17. Gulf of Alaska skates

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Executive Summary

As there are no new survey data available in 2010, ordinarily this document would consist of only an executive summary. Because the Gulf of Alaska (GOA) Other Species group will be separated into its constituent species groups for the 2011 fishing season, a full assessment for GOA skates is presented for information purposes even though skates have been managed separately from the Other Species group since 2005.

Summary of Changes in Assessment Inputs

Changes in the input data:

1) Fully updated groundfish fishery catch data (2010 catch data as of October 10, 2010). There have been substantial changes to the incidental catch data, but the errors occurred within the nontarget reporting table, not the main catch accounting system. As a result, the catch levels from 2003-2008 reported in this SAFE have changed but the original catch accounting data were always correct.
2) An interagency working group is currently developing methods or estimating bycatch in the halibut IFQ fisheries. Until these methods have been finalized, we have removed the estimates of halibut IFQ bycatch previously included in this assessment and report only the relevant catch reported by the Alaska Region's Catch Accounting System.

Summary of Results

We do not recommend any directed fishing for skates in the GOA, due to high incidental catch in groundfish and halibut fisheries and the lack of accurate information regarding the composition of the skate catch. Skates in the GOA are managed under Tier 5, where OFL = *M**biomass and ABC = 0.75**M**biomass. We recommend using an *M* estimate of 0.1, as has been used in past GOA skate assessments, and the average biomass from the last four AFSC trawl surveys.

The harvest recommendation summary table is on the following page. W, C, and E indicate the western, central, and eastern GOA regulatory areas, respectively. Big and longnose skates have area-specific ABCs and gulfwide OFLs; other skates have a gulfwide ABC and OFL.

Quantity/Status		last year 2010	last year 2011	this year 2011	this year 2012
M (natural mortality) - **all GOA skates**		*0.1*	*0.1*	**0.1**	0.1
Specified/recommended Tier - **all GOA skates**		*5*	*5*	**5**	5
big skate (*Raja binoculata*)					
Biomass (2003-2009)	W	7,979	7,979	**7,979**	7,979
	C	27,325	27,325	**27,325**	27,325
	E	9,077	9,077	**9,077**	9,077
	GOA-wide	44,381	44,381	**44,381**	44,381
F_{OFL} (F=M)		*0.1*	*0.1*	**0.1**	0.1
$maxF_{ABC}$ (maximum allowable = 0.75 x F_{OFL})		*0.08*	*0.08*	**0.08**	0.08
Specified/recommended F_{ABC}		*0.08*	*0.08*	**0.08**	0.08
Specified/recommended OFL (t)		*4,438*	*4,438*	**4,438**	4,438
Specified/recommended ABC (t)	W	*598*	*598*	**598**	598
	C	*2,049*	*2,049*	**2,049**	2,049
	E	*681*	*681*	**681**	681
	GOA-wide	*3,329*	*3,329*	**3,329**	3,329
Is the stock being subjected to overfishing?		*no*	*no*	**no**	**no**
longnose skate (*Raja rhina*)					
Biomass (2003-2009)	W	1,086	1,086	**1,086**	1,086
	C	26,790	26,790	**26,790**	26,790
	E	10,155	10,155	**10,155**	10,155
	GOA-wide	38,031	38,031	**38,031**	38,031
F_{OFL} (F=M)		*0.1*	*0.1*	**0.1**	0.1
$maxF_{ABC}$ (maximum allowable = 0.75 x F_{OFL})		*0.08*	*0.08*	**0.08**	0.08
Specified/recommended F_{ABC}		*0.08*	*0.08*	**0.08**	0.08
Specified/recommended OFL (t)		*3,803*	*3,803*	**3,803**	3,803
Specified/recommended ABC (t)	W	*81*	*81*	**81**	81
	C	*2,009*	*2,009*	**2,009**	2,009
	E	*762*	*762*	**762**	762
	GOA-wide	*2,852*	*2,852*	**2,852**	2,852
Is the stock being subjected to overfishing?		*no*	*no*	**no**	**no**
other skates					
Biomass		27,908	27,908	**27,908**	27,908
F_{OFL} (F=M)		*0.1*	*0.1*	**0.1**	0.1
$maxF_{ABC}$ (maximum allowable = 0.75 x F_{OFL})		*0.08*	*0.08*	**0.08**	0.08
Specified/recommended F_{ABC}		*0.08*	*0.08*	**0.08**	0.08
Specified/recommended OFL (t)		*2,791*	*2,791*	**2,791**	2,791
Specified/recommended ABC (t)		*2,093*	*2,093*	**2,093**	2,093
Is the stock being subjected to overfishing?		*no*	*no*	**no**	no
(for Tier 5 stocks, data are not available to determine whether the stock is in an overfished condition)					

Introduction

<u>Description, scientific names, and general distribution</u>

Skates (family Rajidae) are cartilaginous fishes related to sharks. They are dorsoventrally depressed animals with large pectoral "wings" attached to the sides of the head, and long, narrow whiplike tails (Figure 1). At least 15 species of skates in three genera (*Raja*, *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 two *Raja* species, the big skate *R. binoculata* and the longnose skate *R. rhina*, and three *Bathyraja* species, the Aleutian skate, *B. aleutica*, the Bering skate *B. interrupta*, and the Alaska skate *B. parmifera*. 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 1069 m depths (Love *et al* 2005). While these two species have wide depth ranges, they are generally found in shallow waters in the Gulf of Alaska. 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 2322 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 1602 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) area. 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 dominated by the big skate (Figure 2). In continental shelf waters from 100-200 m depth, longnose skates dominate skate biomass, and *Bathyraja* skate species are dominant in the deeper waters extending from 200 to 1000 m or more in depth (Figure 2). The Aleutian skate, *B. aleutica*, is the biomass dominant species within the GOA *Bathyraja* complex, followed by the Bering skate (*B. interrupta*) and then by the Alaska skate (*B. parmifera*) (Table 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 (Figure 3). Longnose skates (Figure 4) and *Bathyraja* skates (Figure 5) are located further offshore and appear to be widespread than big skates

<u>Management units</u>

Since the beginning of domestic fishing in the late 1980s up through 2003, all species of skates in the Gulf of Alaska 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 (Table 3). The Other Species category was established to monitor and protect species groups that are not currently economically important in North Pacific groundfish fisheries, but which were perceived to be ecologically important and of potential economic importance as well. 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 (see below).

There were efforts to manage skates separately prior to the development of the skate target fishery in 2003. In 1999, FMP Amendments 63/63 were initiated to remove the shark and skate species groups from the Other species category in both the BSAI and GOA to better protect these vulnerable, long-lived species (NPFMC 1999). Based on the 1999 stock assessments for Other Species, the Plan Teams recommended that all Other Species be considered in an expanded FMP amendment to establish TACs at the species group level. While this amendment was being revised, the Council recommended to NMFS that Other Species be placed on "bycatch only" status to prevent a directed fishery from developing in the interim. NMFS determined that it did not have regulatory authority for such an action, so aggregate Other Species TACs remained in place up through 2003 in the GOA. FMP amendments to re-define the ABC, OFL and TAC setting process for skate species in the GOA were completed in 2003 as a result of a developing target fishery for two skate species. Beginning in 2008, the remaining species in the GOA Other Species category are managed under an aggregate TAC based on the summed estimates of overfishing level (OFL) and allowable biological catch (ABC) for each species group.

Skate management units have continued to evolve based on stock assessment and Plan Team input. In 2004, the skate species which were the targets of the 2003 fishery (big and longnose skates) were managed together under a single TAC in the Central GOA where the fishery had been concentrated in 2003. The remaining skates were managed as an "other skates" species complex in the Central GOA, and all skates including big and longnose skates were managed as an "other skates" species complex in the Western and Eastern GOA in 2004. As identification of species in the fisheries improved, skate management became more specific. Since 2005, big skates have been managed as a single species group throughout the GOA, as are longnose skates. Furthermore, to address concerns about disproportionate harvest of skates, big skate and longnose skate TACs are managed separately for the Western, Central, and Eastern GOA. The remaining skates (in the genus *Bathyraja*) continue to be managed as a gulfwide species complex because they were not the targets of the fishery and are more difficult to identify. These skates are managed as "other skates," but we also use the term "*Bathyraja* skates" interchangeably in this assessment. **Since 2005, directed fishing has been prohibited for all skate species in the 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, and this combined with the common practice of managing skate species within aggregate complexes 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 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 in order to determine which life history traits might indicate the most effective management measures for each species. 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, and 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).”

<u>Life history and stock structure (Alaska-specific)</u>

Information on fecundity in North Pacific skate species is extremely limited. There are one to seven embryos per egg case in locally occurring *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 Gulf of Alaska skates (although current research is addressing these issues for

Alaska skates in the Eastern Bering sea; J. Hoff, AFSC, pers. comm.; see also the 2009 BSAI skate SAFE, Ormseth and Matta 2009).

Slightly more is known about juvenile and adult life stages for Gulf of Alaska skates. In terms of maximum adult size, the *Raja* species are larger than the *Bathyraja* species found in the area. The big skate, *Raja binoculata*, is the largest skate in the Gulf of Alaska, 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 *Dipturus laevis*, 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) recently 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 2003-present

Table 3 shows a time series of ABC, TAC, and total catch; accompanied by a list of recent relevant management changes for the Other species and skate complexes in the GOA. Until 2003, skates were primarily caught as bycatch in longline and trawl fisheries targeting Pacific halibut and other groundfish. (In this assessment, "bycatch" means incidental or unintentional catch regardless of the disposition of catch—it can be either retained or discarded.) There had been interest expressed in developing markets for skates in the Gulf of Alaska (J. Bang and S. Bolton, Alaska Fishworks Inc., 11 March 2002 personal communication), and the resource became economically valuable in 2003 when the ex-vessel price became equivalent to that of Pacific cod. In 2003, vessels began retaining and delivering skates as a target species in federal waters partly because the market for skates had improved, and partly because catch of Pacific cod could be retained as bycatch in a skate target fishery, even though directed fishing for cod was seasonally closed. The result was a dramatic increase in skate landings (Figure 6). Lower ex-vessel prices and a possible reduction in skate catch-per-unit effort (T. Pearson, NMFS AKRO, pers. comm.) resulted in a sharp decline in skate catches in 2004-2005 (Figure 7 and Table 3). Directed fishing for skates in the GOA has been prohibited since 2005. Fishery observed data, though problematic in the GOA (see below), suggests that incidental catches of skates in the GOA during 2007 (Figure 8) and 2008 (Figure 9) occur throughout the GOA but are highest in the central GOA (also see Tables 3 & 4). The highest skate removals occur in the vicinity of Kodiak Island.

The directed skate fishery developed in the GOA in 2003 in a manner which presented significant assessment problems, many of which continue through the present. A large proportion of the directed fishing is prosecuted on vessels less than 60 ft in length, so there is no at sea observer coverage of the fleet, and no logbook requirements. In addition, many vessels in the GOA large enough to require observers are still sufficiently small (less than 125 ft. LOA) that only 30% of trips need to be observed. These vessels often deliver skates to plants that process monthly volumes of catch that are also too low to require observer coverage. Gaichas (2005) estimated that only 20-25% of the GOA groundfish fishery (not including Pacific halibut) is observed. Historical data is also limited by a lack of species identification. Skates were almost always recorded as "skate unidentified" between 1990 and 2002. However, following a skate species identification special project in 2003 (Stevenson 2004), all observers have been instructed to identify skates to species since 2004. Despite this improvement, fishery catch of skates continues to lack the degree of close monitoring mandated for the management of target groundfish species in Alaska.

Data

Information on skate total catch has evolved and improved since 2003. Details of this evolution are included in previous assessments (e.g. Gaichas 2005), and only a brief summary is included here. Catch estimates for skates in the GOA in 2003 were complicated by the switch from the “Blend” system used from 1991 to 2002 to a new Catch Accounting System (CAS) in 2003. The CAS is maintained by the NMFS Alaska Regional Office (AKRO). The 2003 catch was estimated by combining records from the ADF&G fish ticket database with NMFS fishery observer data. The utility of fish ticket data was limited by the lack of species identification, misidentification, and confusion regarding species codes. Many of these problems appear to have been solved, and we now report skate catch directly from the CAS where it is apportioned among big, longnose, and other skates (Tables 3 & 4). Since 2003, catches of skates have occurred mainly in the Pacific cod, rex sole, arrowtooth flounder, and shallow flatfish fisheries, with the highest catches in the Pacific cod fisheries (Table 5). Bycatch of skates in the IFQ halibut fisheries is discussed below.

Port sampling efforts initiated by the previous assessment author and personnel from NMFS and the Alaska Department of Fish & Game in Kodiak provided some information on species composition and length composition of skate catches landed there (see section on length compositions below). Big skates formed the majority of catches in the 2003 directed fisheries, and the fishery appeared to target (or at least retain) primarily larger skates (Gaichas 2005).

