358			150		1	765	189	22	105	67	1	2,353
2013	302	1	18	48	1	0	964	206	5	12	27	3	3,919
2014	721		0	85	1		893	303	5	28	30	1	2,661
2015	140			0	0		949	474	35	4	27	0	1,711
2016	448			27	2		738	255	15	2	14	1	2,295
2017	385	1		0	1	0	833	364	6	24	11	2	929
2018	534	3		3	3		28	391	2	26	57	8	1,696
2019	726			27	1		79	263	1	39	34	2	1,687
2020	679				1		0	150	1	31	22	1	3,463
2021	6				1		17	158	2		21	0	1,390

Table 4.5. Code values for fishery names used in Table 4.4.

Code	Fishery Name
AF	Arrowtooth Flounder
AM	Atka Mackerel
DWF	Deep Water Flatfish - GOA
FS	Flathead Sole
Ha	Halibut
OS	Other Species
PC	Pacific Cod
PB	Pollock - bottom
PM	Pollock - midwater
RS	Rex Sole - GOA
RF	Rockfish
SF	Sablefish
SWF	Shallow Water Flatfish - GOA
Unid	Blank - Unidentified fishery

Table 4.6. Catch (t) from longline and trawl research cruises from 1979 to 2021.

Year	rock sole	Alaska plaice	butter sole	English sole	northern rock sole	sand sole	southern rock sole	starry flounder	yellowfin sole
1979	13	0	0	0	0	0	0	0	0
1980	54	0	0	0	0	0	0	0	0
1981	2	0	0	0	0	0	0	0	0
1982	17	0	0	0	0	0	0	0	0
1983	43	0	0	0	0	0	0	0	0
1984	419	30	60	42	0	3	0	37	65
1985	37	0	0	0	0	0	0	0	0
1986	23	0	0	0	0	0	0	0	0
1987	430	27	49	57	0	2	0	48	68
1988	38	0	0	0	0	0	0	0	0
1989	21	0	0	0	0	0	0	0	0
1990	291	19	38	46	0	2	0	19	34
1991	23	0	0	0	0	0	0	0	0
1992	16	0	0	0	0	0	0	0	0
1993	353	33	74	66	0	7	0	42	44
1994	5	0	0	0	0	0	0	0	0
1995	9	0	0	0	0	0	0	0	0
1996	3	39	64	51	208	6	298	47	52
1997	4	0	0	0	0	0	0	0	0
1998	5	43	76	55	200	7	290	68	53
1999	23	0	0	0	0	0	0	0	0
2000	11	28	58	24	212	3	247	43	29
2001	3	0	0	0	0	0	0	0	0
2002	2	51	101	62	311	10	378	54	54
2003	7	0	0	0	0	0	0	0	0
2004	13	51	95	61	273	15	340	64	55
2005	24	0	0	0	0	0	0	0	0
2006	5	49	84	71	303	15	358	67	46
2007	10	0	0	0	0	0	0	0	0
2008	3	44	92	85	285	16	347	66	61
2009	3	0	0	0	0	0	0	0	0
2010	3	34	72	58	227	9	269	52	41
2011	2	0	0	0	0	0	0	0	0
2012	9	30	50	45	199	3	231	34	27
2013	15	0	0	0	0	0	0	0	0
2014	5	26	69	74	230	6	293	48	32
2015	7	0	0	0	0	0	0	0	0
2016	6	30	52	75	164	10	190	44	32
2017	14	0	0	0	0	0	0	0	0
2018	1	25	57	100	159	12	212	29	33
2019	6	0	0	0	0	0	0	0	0
2020	2	19	50	114	142	10	218	30	31

Table 4.7. Prohibited species catch (t) from 2010 to 2020 in the shallow water flatfish fishery.

Year		Bairdi Tanner Crab	Blue King Crab	Chinook Salmon	Golden (Brown) King Crab	Halibut	Herring	Non-Chinook Salmon	Opilio Tanner (Snow) Crab	Other King Crab	Red King Crab
2020	PSCNQ Estimate (*)	43,148.488	0.000	0.598	0.063	136.932	6.390	65.952	0.000		0.000
2020	Halibut Mortality (mt)					95.750					
2019	PSCNQ Estimate (*)	52,280.992	0.000	0.000	0.000	145.696	2.117	0.000	0.000		0.000
2019	Halibut Mortality (mt)					99.023					
2018	PSCNQ Estimate (*)	23,478.527	0.000	377.089	0.126	98.624	2.207	497.866	0.000		0.000
2018	Halibut Mortality (mt)					67.953					
2017	PSCNQ Estimate (*)	9,296.890	0.000	0.164	0.037	76.035	0.074	0.148	0.000		0.000
2017	Halibut Mortality (mt)					49.727					
2016	PSCNQ Estimate (*)	9,992.470	0.000	145.596	0.702	90.841	0.528	2.021	0.120		0.000
2016	Halibut Mortality (mt)					59.955					
2015	PSCNQ Estimate (*)	62,241.368	0.000	0.000	0.000	151.598	1.380	0.000	0.000		0.000
2015	Halibut Mortality (mt)					101.571					
2014	PSCNQ Estimate (*)	10,967.086	0.000	697.363	0.000	254.254	0.874	0.000	0.000		0.000
2014	Halibut Mortality (mt)					170.350					
2013	PSCNQ Estimate (*)	118,899.911	0.000	477.248	0.000	240.179	0.086	1,400.826	0.000		0.000
2013	Halibut Mortality (mt)					160.920					
2012	PSCNQ Estimate (*)	3,830.459	0.000	237.264	0.000	366.588	0.000	212.346	0.000		0.000
2012	Halibut Mortality (mt)					260.277					
2011	PSCNQ Estimate (*)	5,311.133	0.000	79.975	0.000	363.413	0.000	724.849	0.000		0.000
2011	Halibut Mortality (mt)					258.024					
2010	PSCNQ Estimate (*)	21,537.904	0.000	1,100.568	0.000	628.996	0.038	432.825	0.000		0.000
2010	Halibut Mortality (mt)					446.587					

Table 4.8. Nontarget species caught (t) in the shallow water flatfish fishery from 2003 to 2017.

Species Group Name	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003
"Benthic urochordata"	0.15	0.02	1.67		0.56			0.41	0.64	2.15	0.74	7.48	0.53	0.29	0.90
"Bivalves"	0.00	0.20		0.00	0.22	0.64	0.58	0.33	0.52	0.60	5.96	2.25	2.71	0.49	0.27
"Brittle star unidentified"	0.00	0.00		0.02				0.00	4.71	0.00	0.08	0.00	0.01		0.00
"Corals Bryozoans - Corals Bryozoans Unidentified"								0.00	0.00		0.01				
"Dark Rockfish"						0.22				0.62					
"Eelpouts"	0.04	0.13	0.23	0.17	0.15			0.08	0.49	0.01		0.03	0.03		0.13
"Eulachon"	0.04	0.06		0.19				0.10	1.64	0.04	0.11			0.03	
"Giant Grenadier"								16.05	13.59			3.98			
"Greenlings"	0.02	0.07		0.06	0.41	0.12	0.75	0.28	1.63	1.14	1.93	0.98	0.93	0.42	0.06
"Grenadier - Ratail Grenadier Unidentified"												0.00	1.41	1.82	
"Hermit crab unidentified"	0.00	0.01	0.01	0.09	0.09	0.00	0.02	0.00	0.16	0.13	0.31	0.16	0.03	0.31	0.42
"Invertebrate unidentified"	0.05					4.11		0.01	0.23	2.43	0.30	6.25	0.01	0.66	12.95
"Large Sculpins - Bigmouth Sculpin"						1.28			18.00	12.58					
"Large Sculpins - Great Sculpin"						25.49			55.27	147.10					
"Large Sculpins - Hemilepidotus Unidentified"									0.82	0.26					
"Large Sculpins - Myoxocephalus Unidentified"						0.26			15.51	0.41					
"Large Sculpins - Plain Sculpin"						0.06				1.77					
"Large Sculpins - Red Irish Lord"						0.03			5.44	0.22					

"Large Sculpins - Warty Sculpin"									8.38	0.02					
"Large Sculpins - Yellow Irish Lord"						208.00			241.77	780.58					
"Large Sculpins"											328.25	119.68	195.80	114.80	14.55
"Misc crabs"	0.01	0.00		1.01	0.31		0.59	0.04	0.89	0.70	0.99	0.11	0.04	0.17	0.35

Table 4.8 cont. Nontarget species caught in the shallow water flatfish fishery from 2003 to 2017.

