18. Assessment of the skate stock complex in the Gulf of Alaska

Olav A. Ormseth
NMFS Alaska Fisheries Science Center, Seattle WA

Executive Summary

There are currently no target fisheries for skates in the Gulf of Alaska (GOA), and directed fishing for skates is prohibited. Incidental catches in other fisheries are sufficiently high that skates are considered to be "in the fishery" and harvest specifications are required. The GOA skate complex is managed as three units. Big skate (*Beringraja binoculata*) and longnose skate (*Raja rhina*) have separate harvest specifications, with Gulf-wide overfishing levels (OFLs) and Acceptable Biological Catches (ABCs) specified for each GOA regulatory area (western [WGOA], central [CGOA], and eastern [EGOA]). All remaining skate species are managed as an "other skates" group, with Gulf-wide harvest specifications. All GOA skates are managed under Tier 5, where OFL and ABC are based on survey biomass estimates and natural mortality rate. Effective January 27, 2016 the Alaska Regional Office indefinitely reduced the maximum retainable amount for all skates in the GOA from 20% to 5%.

Summary of Changes in Assessment Inputs

<u>Changes in the input data:</u>

1) Fully updated fishery catch data (2019 catch data as of October 26, 2019).
2) Biomass estimates and length composition data from the 2019 GOA bottom trawl survey.
3) Fishery length composition data through 2019 (2019 data through October 30, 2019).
4) The assessment now includes abundance information from four additional surveys: the AFSC GOA longline survey, the International Pacific Halibut Commission longline survey, and two bottom-trawl surveys conducted by the Alaska Department of Fish & Game.
5) Non-commercial catch data through 2018.

<u>Changes in the assessment methodology:</u>

1) No changes were made to the assessment methodology.

Summary of Results

1) Big skate biomass increased relative to 2017 (2019 survey estimate of 43,482 t versus 33,610 in 2017). This resulted in a slight increase in the random-effects model biomass estimate and corresponding increase in the overall recommended harvest. Because the distribution of big skate biomass among areas shifted in 2019, the ABC in the CGOA actually declined and the increased ABC occurred in the WGOA and EGOA.

2) The longnose skate biomass decreased in 2019 (survey biomass estimates of 32,279 t in 2019 versus 49,501 t in 2017). The area ABCs fell in the CGOA and EGOA while increasing slightly in the WGOA.

3) The biomass of other skates continues to decline from a peak in 2013. This resulted in reduced OFL and ABC.

4) The increased biomass of big skates on the eastern Bering Sea shelf observed beginning in 2013 continues. There is strong evidence to suggest that these skates originated in the GOA and that

there is exchange between the areas. This movement is likely influencing GOA biomass estimates.

The harvest recommendation summary tables are on the following pages. W, C, and E indicate the Western, Central, and Eastern GOA regulatory areas, respectively. Big and longnose skates have area-specific ABCs and Gulf-wide OFLs; “other skates” have a Gulf-wide ABC and OFL.

big skate (*Beringraja binoculata*)						
		As estimated or *specified last full assessment* for		As estimated or *recommended this* year for:	
Quantity		2018	2019	**2020**	2021
M (natural mortality)		0.1	0.1	**0.1**	0.1
Specified/recommended Tier		5	5	**5**	5
Biomass (t)	W	6,716	6,716	**10,109**	10,109
	C	23,658	23,658	**20,798**	20,798
	E	7,601	7,601	**11,861**	11,861
	GOA-wide	37,975	37,975	**42,779**	42,779
F_{OFL} (*F=M*)		0.1	0.1	**0.1**	0.1
*maxF_{ABC} (F=0.75*M)*		0.075	0.075	**0.075**	0.075
F_{ABC}		0.075	0.075	**0.075**	0.075
OFL (t)	GOA-wide	3,797	3,797	**4,278**	4,278
ABC (t; equal to maximum ABC)	W	504	504	**758**	758
	C	1,774	1,774	**1,560**	1,560
	E	570	570	**890**	890
		As determined *last* year for:		As determined *this* year for:	
Status		2016	2017	**2018**	2019
Overfishing?		*no*	*na*	**no**	na
(for Tier 5 stocks, data are not available to determine whether the stock is in an overfished condition)					

longnose skate (*Raja rhina*)					
Quantity		As estimated or *specified last full assessment* for 2018	2019	As estimated or *recommended this* year for: **2020**	2021
M (natural mortality)		0.1	0.1	**0.1**	0.1
Specified/recommended Tier		5	5	**5**	5
Biomass (t)	W	1,982	1,982	**2,156**	2,156
	C	37,390	37,390	**25,583**	25,583
	E	8,260	8,260	**7,558**	7,558
	GOA-wide	47,632	47,632	**34,487**	34,487
F_{OFL} (*F=M*)		0.1	0.1	**0.1**	0.1
maxF_{ABC} *(F=0.75*M)*		0.075	0.075	**0.075**	0.075
F_{ABC}		0.075	0.075	**0.075**	0.075
OFL (t)	GOA-wide	4,763	4,763	**3,449**	3,449
ABC (t; equal to maximum ABC)	W	149	149	**158**	158
	C	2,804	2,804	**1,875**	1,875
	E	619	619	**554**	554
Status		As determined *last* year for: 2016	2017	As determined *this* year for: **2018**	2019
Overfishing?		*no*	*na*	**no**	na
(for Tier 5 stocks, data are not available to determine whether the stock is in an overfished condition)					

other skates (*Bathyraja* species)					
Quantity		As estimated or *specified last full assessment* for 2018	2019	As estimated or *recommended this* year for: **2020**	2021
M (natural mortality)		0.1	0.1	**0.1**	0.1
Specified/recommended Tier		5	5	**5**	5
Biomass (t)	GOA-wide	18,454	18,454	**11,662**	11,662
F_{OFL} (*F=M*)		0.1	0.1	**0.1**	0.1
maxF_{ABC} *(F=0.75*M)*		0.075	0.075	**0.075**	0.075
F_{ABC}		0.075	0.075	**0.075**	0.075
OFL (t)	GOA-wide	1,845	1,845	**1,166**	1,166
ABC (t; equal to maximum ABC)	GOA-wide	1,384	1,384	**875**	875
Status		As determined *last* year for: 2016	2017	As determined *this* year for: **2018**	2019
Overfishing?		*no*	*na*	**no**	na
(for Tier 5 stocks, data are not available to determine whether the stock is in an overfished condition)					

Risk matrix table analysis and reductions to maximum ABC: All elements in the risk table were scored as 1 (Normal). No reduction from the maximum ABC is recommended.

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ ecosystem considerations*	*Fishery Performance considerations*	***Overall score (highest of the individual scores)***
Level 1: Normal	Level 1: Normal	Level 1: Normal	Level 1: Normal	**Level 1: Normal**

Responses to SSC and Plan Team Comments on Assessments in General

From the December 2018 SSC minutes: The SSC considers the risk table approach an efficient method to organize and report this information and worthy of further investigation...**The SSC requests that all authors fill out the risk table in 2019**, and that the PTs provide comment on the author's results in any cases where a reduction to the ABC may be warranted (concern levels 2-4). The author and PT do not have to recommend a specific ABC reduction, but should provide a complete evaluation to allow for the SSC to come up with a recommendation if they should choose not to do so. The SSC emphasizes that the table should be used to reach a decision, not to justify a decision made a priori.

> *Response*: The risk table was used to evaluate potential ABC reductions and is included in the Harvest Recommendations section of the assessment.

Responses to SSC and Plan Team Comments Specific to this Assessment

From the December 2017 SSC minutes: The SSC concurs with the author's recommendation that values of M be explored in the next assessment. The SSC looks forward to the forthcoming length-based stock assessment for longnose and big skates in the GOA.

> *Response*: Development of population models for big and longnose skates has been delayed for several reasons, including delayed publication of the original student work on those models. Exploring alternative values of M is wrapped up in the model development so is not included in this assessment. The timeline of development for the models is uncertain but it is hoped that a model for at least one species will be available for review in fall 2020.

Introduction

Description, scientific names, and general distribution

Skates (family Rajidae) are flat-bodied cartilaginous fishes related to sharks. At least 15 species of skates in four genera (*Raja*, *Beringraja*, *Bathyraja*, and *Amblyraja*) are found in Alaskan waters and are common from shallow inshore waters to very deep benthic habitats (Eschmeyer *et al* 1983; Stevenson *et al* 2007). In general, *Raja* species are most common and diverse in lower latitudes and shallower waters from the Gulf of Alaska to the Baja peninsula, while *Bathyraja* species are most common and diverse in the higher latitude habitats of the Bering Sea and Aleutian Islands, as well as in the deeper waters off the U.S. west coast. Table 1 lists the species found in Alaska, with their depth distributions and selected life history characteristics, which are outlined in more detail below.

In the Gulf of Alaska (GOA), the most common skate species are a *Raja* species, the longnose skate *R. rhina*; a *Beringraja* species, the big skate *B. binoculata*; and three *Bathyraja* species, the Aleutian skate *B. aleutica*, the Bering skate *B. interrupta*, and the Alaska skate *B. parmifera* (Tables 2 & 3; Figure 1). Big skates were previously in the genus *Raja*. The general range of the big skate extends from the Bering Sea to southern Baja California in depths ranging from 2 to 800 m. The longnose skate has a similar range, from the southeastern Bering Sea to Baja California in 9 to 1,069 m depths (Love *et al* 2005). While these two species have wide depth ranges, they are generally found in shallow waters in the GOA. One deep-dwelling *Amblyraja* species, the roughshoulder skate *A. badia*, ranges throughout the north Pacific from Japan to Central America at depths between 846 and 2,322 m; the four other species in the genus *Raja* are not found in Alaskan waters (Love *et al* 2005; Stevenson *et al* 2007). Within the genus *Bathyraja,* only two of the 13+ north Pacific species are not found in Alaska. Of the remaining 11+ species, only three are commonly found in the Gulf of Alaska. The Aleutian skate ranges throughout the north Pacific from northern Japan to northern California and has been found in waters 16 to 1,602 m deep. The Alaska skate is restricted to higher latitudes from the Sea of Okhotsk to the eastern Gulf of Alaska in depths from 17-392 m (Stevenson *et al* 2007). The range of the Bering skate is difficult to determine at this time as it may actually be a complex of species, with each individual species occupying a different part of its general range from the western Bering Sea to southern California (Love *et al* 2005; Stevenson *et al* 2007).

The species within this assemblage occupy different habitats and regions within the GOA groundfish Fishery Management Plan (FMP). In this assessment, we distinguish habitat primarily by depth for GOA skates. The highest biomass of skates is found in the shallowest continental shelf waters of less than 100-m depth and is normally dominated by big skates, while longnose skates are the most abundant species in the 101-200 m depth zone (Figure 2). The apparent shift in longnose skate biomass to shallower depths observed in 2017 was not repeated in 2019 and runs counter to the long-term average depth distribution (Figure 2). Skates in the *Bathyraja* genus are dominant in the deeper waters extending from 200 to 1000 m or more in depth (Figure 2). These depth distributions are reflected in the spatial distribution of GOA skates. Big skates are located inshore and are most abundant in the central and western GOA (Figures 3& 4). Longnose skates (Figures 4 & 5) are located further offshore and are relatively less abundant in the western GOA.

<u>Life history and stock structure (skates in general)</u>

Skate life cycles are similar to sharks, with 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). Sharks and skates in general have been classified as “equilibrium” life history strategists, 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). While smaller-sized species have been observed to be somewhat more productive, large skate species with late maturation (11+ years) are most vulnerable to heavy fishing pressure (Walker and Hislop 1998; Frisk *et al* 2001; Frisk *et al* 2002). The most extreme cases of overexploitation have been reported in the North Atlantic, where the now ironically named common skate *Dipturus batis* has been extirpated from the Irish Sea (Brander 1981) and much of the North Sea (Walker and Hislop 1998). The mixture of life history traits between smaller and larger skate species has led to apparent population stability for the aggregated “skate” group in many areas where fisheries occur. This has masked the decline of individual skate species in European fisheries (Dulvy *et al* 2000). Similarly, in the Atlantic off New England, declines in barndoor skate *Dipturus laevis* abundance were concurrent with an increase in the biomass of skates as a group (Sosebee 1998).

Several recent studies have explored the effects of fishing on a variety of skate species to determine which life-history traits and stages are the most important for management. While full age-structured modeling is difficult for many of these data-poor species, Leslie matrix models parameterized with information on fecundity, age/size at maturity, and longevity have been applied to identify the life stages most important to population stability. 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 commercially exploited groundfish. The large, leathery egg cases incubate for extended periods (months to a year) 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.

Age and size at maturity and adult size/longevity appear to be more important predictors of resilience to fishing pressure than fecundity or egg survival in the skate populations studied to date. Frisk *et al* (2002) estimated that although annual fecundity per female may be on the order of less than 50 eggs per year (extremely low compared with teleost groundfish), there is relatively high survival of eggs due to the high parental investment (without disturbance from fishing operations). Therefore, egg survival did not appear to be the most important life history stage contributing to population stability under fishing pressure. Juvenile survival appears to be most important to population stability for most North Sea species studied (Walker and Hilsop 1998), and for the small and intermediate sized skates from New England (Frisk *et al* 2002). For the large and long-lived barndoor skates, adult survival was the most important contributor to population stability (Frisk *et al* 2002). In all cases, skate species with the largest adult body sizes (and the empirically related large size/age at maturity, Frisk *et al* 2001) were least resilient to high fishing mortality rates. This is most often attributed to the long juvenile stage during which relatively large yet immature skates are exposed to fishing mortality, and also explains the mechanism for the shift in species composition to smaller skate species in heavily fished areas. Comparisons of length frequencies for surveyed North Sea skates from the mid- and late-1900s led Walker and Hilsop (1998, p. 399) to the conclusion that "all the breeding females, and a large majority of the juveniles, of *Dipturus batis*, *R. fullonica* and *R. clavata* have disappeared, whilst the other species have lost only the very largest individuals." Although juvenile and adult survival may have different importance by skate species, all studies found that one metric, adult size, reflected overall sensitivity to fishing. After modeling several New England skate populations, Frisk *et al* (2002, p. 582) found "a significant negative, nonlinear association between species total allowable mortality, and species maximum size."

There are clear implications of these results for sustainable management of skates in Alaska. After an extensive review of population information for many elasmobranch species, Frisk et al (2001, p. 980) recommended that precautionary management be implemented especially for the conservation of large species:

> "(*i*) size based fishery limits should be implemented for species with either a large size at maturation or late maturation, (*ii*) large species (>100 cm) should be monitored with increased interest and conservative fishing limits implemented, (*iii*) adult stocks should be maintained, as has been recommended for other equilibrium strategists (Winemiller and Rose 1992)."

Life history and stock structure (Alaska-specific)

Information on fecundity in North Pacific skate species is extremely limited. There are one to seven embryos per egg case in North Pacific Ocean *Raja* species (Eschmeyer *et al* 1983), but little is known about frequency of breeding or egg deposition for any of the local species. Similarly, information related to breeding or spawning habitat, egg survival, hatching success, or other early life history characteristics is extremely sparse for GOA skates.

Slightly more is known about juvenile and adult life stages for GOA skates. In terms of maximum adult size, the *Raja* species are larger than the *Bathyraja* species found in the area. *Beringraja binoculata* is the largest skate in the GOA, with maximum sizes observed over 200 cm in the directed fishery in 2003 (see the "Fishery" and "Survey" sections below, for details). Observed sizes for the longnose skate, *Raja rhina*, are somewhat smaller at about 165-170 cm. Therefore, the Gulf of Alaska *Raja* species are in the same size range as the large Atlantic species, i.e., the common skate *Dipturus batis* and the barndoor skate, which historically had estimated maximum sizes of 237 cm and 180 cm, respectively (Walker and Hislop 1998, Frisk *et al* 2002). The maximum observed lengths for *Bathyraja* species from bottom trawl surveys of the GOA range from 86-154 cm.

Known life history parameters of Alaskan skate species are presented in Table 1. Zeiner and Wolf (1993) determined age at maturity and maximum age for big and longnose skates from Monterey Bay, CA. The maximum age of CA big skates was 11-12 years, with maturity occurring at 8-11 years; estimates of maximum age for CA longnose skates were 12-13 years, with maturity occurring at 6-9 years. McFarlane and King (2006) completed a study of age, growth, and maturation of big and longnose skates in the waters off British Columbia (BC), finding maximum ages of 26 years for both species, much older than the estimates of Zeiner and Wolf. Age at 50% maturity occurs at 6-8 years in BC big skates, and at 7-10 years in BC longnose skates. However, these parameter values may not apply to Alaskan stocks. The AFSC Age and Growth Program has recently reported a maximum observed age of 25 years for the longnose skate in the GOA, significantly higher than that found by Zeiner and Wolf but close to that observed by McFarlane and King (Gburski *et al* 2007). In the same study, the maximum observed age for GOA big skates was 15 years, closer to Zeiner and Wolf's results for California big skates.

Fishery

Directed fishery, bycatch, and discards in federal waters

Prior to 2005 directed fishing was allowed for GOA skates and appears to have occurred in some years (Table 4). In 2003 skate catches increased dramatically as a result of targeting of skates in the GOA. This was driven by increases in the ex-vessel prices for skates; sufficiently high prices made it worthwhile to specifically target skates. This directed fishing was especially problematic because skates were managed as part of the "Other Species" assemblage and harvest limits were not directly based on skate abundance. In response to these events skates were separated from "Other Species" and in 2005 directed fishing for skates was prohibited (and remains so).

Interest in retention of skates and directed fishing for skates remains high. The ABC for big skates in the CGOA was exceeded every year during 2010-2013 and in 2016, and the ABC for longnose skates in the WGOA was exceeded in 4 of the years 2007-2013 (Table 5). Incidental catches of big and longnose skates occur in a variety of target fisheries; the greatest catches presently occur in the arrowtooth flounder, Pacific cod, and Pacific halibut fisheries (Table 6). Retention rates of big and longnose skates increased during the late 2000s as the average ex-vessel price for skates was raised (Figure 7). Retention of all skates has declined since 2012 as a result of limits on retention of big skates in the CGOA that have been imposed because of the ABC overages. In 2013, retention of big skate was prohibited in the CGOA for the rest of the year on May 8; in 2014 & 2015 that same action was taken in February almost immediately after target fisheries opened. The repeated overages were a conservation concern and in January 2016 the Alaska Regional Office indefinitely reduced the maximum retainable amount of all skates from 20% to 5%. Despite this change further prohibitions on retention were required during 2016 and 2017. As of October 30, 2019 no prohibitions on retention were issued in 2018 or 2019.

Alaska state-waters fishery 2009-2010

Prior to 2006, directed fishing for skates in state waters was allowed by Commissioner's Permit; in 2006 skates were placed on bycatch status only. In 2008, the Alaska state legislature appropriated funds for developing the data collection (e.g., onboard observers) necessary to open a state-waters directed fishery. In 2009 and 2010, the state conducted a limited skate fishery in the eastern portions of the Prince William Sound (PWS) Inside and Outside Districts. In 2009, the guideline harvest level (GHL) was based on skate exploitation rates in federal groundfish fisheries and NMFS survey estimates of skate biomass. This was changed for 2010, when GHLs were based on ADF&G trawl survey results. The GHLs and harvests for 2009 and 2010 were as follows (in lbs.; harvests exceeding the GHL are indicated in **bold**):

Year	2009		2010	
Skate Species	big	longnose	big	longnose
Inside District GHL (lbs)	20,000	100,000	20,000	110,000
Inside District Harvest (lbs)	**47,220**	68,828	**20,382**	68,681
Outside District GHL (lbs)	30,000	150,000	30,000	155,000
Outside District Harvest (lbs)	**82,793**	59,538	6,190	9,257

* Thanks to Charlie Trowbridge of ADF&G for state-waters skate harvest data.

The big skate GHL was exceeded by a substantial amount in 2009. In 2010, trip catch limits for big skates were imposed to reduce the potential for exceeding the GHL. The improved management resulted in a much smaller overage in the PWS Inside District and no overage in the PWS Outside District. The state-waters skate fishery was discontinued in 2011 after the legislature failed to approve continued funds for data collection.

<u>Management units</u>

Since the beginning of domestic fishing in the late 1980s up through 2003, all species of skates in the GOA were managed under the “Other Species” FMP category (skates, sharks, squids, sculpins, and octopuses). Catch within this category was historically limited by a Total Allowable Catch (TAC) for all “Other Species” calculated as 5% of the sum of the TACs for GOA target species. The “Other Species” category was established to monitor and protect species groups that were not currently economically important in North Pacific groundfish fisheries, but which were perceived to be ecologically important and of potential economic importance. The configuration of the “Other Species” group was relatively stable until 2004, when GOA skates were removed from the category for separate management in response to a developing fishery. In 2004 the skate species that were the targets of the 2003 fishery (big and longnose skates) were managed together under a single TAC in the central GOA (CGOA), where the fishery had been concentrated in 2003. The remaining skates were managed as an “other skates” species complex in the CGOA, and all skates including big and longnose skates were managed as an “other skates” species complex in the western GOA (WGOA) and eastern GOA (EGOA). Since 2005, to address concerns about disproportionate harvest of skates, big skate and longnose skate have had separate ABCs and TACs for the WGOA, CGOA, and EGOA. The remaining skates (”other skates”) continue to be managed as a Gulf-wide species complex because they are not generally retained and are difficult to distinguish at the species level.

Data

Fishery

<u>Catch data</u>

Catches from 1992-2002 were estimated using the Alaska Regional Office Blend system (Table 4). Since 2003 skate catch data are recorded in the Alaska Regional Office Catch Accounting System (CAS; Tables 4-7; Figure 6). Additional details are available in the sections above.

<u>Fishery length compositions</u>

Fishery observers have been required to collect length data for skates in selected fisheries since 2009, and fishery length compositions have been constructed for the years 2009-2017 for big skate (Figure 8) and longnose skate (Figure 9). These data suggest that fisheries are capturing a narrower size range of longnose skate relative to big skate, and that captured longnose skates are typically slightly larger than big skates. For big skate, a shift in the fishery length composition towards smaller skates is evident in recent years. This change is most apparent from 2015 to 2017, when the mode of the length shifted from 100 cm to 76 cm. The 2019 data are incomplete but suggest that this pattern may be reversing itself. A similar shift in the longnose skate fishery size composition after 2013 reversed itself in 2018 with the fishery encountering increasingly larger individuals. Length compositions do not vary substantially among trawl and longline fisheries (Figure 10); this may be because much of the length data comes from retained skates, and skates are generally retained only if they are above a minimum size.

Survey

There are several potential indices of skate abundance in the Gulf of Alaska, including longline and trawl surveys. Because it has the most comprehensive spatial coverage of the available surveys, for this assessment the AFSC summer bottom trawl surveys (BTS) 1984-2019 are the primary source of information on the biomass and distribution of the major skate species. Harvest recommendations are based on the AFSC trawl survey data. Information from four additional sources is included in this report. Three of these surveys (the AFSC longline survey, the International Pacific Halibut Commission (IPHC) longline survey, and the Alaska Department of Fish & Game's (ADFG) bottom trawl surveys around Kodiak Island and the Alaska Peninsula) overlap directly with the NMFS BTS area. Data from these surveys provide additional insight into population trends but do not add materially to the NMFS trawl-survey data. A fourth survey, the ADFG trawl survey in Prince William Sound (PWS), provides biomass estimates in an area not covered by the AFSC BTS and where substantial catches of skates occurs.

