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) A new time series of skate catches by species was created for this assessment, as well as corresponding exploitation rates by species.
2) Catch data have been updated through October 25, 2018.
3) New biomass estimates from the 2018 eastern Bering Sea (EBS) shelf and Aleutian Islands bottom trawl surveys have been added. The EBS slope survey did not occur in 2018.
4) The Alaska skate model now incorporates EBS shelf survey biomass estimates through 2018, EBS shelf size compositions through 2018, fishery length compositions through 2017, and catch data through 2018.
5) Abundance estimates from the AFSC longline survey have been added to the assessment.

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 2018. This model was approved for use in the 2014 and 2016 assessments.
2) A new method for estimating catches of Alaska skate and the other species in the skate complex was created. Estimates from this method were used in the Alaska skate model and to produce exploitation rates for the skates in the "other skates" group.
3) The random effects (RE) model continues to be used for estimating biomass for the "other skates" group, but in a slightly different way from previous assessments. 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 2017 and 2018 survey biomass estimates.

Summary of results

1) The Alaska skate model produced similar results to the 2016 model run, and harvest recommendations are changed only slightly from last year.
2) Big skate biomass has increased substantially in the southeastern Bering Sea. It is likely these skates are part of the Gulf of Alaska population.

3) Exploitation rates of Bering and big skates exceed 0.1. While this is a concern, there are several reasons why these rates are likely acceptable.
4) Alaska skate is common in the northern Bering Sea survey area, and increased abundance there matches the overall increase in the Alaska skate population.
5) The project 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	2018	2019	2019*	2020*
M (natural mortality rate)	0.13	0.13	0.13	0.13
Tier	3a	3a	3a	3a
Projected total (age 0+)	*478,306*	*452,245*	504,551	481,653
Female spawning biomass (t)				
Projected	*107,136*	*103,953*	115,957	114,010
$B_{100\%}$	*180,556*	*180,556*	177,761	177,761
$B_{40\%}$	*72,222*	*72,222*	71,105	71,105
$B_{35\%}$	*63,195*	*63,195*	62,217	62,217
F_{OFL}	*0.092*	*0.092*	0.094	0.094
$maxF_{ABC}$	*0.079*	*0.079*	0.081	0.081
F_{ABC}	*0.079*	*0.079*	0.081	0.081
OFL (t)	*36,655*	*34,189*	39,173	36,965
maxABC (t)	*31,572*	*29,447*	33,730	31,829
ABC (t)	*31,572*	*29,447*	33,730	31,829
	As determined *last* year for:		As determined *this* year for:	
Status	2016	2017	2017	2018
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 2018 (25,682 t); see the Data-Catch section of the Alaska skate assessment.

other skate harvest recommendations				
	As estimated or specified last year for:		As estimated or recommended this year for:	
Quantity	2018	2019	2019	2020
M (natural mortality rate)	0.1	0.1	0.1	0.1
Tier	5	5	5	5
Biomass (t)	*100,130*	*100,130*	119,787	119,787
F_{OFL}	*0.10*	*0.10*	0.10	0.10
maxF_{ABC}	*0.075*	*0.075*	0.075	0.075
F_{ABC}	*0.075*	*0.075*	0.075	0.075
OFL (t)	*10,013*	*10,013*	11,979	11,979
maxABC (t)	*7,510*	*7,510*	8,984	8,984
ABC (t)	*7,510*	*7,510*	8,984	8,984
	As determined *last* year for:		As determined *this* year for:	
Status	2016	2017	2017	2018
Overfishing	No	n/a	No	n/a

aggregate harvest recommendations for the BSAI complex				
	As estimated or specified *last* year for:		As estimated or recommended this year for:	
Quantity	2018	2019	2019	2020
OFL (t)	*46,668*	*44,202*	51,152	48,944
ABC (t)	*39,082*	*36,957*	42,714	40,813

Responses to SSC and Plan Team Comments on Assessments in General

From the October 2017 SSC minutes

"The SSC recommends that, for those sets of environmental and fisheries observations that support the inference of an impending severe decline in stock biomass, the issue of concern be brought to the SSC, with an integrated analysis of the indices in future stock assessment cycles. To be of greatest value, to the extent possible, this information should be presented at the October Council meeting so that there is sufficient time for the Plan Teams and industry to react to the possible reduction in fishing opportunity."

> *Response*: There were no sets of environmental and fisheries observations that supported an inference of an impending severe decline in the BSAI skate complex or individual species in the BSAI.

"The SSC also recommends explicit consideration and documentation of ecosystem and stock assessment status for each stock ... during the December Council meeting to aid in identifying stocks of concern….Implementation of these stock and ecosystem determinations will be an iterative process and will require a dialogue between the stock assessment authors, Plan Teams, ecosystem modelers, ESR editors, and the SSC."

> *Response*: The author supports this concept and looks forward to participating in the process.

From the November 2017 Joint and BSAI Plan Team minutes
The BSAI Plan Team did not make any comments on assessments in general.

From the December 2017 SSC minutes
"The SSC reminds authors of the need to balance the desire to improve model fit with increased risk of model misspecification….In the absence of strict objective guidelines, the SSC recommends that thorough documentation of model evaluation and the logical basis for changes in model complexity be provided in all cases."

> *Response*: Model evaluation is thoroughly documented in the Model Evaluation.

"Report a consistent metric (or set of metrics) to describe fish condition among assessments and ecosystem documents where possible."

> *Response*: This assessment does not incorporate data on fish condition.

"Projections ... clearly illustrate the lack of uncertainty propagation in the 'proj' program used by assessment authors. The SSC encourages authors to investigate alternative methods for projection that incorporate uncertainty in model parameters in addition to recruitment deviations. Further, the SSC noted that projections made on the basis of fishing mortality rates (Fs) only will tend to underestimate the uncertainty (and perhaps introduce bias if the population distribution is skewed). Instead, a two-stage approach that first includes a projection using F to find the catch associated with that F and then a second projection using that fixed catch may produce differing results that may warrant consideration."

> *Response*: This assessment uses the "proj" program for projections, and no formal changes were made to the stock assessment. However some analysis was performed on projection model outputs under varying reference points and will be presented to the Plan Team in November for discussion. Modifications of the current standard projection code were not completed in time for the final 2018 stock assessments.

From the October SSC 2018 minutes
The SSC did not make any comments on assessments in general that were directed to authors. The general recommendations were for the Plan Teams.

Responses to SSC and Plan Team Comments Specific to this Assessment

From the November 2016 Plan Team minutes
"Investigate appropriate Bmsy proxies for skates and relate the values to current harvest recommendations, for example, most elasmobranchs have Bmsy >= B50%, less productive species have been documented to have Bmsy=B79%. The BSAI skate species are likely between these two extremes."

> *Response*: Alternative reference points for Alaska skate were explored using "proj". Results were not included in this report but will be presented to the Plan Team in November for discussion.

"Examine the utility of including IPHC and AFSC longline survey indices in both Model 14.2 and the random effects model for the Tier 5 species."

> *Response*: Data from these surveys are limited to the EBS slope and Aleutian Islands, and depths greater than 200 m. In addition, species composition in the AFSC longline survey is only available starting in 2009 and Bering, Aleutian, and Alaska skate (3 of the most important species) are still reported in aggregate. Due to these limitations the surveys were not considered

to be useful for inclusion in either the Stock Synthesis or RE modeling efforts. However, data from the AFSC longline survey has been included in the Tier 5 assessment section to provide additional information regarding trends in skate abundance.

"Expand on appendix 2 of the SAFE document by reconciling more explicitly the differences between the results of the 2013 and 2014 assessments with respect to the substantial decreases in FOFL and 2015 spawning biomass and the substantial increase in 2015 OFL."

Response: This analysis was not completed in time for inclusion in this report.

<u>From the December 2016 SSC minutes:</u>
"Re-evaluate the use of trawl survey data to apportion longline. The assessment uses trawl survey species composition to apportion Alaska skate from other skates caught in the longline fishery. Trawl species composition from a survey maybe quite different from species composition in the longline fishery. Speciation in the observer data has improved since the Ormseth and Matta (2007) paper referenced in the assessment. The author should compare the observer data from the longline fishery to the trawl survey catch to evaluate this assumption."

Response: The author has developed a new method for estimating the species composition of skate catches, which was presented to the Plan Team in September 2018 and was utilized in several parts of this assessment.

"The assessment should incorporate relevant information pertaining to the relationship between water temperature and recruitment. Development time for some skate species is influenced by water temperature (i.e., warmer water results in shorter development periods). This may functionally affect recruitment trends and variability."

Response: Previous versions of this report have discussed this issue, particularly in regard to embryo development time and the potential for temperature-driven changes in development time to influence apparent year-class size (i.e. embryos deposited in different years may, as a result of different growth rates, emerge from eggcases at the same time). At this time however there is no realistic way to incorporate this possible effect into the Alaska skate assessment model. In addition, recruitment in the model is not linked to spawning biomass (i.e. it considers only deviations from an average level of recruitment).

"The stock structure section for Alaska skates has conflicting and inaccurate information regarding national standard guidelines. This section needs to be updated."

Response: This section has been updated with references to the most recent version of the guidelines.

<u>From the November 2017 Plan Team minutes</u>
"The Team recommends that the author work with FMA and AKRO staff to investigate species composition."

Response: The author worked with FMA staff to develop a new method for estimating species composition.

"The Team requests that the author examine exploitation rates by species for the complex, in particular the endemic species in the Aleutian Islands (leopard and butterfly skates)."

Response: The Tier 5 assessment portion of this report now includes a thorough analysis of exploitation rates for all skate species in the BSAI.

From the September 2018 Plan Team minutes
"The Team recommends that, although this method appears to be a major improvement, the issue of how species composition may be affected by depth should be examined before the method is adopted. This could be addressed by a simple look at the observer data to see if depth-related differences in species composition exist. The November assessment should therefore include an examination of skate stratification by depth in the observer data."

Response: Species composition of skates is highly stratified by depth, as described at length in the introductory section. Depth information is available for the observer data, but not for catch data from the CAS. The new method relies on identical stratification in both the observer and CAS datasets, so depth cannot be used as a stratum. NMFS statistical areas are largely depth-stratified and therefore serve as a reasonable proxy for depth. The majority of skate catches occur in the catcher-processor (CP) sector, which has 100% observer coverage. As a result area-specific species composition from the observer data is consistently matched with are-specific catch estimates. In addition because there are species composition data from every haul there is actually no need for stratification beyond harvest sector and gear type, although the CP data were stratified by area to provide the highest spatial resolution. In the catcher vessel (CV) sector, because observer coverage is partial there is often a mismatch between area availability of species composition versus catch data (i.e. there is often catch data for an area with no corresponding species composition data). In the original analysis this problem was solved by not using area stratification and accepting a certain amount of error in the result (see Appendix 2). After discussions at the September Plan Team meeting, this decision was revisited and a solution was found by creating larger geographical strata for both datasets by aggregating statistical areas. Aggregations were based on similarity in depth and correspondence with observed skate distributions. This allowed complete matching between the datasets with a couple of minor exceptions. The result is improved, albeit only slightly different, estimates of skate species composition.

"The SSC agrees with the Team and recommends that, although this method appears to be an improvement, further investigation of how species composition is affected by depth should be examined before the method is adopted."

Response: Please see the discussion directly above in response to a similar question from the Plan Team.

Introduction

Contents of this report

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

Description, scientific names, and general distribution

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_∞ = 126.29 cm TL, k = 0.120 year^{-1}, t_0 = -1.39 year) and females (L_∞ = 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

<u>Directed fishery</u>
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.

<u>Bycatch and retention</u>
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.

<u>Species composition of skate catches</u>
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, the model was accepted for use in that year, used again in 2016, and is used in this 2018 assessment. 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	2003-2018
KRO historical catch record	catch	1954-2002
NMFS Bottom Trawl Surveys –Eastern Bering Sea Shelf (Annual)	biomass index	1982- 2018
NMFS Bottom Trawl Surveys –Eastern Bering Sea Shelf (Annual)	length composition	2000-2018
NMFS Bottom Trawl Surveys –Eastern Bering Sea Shelf (Annual)	length-at-age	2003, 2007-2009, 2015
NMFS Fishery Monitoring & Analysis program- observed skate catch	length composition	2009-2017

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 1954-2016. 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 2018 were available only through October 25, so the 2018 data are incomplete. To estimate the full 2018 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 2018 data to estimate full-year 2018 catch.

Fishery length compositions

Fishery length compositions from 2009-2017 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 1982-2018 were included in the model (Table 10). 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 1999-2018 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

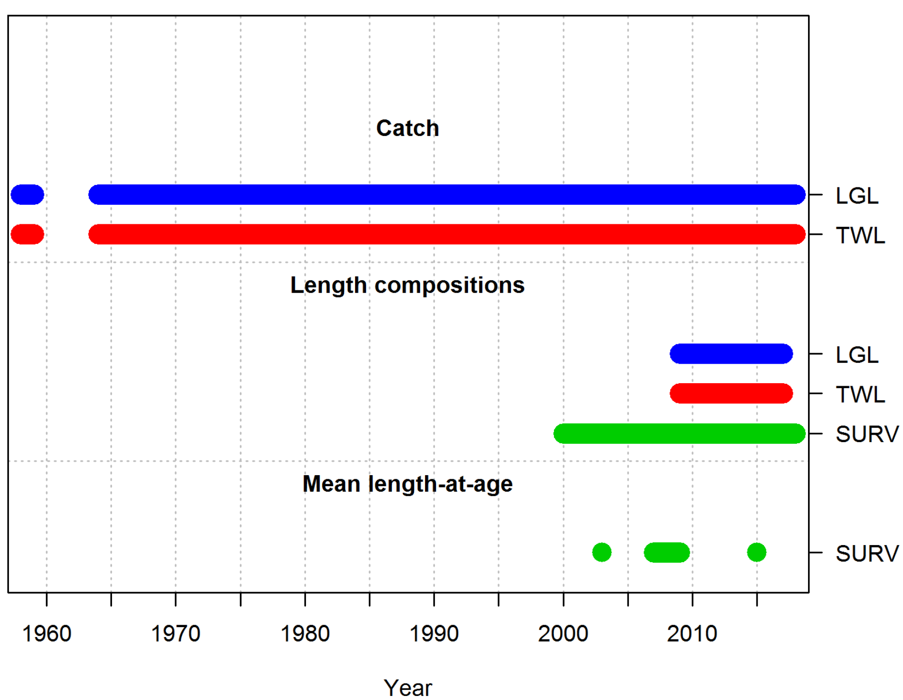
Length composition data from the EBS shelf survey were available from 2000-2018 (Table 11). The survey takes length measurements for every skate in each haul. The haul-specific data are then weighted by the number of skates in each haul to produce an estimate of numbers at length for the entire EBS population. 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

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 at the AFSC.

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 taken regarding 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 is 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 made, these changes had only minor influence on the model.



Summary of data sources included in 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. Unlike previous years, no alternative models are presented but results from the 2016 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.

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:

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

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 true age, the standard deviation of the estimated age was

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[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]

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 obtained through analysis 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 9.0×10^{-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 σ_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 τ_1 and τ_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 τ_1 and τ_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 1950-2018; 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 2016 results for comparison, is located in Table 13. The model was evaluated based on overall quality of fit and comparison of results to the 2016 model run. It was assumed that similar fit to 2016 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), although most of the fitting statistics showed a slightly worse fit than the 2016 model run (Table 13). This appeared to be due to the model not fitting the trawl survey as well as it did in 2016 as well as the inability of the model to predict peaks in recent survey length compositions. The model continues to estimate dome-shaped selectivity for the trawl fishery and survey; in the 2018 run the model also estimates a slight descending limb 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 estimates of ρ and RMSE suggest that, relative to the 2016 run, the 2018 run has a slightly greater retrospective bias in spawning biomass and a slightly lower bias in recruitment. The earliest retrospective years (2007-2008) 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 year 2006 and that year was not included in the analysis.

	$\rho_{\text{rev Mohn}}$	$\rho_{\text{Woods Hole}}$	RMSE
spawning biomass	0.148	0.197	0.176
recruitment	0.060	0.038	0.197

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 1950-2018 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 2018 mode 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 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: $0.05 < B/B_{40\%} < 1$
$F_{OFL} = F_{35\%}$ H $(B/B_{40\%} - 0.05) \times 1/0.95$
$F_{ABC} < F_{40\%}$ H $(B/B_{40\%} - 0.05) \times 1/0.95$
3c) Stock status: B/B40% < 0.05
$F_{OFL} = 0$
$F_{ABC} = 0$

Specification of OFL and ABC
The 2019 estimate of female spawning biomass for BSAI Alaska skates is 115,957 t. The estimate of $B_{40\%}$ is 71,105 t, so $B/B_{40\%}$ is 1.63 and 2019-2020 Alaska skate harvest levels can be assigned according to subtier 3a. Therefore, $F_{OFL}= F_{35\%} = 0.094$ and maximum $F_{ABC}= F_{40\%} = 0.081$. The corresponding 2019 OFL is 39,173 t and maximum allowable ABC is 33,730 t. For 2020, OFL is projected to be 36,965 t and maximum allowable ABC will be 31,829 t. The author recommends setting ABC at the maximum permissible value.

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 2018 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2019 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2018. 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 2017, 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 2016 recommended in the assessment to the max F_{ABC} for 2016. (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 2019 and 2020 is set equal to the estimate of 2018 total catch used in the model.

Scenario 3 (Table 18c): In all future years, F is set equal to the 2014-2018 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 2019 and above its MSY level in 2031 under this scenario, then the stock is not overfished.)

Scenario 7 (Table 18g): In 2019 and 2020, 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 2031, 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. Data regarding species composition of skate catches are in Table 7 and Figures 18 and 19.

Survey

<u>Bottom trawl survey biomass estimates</u>
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 regarding 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 for which it was run; 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 in all years analyzed except for 2007. It is likely that this results 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 2018 RE-model biomass estimates for the other skates group from the EBS shelf (55,568 t), EBS slope (37,840 t), and AI (26,379 t) were combined, equaling a BSAI biomass estimate of 119,787 t. This is ~10% higher than the 2016 estimate. Under Tier 5, $F_{OFL} = M = 0.1$, and OFL = 11,979 t; $F_{ABC} = 0.75*M = .075$, and ABC = 8,984 t.

other skate harvest recommendations				
	As estimated or specified last year for:		As estimated or recommended this year for:	
Quantity	2018	2019	2019	2020
M (natural mortality rate)	0.1	0.1	0.1	0.1
Tier	5	5	5	5
Biomass (t)	100,130	100,130	119,787	119,787
F_{OFL}	0.10	0.10	0.10	0.10
$maxF_{ABC}$	0.075	0.075	0.075	0.075
F_{ABC}	0.075	0.075	0.075	0.075
OFL (t)	10,013	10,013	11,979	11,979
maxABC (t)	7,510	7,510	8,984	8,984
ABC (t)	7,510	7,510	8,984	8,984
	As determined *last* year for:		As determined *this* year for:	
Status	2015	2016	2016	2017
Overfishing	No	n/a	No	n/a

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.
- Skate habitat is only beginning to be described in detail. Current efforts to protect eggcase-containing nursery areas should be supported and additional research is required to gauge the importance of the known nursery areas to skate populations. In addition, the defining characteristics of these nursery habitats need to be described.
- Additional information is required regarding 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, 2011-2018*. 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	23,826	24%
2012	39,100	32,600	24,700	24,827	29%
2013	45,800	38,800	24,000	27,031	29%
2014	41,849	35,383	26,000	27,599	30%
2015	49,575	41,658	25,700	28,266	28%
2016	50,215	42,134	26,000	29,196	23%
2017	49,063	41,144	26,000	31,891	29%
*2018**	46,668	39,082	27,000	*26,368*	*39%*

*2018 data are incomplete; retrieved October 25, 2018

Table 4. Estimated catch (t) of all skate species combined by BSAI area, 1997 - 2018*. 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	22,549	1,277	23,826
2012	23,743	1,084	24,827
2013	25,970	1,061	27,031
2014	26,364	1,235	27,599
2015	26,921	1,345	28,266
2016	27,995	1,201	29,196
2017	30,472	1,420	31,891
*2018**	*24,712*	*1,657*	*26,368*

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

Table 5. Estimated catch (t) of all skate species combined by target fishery, 2003 – 2018*. Source: Alaska Regional Office.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018*
P cod	14,950	18,369	19,456	15,115	13,463	14,311	12,698	11,427	16,692	18,487	20,498	21,894	24,368	25,563	27,514	20,891
YFS	1,524	594	943	1,133	1,409	1,303	1,784	1,904	2,107	2,232	2,683	1,970	1,073	1,295	1,932	2,077
pollock	471	841	732	1,308	1,287	2,758	3,856	1,881	2,353	2,018	1,757	813	824	462	509	584
rock sole	530	500	422	930	996	555	964	1,212	709	634	526	689	284	280	214	284
FHS	625	1,192	839	852	768	663	360	304	112	76	206	272	101	56	90	519
halibut	265	282	130	84	20	1,370	0	24	686	51	332	920	523	354	388	820
Atka	91	143	140	141	153	179	185	246	269	510	345	490	495	662	719	792
G. turbot	221	136	168	121	176	69	209	368	382	357	51	43	209	194	198	100
ATF	103	64	135	282	81	297	191	184	116	207	183	160	98	94	65	14
rockfish	73	23	29	37	72	63	91	53	103	97	232	163	171	139	144	158
sablefish	57	12	26	123	62	41	131	98	140	45	121	109	18	19	8	10
misc	217	94	21	116	70	63	111	3	24	0	2	20	16	20	64	26
KF									92	101	49	57	68	53	35	31
other flat	26	78	42	7	64	2	14	4	3	3	0.1		6	1	8	1
AK plaice				1	2	2	1	5	38	9	45	0	12	3	4	63
total	19,154	22,329	23,084	20,250	18,623	21,677	20,596	17,713	23,826	24,827	27,031	27,599	28,266	29,196	31,891	26,368

*2018 data incomplete; retrieved October 25, 2018.

Table 6. Estimated catch (t) of all skate species combined by reporting area, 2003 – 2018*. Source: Alaska Regional Office.

		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018*
	508	0	0	0	0	0	0	0	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	6,088	6,148	8,259	3,796	1,962	1,819	3,652	4,550
	512	25	205	15	0	0	28	16	13	7	161	50	21	66	4	4	512
	513	2,722	2,747	3,902	2,607	2,321	2,048	2,503	1,872	3,087	1,811	3,412	4,533	5,152	3,668	4,246	3,221
	514	275	67	196	221	445	83	134	78	150	1,588	235	950	1,220	604	224	776
	516	130	408	239	253	398	488	575	664	243	777	968	399	182	121	587	394
EBS	517	2,893	3,020	3,772	2,459	2,175	2,467	3,200	2,822	2,615	3,297	4,729	4,211	4,968	4,306	3,204	1,843
	518	25	6	16	11	5	459	57	42	132	20	54	99	104	83	51	110
	519	184	140	104	69	109	240	56	81	109	122	64	147	107	83	98	147
	521	8,979	10,369	8,513	8,383	7,120	7,755	6,181	6,598	8,690	8,024	7,170	10,833	11,185	12,213	12,987	6,463
	523	304	324	243	282	333	242	264	395	268	1,066	868	656	394	225	157	106
	524	990	1,970	2,116	1,462	1,122	2,426	1,396	1,013	1,161	730	162	720	1,582	4,869	5,262	6,588
	530	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	541	302	466	488	563	340	492	452	465	1,039	776	612	991	869	804	786	996
AI	542	234	280	125	337	400	566	335	453	192	273	363	190	263	173	414	290
	543	118	139	83	67	271	343	419	427	45	35	86	54	213	224	220	371
BSAI total		19,154	22,329	23,084	20,250	18,623	21,677	20,596	17,713	23,826	24,827	27,031	27,599	28,266	29,196	31,891	26,368

*2018 data incomplete; retrieved October 25, 2018.

Table 7a. Skate catch by species for **all gear types** combined, 2007-2017.

skate species	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Alaska	15,861	15,698	16,712	13,116	18,616	19,524	22,074	21,232	21,270	23,141	24,668
Bering	742	2,270	1,662	1,762	1,870	1,832	1,741	2,303	3,123	2,446	3,058
big	422	316	348	729	612	1,102	1,331	1,396	1,210	1,307	1,776
Aleutian	1,026	1,364	1,208	1,234	1,206	1,425	897	1,287	1,385	1,065	1,222
whiteblotched	307	1,730	365	482	971	612	681	980	953	931	890
Commander	185	110	174	164	320	164	191	241	175	181	141
mud	47	144	95	182	157	102	61	42	71	49	61
whitebrow	12	15	19	22	38	27	9	31	13	20	29
egg case	3	12	4	6	8	11	10	16	19	25	24
longnose	3	8	2	15	22	19	31	65	41	27	16
roughtail	10	11	7	18	7	10	6	4	5	4	5
deepsea	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.10
sandpaper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Okhotsk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
butterfly	3.02	0.00	0.16	0.15	0.16	0.00	0.00	0.00	0.00	0.00	0.00

Table 7b. Skate catch by species for **longline gear**, 2007-2017.

	longline										
skate species	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Alaska	8,970	10,031	9,501	7,510	13,161	14,278	16,508	17,398	18,872	20,828	21,617
Bering	637	2,178	1,581	1,725	1,815	1,783	1,688	2,250	3,097	2,425	3,040
big	303	225	258	655	475	999	1,276	1,233	1,032	1,142	1,496
Aleutian	820	1,097	989	1,130	1,059	1,187	745	1,187	1,225	903	1,027
whiteblotched	264	1,597	172	268	648	191	248	359	447	301	299
Commander	184	99	168	158	315	155	190	236	167	174	138
mud	23	111	63	132	114	63	16	14	47	22	35
whitebrow	11	9	16	21	37	24	7	29	11	19	27
egg case	3	1	3	5	3	9	6	14	16	22	22
longnose	1	6	2	6	18	13	21	28	36	12	9
roughtail	9	10	7	18	7	10	6	4	5	4	5
deepsea	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.10*
butterfly	*3.02*	*0.00*	*0.15*	*0.15*	*0.07*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Okhotsk	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
sandpaper	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*

Table 7b. Skate catch by species for **trawl gear** (pelagic and non-pelagic), 2007-2017.

	trawl										
skate species	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Alaska	6,891	5,667	7,211	5,606	5,455	5,246	5,566	3,834	2,398	2,313	3,052
whiteblotched	43	132	193	214	323	422	433	621	505	630	591
big	118	91	89	74	138	102	55	163	178	165	280
Aleutian	206	267	220	103	147	238	152	100	160	163	195
mud	24	33	32	50	43	39	45	28	24	27	26
Bering	105	92	81	37	56	49	53	54	26	21	18
longnose	2	1	0	10	4	5	10	37	6	15	7
Commander	1	11	6	6	4	8	1	5	8	7	3
egg case	0	11	1	0	5	2	4	3	3	4	2
whitebrow	1	6	3	1	1	3	2	3	1	1	2
butterfly	*0.00*	*0.00*	*0.01*	*0.00*	*0.09*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
deepsea	*0.00*	*0.00*	*0.16*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.12*	*0.00*
Okhotsk	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
roughtail	*1.24*	*0.38*	*0.11*	*0.00*	*0.05*	*0.15*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
sandpaper	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*

Table 8. Reconstructed catch data used in the Alaska skate model, by year and gear type. Catch estimates from 2007-2018 use the new catch estimation method are marked in blue bold. Catch estimates for 2018 were incomplete, so the catch as of October 25 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	1987	1,062	3,006
1955	0	0	1988	1,443	4,287
1956	0	0	1989	588	1,752
1957	0	0	1990	688	2,009
1958	8	61	1991	6,246	1,372
1959	21	156	1992	12,586	2,815
1960	0	0	1993	9,072	2,029
1961	0	0	1994	10,554	2,361
1962	0	0	1995	11,050	2,472
1963	0	0	1996	9,381	2,098
1964	43	304	1997	13,059	2,932
1965	150	928	1998	14,100	3,178
1966	130	924	1999	10,288	2,318
1967	537	1,967	2000	13,362	3,055
1968	1,539	9,252	2001	14,244	3,291
1969	690	4,365	2002	15,943	3,571
1970	1,220	6,502	2003	15,580	3,693
1971	856	5,613	2004	16,308	3,892
1972	1,377	4,916	2005	17,661	3,405
1973	3,264	23,062	2006	14,907	3,347
1974	3,700	24,994	**2007**	**8,970**	**6,891**
1975	3,348	22,736	**2008**	**10,031**	**5,667**
1976	1,702	10,897	**2009**	**9,501**	**7,211**
1977	2,559	15,090	**2010**	**7,510**	**5,606**
1978	3,864	25,571	**2011**	**13,161**	**5,455**
1979	2,609	16,207	**2012**	**14,278**	**5,246**
1980	4,578	12,310	**2013**	**16,508**	**5,566**
1981	4,503	12,553	**2014**	**17,398**	**3,834**
1982	2,349	6,437	**2015**	**18,872**	**2,398**
1983	1,971	5,456	**2016**	**20,828**	**2,313**
1984	1,072	2,995	**2017**	**21,617**	**3,052**
1985	1,443	4,045	**2018**	**21,731**	**3,951**
1986	1,301	3,675			

Table 9a. Alaska skate length compositions from the BSAI longline fisheries, 2009-2017. 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
4	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
12	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
20	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
28	0.000	0.000	0.000	0.003	0.000	0.001	0.000	0.001	0.001
32	0.001	0.001	0.000	0.007	0.000	0.002	0.000	0.001	0.001
36	0.001	0.001	0.001	0.010	0.001	0.002	0.000	0.003	0.002
40	0.003	0.002	0.003	0.013	0.002	0.004	0.001	0.005	0.006
44	0.006	0.006	0.007	0.018	0.003	0.005	0.003	0.006	0.009
48	0.011	0.014	0.014	0.021	0.008	0.008	0.006	0.010	0.019
52	0.020	0.024	0.020	0.025	0.013	0.014	0.011	0.015	0.023
56	0.025	0.032	0.027	0.030	0.022	0.021	0.017	0.019	0.022
60	0.034	0.046	0.041	0.041	0.031	0.033	0.030	0.028	0.022
64	0.044	0.056	0.050	0.053	0.038	0.040	0.039	0.038	0.026
68	0.058	0.069	0.064	0.068	0.056	0.055	0.055	0.047	0.038
72	0.063	0.070	0.077	0.072	0.069	0.063	0.059	0.053	0.046
76	0.068	0.062	0.074	0.072	0.079	0.071	0.064	0.058	0.053
80	0.068	0.071	0.077	0.080	0.093	0.083	0.075	0.063	0.062
84	0.067	0.067	0.076	0.077	0.097	0.087	0.081	0.075	0.068
88	0.081	0.071	0.082	0.087	0.105	0.107	0.097	0.090	0.087
92	0.094	0.090	0.095	0.094	0.115	0.125	0.125	0.126	0.125
96	0.124	0.103	0.112	0.098	0.117	0.121	0.135	0.148	0.153
100	0.119	0.104	0.106	0.078	0.089	0.094	0.115	0.121	0.135
104	0.067	0.057	0.049	0.034	0.040	0.043	0.052	0.062	0.066
108	0.030	0.028	0.018	0.013	0.013	0.015	0.019	0.022	0.024
112	0.009	0.013	0.004	0.003	0.003	0.004	0.006	0.005	0.007
116	0.005	0.006	0.001	0.001	0.002	0.001	0.003	0.003	0.003
120	0.001	0.004	0.001	0.001	0.001	0.001	0.003	0.001	0.002
124	0.001	0.001	0.000	0.000	0.000	0.000	0.001	0.001	0.001
128	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
132	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
N	67	65	72	77	85	87	88	80	79

Table 9b. Alaska skate length compositions from the BSAI trawl fisheries, 2009-2017. 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
4	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
12	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.001
16	0.001	0.002	0.000	0.000	0.000	0.000	0.002	0.001	0.001
20	0.003	0.004	0.002	0.002	0.001	0.001	0.003	0.003	0.003
24	0.011	0.011	0.012	0.003	0.006	0.007	0.010	0.007	0.007
28	0.024	0.018	0.020	0.010	0.009	0.012	0.015	0.012	0.007
32	0.034	0.031	0.026	0.011	0.010	0.015	0.032	0.015	0.017
36	0.051	0.037	0.034	0.017	0.020	0.020	0.040	0.024	0.015
40	0.063	0.053	0.049	0.034	0.039	0.031	0.049	0.026	0.027
44	0.064	0.055	0.059	0.042	0.047	0.031	0.046	0.028	0.031
48	0.056	0.050	0.052	0.052	0.050	0.040	0.055	0.042	0.045
52	0.051	0.042	0.047	0.049	0.051	0.041	0.048	0.038	0.043
56	0.044	0.041	0.040	0.043	0.045	0.046	0.043	0.036	0.042
60	0.043	0.043	0.038	0.044	0.042	0.050	0.042	0.048	0.046
64	0.048	0.048	0.039	0.046	0.043	0.046	0.047	0.046	0.044
68	0.049	0.056	0.053	0.054	0.050	0.054	0.052	0.056	0.051
72	0.048	0.053	0.060	0.069	0.055	0.060	0.049	0.056	0.059
76	0.041	0.049	0.059	0.070	0.058	0.051	0.040	0.050	0.058
80	0.052	0.054	0.059	0.080	0.068	0.070	0.061	0.056	0.059
84	0.044	0.054	0.053	0.071	0.069	0.076	0.061	0.063	0.061
88	0.059	0.056	0.060	0.077	0.080	0.087	0.065	0.076	0.078
92	0.059	0.069	0.069	0.073	0.081	0.089	0.083	0.099	0.090
96	0.056	0.068	0.068	0.069	0.077	0.086	0.074	0.102	0.092
100	0.049	0.055	0.058	0.051	0.058	0.055	0.053	0.066	0.069
104	0.029	0.029	0.025	0.022	0.029	0.021	0.021	0.028	0.037
108	0.010	0.013	0.010	0.008	0.007	0.005	0.005	0.012	0.012
112	0.006	0.004	0.002	0.002	0.002	0.002	0.002	0.004	0.004
116	0.002	0.003	0.002	0.000	0.001	0.001	0.001	0.002	0.000
120	0.001	0.001	0.001	0.000	0.001	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
128	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000
132	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000
N	56	61	56	50	61	54	45	45	56

Table 10. Estimates of Alaska skate biomass (t) from the EBS shelf bottom trawl survey, 1982-2018. 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.

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	312,998	0.17
2000	299,151	0.06
2001	402,909	0.06
2002	347,874	0.07
2003	353,600	0.06
2004	402,141	0.05
2005	461,897	0.05
2006	424,465	0.05
2007	458,112	0.07
2008	346,735	0.06
2009	338,823	0.07
2010	351,704	0.06
2011	392,502	0.05
2012	351,608	0.06
2013	375,161	0.07
2014	392,427	0.05
2015	433,406	0.06
2016	531,676	0.04
2017	515,672	0.07
2018	526,671	0.05

Table 11. Alaska skate EBS shelf survey length compositions, 2000-2018. 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.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
N	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200

Table 12. Input parameter values for model 14.2. Where parameters were estimated freely within the model, minimum and maximum bounds are shown.

