# 18. Assessment of the skate stock complex in the Bering Sea and Aleutian Islands

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## Executive Summary

The Bering Sea and Aleutian Islands (BSAI) skate complex is managed in aggregate, with a single set of harvest specifications applied to the entire complex. However, to generate the harvest recommendations the stock is divided into two units. Harvest recommendations for Alaska skate *Bathyraja parmifera*, the most abundant skate species in the BSAI, are made using the results of an age structured model and Tier 3. The remaining species ("other skates") are managed under Tier 5. The Tier 3 and Tier 5 recommendations are combined to generate recommendations for the complex as a whole.

### Summary of Changes in Assessment Inputs

Changes in the input data:

1) Catch data have been updated through October 23, 2020.
2) New biomass estimates from the 2019 eastern Bering Sea (EBS) shelf survey were added; the EBS shelf survey was not conducted in 2020 due to the coronavirus pandemic.
3) The Alaska skate model now incorporates EBS shelf survey biomass estimates through 2019, EBS shelf size compositions through 2019, fishery length compositions through 2019, and catch data through 2020.

Changes in assessment methodology:

1) There were no changes to the Alaska skate assessment methodology. Only one model, 14.2, is presented here with data through 2020.
2) The random effects (RE) model continues to be used for estimating biomass for the "other skates" group. Rather than run a single model for all skates in aggregate, individual RE models were constructed for each species separately in each area where they were sufficiently abundant to enable a model run. Less common species were run in aggregate in each area. The RE-model estimates for the various species were then summed to produce a biomass estimate used for harvest recommendations. The RE models were also updated to include the 2019 EBS shelf biomass estimates.

### Summary of results

1) The Alaska skate model produced results very similar to the 2018 assessment, likely because the biomass and size structure of the population have remained fairly constant.
2) The biomass of Other Skates on the EBS shelf is declining, but is still above the long-term mean.
3) The projection model indicates that Alaska skate is not overfished, subject to overfishing, or approaching an overfished condition.

| Alaska skate harvest recommendations | | | | |
|---|---|---|---|---|
| | As estimated or specified *last* year for: | | As estimated or recommended *this* year for: | |
| Quantity | 2020 | 2021 | 2021* | 2022* |
| *M* (natural mortality rate) | 0.13 | 0.13 | 0.13 | 0.13 |
| Tier | 3a | 3a | 3a | 3a |
| Projected total (age 0+) | 491,974 | 478,477 | 504,691 | 484,731 |
| Female spawning biomass (t) | | | | |
| Projected | 117,973 | 114,985 | 123,390 | 119,498 |
| $B_{100\%}$ | 177,761 | 177,761 | 178,425 | 178,425 |
| $B_{40\%}$ | 71,105 | 71,105 | 71,370 | 71,370 |
| $B_{35\%}$ | 62,217 | 62,217 | 62,449 | 62,449 |
| $F_{OFL}$ | 0.094 | 0.094 | .092 | .092 |
| $maxF_{ABC}$ | 0.081 | 0.081 | .079 | .079 |
| $F_{ABC}$ | 0.081 | 0.081 | .079 | .079 |
| OFL (t) | 37,813 | 36,310 | 38,580 | 36,655 |
| maxABC (t) | 32,559 | 31,264 | 33,219 | 31,560 |
| ABC (t) | 32,559 | 31,264 | 33,219 | 31,560 |
| | As determined *last* year for: | | As determined *this* year for: | |
| Status | 2018 | 2019 | 2019 | 2020 |
| 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 catches equal to the estimated total Alaska skate catch for 2020; see the Data-Catch section of the Alaska skate assessment.

| other skate harvest recommendations | | | | |
|---|---|---|---|---|
| Quantity | As estimated or specified last year for: 2020 | 2021 | As estimated or recommended this year for: 2021 | 2022 |
| *M* (natural mortality rate) | 0.1 | 0.1 | 0.1 | 0.1 |
| Tier | 5 | 5 | 5 | 5 |
| Biomass (t) | 119,787 | 119,787 | 107,174 | 107,174 |
| $F_{OFL}$ | 0.10 | 0.10 | 0.10 | 0.10 |
| max$F_{ABC}$ | 0.075 | 0.075 | 0.075 | 0.075 |
| $F_{ABC}$ | 0.075 | 0.075 | 0.075 | 0.075 |
| OFL (t) | 11,979 | 11,979 | 10,717 | 10,717 |
| maxABC (t) | 8,984 | 8,984 | 8,038 | 8,038 |
| ABC (t) | 8,984 | 8,984 | 8,038 | 8,038 |
| Status | As determined *last* year for: 2018 | 2019 | As determined *this* year for: 2019 | 2020 |
| Overfishing | No | n/a | No | n/a |

| aggregate harvest recommendations for the BSAI complex | | | | |
|---|---|---|---|---|
| Quantity | As estimated or specified *last* year for: 2020 | 2021 | As estimated or recommended this year for: 2021 | 2022 |
| OFL (t) | 49,792 | 48,289 | 49,297 | 47,372 |
| maxABC (t) | 41,543 | 40,248 | 41,257 | 39,598 |
| ABC (t) | 41,543 | 40,248 | 41,257 | 39,598 |

| *Assessment-related considerations* | *Population dynamics considerations* | *Environmental/ ecosystem considerations* | *Fishery Performance considerations* |
|---|---|---|---|
| Level 1: no increased concerns | Level 1: no increased concerns | Level 1: no increased concerns | Level 1: no increased concerns |

## Responses to SSC and Plan Team Comments on Assessments in General

SSC comments on the use of risk tables

The SSC made lengthy recommendations regarding the use of risk tables in the minutes of their December 2019 meeting, which can be accessed at https://www.npfmc.org/meeting-minutes/. For brevity, the comments are not repeated in this document.

*Response*: This document complies with the clarifications and expectations reflected in the SSC's recommendations regarding the risk table.

## Responses to SSC and Plan Team Comments Specific to this Assessment

<u>Combined Plan Team and SSC comments, 2018 & 2019</u>

Because the BSAI skate assessment alternates between a full assessment in even years and a partial assessment in odd years, comments from the Plan Teams and SSC accumulate for 2 years before they are addressed in a full assessment. The following list of recommendations from the December 2019 SSC minutes encapsulates this agglomeration, so the following is intended as a response to the comments from both groups:

*Comment*: Explore the implications of using a random effects models for aggregates of species with different life histories and vital parameters.

> *Response*: This assessment includes a comparison of 2 approaches for estimating Other Skate (i.e. all skates except the Tier 3 Alaska skate) biomass using the random-effects (RE) model. The analyses were performed using (1) biomass and uncertainty data for the complex in aggregate and (2) biomass and uncertainty data for each species separately, with the resulting biomass estimates combined to create a single biomass estimate for the complex. While the point estimates of biomass were very similar between these approaches, the uncertainty was much larger for the latter approach where RE models were run for each species separately. Separate runs of the RE model were considered important for calculating species-specific exploitation rates, but the harvest recommendations are based on the RE model run in aggregate.

*Comment*: Conduct sensitivity runs to examine potential biases in ageing.

> *Response*: Previous assessments explored alternative models using differing assumptions regarding maximum age. A more thorough analysis of ageing bias has yet to be explored.

*Comment*: Consider whether separating Alaska skate from the skate complex is advisable to avoid potential undue exploitation on the other skate species.

> *Response*: This approach to management of skates has previously been explored by the Plan Team (c. 2011). At that time it was determined that the conservation concern was insufficient to warrant splitting the complex. Overall exploitation of the Other Skates group remains low. The 2018 assessment suggested that the exploitation of individual species in the Other Skate group (specifically Bering skate and big skate) has the potential to be of concern, but the available data suggest that Bering and big skate populations are not negatively impacted. In any case, skate management would need to occur at the individual species level to reliably prevent undue exploitation. Much of this discussion is also mooted due to the lack of species-specific catch accounting in the BSAI, which would make an Other Skates ACL unenforceable.

*Comment*: Fill out/update a stock-structure template for the skate complex.

> *Response*: A stock structure template was completed for the BSAI skate complex in 2012 that focused on the complex rather than individual species. Genetic analyses published in 2019 provide information that will be useful for updating the information regarding the population structure of Alaska skate, but this has not yet been completed.

*Comment*: Work to integrate IPHC longline data into the assessment.

> *Response*: The spatial coverage of the IPHC and AFSC longline surveys does not correspond to the spatial distribution of Alaska skate, so those data are not useful for the Alaska skate population model. The IPHC data does have the potential to supplement our understanding of species in the Other Skates group but have not yet been incorporated into the assessment.

# General Introduction

<u>Contents of this report</u>
Because two different assessment methodologies are used for skates, this report deviates somewhat from the format of other Stock Assessment and Fishery Evaluation (SAFE) documents. The report contains the following sections:

1) General introduction for all Bering Sea and Aleutian Islands (BSAI) skates
2) Description of the Tier 3 assessment for the Alaska skates
3) Description of the Tier 5 assessment for Other Skates
4) Harvest recommendations for all BSAI skates
5) Ecosystem considerations
6) Tables & Figures
7) Appendix containing supplementary catch information

<u>Description, scientific names, and general distribution</u>
Skates (family Rajidae) are cartilaginous fishes related to sharks. At least 15 species of skates in four genera, *Raja*, *Beringraja*, *Bathyraja*, and *Amblyraja,* are distributed throughout the eastern North Pacific and are common from shallow inshore waters to very deep benthic habitats (Eschmeyer et al. 1983, Stevenson et al. 2006). Table 1 lists the species found in Alaskan waters, with their depth distributions and selected life history characteristics.

The species within the skate assemblage occupy different habitats and regions within the BSAI Fishery Management Plan (FMP) area (Figure 1). In this assessment, we distinguish three habitat areas: the eastern Bering Sea (EBS) shelf (< 200 m depth), the EBS slope (> 200 m depth), and the Aleutian Islands (AI) region. Skate species composition varies widely among the regions, with the highest diversity observed on the EBS slope (Table 2 & Figure 2). The areas also differ in skate abundance with the vast majority (88% in 2016) of skate biomass found on the EBS shelf (Table 2 & Figure 3). In 2016 the slope had 8% of the skate biomass and the AI 4%; before the 2012 survey biomass was higher in the AI than on the slope. Within the BSAI, skate abundance and species composition also vary by depth and species diversity is generally greatest on the upper continental slope at 250 to 500 m depth (Figures 4 & 5; Stevenson et al. 2006). On the EBS slope skate biomass is highest in the 200-400 m depth stratum, and in the AI biomass is greatest between 100 m and 200 m (Figure 5).

The EBS shelf skate complex is dominated by a single species, the Alaska skate (*Bathyraja parmifera*) (Table 2; Figures 2 & 6). The Alaska skate is distributed throughout the EBS shelf habitat area (Figure 6), most commonly at depths of 50 to 200 m (Stevenson 2004), and has accounted for between 91% and 97% of aggregate skate biomass estimates since species identification became reliable in 1999. Alaska skate is also found on the EBS slope and in the AI, but in much smaller numbers. Bottom trawl surveys of the northern Bering Sea (NBS) conducted by the AFSC in 2010, 2017, and 2018 indicate that substantial numbers of Alaska skate occur in the NBS area (Figures 6 & 7); they are also the only skate species that has been observed so far in the NBS. Based on frequency of occurrence, the Bering skate *B. interrupta* is the next most common species on the EBS shelf and is distributed on the outer continental shelf and the EBS slope (Table 2; Figures 2 & 8). Big skate *Beringraja binoculata* has historically been a rare species in the BSAI, occurring mainly in the extreme southern portion of the EBS shelf. The biomass of big skate in the EBS has increased substantially since 2014; the Tier 5 assessment in this report covers this issue in greater detail.

The dominant species on the EBS slope is the Aleutian skate *B. aleutica* (Table 2; Figures 2 & 9). This species is also present on the EBS shelf and in the AI. A number of other species are found on the slope in significant numbers, including Alaska skate, Commander skate *B. lindbergi*, whiteblotched skate *B.*

*maculata*, whitebrow skate *B. minispinosa*, roughtail skate *B. trachura*, and mud skate *B. taranetzi* (Table 2). Commander skate is almost entirely exclusive to the EBS slope (Table 2 & Figure 10), while mud skate occurs on the EBS slope and in the AI (Table 2 & Figure 11). Two rare species, the deepsea skate *B. abyssicola* and roughshoulder skate *Amblyraja badia*, have only recently been reported from EBS slope bottom trawl surveys (Stevenson and Orr 2005). The Okhotsk skate *B. violacea* is also occasionally found on the EBS slope.

The skate complex in the AI is quite distinct from the EBS shelf and slope complexes, with different species dominating the biomass as well as two endemic species, butterfly skate *Bathyraja mariposa* and leopard skate *Bathyraja* sp. cf. *parmifera* (J. Orr, AFSC, pers. comm.). The leopard skate was previously thought to be a color morph of Alaska skate, which occurs in low numbers in the eastern AI, but since 2010 has been treated as a separate species. The most abundant species in the AI is the whiteblotched skate, which is found primarily in the eastern and far western Aleutian Islands (Table 2; Figures 2 & 12). Leopard skate is found primarily to the west of Amchitka Pass, i.e. mainly in the western Aleutians (Table 2 & Figure 13). Aleutian skates are also common in the AI. The mud skate is relatively common in the AI but represents a lower proportion of total biomass because of its smaller body size.

Management units

In the North Pacific, skate species were originally managed as part of the “Other Species” management category within the BSAI Fishery Management Plan (FMP). In October 2009 the NPFMC approved amendment 95 to the BSAI FMP, which separated skates from the BSAI Other Species complex. Beginning in 2011, skates are managed as a single complex with skate-specific ABC and OFL. Currently skates are taken only as bycatch in fisheries directed at target species in the BSAI, so future catches of skates are mainly dependent on the distribution of and limitations placed on target fisheries.

Stock structure

In September 2012 a report on skate stock structure was submitted to the Plan Team. The report was an evaluation of the potential for conservation concerns arising from among-species differences in spatial distribution within the Bering Sea and Aleutian Islands (BSAI) skate complex and the distribution of fishery catches. Evaluation of spatial management concerns is seriously hampered by a lack of reliable species-level catch accounting, which is the highest priority for enhancing skate conservation and management. Although too sparse to properly evaluate the issue, the available data suggest that the current spatial management practice (i.e. BSAI-wide harvest specifications and catch accounting) is appropriate for this complex. The overall exploitation rate is low relative to natural mortality. The highest catch rates occur in the region where Alaska skate (the most abundant and data-rich of all species in the complex) is predominant. The spatial distribution of catches mirrors the spatial distribution of the various species. Biomass trends for all species in all areas appear to be stable, although biomass timeseries are too short and estimates too variable for proper evaluation.

It is important to note that the difference in species composition among the different BSAI subareas is not consistent with the National Standard guidelines regarding stock complexes, which state “Where practicable, the group of stocks should have a similar geographic distribution, life history characteristics, and vulnerabilities to fishing pressure such that the impact of management actions on the stocks is similar.” (CFR 50 §600.310, 6.2.i)

Life history

Skates have relatively low fecundity, slow growth to large body sizes, and dependence of population stability on high survival rates of a few well developed offspring (Moyle and Cech 1996). As a result they can be considered “equilibrium” life history strategists (Winemiller and Rose 1992), with very low intrinsic rates of population increase implying that sustainable harvest is possible only at very low to moderate fishing mortality rates (King and McFarlane 2003). Within this general equilibrium life history strategy, there can still be considerable variability between skate species in terms of life history parameters (Walker and Hislop 1998). Major life stages include the egg stage, the juvenile stage, and the adult stage (summarized here based on Frisk et al. 2002). All skate species are oviparous (egg-laying), investing considerably more energy per large, well-protected embryo than most commercially exploited teleost groundfish. The large, leathery egg cases incubate for extended periods in benthic habitats, exposed to some level of predation and physical damage, until the fully formed juveniles hatch. The juvenile stage lasts from hatching through maturity, several years to over a decade depending on the species. The reproductive adult stage may last several more years to decades depending on the species.

Known life history parameters of Alaskan skate species are presented in Table 1. Considerable research has been directed at skates in the Bering Sea within recent years. Graduate students at the University of Washington and California State University (Moss Landing Marine Laboratories) have completed several projects detailing aspects of life history and population dynamics of several Bering Sea species. A comprehensive study on the age, growth, and reproductive biology of the Alaska skate, the most common skate species on the eastern Bering Sea shelf, was completed in 2006 (Matta 2006). Age and size at 50% maturity were 9 years and 92 cm TL for males and 10 years and 93 cm TL for females (Table 1). Von Bertalanffy growth parameters were estimated for males ($L_\infty$ = 126.29 cm TL, $k$ = 0.120 year$^{-1}$, $t_0$ = -1.39 year) and females ($L_\infty$ = 144.62 cm TL, $k$ = 0.087 year$^{-1}$, $t_0$ = -1.75 year), although length-at-age data were fit slightly better by a Gompertz growth function for both sexes. Based on seasonal reproductive data, including ova diameter, gonadosomatic index (GSI), and the presence of egg cases, the Alaska skate appears to be reproductively active throughout the year. A reproductive resting phase (e.g. 'spent' gonads) was never observed in either large males or females, and females containing egg cases were encountered during each month of collection. Annual fecundity was estimated to average 21 to 37 eggs per year, based on the relationship between annual reproductive effort and natural mortality (Gunderson 1997). While the fecundity estimate needs to be validated using direct methods, fecundity is still likely to be low for the Alaska skate, as is typical for most elasmobranchs.

Hoff (2007) examined skate reproduction and skate nursery habitat of the Alaska skate and the Aleutian skate from the eastern Bering Sea. The relationships between successful skate reproduction and selected nursery grounds were examined. Vulnerability sources, reproductive cycles, habitat selection criteria, and physical factors controlling reproduction were addressed. To date, six nursery sites for three different skate species have been described in the eastern Bering Sea (Figure 14), and there is ample evidence that additional nursery areas exist. All sites are located along the shelf-slope interface in approximately 140-360 m of water. Two sites, those of the Alaska and Aleutian skates, have been studied in detail through seasonal monitoring. An index location at each nursery site was re-sampled approximately once every 60 days from June 2004 through July 2005 for a total of eight sampling periods. During each sampling period data on mortality, reproductive cycles, embryo developmental, species utilization and adult reproductive states were examined.

The Alaska skate nursery in Bering Canyon (Figure 14) is located in 149 meters of water near the shelf-slope interface in a highly productive area of the eastern Bering Sea. The nursery is small in area (< 2 nautical miles), persistent, and highly productive. Density estimates from trawling showed the most active part of the nursery contained >100,000 eggs/km$^2$. Two peak reproductive periods during summer and winter were evident in the Alaska skate nursery. During each active period the nursery showed high densities of mature reproductive adults and high numbers of newly deposited egg cases. Although there are peak reproductive periods at any single sampling time, the nursery contained embryos in all stages of development, and specific cohorts were easily discernible from frequency stage monitoring (Figure 15). Cohort analysis based on embryo lengths measured at an Alaska skate nursery site in the EBS suggested that the Alaska skate has an egg-case development time of over 3 years, possibly due to the cold ocean temperatures in the EBS (Figure 16; Hoff 2007). Captive studies at the Alaska Sealife Center (Seward, AK) have provided preliminary data that validate this conclusion (J. Guthridge, ASLC, pers. comm.). The field observations are also consistent with development times observed in other skate species. For example, thorny skate *Raja radiata* embryos spend approximately 2.5 years in the egg-case development stage at warmer temperatures than those found in the EBS (Berestovskii 1994 cited in Hoff 2007).

The Oregon triton *Fusitriton oregonensis* was the most likely predator on newly deposited egg cases and mortality rate was estimated at 3.64% per year (Hoff 2007). After hatching, young skates were vulnerable to predation by Pacific cod *Gadus macrocephalus* and Pacific halibut *Hippoglossus stenolepis*. Predation by these two large fish species peaked during the summer and winter periods and was highly correlated with hatching events. The Alaska skate nursery site was occupied by mature male and female skates throughout the year, with juvenile and newly hatched individuals extremely rare. Evidence suggests that newly hatched skates quickly move out of the nursery site and immature skates are infrequent visitors to nursery sites. Some degree of intra-species habitat partitioning is evident and is being examined for the Alaska skate throughout the eastern Bering Sea shelf environment.

# Fishery

Directed fishery

In the BSAI, there is no directed fishery for skates at present but there is some interest in developing skate fisheries in Alaska. A directed skate fishery developed in federal waters of the Gulf of Alaska in 2003 (Gaichas et al. 2003), and despite the closure of that fishery interest remains. A small state-waters fishery was conducted in Prince William Sound in 2009 and 2010. Retention of large incidentally-caught skates occurs, indicative of their market value.

Bycatch and retention

Skates are caught incidentally in substantial numbers in BSAI fisheries (Tables 3-4 and Figure 17). At present the Alaska regional office’s Catch Accounting System (CAS) only reports species-specific catch for selected skate species, and these estimates are complicated by limitations of observer data (see below).

Skates are caught in almost all fisheries and areas of the Bering Sea shelf, but most of the skate bycatch is in the hook and line fishery for Pacific cod. Trawl fisheries for pollock, rock sole, flathead sole, and yellowfin sole also catch significant amounts (Table 5). In this assessment, "bycatch" is interpreted as incidental or unintentional catch regardless of the disposition of catch – it can be either retained or discarded. Approximately 1/3 of captured skates are retained, with the retention rate during 2011-2017 varying from 23% to 30% (Table 3). The preliminary estimate for 2018 is 39%, which may indicate increased retention of skates. Skates that are discarded may survive, depending upon catch handling practices, but reliable information regarding skate discard mortality does not yet exist for Alaska fisheries. Data from Gulf of Alaska fisheries suggests that larger skates are preferentially retained.

Incidental catches of skates in the BSAI have increased every year since 2010 (Tables 5 & 6). The NMFS reporting areas encompassing the EBS outer shelf (521 and 517) have historically experienced the highest incidental skate catch rates in the BSAI, but in recent years other areas have seen increased catches (Table 6 & Figure 12). These include area 509, which includes the part of the middle shelf domain immediately north of the Alaska Peninsula. Catches of skates in the northernmost area, 524, have increased substantially since 2015. This may be due to a shift in fishing effort to the north as fishers respond to changes in the distribution of Pacific cod.

Species composition of skate catches

Historically, skates were almost always recorded as "skate unidentified", with very few exceptions between 1990 and 2002. Beginning in 2005, additional training greatly increased observers’ ability to identify skates to species. However, many skates are still only identified to the genus level because most skates are caught in longline fisheries, and if the animal drops off the longline it cannot be identified to species by the observer. In September 2018 a new method for estimating the species composition of skates was presented to the Plan Team and accepted for use in this assessment (see Appendix 2 for details). The new method uses observer data regarding the subset of skates that are identified to species and applies this species composition data to the aggregate skate catch from the CAS.

Alaska skate is the most abundant species in BSAI catches (73% in 2017; Table 7 and Figures 18-19). Substantial numbers of Bering, Aleutian, and whiteblotched are also captured and since 2011 catches of big skates has also increased. Species composition varies among gears. In longline fisheries Bering, big, and Aleutian skate are the most common species caught after Alaska skate (Table 7 and Figure 19). In trawl fisheries whiteblotched skate is the most common secondary species (Table 7 and Figure 19). Species composition of longline catches varies slightly over time, but without a clear trend; in contrast, data from trawl fisheries indicate increasing proportions of big skate and particularly whiteblotched skate. Further discussion of species-specific catches, including exploitation rates, is in the Tier 5 assessment section.

# ALASKA SKATE – Tier 3 assessment

Overview

The BSAI Alaska skate population model has been used since 2008 for making harvest recommendations. The model was substantially revised in 2014 and the model accepted for use in that year has been used ever since. Unlike previous years, no alternative models are presented.

## Data

Summary of data used in the Alaska skate model

| source | data | years |
|---|---|---|
| AKRO Catch Accounting System | catch | 2003-2020 |
| AKRO historical catch record | catch | 1954-2002 |
| NMFS Bottom Trawl Surveys – EBS Shelf (Annual) | biomass index | 1982- 2020 |
| NMFS Bottom Trawl Surveys – EBS Shelf (Annual) | length composition | 2000-2020 |
| NMFS Bottom Trawl Surveys – EBS Shelf (Annual) | length-at-age | 2003, 2007-2009, 2015 |
| NMFS FMA program - observed skate catch | length composition | 2009-2019 |

### Fishery

Catch data

Incidental catches of skates in the BSAI occur in several target fisheries but can be broken down into catches by two gear types: longline and trawl (Table 8 & Figure 20). These fisheries have different selectivities and the majority of catches occur in the longline fisheries. Retention of skates is high and discard mortality is assumed to be 100%; therefore all captured skates are assumed to be dead. The model uses catch data from 1954-2020. All data regarding Alaska skate catches rely to some degree on assumptions regarding the proportion of Alaska skates in the total skate catch. The earlier data also rely on assumptions regarding removals by gear type:

- *1954-1996*: Reconstruction of skate catches relied heavily on two assumptions: 1) that the proportion of trawl vs. longline effort was represented by the proportion of yellowfin sole catch vs. Pacific cod catch, and 2) that the total catch of Alaska skates could be estimated by subdividing the catch of an “Other Species” group (skates, sculpins, sharks, and octopus) based on the proportion of skates in Other Species catches in the modern era (2003-2013) and the proportion of Alaska skates in recent trawl surveys (1999-2013).

- *1997-2006*: Skate-specific catches are available during the modern era from two sources: the Blend database (1992-2002) and the Catch Accounting System (CAS) maintained by the Alaska Regional Office (AKRO). Specific catch data for Alaska skate either do not exist or are unreliable, due to the difficulty of identifying *Bathyraja* species skates in longline fisheries. Therefore, the catches were partitioned based on survey species composition during 1999-2006 and the distribution of effort among the EBS shelf and slope and the Aleutian Islands (AI).
- *2007*-present: Beginning with data from 2007, catches of Alaska skates are estimated using the new method based on observer species composition data. The cutoff of 2007 was chosen because this is the first year in which the majority of sampled skates were identified to species.

Catch data for 2020 were available only through October 23, so the 2020 data are incomplete. To estimate the full 2020 catch, the average increase in reported catch from early October to the end of the year for the last five years was used to create a correction factor that was applied to the incomplete 2020 data to estimate full-year 2020 catch.

Fishery length compositions

Fishery length compositions from 2009-2019 were included for both gear types. Length data for the Alaska skate were collected during 2007 & 2008 as a special project by fishery observers, but the datasets are incomplete. In 2008 the observer manual was changed to require collection of skate lengths on every haul where they were present in the target fisheries for Pacific cod and flatfishes, and this change was fully implemented for 2009. Therefore, 2009 is considered the first year of reliable fishery length composition data for Alaska skate. Length data were aggregated into 4-cm bins and converted to proportions as for the survey data (Table 9). Sample size is discussed below.

## Survey

Survey biomass

Three bottom trawl surveys are conducted in the BSAI region: EBS shelf, EBS slope, and the Aleutian Islands. Because the Alaska skate population is concentrated on the EBS shelf, and the EBS shelf survey provides yearly estimates of biomass, biomass estimates from only the EBS shelf survey are used in this model. Survey efforts on the EBS shelf began in the 1970s, but survey methodology was only standardized in 1982; as a result, the survey time series is considered to begin in 1982. In 1987, two additional strata (82 and 90) were added to the survey. To use consistent data from the entire time series, this assessment includes only the “standard” dataset which does not incorporate the additional strata. Alaska skate biomass in these strata is approximately 20,000 t. Biomass estimates from 1982-2019 were included in the model (Table 10); due to the coronavirus pandemic, survey data were not available for 2020. Reliable skate species identification in the survey is only available starting in 1999. For each survey prior to 1999, total skate biomass estimates were partitioned into Alaska skate and “other” skates based on the average proportion (0.95) of Alaska skate in the 1999-2019 surveys. The modeling software employs the coefficient of variation (CV) as the standard deviation ($s$) associated with each estimate. For the estimates prior to 1999, the value of $s$ for the entire skate complex was used.

Survey length compositions

Length composition data from the EBS shelf survey were available from 2000-2019 (Table 11). The survey takes length measurements for every skate in each haul. The haul-specific data are then weighted by the number of skates in each haul to produce an estimate of numbers at length for the entire EBS population. The length data were aggregated into 4-cm bins and converted to proportions for inclusion in the model. Sample size is discussed below.

Length at age (LAA)
Five LAA datasets from the years 2003 (N=182), 2007 (N=237), 2008 (N=165), 2009 (N=330), and 2015 (N=313) were included in the model. Age was determined through examination of annual growth rings in vertebral thin sections following hatching from the eggcase. All five datasets used vertebrae collected during the EBS shelf survey. The 2003 dataset was generated during a graduate student project (Matta 2006); the remaining datasets resulted from production ageing from the AFSC Age and Growth Lab.

Sample size
Appropriate sample size (N) for the length compositions and LAA data can be difficult to determine. Previous versions of the model used N=100 for all length compositions. After exploring the literature, including other SAFE reports conducted by the AFSC, and through discussions with other assessment authors, the following approach was used for sample size. In general, hauls are considered to be the sampling unit rather than individual length measurements. The total number of hauls each year varies little for the survey, so N=200 was used for all survey length compositions. In the fisheries, a large number of hauls are sampled, so the square root of the number of hauls was used for input N to avoid overemphasis on fishery length compositions. For the LAA data, the actual number of individuals was used as input N. Some exploration of the effect of changing input Ns was performed: for example, fishery length composition N was set equal to the survey N. Unless very large changes were assumed, these changes had only minor influence on the model.

# Analytic Approach

## General model structure

The model was constructed using Stock Synthesis 3 (SS3) assessment software[1] (Methot 2005, 2007). Stock Synthesis allows the flexibility to incorporate both age- and size-structured information in an age-structured model. In the model described here, natural mortality is the only parameter that is explicitly age-based; selectivity, maturity, and mean body weight are length-based parameters. Length-at-age data and estimates of ageing error are used by SS3 to convert the size-based information into age-specific values that can be used to model the population through time.

Model 14.2 was accepted by the Plan Team and SSC in 2014 and is again the author’s preferred model. Similar to 2018, no alternative models are included but results from the 2018 run are presented for comparison. The model continues a number of assumptions used since the model was first created. The entire BSAI was treated as one homogenous area. Because growth and maturity patterns are similar for males and females, only one sex was specified. Spawning was assumed to occur at the midpoint of the year. No informative priors were used. It was assumed that parameters did not vary with season or year and were not influenced by environmental conditions. All parameters are listed in Table 12 and described in more detail below.

[1] NOAA Fisheries Toolbox Version 3.23b, 2011. Stock Synthesis 3, Richard Methot, Northwest Fisheries Science Center, Seattle, WA. [Internet address: http://nft/nefsc.noaa.gov]

## Parameters estimated outside the assessment model

Natural mortality (M)
In 2007, a value of 0.13 was chosen from a set of *M* values estimated using different life history parameters (Matta 2006): growth parameters (Alverson and Carney 1975, Pauly 1980, Charnov 1993), longevity (Hoenig 1983), reproductive potential (Rikhter and Efanov 1976, Roff 1986), von Bertalanffy k (Jensen 1996, Gunderson 2003), and age at maturity (Jensen 1996). Previous runs of the model have demonstrated that this value of *M* provides the best model fit, so *M* in the model continues to be fixed at 0.13.

Length at maturity
SS3 incorporates female maturity parameters into the model using the following equation:

$$\text{proportion mature} = \frac{1}{1+e^{b(L-L_{50})}},$$

where $L_{50}$ is the length at 50% maturity and $b$ is a slope parameter. Maturity parameters were obtained from Matta (2006), where $b$ = -0.548 and $L_{50}$ = 93.28 cm TL. Maturity was estimated directly from paired length and maturity stage data; maturity stage was easily assessed through macroscopic examination of the reproductive organs.

Ageing error
Each vertebra was aged three independent times by a primary age reader without knowledge of the specimen's biological information. For each age, the standard deviation of the estimated age was calculated from the three reads of each vertebra and incorporated into the model to account for variability in age determination.

Survey catchability
The approach to survey catchability remains unchanged from previous models. Survey catchability was fixed at 1. The EBS shelf survey appears to sample Alaska skates very reliably, with CVs of approximately 0.05. In addition, we did not adjust catchability for the segments of the Alaska skate population (AI and EBS slope) that are not observed by the EBS shelf survey. Over 96% of the Alaska skate population is on the shelf and surveys from the other areas are infrequent.

Weight at length
Parameters from the allometric length-weight relationship ($W = aTL^b$, where W is weight in kg and TL is total length in cm) were estimated from data obtained during an Alaska skate tagging project conducted aboard EBS shelf surveys 2008-2010 (O. Ormseth, unpublished data). Parameters were not significantly different between sexes, so data were combined. For sexes combined, $a$ was estimated as $9.0 \times 10^{-6}$ and $b$ was estimated as 2.9617 (Figure 21; $r^2$ = 0.93, N = 1,515).

Spawner-recruit parameters
A Beverton-Holt function is specified and steepness fixed at 1.0 to create a mean level of recruitment. All models used a fixed $\sigma_R$ value of 0.4.

## Parameters estimated inside the assessment model

Growth parameters

An analysis by Matta (2006) suggested that a Gompertz growth model best fit the length-at-age data for Alaska skate. As in the 2012 model, the Gompertz growth function was approximated in SS3 by choosing the Schnute 4-parameter growth model option (Schnute 1981). The Schnute model takes the form:

$$Y(t) = \left\{ y_1^{\gamma} + \left(y_2^{\gamma} - y_1^{\gamma}\right) \frac{1 - exp[-\kappa(t - \tau_1)]}{1 - exp[-\kappa(\tau_2 - \tau_1)]} \right\}^{1/\gamma}$$

where $Y(t)$ is length at age t; $y_1$ and $y_2$ are the length at ages $\boldsymbol{\tau}_1$ and $\boldsymbol{\tau}_2$, respectively; and κ and γ are parameters that control the shape of the growth curve. In SS3, κ is referred to as the von Bertalanffy *k* parameter and γ is referred to as the Richards coefficient. All growth parameters were estimated within the model, as were the two uncertainty parameters (CV of LAA at ages $\boldsymbol{\tau}_1$ and $\boldsymbol{\tau}_2$).

Length selectivity

All length selectivity parameters were estimated within the model. All models used a double-normal selectivity function recommended in the documentation for SS3 (Methot 2012). The double-normal is defined by six parameters for each fishery or survey, where p1 is the peak or ascending inflection size, p2 is the width of the plateau, p3 is the ascending width, p4 is the descending width, p5 is the selectivity at the first length bin, and p6 is the selectivity at the last length bin. Selectivity parameters are summarized in Table 11. All bounds were the default values specified in the SS3 documentation.

Spawner-recruit parameters

The natural log of unfished recruitment ($R_0$) was estimated within the model. In addition, recruitment deviations were estimated for 1950-2020; in SS3 each deviation is considered a separate parameter.

Initial fishing mortality

Initial fishing mortality was fixed at zero.

# Results

## Model Evaluation

Model evaluation criteria

A summary of model fit statistics, with 2018 results for comparison, is located in Table 13. The model was evaluated based on overall quality of fit and comparison of results to previous runs. It was assumed that similar fits to 2018 indicated a successful model run. The following criteria were used:

1) Standard deviation of the parameter estimates was converted to CV; a lower CV indicated a better fit.
2) Model fit to the survey data was conducted by comparing root mean squared error (RMSE), the average standardized residual, the correlation between observed and predicted values and the proportion of survey biomass estimates where the model estimate was within the 95% confidence interval (CI) of the observed value. For RMSE and the average residual, lower values indicated a better fit. For the correlation and the proportion of model estimates within the CIs, higher values indicated a better fit.
3) Comparison of effective sample sizes ($N_{eff}$) for length compositions, with higher $N_{eff}$ indicating better fit to the data.

4) Comparison of effective sample sizes ($N_{eff}$) for LAA datasets, with higher $N_{eff}$ indicating better fit to the data.
5) Visual inspection of model fits to length compositions and LAA data.
6) Reasonable estimates of fishery length selectivity parameters.
7) Analysis of retrospective patterns.

Evaluation of model criteria
Overall the model fit the data reasonably well (Table 13 and Figures 22-27), with results very similar to the 2018 model run (Table 13). The model continues to estimate dome-shaped selectivity for the trawl fishery and survey and asymptotic selectivity for the longline fishery (Figure 23).

The retrospective pattern for spawning biomass and recruitment (Figure 28), as well as the associated statistics (see table below) suggest that the model has some retrospective bias but is generally stable, with a high level of agreement among years. The earliest retrospective year (2008) had the greatest divergence, likely because fishery length compositions are available starting only in 2009. The model was unable to produce meaningful results for the retrospective years 2006-2007 and they were not included in the analysis.

| Alaska skate model retrospective bias diagnostics | | | |
|---|---|---|---|
| | $\rho_{\text{rev Mohn}}$ | $\rho_{\text{Woods Hole}}$ | RMSE |
| spawning biomass | 0.135 | 0.150 | 0.165 |
| recruitment | 0.004 | 0.033 | 0.195 |

## Time series results

Definitions
Biomass is shown as total (age 0+) biomass (metric tons; t) of all Alaska skates in the population, and as spawning biomass (for both sexes; t). Recruitment is reported as the number (in thousands) of Alaska skates at age 0. The CV is included for spawning biomass and age-0 recruits.

Biomass time series
Time series of total biomass and spawning biomass estimates from 1950-2020 are reported in Table 14. Spawning biomass is also shown in Figure 29. The model suggests that the skate population declined beginning in the 1950s, with the steepest decline during the 1970s. The population then rebounded dramatically during the 1980s, increasing until ~1995. It then declined slightly and began to increase in 2007. The 2020 model run estimates that total biomass has decreased slightly since 2015 but spawning biomass continues to increase. These estimates are likely the result of low recruitment estimates in recent years and an increase in the average age of skates in the population.

Recruitment
Time series of age-0 recruitment are reported in Table 15 and Figure 30. The model suggests that a period of increased recruitment occurred between the years 1980-1984, with the highest level of recruitment in 1982. The model also estimates that recruitment increased during the 2000s, then declined and has been consistently low since 2010 with the exception of somewhat stronger year classes in 2016-2018 (although the model’s ability to predict these recent years is low).

Exploitation rate
A time series of exploitation (catch/total biomass) is given in Table 16. These rates suggest that skates experienced the greatest fishing pressure in the 1970s and that most of these removals occurred in the trawl fishery. Exploitation rates have been fairly stable (~0.4-0.5) since the 1990s.

Numbers at age
Model 14.2 indicates that the large year classes that occurred in the 1980s are essentially gone from the population and that the moderately-sized year classes of the 2000s are beginning to show up in the older population (Table 17 and Figure 31).

Phase-plane plot
The trajectory of relative spawning biomass vs. relative fishing mortality (Figure 32) reflects the high $F$ and decrease in biomass during the 1970s, as well the subsequent increase in biomass. In recent years the relationship between the two variables has been consistent, with spawning biomass well above $B_{35\%}$ and $F$ well below $F_{35\%}$.

## Harvest recommendations

Reference points and tier assignment
This assessment using the base model provides reliable estimates of $B_0$, $B_{40\%}$, and the fishing mortality rates corresponding to $F_{40\%}$ and $F_{35\%}$. Therefore, management recommendations are made under Tier 3 of the BSAI Groundfish Fishery Management Plan. Using Tier 3, ABC and OFL are set according to the following criteria:

3a) Stock status: $B/B_{40\%} > 1$
$F_{OFL} = F_{35\%}$
$F_{ABC} \leq F_{40\%}$
3b) Stock status: $0.05 < B/B_{40\%} < 1$
$F_{OFL} = F_{35\%}$ x $(B/B_{40\%} - 0.05) \times 1/0.95$
$F_{ABC} < F_{40\%}$ x $(B/B_{40\%} - 0.05) \times 1/0.95$
3c) Stock status: $B/B40\% < 0.05$
$F_{OFL} = 0$
$F_{ABC} = 0$

Specification of OFL and ABC
The 2021 estimate of female spawning biomass for BSAI Alaska skates is 123,390 t. The estimate of $B_{40\%}$ is 71,370 t, so $B/B_{40\%}$ is 1.73 and 2021-2022 Alaska skate harvest levels can be assigned according to subtier 3a. Therefore, $F_{OFL}= F_{35\%} = 0.092$ and maximum $F_{ABC}= F_{40\%} = 0.079$. The corresponding 2021 OFL is 38,580 t and maximum allowable ABC is 33,219 t. For 2022, OFL is projected to be 36,655 t and maximum allowable ABC will be 31,560 t. The author recommends setting ABC at the maximum permissible value.

## Risk Table and ABC Recommendation

Overview

The following template is used to complete the risk table:

| | *Assessment-related considerations* | *Population dynamics considerations* | *Environmental/ecosystem considerations* | *Fishery Performance* |
|---|---|---|---|---|
| Level 1: Normal | Typical to moderately increased uncertainty/minor unresolved issues in assessment. | Stock trends are typical for the stock; recent recruitment is within normal range. | No apparent environmental/ecosystem concerns | No apparent fishery/resource-use performance and/or behavior concerns |
| Level 2: Substantially increased concerns | Substantially increased assessment uncertainty/ unresolved issues. | Stock trends are unusual; abundance increasing or decreasing faster than has been seen recently, or recruitment pattern is atypical. | Some indicators showing adverse signals relevant to the stock but the pattern is not consistent across all indicators. | Some indicators showing adverse signals but the pattern is not consistent across all indicators |
| Level 3: Major Concern | Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias. | Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns. | Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or down trophic levels (i.e., predators and prey of the stock) | Multiple indicators showing consistent adverse signals a) across different sectors, and/or b) different gear types |
| Level 4: Extreme concern | Severe problems with the stock assessment; severe retrospective bias. Assessment considered unreliable. | Stock trends are unprecedented; More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns. | Extreme anomalies in multiple ecosystem indicators that are highly likely to impact the stock; Potential for cascading effects on other ecosystem components | Extreme anomalies in multiple performance indicators that are highly likely to impact the stock |

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. These considerations are stock assessment considerations, population dynamics considerations, environmental/ecosystem considerations, and fishery performance. Examples of the types of concerns that might be relevant include the following:

1. Assessment considerations—data-inputs: biased ages, skipped surveys, lack of fishery-independent trend data; model fits: poor fits to fits to fishery or survey data, inability to simultaneously fit multiple data inputs; model performance: poor model convergence, multiple minima in the likelihood surface, parameters hitting bounds; estimation uncertainty: poorly-estimated but influential year classes; retrospective bias in biomass estimates.

2. Population dynamics considerations—decreasing biomass trend, poor recent recruitment, inability of the stock to rebuild, abrupt increase or decrease in stock abundance.

3. Environmental/ecosystem considerations—adverse trends in environmental/ecosystem indicators, ecosystem model results, decreases in ecosystem productivity, decreases in prey abundance or availability, increases or increases in predator abundance or productivity.

4. Fishery performance—fishery CPUE is showing a contrasting pattern from the stock biomass trend, unusual spatial pattern of fishing, changes in the percent of TAC taken, changes in the duration of fishery openings.

<u>Assessment considerations</u>
*The model for Alaska skate appears to be rather stable, as results have not changed much over the last few assessments. There is limited retrospective bias. As a result, there are no assessment concerns for Alaska skate. The Other Skate group is managed under Tier 5, so is by definition data-limited. There are no assessment concerns for that group. A continuing concern is the lack of EBS slope data, but that is unlikely to be resolved soon and does not affect the risk assessment because very little skate biomass is observed on the shelf. Rated Level 1, normal.*

<u>Population dynamics considerations</u>
*The biomass of Alaska skates is remarkably stable. The biomass of Other Skates, in particular Aleutian skate and Bering skate, has been decreasing in recent years. However, the populations are still above the long-term average, so at this point that are no concerns. Rated Level 1, normal.*

<u>Environmental/Ecosystem considerations (contributed by Ebett Siddon)</u>
*The BSAI skates complex contains multiple stocks including the whiteblotched skate in the Aleutians, the Alaska skate common over the shelf, the Bering skate over the outer shelf, and a more diverse mix over the slope. Skates are mobile, demersal animals that are fairly ubiquitous (although there is depth stratification in the species composition) and are generalists in terms of prey. Limited knowledge of these species is available to identify stock-specific indicators. Therefore, indicators of ecosystem status are considered with respect to benthic productivity more generally.*

**<u>Environmental processes</u>**: *Following two years of physical oceanographic perturbations, the eastern Bering Sea experienced a return to near-normal climatic conditions in 2020. Summer bottom temperatures and spatial extent of the cold pool were average based on the ROMS hindcast model and observations from the 2020 Dyson cruise (Siddon, 2020).*

**<u>Prey</u>**: *Prey resources for skates include benthic infauna as well as epifauna and fish. Direct measurements of infaunal biomass are not available; trends in epifauna reflect infaunal prey availability while also indicating a direct prey resource to flatfish. Trends in the abundance of motile epifauna remained above the long-term mean in 2019 (no 2020 survey), although decreased 10% from 2018 (Whitehouse, 2019). This indicates sufficient benthic prey availability for skates over the southern Bering Sea shelf.*

**<u>Predators:</u>** *No information on major sources of predation for this stock complex exist.*

**Competitors:** *Potential competitors to this stock complex include flatfish stocks and stock complexes that comprise the benthic foragers guild and the apex predators guild (Whitehouse, 2019). The trend in biomass of the benthic foragers guild has been declining since approximately 2010 and remained below the long term mean in 2019 (Whitehouse, 2019), suggesting a reduction in prey competition from this guild. The biomass within the apex predator guild increased slightly (2%) from 2018 to 2019 and remains at the long term mean.*

*Summary for Environmental/Ecosystem considerations:*

- *Summer bottom temperatures and spatial extent of the cold pool were average, indicating a cooler thermal experience for flatfish stocks;*
- *Prey abundance (motile epifauna) remained above the long-term mean in 2019, although decreased 10% from 2018, indicating sufficient prey availability;*
- *Benthic forager biomass (potential competitors) remained below the long term mean in 2019, suggesting a reduction in prey competition from this guild;*
- *Apex predator biomass (potential competitors) increased slightly from 2018 to 2019 and remains at the long term mean.*

*Proper evaluation of risk is difficult for a data-limited stock. However, the available data suggest there are no apparent ecosystem concerns--level 1.*

Fishery performance

*Skates are a bycatch species and the amount of harvest depends on skate abundance and the behavior of target fisheries. Skate catches declined in 2019 and 2020, perhaps as a result of changes in the Pacific cod fishery.*

Summary and ABC recommendation

| *Assessment-related considerations* | *Population dynamics considerations* | *Environmental/ ecosystem considerations* | *Fishery Performance considerations* |
|---|---|---|---|
| Level 1: no increased concerns | Level 1: no increased concerns | Level 1: no increased concerns | Level 1: no increased concerns |

Proper evaluation of risk is difficult for a data-limited stock. However the available data suggest no concerns that rise above Level 1. No reduction to maximum ABC is recommended.

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). Results of the projection exercise are in Table 17.

For each scenario, the projections begin with the vector of 2020 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2021 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2020. 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 is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios are sometimes used in Environmental Assessments. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2021, are as follows ("max $F_{ABC}$" = maximum permissible $F_{ABC}$ under Amendment 56):

Scenario 1 (Table 18a): In all future years, $F$ is set equal to max $F_{ABC}$. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2 (Table 18b): In all future years, $F$ is set equal to a constant fraction of max $F_{ABC}$, where this fraction is equal to the ratio of the $F_{ABC}$ value for 2021 recommended in the assessment to the max $F_{ABC}$ for 2021. (Rationale: When $F_{ABC}$ is set at a value below max $F_{ABC}$, it is often set at the value recommended in the stock assessment). For Alaska skates the recommended $F_{ABC}$ is typically the max $F_{ABC}$, however the total catch is usually well below ABC (Table 3). Therefore, for Scenario 2 the catch in 2021 and 2022 is set equal to the estimate of 2020 total catch used in the model.

Scenario 3 (Table 18c): In all future years, F is set equal to the 2016-2020 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 4 (Table 18d): In all future years, $F$ is set equal to 50% of max $F_{ABC}$. (Rationale: This scenario provides a likely lower bound on $F_{ABC}$ that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 5 (Table 18e): 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 follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6 (Table 18f): 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 above its MSY level in 2021 and above its MSY level in 2033 under this scenario, then the stock is not overfished.)

Scenario 7 (Table 18g): In 2021 and 2022, F is set equal to max $F_{ABC}$, and in all subsequent years, $F$ is set equal to $F_{OFL}$. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2031 under this scenario, then the stock is not approaching an overfished condition.)

Status: The projections for Scenarios 6 & 7 indicate that the Alaska skate stock will be above $B_{35\%}$ in 2033, so Alaska skates are not currently in an overfished condition and are not approaching an overfished condition.

# OTHER SKATES – Tier 5 assessment

## Data

### Fishery

Fishery data regarding the skate complex have been in Tables 3-6 and Figures 17 and 20. Species composition data of skate catches are given in Table 7 and Figures 18 and 19.

### Survey

Bottom trawl survey biomass estimates
Three bottom trawl surveys are conducted in the BSAI region: EBS shelf, EBS slope, and the AI. The EBS shelf survey is conducted annually; the other two are biennial and are scheduled to occur in even years. Due to problems with vessel contracting there was no EBS slope survey in 2018, which is unfortunate because many of the populations in the “other skates” group occur mainly on the slope. The EBS slope survey is critical to this assessment and continuation of regular slope surveys should be a priority for the AFSC.

Time series of biomass estimates for the skate complex vary according to survey (Table 19 and Figure 33). Data from AI are available from 1980, although the 1980-1986 AI surveys were conducted jointly with Japan and used a different design and gears from the current survey. Survey efforts on the EBS shelf began in the 1970s, but survey methodology was only standardized in 1982; as a result, the survey time series is considered to begin in 1982. In 1987, two additional strata (82 and 90) were added to the survey so estimates presented here from 1987-present are not directly comparable to 1982-1986 estimates (Alaska skate biomass in these strata is approximately 20,000 t). A standardized EBS slope survey was begun in 2002. To properly assess skate species in the BSAI it is necessary to have contemporary estimates from all 3 surveys; due to missed AI and EBS slope surveys this has only occurred in 2002, 2004, 2010, 2012, and 2016 (Table 20). Reliable skate species identification in the surveys is only available starting in 1999. Biomass estimates for individual skate species therefore begin in 1999, 2000, and 2002 for the EBS shelf, AI, and EBS slope surveys respectively (Table 21).

AFSC longline survey
The AFSC conducts alternating biennial longline surveys on the EBS slope and in the AI in depths from 200 m to 1,000 m. Data for skates in aggregate are available from 2000; species composition data are available from 2009, although Aleutian, Bering, and Alaska skate are combined in a single category. Outputs from this survey are relative abundance, reported here as relative population numbers (RPNs).

## Analytic Approach

### General model structure

Harvest recommendations for the “other skates” complex are made under Tier 5 guidelines, where OFL is equal to survey biomass * natural mortality. Although no model is used for harvest recommendations, since 2014 biomass estimates have been produced using a random-effects (RE) model developed by the Plan Teams. In past years separate RE models were run for each survey (i.e. EBS shelf, EBS slope, AI) but the survey biomass estimates and uncertainty upon which the RE model is based were aggregated for all species except Alaska skate before running the model. Beginning with this assessment, for each survey separate RE models are run for the individual species that are sufficiently common in that area to provide a time series usable by the model (i.e. species that consistently appear in survey data and do not display extreme uncertainty). Data for the remaining species in each area were aggregated into a “minor skates” group for use in the model. For the EBS shelf survey, minor species included longnose, mud, Okhotsk, and whiteblotched skate. For the EBS slope survey, minor species included deepsea and longnose skates. Minor species in the AI included longnose, mud, roughtail, Commander, butterfly, and whitebrow skates. For all surveys, unidentified skate biomass was included in the minor skates group.