AFSC bottom trawl survey biomass estimates

On a Gulf-wide basis, the biomass of all three species groups increased during the 1990s (Tables 2, 3 & 8; Figures 11 & 12). Beginning with a high estimate in 2011 (which also had a large variance, due to a single large haul in the EGOA), big skate biomass has fluctuated substantially but the overall trend suggests a slight decrease in the population. The biomass of longnose skates increased from 2011-2017, but the 2019 biomass estimate was substantially lower than in 2017. The biomass of Other Skates has declined steadily since 2013, mainly as a result of reduced abundance of Aleutian skate (Figures 12 and 13). Area-specific biomass estimates have shown greater fluctuations (Table 8 & Figures 14 and 15). In 2019, big skate biomass declined in the CGOA but increased in the other areas, resulting in an overall increase in biomass (Figure 14). The greatest relative reduction has occurred in the EGOA. Longnose skate biomass estimates in the WGOA have high variance, as that species is less abundant there. Decreases in longnose biomass were observed in both the CGOA and EGOA in 2019 (Figure 15). The decline in other skate biomass has occurred mainly in the CGOA.

AFSC trawl survey length compositions

The survey length composition of big skates is diffuse, with few clear size modes (Figure 16). Since 2003, the composition has been fairly stable, with the majority of individuals clustered between approximately 76 and 148 cm. An apparent abundance of large big skates in 2001 may be due to the lack of survey effort in the EGOA, where smaller skates are more common (see below). The 2009, 2011, 2013, and 2019 surveys captured more small skates than in previous years, which may indicate an increase in recruitment or a decrease in the number of larger skates. In contrast to big skates, the data for longnose skates display a consistent size mode at approximately 120 cm (Figure 17). Since 2011 this distribution seems to have shifted slightly, with an increase in smaller sizes and the possible emergence of two length modes.

The length distribution of big skates differs among GOA regulatory areas (Figure 18). The largest big skates tend to be found in the WGOA and the smallest big skates in the EGOA. Intermediate sizes dominate in the CGOA, where a size mode is more distinct than in the other areas. The length composition of longnose skates varies much less among the areas (Figure 19), although data for longnose in the WGOA are sparse. These patterns may reflect differences in migratory behavior. The pattern for big skates is similar to patterns observed in the Alaska skate population in the Bering Sea, where there appears to be an ontogenetic migration as skates mature (Hoff 2007). A similar process may exist for GOA big skates.

AFSC longline survey

Since 1986 the AFSC has conducted a longline survey in the GOA designed primarily for estimating sablefish abundance (Malecha et al 2019). Because sablefish occur mainly at greater depths this survey does not sample bottom depths shallower than 150 m, and thus does not sample the majority of big skate habitat and only partially samples the habitat of longnose skate (Figure 21). As a result the survey mainly represents the abundance of Aleutian, Bering, and Alaska skates with some longnose skate information (Figure 22). Identification to species began only in 2009 and due to difficulty in differentiating among Bathyraja species, Aleutian, Bering, and Alaska are counters as members of a single “ABA” complex. Based on AFSC bottom trawl survey data the majority of this complex is likely Aleutian skate. The survey provides relative abundance information and this assessment includes relative population numbers (RPNs). Total skate RPNs increased steadily from the mid-1980s to approximately 2009 after which they declined approximately 50% by 2016 (Figure 23). The RPNs of the ABA complex declined steeply from 2009 until 2016 and likely contributed most of the decline in total skate abundance. These AFSC longline survey results concur with the decline in Aleutian skate biomass observed in the BTS (Figures 12 and 13) except that longline-survey RPNs stabilized after 2016 while BTS estimates continued to decline.

IPHC longline survey

Longline surveys have been carries out by the IPHC along the west coasts of the U.S. and Canada, including the Bering Sea and Aleutian Islands, since 1963 (Goen et al 2017). Unlike the AFSC longline survey, the majority of stations in the IPHC survey occur at depths from 0 to 200 m (the 100-200 m stratum has the most sampling effort). Skates are identified to species beginning in 2003. The raw catch data from the survey were combined with geographic area estimates to generate RPNs for the GOA (C. Tribuzio, AFSC, unpublished data). Aggregation of three species into the ABA complex was repeated for analyzing these data. The abundance estimates for big and longnose skates display a decreasing trend in recent years (Figure 24); this is pronounced for longnose skates and is in contrast the relatively slight decrease in BTS biomass estimates (Figure 11). The IPHC data for the ABA complex show a similar declining trend to the AFSC BTS and longline data (Figures 12 and 13).

ADF&G Kodiak-area bottom trawl survey

The ADF&G has been conducting a large-mesh BTS in the CGOA and WGOA since 1988 (Spalinger and Knutson 2018). Survey stations are located around Kodiak Island and along the southern coast of the Alaska Peninsula (Figure 25). Although the main goal of this survey is to measure the abundance of commercial crab species it also provides information on groundfishes including skates. Identification of big and longnose skates began in 1995 and *Bathyraja* skates in 2003. Catch per unit effort (CPUE) of big skates in this survey has increased since 2013, while the CPUE of longnose skates appears stable (Figure 26). Discrepancies with the AFSC BTS results may be explained by the distribution of many of the survey stations in the WGOA where AFSC biomass estimates are increasing. Similar to the other surveys, the CPUE of Aleutian skates in this survey has been decreasing during the 2010s.

ADF&G Prince William Sound and Cook Inlet bottom trawl survey

Trawl surveys in the Cook Inlet area (Kamishak and Kachemak Bays) and PWS have been performed by the ADF&G since 1991 (Figure 25; Goldman et al 2018). Identification of big and longnose skates began reliably in 1999; because the available *Bathyraja* species data remain uncertain they are not included in this report. Analysis was limited to the core stations (Figure 25) that are sampled consistently in each survey. The PWS data are of particular interest for this assessment because the AFSC BTS does not sample PWS, so the biomass estimates used for harvest recommendations do not include skates in the

PWS. To generate PWS biomass estimates, mean CPUE for each species was multiplied by the area of the core survey region (249.6 nmi^2 or 85,610 hectares). While skates, especially longnose, occur outside the core area in PWS, the sampling outside of the core is insufficient to reliably estimate additional biomass (M. Byerly, ADF&G, pers. comm.).

The CPUE of big skates is lower than that of longnose skates in PWS, and they occur less frequently (Figures 27 and 28). Big skate CPUE increased from 2011 to 2015 and has been stable since then; longnose skate CPUE is variable and displays no overall trend (Figure 27). While the frequency of occurrence (FO) of longnose skate in PWS and Kachemak Bay is stable among years, big skate FO displays a marked decadal pattern (Figure 28). The estimated biomass of big skates was 562 t in 2018 while the longnose skate biomass estimate was 1,117 t (Table 9).

Analytic Approach

Skates in the GOA are managed using Tier 5. Under Tier 5, $F_{OFL} = M$ and OFL = F_{OFL} * survey biomass. Maximum permissible ABC is calculated as 0.75 * F_{OFL} * survey biomass.

To produce biomass estimates suitable for harvest recommendations, biomass was estimated using a random effects (RE) model developed by the Joint Plan Team Survey Averaging Working Group. For each group (big, longnose, and other), a Gulf-wide RE model was used to determine the recommended OFL and Gulf-wide ABC. For big and longnose skate, area-specific RE models were run and the results used to apportion ABC among areas according to the area's proportion of overall biomass.

Parameter estimates

<u>Natural mortality (*M*)</u>

A value of M = 0.1 has been used for GOA skate harvest recommendations since 2003. During the CIE review of non-target stock assessments in 2013, several reviewers felt that the use of 0.1 was overly conservative and did not include the best available data. The author agrees that the value of *M* requires more exploration; for the time being this assessment continues to use an *M* of 0.1.

Results

Conclusions

1) The AFSC BTS estimate of big skate biomass increased relative to 2017 (2019 survey estimate of 43,482 t versus 33,610 in 2017). This resulted in a slight increase in the random-effects model biomass estimate and corresponding increase in the overall recommended harvest. Because the distribution of big skate biomass among areas shifted in 2019, the ABC in the CGOA actually declined and the increased ABC occurred in the WGOA and EGOA.
2) The AFSC BTS estimate of longnose skate biomass decreased in 2019 (survey biomass estimates of 32,279 t in 2019 versus 49,501 t in 2017). The area ABCs fell in the CGOA and EGOA while increasing slightly in the WGOA.
3) The AFSC BTS-estimated biomass of other skates continues to decline from a peak in 2013. This resulted in reduced OFL and ABC.
4) The additional surveys included in the report support conclusion of a substantial decline in *Bathyraja* skate biomass since 2009 and that the current level of abundance is similar to the level

in the 1990s. Discrepancies among surveys regarding big and longnose skates are likely due to the uncertainty of the estimates and the spatial distribution of each survey. However the decline in longnose skate RPNs observed in the IPHC survey should be monitored in future assessments.

5) The increased biomass of big skates on the eastern Bering Sea shelf observed beginning in 2013 continues (Figures 29 and 30). There is strong evidence to suggest that these skates originated in the GOA and that there is exchange between the areas. This movement is likely influencing GOA biomass estimates.

Exploitation rates

Gulf-wide and PWS-specific exploitation rates (catch/biomass) were calculated for big, longnose, and other skates (Table 9). During 2005-2019 the exploitation rate of big skates has varied between 0.02 and 0.06, and the 2019 value (using partial catch data) was 0.03. Exploitation of longnose skate during this period ranged from 0.02 to 0.04 and was 0.03 in 2019. The exploitation rate of other skates has been higher, ranging from 0.02 to 0.09. For all three stocks rates were highest during 2009-2013 and have since declined, likely as a result of reduced retention allowances. The PWS-specific exploitation rates of big and longnose skates have been considerably higher than the Gulf-wide rates in some years (particularly for big skate; the rate was 0.25 and 0.17 in 2013 and 20914, respectively). The PWS estimates may be inflated due to the limited survey area used to convert CPUE into biomass estimates.

Harvest recommendations

Big skate
The RE-model estimate of big skate biomass for 2019 is 42,779 t, so OFL = 4,278 t and maximum ABC = 3,208 t. Area biomass estimates are 10,109 t (23.6%) for the WGOA; 20,798 t (48.6%) for the CGOA; and 11,861 t (27.7%) for the EGOA. The resulting area-specific ABCs are 758 t for the WGOA; 1,560 t for the CGOA; and 890 t for the EGOA.

Longnose skate
The RE-model estimate of longnose skate biomass for 2019 is 34,487 t, so OFL = 3,449 t and maximum ABC = 2,587 t. Area biomass estimates are 2,156 t (6.1%) for the WGOA; 25,583 t (72.5%) for the CGOA; and 7,558 t (21.4%) for the EGOA. The resulting area-specific ABCs are 158 t for the WGOA; 1,875 t for the CGOA; and 554 t for the EGOA.

Other skates
The RE-model estimate of other skate biomass for 2019 is 11,662 t, so OFL = 1,166 t and maximum ABC = 875 t. The other skate ABC is not apportioned among areas.

Should the ABC be reduced below the maximum permissible ABC?

In 2018 the SSC recommended that assessment authors and plan teams use the risk matrix table below when determining whether to recommend an ABC lower than the maximum permissible:

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

Evaluation for risk for GOA skates (all species) in 2019

Assessment-related considerations: Skates in the GOA are managed under Tier 5 and are thus by definition data-limited. Skate biomass is reliably estimated by the bottom trawl survey, the RE model performs well for all stocks and stock/area combinations. There are no considerations that would warrant reducing the ABC below maximum permissible. Rated Level 1, normal.

Population dynamics considerations: The biomass of big and longnose skate is relatively stable after increases in the 1990s (Figure 11). The survey and fishery size compositions suggest there have been fewer large skates in recent years but that new individuals may be recruiting to each population (Figures 16 and 17). The biomass of other skates, mainly Aleutian skate, has dropped substantially in recent years (Figures 11-13). The current biomass level is approximately the same as in 1996, so the low biomass is not unprecedented, and there appears to be some new recruitment (Figure 20). All of the skate biomass changes are accounted for in the RE model. As a result of these observations there are no undue concerns regarding dynamics. Rated Level 1, normal.

Environmental/ecosystem considerations: All marine organisms are influenced by water temperature, so the recent occurrences of marine heatwaves in the GOA have the potential to impact GOA skates. Skates may experience similar heatwave-related stresses to other large groundfishes (e.g. Pacific cod) where higher temperatures increase metabolic demands and the need to find adequate prey. This might be exacerbated by the reduced productivity associated with heatwaves in the GOA. However the data do not exist to evaluate whether and to what extent this might have occurred, and there do not appear to be ecosystem considerations that are not adequately addressed through the Tier 5 harvest recommendation process. For these reasons this consideration is rated Level 1, normal.

Fishery performance: As a nontarget stock, catches of skates in the GOA are influenced by their abundance and by the behavior of target fisheries. Recent changes in maximum retention amounts appear to have reduced targeting and retention of skates. Rated Level 1, normal.

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

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ ecosystem considerations*	*Fishery Performance considerations*	***Overall score (highest of the individual scores)***
Level 1: Normal	Level 1: Normal	Level 1: Normal	Level 1: Normal	**Level 1: Normal**

Ecosystem Considerations

In the following tables, we summarize ecosystem considerations for GOA skates and the entire groundfish fishery where they are caught incidentally. The observation column represents the best attempt to summarize the past, present, and foreseeable future trends. The interpretation column provides details on how ecosystem trends might affect the stock (ecosystem effects on the stock) or how the fishery trend affects the ecosystem (fishery effects on the ecosystem). The evaluation column indicates whether the trend is of: *no concern, probably no concern, possible concern, definite concern,* or *unknown.*

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

Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Non-pandalid shrimp, other benthic organisms	Trends are not currently measured directly, only short time series of food habits data exist for potential retrospective measurement	Unknown	Unknown
Sand lance, capelin, other forage fish	Trends are not currently measured directly, only short time series of food habits data exist for potential retrospective measurement	Unknown	Unknown
Commercial flatfish	Increasing to steady populations currently at high biomass levels	Adequate forage available for piscivorous skates	No concern
Pollock	High population level in early 1980s declined to stable low level at present	Currently a small component of skate diets, skate populations increased over same period	No concern
Predator population trends			
Steller sea lions	Declined from 1960s, low but level recently	Lower mortality on skates?	No concern
Sharks	Population trends unknown	Unknown	Unknown
Sperm whales	Populations recovering from whaling?	Possibly higher mortality on skates? But still a very small proportion of mortality	No concern
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, initiate study for GOA big and longnose skates	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	Varies from 6,000 to 10,000 + tons annually including halibut fishery	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, but directed skate catch was concentrated in isolated areas in 2003	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	2005 survey sampling suggests possible decrease in largest big skates	Larger big skates more rare due to fishing or other factors?	Possible concern
Fishery contribution to discards and offal production	Skate discard a moderate proportion of skate catch, many 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 still being described; fishery effects on them difficult to determine	Unknown	Unknown

Data gaps and research priorities

Because fishing mortality appears to be a larger proportion of skate mortality in the GOA than predation mortality, highest priority research should continue to focus on direct fishing effects on skate populations. The most important component of this research is to fully evaluate the catch and discards in all fisheries capturing skates. It is also vital to continue research on the productive capacity of skate populations, including information on age and growth, maturity, fecundity, and habitat associations.

Although predation appears less important than fishing mortality on adult skates, juvenile skates and skate egg cases are likely much more vulnerable to predation. This effect has not been evaluated in population or ecosystem models. We expect to learn more about the effects of predation on skates, especially as juveniles, with the completion of Jerry Hoff’s (AFSC, RACE) research on skate nursery areas in the Bering Sea.

Skate habitat is only beginning to be described in detail. Adults appear capable of significant mobility in response to general habitat changes. However, eggs are limited to isolated nursery grounds and juveniles use different habitats than adults. Disturbance to these habitats could have disproportionate population effects. Changes in these habitats have not been monitored historically, so assessments of habitat quality and its trends are not currently available. We recommend continued study on skate nursery areas to evaluate importance to population production.

Acknowledgements

We thank those that provided data for the assessment: the bottom trawl survey group at the AFSC, the longline survey group at ABL, Mike Byerly and Kally Spalinger at ADF&G, and Cindy Tribuzio who provided the IPHC data. The information in this assessment has benefited greatly from the hard work of previous assessment authors, especially Sarah Gaichas (NEFSC). We also thank all of the AFSC and ADF&G personnel who have provided data, advice, and other assistance.

Literature Cited

Brander, K. 1981. Disappearance of common skate *Raja batis* from Irish Sea. Nature 290: 48-49.

Casey, J.M. and R.A. Myers. 1998. Near extinction of a large, widely distributed fish. Science 281(5377):690-692.

Dulvy, N.K., J.D. Metcalfe, J. Glanville, M.G. Pawson, and J.D. Reynolds. 2000. Fishery stability, local extinctions, and shifts in community structure in skates. Conservation Biology 14(1): 283-293.

Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Co., Boston: 336 pp.

Frisk, M.G., T. J. Miller, and M. J. Fogarty. 2001. Estimation and analysis of biological parameters in elasmobranch fishes: a comparative life history study. Can. J. Fish. Aquat. Sci. 58: 969-981.

Frisk, M. G. , T. J. Miller, and M. J. Fogarty. 2002. The population dynamics of little skate *Leucoraja erinacea*, winter skate *Leucoraja ocellata*, and barndoor skate *Dipturus leavis*: predicting exploitation limits using matrix analysis. ICES J. Mar. Sci. 59: 576-586.

Gaichas, S., J. Ianelli, and L. Fritz. 1999. Other species considerations for the Gulf of Alaska.

Gburski, C.M., S.K. Gaichas, and D.K. Kimura. 2007. Age and growth of big skate (*Raja binoculata*) and longnose skate (*R. rhina*) and implications to the skate fisheries in the Gulf of Alaska. Env. Bio. Fishes 80: 337-349.

Goen, J., T. Geernaert, E. Henry, E. Soderlund, A. Ranta, T. Kong, J. Forsberg. 2017. Fishery-Independent Setline Survey (FISS) design and implementation in 2017, including current and future expansions (IPHC-2018-AM094-06) Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2017. IPHC-2017-RARA27-R: 117

Goldman, K. J., M. Byerly, J. Mumm, J. Rumble, and J. Zheng. 2018. Bottom trawl surveys for Tanner crab in Lower Cook Inlet and Prince William Sound 1990–2015, with harvest strategy recommendations for Prince William Sound. Alaska Department of Fish and Game, Fishery Manuscript 18-02, Anchorage

Hoff, G.R. 2007. Reproductive biology of the Alaska skate Bathyraja parmifera, with regard to nursery sites, embryo development and predation. Ph.D. Dissertation, University of Washington, Seattle. 161 pp.

King, J.R., and G.A. McFarlane, 2003. Marine fish life history strategies: applications to fishery management. Fish. Man. And Ecology, 10: 249-264.

Love, M.S., C.W. Mecklenberg, T.A. Mecklenberg, and L.K. Thorsteinson. 2005. Resource inventory of marine and estuarine fishes of the West Coast and Alaska: a checklist of north Pacific and Arctic Ocean species from Baja California to the Alaska-Yukon Border. U.S. Department of the Interior, U.S. Geological Survey, Biological Resources Division, Seattle, Washington, 98104, OCS Study MMS 2005-030 and USGS/NBII 2005-001.

Malecha, P., C. Rodgveller, C. Lunsford, and K. Siwicke. 2019. The 2018 longline survey of the Gulf of Alaska and eastern Aleutian Islands on the FV Alaskan Leader: Cruise Report AL-18-01. AFSC Processed Rep. 2019-02, 30 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

McFarlane, G.A. and J.R. King. 2006. Age and growth of big skate (*Raja binoculata*) and longnose skate (*Raja rhina*) in British Columbia waters. Fish Res. 78: 169-178.

Moyle, P.B., and J.J. Cech, Jr., 1996. Fishes, an introduction to ichthyology (Third edition). Prentice Hall: New Jersey, 590 pp.

Orlov, A.M., 1998. The diets and feeding habits of some deep-water benthic skates (Rajidae) in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka. Alaska Fishery Research Bulletin 5(1): 1-17.

Orlov, A.M., 1999. Trophic relationships of commercial fishes in the Pacific waters off southeastern Kamchatka and the northern Kuril Islands. Pages 231-263 in Ecosystem Approaches for Fishery Management, Alaska Sea Grant College Program AK-SG-99-01, University of Alaska Fairbanks, 756 pp.

Sosebee, K., 1998. Skates. In Status of Fishery Resources off the Northeastern United States for 1998 (Stephen H. Clark, ed.), p. 114-115. NOAA Technical Memorandum NMFS-NE-115.

Spalinger, K., and M. Knutson. 2018. Large-mesh bottom trawl survey of crab and groundfish: Kodiak, Chignik, South Peninsula, and Eastern Aleutian Management Districts, 2017. Alaska Department of Fish and Game, Fishery Management Report No. 18-15, Anchorage.

Stevenson, D. 2004. Identification of skates, sculpins, and smelts by observers in north Pacific groundfish fisheries (2002-2003), U.S. Department of Commerce Technical Memorandum NMFS-AFSC-142. 67 p.

Stevenson, D. E., Orr, J. W., Hoff, G. R., and McEachran, J. D. 2007. Field guide to sharks, skates, and ratfish of Alaska. Alaska Sea Grant.

Wakefield, W.W. 1984. Feeding relationships within assemblages of nearshore and mid-continental shelf benthic fishes off Oregon. M.S. Thesis, OSU.

Walker, P.A., and R. G. Hislop, 1998. Sensitive skates or resilient rays? Spatial and temporal shifts in ray species composition in the central and north-western North Sea between 1930 and the present day. ICES J. Mar Sci., 55: 392-402.

Winemiller, K.O., and K.A. Rose, 1992. Patterns of life history diversification in North American fishes: implications for population regulation. Can. J. Fish. Aquat. Sci. 49: 2196-2218.

Zeiner, S.J. and P. Wolf, 1993. Growth characteristics and estimates of age at maturity of two species of skates (*Raja binoculata* and *Raja rhina*) from Monterey Bay, California. In Conservation biology of elasmobranchs (S. Branstetter, ed.), p. 39-52. NOAA Technical Report NMFS 115.