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)	9.00×10^{-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
	σ_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 2016 run of the model are included for comparison (in *italics*). CV= coefficient of variation.

model number	*14.2*	14.2
Description	*2016 run*	**2018 run**
likelihood components		
survey	*-13.9165*	-7.56
length comps	*100.518*	117.81
LAA	*156.543*	158.94
recruitment	*-41.0821*	-42.35
total	*202.087*	226.86
# of parameters estimated	*91*	94
L_amin	*14.0*	13.98
CV	*0.032*	0.424
L_amax	*102.0*	102.04
CV	*0.003*	0.259
K	*0.38*	0.38
CV	*0.019*	0.007
CV young	*0.35*	0.35
CV	*0.0001*	0.00003
CV old	*0.05*	0.05
CV	*0.052*	0.00004
ln (Rzero)	*10.12*	10.11
CV	*0.004*	0.037
unfished spawning biomass_	*334,622*	331,810
CV	*0.043*	0.040
unfished recruitment	*24,738*	24,585
CV	*0.040*	0.037
RMSE_survey	*0.141*	0.147
% within survey CI	*70.6%*	63.9%
correlation obs-pred	*0.764*	0.761
mean longline input N	*77.3*	77.8
mean longline eff N	*1000.4*	884.2
mean longline effN/N	*12.94*	11.54
mean trawl input N	*54.7*	53.8
mean trawl eff N	*705.4*	896.9
mean trawl effN/N	*12.89*	17.00
mean survey input N	*200.0*	200.0
mean survey eff N	*887.6*	870.1
mean survey effN/N	*4.44*	4.35
mean LAA N	*223.8*	223.8
mean LAA eff N	*2976.2*	3035.3
mean LAA eff N/N	*13.30*	14.32

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 2016 model run are included for comparison.

year	total biomass	spawning biomass		*2016 spawning biomass*	year	total biomass	spawning biomass		*2016 spawning biomass*
		estimate	CV				estimate	CV	
unfished	558,064	331,810	0.040	*334,622*	**1984**	240,236	107,743	0.117	*111,608*
1950	557,958	331,810	0.040	*334,622*	**1985**	262,303	108,852	0.109	*112,613*
1951	557,722	331,810	0.040	*334,622*	**1986**	288,538	110,928	0.101	*114,589*
1952	557,233	331,810	0.040	*334,622*	**1987**	319,419	115,266	0.092	*118,810*
1953	556,305	331,810	0.040	*334,622*	**1988**	352,881	122,722	0.084	*126,101*
1954	554,706	331,810	0.040	*334,622*	**1989**	383,349	133,669	0.080	*136,806*
1955	552,210	331,810	0.040	*334,622*	**1990**	413,085	152,516	0.083	*155,263*
1956	548,675	331,810	0.040	*334,622*	**1991**	436,714	180,475	0.071	*184,447*
1957	544,094	331,810	0.040	*334,622*	**1992**	449,231	206,112	0.067	*211,500*
1958	538,594	331,810	0.040	*334,622*	**1993**	448,441	223,962	0.067	*230,773*
1959	532,312	330,347	0.042	*333,171*	**1994**	447,665	237,975	0.066	*245,935*
1960	525,437	327,905	0.047	*330,754*	**1995**	442,500	244,562	0.066	*253,273*
1961	518,445	324,724	0.053	*327,616*	**1996**	435,361	245,403	0.065	*254,465*
1962	511,297	320,922	0.060	*323,873*	**1997**	430,088	243,814	0.064	*252,926*
1963	504,078	316,757	0.067	*319,781*	**1998**	421,319	237,455	0.064	*246,477*
1964	496,835	312,428	0.072	*315,536*	**1999**	413,225	229,743	0.064	*238,713*
1965	489,240	307,836	0.077	*311,036*	**2000**	412,327	224,932	0.064	*233,977*
1966	480,929	302,793	0.081	*306,096*	**2001**	410,542	217,304	0.065	*226,481*
1967	472,677	297,797	0.084	*301,204*	**2002**	410,563	209,263	0.066	*218,605*
1968	463,040	291,906	0.086	*295,426*	**2003**	411,494	202,256	0.067	*211,840*
1969	445,306	280,824	0.089	*284,504*	**2004**	415,179	198,786	0.066	*208,672*
1970	433,667	273,412	0.090	*277,200*	**2005**	419,866	195,868	0.065	*205,882*
1971	419,726	264,359	0.092	*268,258*	**2006**	425,384	194,515	0.064	*204,521*
1972	407,496	256,190	0.093	*260,177*	**2007**	434,825	196,585	0.064	*206,550*
1973	395,964	248,229	0.093	*252,287*	**2008**	447,995	202,019	0.062	*211,270*
1974	365,126	227,965	0.097	*232,198*	**2009**	462,758	209,451	0.061	*216,781*
1975	333,136	206,590	0.103	*210,961*	**2010**	477,782	215,752	0.061	*221,966*
1976	305,168	187,321	0.108	*191,762*	**2011**	496,953	222,581	0.060	*227,299*
1977	292,119	176,875	0.109	*181,277*	**2012**	510,541	227,663	0.060	*230,952*
1978	275,514	163,922	0.112	*168,290*	**2013**	521,583	235,066	0.059	*236,675*
1979	248,938	144,724	0.119	*149,089*	**2014**	527,119	242,017	0.059	*241,848*
1980	235,108	132,660	0.122	*136,944*	**2015**	529,231	251,250	0.059	*247,994*
1981	226,024	122,480	0.124	*126,660*	**2016**	526,287	258,005	0.059	*251,012*
1982	220,458	113,254	0.125	*117,337*	**2017**	516,211	265,153	0.058	*n/a*
1983	227,153	109,574	0.122	*113,545*	**2018**	499,608	268,836	0.059	*n/a*

Table 15. Time series of age 0 recruits (1000s) predicted by Model 14.2. CV = coefficient of variation. Estimates from the 2016 model run are included for comparison.

year	age-0 recruits		2016 estimate	year	age-0 recruits		2016 estimate
	estimate	CV			estimate	CV	
unfished	24,585	0.037	*24,738*	**1984**	28,615	0.439	*29,749*
1950	21,099	0.391	*21,314*	**1985**	23,955	0.396	*24,665*
1951	20,923	0.389	*21,146*	**1986**	21,627	0.375	*22,110*
1952	20,729	0.387	*20,960*	**1987**	20,725	0.365	*21,084*
1953	20,516	0.385	*20,755*	**1988**	20,613	0.362	*20,945*
1954	20,282	0.383	*20,531*	**1989**	21,064	0.362	*21,495*
1955	20,027	0.381	*20,286*	**1990**	22,085	0.360	*22,792*
1956	19,752	0.378	*20,021*	**1991**	22,090	0.352	*23,074*
1957	19,459	0.375	*19,737*	**1992**	19,316	0.343	*20,170*
1958	19,150	0.372	*19,438*	**1993**	19,567	0.338	*20,368*
1959	18,827	0.369	*19,125*	**1994**	24,591	0.342	*25,555*
1960	18,496	0.366	*18,803*	**1995**	29,992	0.320	*31,018*
1961	18,161	0.363	*18,476*	**1996**	25,957	0.339	*26,491*
1962	17,824	0.359	*18,147*	**1997**	28,451	0.326	*28,839*
1963	17,489	0.356	*17,821*	**1998**	30,770	0.326	*31,319*
1964	17,161	0.353	*17,500*	**1999**	32,682	0.309	*33,493*
1965	16,844	0.349	*17,190*	**2000**	35,048	0.275	*36,177*
1966	16,549	0.346	*16,900*	**2001**	29,650	0.270	*30,427*
1967	16,285	0.344	*16,642*	**2002**	27,099	0.287	*27,572*
1968	16,050	0.341	*16,415*	**2003**	33,563	0.292	*33,819*
1969	15,833	0.339	*16,208*	**2004**	41,296	0.293	*41,340*
1970	15,610	0.337	*15,998*	**2005**	39,230	0.327	*38,579*
1971	15,389	0.334	*15,786*	**2006**	42,814	0.302	*40,668*
1972	15,209	0.332	*15,611*	**2007**	33,834	0.364	*32,152*
1973	15,116	0.331	*15,517*	**2008**	42,632	0.300	*39,826*
1974	15,156	0.331	*15,554*	**2009**	36,146	0.322	*33,109*
1975	15,387	0.333	*15,768*	**2010**	31,319	0.324	*26,151*
1976	15,931	0.337	*16,273*	**2011**	25,893	0.315	*20,293*
1977	16,996	0.344	*17,271*	**2012**	22,890	0.293	*18,655*
1978	18,937	0.359	*19,105*	**2013**	18,057	0.299	*17,476*
1979	22,359	0.384	*22,372*	**2014**	16,538	0.294	*18,571*
1980	28,354	0.434	*28,138*	**2015**	16,160	0.309	*18,429*
1981	39,141	0.541	*38,659*	**2016**	21,150	0.334	*24,738*
1982	52,166	0.596	*56,006*	**2017**	26,170	0.375	*n/a*
1983	37,611	0.532	*39,675*	**2018**	22,516	0.404	*n/a*

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

year	longline	trawl	total F	year	longline	trawl	total F
1958	0.000	0.000	0.000	**1987**	0.016	0.001	0.017
1959	0.000	0.000	0.000	**1988**	0.033	0.002	0.034
1960	0.001	0.000	0.001	**1989**	0.024	0.001	0.025
1961	0.002	0.000	0.003	**1990**	0.028	0.002	0.029
1962	0.002	0.000	0.003	**1991**	0.029	0.002	0.031
1963	0.006	0.000	0.006	**1992**	0.025	0.001	0.027
1964	0.025	0.002	0.027	**1993**	0.036	0.002	0.038
1965	0.012	0.001	0.013	**1994**	0.040	0.002	0.042
1966	0.019	0.002	0.021	**1995**	0.029	0.002	0.031
1967	0.016	0.001	0.018	**1996**	0.037	0.002	0.039
1968	0.016	0.001	0.018	**1997**	0.040	0.002	0.042
1969	0.073	0.006	0.079	**1998**	0.045	0.002	0.047
1970	0.087	0.008	0.094	**1999**	0.044	0.002	0.046
1971	0.086	0.008	0.094	**2000**	0.045	0.002	0.047
1972	0.044	0.004	0.049	**2001**	0.046	0.002	0.048
1973	0.065	0.006	0.071	**2002**	0.040	0.002	0.042
1974	0.119	0.011	0.130	**2003**	0.036	0.002	0.037
1975	0.082	0.008	0.090	**2004**	0.034	0.002	0.035
1976	0.076	0.007	0.083	**2005**	0.034	0.002	0.036
1977	0.080	0.007	0.087	**2006**	0.026	0.001	0.027
1978	0.041	0.003	0.045	**2007**	0.035	0.002	0.036
1979	0.034	0.003	0.036	**2008**	0.036	0.002	0.038
1980	0.017	0.001	0.018	**2009**	0.039	0.002	0.041
1981	0.021	0.001	0.022	**2010**	0.037	0.002	0.039
1982	0.017	0.001	0.018	**2011**	0.037	0.002	0.039
1983	0.012	0.001	0.013	**2012**	0.041	0.002	0.043
1984	0.016	0.001	0.016	**2013**	0.045	0.002	0.048
1985	0.006	0.000	0.006	**2014**	0.050	0.003	0.052
1986	0.006	0.000	0.007				

Table 17a. Numbers at age (1000s), 1950-1984, as 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	21,099	21,588	18,956	16,645	14,616	12,834	11,270	9,896	8,690	7,630	6,700	5,883	5,166	4,536	3,983	3,498	3,071	2,697	2,368	2,080	1,826	1,603	1,408	1,236	1,086	7,820
1951	20,923	18,527	18,956	16,645	14,616	12,834	11,270	9,896	8,690	7,630	6,700	5,883	5,166	4,536	3,983	3,498	3,071	2,697	2,368	2,080	1,826	1,603	1,408	1,236	1,086	7,820
1952	20,729	18,373	16,268	16,645	14,616	12,834	11,270	9,896	8,690	7,630	6,700	5,883	5,166	4,536	3,983	3,498	3,071	2,697	2,368	2,080	1,826	1,603	1,408	1,236	1,086	7,820
1953	20,516	18,202	16,133	14,285	14,616	12,834	11,270	9,896	8,690	7,630	6,700	5,883	5,166	4,536	3,983	3,498	3,071	2,697	2,368	2,080	1,826	1,603	1,408	1,236	1,086	7,820
1954	20,282	18,015	15,983	14,166	12,544	12,834	11,270	9,896	8,690	7,630	6,700	5,883	5,166	4,536	3,983	3,498	3,071	2,697	2,368	2,080	1,826	1,603	1,408	1,236	1,086	7,820
1955	20,027	17,809	15,819	14,035	12,439	11,015	11,270	9,896	8,690	7,630	6,700	5,883	5,166	4,536	3,983	3,498	3,071	2,697	2,368	2,080	1,826	1,603	1,408	1,236	1,086	7,820
1956	19,752	17,586	15,638	13,890	12,324	10,923	9,672	9,896	8,690	7,630	6,700	5,883	5,166	4,536	3,983	3,498	3,071	2,697	2,368	2,080	1,826	1,603	1,408	1,236	1,086	7,820
1957	19,459	17,344	15,442	13,732	12,197	10,822	9,591	8,493	8,690	7,630	6,700	5,883	5,166	4,536	3,983	3,498	3,071	2,697	2,368	2,080	1,826	1,603	1,408	1,236	1,086	7,820
1958	19,150	17,087	15,230	13,559	12,058	10,710	9,502	8,422	7,458	7,630	6,700	5,883	5,166	4,536	3,983	3,498	3,071	2,697	2,368	2,080	1,826	1,603	1,408	1,236	1,086	7,820
1959	18,827	16,815	15,004	13,373	11,906	10,587	9,403	8,343	7,394	6,547	6,699	5,883	5,165	4,536	3,983	3,497	3,071	2,697	2,368	2,079	1,826	1,603	1,408	1,236	1,085	7,819
1960	18,496	16,532	14,765	13,173	11,741	10,452	9,293	8,254	7,323	6,491	5,747	5,880	5,164	4,534	3,981	3,496	3,070	2,696	2,367	2,079	1,825	1,603	1,407	1,236	1,085	7,816
1961	18,161	16,242	14,517	12,965	11,568	10,309	9,177	8,160	7,248	6,430	5,699	5,047	5,164	4,534	3,981	3,496	3,070	2,696	2,367	2,079	1,825	1,603	1,407	1,236	1,085	7,816
1962	17,824	15,947	14,262	12,747	11,384	10,157	9,053	8,059	7,166	6,364	5,647	5,005	4,431	4,534	3,981	3,496	3,070	2,696	2,367	2,079	1,825	1,603	1,407	1,236	1,085	7,816
1963	17,489	15,651	14,003	12,523	11,193	9,997	8,919	7,949	7,076	6,292	5,588	4,958	4,394	3,891	3,981	3,496	3,070	2,696	2,367	2,079	1,825	1,603	1,407	1,236	1,085	7,816
1964	17,161	15,357	13,743	12,296	10,997	9,829	8,778	7,832	6,980	6,214	5,525	4,907	4,354	3,859	3,417	3,496	3,070	2,696	2,367	2,079	1,825	1,603	1,407	1,236	1,085	7,816
1965	16,844	15,069	13,484	12,065	10,793	9,651	8,625	7,702	6,872	6,124	5,452	4,848	4,306	3,820	3,386	2,998	3,068	2,694	2,365	2,077	1,824	1,602	1,406	1,235	1,084	7,811
1966	16,549	14,790	13,229	11,834	10,583	9,461	8,456	7,555	6,747	6,019	5,364	4,775	4,246	3,772	3,347	2,966	2,627	2,688	2,360	2,073	1,820	1,598	1,403	1,232	1,082	7,794
1967	16,285	14,531	12,985	11,610	10,379	9,276	8,290	7,408	6,618	5,909	5,272	4,699	4,183	3,720	3,305	2,932	2,599	2,302	2,355	2,068	1,816	1,595	1,400	1,230	1,080	7,778
1968	16,050	14,300	12,754	11,388	10,169	9,079	8,106	7,239	6,467	5,777	5,158	4,602	4,102	3,652	3,248	2,886	2,561	2,270	2,010	2,057	1,807	1,586	1,393	1,223	1,074	7,738
1969	15,833	14,094	12,529	11,133	9,880	8,767	7,792	6,941	6,192	5,529	4,939	4,412	3,938	3,512	3,129	2,784	2,475	2,197	1,948	1,725	1,765	1,551	1,362	1,196	1,050	7,565
1970	15,610	13,903	12,362	10,970	9,719	8,599	7,613	6,759	6,018	5,368	4,793	4,282	3,826	3,416	3,048	2,716	2,417	2,148	1,907	1,691	1,498	1,533	1,347	1,183	1,039	7,482
1971	15,389	13,707	12,188	10,807	9,546	8,417	7,422	6,559	5,818	5,178	4,619	4,125	3,687	3,295	2,944	2,627	2,342	2,085	1,853	1,646	1,459	1,293	1,323	1,162	1,021	7,353
1972	15,209	13,513	12,018	10,660	9,414	8,281	7,280	6,409	5,661	5,020	4,468	3,986	3,561	3,184	2,847	2,544	2,271	2,025	1,803	1,603	1,423	1,262	1,118	1,145	1,005	7,244
1973	15,116	13,355	11,850	10,516	9,292	8,174	7,169	6,291	5,533	4,885	4,331	3,856	3,441	3,075	2,751	2,460	2,199	1,963	1,751	1,559	1,386	1,231	1,092	967	990	7,135
1974	15,156	13,273	11,651	10,224	8,910	7,728	6,710	5,845	5,115	4,494	3,968	3,522	3,140	2,807	2,513	2,251	2,016	1,804	1,611	1,438	1,281	1,139	1,012	897	795	6,679
1975	15,387	13,309	11,565	10,020	8,606	7,336	6,265	5,396	4,685	4,094	3,598	3,180	2,828	2,526	2,263	2,030	1,821	1,632	1,461	1,307	1,166	1,039	924	821	728	6,067
1976	15,931	13,511	11,597	9,947	8,436	7,088	5,950	5,041	4,327	3,751	3,279	2,885	2,554	2,276	2,037	1,828	1,642	1,475	1,323	1,185	1,060	946	843	750	667	5,518
1977	16,996	13,989	11,817	10,076	8,548	7,168	5,975	4,994	4,223	3,623	3,141	2,747	2,419	2,144	1,912	1,713	1,539	1,383	1,242	1,115	999	894	798	711	633	5,216
1978	18,937	14,924	12,213	10,217	8,573	7,154	5,929	4,911	4,093	3,457	2,966	2,573	2,254	1,988	1,764	1,576	1,413	1,270	1,142	1,027	922	826	739	660	588	4,838
1979	22,359	16,628	12,967	10,424	8,469	6,895	5,633	4,616	3,805	3,166	2,674	2,297	1,998	1,755	1,552	1,381	1,236	1,110	999	899	808	726	651	583	520	4,278
1980	28,354	19,634	14,495	11,166	8,797	7,000	5,615	4,551	3,716	3,059	2,545	2,153	1,852	1,614	1,420	1,258	1,121	1,004	903	813	732	658	591	530	474	3,909
1981	39,141	24,898	17,138	12,528	9,491	7,343	5,760	4,577	3,690	3,005	2,472	2,058	1,742	1,502	1,311	1,155	1,024	914	819	736	663	597	537	483	433	3,579
1982	52,166	34,370	21,726	14,798	10,628	7,900	6,020	4,676	3,695	2,970	2,417	1,990	1,659	1,407	1,214	1,062	937	831	742	665	599	539	486	437	393	3,263
1983	37,611	45,807	30,082	18,913	12,766	9,078	6,695	5,076	3,931	3,102	2,492	2,029	1,671	1,394	1,184	1,022	894	789	701	626	561	505	455	410	369	3,084
1984	28,615	33,026	40,117	26,230	16,370	10,960	7,745	5,687	4,302	3,327	2,624	2,109	1,718	1,416	1,182	1,004	868	760	670	595	532	477	429	387	348	2,935

Table 17b. Numbers at age (1000s), 1985-2018, as 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	23,955	25,127	28,961	35,101	22,865	14,211	9,484	6,687	4,904	3,707	2,866	2,261	1,818	1,481	1,221	1,020	867	749	656	579	514	459	412	371	334	2,835
1986	21,627	21,035	22,028	25,321	30,550	19,801	12,258	8,159	5,743	4,209	3,180	2,460	1,941	1,561	1,273	1,050	877	745	644	564	498	442	395	354	319	2,727
1987	20,725	18,990	18,446	19,275	22,075	26,527	17,138	10,587	7,037	4,951	3,627	2,741	2,121	1,674	1,347	1,098	906	757	644	557	487	430	382	341	306	2,631
1988	20,613	18,199	16,659	16,157	16,838	19,227	23,051	14,869	9,176	6,097	4,289	3,142	2,375	1,838	1,451	1,168	953	786	657	558	483	423	373	332	296	2,548
1989	21,064	18,100	15,961	14,581	14,092	14,632	16,660	19,935	12,845	7,922	5,263	3,703	2,714	2,052	1,588	1,255	1,010	824	680	568	483	418	366	323	287	2,461
1990	22,085	18,496	15,887	13,998	12,771	12,326	12,784	14,546	17,398	11,208	6,912	4,592	3,231	2,368	1,791	1,387	1,095	882	719	593	496	422	365	319	282	2,399
1991	22,090	19,392	16,234	13,932	12,259	11,168	10,766	11,157	12,689	15,174	9,774	6,029	4,006	2,819	2,066	1,563	1,210	956	769	628	518	433	368	318	279	2,340
1992	19,316	19,397	17,021	14,238	12,201	10,708	9,721	9,335	9,644	10,946	13,078	8,422	5,195	3,452	2,429	1,781	1,347	1,043	824	663	541	447	373	317	275	2,258
1993	19,567	16,962	17,017	14,911	12,435	10,601	9,239	8,324	7,944	8,175	9,262	11,061	7,124	4,395	2,921	2,056	1,508	1,141	883	698	562	458	378	316	269	2,146
1994	24,591	17,182	14,884	14,917	13,042	10,837	9,192	7,967	7,146	6,800	6,988	7,915	9,453	6,089	3,758	2,498	1,759	1,290	976	756	597	481	392	324	271	2,066
1995	29,992	21,594	15,075	13,043	13,038	11,350	9,375	7,901	6,812	6,089	5,786	5,944	6,733	8,042	5,182	3,198	2,127	1,497	1,098	831	644	509	409	334	276	1,990
1996	25,957	26,336	18,945	13,209	11,397	11,340	9,809	8,047	6,744	5,794	5,171	4,911	5,045	5,716	6,830	4,402	2,717	1,807	1,272	933	706	547	432	348	284	1,926
1997	28,451	22,793	23,109	16,605	11,550	9,925	9,821	8,446	6,894	5,760	4,942	4,409	4,188	4,303	4,876	5,827	3,756	2,319	1,542	1,086	797	603	467	369	297	1,887
1998	30,770	24,982	19,993	20,238	14,492	10,022	8,546	8,386	7,161	5,820	4,853	4,162	3,713	3,528	3,626	4,110	4,913	3,167	1,956	1,301	916	672	509	394	311	1,842
1999	32,682	27,019	21,911	17,505	17,651	12,560	8,611	7,274	7,083	6,019	4,881	4,068	3,488	3,113	2,959	3,043	3,450	4,124	2,659	1,642	1,092	769	564	427	331	1,809
2000	35,048	28,698	23,705	19,199	15,294	15,349	10,852	7,388	6,205	6,020	5,107	4,140	3,451	2,960	2,642	2,512	2,583	2,929	3,503	2,259	1,395	928	654	480	363	1,817
2001	29,650	30,775	25,171	20,755	16,747	13,258	13,194	9,243	6,245	5,220	5,054	4,285	3,474	2,896	2,485	2,219	2,110	2,171	2,462	2,944	1,898	1,172	780	549	403	1,833
2002	27,099	26,036	26,990	22,034	18,096	14,504	11,378	11,212	7,790	5,237	4,367	4,225	3,583	2,906	2,423	2,080	1,858	1,767	1,818	2,062	2,466	1,590	982	653	460	1,873
2003	33,563	23,795	22,831	23,620	19,198	15,650	12,416	9,634	9,406	6,498	4,357	3,631	3,513	2,980	2,418	2,017	1,732	1,547	1,472	1,514	1,718	2,055	1,325	818	545	1,945
2004	41,296	29,471	20,866	19,980	20,579	16,603	13,400	10,517	8,087	7,852	5,410	3,625	3,022	2,925	2,482	2,015	1,681	1,444	1,290	1,227	1,263	1,433	1,714	1,105	683	2,076
2005	39,230	36,262	25,842	18,258	17,402	17,787	14,202	11,335	8,814	6,738	6,525	4,493	3,011	2,511	2,431	2,064	1,676	1,399	1,201	1,074	1,021	1,051	1,193	1,426	920	2,296
2006	42,814	34,448	31,800	22,618	15,911	15,049	15,218	12,008	9,489	7,332	5,589	5,409	3,725	2,497	2,083	2,017	1,713	1,391	1,161	998	892	849	873	991	1,185	2,672
2007	33,834	37,595	30,213	27,840	19,724	13,783	12,918	12,934	10,122	7,957	6,134	4,674	4,523	3,116	2,089	1,743	1,689	1,435	1,165	973	836	747	711	732	830	3,232
2008	42,632	29,709	32,951	26,401	24,195	17,021	11,807	10,993	10,951	8,545	6,709	5,171	3,941	3,816	2,630	1,764	1,473	1,427	1,213	985	823	707	632	601	619	3,434
2009	36,146	37,435	26,048	28,819	22,983	20,929	14,618	10,070	9,326	9,260	7,215	5,663	4,366	3,329	3,225	2,223	1,492	1,246	1,208	1,026	833	696	598	535	509	3,430
2010	31,319	31,740	32,812	22,764	25,050	19,839	17,935	12,445	8,530	7,876	7,810	6,084	4,777	3,685	2,811	2,724	1,879	1,261	1,053	1,021	868	705	589	506	452	3,332
2011	25,893	27,501	27,833	28,709	19,837	21,716	17,104	15,385	10,635	7,273	6,708	6,652	5,183	4,071	3,142	2,397	2,324	1,603	1,076	899	872	741	602	503	432	3,230
2012	22,890	22,736	24,115	24,351	25,009	17,171	18,652	14,577	13,029	8,971	6,125	5,648	5,601	4,366	3,431	2,648	2,021	1,960	1,352	908	758	735	625	508	424	3,090
2013	18,057	20,100	19,938	21,102	21,220	21,655	14,751	15,894	12,340	10,985	7,550	5,153	4,752	4,714	3,676	2,890	2,231	1,703	1,652	1,140	765	639	620	527	428	2,963
2014	16,538	15,856	17,624	17,444	18,379	18,355	18,568	12,534	13,406	10,361	9,205	6,324	4,316	3,982	3,952	3,083	2,424	1,872	1,430	1,386	957	643	537	520	442	2,847
2015	16,160	14,522	13,908	15,434	15,220	15,940	15,785	15,825	10,602	11,286	8,703	7,728	5,310	3,625	3,345	3,321	2,592	2,038	1,574	1,202	1,166	805	540	451	438	2,767
2016	21,150	14,190	12,741	12,187	13,485	13,224	13,733	13,472	13,397	8,930	9,484	7,309	6,490	4,460	3,046	2,811	2,792	2,179	1,714	1,324	1,011	981	677	455	380	2,695
2017	26,170	18,572	12,449	11,164	10,646	11,708	11,377	11,693	11,369	11,242	7,474	7,932	6,113	5,429	3,732	2,549	2,354	2,338	1,824	1,435	1,109	847	821	567	381	2,576
2018	22,516	22,980	16,290	10,903	9,742	9,227	10,048	9,656	9,830	9,502	9,371	6,225	6,607	5,093	4,525	3,111	2,126	1,963	1,950	1,522	1,197	925	706	685	473	2,467

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
2019	25,682	25,682	25,682	25,682	0
2020	25,682	25,682	25,682	25,682	0
2021	29,931	29,946	29,949	29,968	12
2022	27,926	27,986	27,993	28,069	46
2023	26,329	26,496	26,517	26,728	135
2024	25,088	25,466	25,511	26,002	301
2025	24,169	24,815	24,912	25,804	529
2026	23,469	24,544	24,623	25,821	771
2027	23,097	24,485	24,544	25,998	991
2028	22,194	24,066	24,197	26,154	1,367
2029	21,497	23,680	23,853	26,322	1,655
2030	21,241	23,764	23,880	26,912	1,889
2031	21,297	24,133	24,113	27,408	2,056

projected female spawning biomass (t) – Scenario 1					
year	L90%CI	median	mean	U90%CI	SD
2019	115,957	115,957	115,957	115,957	0
2020	114,010	114,010	114,010	114,011	0
2021	109,644	109,644	109,645	109,645	1
2022	103,117	103,118	103,118	103,119	0
2023	95,929	95,930	95,930	95,931	0
2024	88,716	88,717	88,718	88,719	1
2025	82,124	82,143	82,146	82,170	15
2026	76,576	76,698	76,717	76,877	98
2027	72,159	72,602	72,656	73,221	347
2028	68,852	69,837	69,970	71,237	796
2029	66,601	68,261	68,519	70,751	1,367
2030	65,102	67,794	68,001	70,999	1,945
2031	64,477	67,976	68,074	71,570	2,439

projected fishing mortality rate – Scenario 1					
year	L90%CI	median	mean	U90%CI	SD
2019	0.061	0.061	0.061	0.061	0.000
2020	0.065	0.065	0.065	0.065	0.000
2021	0.081	0.081	0.081	0.081	0.000
2022	0.081	0.081	0.081	0.081	0.000
2023	0.081	0.081	0.081	0.081	0.000
2024	0.081	0.081	0.081	0.081	0.000
2025	0.081	0.081	0.081	0.081	0.000
2026	0.081	0.081	0.081	0.081	0.000
2027	0.081	0.081	0.081	0.081	0.000
2028	0.078	0.079	0.079	0.081	0.001
2029	0.075	0.077	0.078	0.080	0.002
2030	0.074	0.077	0.077	0.081	0.002
2031	0.073	0.077	0.077	0.081	0.003

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
2019	25,682	25,682	25,682	25,682	0
2020	25,682	25,682	25,682	25,682	0
2021	29,931	29,946	29,949	29,968	12
2022	27,926	27,986	27,993	28,069	46
2023	26,329	26,496	26,517	26,728	135
2024	25,088	25,466	25,511	26,002	301
2025	24,169	24,815	24,912	25,804	529
2026	23,469	24,544	24,623	25,821	771
2027	23,097	24,485	24,544	25,998	991
2028	22,194	24,066	24,197	26,154	1,367
2029	21,497	23,680	23,853	26,322	1,655
2030	21,241	23,764	23,880	26,912	1,889
2031	21,297	24,133	24,113	27,408	2,056

projected female spawning biomass - Scenario 2					
year	L90%CI	median	mean	U90%CI	SD
2019	115,957	115,957	115,957	115,957	0
2020	114,010	114,010	114,010	114,011	0
2021	109,644	109,644	109,645	109,645	1
2022	103,117	103,118	103,118	103,119	0
2023	95,929	95,930	95,930	95,931	0
2024	88,716	88,717	88,718	88,719	1
2025	82,124	82,143	82,146	82,170	15
2026	76,576	76,698	76,717	76,877	98
2027	72,159	72,602	72,656	73,221	347
2028	68,852	69,837	69,970	71,237	796
2029	66,601	68,261	68,519	70,751	1,367
2030	65,102	67,794	68,001	70,999	1,945
2031	64,477	67,976	68,074	71,570	2,439

projected fishing mortality rate - Scenario 2					
year	L90%CI	median	mean	U90%CI	SD
2019	0.058	0.058	0.058	0.058	0.000
2020	0.061	0.061	0.061	0.061	0.000
2021	0.065	0.065	0.065	0.065	0.000
2022	0.081	0.081	0.081	0.081	0.000
2023	0.081	0.081	0.081	0.081	0.000
2024	0.081	0.081	0.081	0.081	0.000
2025	0.081	0.081	0.081	0.081	0.000
2026	0.081	0.081	0.081	0.081	0.000
2027	0.081	0.081	0.081	0.081	0.000
2028	0.081	0.081	0.081	0.081	0.000
2029	0.078	0.079	0.079	0.081	0.001
2030	0.075	0.077	0.078	0.080	0.002
2031	0.074	0.077	0.077	0.081	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
2019	25,682	25,682	25,682	25,682	0
2020	25,682	25,682	25,682	25,682	0
2021	16,581	16,589	16,590	16,601	7
2022	15,976	16,008	16,012	16,054	25
2023	15,516	15,608	15,620	15,736	74
2024	15,187	15,398	15,423	15,697	168
2025	14,980	15,344	15,401	15,902	300
2026	14,853	15,468	15,511	16,207	446
2027	14,862	15,687	15,707	16,574	583
2028	14,936	15,888	15,950	16,917	707
2029	15,019	16,137	16,212	17,558	816
2030	15,243	16,434	16,476	17,872	908
2031	15,461	16,612	16,724	18,507	976

projected female spawning biomass (t) - Scenario 3					
year	L90%CI	median	mean	U90%CI	SD
2019	115,957	115,957	115,957	115,957	0
2020	114,010	114,010	114,010	114,011	0
2021	111,270	111,271	111,271	111,272	1
2022	108,408	108,408	108,408	108,409	1
2023	104,454	104,454	104,454	104,455	0
2024	99,997	99,999	99,999	100,001	1
2025	95,722	95,742	95,745	95,770	16
2026	92,142	92,273	92,293	92,464	105
2027	89,433	89,922	89,982	90,607	383
2028	87,555	88,713	88,868	90,335	935
2029	86,378	88,498	88,801	91,566	1,723
2030	85,767	89,169	89,518	93,592	2,599
2031	85,792	90,571	90,725	95,840	3,423

projected fishing mortality rate - Scenario 3					
year	L90%CI	median	mean	U90%CI	SD
2019	0.061	0.061	0.061	0.061	0.000
2020	0.065	0.065	0.065	0.065	0.000
2021	0.044	0.044	0.044	0.044	0.000
2022	0.044	0.044	0.044	0.044	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

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

2019	25,682	25,682	25,682	25,682	0
2020	25,682	25,682	25,682	25,682	0
2021	15,953	15,961	15,963	15,973	6
2022	15,394	15,425	15,429	15,469	24
2023	14,972	15,061	15,072	15,183	72
2024	14,673	14,875	14,900	15,163	161
2025	14,488	14,839	14,894	15,377	289
2026	14,381	14,973	15,014	15,686	430
2027	14,401	15,197	15,215	16,053	563
2028	14,482	15,401	15,461	16,396	682
2029	14,571	15,651	15,724	17,019	788
2030	14,795	15,949	15,987	17,333	878
2031	15,012	16,129	16,235	17,965	945

projected female spawning biomass (t) - Scenario 4					
year	L90%CI	median	mean	U90%CI	SD
2019	115,957	115,957	115,957	115,957	0
2020	114,010	114,010	114,010	114,011	0
2021	111,346	111,346	111,346	111,347	1
2022	108,658	108,659	108,659	108,660	1
2023	104,865	104,866	104,866	104,867	0
2024	100,552	100,554	100,554	100,556	1
2025	96,402	96,422	96,425	96,450	16
2026	92,934	93,065	93,085	93,257	106
2027	90,326	90,817	90,878	91,506	385
2028	88,540	89,705	89,861	91,336	940
2029	87,446	89,583	89,888	92,674	1,736
2030	86,915	90,339	90,696	94,807	2,622
2031	87,012	91,831	91,990	97,159	3,457

projected fishing mortality rate - Scenario 4					
year	L90%CI	median	mean	U90%CI	SD
2019	0.061	0.061	0.061	0.061	0.000
2020	0.065	0.065	0.065	0.065	0.000
2021	0.042	0.042	0.042	0.042	0.000
2022	0.042	0.042	0.042	0.042	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

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
2019	0	0	0	0	0

2020	0	0	0	0	0
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

projected female spawning biomass (t) - Scenario 5					
year	L90%CI	median	mean	U90%CI	SD
2019	115,957	115,957	115,957	115,957	0
2020	114,010	114,010	114,010	114,011	0
2021	113,249	113,250	113,250	113,251	1
2022	115,102	115,103	115,103	115,104	1
2023	115,668	115,668	115,668	115,669	1
2024	115,418	115,420	115,420	115,422	1
2025	115,020	115,041	115,044	115,071	17
2026	115,051	115,193	115,215	115,401	114
2027	115,754	116,303	116,373	117,077	432
2028	117,119	118,470	118,650	120,385	1,093
2029	118,988	121,570	121,936	125,306	2,093
2030	121,358	125,476	125,962	131,121	3,268
2031	123,967	130,114	130,399	137,124	4,434

projected fishing mortality rate - Scenario 5					
year	L90%CI	median	mean	U90%CI	SD
2019	0.000	0.000	0.000	0.000	0.000
2020	0.000	0.000	0.000	0.000	0.000
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

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
2019	39,173	39,173	39,173	39,173	0
2020	35,872	35,875	35,876	35,880	3

2021	32,913	32,930	32,933	32,956	14
2022	30,459	30,528	30,537	30,625	54
2023	28,537	28,732	28,756	29,002	157
2024	27,069	27,507	27,560	28,127	349
2025	26,000	26,746	26,856	27,879	609
2026	24,135	25,334	25,427	26,795	874
2027	22,456	24,005	24,062	25,757	1,117
2028	21,497	23,365	23,509	25,543	1,393
2029	21,117	23,356	23,531	26,013	1,700
2030	21,186	23,775	23,919	27,276	2,005
2031	21,508	24,431	24,492	28,033	2,267

projected female spawning biomass (t) - Scenario 6					
year	L90%CI	median	mean	U90%CI	SD
2019	114,413	114,413	114,413	114,413	0
2020	109,098	109,098	109,098	109,098	0
2021	102,642	102,642	102,642	102,642	0
2022	95,323	95,323	95,323	95,323	0
2023	87,618	87,618	87,618	87,618	0
2024	80,135	80,136	80,136	80,137	1
2025	73,466	73,484	73,487	73,510	15
2026	68,075	68,190	68,207	68,357	92
2027	64,156	64,561	64,610	65,122	317
2028	61,533	62,448	62,569	63,752	734
2029	59,941	61,516	61,744	63,877	1,284
2030	59,015	61,573	61,763	64,575	1,833
2031	58,848	62,296	62,285	65,470	2,288

projected fishing mortality rate - Scenario 6					
year	L90%CI	median	mean	U90%CI	SD
2019	0.092	0.092	0.092	0.092	0.000
2020	0.094	0.094	0.094	0.094	0.000
2021	0.094	0.094	0.094	0.094	0.000
2022	0.094	0.094	0.094	0.094	0.000
2023	0.094	0.094	0.094	0.094	0.000
2024	0.094	0.094	0.094	0.094	0.000
2025	0.094	0.094	0.094	0.094	0.000
2026	0.094	0.094	0.094	0.094	0.000
2027	0.090	0.090	0.090	0.091	0.000
2028	0.085	0.085	0.085	0.086	0.000
2029	0.081	0.082	0.082	0.084	0.001
2030	0.079	0.081	0.081	0.084	0.002
2031	0.077	0.081	0.081	0.085	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	33,730	33,730	33,730	33,730	0
2020	31,265	31,268	31,269	31,273	2
2021	33,699	33,716	33,719	33,742	14

2022	31,136	31,205	31,214	31,302	54
2023	29,113	29,307	29,331	29,577	157
2024	27,552	27,990	28,042	28,610	349
2025	26,401	27,147	27,257	28,281	609
2026	24,980	26,205	26,300	27,698	893
2027	23,065	24,641	24,696	26,417	1,134
2028	21,934	23,819	23,964	26,015	1,406
2029	21,421	23,672	23,847	26,339	1,708
2030	21,386	23,971	24,126	27,505	2,007
2031	21,637	24,549	24,614	28,143	2,265

projected female spawning biomass (t) - Scenario 7

year	L90%CI	median	mean	U90%CI	SD
2019	115,039	115,039	115,039	115,039	0
2020	111,140	111,140	111,140	111,140	0
2021	105,358	105,358	105,358	105,358	0
2022	97,826	97,826	97,826	97,826	0
2023	89,881	89,881	89,881	89,881	0
2024	82,146	82,147	82,147	82,148	1
2025	75,221	75,240	75,242	75,266	15
2026	69,531	69,646	69,663	69,813	92
2027	65,279	65,683	65,732	66,242	316
2028	62,383	63,294	63,415	64,592	731
2029	60,566	62,132	62,359	64,482	1,277
2030	59,457	62,000	62,189	64,985	1,822
2031	59,144	62,569	62,559	65,724	2,275

projected fishing mortality rate - Scenario 7

year	L90%CI	median	mean	U90%CI	SD
2019	0.081	0.081	0.081	0.081	0.000
2020	0.081	0.081	0.081	0.081	0.000
2021	0.094	0.094	0.094	0.094	0.000
2022	0.094	0.094	0.094	0.094	0.000
2023	0.094	0.094	0.094	0.094	0.000
2024	0.094	0.094	0.094	0.094	0.000
2025	0.094	0.094	0.094	0.094	0.000
2026	0.092	0.092	0.092	0.093	0.000
2027	0.086	0.087	0.087	0.088	0.000
2028	0.082	0.083	0.084	0.085	0.001
2029	0.080	0.082	0.082	0.085	0.002
2030	0.078	0.082	0.082	0.086	0.003
2031	0.078	0.082	0.082	0.087	0.003

Table 19. Survey biomass estimates for all skates in the BSAI. * Before 1987, the EBS shelf survey did not sample strata 82 and 90 in the northwest EBS. ** 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	
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	

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

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

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

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

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.