Species Group Name	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003
"Misc crustaceans"	0.00							0.00							
"Misc fish"	4.08	1.74	10.96	11.99	15.20	1.67	29.32	10.51	44.71	49.27	129.42	24.41	6.59	7.85	32.70
"Misc inverts (worms etc)"				0.00						0.02	0.05				
"Other Sculpins"						0.08			170.60	13.69	52.05	5.50	3.92	14.42	98.50
"Other osmerids"				0.03	0.03						0.01			0.00	0.05
"Pacific Sand lance"		0.00			0.00					0.00			0.00		
"Pacific Sandfish"					0.11	0.00									
"Pandalid shrimp"	0.02	0.03		0.09	0.06		0.00	0.16	0.08	0.00	0.01		0.05	0.00	0.03
"Polychaete unidentified"	0.05		0.06							0.02	0.11		0.00		
"Scypho jellies"	0.10	3.97	11.82	1.50	0.13	0.97	0.23	5.43	1.58	0.96	0.00	0.48	0.14	0.23	6.34
"Sea anemone unidentified"	0.71	0.79	0.58	5.58	10.16	3.31	2.73	2.86	19.98	8.64	24.08	2.20	21.46	3.20	5.04
"Sea pens whips"		0.00							0.01	0.17	0.26	0.04	0.02		
"Sea star"	2.09	10.91	22.84	19.63	20.70	13.90	8.76	15.29	22.40	35.24	56.29	39.40	49.05	28.72	32.81
"Snails"	0.04	0.26	0.73	0.45	0.13	0.03	0.05	0.12	0.38	0.15	1.71	0.28	0.15	0.06	0.68
"Sponge unidentified"	0.01	0.11		0.01		0.00	0.09		1.07	1.75	0.01	0.08	0.12	1.82	0.58
"State-managed Rockfish"	0.61	12.18		3.65	0.53		1.24	0.45							
"Stichaeidae"	0.04	0.00		0.00	0.00			0.00	0.01	0.01	0.01	0.18			
"urchins dollars cucumbers"	0.00	0.04	0.20	0.14	0.09	0.24	0.12	0.01	0.97	1.30	0.41	0.29	0.05	0.66	1.30

Table 4.9. Proportion (by weight) of catch for shallow-water flatfish that is retained for the Gulf ofAlaska fisheries.

Year	Proportion Retained
1993	0.65
1994	0.73
1995	0.71
1996	0.87
1997	0.81
1998	0.83
1999	0.77
2000	0.89
2001	0.91
2002	0.91
2003	0.97
2004	0.93
2005	0.96
2006	0.96
2007	0.97
2008	0.96
2009	0.99
2010	0.91
2011	0.95
2012	0.95
2013	0.96
2014	0.91
2015	0.89
2016	0.94
2017	0.80
2018	0.92
2019	0.89
2020	0.95
2021*	0.81

*As of October 11, 2021.

Table 4.10. Biomass estimates from the NMFS bottom-trawl survey from 1984 to 2021. In 1984, 1987, 1999, 2007, to 2015 depths surveyed were to 1000 meters. In 1990, 1993 and 1996 depths were surveyed to 500 meters. In 2003 and 2005 the survey extended to 700 meters.

Year	Northern rock sole	Southern rock sole	Alaska plaice	Butter sole	English sole	Sand sole	Starry flounder	Yellowfin sole
1984			1,912	22,503	3,202	1,216	14,292	91,334
1987			4,830	19,273	7,243	82	14,140	56,132
1990			5,977	17,339	7,598	130	10,218	57,524
1993			2,524	29,907	8,454	479	40,288	79,017
1996	78,845	127,390	4,870	20,916	7,946	940	27,309	47,789
1999	61,543	106,235	8,680	14,188	14,433	234	46,656	48,313
2001	64,809	122,492	3,639	8,946	3,467	275	71,810	55,197
2003	79,648	126,819	5,072	31,116	17,830	1,359	58,526	54,727
2005	91,453	147,580	7,936	26,226	14,600	2,379	26,586	48,694
2007	102,641	162,358	12,246	29,907	12,386	3,286	74,454	42,422
2009	95,846	191,765	7,788	15,405	18,671	2,808	33,264	33,414
2011	72,875	120,573	12,266	19,695	16,720	755	39,757	46,576
2013	74,586	131,441	8,044	8,122	18,121	703	30,028	23,016
2015	52,370	125,518	5,450	16,352	17,500	304	23,513	24,814
2017	55,047	107,985	13,784	13,862	12,789	2,020	28,013	51,547
2019	39,875	100,698	4,617	13,190	18,414	3,023	34,800	19,101
2021	51,498	129,601	2,159	9,549	37,025	3,503	23,101	18,840

Table 4.11. CV of biomass estimates from the NMFS bottom-trawl surveys from 1984 to 2021.

Year	Northern rock sole	Southern rock sole	Alaska plaice	Butter sole	English sole	Sand sole	Starry flounder	Yellowfin sole
1984			0.27	0.33	0.42	0.72	0.32	0.25
1987			0.25	0.44	0.35	0.98	0.27	0.23
1990			0.35	0.39	0.46	0.79	0.42	0.43
1993			0.34	0.30	0.48	0.46	0.33	0.26
1996	0.13	0.10	0.22	0.28	0.28	0.59	0.54	0.19
1999	0.25	0.10	0.33	0.19	0.29	0.45	0.25	0.31
2001	0.15	0.12	0.24	0.37	0.60	0.85	0.64	0.44
2003	0.12	0.10	0.19	0.22	0.29	0.64	0.28	0.22
2005	0.11	0.10	0.23	0.27	0.31	0.41	0.28	0.23
2007	0.12	0.07	0.34	0.34	0.30	0.41	0.28	0.28
2009	0.17	0.12	0.23	0.24	0.26	0.77	0.22	0.24
2011	0.17	0.09	0.37	0.25	0.26	0.46	0.28	0.29
2013	0.18	0.11	0.29	0.39	0.41	0.68	0.41	0.32
2015	0.15	0.08	0.37	0.25	0.26	0.72	0.23	0.35
2017	0.15	0.09	0.32	0.27	0.28	0.54	0.30	0.27
2019	0.19	0.09	0.36	0.24	0.22	0.41	0.38	0.32
2021	0.27	0.08	0.37	0.30	0.17	0.87	0.31	0.32

Table 4.12a. Biomass estimates (t) for Gulf of Alaska Alaska plaice, based on the bottom trawl survey, by North Pacific Fishery Management Council regulatory area.

Alaska plaice	Central GOA	Eastern GOA	Western GOA	Total
1984	1,487	43	383	1,912
1987	3,250	27	1,553	4,830
1990	3,137	0	2,840	5,977
1993	917	0	1,608	2,524
1996	2,575	0	2,295	4,870
1999	3,033	0	5,646	8,680
2001	1,524		2,116	3,639
2003	2,147	0	2,926	5,072
2005	5,459	0	2,477	7,936
2007	8,831	0	3,415	12,246
2009	2,401	0	5,387	7,788
2011	6,995	0	5,271	12,266
2013	2,747	0	5,297	8,044
2015	758	0	4,692	5,450
2017	8,998	0	4,785	13,784
2019	1,548	0	3,069	4,617
2021	964	0	1,195	2,159

Table 4.12b. Biomass estimates (t) for Gulf of Alaska butter sole, based on the bottom trawl survey, by North Pacific Fishery Management Council regulatory area.