Biomass estimates in the AI for Alaska and leopard skate are complicated by the fact that leopard skate was not treated as a separate species until the 2010 survey. Therefore the 2000-2006 estimates for Alaska skate include both species and no estimates exist for leopard skate during that period. For the purposes of generating useful RE biomass estimates, the 2000-2006 Alaska skate survey biomass estimates (including variance) were partitioned into Alaska and leopard skate according the proportions of the 2 species in the 2010-2016 surveys.

## Parameter Estimates

Natural Mortality (M)

There is a great deal of uncertainty regarding reliable estimates of *M* for the skate complex. This assessment used the value of *M*=0.1 that has been used consistently in the BSAI and GOA for skates.

# Results

## Changes in distribution

The data on the spatial distributions of skates presented earlier in this report (Figures 6-13) suggest that most species have fairly stable distributions, although relative biomass proportions may shift over time for some species. A notable exception to this observation are the changes in big skate distribution and abundance in the southeastern Bering Sea (Table 21 and Figure 34). The biomass estimate for big skate in the EBS shelf survey increased from 3,596 t in 2014 to 28,731 t in 2018. This increase has occurred mainly in the extreme south of the survey area, just north of the Alaska Peninsula. It is likely that these big skates do not form an independent population but are instead an extension of the big skate population in the GOA. In the GOA, big skates display a longitudinal cline in mean size, with the largest skates in the western GOA (WGOA; Figure 35). The mean 2015-2017 survey size composition for EBS big skates almost exactly matches the size composition in the WGOA. In addition, zero big skates smaller than 70 cm have been observed in the EBS, which suggests there is no spawning and development of juveniles in that region.

## Abundance trends

Bottom trawl survey

Trends in overall skate biomass differ by area (Figure 33). Skate biomass on the EBS shelf has leveled out after increasing substantially from 2012-2017. Biomass on the EBS slope is variable with no clear trend. In the AI, skate biomass shows a declining trend with some annual variation.

The RE model produced useful estimates for all species modeled; results are in Tables 22 and 23 and Figures 36-38. On the EBS shelf, all of the modeled skates (Alaska, Aleutian, Bering, and big) showed increasing trends and this was most pronounced for big skate (Figure 36). On the EBS slope, Commander and Aleutian skate have increasing trends while Bering skate biomass declined from 2012 to 2016 (Figure 37). The biomass of other skate species on the slope has been relatively stable. In the AI, whiteblotched skate (which has the highest abundance) has shown a decreasing trend since 2006 and leopard skate has declined markedly since 2010 (Figure 38). No species have an increasing trend in the AI.

AFSC longline survey

Data from these surveys are displayed in Figures 39 and 40. The abundance trends appear similar the trawl survey results, showing variable RPNs with no clear trend for the EBS slope and a declining trend for the AI. Data for species and species groups have less agreement with the survey and RE-model biomass estimates, but the longline time series is much shorter and it is difficult to directly compare the two datasets.

## Exploitation rates

Species-specific catch estimates were combined with survey biomass estimates for the three years when biomass estimates were available from all three surveys (2010, 2012, and 2016; catches by species are only available starting in 2016). For most species the exploitation rate is much less than 0.1 (Table 24). However Bering skate and big skate had rates in excess of 0.1 in all three years. For these species, catches were compared to RE model estimates to obtain greater detail (model estimates were aggregated among areas).

*Bering skate*: The exploitation rate of Bering skate varied from 0.056 in 2007 to 0.212 in 2015 (Table 25 and Figure 41) and exceeded 0.1 during 2008-2018. Explitation rates have declined since 2017 and the 2019 rate was 0.09. It is likely that these patterns result from the high fishing activity of the Pacific cod longline fishery on the outer EBS shelf where Bering skate is concentrated. If Bering skate was managed as a separate stock, the limit exploitation rate would likely be 0.1 (i.e. the Tier 5 estimate would be based on an $F_{OFL}$ of 0.1). Therefore these exploitation rates are a matter of concern for conservation of Bering skate in the BSAI. This concern is ameliorated by several factors, including (1) the observation that Bering skate biomass has increased from 2011-2017, (2) survey and fishery length compositions (Figures 42-44) suggest that a strong year class will soon recruit to the adult population, (3) Bering skate appear to have similar longevity to Alaska skate, for which $M$ is estimated at 0.13, and (4) the low retention rate of Bering skates (4% - 22%; 7% average since 2014; the overall skate complex retention rate is 23%-30%). The low retention rate may be a result of the relatively small size of Bering skate (maximum length ~ 80 cm) that makes them less valuable than other species. While retention rates do not factor into skate catch accounting and discard mortality rates are unknown, the low retention may reduce the overall mortality of captured Bering skates.

*Big skate*: The exploitation rate of big skate in the BSAI varied from 0.091 in 2009 to 0.317 in 2012 (Table 25). Analysis of big skate exploitation in the BSAI is complicated by the probability that big skates in the BSAI belong to the GOA population (as discussed above). To better understand fishing impacts on a hypothesized Alaska-wide big skate population, RE-model biomass estimates for big skates in the GOA and BSAI were combined, as were catch estimates (Table 25). The combined GOA/BSAI exploitation rate for big skates varied from 0.038 to 0.079 in 2013, which are well below the $F_{OFL}$ of 0.1 specified for big skate in the GOA. Retention of big skates in the BSAI ranged between 14%-57% between 2007 and 2017.

## Harvest recommendations

The 2019 RE-model biomass estimates for the other skates group from the EBS shelf was combined with the 2018 estimates from the EBS slope and AI , equaling a BSAI biomass estimate of 107,174 t. This is ~10% lower than the 2018 estimate. Under Tier 5, $F_{OFL} = M = 0.1$, and OFL = 10,717 t; $F_{ABC} = 0.75*M = .075$, and ABC = 8,038 t.

# Ecosystem Considerations

This section focuses on the Alaska skate in both the EBS and AI, with all other species found in each area summarized within the group "Other Skates." We also include supplemental information on the other biomass dominant species in the AI, the Aleutian and whiteblotched skates.

Skates are predators in the BSAI FMP area. Some species are piscivorous while others specialize in benthic invertebrates; additionally, at least three species, deepsea skate, roughtail skate, and longnose skate, are benthophagic during the juvenile stage but become piscivorous as they grow larger (Ebert 2003, Robinson 2006). Each skate species would occupy a slightly different position in EBS and AI food webs based upon its feeding habits, but in general skates as a group are predators at a relatively high trophic level. For simplicity, we show the food webs for all skate species combined in each system (Figure 45; EBS in upper panel, AI in lower panel). In the EBS food web, the skate biomass and therefore the general skate food web position is dominated by the Alaska skate, which eats primarily pollock (as do most other piscivorous animals in the EBS). The food web indicates that aside from sperm whales, most of the "predators" of EBS skates are fisheries, and that cod and halibut are both predators and prey of skates. The AI food web shows skates with different predators and prey than in the EBS, but still at the same moderately high trophic level. Relative to EBS skates, AI skates display more diet diversity (because the species complex is more diverse than in the Alaska skate-dominated EBS), and have more non-fishery predators including sharks and sea lions. These food webs were derived from mass balance ecosystem models assembling information on the food habits, biomass, productivity and consumption for all major living components in each system (Aydin et al. 2007).

The density and mortality patterns for skates also differ greatly between the EBS and AI ecosystems. The biomass density of Alaska skates is much higher in the EBS than in the AI (Figure 46 upper left panel) and we now know that what was previous thought to be Alaska skate in the AI was likely the leopard skate. The density of Alaska skates in the EBS also far exceeds that of all other *Bathyraja* species in any area (Figure 46 upper right panel), but the density of other *Bathyraja* skates is highest in the AI. One simple way to evaluate ecosystem (predation) effects relative to fishing effects is to measure the proportions of overall mortality attributable to each source. The lower panels of Figure 46 distinguish predation from fishing mortality, and further distinguish these measured sources of mortality from sources that are not explained within the ecosystem models. The models are based on early 1990s fishing and food habits information. While there are many uncertainties in estimating these mortality rates, the results suggest that (early 1990s) fishing mortality exceeded predation mortality for Alaska skates and for Other Skates in the EBS and AI. Furthermore, predation mortality appeared to be higher for AI skates than for EBS skates, both for Alaska and Other Skate species in the early 1990s, suggesting that skates experience higher overall mortality in the AI relative to the EBS. One source of uncertainty in these results is that all skate species in all areas were assumed to have the same total mortality rate, which is an oversimplification, but one which is consistent with the assumptions regarding natural mortality rate (the same for all skate species) in this stock assessment. We expect to improve on these default assumptions as data on productivity and catch for the skate species in each area continue to improve.

In terms of annual tons removed, it is instructive to compare fishery catches with predator consumption of skates. We estimate that fisheries were annually removing about 13,000 and 1,000 tons of skates from the EBS and AI, respectively, on average during the early 1990s (Fritz 1996, 1997). While estimates of predator consumption of skates are perhaps more uncertain than catch estimates, the ecosystem models incorporate uncertainty in partitioning estimated consumption of skates between their major predators in each system. The predators with the highest overall consumption of Alaska skates in the EBS are sperm whales, which account for less than 2% of total skate mortality and consumed between 500 and 2,500 tons of skates annually in the early 1990s. Consumption of EBS Alaska skates by Pacific halibut and cod are too small to be reliably estimated (Figure 47, left panels). Similarly, sperm whales account for less than 2% of Other Skate mortality in the EBS, but are still the primary predator of Other Skates there, consuming an estimated 50 to 400 tons annually. Pacific halibut consume very small amounts of Other Skates in the EBS, according to early 1990s information integrated in ecosystem models (Figure 47, right panels). The predators with the highest consumption of Alaska skates in the AI are also sperm whales, which account for less than 2% of total skate mortality and consumed between 20 and 120 tons of skates annually in the early 1990s. Pinnipeds (e.g. Steller sea lions) and sharks also contributed to Alaska skate mortality in the AI, averaging less than 50 tons annually (Figure 48, left panels). Similarly, sperm whales account for less than 2% of Other Skate mortality in the AI, but are still the primary predator of Other Skates there, consuming an estimated 20 to 150 tons annually. Pinnipeds and sharks consume very small amounts of Other Skates in the AI, according to early 1990s information (Figure 48, right panels). Gerald Hoff's research on skate nursery areas suggests that gastropod predation on skate egg cases may account for a significant portion of mortality during the embryonic stage, and Pacific cod and Pacific halibut consume substantial numbers of newly hatched juvenile skates within nursery areas. These sources of mortality may be included in future stock assessments.

Diets of skates are derived from food habits collections taken in conjunction with EBS and AI trawl surveys. Skate food habits information is more complete for the EBS than for the AI, but we present the best available data for both systems here. Over 40% of EBS Alaska skate diet measured in the early 1990s was adult pollock, and another 15% of the diet was fishery offal, suggesting that Alaska skates are opportunistic piscivores (Figure 49, upper left panel). Eelpouts, rock soles, sandlance, arrowtooth flounder, salmon, and sculpins made up another 25 - 30% of Alaska skates' diet, and invertebrate prey made up the remainder of their diet. This diet composition combined with estimated consumption rates and the high biomass of Alaska skates in the EBS results in an annual consumption estimate of 200,000 - 350,000 tons of pollock annually (Figure 49, lower left panel). EBS Other Skates also consume pollock (45% of combined diets), but their lower biomass results in consumption estimates ranging from 20,000 - 70,000 tons of pollock annually (Figure 49, right panels). Other Skates tend to consume more invertebrates than Alaska skates in the EBS, so estimates of benthic epifaunal consumption due to Other Skates range up to 50,000 tons annually, higher than those for Alaska skates despite the disparity in biomass between the groups (Figure 49, lower panels).

Because Alaska skates and all Other Skates are distributed differently in the EBS, with Alaska skates dominating the shallow shelf areas and the more diverse species complex located on the outer shelf and slope, we might expect different ecosystem relationships for skates in these habitats based on differences in food habits among the species. Similarly, in the AI the unique skate complex has different diet compositions and consumption estimates from those estimated for EBS skates. The skate in the AI formerly known as the Alaska skate (now identified as the leopard skate) is opportunistically piscivorous like its EBS relative, feeding on the common commercial forage fish, Atka mackerel (65% of diet) and pollock (14% of diet), as well as fishery offal (7% of diet; Figure 50 upper left panel). Diets of Other Skates in the AI are more dominated by benthic invertebrates, especially shrimp (42% of diet), but include more pelagic prey such as juvenile pollock, adult Atka mackerel, adult pollock and squids (totaling 45% of diet; Figure 50 upper right panel). Estimated annual consumption of Atka mackerel by AI leopard skates in the early 1990s ranged from 7,000 to 15,000 tons, while pollock consumption was below 5,000 tons (Figure 50 lower left panel). Shrimp consumption by AI Other Skates was estimated to range from 4,000 to 15,000 tons annually in the early 1990s, and consumption of pollock ranged from 2,000 to 10,000 tons (Figure 50 lower right panel). Atka mackerel consumption by AI Other Skates was estimated to be below 5,000 tons annually. The diet composition estimated for AI Other Skates is likely dominated by the biomass dominant species in that system, whiteblotched skate and Aleutian skate. The diet compositions of both Aleutian and whiteblotched skates in the AI appear to be fairly diverse (Figure 51), and are described in further detail in Yang (2007) along with the diets of big skate, Bering skate, Alaska skate, roughtail skate, and mud skate in the AI. In the future, we hope to use diet compositions to make separate consumption estimates for whiteblotched and Aleutian skates along with leopard skates in the AI.

Ecosystem Effects on Stock and Fishery Effects on the Ecosystem: Summary
In the following tables, we summarize ecosystem considerations for BSAI skates and the entire groundfish fishery where they are caught incidentally.

Ecosystem effects on BSAI Skates (evaluating level of concern for skate populations)

| Indicator | Observation | Interpretation | Evaluation |
|---|---|---|---|
| | Prey availability or abundance trends | | |
| Pollock | Currently declining from high biomass levels | Probably still adequate forage available for piscivorous skates | Probably no concern |
| Atka mackerel | Cyclically varying population with slight upward trend overall 1977 - 2005 | Adequate forage available for piscivorous skates | No concern |
| Shrimp/Benthic invertebrates | Trends are not currently measured directly, only short time series of food habits data exist for potential retrospective measurement | Unknown | Unknown |
| | Predator population trends | | |
| Sperm whales | Populations recovering from whaling? | Possibly higher mortality on skates? But still a very small proportion of mortality | No concern |
| Steller sea lions | Declined from 1960s, low but level recently | Lower mortality on skates? | No concern |
| Sharks | Population trends unknown | Unknown | Unknown |
| Changes in habitat quality | | | |
| Benthic ranging from shallow shelf to deep slope, isolated nursery areas in specific locations | Skate habitat is only beginning to be described in detail. Adults appear adaptable and mobile in response to habitat changes. Eggs are limited to isolated nursery grounds and juveniles use different habitats than adults. Changes in these habitats have not been monitored historically, so assessments of habitat quality and its trends are not currently available. | Continue study on small nursery areas to evaluate importance to population production | Possible concern if nursery grounds are disturbed or degraded. |

Groundfish fishery effects on ecosystem via skate bycatch *(evaluating level of concern for ecosystem)*

| Indicator | Observation | Interpretation | Evaluation |
|---|---|---|---|
| | Fishery contribution to bycatch | | |
| Skate catch | Has varied from 12,226 t - 22,982 t from 1992-2007 | Largest portion of total mortality for skates | Possible concern |
| Forage availability | Skates have few predators, and skates are small proportion of diets for their predators | Fishery removal of skates has a small effect on predators | Probably no concern |
| | | Fishery concentration in space and time | |
| | Skate bycatch is spread throughout FMP areas, although higher proportion of skate bycatch occurs on outer continental shelf and upper slope | Potential impact to skate populations if fishery disturbs nursery or other important habitat, but small effect on skate predators | Possible concern for skates, probably no concern for skate predators |
| | | Fishery effects on amount of large size target fish | |
| | Survey length compositions (2000 - 2007) suggest that large size classes of Alaska skates appear to be stable | Fishery removals do not appear to have an effect on size structure | Probably no concern |
| | | Fishery contribution to discards and offal production | |
| | Skate discard is a relatively high proportion of skate catch, some incidentally caught skates are retained and processed | Unclear whether discard of skates has ecosystem effect | Unknown |
| | | Fishery effects on age-at-maturity and fecundity | |
| | Skate age at maturity and fecundity are just now being described; fishery effects on them difficult to determine due to lack of unfished population to compare with | Unknown | Unknown |

## Data gaps and research priorities

- In the Alaska skate model, we assumed a catch rate with 100% mortality. In reality, skate mortality is dependent upon the time spent out of water, the type of gear, and handling practices after capture. From fishery observer data, approximately 30% of skates are retained; however, we currently have no information regarding the survival of skates that are discarded at sea.
- Biomass indices from the EBS slope and AI are critical pieces of information for managing BSAI skates. The survey efforts in these regions need to continue and should have a high priority.
- We have conducted a tagging program for Alaska skates on the EBS shelf since 2008. Any additional information regarding movement of skates would be valuable.
- Fecundity is a very difficult quantity to measure in skates, as individuals of some species may reproduce throughout the year and thus the number of mature or maturing eggs present in the ovary may represent only a fraction of the annual reproductive output. Reliable fecundity estimates for Alaska skates are a research priority.
- Additional information is required on the mortality rate of early life stages of skates, both inside their eggcases and when they emerge as free-swimming juveniles.

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# Tables

Table 1. Life history and depth distribution information available for BSAI skate species, from Stevenson (2004) unless otherwise noted.

| Species | Common name | Max obs. length (TL cm) | Max obs. age | Age, length Mature (50%) | Feeding mode [2] | N embryos/ egg case [1] | Depth range (m) [9] |
|---|---|---|---|---|---|---|---|
| Bathyraja abyssicola | deepsea skate | 135 (M) [10] 157 (F) [11] | ? | 110 cm (M) [11] 145 cm (F) [13] | benthophagic; predatory [11] | 1 [13] | 362-2904 |
| Bathyraja aleutica | Aleutian skate | 150 (M) 154 (F) [12] | 14 [6] | 121 cm (M) 133 cm (F) [12] | Predatory | 1 | 15-1602 |
| Bathyraja interrupta | Bering skate (complex?) | 83 (M) 82 (F) [12] | 19 [6] | 67 cm (M) 70 cm (F) [12] | Benthophagic | 1 | 26-1050 |
| Bathyraja lindbergi | Commander skate | 97 (M) 97 (F) [12] | ? | 78 cm (M) 85 cm (F) [12] | ? | 1 | 126-1193 |
| Bathyraja maculata | whiteblotched skate | 120 | ? | 94 cm (M) 99 cm (F) [12] | Predatory | 1 | 73-1193 |
| Bathyraja mariposa [3] | butterfly skate | 76 | ? | ? | ? | 1 | 90-448 |
| Bathyraja minispinosa | whitebrow skate | 83[10] | ? | 70 cm (M) 66 cm (F) [12] | Benthophagic | 1 | 150-1420 |
| Bathyraja parmifera | Alaska skate | 118 (M) 119 (F) [4] | 15 (M) 17 (F) [4] | 9 yrs, 92cm (M) 10 yrs, 93cm(F) [4] | Predatory | 1 | 17-392 |
| Bathyraja sp. cf. parmifera | "Leopard" parmifera | 133 (M) 139 (F) | ? | ? | Predatory | ? | 48-396 |
| Bathyraja taranetzi | mud skate | 67 (M) 77 (F) [12] | ? | 56 cm (M) 63 cm (F) [12] | predatory [13] | 1 | 58-1054 |
| Bathyraja trachura | roughtail skate | 91 (M) [14] 89 (F) [11] | 20 (M) 17 (F) [14] | 13 yrs, 76 cm (M) 14 yrs, 74 cm (F)[14, 12] | benthophagic; predatory [11] | 1 | 213-2550 |
| Bathyraja violacea | Okhotsk skate | 73 | ? | ? | Benthophagic | 1 | 124-510 |
| Amblyraja badia | roughshoulder skate | 95 (M) 99 (F) [11] | ? | 93 cm (M) [11] | predatory [11] | 1 [13] | 1061-2322 |
| Raja binoculata | big skate | 244 | 15 [5] | 6-8 yrs, 72-90 cm [7] | predatory [8] | 1-7 | 16-402 |
| Raja rhina | longnose skate | 180 | 25 [5] | 7-10 yrs, 65-83 cm [7] | benthophagic; predatory [15] | 1 | 9-1069 |

[1] Eschemeyer 1983. [2] Orlov 1998 & 1999 (Benthophagic eats mainly amphipods, worms. Predatory diet primarily fish, cephalopods). [3] Stevenson et al. 2004. [4] Matta 2006. [5] Gburski et al. 2007. [6] Gburski unpub data. [7] McFarlane & King 2006. [8] Wakefield 1984. [9] Stevenson et al. 2006. [10] Mecklenberg et al. 2002. [11] Ebert 2003. [12] Ebert 2005. [13] Ebert unpub data. [14] Davis 2006. [15] Robinson 2006.

Table 2. Species composition of the EBS and AI skate complexes from 2016, the last year in which all BSAI areas were surveyed within the same year.

| skate species | EBS shelf | | EBS slope | | Aleutian Islands | | total BSAI | |
|---|---|---|---|---|---|---|---|---|
| | biomass estimate (t) | CV | biomass estimate (t) | CV | biomass estimate (t) | CV | biomass estimate (t) | CV |
| Alaska | 531,676 | 0.04 | 8,965 | 0.30 | 1,808 | 0.46 | 542,449 | 0.04 |
| Aleutian | 14,449 | 0.27 | 23,204 | 0.20 | 3,703 | 0.21 | 41,355 | 0.15 |
| whiteblotched | 245 | 1.00 | 5,065 | 0.21 | 15,380 | 0.19 | 20,690 | 0.15 |
| Bering | 10,981 | 0.12 | 1,963 | 0.20 | 50 | 0.55 | 12,994 | 0.11 |
| big | 10,668 | 0.54 | - | - | 1,306 | 0.87 | 11,974 | 0.49 |
| Commander | - | - | 5,511 | 0.16 | 29 | 1.00 | 5,540 | 0.16 |
| leopard | - | - | - | - | 4,220 | 0.40 | 4,220 | 0.40 |
| roughtail | - | - | 2,283 | 0.14 | - | - | 2,283 | 0.14 |
| mud | 506 | 0.54 | 577 | 0.22 | 1,165 | 0.20 | 2,248 | 0.17 |
| whitebrow | - | - | 1,359 | 0.15 | - | - | 1,359 | 0.15 |
| deepsea | - | - | 223 | 0.54 | - | - | 223 | 0.54 |
| butterfly | - | - | - | - | 86 | 0.31 | 86 | 0.31 |
| Bathyraja sp. | - | - | 0.1 | 1.00 | 21 | 0.85 | 21 | 0.84 |
| skate unID | - | - | 2 | 1.00 | - | - | 2 | 1.00 |
| longnose | - | - | - | - | - | - | - | - |
| all skates | 568,525 | 0.04 | 49,152 | 0.11 | 27,768 | 0.14 | 645,444 | 0.04 |

Table 3. Time series of OFL, ABC, TAC, catch, and retention for the BSAI skate complex, 2011-2020*. All values are in metric tons except for retention rate. Prior to 2011 skates were managed as part of the Other Species complex; data regarding catch in that era can be found in previous BSAI skate assessments. Source: Alaska Regional Office.

| year | skate complex OFL | skate complex ABC | skate complex TAC | skate complex catch | skate retention rate |
|---|---|---|---|---|---|
| 2011 | 37,800 | 31,500 | 16,500 | 24,004 | 24% |
| 2012 | 39,100 | 32,600 | 24,700 | 24,968 | 29% |
| 2013 | 45,800 | 38,800 | 24,000 | 27,035 | 29% |
| 2014 | 41,849 | 35,383 | 26,000 | 27,582 | 30% |
| 2015 | 49,575 | 41,658 | 25,700 | 28,276 | 28% |
| 2016 | 50,215 | 42,134 | 26,000 | 29,175 | 23% |
| 2017 | 49,063 | 41,144 | 26,000 | 31,875 | 29% |
| 2018 | 46,668 | 39,082 | 27,000 | 31,167 | *39%* |
| 2019 | 51,152 | 42,714 | 26,000 | 20,139 | *48%* |
| *2020** | 49,792 | 41,543 | 16,313 | 15,620 | *46%* |

*2020 data are incomplete; retrieved October 23, 20120

Table 4. Estimated catch (t) of all skate species combined by BSAI area, 1997 - 2020*. Source: Alaska Regional Office.

| | EBS | AI | total |
|---|---|---|---|
| 1997 | 16,890 | 857 | 17,747 |
| 1998 | 18,189 | 1128 | 19,317 |
| 1999 | 13,277 | 802 | 14,079 |
| 2000 | 17,068 | 1808 | 18,876 |
| 2001 | 18,061 | 2510 | 20,571 |
| 2002 | 20,583 | 695 | 21,278 |
| 2003 | 18,500 | 655 | 19,154 |
| 2004 | 21,445 | 885 | 22,329 |
| 2005 | 22,388 | 696 | 23,084 |
| 2006 | 19,283 | 966 | 20,250 |
| 2007 | 17,612 | 1,011 | 18,623 |
| 2008 | 20,276 | 1,401 | 21,677 |
| 2009 | 19,390 | 1,206 | 20,596 |
| 2010 | 16,368 | 1,345 | 17,713 |
| 2011 | 22,723 | 1,281 | 24,004 |
| 2012 | 23,879 | 1,089 | 24,968 |
| 2013 | 25,972 | 1,063 | 27,035 |
| 2014 | 26,349 | 1,232 | 27,582 |
| 2015 | 26,922 | 1,353 | 28,276 |
| 2016 | 27,974 | 1,201 | 29,175 |
| 2017 | 30,444 | 1,431 | 31,875 |
| 2018 | 29,430 | 1,737 | 31,167 |
| 2019 | 18,867 | 1,272 | 20,139 |
| *2020** | 14,681 | 939 | 15,620 |

*2018 data are incomplete; retrieved October 25, 2018.

Table 5. Estimated catch (t) of all skate species combined by target fishery, 2003 – 2020*. Source: Alaska Regional Office.

| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| P cod | 14,950 | 18,369 | 19,456 | 15,115 | 13,463 | 14,311 | 12,698 | 11,427 | 16,859 |
| YFS | 1,524 | 594 | 943 | 1,133 | 1,409 | 1,303 | 1,784 | 1,904 | 2,107 |
| FHS | 625 | 1,192 | 839 | 852 | 768 | 663 | 360 | 304 | 112 |
| halibut | 265 | 282 | 130 | 84 | 20 | 1,370 | 0 | 24 | 694 |
| pollock | 471 | 841 | 732 | 1,308 | 1,287 | 2,758 | 3,856 | 1,881 | 2,352 |
| Atka | 91 | 143 | 140 | 141 | 153 | 179 | 185 | 246 | 269 |
| rock sole | 530 | 500 | 422 | 930 | 996 | 555 | 964 | 1,212 | 709 |
| rockfish | 73 | 23 | 29 | 37 | 72 | 63 | 91 | 53 | 104 |
| G. turbot | 221 | 136 | 168 | 121 | 176 | 69 | 209 | 368 | 383 |
| ATF | 103 | 64 | 135 | 282 | 81 | 297 | 191 | 184 | 116 |
| misc | 217 | 94 | 21 | 116 | 70 | 63 | 111 | 3 | 23 |
| KF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 92 |
| AK plaice | 0 | 0 | 0 | 1 | 2 | 2 | 1 | 5 | 38 |
| sablefish | 57 | 12 | 26 | 123 | 62 | 41 | 131 | 98 | 141 |
| other flat | 26 | 78 | 42 | 7 | 64 | 2 | 14 | 4 | 3 |
| total | 19,154 | 22,329 | 23,084 | 20,250 | 18,623 | 21,677 | 20,596 | 17,713 | 24,004 |

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| P cod | 18,622 | 20,499 | 21,894 | 24,367 | 25,581 | 27,525 | 25,195 | 13,110 | 11,367 |
| YFS | 2,235 | 2,683 | 1,970 | 1,073 | 1,295 | 1,932 | 2,562 | 3,493 | 1,506 |
| FHS | 76 | 206 | 272 | 101 | 56 | 90 | 519 | 1,006 | 347 |
| halibut | 56 | 342 | 904 | 533 | 355 | 422 | 829 | 513 | 256 |
| pollock | 2,018 | 1,757 | 813 | 824 | 423 | 448 | 509 | 509 | 816 |
| Atka | 510 | 345 | 490 | 495 | 662 | 719 | 863 | 488 | 369 |
| rock sole | 632 | 526 | 689 | 284 | 280 | 214 | 284 | 312 | 193 |
| rockfish | 97 | 227 | 163 | 171 | 139 | 144 | 165 | 294 | 209 |
| G. turbot | 357 | 51 | 43 | 209 | 194 | 198 | 100 | 123 | 99 |
| ATF | 207 | 183 | 160 | 98 | 94 | 65 | 14 | 122 | 279 |
| misc | 0 | 0 | 20 | 16 | 20 | 64 | 26 | 98 | 2 |
| KF | 101 | 49 | 57 | 68 | 53 | 35 | 31 | 44 | 137 |
| AK plaice | 9 | 45 | 0 | 12 | 3 | 4 | 63 | 11 | 22 |
| sablefish | 46 | 121 | 108 | 18 | 19 | 8 | 9 | 9 | 5 |
| other flat | 3 | 0 | | 6 | 1 | 8 | 1 | 9 | 13 |
| total | 24,968 | 27,035 | 27,582 | 28,276 | 29,175 | 31,875 | 31,167 | 20,139 | 15,620 |

*2020 data incomplete; retrieved October 23, 2020.

Table 6. Estimated catch (t) of all skate species combined by reporting area, 2003 – 2020*. Source: Alaska Regional Office.

| | | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|
| | 508 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 509 | 1,972 | 2,189 | 3,271 | 3,537 | 3,584 | 4,040 | 5,009 | 2,791 | 6,081 |
| | 512 | 25 | 205 | 15 | 0 | 0 | 28 | 16 | 13 | 7 |
| | 513 | 2,722 | 2,747 | 3,902 | 2,607 | 2,321 | 2,048 | 2,503 | 1,872 | 3,099 |
| | 514 | 275 | 67 | 196 | 221 | 445 | 83 | 134 | 78 | 150 |
| | 516 | 130 | 408 | 239 | 253 | 398 | 488 | 575 | 664 | 243 |
| EBS | 517 | 2,893 | 3,020 | 3,772 | 2,459 | 2,175 | 2,467 | 3,200 | 2,822 | 2,626 |
| | 518 | 25 | 6 | 16 | 11 | 5 | 459 | 57 | 42 | 136 |
| | 519 | 184 | 140 | 104 | 69 | 109 | 240 | 56 | 81 | 109 |
| | 521 | 8,979 | 10,369 | 8,513 | 8,383 | 7,120 | 7,755 | 6,181 | 6,598 | 8,803 |
| | 523 | 304 | 324 | 243 | 282 | 333 | 242 | 264 | 395 | 284 |
| | 524 | 990 | 1,970 | 2,116 | 1,462 | 1,122 | 2,426 | 1,396 | 1,013 | 1,184 |
| | 530 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | |
| | 541 | 302 | 466 | 488 | 563 | 340 | 492 | 452 | 465 | 1,043 |
| AI | 542 | 234 | 280 | 125 | 337 | 400 | 566 | 335 | 453 | 192 |
| | 543 | 118 | 139 | 83 | 67 | 271 | 343 | 419 | 427 | 45 |
| BSAI total | | 19,154 | 22,329 | 23,084 | 20,250 | 18,623 | 21,677 | 20,596 | 17,713 | 24,004 |

| | | 2,012 | 2,013 | 2,014 | 2,015 | 2,016 | 2,017 | 2,018 | 2,019 | *2,020** |
|---|---|---|---|---|---|---|---|---|---|---|
| | 508 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *0* |
| | 509 | 6,147 | 8,260 | 3,796 | 1,962 | 1,827 | 3,627 | 4,990 | 803 | *767* |
| | 512 | 161 | 50 | 21 | 66 | 4 | 4 | 516 | 0 | *0* |
| | 513 | 1,806 | 3,422 | 4,539 | 5,153 | 3,661 | 4,253 | 3,856 | 5,191 | *1,927* |
| | 514 | 1,586 | 227 | 948 | 1,220 | 604 | 225 | 798 | 942 | *181* |
| | 516 | 776 | 968 | 399 | 182 | 120 | 585 | 390 | 77 | *57* |
| EBS | 517 | 3,319 | 4,725 | 4,207 | 4,968 | 4,292 | 3,183 | 2,238 | 1,176 | *649* |
| | 518 | 20 | 54 | 95 | 106 | 83 | 51 | 112 | 114 | *54* |
| | 519 | 122 | 67 | 147 | 105 | 83 | 90 | 155 | 170 | *82* |
| | 521 | 8,148 | 7,171 | 10,829 | 11,193 | 12,206 | 13,007 | 7,428 | 6,856 | *8,429* |
| | 523 | 1,069 | 868 | 654 | 394 | 225 | 157 | 124 | 181 | *266* |
| | 524 | 726 | 161 | 715 | 1,574 | 4,869 | 5,262 | 8,824 | 3,357 | *2,269* |
| | 530 | | | | | | | | | |
| | 541 | 776 | 614 | 991 | 878 | 804 | 786 | 1,074 | 791 | *592* |
| AI | 542 | 277 | 362 | 188 | 263 | 174 | 425 | 290 | 244 | *160* |
| | 543 | 35 | 86 | 53 | 213 | 224 | 220 | 373 | 237 | *188* |
| BSAI total | | 24,968 | 27,035 | 27,582 | 28,276 | 29,175 | 31,875 | 31,167 | 20,139 | *15,620* |

*2020 data incomplete; retrieved October 23, 2020.

Table 7a. Skate catch by species for **all gear types** combined, 2007-2020. The 2020 data are incomplete; data retrieved October 23, 2020.

| skate species | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | *2020** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alaska | 15,861 | 15,698 | 16,712 | 11,157 | 18,773 | 19,630 | 22,050 | 21,211 | 21,261 | 23,116 | 24,635 | 24,640 | 15,510 | *12,459* |
| Bering | 742 | 2,270 | 1,662 | 564 | 1,897 | 1,858 | 1,738 | 2,300 | 3,122 | 2,456 | 3,057 | 1,795 | 1,288 | *974* |
| big | 422 | 316 | 348 | 260 | 615 | 1,096 | 1,329 | 1,375 | 1,243 | 1,345 | 1,822 | 2,154 | 1,284 | *411* |
| whiteblotched | 307 | 1,730 | 365 | 289 | 977 | 616 | 700 | 994 | 953 | 926 | 886 | 1,110 | 945 | *730* |
| Aleutian | 1,026 | 1,364 | 1,208 | 837 | 1,212 | 1,442 | 905 | 1,309 | 1,392 | 1,051 | 1,220 | 855 | 907 | *702* |
| Commander | 185 | 110 | 174 | 150 | 312 | 167 | 203 | 246 | 174 | 177 | 143 | 161 | 113 | *225* |
| mud | 47 | 144 | 95 | 54 | 153 | 103 | 62 | 42 | 72 | 49 | 61 | 115 | 70 | *101* |
| whitebrow | 12 | 15 | 19 | 10 | 37 | 27 | 9 | 31 | 13 | 20 | 29 | 8 | 16 | *17* |
| roughtail | 10 | 11 | 7 | 9 | 7 | 10 | 6 | 4 | 5 | 4 | 5 | 4 | 3 | *0* |
| longnose | 3 | 8 | 2 | 5 | 22 | 19 | 31 | 69 | 42 | 33 | 17 | 326 | 3 | *1* |
| butterfly | 3.02 | 0 | 0.16 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *0* |
| deepsea | 0 | 0 | 0.16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *0* |

Table 7b. Skate catch by species for **longline gear**, 2007-2020. The 2020 data are incomplete; data retrieved October 23, 2020.

| | longline | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| skate species | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | *2020** |
| Alaska | 8,970 | 10,031 | 9,501 | 5,634 | 13,318 | 14,382 | 16,483 | 17,376 | | 20,813 | 21,604 | 20,348 | 10,057 | *9,476* |
| Bering | 637 | 2,178 | 1,581 | 449 | 1,841 | 1,809 | 1,686 | 2,247 | 3,096 | 2,435 | 3,039 | 1,767 | 1,258 | *952* |
| big | 303 | 225 | 258 | 170 | 477 | 994 | 1,274 | 1,212 | 1,036 | 1,142 | 1,510 | 1,930 | 1,032 | *95* |
| Aleutian | 820 | 1,097 | 989 | 640 | 1,063 | 1,204 | 751 | 1,209 | 1,239 | 912 | 1,030 | 707 | 598 | *373* |
| whiteblotched | 264 | 1,597 | 172 | 219 | 651 | 194 | 266 | 372 | 493 | 318 | 350 | 437 | 399 | *264* |
| Commander | 184 | 99 | 168 | 150 | 307 | 158 | 202 | 241 | 171 | 175 | 141 | 160 | 106 | *213* |
| mud | 23 | 111 | 63 | 17 | 109 | 64 | 16 | 14 | 47 | 21 | 35 | 66 | 23 | *46* |
| whitebrow | 11 | 9 | 16 | 9 | 36 | 25 | 7 | 29 | 11 | 19 | 28 | 5 | 7 | *15* |
| roughtail | 9 | 10 | 7 | 7 | 7 | 10 | 6 | 4 | 5 | 4 | 5 | 3 | 3 | *0* |
| longnose | 1 | 6 | 2 | 1 | 18 | 13 | 21 | 31 | 37 | 12 | 9 | 317 | 2 | *0* |
| butterfly | *3* | *0* | *0* | *3* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | 0 | 0 | *0* |
| deepsea | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | 0 | 0 | *0* |

Table 7b. Skate catch by species for **trawl gear** (pelagic and non-pelagic), 2007-2020. The 2020 data are incomplete; data retrieved October 23, 2020.

| trawl | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| skate species | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020* |
| Alaska | 6,891 | 5,667 | 7,211 | 5,523 | 5,455 | 5,247 | 5,568 | 3,835 | 2,428 | 2,302 | 3,030 | 4,292 | 5,453 | 2,983 |
| whiteblotched | 43 | 132 | 193 | 70 | 326 | 422 | 434 | 622 | 460 | 607 | 535 | 673 | 545 | 466 |
| Aleutian | 206 | 267 | 220 | 197 | 149 | 238 | 153 | 100 | 153 | 139 | 189 | 148 | 309 | 330 |
| big | 118 | 91 | 89 | 90 | 138 | 102 | 55 | 163 | 207 | 202 | 312 | 224 | 252 | 317 |
| mud | 24 | 33 | 32 | 37 | 44 | 39 | 45 | 28 | 24 | 27 | 26 | 48 | 46 | 55 |
| Bering | 105 | 92 | 81 | 115 | 56 | 49 | 53 | 53 | 26 | 21 | 18 | 28 | 31 | 22 |
| whitebrow | 1 | 6 | 3 | 1 | 1 | 3 | 2 | 3 | 1 | 1 | 2 | 3 | 9 | 2 |
| Commander | 1 | 11 | 6 | 0 | 4 | 8 | 1 | 5 | 4 | 3 | 2 | 1 | 7 | 13 |
| longnose | 2 | 1 | 0 | 4 | 4 | 5 | 10 | 37 | 6 | 21 | 8 | 9 | 1 | 1 |
| roughtail | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| butterfly | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| deepsea | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 8. Reconstructed catch data used in the Alaska skate model, by year and gear type. Catch estimates from 2007-2020 use the new catch estimation method and are marked in **blue bold**. Catch estimates for 2020 were incomplete, so the catch as of October 23 was expanded by a correction factor based on seasonal catch patterns from the last 5 years.

| year | longline | trawl | year | longline | trawl |
|---|---|---|---|---|---|
| 1954 | 0 | 0 | 1988 | 1,443 | 4,287 |
| 1955 | 0 | 0 | 1989 | 588 | 1,752 |
| 1956 | 0 | 0 | 1990 | 688 | 2,009 |
| 1957 | 0 | 0 | 1991 | 6,246 | 1,372 |
| 1958 | 8 | 61 | 1992 | 12,586 | 2,815 |
| 1959 | 21 | 156 | 1993 | 9,072 | 2,029 |
| 1960 | 0 | 0 | 1994 | 10,554 | 2,361 |
| 1961 | 0 | 0 | 1995 | 11,050 | 2,472 |
| 1962 | 0 | 0 | 1996 | 9,381 | 2,098 |
| 1963 | 0 | 0 | 1997 | 13,059 | 2,932 |
| 1964 | 43 | 304 | 1998 | 14,100 | 3,178 |
| 1965 | 150 | 928 | 1999 | 10,288 | 2,318 |
| 1966 | 130 | 924 | 2000 | 13,362 | 3,055 |
| 1967 | 537 | 1,967 | 2001 | 14,244 | 3,291 |
| 1968 | 1,539 | 9,252 | 2002 | 15,943 | 3,571 |
| 1969 | 690 | 4,365 | 2003 | 15,580 | 3,693 |
| 1970 | 1,220 | 6,502 | 2004 | 16,308 | 3,892 |
| 1971 | 856 | 5,613 | 2005 | 17,661 | 3,405 |
| 1972 | 1,377 | 4,916 | 2006 | 14,907 | 3,347 |
| 1973 | 3,264 | 23,062 | **2007** | **8,973** | **6,893** |
| 1974 | 3,700 | 24,994 | **2008** | **10,032** | **5,667** |
| 1975 | 3,348 | 22,736 | **2009** | **9,503** | **7,213** |
| 1976 | 1,702 | 10,897 | **2010** | **7,514** | **5,608** |
| 1977 | 2,559 | 15,090 | **2011** | **13,318** | **5,455** |
| 1978 | 3,864 | 25,571 | **2012** | **14,382** | **5,247** |
| 1979 | 2,609 | 16,207 | **2013** | **16,483** | **5,568** |
| 1980 | 4,578 | 12,310 | **2014** | **17,376** | **3,835** |
| 1981 | 4,503 | 12,553 | **2015** | **18,833** | **2,428** |
| 1982 | 2,349 | 6,437 | **2016** | **20,813** | **2,302** |
| 1983 | 1,971 | 5,456 | **2017** | **21,604** | **3,030** |
| 1984 | 1,072 | 2,995 | **2018** | **20,348** | **4,292** |
| 1985 | 1,443 | 4,045 | **2019** | **10,057** | **5,453** |
| 1986 | 1,301 | 3,675 | **2020** | **11,819** | **3,720** |
| 1987 | 1,062 | 3,006 | | | |

Table 9a. Alaska skate length compositions from the BSAI longline fisheries, 2009-2019. Bin number is the lower limit of each 4 cm length interval. N = sample size used in the model (square root of number of sampled hauls).

| bin | **longline** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| 4 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 8 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 16 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 20 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 24 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| 28 | 0.000 | 0.000 | 0.000 | 0.003 | 0.000 | 0.001 | 0.000 | 0.001 | 0.001 | 0.000 | 0.004 |
| 32 | 0.001 | 0.001 | 0.000 | 0.007 | 0.000 | 0.002 | 0.000 | 0.001 | 0.001 | 0.001 | 0.004 |
| 36 | 0.001 | 0.001 | 0.001 | 0.010 | 0.001 | 0.002 | 0.000 | 0.003 | 0.002 | 0.002 | 0.004 |
| 40 | 0.003 | 0.002 | 0.003 | 0.013 | 0.002 | 0.004 | 0.001 | 0.005 | 0.006 | 0.004 | 0.006 |
| 44 | 0.006 | 0.006 | 0.007 | 0.018 | 0.003 | 0.005 | 0.003 | 0.006 | 0.009 | 0.008 | 0.009 |
| 48 | 0.011 | 0.014 | 0.014 | 0.021 | 0.008 | 0.008 | 0.006 | 0.010 | 0.019 | 0.016 | 0.016 |
| 52 | 0.020 | 0.024 | 0.020 | 0.025 | 0.013 | 0.014 | 0.011 | 0.015 | 0.023 | 0.023 | 0.020 |
| 56 | 0.025 | 0.032 | 0.027 | 0.030 | 0.022 | 0.021 | 0.017 | 0.019 | 0.022 | 0.022 | 0.022 |
| 60 | 0.034 | 0.046 | 0.041 | 0.041 | 0.031 | 0.033 | 0.030 | 0.028 | 0.022 | 0.028 | 0.024 |
| 64 | 0.044 | 0.056 | 0.050 | 0.053 | 0.038 | 0.040 | 0.039 | 0.038 | 0.026 | 0.033 | 0.025 |
| 68 | 0.058 | 0.069 | 0.064 | 0.068 | 0.056 | 0.055 | 0.055 | 0.047 | 0.038 | 0.046 | 0.038 |
| 72 | 0.063 | 0.070 | 0.077 | 0.072 | 0.069 | 0.063 | 0.059 | 0.053 | 0.046 | 0.056 | 0.043 |
| 76 | 0.068 | 0.062 | 0.074 | 0.072 | 0.079 | 0.071 | 0.064 | 0.058 | 0.053 | 0.062 | 0.049 |
| 80 | 0.068 | 0.071 | 0.077 | 0.080 | 0.093 | 0.083 | 0.075 | 0.063 | 0.062 | 0.078 | 0.056 |
| 84 | 0.067 | 0.067 | 0.076 | 0.077 | 0.097 | 0.087 | 0.081 | 0.075 | 0.068 | 0.081 | 0.064 |
| 88 | 0.081 | 0.071 | 0.082 | 0.087 | 0.105 | 0.107 | 0.097 | 0.090 | 0.087 | 0.097 | 0.080 |
| 92 | 0.094 | 0.090 | 0.095 | 0.094 | 0.115 | 0.125 | 0.125 | 0.126 | 0.125 | 0.114 | 0.121 |
| 96 | 0.124 | 0.103 | 0.112 | 0.098 | 0.117 | 0.121 | 0.135 | 0.148 | 0.153 | 0.130 | 0.164 |
| 100 | 0.119 | 0.104 | 0.106 | 0.078 | 0.089 | 0.094 | 0.115 | 0.121 | 0.135 | 0.113 | 0.149 |
| 104 | 0.067 | 0.057 | 0.049 | 0.034 | 0.040 | 0.043 | 0.052 | 0.062 | 0.066 | 0.052 | 0.072 |
| 108 | 0.030 | 0.028 | 0.018 | 0.013 | 0.013 | 0.015 | 0.019 | 0.022 | 0.024 | 0.018 | 0.020 |
| 112 | 0.009 | 0.013 | 0.004 | 0.003 | 0.003 | 0.004 | 0.006 | 0.005 | 0.007 | 0.007 | 0.006 |
| 116 | 0.005 | 0.006 | 0.001 | 0.001 | 0.002 | 0.001 | 0.003 | 0.003 | 0.003 | 0.005 | 0.003 |
| 120 | 0.001 | 0.004 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 | 0.001 | 0.002 | 0.002 | 0.001 |
| 124 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 |
| 128 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| 132 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| N | 67 | 65 | 72 | 77 | 85 | 87 | 88 | 80 | 79 | 77 | 82 |

Table 9b. Alaska skate length compositions from the BSAI trawl fisheries, 2009-2019. Bin number is the lower limit of each 4 cm length interval. N = sample size used in the model (square root of number of sampled hauls).

| bin | trawl | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| 4 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 8 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 |
| 16 | 0.001 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.001 | 0.001 | 0.000 | 0.001 |
| 20 | 0.003 | 0.004 | 0.002 | 0.002 | 0.001 | 0.001 | 0.003 | 0.003 | 0.003 | 0.002 | 0.003 |
| 24 | 0.011 | 0.011 | 0.012 | 0.003 | 0.006 | 0.007 | 0.010 | 0.007 | 0.007 | 0.022 | 0.017 |
| 28 | 0.024 | 0.018 | 0.020 | 0.010 | 0.009 | 0.012 | 0.015 | 0.012 | 0.007 | 0.030 | 0.025 |
| 32 | 0.034 | 0.031 | 0.026 | 0.011 | 0.010 | 0.015 | 0.032 | 0.015 | 0.017 | 0.023 | 0.026 |
| 36 | 0.051 | 0.037 | 0.034 | 0.017 | 0.020 | 0.020 | 0.040 | 0.024 | 0.015 | 0.021 | 0.024 |
| 40 | 0.063 | 0.053 | 0.049 | 0.034 | 0.039 | 0.031 | 0.049 | 0.026 | 0.027 | 0.022 | 0.018 |
| 44 | 0.064 | 0.055 | 0.059 | 0.042 | 0.047 | 0.031 | 0.046 | 0.028 | 0.031 | 0.019 | 0.018 |
| 48 | 0.056 | 0.050 | 0.052 | 0.052 | 0.050 | 0.040 | 0.055 | 0.042 | 0.045 | 0.026 | 0.020 |
| 52 | 0.051 | 0.042 | 0.047 | 0.049 | 0.051 | 0.041 | 0.048 | 0.038 | 0.043 | 0.027 | 0.024 |
| 56 | 0.044 | 0.041 | 0.040 | 0.043 | 0.045 | 0.046 | 0.043 | 0.036 | 0.042 | 0.028 | 0.025 |
| 60 | 0.043 | 0.043 | 0.038 | 0.044 | 0.042 | 0.050 | 0.042 | 0.048 | 0.046 | 0.030 | 0.034 |
| 64 | 0.048 | 0.048 | 0.039 | 0.046 | 0.043 | 0.046 | 0.047 | 0.046 | 0.044 | 0.038 | 0.042 |
| 68 | 0.049 | 0.056 | 0.053 | 0.054 | 0.050 | 0.054 | 0.052 | 0.056 | 0.051 | 0.046 | 0.053 |
| 72 | 0.048 | 0.053 | 0.060 | 0.069 | 0.055 | 0.060 | 0.049 | 0.056 | 0.059 | 0.051 | 0.059 |
| 76 | 0.041 | 0.049 | 0.059 | 0.070 | 0.058 | 0.051 | 0.040 | 0.050 | 0.058 | 0.051 | 0.057 |
| 80 | 0.052 | 0.054 | 0.059 | 0.080 | 0.068 | 0.070 | 0.061 | 0.056 | 0.059 | 0.057 | 0.074 |
| 84 | 0.044 | 0.054 | 0.053 | 0.071 | 0.069 | 0.076 | 0.061 | 0.063 | 0.061 | 0.062 | 0.075 |
| 88 | 0.059 | 0.056 | 0.060 | 0.077 | 0.080 | 0.087 | 0.065 | 0.076 | 0.078 | 0.079 | 0.082 |
| 92 | 0.059 | 0.069 | 0.069 | 0.073 | 0.081 | 0.089 | 0.083 | 0.099 | 0.090 | 0.102 | 0.101 |
| 96 | 0.056 | 0.068 | 0.068 | 0.069 | 0.077 | 0.086 | 0.074 | 0.102 | 0.092 | 0.112 | 0.098 |
| 100 | 0.049 | 0.055 | 0.058 | 0.051 | 0.058 | 0.055 | 0.053 | 0.066 | 0.069 | 0.091 | 0.073 |
| 104 | 0.029 | 0.029 | 0.025 | 0.022 | 0.029 | 0.021 | 0.021 | 0.028 | 0.037 | 0.039 | 0.036 |
| 108 | 0.010 | 0.013 | 0.010 | 0.008 | 0.007 | 0.005 | 0.005 | 0.012 | 0.012 | 0.016 | 0.011 |
| 112 | 0.006 | 0.004 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.004 | 0.004 | 0.003 | 0.002 |
| 116 | 0.002 | 0.003 | 0.002 | 0.000 | 0.001 | 0.001 | 0.001 | 0.002 | 0.000 | 0.001 | 0.001 |
| 120 | 0.001 | 0.001 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 124 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 128 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 |
| 132 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| N | 56 | 61 | 56 | 50 | 61 | 54 | 45 | 45 | 56 | 53 | 49 |

Table 10. Estimates of Alaska skate biomass (t) from the EBS shelf bottom trawl survey, 1982-2019. Estimates and CVs 1999-present were obtained directly from trawl survey data when species identification was reliable. Estimates and CVs prior to 1999 (in *italics*) were partitioned using species composition data from 1999-2018. No surveys were conducted in 2020.

| year | biomass | CV |
|---|---|---|
| *1982* | *166,457* | *0.10* |
| *1984* | *188,482* | *0.08* |
| *1985* | *163,239* | *0.13* |
| *1986* | *253,342* | *0.14* |
| *1987* | *337,865* | *0.09* |
| *1988* | *349,786* | *0.12* |
| *1989* | *392,634* | *0.08* |
| *1990* | *457,619* | *0.11* |
| *1991* | *429,660* | *0.09* |
| *1992* | *378,474* | *0.09* |
| *1993* | *368,769* | *0.07* |
| *1994* | *383,556* | *0.08* |
| *1995* | *342,536* | *0.08* |
| *1996* | *400,012* | *0.06* |
| *1997* | *396,800* | *0.07* |
| *1998* | *350,056* | *0.05* |
| 1999 | 323,240 | 0.17 |
| 2000 | 311,977 | 0.06 |
| 2001 | 414,539 | 0.06 |
| 2002 | 364,004 | 0.07 |
| 2003 | 372,379 | 0.05 |
| 2004 | 424,808 | 0.05 |
| 2005 | 487,046 | 0.05 |
| 2006 | 437,737 | 0.05 |
| 2007 | 479,043 | 0.07 |
| 2008 | 361,300 | 0.06 |
| 2009 | 350,233 | 0.06 |
| 2010 | 366,186 | 0.06 |
| 2011 | 410,340 | 0.05 |
| 2012 | 369,881 | 0.06 |
| 2013 | 386,816 | 0.06 |
| 2014 | 404,380 | 0.05 |
| 2015 | 448,224 | 0.06 |
| 2016 | 550,892 | 0.04 |
| 2017 | 544,657 | 0.07 |
| 2018 | 545,994 | 0.05 |
| 2019 | 491,109 | 0.05 |
| 2020 | no survey | |

Table 11. Alaska skate EBS shelf survey length compositions, 2000-2019. Bin number is the lower limit of each 4 cm length bin; data are proportions of each bin. N = sample size used in the model. No surveys were conducted in 2020.