	Bering		big		Alaska		Aleutian		minor species	
	estimate	CV	estimate	CV	estimate	CV	estimate	CV	estimate	CV
2000	14,158	0.11	2,625	0.49	327,088	0.05	2,283	0.40	638	0.28
2001	13,687	0.09	2,091	0.40	388,404	0.05	2,326	0.39	443	0.29
2002	13,093	0.08	1,758	0.37	372,678	0.05	3,615	0.31	1,073	0.36
2003	12,597	0.07	1,626	0.43	380,320	0.04	7,130	0.37	963	0.19
2004	11,755	0.07	1,505	0.39	424,191	0.04	4,267	0.29	976	0.49
2005	11,152	0.08	1,699	0.36	469,736	0.04	5,376	0.33	989	0.44
2006	11,068	0.07	1,679	0.37	443,944	0.04	4,858	0.29	641	0.43
2007	10,788	0.08	2,075	0.36	445,203	0.06	3,656	0.30	911	0.50
2008	10,911	0.08	2,705	0.34	374,624	0.05	3,988	0.32	617	0.36
2009	11,253	0.07	3,418	0.32	359,555	0.05	3,072	0.32	371	0.47
2010	11,287	0.07	3,471	0.34	371,263	0.05	3,322	0.27	291	0.48
2011	11,139	0.08	3,538	0.36	399,326	0.04	3,571	0.33	339	0.37
2012	11,272	0.08	3,053	0.41	379,442	0.05	5,096	0.27	572	0.40
2013	11,638	0.08	4,020	0.40	389,855	0.05	8,761	0.27	476	0.52
2014	11,983	0.07	5,530	0.35	409,658	0.04	9,208	0.28	396	0.46
2015	12,197	0.07	9,734	0.31	455,618	0.05	11,445	0.27	571	0.39
2016	12,411	0.07	11,686	0.31	537,765	0.04	14,893	0.22	753	0.31
2017	13,170	0.08	14,928	0.28	543,236	0.05	21,237	0.33	592	0.44
2018	13,599	0.09	20,951	0.35	545,529	0.04	19,665	0.29	1,353	0.36

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.

	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
2017	2,296	0.19	735		2,205		21,488		4,765		4,683		1,496		9,085		172	
2018	2,296	0.19	735		2,205		21,488		4,765		4,683		1,496		9,085		172	

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.

	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, 2002-2018 (i.e. all groups included in Table 21 with the exception of Alaska skate). The 2018 total BSAI estimate was used for harvest recommendations.

	total EBS shelf	total EBS slope	total AI	total BSAI
2002	19,539	31,523	32,973	84,036
2003	22,316	31,275	36,666	90,257
2004	18,502	31,040	40,807	90,349
2005	19,215	31,495	43,019	93,730
2006	18,246	31,962	45,363	95,572
2007	17,429	32,441	44,889	94,760
2008	18,222	32,932	44,482	95,635
2009	18,114	33,804	44,138	96,056
2010	18,371	34,706	43,857	96,934
2011	18,587	35,818	40,343	94,748
2012	19,993	36,973	37,132	94,098
2013	24,894	37,165	35,836	97,895
2014	27,117	37,373	34,815	99,305
2015	33,947	37,599	31,118	102,664
2016	39,744	37,840	27,918	105,501
2017	49,926	37,840	27,041	114,807
2018	55,568	37,840	26,379	119,787

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 and big skates based on biomass estimates from the random-effect model.

		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Bering BSAI	biomass	13,312	13,498	13,939	14,082	14,053	14,315	14,514	14,704	14,726	14,769	15,533
	catch	742	2,270	1,662	1,762	1,870	1,832	1,741	2,303	3,123	2,446	3,058
	exploitation rate	0.056	0.168	0.119	0.125	0.133	0.128	0.120	0.157	0.212	0.166	0.197
big BSAI	biomass	2,493	3,124	3,837	3,890	3,957	3,472	4,438	5,949	10,153	12,105	15,346
	catch	422	316	348	729	612	1,102	1,331	1,396	1,210	1,307	1,776
	exploitation rate	0.169	0.101	0.091	0.187	0.155	0.317	0.300	0.235	0.119	0.108	0.116
big GOA	biomass	41,449	42,080	42,921	44,893	47,669	45,684	44,091	44,683	45,680	41,448	37,975
	catch	1,594	1,418	2,082	2,517	2,312	2,006	2,520	1,671	1,519	2,100	1,510
	exploitation rate	0.038	0.034	0.049	0.056	0.048	0.044	0.057	0.037	0.033	0.051	0.040
big BSAI + GOA	biomass	43,943	45,204	46,758	48,783	51,626	49,155	48,529	50,632	55,833	53,553	53,321
	catch	2,016	1,734	2,429	3,246	2,924	3,108	3,851	3,067	2,728	3,407	3,286
	exploitation rate	0.046	0.038	0.052	0.067	0.057	0.063	0.079	0.061	0.049	0.064	0.062

Figures

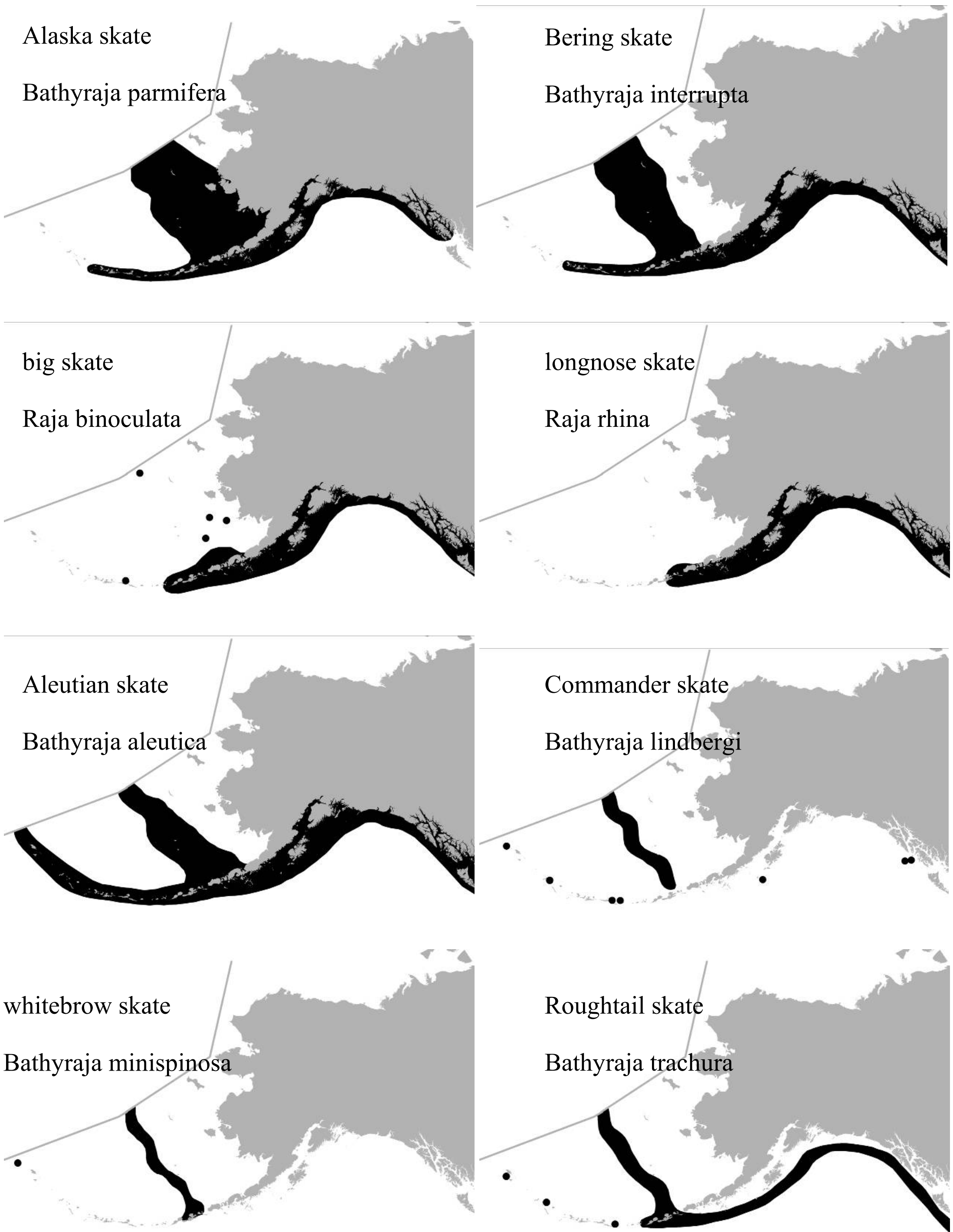


Figure 1. Distribution of skate species in Alaskan waters. These maps were created primarily using survey data, although observer records were included whenever positive species identification was possible (through voucher specimens or photographs). (Source: Stevenson et al. 2007)

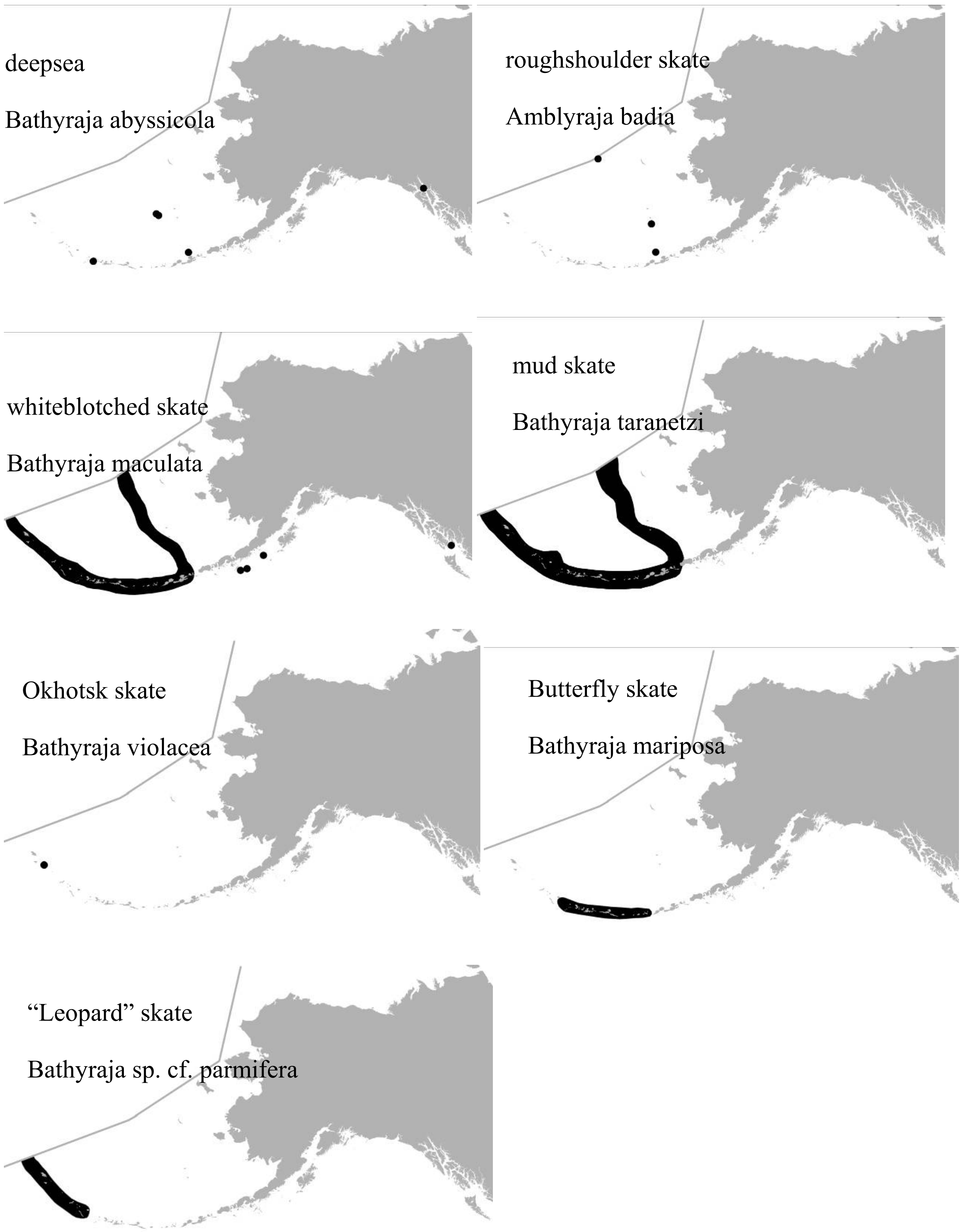


Figure 1 continued. Distribution of skate species in Alaskan waters. (Source: Stevenson et al. 2007)

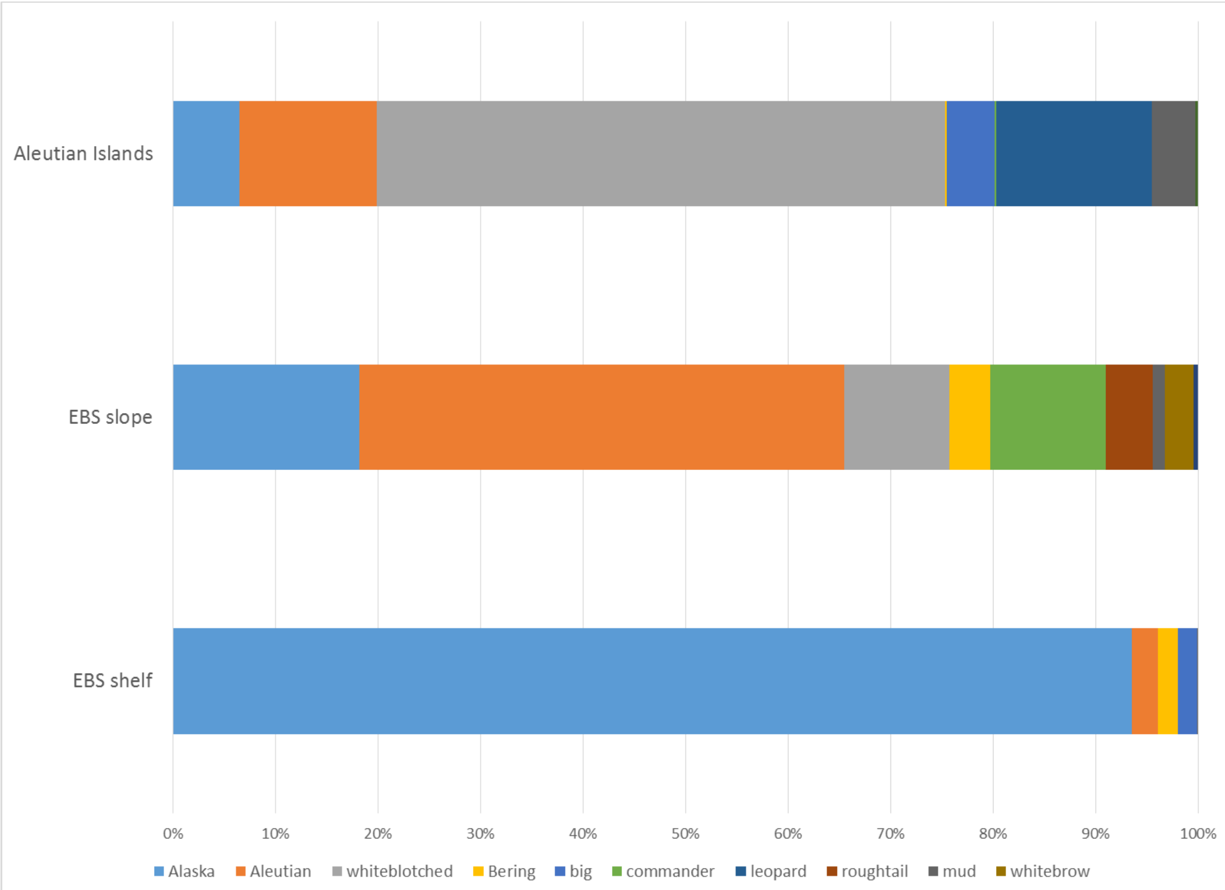


Figure 2. Skate species composition (by weight) in 2016 for the Aleutian Islands, eastern Bering Sea (EBS) slope, and EBS shelf. Data are from AFSC bottom-trawl surveys conducted in each region during 2016, the most recent year in which all 3 surveys in the BSAI were conducted in the same year.

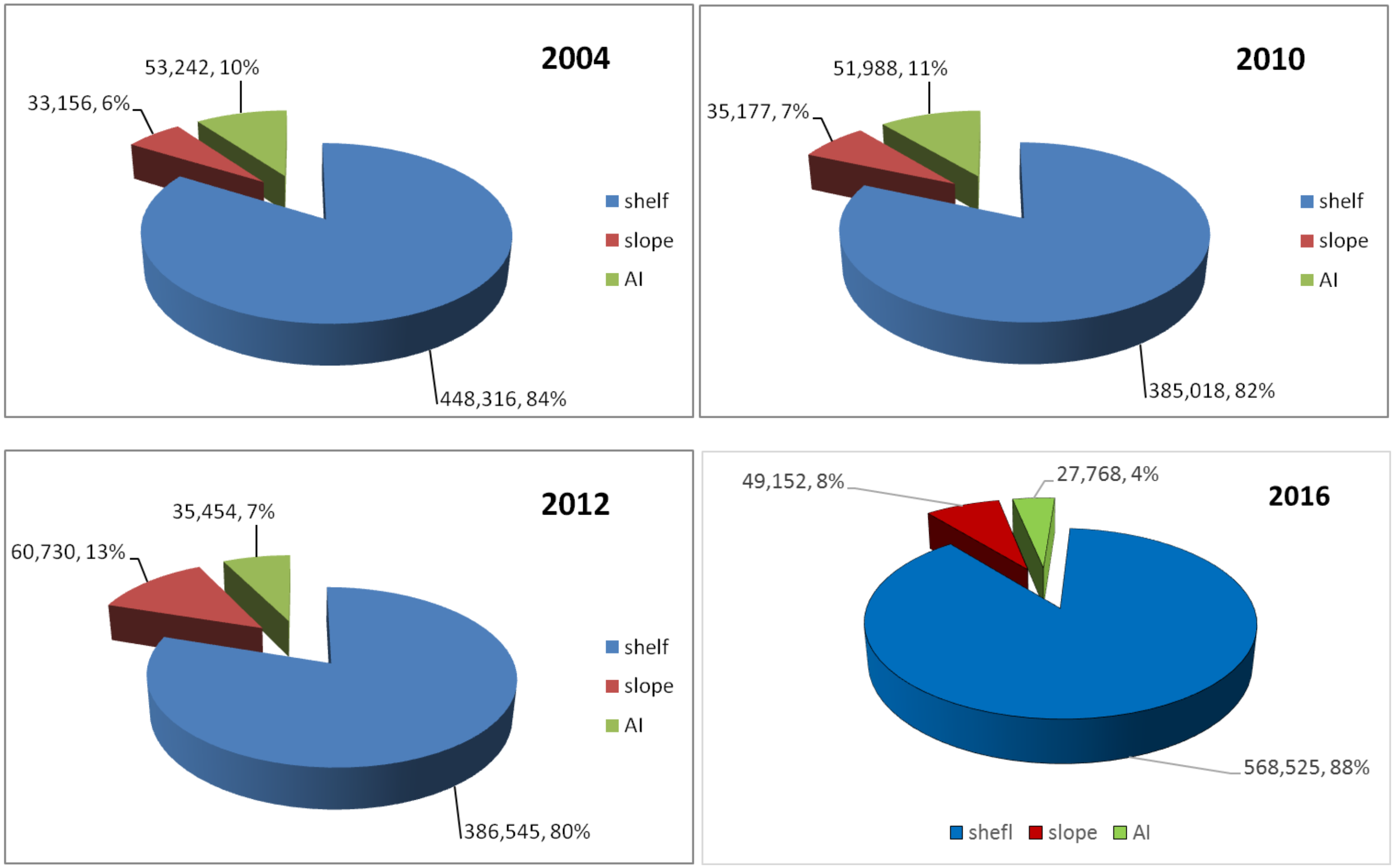


Figure 3. Distribution of skate biomass in the 3 subregions of the BSAI in 2004, 2010, 2012, and 2016 (2016 is the most recent year when all 3 surveys in the BSAI were conducted in the same year). Data are biomass estimates (t) and relative proportions from AFSC groundfish surveys.

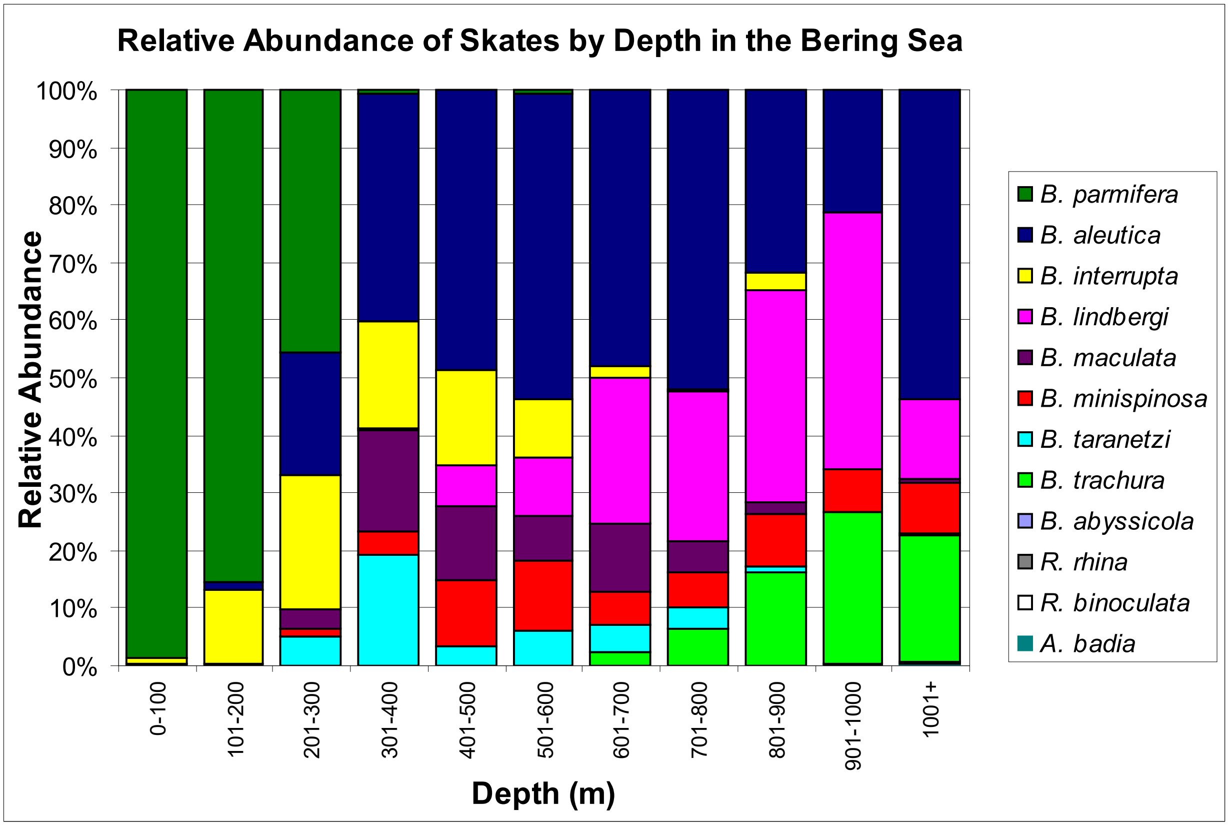


Figure 4. Relative abundance of skate species in the EBS by depth. (Source: Stevenson et al. 2006.)

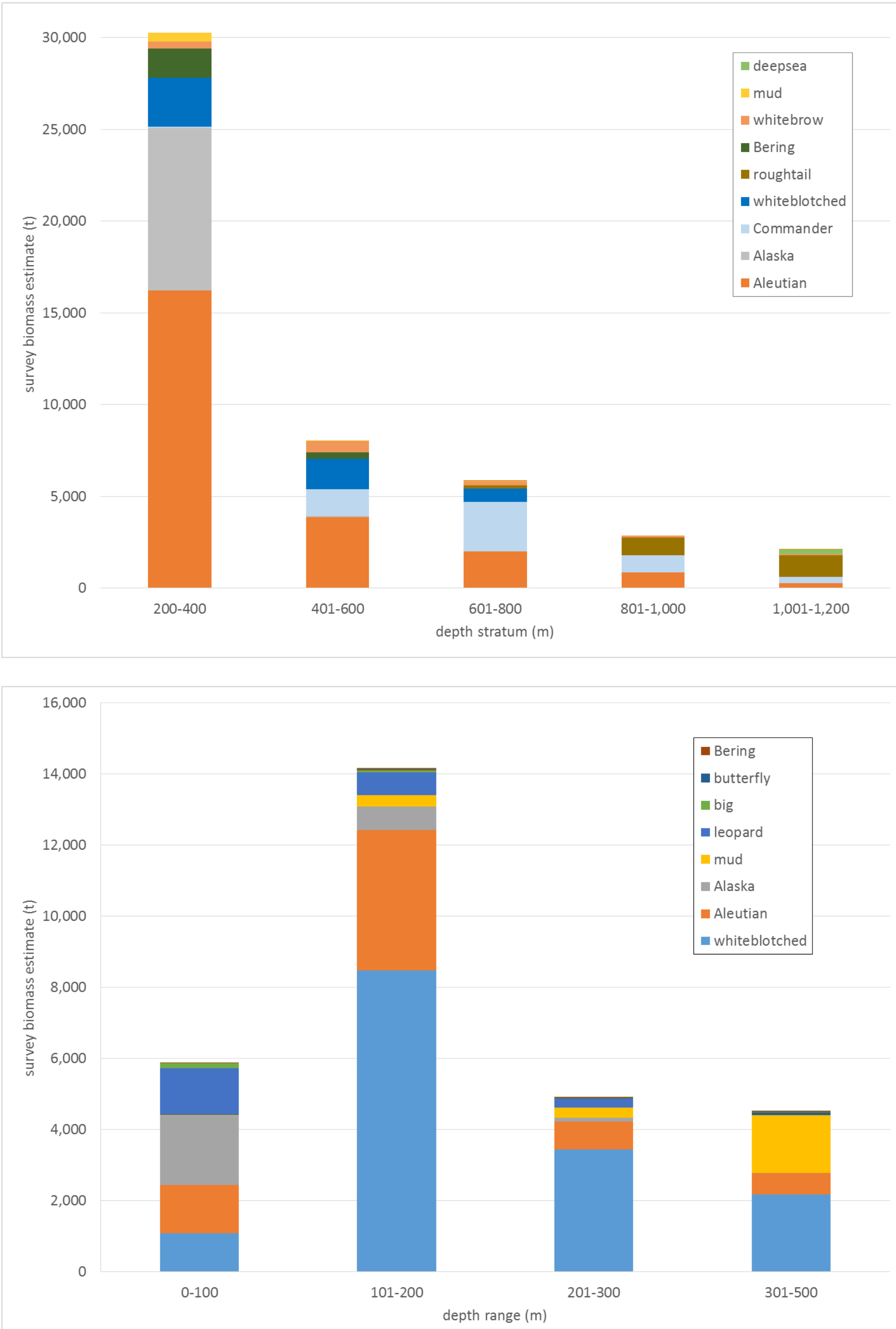
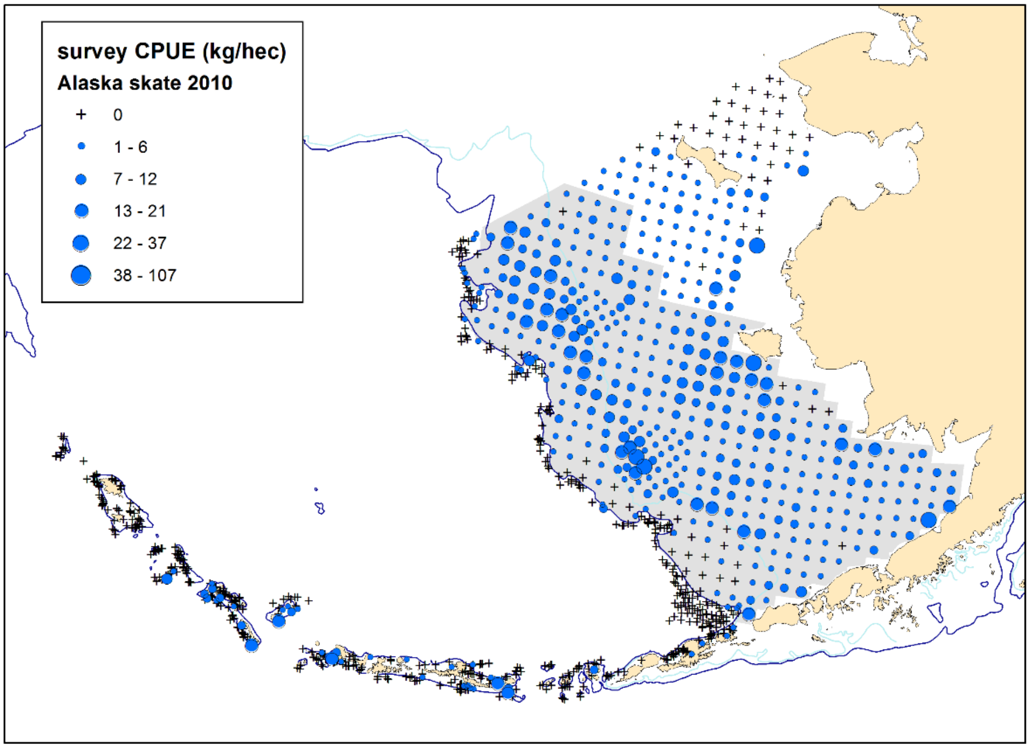


Figure 5. Skate biomass and species distribution by depth zone on the EBS slope (top panel) and in the Aleutian Islands (bottom panel), as observed in 2016 AFSC bottom trawl surveys.



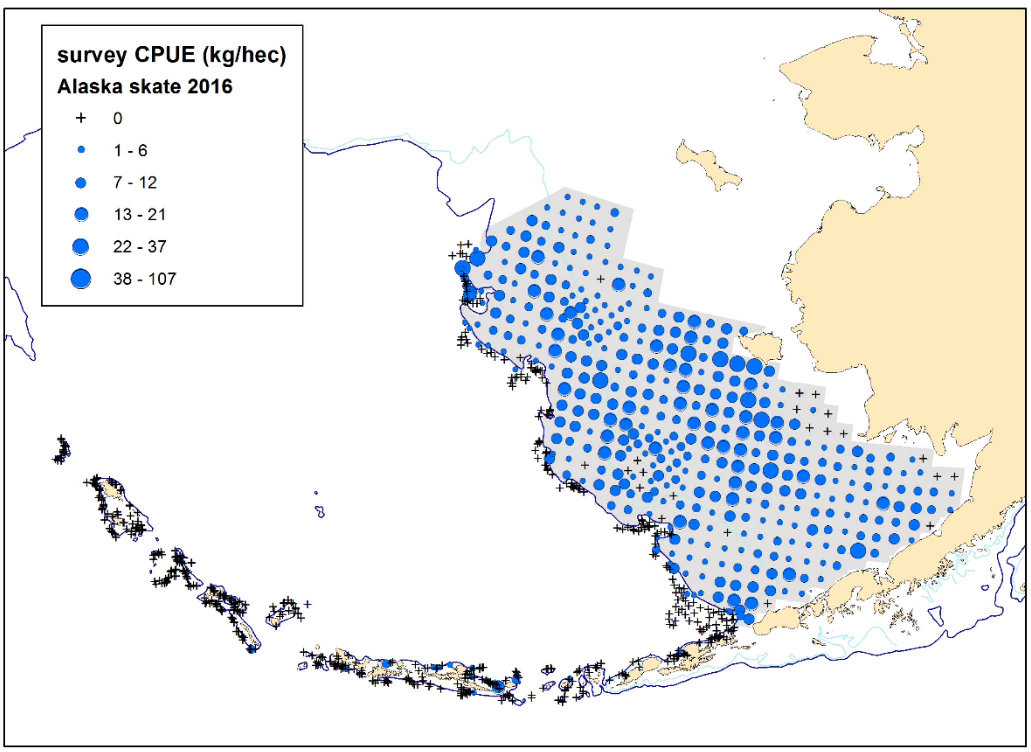


Figure 6. AFSC bottom trawl survey catch-per-unit-effort (CPUE) of Alaska skate in 2010 (top) and 2016 (bottom). Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf survey, the EBS slope survey, and the Aleutian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

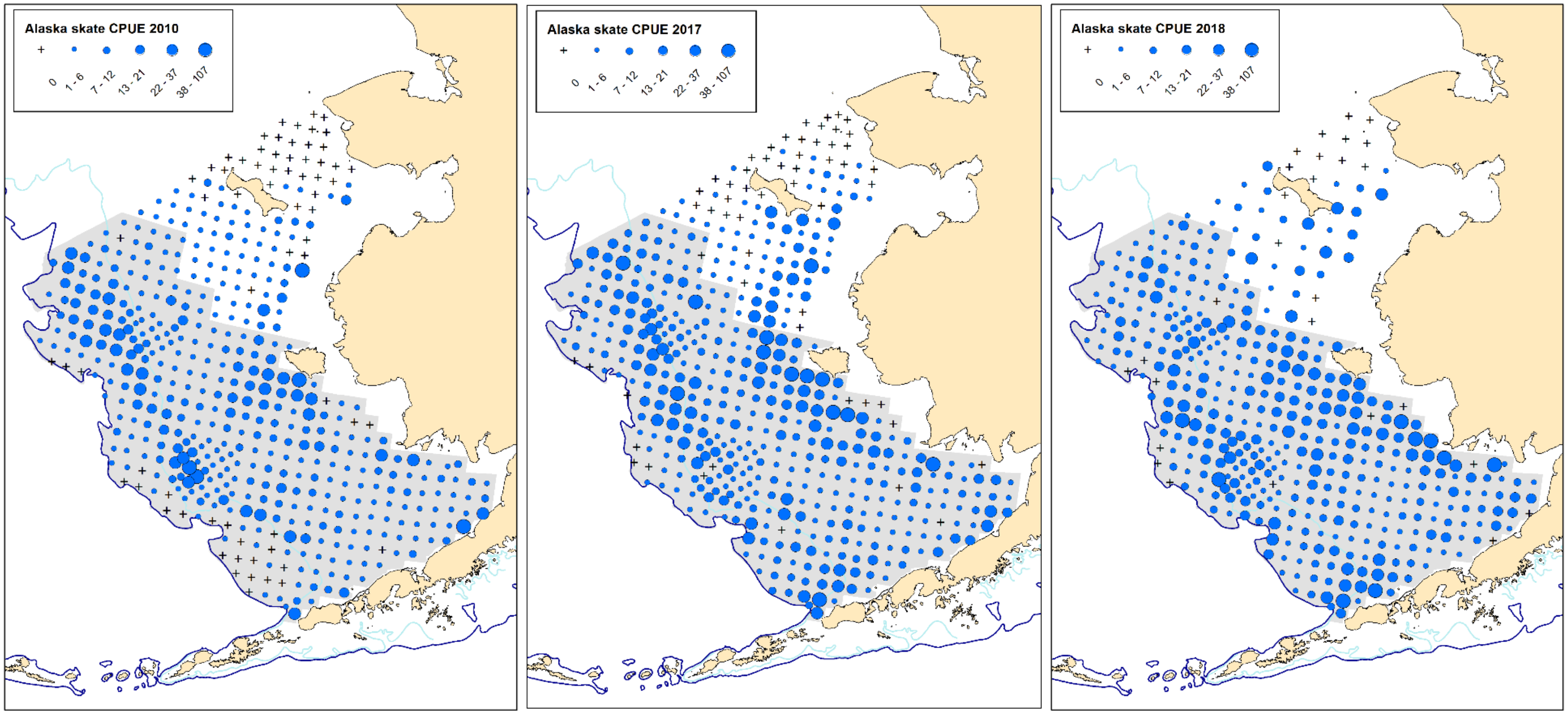


Figure 7. Eastern Bering Sea (EBS) AFSC bottom trawl survey catch-per-unit-effort (CPUE; kg/hec) of **Alaska skate** in 2010, 2017, and 2018. Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf and the northern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