For the 2009 assessment, retention rates of skates in the GOA were estimated using groundfish observer records (Table 6). Prior to 2002, skates were reported only as “unidentified” and retention rates were low (6-33%). The retention of big skates increased dramatically in 2003 (92%), as did the retention of longnose skates (59%) and unidentified skates (45%). This is consistent with the development of a target fishery. Although retention rates have declined in subsequent years, retention of big and longnose skates was still high in 2008 (63% and 49%, respectively; Table 6). This suggests that there continues to be a market for skates.

Bycatch and discards of skates in groundfish fisheries, 1997-2002

Until 2003, skates were primarily caught as bycatch in both longline and trawl fisheries directed at Pacific halibut and other groundfish. Separate catch records for skates were not kept; the only official catch records prior to 2003 are for the Other Species complex in the GOA. Incidental catch of skates (all species in aggregate) in federal groundfish fisheries between 2007 and 2010 (Table 7) were obtained from the Alaska Regional Office.

Alaska state-waters fishery 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 necessary to open a state-waters directed fishery. For the last two years, the state has 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 (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 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 Inside District and no overage in the Outside District.

[Discussion of fishery length compositions is included in the survey length data section for purposes of comparison.]

Survey biomass in aggregate and by species

There are several potential indices of skate abundance in the Gulf of Alaska, including longline and trawl surveys. The sablefish longline survey conducted by the NMFS Auke Bay lab only recently (2006) began to identify skates to species and those data are not included. Although many skates are identified to species on IPHC longline surveys, sampling of non-halibut species during these surveys is restricted in scope and is nonrandom, so this survey is also of limited use for skate stock assessment. For this assessment, we use the NMFS summer bottom trawl surveys 1984-2009 as our primary source of information on the biomass and distribution of the major skate species. Bottom trawl surveys are generally considered reliable estimators of skate biomass for trawlable areas and a recent study in the Bering Sea suggests that catchability is relatively high (Kotwicki and Weinberg 2005).

Survey trends for the entire GOA by species between 1984 and 2009 are displayed in Figures 11 (big and longnose skates) and 12 (*Bathyraja* skates). Biomass estimates specific to GOA regulatory areas (Western [management area 610], Central [620-630], and Eastern [640-650] are shown in Table 11. Note that not all surveys covered the same areas and depths; the 1990, 1993, and 1996 surveys covered depths to 500 m, the 1984, 1987, 1999 and 2005 surveys covered depths to 1000 m, and the 2003 survey covered to 700 m. Due to limited resources, the 2001 survey did not extend to the Eastern GOA and went only to 500 m in the Central and Western GOA. Therefore the observed trends in skate species biomass may reflect a combination of actual population dynamics and survey coverage. It is possible that what appears to be an increase in skate biomass overall between the early and late 1990s is simply the result of sampling more (deeper) skate habitat in the late 90s combined with differences in survey strategy between the cooperative surveys conducted during the 1980s and the NMFS surveys of the 1990s. Similarly, species identification of skates was problematic in early survey years (reflected in the relatively higher proportion of biomass in the "skate unidentified" category) and became most reliable for surveys starting in 1999.

Despite inconsistencies in survey coverage and species identification, it is clear that big skates *Raja binoculata* and longnose skates *R. rhina* dominate the skate biomass in the GOA (Tables 2 & 11; Figures 11-14). *Bathyraja* species compose about a third of total GOA skate biomass, with the majority of these being the Aleutian skate *B. aleutica*, followed by the Bering skate *B. interrupta*, and then by the Alaska skate *B. parmifera* (Figure 12). This contrasts greatly with the situation in the Eastern Bering Sea, where *B. parmifera* dominates skate biomass by more than an order of magnitude over any other skate species. Skate biomass is also concentrated in the Central GOA (Table 11). The gulfwide species composition of skates has changed slightly over the last ten years (Figure 13). The fraction of big and longnose skates has decreased slightly. The ratio of big to longnose skate appears fairly stable. These results should be considered relative to the caveats listed above regarding survey coverage and species identification.

Skate species composition also differs by area. In the Western GOA in 2009, the biomass of big skates was much larger than for the other skates species, and *Bathyraja* skate outnumbered longnose skates (Figure 14). The diversity of *Bathyraja* skates was also higher in the Western GOA. In the Central GOA, big and longnose skates were dominant but the were also a substantial number of Aleutian skates. Very few *Bathyraja* skates were observed in the Eastern GOA (Figure 14).

<u>Survey and fishery length compositions</u>

Discussion of fishery length compositions is included here rather than in the fishery section for purposes of comparison. Length data are collected for skates during the GOA trawl surveys. Limited length data are available for fisheries prior to 2009. For the 2009 fishing season, changes were made to the observer manual requiring the collection of length data for skates caught in the Pacific cod and flatfish fisheries, resulting in a substantial increase in length samples from 2009. Although the 2009 catch and observer data are incomplete, the preliminary fishery length composition is included here.

The survey length composition of big skates is diffuse, with few clear size modes (Figure 15). Since 2003, the composition has been fairly stable, with the majority of individuals clustered between approximately 76-148 cm. An apparent abundance of large big skates in 2001 may be due to the lack of survey effort in the Eastern GOA (see below). The 2009 survey captured more small skates than in recent years, which may indicate an increase in recruitment. In contrast to big skates, the data for longnose skates display a clear size mode at approximately 120 cm (Figure 16). The longnose length composition also appears to be stable over the last ten years.

The length distribution of big skates differs among GOA regulatory areas (Figure 17). The largest big skates tend to be found in the Western GOA and the smallest big skates in the Eastern GOA. Intermediate sizes dominate in the Central GOA, where a size mode is more distinct than in the other areas. The length composition of longnose skates varies much less among the areas, although small longnose skates are found mainly in the Eastern GOA. 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 offshore as skates mature (Hoff 2007). A similar process may exist for GOA big skates. There is no substantial variation in the length compositions of longnose skates from the three areas (Figure 18).

The limited length composition data from fishery catches during 2003-2005 suggest that fisheries are targeting, or at least retaining, large skates (Figure 19). There do not seem to be substantial differences among gear types, which supports the idea that larger skates are being retained. This is also supported by the preliminary data from 2009 that includes a larger number of small skates relative to 2003-2005 (Figure 20). The 2009 data come from at-sea observers and are likely to reflect both retained and discarded catch. The 2003-2005 data are based on landings. A comparison of the 2003 survey length composition to fishery length compositions from that year (Figure 21) demonstrates the preferential targeting and/or retention of larger skates by the fisheries.

Analytic Approach

Skates in the GOA are managed using Tier 5. Under Tier 5, F_{OFL} = M and OFL = F_{OFL} * average survey biomass. Maximum permissible ABC is calculated as 0.75 * F_{OFL} * average survey biomass. Tier 5 is recommended because a reliable estimate of biomass exists for big and longnose skates and the *Bathyraja* complex and Tier 6 (ABC = average catch) is problematic due to an unreliable catch history. Tier 5 management also requires an estimate of natural mortality (*M*):

Parameters Estimated Independently: *M*

Because the only life history information currently available for Gulf of Alaska skate relates to maximum size, we use two methods to infer the parameters important to management which are age/size at maturity and natural mortality. In particular, *M* is used as an approximation of the fishing mortality rate believed to produce the maximum sustainable yield in equilibrium populations experiencing logistic population growth under NPFMC's Tier 5 stock assessment approach. First, we use Frisk *et al*'s (2001) empirical method to estimate length at maturity from maximum length for all skate species where data are available. Second, we assumed that the largest skate species in the GOA would share the general characteristics found for other large elasmobranchs worldwide and some of the specific characteristics of the large Atlantic species, *Dipturus batis* and *D. laevis*.

Frisk et al (2002) derived an estimate of natural mortality of 0.09 using Hoenig's (1983) method for barndoor skates which was based on the longevity of common skates of approximately 50 years. In addition, Frisk et al (2001) estimated that on average, medium sized (100-199 cm) elasmobranchs have a potential rate of population increase around 0.21. The intrinsic rate of increase parameter (*r)* from the logistic growth model is related to the exploitation rate F at MSY and therefore the overfishing limit (OFL) as defined by the North Pacific Fishery Management Council could be specified as follows:

$$F_{MSY} = F_{OFL} = r/2$$

This relationship is derived from the logistic growth equation (see e.g. Murray 1989, chapter 1). If the potential rate of population increase estimated by Frisk et al (2001) for medium sized elasmobranchs is viewed as analogous to the logistic model parameter *r*, this would define $F_{MSY} = F_{OFL}$ =(0.21/2)=0.105. Therefore, for the purposes of calculating a Tier 5 F_{OFL} based on *M*, we used an *M* between 0.09 (based on longevity of barndoor skates) and 0.105 (based on r/2) of 0.10 for the big skate *Raja binoculata* and the longnose skate *R. rhina.* Because little is known about *Bathyraja* species anywhere, a precautionary approach was applied in estimating *M* for these species in the Gulf of Alaska; it is estimated to be 0.10 until further information can be collected, although it is possible that these species are slightly more productive than the larger *Raja* species. The use of M = 0.1 for GOA skates has been approved by the GOA Plan Team and the SSC.

Lending further support to using M=0.10 is an analysis which was undertaken to explore alternative methods to estimate natural mortality (M) for skates. Several methods were employed based on correlations of M with life history parameters including growth parameters (Alverson and Carney 1975, Pauly 1980, Charnov 1993), longevity (Hoenig 1983), and reproductive potential (Rikhter and Efanov 1976, Roff 1986). Because Alaska specific information is not yet available, M was estimated using the methods as applied to data for California big and longnose skates. Considering the uncertainty inherent in applying this method, we elected to use the lowest estimates of M derived from any of these methods which corresponds well with the M=0.10 estimated above (Table 12).

Assemblage analysis and recommendations

At present, the target species big and longnose skates are managed as individual species in the GOA. Single species management is appropriate for these target species, which also dominate the skate biomass in the GOA. *Bathyraja* species of skates in the GOA are currently managed within the GOA “other skates” management complex. As long as commercial interest in GOA *Bathyraja* skate species remains low, managing *Bathyraja* species within the “other skates” assemblage provides the appropriate balance of protection for these skate species with management simplicity. However, we recommend continued monitoring of the skate species composition landed at GOA ports by samplers trained in skate species identification to ensure that any increased commercial interest in GOA other skates is detected in time for appropriate management measures to be implemented.

Results

Acceptable Biological Catch, Overfishing Limit, and Area Allocation of Harvests

We recommend the following management measures be applied to GOA skates in 2010 and 2011:

- Continued individual species ABC and OFL for the two species of interest to target fisheries, the big skate (*Raja binoculata*) and the longnose skate (*Raja rhina*).
- Area-specific ABC and OFL for *Raja binoculata* and *Raja rhina.*
- Continued genus level ABC and OFL (gulfwide) for the *Bathyraja* species complex.

The following are recommended Tier 5 ABC and OFL for big, longnose, and *Bathyraja* skates in the GOA, based on the average biomass from the last four GOA trawl surveys (2003-2009) and *M* =0.10, which is considered a reasonable approximation of big and longnose skate *M* by the Plan Team and SSC. We note that the proxy *M* was applied to all species although it was based on the most sensitive skate species, so it is more likely an underestimate of *M* for less sensitive species which results in conservative specifications.

harvest recommendations for GOA skates in 2011-2012				
		big	**longnose**	**other skates**
M		0.1	0.1	0.1
average biomass	W	7,979	1,086	
	C	27,325	26,790	
	E	9,077	10,155	
	gulfwide	44,381	38,031	27,908
ABC	W	**598**	**81**	
	C	**2,049**	**2,009**	
	E	**681**	**762**	
	gulfwide	3,329	2,852	**2,093**
OFL	W	**798**	**109**	
	C	**2,732**	**2,679**	
	E	**908**	**1,015**	
	gulfwide	4,438	3,803	**2,791**

Given the continued uncertainty regarding the bycatch of skates in Pacific halibut fisheries, we recommend that direct observation of these fisheries be initiated to monitor this substantial bycatch. Using the Gaichas 2005 estimate of skate bycatch in the halibut fishery, the combined total fishery catch of skates in the GOA could exceed the entire ABC of big, longnose, and other skates, and possibly the Gulfwide OFL for longnose skates. Therefore, **we do not recommend any directed fishing for GOA skates**. In addition, information on *Bathyraja* species should be closely monitored to ensure that target fisheries do not expand to these poorly understood species before basic life history information can be collected to ensure effective management.