Butter sole	Central GOA	Eastern GOA	Western GOA	Total
1984	20,083	949	1,471	22,503
1987	14,445	777	4,051	19,273
1990	14,051	2,121	1,167	17,339
1993	23,277	2,906	3,724	29,907
1996	14,547	104	6,265	20,916
1999	7,929	1,274	4,985	14,188
2001	5,605		3,341	8,946
2003	25,090	2,655	3,370	31,116
2005	20,242	31	5,952	26,226
2007	20,830	2,010	7,068	29,907
2009	12,964	1,539	902	15,405
2011	7,541	5,466	6,687	19,695
2013	5,524	1,717	880	8,122
2015	7,887	3,263	5,202	16,352
2017	8,478	3,266	2,119	13,862
2019	6,963	2,277	3,950	13,190
2021	6,438	587	2,524	9,549

Table 4.12c. Biomass estimates (t) for Gulf of Alaska English sole, based on the bottom trawl survey, by North Pacific Fishery Management Council regulatory area.

English sole	Central GOA	Eastern GOA	Western GOA	Total
1984	605	2,566	31	3,202
1987	1,085	5,747	411	7,243
1990	450	6,336	811	7,598
1993	1,874	5,341	1,239	8,454
1996	1,936	5,713	297	7,946
1999	3,066	10,803	563	14,433
2001	3,378		89	3,467
2003	5,361	12,135	334	17,830
2005	4,396	9,379	825	14,600
2007	5,142	6,624	620	12,386
2009	8,797	8,970	903	18,671
2011	5,932	9,827	961	16,720
2013	4,263	12,193	1,666	18,121
2015	4,238	12,757	505	17,500
2017	3,716	6,634	2,439	12,789
2019	9,482	6,464	2,468	18,414
2021	22,853	11,734	2,438	37,025

Table 4.12d. Biomass estimates (t) for Gulf of Alaska sand sole, based on the bottom trawl survey, by North Pacific Fishery Management Council regulatory area.

Sand sole	Central GOA	Eastern GOA	Western GOA	Total
1984	1,216	0	0	1,216
1987	0	82	0	82
1990	98	32	0	130
1993	390	8	81	479
1996	757	183	0	940
1999	117	56	61	234
2001	232		43	275
2003	1,331	28	0	1,359
2005	2,318	0	61	2,379
2007	2,761	177	348	3,286
2009	2,772	0	36	2,808
2011	722	0	33	755
2013	703	0	0	703
2015	286	18	0	304
2017	1,980	17	23	2,020
2019	3,004	0	19	3,023
2021	3,407	0	96	3,503

Table 4.12e. Biomass estimates (t) for Gulf of Alaska starry flounder, based on the bottom trawl survey by North Pacific Fishery Management Council regulatory area.

Starry flounder	Central GOA	Eastern GOA	Western GOA	Total
1984	10,991	1,956	1,345	14,292
1987	6,041	3,087	5,012	14,140
1990	5,501	3,141	1,577	10,218
1993	31,318	5,193	3,778	40,288
1996	9,610	1,518	16,181	27,309
1999	28,761	7,262	10,634	46,656
2001	57,507		14,303	71,810
2003	49,789	3,382	5,355	58,526
2005	10,106	358	16,122	26,586
2007	46,000	16,411	12,043	74,454
2009	19,960	3,151	10,154	33,264
2011	14,774	19,314	5,670	39,757
2013	11,617	362	18,049	30,028
2015	11,190	5,546	6,777	23,513
2017	14,151	3,665	10,196	28,013
2019	21,225	3,624	9,951	34,800
2021	14,055	6,200	2,845	23,101

Table 4.12f. Biomass estimates (t) for Gulf of Alaska yellowfin sole, based on the bottom trawl survey by North Pacific Fishery Management Council regulatory area.

Yellowfin sole	Central GOA	Eastern GOA	Western GOA	Total
1984	26,244	64	65,027	91,334
1987	24,978	0	31,153	56,132
1990	10,218	0	47,306	57,524
1993	10,660	0	68,357	79,017
1996	17,704	229	29,857	47,789
1999	11,854	85	36,374	48,313
2001	5,611		49,586	55,197
2003	12,549	0	42,178	54,727
2005	25,418	0	23,276	48,694
2007	20,985	0	21,437	42,422
2009	21,627	92	11,695	33,414
2011	20,139	380	26,057	46,576
2013	7,612	0	15,405	23,016
2015	8,576	0	16,238	24,814
2017	11,993	0	39,554	51,547
2019	9,716	0	9,385	19,101
2021	3,670	0	15,171	18,840

Table 4.12g. Biomass estimates (t) for Gulf of Alaska rock sole unidentified based on the bottom trawl survey by North Pacific Fishery Management Council regulatory area.

Rock sole unid.	Central GOA	Eastern GOA	Western GOA	Total
1984	77,115	527	59,981	137,623
1987	72,971	1,422	49,000	123,393
1990	75,511	2,298	78,223	156,032
1993	83,163	1,554	88,274	172,991
1996	108	0	0	108
2007	0	0	0	0
2013	9	0	0	9
2015	12	0	0	12
2019	0	0	567	567

Table 4.12h. Biomass estimates (t) for Gulf of Alaska northern rock sole, based on the bottom trawl survey, by North Pacific Fishery Management Council regulatory area.

Northern rock sole	Central GOA	Eastern GOA	Western GOA	Total
1996	15,962	0	62,883	78,845
1999	16,334	31	45,178	61,543
2001	27,535		37,274	64,809
2003	36,521	0	43,127	79,648
2005	32,871	0	58,582	91,453
2007	37,078	0	65,563	102,641
2009	39,635	25	56,186	95,846
2011	27,717	96	45,063	72,875
2013	27,139	0	47,447	74,586
2015	25,409	4	26,958	52,370
2017	26,227	0	28,820	55,047
2019	11,931	0	27,944	39,875
2021	29,270	0	22,229	51,498

Table 4.12i. Biomass estimates (t) for Gulf of Alaska southern rock sole based on the bottom trawl survey by North Pacific Fishery Management Council regulatory area.

Southern rock sole	Central GOA	Eastern GOA	Western GOA	Total
1996	76,647	3,323	47,420	127,390
1999	54,782	6,355	45,098	106,235
2001	63,181		59,311	122,492
2003	64,803	6,900	55,116	126,819
2005	74,533	9,095	63,952	147,580
2007	75,330	8,823	78,205	162,358
2009	104,647	4,398	82,720	191,765
2011	62,156	7,098	51,319	120,573
2013	68,759	4,581	58,101	131,441
2015	57,134	4,937	63,448	125,518
2017	59,335	8,162	40,487	107,985
2019	58,464	4,460	37,775	100,698
2021	54,813	5,372	69,416	129,601

Table 4.13a. Percent shallow water flatfish biomass by area estimated from random effects model fit to combined species (including rock sole).

	Western	Central	Yakutat	Southeast
Random Effects model 2021 assessment percentage	42.18	49.5	5.5	2.8
Random effects Model 2021 Biomass estimates	112,716	132,366	14,704	7,426
λ	-2.546	-2.4057	-9.708e-01	-1.0172
s.e. λ	3.2167e-01	3.0737e-01	3.1696e-01	2.7237e-01
σ_p^2	0.00614	0.00813	0.1436	0.1308

Table 4.13b. 2021 biomass and parameter estimates by species estimated using the random effects model. Percent biomass by species was used to adjust 2021 biomass so that the sum of species is equal to the random effects model estimated 2021 biomass fit to all species combined (excluding rock sole).