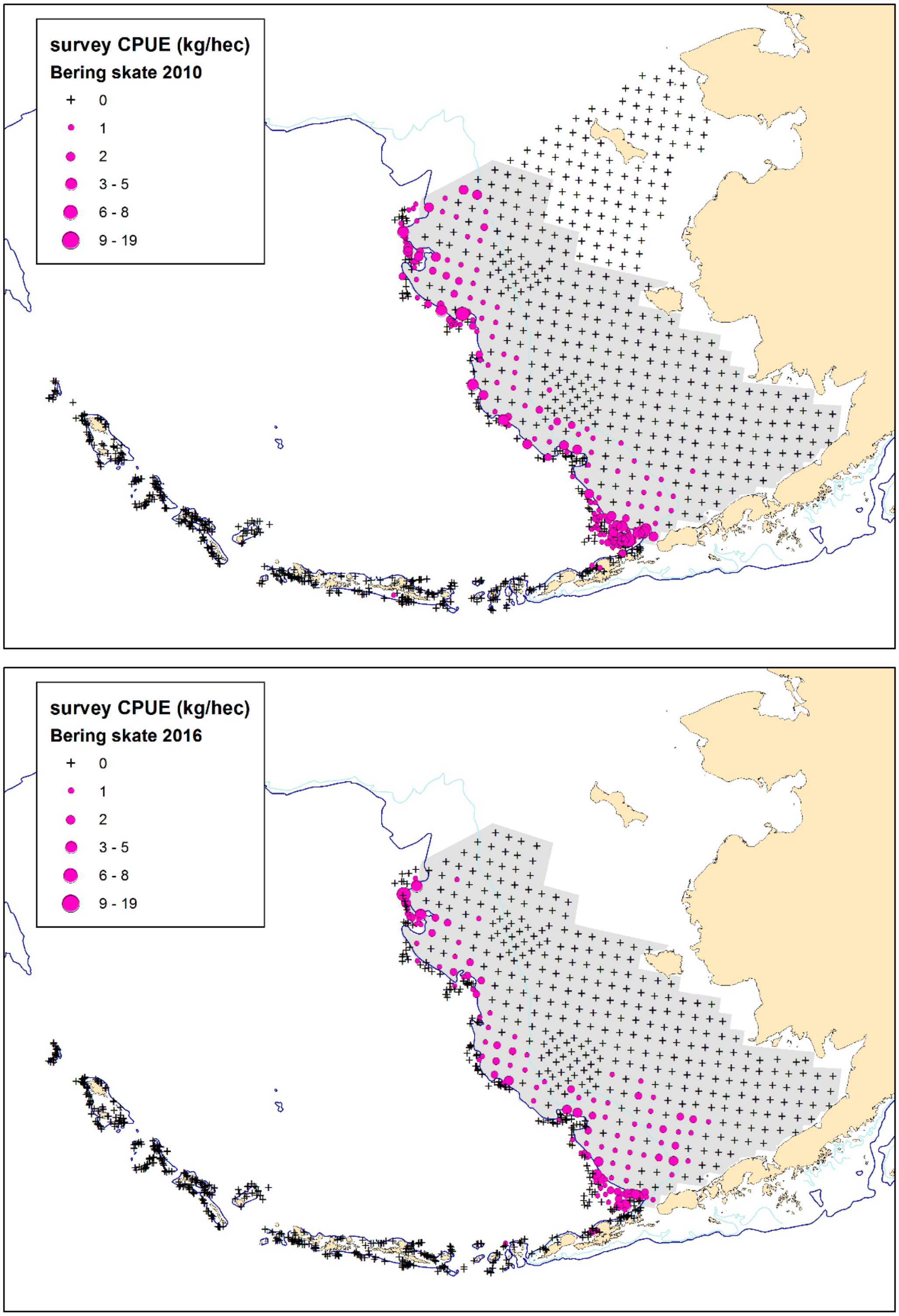


Figure 8. AFSC bottom trawl survey catch-per-unit-effort (CPUE) of **Bering skate** in 2010 (top) and 2016 (bottom). Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf survey, the EBS slope survey, and the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

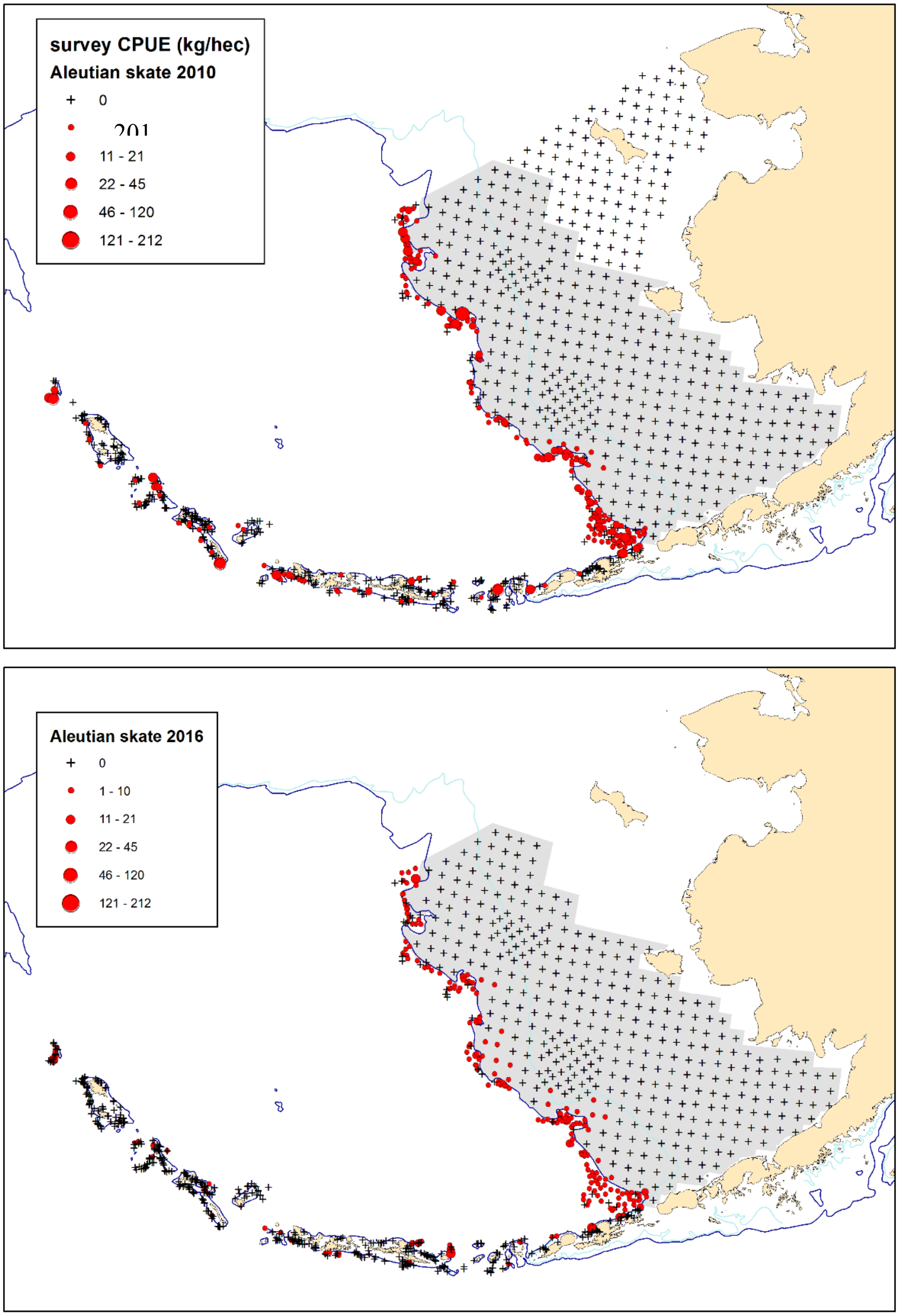


Figure 9. AFSC bottom trawl survey catch-per-unit-effort (CPUE) of **Aleutian skate** in 2010 (top) and 2016 (bottom). Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf survey, the EBS slope survey, and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

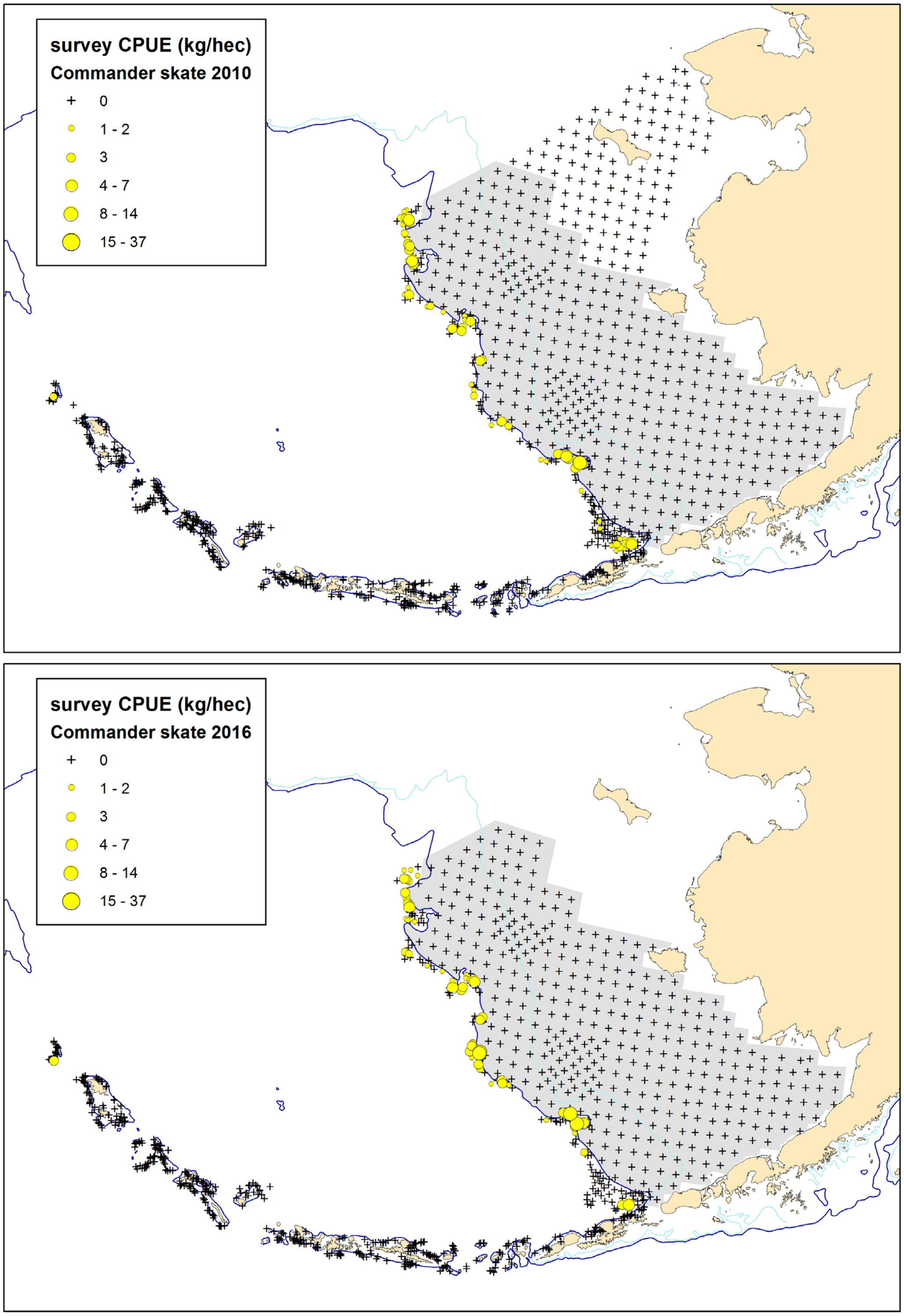


Figure 10. AFSC bottom trawl survey catch-per-unit-effort (CPUE) of **Commander skate** in 2010 (top) and 2016 (bottom). Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf survey, the EBS slope survey, and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

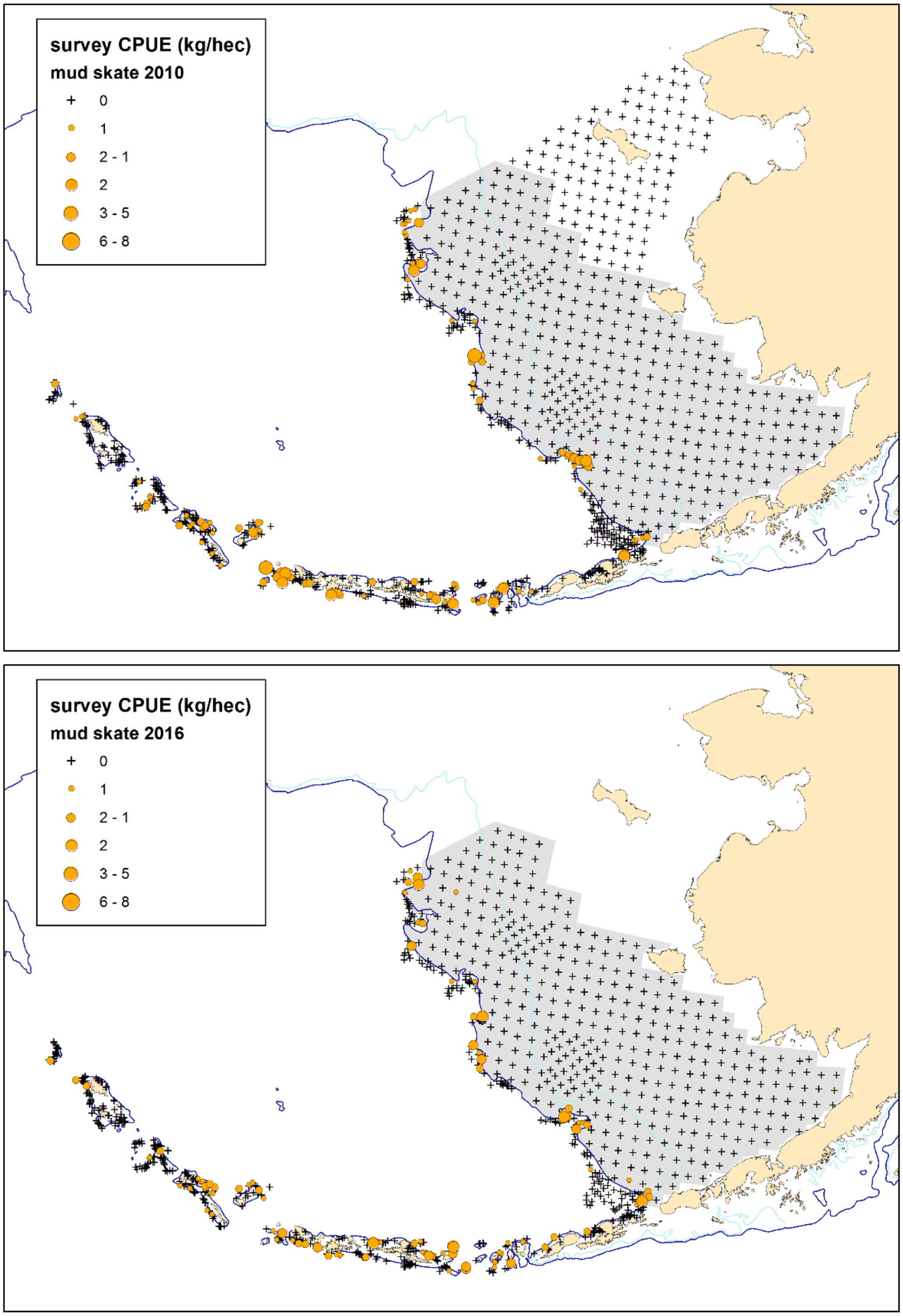


Figure 11. AFSC bottom trawl survey catch-per-unit-effort (CPUE) of **mud skate** in 2010 (top) and 2016 (bottom). Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf survey, the EBS slope survey, and the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

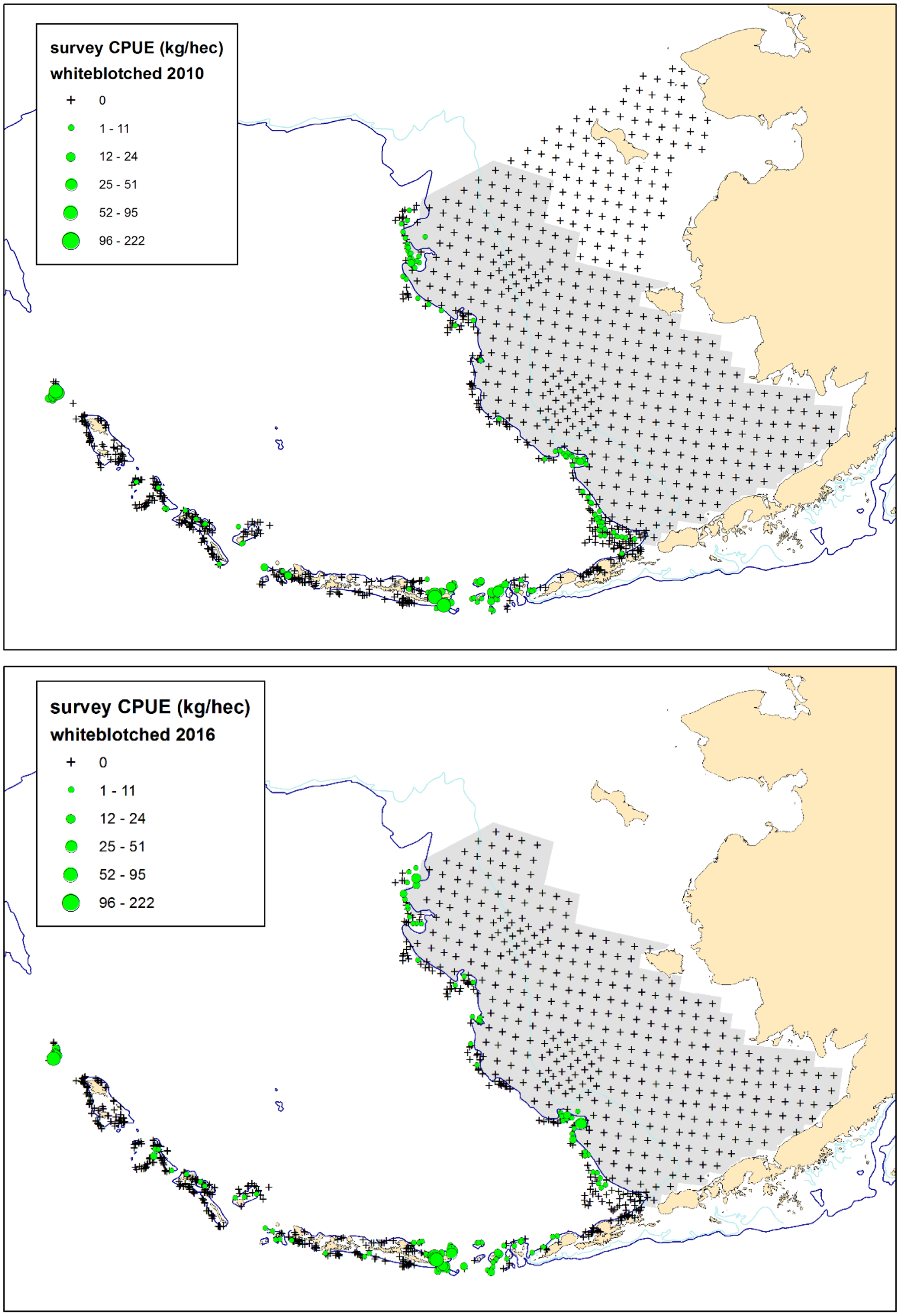
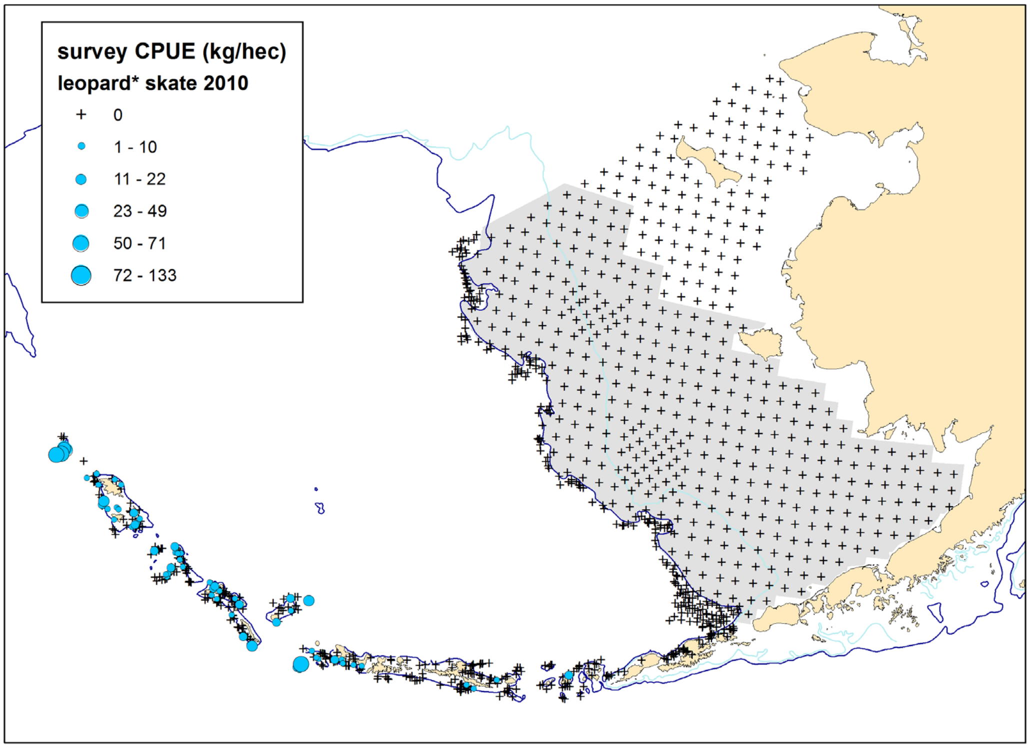


Figure 12. AFSC bottom trawl survey catch-per-unit-effort (CPUE) of **whiteblotched skate** in 2010 (top) and 2016 (bottom). Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf survey, the EBS slope survey,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



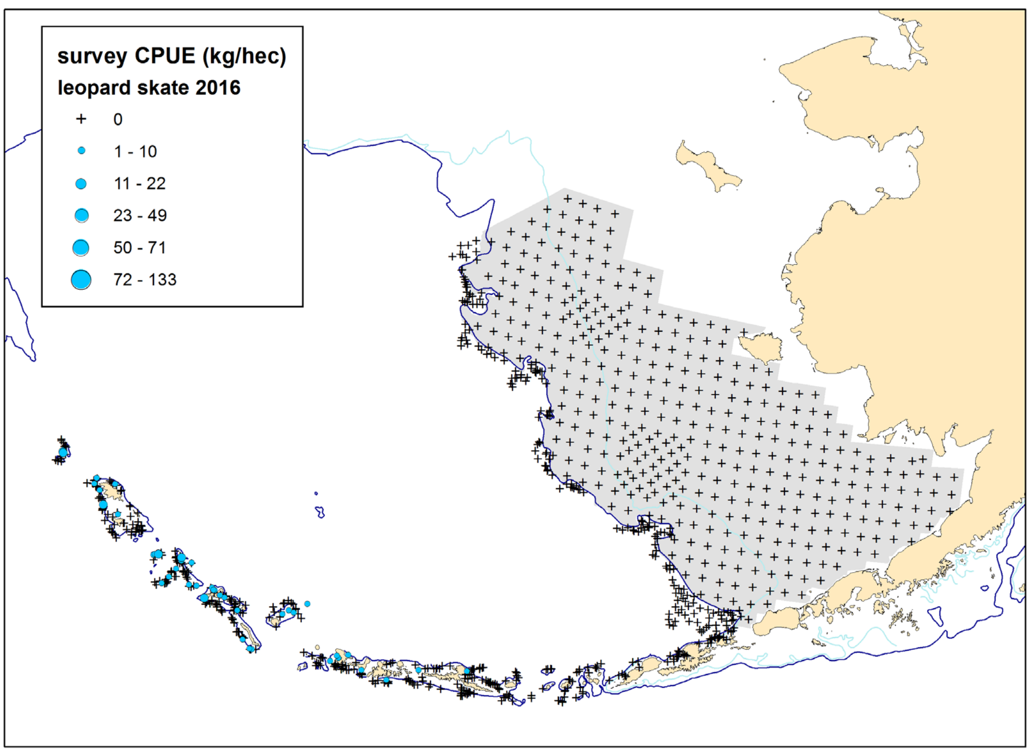


Figure 13. AFSC bottom trawl survey catch-per-unit-effort (CPUE) of **leopard skate** in 2010 (top) and 2016 (bottom). Symbol size is proportional to CPUE at each survey station and crosses indicate no catch of Alaska skate at that station. Data include the EBS shelf survey, the EBS slope survey, and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

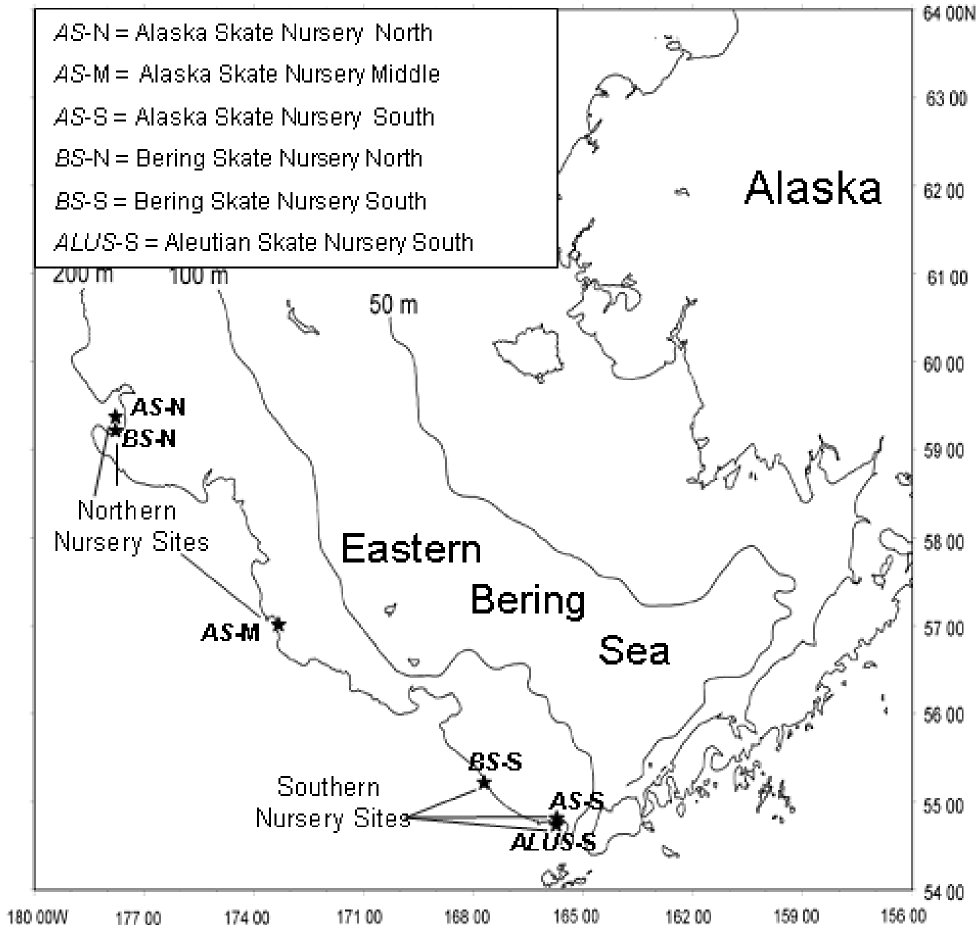


Figure 14. Map of the eastern Bering Sea with the six known skate nursery site locations and designations as a northern or southern nursery site. (See the legend for nursery site designation.) Source: Gerald Hoff, AFSC, unpublished data.

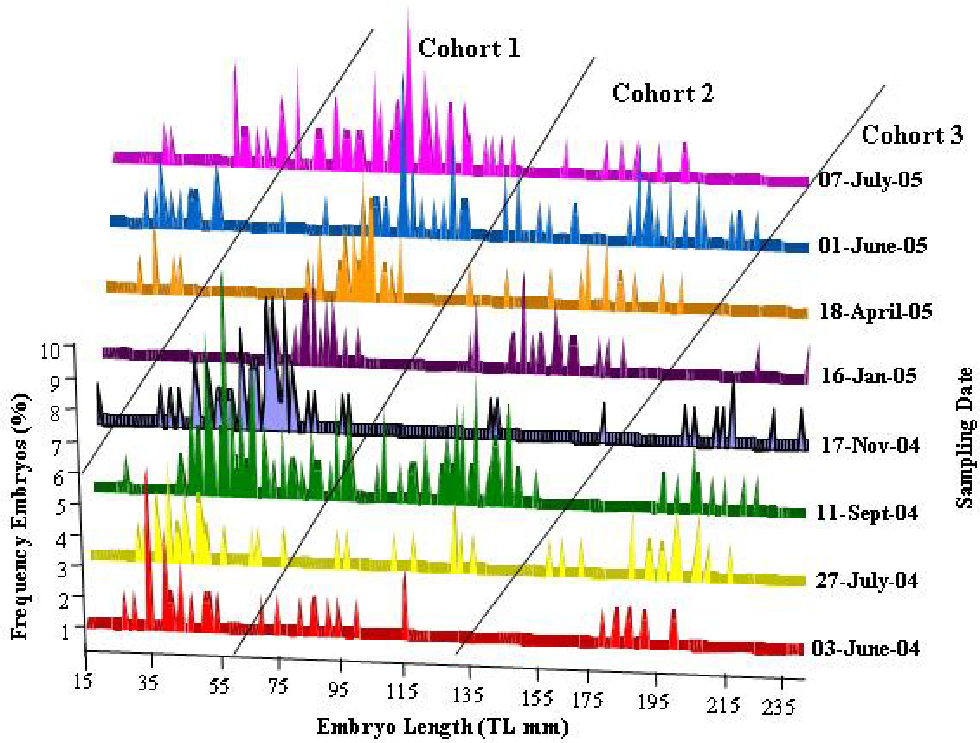


Figure 15. Embryo length composition data used in a cohort analysis of embryo development time. Figure is from G. Hoff (AFSC, pers. comm.).

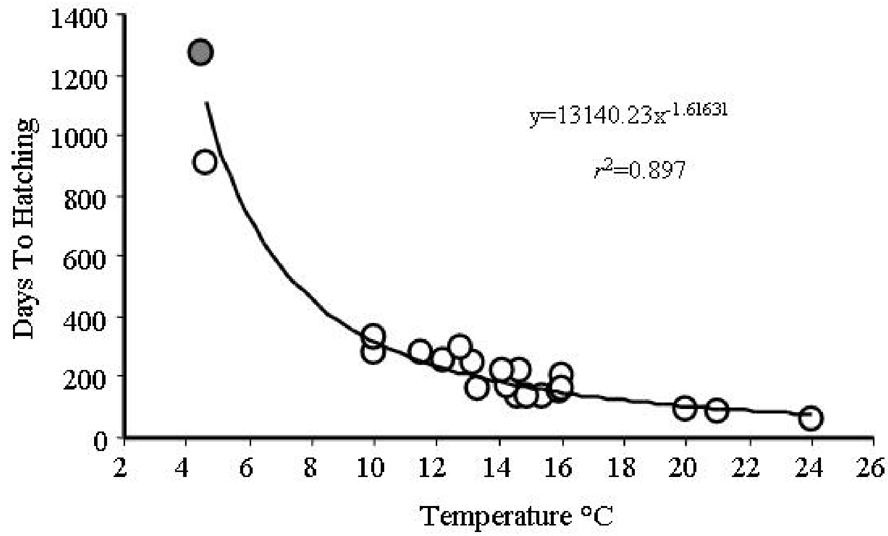


Figure 16. Ocean temperature versus embryo development time for 21 skate species. Dark grey circle is the Alaska skate. Equation and R^2 are the values of the fitted relationship. Figure is from G. Hoff (AFSC, pers. comm.)

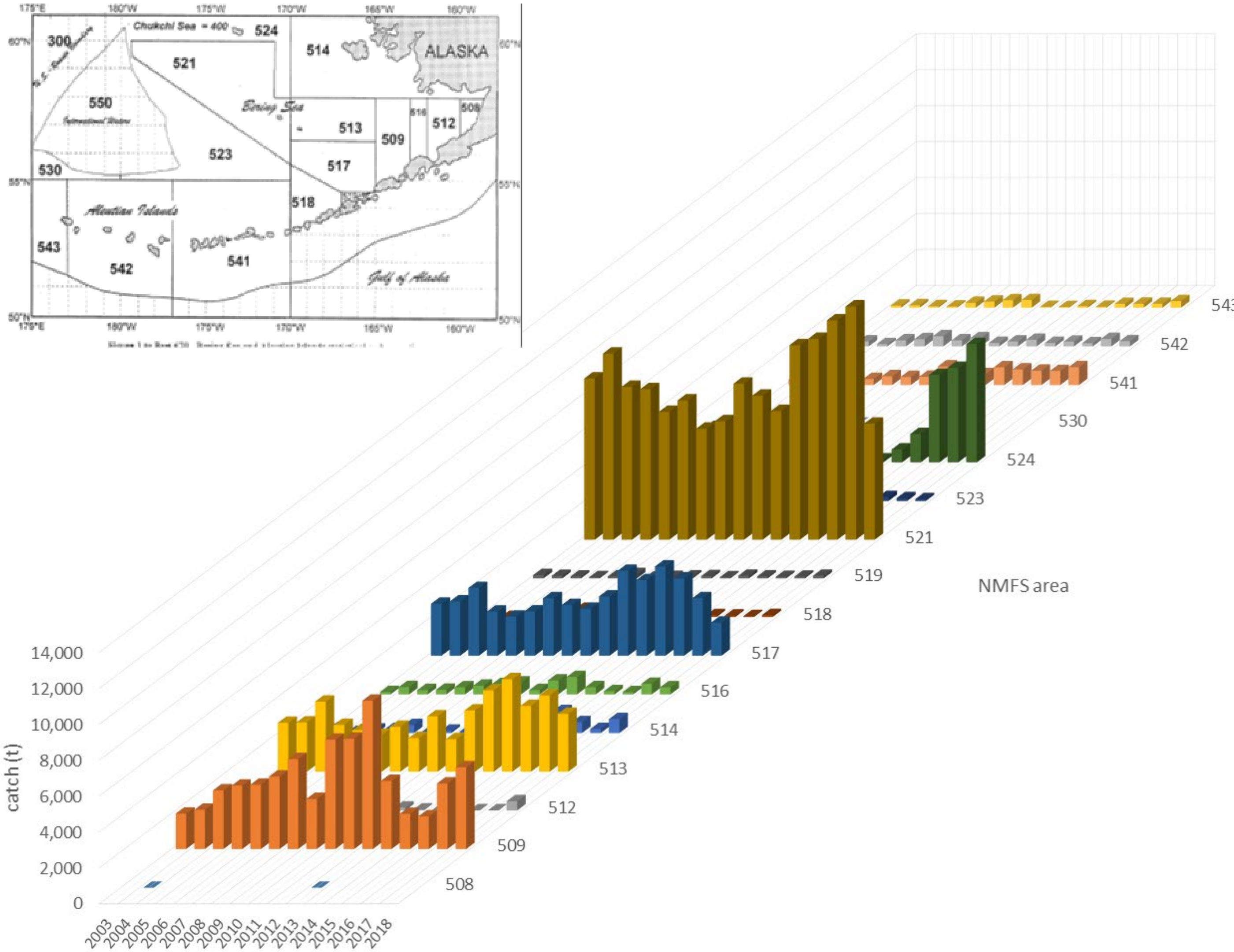


Figure 17. Total skate catch (all species combined) by FMP reporting area (see inset map) for both the EBS and the AI, 2003 - 2018. Source: AKRO CAS. 2018 data are incomplete; retrieved October 25, 2018.