Ecosystem Considerations

This section focuses on the big skate and the longnose skate in the GOA, with all other species found in the area summarized within in the group “Other skates.” Skates are predators in the GOA FMP area, but some species are piscivorous while others specialize in benthic invertebrates (Table 1). Each skate species occupies a slightly different position in the GOA food web based upon its feeding habits. We show the food webs for big skates, longnose skates, and other skates in the GOA (Figures 22-25). Longnose skates have the highest trophic level of any skate, followed by big skates at a relatively high trophic level, and other skates in the GOA have a much lower trophic level. All of the skates have relatively few predators aside from fisheries, and diverse prey ranging from benthic invertebrates to pelagic fish. Viewing the food web of each species group along with basic depth distribution further characterizes the ecological relationships for each group. Big skates primarily occupy the shallowest habitats of the GOA continental shelf from 1 to 100 m depth (Figure 2), where they feed on both pelagic and demersal fish and bivalves, benthic amphipods and other benthic crustaceans, and even some benthic detritus (Figure 22). Longnose skates are distributed throughout all depths, but are dominant in deeper continental shelf habitats from 100-200 m depth (Figure 2), and feed almost exclusively on fish above trophic level 3 as well as non-pandalid (NP) shrimp (Figure 23). Other skates are also found in all depth ranges, but are dominant in depths greater than 200 m (Figure 2) and tend to feed on the same fish and benthic invertebrates as big skates, but a wider variety including worms, brittle stars and Pandalid shrimp (Figure 24). In aggregate, GOA skates are connected directly as predator or prey with almost all other groups in the food webs, with the exception of pelagic zooplankton and phytoplankton. These food webs were derived from mass balance ecosystem models assembling information on the food habits, biomass, productivity and consumption for all major living components in each system (Aydin *et al* 2007).

One simple way to evaluate ecosystem (predation) effects relative to fishing effects is to measure the proportions of overall mortality attributable to each source. Figure 25 shows the proportions of total mortality attributable to predation and to fishing mortality for big, longnose, and other skates in the GOA, and further distinguish these measured sources of mortality from sources that are not explained within the ecosystem models. We note that recent fishing mortality increases for big skates are not accounted for in this plot, which is based on early 1990s fishing and food habits information collected prior to the beginning of directed fishing. However, the ecosystem model was parameterized to account for incidental catch mortality from halibut fisheries (see the top panels of Figures 26-28), so a full range of incidental fishing effects was included. While there are many uncertainties in estimating these mortality rates, the results suggest that (early 1990s) incidental fishing mortality exceeded predation mortality for all of these GOA skate groups. One source of uncertainty in these results is that all skate species in all areas were assumed to have the same total mortality rate, which is an oversimplification, but one which is consistent with the assumptions regarding natural mortality rate (the same for all skate species) in this stock assessment. We expect to improve on these default assumptions as information on productivity and catch for individual skate species in each area continues to improve.

Skates have few natural predators, and information on consumption by these predators is difficult to obtain. In the GOA, skate predators include marine mammals such as Steller sea lions and sperm whales (which may consume adult or juvenile skates), and spiny dogfish (which likely consume juvenile skates). We have not accounted for any predation on skate eggs by other predators, but Jerry Hoff's research in the Bering Sea suggests that Pacific cod and Pacific halibut may feed on newly hatched juvenile skates and that gastropods consume substantial numbers of skate embryos by drilling through deposited egg cases (J. Hoff, AFSC, pers. comm., and see also the BSAI skate SAFE, Ormseth and Matta 2008). Therefore, the information presented on skate mortality sources in Figures 26-28 will be updated as catch and predation information improve.

In terms of annual tons removed, it is instructive to compare fishery catches with predator consumption of skates. We estimate that groundfish fisheries were annually removing about 1,000 to 3,000 tons of skates from the GOA on average during the early 1990s (Table 3), and there is unquantified catch in the IFQ halibut fisheries. While estimates of predator consumption of skates are perhaps more uncertain than catch estimates, the ecosystem models incorporate uncertainty in partitioning estimated consumption of skates between their major predators in each system. The predators with the highest overall consumption of big skates in the GOA are pinnipeds (adult and juvenile Steller sea lions), which account for more than 8% of total skate mortality and consumed between 200 and 900 tons of skates annually in the early 1990s (Figure 26). Consumption of big skates by sharks is more uncertain; dogfish accounted for nearly 10% of skate mortality, and consumption estimates ranged from 100 to 1,500 tons of big skates annually (Figure 26). Sperm whales account for less than 4% of big skate mortality in the GOA, consuming an estimated 50 to 400 tons annually. Longnose skates have always had much higher mortality from fisheries than from predator consumption, according to early 1990s information integrated in ecosystem models (Figure 27), but predator consumption estimates are very similar to those estimated for big skates. Pinnipeds, sharks, and toothed whales combined were estimated to consume anywhere from 200 to 1,200 tons of longnose skates annually (Figure 27). The predators with the highest consumption of Other skates in the GOA are also pinnipeds, sharks, and sperm whales, but there is also some consumption of this group by skates (Figure 28). The annual tonnage consumed of this group by all predators, between 100 and 1,000 tons of other skates annually in the early 1990s, is somewhat lower than that for big and longnose skates, reflecting their deeper distribution and overall lower biomass relative to the *Raja* species.

Diets of skates are derived from food habits collections taken throughout the north Pacific range of these species, because systematic sampling of skate food habits on NMFS GOA trawl surveys has only recently begun. In general, diets estimated from other areas were modified by the limited field observations available from Alaska. *Raja* diets evaluated from collections in Oregon (Wakefield 1984) were modified based on qualitative observations from the 2003 GOA trawl survey, and *Bathyraja* diets evaluated from collections in the Kuril Islands and Kamchatka (Orlov 1996) were modified based on limited sampling for these species in the BSAI and GOA regions. We expect to incorporate recent quantitative skate food habits collections from the GOA in future assessments.

Using available information, we estimate that non-pandalid (Crangon) shrimps compose over 44% of GOA big skate diet, and another 12% of the diet was sandlance (Figure 29). Arrowtooth flounder, eelpouts, pollock, capelin, and halibut made up another 30% of big skates' diet, and combined detritus, groundfish, and invertebrate prey made up the remainder of their diet. This diet composition combined with estimated consumption rates and the moderately high biomass of big skates in the GOA results in an annual consumption estimate of 5,000 to 60,000 tons of shrimp annually, with approximately another 20,000 tons each of forage fish and groundfish consumption (Figure 29). Longnose skates consume primarily flatfish, pollock, capelin and sandlance, which account for more than 60% of their diet, so the consumption of fish by longnose skates amounts to about 5,000 to 20,000 tons of combined flatfish annually, 2,000 to 11,000 tons of forage fish, and 2,000 to 7,000 tons of pollock annually (Figure 30). Other skates tend to consume more invertebrates than big and longnose skates in the GOA, so estimates of benthic crustacean consumption due to other skates range up to 35,000 tons annually, much higher than those for big and longnose skates despite the disparity in biomass between the groups (Figure 31). Because big skates, longnose skates and other skates are distributed differently in the GOA, with big skates dominating the shallow shelf areas, longnose skates in intermediate depths, and the more diverse species complex located on the outer shelf and slope, we might expect different ecosystem relationships for skates in these habitats based on different food habits for the species.

Examining the trophic relationships of GOA skates provides a context for assessing fishery interactions beyond the direct effect of bycatch mortality. In the GOA, while big and longnose skates do feed on commercially important fish species, they also rely on non-commercial species such as shrimp and forage fish. Therefore, management practices that promote the health of commercial flatfish and pollock as well as forage species will be beneficial to skates. Because skates are at a relatively high trophic level in both systems, predation mortality is less significant than fishing mortality. Steller sea lions are one of the most important predators of skates in the GOA, so it seems possible that this source of predation mortality is lower now for skates than it may have been in the past when Steller populations were higher. Perhaps any release of skates from Steller sea lion predation mortality is now being compensated by increased fishing mortality with as commercial interest in skates has increased recently. However, it is difficult to assess the relative magnitude of these effects over time as historical predator food habits data and catch data for skates are both so sparse. Given that fishing mortality is the largest known source of mortality for skates, the assessment of skate population dynamics and response to fishing should be continued and improved in the GOA as it represents the primary skate assessment ecosystem consideration as well.

Ecosystem Effects on Stock and Fishery Effects on the Ecosystem: Summary

In the following table, we summarize ecosystem considerations for GOA skates and the entire groundfish fishery where they are caught incidentally. Because there is no bycatch information from the directed skate fishery or from the halibut fishery in the GOA at present, we attempt to evaluate the ecosystem effects of skate bycatch from the combined groundfish fisheries operating in these areas in the second portion of the summary table. 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
Sandlance, 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

Accurate species identification of the catch is essential to understanding the effects of removals on the population dynamics of individual skate species. We highly recommend continued port sampling to verify information from the fish ticket database.

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. All of this research has been initiated for major skate species in the GOA; it should be fully funded to completion.

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 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, but any effects on the small scale nursery habitats crucial to reproduction could have disproportionate population effects. 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. We recommend continued study on skate nursery areas to evaluate importance to population production.

We do not see any conflict at present between commercial fishing and skate foraging on flatfish, and pollock appear to be a minor component of skate diets in the GOA, but we do recommend continued monitoring of skate populations and food habits at appropriate spatial scales to ensure that these trophic relationships remain intact as fishing for these commercial forage species continues and evolves.

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Literature Cited

Agnew, D.J., C.P. Nolan, J.R. Beddington, and R. Baranowski, 2000. Approaches to the assessment and management of multispecies skate and ray fisheries using the Falkland Islands fishery as an example. Can. J. Fish. Aquat. Sci. 57: 429-440.

Allen, M.J., and G.B. Smith, 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. NOAA Technical Report NMFS 66, 151 pp.

Alverson, D.L., and W.T. Pereyra, 1969. Demersal fish explorations in the northeastern Pacific Ocean: An evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts. J. Fish. Res. Bd. Canada 26: 1985-2001.

Alverson, D.L., and M.J. Carney. 1975. A graphic review of the growth and decay of population cohorts. J. Cons. Int. Explor. Mer 36:133-143.

Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. 2007. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-178, 298 p.

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.

Charnov, E.L. 1993. Life history invariants some explorations of symmetry in evolutionary ecology. Oxford University Press Inc., New York. 167p.

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.

Hoenig, J.M., 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82(1): 898-902.

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.

Ishihara, H. and R. Ishiyama, 1985. Two new North Pacific skates (Rajidae) and a revised key to *Bathyraja* in the area. Jpn. J. Ichthyol. 32(2): 143-179.

King, J. R., and G. A. McFarlane, 2002. Preliminary results of Big Skate (*Raja binoculata*) Age Determination Project. Unpub. Man. DFO.

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

Kotwicki, S., and Weinberg, K.L. 2005. Estimating capture probability of a survey bottom trawl for Bering Sea skates (*Bathyraja spp.*) and other fish. Alaska Fishery Research Bulletin 11(2): 135-145.

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.

Martin, L. and G.D. Zorzi, 1993. Status and review of the California skate fishery. In Conservation biology of elasmobranchs (S. Branstetter, ed.), p. 39-52. NOAA Technical Report NMFS 115.

McEachran, J.D., and K.A. Dunn, 1998. Phylogenetic analysis of skates, a morphologically conservative clade of elasmobranchs (Chondrichthyes: Rajidae). Copeia, 1998(2), 271-290.

McEachran, J.D. and T. Miyake, 1990a. Phylogenetic relationships of skates: a working hypothesis (Chondrichthyes: Rajoidei). In Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries (H.L. Pratt, Jr., S.R. Gruber, and T. Taniuchi, eds.), p. 285-304. NOAA Technical Report NMFS 90.

McEachran, J.D. and T. Miyake, 1990a. Phylogenetic relationships of skates: a working hypothesis (Chondrichthyes: Rajoidei). In Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries (H.L. Pratt, Jr., S.R. Gruber, and T. Taniuchi, eds.), p. 285-304. NOAA Technical Report NMFS 90.

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.

Murray, J.D., 1989. Mathematical Biology. Springer-Verlag: New York. 767 pp.

Musick, J.A., S.A. Berkeley, G.M. Cailliet, M. Camhi, G. Huntsman, M. Nammack, and M.L. Warren, Jr., 2000. Protection of marine fish stocks at risk of extinction. Fisheries 25(3):6-8.

Nelson, J. S., 1994. Fishes of the world, Third edition. John Wiley and Sons, Inc., New York: 600 pp.

NMFS 2000. Skate complex. In Draft 30th Northeast Regional Stock Assessment Workshop (30th SAW), Stock assessment review committe (SARC) consensus summary of assessments, p. 7-173.

NMFS PSEIS 2001. Draft Programmatic Environmental Impact Statement.

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.

Pauly, D. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer 39(2):175-192.

Rikhter, V.A., and V.N. Efanov. 1976. On one of the approaches to estimation of natural mortality of fish populations. ICNAF Res. Doc. 76/VI/8. Serial N. 3777. 13p.