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 8 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 16 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 20 | 0.005 | 0.010 | 0.008 | 0.005 | 0.003 | 0.005 | 0.004 | 0.008 | 0.004 | 0.010 | 0.003 | 0.004 | 0.004 | 0.003 | 0.003 | 0.006 | 0.003 | 0.003 | 0.004 | 0.005 |
| 24 | 0.035 | 0.031 | 0.026 | 0.027 | 0.015 | 0.019 | 0.026 | 0.029 | 0.017 | 0.021 | 0.016 | 0.015 | 0.009 | 0.012 | 0.008 | 0.014 | 0.006 | 0.007 | 0.021 | 0.017 |
| 28 | 0.044 | 0.045 | 0.035 | 0.023 | 0.024 | 0.021 | 0.025 | 0.019 | 0.018 | 0.020 | 0.016 | 0.021 | 0.015 | 0.012 | 0.017 | 0.016 | 0.008 | 0.007 | 0.020 | 0.010 |
| 32 | 0.037 | 0.045 | 0.048 | 0.038 | 0.026 | 0.028 | 0.031 | 0.027 | 0.025 | 0.032 | 0.016 | 0.026 | 0.017 | 0.020 | 0.014 | 0.015 | 0.011 | 0.009 | 0.017 | 0.014 |
| 36 | 0.048 | 0.042 | 0.049 | 0.036 | 0.029 | 0.036 | 0.031 | 0.038 | 0.036 | 0.042 | 0.027 | 0.027 | 0.020 | 0.027 | 0.027 | 0.017 | 0.013 | 0.014 | 0.024 | 0.020 |
| 40 | 0.047 | 0.044 | 0.052 | 0.043 | 0.044 | 0.043 | 0.041 | 0.051 | 0.046 | 0.050 | 0.035 | 0.040 | 0.029 | 0.031 | 0.027 | 0.025 | 0.018 | 0.016 | 0.029 | 0.021 |
| 44 | 0.046 | 0.049 | 0.055 | 0.047 | 0.050 | 0.052 | 0.047 | 0.046 | 0.056 | 0.053 | 0.045 | 0.054 | 0.043 | 0.042 | 0.034 | 0.026 | 0.026 | 0.019 | 0.026 | 0.025 |
| 48 | 0.055 | 0.043 | 0.052 | 0.083 | 0.059 | 0.054 | 0.052 | 0.058 | 0.054 | 0.052 | 0.039 | 0.061 | 0.049 | 0.047 | 0.046 | 0.036 | 0.030 | 0.022 | 0.030 | 0.027 |
| 52 | 0.062 | 0.052 | 0.062 | 0.049 | 0.068 | 0.051 | 0.049 | 0.050 | 0.062 | 0.061 | 0.048 | 0.062 | 0.056 | 0.065 | 0.041 | 0.038 | 0.035 | 0.029 | 0.033 | 0.023 |
| 56 | 0.061 | 0.047 | 0.053 | 0.039 | 0.053 | 0.060 | 0.054 | 0.054 | 0.063 | 0.064 | 0.053 | 0.060 | 0.057 | 0.060 | 0.054 | 0.049 | 0.040 | 0.036 | 0.035 | 0.024 |
| 60 | 0.061 | 0.057 | 0.047 | 0.043 | 0.055 | 0.061 | 0.057 | 0.049 | 0.060 | 0.068 | 0.053 | 0.064 | 0.057 | 0.055 | 0.064 | 0.049 | 0.041 | 0.042 | 0.034 | 0.035 |
| 64 | 0.042 | 0.047 | 0.041 | 0.040 | 0.044 | 0.051 | 0.056 | 0.060 | 0.061 | 0.057 | 0.060 | 0.061 | 0.060 | 0.056 | 0.057 | 0.059 | 0.058 | 0.047 | 0.045 | 0.035 |
| 68 | 0.036 | 0.048 | 0.049 | 0.053 | 0.052 | 0.044 | 0.050 | 0.057 | 0.049 | 0.050 | 0.067 | 0.060 | 0.059 | 0.051 | 0.065 | 0.060 | 0.051 | 0.056 | 0.048 | 0.045 |
| 72 | 0.036 | 0.047 | 0.043 | 0.042 | 0.048 | 0.048 | 0.050 | 0.052 | 0.050 | 0.052 | 0.058 | 0.061 | 0.068 | 0.062 | 0.064 | 0.055 | 0.051 | 0.054 | 0.056 | 0.054 |
| 76 | 0.028 | 0.039 | 0.043 | 0.047 | 0.052 | 0.041 | 0.050 | 0.045 | 0.051 | 0.045 | 0.057 | 0.053 | 0.069 | 0.066 | 0.055 | 0.055 | 0.052 | 0.063 | 0.060 | 0.051 |
| 80 | 0.039 | 0.033 | 0.030 | 0.048 | 0.041 | 0.041 | 0.039 | 0.046 | 0.047 | 0.048 | 0.056 | 0.048 | 0.065 | 0.064 | 0.052 | 0.051 | 0.057 | 0.071 | 0.054 | 0.064 |
| 84 | 0.031 | 0.028 | 0.027 | 0.039 | 0.044 | 0.041 | 0.046 | 0.037 | 0.043 | 0.043 | 0.063 | 0.048 | 0.048 | 0.054 | 0.058 | 0.065 | 0.069 | 0.066 | 0.060 | 0.065 |
| 88 | 0.037 | 0.038 | 0.046 | 0.046 | 0.048 | 0.053 | 0.040 | 0.043 | 0.047 | 0.046 | 0.059 | 0.047 | 0.067 | 0.062 | 0.078 | 0.071 | 0.084 | 0.080 | 0.067 | 0.069 |
| 92 | 0.054 | 0.067 | 0.056 | 0.056 | 0.061 | 0.054 | 0.063 | 0.065 | 0.057 | 0.051 | 0.073 | 0.055 | 0.066 | 0.068 | 0.088 | 0.094 | 0.114 | 0.110 | 0.090 | 0.102 |
| 96 | 0.074 | 0.074 | 0.070 | 0.080 | 0.074 | 0.066 | 0.071 | 0.063 | 0.059 | 0.057 | 0.074 | 0.059 | 0.066 | 0.071 | 0.071 | 0.086 | 0.104 | 0.116 | 0.105 | 0.116 |
| 100 | 0.065 | 0.071 | 0.058 | 0.061 | 0.069 | 0.071 | 0.064 | 0.059 | 0.056 | 0.048 | 0.048 | 0.048 | 0.049 | 0.043 | 0.046 | 0.070 | 0.082 | 0.079 | 0.088 | 0.113 |
| 104 | 0.040 | 0.029 | 0.030 | 0.037 | 0.030 | 0.041 | 0.040 | 0.030 | 0.026 | 0.022 | 0.025 | 0.018 | 0.019 | 0.023 | 0.022 | 0.033 | 0.034 | 0.039 | 0.040 | 0.047 |
| 108 | 0.013 | 0.013 | 0.012 | 0.012 | 0.008 | 0.012 | 0.012 | 0.011 | 0.009 | 0.006 | 0.007 | 0.006 | 0.005 | 0.005 | 0.005 | 0.008 | 0.009 | 0.013 | 0.010 | 0.013 |
| 112 | 0.002 | 0.002 | 0.005 | 0.003 | 0.003 | 0.002 | 0.002 | 0.004 | 0.001 | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 | 0.001 | 0.002 | 0.003 | 0.003 | 0.004 |
| 116 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 |
| 120 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 124 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 128 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 132 | 0.002 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| N | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200.000 |

Table 12. Input parameter values for model 14.2. Minimum and maximum bounds are shown for parameters estimated freely within the model.

| parameter type | parameter | value | min | max | fix? |
|---|---|---|---|---|---|
| growth and natural mortality | natural mortality (*M*) | 0.13 | | | X |
| | length at A1 (L1) | 20 | -10 | 30 | |
| | length at A2 (L2) | 110 | 70 | 150 | |
| | von Bertalanffy coefficient (κ) | 0.15 | 0.05 | 0.50 | |
| | Richards coefficient (γ) | 0.1 | -1 | 2 | |
| | CV of LAA @ L1 | 0.1 | 0.05 | 0.35 | |
| | CV of LAA @ L2 | 0.1 | 0.05 | 0.25 | |
| length-weight relationship | coefficient (a) | $9.00 \times 10^{-6}$ | | | X |
| | exponent (b) | 2.962 | | | X |
| length at maturity | length at 50% maturity (a) | 93.28 | | | X |
| | slope (b) | -0.548 | | | X |
| stock-recruit function | ln virgin recruitment level ($R_0$) | 10.00 | 5 | 15 | |
| | steepness | 1 | | | X |
| | $\sigma_R$ | 0.4 | | | X |
| EBS shelf survey catchability | ln catchability (q) | 0 | | | X |
| longline length selectivity | peak (p1) | 111 | 7.6 | 126 | |
| | top (p2) | -0.1 | -6 | 4 | |
| | ascending width (p3) | 4.9 | -1 | 9 | |
| | descending width (p4) | 4.7 | -1 | 9 | |
| | selectivity at first size bin (p5) | -2.2 | -5 | 9 | |
| | selectivity at last size bin (p6) | 9 | -5 | 9 | |
| trawl length selectivity | peak (p1) | 49 | 7.6 | 126 | |
| | top (p2) | -5 | -6 | 4 | |
| | ascending width (p3) | 4.8 | -1 | 9 | |
| | descending width (p4) | 4.4 | -1 | 9 | |
| | selectivity at first size bin (p5) | -0.7 | -5 | 9 | |
| | selectivity at last size bin (p6) | 9 | -5 | 9 | |
| survey length selectivity | peak (p1) | 49 | 7.6 | 126 | |
| | top (p2) | -5 | -6 | 4 | |
| | ascending width (p3) | 4.8 | -1 | 9 | |
| | descending width (p4) | 4.4 | -1 | 9 | |
| | selectivity at first size bin (p5) | -0.7 | -5 | 9 | |
| | selectivity at last size bin (p6) | 9 | -5 | 9 | |
| initial fishing mortality | longline fishery F | 0 | 0 | 1 | |
| | trawl fishery F | 0 | 0 | 1 | |

Table 13. Selected parameter estimates and model fit statistics for model 14.2. Results from the 2018 run of the model are included for comparison (in *italics*). CV= coefficient of variation.

| model number | *14.2* | 14.2 |
|---|---|---|
| Description | 2018 run | **2020 run** |
| **likelihood components** | | |
| survey | -7.56 | -5.59 |
| length comps | 117.81 | 132.11 |
| LAA | 158.94 | 161.00 |
| recruitment | -42.35 | -40.96 |
| total | 226.86 | 246.58 |
| # of parameters estimated | 94 | 94 |
| L_amin | 13.98 | 13.98 |
| SD | 0.424 | 0.419 |
| L_amax | 102.04 | 101.96 |
| SD | 0.259 | 0.230 |
| K | 0.38 | 0.38 |
| SD | 0.007 | .017 |
| CV young | 0.35 | 0.35 |
| SD | 0.00003 | 0.00008 |
| CV old | 0.05 | 0.05 |
| SD | 0.0004 | 0.00031 |
| ln (Rzero) | 10.11 | 10.12 |
| SD | 0.037 | 0.036 |
| unfished spawning biomass (t) | 331,810 | 334,279 |
| CV | 0.040 | 0.038 |
| unfished recruitment (1000s) | 24,585 | 24,879 |
| SD | 0.037 | 0.036 |
| RMSE_survey | 0.147 | 0.146 |
| % within survey CI | 63.9% | 75.7% |
| correlation obs-pred | 0.761 | 0.782 |
| mean longline input N | 77.8 | 78.1 |
| mean longline eff N | 884.2 | 738.9 |
| mean longline effN/N | 11.54 | 9.46 |
| mean trawl input N | 53.8 | 53.3 |
| mean trawl eff N | 896.9 | 851.9 |
| mean trawl effN/N | 17.0 | 16.0 |
| mean survey input N | 200.0 | 200.0 |
| mean survey eff N | 870.1 | 841.0 |
| mean survey effN/N | 4.4 | 4.2 |

Table 14. Time series of total (age 0+) biomass (t) and spawning biomass (t) and the number of age 0 recruits (1000s) predicted by Model 14.2. CV = coefficient of variation. Estimates from the 2018 model run are included for comparison.

| year | total biomass | spawning biomass | | *2018 spawning biomass* | year | total biomass | spawning biomass | | *2018 spawning biomass* |
|---|---|---|---|---|---|---|---|---|---|
| | | estimate | CV | | | | estimate | CV | |
| **unfished** | 563,833 | 334,279 | 0.038 | *331,810* | **1985** | 260,340 | 107,739 | 0.108 | *108,852* |
| **1950** | 563,723 | 334,279 | 0.038 | *331,810* | **1986** | 286,093 | 109,749 | 0.099 | *110,928* |
| **1951** | 563,476 | 334,279 | 0.038 | *331,810* | **1987** | 316,309 | 114,029 | 0.091 | *115,266* |
| **1952** | 562,966 | 334,279 | 0.038 | *331,810* | **1988** | 348,980 | 121,445 | 0.083 | *122,722* |
| **1953** | 561,998 | 334,279 | 0.038 | *331,810* | **1989** | 378,656 | 132,377 | 0.079 | *133,669* |
| **1954** | 560,330 | 334,279 | 0.038 | *331,810* | **1990** | 407,742 | 151,182 | 0.080 | *152,516* |
| **1955** | 557,725 | 334,279 | 0.038 | *331,810* | **1991** | 430,987 | 178,115 | 0.070 | *180,475* |
| **1956** | 554,037 | 334,279 | 0.038 | *331,810* | **1992** | 443,466 | 202,830 | 0.065 | *206,112* |
| **1957** | 549,256 | 334,279 | 0.038 | *331,810* | **1993** | 443,019 | 219,892 | 0.065 | *223,962* |
| **1958** | 543,514 | 334,279 | 0.038 | *331,810* | **1994** | 442,927 | 233,371 | 0.065 | *237,975* |
| **1959** | 536,956 | 332,767 | 0.041 | *330,347* | **1995** | 438,760 | 239,748 | 0.064 | *244,562* |
| **1960** | 529,779 | 330,242 | 0.045 | *327,905* | **1996** | 432,863 | 240,680 | 0.064 | *245,403* |
| **1961** | 522,468 | 326,945 | 0.051 | *324,724* | **1997** | 429,018 | 239,419 | 0.063 | *243,814* |
| **1962** | 514,989 | 322,997 | 0.058 | *320,922* | **1998** | 421,821 | 233,635 | 0.062 | *237,455* |
| **1963** | 507,430 | 318,667 | 0.065 | *316,757* | **1999** | 415,372 | 226,706 | 0.062 | *229,743* |
| **1964** | 499,841 | 314,161 | 0.071 | *312,428* | **2000** | 416,127 | 222,786 | 0.062 | *224,932* |
| **1965** | 491,899 | 309,383 | 0.076 | *307,836* | **2001** | 415,966 | 216,133 | 0.063 | *217,304* |
| **1966** | 483,240 | 304,150 | 0.079 | *302,793* | **2002** | 417,512 | 209,091 | 0.064 | *209,263* |
| **1967** | 474,639 | 298,961 | 0.082 | *297,797* | **2003** | 419,826 | 203,143 | 0.064 | *202,256* |
| **1968** | 464,659 | 292,875 | 0.085 | *291,906* | **2004** | 424,706 | 200,774 | 0.063 | *198,786* |
| **1969** | 446,598 | 281,594 | 0.087 | *280,824* | **2005** | 430,390 | 198,833 | 0.062 | *195,868* |
| **1970** | 434,638 | 273,994 | 0.089 | *273,412* | **2006** | 436,739 | 198,418 | 0.061 | *194,515* |
| **1971** | 420,387 | 264,754 | 0.090 | *264,359* | **2007** | 446,870 | 201,316 | 0.060 | *196,585* |
| **1972** | 407,857 | 256,407 | 0.091 | *256,190* | **2008** | 460,684 | 207,403 | 0.059 | *202,019* |
| **1973** | 396,031 | 248,276 | 0.092 | *248,229* | **2009** | 476,149 | 215,349 | 0.058 | *209,451* |
| **1974** | 364,936 | 227,828 | 0.096 | *227,965* | **2010** | 492,008 | 221,991 | 0.058 | *215,752* |
| **1975** | 332,727 | 206,289 | 0.101 | *206,590* | **2011** | 512,232 | 229,038 | 0.057 | *222,581* |
| **1976** | 304,570 | 186,881 | 0.106 | *187,321* | **2012** | 527,015 | 234,248 | 0.057 | *227,663* |
| **1977** | 291,339 | 176,326 | 0.108 | *176,875* | **2013** | 539,561 | 241,820 | 0.057 | *235,066* |
| **1978** | 274,566 | 163,273 | 0.111 | *163,922* | **2014** | 546,947 | 249,105 | 0.057 | *242,017* |
| **1979** | 247,860 | 143,977 | 0.117 | *144,724* | **2015** | 551,050 | 259,031 | 0.056 | *251,250* |
| **1980** | 233,928 | 131,840 | 0.120 | *132,660* | **2016** | 550,085 | 266,532 | 0.056 | *258,005* |
| **1981** | 224,773 | 121,598 | 0.122 | *122,480* | **2017** | 541,841 | 274,746 | 0.056 | *265,153* |
| **1982** | 219,098 | 112,313 | 0.123 | *113,254* | **2018** | 526,621 | 279,688 | 0.056 | *268,836* |
| **1983** | 225,675 | 108,578 | 0.120 | *109,574* | **2019** | 506,899 | 281,272 | 0.056 | *n/a* |
| **1984** | 238,578 | 106,692 | 0.115 | *107,743* | **2020** | 492,957 | 284,268 | 0.056 | *n/a* |

Table 15. Time series of age 0 recruits (1000s) predicted by Model 14.2. CV = coefficient of variation. Estimates from the 2018 model run are included for comparison.

| year | age-0 recruits | | *2018* | year | age-0 recruits | | *2018* |
|---|---|---|---|---|---|---|---|
| | estimate | CV | *estimate* | | estimate | CV | *estimate* |
| **unfished** | 24,879 | 0.036 | *24,585* | **1985** | 23,813 | 0.392 | *23,955* |
| **1950** | 21,248 | 0.390 | *21,099* | **1986** | 21,609 | 0.373 | *21,627* |
| **1951** | 21,060 | 0.388 | *20,923* | **1987** | 20,828 | 0.364 | *20,725* |
| **1952** | 20,853 | 0.386 | *20,729* | **1988** | 20,859 | 0.362 | *20,613* |
| **1953** | 20,625 | 0.384 | *20,516* | **1989** | 21,485 | 0.363 | *21,064* |
| **1954** | 20,377 | 0.382 | *20,282* | **1990** | 22,728 | 0.362 | *22,085* |
| **1955** | 20,106 | 0.379 | *20,027* | **1991** | 22,880 | 0.354 | *22,090* |
| **1956** | 19,815 | 0.376 | *19,752* | **1992** | 20,012 | 0.346 | *19,316* |
| **1957** | 19,506 | 0.374 | *19,459* | **1993** | 20,306 | 0.341 | *19,567* |
| **1958** | 19,180 | 0.370 | *19,150* | **1994** | 25,614 | 0.346 | *24,591* |
| **1959** | 18,841 | 0.367 | *18,827* | **1995** | 31,237 | 0.324 | *29,992* |
| **1960** | 18,493 | 0.364 | *18,496* | **1996** | 26,825 | 0.343 | *25,957* |
| **1961** | 18,141 | 0.361 | *18,161* | **1997** | 29,491 | 0.329 | *28,451* |
| **1962** | 17,788 | 0.357 | *17,824* | **1998** | 31,779 | 0.330 | *30,770* |
| **1963** | 17,439 | 0.354 | *17,489* | **1999** | 33,494 | 0.312 | *32,682* |
| **1964** | 17,096 | 0.350 | *17,161* | **2000** | 35,791 | 0.276 | *35,048* |
| **1965** | 16,766 | 0.347 | *16,844* | **2001** | 30,204 | 0.271 | *29,650* |
| **1966** | 16,460 | 0.344 | *16,549* | **2002** | 27,631 | 0.288 | *27,099* |
| **1967** | 16,186 | 0.341 | *16,285* | **2003** | 34,329 | 0.292 | *33,563* |
| **1968** | 15,939 | 0.339 | *16,050* | **2004** | 42,135 | 0.295 | *41,296* |
| **1969** | 15,709 | 0.336 | *15,833* | **2005** | 40,215 | 0.331 | *39,230* |
| **1970** | 15,475 | 0.334 | *15,610* | **2006** | 44,607 | 0.304 | *42,814* |
| **1971** | 15,246 | 0.332 | *15,389* | **2007** | 35,121 | 0.371 | *33,834* |
| **1972** | 15,063 | 0.330 | *15,209* | **2008** | 44,573 | 0.305 | *42,632* |
| **1973** | 14,965 | 0.329 | *15,116* | **2009** | 38,130 | 0.329 | *36,146* |
| **1974** | 15,003 | 0.329 | *15,156* | **2010** | 33,168 | 0.334 | *31,319* |
| **1975** | 15,240 | 0.330 | *15,387* | **2011** | 28,536 | 0.324 | *25,893* |
| **1976** | 15,804 | 0.334 | *15,931* | **2012** | 26,366 | 0.294 | *22,890* |
| **1977** | 16,903 | 0.342 | *16,996* | **2013** | 19,980 | 0.299 | *18,057* |
| **1978** | 18,894 | 0.356 | *18,937* | **2014** | 16,850 | 0.287 | *16,538* |
| **1979** | 22,391 | 0.382 | *22,359* | **2015** | 15,346 | 0.294 | *16,160* |
| **1980** | 28,476 | 0.430 | *28,354* | **2016** | 19,526 | 0.307 | *21,150* |
| **1981** | 39,189 | 0.525 | *39,141* | **2017** | 26,107 | 0.322 | *26,170* |
| **1982** | 49,743 | 0.569 | *52,166* | **2018** | 22,687 | 0.363 | *22,516* |
| **1983** | 36,851 | 0.511 | *37,611* | **2019** | 24,879 | 0.036 | *n/a* |
| **1984** | 28,292 | 0.431 | *28,615* | **2020** | 24,879 | 0.036 | *n/a* |

Table 16. Time series of exploitation rates (catch/total biomass) estimated by model 14.2.

| year | longline | trawl | total F | year | longline | trawl | total F |
|---|---|---|---|---|---|---|---|
| **1958** | 0.000 | 0.000 | 0.000 | **1991** | 0.016 | 0.003 | 0.019 |
| **1959** | 0.000 | 0.000 | 0.000 | **1992** | 0.031 | 0.007 | 0.038 |
| **1960** | 0.000 | 0.000 | 0.000 | **1993** | 0.022 | 0.005 | 0.028 |
| **1961** | 0.000 | 0.000 | 0.000 | **1994** | 0.026 | 0.006 | 0.032 |
| **1962** | 0.000 | 0.000 | 0.000 | **1995** | 0.028 | 0.006 | 0.034 |
| **1963** | 0.000 | 0.000 | 0.000 | **1996** | 0.024 | 0.006 | 0.030 |
| **1964** | 0.000 | 0.001 | 0.001 | **1997** | 0.034 | 0.008 | 0.042 |
| **1965** | 0.000 | 0.002 | 0.003 | **1998** | 0.038 | 0.009 | 0.046 |
| **1966** | 0.000 | 0.002 | 0.003 | **1999** | 0.028 | 0.006 | 0.034 |
| **1967** | 0.001 | 0.005 | 0.006 | **2000** | 0.037 | 0.008 | 0.045 |
| **1968** | 0.004 | 0.023 | 0.027 | **2001** | 0.039 | 0.009 | 0.048 |
| **1969** | 0.002 | 0.011 | 0.013 | **2002** | 0.044 | 0.010 | 0.054 |
| **1970** | 0.003 | 0.017 | 0.021 | **2003** | 0.043 | 0.010 | 0.053 |
| **1971** | 0.002 | 0.016 | 0.018 | **2004** | 0.044 | 0.010 | 0.054 |
| **1972** | 0.004 | 0.014 | 0.018 | **2005** | 0.047 | 0.009 | 0.056 |
| **1973** | 0.009 | 0.070 | 0.079 | **2006** | 0.039 | 0.009 | 0.048 |
| **1974** | 0.012 | 0.082 | 0.094 | **2007** | 0.023 | 0.017 | 0.040 |
| **1975** | 0.011 | 0.082 | 0.093 | **2008** | 0.025 | 0.014 | 0.039 |
| **1976** | 0.006 | 0.042 | 0.048 | **2009** | 0.023 | 0.017 | 0.040 |
| **1977** | 0.010 | 0.061 | 0.071 | **2010** | 0.017 | 0.012 | 0.030 |
| **1978** | 0.016 | 0.113 | 0.129 | **2011** | 0.030 | 0.012 | 0.041 |
| **1979** | 0.012 | 0.078 | 0.090 | **2012** | 0.031 | 0.011 | 0.042 |
| **1980** | 0.023 | 0.062 | 0.085 | **2013** | 0.035 | 0.011 | 0.046 |
| **1981** | 0.024 | 0.066 | 0.089 | **2014** | 0.036 | 0.008 | 0.043 |
| **1982** | 0.013 | 0.034 | 0.047 | **2015** | 0.038 | 0.005 | 0.043 |
| **1983** | 0.010 | 0.028 | 0.038 | **2016** | 0.042 | 0.005 | 0.046 |
| **1984** | 0.005 | 0.014 | 0.019 | **2017** | 0.044 | 0.006 | 0.050 |
| **1985** | 0.007 | 0.017 | 0.024 | **2018** | 0.043 | 0.009 | 0.052 |
| **1986** | 0.005 | 0.014 | 0.019 | **2019** | 0.022 | 0.012 | 0.034 |
| **1987** | 0.004 | 0.010 | 0.014 | **2020** | 0.026 | 0.009 | 0.035 |
| **1988** | 0.005 | 0.013 | 0.018 | | | | |
| **1989** | 0.002 | 0.005 | 0.007 | | | | |
| **1990** | 0.002 | 0.005 | 0.007 | | | | |

Table 17a. Numbers at age (1000s), 1950-1984, estimated by Model 14.2.

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1950 | 21,248 | 21,846 | 19,183 | 16,844 | 14,791 | 12,988 | 11,405 | 10,014 | 8,794 | 7,722 | 6,780 | 5,954 | 5,228 | 4,591 | 4,031 | 3,540 | 3,108 | 2,729 | 2,397 | 2,104 | 1,848 | 1,623 | 1,425 | 1,251 | 1,099 | 7,913 |
| 1951 | 21,060 | 18,657 | 19,183 | 16,844 | 14,791 | 12,988 | 11,405 | 10,014 | 8,794 | 7,722 | 6,780 | 5,954 | 5,228 | 4,591 | 4,031 | 3,540 | 3,108 | 2,729 | 2,397 | 2,104 | 1,848 | 1,623 | 1,425 | 1,251 | 1,099 | 7,913 |
| 1952 | 20,853 | 18,493 | 16,383 | 16,844 | 14,791 | 12,988 | 11,405 | 10,014 | 8,794 | 7,722 | 6,780 | 5,954 | 5,228 | 4,591 | 4,031 | 3,540 | 3,108 | 2,729 | 2,397 | 2,104 | 1,848 | 1,623 | 1,425 | 1,251 | 1,099 | 7,913 |
| 1953 | 20,625 | 18,311 | 16,238 | 14,386 | 14,791 | 12,988 | 11,405 | 10,014 | 8,794 | 7,722 | 6,780 | 5,954 | 5,228 | 4,591 | 4,031 | 3,540 | 3,108 | 2,729 | 2,397 | 2,104 | 1,848 | 1,623 | 1,425 | 1,251 | 1,099 | 7,913 |
| 1954 | 20,377 | 18,111 | 16,079 | 14,259 | 12,632 | 12,988 | 11,405 | 10,014 | 8,794 | 7,722 | 6,780 | 5,954 | 5,228 | 4,591 | 4,031 | 3,540 | 3,108 | 2,729 | 2,397 | 2,104 | 1,848 | 1,623 | 1,425 | 1,251 | 1,099 | 7,913 |
| 1955 | 20,106 | 17,893 | 15,903 | 14,119 | 12,521 | 11,092 | 11,405 | 10,014 | 8,794 | 7,722 | 6,780 | 5,954 | 5,228 | 4,591 | 4,031 | 3,540 | 3,108 | 2,729 | 2,397 | 2,104 | 1,848 | 1,623 | 1,425 | 1,251 | 1,099 | 7,913 |
| 1956 | 19,815 | 17,655 | 15,711 | 13,965 | 12,398 | 10,994 | 9,740 | 10,014 | 8,794 | 7,722 | 6,780 | 5,954 | 5,228 | 4,591 | 4,031 | 3,540 | 3,108 | 2,729 | 2,397 | 2,104 | 1,848 | 1,623 | 1,425 | 1,251 | 1,099 | 7,913 |
| 1957 | 19,506 | 17,400 | 15,503 | 13,796 | 12,262 | 10,886 | 9,654 | 8,553 | 8,794 | 7,722 | 6,780 | 5,954 | 5,228 | 4,591 | 4,031 | 3,540 | 3,108 | 2,729 | 2,397 | 2,104 | 1,848 | 1,623 | 1,425 | 1,251 | 1,099 | 7,913 |
| 1958 | 19,180 | 17,128 | 15,279 | 13,613 | 12,114 | 10,767 | 9,559 | 8,477 | 7,510 | 7,722 | 6,780 | 5,954 | 5,228 | 4,591 | 4,031 | 3,540 | 3,108 | 2,729 | 2,397 | 2,104 | 1,848 | 1,623 | 1,425 | 1,251 | 1,099 | 7,913 |
| 1959 | 18,841 | 16,841 | 15,040 | 13,416 | 11,953 | 10,636 | 9,454 | 8,393 | 7,443 | 6,594 | 6,779 | 5,953 | 5,227 | 4,590 | 4,030 | 3,539 | 3,108 | 2,729 | 2,396 | 2,104 | 1,848 | 1,622 | 1,425 | 1,251 | 1,098 | 7,912 |
| 1960 | 18,493 | 16,544 | 14,788 | 13,205 | 11,778 | 10,493 | 9,337 | 8,298 | 7,367 | 6,533 | 5,788 | 5,951 | 5,225 | 4,588 | 4,029 | 3,538 | 3,107 | 2,728 | 2,395 | 2,103 | 1,847 | 1,622 | 1,424 | 1,251 | 1,098 | 7,910 |
| 1961 | 18,141 | 16,239 | 14,527 | 12,985 | 11,595 | 10,343 | 9,214 | 8,199 | 7,287 | 6,469 | 5,737 | 5,082 | 5,225 | 4,588 | 4,029 | 3,538 | 3,107 | 2,728 | 2,395 | 2,103 | 1,847 | 1,622 | 1,424 | 1,251 | 1,098 | 7,910 |
| 1962 | 17,788 | 15,930 | 14,259 | 12,756 | 11,402 | 10,182 | 9,082 | 8,091 | 7,199 | 6,398 | 5,680 | 5,037 | 4,463 | 4,588 | 4,029 | 3,538 | 3,107 | 2,728 | 2,395 | 2,103 | 1,847 | 1,622 | 1,424 | 1,251 | 1,098 | 7,910 |
| 1963 | 17,439 | 15,620 | 13,988 | 12,521 | 11,201 | 10,012 | 8,941 | 7,975 | 7,104 | 6,322 | 5,618 | 4,988 | 4,423 | 3,919 | 4,029 | 3,538 | 3,107 | 2,728 | 2,395 | 2,103 | 1,847 | 1,622 | 1,424 | 1,251 | 1,098 | 7,910 |
| 1964 | 17,096 | 15,313 | 13,716 | 12,283 | 10,995 | 9,836 | 8,792 | 7,851 | 7,002 | 6,238 | 5,551 | 4,933 | 4,380 | 3,884 | 3,441 | 3,538 | 3,107 | 2,728 | 2,395 | 2,103 | 1,847 | 1,622 | 1,424 | 1,251 | 1,098 | 7,910 |
| 1965 | 16,766 | 15,012 | 13,445 | 12,042 | 10,781 | 9,649 | 8,631 | 7,714 | 6,888 | 6,144 | 5,474 | 4,870 | 4,329 | 3,843 | 3,408 | 3,019 | 3,104 | 2,726 | 2,394 | 2,102 | 1,846 | 1,621 | 1,423 | 1,250 | 1,097 | 7,904 |
| 1966 | 16,460 | 14,722 | 13,179 | 11,800 | 10,562 | 9,451 | 8,455 | 7,561 | 6,757 | 6,034 | 5,382 | 4,795 | 4,267 | 3,792 | 3,367 | 2,986 | 2,645 | 2,720 | 2,388 | 2,097 | 1,842 | 1,617 | 1,420 | 1,247 | 1,095 | 7,888 |
| 1967 | 16,186 | 14,453 | 12,924 | 11,566 | 10,350 | 9,259 | 8,282 | 7,407 | 6,623 | 5,919 | 5,285 | 4,714 | 4,200 | 3,738 | 3,322 | 2,950 | 2,616 | 2,318 | 2,383 | 2,093 | 1,838 | 1,614 | 1,417 | 1,244 | 1,093 | 7,871 |
| 1968 | 15,939 | 14,213 | 12,685 | 11,335 | 10,131 | 9,054 | 8,092 | 7,233 | 6,467 | 5,782 | 5,167 | 4,614 | 4,116 | 3,667 | 3,264 | 2,901 | 2,576 | 2,285 | 2,025 | 2,082 | 1,828 | 1,605 | 1,410 | 1,238 | 1,087 | 7,831 |
| 1969 | 15,709 | 13,996 | 12,450 | 11,073 | 9,838 | 8,740 | 7,775 | 6,930 | 6,188 | 5,530 | 4,944 | 4,420 | 3,949 | 3,524 | 3,142 | 2,798 | 2,488 | 2,210 | 1,960 | 1,737 | 1,787 | 1,569 | 1,378 | 1,210 | 1,063 | 7,655 |
| 1970 | 15,475 | 13,794 | 12,276 | 10,901 | 9,668 | 8,565 | 7,591 | 6,745 | 6,009 | 5,364 | 4,794 | 4,287 | 3,833 | 3,425 | 3,058 | 2,727 | 2,429 | 2,160 | 1,919 | 1,702 | 1,509 | 1,551 | 1,363 | 1,197 | 1,051 | 7,571 |
| 1971 | 15,246 | 13,588 | 12,091 | 10,732 | 9,489 | 8,377 | 7,395 | 6,541 | 5,807 | 5,171 | 4,616 | 4,127 | 3,691 | 3,302 | 2,952 | 2,636 | 2,351 | 2,095 | 1,863 | 1,655 | 1,469 | 1,302 | 1,339 | 1,176 | 1,033 | 7,440 |
| 1972 | 15,063 | 13,388 | 11,913 | 10,575 | 9,351 | 8,235 | 7,247 | 6,387 | 5,646 | 5,010 | 4,462 | 3,984 | 3,563 | 3,188 | 2,853 | 2,551 | 2,279 | 2,033 | 1,811 | 1,612 | 1,432 | 1,270 | 1,126 | 1,158 | 1,017 | 7,329 |
| 1973 | 14,965 | 13,227 | 11,738 | 10,423 | 9,220 | 8,121 | 7,130 | 6,263 | 5,514 | 4,872 | 4,324 | 3,851 | 3,440 | 3,077 | 2,754 | 2,465 | 2,205 | 1,970 | 1,758 | 1,566 | 1,394 | 1,238 | 1,099 | 974 | 1,002 | 7,218 |
| 1974 | 15,003 | 13,140 | 11,531 | 10,128 | 8,842 | 7,680 | 6,674 | 5,817 | 5,094 | 4,481 | 3,959 | 3,517 | 3,137 | 2,806 | 2,514 | 2,254 | 2,020 | 1,808 | 1,617 | 1,443 | 1,286 | 1,145 | 1,017 | 903 | 800 | 6,755 |
| 1975 | 15,240 | 13,174 | 11,441 | 9,917 | 8,537 | 7,293 | 6,235 | 5,371 | 4,663 | 4,079 | 3,588 | 3,174 | 2,824 | 2,524 | 2,262 | 2,030 | 1,822 | 1,635 | 1,464 | 1,310 | 1,170 | 1,043 | 928 | 825 | 732 | 6,130 |
| 1976 | 15,804 | 13,382 | 11,470 | 9,840 | 8,360 | 7,043 | 5,922 | 5,019 | 4,307 | 3,735 | 3,267 | 2,877 | 2,549 | 2,273 | 2,035 | 1,827 | 1,642 | 1,475 | 1,324 | 1,187 | 1,062 | 949 | 846 | 753 | 670 | 5,570 |
| 1977 | 16,903 | 13,878 | 11,699 | 9,965 | 8,461 | 7,110 | 5,941 | 4,972 | 4,205 | 3,607 | 3,128 | 2,738 | 2,413 | 2,140 | 1,909 | 1,711 | 1,537 | 1,382 | 1,243 | 1,116 | 1,000 | 895 | 800 | 713 | 635 | 5,260 |
| 1978 | 18,894 | 14,843 | 12,109 | 10,115 | 8,487 | 7,090 | 5,885 | 4,884 | 4,075 | 3,443 | 2,953 | 2,563 | 2,246 | 1,982 | 1,761 | 1,573 | 1,411 | 1,269 | 1,141 | 1,026 | 922 | 827 | 740 | 661 | 590 | 4,874 |
| 1979 | 22,391 | 16,591 | 12,882 | 10,333 | 8,397 | 6,840 | 5,590 | 4,584 | 3,784 | 3,152 | 2,663 | 2,287 | 1,990 | 1,748 | 1,547 | 1,377 | 1,233 | 1,107 | 997 | 897 | 807 | 726 | 651 | 583 | 521 | 4,303 |
| 1980 | 28,476 | 19,661 | 14,451 | 11,091 | 8,730 | 6,950 | 5,575 | 4,517 | 3,690 | 3,042 | 2,534 | 2,143 | 1,844 | 1,607 | 1,414 | 1,253 | 1,117 | 1,001 | 900 | 810 | 730 | 657 | 590 | 530 | 474 | 3,926 |
| 1981 | 39,189 | 25,004 | 17,151 | 12,488 | 9,434 | 7,294 | 5,722 | 4,545 | 3,662 | 2,984 | 2,458 | 2,048 | 1,735 | 1,494 | 1,304 | 1,149 | 1,020 | 910 | 815 | 733 | 661 | 595 | 536 | 482 | 432 | 3,590 |
| 1982 | 49,743 | 34,411 | 21,804 | 14,807 | 10,602 | 7,860 | 5,983 | 4,645 | 3,668 | 2,947 | 2,400 | 1,978 | 1,651 | 1,400 | 1,208 | 1,055 | 931 | 827 | 738 | 662 | 596 | 537 | 483 | 435 | 391 | 3,268 |
| 1983 | 36,851 | 43,679 | 30,108 | 18,979 | 12,778 | 9,061 | 6,663 | 5,044 | 3,904 | 3,079 | 2,473 | 2,014 | 1,661 | 1,387 | 1,177 | 1,016 | 889 | 784 | 697 | 622 | 558 | 502 | 452 | 408 | 367 | 3,086 |
| 1984 | 28,292 | 32,359 | 38,243 | 26,250 | 16,432 | 10,975 | 7,731 | 5,660 | 4,274 | 3,304 | 2,605 | 2,092 | 1,705 | 1,407 | 1,176 | 999 | 863 | 754 | 666 | 592 | 528 | 474 | 427 | 384 | 346 | 2,933 |

Table 17b. Numbers at age (1000s), 1985-2020 estimated by Model 14.2.

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | 23,813 | 24,843 | 28,372 | 33,460 | 22,886 | 14,267 | 9,497 | 6,674 | 4,880 | 3,683 | 2,847 | 2,244 | 1,803 | 1,470 | 1,214 | 1,014 | 862 | 744 | 651 | 575 | 511 | 456 | 409 | 368 | 332 | 2,832 |
| 1986 | 21,609 | 20,910 | 21,776 | 24,804 | 29,126 | 19,823 | 12,307 | 8,169 | 5,732 | 4,187 | 3,159 | 2,442 | 1,926 | 1,548 | 1,263 | 1,043 | 872 | 741 | 640 | 560 | 494 | 439 | 392 | 352 | 317 | 2,721 |
| 1987 | 20,828 | 18,975 | 18,335 | 19,053 | 21,627 | 25,294 | 17,157 | 10,628 | 7,046 | 4,940 | 3,608 | 2,723 | 2,105 | 1,661 | 1,336 | 1,089 | 900 | 753 | 639 | 553 | 483 | 427 | 379 | 339 | 304 | 2,623 |
| 1988 | 20,859 | 18,289 | 16,644 | 16,058 | 16,645 | 18,839 | 21,979 | 14,884 | 9,211 | 6,104 | 4,279 | 3,126 | 2,359 | 1,825 | 1,440 | 1,158 | 945 | 780 | 653 | 555 | 479 | 419 | 370 | 329 | 294 | 2,539 |
| 1989 | 21,485 | 18,317 | 16,038 | 14,567 | 14,008 | 14,466 | 16,323 | 19,005 | 12,855 | 7,951 | 5,268 | 3,694 | 2,699 | 2,037 | 1,576 | 1,244 | 1,001 | 817 | 675 | 564 | 480 | 414 | 363 | 320 | 285 | 2,450 |
| 1990 | 22,728 | 18,866 | 16,075 | 14,065 | 12,759 | 12,253 | 12,639 | 14,251 | 16,585 | 11,216 | 6,937 | 4,596 | 3,223 | 2,355 | 1,778 | 1,376 | 1,086 | 874 | 713 | 589 | 493 | 419 | 362 | 317 | 280 | 2,388 |
| 1991 | 22,880 | 19,957 | 16,557 | 14,097 | 12,318 | 11,157 | 10,701 | 11,030 | 12,431 | 14,464 | 9,781 | 6,050 | 4,009 | 2,811 | 2,055 | 1,551 | 1,201 | 948 | 762 | 622 | 514 | 430 | 365 | 316 | 276 | 2,328 |
| 1992 | 20,012 | 20,091 | 17,516 | 14,521 | 12,345 | 10,758 | 9,709 | 9,277 | 9,532 | 10,721 | 12,465 | 8,427 | 5,212 | 3,454 | 2,422 | 1,771 | 1,337 | 1,035 | 817 | 657 | 536 | 443 | 371 | 315 | 272 | 2,245 |
| 1993 | 20,306 | 17,573 | 17,624 | 15,343 | 12,681 | 10,723 | 9,278 | 8,310 | 7,891 | 8,077 | 9,070 | 10,539 | 7,125 | 4,408 | 2,921 | 2,049 | 1,498 | 1,131 | 875 | 691 | 556 | 454 | 375 | 314 | 267 | 2,130 |
| 1994 | 25,614 | 17,831 | 15,419 | 15,448 | 13,419 | 11,048 | 9,294 | 7,998 | 7,132 | 6,754 | 6,904 | 7,750 | 9,006 | 6,089 | 3,767 | 2,497 | 1,752 | 1,280 | 967 | 748 | 591 | 475 | 388 | 321 | 268 | 2,049 |
| 1995 | 31,237 | 22,492 | 15,644 | 13,511 | 13,501 | 11,675 | 9,555 | 7,987 | 6,837 | 6,077 | 5,746 | 5,872 | 6,591 | 7,660 | 5,180 | 3,205 | 2,125 | 1,491 | 1,090 | 823 | 637 | 503 | 405 | 330 | 273 | 1,972 |
| 1996 | 26,825 | 27,429 | 19,731 | 13,706 | 11,805 | 11,740 | 10,087 | 8,199 | 6,815 | 5,814 | 5,160 | 4,877 | 4,984 | 5,595 | 6,503 | 4,398 | 2,722 | 1,804 | 1,266 | 926 | 699 | 541 | 427 | 344 | 280 | 1,907 |
| 1997 | 29,491 | 23,555 | 24,066 | 17,293 | 11,983 | 10,279 | 10,166 | 8,683 | 7,024 | 5,822 | 4,960 | 4,400 | 4,159 | 4,251 | 4,773 | 5,548 | 3,752 | 2,322 | 1,540 | 1,080 | 790 | 597 | 462 | 365 | 293 | 1,867 |
| 1998 | 31,779 | 25,896 | 20,660 | 21,075 | 15,092 | 10,397 | 8,848 | 8,678 | 7,363 | 5,931 | 4,907 | 4,178 | 3,707 | 3,504 | 3,582 | 4,022 | 4,676 | 3,163 | 1,958 | 1,298 | 911 | 666 | 503 | 389 | 307 | 1,821 |
| 1999 | 33,494 | 27,905 | 22,711 | 18,087 | 18,380 | 13,078 | 8,932 | 7,531 | 7,331 | 6,191 | 4,977 | 4,115 | 3,504 | 3,109 | 2,940 | 3,006 | 3,376 | 3,925 | 2,655 | 1,643 | 1,090 | 765 | 559 | 422 | 327 | 1,787 |
| 2000 | 35,791 | 29,411 | 24,481 | 19,898 | 15,803 | 15,983 | 11,299 | 7,664 | 6,426 | 6,234 | 5,257 | 4,224 | 3,493 | 2,974 | 2,640 | 2,496 | 2,552 | 2,867 | 3,333 | 2,255 | 1,396 | 925 | 649 | 475 | 359 | 1,795 |
| 2001 | 30,204 | 31,428 | 25,794 | 21,434 | 17,358 | 13,699 | 13,739 | 9,626 | 6,482 | 5,411 | 5,239 | 4,415 | 3,548 | 2,934 | 2,499 | 2,218 | 2,098 | 2,145 | 2,409 | 2,802 | 1,895 | 1,173 | 778 | 546 | 399 | 1,811 |
| 2002 | 27,631 | 26,522 | 27,560 | 22,579 | 18,689 | 15,034 | 11,758 | 11,679 | 8,119 | 5,441 | 4,532 | 4,386 | 3,696 | 2,970 | 2,457 | 2,093 | 1,858 | 1,757 | 1,797 | 2,019 | 2,348 | 1,588 | 983 | 652 | 457 | 1,852 |
| 2003 | 34,329 | 24,263 | 23,255 | 24,118 | 19,674 | 16,164 | 12,872 | 9,961 | 9,808 | 6,782 | 4,534 | 3,774 | 3,652 | 3,078 | 2,474 | 2,047 | 1,744 | 1,548 | 1,465 | 1,498 | 1,683 | 1,957 | 1,324 | 820 | 543 | 1,925 |
| 2004 | 42,135 | 30,144 | 21,274 | 20,350 | 21,015 | 17,018 | 13,845 | 10,911 | 8,371 | 8,200 | 5,657 | 3,779 | 3,146 | 3,045 | 2,567 | 2,064 | 1,707 | 1,455 | 1,292 | 1,222 | 1,250 | 1,404 | 1,633 | 1,105 | 684 | 2,060 |
| 2005 | 40,215 | 36,999 | 26,430 | 18,615 | 17,727 | 18,168 | 14,563 | 11,720 | 9,155 | 6,987 | 6,827 | 4,707 | 3,145 | 2,618 | 2,534 | 2,137 | 1,718 | 1,422 | 1,212 | 1,076 | 1,018 | 1,041 | 1,170 | 1,361 | 921 | 2,286 |
| 2006 | 44,607 | 35,313 | 32,444 | 23,132 | 16,223 | 15,333 | 15,550 | 12,323 | 9,825 | 7,631 | 5,808 | 5,672 | 3,910 | 2,612 | 2,176 | 2,106 | 1,776 | 1,429 | 1,182 | 1,008 | 895 | 847 | 866 | 973 | 1,131 | 2,667 |
| 2007 | 35,121 | 39,169 | 30,969 | 28,403 | 20,174 | 14,056 | 13,167 | 13,226 | 10,400 | 8,253 | 6,396 | 4,865 | 4,751 | 3,275 | 2,189 | 1,823 | 1,765 | 1,489 | 1,198 | 991 | 845 | 750 | 710 | 726 | 816 | 3,185 |
| 2008 | 44,573 | 30,840 | 34,326 | 27,064 | 24,695 | 17,421 | 12,050 | 11,214 | 11,211 | 8,791 | 6,968 | 5,400 | 4,108 | 4,013 | 2,768 | 1,851 | 1,542 | 1,493 | 1,260 | 1,013 | 839 | 715 | 635 | 601 | 614 | 3,385 |
| 2009 | 38,130 | 39,140 | 27,036 | 30,023 | 23,567 | 21,372 | 14,970 | 10,285 | 9,523 | 9,492 | 7,434 | 5,890 | 4,565 | 3,475 | 3,395 | 2,342 | 1,566 | 1,305 | 1,264 | 1,067 | 858 | 710 | 605 | 538 | 509 | 3,387 |
| 2010 | 33,168 | 33,482 | 34,302 | 23,629 | 26,108 | 20,357 | 18,328 | 12,755 | 8,722 | 8,053 | 8,017 | 6,278 | 4,976 | 3,858 | 2,937 | 2,871 | 1,981 | 1,325 | 1,104 | 1,070 | 903 | 726 | 601 | 512 | 455 | 3,298 |
| 2011 | 28,536 | 29,124 | 29,358 | 30,015 | 20,598 | 22,644 | 17,560 | 15,732 | 10,909 | 7,444 | 6,867 | 6,836 | 5,354 | 4,244 | 3,292 | 2,507 | 2,451 | 1,692 | 1,132 | 943 | 914 | 771 | 620 | 513 | 438 | 3,205 |
| 2012 | 26,366 | 25,058 | 25,536 | 25,686 | 26,153 | 17,836 | 19,457 | 14,974 | 13,335 | 9,214 | 6,277 | 5,789 | 5,762 | 4,514 | 3,580 | 2,777 | 2,115 | 2,068 | 1,428 | 955 | 796 | 771 | 651 | 524 | 433 | 3,075 |
| 2013 | 19,980 | 23,152 | 21,972 | 22,346 | 22,388 | 22,653 | 15,329 | 16,592 | 12,689 | 11,258 | 7,766 | 5,288 | 4,877 | 4,856 | 3,805 | 3,018 | 2,342 | 1,784 | 1,744 | 1,204 | 806 | 672 | 651 | 549 | 442 | 2,960 |
| 2014 | 16,850 | 17,544 | 20,299 | 19,224 | 19,468 | 19,374 | 19,437 | 13,038 | 14,015 | 10,674 | 9,452 | 6,517 | 4,438 | 4,094 | 4,078 | 3,196 | 2,535 | 1,967 | 1,499 | 1,466 | 1,012 | 677 | 564 | 547 | 461 | 2,859 |
| 2015 | 15,346 | 14,796 | 15,388 | 17,776 | 16,776 | 16,889 | 16,671 | 16,581 | 11,044 | 11,820 | 8,985 | 7,952 | 5,483 | 3,734 | 3,445 | 3,432 | 2,690 | 2,134 | 1,656 | 1,262 | 1,234 | 852 | 570 | 475 | 460 | 2,796 |
| 2016 | 19,526 | 13,476 | 12,981 | 13,484 | 15,532 | 14,578 | 14,557 | 14,241 | 14,058 | 9,321 | 9,955 | 7,562 | 6,692 | 4,614 | 3,143 | 2,900 | 2,889 | 2,265 | 1,797 | 1,395 | 1,063 | 1,039 | 717 | 480 | 400 | 2,742 |
| 2017 | 26,107 | 17,145 | 11,822 | 11,375 | 11,780 | 13,489 | 12,549 | 12,409 | 12,040 | 11,825 | 7,822 | 8,348 | 6,341 | 5,612 | 3,870 | 2,636 | 2,433 | 2,424 | 1,900 | 1,507 | 1,170 | 891 | 872 | 602 | 403 | 2,636 |
| 2018 | 22,687 | 22,925 | 15,039 | 10,355 | 9,928 | 10,214 | 11,586 | 10,667 | 10,456 | 10,091 | 9,887 | 6,536 | 6,974 | 5,298 | 4,689 | 3,234 | 2,203 | 2,033 | 2,026 | 1,588 | 1,260 | 978 | 745 | 729 | 503 | 2,541 |
| 2019 | 24,879 | 19,921 | 20,103 | 13,163 | 9,025 | 8,592 | 8,754 | 9,828 | 8,972 | 8,750 | 8,425 | 8,249 | 5,452 | 5,819 | 4,421 | 3,914 | 2,700 | 1,840 | 1,698 | 1,692 | 1,326 | 1,053 | 817 | 622 | 609 | 2,542 |
| 2020 | 24,879 | 21,846 | 17,467 | 17,589 | 11,472 | 7,823 | 7,401 | 7,497 | 8,379 | 7,630 | 7,432 | 7,155 | 7,006 | 4,632 | 4,946 | 3,758 | 3,328 | 2,296 | 1,565 | 1,444 | 1,439 | 1,128 | 895 | 695 | 529 | 2,681 |