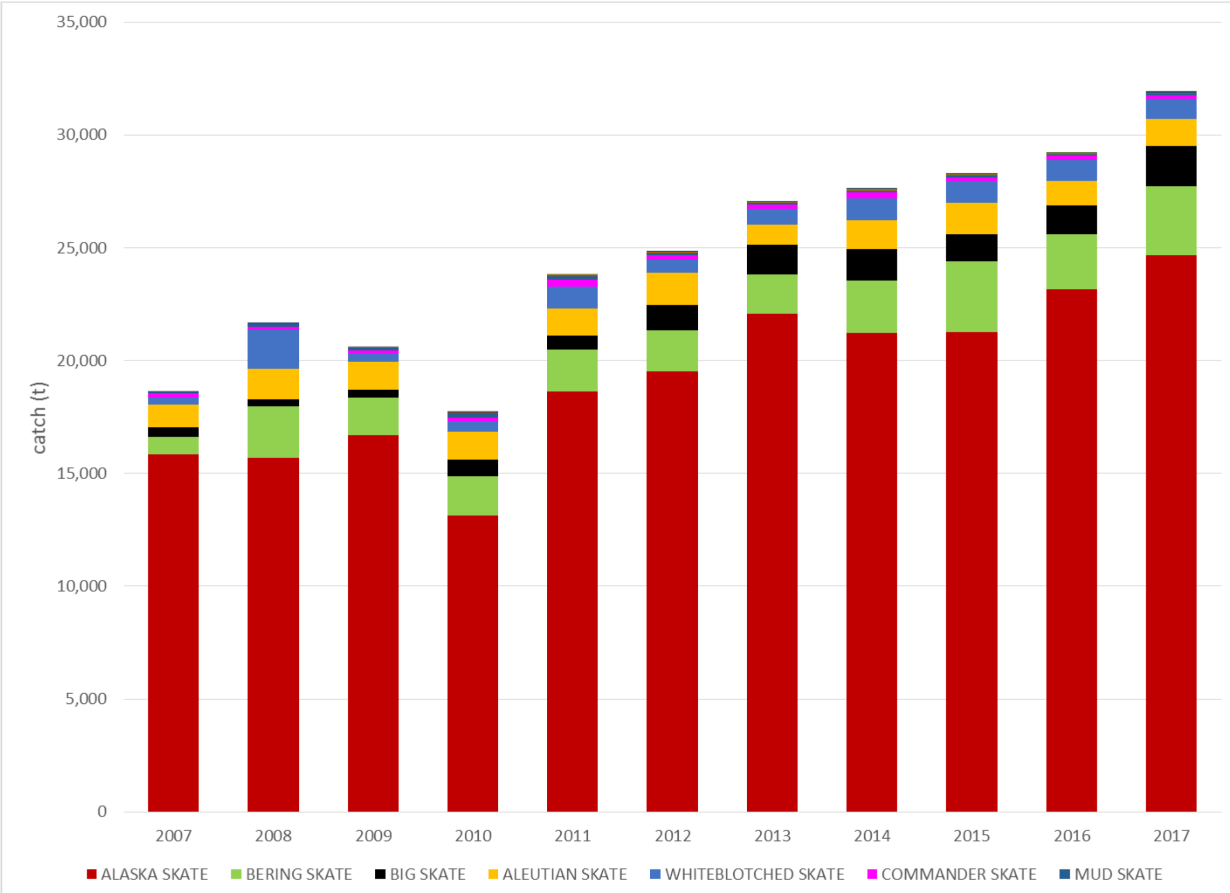


Figure 18. Catches of skates in the BSAI by species, 2007-2017.

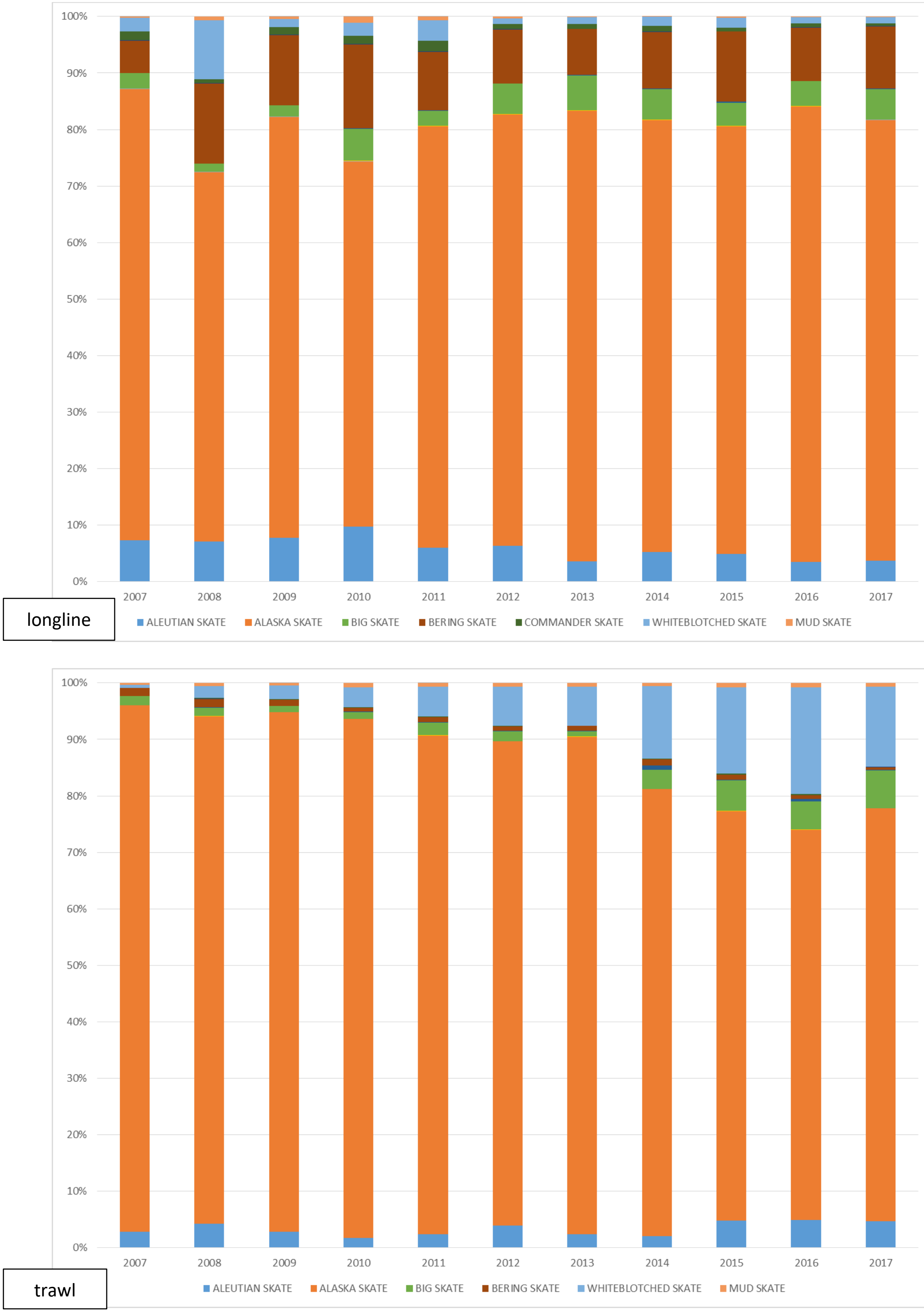


Figure 19. Species composition of skate catches in the BSAI by gear type, 2007-2017. Top panel shows data from longline fisheries, bottom panel shows data from trawl fisheries (pelagic and non-pelagic).

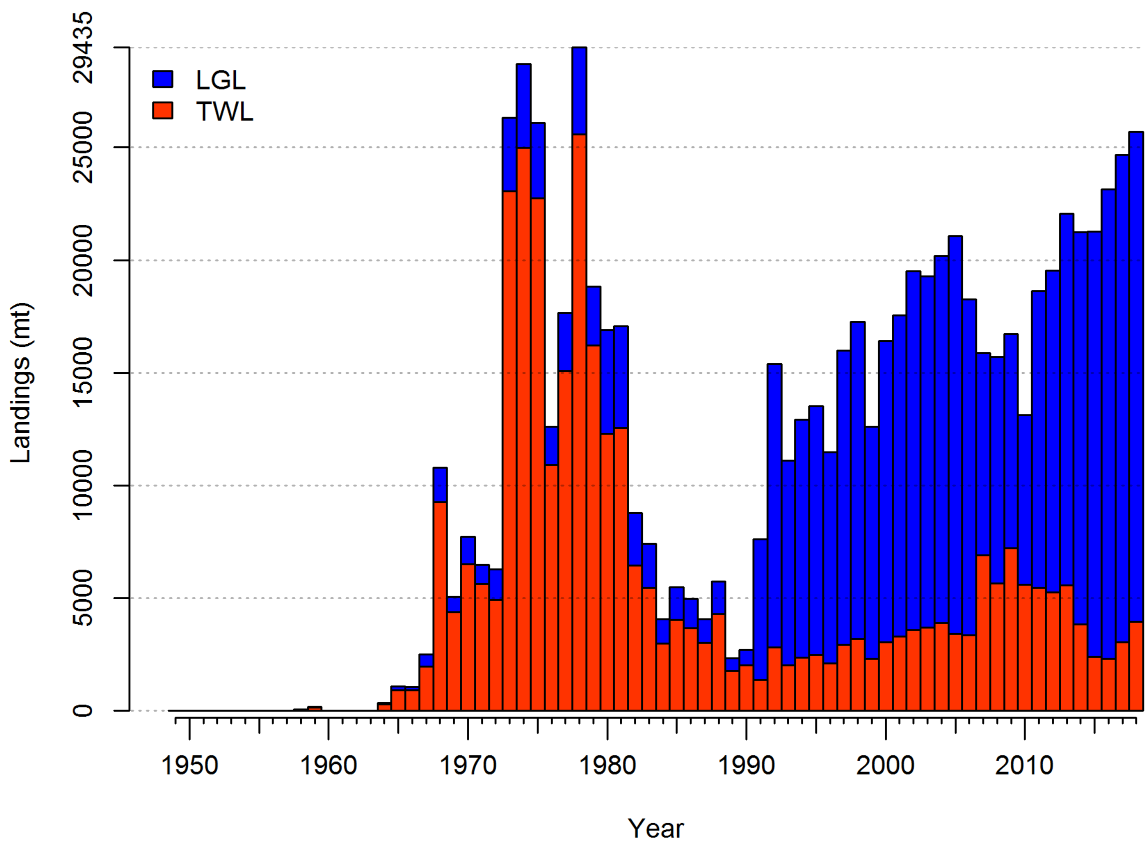


Figure 20. Estimated catches of Alaska skates (t) in the BSAI 1954-2018. LGL = longline fishery, TWL = trawl fishery.

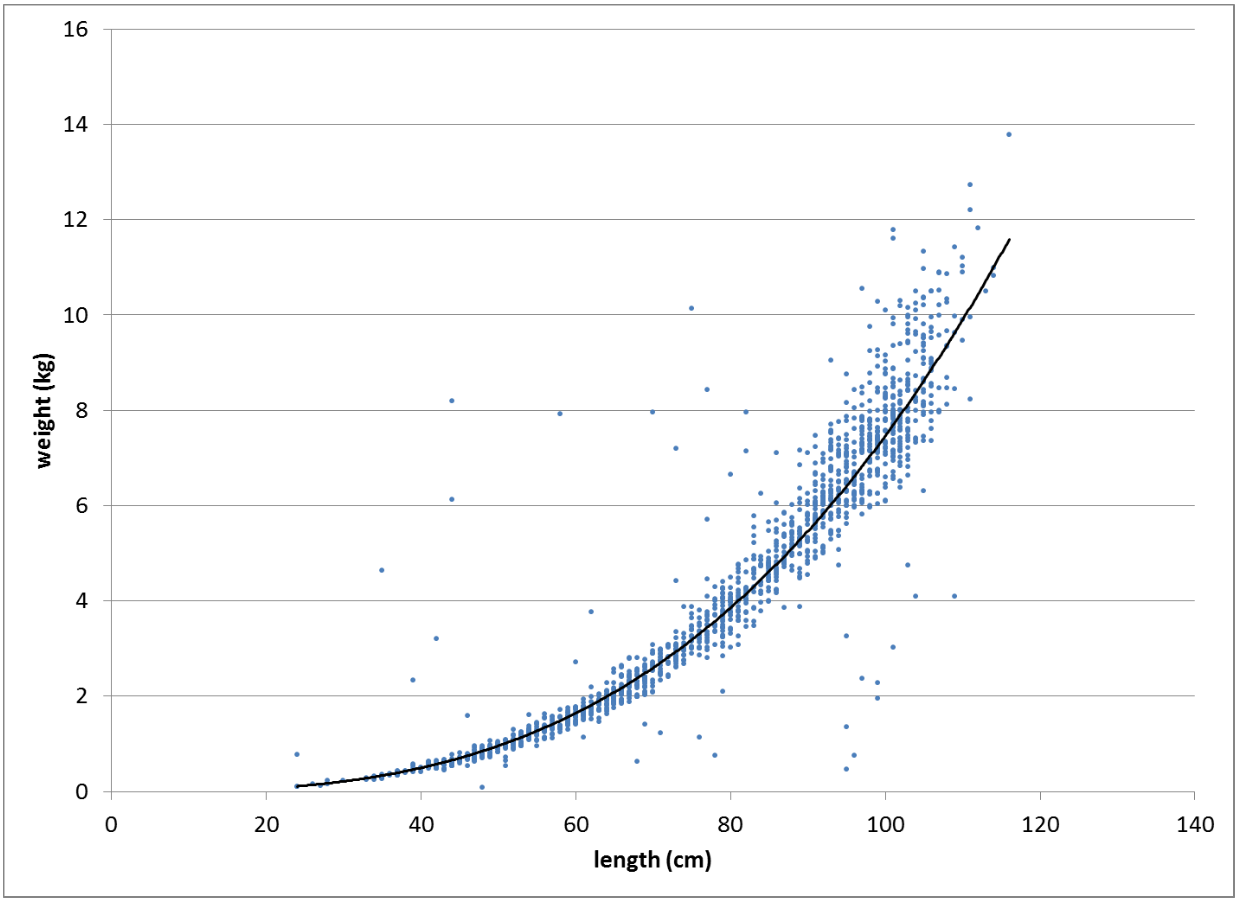


Figure 21. Length-weight relationship for Alaska skates captured in the EBS shelf trawl survey, 2008-2010. Black line indicates line of best fit to the data, $r^2 = 0.93$, N = 1,515.

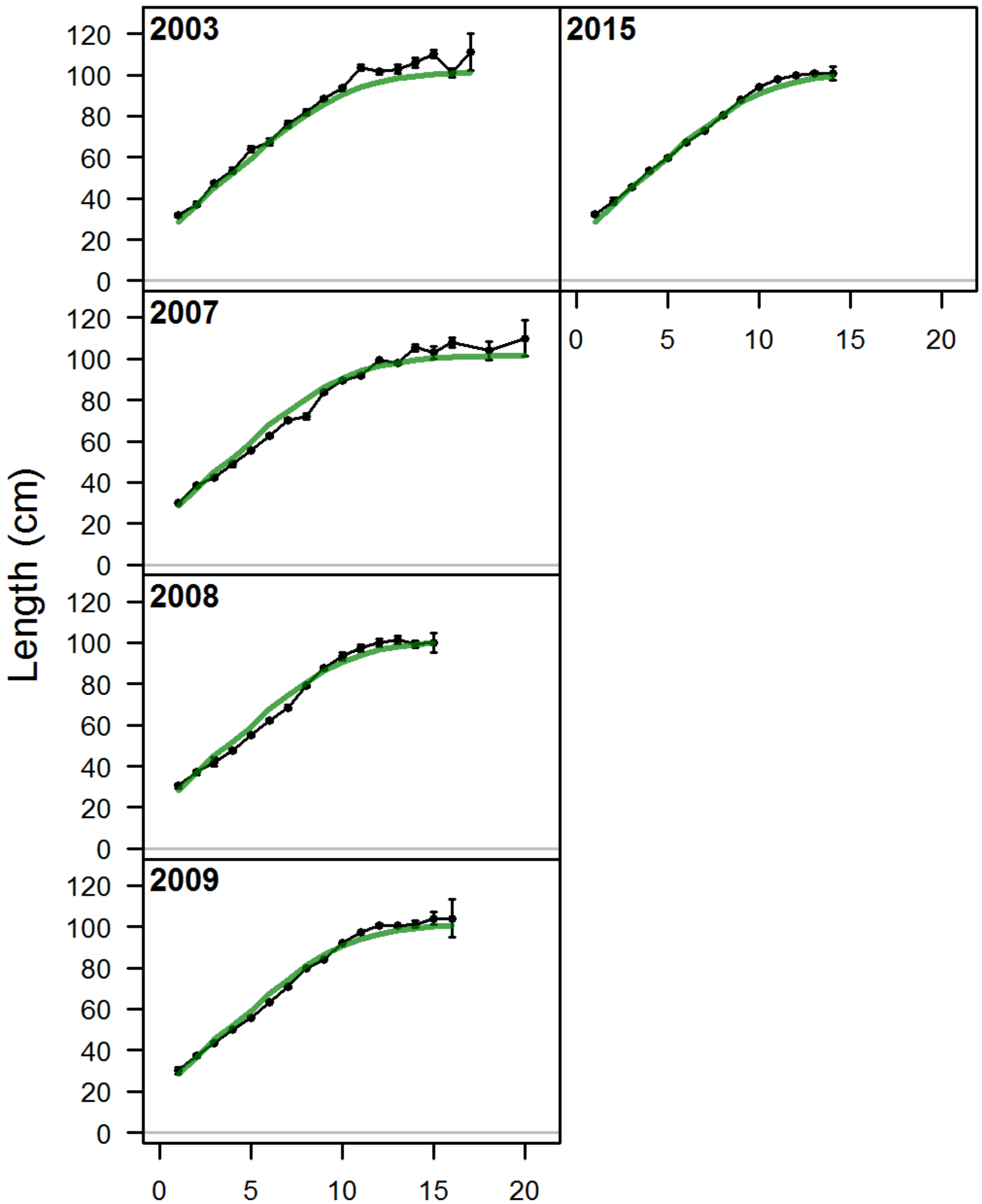


Figure 22. Observed (black circles) and model-predicted (green line) length-at-age for Model 14.2.

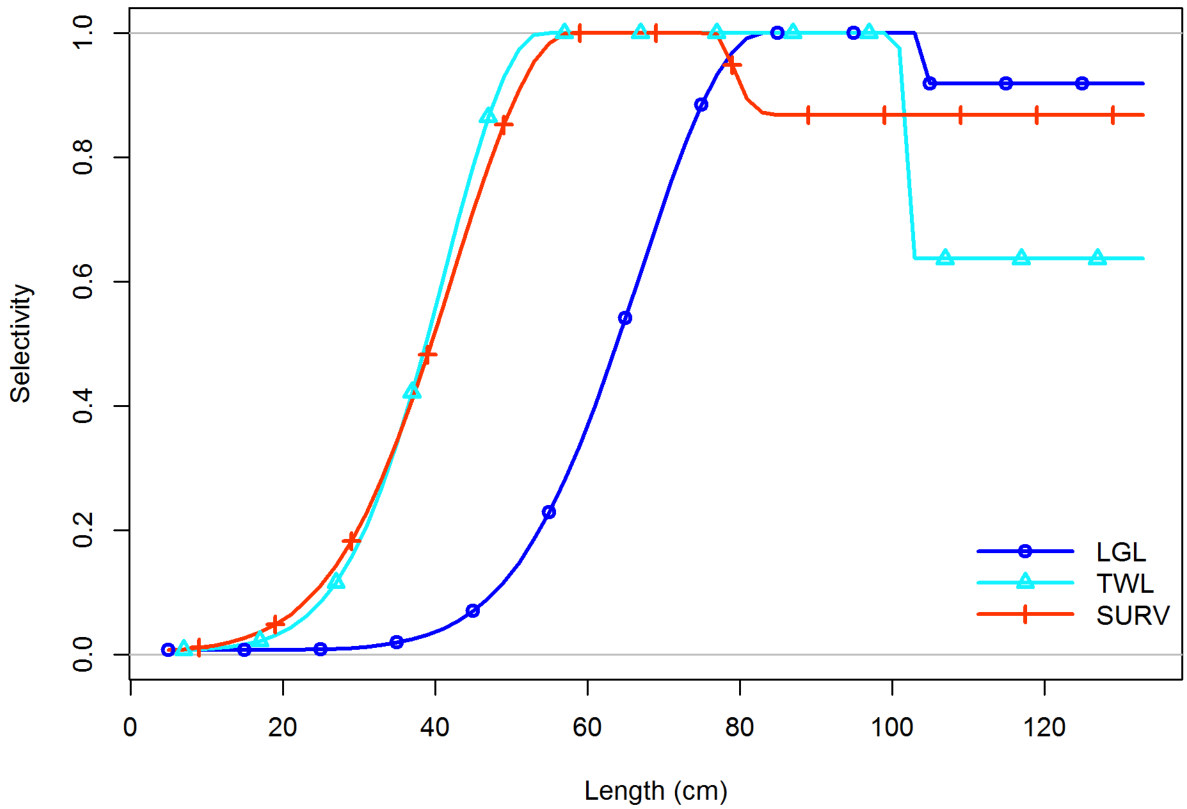


Figure 23. Selectivity functions estimated by model 14.2. LGL = longline fishery, TWL = trawl fishery, SURV = trawl survey.

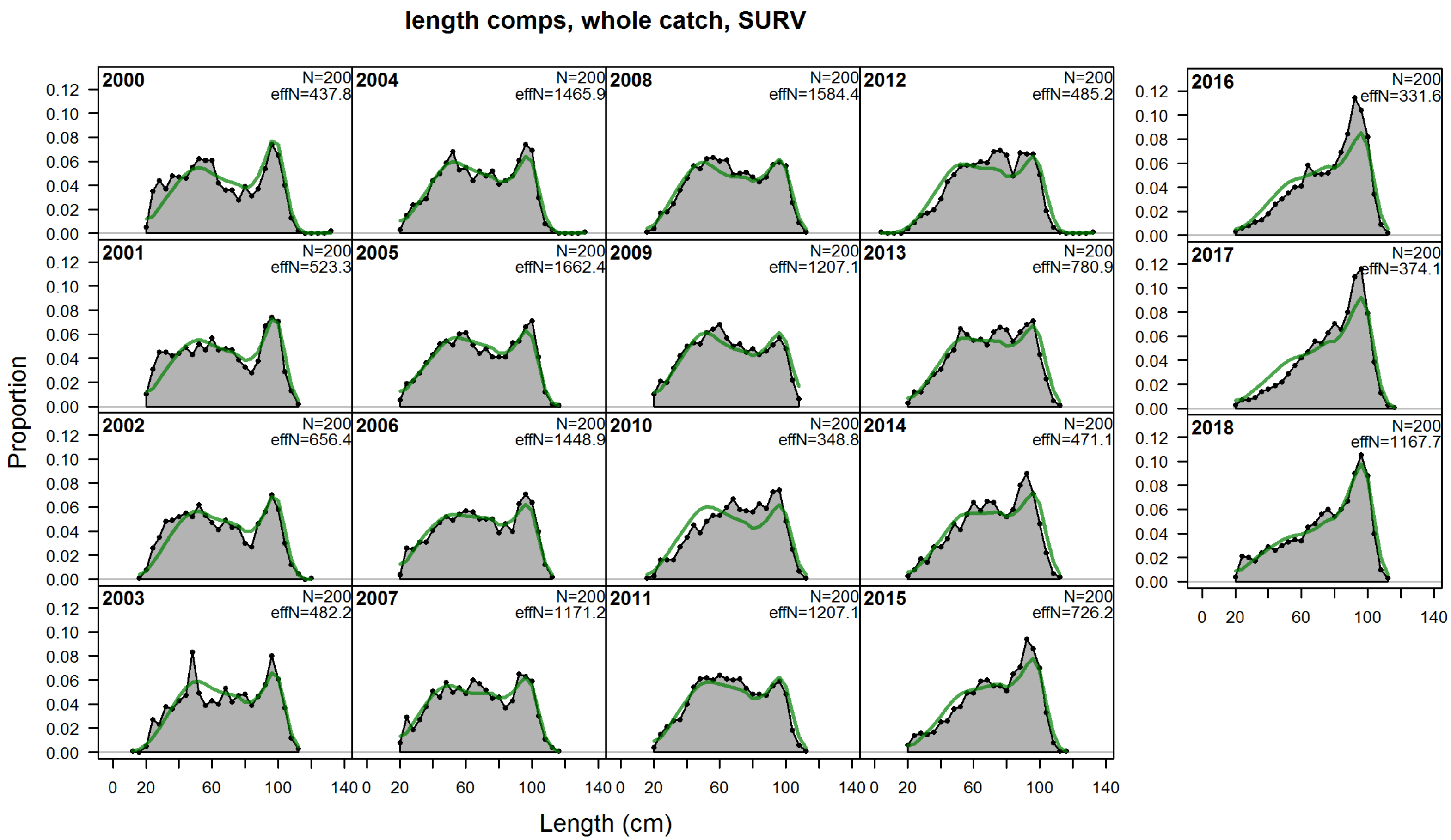


Figure 24. EBS shelf survey length compositions from 2000-2018. Grey shading = observed proportions; green line = model predictions. X-axis values are lengths in cm.

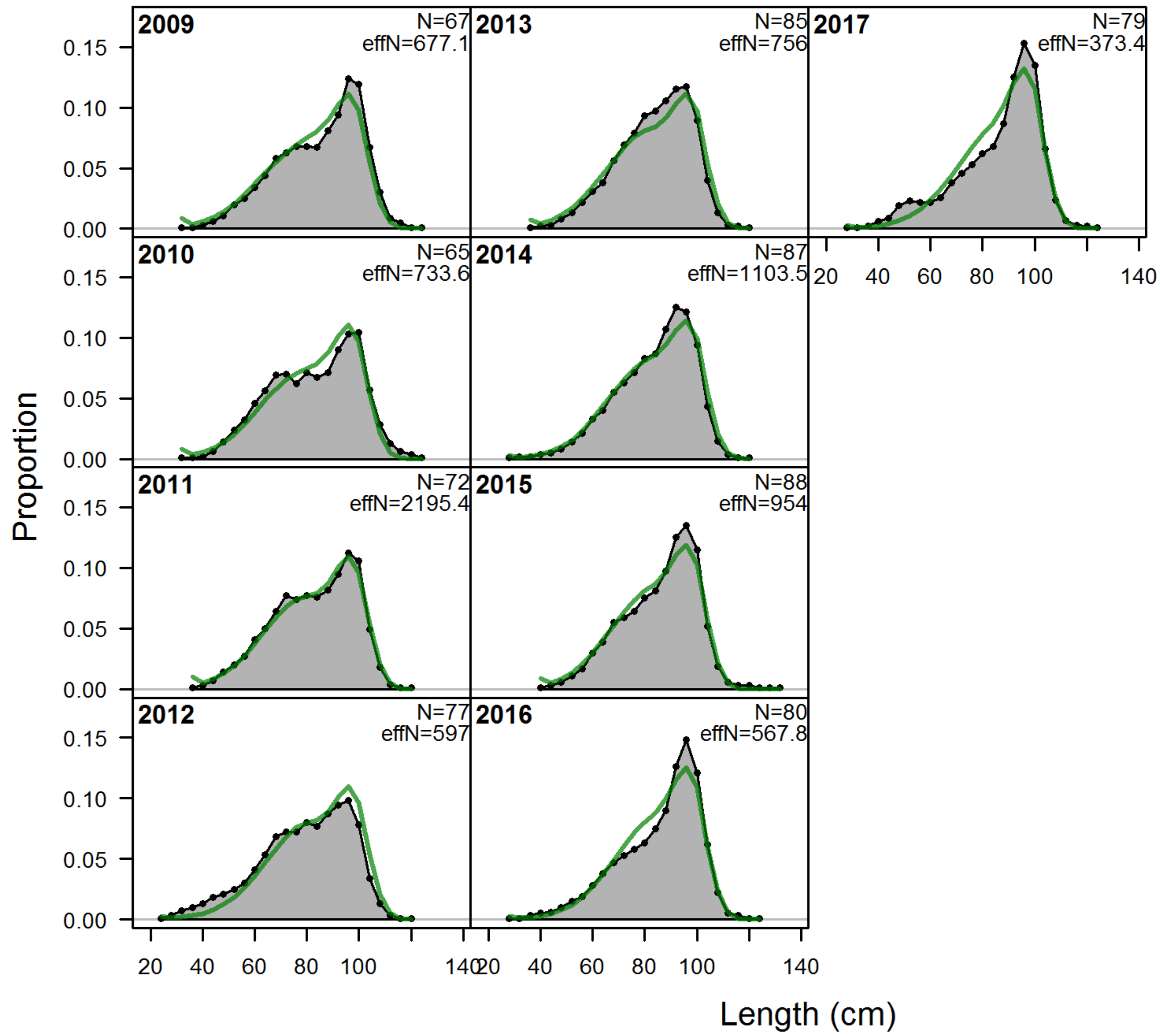


Figure 25. Observed and model-predicted length compositions from the 2009-207 **longline** fisheries, with model predictions. Grey shading = observed proportions; green line = model predictions.

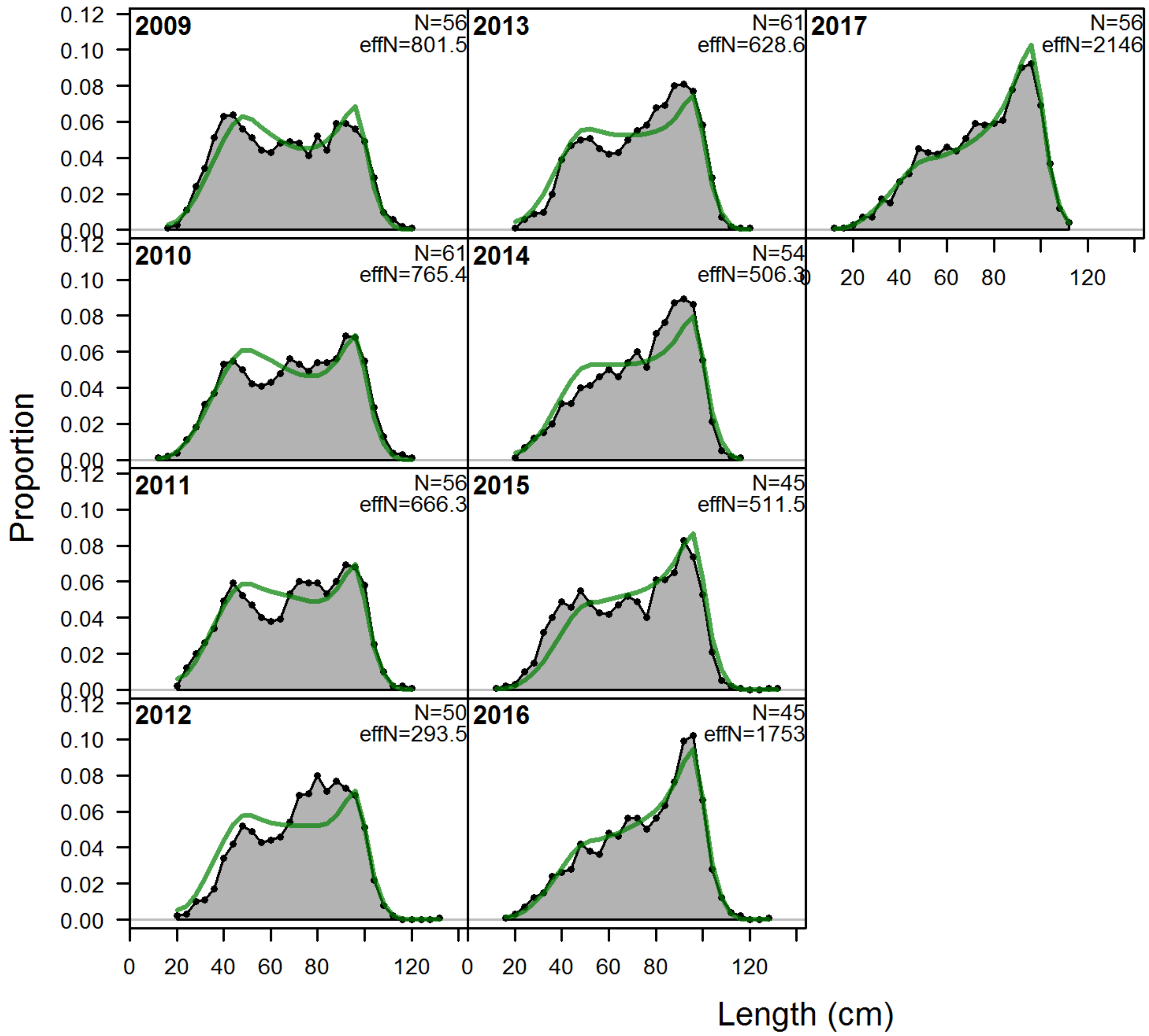


Figure 26. Observed and model-predicted length compositions from the 2009-2017 **trawl** fisheries, with model predictions. Grey shading = observed proportions; green line = model predictions.

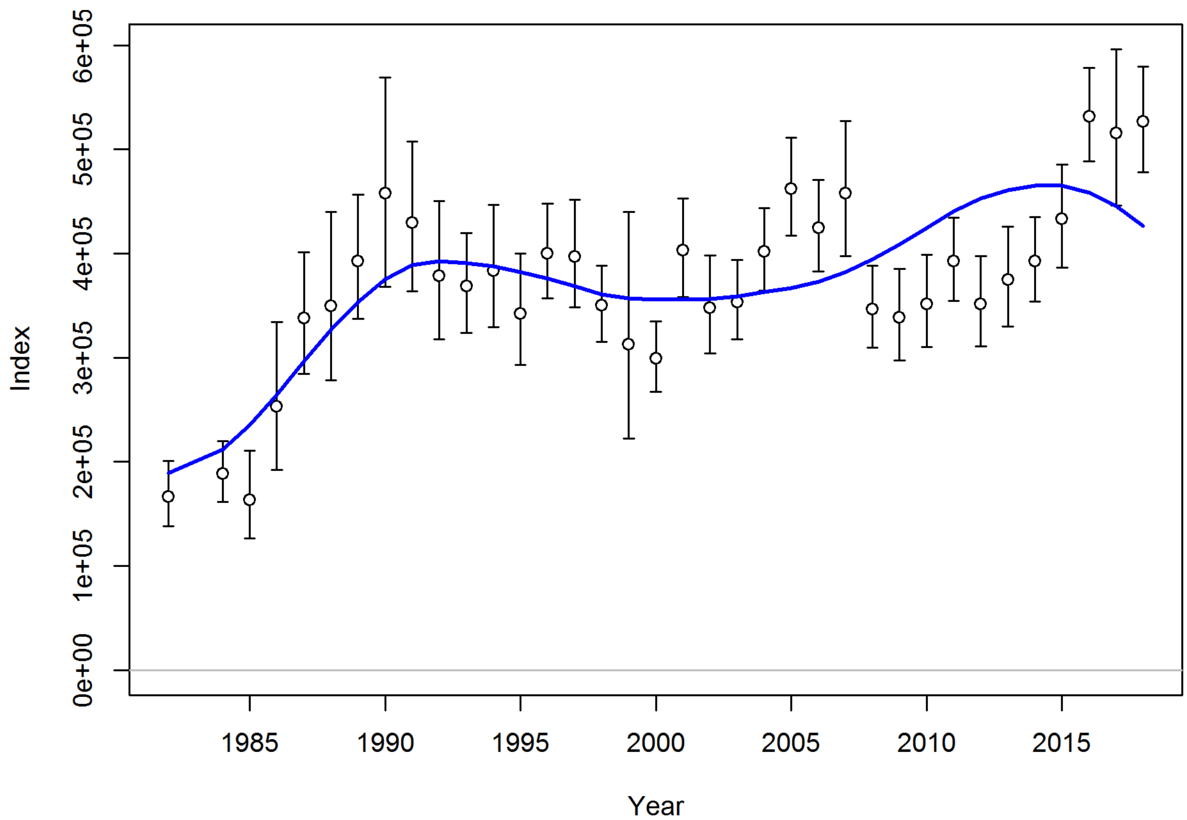


Figure 27. Observed and predicted Alaska skate biomass, 1982-2018. Symbols are biomass (circles) from EBS shelf surveys, with confidence intervals (± 2 SE); blue line is predicted survey biomass from the model 14.2.

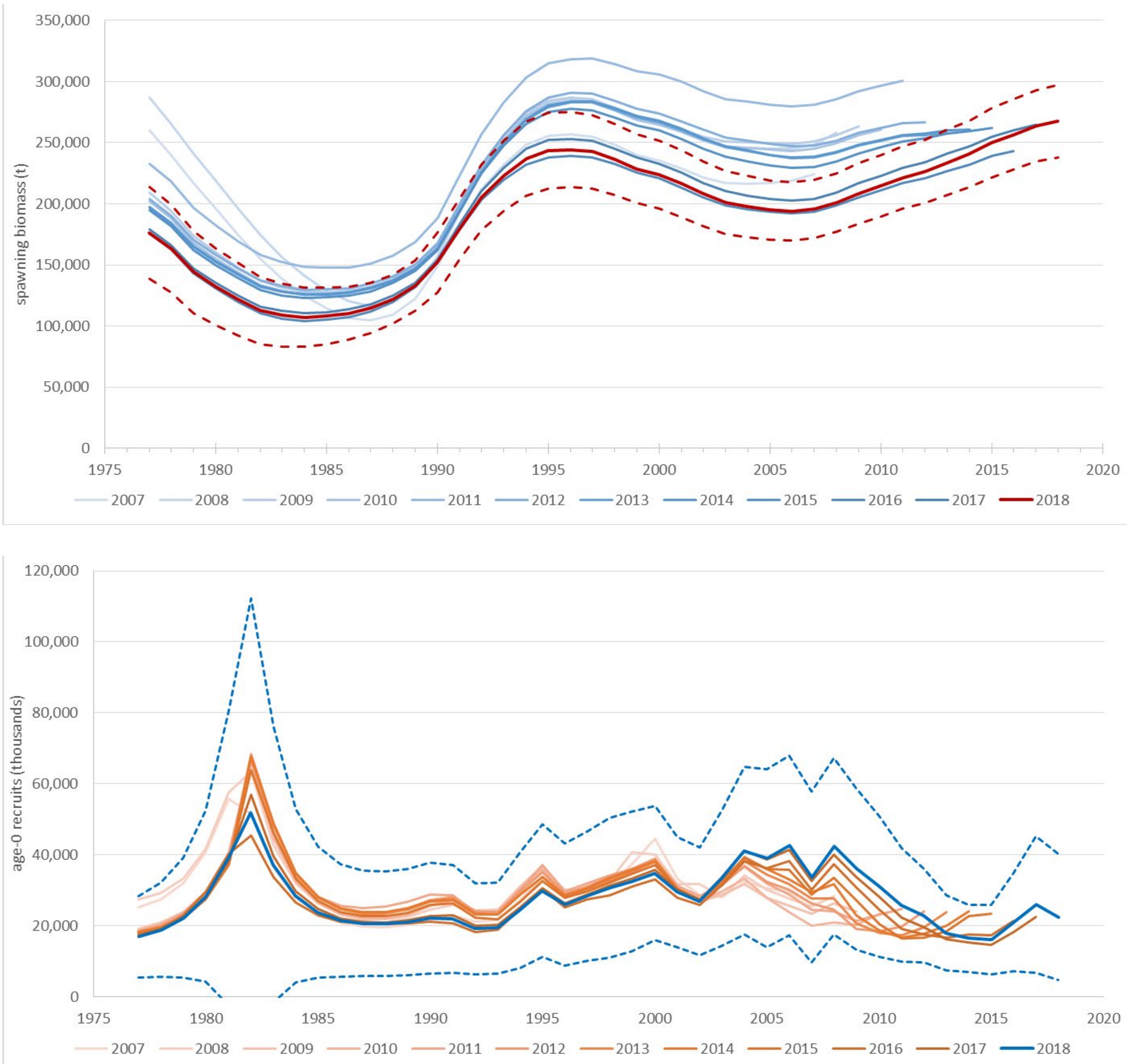


Figure 28. Retrospective analysis for estimates of spawning biomass (top panel) and age-0 recruitment (bottom panel) from model 14.2. Units for recruitment are in 1000s of individuals. Dashed lines show 95% confidence intervals for the current year's estimate.