Roff, D.A. 1986. The evolution of life history parameters in teleosts. Can. J. Fish. Aquat. Sci. 41:989-1000.

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.

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., J.W. Orr, G.R. Hoff, and J.D. McEachran. 2004. *Bathyraja mariposa*: a new species of skate (Rajidae: Arhynchobatinae) from the Aleutian Islands. Copeia 2004(2):305-314.

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.

Thompson, G.G., 1993. A proposal for a threshold stock size and maximum fishing mortality rate. Pages 303-320 in Risk evaluation and biological reference points for fisheries management (S.J. Smith, J.J. Hunt, and D. Rivard, eds.). Can. Spec. Publ. Fish. Aquat. Sci. 120, 440 pp.

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
Raja binoculata	big skate	244	15 [5]	6-8 yrs, 72-90 cm [7]	predatory [8]	1-7	16-402
Raja rhina	longnose skate	180	25 [5]	7-10 yrs, 65-83 cm [7]	benthophagic; predatory [15]	1	9-1069

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

Table 2. Biomass of skate species from recent complete GOA bottom trawl surveys, 2003-2009, and the most recent 4-year average biomass.

species	2003	2005	2007	2009	4-survey average
big skate	**55,397**	**39,320**	**38,458**	**44,349**	**44,381**
longnose skate	**39,603**	**41,449**	**34,421**	**36,652**	**38,031**
Aleutian skate	15,813	24,253	25,399	19,070	21,134
Bering skate	3,701	4,337	3,801	4,126	3,991
Alaska skate	1,908	700	1,795	2,750	1,788
roughtail skate	0	139	948	356	361
unidentified skates	36	115	60	951	291
whiteblotched skate	264	502	197	199	290
whitebrow skate	52	0	118	0	42
Bathyraja sp	1	18	16	0	9
mud skate	0	0	0	10	2
other skates subtotal	**21,775**	**30,063**	**32,334**	**27,461**	**27,908**
total skates	116,775	110,832	105,212	108,463	110,320

Table 3. Time series of TAC and catch for GOA Other Species and skates, with estimated skate catch. Until 2008, no ABC or OFL were determined for GOA Other Species. From 2004 on, only the TAC for GOA skates is shown.

	TAC			Other Species catch	est. skate catch			management method
	W	C	E		W	C	E	
1992		13,432		12,313		1,835		Other species TAC (included Atka)
1993		14,602		6,867		3,882		Other species TAC (included Atka)
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 gulfwide + big/longnose W/E
2005	727	2,463	809		26	811	67	big
	66	1,972	780		37	993	173	longnose
		1,327				719		other skates gulfwide
2006	695	2,250	599		72	1,268	359	big
	65	1,969	861		57	679	239	longnose
		1,617				1,402		other skates gulfwide
2007	695	2,250	599		69	1,517	9	big
	65	1,969	861		76	966	336	longnose
		1,617				1,241		other skates gulfwide
2008	632	2,065	633		132	1,242	48	big
	78	2,041	768		34	965	115	longnose
		2,104				1,403		other skates gulfwide
2009	632	2,065	633		73	1,803	104	big
	78	2,041	768		78	1,019	243	longnose
		2,104				1,341		other skates gulfwide
2010*	598	2,049	681		132	1,833	158	big
	81	2,009	762		83	723	145	longnose
		2,093				1,350		other skates gulfwide

* 2010 catch is incomplete; retrieved October 10,2009.

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 2003-2009 from AKRO Catch Accounting System (CAS). Port sampling indicates that more of the catch in 2005 was big skates than longnose skates, and that there are some problems with incorrect reporting of all retained skates as longnose skates on fish tickets in multiple sampled plants. See Table 8 for additional estimated skate catch from Pacific halibut fisheries.

Table 4. Catch of big, longnose, and other skates by regulatory area. Data are from the Alaska Regional Office Catch Accounting System. * 2010 are incomplete; retrieved October 10, 2010.

TOTAL GOA								
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009***	**2010***
big	0	1,204	904	1,699	1,595	1,422	1,980	2,123
longnose	53	539	1,202	976	1,378	1,114	1,340	951
other	4,527	1,277	719	1,402	1,241	1,403	1,341	1,350
total	4,580	3,019	2,826	4,077	4,213	3,939	4,660	4,423

WGOA								
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010***
big	0	63	26	72	69	132	73	132
longnose	1	28	37	57	76	34	78	83
other	571	358	163	354	479	253	336	374
total	572	449	226	483	623	419	487	589

CGOA								
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010***
big	0	1,125	811	1,268	1,517	1,242	1,803	1,833
longnose	40	444	993	679	966	965	1,019	723
other	3,802	794	506	988	672	1,059	882	891
total	3,843	2,362	2,310	2,935	3,155	3,265	3,703	3,447

EGOA								
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010***
big	0	16	67	359	9	48	104	158
longnose	11	67	173	239	336	115	243	145
other	154	125	50	60	90	91	123	84
total	165	208	290	659	435	254	470	387

Table 5. Catches of skates by target fishery, 2003-2010. Data in all of Table 5 are from the Alaska Regional Office Catch Accounting System. * 2010 are incomplete; retrieved October 10, 2010.

Table 5a. Big skate catch, GOA, 2003-2010.

BIG SKATE								
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010***
arrowtooth	0	4	0	0	0	0	0	1
flathead sole	0	38	21	30	23	66	53	93
IFQ halibut	0	24	37	577	11	36	92	32
other target	0	376	56	27	0	2	9	3
Pacific cod	0	331	222	417	537	586	550	911
rex sole	0	31	49	99	74	70	264	133
rockfish	0	16	19	4	0	4	4	11
sablefish	0	6	24	9	6	3	5	11
shallow flatfish	0	237	251	350	608	414	535	514
pollock	0	1	2	23	38	22	34	24
total	0	1,204	904	1,699	1,595	1,422	1,980	2,123

Table 5b. Longnose skate catch**,** GOA**,** 2003-2010..

LONGNOSE SKATE								
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010***
arrowtooth	14	63	373	135	165	212	152	139
deep flatfish	0	3	1	0	0	0	0	1
flathead sole	9	7	11	11	13	11	24	21
IFQ halibut	1	35	106	197	394	109	380	107
other target	0	155	137	2	0	0	8	14
Pacific cod	10	83	139	165	306	361	325	368
rex sole	0	13	19	29	24	36	82	41
rockfish	1	32	20	21	17	12	17	12
sablefish	16	121	113	305	264	123	79	97
shallow flatfish	3	26	278	97	168	227	239	146
pollock	0	0	5	13	27	24	35	6
total	53	539	1,202	975	1,378	1,114	1,340	951

Table 5c. Other skates catch, GOA, 2003-2010.

OTHER SKATES								
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010***
arrowtooth	195	173	194	64	122	88	99	124
deep flatfish	0	1	0	0	0	0	0	0
flathead sole	191	44	38	12	20	5	13	14
IFQ halibut	191	73	47	78	108	58	253	29
other target	1,971	251	2	3	0	16	30	0
Pacific cod	806	490	175	981	529	958	689	968
rex sole	346	46	36	56	103	22	60	34
rockfish	105	19	59	49	20	10	13	27
sablefish	153	113	129	128	260	134	83	120
shallow flatfish	559	65	36	27	70	107	98	28
pollock	11	2	1	5	9	6	3	6
total	4,527	1,277	719	1,402	1,240	1,403	1,341	1,349

Table 5d. Total GOA skate catch by target fishery, 2003-2010.

ALL GOA SKATES								
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010***
arrowtooth	349	376	792	362	585	520	684	653
deep flatfish	0	8	1	0	0	0	0	2
flathead sole	200	89	70	54	56	81	89	128
IFQ halibut	191	133	190	852	513	203	725	168
other target	1,971	782	195	32	0	18	47	16
Pacific cod	816	904	536	1,563	1,372	1,905	1,564	2,247
rex sole	346	89	104	183	200	127	406	207
rockfish	106	67	98	74	38	25	34	50
sablefish	169	240	265	442	530	260	167	228
shallow flatfish	562	328	565	474	845	748	873	688
pollock	11	3	8	41	74	51	72	36
total	4,580	3,019	2,826	4,077	4,213	3,939	4,660	4,423

Table 6. Retention rates of skates in GOA fisheries, 1997-2009. Data are from tables published by the Alaska Regional Office. * 2010 data are incomplete.

	other skates	**big skate**	**longnose skate**
2007	27%	46%	28%
2008	17%	70%	64%
2009	18%	76%	51%
2010*	11%	74%	62%

Table 7. Estimated GOA groundfish catch (t) of skates by target fishery, gear, and area, 1997-2002. See text for explanation of data sources and estimation methods.

target	gear	1997	1998	1999	2000	2001	2002
arrowtooth	trawl	133	21	49	182	48	174
deep flatfish	trawl	42	31	17	5	7	14
flathead sole	trawl	139	130		2	26	102
rex sole	trawl	489	172	331	142	107	230
shallow flatfish	trawl	427	186	70	275	171	400
flatfish subtotal		**1,229**	**540**	**467**	**607**	**359**	**920**
Pacific cod	longline	478	461	789	1,823	617	5,005
	pot	1	0	0	0	0	0
	trawl	476	411	385	219	272	120
Pacific cod subtotal		**954**	**873**	**1,174**	**2,042**	**889**	**5,125**
pollock	trawl	31	52	24	87	53	10
rockfish	longline	223		22	75	75	4
	trawl	70	39	71	77	126	113
rockfish subtotal		**293**	**39**	**92**	**151**	**201**	**117**
sablefish	longline	166	2,834	243	336	262	305
	trawl				0	1	0
sablefish subtotal		**166**	**2,834**	**243**	**336**	**263**	**305**
unknown target		446	138	0	14	63	7
total catch		**3,120**	**4,476**	**2,000**	**3,238**	**1,828**	**6,484**

Area	1997	1998	1999	2000	2001	2002
610	212	200	625	299	229	541
620	749	381	292	305	109	464
630	1,883	1,066	958	2,367	1,371	5,353
640	103	89	31	37	34	23
650	173	68	95	230	86	103
659	0	2,672	0			
total catch	**3,120**	**4,476**	**2,000**	**3,238**	**1,828**	**6,484**

Table 8. Survey biomass estimates for skates in each GOA area, 1984-2009.

	species	**1984**	**1987**	**1990**	**1993**	**1996**	**1999**	**2001**	**2003**	**2005**	**2007**	**2009**
WGOA	big	3,339	4,313	1,745	2,287	13,130	11,038	8,425	9,602	9,792	5,872	6,652
	longnose	0	41	1,045	105	278	1,747	104	782	1,719	628	1,214
	Aleutian	358	112	139	292	82	1,928	1,858	4,401	1,453	3,333	3,051
	Bering	45	20	28	0	52	218	170	39	86	0	283
	Alaska	0	0	0	0	119	220	1,213	265	211	177	1,728
	roughtail	0	0	0	0	43	0	0	0	0	82	0
	Bathyraja sp.	0	91	0	651	453	0	0	0	0	0	0
	mud	0	0	0	0	0	46	0	0	0	0	10
	whiteblotched	0	0	0	0	0	544	0	173	502	197	199
	whitebrow	0	0	0	0	0	0	0	0	0	33	0
	total WGOA skates	**4,067**	**4,837**	**2,956**	**3,348**	**14,168**	**15,741**	**11,774**	**15,264**	**13,799**	**10,344**	**13,987**
CGOA	big	17,635	20,855	9,071	21,586	26,544	34,007	30,658	33,814	25,544	23,249	26,691
	longnose	2,280	2,667	8,708	14,158	20,328	29,872	23,171	25,741	29,853	26,034	25,534
	Aleutian	1,235	601	896	60	5,681	8,055	4,734	10,772	22,395	21,928	15,725
	Bering	230	519	1,861	107	1,492	3,371	2,423	3,526	3,910	3,466	3,370
	Alaska	0	14	771	0	810	1,272	2,422	1,579	489	1,618	1,021
	roughtail	51	182	0	0	0	614	0	0	139	495	356
	Bathyraja sp.	0	32	0	3,572	1,566	0	14	1	0	16	0
	mud	0	0	0	0	0	0	0	0	0	0	0
	whiteblotched	0	0	0	0	0	925	0	0	0	0	0
	whitebrow	8	0	0	0	0	0	0	0	0	84	0
	total CGOA skates	**23,548**	**26,112**	**30,924**	**39,513**	**56,546**	**78,148**	**63,440**	**75,465**	**82,389**	**76,914**	**72,775**
EGOA	big	6,566	2,925	11,501	15,836	3,391	9,606		11,981	3,984	9,337	11,007
	longnose	6,722	3,923	2,242	3,539	5,620	7,714		13,081	9,876	7,759	9,904
	Aleutian	0	25	216	0	796	1,310		640	406	138	295
	Bering	187	68	159	119	673	229		136	341	335	473
	Alaska	4	0	107	0	0	76		63	0	0	0
	roughtail	0	0	0	0	0	63		0	0	371	0
	Bathyraja sp.	0	0	0	470	3	0		0	17	0	0
	mud	0	0	0	0	0	0		0	0	0	0
	whiteblotched	0	0	0	0	0	0		91	0	0	0
	whitebrow	0	0	0	0	0	0		52	0	0	0
	total EGOA skates	**13,575**	**7,114**	**14,367**	**20,841**	**10,487**	**19,040**		**26,046**	**14,643**	**17,955**	**21,701**

Table 9. Alternative methods for estimating M based on life history information from big and longnose skates (see text for methods and references). "Age mature" (T_{mat}) was given a range for M estimates by the Rikhter and Efanov method to account for uncertainty in this parameter. Study areas are indicated as CA (California), GOA (Gulf of Alaska), and BC (British Columbia). Life history parameter sources: Zeiner and Wolf 1993, Gburski et al. 2007, McFarlane and King 2006.