Table 18a. Projected catch, female spawning biomass, and fishing mortality rate for **Harvest Scenario 1**.

| projected catch (t) – Scenario 1 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 21,832 | 21,832 | 21,832 | 21,832 | 0 |
| 2022 | 21,832 | 21,832 | 21,832 | 21,832 | 0 |
| 2023 | 30,114 | 30,132 | 30,135 | 30,159 | 15 |
| 2024 | 28,350 | 28,417 | 28,426 | 28,514 | 54 |
| 2025 | 26,928 | 27,115 | 27,141 | 27,387 | 154 |
| 2026 | 25,770 | 26,187 | 26,241 | 26,790 | 337 |
| 2027 | 24,860 | 25,562 | 25,670 | 26,649 | 583 |
| 2028 | 24,114 | 25,267 | 25,353 | 26,659 | 841 |
| 2029 | 23,648 | 25,151 | 25,212 | 26,786 | 1,072 |
| 2030 | 23,176 | 25,062 | 25,140 | 26,892 | 1,315 |
| 2031 | 22,348 | 24,649 | 24,807 | 27,178 | 1,695 |
| 2032 | 21,870 | 24,650 | 24,686 | 27,541 | 1,956 |
| 2033 | 21,761 | 24,815 | 24,751 | 28,366 | 2,138 |

| projected female spawning biomass (t) – Scenario 1 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 123,390 | 123,390 | 123,390 | 123,390 | 0 |
| 2022 | 119,497 | 119,497 | 119,498 | 119,498 | 0 |
| 2023 | 112,945 | 112,946 | 112,946 | 112,947 | 1 |
| 2024 | 104,262 | 104,263 | 104,263 | 104,264 | 1 |
| 2025 | 95,922 | 95,923 | 95,923 | 95,923 | 0 |
| 2026 | 88,562 | 88,563 | 88,563 | 88,564 | 0 |
| 2027 | 82,489 | 82,511 | 82,514 | 82,543 | 18 |
| 2028 | 77,643 | 77,773 | 77,795 | 77,971 | 108 |
| 2029 | 73,761 | 74,235 | 74,299 | 74,917 | 379 |
| 2030 | 70,662 | 71,723 | 71,889 | 73,303 | 887 |
| 2031 | 68,326 | 70,116 | 70,442 | 72,983 | 1,548 |
| 2032 | 66,577 | 69,482 | 69,769 | 73,243 | 2,199 |
| 2033 | 65,634 | 69,432 | 69,611 | 73,723 | 2,749 |

| projected fishing mortality rate – Scenario 1 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 0.051 | 0.051 | 0.051 | 0.051 | 0.000 |
| 2022 | 0.054 | 0.054 | 0.054 | 0.054 | 0.000 |
| 2023 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2024 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2025 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2026 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2027 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2028 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2029 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2030 | 0.078 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2031 | 0.076 | 0.078 | 0.078 | 0.079 | 0.001 |
| 2032 | 0.074 | 0.077 | 0.077 | 0.079 | 0.002 |
| 2033 | 0.073 | 0.077 | 0.077 | 0.079 | 0.002 |

Table 18b. Projected catch, female spawning biomass, and fishing mortality rate for **Harvest Scenario 2**.

| projected catch - Scenario 2 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 21,832 | 21,832 | 21,832 | 21,832 | 0 |
| 2022 | 21,832 | 21,832 | 21,832 | 21,832 | 0 |
| 2023 | 30,114 | 30,132 | 30,135 | 30,159 | 15 |
| 2024 | 28,350 | 28,417 | 28,426 | 28,514 | 54 |
| 2025 | 26,928 | 27,115 | 27,141 | 27,387 | 154 |
| 2026 | 25,770 | 26,187 | 26,241 | 26,790 | 337 |
| 2027 | 24,860 | 25,562 | 25,670 | 26,649 | 583 |
| 2028 | 24,114 | 25,267 | 25,353 | 26,659 | 841 |
| 2029 | 23,648 | 25,151 | 25,212 | 26,786 | 1,072 |
| 2030 | 23,176 | 25,062 | 25,140 | 26,892 | 1,315 |
| 2031 | 22,348 | 24,649 | 24,807 | 27,178 | 1,695 |
| 2032 | 21,870 | 24,650 | 24,686 | 27,541 | 1,956 |
| 2033 | 21,761 | 24,815 | 24,751 | 28,366 | 2,138 |

| projected female spawning biomass - Scenario 2 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 123,390 | 123,390 | 123,390 | 123,390 | 0 |
| 2022 | 119,497 | 119,497 | 119,498 | 119,498 | 0 |
| 2023 | 112,945 | 112,946 | 112,946 | 112,947 | 1 |
| 2024 | 104,262 | 104,263 | 104,263 | 104,264 | 1 |
| 2025 | 95,922 | 95,923 | 95,923 | 95,923 | 0 |
| 2026 | 88,562 | 88,563 | 88,563 | 88,564 | 0 |
| 2027 | 82,489 | 82,511 | 82,514 | 82,543 | 18 |
| 2028 | 77,643 | 77,773 | 77,795 | 77,971 | 108 |
| 2029 | 73,761 | 74,235 | 74,299 | 74,917 | 379 |
| 2030 | 70,662 | 71,723 | 71,889 | 73,303 | 887 |
| 2031 | 68,326 | 70,116 | 70,442 | 72,983 | 1,548 |
| 2032 | 66,577 | 69,482 | 69,769 | 73,243 | 2,199 |
| 2033 | 65,634 | 69,432 | 69,611 | 73,723 | 2,749 |

| projected fishing mortality rate - Scenario 2 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 0.035 | 0.035 | 0.035 | 0.035 | 0.000 |
| 2022 | 0.051 | 0.051 | 0.051 | 0.051 | 0.000 |
| 2023 | 0.054 | 0.054 | 0.054 | 0.054 | 0.000 |
| 2024 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2025 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2026 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2027 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2028 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2029 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2030 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2031 | 0.078 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2032 | 0.076 | 0.078 | 0.078 | 0.079 | 0.001 |
| 2033 | 0.074 | 0.077 | 0.077 | 0.079 | 0.002 |

Table 18c. Projected catch, female spawning biomass, and fishing mortality rate for **Harvest Scenario 3**.

| projected catch (t) - Scenario 3 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 21,832 | 21,832 | 21,832 | 21,832 | 0 |
| 2022 | 21,832 | 21,832 | 21,832 | 21,832 | 0 |
| 2023 | 30,114 | 30,132 | 30,135 | 30,159 | 15 |
| 2024 | 28,350 | 28,417 | 28,426 | 28,514 | 54 |
| 2025 | 71,677 | 72,704 | 72,850 | 74,246 | 850 |
| 2026 | 52,635 | 54,645 | 54,915 | 57,533 | 1,625 |
| 2027 | 41,589 | 44,849 | 45,024 | 48,746 | 2,352 |
| 2028 | 35,537 | 39,677 | 39,691 | 43,455 | 2,813 |
| 2029 | 32,304 | 36,575 | 36,870 | 41,252 | 3,092 |
| 2030 | 30,543 | 35,007 | 35,457 | 40,822 | 3,342 |
| 2031 | 30,454 | 34,069 | 34,839 | 40,943 | 3,546 |
| 2032 | 30,011 | 33,747 | 34,603 | 40,952 | 3,608 |
| 2033 | 29,881 | 33,600 | 34,489 | 41,207 | 3,561 |

| projected female spawning biomass (t) - Scenario 3 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 115,957 | 115,957 | 115,957 | 115,957 | 0 |
| 2022 | 114,010 | 114,010 | 114,010 | 114,011 | 0 |
| 2023 | 111,270 | 111,271 | 111,271 | 111,272 | 1 |
| 2024 | 108,408 | 108,408 | 108,408 | 108,409 | 1 |
| 2025 | 104,454 | 104,454 | 104,454 | 104,455 | 0 |
| 2026 | 99,997 | 99,999 | 99,999 | 100,001 | 1 |
| 2027 | 95,722 | 95,742 | 95,745 | 95,770 | 16 |
| 2028 | 92,142 | 92,273 | 92,293 | 92,464 | 105 |
| 2029 | 89,433 | 89,922 | 89,982 | 90,607 | 383 |
| 2030 | 87,555 | 88,713 | 88,868 | 90,335 | 935 |
| 2031 | 86,378 | 88,498 | 88,801 | 91,566 | 1,723 |
| 2032 | 85,767 | 89,169 | 89,518 | 93,592 | 2,599 |
| 2033 | 85,792 | 90,571 | 90,725 | 95,840 | 3,423 |

| projected fishing mortality rate - Scenario 3 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 0.061 | 0.061 | 0.061 | 0.061 | 0.000 |
| 2022 | 0.065 | 0.065 | 0.065 | 0.065 | 0.000 |
| 2023 | 0.044 | 0.044 | 0.044 | 0.044 | 0.000 |
| 2024 | 0.044 | 0.044 | 0.044 | 0.044 | 0.000 |
| 2025 | 0.044 | 0.044 | 0.044 | 0.044 | 0.000 |
| 2026 | 0.044 | 0.044 | 0.044 | 0.044 | 0.000 |
| 2027 | 0.044 | 0.044 | 0.044 | 0.044 | 0.000 |
| 2028 | 0.044 | 0.044 | 0.044 | 0.044 | 0.000 |
| 2029 | 0.044 | 0.044 | 0.044 | 0.044 | 0.000 |
| 2030 | 0.044 | 0.044 | 0.044 | 0.044 | 0.000 |
| 2031 | 0.044 | 0.044 | 0.044 | 0.044 | 0.000 |
| 2032 | 0.044 | 0.044 | 0.044 | 0.044 | 0.000 |
| 2033 | 0.044 | 0.044 | 0.044 | 0.044 | 0.000 |

Table 18d. Projected catch, female spawning biomass, and fishing mortality rate for **Harvest Scenario 4**.

| projected catch (t) - Scenario 4 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 21,832 | 21,832 | 21,832 | 21,832 | 0 |
| 2022 | 21,832 | 21,832 | 21,832 | 21,832 | 0 |
| 2023 | 16,047 | 16,057 | 16,058 | 16,071 | 8 |
| 2024 | 15,616 | 15,651 | 15,656 | 15,702 | 28 |
| 2025 | 15,297 | 15,396 | 15,410 | 15,540 | 82 |
| 2026 | 15,058 | 15,281 | 15,311 | 15,606 | 181 |
| 2027 | 14,894 | 15,277 | 15,337 | 15,875 | 318 |
| 2028 | 14,764 | 15,405 | 15,457 | 16,190 | 469 |
| 2029 | 14,754 | 15,618 | 15,637 | 16,545 | 610 |
| 2030 | 14,793 | 15,781 | 15,849 | 16,861 | 736 |
| 2031 | 14,857 | 15,997 | 16,075 | 17,505 | 849 |
| 2032 | 15,019 | 16,295 | 16,303 | 17,817 | 947 |
| 2033 | 15,192 | 16,414 | 16,520 | 18,386 | 1,021 |

| projected female spawning biomass (t) - Scenario 4 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 123,390 | 123,390 | 123,390 | 123,390 | 0 |
| 2022 | 119,497 | 119,497 | 119,498 | 119,498 | 0 |
| 2023 | 114,689 | 114,690 | 114,690 | 114,691 | 1 |
| 2024 | 109,831 | 109,832 | 109,832 | 109,833 | 1 |
| 2025 | 104,794 | 104,795 | 104,795 | 104,796 | 1 |
| 2026 | 100,282 | 100,282 | 100,282 | 100,283 | 0 |
| 2027 | 96,706 | 96,728 | 96,732 | 96,762 | 19 |
| 2028 | 94,087 | 94,227 | 94,251 | 94,440 | 116 |
| 2029 | 92,191 | 92,718 | 92,788 | 93,476 | 421 |
| 2030 | 90,816 | 92,060 | 92,243 | 93,886 | 1,025 |
| 2031 | 89,851 | 92,121 | 92,485 | 95,518 | 1,891 |
| 2032 | 89,216 | 92,939 | 93,309 | 97,787 | 2,855 |
| 2033 | 89,137 | 94,301 | 94,487 | 100,118 | 3,756 |

| projected fishing mortality rate - Scenario 4 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 0.051 | 0.051 | 0.051 | 0.051 | 0.000 |
| 2022 | 0.054 | 0.054 | 0.054 | 0.054 | 0.000 |
| 2023 | 0.042 | 0.042 | 0.042 | 0.042 | 0.000 |
| 2024 | 0.042 | 0.042 | 0.042 | 0.042 | 0.000 |
| 2025 | 0.042 | 0.042 | 0.042 | 0.042 | 0.000 |
| 2026 | 0.042 | 0.042 | 0.042 | 0.042 | 0.000 |
| 2027 | 0.042 | 0.042 | 0.042 | 0.042 | 0.000 |
| 2028 | 0.042 | 0.042 | 0.042 | 0.042 | 0.000 |
| 2029 | 0.042 | 0.042 | 0.042 | 0.042 | 0.000 |
| 2030 | 0.042 | 0.042 | 0.042 | 0.042 | 0.000 |
| 2031 | 0.042 | 0.042 | 0.042 | 0.042 | 0.000 |
| 2032 | 0.042 | 0.042 | 0.042 | 0.042 | 0.000 |
| 2033 | 0.042 | 0.042 | 0.042 | 0.042 | 0.000 |

Table 18e. Projected catch, female spawning biomass, and fishing mortality rate for **Harvest Scenario 5**.

| projected catch (t) - Scenario 5 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 0 | 0 | 0 | 0 | 0 |
| 2022 | 0 | 0 | 0 | 0 | 0 |
| 2023 | 0 | 0 | 0 | 0 | 0 |
| 2024 | 0 | 0 | 0 | 0 | 0 |
| 2025 | 0 | 0 | 0 | 0 | 0 |
| 2026 | 0 | 0 | 0 | 0 | 0 |
| 2027 | 0 | 0 | 0 | 0 | 0 |
| 2028 | 0 | 0 | 0 | 0 | 0 |
| 2029 | 0 | 0 | 0 | 0 | 0 |
| 2030 | 0 | 0 | 0 | 0 | 0 |
| 2031 | 0 | 0 | 0 | 0 | 0 |
| 2032 | 0 | 0 | 0 | 0 | 0 |
| 2033 | 0 | 0 | 0 | 0 | 0 |

| projected female spawning biomass (t) - Scenario 5 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 123,390 | 123,390 | 123,390 | 123,390 | 0 |
| 2022 | 119,497 | 119,497 | 119,498 | 119,498 | 0 |
| 2023 | 116,640 | 116,641 | 116,641 | 116,642 | 1 |
| 2024 | 116,305 | 116,306 | 116,306 | 116,307 | 1 |
| 2025 | 115,513 | 115,513 | 115,514 | 115,515 | 1 |
| 2026 | 114,987 | 114,988 | 114,988 | 114,989 | 1 |
| 2027 | 115,219 | 115,243 | 115,246 | 115,278 | 20 |
| 2028 | 116,284 | 116,436 | 116,462 | 116,667 | 126 |
| 2029 | 117,941 | 118,533 | 118,612 | 119,385 | 473 |
| 2030 | 119,944 | 121,391 | 121,603 | 123,547 | 1,194 |
| 2031 | 122,118 | 124,886 | 125,302 | 128,975 | 2,282 |
| 2032 | 124,500 | 128,944 | 129,490 | 135,113 | 3,560 |
| 2033 | 127,017 | 133,726 | 133,904 | 141,231 | 4,820 |

| projected fishing mortality rate - Scenario 5 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2022 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2023 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2024 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2025 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2026 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2027 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2028 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2029 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2030 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2031 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2032 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2033 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

Table 18f. Projected catch, female spawning biomass, and fishing mortality rate for **Harvest Scenario 6**.

| projected catch (t) - Scenario 6 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 38,580 | 38,580 | 38,580 | 38,580 | 0 |
| 2022 | 35,320 | 35,324 | 35,325 | 35,331 | 4 |
| 2023 | 32,652 | 32,672 | 32,676 | 32,703 | 17 |
| 2024 | 30,535 | 30,613 | 30,624 | 30,727 | 63 |
| 2025 | 28,865 | 29,081 | 29,112 | 29,398 | 179 |
| 2026 | 27,532 | 28,017 | 28,077 | 28,712 | 390 |
| 2027 | 26,510 | 27,317 | 27,442 | 28,565 | 670 |
| 2028 | 24,530 | 25,827 | 25,938 | 27,426 | 951 |
| 2029 | 23,016 | 24,701 | 24,757 | 26,609 | 1,219 |
| 2030 | 22,071 | 24,090 | 24,260 | 26,477 | 1,519 |
| 2031 | 21,665 | 24,047 | 24,252 | 26,798 | 1,850 |
| 2032 | 21,584 | 24,390 | 24,557 | 28,299 | 2,178 |
| 2033 | 21,829 | 24,910 | 25,022 | 28,932 | 2,463 |

| projected female spawning biomass (t) - Scenario 6 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 121,342 | 121,342 | 121,342 | 121,342 | 0 |
| 2022 | 113,019 | 113,019 | 113,019 | 113,019 | 0 |
| 2023 | 103,972 | 103,972 | 103,972 | 103,972 | 0 |
| 2024 | 94,801 | 94,801 | 94,801 | 94,801 | 0 |
| 2025 | 86,221 | 86,221 | 86,221 | 86,221 | 0 |
| 2026 | 78,802 | 78,802 | 78,802 | 78,802 | 0 |
| 2027 | 72,785 | 72,805 | 72,808 | 72,836 | 17 |
| 2028 | 68,185 | 68,308 | 68,328 | 68,493 | 101 |
| 2029 | 64,863 | 65,296 | 65,354 | 65,918 | 346 |
| 2030 | 62,533 | 63,507 | 63,649 | 64,931 | 797 |
| 2031 | 60,998 | 62,664 | 62,932 | 65,240 | 1,390 |
| 2032 | 59,978 | 62,690 | 62,905 | 65,948 | 1,982 |
| 2033 | 59,598 | 63,285 | 63,292 | 66,818 | 2,467 |

| projected fishing mortality rate - Scenario 6 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2021 | 0.093 | 0.093 | 0.093 | 0.093 | 0.000 |
| 2022 | 0.093 | 0.093 | 0.093 | 0.093 | 0.000 |
| 2023 | 0.093 | 0.093 | 0.093 | 0.093 | 0.000 |
| 2024 | 0.093 | 0.093 | 0.093 | 0.093 | 0.000 |
| 2025 | 0.093 | 0.093 | 0.093 | 0.093 | 0.000 |
| 2026 | 0.093 | 0.093 | 0.093 | 0.093 | 0.000 |
| 2027 | 0.093 | 0.093 | 0.093 | 0.093 | 0.000 |
| 2028 | 0.088 | 0.088 | 0.088 | 0.089 | 0.000 |
| 2029 | 0.084 | 0.084 | 0.084 | 0.085 | 0.000 |
| 2030 | 0.080 | 0.082 | 0.082 | 0.084 | 0.001 |
| 2031 | 0.078 | 0.081 | 0.081 | 0.084 | 0.002 |
| 2032 | 0.077 | 0.081 | 0.081 | 0.085 | 0.003 |
| 2033 | 0.076 | 0.082 | 0.082 | 0.086 | 0.003 |

Table 18g. Projected catch, female spawning biomass, and fishing mortality rate for **Harvest Scenario 7**.

| projected catch (t) - Scenario 7 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2019 | 33,219 | 33,219 | 33,219 | 33,219 | 0 |
| 2020 | 30,777 | 30,780 | 30,781 | 30,786 | 3 |
| 2021 | 33,414 | 33,434 | 33,438 | 33,465 | 17 |
| 2022 | 31,194 | 31,272 | 31,283 | 31,386 | 63 |
| 2023 | 29,428 | 29,644 | 29,675 | 29,961 | 179 |
| 2024 | 28,007 | 28,493 | 28,552 | 29,188 | 390 |
| 2025 | 26,907 | 27,714 | 27,838 | 28,962 | 671 |
| 2026 | 25,366 | 26,691 | 26,804 | 28,324 | 970 |
| 2027 | 23,623 | 25,334 | 25,391 | 27,269 | 1,237 |
| 2028 | 22,508 | 24,545 | 24,716 | 26,951 | 1,533 |
| 2029 | 21,969 | 24,364 | 24,568 | 27,122 | 1,859 |
| 2030 | 21,790 | 24,590 | 24,764 | 28,502 | 2,181 |
| 2031 | 21,957 | 25,022 | 25,145 | 29,061 | 2,461 |

| projected female spawning biomass (t) - Scenario 7 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2019 | 122,002 | 122,002 | 122,002 | 122,002 | 0 |
| 2020 | 115,122 | 115,122 | 115,122 | 115,122 | 0 |
| 2021 | 106,707 | 106,707 | 106,707 | 106,707 | 0 |
| 2022 | 97,274 | 97,274 | 97,274 | 97,274 | 0 |
| 2023 | 88,428 | 88,428 | 88,428 | 88,428 | 0 |
| 2024 | 80,750 | 80,750 | 80,750 | 80,750 | 0 |
| 2025 | 74,487 | 74,508 | 74,511 | 74,539 | 17 |
| 2026 | 69,604 | 69,725 | 69,746 | 69,910 | 101 |
| 2027 | 65,963 | 66,394 | 66,452 | 67,014 | 345 |
| 2028 | 63,367 | 64,338 | 64,479 | 65,756 | 794 |
| 2029 | 61,613 | 63,270 | 63,537 | 65,834 | 1,383 |
| 2030 | 60,414 | 63,111 | 63,325 | 66,350 | 1,971 |
| 2031 | 59,892 | 63,555 | 63,563 | 67,068 | 2,453 |

| projected fishing mortality rate - Scenario 7 | | | | | |
|---|---|---|---|---|---|
| year | L90%CI | median | mean | U90%CI | SD |
| 2019 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2020 | 0.079 | 0.079 | 0.079 | 0.079 | 0.000 |
| 2021 | 0.093 | 0.093 | 0.093 | 0.093 | 0.000 |
| 2022 | 0.093 | 0.093 | 0.093 | 0.093 | 0.000 |
| 2023 | 0.093 | 0.093 | 0.093 | 0.093 | 0.000 |
| 2024 | 0.093 | 0.093 | 0.093 | 0.093 | 0.000 |
| 2025 | 0.093 | 0.093 | 0.093 | 0.093 | 0.000 |
| 2026 | 0.090 | 0.090 | 0.090 | 0.091 | 0.000 |
| 2027 | 0.085 | 0.086 | 0.086 | 0.087 | 0.000 |
| 2028 | 0.082 | 0.083 | 0.083 | 0.085 | 0.001 |
| 2029 | 0.079 | 0.081 | 0.082 | 0.085 | 0.002 |
| 2030 | 0.078 | 0.081 | 0.082 | 0.086 | 0.003 |
| 2031 | 0.077 | 0.082 | 0.082 | 0.087 | 0.003 |

Table 19a. Survey biomass estimates for all skates in the BSAI, **1980-1986**. Before 1987 the EBS shelf survey did not sample strata 82 and 90 in the northwest EBS, and the 1980-1986 Aleutian Islands surveys used a different design and gears and are not directly comparable to the standardized 1991-2018 surveys.

| year | EBS shelf | EBS slope | Aleutian Islands | BSAI total |
|---|---|---|---|---|
| 1980 | | | 4,257 | |
| 1981 | | | | |
| 1982 | 164,088 | | | |
| 1983 | 161,435 | | 9,750 | |
| 1984 | 186,980 | | | |
| 1985 | 149,575 | | | |
| 1986 | 251,343 | | 15,514 | |

Table 19. Survey biomass estimates for all skates in the BSAI, **1987-2019**. *Before 1987 the EBS shelf survey did not sample strata 82 and 90 in the northwest EBS, and **the 1980-1986 Aleutian Islands surveys used a different design and gears and are not directly comparable to the standardized 1991-2019 surveys. The EBS shelf survey was not conducted in 2020.

| year | EBS shelf* | EBS slope | Aleutian Islands** | BSAI total |
|---|---|---|---|---|
| 1987 | 356,530 | | | |
| 1988 | 369,934 | | | |
| 1989 | 418,424 | | | |
| 1990 | 483,735 | | | |
| 1991 | 453,788 | | 15,009 | |
| 1992 | 399,625 | | | |
| 1993 | 389,285 | | | |
| 1994 | 404,888 | | 24,991 | |
| 1995 | 361,694 | | | |
| 1996 | 422,747 | | | |
| 1997 | 418,782 | | 29,001 | |
| 1998 | 369,576 | | | |
| 1999 | 354,614 | | | |
| 2000 | 336,906 | | 29,219 | |
| 2001 | 432,174 | | | |
| 2002 | 382,842 | 69,232 | 34,465 | 486,540 |
| 2003 | 405,184 | | | |
| 2004 | 439,640 | 33,156 | 53,225 | 526,021 |
| 2005 | 507,952 | | | |
| 2006 | 456,300 | | 54,214 | |
| 2007 | 496,300 | | | |
| 2008 | 381,052 | 36,384 | | |
| 2009 | 370,417 | | | |
| 2010 | 385,129 | 35,177 | 51,941 | 472,247 |
| 2011 | 428,194 | | | |
| 2012 | 386,702 | 59,687 | 35,405 | 481,794 |
| 2013 | 413,817 | | | |
| 2014 | 428,919 | | 42,905 | |
| 2015 | 487,575 | | | |
| 2016 | 587,920 | 49,152 | 27,768 | 664,839 |
| 2017 | 610,771 | | | |
| 2018 | 610,067 | | 29,489 | |
| 2019 | 528,826 | | | |

Table 20. Total BSAI biomass estimates by species for the 4 years since 2000 when surveys were conducted in each area (EBS shelf, EBS slope, AI) in the same year. The “other skates” row in the first part of the table includes all the species listed in the second part of the table.

| | 2002 | | 2004 | | 2010 | | 2012 | | 2016 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | biomass | CV | biomass | CV | biomass | CV | biomass | CV | biomass | CV |
| Alaska | 394,544 | 0.11 | 419,311 | 0.05 | 356,681 | 0.06 | 372,213 | 0.06 | 542,449 | 0.04 |
| other skates | 75,474 | 0.08 | 83,411 | 0.11 | 99,941 | 0.08 | 90,787 | 0.06 | 102,996 | 0.09 |
| all skates | 470,018 | 0.09 | 502,722 | 0.04 | 456,622 | 0.05 | 463,000 | 0.05 | 645,444 | 0.04 |
| | | | | | | | | | | |
| other skates | | | | | | | | | | |
| Aleutian | 26,258 | 0.18 | 29,000 | 0.20 | 30,775 | 0.15 | 33,013 | 0.10 | 41,355 | 0.15 |
| whiteblotched | 20,893 | 0.15 | 29,697 | 0.22 | 28,339 | 0.17 | 21,455 | 0.16 | 20,690 | 0.15 |
| Bering | 15,642 | 0.13 | 13,310 | 0.10 | 13,726 | 0.12 | 13,379 | 0.13 | 12,994 | 0.11 |
| big | 1,692 | 0.53 | 901 | 0.59 | 4,081 | 0.57 | 1,356 | 0.61 | 11,974 | 0.49 |
| commander | 3,656 | 0.16 | 4,194 | 0.15 | 3,461 | 0.15 | 4,509 | 0.13 | 5,540 | 0.16 |
| leopard | | | | | 12,958 | 0.21 | 10,421 | 0.24 | 4,220 | 0.40 |
| roughtail | 1,624 | 0.14 | 1,678 | 0.12 | 2,103 | 0.16 | 2,299 | 0.15 | 2,283 | 0.14 |
| mud | 2,706 | 0.15 | 2,509 | 0.14 | 2,122 | 0.17 | 2,429 | 0.18 | 2,248 | 0.17 |
| whitebrow | 1,567 | 0.23 | 1,789 | 0.20 | 1,908 | 0.19 | 1,409 | 0.14 | 1,359 | 0.15 |
| deepsea | | | 164 | 0.73 | 345 | 0.64 | 90 | 1.00 | 223 | 0.54 |
| butterfly | | | | | 123 | 0.49 | 307 | 0.32 | 86 | 0.31 |
| Bathyraja sp. | 68 | 0.59 | 21 | 0.49 | 1 | 1.00 | | | 21 | 0.84 |
| misc skates | 37 | 0.84 | 139 | 0.39 | | | 1 | 0.00 | 2 | 1.00 |
| longnose | 915 | 0.71 | | | | | 120 | 1.00 | | |
| Okhotsk | 415 | 0.56 | 8 | 1.00 | | | | | | |

Table 21a. Survey biomass estimates for Alaska skate, other skates, and total skates by area and year.

| | | Alaska | | other skates | | all skates | |
|---|---|---|---|---|---|---|---|
| | | biomass | CV | biomass | CV | biomass | CV |
| EBS slope | 2002 | 35,932 | 0.95 | 33,300 | 0.14 | 69,232 | 0.50 |
| | 2004 | 4,248 | 0.33 | 28,909 | 0.08 | 33,156 | 0.08 |
| | 2008 | 4,318 | 0.32 | 33,066 | 0.08 | 36,384 | 0.08 |
| | 2010 | 1,296 | 0.32 | 33,882 | 0.12 | 35,177 | 0.12 |
| | 2012 | 19,102 | 0.27 | 40,585 | 0.08 | 59,687 | 0.10 |
| | 2016 | 8,965 | 0.30 | 40,187 | 0.12 | 49,152 | 0.11 |
| AI | 2000 | 9,801 | 0.15 | 19,418 | 0.11 | 29,219 | 0.09 |
| | 2002 | 10,739 | 0.20 | 23,727 | 0.14 | 34,465 | 0.11 |
| | 2004 | 12,923 | 0.22 | 40,302 | 0.20 | 53,225 | 0.16 |
| | 2006 | 13,502 | 0.19 | 40,711 | 0.14 | 54,214 | 0.12 |
| | 2010 | 3,681 | 0.20 | 48,260 | 0.14 | 51,941 | 0.11 |
| | 2012 | 1,503 | 0.31 | 33,902 | 0.13 | 35,405 | 0.12 |
| | 2014 | 3,515 | 0.40 | 39,390 | 0.12 | 42,905 | 0.12 |
| | 2016 | 1,808 | 0.46 | 25,960 | 0.15 | 27,768 | 0.14 |
| | 2018 | 2,720 | 0.20 | 26,769 | 0.14 | 29,489 | 0.14 |
| EBS shelf | 1999 | 312,998 | 0.06 | 15,575 | 0.43 | 328,574 | 0.17 |
| | 2000 | 311,977 | 0.06 | 24,930 | 0.21 | 336,906 | 0.06 |
| | 2001 | 414,539 | 0.06 | 17,635 | 0.15 | 432,174 | 0.06 |
| | 2002 | 364,004 | 0.07 | 18,838 | 0.15 | 382,842 | 0.06 |
| | 2003 | 372,379 | 0.05 | 32,805 | 0.25 | 405,184 | 0.05 |
| | 2004 | 424,808 | 0.05 | 14,832 | 0.13 | 439,640 | 0.05 |
| | 2005 | 487,046 | 0.05 | 20,906 | 0.26 | 507,952 | 0.05 |
| | 2006 | 437,737 | 0.05 | 18,562 | 0.16 | 456,300 | 0.05 |
| | 2007 | 479,043 | 0.07 | 17,257 | 0.22 | 496,300 | 0.07 |
| | 2008 | 361,300 | 0.06 | 19,752 | 0.22 | 381,052 | 0.05 |
| | 2009 | 350,233 | 0.06 | 20,184 | 0.17 | 370,417 | 0.06 |
| | 2010 | 366,186 | 0.06 | 18,942 | 0.17 | 385,129 | 0.06 |
| | 2011 | 410,340 | 0.05 | 17,854 | 0.25 | 428,194 | 0.05 |
| | 2012 | 369,881 | 0.06 | 16,821 | 0.15 | 386,702 | 0.06 |
| | 2013 | 386,816 | 0.06 | 27,002 | 0.23 | 413,817 | 0.06 |
| | 2014 | 404,380 | 0.05 | 24,538 | 0.18 | 428,919 | 0.05 |
| | 2015 | 448,224 | 0.06 | 39,351 | 0.23 | 487,575 | 0.05 |
| | 2016 | 550,892 | 0.04 | 37,027 | 0.19 | 587,920 | 0.04 |
| | 2017 | 544,657 | 0.07 | 66,114 | 0.33 | 610,771 | 0.07 |
| | 2018 | 545,994 | 0.05 | 64,073 | 0.22 | 610,067 | 0.05 |
| | 2019 | 491,109 | 0.05 | 37,717 | 0.16 | 528,826 | 0.05 |
| | 2020 | | | no survey | | | |

Table 21b. Survey biomass estimates for miscellaneous, Aleutian, Bering, and whiteblotched skates by area and year (part of the "other skates" category in Table 19). Miscellaneous skates includes skates not identified to species.

| | | misc skates | | Aleutian | | Bering | | whiteblotched | |
|---|---|---|---|---|---|---|---|---|---|
| | | biomass | CV | biomass | CV | biomass | CV | biomass | CV |
| EBS slope | 2002 | 0 | n/a | 18,655 | 0.24 | 2,873 | 0.18 | 3,928 | 0.23 |
| | 2004 | 0 | n/a | 14,987 | 0.14 | 1,953 | 0.11 | 3,450 | 0.16 |
| | 2008 | 0 | n/a | 16,682 | 0.15 | 2,443 | 0.16 | 4,441 | 0.17 |
| | 2010 | 0 | n/a | 18,721 | 0.22 | 2,780 | 0.16 | 4,055 | 0.14 |
| | 2012 | 0 | n/a | 22,377 | 0.12 | 3,442 | 0.16 | 5,753 | 0.20 |
| | 2016 | 2 | 1.00 | 23,204 | 0.20 | 1,963 | 0.20 | 5,065 | 0.21 |
| AI | 2000 | 1 | 0.97 | 3,398 | 0.18 | 2 | 1.00 | 13,622 | 0.15 |
| | 2002 | 15 | 0.46 | 4,711 | 0.17 | 229 | 0.93 | 16,728 | 0.18 |
| | 2004 | 3 | 0.76 | 11,519 | 0.45 | 147 | 0.75 | 26,247 | 0.25 |
| | 2006 | 30 | 0.99 | 6,692 | 0.23 | 186 | 0.55 | 29,714 | 0.19 |
| | 2010 | 0 | n/a | 8,721 | 0.21 | 56 | 0.45 | 24,151 | 0.20 |
| | 2012 | 1 | 0.87 | 6,072 | 0.18 | 109 | 0.17 | 15,360 | 0.20 |
| | 2014 | 3 | 0.95 | 7,563 | 0.24 | 137 | 0.36 | 22,400 | 0.18 |
| | 2016 | 21 | 0.85 | 3,703 | 0.21 | 50 | 0.55 | 15,380 | 0.19 |
| | 2018 | 0 | n/a | 6,690 | 0.29 | 74 | 0.40 | 15,182 | 0.21 |
| EBS shelf | 1999 | 2,159 | 0.55 | 0 | n/a | 9,084 | 0.21 | 0 | n/a |
| | 2000 | 253 | 0.31 | 2,232 | 0.54 | 16,842 | 0.16 | 0 | n/a |
| | 2001 | 230 | 0.30 | 1,232 | 0.61 | 14,263 | 0.14 | 0 | n/a |
| | 2002 | 190 | 0.43 | 2,893 | 0.47 | 12,746 | 0.16 | 237 | 1.00 |
| | 2003 | 424 | 0.20 | 18,253 | 0.43 | 13,602 | 0.12 | 0 | n/a |
| | 2004 | 177 | 0.00 | 2,494 | 0.41 | 11,209 | 0.12 | 0 | n/a |
| | 2005 | 187 | 0.68 | 8,223 | 0.56 | 8,774 | 0.17 | 1,070 | 1.00 |
| | 2006 | 48 | 0.67 | 5,568 | 0.41 | 11,674 | 0.13 | 182 | 1.00 |
| | 2007 | 22 | 0.92 | 2,718 | 0.43 | 9,480 | 0.14 | 3,234 | 0.92 |
| | 2008 | 135 | 0.48 | 6,278 | 0.57 | 9,943 | 0.16 | 238 | 1.00 |
| | 2009 | 22 | 0.91 | 2,171 | 0.49 | 13,274 | 0.18 | 216 | 1.00 |
| | 2010 | 40 | 0.77 | 3,332 | 0.35 | 11,992 | 0.14 | 133 | 1.00 |
| | 2011 | 82 | 0.49 | 2,525 | 0.54 | 9,795 | 0.17 | 0 | n/a |
| | 2012 | 158 | 0.51 | 4,565 | 0.37 | 10,190 | 0.16 | 342 | 1.00 |
| | 2013 | 41 | 0.00 | 11,483 | 0.35 | 12,099 | 0.28 | 0 | n/a |
| | 2014 | 73 | 0.67 | 8,149 | 0.41 | 12,570 | 0.15 | 0 | n/a |
| | 2015 | 87 | 0.63 | 11,084 | 0.40 | 12,210 | 0.13 | 0 | n/a |
| | 2016 | 178 | 0.39 | 14,449 | 0.27 | 10,981 | 0.12 | 245 | 1.00 |
| | 2017 | 105 | 0.58 | 36,900 | 0.56 | 15,249 | 0.17 | 0 | n/a |
| | 2018 | 21 | 0.38 | 18,922 | 0.33 | 14,564 | 0.11 | 666 | 0.70 |
| | 2019 | 33 | 0.42 | 14,899 | 0.27 | 10,091 | 0.12 | 0 | n/a |
| | 2020 | No survey | | | | | | | |

Table 21c. Survey biomass estimates (t) for big, mud, roughtail, commander, and whitebrow skates (part of the "other skates" category in Table 19) by area and year.

| | | big skate | | mud | | roughtail | | Commander | | whitebrow | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | biomass | CV | biomass | CV | biomass | CV | biomass | CV | biomass | CV |
| EBS slope | 2002 | 0 | n/a | 927 | 0.32 | 1,624 | 0.14 | 3,656 | 0.16 | 1,537 | 0.23 |
| | 2004 | 0 | n/a | 702 | 0.20 | 1,677 | 0.12 | 4,194 | 0.15 | 1,755 | 0.20 |
| | 2008 | 0 | n/a | 978 | 0.22 | 2,134 | 0.13 | 3,342 | 0.15 | 1,874 | 0.17 |
| | 2010 | 0 | n/a | 576 | 0.25 | 2,103 | 0.16 | 3,393 | 0.15 | 1,908 | 0.19 |
| | 2012 | 0 | n/a | 866 | 0.30 | 2,298 | 0.15 | 4,423 | 0.13 | 1,336 | 0.15 |
| | 2016 | 0 | n/a | 577 | 0.22 | 2,283 | 0.14 | 5,511 | 0.16 | 1,359 | 0.15 |
| AI | 2000 | 1,049 | 0.56 | 1,296 | 0.13 | 0 | 1.31 | 51 | 0.71 | 0 | n/a |
| | 2002 | 203 | 0.62 | 1,779 | 0.16 | 0 | n/a | 31 | 1.00 | 30 | 0.71 |
| | 2004 | 422 | 0.53 | 1,807 | 0.17 | 1 | 0.98 | 0 | n/a | 34 | 1.00 |
| | 2006 | 568 | 0.72 | 2,970 | 0.28 | 0 | n/a | 161 | 1.00 | 0 | n/a |
| | 2010 | 637 | 0.83 | 1,546 | 0.22 | 0 | 1.21 | 68 | 1.00 | 0 | n/a |
| | 2012 | 195 | 0.65 | 1,277 | 0.15 | 2 | 0.86 | 86 | 0.66 | 72 | 0.69 |
| | 2014 | 0 | n/a | 1,831 | 0.25 | 0 | n/a | 0 | n/a | 8 | 0.73 |
| | 2016 | 1,306 | 0.87 | 1,165 | 0.20 | 0 | n/a | 29 | 1.00 | 0 | n/a |
| | 2018 | 185 | 0.62 | 2,255 | 0.52 | 2 | 1.00 | 52 | 0.71 | 51 | 0.64 |
| EBS shelf | 1999 | 6,492 | 1.00 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2000 | 5,155 | 0.83 | 448 | 0.48 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2001 | 1,811 | 0.78 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2002 | 1,489 | 0.59 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2003 | 0 | n/a | 526 | 0.37 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2004 | 951 | 0.71 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2005 | 2,307 | 0.71 | 186 | 0.86 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2006 | 1,036 | 0.68 | 55 | 1.00 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2007 | 1,804 | 0.76 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2008 | 2,870 | 0.63 | 125 | 1.00 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2009 | 4,500 | 0.50 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2010 | 3,445 | 0.66 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2011 | 5,263 | 0.72 | 189 | 0.70 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2012 | 1,161 | 0.70 | 286 | 1.00 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2013 | 3,379 | 1.00 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2014 | 3,596 | 0.60 | 149 | 1.00 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2015 | 15,438 | 0.49 | 190 | 1.00 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2016 | 10,668 | 0.54 | 506 | 0.54 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2017 | 13,716 | 0.41 | 144 | 1.00 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2018 | 28,731 | 0.42 | 618 | 0.51 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2019 | 11,847 | 0.37 | 880 | 0.49 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2020 | No survey | | | | | | | | | |

Table 21d. Survey biomass estimates for longnose, Okhotsk, deepsea, leopard, and butterfly skates, by area and year.

| | | longnose | | Okhotsk | | deepsea | | leopard | | butterfly | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | biomass | CV | biomass | CV | biomass | CV | biomass | CV | biomass | CV |
| EBS slope | 2002 | 0 | n/a | 47 | 0.59 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2004 | 0 | n/a | 8 | 1.00 | 164 | 0.73 | 0 | n/a | 0 | n/a |
| | 2008 | 12 | 1.00 | 0 | n/a | 160 | 0.62 | 0 | n/a | 0 | n/a |
| | 2010 | 0 | n/a | 0 | n/a | 345 | 0.64 | 0 | n/a | 0 | n/a |
| | 2012 | 0 | n/a | 0 | n/a | 90 | 1.00 | 0 | n/a | 0 | n/a |
| | 2016 | 0 | n/a | 0 | n/a | 223 | 0.54 | 0 | n/a | 0 | n/a |
| AI | 2000 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2002 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2004 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 122 | 0.44 |
| | 2006 | 0 | n/a | 0 | n/a | 0 | n/a | 4 | 1.00 | 385 | 0.40 |
| | 2010 | 0 | n/a | 0 | n/a | 0 | n/a | 12,958 | 0.21 | 123 | 0.49 |
| | 2012 | 0 | n/a | 0 | n/a | 0 | n/a | 10,421 | 0.24 | 307 | 0.32 |
| | 2014 | 0 | n/a | 0 | n/a | 0 | n/a | 7,040 | 0.23 | 409 | 0.37 |
| | 2016 | 0 | n/a | 0 | n/a | 0 | n/a | 4,220 | 0.40 | 86 | 0.31 |
| | 2018 | 0 | n/a | 0 | n/a | 0 | n/a | 2,198 | 0.24 | 81 | 0.90 |
| EBS shelf | 1999 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2000 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2001 | 0 | n/a | 98 | 1.00 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2002 | 915 | 0.71 | 368 | 0.62 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2003 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2004 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2005 | 0 | n/a | 159 | 1.00 | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2006 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2007 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2008 | 162 | 1.00 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2009 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2010 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2011 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2012 | 120 | 1.00 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2013 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2014 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2015 | 343 | 1.00 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2016 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2017 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2018 | 550 | 0.78 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2019 | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 | n/a |
| | 2020 | No survey | | | | | | | | | |

Table 22a. Biomass estimates (t) and coefficients of variation (CV) from the random-effects model for skate species and species groups in in the **EBS shelf** survey area. “Minor species” indicates an aggregation of rarer species that are not consistently observed in the survey. No survey was conducted in 2020.

| | Bering | | big | | Aleutian | | minor species | |
|---|---|---|---|---|---|---|---|---|
| | estimate | CV | estimate | CV | estimate | CV | estimate | CV |
| 2000 | 13,591 | 0.09 | 2,549 | 0.47 | 2,330 | 0.40 | 480 | 0.38 |
| 2001 | 13,041 | 0.08 | 2,082 | 0.39 | 2,404 | 0.38 | 501 | 0.38 |
| 2002 | 12,566 | 0.07 | 1,777 | 0.36 | 3,639 | 0.30 | 711 | 0.35 |
| 2003 | 11,785 | 0.07 | 1,656 | 0.41 | 6,804 | 0.36 | 625 | 0.27 |
| 2004 | 11,218 | 0.08 | 1,543 | 0.38 | 4,320 | 0.28 | 657 | 0.37 |
| 2005 | 11,112 | 0.07 | 1,721 | 0.35 | 5,290 | 0.32 | 690 | 0.40 |
| 2006 | 10,850 | 0.08 | 1,721 | 0.36 | 4,812 | 0.28 | 594 | 0.35 |
| 2007 | 10,950 | 0.08 | 2,101 | 0.35 | 3,697 | 0.29 | 651 | 0.43 |
| 2008 | 11,245 | 0.07 | 2,698 | 0.32 | 3,960 | 0.31 | 509 | 0.33 |
| 2009 | 11,275 | 0.07 | 3,369 | 0.31 | 3,127 | 0.31 | 392 | 0.43 |
| 2010 | 11,146 | 0.08 | 3,459 | 0.33 | 3,358 | 0.27 | 337 | 0.51 |
| 2011 | 11,258 | 0.08 | 3,556 | 0.34 | 3,650 | 0.32 | 346 | 0.46 |
| 2012 | 11,567 | 0.08 | 3,177 | 0.39 | 5,143 | 0.26 | 432 | 0.35 |
| 2013 | 11,854 | 0.07 | 4,132 | 0.38 | 8,625 | 0.26 | 433 | 0.43 |
| 2014 | 12,000 | 0.07 | 5,613 | 0.33 | 9,229 | 0.27 | 433 | 0.46 |
| 2015 | 12,088 | 0.07 | 9,474 | 0.30 | 11,445 | 0.26 | 530 | 0.36 |
| 2016 | 12,526 | 0.08 | 11,321 | 0.30 | 14,768 | 0.22 | 647 | 0.31 |
| 2017 | 12,579 | 0.07 | 14,001 | 0.27 | 20,171 | 0.32 | 721 | 0.34 |
| 2018 | 11,909 | 0.08 | 17,658 | 0.30 | 18,334 | 0.25 | 1,087 | 0.35 |
| 2019 | 13,591 | 0.09 | 14,261 | 0.29 | 15,781 | 0.24 | 1,004 | 0.34 |

Table 22b. Biomass estimates (t) and coefficients of variation (CV) from the random-effects model for skate species and species groups in in the **EBS slope survey** area. "Minor species" indicates an aggregation of rarer species that are not consistently observed in the survey (no slope surveys have been conducted since 2016).

| | Bering | | mud | | roughtail | | Aleutian | | Commander | | whiteblotched | | whitebrow | | Alaska | | minor species | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | estimate | CV | estimate | CV | estimate | CV | estimate | CV | estimate | CV | estimate | CV | estimate | CV | estimate | CV | estimate | CV |
| 2002 | 2,472 | 0.15 | 735 | 0.10 | 1,750 | 0.11 | 17,001 | 0.13 | 3,809 | 0.11 | 3,959 | 0.14 | 1,626 | 0.13 | 22,386 | 0.75 | 172 | 0.23 |
| 2003 | 2,304 | 0.13 | 735 | 0.10 | 1,772 | 0.11 | 16,858 | 0.13 | 3,844 | 0.11 | 3,961 | 0.14 | 1,629 | 0.13 | 10,112 | 0.84 | 172 | 0.23 |
| 2004 | 2,148 | 0.12 | 735 | 0.10 | 1,795 | 0.10 | 16,716 | 0.12 | 3,879 | 0.10 | 3,963 | 0.13 | 1,632 | 0.13 | 4,568 | 0.31 | 172 | 0.23 |
| 2005 | 2,228 | 0.14 | 735 | 0.10 | 1,848 | 0.09 | 17,010 | 0.12 | 3,841 | 0.11 | 4,033 | 0.12 | 1,629 | 0.13 | 4,456 | 0.93 | 172 | 0.23 |
| 2006 | 2,310 | 0.15 | 735 | 0.10 | 1,901 | 0.09 | 17,309 | 0.12 | 3,803 | 0.11 | 4,105 | 0.11 | 1,627 | 0.12 | 4,346 | 1.06 | 172 | 0.23 |
| 2007 | 2,396 | 0.14 | 735 | 0.10 | 1,957 | 0.09 | 17,614 | 0.11 | 3,765 | 0.12 | 4,178 | 0.10 | 1,625 | 0.12 | 4,239 | 0.93 | 172 | 0.23 |
| 2008 | 2,485 | 0.11 | 735 | 0.10 | 2,014 | 0.08 | 17,923 | 0.10 | 3,728 | 0.12 | 4,252 | 0.09 | 1,623 | 0.12 | 4,135 | 0.30 | 172 | 0.23 |
| 2009 | 2,604 | 0.13 | 735 | 0.10 | 2,049 | 0.09 | 18,543 | 0.10 | 3,786 | 0.11 | 4,307 | 0.09 | 1,608 | 0.11 | 2,502 | 0.77 | 172 | 0.23 |
| 2010 | 2,729 | 0.12 | 735 | 0.10 | 2,085 | 0.09 | 19,184 | 0.10 | 3,845 | 0.11 | 4,363 | 0.09 | 1,593 | 0.09 | 1,514 | 0.32 | 172 | 0.23 |
| 2011 | 2,830 | 0.15 | 735 | 0.10 | 2,120 | 0.09 | 19,899 | 0.10 | 4,027 | 0.09 | 4,471 | 0.11 | 1,565 | 0.08 | 5,134 | 0.76 | 172 | 0.23 |
| 2012 | 2,935 | 0.15 | 735 | 0.10 | 2,154 | 0.10 | 20,641 | 0.10 | 4,217 | 0.09 | 4,581 | 0.13 | 1,538 | 0.10 | 17,416 | 0.27 | 172 | 0.23 |
| 2013 | 2,760 | 0.16 | 735 | 0.10 | 2,167 | 0.11 | 20,849 | 0.12 | 4,348 | 0.12 | 4,606 | 0.14 | 1,527 | 0.11 | 14,801 | 0.92 | 172 | 0.23 |
| 2014 | 2,596 | 0.16 | 735 | 0.10 | 2,180 | 0.11 | 21,060 | 0.13 | 4,483 | 0.14 | 4,632 | 0.15 | 1,517 | 0.12 | 12,579 | 1.06 | 172 | 0.23 |
| 2015 | 2,442 | 0.17 | 735 | 0.10 | 2,192 | 0.11 | 21,273 | 0.14 | 4,622 | 0.15 | 4,658 | 0.16 | 1,506 | 0.13 | 10,690 | 0.93 | 172 | 0.23 |
| 2016 | 2,296 | 0.19 | 735 | 0.10 | 2,205 | 0.11 | 21,488 | 0.15 | 4,765 | 0.17 | 4,683 | 0.16 | 1,496 | 0.15 | 9,085 | 0.29 | 172 | 0.23 |