Tables

Table 1. Life history and depth distribution information available for BSAI and GOA 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
Beringraja binoculata	big skate	244	15 [5]	4.8 yrs, 68 cm (F) 6.1 yrs, 87 cm (M) [6]	predatory [8]	1-7	16-402
Raja rhina	longnose skate	180	25 [5]	12.3 yrs, 96 cm (F) 8.8 yrs, 72 cm (M) [6]	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. Gulf-wide biomass estimates (t) and coefficients of variation (CV) for the three managed skate groups in the Gulf of Alaska, 1990-2019. Estimates are bottom trawl survey estimates (survey) or estimates from a random effects model fitted to the survey time series (RE model).

	big skate				longnose skate				other skates			
	survey		RE model		survey		RE model		survey		RE model	
	estimate	CV	estimate	CV	estimate	CV	estimate	CV	estimate	CV	estimate	CV
1990	22,316	0.25	35,119	0.28	11,995	0.22	14,808	0.18	13,921	0.24	11,549	0.22
1991			36,366	0.23			15,935	0.17			9,786	0.24
1992			37,657	0.18			17,148	0.15			8,291	0.22
1993	39,733	0.18	38,994	0.14	17,803	0.12	18,453	0.11	6,142	0.15	7,025	0.14
1994			40,267	0.12			20,689	0.14			8,318	0.22
1995			41,582	0.11			23,196	0.14			9,850	0.22
1996	43,064	0.17	42,939	0.10	26,226	0.14	26,006	0.11	11,768	0.17	11,663	0.14
1997			44,321	0.11			28,932	0.14			13,575	0.22
1998			45,747	0.13			32,186	0.14			15,801	0.21
1999	54,650	0.15	47,219	0.14	39,333	0.14	35,807	0.12	18,879	0.11	18,393	0.11
2000			47,208	0.14			36,665	0.15			19,286	0.22
2001			47,198	0.14			37,544	0.15			20,223	0.24
2002			47,187	0.13			38,444	0.13			21,205	0.22
2003	55,397	0.16	47,177	0.12	39,603	0.09	39,366	0.08	21,739	0.11	22,236	0.11
2004			45,853	0.10			39,816	0.11			25,520	0.18
2005	39,320	0.16	44,567	0.09	41,370	0.08	40,271	0.07	29,998	0.11	29,289	0.10
2006			44,305	0.10			38,060	0.11			30,393	0.18
2007	39,630	0.19	44,044	0.10	34,470	0.11	35,969	0.09	32,289	0.11	31,538	0.10
2008			44,373	0.10			36,211	0.11			29,296	0.18
2009	44,349	0.16	44,704	0.09	36,652	0.09	36,454	0.08	27,399	0.12	27,213	0.11
2010			45,104	0.10			36,275	0.11			24,665	0.18
2011	67,883	0.35	45,507	0.11	33,911	0.11	36,097	0.09	21,364	0.10	22,355	0.10
2012			45,237	0.11			39,035	0.11			25,508	0.18
2013	38,234	0.25	44,968	0.10	44,484	0.10	42,213	0.09	30,705	0.11	29,106	0.11
2014			45,238	0.11			42,109	0.11			26,816	0.18
2015	58,047	0.17	45,509	0.11	41,926	0.09	42,005	0.08	25,186	0.11	24,706	0.10
2016			43,993	0.10			42,065	0.12			20,859	0.18
2017	33,610	0.17	42,528	0.11	49,501	0.16	42,126	0.11	17,820	0.13	17,612	0.11
2018			42,653	0.11			38,115	0.12			14,331	0.19
2019	43,482	0.16	42,779	0.11	32,279	0.11	34,487	0.10	10,736	0.15	11,662	0.14

Table 3. Biomass estimates (t) from the AFSC bottom trawl survey in the Gulf of Alaska (GOA) for skates in each GOA regulatory area, 1999-2019.

		1999	**2001**	**2003**	**2005**	**2007**	**2009**	**2011**	**2013**	**2015**	**2017**	**2019**
WGOA	big	11,038	8,425	9,602	9,792	5,872	6,652	6,251	10,669	13,449	5,068	12,179
	longnose	1,747	104	782	1,719	628	1,214	941	2,127	708	2,133	2,221
	Aleutian	1,928	1,858	4,401	1,453	3,333	3,051	873	2,970	2,514	3,701	1,272
	Bering	218	170	39	86	0	283	237	37	142	255	401
	Alaska	220	1,213	265	211	177	1,728	333	1,124	802	405	291
	whiteblotched	544	0	173	502	197	199	487	0	359	96	87
	mud	46	0	0	0	0	10	7	0	43	0	15
	roughtail	0	0	0	0	82	0	0	0	0	0	0
	whitebrow	0	0	0	0	33	0	0	0	0	0	0
	misc	0	0	0	36	0	838	26	0	37	0	0
	total WGOA	15,740	11,770	15,262	13,797	10,322	13,975	9,155	16,926	18,053	11,658	16,465
CGOA	longnose	29,872	23,171	25,741	29,853	26,083	25,534	23,609	28,274	34,243	39,219	22,709
	big	34,007	30,658	33,814	25,544	24,420	26,691	21,761	12,810	32,038	22,878	18,371
	Aleutian	8,055	4,734	10,772	22,395	21,928	15,725	13,409	17,972	15,950	9,184	6,374
	Bering	3,371	2,426	3,526	3,910	3,480	3,370	3,429	3,501	2,788	2,352	1,246
	Alaska	1,272	2,422	1,579	489	1,620	1,021	708	2,907	947	303	456
	mud	0	0	0	0	0	0	0	0	0	0	47
	roughtail	614	0	0	139	495	356	0	0	326	61	0
	whiteblotched	925	0	0	0	0	0	0	0	0	0	0
	whitebrow	0	0	0	0	84	0	0	72	0	0	0
	misc	8	12	1	0	16	51	0	0	0	0	0
	total CGOA	78,124	63,421	75,433	82,331	78,125	72,748	62,916	65,537	86,292	73,998	49,202
EGOA	big	9,606		11,981	3,984	9,337	11,007	39,870	14,755	12,560	5,664	12,931
	longnose	7,714		13,081	9,797	7,759	9,904	9,362	14,083	6,975	8,150	7,350
	Aleutian	1,310		640	406	138	295	1,663	1,697	657	326	356
	Bering	229		136	342	335	473	191	426	180	1,136	144
	misc	0	0	0	31	0	0	0	0	1	0	49
	Alaska	76		63	0	0	0	0	0	0	0	0
	mud	0		0	0	0	0	0	0	0	0	0
	roughtail	63		0	0	371	0	0	0	442	0	0
	whiteblotched	0		91	0	0	0	0	0	0	0	0
	whitebrow	0		52	0	0	0	0	0	0	0	0
	total EGOA	18,998	0	26,043	14,559	17,941	21,678	51,087	30,960	20,814	15,275	20,830
total GOA		112,863	75,192	116,738	110,688	106,388	108,401	123,158	113,423	125,159	100,931	86,497

Table 4. Total allowable catch (TAC) and catch for GOA "Other Species" and skates, with estimated skate catch, 1992-2004. Before 2004, skate were managed as part of the Other Species group; in 2004 skates were managed separately. Management changed again in 2005 and "modern era" results are included in Table 5.

	TAC	Other Species catch	est. skate catch	management method
1992	13,432	12,313	1,835	Other species TAC
1993	14,602	6,867	3,882	Other species TAC
1994	14,505	2,721	1,770	Other species TAC
1995	13,308	3,421	1,273	Other species TAC
1996	12,390	4,480	1,868	Other species TAC
1997	13,470	5,439	3,120	Other species TAC
1998	15,570	3,748	4,476	Other species TAC
1999	14,600	3,858	2,000	Other species TAC
2000	14,215	5,649	3,238	Other species TAC
2001	13,619	4,801	1,828	Other species TAC
2002	11,330	3,748	6,484	Other species TAC
2003	11,260	6,262	4,527	Other species TAC
2004	3,284	5,865	1,569	Big/Longnose CGOA
	3,709		1,451	other skates Gulf-wide + big/longnose W/E

Sources: TAC and Other species catch from AKRO catch statistics website. Estimated skate catch 1992-1996 from Gaichas et al 1999. Estimated skate catch 1997-2002 from Gaichas et al 2003 (see Table 7 in this assessment). Estimated skate catch 2003-2004 from AKRO Catch Accounting System (CAS).

Table 5. Harvest specifications and catch (t) for skates in the GOA, 2005-2019 (the current management regime for GOA skates was initiated in 2005). ABC and catch are divided by GOA regulatory area (**W**estern, **C**entral, **E**astern) for big and longnose skates; for “other skates”, the ABC column indicates the Gulf-wide ABC. The additional EGOA catch field (E_2) includes catches in EGOA inside waters (area 649, Prince William Sound; area 659, Southeast Inside), which do not count towards the TAC. Red-shaded cells with bold text indicate years/areas where the catch exceeded the ABC. The 2019 catch data are incomplete; retrieved October 26, 2019.

	species/ group	**ABC**				**OFL**	**estimated skate catch**				
		W	**C**	**E**	**GOA**		**W**	**C**	**E**	**(E_2)**	**GOA**
	big	727	2,463	809		5,332	26	811	65	(67)	903
2005	longnose	66	1,972	780		3,757	37	993	162	(173)	1,192
	other				1,327	1,769	163	506	42	(50)	711
	big	695	2,250	599		4,726	72	1,272	344	(388)	1,688
2006	longnose	65	1,969	861		3,860	57	682	219	(296)	957
	other				1,617	2,156	354	988	51	(72)	1,393
	big	695	2,250	599		4,726	69	1,518	8	(11)	1,594
2007	longnose	65	1,969	861		3,860	76	978	342	(388)	1,396
	other				1,617	2,156	479	690	88	(107)	1,257
	big	632	2,065	633		4,439	132	1,241	45	(49)	1,418
2008	longnose	78	2,041	768		3,849	34	965	113	(130)	1,112
	other				2,104	2,806	252	1,053	69	(103)	1,374
	big	632	2,065	633		4,439	79	1,903	100	(137)	2,082
2009	longnose	78	2,041	768		3,849	**79**	1,096	244	(319)	1,419
	other				2,104	2,806	343	1,092	113	(160)	1,548
	big	598	2,049	681		4,438	148	2,228	149	(179)	2,525
2010	longnose	81	2,009	762		3,803	106	849	132	(198)	1,087
	other				2,093	2,791	421	988	84	(124)	1,493
	big	598	2,049	681		4,438	110	2,111	90	(134)	2,312
2011	longnose	81	2,009	762		3,803	70	892	75	(136)	1,037
	other				2,093	2,791	313	1,008	67	(116)	1,388
	big	469	1,793	1,505		5,023	65	1,903	38	(62)	2,007
2012	longnose	70	1,879	676		3,500	39	802	94	(135)	934
	other				2,030	2,706	256	849	105	(146)	1,209
	big	469	1,793	1,505		5,023	122	2,319	79	(222)	2,520
2013	longnose	70	1,879	676		3,500	90	1,257	422	(782)	1,768
	other				2,030	2,706	218	1,487	174	(370)	1,878
	big	589	1,532	1,641		5,016	157	1,412	103	(233)	1,672
2014	longnose	107	1,935	834		3,835	59	1,159	355	(576)	1,573
	other				1,989	2,652	305	1,370	240	(496)	1,915

Table 5 continued. Harvest specifications and catch (t) for skates in the GOA, 2005-2019 (the current management regime for GOA skates was initiated in 2005.

	species/ group	ABC				OFL	estimated skate catch				
		W	C	E	GOA		W	C	E	(E_2)	GOA
2015	big	589	1,532	1,641		5,016	237	1,225	58	(139)	1,520
	longnose	107	1,935	834		3,835	138	1,176	357	(618)	1,672
	other				1,989	2,652	571	1,039	175	(342)	1,785
2016	big	908	1,850	1,056		5,086	165	1,885	51	(147)	2,101
	longnose	61	2,513	632		4,274	154	888	355	(584)	1,397
	other				1,919	2,558	461	1,046	160	(347)	1,667
2017	big	908	1,850	1,056		5,086	190	1,336	126	(213)	1,652
	longnose	61	2,513	632		4,274	189	717	298	(509)	1,204
	other				1,919	2,558	589	849	136	(246)	1,574
2018	big	504	1,774	570		3,797	309	982	78	(134)	1,369
	longnose	149	2,804	619		4,763	57	608	248	(408)	914
	other				1,384	1,845	182	430	148	(285)	759
2019*	big	504	1,774	570		3,797	*15*	*961*	*106*	*(188)*	*1,181*
	longnose	149	2,804	619		4,763	59	608	312	(477)	979
	other				1,384	1,845	*11*	*531*	*115*	*(229)*	*857*

* 2019 catch data are incomplete; retrieved October 26, 2019.

Table 6a. Catches of **big skate** (t) by target fishery, 2005-2019. Data are from the Alaska Regional Office Catch Accounting System. Data do not include catches in areas 649 or 659. * 2019 are incomplete; retrieved on October 26, 2019.

big skate															
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019*
IFQ halibut	36	566	11	34	163	42	138	35	419	413	343	673	571	618	*280*
arrowtooth	225	163	299	219	433	484	818	678	949	190	237	598	324	470	*574*
pollock	2	23	38	22	34	47	93	48	228	171	63	100	115	89	*62*
Pacific cod	222	417	536	584	552	930	921	735	611	840	772	637	587	87	*169*
shallow flatfish	251	350	608	413	535	706	191	288	141	26	72	68	29	59	*50*
sablefish	23	8	6	5	6	11	6	3	8	3	6	7	16	35	*28*
rex sole	49	99	74	70	264	172	106	149	145	25	19	5	1	5	*0*
other	56	27	0	2	38	5	1	0.2	1	0	0.1	1	0	4	*0*
rockfish	19	4	0.4	4	4	14	8	13	2	4	7	5	6	3	*4*
flathead sole	21	30	23	66	53	112	31	57	15	0	2	6	0	0.4	*14*
Atka mackerel	0	0	0	0	0	0	0	0	0	0	0	1	3	0.2	*0*
deep flatfish	0	0	0	0	0	1	1	0	0	0	0	0	0	0	*0*
total	903	1,688	1,594	1,418	2,082	2,525	2,312	2,007	2,520	1,672	1,520	2,101	1,652	1,369	*1,181*

Table 6b. Catches of **longnose skate** (t) by target fishery, 2005-2019. Data are from the Alaska Regional Office Catch Accounting System. Data do not include catches in areas 649 or 659. * 2019 are incomplete; retrieved on October 26, 2019.

	longnose skate														
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019*
IFQ halibut	103	186	400	105	421	107	164	114	697	421	503	361	386	313	*373*
arrowtooth	373	135	165	212	152	166	238	190	218	304	250	273	193	276	*284*
sablefish	105	298	277	126	81	109	101	121	323	159	122	153	164	151	*160*
Pacific cod	139	165	305	359	339	411	334	307	348	415	613	490	370	72	*88*
rockfish	20	21	17	12	17	12	25	23	23	26	33	46	42	44	*27*
pollock	5	13	27	24	35	10	35	9	25	180	87	47	33	35	*17*
shallow flatfish	278	97	168	227	239	173	78	65	70	36	26	17	5	13	*17*
rex sole	19	29	24	36	82	52	44	45	54	23	21	4	8	8	*5*
other	137	2	0	0.3	30	16	0.3	0	1	0	7	0.4	3	2	*0*
Atka mackerel	0	0	0	0	0	0	0	0	1	0	0	1	0.1	0.1	*0*
flathead sole	11	11	13	11	24	30	17	60	8	11	10	6	0.3	0.04	*7*
deep flatfish	1	0	0	0.01	0	1	0.3	0	0	0	0	0	0	0	*0*
total	1,192	957	1,396	1,112	1,419	1,087	1,037	934	1,768	1,573	1,672	1,397	1,204	914	*979*

Table 6c. Catches of **Other Skates** by target fishery (t), 2005-2019. Data are from the Alaska Regional Office Catch Accounting System. Data do not include catches in areas 649 or 659. * 2019 are incomplete; retrieved on October 26, 2019.

	other skates														
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019*
IFQ halibut	47	74	109	32	256	39	154	101	683	534	290	258	204	199	*262*
sablefish	122	124	262	144	89	131	135	148	200	169	177	150	168	193	*190*
Pacific cod	175	980	527	945	887	1,058	775	686	806	935	1,080	982	971	186	*238*
arrowtooth	194	64	123	88	99	133	251	178	63	164	118	235	187	140	*130*
rockfish	59	49	20	10	13	28	15	20	18	45	21	18	22	27	*27*
shallow flatfish	36	27	79	107	98	36	20	33	44	28	30	17	10	6	*3*
rex sole	36	56	103	22	60	41	21	20	33	21	13	0.2	3	4	*3*
pollock	1	5	9	6	3	7	2	6	24	17	18	5	5	4	*3*
Atka mackerel	0	0	0	0	0	0.05	2	0	0.004	0	0	0	1	0	*0*
deep flatfish	0	0	0	0	0	0.1	0	0	0	1	0	0	0	0	*0*
flathead sole	38	12	20	5	13	19	13	17	8	1	8	3	0	0	*2*
other	2	3	4	16	30	0	0	0	0.03	0	30	0	2	0	*0*
total	711	1,393	1,257	1,374	1,548	1,493	1,388	1,209	1,878	1,915	1,785	1,667	1,574	759	*857*

Table 7. Retention rates of skates in GOA fisheries, 2005-2019. Data are from the NMFS Alaska Regional Office. Retention rates in 2013-2017 were influenced by management actions including a 2016 permanent reduction in the maximum retention allowance (see footnotes).

	big	longnose	other
2005	72%	70%	16%
2006	54%	32%	19%
2007	49%	29%	20%
2008	70%	59%	15%
2009	70%	45%	13%
2010	71%	64%	15%
2011	80%	61%	17%
2012	94%	71%	13%
2013[1]	62%	38%	2%
2014[2]	26%	55%	5%
2015[3]	16%	52%	6%
2016[4+]	32%	33%	6%
2017[5]	34%	28%	8%
2018	35%	31%	6%
*2019**	*55%*	*28%*	*8%*
2005-2015 average	60%	52%	13%
2016-2018 average	34%	31%	7%

[1] On May 8, 2013 retention of big skate was prohibited in the CGOA.
[2] On February 5, 2014 retention of big skate was prohibited in the CGOA.
[3] On February 11, 2015 retention of big skate was prohibited in the CGOA.
[4] The following management actions related to skates in the GOA occurred during 2016:

- retention of longnose skates in the WGOA was prohibited on April 25, 2016.
- retention of big skates in the CGOA was prohibited on September 27, 2016.

[+] **Effective January 27, 2016 the maximum retention allowance for skates (all species, GOA-wide) was reduced to 5%.**
[5] On September 20, 2017 retention of longnose skates in the WGOA was prohibited.

* 2019 data are incomplete; retrieved October 15, 2019

Table 8a. Biomass estimates (t) and coefficients of variation (CV) for **big skates** in 3 regions of the Gulf of Alaska. Estimates are annual trawl survey estimates (survey) or estimates from a random effects model fitted to each survey time series (RE model).

	WGOA				CGOA				EGOA			
	survey		RE model		survey		RE model		survey		RE model	
	estimate	CV	estimate	CV	estimate	CV	estimate	CV	estimate	CV	estimate	CV
1990	1,745	0.45	2,239	0.38	9,071	0.34	15,569	0.30	11,501	0.38	11,435	0.33
1991			2,483	0.39			17,138	0.26			11,388	0.38
1992			2,754	0.36			18,865	0.21			11,341	0.37
1993	2,312	0.32	3,055	0.28	21,586	0.18	20,766	0.15	15,836	0.36	11,294	0.32
1994			4,218	0.32			22,321	0.17			8,562	0.34
1995			5,825	0.33			23,993	0.17			6,490	0.34
1996	13,130	0.40	8,044	0.31	26,544	0.19	25,790	0.14	3,391	0.29	4,920	0.31
1997			8,649	0.34			27,278	0.17			5,841	0.35
1998			9,299	0.31			28,853	0.17			6,934	0.34
1999	11,038	0.26	9,998	0.23	34,007	0.20	30,518	0.15	9,606	0.33	8,232	0.28
2000			9,551	0.28			30,475	0.16			8,422	0.36
2001	8,425	0.34	9,124	0.24	30,658	0.21	30,431	0.15			8,617	0.39
2002			9,211	0.27			30,287	0.16			8,816	0.37
2003	9,602	0.28	9,299	0.22	33,814	0.21	30,143	0.15	11,981	0.37	9,019	0.29
2004			9,075	0.27			28,493	0.16			7,451	0.32
2005	9,792	0.32	8,857	0.24	25,544	0.21	26,933	0.14	3,984	0.35	6,156	0.31
2006			7,965	0.29			26,124	0.16			7,391	0.32
2007	5,872	0.42	7,163	0.27	24,420	0.26	25,339	0.15	9,337	0.33	8,875	0.25
2008			7,058	0.30			24,849	0.16			10,145	0.30
2009	6,652	0.36	6,954	0.25	26,691	0.21	24,369	0.14	11,007	0.31	11,596	0.25
2010			7,051	0.28			22,933	0.15			14,021	0.36
2011	6,251	0.30	7,149	0.23	21,761	0.17	21,582	0.13	39,870	0.57	16,953	0.41
2012			8,213	0.28			20,194	0.16			15,584	0.40
2013	10,669	0.40	9,436	0.26	12,810	0.20	18,895	0.17	14,755	0.52	14,325	0.34
2014			10,190	0.28			21,446	0.15			13,023	0.36
2015	13,449	0.24	11,005	0.21	32,038	0.19	24,341	0.15	12,560	0.53	11,839	0.33
2016			9,013	0.26			23,463	0.16			10,530	0.36
2017	5,068	0.29	7,382	0.24	22,878	0.21	22,618	0.15	5,664	0.47	9,366	0.34
2018			8,639	0.28			21,689	0.17			10,540	0.33
2019	12,179	0.31	10,109	0.26	18,371	0.25	20,798	0.18	12,931	0.27	11,861	0.25

Table 8b. Biomass estimates (t) and coefficients of variation (CV) for **longnose skates** in 3 regions of the Gulf of Alaska. Estimates are annual trawl survey estimates (survey) or estimates from a random effects model fitted to each survey time series (RE model).

	WGOA				CGOA				EGOA			
	survey		RE model		survey		RE model		survey		RE model	
	estimate	CV	estimate	CV	estimate	CV	estimate	CV	estimate	CV	estimate	CV
1990	1,045	0.64	608	0.59	8,708	0.28	12,253	0.21	2,242	0.25	2,698	0.22
1991			439	0.60			13,055	0.19			2,986	0.23
1992			316	0.60			13,909	0.17			3,306	0.21
1993	105	0.64	228	0.60	14,158	0.15	14,819	0.12	3,539	0.19	3,659	0.16
1994			263	0.63			16,300	0.14			4,191	0.20
1995			302	0.59			17,930	0.14			4,800	0.20
1996	278	0.59	348	0.47	20,328	0.17	19,723	0.12	5,620	0.18	5,497	0.15
1997			471	0.54			21,350	0.14			6,142	0.19
1998			638	0.54			23,111	0.14			6,864	0.19
1999	1,747	0.49	864	0.47	29,872	0.17	25,018	0.13	7,714	0.17	7,670	0.15
2000			565	0.49			24,827	0.13			8,513	0.20
2001	104	0.64	369	0.60	23,171	0.16	24,639	0.11			9,448	0.22
2002			525	0.52			25,357	0.12			10,485	0.20
2003	782	0.43	746	0.35	25,741	0.12	26,096	0.09	13,081	0.15	11,637	0.14
2004			995	0.44			27,266	0.11			10,785	0.17
2005	1,719	0.35	1,327	0.33	29,853	0.09	28,489	0.08	9,797	0.18	9,995	0.14
2006			1,050	0.43			27,516	0.11			9,468	0.18
2007	628	0.44	831	0.37	26,083	0.12	26,576	0.09	7,759	0.24	8,969	0.16
2008			936	0.47			26,162	0.11			9,317	0.18
2009	1,214	0.58	1,056	0.41	25,534	0.10	25,755	0.08	9,904	0.18	9,679	0.14
2010			1,074	0.46			25,668	0.11			9,815	0.18
2011	941	0.41	1,093	0.34	23,609	0.14	25,581	0.10	9,362	0.19	9,953	0.14
2012			1,381	0.42			27,032	0.12			10,741	0.17
2013	2,127	0.32	1,745	0.30	28,274	0.14	28,565	0.10	14,083	0.17	11,591	0.15
2014			1,350	0.43			30,422	0.11			9,857	0.18
2015	708	0.41	1,045	0.39	34,243	0.10	32,399	0.09	6,975	0.22	8,383	0.16
2016			1,423	0.43			31,833	0.12			8,209	0.19
2017	2,133	0.30	1,939	0.27	39,219	0.20	31,276	0.12	8,150	0.22	8,040	0.16
2018			2,045	0.42			28,287	0.13			7,795	0.19
2019	2,221	0.37	2,156	0.34	22,709	0.13	25,583	0.12	7,350	0.18	7,558	0.16

Table 9. Exploitation rates for the three skate species groups in the Gulf of Alaska. The table also includes biomass estimates for big and longnose skates in Prince William Sound based on surveys conducted by the Alaska Department of Fish & Game.