Species	**Area**	**Sex**	**Hoenig**	**T_{mat}**	**Rikhter & Efanov**	**Alverson & Carney**	**Charnov**	**Roff**
Big skate	CA	*males*	0.38					
	CA	*females*	0.35					
	CA	*both*		8	0.19			
	CA			9	0.16			
	CA			10	0.13			
	CA			11	0.12			
	CA			12	**0.10**			
	GOA	*males*	0.28			0.33	0.28	
	GOA	*females*	0.30			0.45	0.15	
	BC	*males*	0.17			0.25	**0.10**	0.34
	BC	*females*	0.16			0.25	0.08	0.27
	BC	*both*		5	0.32			
	BC			6	0.26			
	BC			7	0.22			
	BC			8	0.19			
Longnose skate	CA	*males*	0.32			0.31	0.44	0.23
	CA	*females*	0.35			0.45	0.29	0.03
	CA	*both*		7	0.22		0.31	
	CA			8	0.19			
	CA			9	0.16			
	CA			10	0.13			
	GOA	*males*	0.17			0.24	0.11	
	GOA	*females*	0.17			0.28	0.07	
	BC	*males*	0.18			0.25	0.13	0.21
	BC	*females*	0.16			0.22	0.11	0.12
	BC	*both*		6	0.26			
	BC			7	0.22			
	BC			8	0.19			
	BC			9	0.16			
	BC			10	0.13			

Figures

Figure 1. Big skate, *Raja binoculata*, with previous stock assessment author for scale.

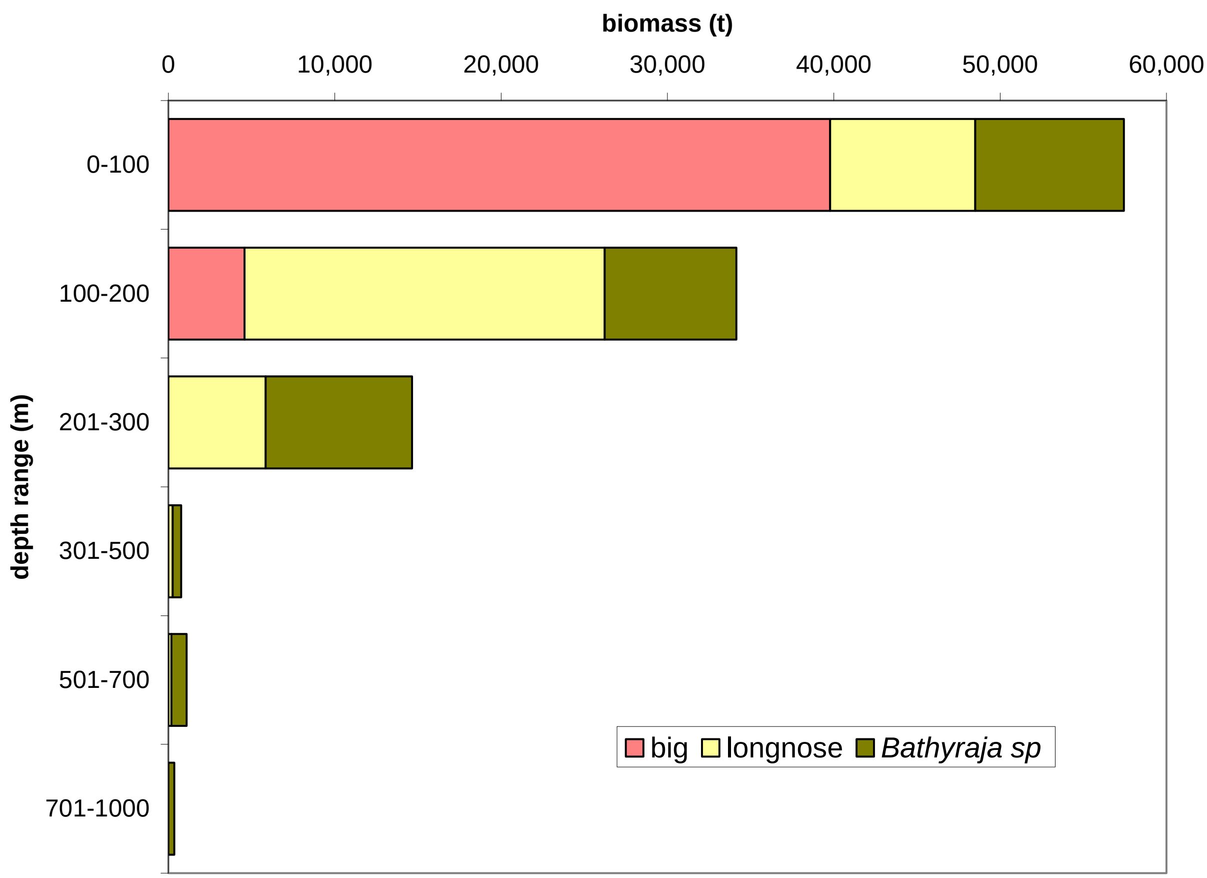


Figure 2. Biomass at depth for major GOA skate species: big, longnose, and *Bathyraja* sp. complex.

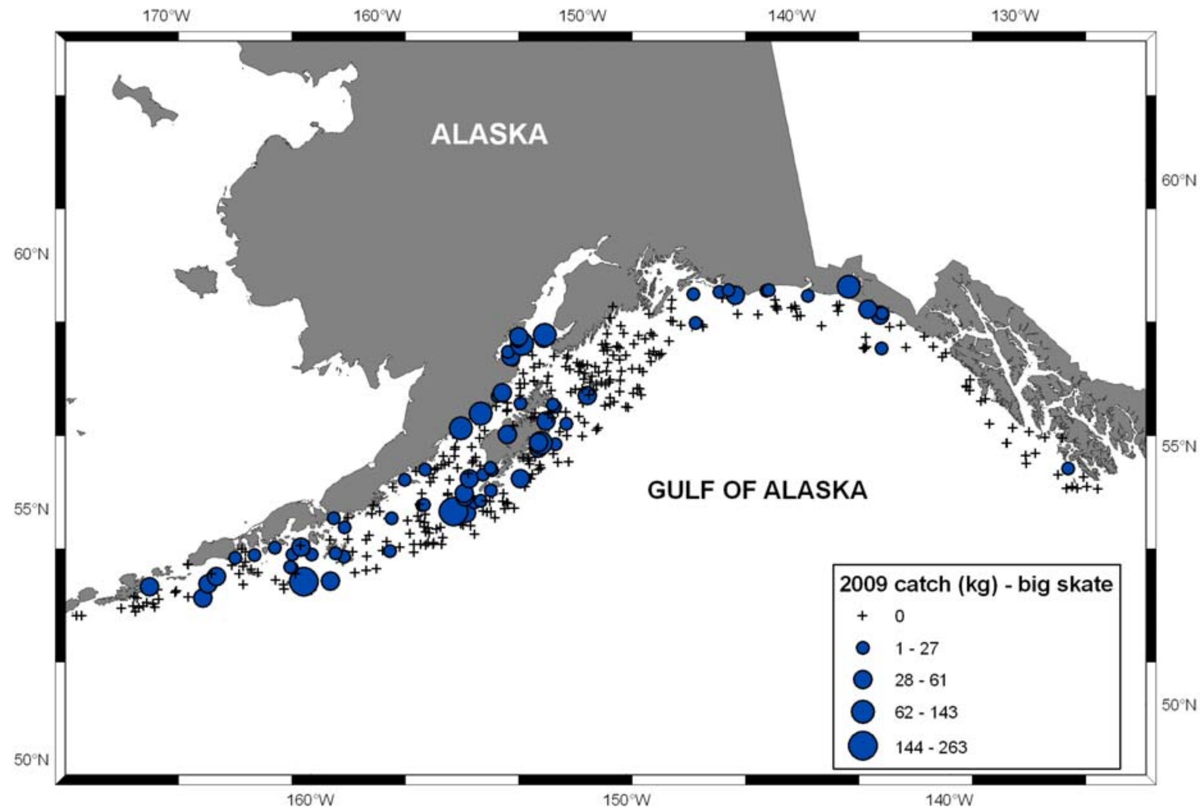


Figure 3. Distribution of big skate (*Raja binoculata*) catches in the 2009 GOA bottom trawl survey.

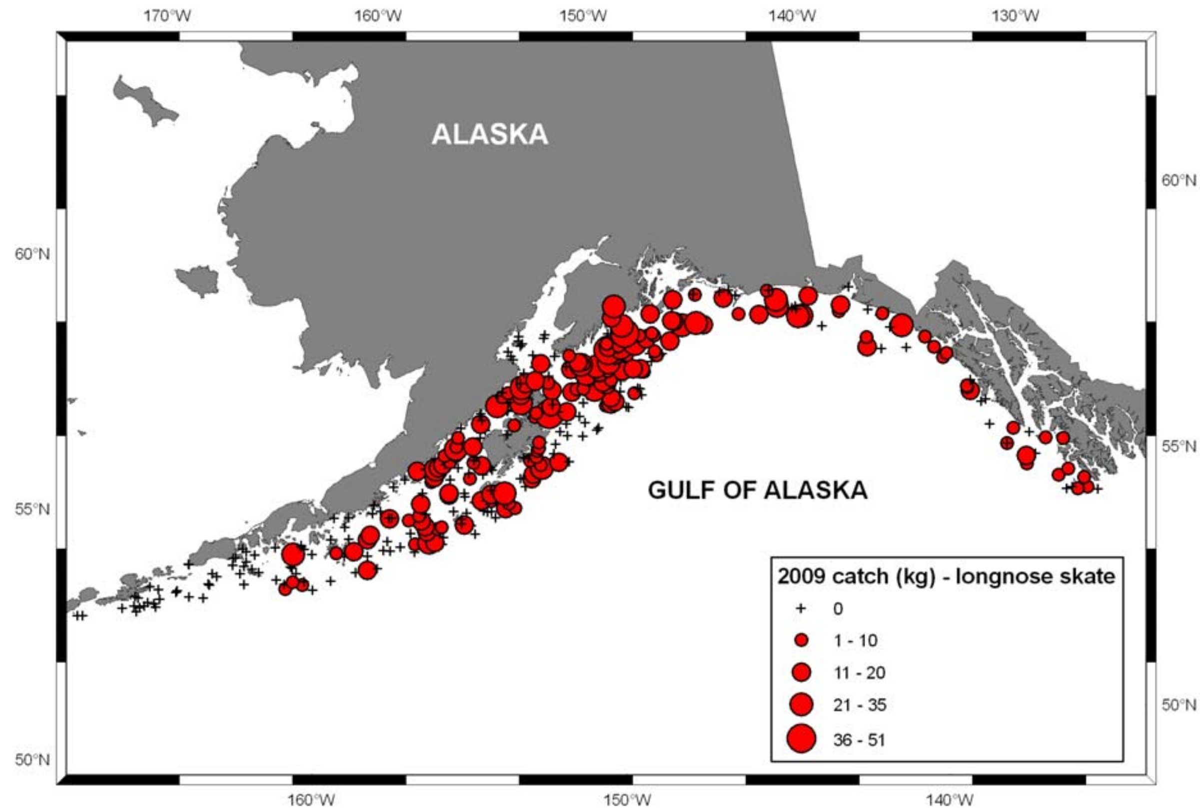


Figure 4. Distribution of longnose skate (*Raja rhina*) catches in the 2009 GOA bottom trawl survey.