Table 22c. Biomass estimates (t) and coefficients of variation (CV) from the random-effects model for skate species and species groups in in the **Aleutian Islands** survey area. "Minor species" indicates an aggregation of rarer species that are not consistently observed in the survey. No survey was conducted in 2020.

| | Bering | | big | | Alaska | | Aleutian | | whiteblotched | | leopard | | minor species | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | estimate | CV | estimate | CV | estimate | CV | estimate | CV | estimate | CV | estimate | CV | estimate | CV |
| 2000 | 9 | 0.97 | 419 | 0.21 | 2,747 | 0.10 | 3,836 | 0.17 | 14,880 | 0.14 | 7,545 | 0.16 | 1,459 | 0.13 |
| 2001 | 27 | 0.77 | 419 | 0.21 | 2,747 | 0.10 | 4,293 | 0.18 | 16,200 | 0.16 | 7,892 | 0.22 | 1,609 | 0.13 |
| 2002 | 84 | 0.66 | 419 | 0.21 | 2,747 | 0.10 | 4,805 | 0.14 | 17,637 | 0.13 | 8,254 | 0.18 | 1,775 | 0.11 |
| 2003 | 105 | 0.72 | 419 | 0.21 | 2,747 | 0.10 | 5,489 | 0.19 | 19,924 | 0.16 | 8,840 | 0.23 | 1,889 | 0.14 |
| 2004 | 132 | 0.55 | 419 | 0.21 | 2,747 | 0.10 | 6,271 | 0.22 | 22,507 | 0.16 | 9,468 | 0.19 | 2,010 | 0.13 |
| 2005 | 145 | 0.66 | 419 | 0.21 | 2,747 | 0.10 | 6,471 | 0.21 | 23,987 | 0.18 | 9,824 | 0.23 | 2,173 | 0.18 |
| 2006 | 160 | 0.47 | 419 | 0.21 | 2,747 | 0.10 | 6,677 | 0.18 | 25,563 | 0.17 | 10,194 | 0.18 | 2,350 | 0.22 |
| 2007 | 128 | 0.74 | 419 | 0.21 | 2,747 | 0.10 | 6,880 | 0.22 | 24,662 | 0.19 | 10,579 | 0.27 | 2,221 | 0.21 |
| 2008 | 102 | 0.80 | 419 | 0.21 | 2,747 | 0.10 | 7,090 | 0.23 | 23,792 | 0.20 | 10,979 | 0.29 | 2,099 | 0.20 |
| 2009 | 82 | 0.72 | 419 | 0.21 | 2,747 | 0.10 | 7,306 | 0.21 | 22,953 | 0.18 | 11,394 | 0.27 | 1,984 | 0.17 |
| 2010 | 66 | 0.40 | 419 | 0.21 | 2,747 | 0.10 | 7,528 | 0.18 | 22,144 | 0.15 | 11,825 | 0.18 | 1,876 | 0.14 |
| 2011 | 84 | 0.57 | 419 | 0.21 | 2,747 | 0.10 | 6,967 | 0.18 | 20,327 | 0.16 | 10,711 | 0.23 | 1,836 | 0.14 |
| 2012 | 108 | 0.17 | 419 | 0.21 | 2,747 | 0.10 | 6,448 | 0.14 | 18,658 | 0.14 | 9,701 | 0.19 | 1,797 | 0.11 |
| 2013 | 116 | 0.56 | 419 | 0.21 | 2,747 | 0.10 | 6,340 | 0.17 | 19,046 | 0.15 | 8,099 | 0.23 | 1,816 | 0.14 |
| 2014 | 125 | 0.32 | 419 | 0.21 | 2,747 | 0.10 | 6,233 | 0.16 | 19,443 | 0.13 | 6,762 | 0.18 | 1,834 | 0.14 |
| 2015 | 87 | 0.60 | 419 | 0.21 | 2,747 | 0.10 | 5,517 | 0.18 | 18,035 | 0.15 | 5,359 | 0.25 | 1,700 | 0.15 |
| 2016 | 61 | 0.45 | 419 | 0.21 | 2,747 | 0.10 | 4,884 | 0.19 | 16,730 | 0.14 | 4,248 | 0.24 | 1,576 | 0.15 |
| 2017 | 67 | 0.61 | 419 | 0.21 | 2,747 | 0.10 | 5,224 | 0.20 | 16,326 | 0.17 | 3,377 | 0.27 | 1,629 | 0.19 |
| 2018 | 72 | 0.37 | 419 | 0.21 | 2,747 | 0.10 | 5,588 | 0.21 | 15,932 | 0.17 | 2,684 | 0.23 | 1,683 | 0.21 |

Table 23. Aggregated biomass estimates from the random effects model for the “other skates” group, 2002-2019 (i.e. all groups included in Table 21 with the exception of Alaska skate). The 2019 total BSAI estimate was used for harvest recommendations. No survey was conducted in 2020.

| | total EBS shelf | total EBS slope | total AI | total BSAI |
|---|---|---|---|---|
| 2002 | 19,169 | 31,523 | 32,973 | 83,665 |
| 2003 | 21,652 | 31,275 | 36,666 | 89,593 |
| 2004 | 18,305 | 31,040 | 40,807 | 90,152 |
| 2005 | 18,920 | 31,495 | 43,019 | 93,434 |
| 2006 | 18,239 | 31,962 | 45,363 | 95,564 |
| 2007 | 17,299 | 32,441 | 44,889 | 94,629 |
| 2008 | 18,117 | 32,932 | 44,482 | 95,531 |
| 2009 | 18,133 | 33,804 | 44,138 | 96,075 |
| 2010 | 18,429 | 34,706 | 43,857 | 96,992 |
| 2011 | 18,697 | 35,818 | 40,343 | 94,858 |
| 2012 | 20,011 | 36,973 | 37,132 | 94,116 |
| 2013 | 24,757 | 37,165 | 35,836 | 97,758 |
| 2014 | 27,128 | 37,373 | 34,815 | 99,316 |
| 2015 | 33,449 | 37,599 | 31,118 | 102,166 |
| 2016 | 38,823 | 37,840 | 27,918 | 104,581 |
| 2017 | 47,419 | 37,840 | 27,041 | 112,300 |
| 2018 | 49,657 | 37,840 | 26,379 | 113,876 |
| 2019 | 42,955 | 37,840 | 26,379 | 107,174 |

Table 24. Estimated exploitation rates for BSAI skate species based on survey biomass estimates for those years where all 3 BSAI regions were surveyed and catch species composition was available. Blue bold indicates values greater than 0.1

| | 2010 | 2012 | 2016 |
|---|---|---|---|
| Alaska | 0.035 | 0.050 | 0.041 |
| Aleutian | 0.040 | 0.043 | 0.026 |
| Bering | **0.119** | **0.133** | **0.188** |
| big | **0.179** | **0.812** | **0.109** |
| butterfly | 0.001 | 0.000 | 0.000 |
| Commander | 0.047 | 0.036 | 0.033 |
| deepsea | 0.000 | 0.000 | 0.001 |
| longnose | 0.000 | **0.155** | 0.000 |
| mud | 0.086 | 0.042 | 0.022 |
| roughtail | 0.009 | 0.004 | 0.002 |
| whiteblotched | 0.017 | 0.029 | 0.045 |
| whitebrow | 0.012 | 0.019 | 0.014 |

Table 25. Estimated exploitation rates for Bering skates based on biomass estimates from the random-effects model.

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| biomass | 13,373 | 13,537 | 13,931 | 14,070 | 14,060 | 14,301 | 14,444 | 14,574 | 14,529 | 14,446 | 14,889 | 14,947 | 14,277 |
| catch | 742 | 2,270 | 1,662 | 564 | 1,897 | 1,858 | 1,738 | 2,300 | 3,122 | 2,456 | 3,057 | 1,795 | 1,288 |
| **expl rate** | **0.06** | **0.17** | **0.12** | **0.04** | **0.13** | **0.13** | **0.12** | **0.16** | **0.21** | **0.17** | **0.21** | **0.12** | **0.09** |

# Figures

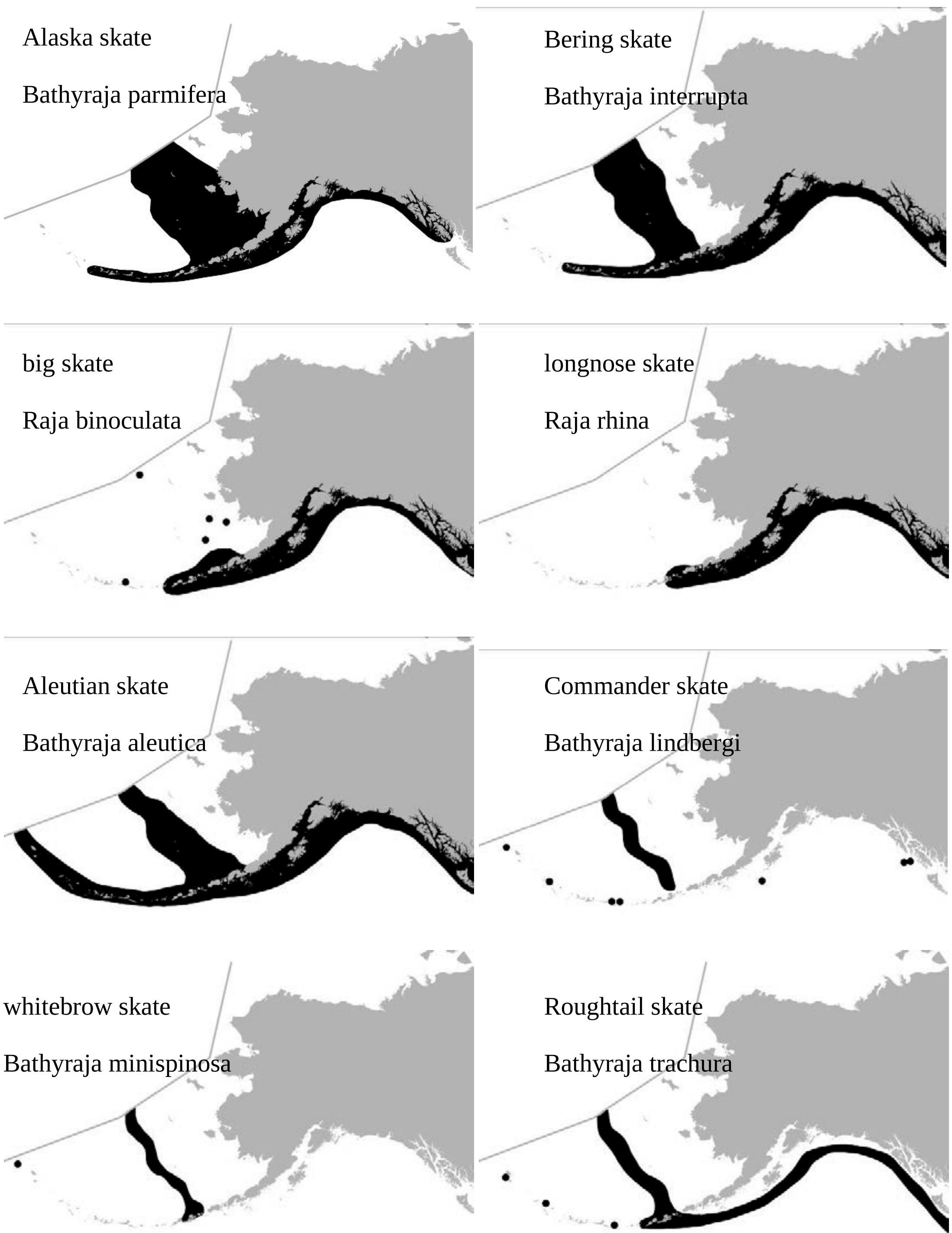



Figure 1. Distribution of skate species in Alaskan waters. These maps were created primarily using survey data, although observer records were included whenever positive species identification was possible (through voucher specimens or photographs). (Source: Stevenson et al. 2007)

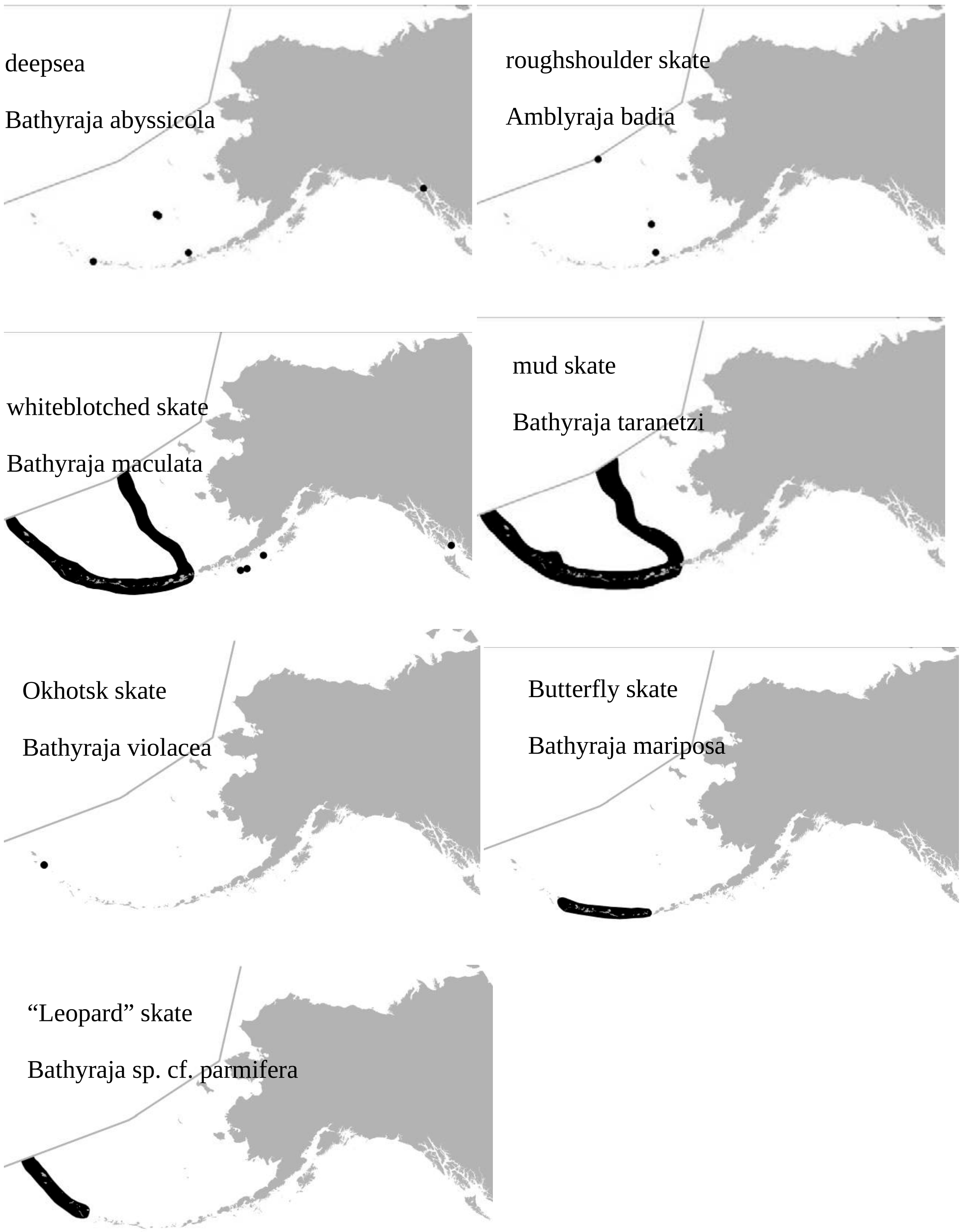



Figure 1 continued. Distribution of skate species in Alaskan waters. (Source: Stevenson et al. 2007)

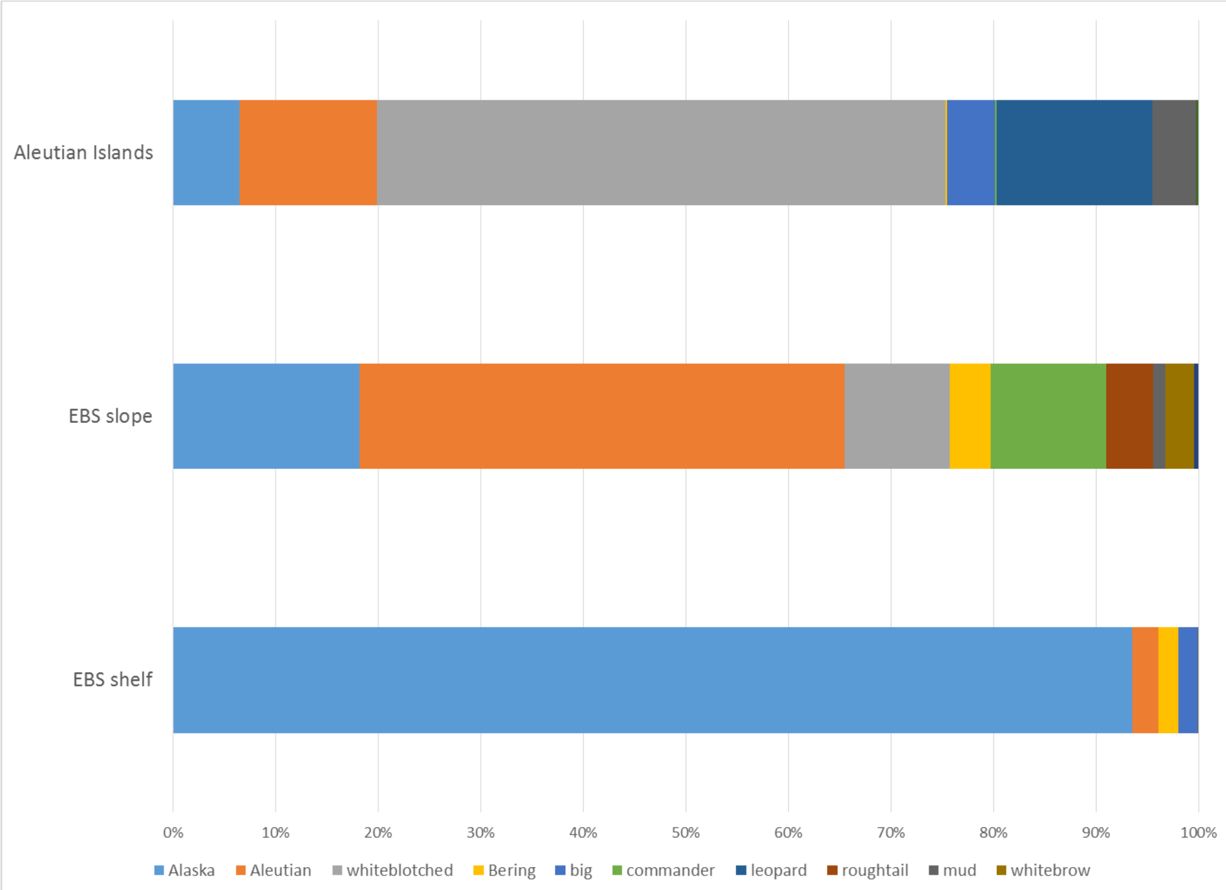



Figure 2. Skate species composition (by weight) in 2016 for the Aleutian Islands, eastern Bering Sea (EBS) slope, and EBS shelf. Data are from AFSC bottom-trawl surveys conducted in each region during 2016, the most recent year in which all 3 surveys in the BSAI were conducted in the same year.

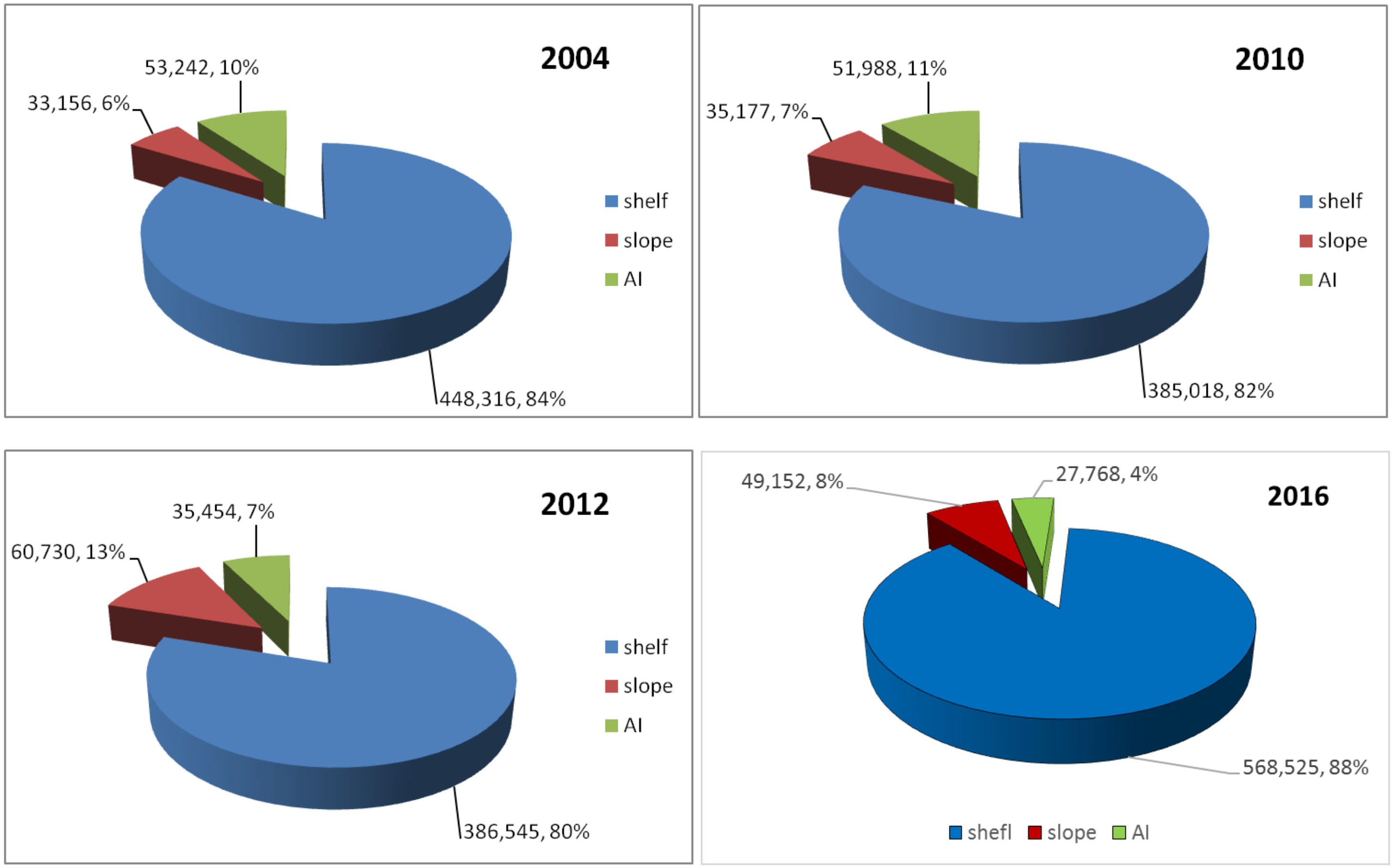



Figure 3. Distribution of skate biomass in the 3 subregions of the BSAI in 2004, 2010, 2012, and 2016 (2016 is the most recent year when all 3 surveys in the BSAI were conducted in the same year). Data are biomass estimates (t) and relative proportions from AFSC groundfish surveys.

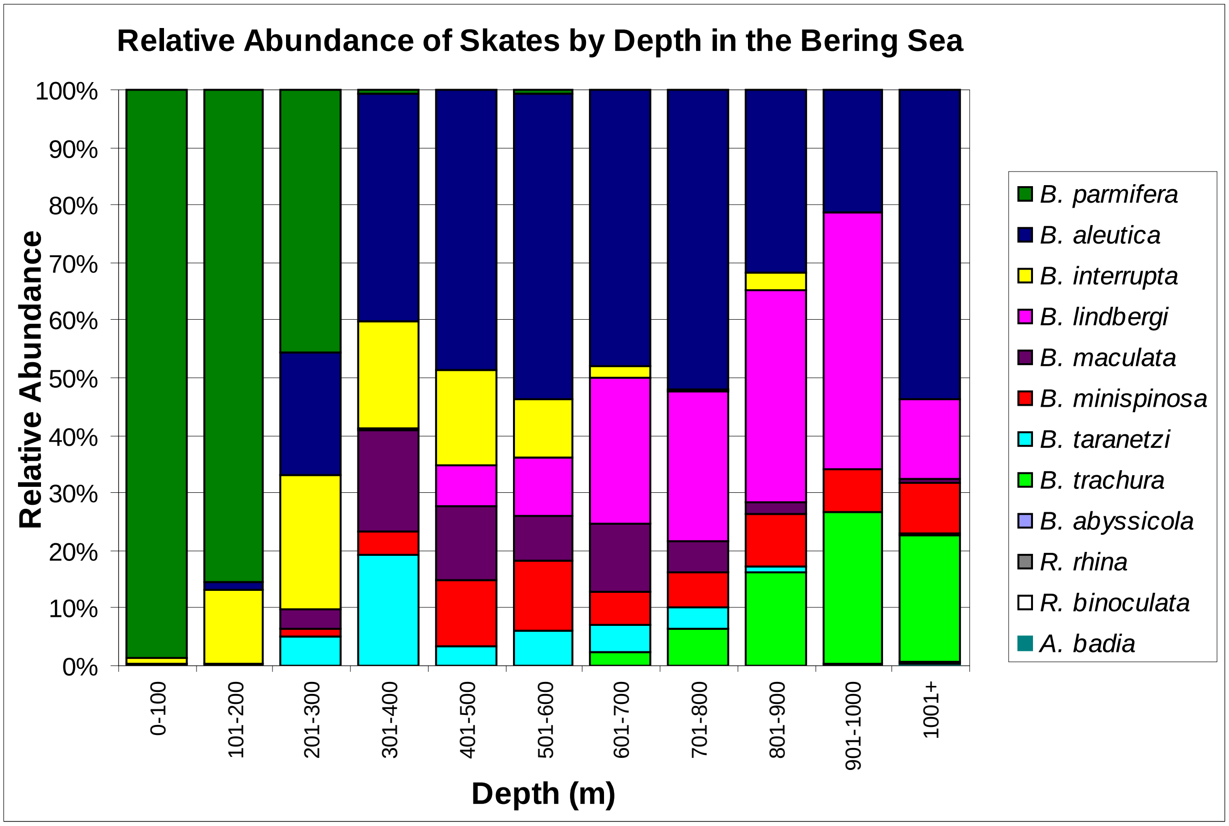



Figure 4. Relative abundance of skate species in the EBS by depth. (Source: Stevenson et al. 2006.)

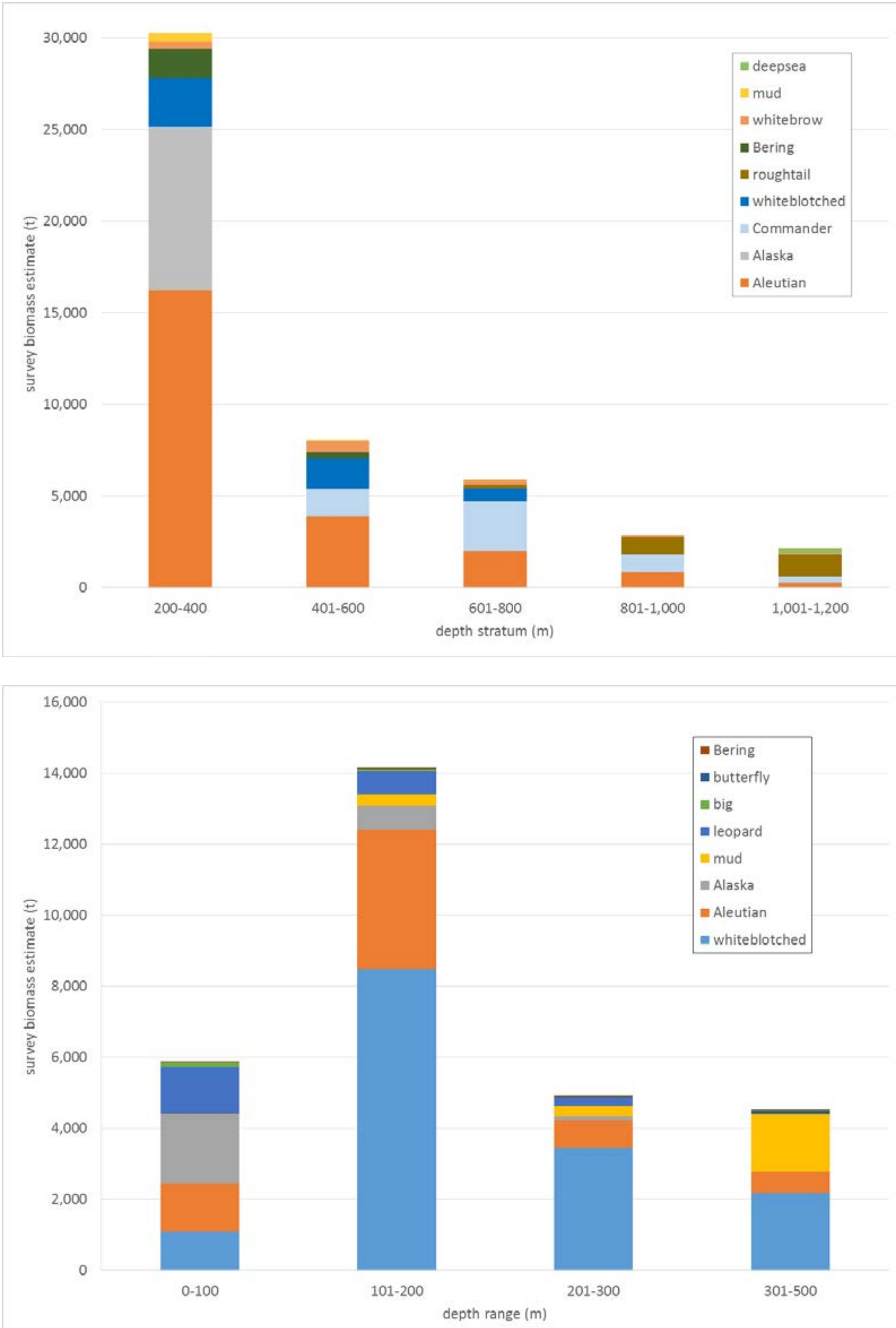
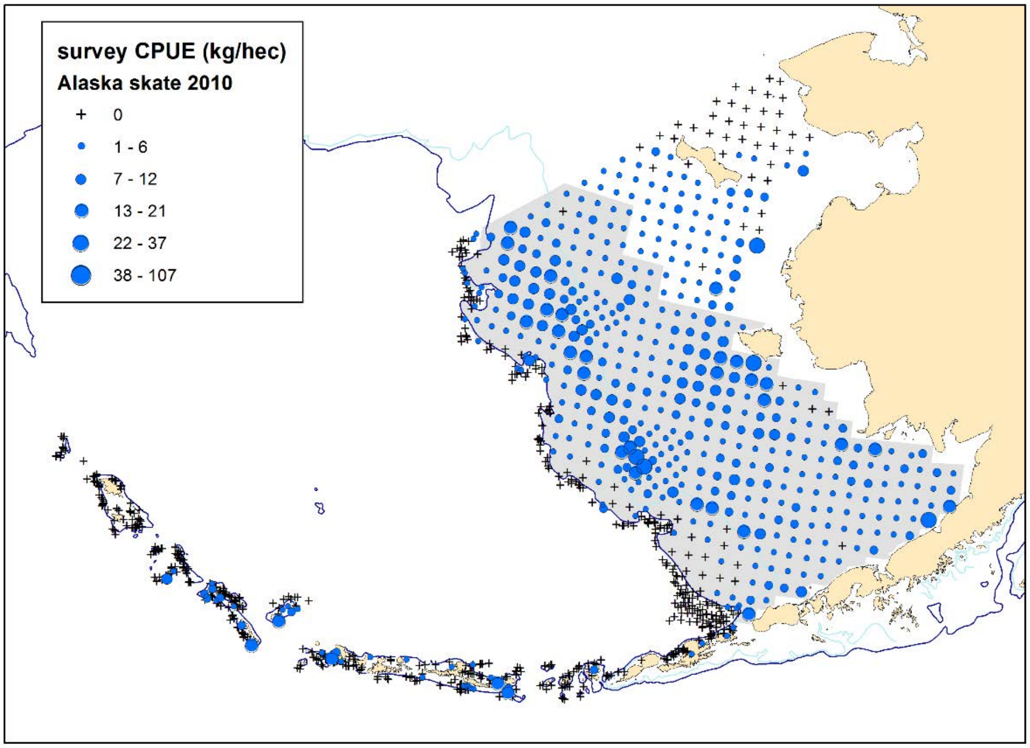



Figure 5. Skate biomass and species distribution by depth zone on the EBS slope (top panel) and in the Aleutian Islands (bottom panel), as observed in 2016 AFSC bottom trawl surveys.



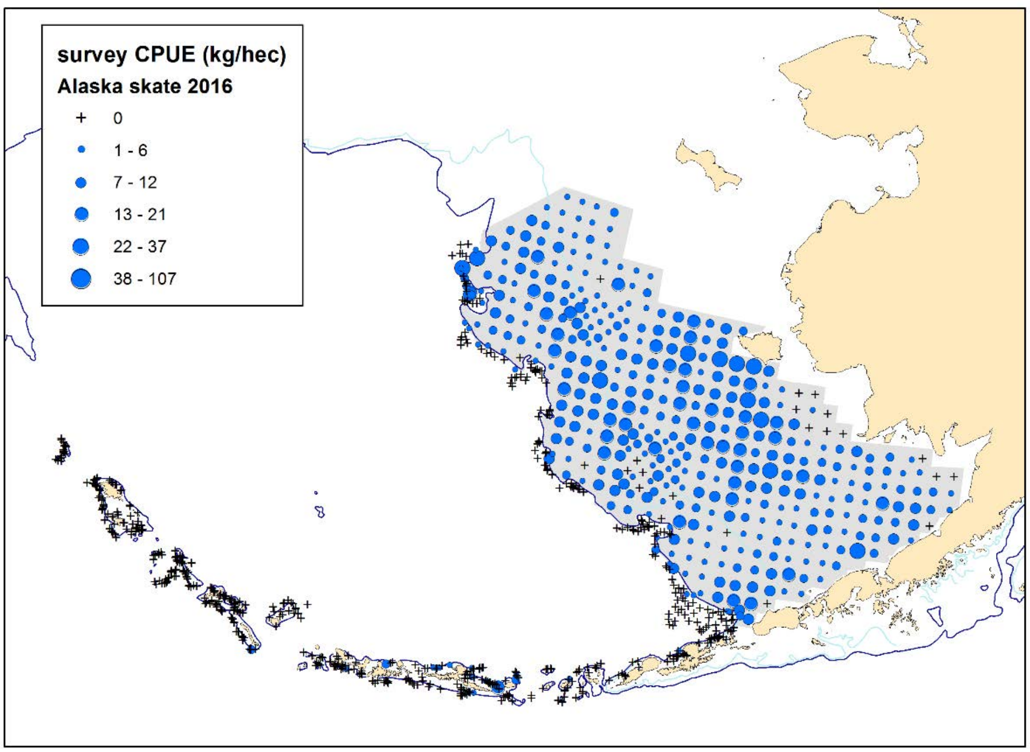




Figure 6. AFSC bottom trawl survey catch-per-unit-effort (CPUE) of Alaska skate in 2010 (top) and 2016 (bottom). Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf survey, the EBS slope survey, and the Aleutian Islands survey. Grey shaded area = extent of the annual EBS shelf survey.

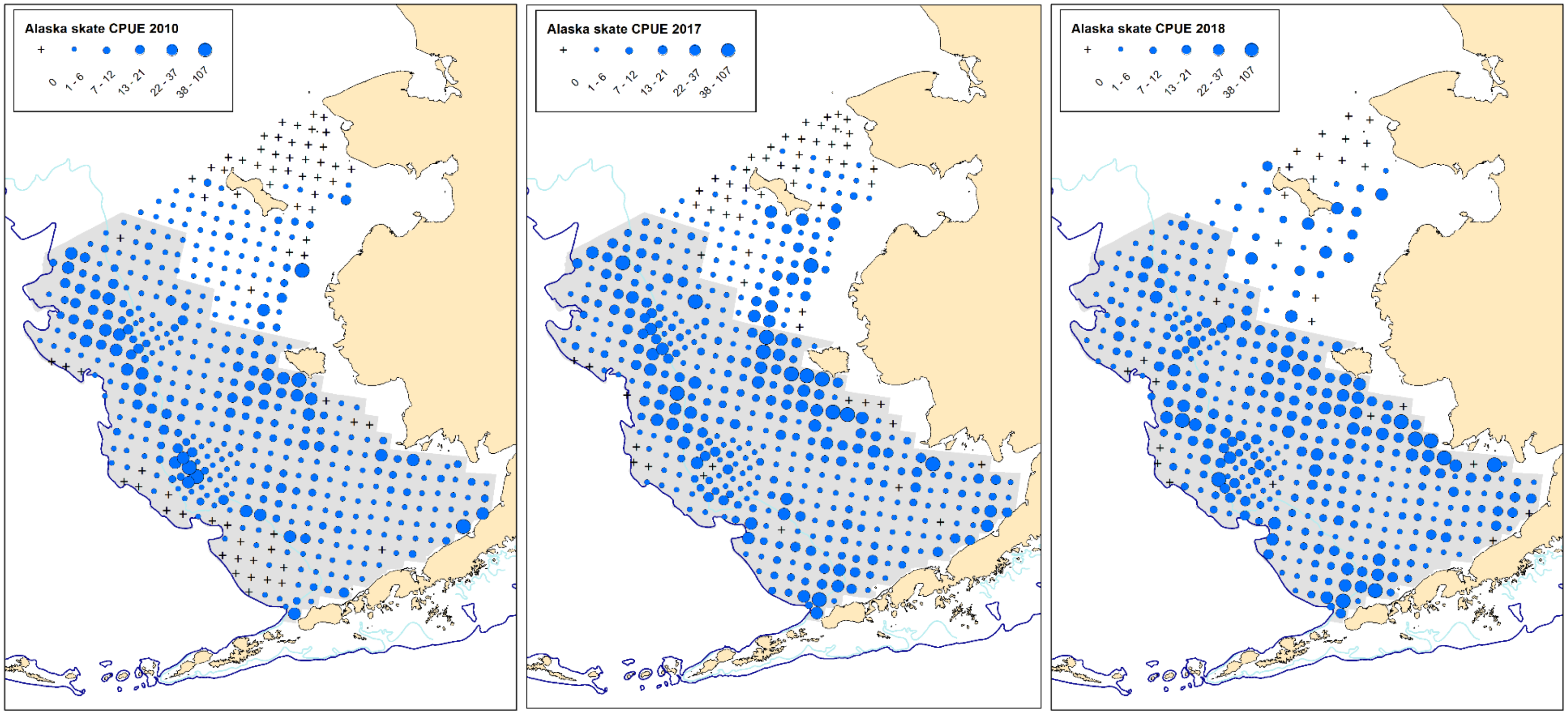
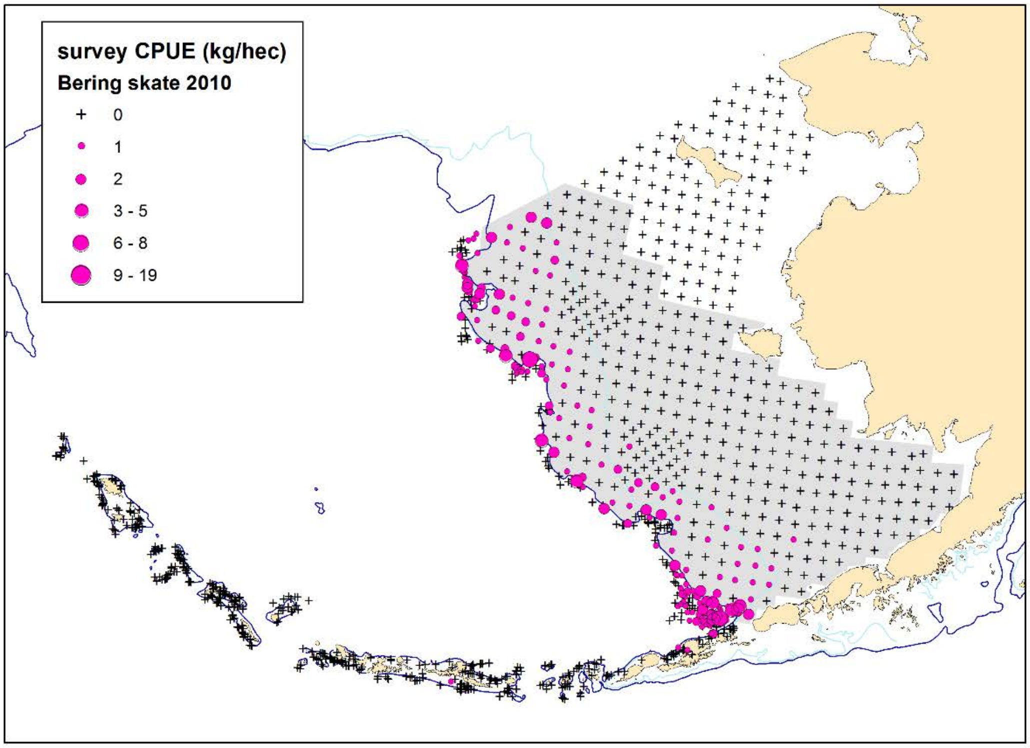



Figure 7. Eastern Bering Sea (EBS) AFSC bottom trawl survey catch-per-unit-effort (CPUE; kg/hec) of **Alaska skate** in 2010, 2017, and 2018. Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf and the northern Bering Sea surveys. Grey shaded area = extent of the annual EBS shelf survey.



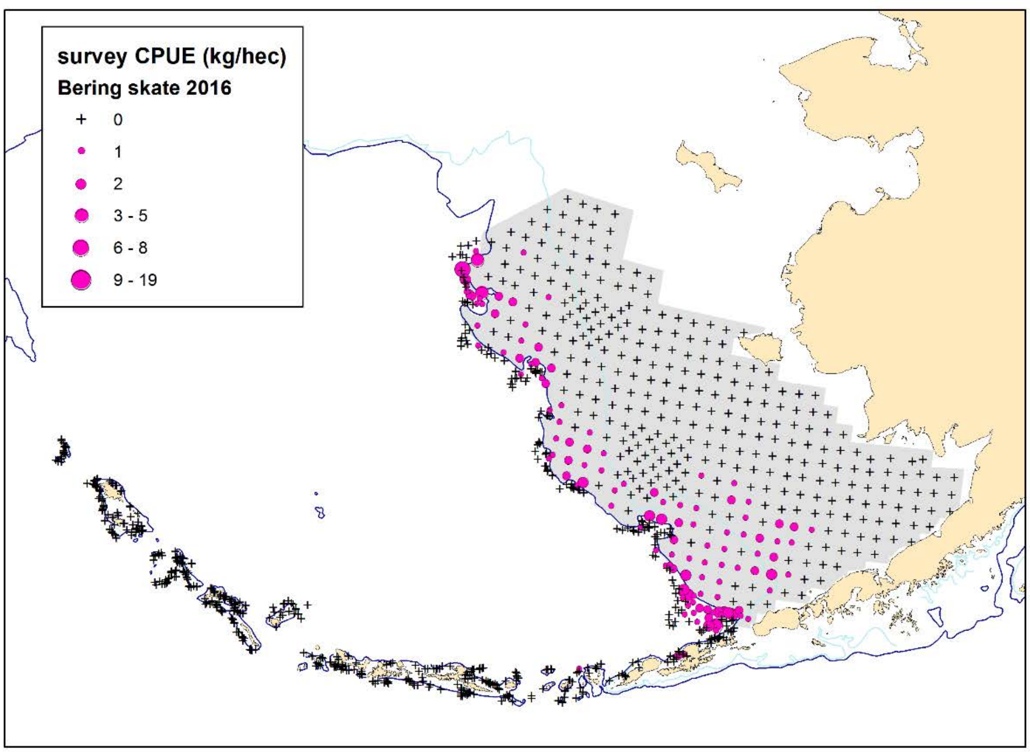




Figure 8. AFSC bottom trawl survey catch-per-unit-effort (CPUE) of **Bering skate** in 2010 (top) and 2016 (bottom). Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf survey, the EBS slope survey, and the Aleutian Islands survey. Grey shaded area = extent of the annual EBS shelf survey.

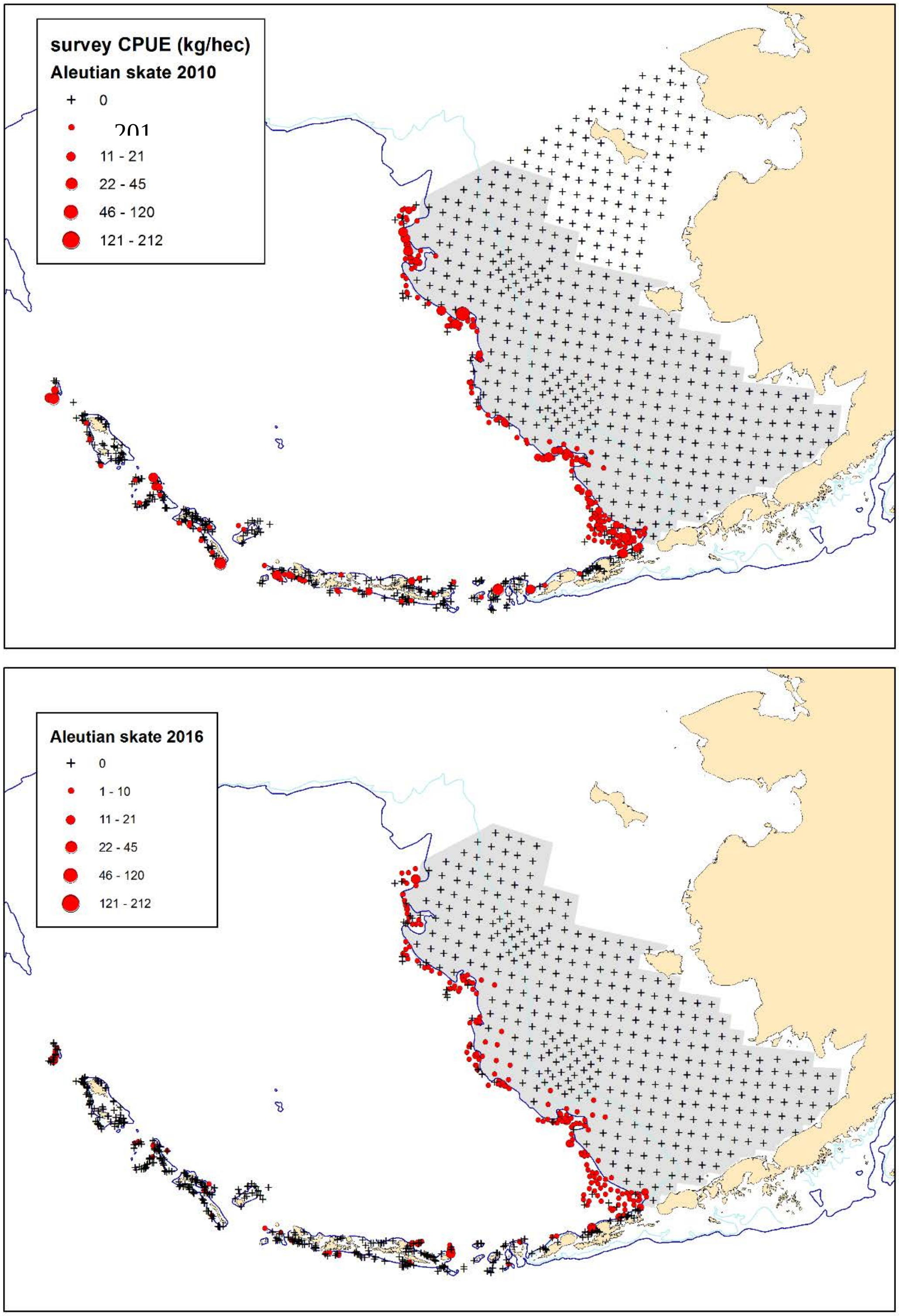



Figure 9. AFSC bottom trawl survey catch-per-unit-effort (CPUE) of **Aleutian skate** in 2010 (top) and 2016 (bottom). Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf survey, the EBS slope survey, and the Aleutian Islands survey. Grey shaded area = extent of the annual EBS shelf survey.