	PWS biomass		Area 649 catch		PWS expl. rate		Gulf-wide expl. rates		
	longnose	big	longnose	big	longnose	big	big	longnose	other
1999	1,459	336							
2000									
2001	1,833	56							
2002									
2003	1,600	77							
2004									
2005	1,417	131	0.7	0.0	0.00	0.00	0.02	0.03	0.02
2006			10.7	7.2			0.04	0.03	0.05
2007	294	5	8.1	0.3	0.03	0.05	0.04	0.04	0.04
2008			4.3	0.7			0.03	0.03	0.05
2009	971	274	60	28	0.06	0.10	0.05	0.04	0.06
2010			50	25			0.06	0.03	0.06
2011	1,140	282	42	40	0.04	0.14	0.05	0.03	0.06
2012			25	19			0.04	0.02	0.05
2013	1,306	160	95	40	0.07	0.25	0.06	0.04	0.06
2014	1,341	436	58	76	0.04	0.17	0.04	0.04	0.07
2015	1,456	532	115	30	0.08	0.06	0.03	0.04	0.07
2016			71	48			0.05	0.03	0.08
2017	846	506	55	60	0.07	0.12	0.04	0.03	0.09
2018	1,117	562	26	24	0.02	0.04	0.03	0.02	0.05
2019			30	25			0.03	0.03	0.07

Figures

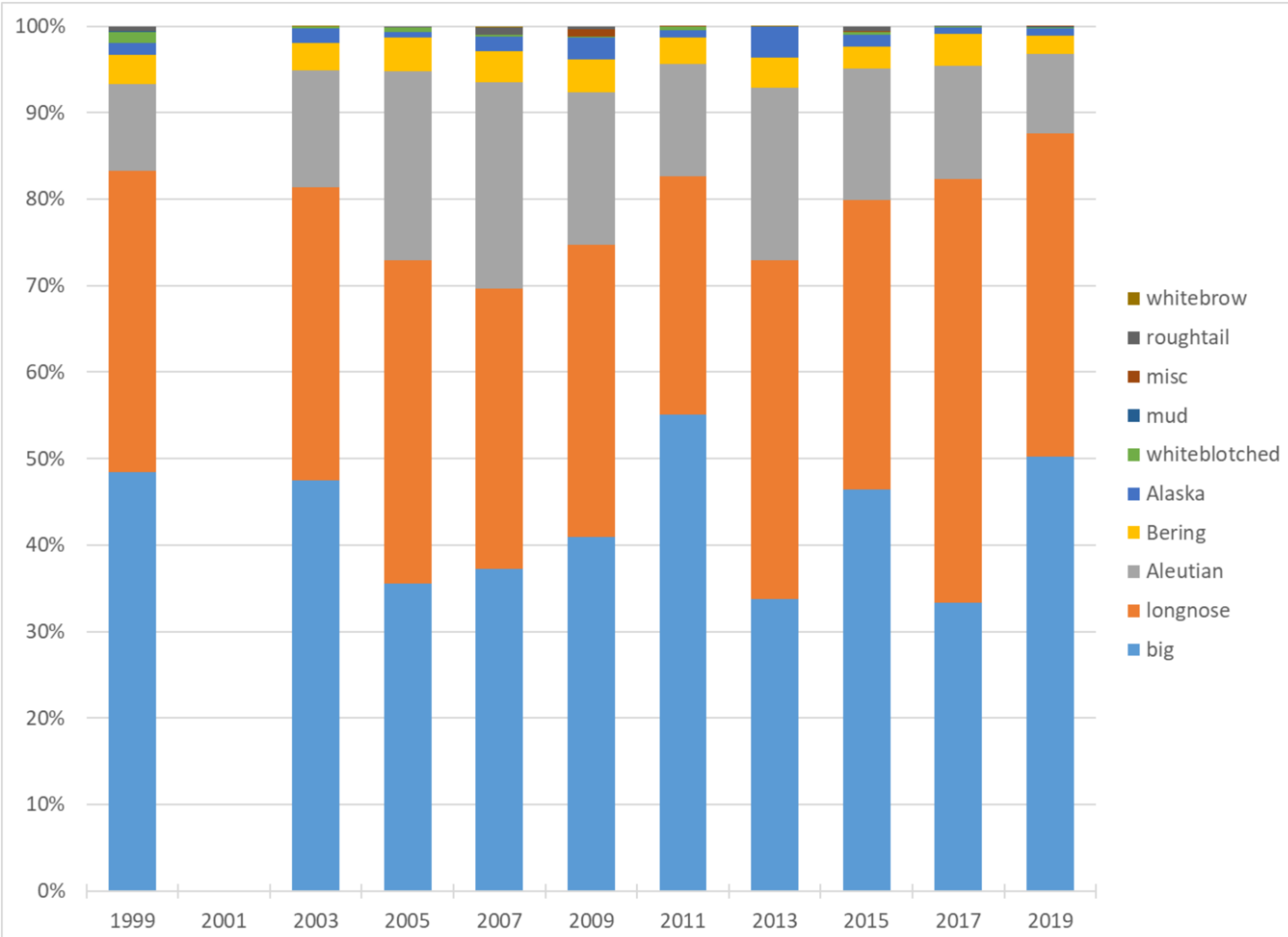

Figure 1. Species composition of the Gulf of Alaska (GOA) skate complex, 1999-2019. Data are Gulf-wide estimates from the NMFS GOA bottom trawl survey. The 2001 survey did not sample in the eastern GOA.

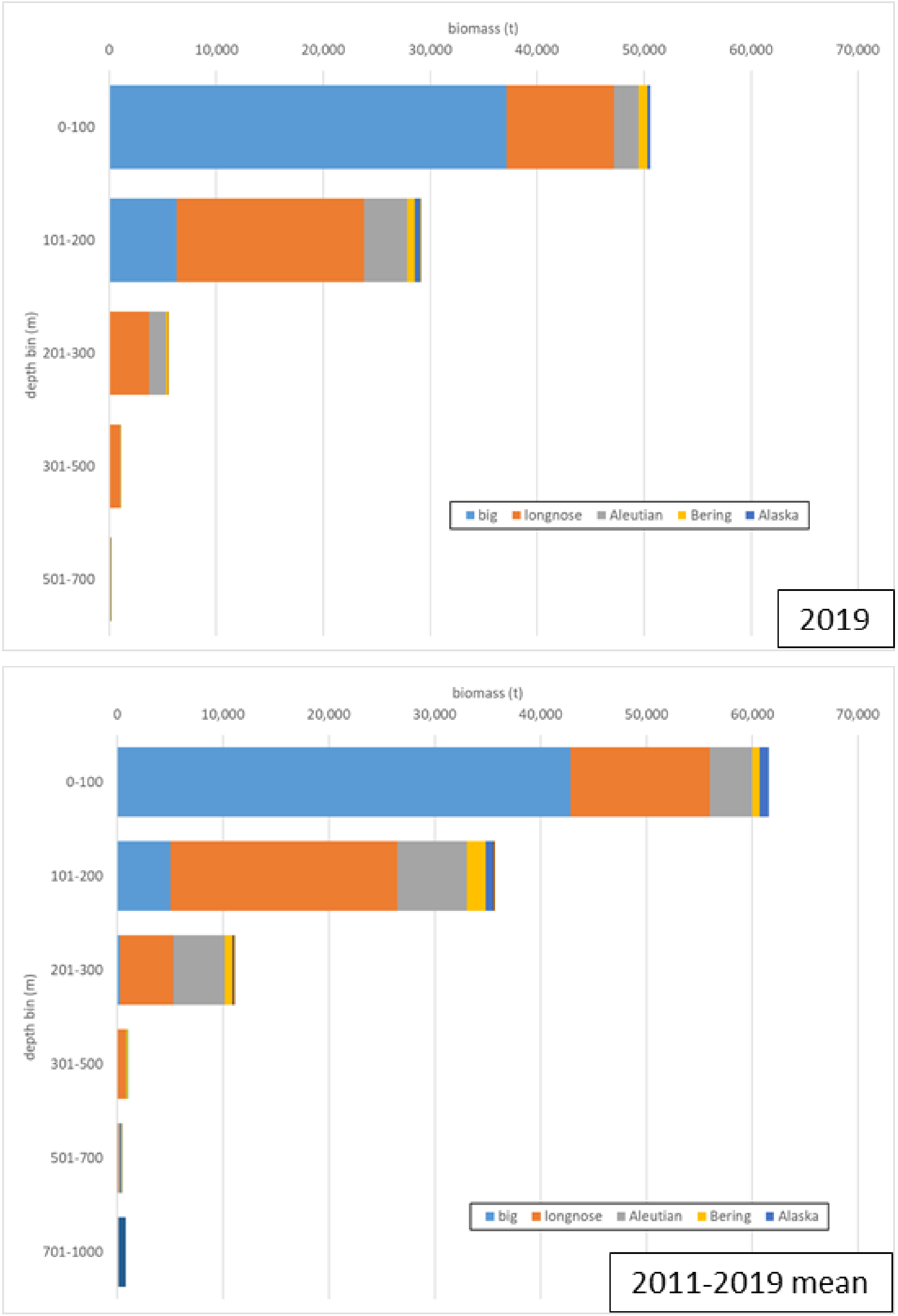

Figure 2. Biomass estimates (t) of skates at depth from the Gulf of Alaska bottom trawl survey conducted by NMFS. Data include 2019 estimates (top panel) and mean biomass estimates during 2011-2019 (bottom panel).The 2019 survey did not sample the deepest stratum (701-1000 m). Legend includes only major species.

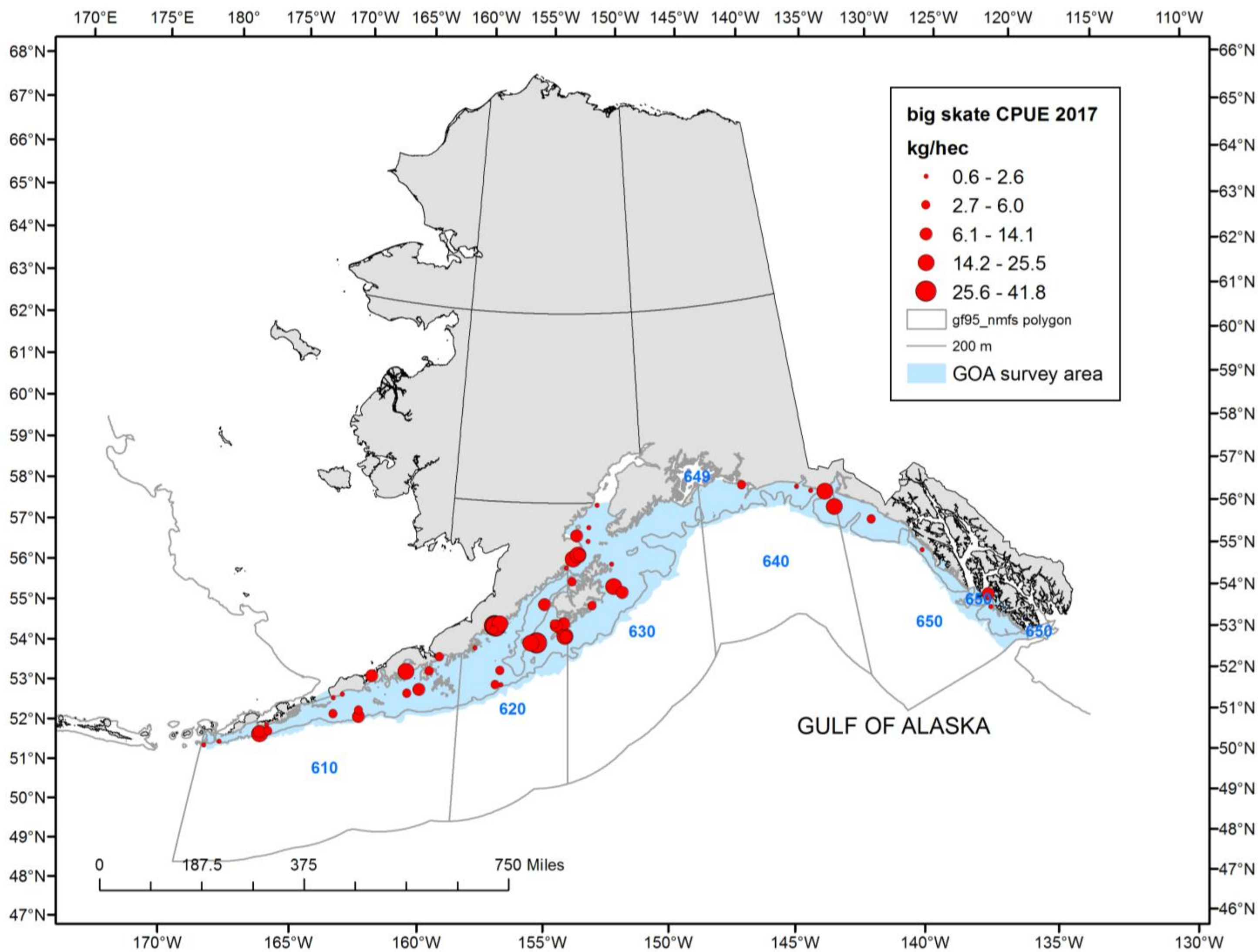

Figure 3. Catch-per-unit-effort of **big skates** in the AFSC Gulf of Alaska bottom trawl survey during 2019. Survey extent is shown by blue shading. Blue lettering indicates NMFS statistical area; GOA regulatory areas are western GOA (area 610), central GOA (areas 620 & 630), and eastern GOA (areas 640-659).

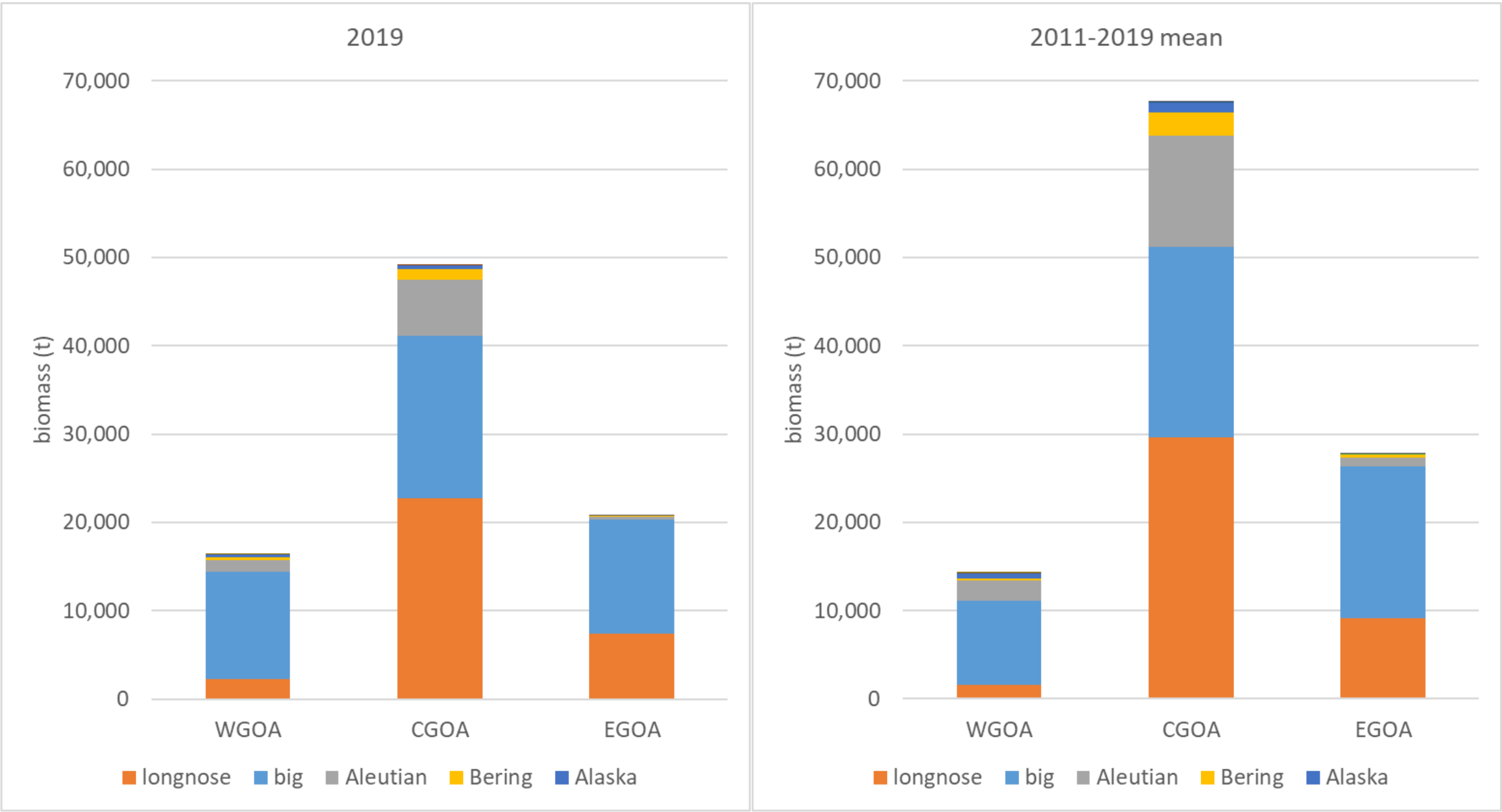

Figure 4. Species composition of skates in the three regulatory areas of the Gulf of Alaska (GOA) in 2019 (left panel) and during 2011-2019 (right panel). Data are from the NMFS bottom trawl survey. WGOA= western GOA, CGOA = central GOA, EGOA = eastern GOA. Legend includes only major species.

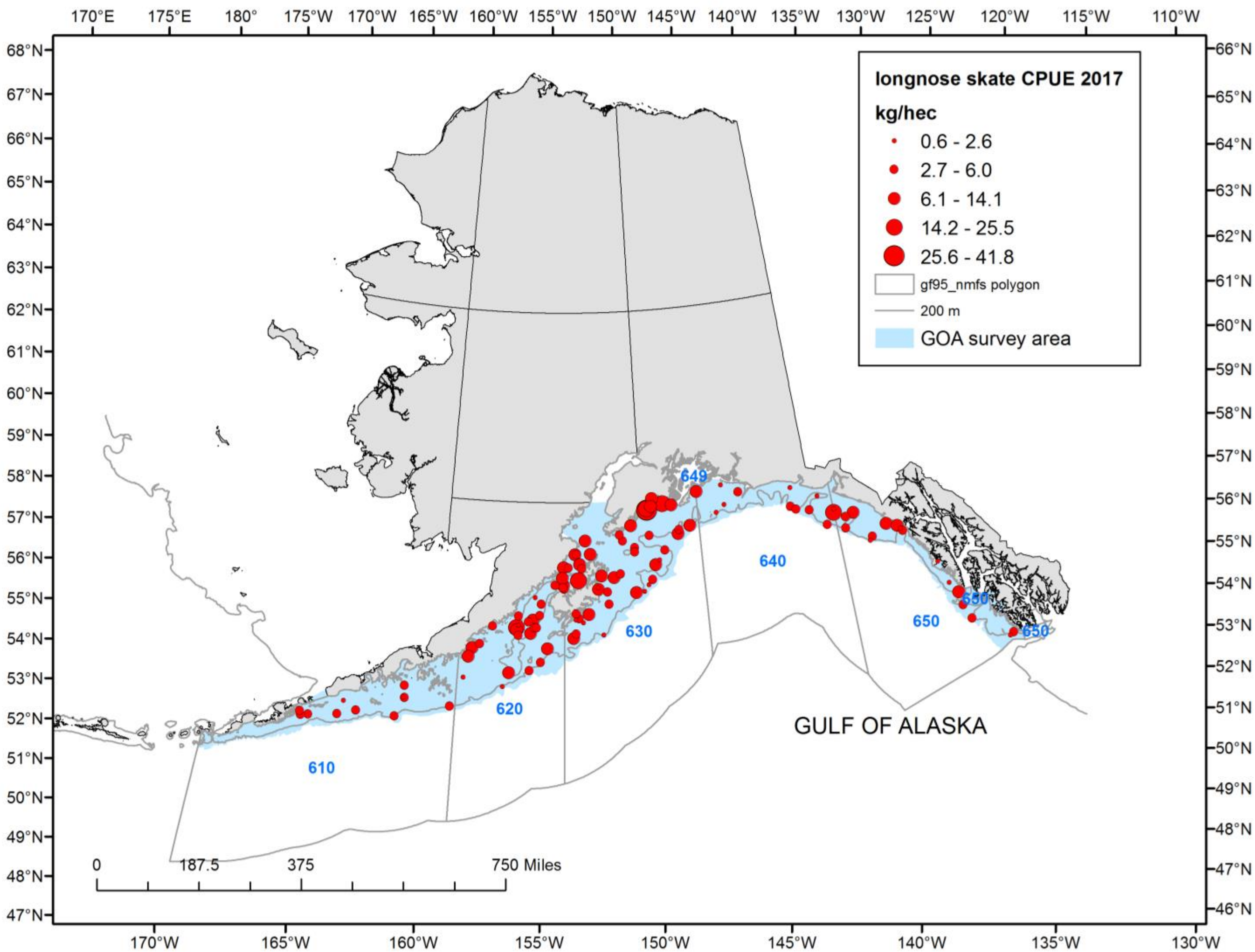

Figure 5. Catch-per-unit-effort of **longnose** skates in the AFSC Gulf of Alaska (GOA) bottom trawl survey during 2019. Survey extent is shown by blue shading. Blue lettering indicates NMFS statistical area; GOA regulatory areas are western GOA (area 610), central GOA (areas 620 & 630), and eastern GOA (areas 640-659).