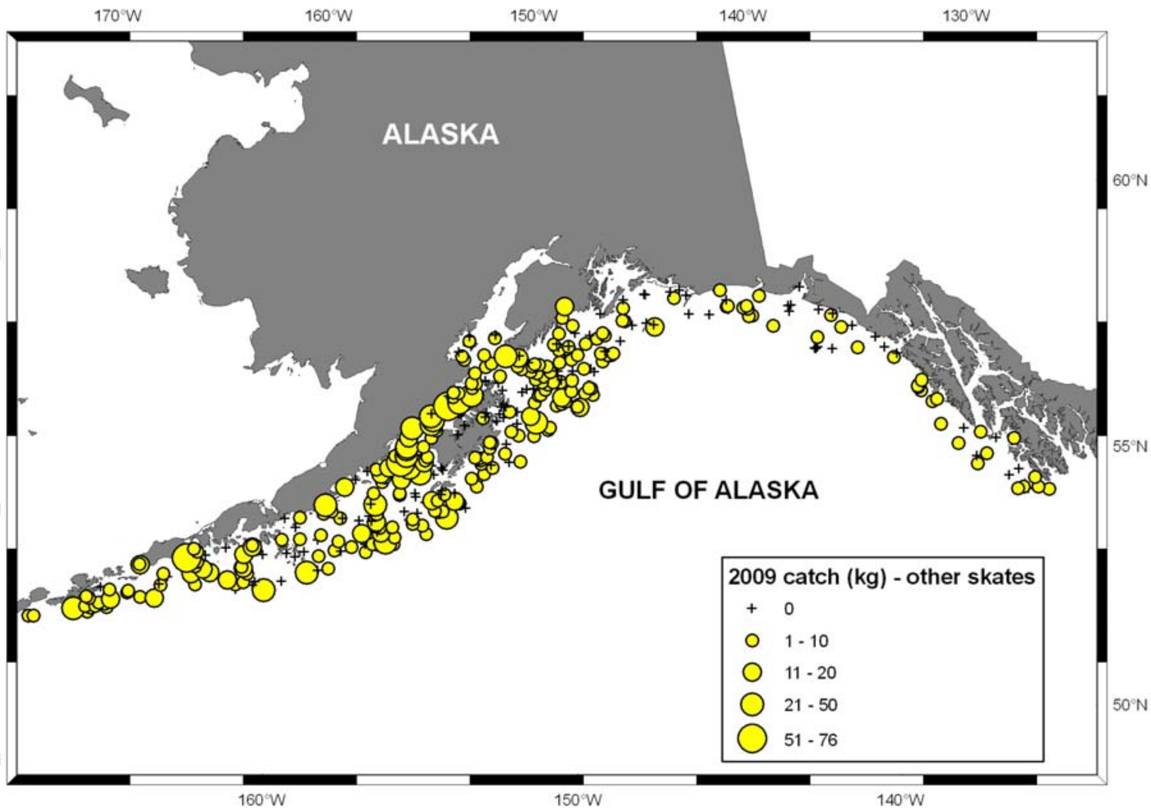


Figure 5. Distribution of *Bathyraja* sp. skate catches in the 2009 GOA bottom trawl survey.

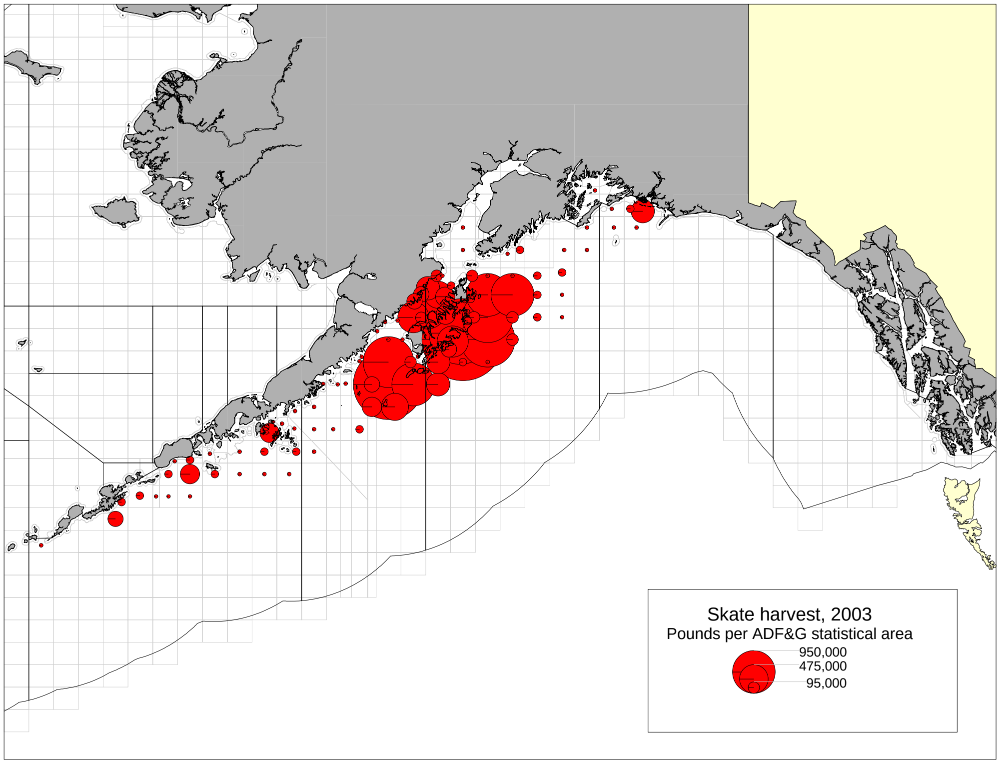


Figure 6. Skate catch in the GOA from fish ticket database in 2003.

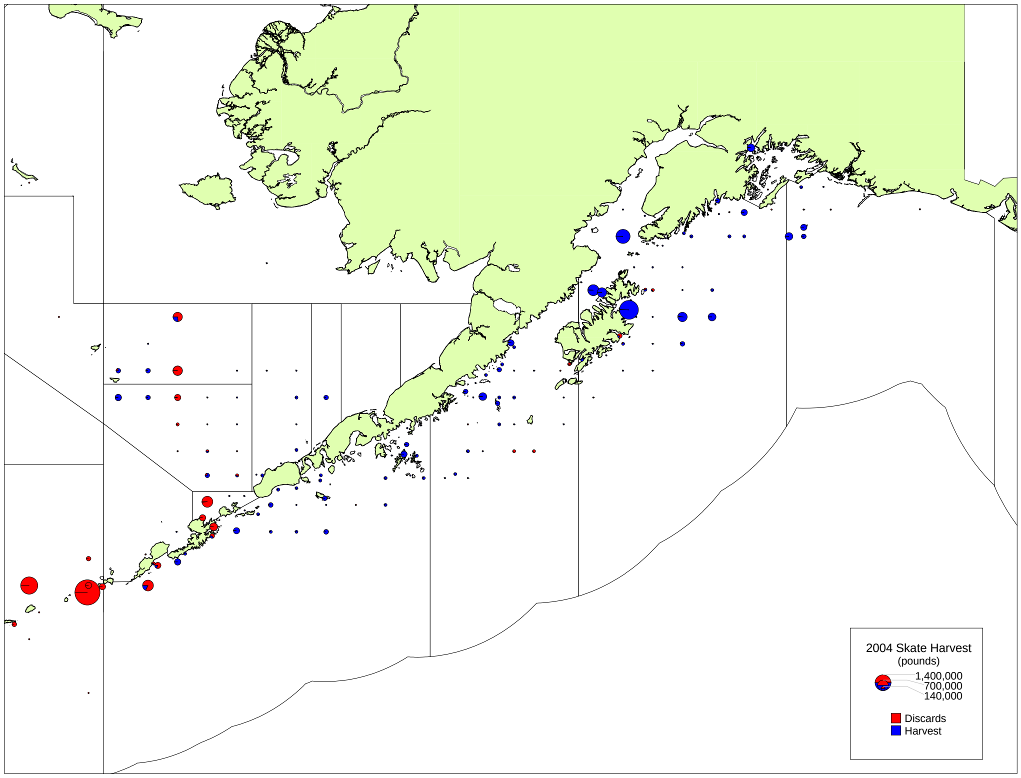


Figure 7. Skate catch in the GOA from fish ticket database in 2004.

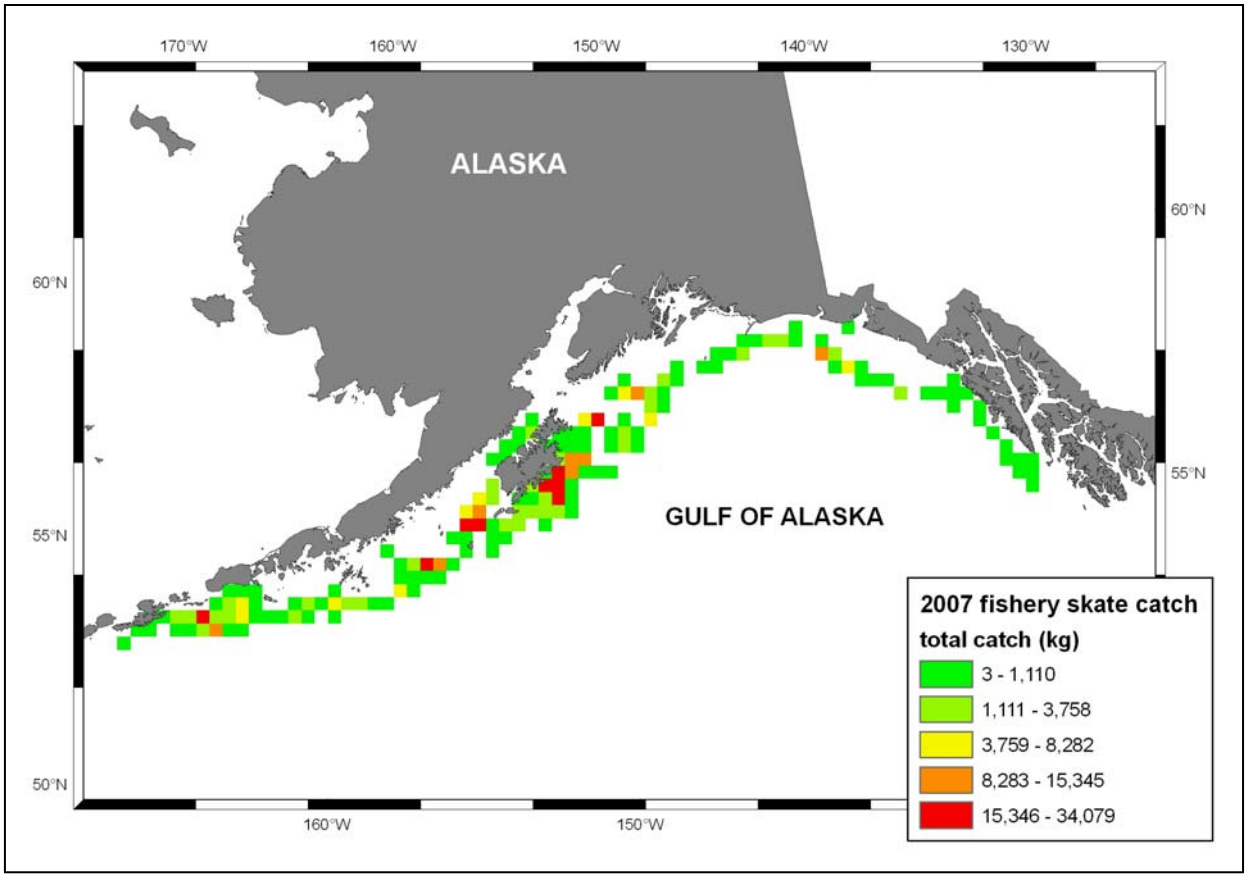


Figure 8. Distribution of observed skate incidental catches in 2007. Data displayed are the total catch in each grid cell (30 km x 30 km). Data are from the AFSC Fishery Monitoring and Analysis program and are aggregated for confidentiality purposes.