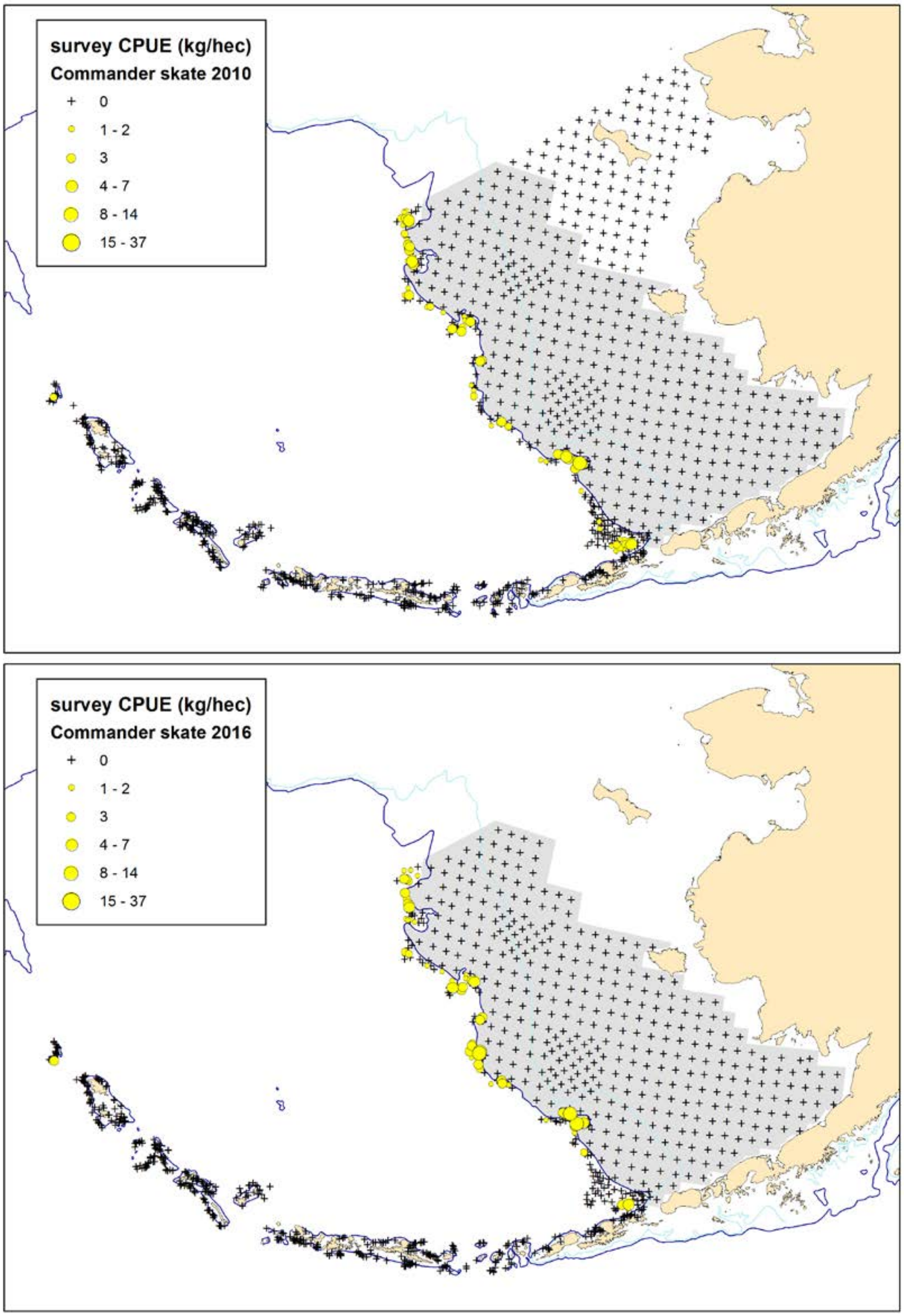
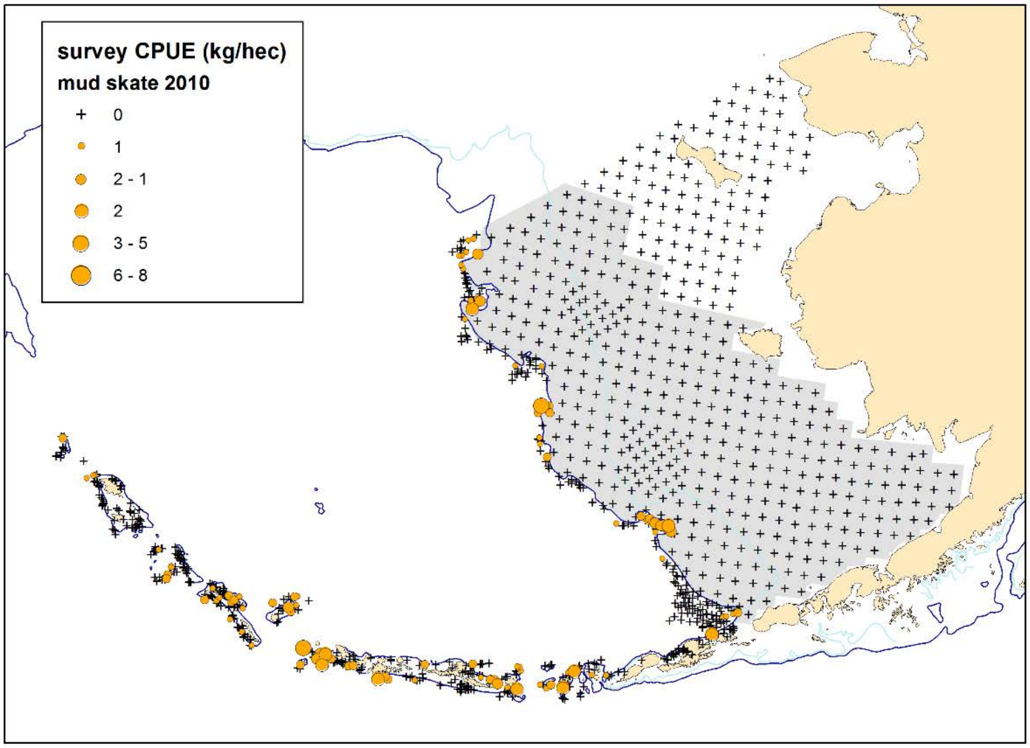



Figure 10. AFSC bottom trawl survey catch-per-unit-effort (CPUE) of **Commander skate** in 2010 (top) and 2016 (bottom). Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf survey, the EBS slope survey, and the Aleutian Islands survey. Grey shaded area = extent of the annual EBS shelf survey.



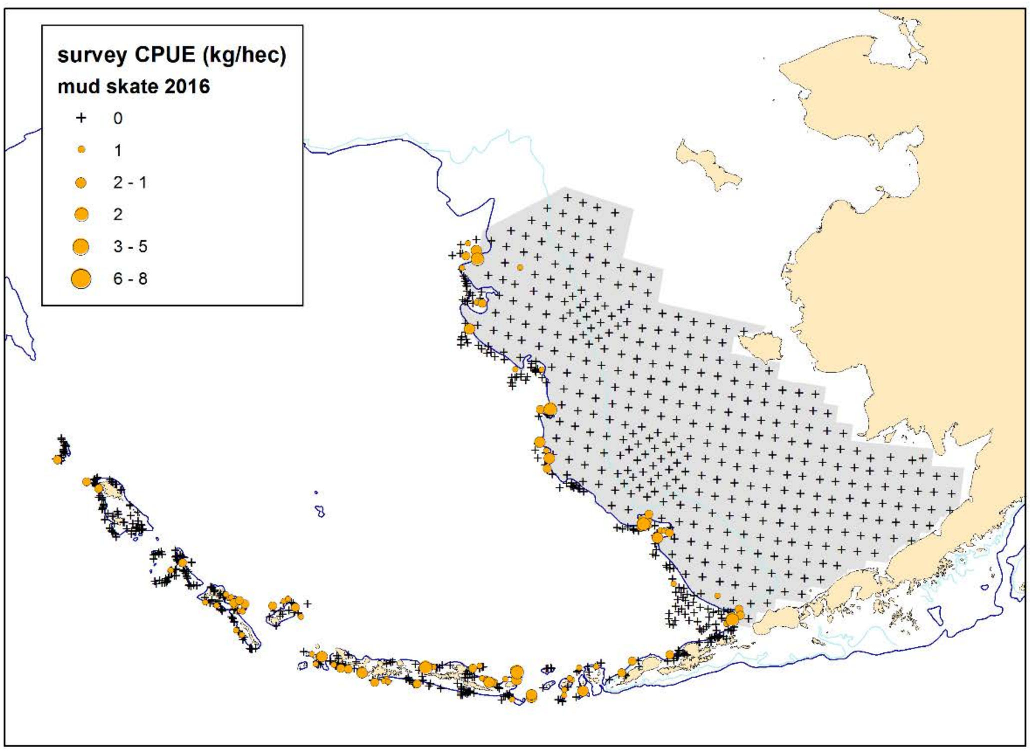
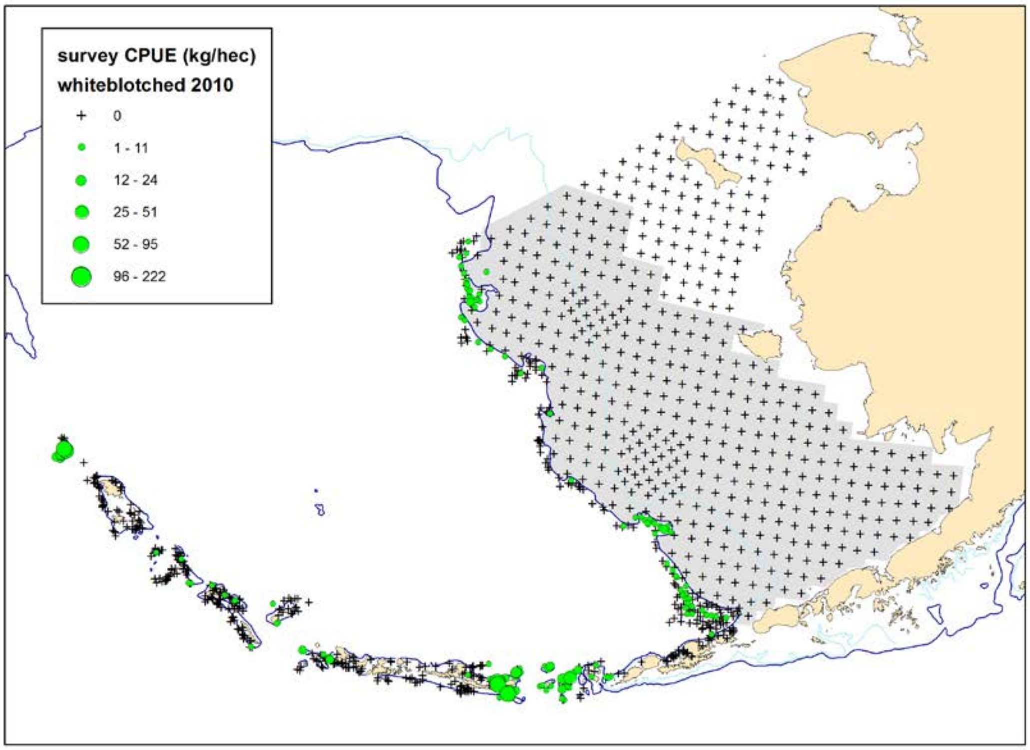




Figure 11. AFSC bottom trawl survey catch-per-unit-effort (CPUE) of **mud skate** in 2010 (top) and 2016 (bottom). Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf survey, the EBS slope survey, and the Aleutian Islands survey. Grey shaded area = extent of the annual EBS shelf survey.



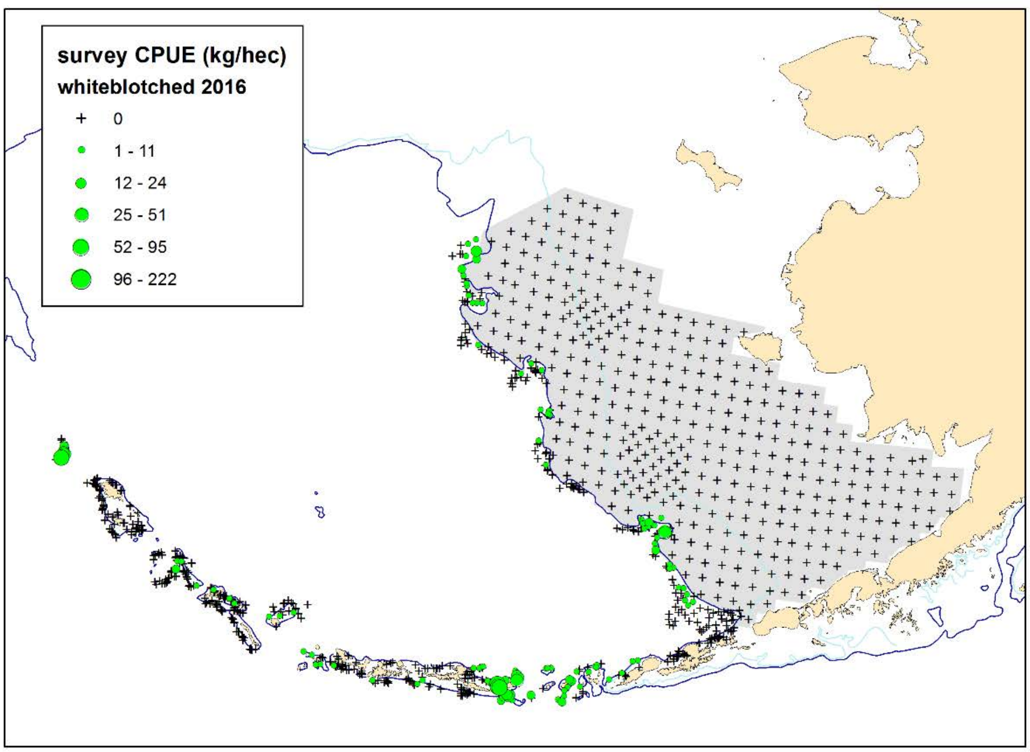
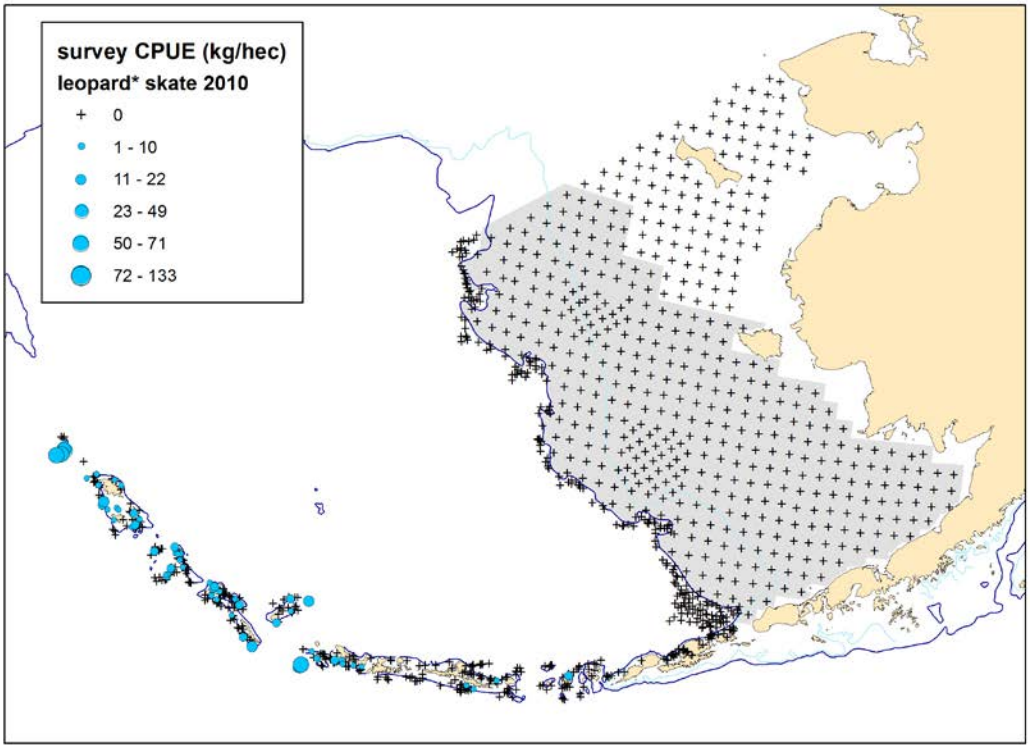




Figure 12. AFSC bottom trawl survey catch-per-unit-effort (CPUE) of **whiteblotched skate** in 2010 (top) and 2016 (bottom). Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf survey, the EBS slope survey, and the Aleutian Islands survey. Grey shaded area = extent of the annual EBS shelf survey.



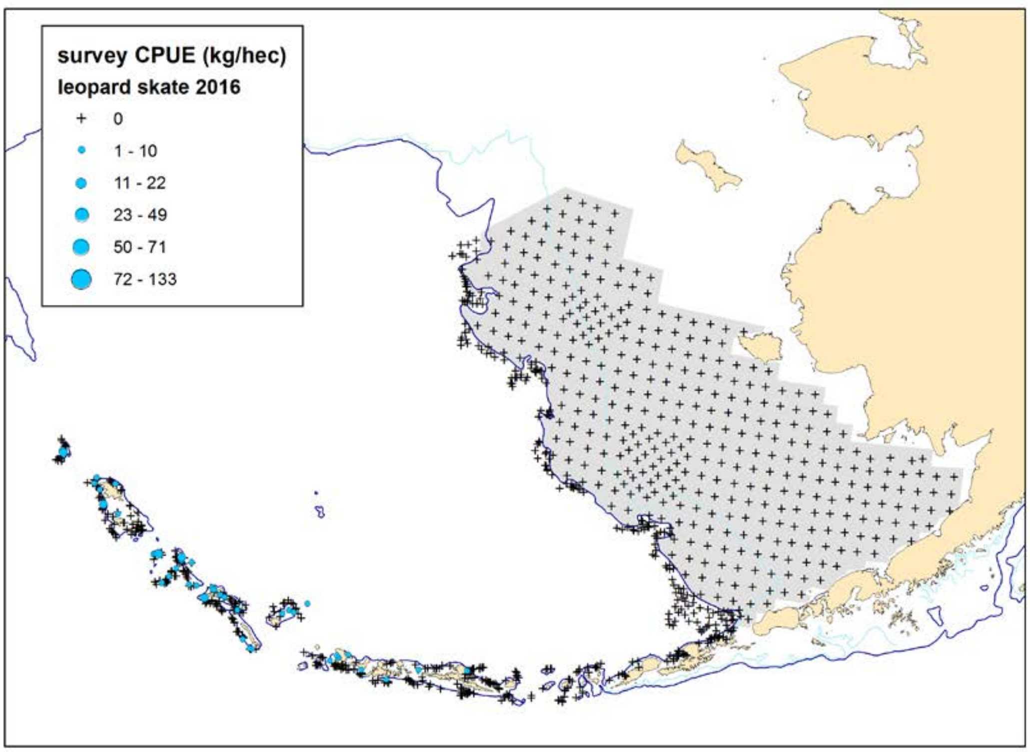




Figure 13. AFSC bottom trawl survey catch-per-unit-effort (CPUE) of **leopard skate** in 2010 (top) and 2016 (bottom). Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf survey, the EBS slope survey, and the Aleutian Islands survey. Grey shaded area = extent of the annual EBS shelf survey.

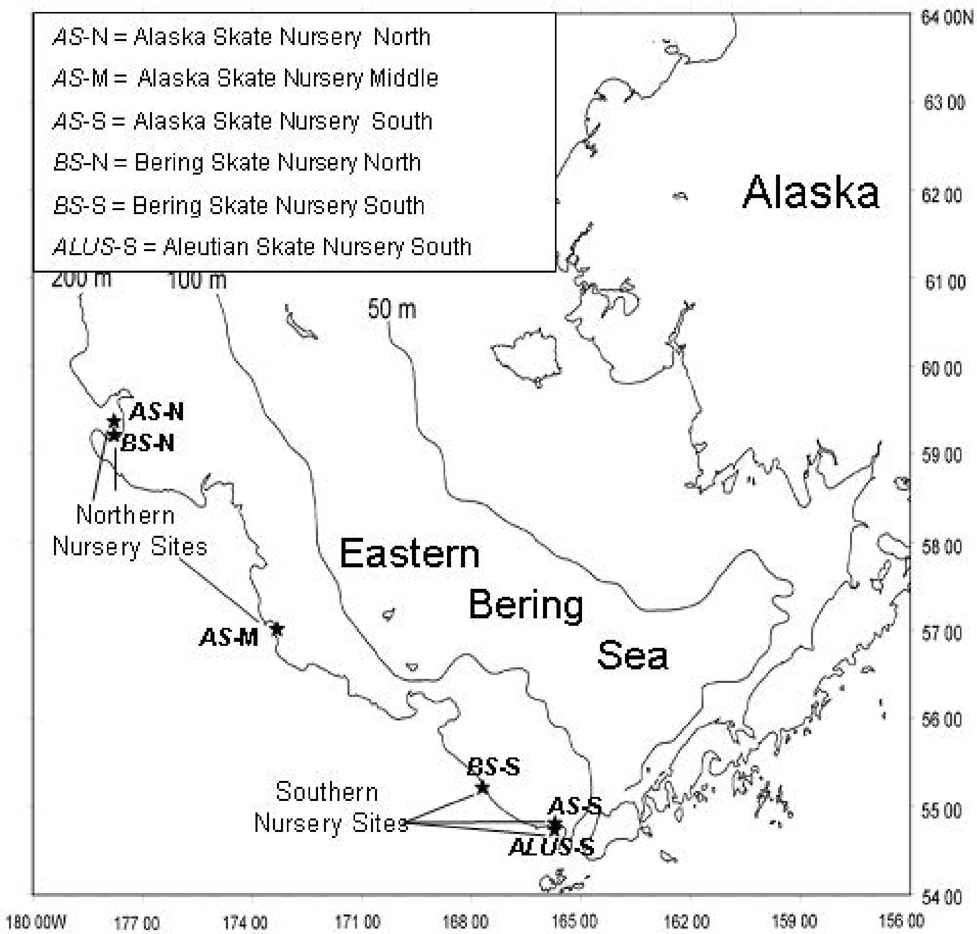



Figure 14. Map of the eastern Bering Sea with the six known skate nursery site locations and designations as a northern or southern nursery site. (See the legend for nursery site designation.) Source: Gerald Hoff, AFSC.

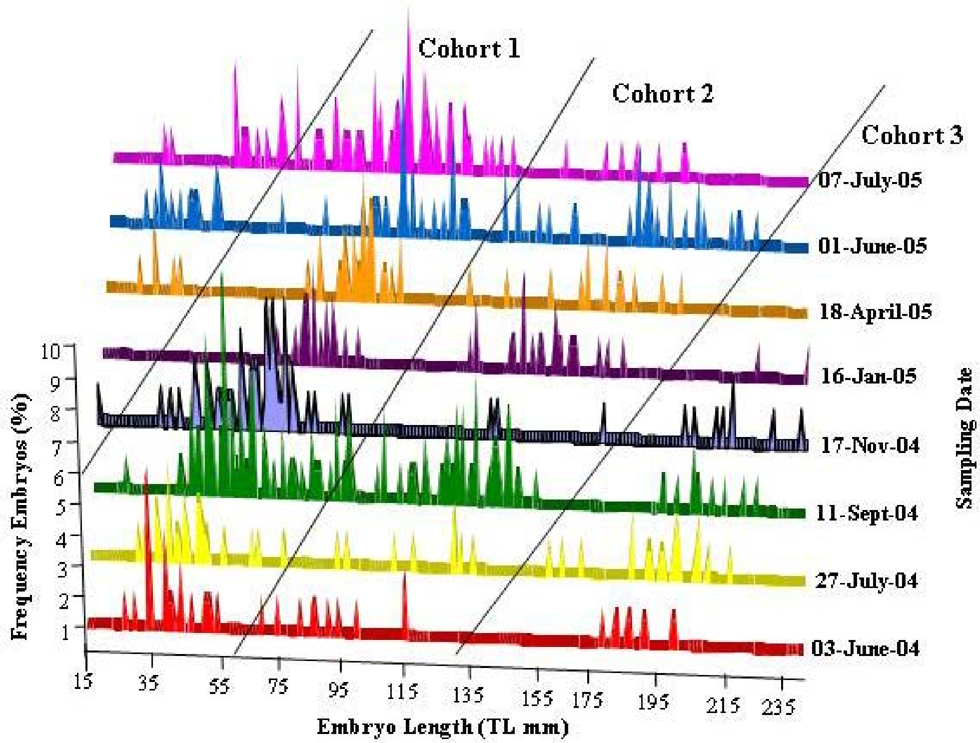



Figure 15. Embryo length composition data used in a cohort analysis of embryo development time. Figure is from G. Hoff (AFSC, pers. comm.).

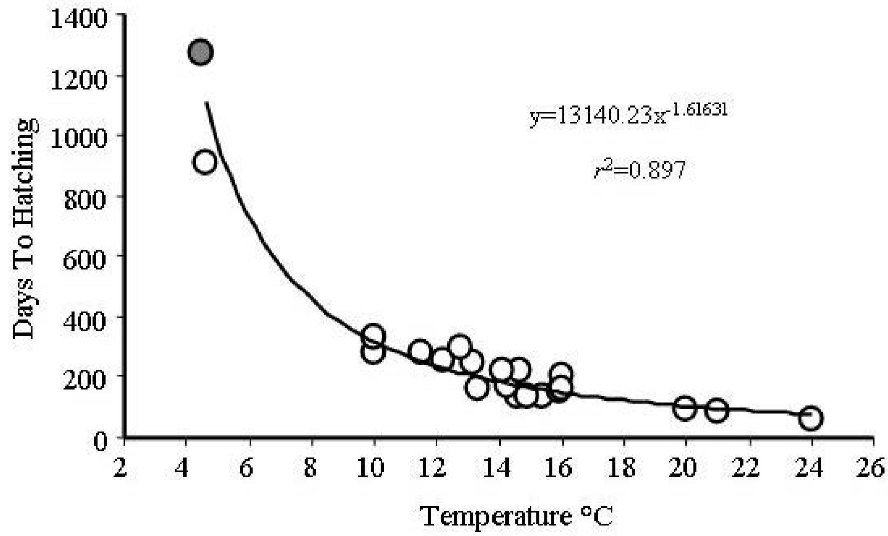



Figure 16. Ocean temperature versus embryo development time for 21 skate species. Dark grey circle is the Alaska skate. Equation and $R^2$ are the values of the fitted relationship. Figure is from G. Hoff (AFSC, pers. comm.)

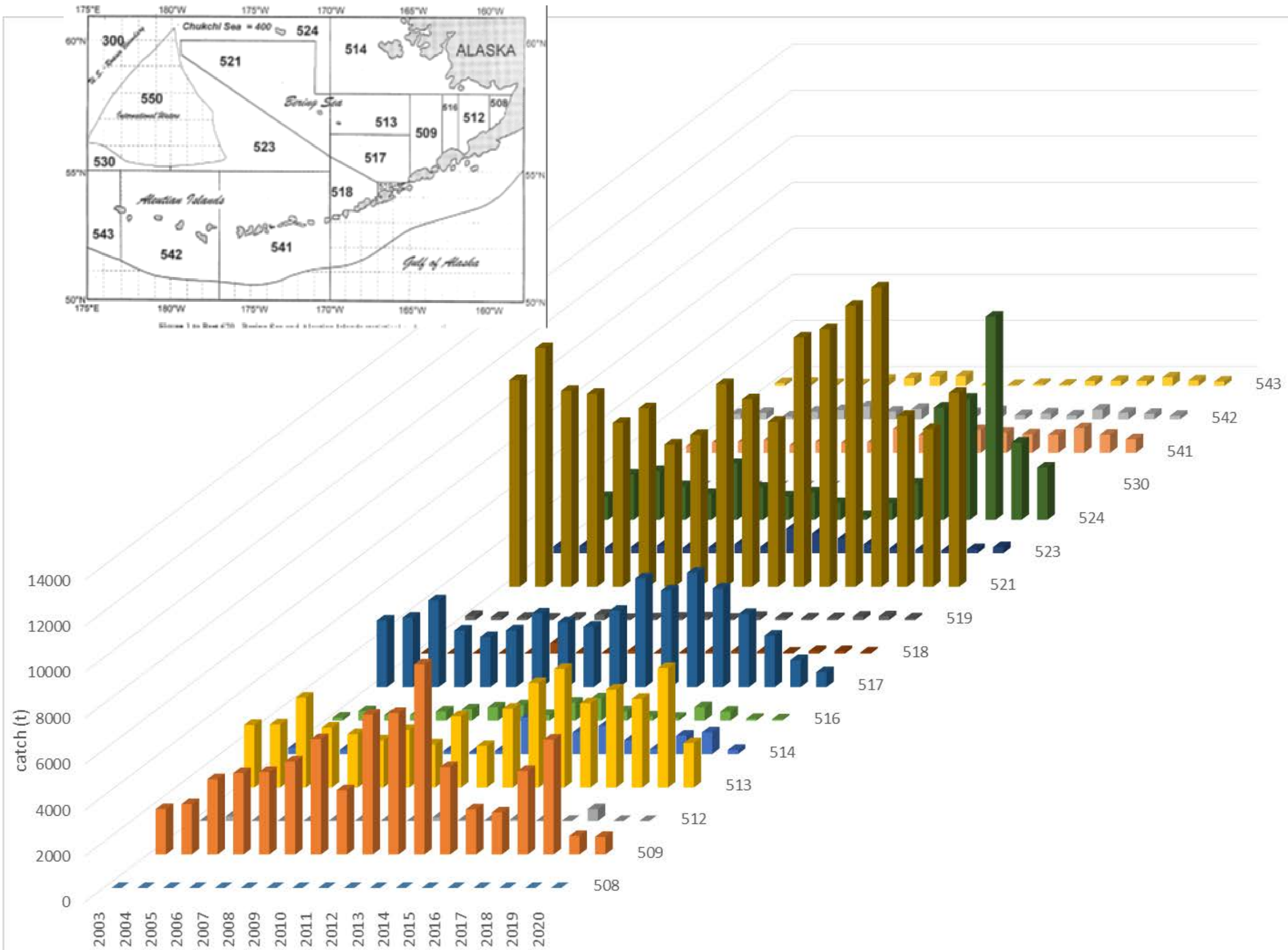



Figure 17. Total skate catch (all species combined) by FMP reporting area (see inset map) for both the EBS and the AI, 2003 - 2020. Source: AKRO CAS. 2020 data are incomplete; retrieved October 23, 2020.

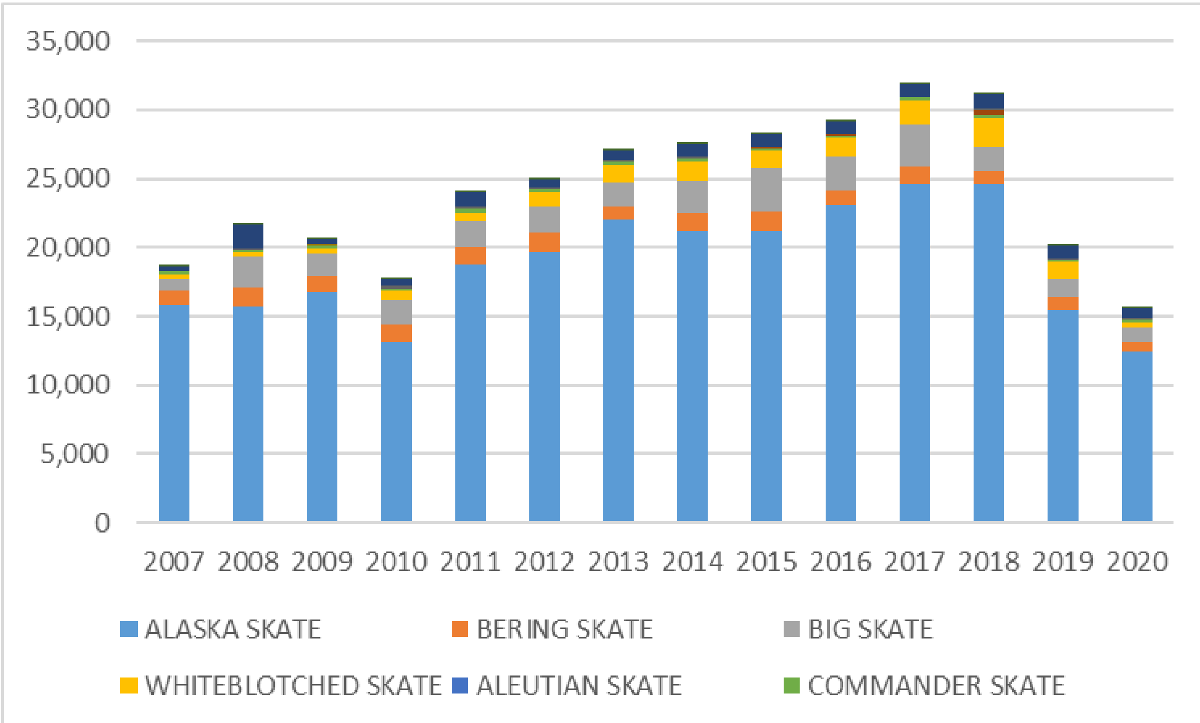



Figure 18. Catches of skates in the BSAI by species, 2007-2020. 2020 data are incomplete; retrieved October 23, 2020.

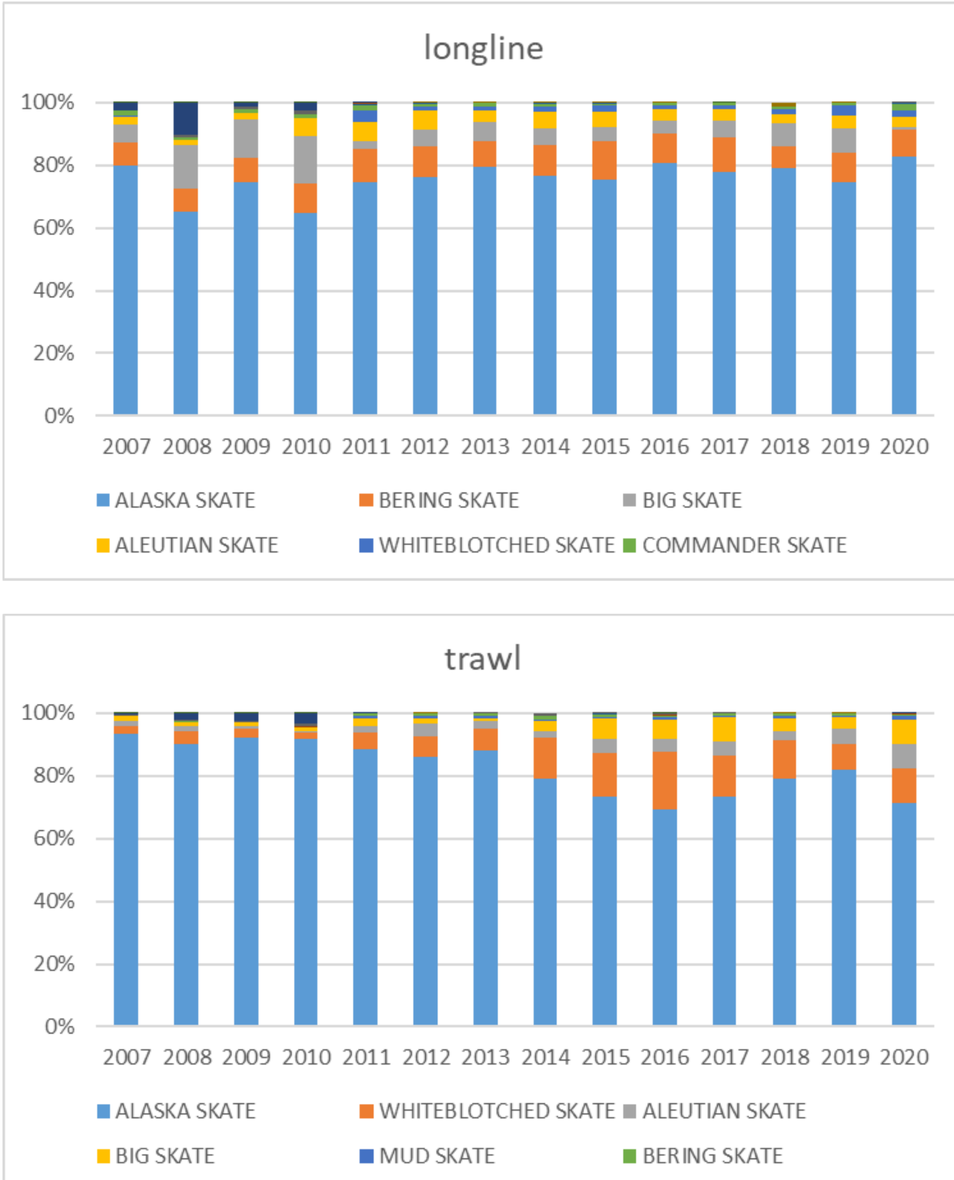



Figure 19. Species composition of skate catches in the BSAI by gear type, 2007-2020. Top panel shows data from longline fisheries, bottom panel shows data from trawl fisheries (pelagic and non-pelagic). 2020 data are incomplete; retrieved October 23, 2020.

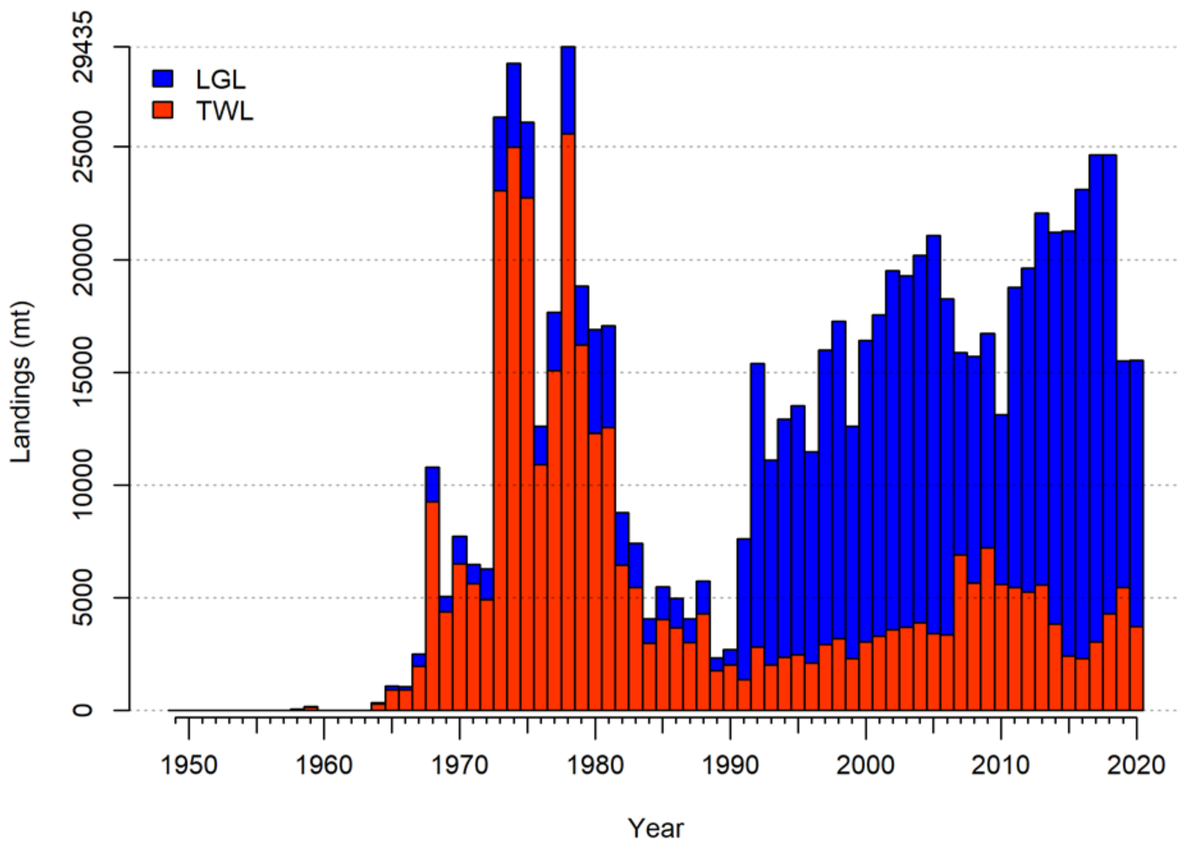



Figure 20. Estimated catches of Alaska skates (t) in the BSAI 1954-2020. LGL = longline fishery, TWL = trawl fishery.

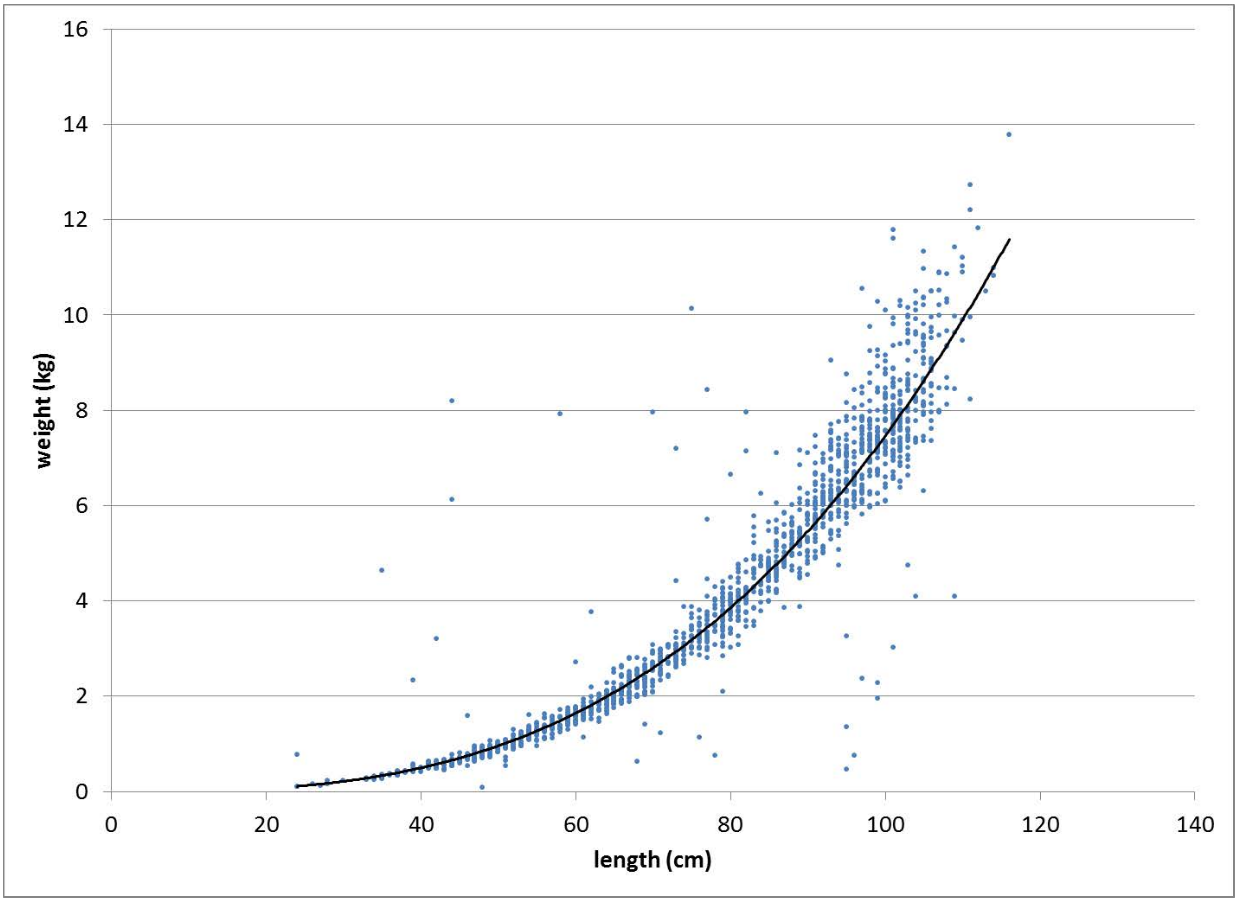



Figure 21. Length-weight relationship for Alaska skates captured in the EBS shelf trawl survey, 2008-2010. Black line indicates line of best fit to the data, $R^2$ = 0.93, N = 1,515.

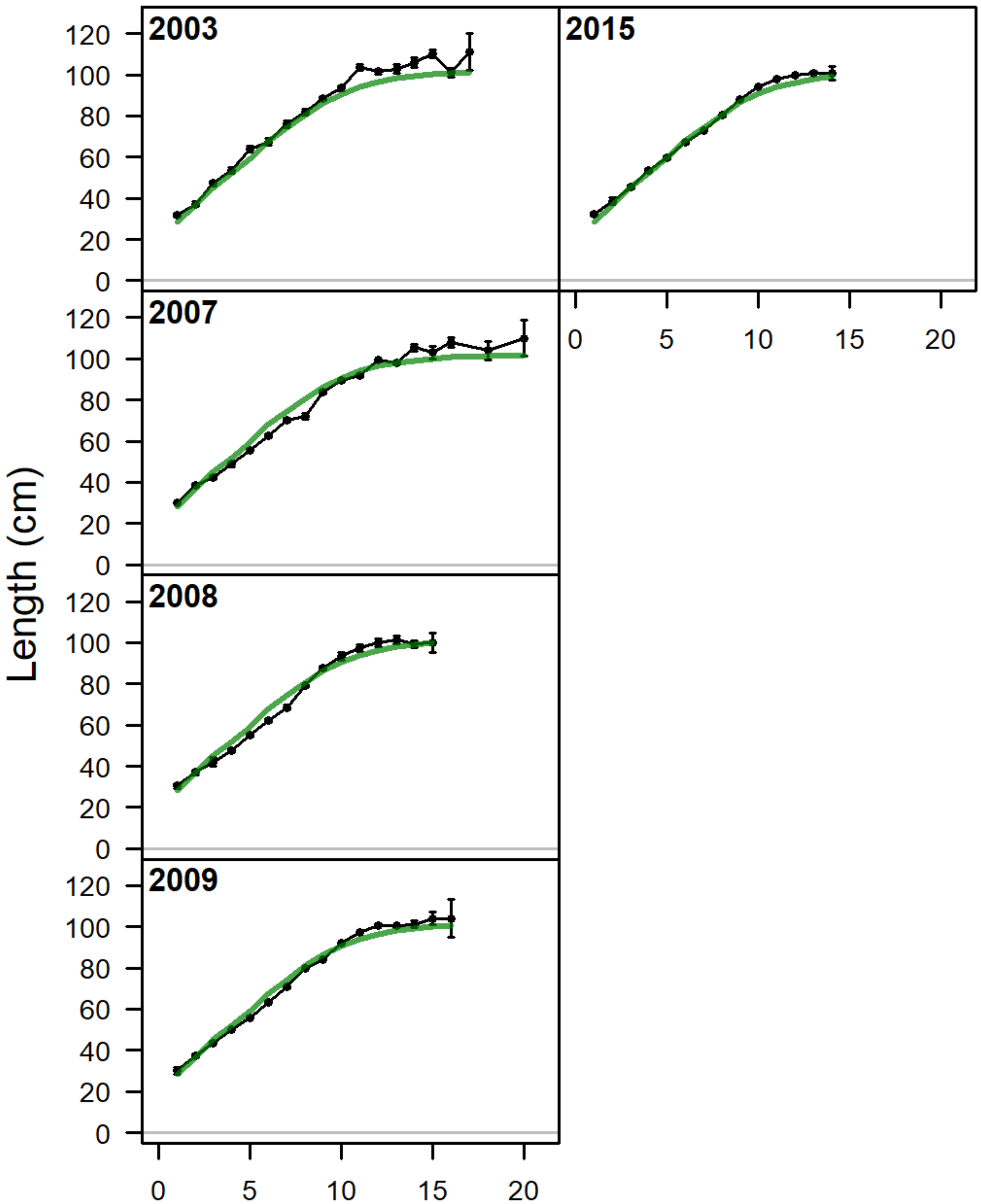



Figure 22. Observed (black circles) and model-predicted (green line) length-at-age for Model 14.2.

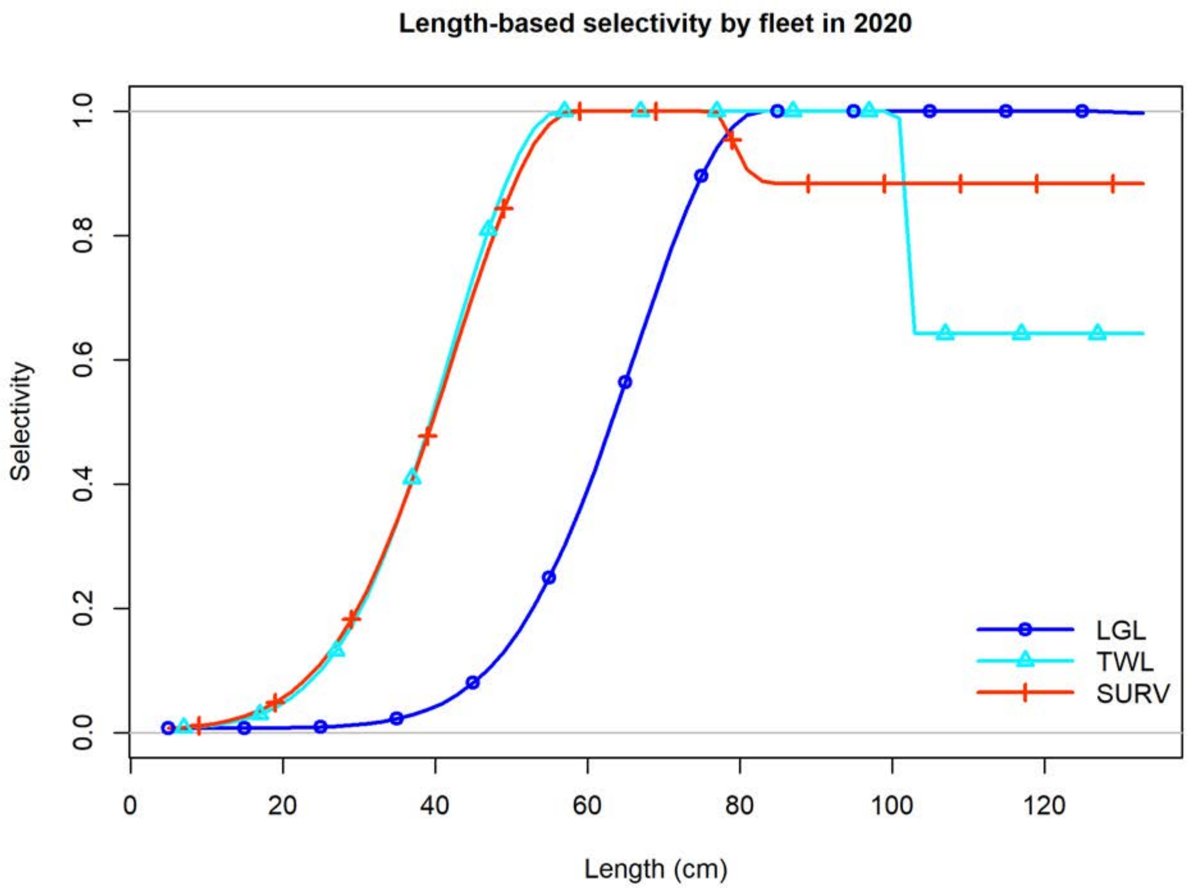



Figure 23. Selectivity functions estimated by model 14.2. LGL = longline fishery, TWL = trawl fishery, SURV = trawl survey.

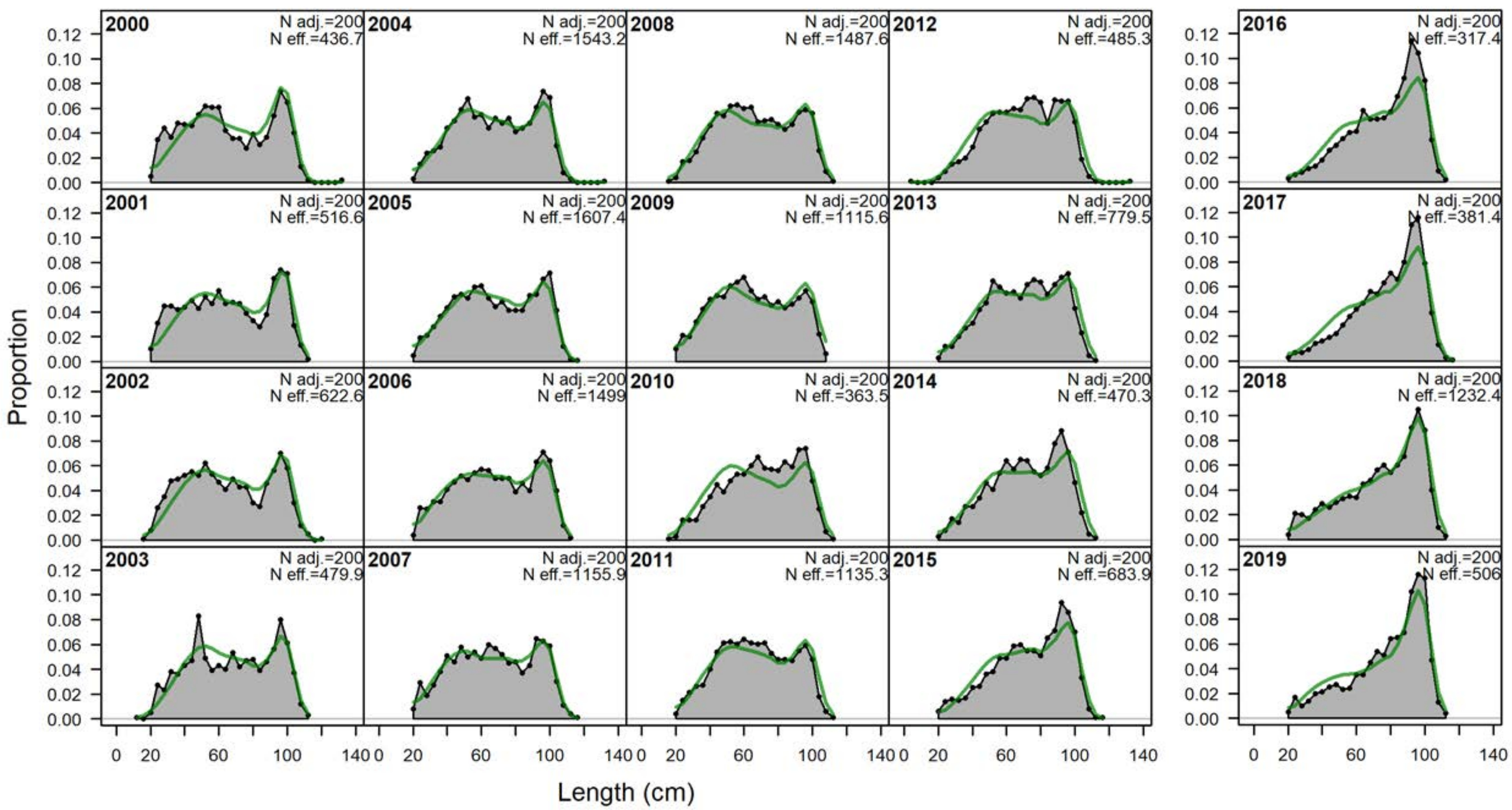



Figure 24. EBS shelf survey length compositions from 2000-2019. Grey shading = observed proportions; green line = model predictions. X-axis values are lengths in cm.