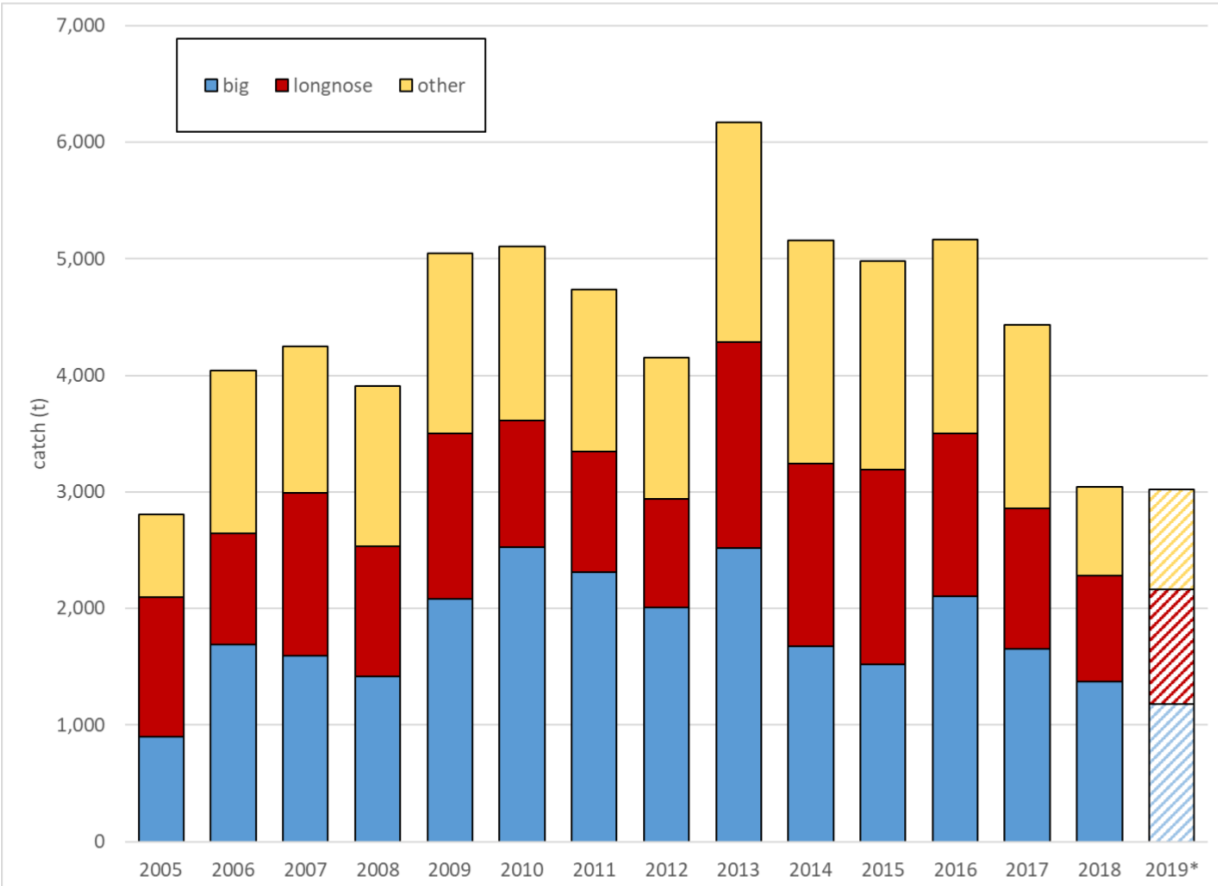

Figure 6. Catch (t) of the three main skate groups in the Gulf of Alaska, 2005-2019. Data are from the AK Regional Office. The 2019 data are incomplete; retrieved on October 26, 2019.

Figure 7. Retention rates of captured skates and average ex-vessel price, 2005-2018. Retention data are from the NMFS Alaska Regional Office; price data are from the Alaska Department of Fish & Game. Management actions by NMFS to limit retention began in 2013 (arrow).

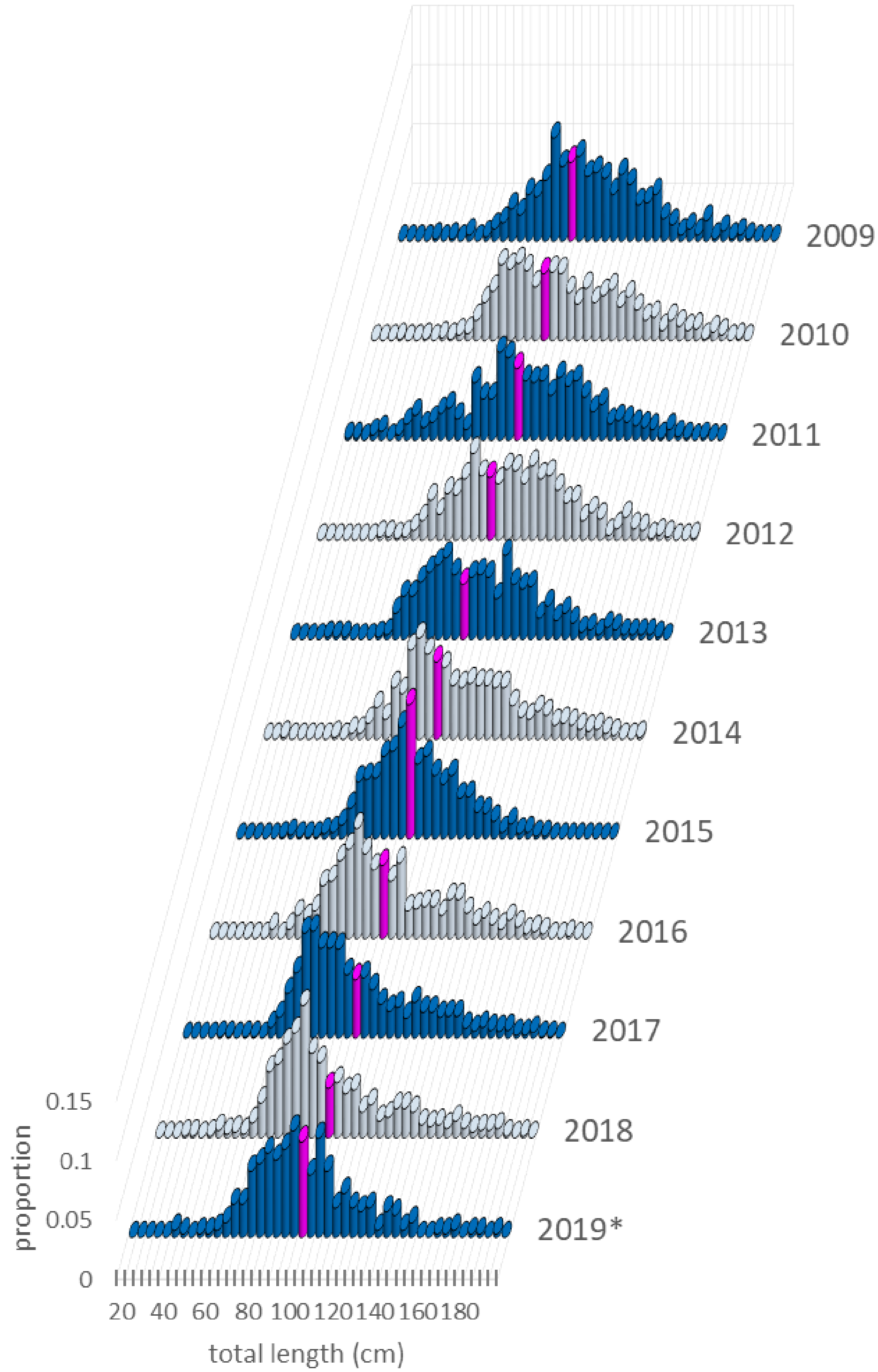

Figure 8. Length compositions of fishery catches (trawl and longline combined) for **big skates** in the Gulf of Alaska, 2009-2019. Data are in 4-cm length bins; fuchsia column indicates the 100-103 cm length bin in each dataset. **The 2019 data are incomplete; retrieved on October 30, 2019.**

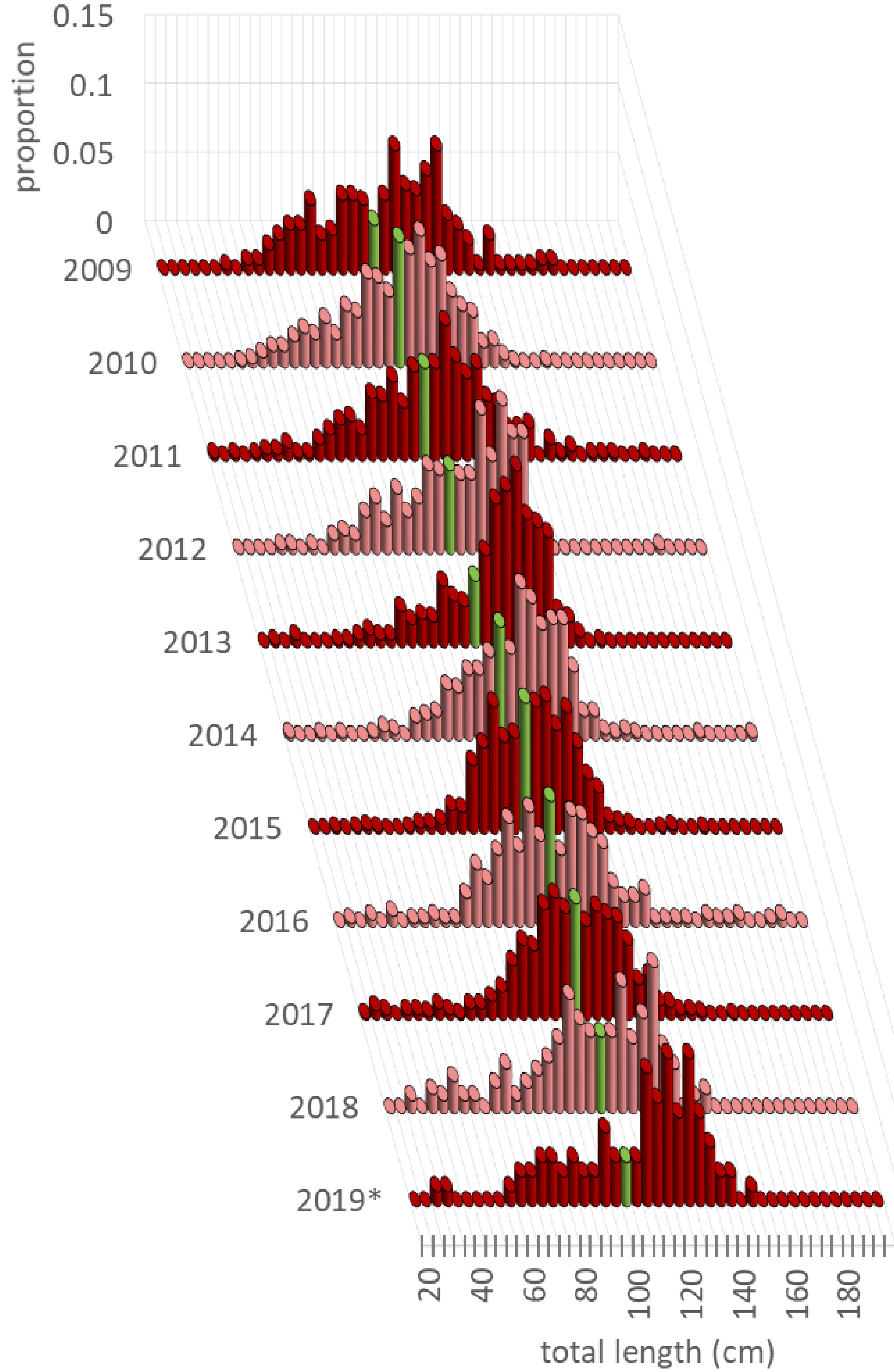

Figure 9. Length compositions of fishery catches (trawl and longline combined) for longnose skates in the Gulf of Alaska, 2009-2019. Data are in 4-cm length bins; green column indicates the 100-103 cm length bin in each dataset. **The 2019 data are incomplete; retrieved on October 30, 2019.**

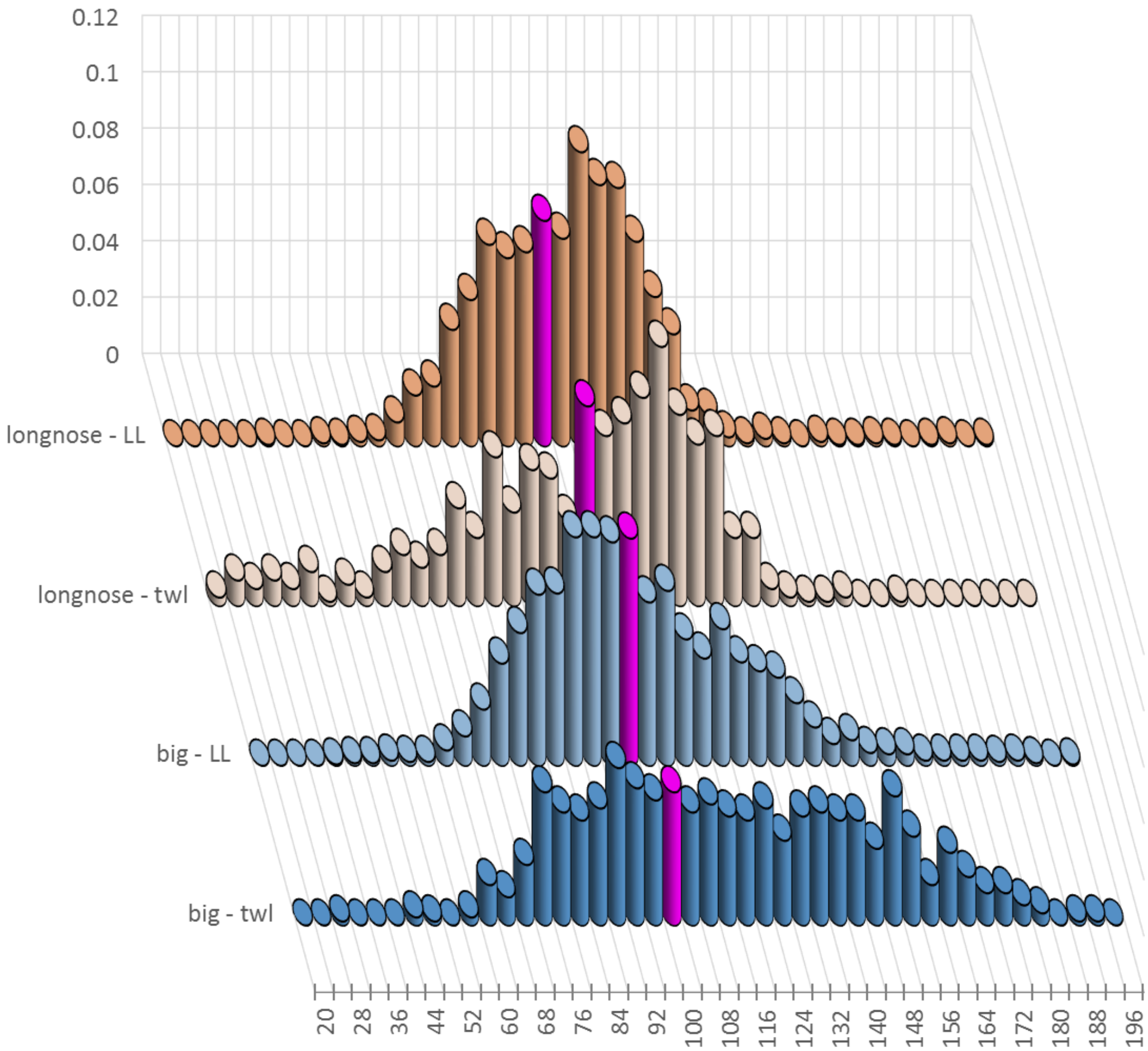

Figure 10. Comparison of trawl and longline fishery length compositions for big and longnose skates in the Gulf of Alaska, aggregated over the years 2013-2019. Data are in 4-cm length bins; fuchsia column indicates the 100-103 cm length bin in each dataset.

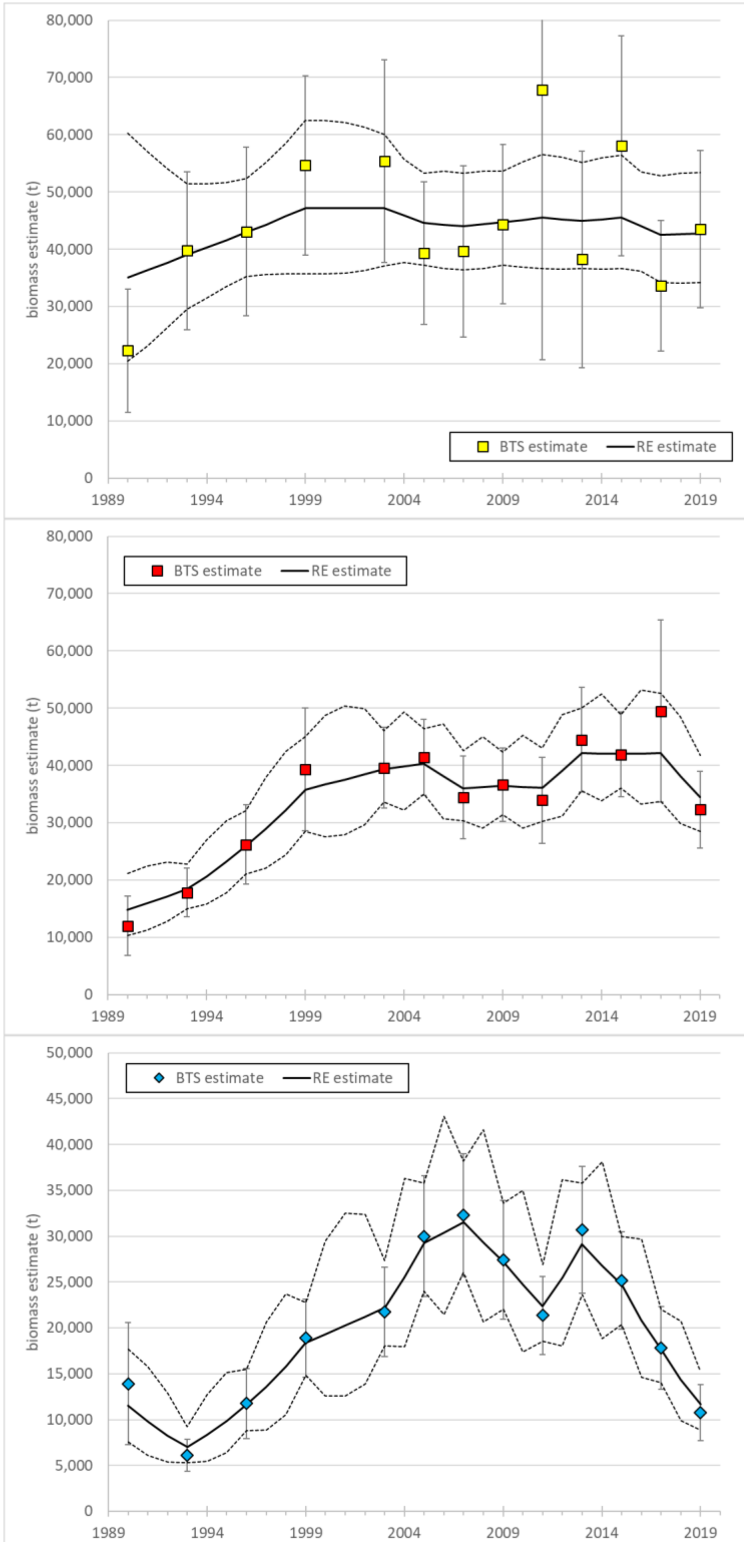

Figure 11. Biomass estimates (t) for big skates (top), longnose skates (middle), and Other Skates (bottom), 1990-2019, from the AFSC bottom trawl survey (BTS) in the Gulf of Alaska. Filled symbols indicate survey biomass estimates with 95% confidence interval (CI) shown as error bars. Black line indicates biomass estimate from the random-effects (RE) model; dashed black lines indicate 95% CI. Note that vertical scales differ among the plots.

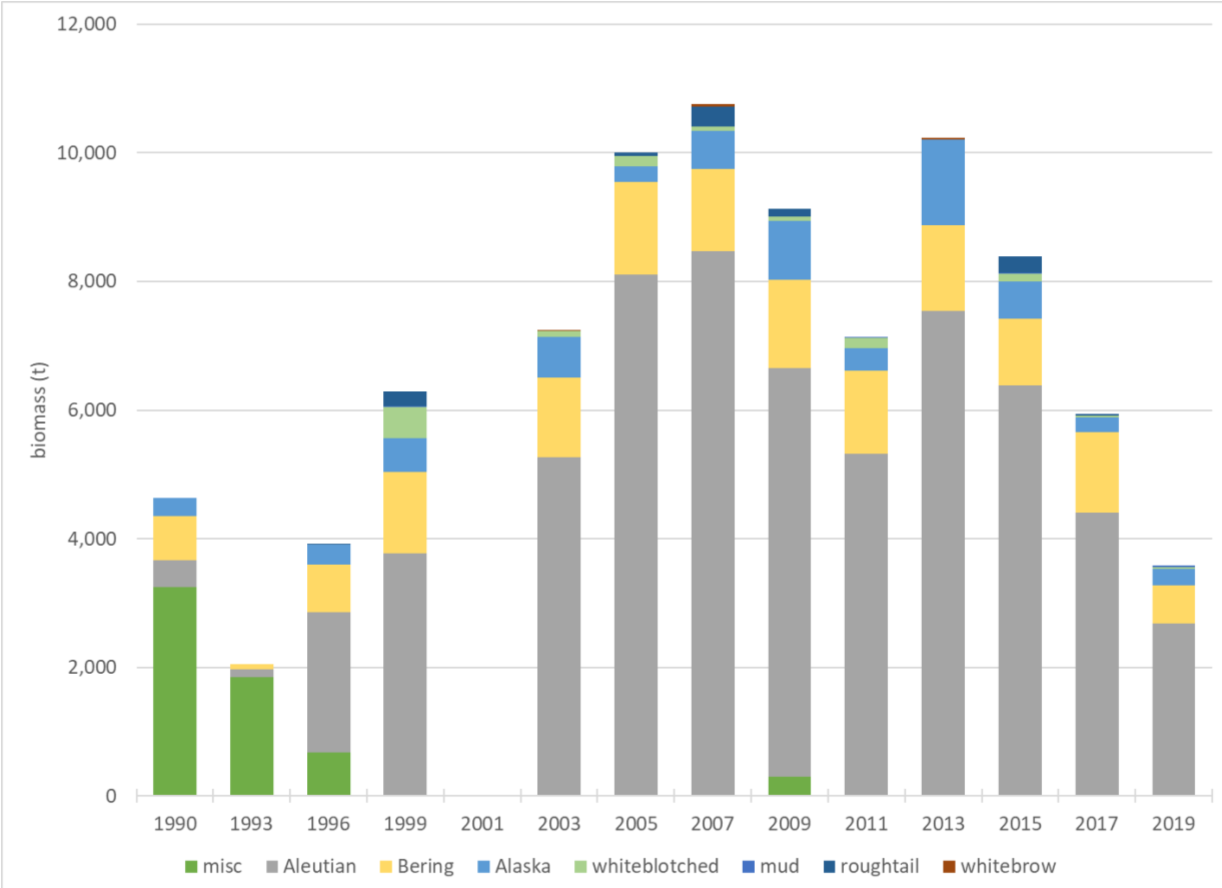

Figure 12. Biomass trends for *Bathyraja* skates (i.e. Other Skates) in the Gulf of Alaska (GOA), 1990-2019. Data are from the NMFS GOA bottom trawl survey. Complete identification to species of all *Bathyraja* skates was not achieved until the 1999 survey. The 2001 survey did not sample in the eastern GOA so estimates for that year are omitted. For information regarding the uncertainty of the Other Skates biomass estimate see Figure 11.