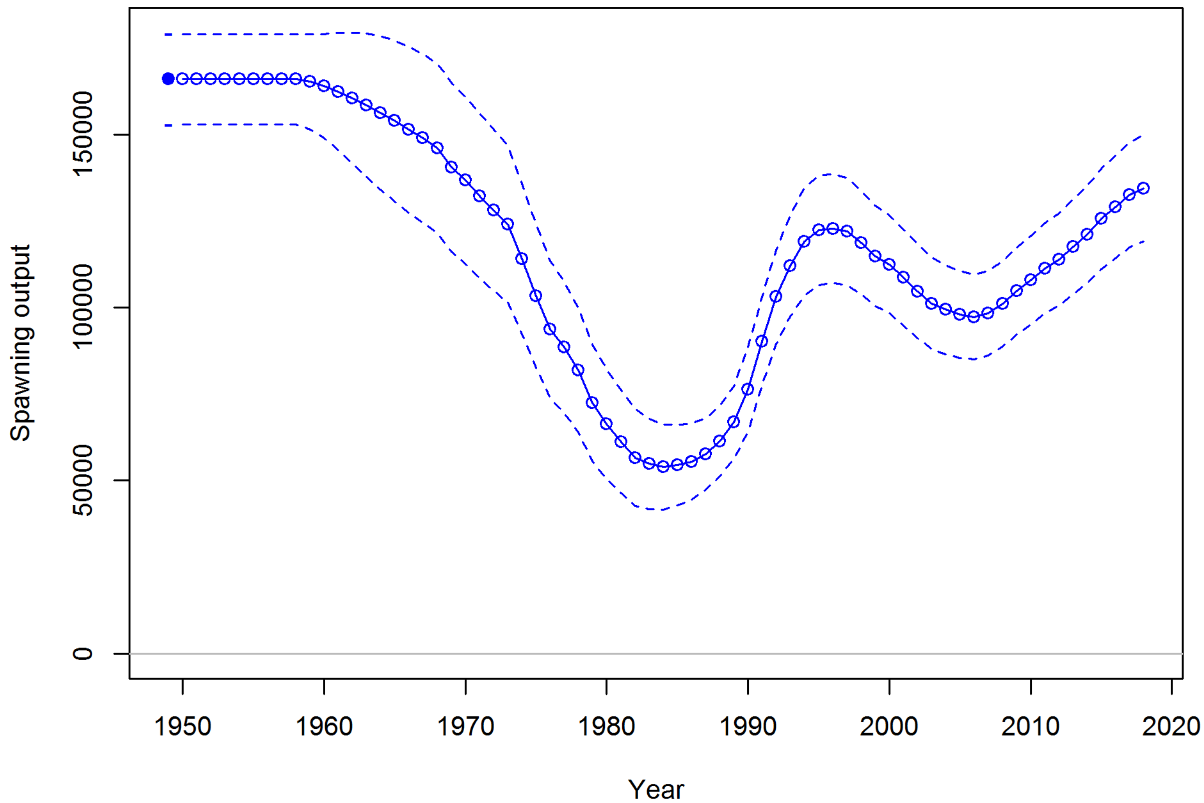


Figure 29. Model estimate of Alaska skate female spawning biomass (t). Dashed lines indicate 95% confidence interval.

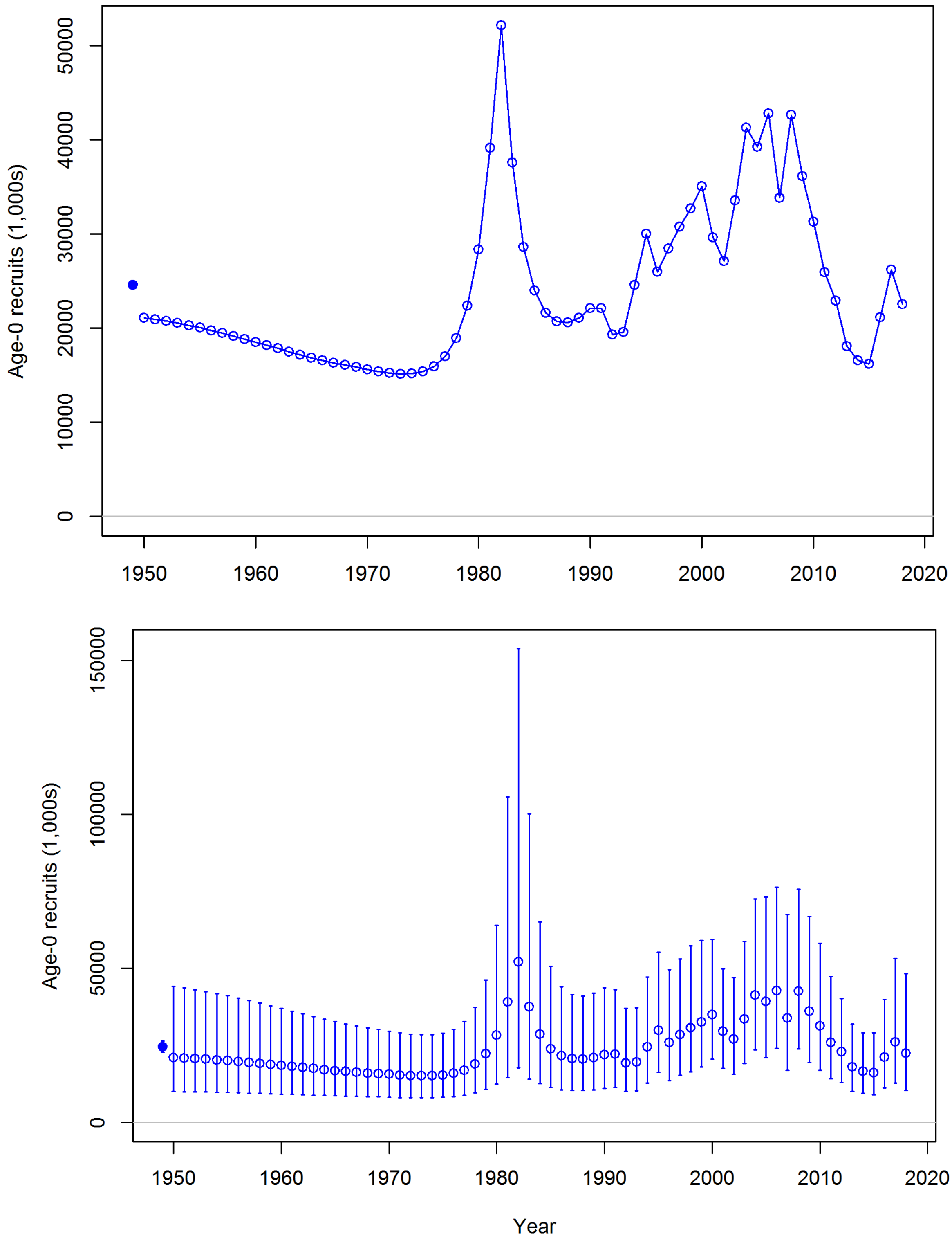


Figure 30. Model estimates of age-0 recruitment (1000s of individuals) of Alaska skates. Data are the same in both panels; the bottom panel includes 95% confidence intervals.

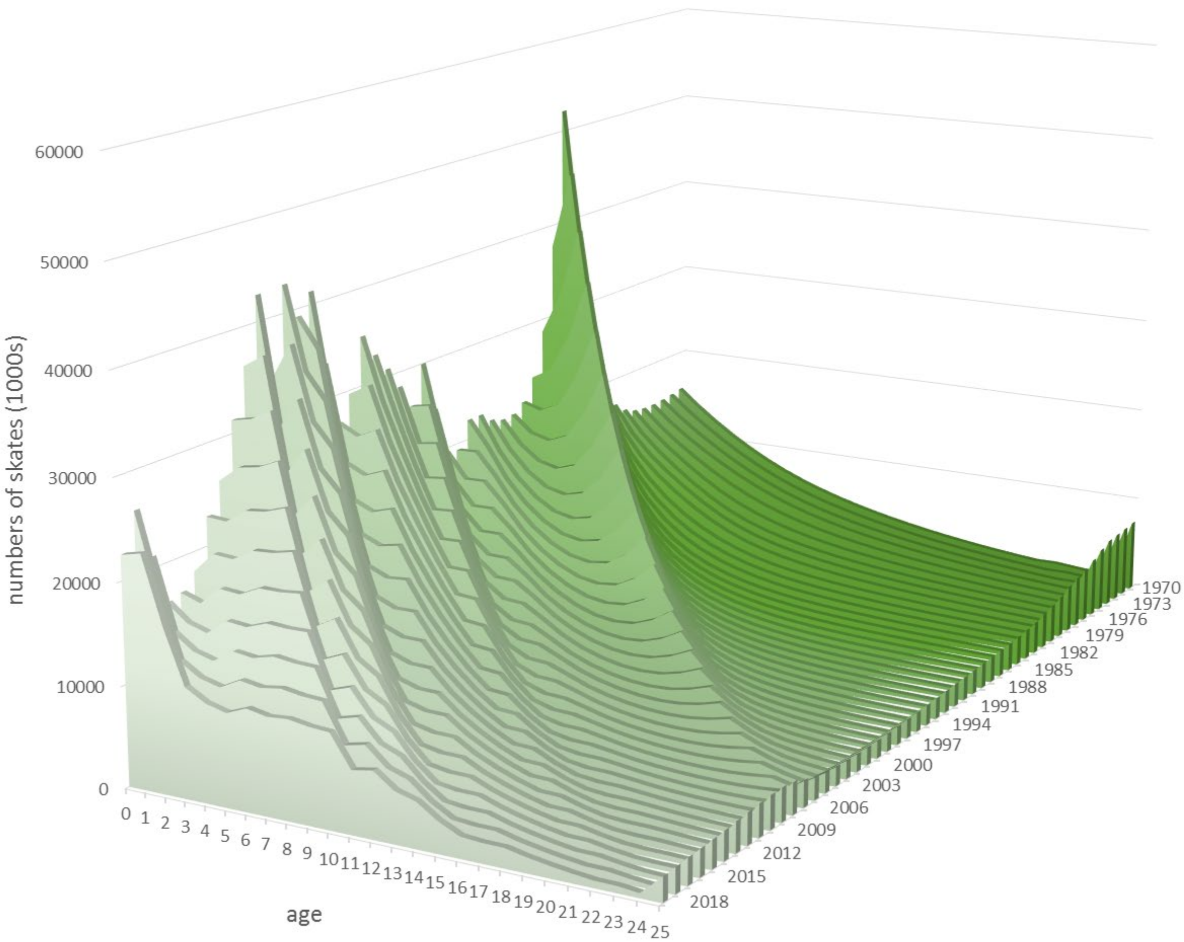


Figure 31. Estimated numbers at age from the preferred model, Model 14.2. Circles are millions of skates; red line indicates average age in the population.

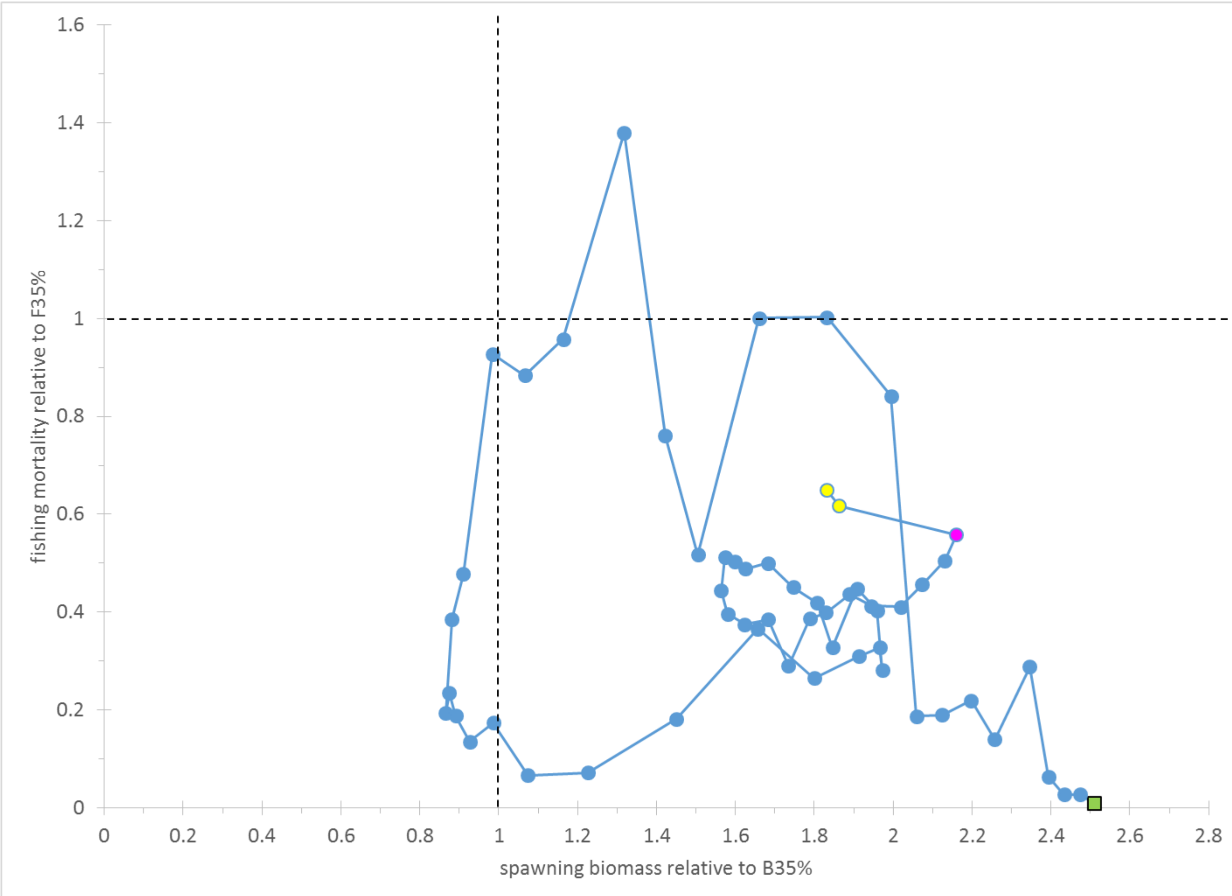


Figure 32. Trajectory of relative fishing mortality and relative spawning biomass as estimated by Model 14.2. Green square marks the beginning of the time series (1964); purple circle indicates 2018; yellow circles indicate projected years 2019 & 2020. Vertical dashed line indicates B35%; horizontal dashed line indicates F35%.

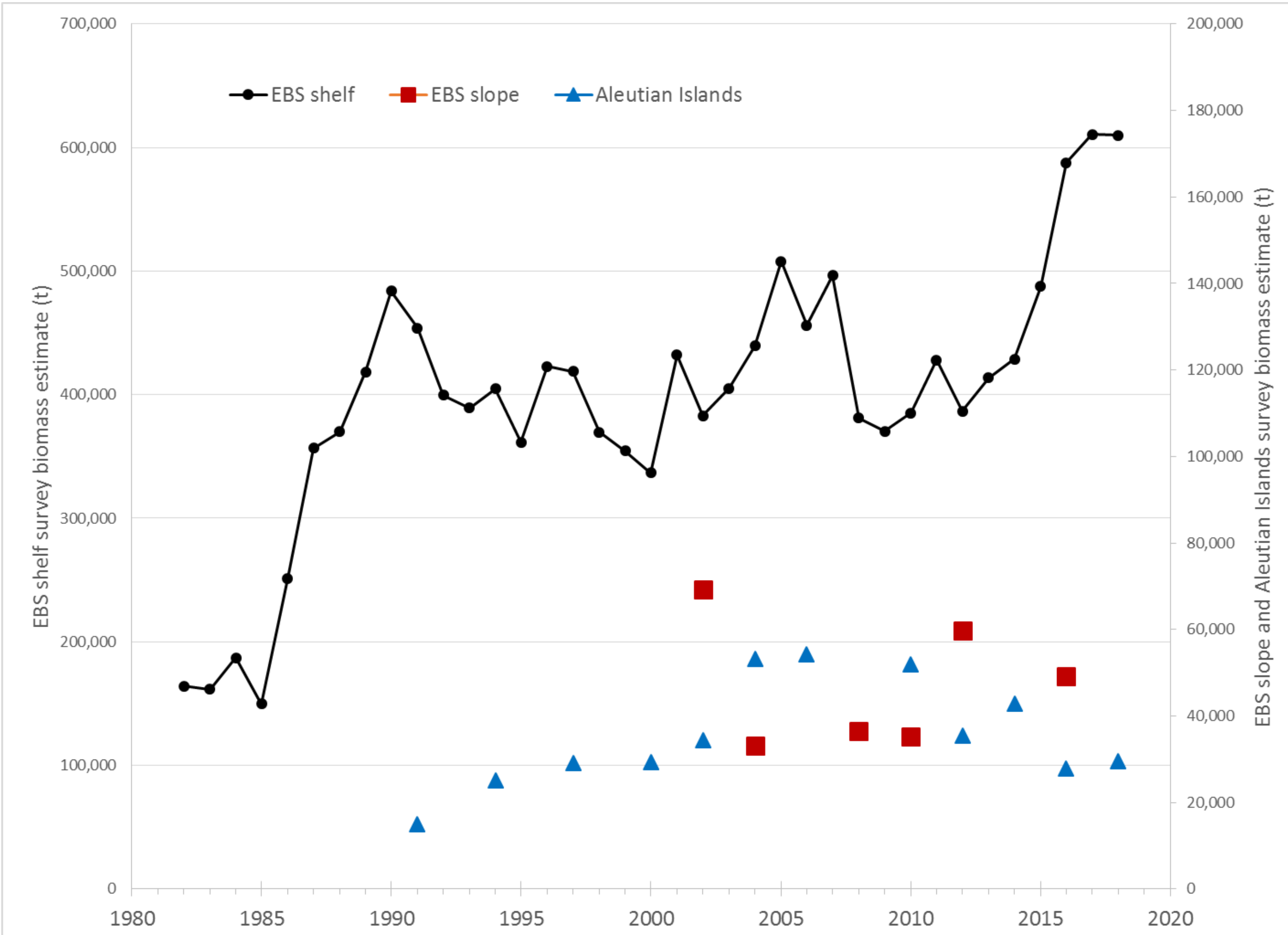


Figure 33. Aggregated skate biomass (t) and 95% confidence intervals estimated from RACE bottom trawl surveys in each of the three major habitat areas (1982 – 2018). Note that slope and AI estimates are much smaller and pertain to the secondary y-axis.

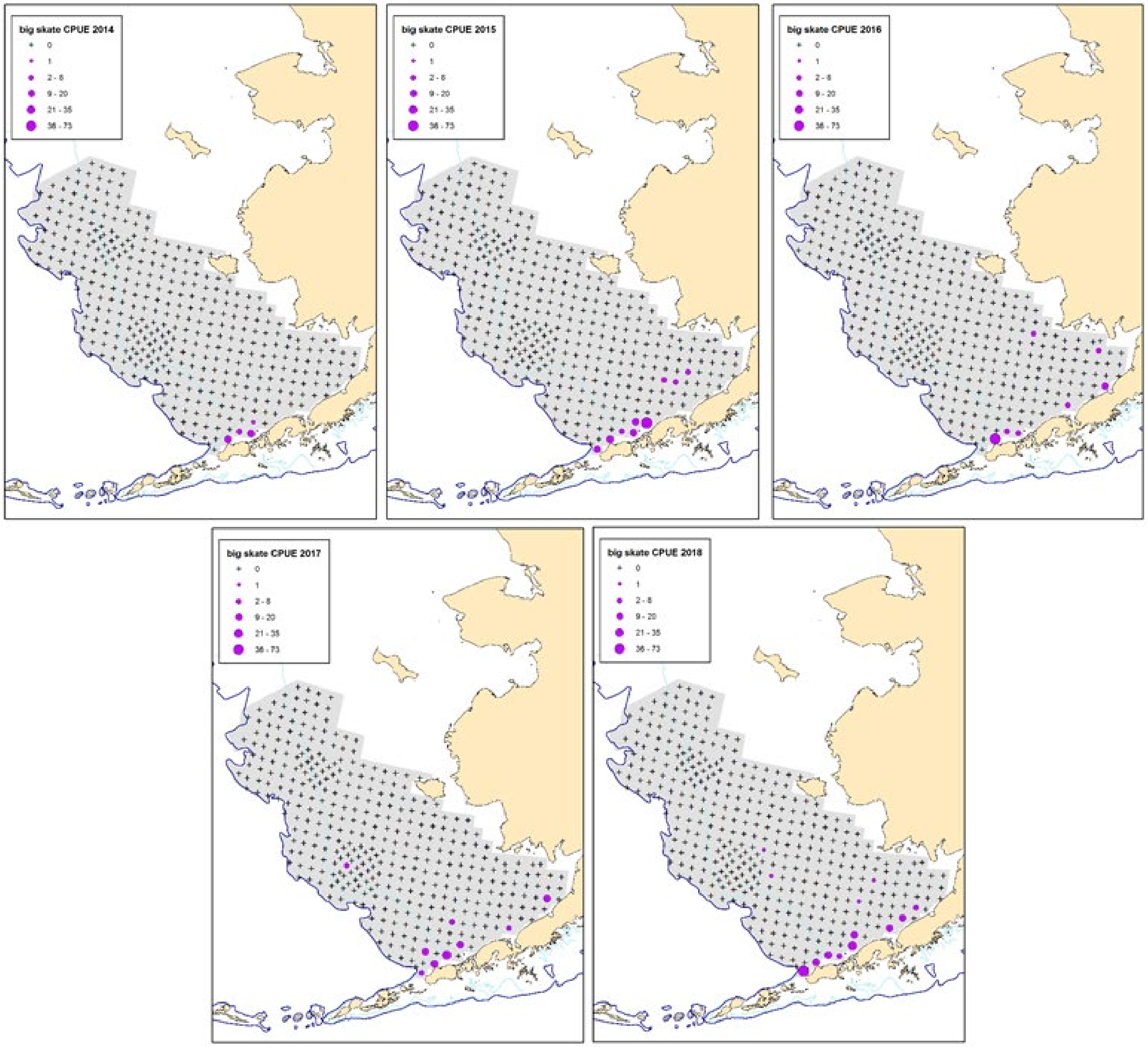


Figure 34. Changes in big skate distribution in the southeastern Bering Sea, 2014-2018. Data area from the AFSC bottom trawl survey.

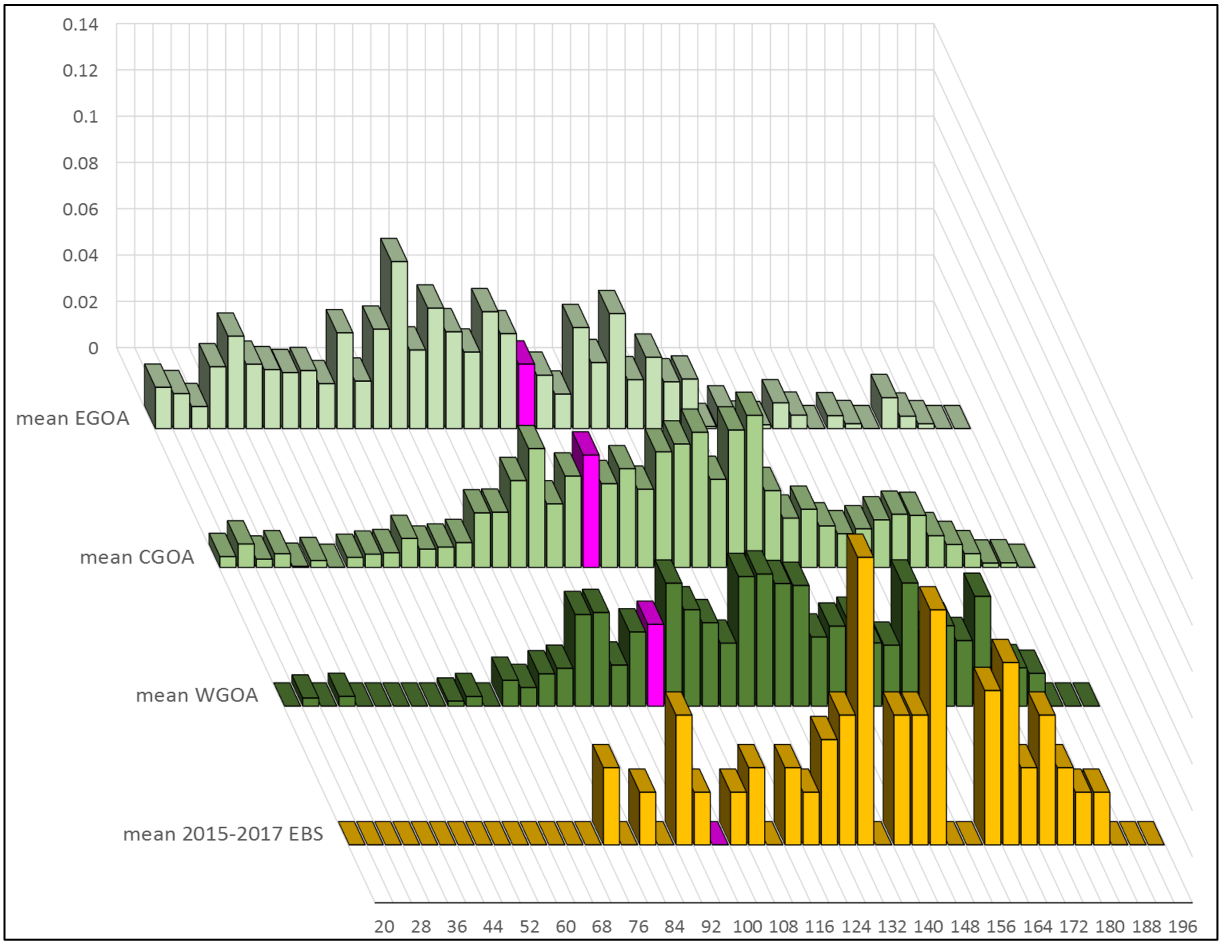


Figure 35. Comparison of mean survey length compositions for big skates. Data are from the 3 regulatory areas in the Gulf of Alaska (GOA [(W)estern, (C)entral, and (E)astern]) and from the eastern Bering Sea (EBS) shelf survey.

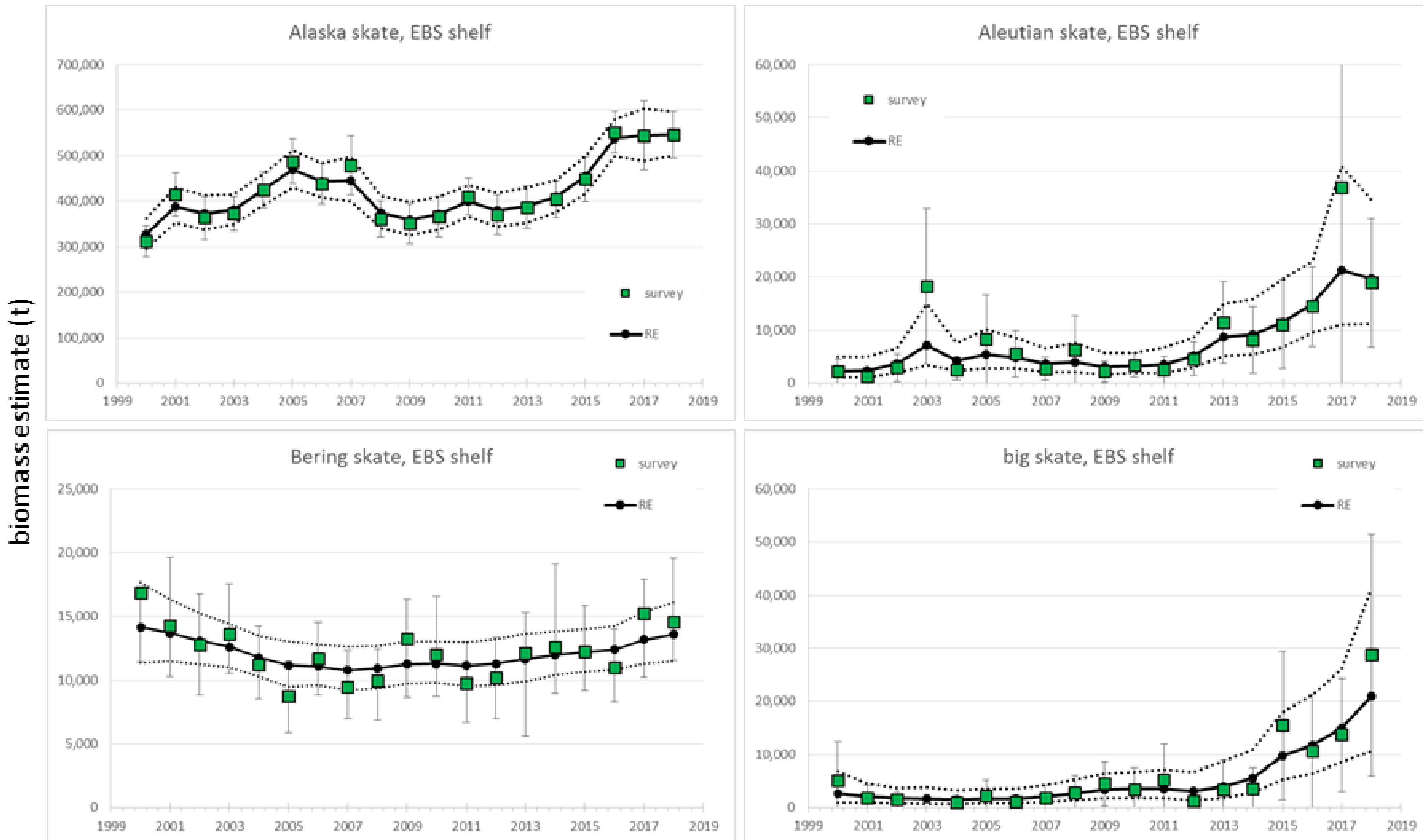


Figure 36. Biomass estimates for skate species on the **EBS shelf**. Squares indicate trawl survey biomass estimates ("survey"). Dotted black lines are biomass estimates from a random-effects model (RE) based on the survey data. Error bars indicate 95% confidence interval (CI) for survey data; dashed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

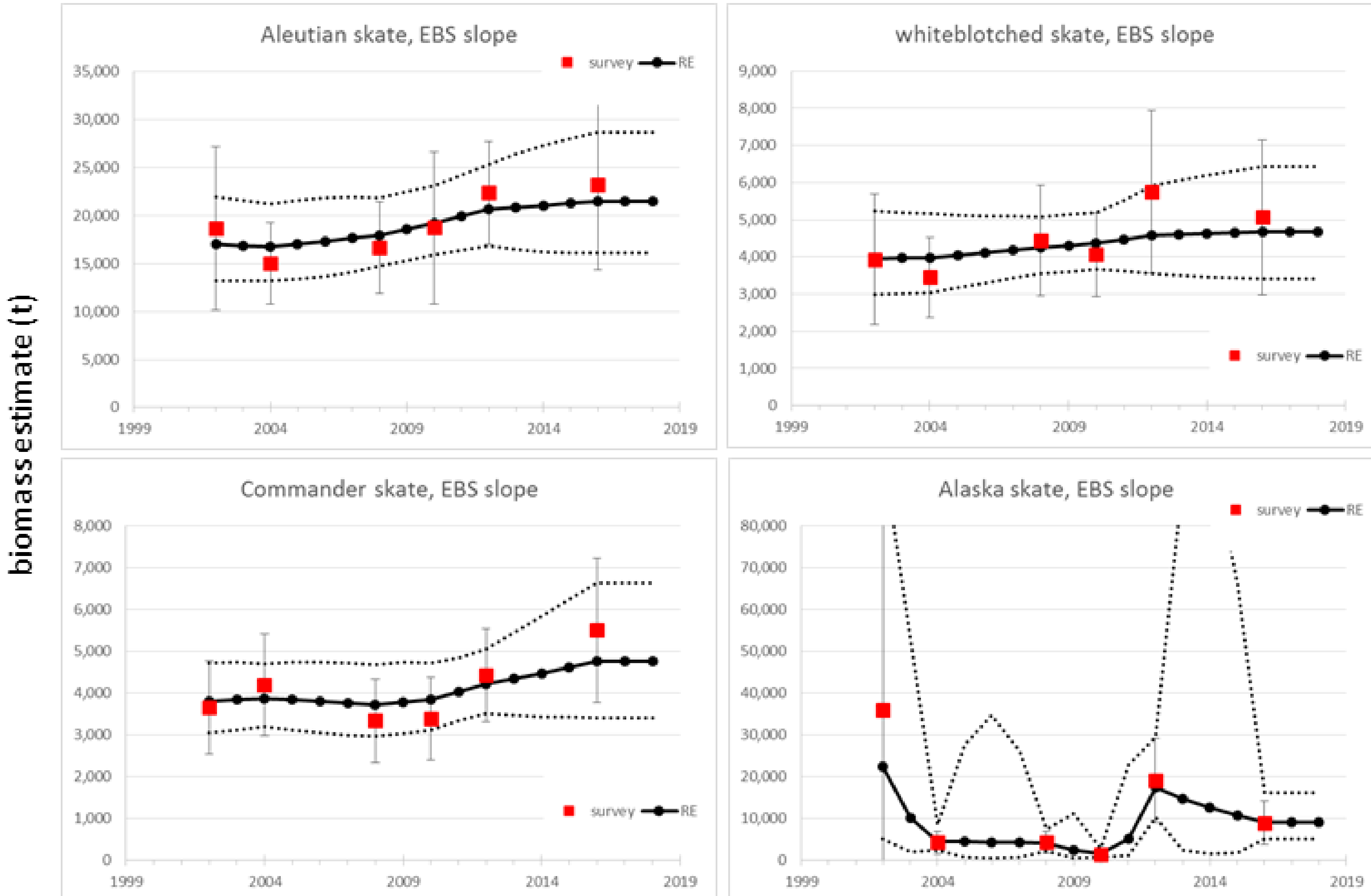


Figure 37a. Biomass estimates for skate species on the **EBS slope**. Squares indicate trawl survey biomass estimates ("survey"). Dotted black lines are biomass estimates from a random-effects model (RE) based on the survey data. Error bars indicate 95% confidence interval (CI) for survey data; dashed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