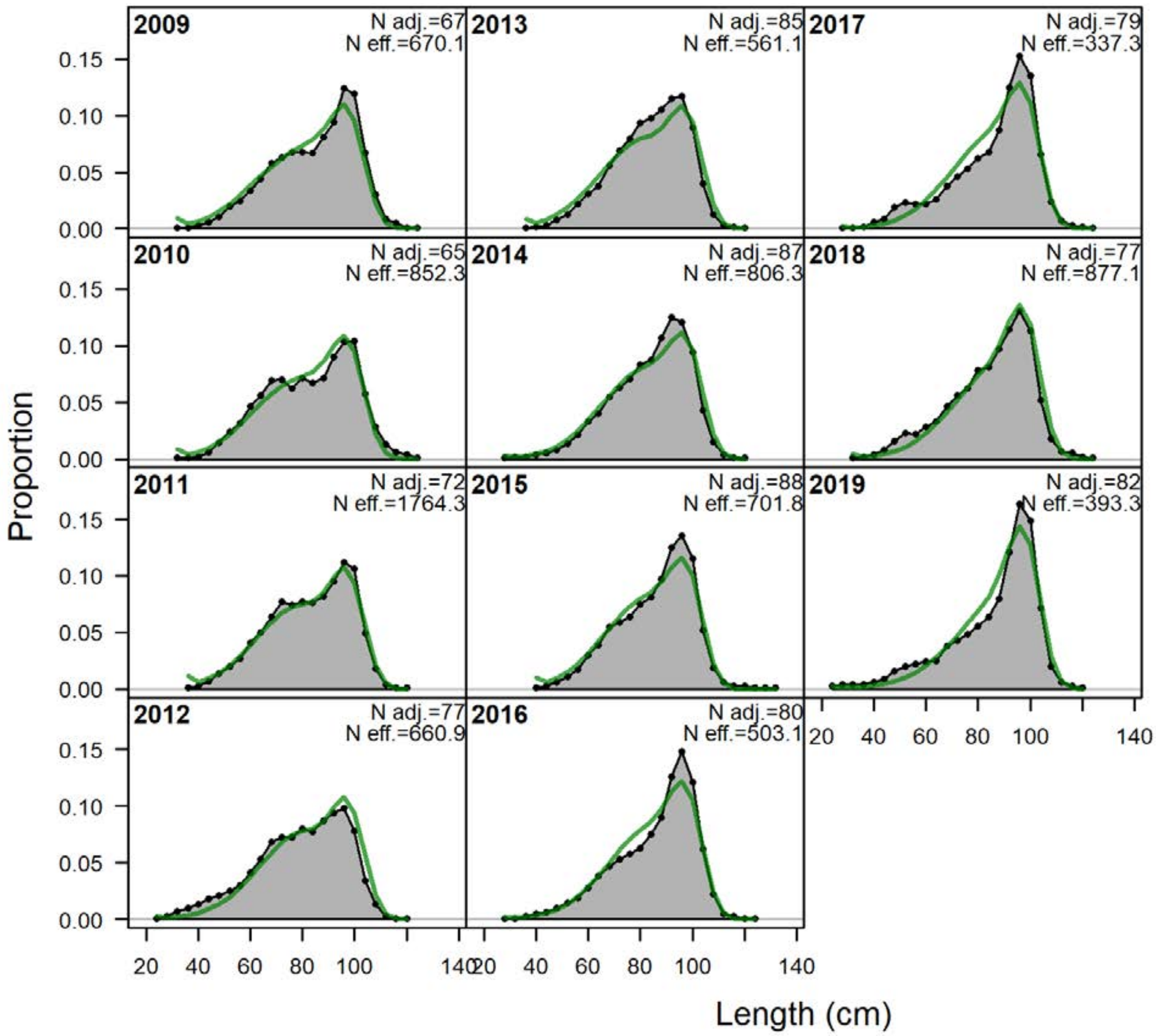



Figure 25. Observed and model-predicted length compositions from the 2009-2019 **longline** fisheries, with model predictions. Grey shading = observed proportions; green line = model predictions.

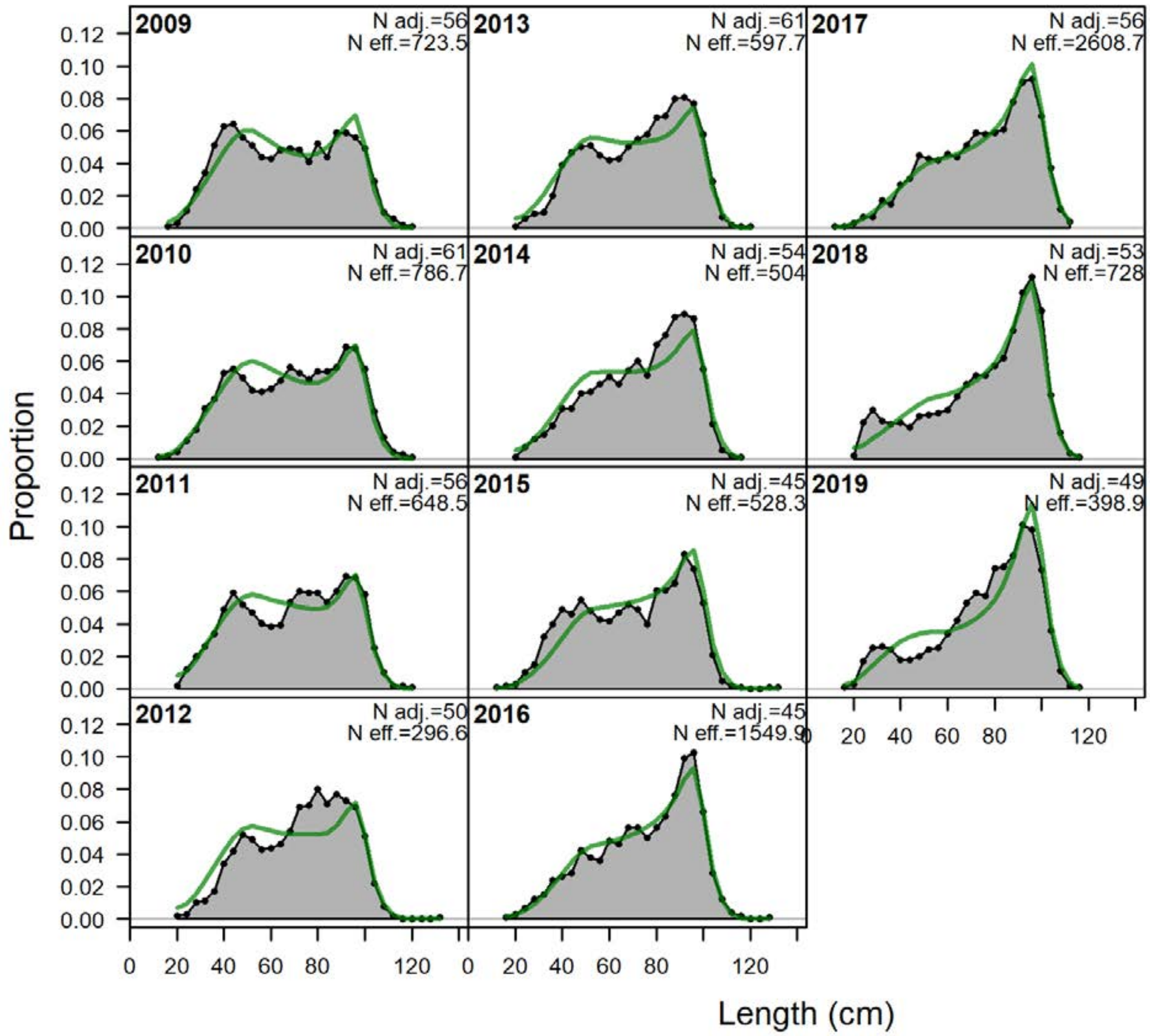



Figure 26. Observed and model-predicted length compositions from the 2009-2019 **trawl** fisheries, with model predictions. Grey shading = observed proportions; green line = model predictions.

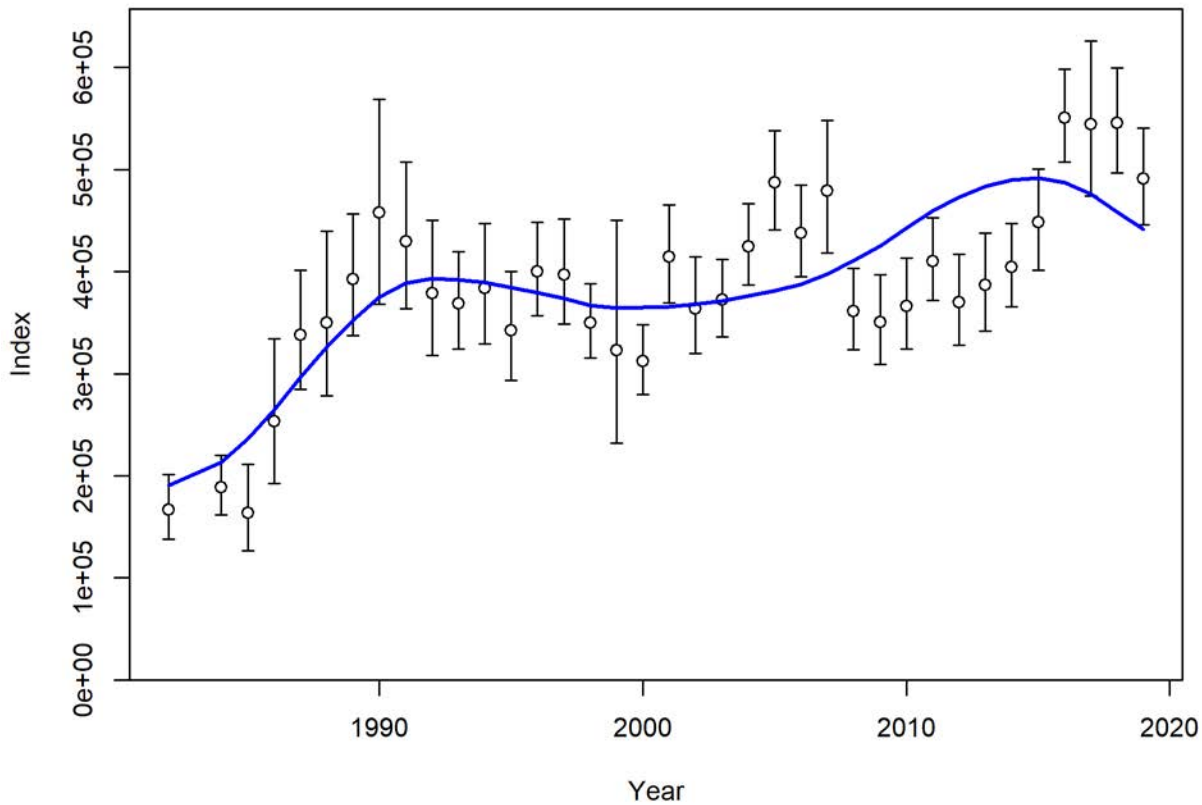



Figure 27. Observed and predicted Alaska skate biomass, 1982-2019. Symbols are biomass (circles) from EBS shelf surveys, with confidence intervals (± 2 SE); blue line is predicted survey biomass from the model 14.2.

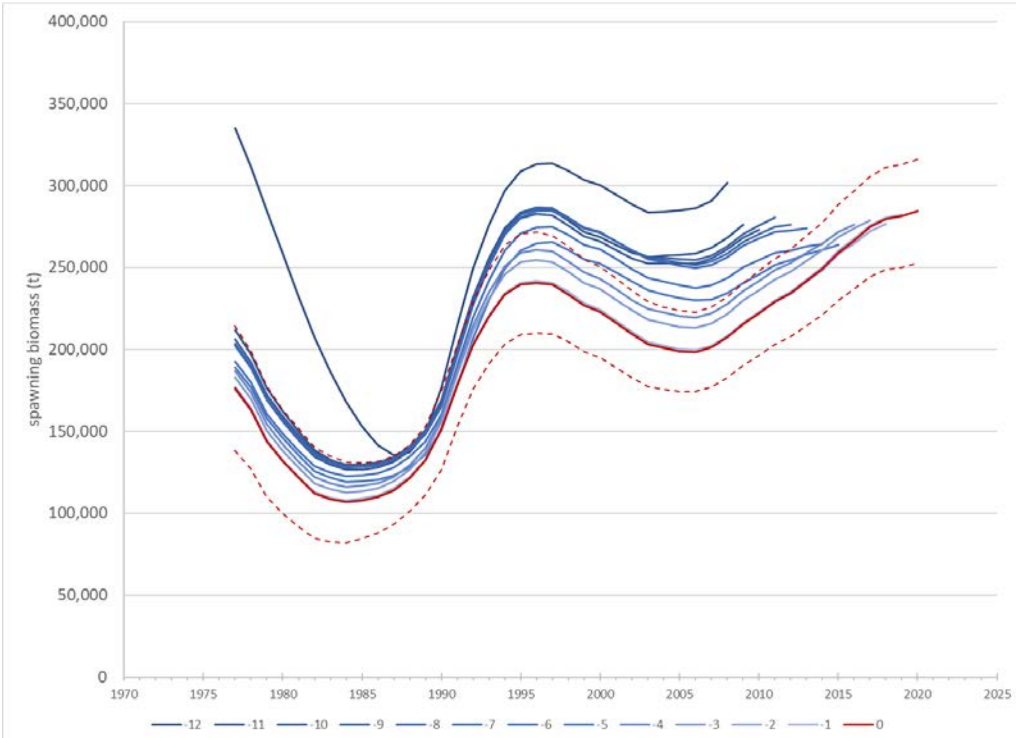




Figure 28. Retrospective analysis for estimates of spawning biomass (top panel) and age-0 recruitment (bottom panel) from model 14.2. Units for recruitment are in 1000s of individuals. Dashed lines show 95% confidence intervals for the current year's estimate.

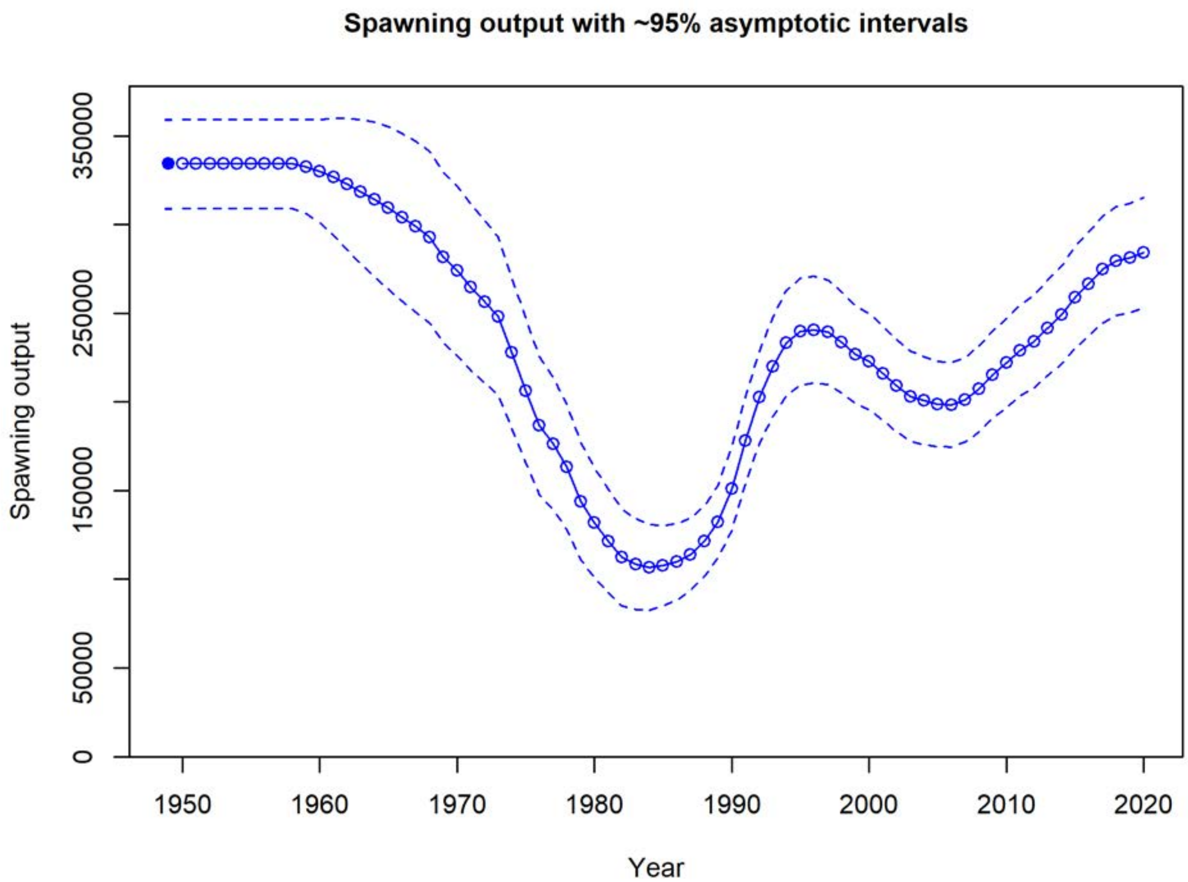



Figure 29. Model estimate of Alaska skate female spawning biomass (t). Dashed lines indicate 95% confidence interval.

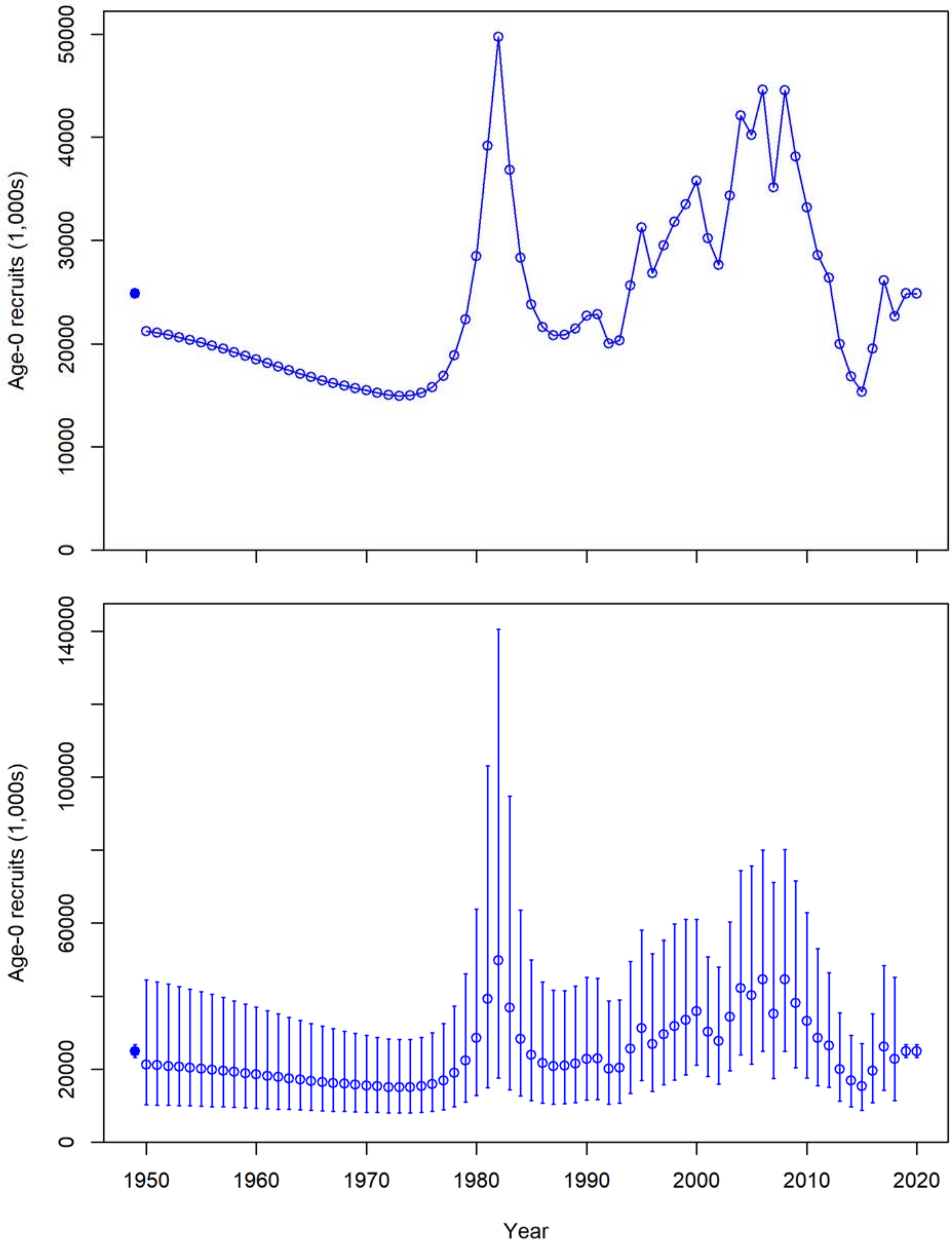



Figure 30. Model estimates of age-0 recruitment (1000s of individuals) of Alaska skates. Data are the same in both panels; the bottom panel includes 95% confidence intervals.

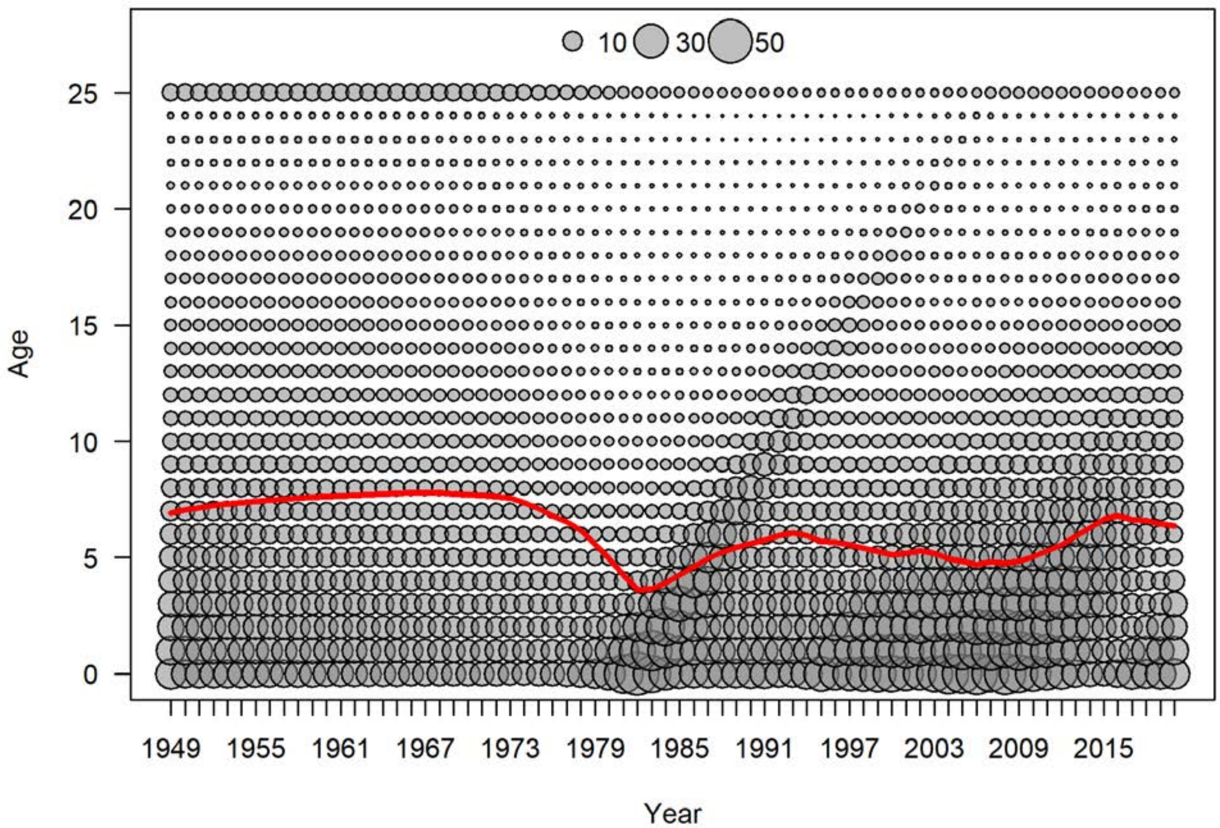



Figure 31. Estimated numbers at age from the preferred model, Model 14.2. Circles are millions of skates; red line indicates average age in the population.

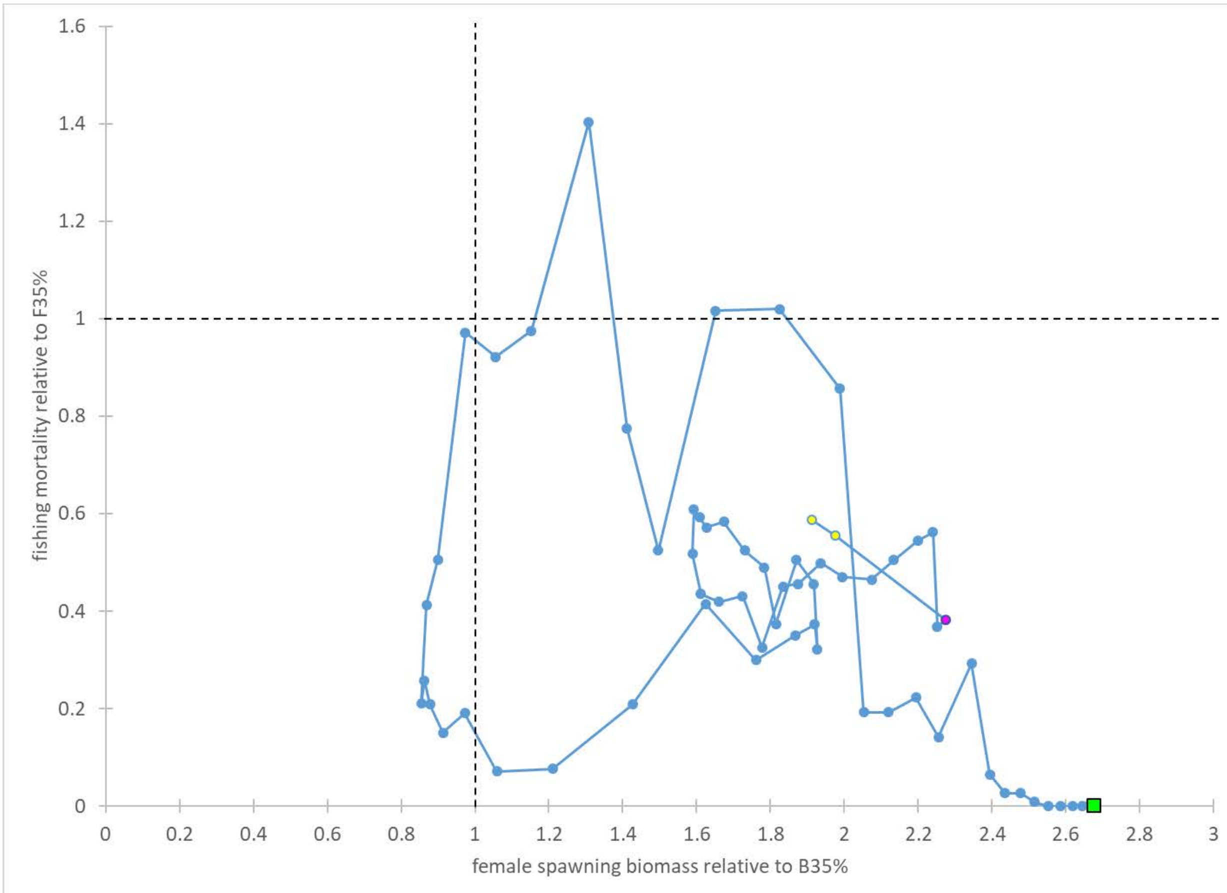



Figure 32. Trajectory of relative fishing mortality and relative spawning biomass as estimated by the 2020 run of Model 14.2. Green square marks the beginning of the time series (1950); purple circle indicates 2020; yellow circles indicate projected years 2021 and 2022. Vertical dashed line indicates *B35%*; horizontal dashed line indicates *F35%*.

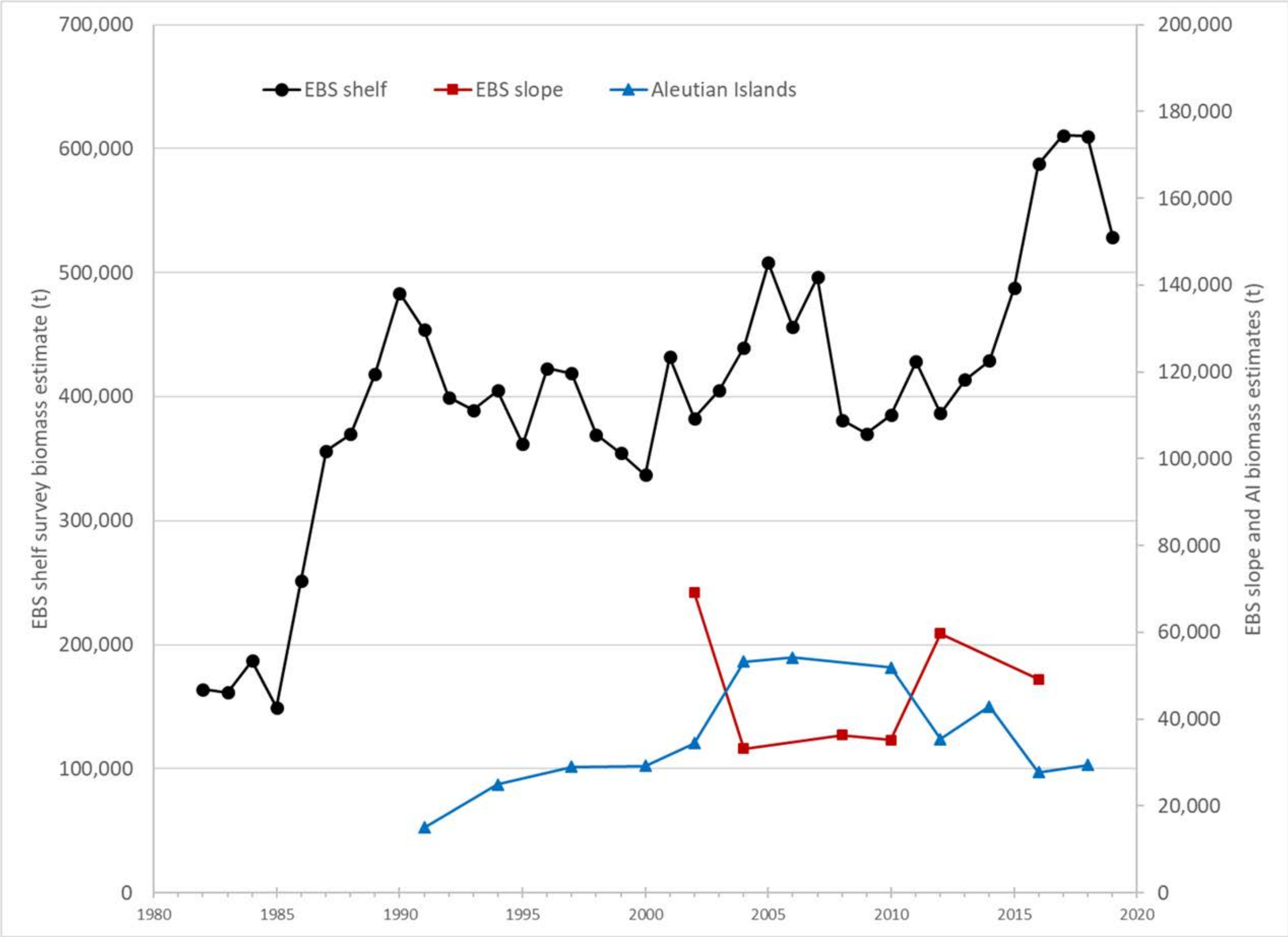



Figure 33. Aggregated skate biomass (t) and 95% confidence intervals estimated from RACE bottom trawl surveys in each of the three major habitat areas (1982 – 2019). Note that slope and AI estimates are much smaller and pertain to the secondary y-axis.

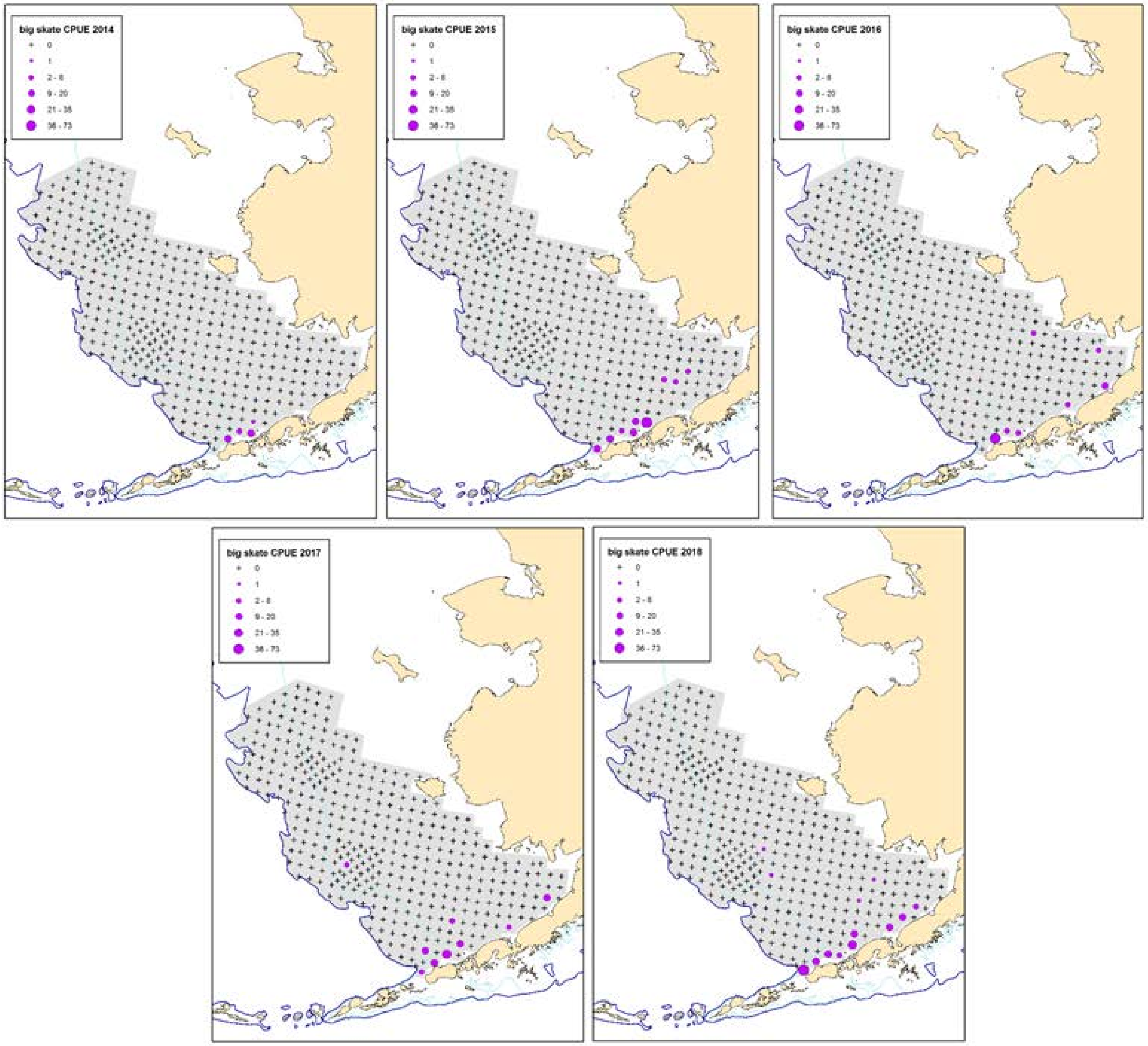



Figure 34. Big skate distribution in the southeastern Bering Sea, 2014-2018. Data are from the AFSC bottom trawl survey.

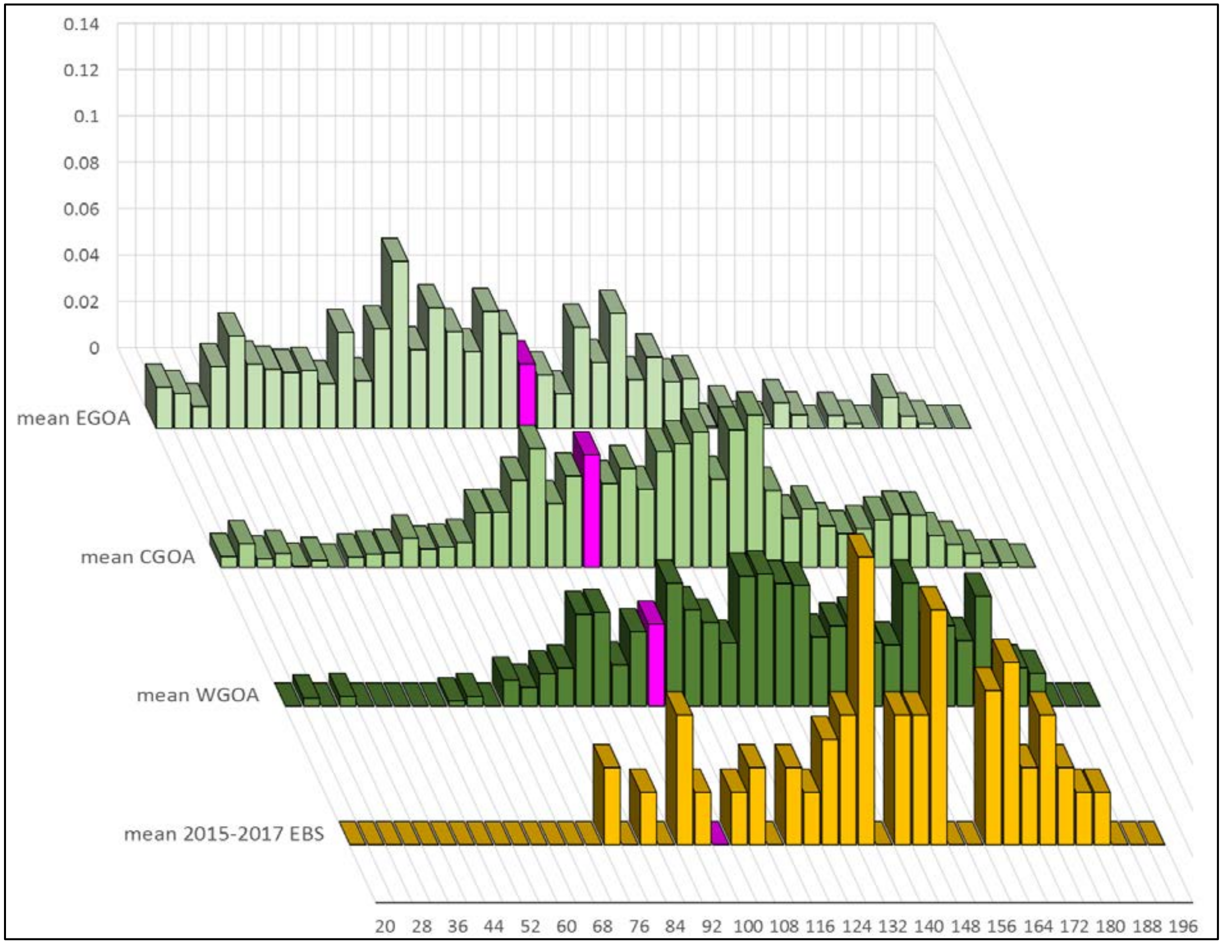



Figure 35. Comparison of mean survey length compositions for big skates. The 100-103 cm length bin is marked in fuchsia for reference. Data are from the 3 regulatory areas in the Gulf of Alaska (GOA [(W)estern, (C)entral, and (E)astern]) and from the eastern Bering Sea (EBS) shelf survey.

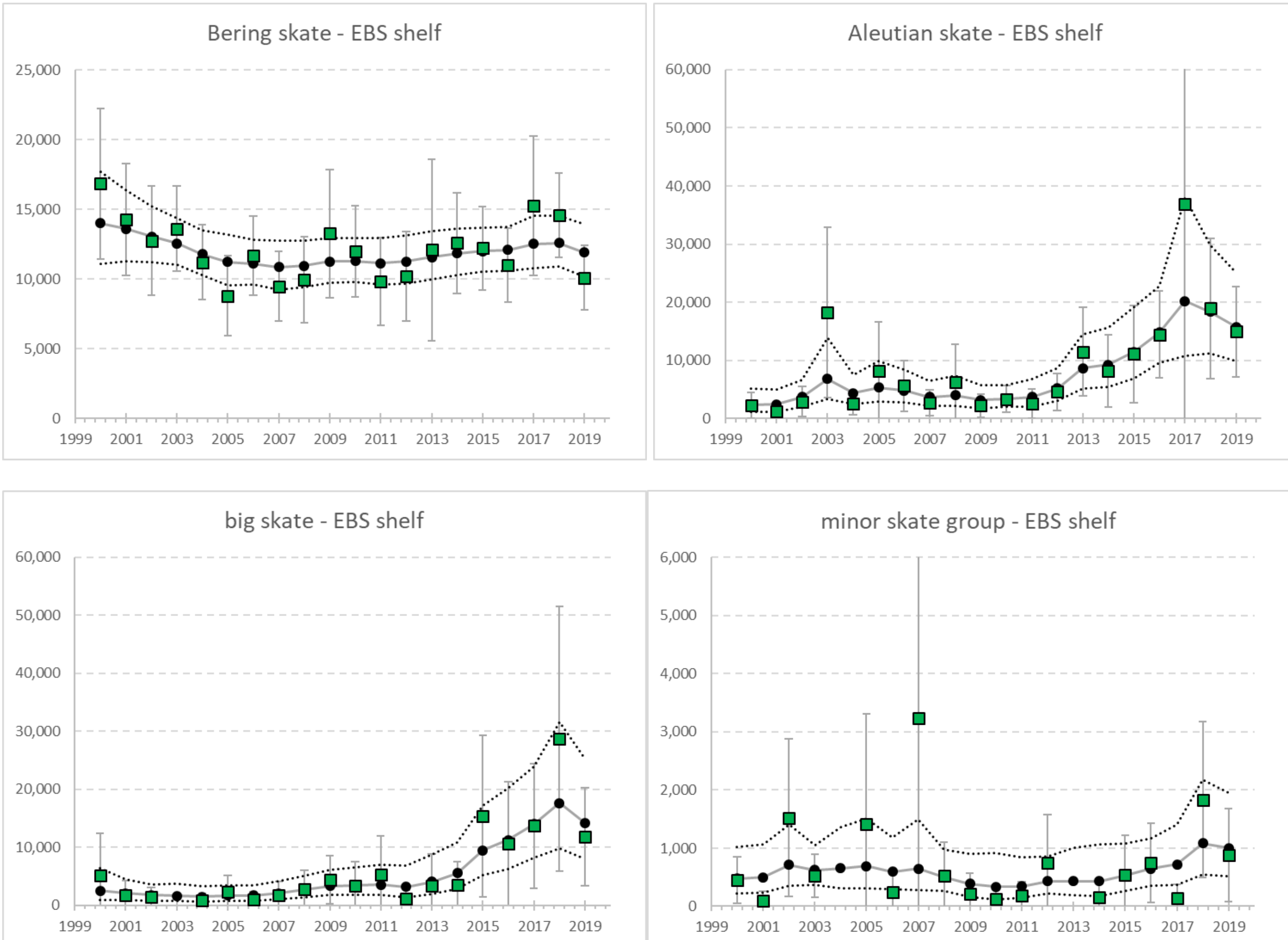



Figure 36. Biomass estimates for skate species on the **EBS shelf**. Squares indicate trawl survey biomass estimates ("survey"). Dotted black lines are biomass estimates from a random-effects model (RE) based on the survey data. Error bars indicate 95% confidence interval (CI) for survey data; dashed lines indicate 95% CI for RE model.

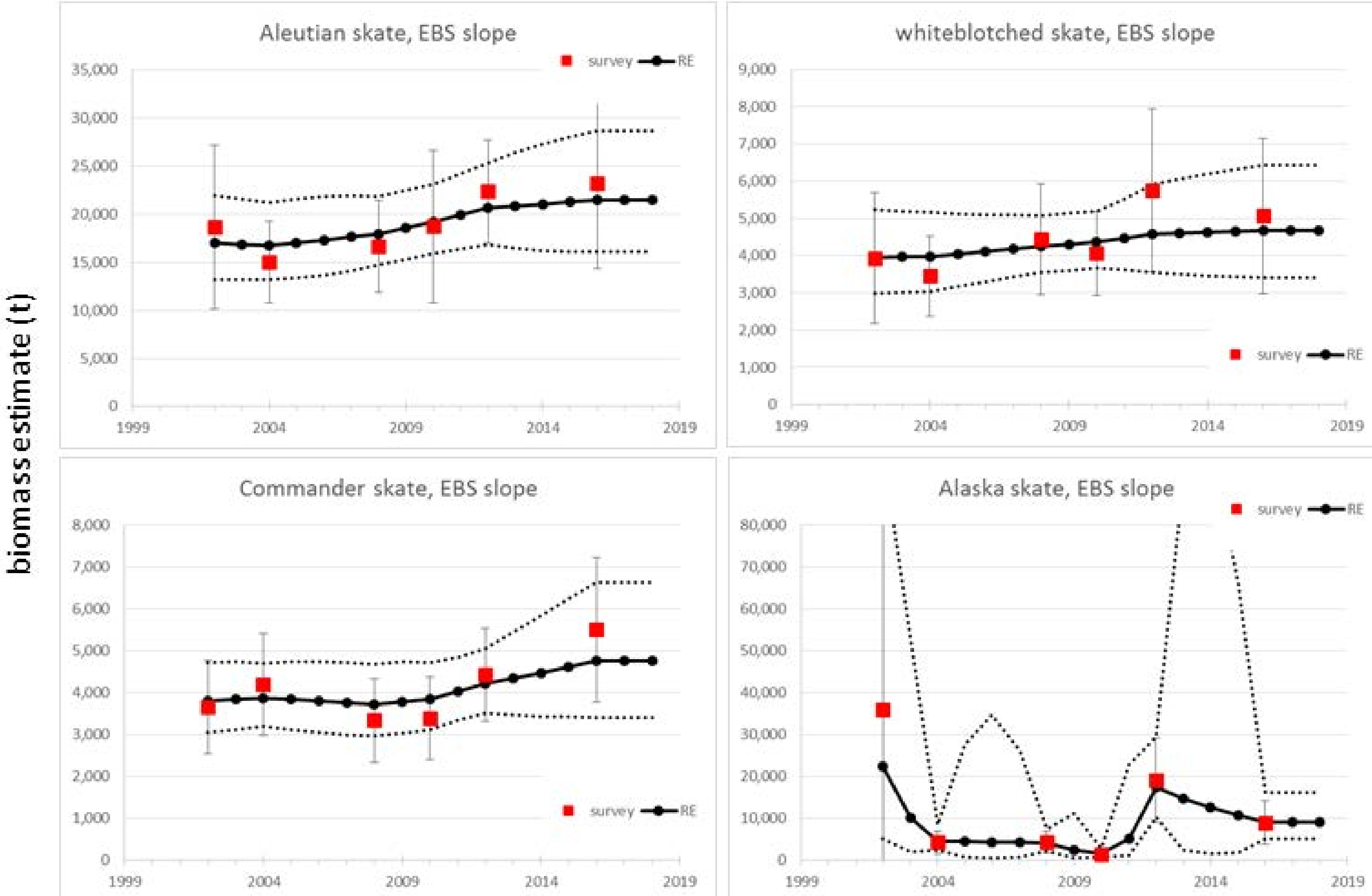



Figure 37a. Biomass estimates for skate species on the **EBS slope**. Squares indicate trawl survey biomass estimates ("survey"). Dotted black lines are biomass estimates from a random-effects model (RE) based on the survey data. Error bars indicate 95% confidence interval (CI) for survey data; dashed lines indicate 95% CI for RE model.

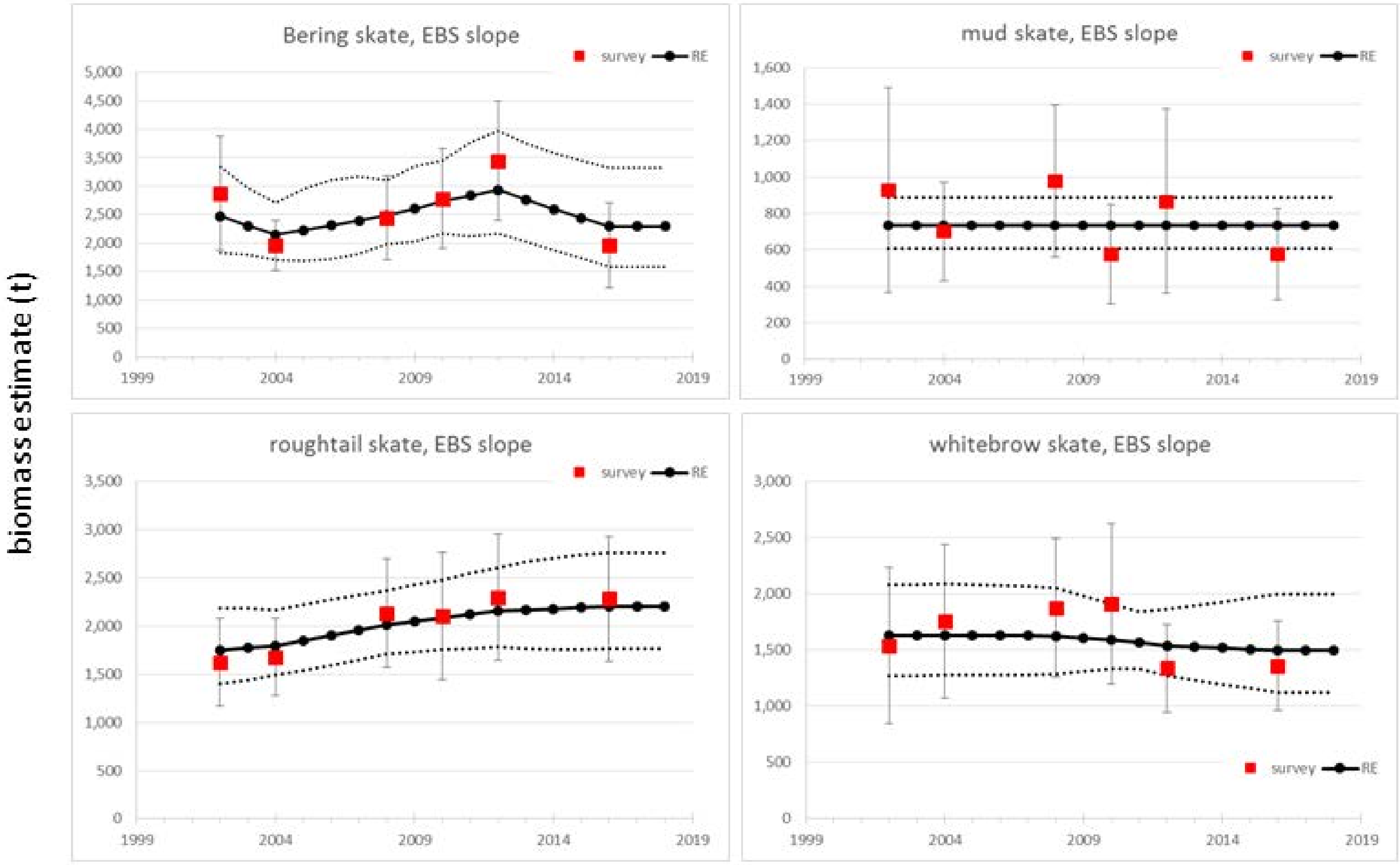



Figure 37b. Biomass estimates for skate species on the **EBS slope**. Squares indicate trawl survey biomass estimates ("survey"). Dotted black lines are biomass estimates from a random-effects model (RE) based on the survey data. Error bars indicate 95% confidence interval (CI) for survey data; dashed lines indicate 95% CI for RE model.