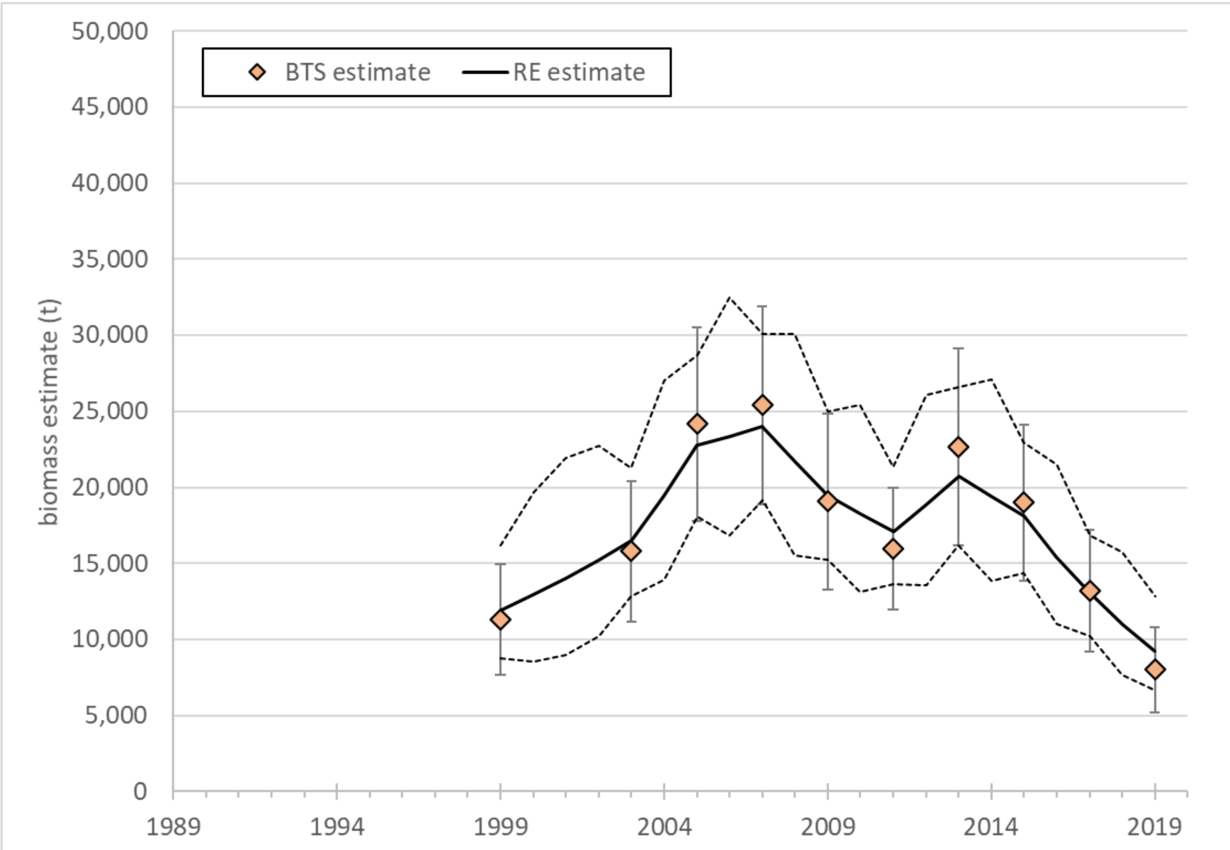

Figure 13. Biomass estimates (t) for Aleutian skate, 1999-2019, from the AFSC bottom trawl survey (BTS) in the Gulf of Alaska. Filled symbols indicate survey biomass estimates with 95% confidence interval (CI) shown as error bars. Black line indicates biomass estimate from the random-effects (RE) model; dashed black lines indicate 95% CI.

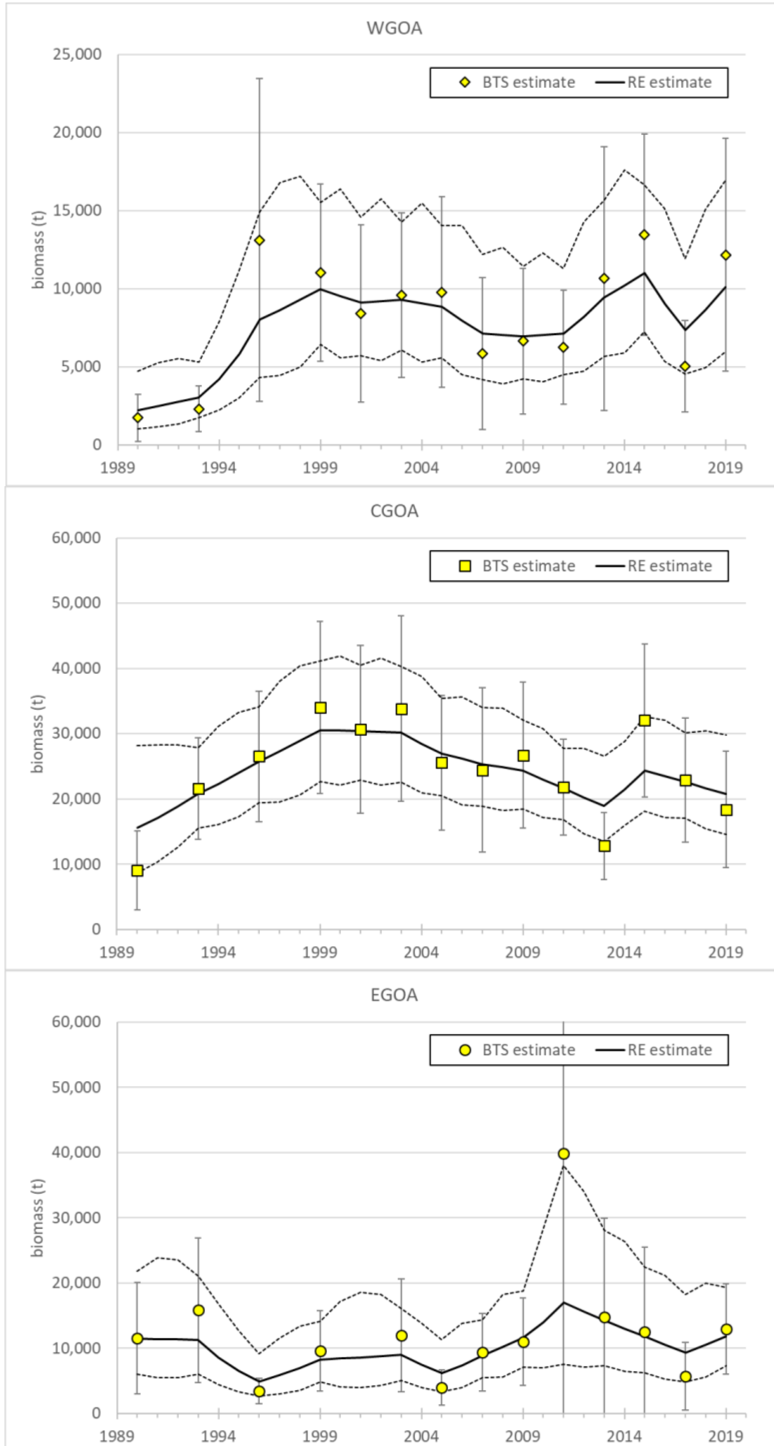

Figure 14. Biomass estimates (t) for **big skate** in 3 Gulf of Alaska (GOA) regions from the GOA trawl survey (colored dots) and predictions from a random-effects model based on those estimates (black line), 1990-2019. 95% confidence intervals are indicated by error bars and dotted black lines for the survey and model estimates, respectively. Note that vertical scales differ among the plots.

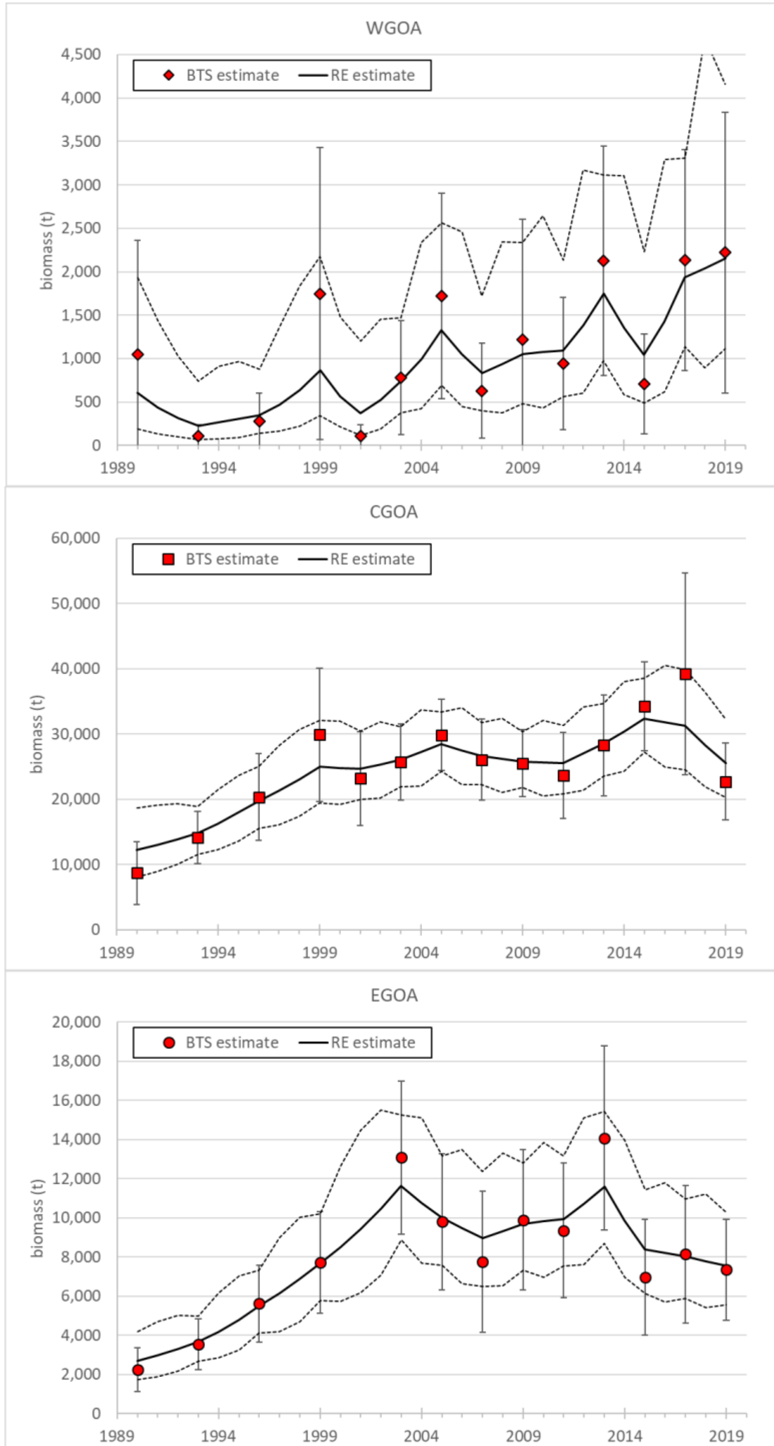

Figure 15. Biomass estimates (t) for **longnose skates** in 3 Gulf of Alaska (GOA) regions from the GOA trawl survey (colored dots) and predictions from a random-effects model based on those estimates (black line) for other skates, 1990-2019. 95% confidence intervals are indicated by error bars and dotted black lines for the survey and model estimates, respectively. Note that vertical scales differ among the plots.

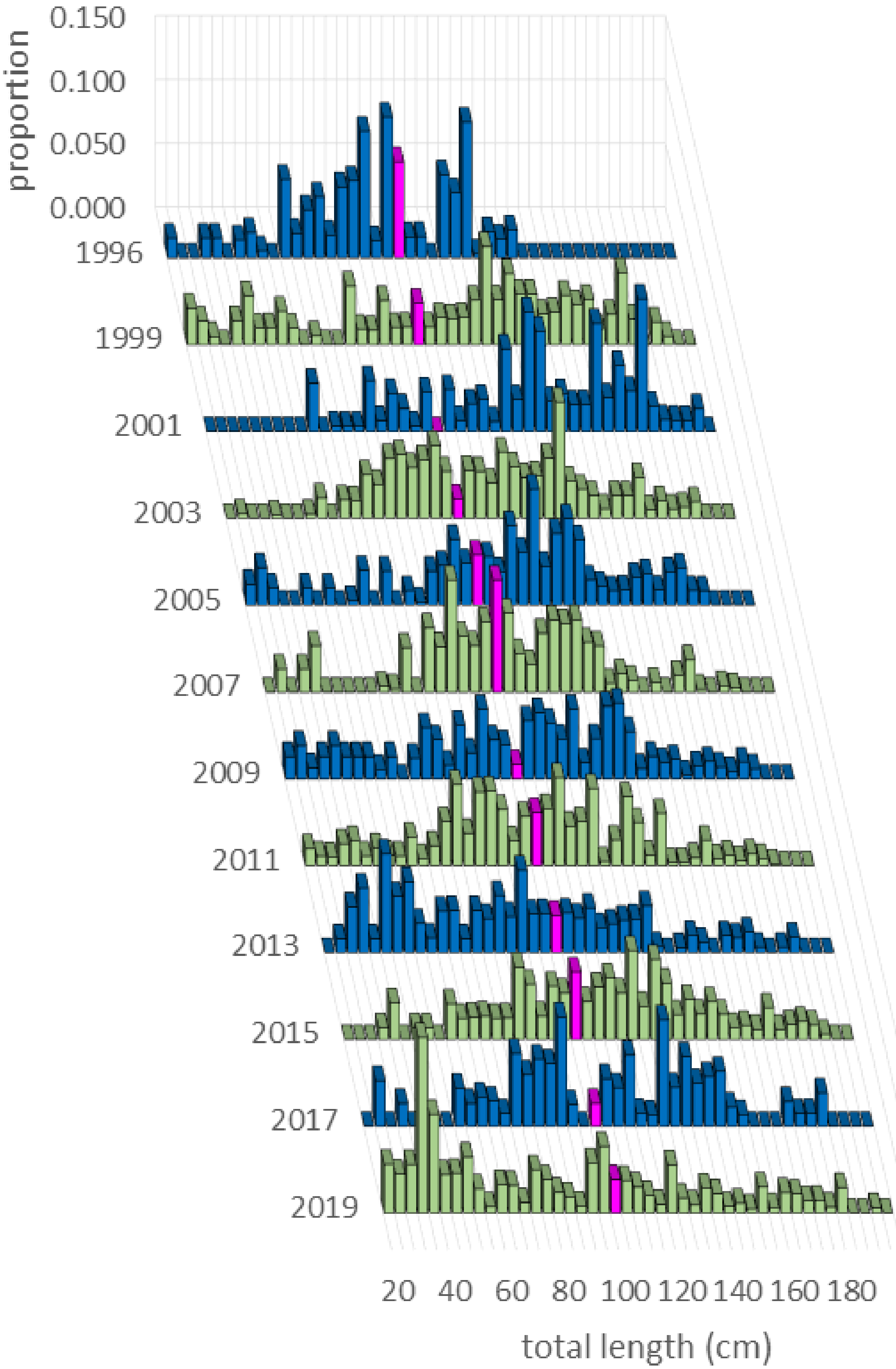

Figure 16. Length compositions of **big skates**, 1996-2019, from the AFSC bottom trawl survey in the Gulf of Alaska. Data are in 4-cm length bins; fuchsia column indicates the 100-103 cm length bin in each dataset.

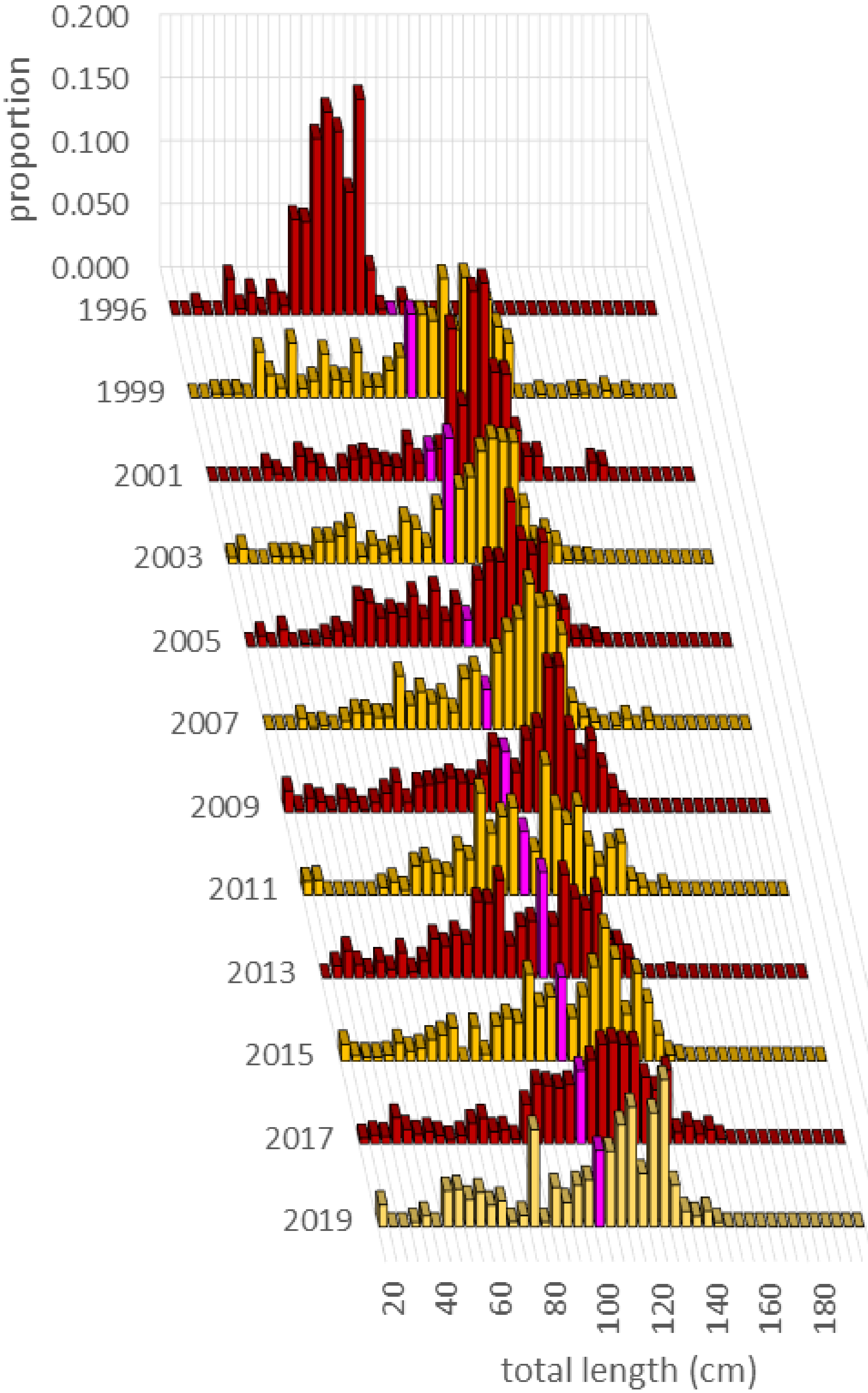

Figure 17. Length compositions of **longnose skates**, 1996-2019, from the AFSC bottom trawl survey in the Gulf of Alaska. Data are in 4-cm length bins; fuchsia column indicates the 100-103 cm length bin in each dataset.

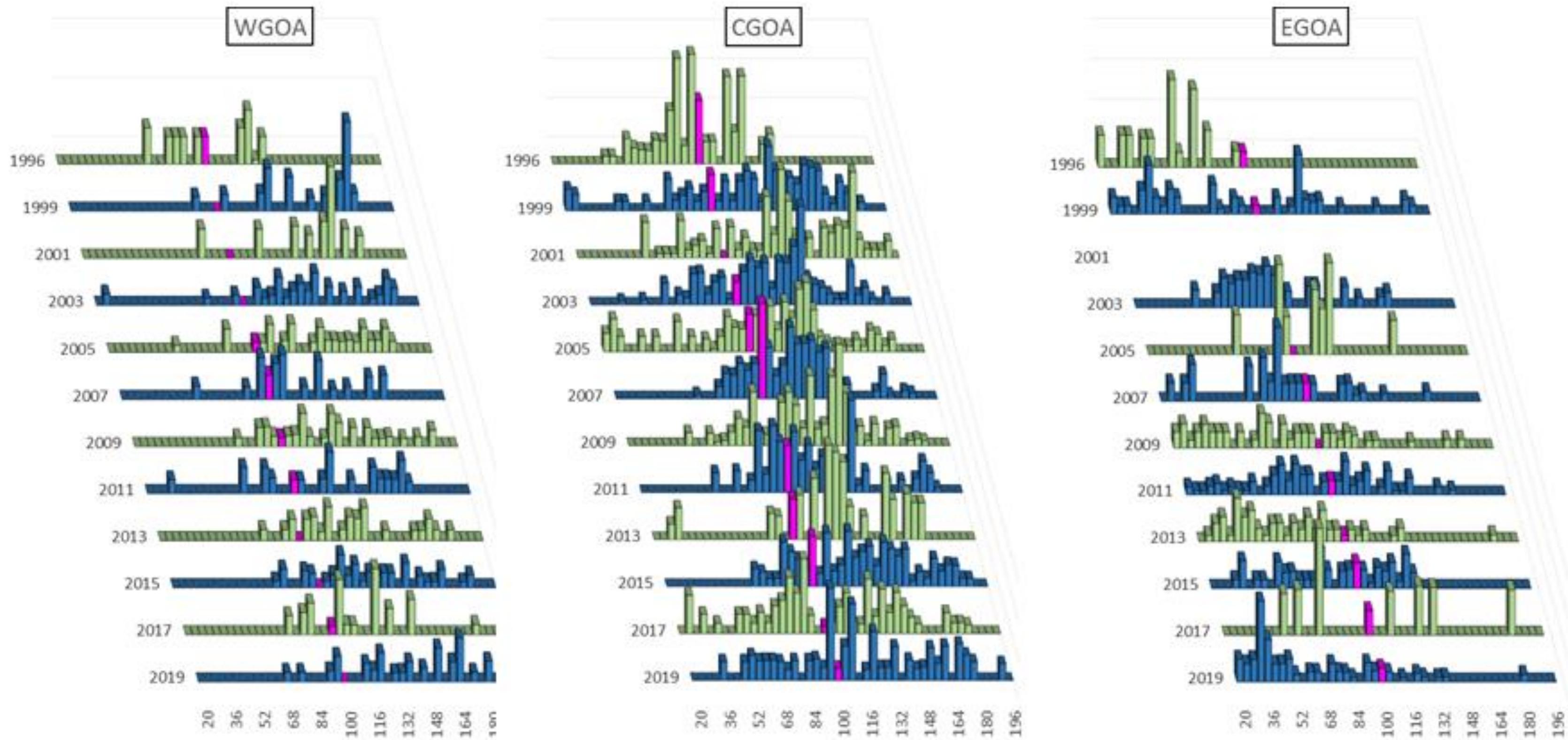

Figure 18. Length compositions of **big skates**, 1996-2019, from the AFSC bottom trawl survey in the Gulf of Alaska. Data are separated by regulatory area: WGOA = western GOA, CGOA = central GOA, EGOA = eastern GOA. Data are in 4-cm length bins; fuchsia column indicates the 100-103 cm length bin in each dataset.