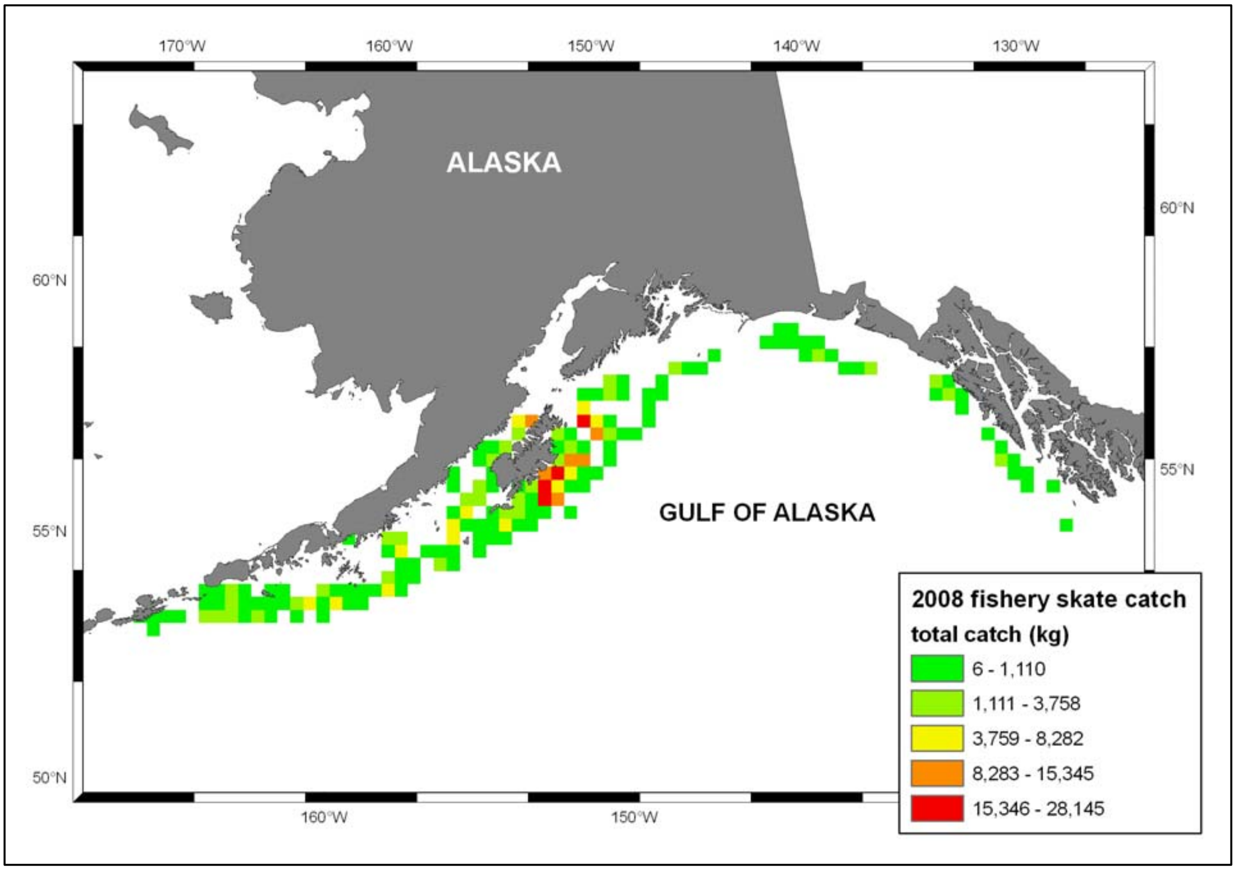


Figure 9. Distribution of observed skate incidental catches in 2008. Data displayed are the total catch in each grid cell (30 km x 30 km). Data are from the AFSC Fishery Monitoring and Analysis program and are aggregated for confidentiality purposes.

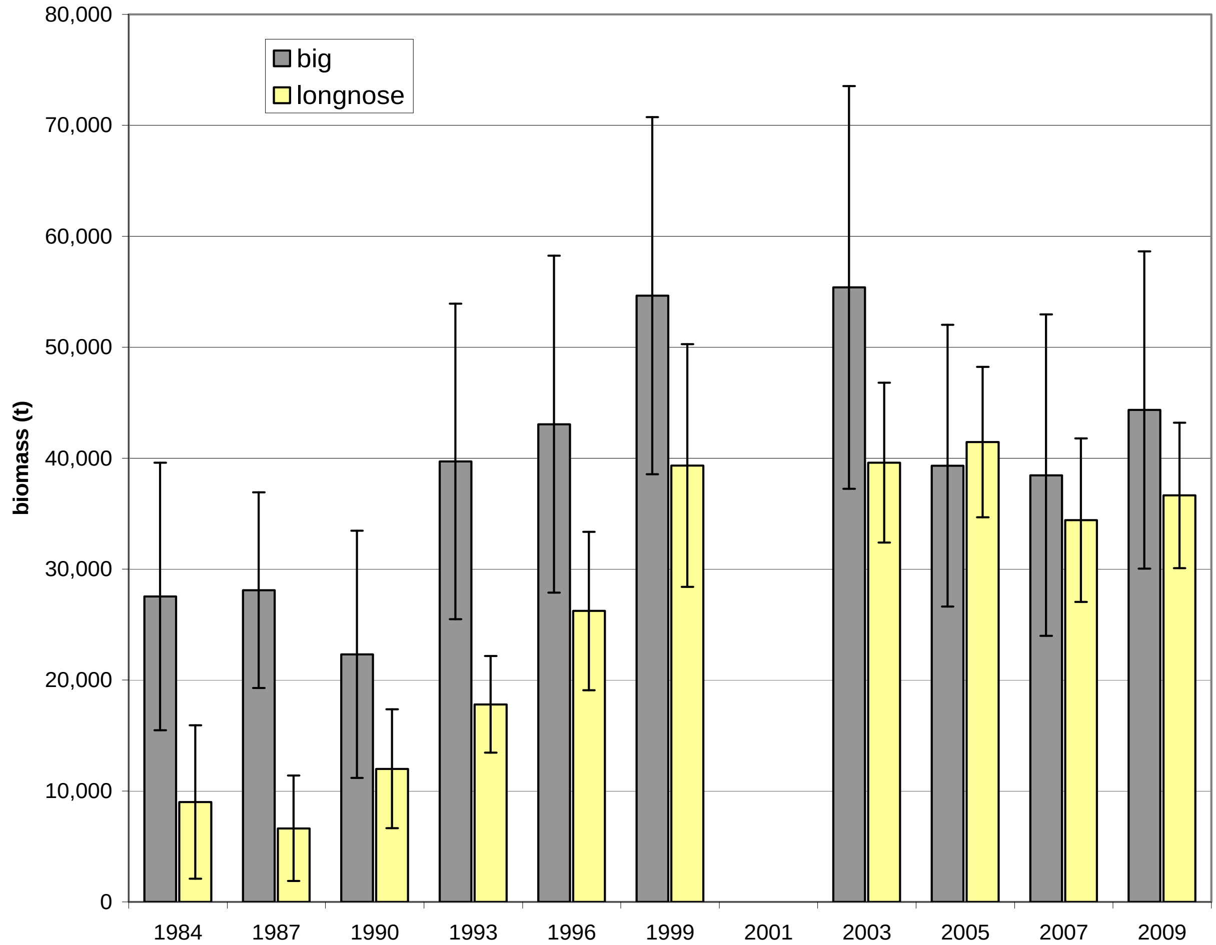


Figure 10. NMFS GOA bottom trawl survey biomass trends for big and longnose skates, 1984-2009. Error bars show plus/minus 2 standard deviations. The 2001 survey did not sample in the EGOA and is not included in the time series.

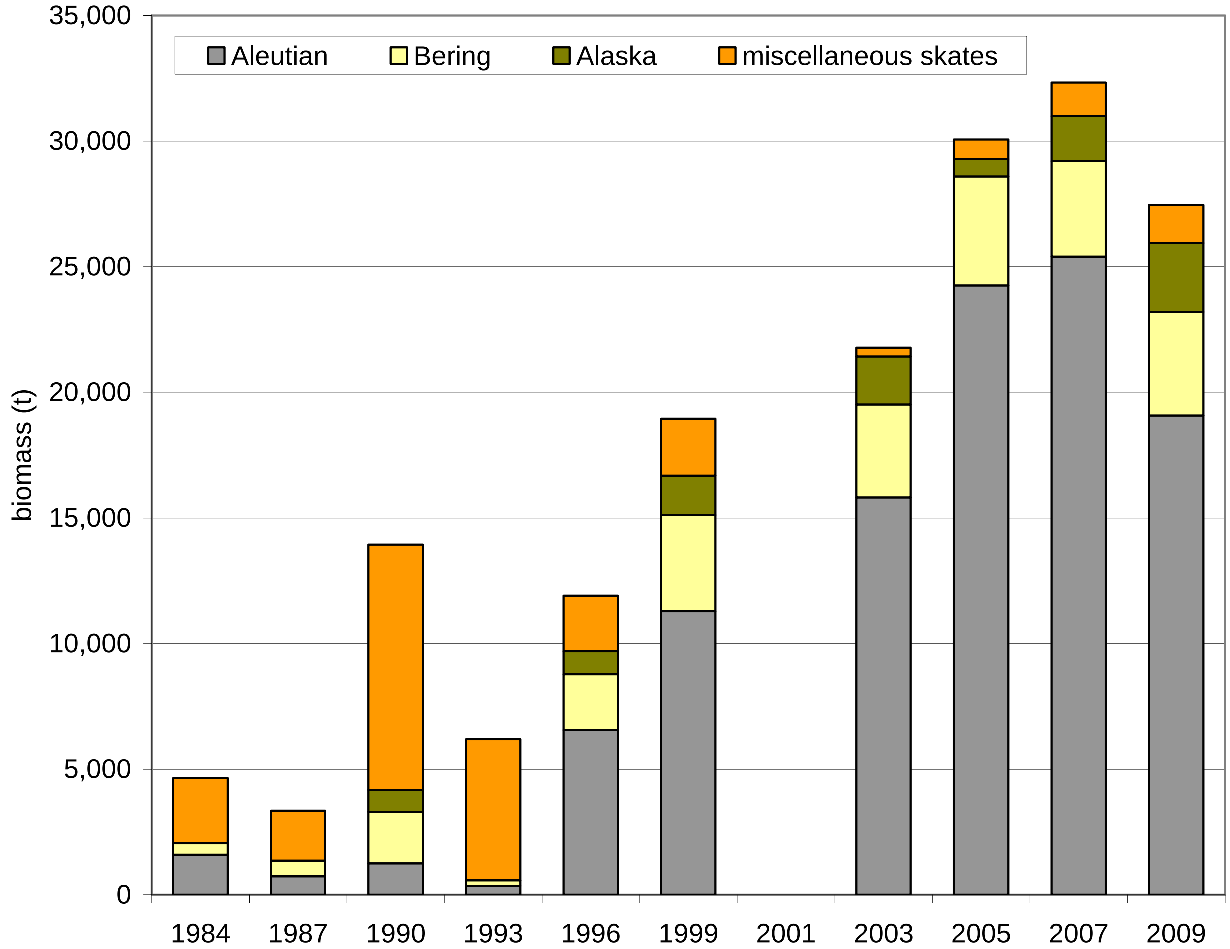


Figure 11. NMFS GOA bottom trawl survey biomass trends for Bathyraja skates, 1984-2009. “Miscellaneous skates” contains all skates not listed by species. The 2001 survey did not sample in the EGOA and is not included in the time series.

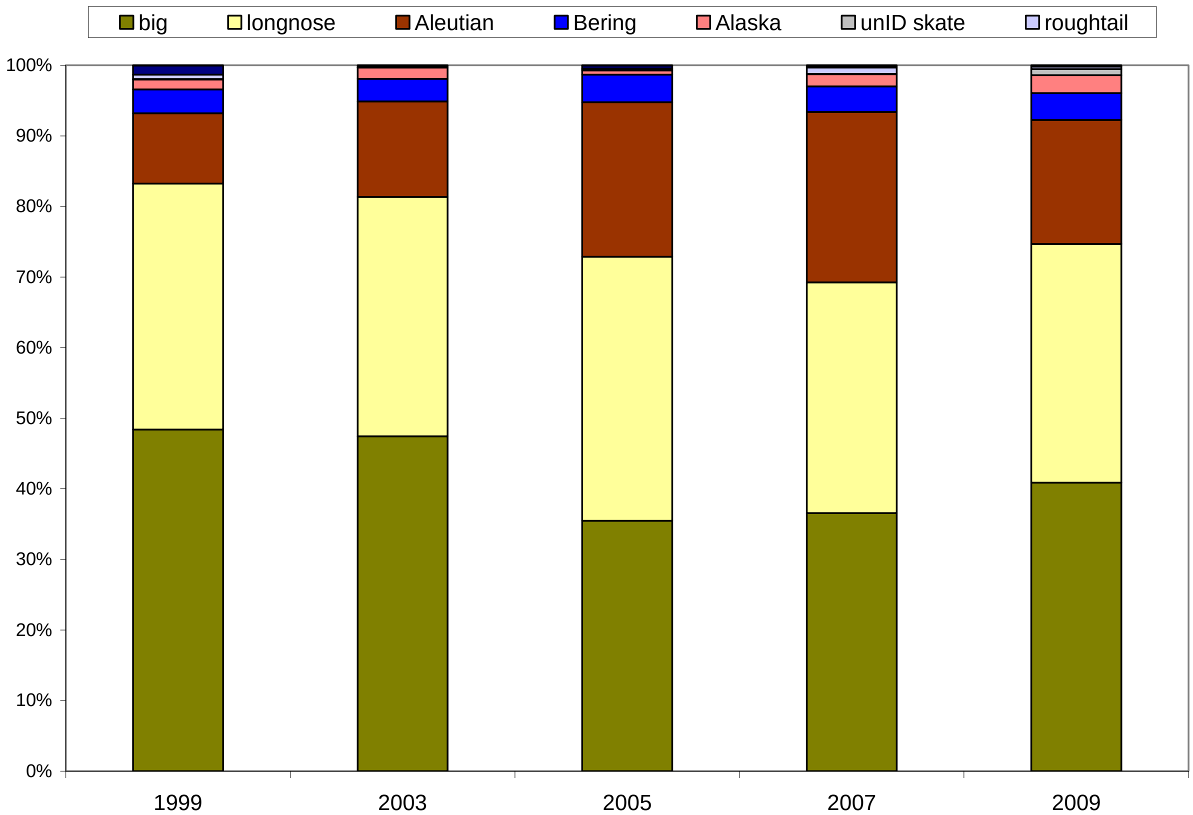


Figure 12. Gulfwide species composition of GOA skates, 1999-2009. The 2001 survey did not sample in the EGOA and is not included in the time series.