Species	Random effects biomass (t) 2021	Percent	Adjusted 2021 biomass (t)	λ	s.e.	σ^2
butter	12,172	12.1	11,873	-2.2075	5.131e-01	0.0121
english	30,618	3.0	29,867	-1.7647	3.432e-01	0.0293
plaice	3,277	3.3	3,196	-1.3542	3.719e-01	0.0666
sand	3,075	3.1	3,000	-6.61e-01	3.087e-01	0.2666
starry	26,073	25.9	25,433	-1.7543	3.749e-01	0.0299
yellowfin	25,460	25.3	24,835	-2.2505	4.321e-01	0.0111
Random effects 2021 biomass (t) from fit to sum of species	98,205	-	-	-2.7543	4.939e-01	0.0041

Table 4.14. Von Bertalanffy parameter estimates for yellowfin sole in the Gulf of Alaska from the 1987 bottom trawl survey.

Species	Linf	K	t_0
males	32.8	0.19	-2.24
females	38.2	0.14	-2.18
combined	34	0.18	-1.82

Table 4.15. Food habits of shallow water flatfish. Percent observed stomach contents in parentheses where available (Livingston and Goiney, 1983).

Fish species	Observed stomach contents
rock sole-adults	fish(40%) polychaetes(27%), clam siphons(10%)
rock sole-juveniles	fish(10%), polychaetes(45%), clam siphons(15%), gammarids(8%)
yellowfin sole	Polychaetes, shrimp, fish, tanner crab, clam siphons
English sole	Polychaetes, ophiuroidea, ophiura sarsi, amphipoda, bivalves
sand sole	fish with a high frequency of arrowtooth flounder(only 4 stomachs out of 10 with food)
starry flounder	Echiuroidea(starfish), ophiuroidea(brittle star), fish, shrimp, crabs
butter sole	Polychaetes, ophiuroidea, crustacea, shrimp, tanner crab, fish

Table 4.16. Calculations of the 2022 and 2023 shallow-water flatfish ABC and OFL levels by species including values for Tier 3a for northern and southern rock sole (See Bryan, et al. 2021). Species splits were estimated using the random effects model.

Species						As *specified last* year for:				As *recommended this* year for:			
						2021		2022		2022		2023	
Shallow-water flatfish	Tier	FABC	FOFL	2021 Biomass[1]	2022 Biomass[1]	ABC	OFL	ABC	OFL	ABC	OFL	ABC	OFL
Northern rock sole	3a	*	*	94,612	98,387	17,756	21,080	17,851	21,191	11,882	14,027	12,551	14,810
Southern rock sole	3a	*	*	144,833	163,737	22,990	27,204	23,614	27,943	25,555	30,228	27,441	32,514
Yellowfin sole	5	0.15	0.2	31,259	24,835	4,689	6,252	4,689	6,252	3,725	4,967	3,725	4,967
Butter sole	5	0.15	0.2	14,304	11,873	2,146	2,861	2,146	2,861	1,781	2,375	1,781	2,375
Starry flounder	5	0.15	0.2	30,605	25,433	4,591	6,121	4,591	6,121	3,814	5,086	3,814	5,086
English sole	5	0.15	0.2	16,943	29,867	2,541	3,389	2,541	3,389	4,480	5,973	4,480	5,973
Sand sole	5	0.15	0.2	2,673	3,000	401	535	401	535	450	600	450	600
Alaska plaice	5	0.15	0.2	6,997	3,196	1,050	1,399	1,050	1,399	479	639	479	639
Total[2]				342,226	360,328	56,164	68,841	56,883	69,691	52,166	63,895	54,721	66,964

[1] 2022 estimate from random effects model fit to survey biomass estimates except northern and southern rock sole age 0+ 2020 model estimates from Bryan, et al., 2021.

[2] Sum of columns may not equal totals due to rounding.

* Estimates are from the summation of area-specific model estimates with species-specific natural mortality.

Figures

Figure 4.1. Catch (t) of shallow water flatfish by species from 1993 to October 11, 2021. Scale of y-axis is different for each species.

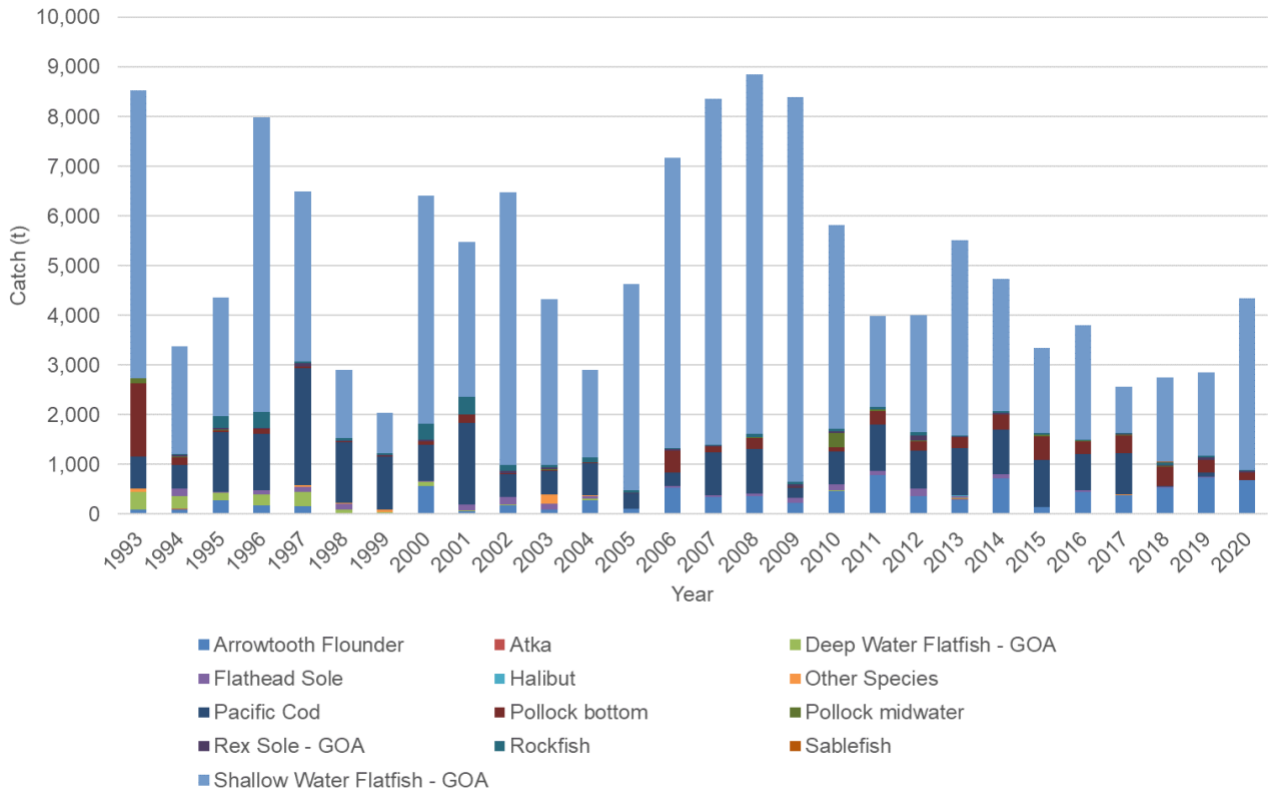

Figure 4.2. Catch of shallow water flatfish by fishery and year from AKFIN database for 1991 to October 11, 2021.