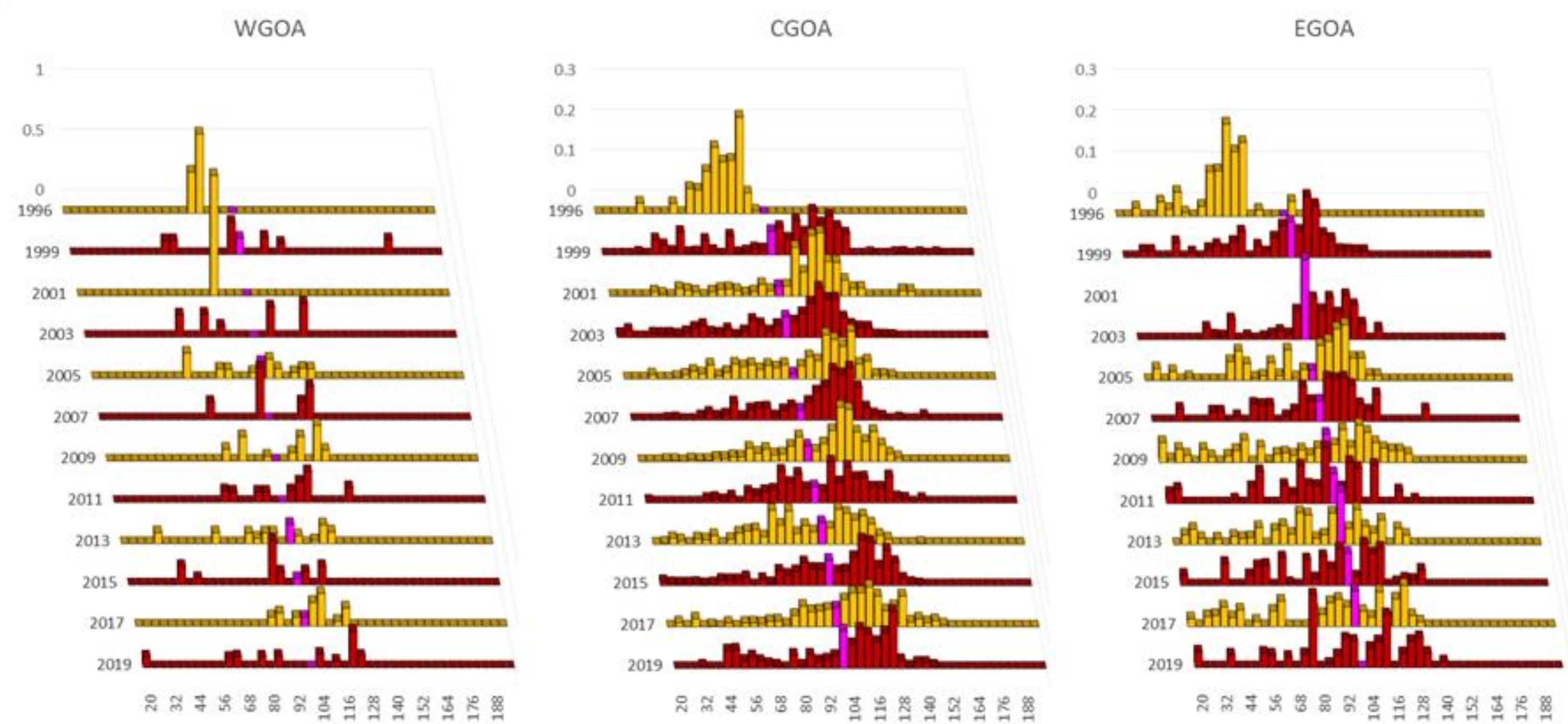

Figure 19. Length compositions of **longnose**, 1996-2019, from the AFSC bottom trawl survey in the Gulf of Alaska (GOA). Data are separated by regulatory area: WGOA = western GOA, CGOA = central GOA, EGOA = eastern GOA. Data are in 4-cm length bins; fuchsia column indicates the 100-103 cm length bin in each dataset.

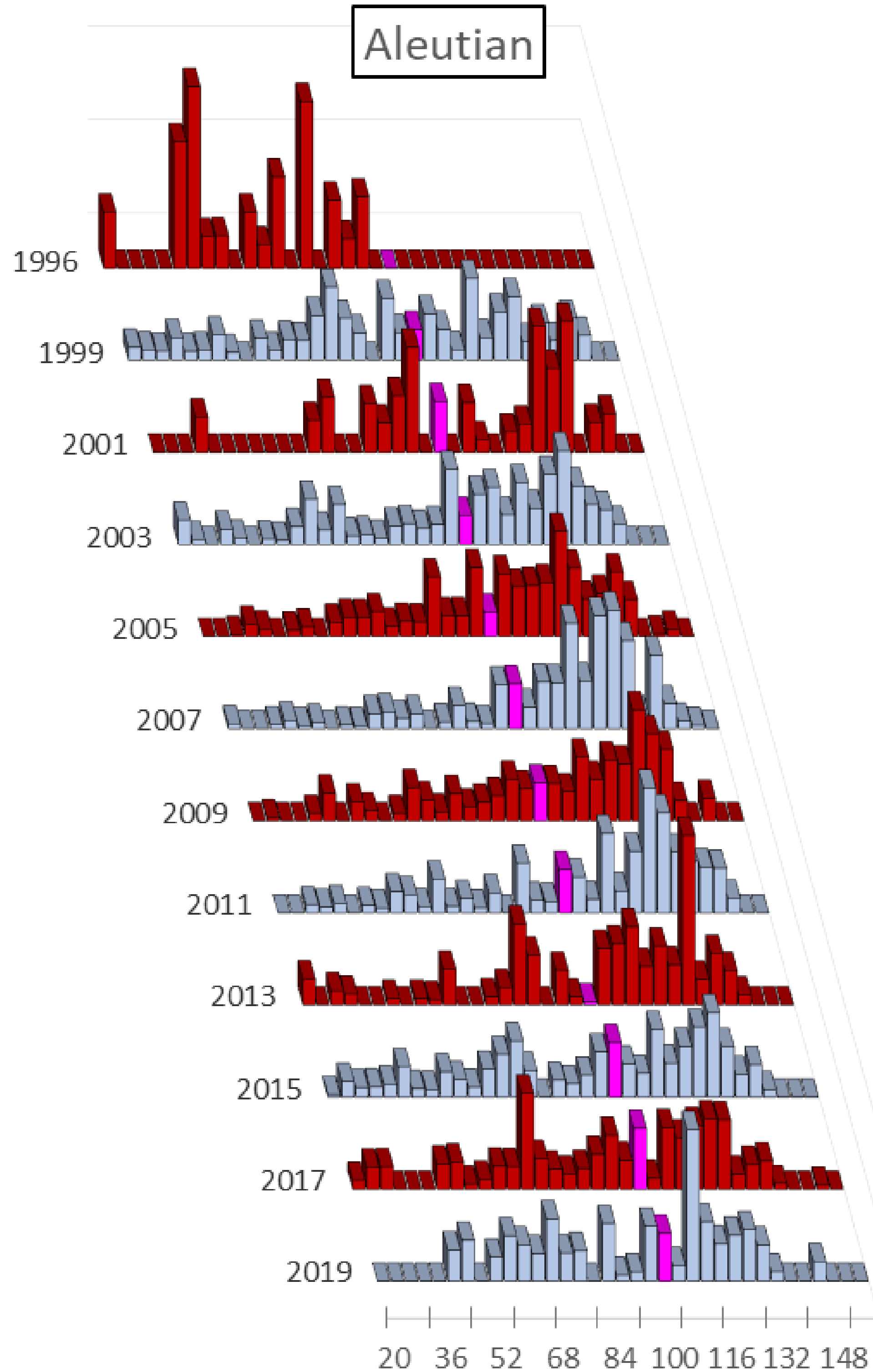

Figure 20. Length compositions of **Aleutian skates**, 1996-2019, from the AFSC bottom trawl survey in the Gulf of Alaska. Data are in 4-cm length bins; fuchsia column indicates the 100-103 cm length bin in each dataset

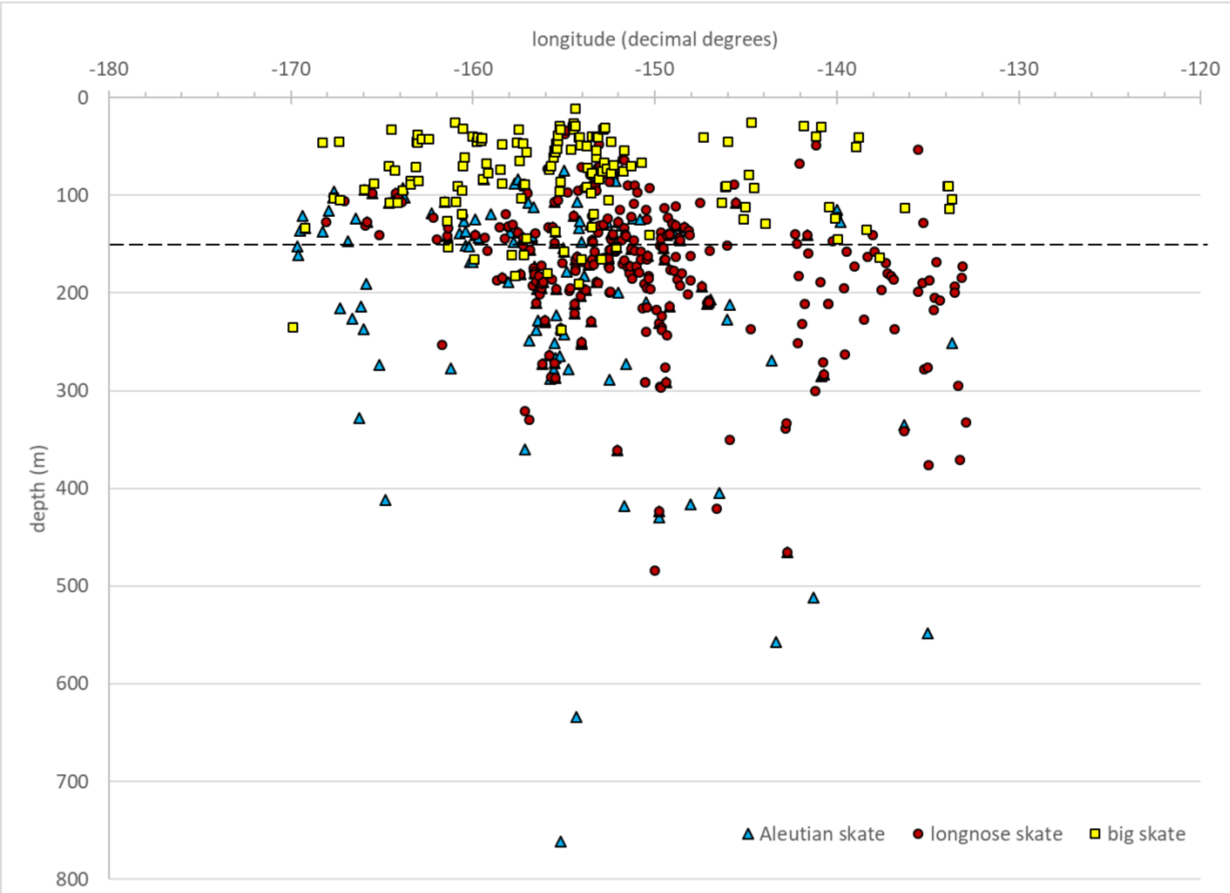

Figure 21. Depths at which catches of three skate species occurred in the NMFS Gulf of Alaska bottom trawl survey, 2015-2017. Data are separated along the x-axis by the longitude at the end of the relevant haul.

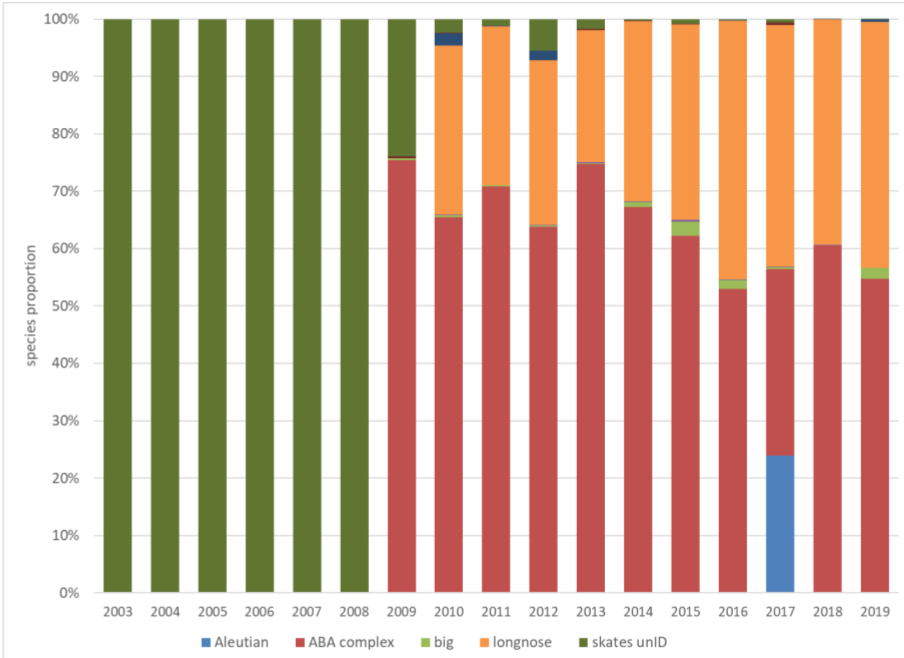

Figure 22. Species composition of skate catches in the AFSC Gulf of Alaska longline survey. “ABA complex” refers to an aggregate group containing Aleutian, Bering, and Alaska skates.

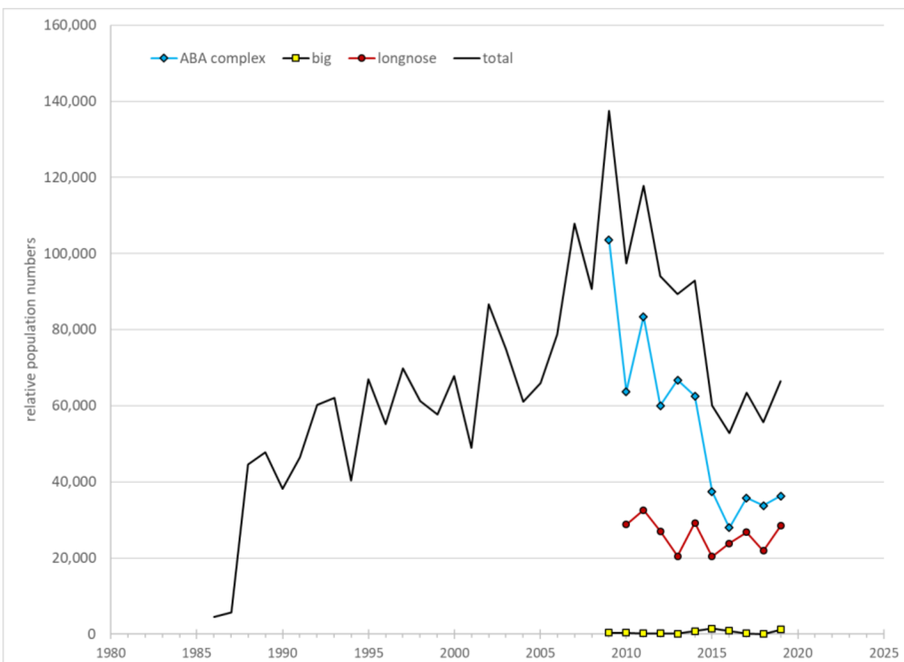

Figure 23. Relative population numbers of skates in the Gulf of Alaska, 1986-2019, as estimated by the AFSC longline survey. “ABA complex” refers to an aggregate group containing Aleutian, Bering, and Alaska skates.

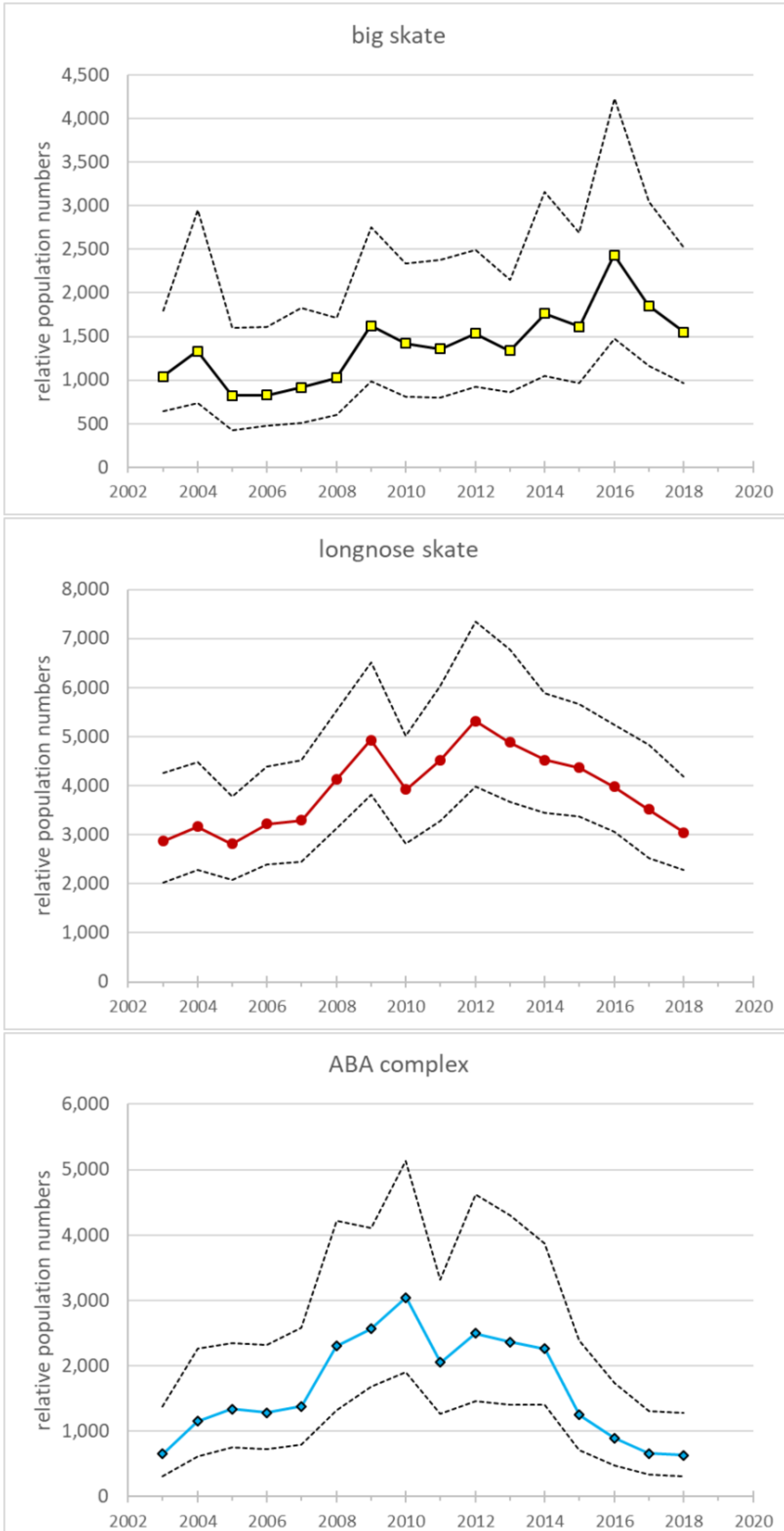

Figure 24. Relative population numbers for three skate species groups in the Gulf of Alaska, 2003-2018, as estimated by the International Pacific Halibut Commission longline survey. "ABA complex" refers to an aggregate group containing Aleutian, Bering, and Alaska skates.

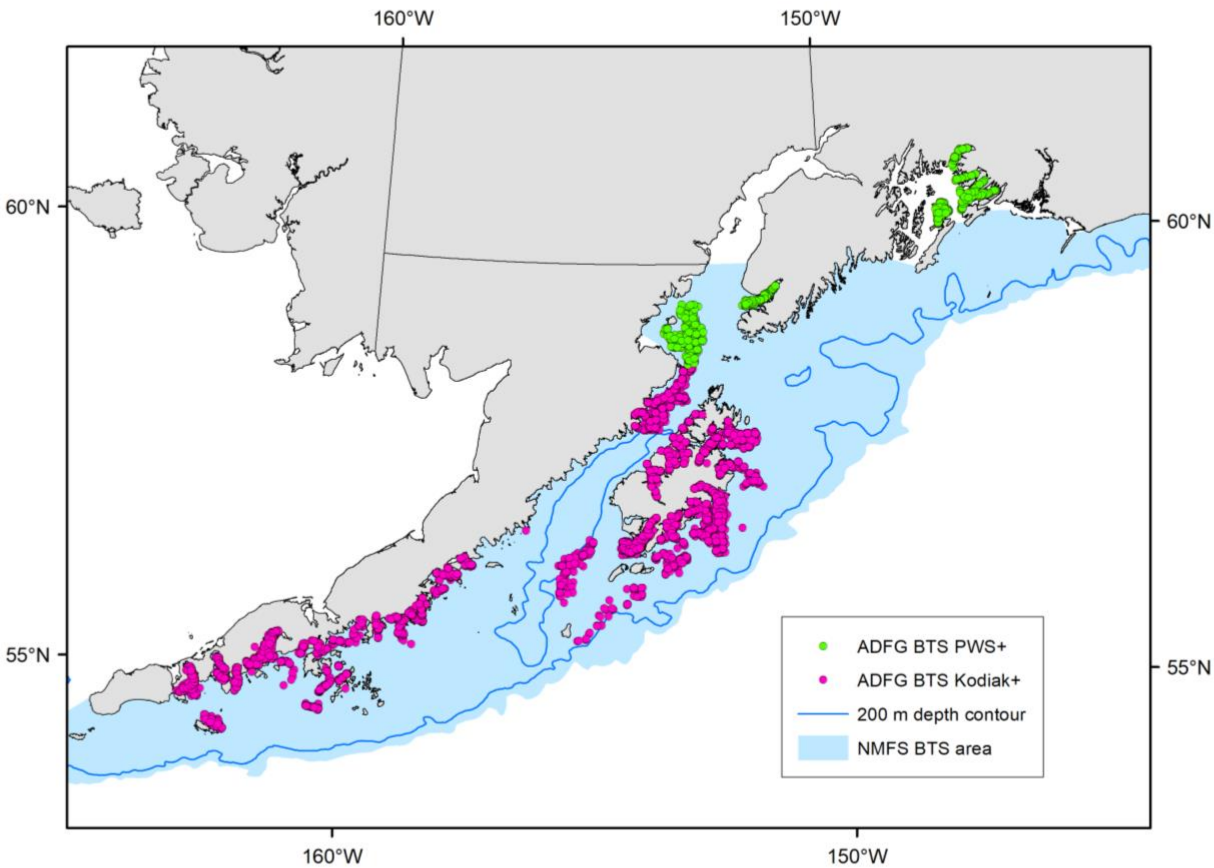

Figure 25. Locations of bottom trawl surveys (BTS) conducted by NMFS and the Alaska Department of Fish & Game in the Gulf of Alaska.