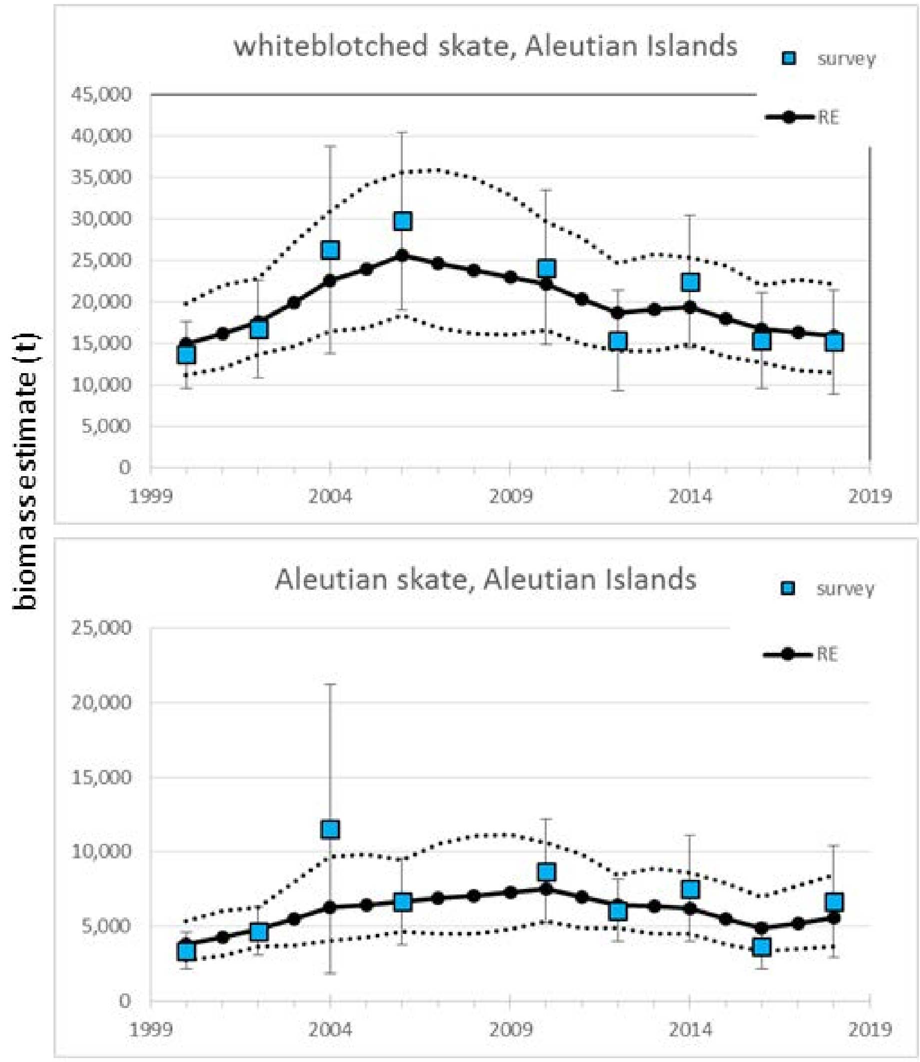
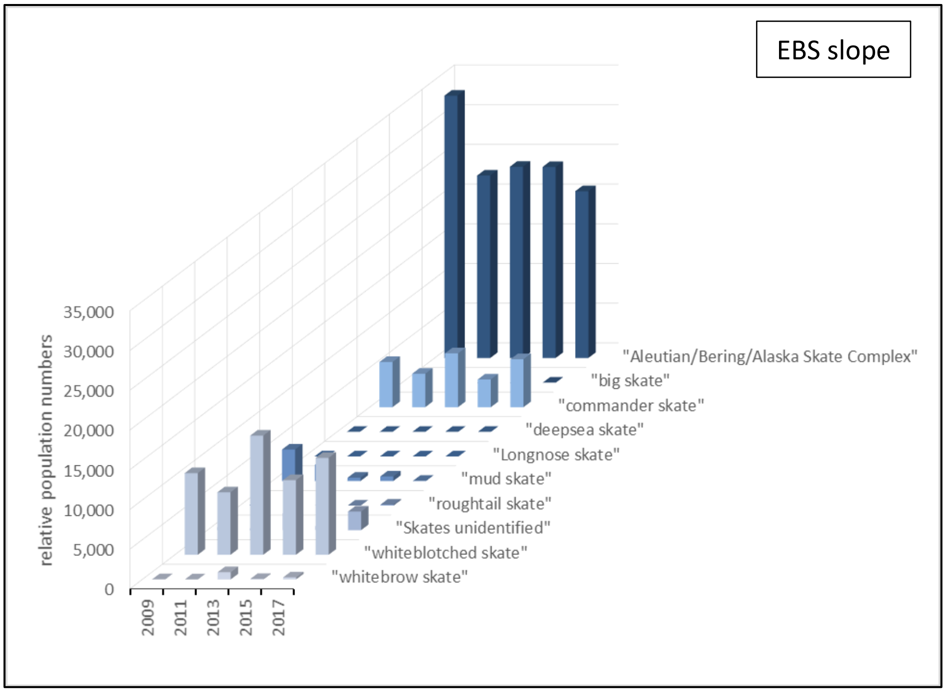



Figure 38a. Biomass estimates for skate species in the **Aleutian Islands**. Squares indicate trawl survey biomass estimates ("survey"). Dotted black lines are biomass estimates from a random-effects model (RE) based on the survey data. Error bars indicate 95% confidence interval (CI) for survey data; dashed lines indicate 95% CI for RE model.


Figure 38b. Biomass estimates for skate species in the **Aleutian Islands**. Squares indicate trawl survey biomass estimates ("survey"). Dotted black lines are biomass estimates from a random-effects model (RE) based on the survey data. Error bars indicate 95% confidence interval (CI) for survey data; dashed lines indicate 95% CI for RE model.


Figure 39. Relative population numbers for the aggregate skate complex from AFSC longline surveys on the EBS slope and in the Aleutian Islands (AI), 2000-2018.



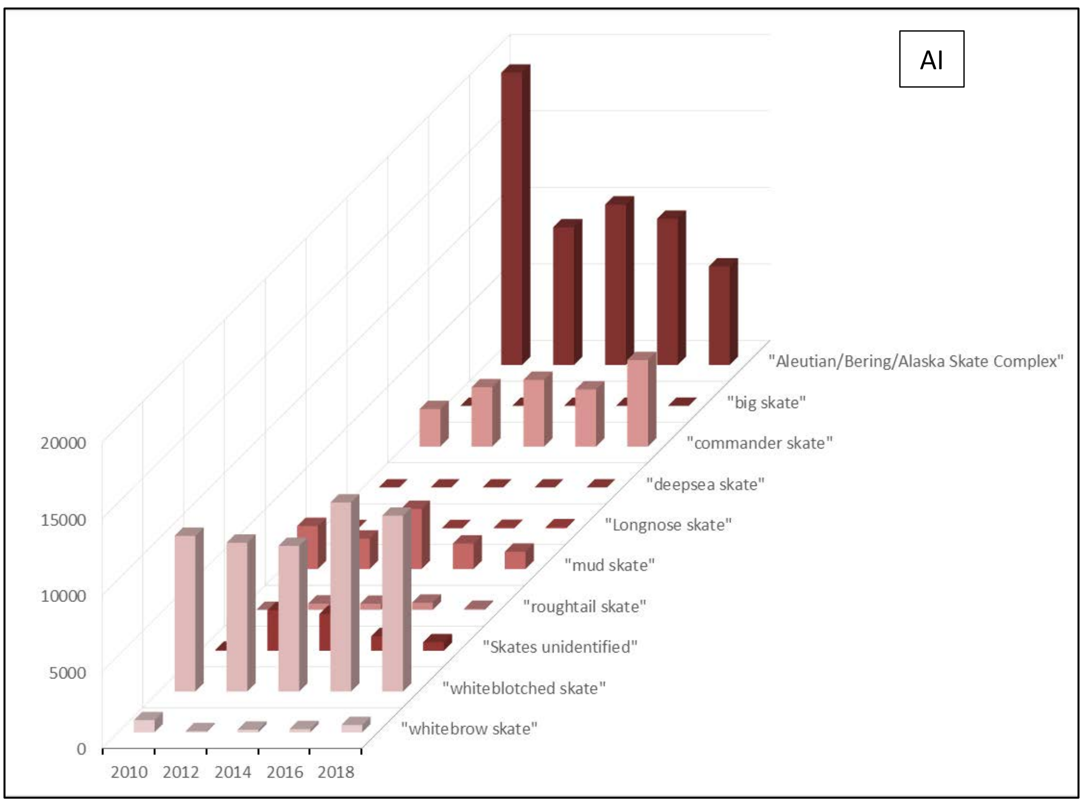




Figure 40. Relative population numbers for skate species and species groups from AFSC longline surveys on the EBS slope (top panel) and in the Aleutian Islands (AI; bottom panel), 2009-2018.

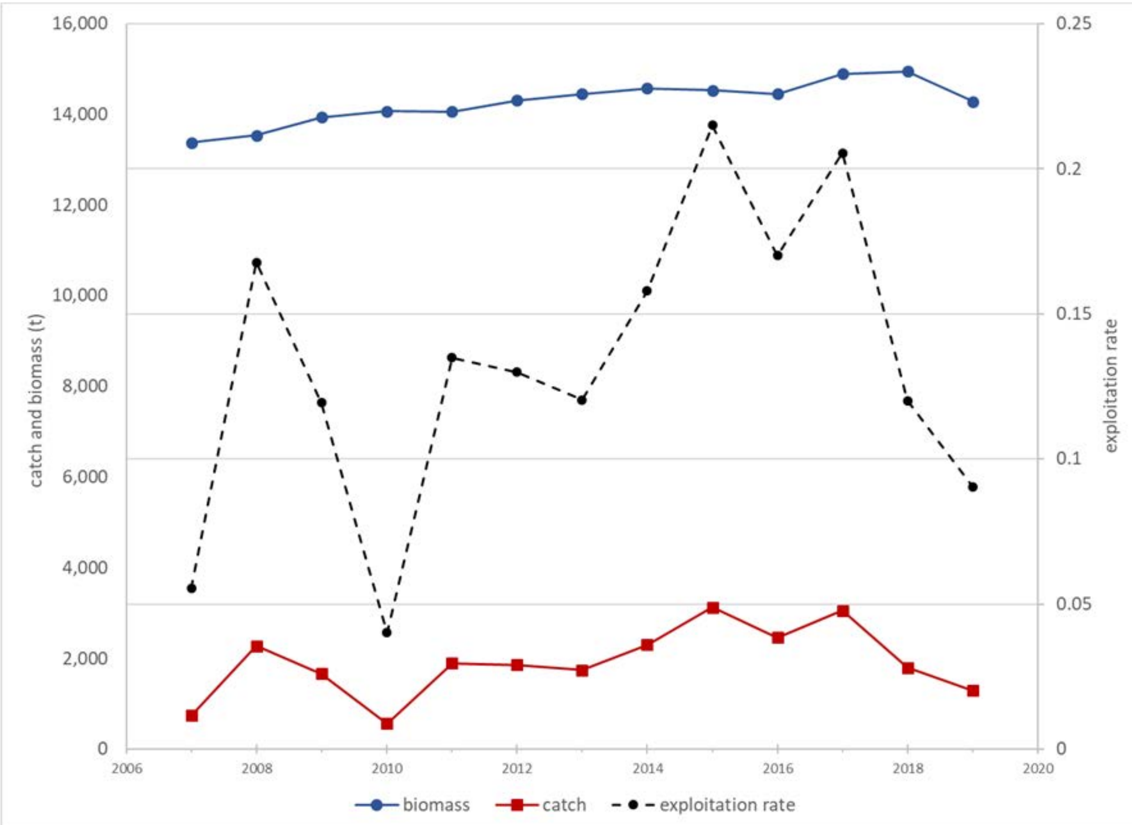



Figure 41. Biomass, catch, and exploitation rate for Bering skate in the Bering Sea and Aleutian Islands region, 2007-2019. Biomass is from the random-effects model and exploitation rate = catch/biomass. Exploitation rate is on the secondary axis.

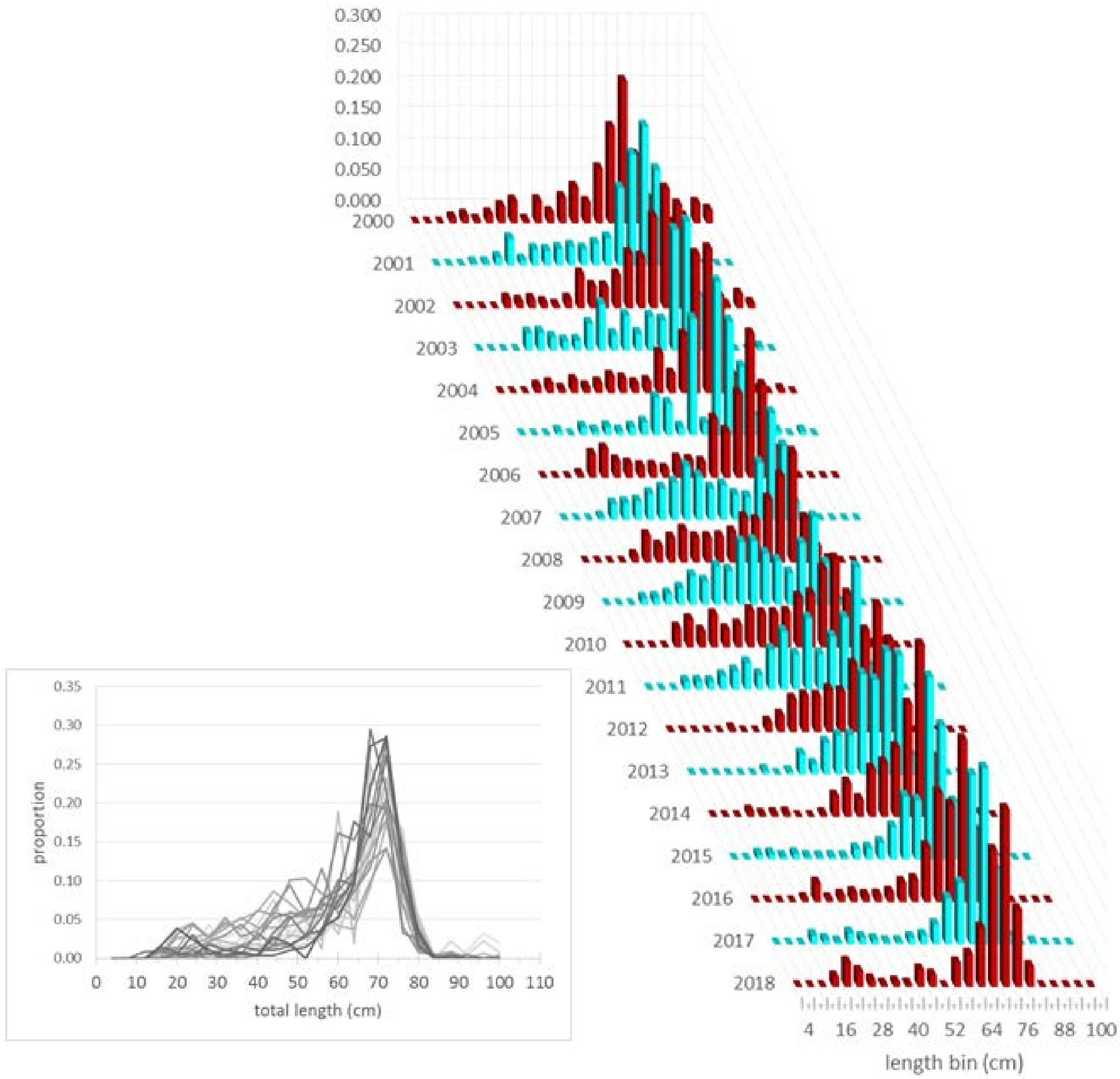



Figure 42. Survey length compositions for Bering skates from the eastern Bering Sea shelf survey. Data are the same in both plots.

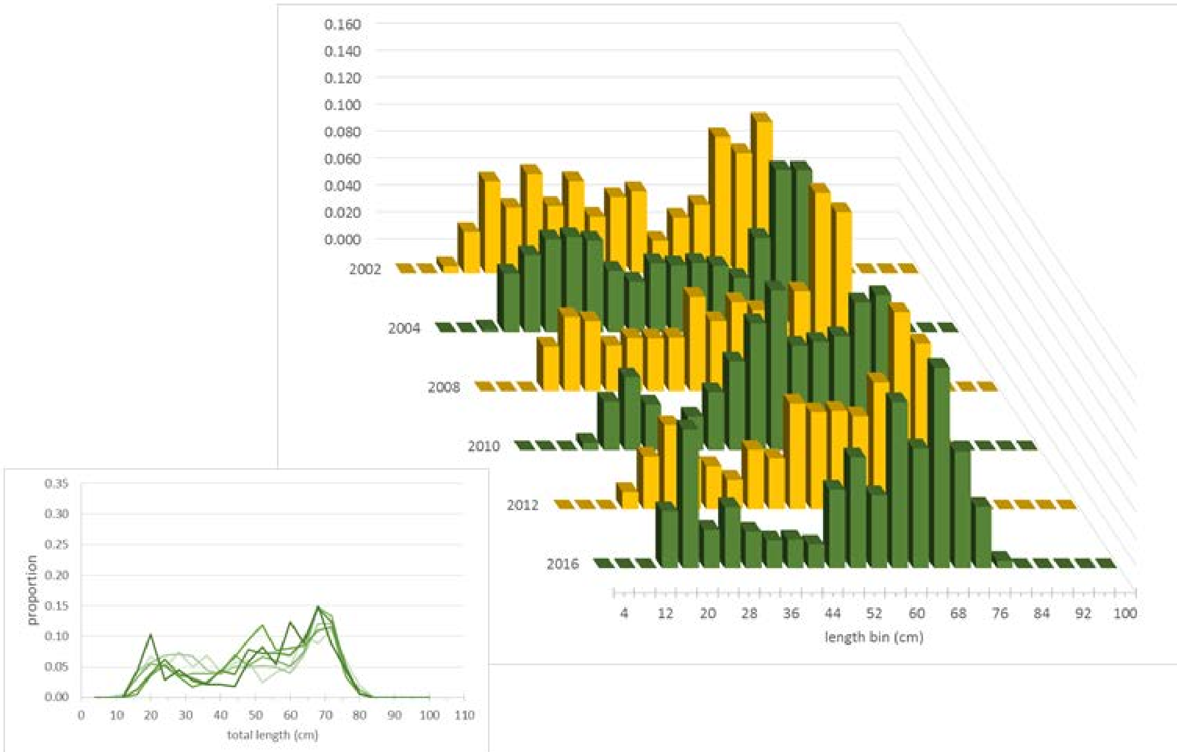



Figure 43. Survey length compositions for Bering skates from the eastern Bering Sea slope survey. Data are the same in both plots.

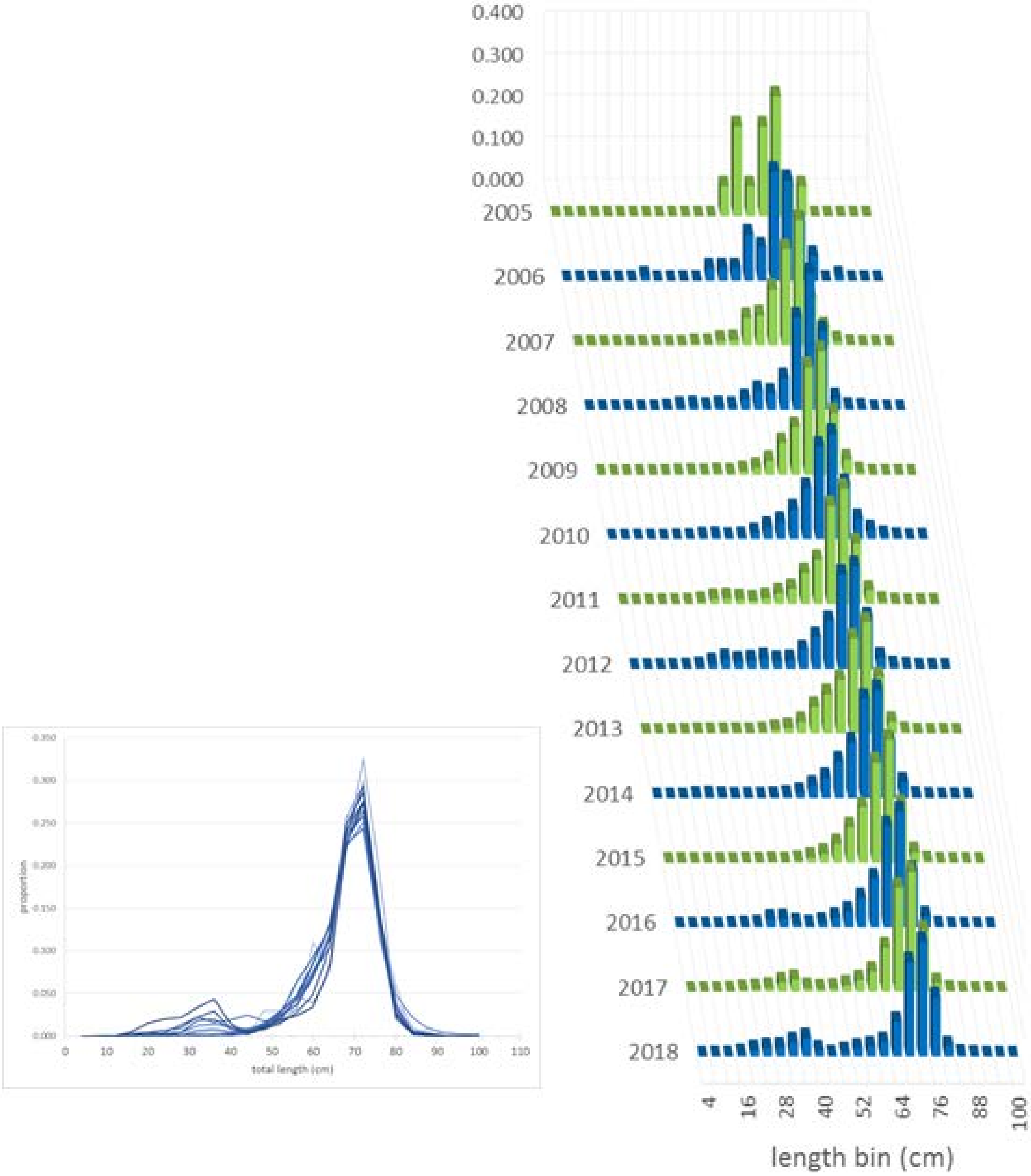



Figure 44. Fishery length compositions (all gears combined) for Bering skates in the Bering Sea and Aleutian Islands region. Data are the same in both plots.

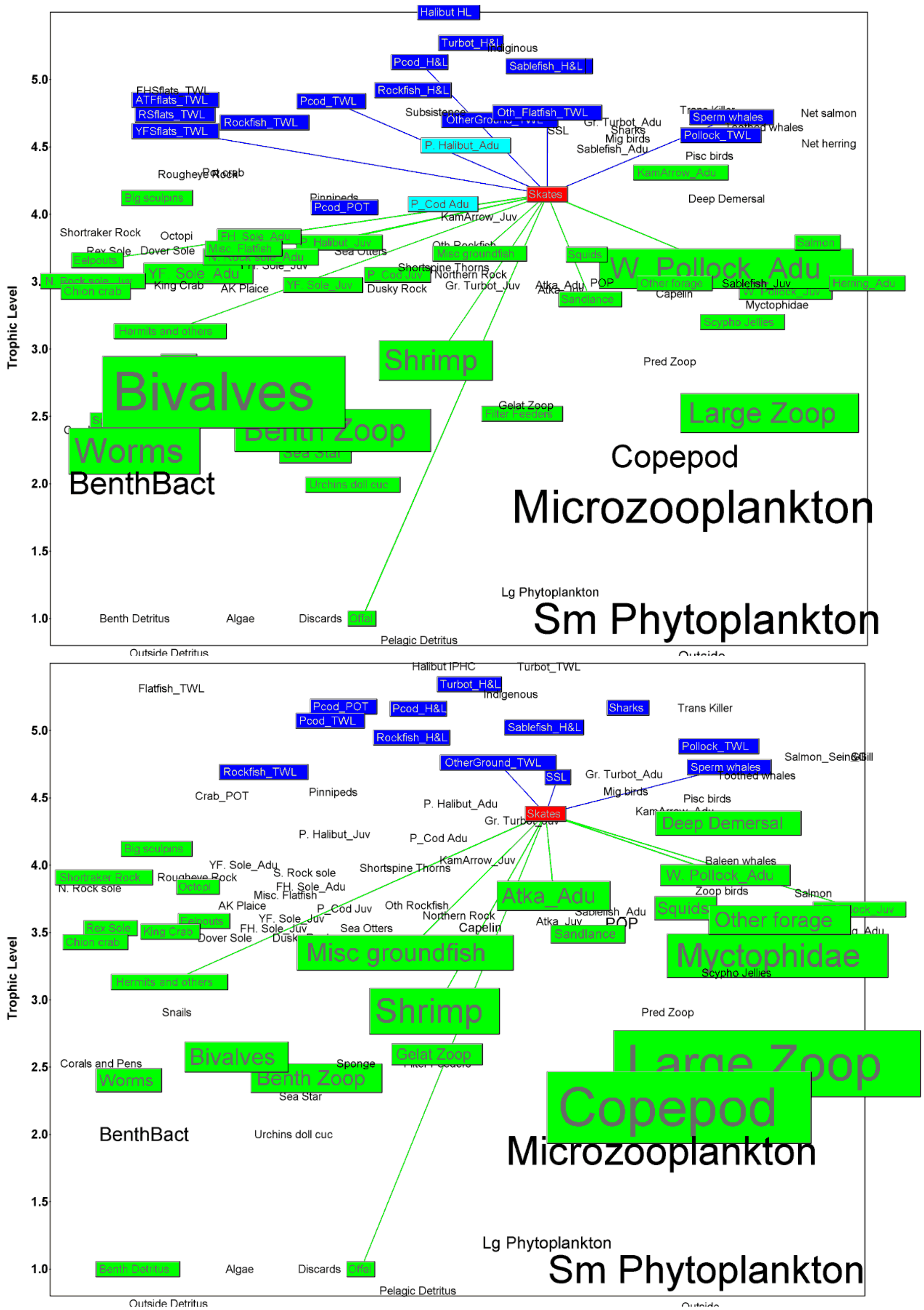



Figure 45. EBS (upper panel) and AI (lower panel) skate food webs derived from mass balance ecosystem models, with skate species aggregated in each area. Source: K. Aydin, AFSC, code available upon request.

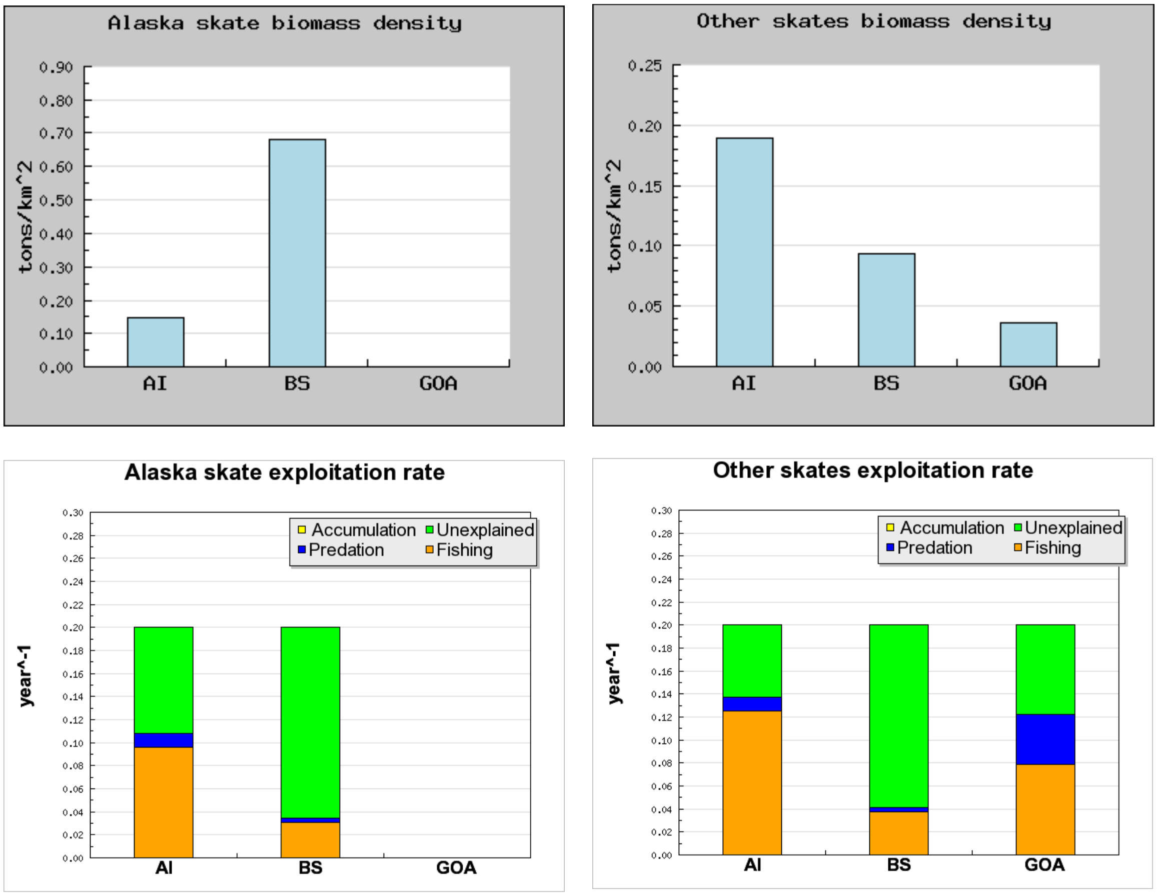



Figure 46. Comparative density (upper panels) and exploitation rate (lower panels) of Alaska (left panels) and all other Bathyraja (right panels) skates in the AI, EBS, and GOA (early 1990s, before fishery in GOA). (Alaska skates are a very small component of skate biomass in the GOA, and are not modeled separately.) Note that the Other skates plot does not include the most common species in that region, the big skate and longnose skate—see the GOA skate SAFE for information on those skates. Biomass density plots are from trawl survey data; exploitation rate plots are derived from catch and biomass estimates and from assumed estimates of skate productivity (approximated from Frisk et al. 2001).

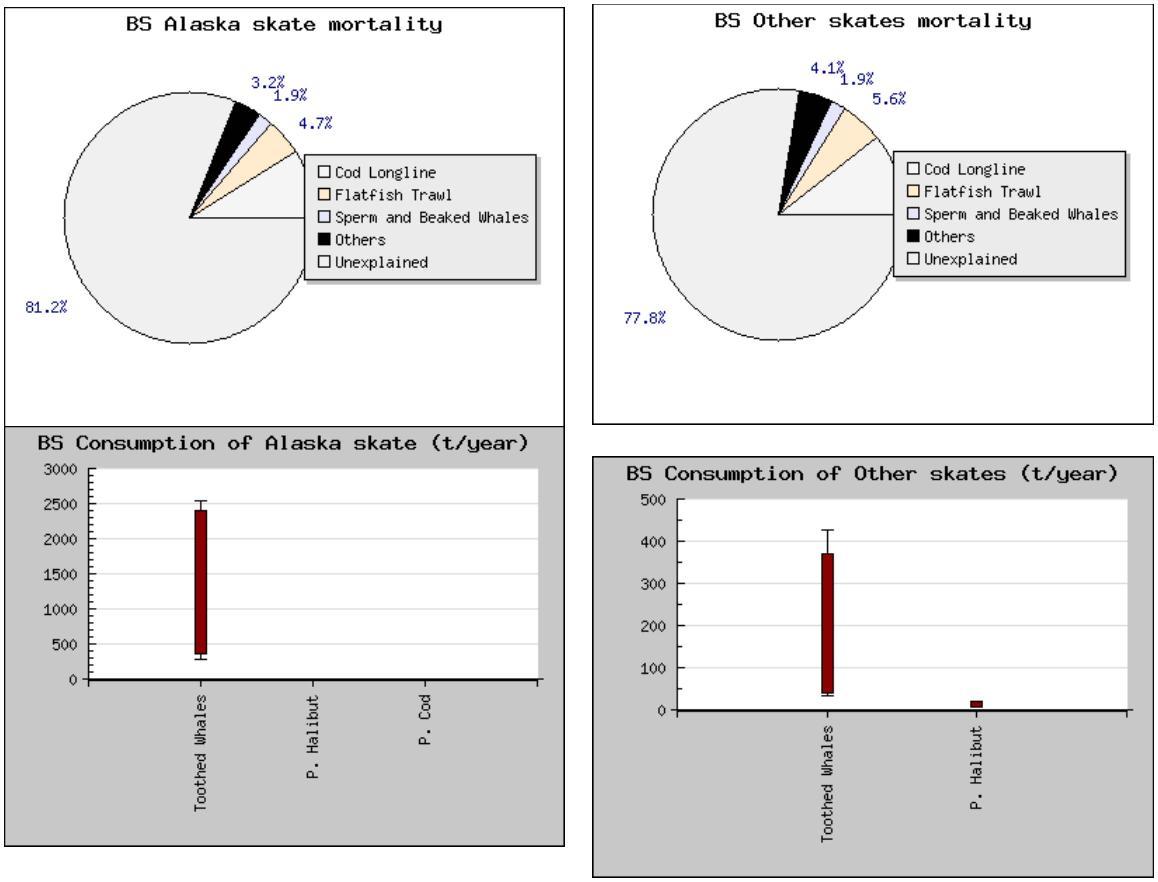



Figure 47. Mortality sources and consumption of skates in the EBS—mortality pie (upper panels) and estimates of annual consumption by predators (lower panels) for EBS Alaska skates (left panels) and all other EBS skates (right panels). Model outputs were derived from diet compositions, production rates, and consumption rates of skate predators, and from skate catch data.

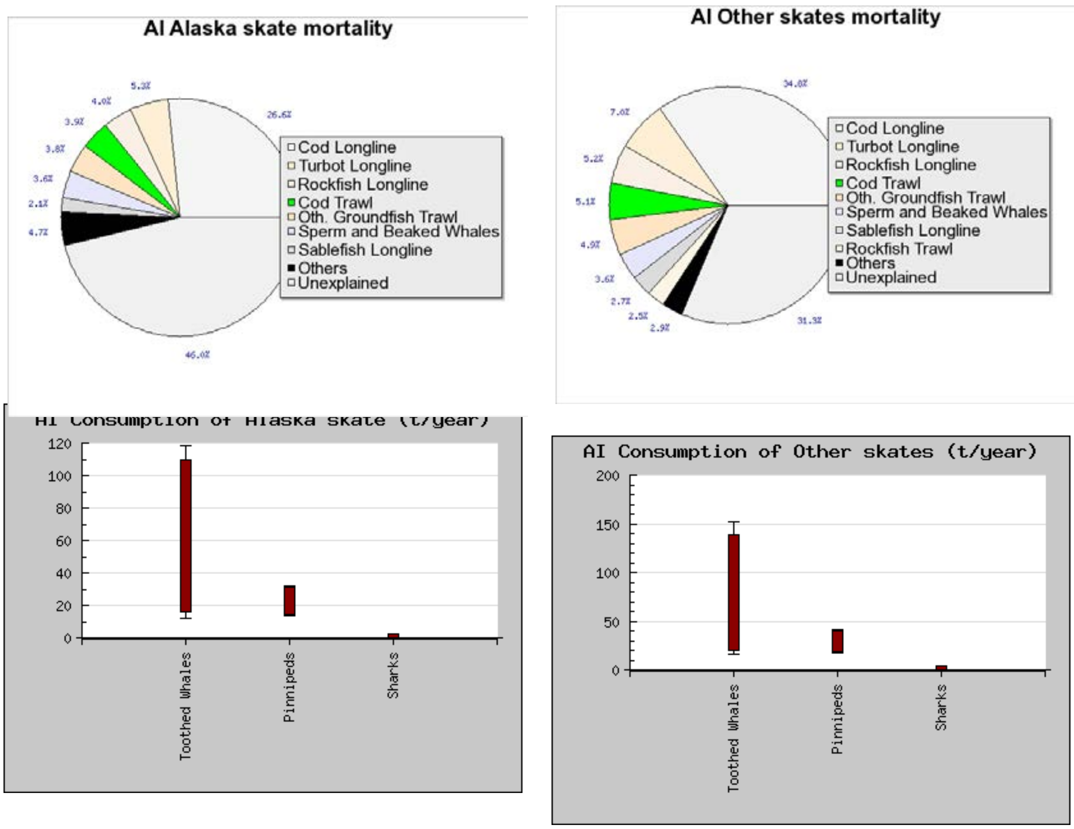



Figure 48. Mortality sources and consumption of skates in the AI—mortality pie chart (upper panels) and estimates of annual consumption by predators (lower panels) for AI (former) Alaska skate (left panels) and AI Other Skates (right panels). Model outputs were derived from diet compositions, production rates, and consumption rates of skate predators, and from skate catch data.

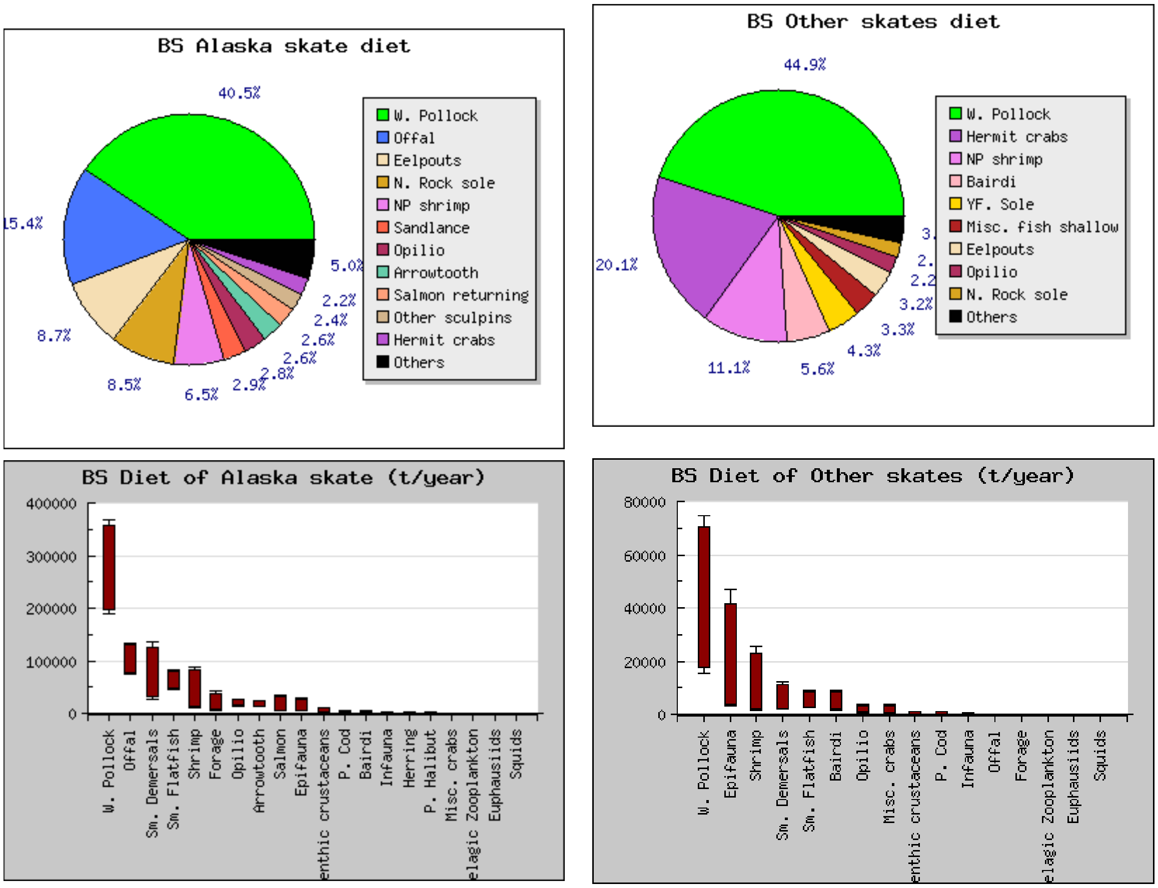



Figure 49. Diet composition (upper panels) and annual estimated prey consumption by skates (lower panels) for EBS Alaska skates (left panels) and Other Skates (right panels). Results were generated from stomach content collections occurring during RACE trawl surveys.

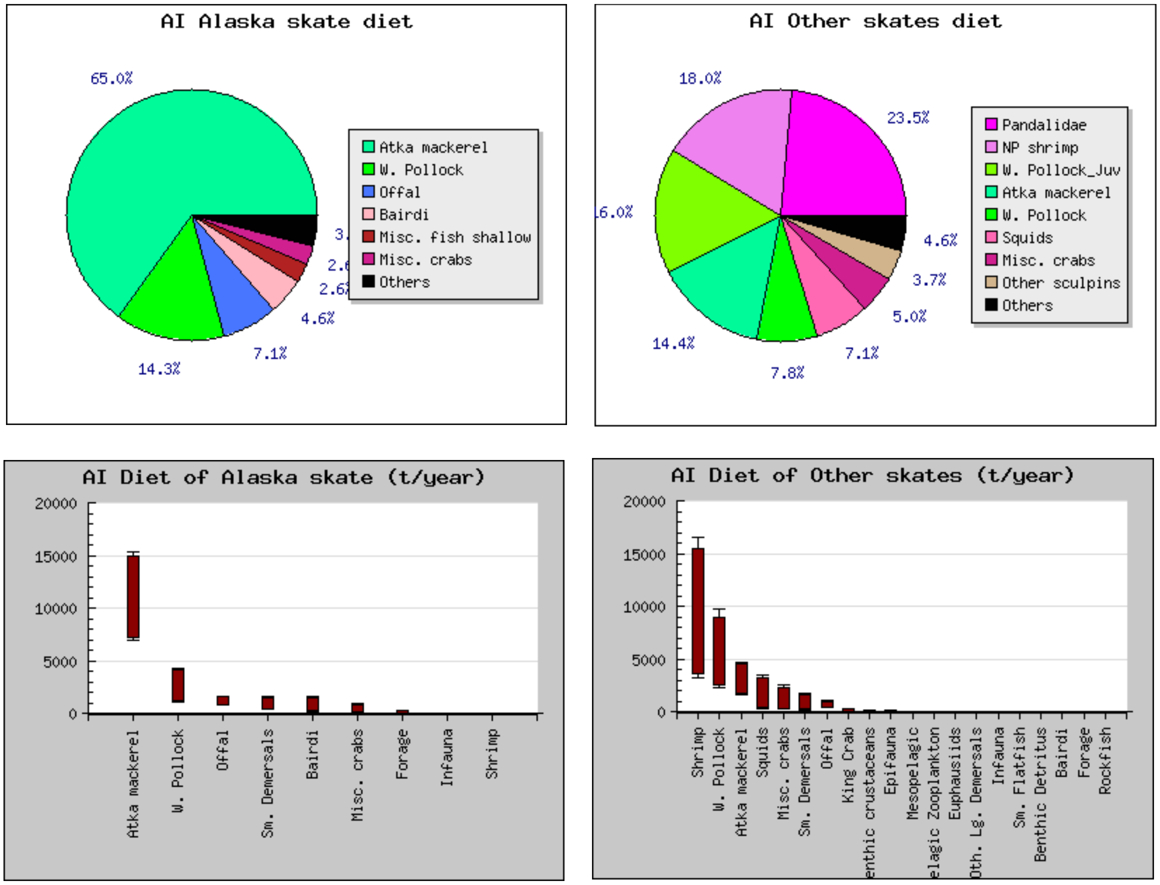
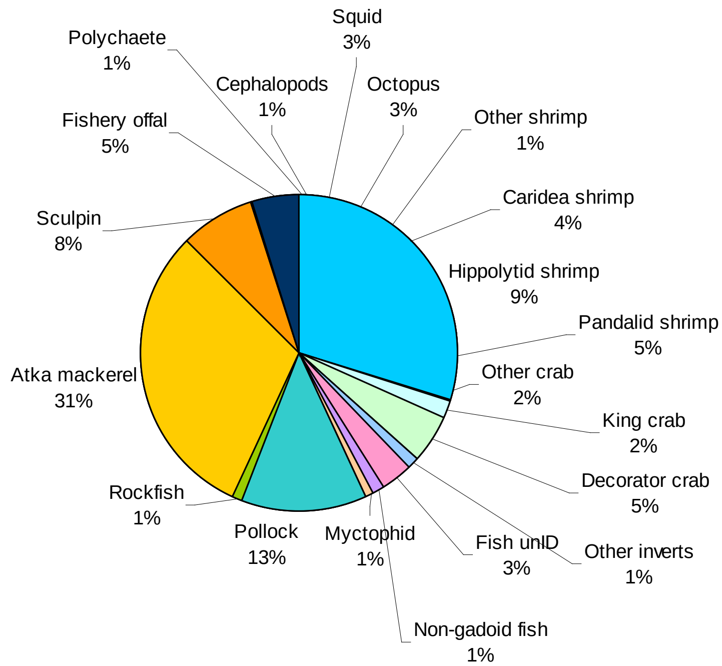



Figure 50. Diet composition (upper panels) and annual estimated prey consumption by skates (lower panels) for AI Alaska skates (left panels) and Other Skates (right panels). Consumption rates were estimated using published diet data from the Kuril Islands (Orlov 1998, 1999) and estimated prey densities.

AI whiteblotched skate (*Bathyraja maculata*)

Diet composition (n = 69 stomachs)




AI Aleutian skate (Bathyraja aleutica)

Diet composition (n = 19 stomachs)

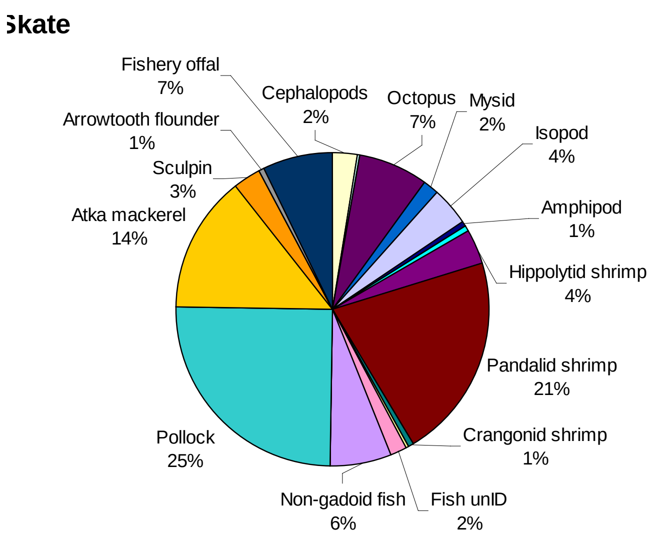



Figure 51. Diet composition (by weight) for the other two biomass-dominant skate species in the Aleutian Islands (AI, which are included in the "Other Skates" group in the previous figure): whiteblotched skate (top) and Aleutian skate (bottom). Results were generated from stomach content collections occurring during trawl surveys, and are described in more detail in Yang (2007).

## Appendix 1: Supplementary catch information

This section is provided to comply with the National Standard guidelines requirement for complete catch accounting. The appendix contains data concerning non-commercial catches of skates (in kilograms) and was obtained from the Alaska regional office.

| | ADFG | | IPHC | NMFS | | | | | | total |
|---|---|---|---|---|---|---|---|---|---|---|
| | larger-mesh trawl survey | misc | annual longline survey | AFSC annual longline survey | EBS shelf bottom trawl survey | EBS slope bottom trawl survey | AI bottom trawl survey | NBS bottom trawl survey | misc | |
| 1988 | | | | 132 | | | | | | 132 |
| 1996 | | | | 5,359 | | | | | | 5,359 |
| 1997 | | | | 14,827 | | | | | | 14,827 |
| 1998 | | | | 10,849 | | | | | | 10,849 |
| 1999 | | | | 14,076 | | | | | | 14,076 |
| 2000 | | | | 8,926 | | | | | | 8,926 |
| 2001 | | | | 14,832 | | | | | | 14,832 |
| 2002 | | | | 8,104 | | | | | | 8,104 |
| 2003 | | | | 17,131 | | | | | | 17,131 |
| 2004 | | | | 6,886 | | | | | | 6,886 |
| 2005 | | | | 14,046 | | | | | | 14,046 |
| 2006 | | | | 10,570 | | | | | | 10,570 |
| 2007 | | | | 22,576 | | | | | | 22,576 |
| 2008 | | | | 11,326 | | | | | 3 | 11,329 |
| 2009 | | | | 7,455 | | | | | | 7,455 |
| 2010 | 232 | 568 | 41,976 | 6,093 | | 9,567 | 7,675 | 4,929 | 31,118 | 102,157 |
| 2011 | 215 | 2 | 25,617 | 5,393 | 34,540 | | | | 21,262 | 87,029 |
| 2012 | 139 | 23 | 27,786 | 7,459 | 29,330 | 17,593 | 4,889 | | 1,080,948 | 1,168,167 |
| 2013 | 138 | | 42,782 | 7,980 | 28,925 | | | | 211 | 80,036 |
| 2014 | 119 | | 55,220 | 11,698 | 29,396 | | 6,166 | | | 102,599 |
| 2015 | 117 | | 42,530 | 5,836 | 33,217 | | | | | 81,701 |
| 2016 | 113 | 96 | 51,004 | 7,760 | 20,498 | 9,191 | 3,941 | | | 92,603 |
| 2017 | 102 | 177 | 42,615 | 8,573 | 21,712 | | | 2,695 | | 75,873 |
| 2018 | 110 | 14 | 30,238 | 9,897 | 21,485 | | 5,114 | 1,543 | 63 | 68,464 |
| 2019 | 146 | | 33,479 | 3,253 | 18,430 | | | 3,179 | 7 | 58,494 |