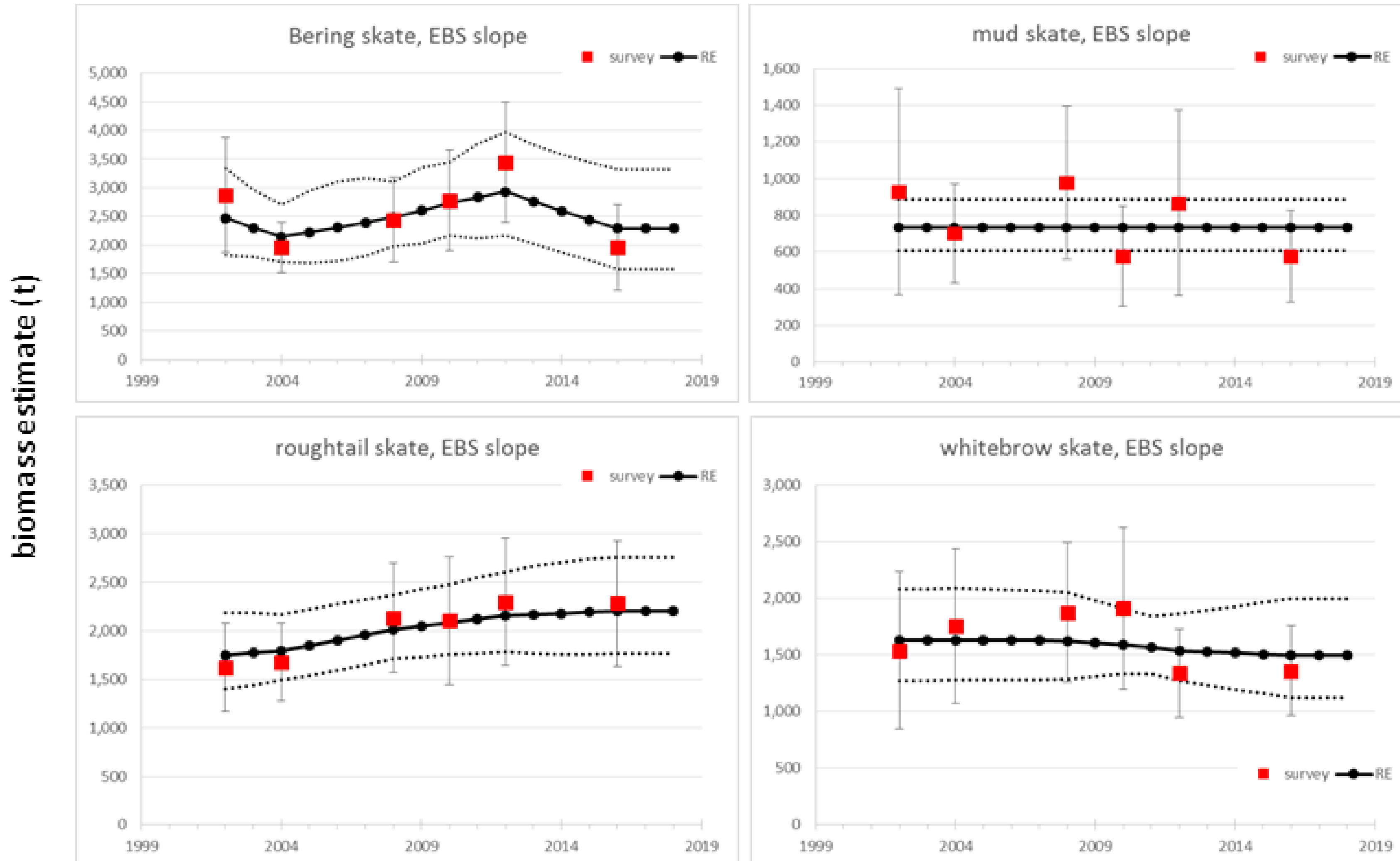


Figure 37b. Biomass estimates for skate species on the **EBS slope**. Squares indicate trawl survey biomass estimates ("survey"). Dotted black lines are biomass estimates from a random-effects model (RE) based on the survey data. Error bars indicate 95% confidence interval (CI) for survey data; dashed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

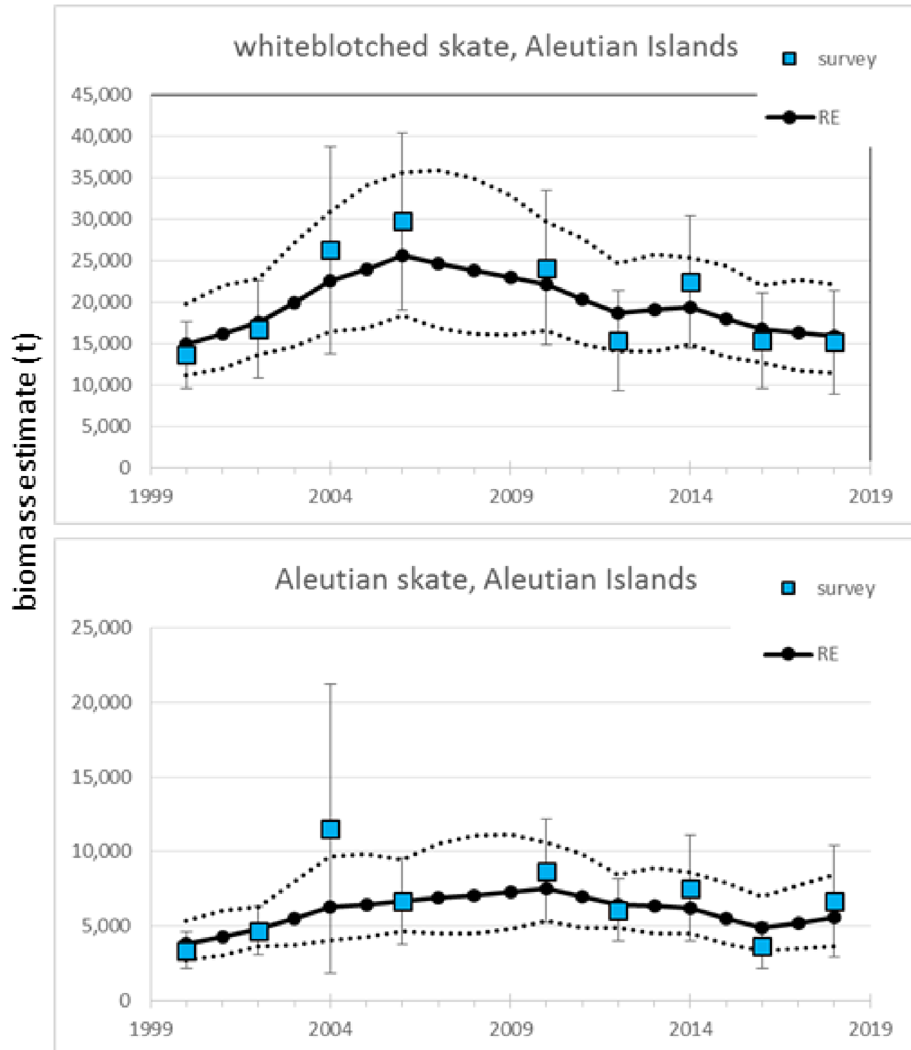
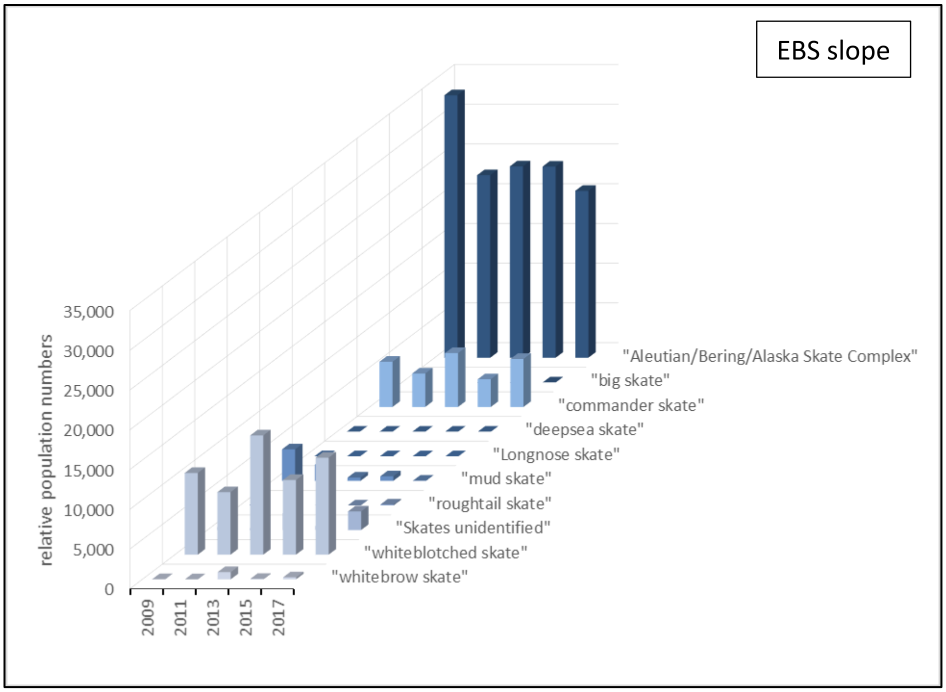


Figure 38a. Biomass estimates for skate species in the **Aleutian Islands**. Squares indicate trawl survey biomass estimates ("survey"). Dotted black lines are biomass estimates from a random-effects model (RE) based on the survey data. Error bars indicate 95% confidence interval (CI) for survey data;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



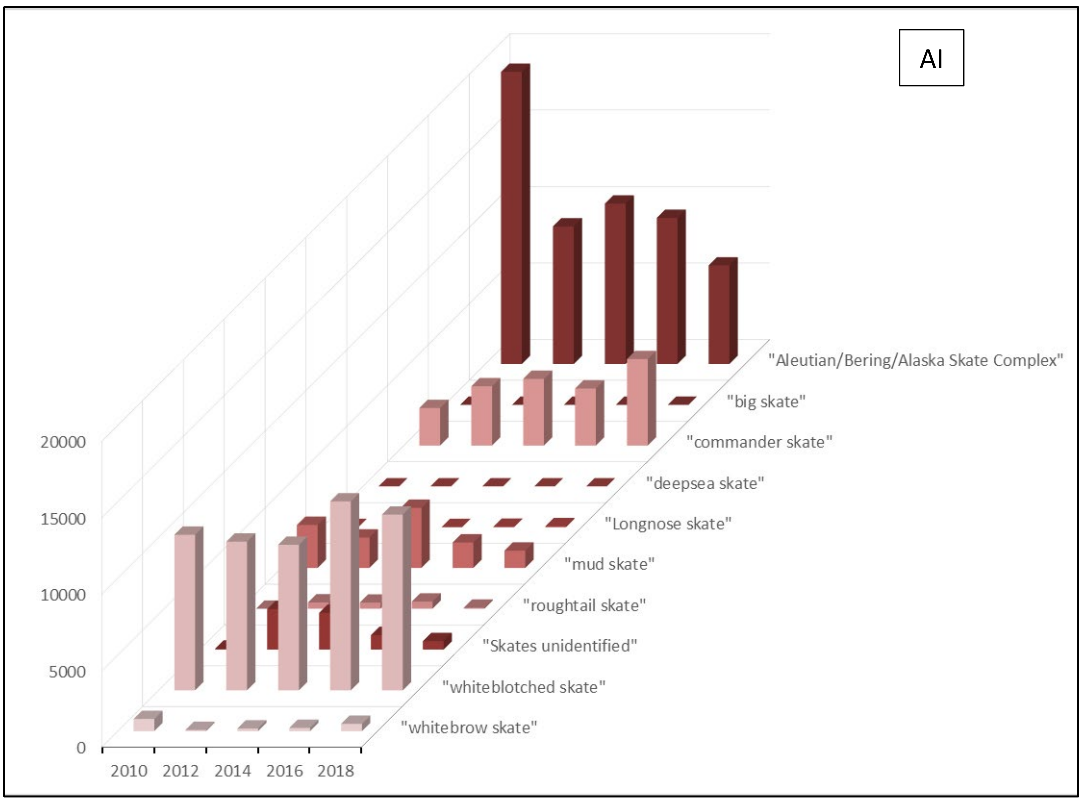


Figure 40. Relative population numbers for skate species and species groups from AFSC longline surveys on the EBS slope (top panel) and in the Aleutian Islands (AI; bottom panel), 2009-2018.

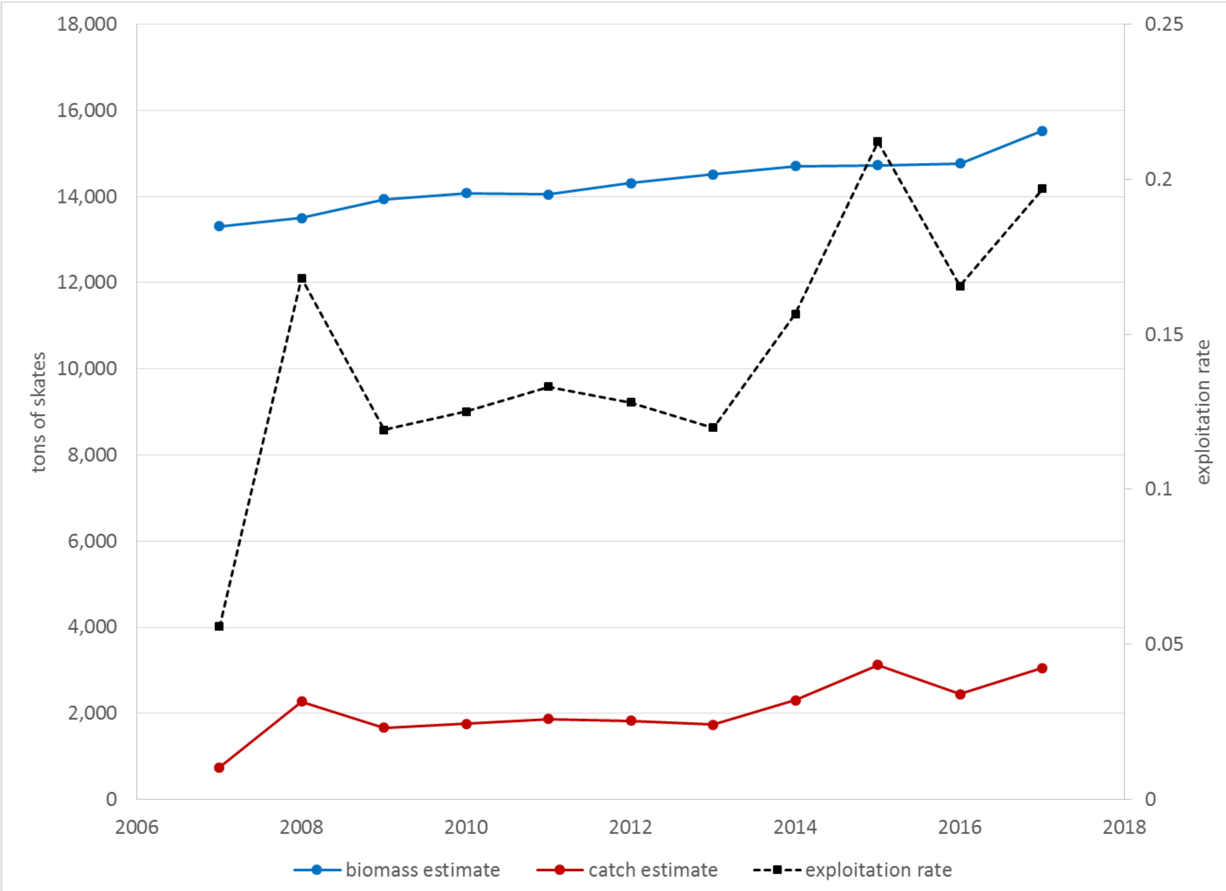


Figure 41. Biomass, catch, and exploitation rate for Bering skate in the Bering Sea and Aleutian Islands region. Exploitation rate is on the secondary axis.

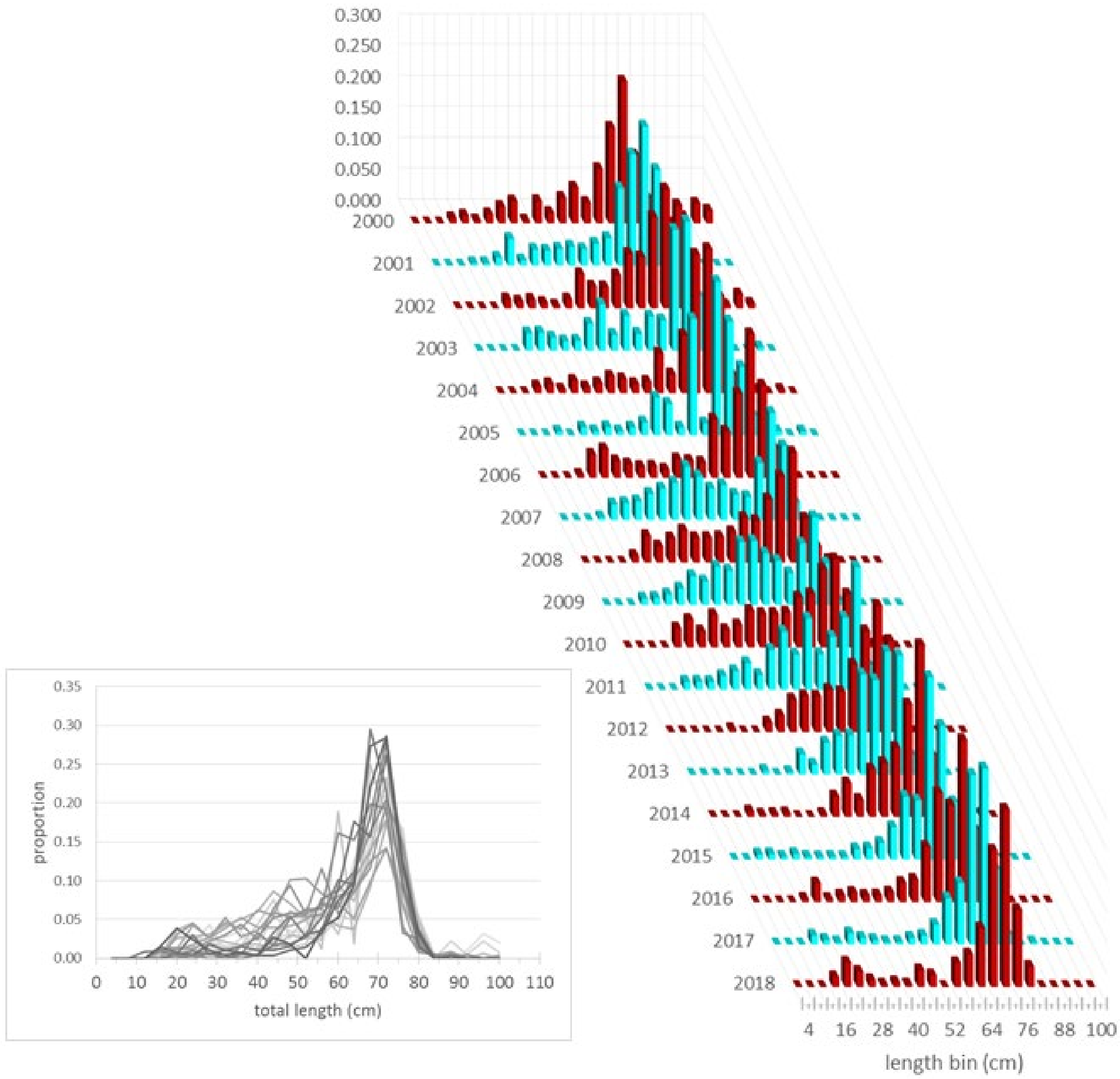


Figure 42. Survey length compositions for Bering skates in the eastern Bering Sea shelf survey. Data are the same in both plots.

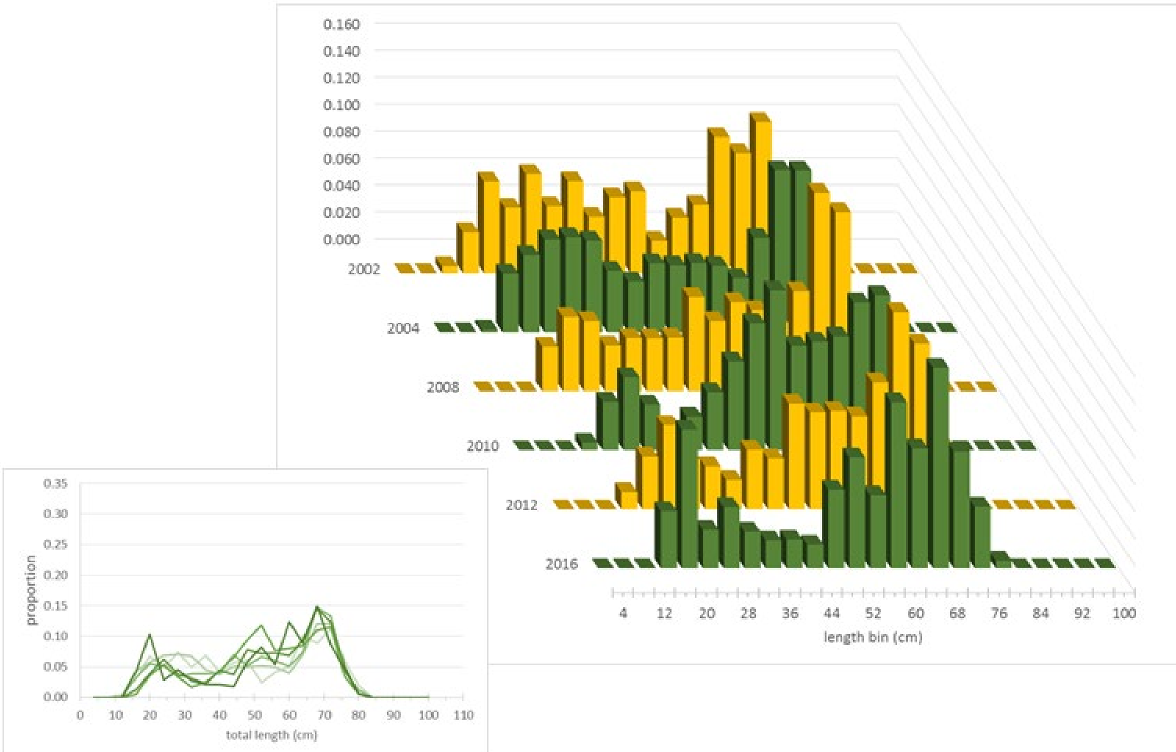

0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
2002
2004
2008
2010
2012
2016
4 12 20 28 36 44 52 60 68 76 84 92 100
length bin (cm)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
proportion
0 10 20 30 40 50 60 70 80 90 100 110
total length (cm)

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

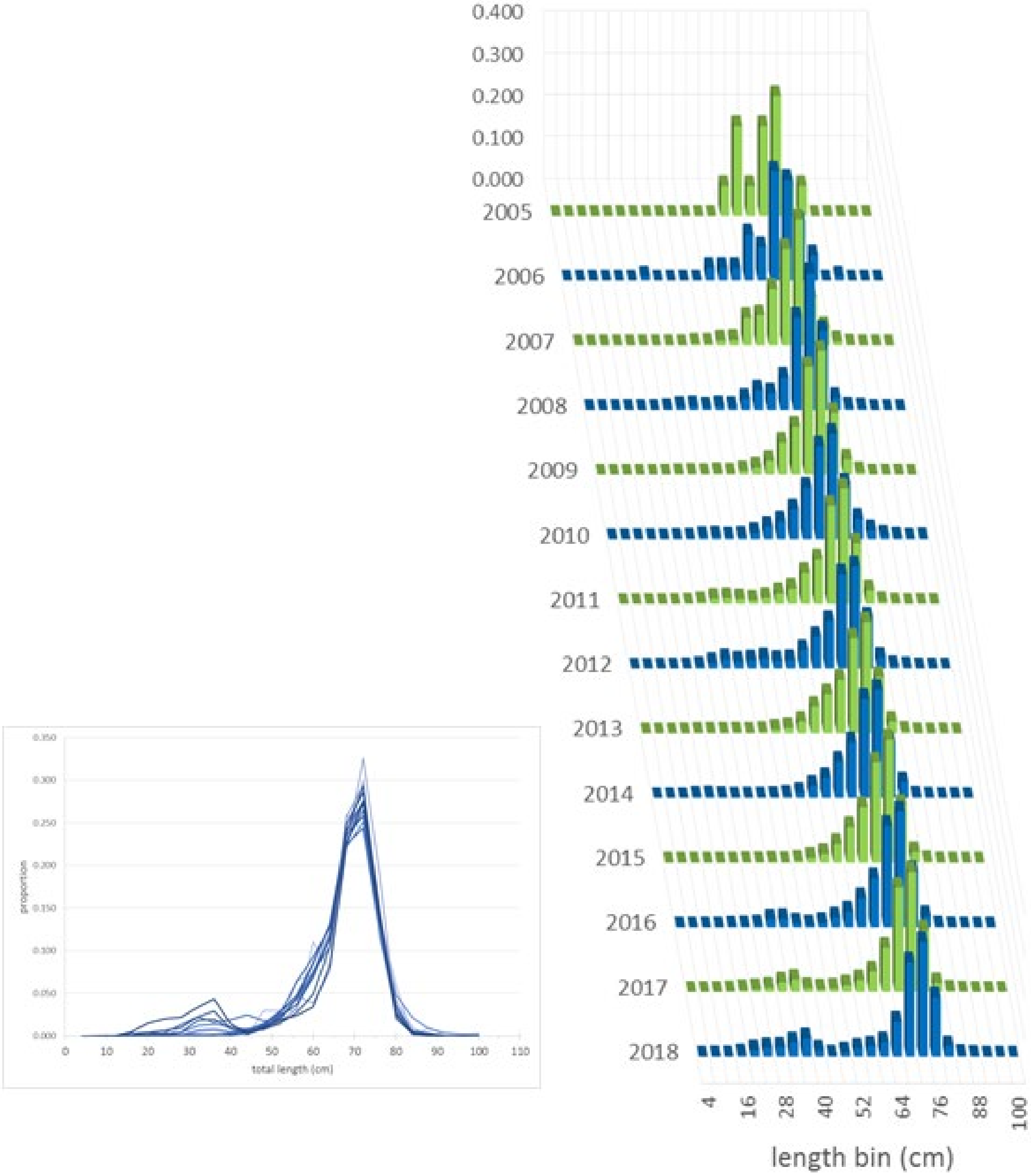


Figure 44. Fishery length compositions (all gears combined) for Bering skates in the Bering Sea and Aleutian Islands region. Data are the same in both plots.

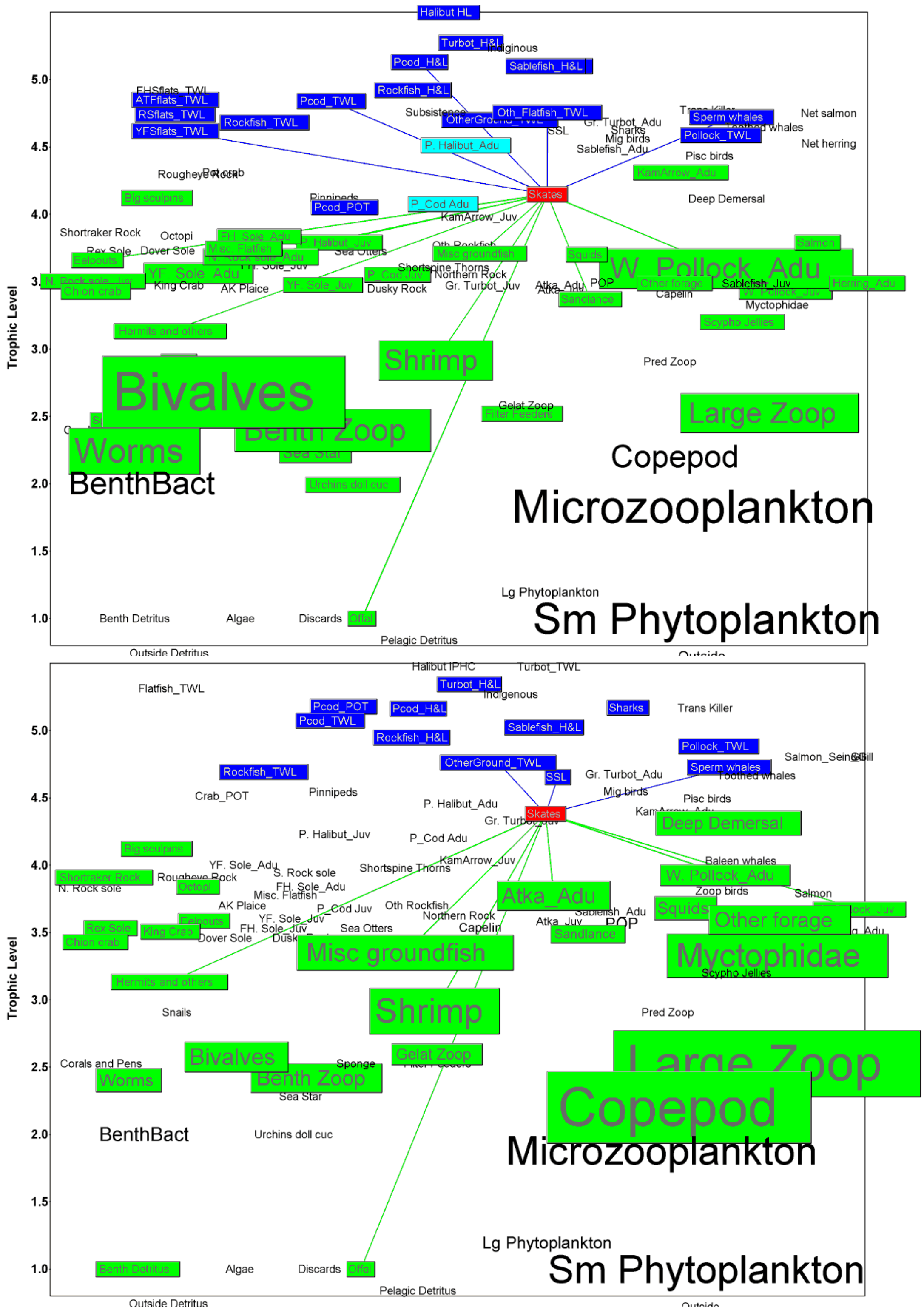


Figure 45. EBS (upper panel) and AI (lower panel) skate food webs derived from mass balance ecosystem models, with skate species aggregated in each area. Source: K. Aydin, AFSC, code available upon request.

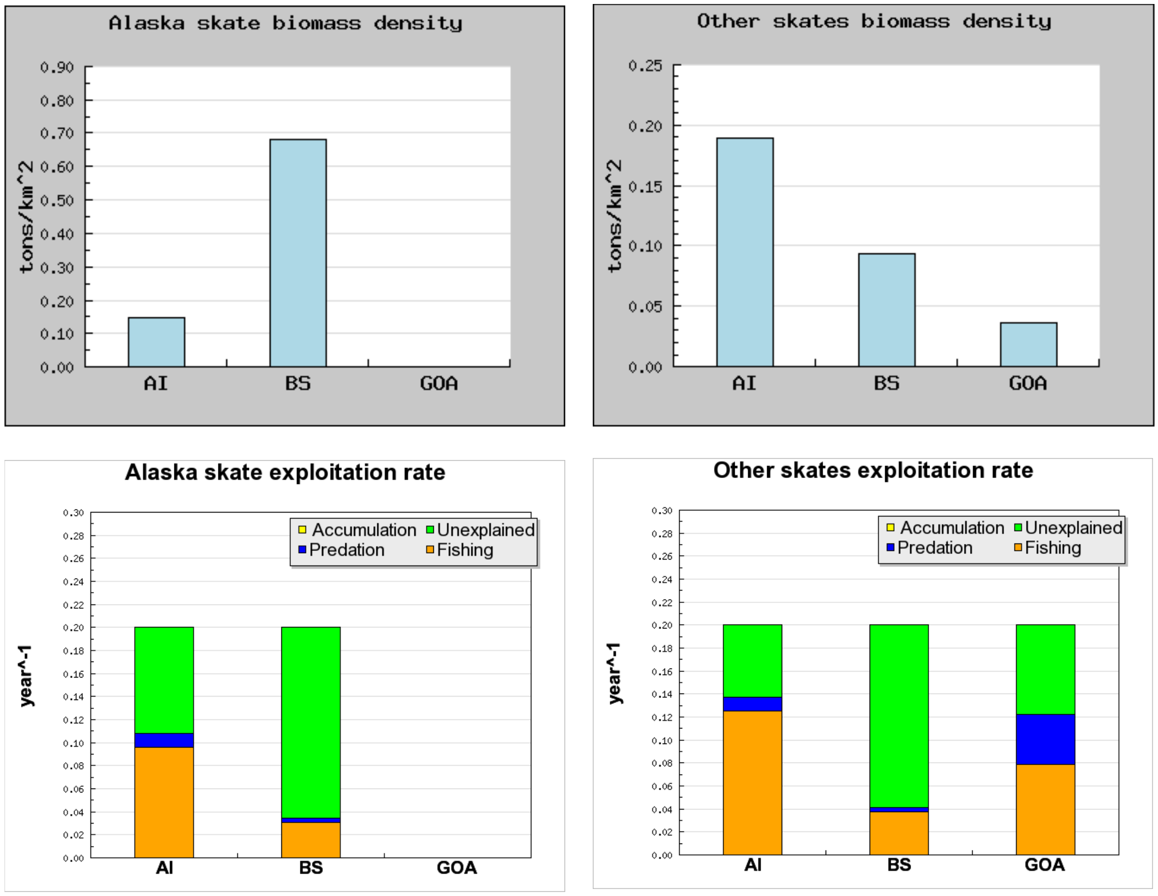


Figure 46. Comparative density (upper panels) and exploitation rate (lower panels) of Alaska (left panels) and all other Bathyraja (right panels) skates in the AI, EBS, and GOA (early 1990s, before fishery in GOA). (Alaska skates are a very small component of skate biomass in the GOA, and are therefore 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).