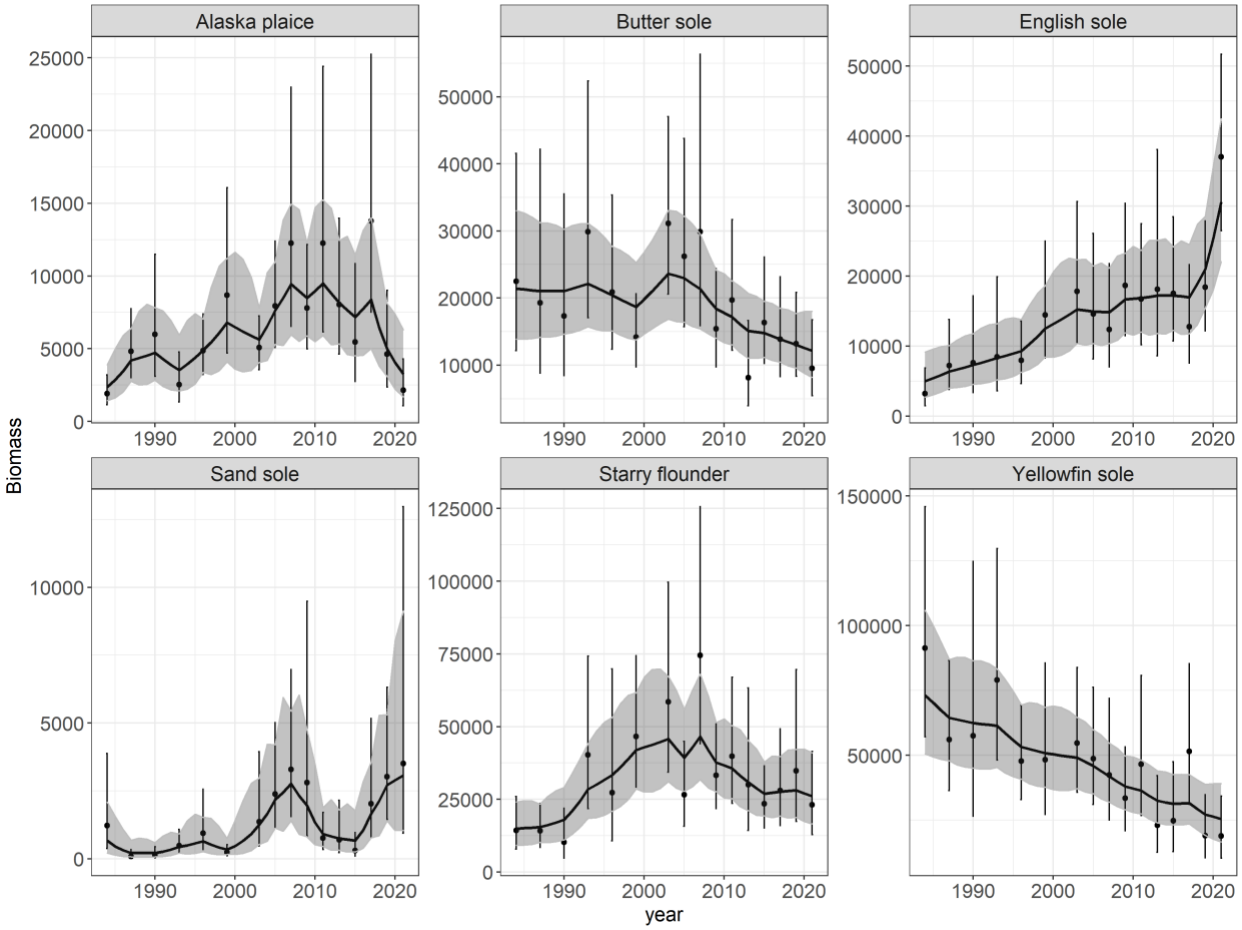

Figure 4.3. NMFS survey biomass estimates and fit of random effects model by shallow water flatfish species for 1984 to 2021. The points and error bars represent the GOA trawl survey biomass estimates and 95% confidence intervals. The solid line and gray area represents the random effects model biomass estimates and 95% confidence intervals, respectively.

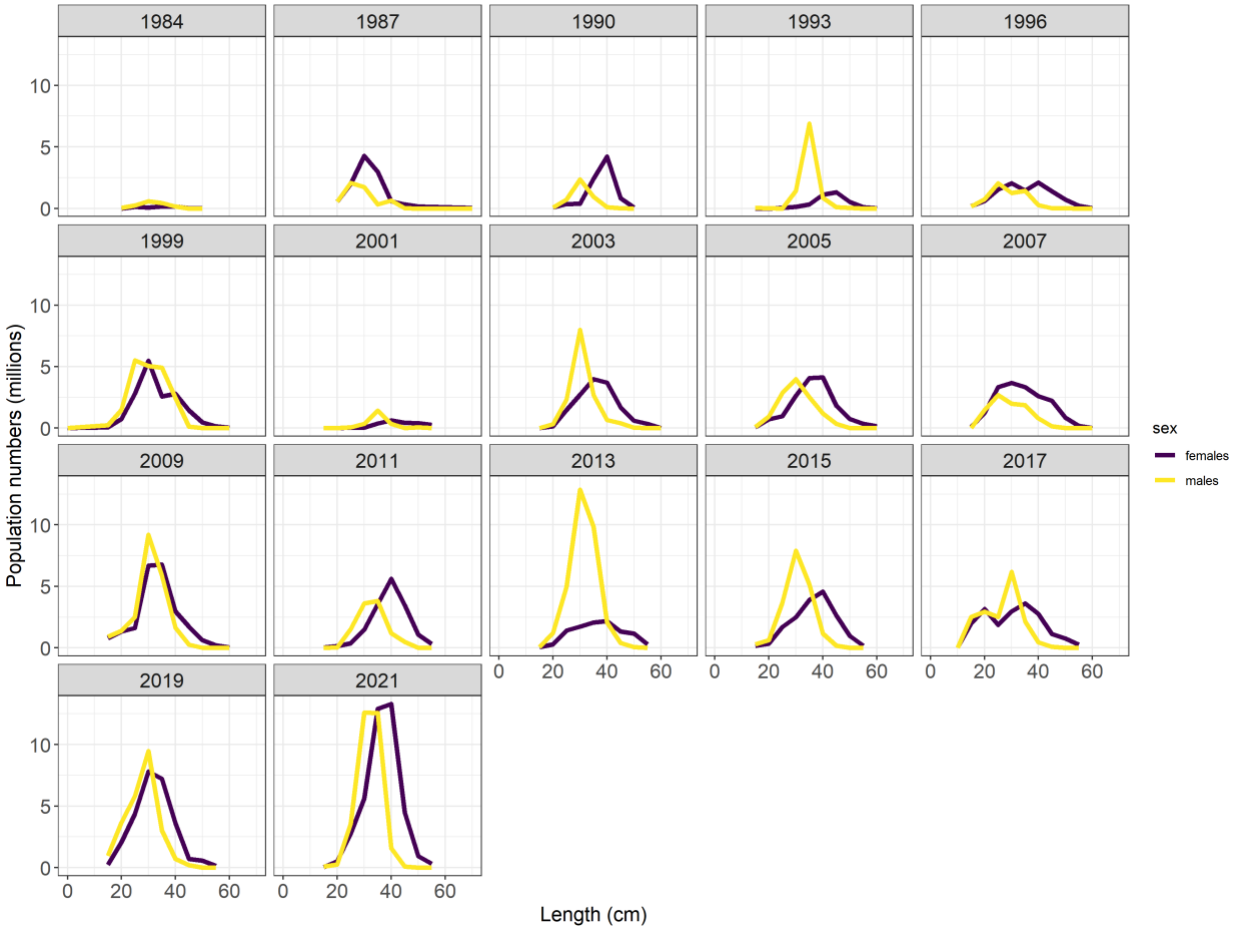

Figure 4.4. Population size composition (females solid line, males dashed line) of English sole as estimated from the NMFS bottom trawl surveys, 1984-2021.