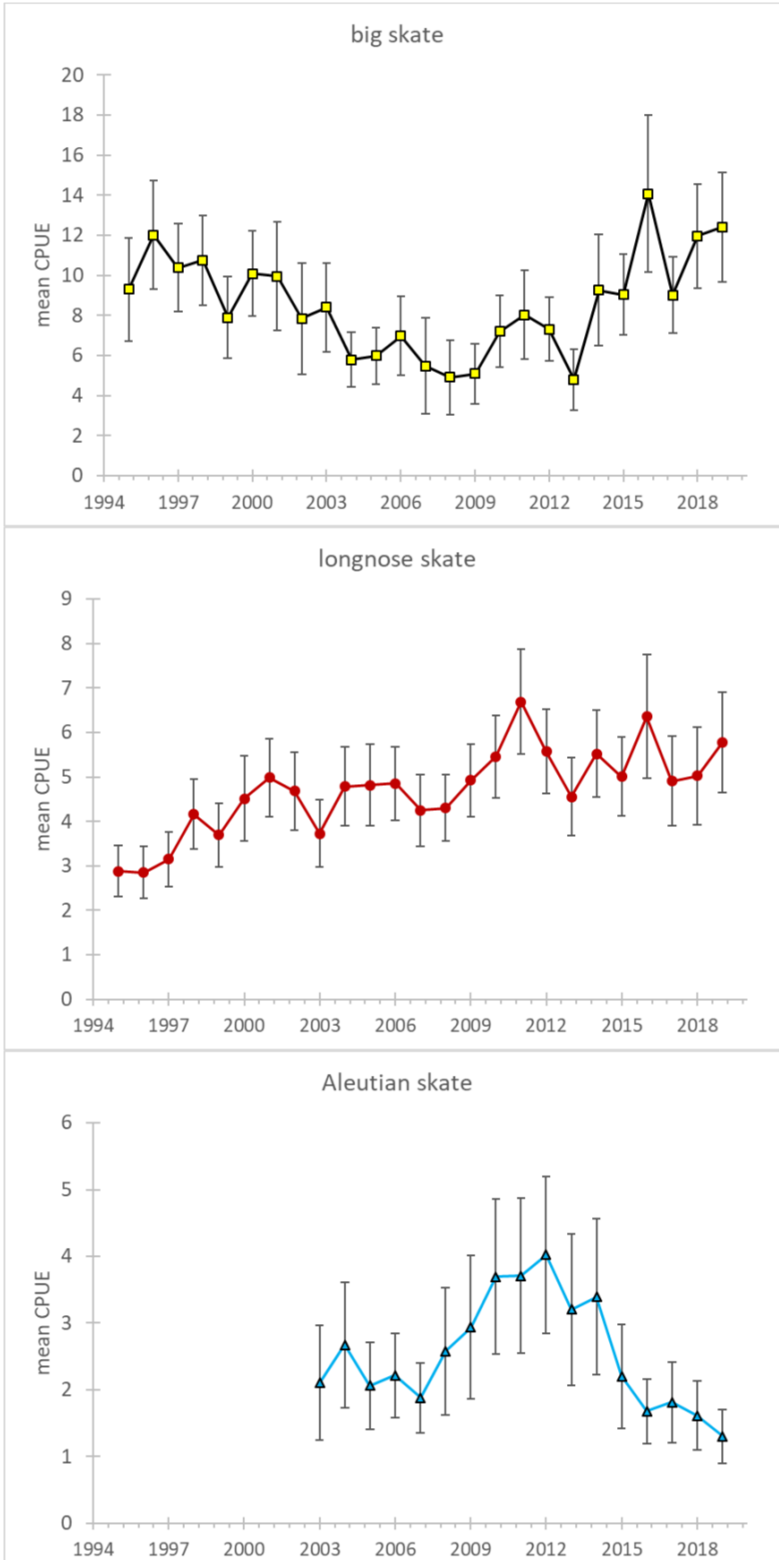

Figure 26. Mean CPUE for three skate species in bottom trawl surveys conducted in the central and western Gulf of Alaska by the Alaska Department of Fish & Game, 1995-2019. Identification of Aleutian skate to species began only in 2003.

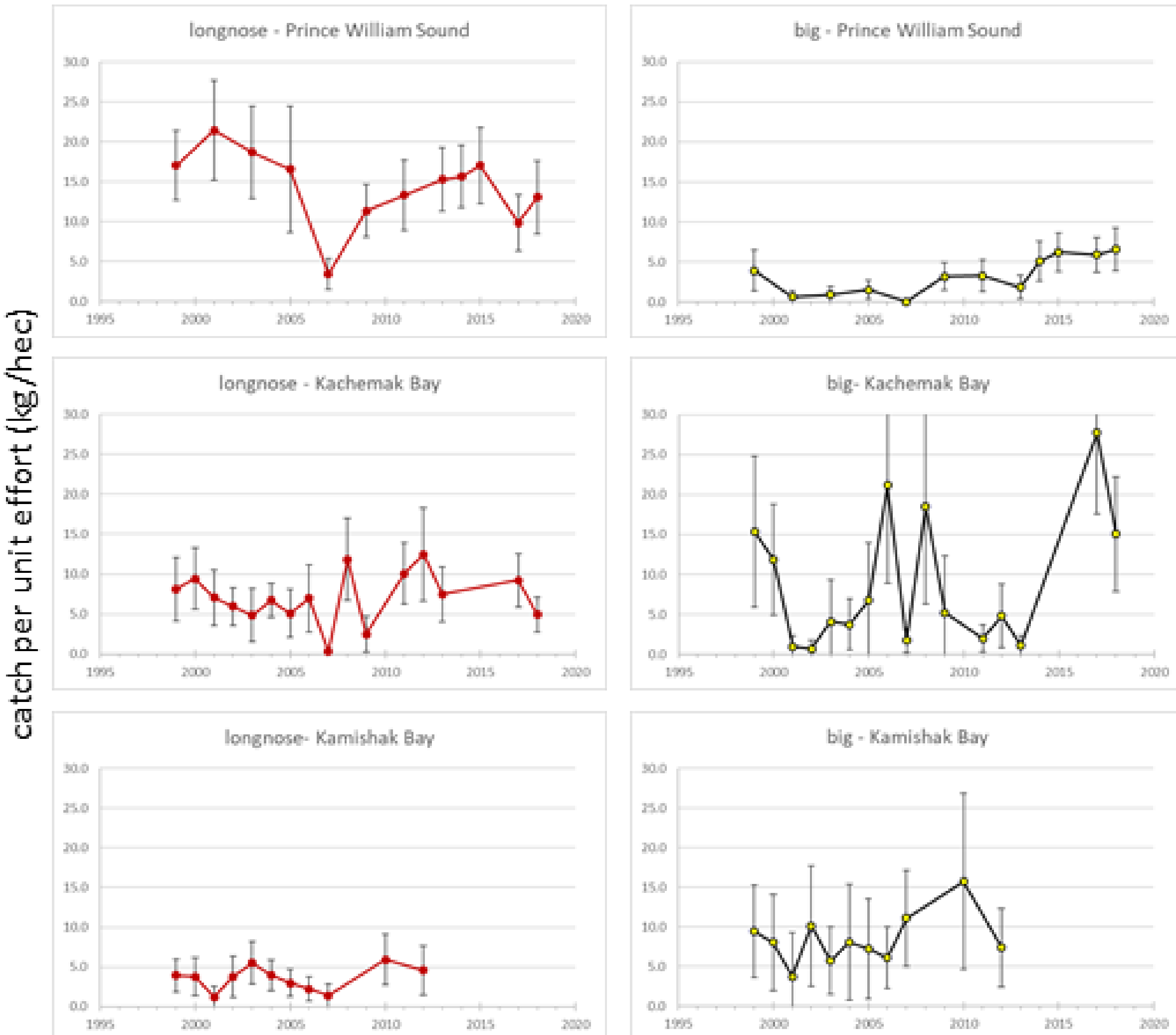

Figure 27. Mean catch per unit effort (kg/hec) of big and longnose skates in bottom trawl surveys conducted by the Alaska Department of Fish & Game at three nearshore locations in the Gulf of Alaska.

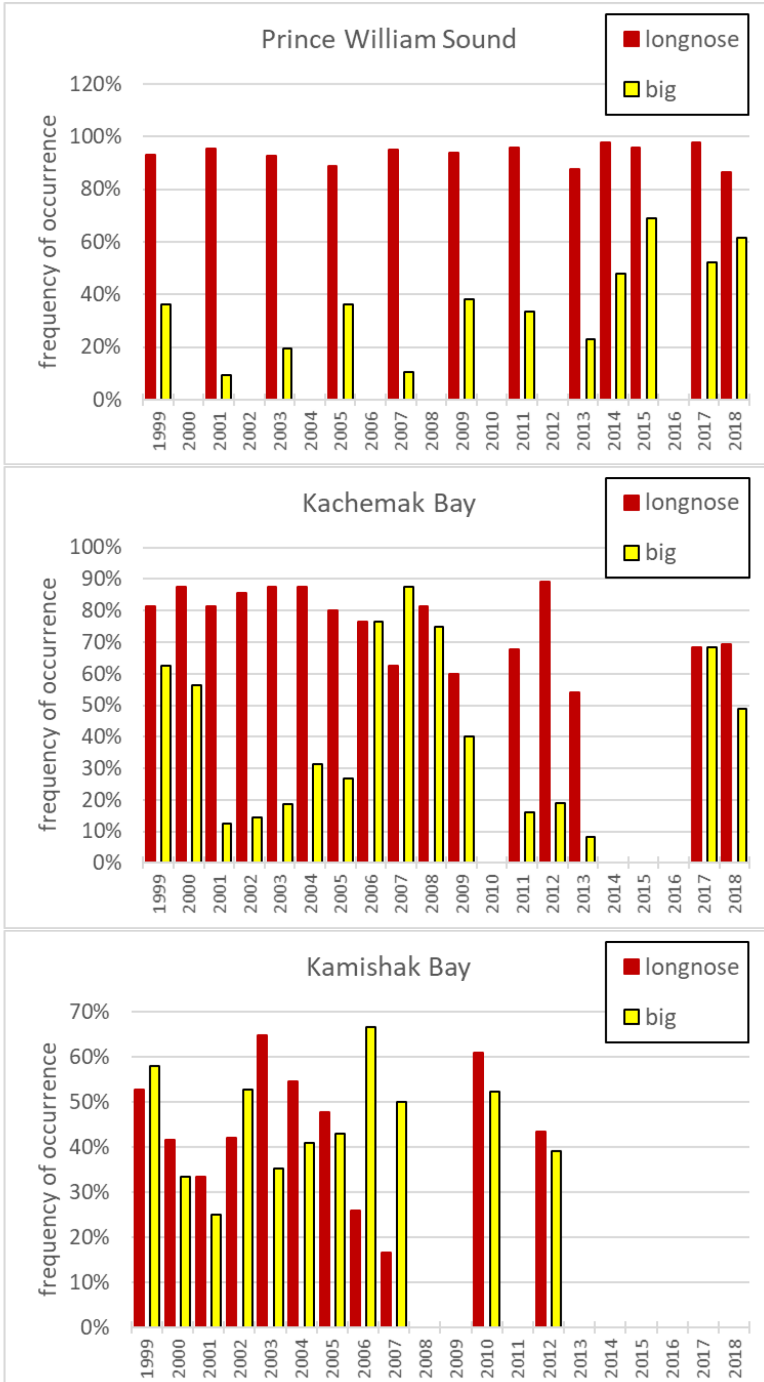

Figure 28. Frequency of occurrence of big and longnose skates in bottom trawl surveys conducted by the Alaska Department of Fish & Game at three nearshore locations in the Gulf of Alaska.

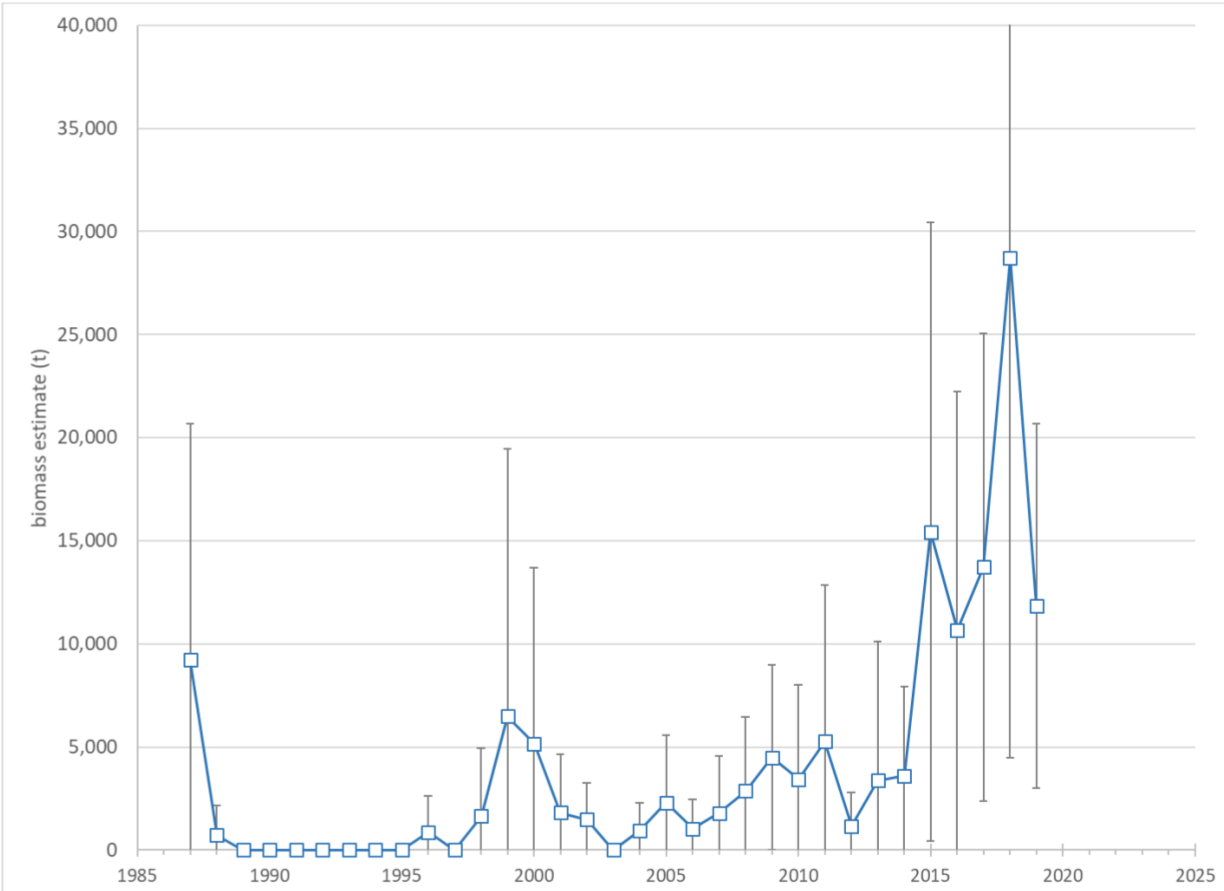

Figure 29. Estimated biomass (t) of big skates on the eastern Bering Sea shelf, from the AFSC bottom trawl survey. Error bars indicate 95% confidence interval.

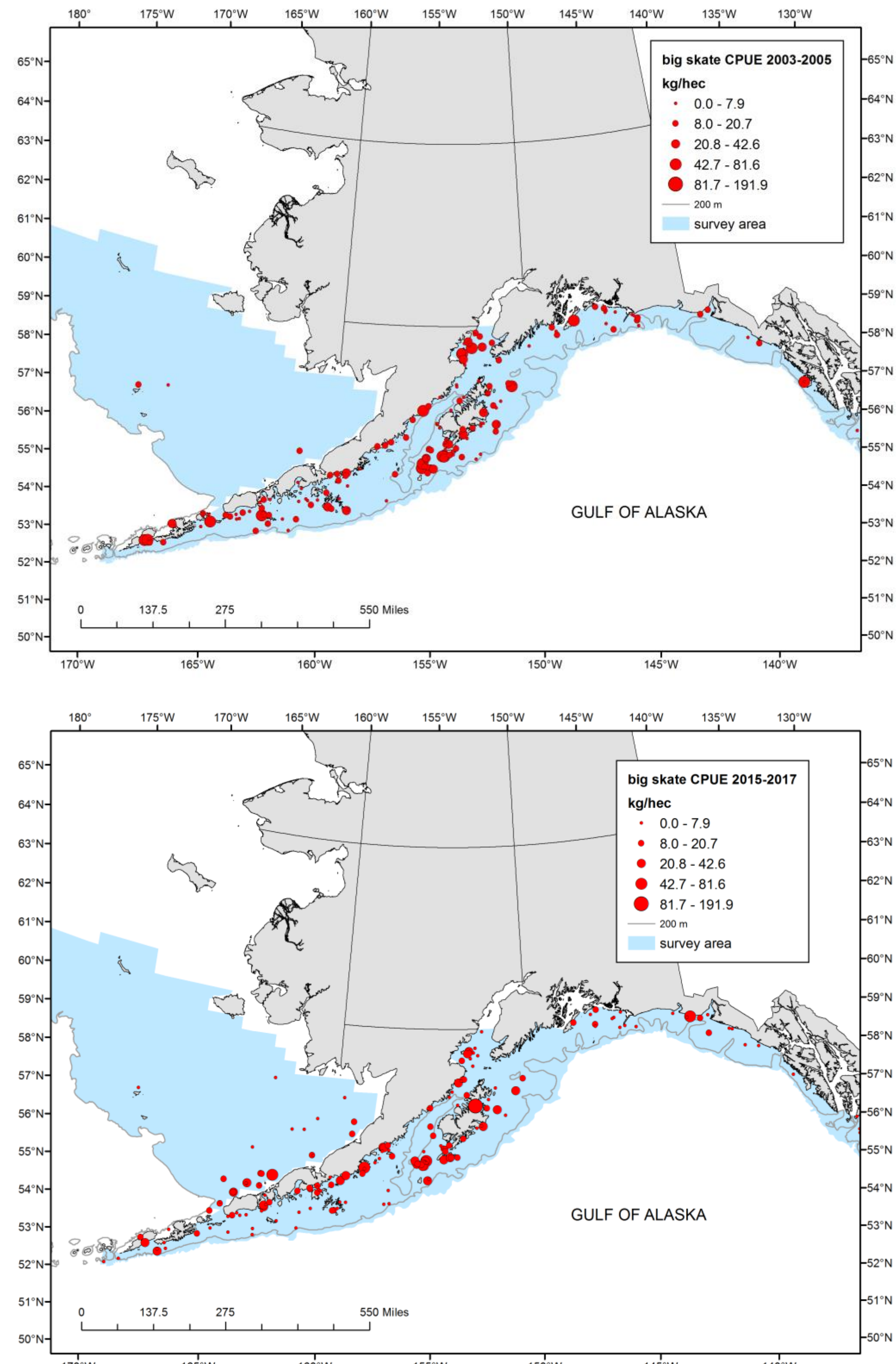

Figure 30. Trawl survey catch-per-unit-effort (CPUE; kg/hec) of big skates during periods of low (2003-2005, top panel) and high (2015-2017) frequency of occurrence.

Appendix A: Summary of non-commercial catches. Data are from the AK Regional Office.

Table A-1. Noncommercial catches (kg) of big skates in the GOA.

	Annual Longline Survey	Gulf of Alaska Bottom Trawl Survey	IPHC Annual Longline Survey	Large-Mesh Trawl Survey	Sablefish Longline Survey	Salmon EFP 13-01	Scallop Dredge Survey	Shelikof Acoustic Survey	Shumagins Acoustic Survey	Small-Mesh Trawl Survey	**total**
agency	NMFS	NMFS	IPHC	ADFG	ADFG	NMFS	ADFG	NMFS	NMFS	ADFG	
1999				1,489	22						1,512
2000				1,255	18					96	1,369
2001				744							744
2002				821	17						839
2003				679	25					305	1,009
2004				567	131					445	1,143
2005				924	30		0			172	1,126
2006				1,322	70		0			142	1,534
2007				1,715						36	1,751
2008				670							670
2009	80			609			24				713
2010	369		15,305	6,114				19	39	307	22,153
2011	189	2,542	24,572	6,444						737	34,485
2012	120		26,127	5,519			1			605	32,371
2013	70	1,300	25,562	3,467						127	30,525
2014	130		29,437	522		59					30,147
2015	628	2,931	32,865	8,136			0			164	44,724
2016	239		28,183	10,637			1			473	39,533
2017	150	1,291	19,934	10,841			3		22	137	32,377
2018	10		23,038	10,535						65	33,648

Table A-2. Noncommercial catches (kg) of longnose skates in the GOA.

	Annual Longline Survey	Golden King Crab Pot Survey	Gulf of Alaska Bottom Trawl Survey	IPHC Annual Longline Survey	Large-Mesh Trawl Survey	Sablefish Longline Survey	Salmon EFP 13-01	Scallop Dredge Survey	Shumagins Acoustic Survey	Small-Mesh Trawl Survey	**total**
agency	NMFS	ADFG	NMFS	IPHC	ADFG	ADFG	NMFS	ADFG	NMFS	ADFG	
1998						2					2
1999					3,418	886					4,304
2000					622	813				70	1,506
2001					2,941	660					3,601
2002					393	643					1,035
2003					2,594	51				255	2,900
2004					891	667				121	1,679
2005					3,028	62		7		398	3,495
2006		8			392	599				280	1,278
2007					1,541					278	1,819
2008					438						438
2009					1,475			10			1,485
2010	11,921			45,818	4,600				14	213	62,566
2011	15,164		1,569	74,655	6,937			13		362	98,700
2012	13,106			59,265	4,352					199	76,922
2013	9,006		1,865	83,970	3,803		85	65		75	98,869
2014	12,651			67,068	1,433		284				81,436
2015	11,175		2,525	73,371	6,853					256	94,180
2016	10,832			36,667	5,016			12		105	52,632
2017	13,404		2,019	26,098	5,851			7			47,399
2018	7,641			44,069	5,433						57,206

Table A-3. Noncommercial catches (kg) of "other skates" in the GOA.

	Annual Longline Survey	Golden King Crab Pot Survey	Gulf of Alaska Bottom Trawl Survey	IPHC Annual Longline Survey	Large-Mesh Trawl Survey	Sablefish Longline Survey	Salmon EFP 13-01	Scallop Dredge Survey	Shelikof Acoustic Survey	Small-Mesh Trawl Survey	Subsistence Fishery	**total**
agency	NMFS	ADFG	NMFS	IPHC	ADFG	ADFG	NMFS	ADFG	NMFS	ADFG	ADFG	
1984											151	151
1985											1	1
1989											7	7
1990	9,388											9,388
1991	9,697										182	9,879
1992	10,306										158	10,464
1993	11,351										19	11,370
1994	7,307											7,307
1995	19,191											19,191
1996	17,740										57	17,797
1997	20,490										156	20,646
1998	16,121				2,109			10			29	18,269
1999	17,157				1,385							18,542
2000	17,603				408						50	18,062
2001	15,375				1,201			6				16,583
2002	22,079				342			0				22,421
2003	21,302				1,275			10			138	22,725
2004	17,613				409			19				18,041
2005	16,680				1,288	78		33		46		18,124
2006	21,515	3			974			2		162		22,656
2007	30,233				872			33		95		31,233
2008	25,839							7				25,846
2009	11,493				605			67				12,165
2010	828			44,647	4,153			6	47	53		49,733
2011	445		1,328	24,736	3,512			4		49		30,074
2012	1,513			25,744	3,719					53		31,029
2013	651		1,629	24,110	3,109		8	2		53		29,562
2014	277			32,381	3,233					186		36,076
2015	261		2,021	15,896	2,578							20,756
2016	108			9,909	1,713			59		4		11,793
2017	326		808	8,351	1,810			70				11,374
2018	77			8,073	1,597							9,747