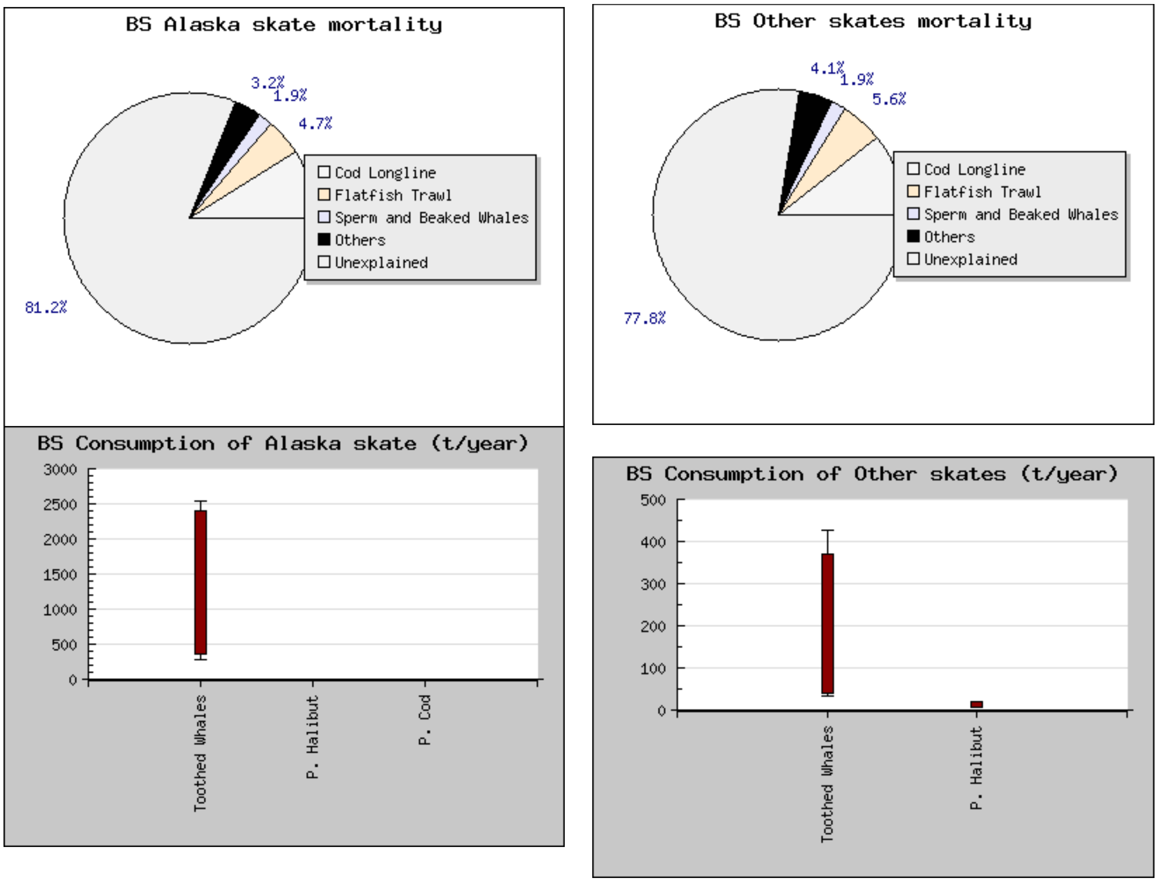


Figure 47. Mortality sources and consumption of skates in the EBS—mortality pie (upper panels) and estimates of annual consumption by predators (lower panels) for EBS Alaska skates (left panels) and all other EBS skates (right panels). Model outputs were derived from diet compositions, production rates,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

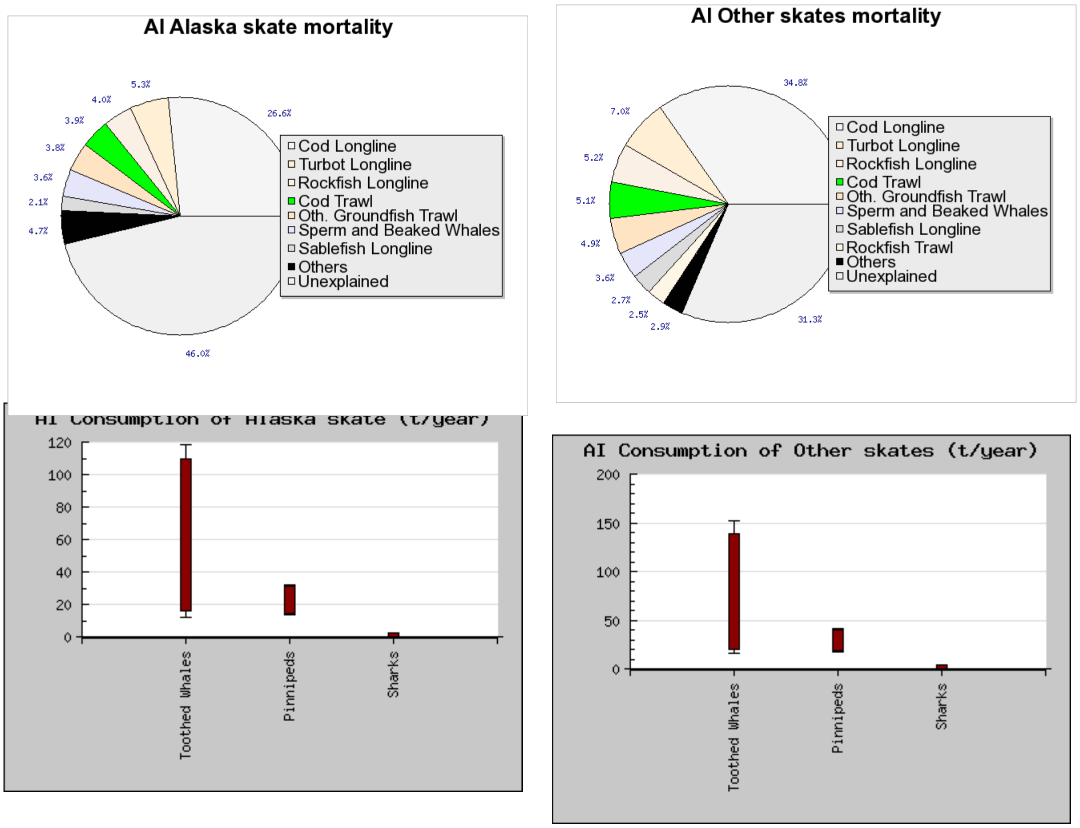


Figure 48. Mortality sources and consumption of skates in the AI—mortality pie (upper panels) and estimates of annual consumption by predators (lower panels) for AI (former) Alaska skate (left panels) and AI Other Skates (right panels). Model outputs were derived from diet compositions, production rates,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

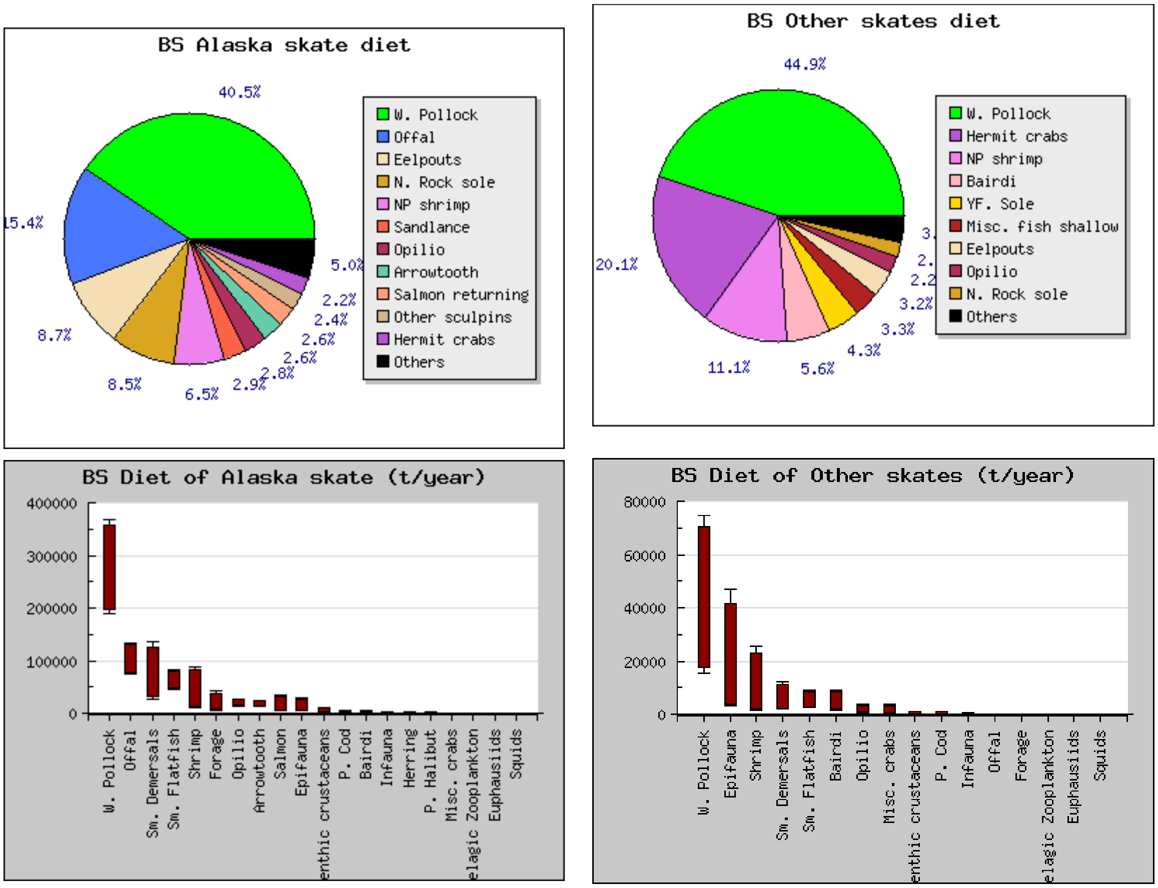


Figure 49. Diet composition (upper panels) and annual estimated prey consumption by skates (lower panels) for EBS Alaska skates (left panels) and Other Skates (right panels). Results were generated from stomach content collections occurring during RACE trawl surveys.

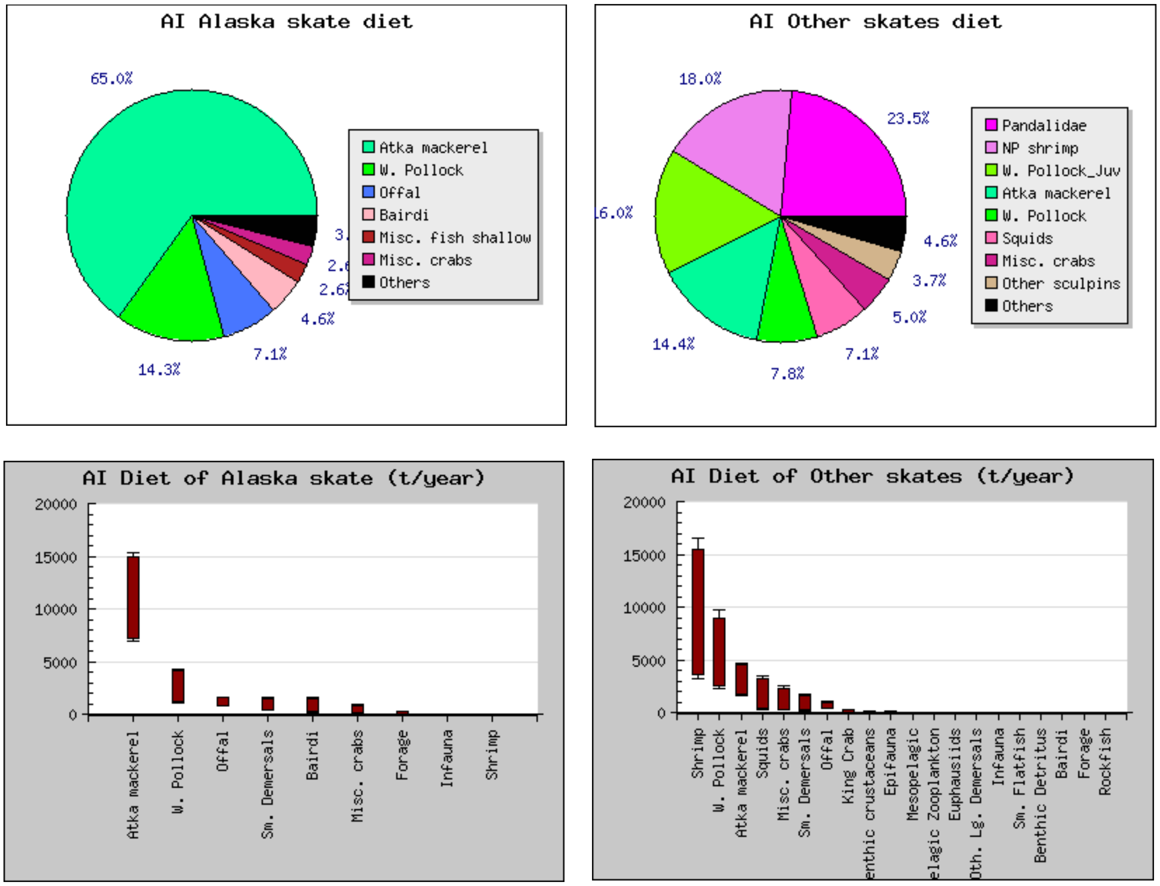
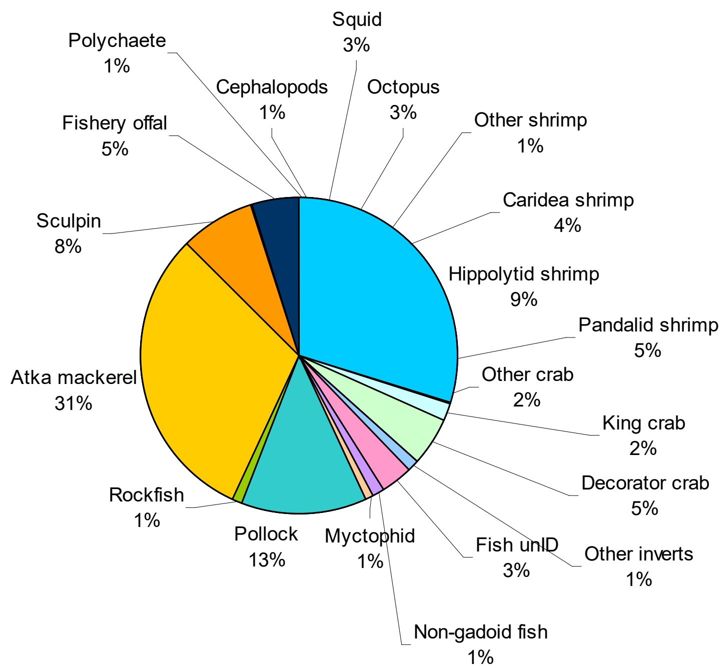


Figure 50. Diet composition (upper panels) and annual estimated prey consumption by skates (lower panels) for AI Alaska skates (left panels) and Other Skates (right panels). Consumption rates were estimated using published diet data from the Kuril Islands (Orlov 1998, 1999) and estimated prey densities.

AI whiteblotched skate (*Bathyraja maculata*)

Diet composition (n = 69 stomachs)



AI Aleutian skate (Bathyraja aleutica)

Diet composition (n = 19 stomachs)

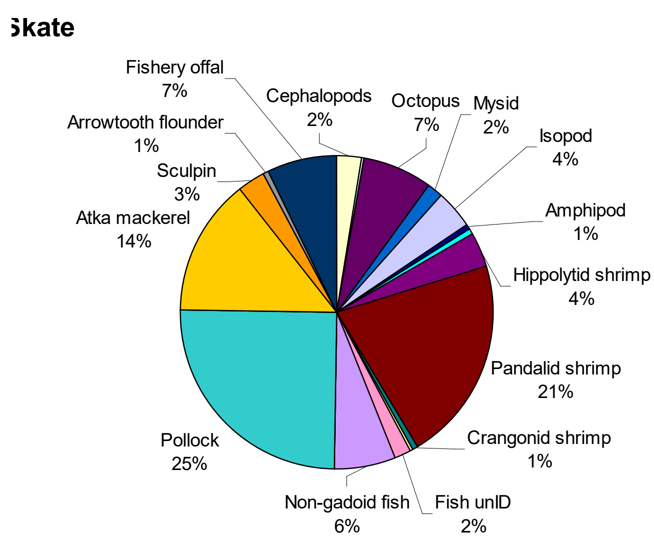


Figure 51. Diet composition (by weight) for the other two biomass-dominant skate species in the Aleutian Islands (AI, which are included in the "Other Skates" group in the previous figure): whiteblotched skate (top) and Aleutian skate (bottom). Results were generated from stomach content collections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

	Golden King Crab Pot Survey	Large-Mesh Trawl Survey	Pribilof Islands Crab Survey	St. Mathews Crab Survey	IPHC Annual Longline Survey	Aleutian Island Bottom Trawl Survey	Aleutian Islands Cooperative Acoustic Survey	Annual Longline Survey	Atka Tagging Survey	Bering Sea Bottom Trawl Survey	Bering Sea Slope Survey	Eastern Bering Sea Bottom Trawl Survey	Northern Bering Sea Bottom Trawl Survey	Pollock EFP 11-01	total
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							3	11,326							11,329
2009								7,455							7,455
2010		232		568	41,976	7,675		6,093		31,118	9,567		4,929		102,157
2011		215	2		25,617			5,393	19,786			34,540		1,451	87,004
2012	23	139			27,786	4,889		7,459			17,593	29,330		1,080,877	1,168,097
2013		138			42,782			7,980				28,925			79,824
2014		119			55,220	6,166		11,698				29,396			102,599
2015		117			42,530			5,836				33,217			81,701
2016		113	96		51,004	3,941		7,760			9,191	20,498			92,603
2017		102		177	42,615			8,573				21,712	2,695		75,873

Appendix 2: Estimation of skate species composition in BSAI catches

Executive Summary

Skates in the Bering Sea and Aleutian Islands (BSAI) management area are managed as a single complex, and official catches are tracked at the complex level (i.e. a single skate catch record). Prior to the 2018 assessment, trawl-survey species composition data were used to estimate catches of Alaska skates for use in the Alaska skate population model. These estimates are likely not entirely representative of commercial catches, particularly those from the longline fleet. For the 2018 assessment a new method is used that applies species composition data from observed catches to the total skate catch data from the Catch Accounting System. The new method is an improvement over using survey. The new estimates of Alaska skate catch are slightly lower than the current estimates but had minimal effect on the population model. The new approach will also be useful for tracking the exploitation of species other than Alaska skate.

Description of the problem

In the Bering Sea and Aleutian Islands (BSAI) management area, skates are not targeted but are captured incidentally in large numbers. The majority of this incidental catch (80-90%) occurs in longline fisheries, particularly those targeting Pacific cod. Fishery observers aboard longline vessels conduct their species composition sampling primarily by watching the haulback of the longline and identifying and counting organisms as they emerge from the water and are brought up to the rail. This counting occurs during multiple discrete periods (“tally periods”) that are designed to be representative of each longline haul. Because the observers cannot directly examine each organism, species that are hard to identify at a distance are recorded at coarser taxonomic groupings. During the tally period, a subset of the tallied species are set aside for species identification and weighing.

Skates in the BSAI occur in two main genera, *Bathyraja* and *Raja* (although big skate has recently been reclassified into its own genus *Beringraja*). Observers record these groups as soft snout skate and stiff snout skate, respectively. Stiff snout skates (longnose skate *Raja rhina* and big skate *Beringraja binoculata*) are relatively easy to identify visually to species and are often tallied as individual species. In contrast, soft snout skates are difficult to distinguish without examining features such as spine number and placement and only the subset of individuals that has been set aside for the observer are identified to species. The resulting species composition is not applied to the remaining tallied but unexamined skates, so the final catch composition data include a mix of species and the soft snout/stiff snout groups (Table 1). The majority (> 80%) of skate catches are recorded as soft snout skates.

An additional issue is that before the mid-2000s observers were not sufficiently trained in the identification of soft snout skates so even skates that were examined were mainly recorded as “skate unidentified”. A concerted effort to enhance observer skate species identification was very successful and after 2007 almost all examined skates have been identified to species (Table 1).

The incomplete species composition data are carried into the official catch estimates from the Alaska Regional Office (AKRO) Catch Accounting System (CAS). Because the CAS relies heavily on observer data for species composition, species-level catch estimates are limited by the information in the observer database and the majority of BSAI skate catches are reported in the “other skate” category (Table 2). The AKRO does categorize catches for the more abundant skate species (Alaska, whiteblotched, Aleutian, big, and longnose) but for the soft snout skates these records are incomplete. In addition because BSAI skates are managed as a complex with a single aggregate set of harvest specifications, catch accounting and public reporting of skate catches in the BSAI occurs for only one “unidentified skate” category.

Since 2008 an age-structured model has been used to assess Alaska skate, the most abundant skate species in the BSAI. This model requires species-specific catch estimates, and since 2008 an estimate of Alaska skate catches has been made by applying species composition data from the bottom trawl surveys to the CAS data in an area-stratified approach. While this method has been acceptable for the purposes of the model trawl-survey data, survey data are likely not entirely representative of commercial catches, particularly those from the longline fleet. In 2018 a new method for estimating skate catches was developed to (1) establish annual catch estimates for all skate species in the BSAI, and (2) improve the catch estimates used for the Alaska skate population model.

Methodology

The catch estimation methods described here rely on the primary assumption that the subset of skates that are set aside and examined during the tally period are representative of all skates counted during the tally period. This is similar to the general assumption that observer samples are representative of the entire haul. Following on this, for this analysis the "stiff snout" and "soft snout" categories are ignored and the resulting species-level catch reporting is used as the underlying species composition, which was then applied to the total skate catch. To overcome differences in observer sampling design and observer coverage, both data streams (observer species composition and CAS skate catch) were stratified by vessel type, gear type, and NMFS statistical area. The catch estimation involved 9 steps (see Figure 1):

1) Haul-level catch data for all skate taxonomic categories (85-98, 159-168) were downloaded from the "Debriefed" tables in the OBSINT observer database for all years 2003-2017 (the current CAS began in 2003).

2) Catch data for all skate groups (700-705) were downloaded from the CAS for the years 2003-2017 (table V_CAS_TXN_PRIMARY_ALL).

3) For each year, data were first stratified by vessel type: catcher processor (CP) and catcher vessel (CV). Observer sampling differs between these vessel types; CPs also have full observer coverage while coverage for CVs is partial.

4) Data were then stratified by gear type: non-pelagic trawl, pelagic trawl, pot, and longline.

5) The CP and CV data were treated differently in regards to spatial stratification. Because CPs are full coverage, observer species composition data were available for all statistical areas where the CAS reported catches. In contrast, there was often a mismatch between CV data in this regard. To overcome this problem, for CV data only statistical areas were aggregated to create larger strata (Table 3). The criteria for these aggregations were to preserve the area/depth stratification of the individual areas as well as to coincide with skate distribution patterns. As a result, CP data were stratified by vessel type/gear type/statistical area while CV data were stratified by vessel type/gear type/aggregation stratum.

6) Within each stratum, the extrapolated catch of each skate species was summed and the values were used to construct skate species proportions specific to that stratum.

7) These proportions were then multiplied by the total skate catch in the matching stratum from the CAS data. In a very few cases within the CV data matching strata were not available; in these cases composition data from the nearest stratum were used.

8) The CP and CV data were merged to provide complete estimates of skate catch stratified by year, species, and gear type. Statistical area estimates are also available for CP data.

9) Catches in the "skate unidentified" category were apportioned to each remaining species group according to their proportion in the stratum.

Results

Overall results: The analysis yielded complete results for all species, which were incorporated into the 2018 assessment. During 2003-2006 the majority of skate catches were reported as "skate unidentified" (Table 4, Figure 2), but the proportion of skates in that category declined steadily from 2003-2011 so that in 2017 only 0.4% of skates were recorded as unidentified. To provide the best possible species-level estimate of catches, the "skate unidentified" catches were apportioned to each species according to their proportion in each stratum. For the assessment, the new method was only applied for data beginning in 2007.

Alaska skate catch estimation, new versus old: Estimates of total Alaska skate catch using the new method are slightly lower than those produced using the existing methods (Figure 3). Except for 2017 the new estimates for longline fisheries are consistently lower than the current estimates. In contrast, for trawl catches the relationship between the two estimates has been variable. The lower estimates from the new methods in recent years (Figure 3) may reflect the change in species composition within the trawl data.

Effect of new catch estimates on the Alaska skate model: The model used in the 2016 assessment was re-run replacing the 2003-2016 data with the new catch estimates. The new data had a minimal effect on the model, slightly influencing reference point estimates and estimates of F (Table 5; differences in estimates of F were too small to be shown at the resolution in the table).

Conclusions

1) The methods for skate catch estimation presented here is a marked improvement over the existing method, and the new approach should be used for estimating Alaska skate catches used in the population model.

2) Although official skate catch is tracked only at the complex level, the species-level catches generated using the new method will be useful for discerning trends in catches of individual species. This will be particularly useful for identifying increases in exploitation rates.

3) Due to the severe lack of species identification in observer coverage before 2003, pre-2003 estimates of Alaska skate catch should continue to be made using the existing survey-based method. In addition because during 2003-2006 most skates were not identified to species the new method should be applied beginning in 2007.

Tables

Table 1. Proportions (by weight) of skate taxonomic groupings in observed longline catches in the Bering Sea and Aleutian Islands management area, 2014-2017. Highlighted rows indicate skates identified only to genus.

.taxonomic group	2014	2015	2016	2017
soft snout skate	0.813	0.830	0.839	0.864
Alaska skate	0.136	0.123	0.119	0.102
Bering skate	0.020	0.021	0.015	0.014
big skate	0.014	0.011	0.010	0.010
Aleutian skate	0.009	0.009	0.006	0.005
stiff snout skate	0.001	0.001	0.004	0.002
whiteblotched skate	0.002	0.002	0.002	0.001
Commander skate	0.002	0.001	0.001	0.001
skate unidentified	0.004	0.000	0.004	0.000
mud skate	0.000	0.000	0.000	0.000
whitebrow skate	0.000	0.000	0.000	0.000
skate egg case unidentified	0.000	0.000	0.000	0.000
longnose skate	0.000	0.000	0.000	0.000
roughtail skate	0.000	0.000	0.000	0.000
deepsea skate	0.000	0.000	0.000	0.000

Table 2. Incidental catches of skates in the Alaska Regional Office Catch Accounting System, 2011-2018. Data for 2018 are partial; retrieved August 21, 2018. Catches are categorized by total catch (all gear types) and by longline and trawl gears.

species code	species name	2011	2012	2013	2014	2015	2016	2017	2018
	total catch								
700	other skate	15,945	16,133	17,498	18,957	21,266	22,248	24,316	12,014
703	Alaska skate	6,941	7,357	8,386	7,049	5,593	5,417	6,067	3,843
705	whiteblotched skate	480	503	592	806	652	751	695	532
702	big skate	186	308	240	387	360	445	487	273
704	Aleutian skate	266	520	306	384	379	320	322	220
701	longnose skate	10	5	10	16	16	14	3	17
	longline only								
700	other skate	15,268	15,506	17,150	18,656	21,053	22,072	24,113	11,765
703	Alaska skate	2,001	2,563	3,043	3,336	3,228	3,183	3,051	1,365
702	big skate	97	269	208	288	278	305	306	158
705	whiteblotched skate	139	51	134	173	142	104	100	145
704	Aleutian skate	141	322	170	293	243	185	144	139
701	longnose skate	3	2	6	7	13	2	2	14
	trawl only								
703	Alaska skate	4,940	4,794	5,343	3,714	2,365	2,234	3,016	2,478
705	whiteblotched skate	341	453	457	633	510	648	595	388
700	other skate	676	627	347	301	213	176	203	249
702	big skate	88	40	32	99	82	140	181	115
704	Aleutian skate	125	198	136	92	136	135	179	81
701	longnose skate	7	2	5	9	3	12	1	3

Table 3. Strata used in the aggregation of catcher vessel observer data and data from the Catch Accounting System. Stratum 5 is missing because it originally contained area 541 but this was combined with areas 542 and 543 after analysis of the results.

stratum	description	NMFs statistical areas included
1	outer EBS shelf and slope	521, 523
2	horseshoe area	517, 518, 519
3	SE Bering Sea/ middle shelf	509, 512, 513, 516
4	inner EBS shelf	508, 514
6	Aleutian Islands	541, 542, 543
7	northern EBS	524

Table 4. Species-specific catch estimates for BSAI skates, 2003-2017. “Skate unID” = unidentified skates which comprise the majority of the catch during 2003-2005.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Alaska	1,416	6,709	8,695	9,287	11,871	14,777	16,290	13,250	19,124	19,435	22,023	20,813	21,477	22,599	25,098
Bering	50	321	402	14	430	1,738	1,371	1,515	1,590	1,517	1,601	2,080	2,987	2,377	2,753
big	48	177	530	397	414	191	439	983	622	1,142	1,611	1,499	1,287	1,482	1,773
Aleutian	119	401	506	298	578	1,033	954	1,064	873	1,152	787	1,067	1,297	1,010	1,055
whiteblotched	20	277	121	60	170	1,454	340	427	1,132	581	694	1,214	831	914	861
skate unID	17,491	14,329	12,718	9,658	5,029	2,274	953	160	136	697	82	560	83	581	136
commander	3	14	47	4	93	87	134	104	174	108	120	203	109	107	82
mud	4	34	37	240	25	95	91	171	117	93	58	42	95	49	58
skate egg case	2	6	7	1	2	8	3	7	7	13	12	21	34	35	26
whitebrow	0.3	8.2	10.8	259.9	4.5	8.5	14.1	20.0	25.0	18.6	7.6	27.3	12.0	14.1	25.6
longnose	1.2	39.9	7.1	2.1	0.6	4.8	2.0	13.5	21.0	20.1	31.4	69.1	52.0	25.1	20.2
roughtail	0.2	13.7	2.9	17.9	3.5	6.6	4.2	15.4	5.6	4.0	3.6	3.8	2.2	2.1	3.7
deepsea	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	47.1	0.0	0.0	0.0	0.1	0.0
sandpaper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Okhotsk	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
butterfly	0.0	0.0	0.0	9.6	1.7	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
total	19,154	22,329	23,084	20,250	18,623	21,677	20,596	17,730	23,827	24,827	27,031	27,599	28,266	29,196	31,891

Table 5. Comparison of selected Alaska skate base model results using new versus old catch estimation methods.

	new catch	old catch
total likelihood	202.087	202.119
R_0	24,738	24,685
B_0	334,622	333,800
2016 B	251,012	250,165
2016 longline F	0.049	0.049
2016 trawl F	0.003	0.003

Figures

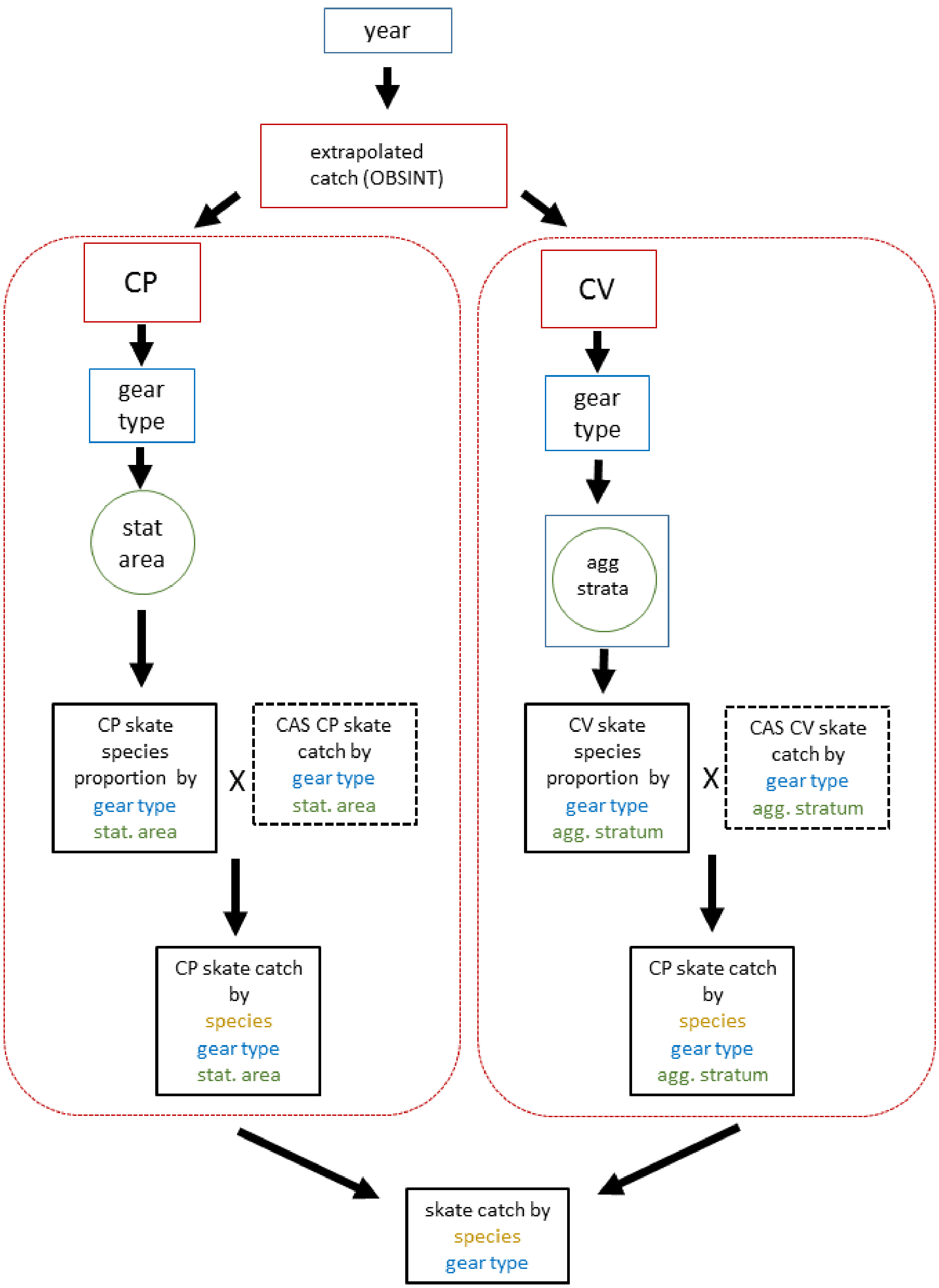


Figure 1. Graphical representation of the proposed skate catch estimation approach. CP = catcher-processor, CV = catcher vessel, CAS = Catch Accounting System, OTC = official total catch.

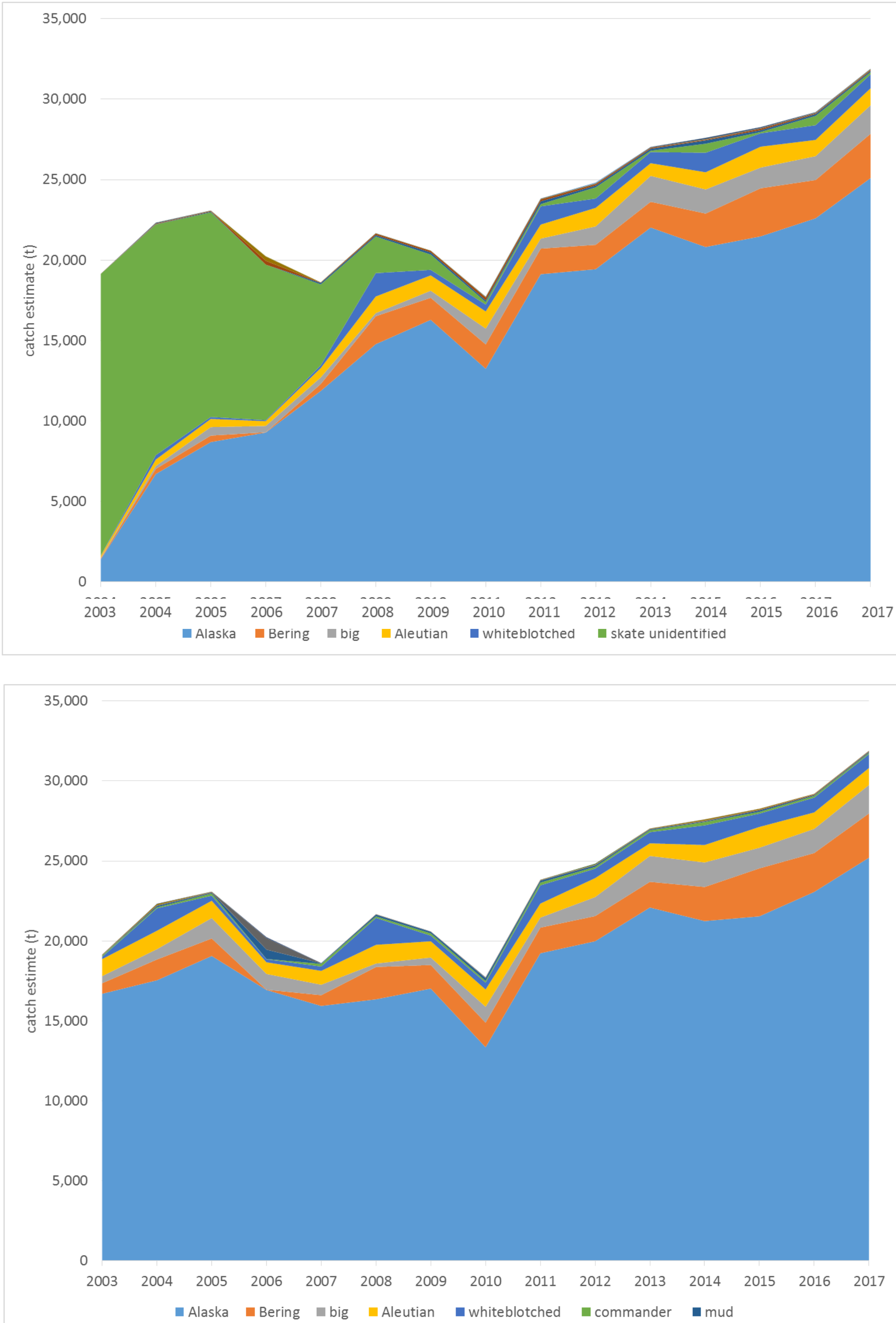


Figure 2. Estimated catches of skate species in the Bering Sea and Aleutian Islands, 2003-2017. Upper panel includes the “skate unidentified” category; lower panel displays data where the “skate unidentified” category has been apportioned to individual species.

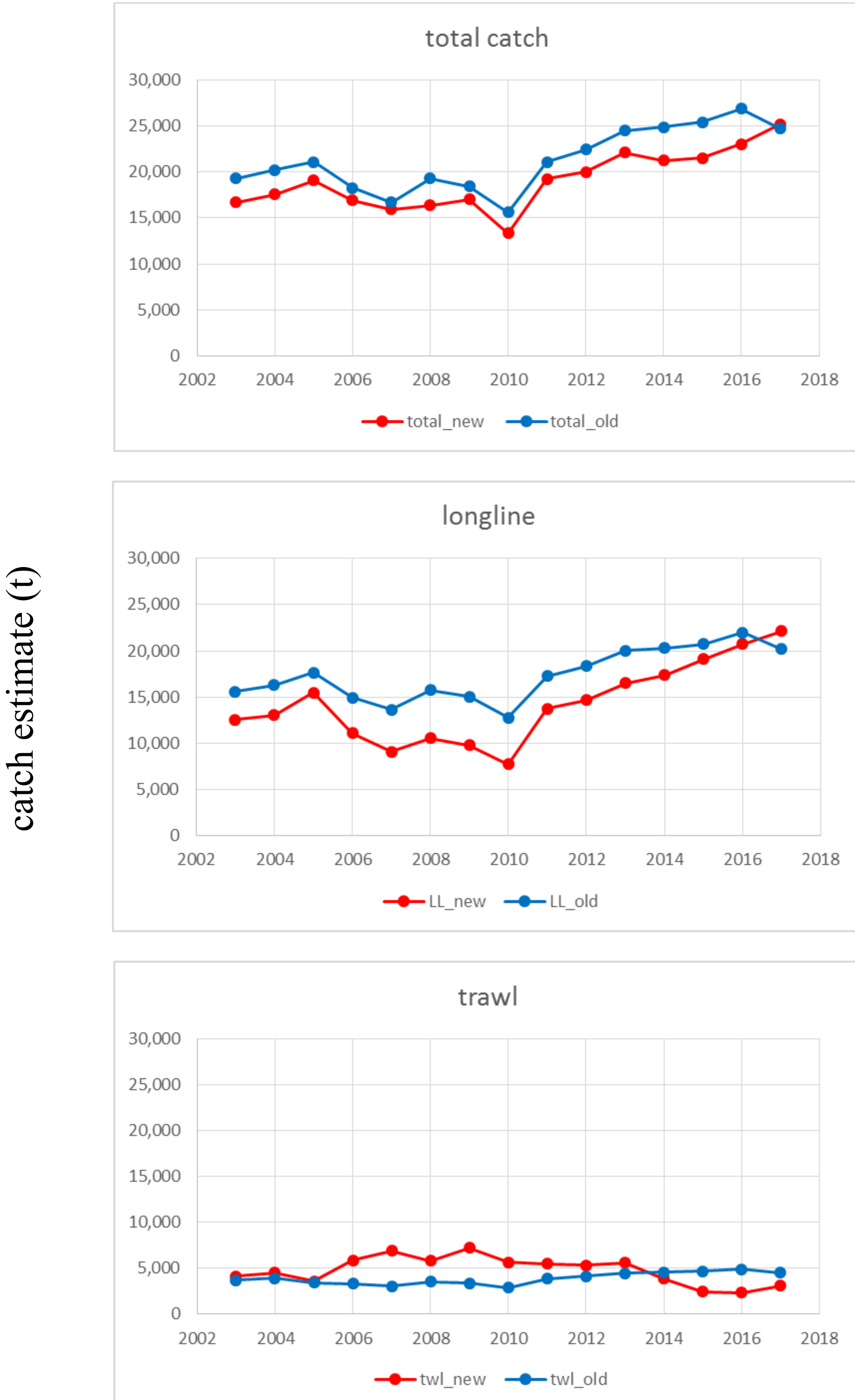


Figure 3. Comparison of catch estimates of Alaska skate, 2003-2017, between new (red) and old (blue) estimation methods. Data are shown as total catch (top), longline catch (middle), and trawl catch (bottom).