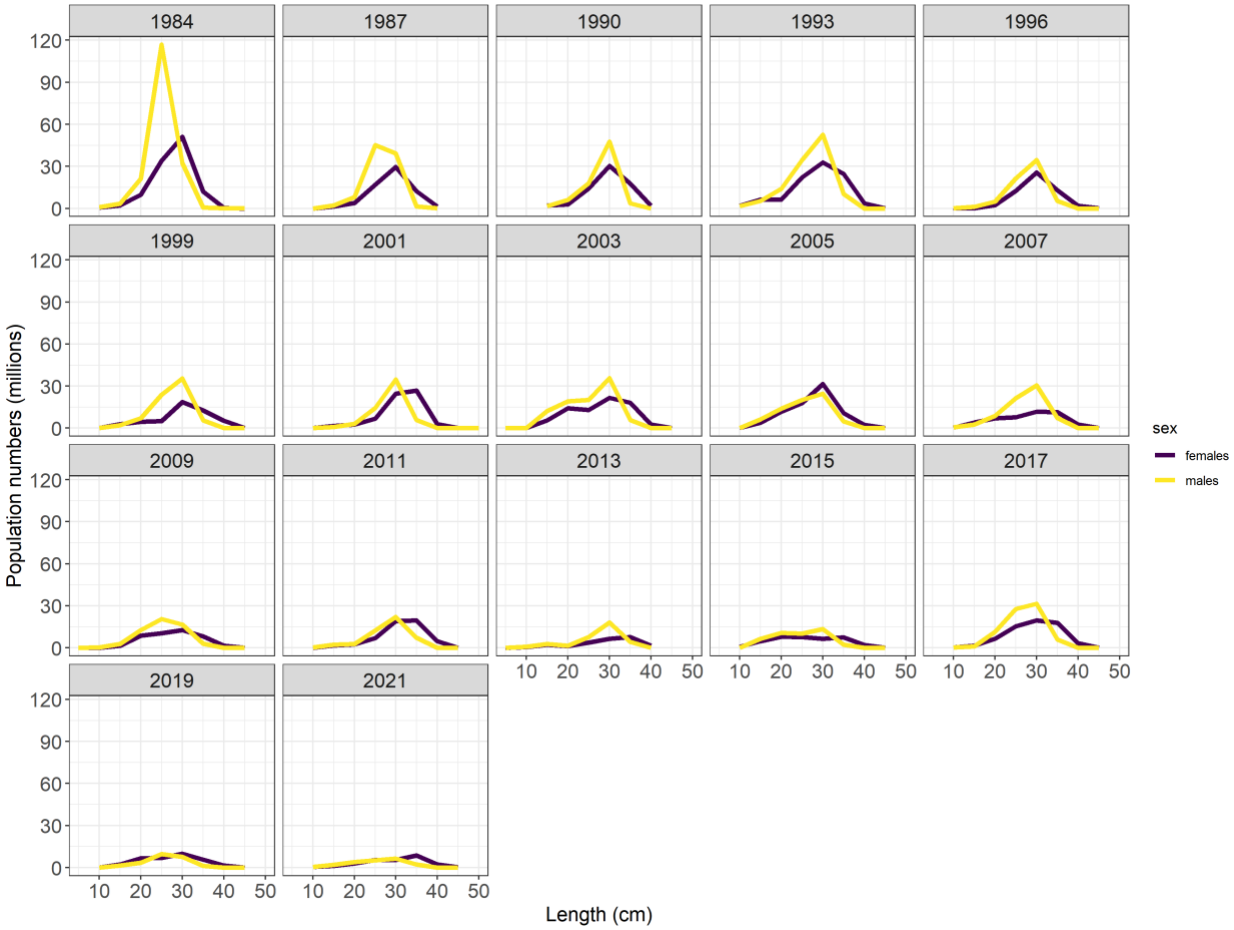

Figure 4.5. Population size composition (females purple line, males yellow line) of yellowfin sole as estimated from the NMFS bottom trawl surveys, 1984-2021.

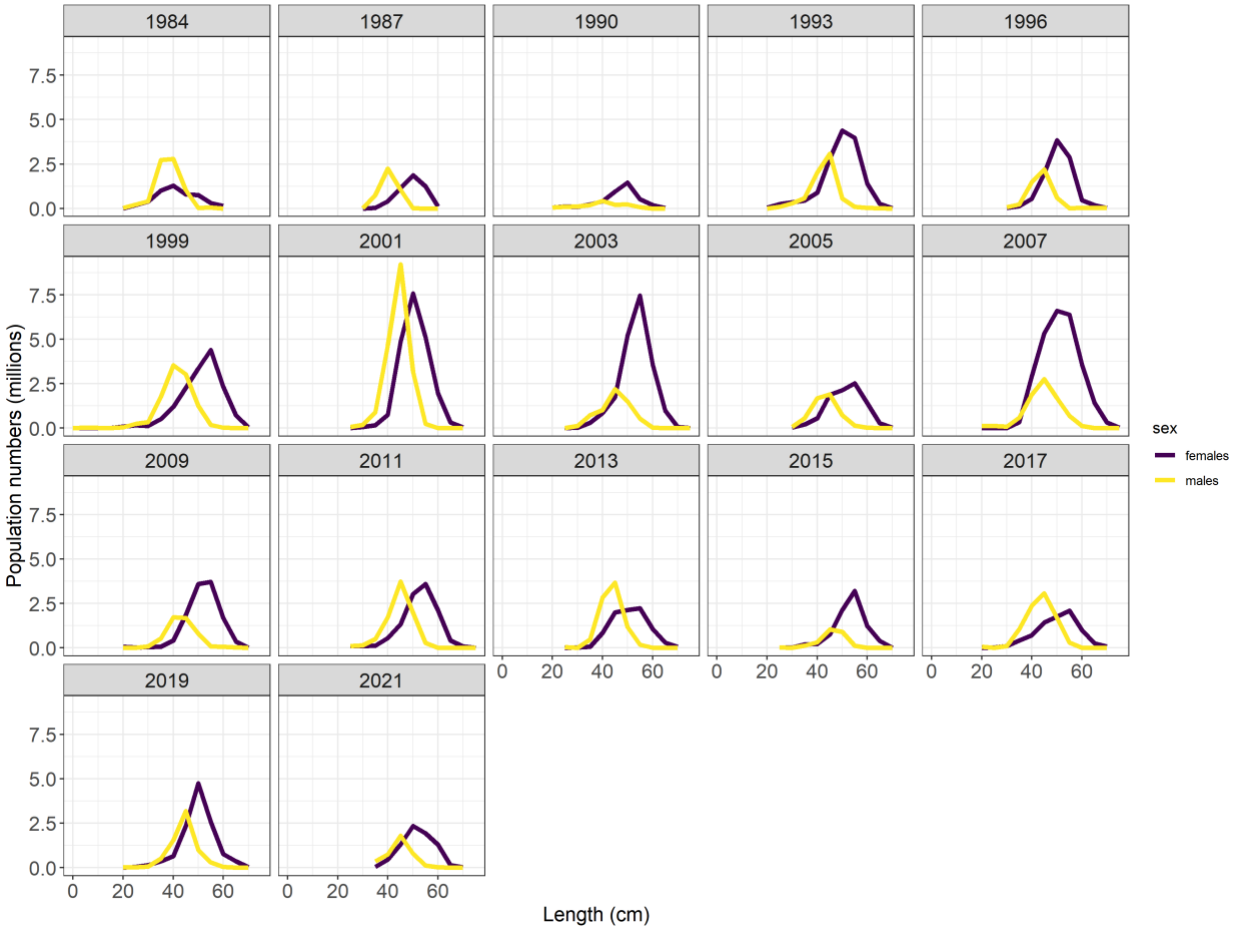

Figure 4.6. Population size composition (females purple line, males yellow line of starry flounder as estimated from the NMFS bottom trawl surveys, 1984-2021.

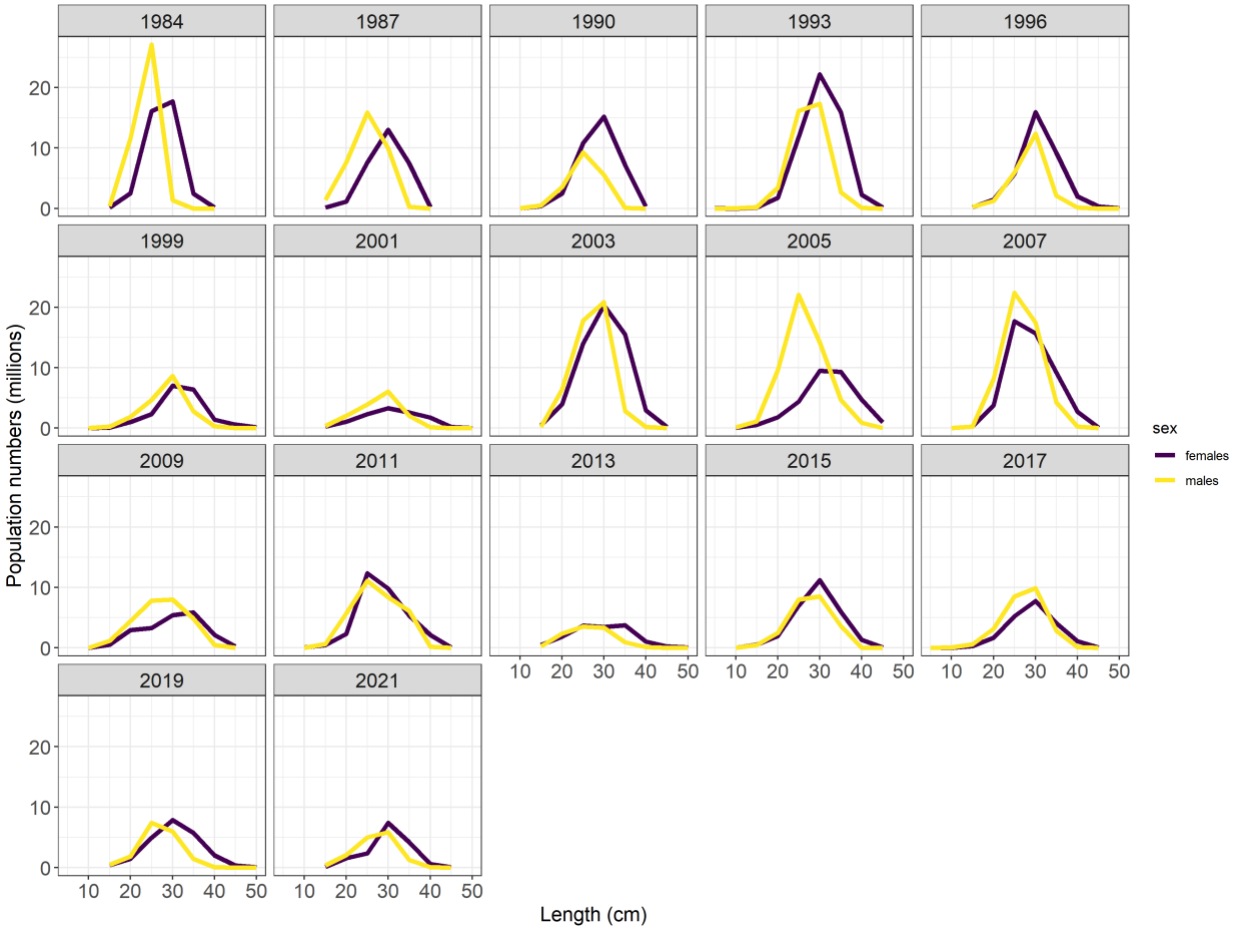

Figure 4.7. Population size composition (females purple line, males yellow line) of butter sole as estimated from the NMFS bottom trawl surveys, 1984-2021.

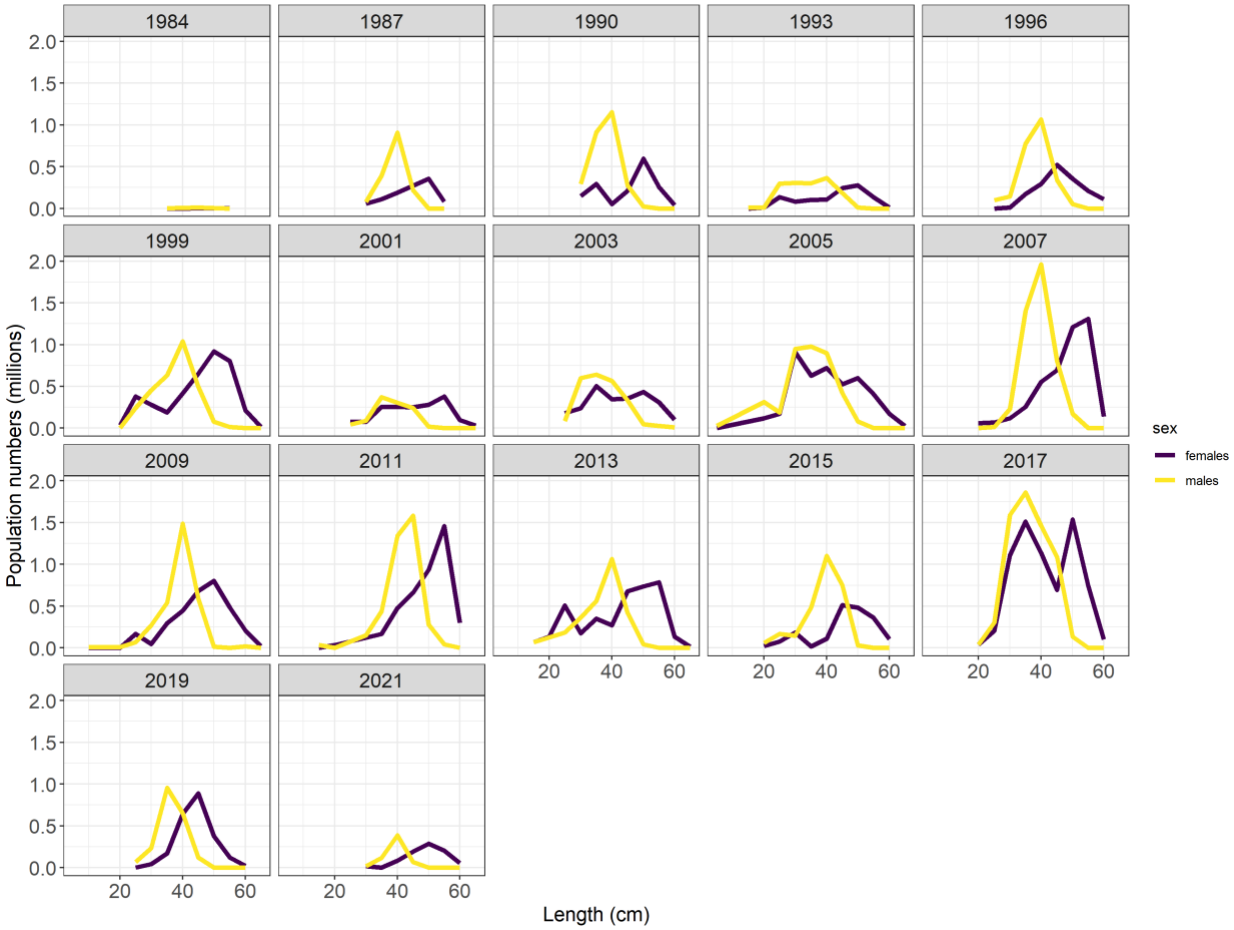

Figure 4.8. Population size composition (females purple line, males yellow line) of Alaska plaice as estimated from the NMFS bottom trawl surveys, 1984-2021.

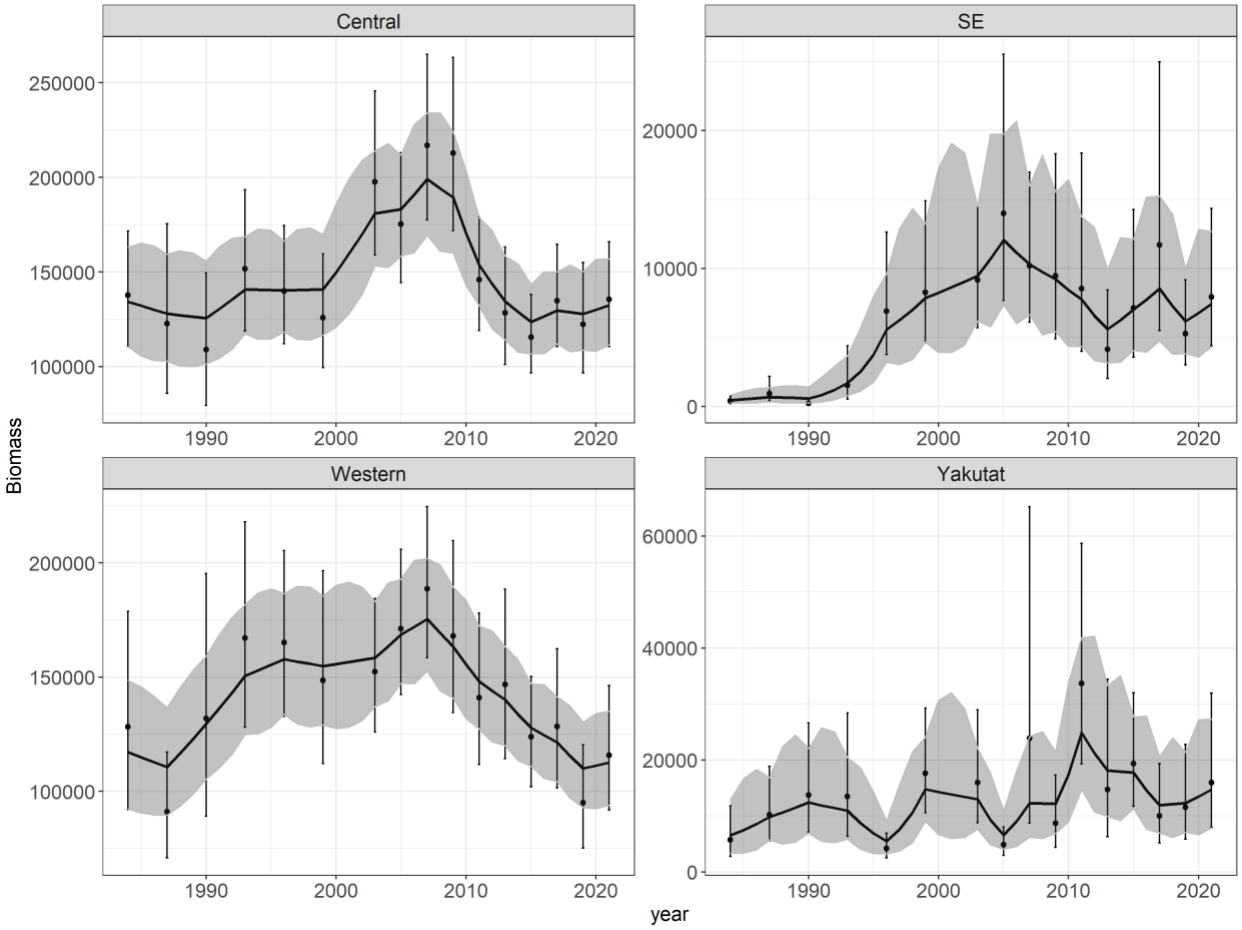

Figure 4.9. Fit of random effects model to the shallow-water flatfish survey biomass 1984 to 2021 (including rock sole) by area. The points and error bars represent the GOA trawl survey biomass estimates and 95% confidence intervals. The solid line and gray area represents the random effects model biomass estimates and 95% confidence intervals, respectively.

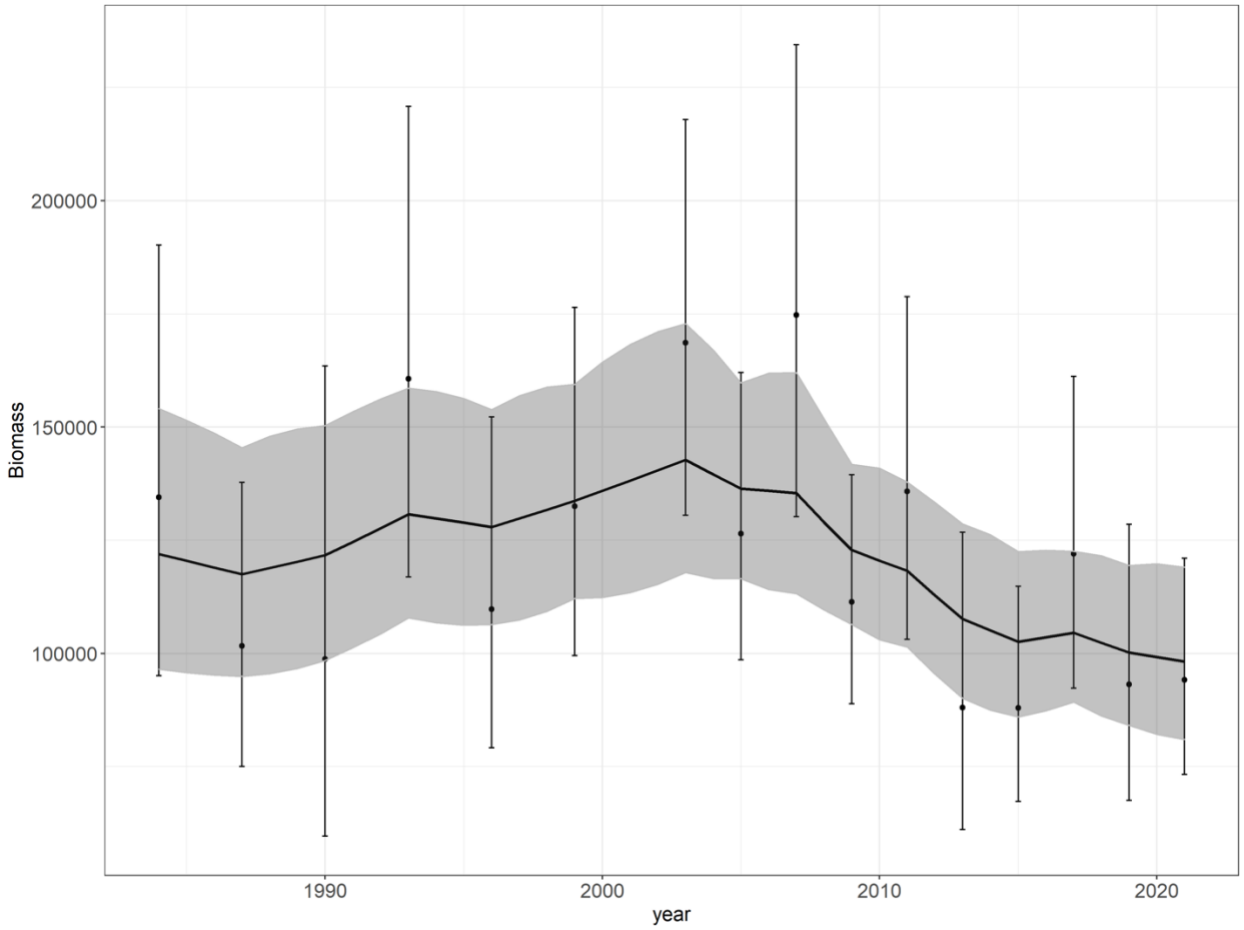

Figure 4.10. Fit of random effects model to the shallow-water flatfish survey biomass 1984 to 2021 (excluding Rock sole). The points and error bars represent the GOA trawl survey biomass estimate and 95% confidence intervals. The solid line and gray area represents the random effects model biomass estimates and 95% confidence intervals, respectively.