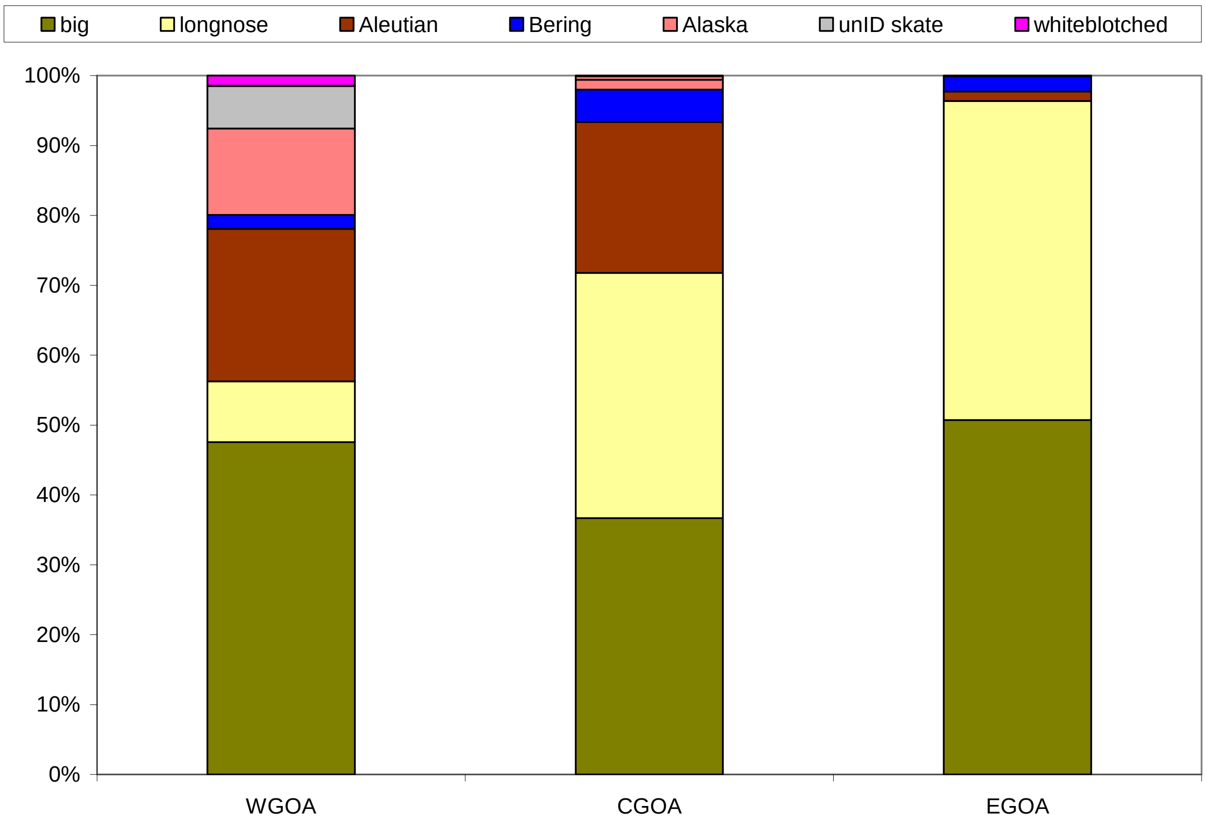


Figure 13. Species composition of GOA skates by GOA regulatory area, 2009.

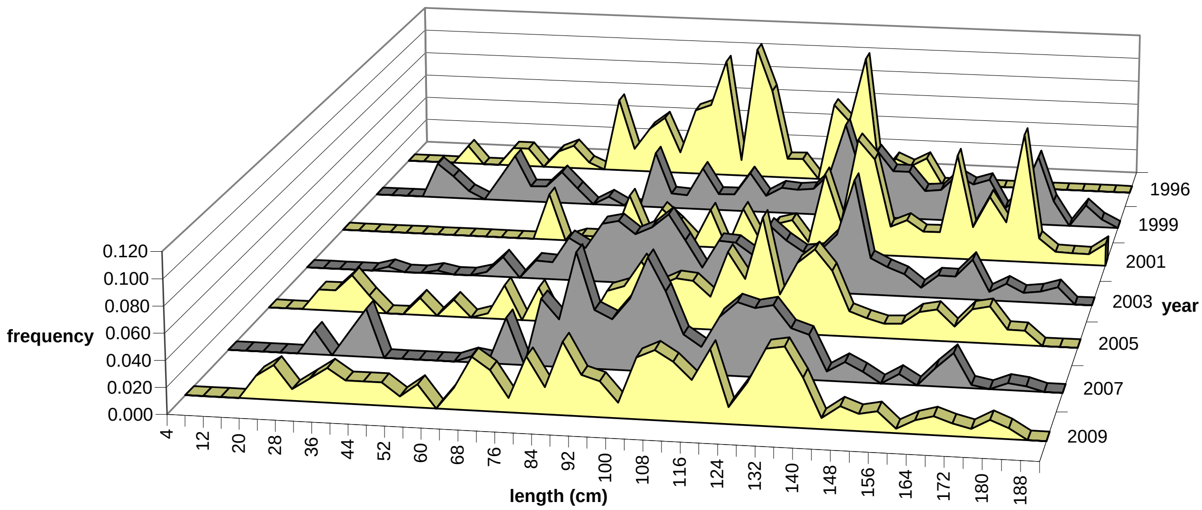


Figure 14. NMFS GOA trawl survey size composition for big skates (both sexes combined) in the entire GOA, 1996-2009.

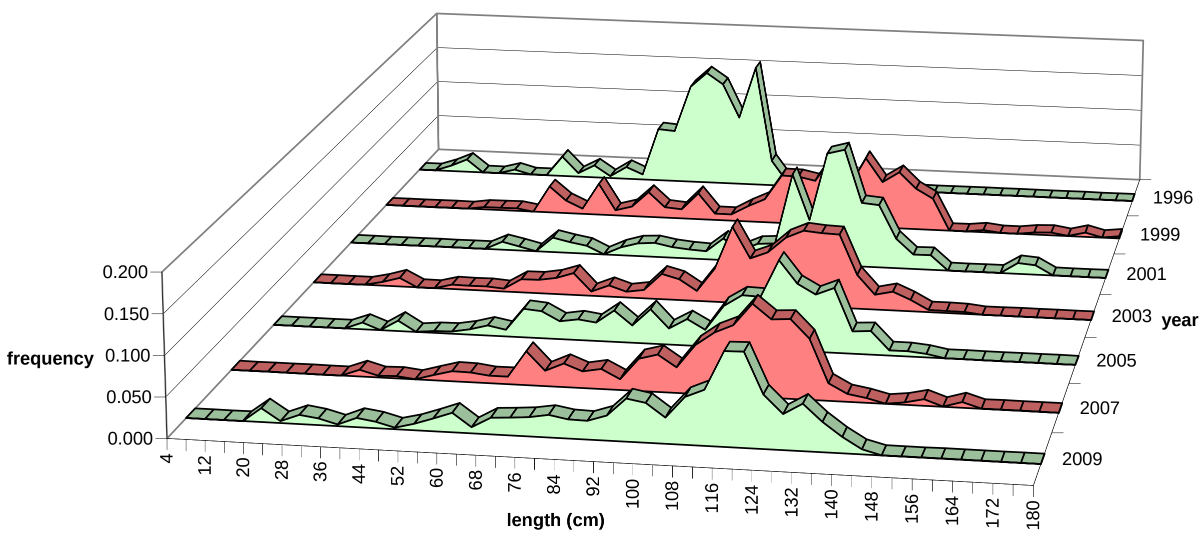
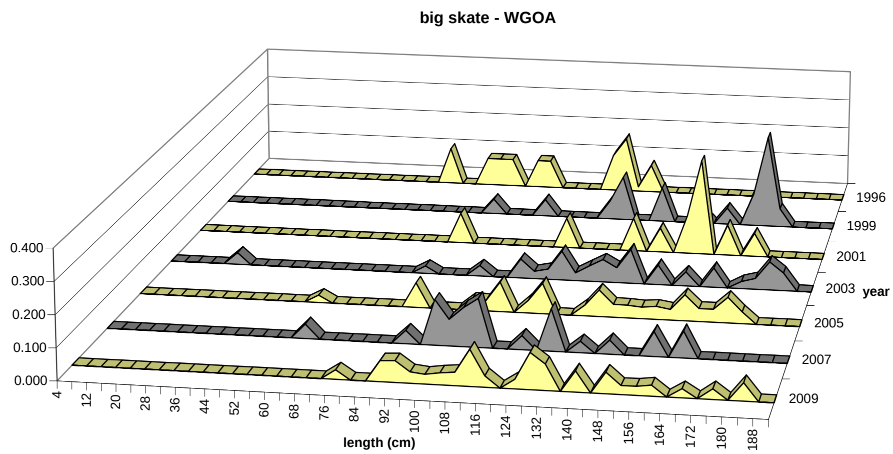
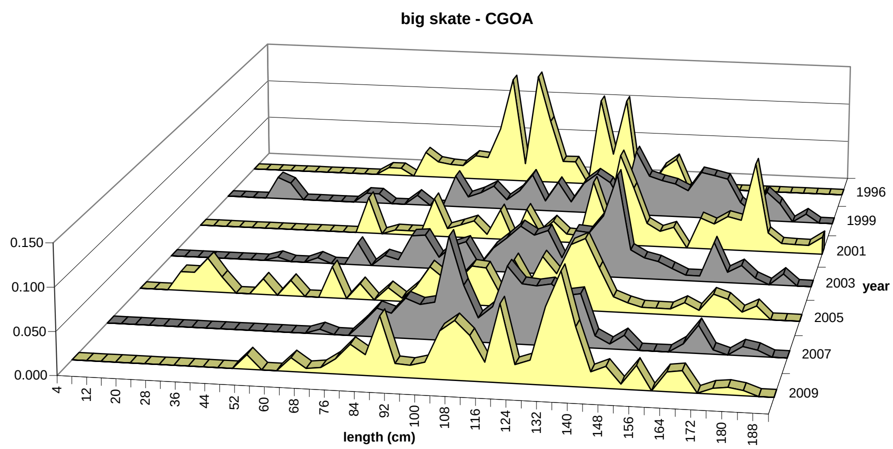


Figure 15. NMFS GOA trawl survey size composition for longnose skates (both sexes combined) in the entire GOA, 1996-2009.





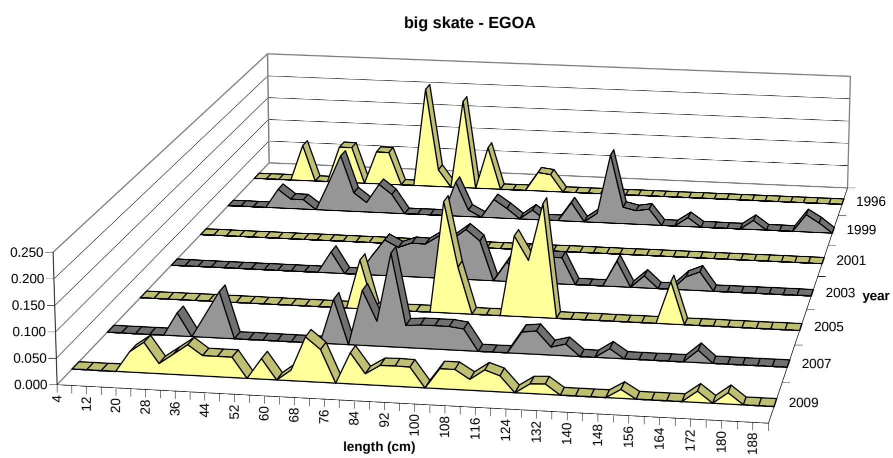


Figure 16. Big skate trawl survey length composition by regulatory area, 1996-2009.

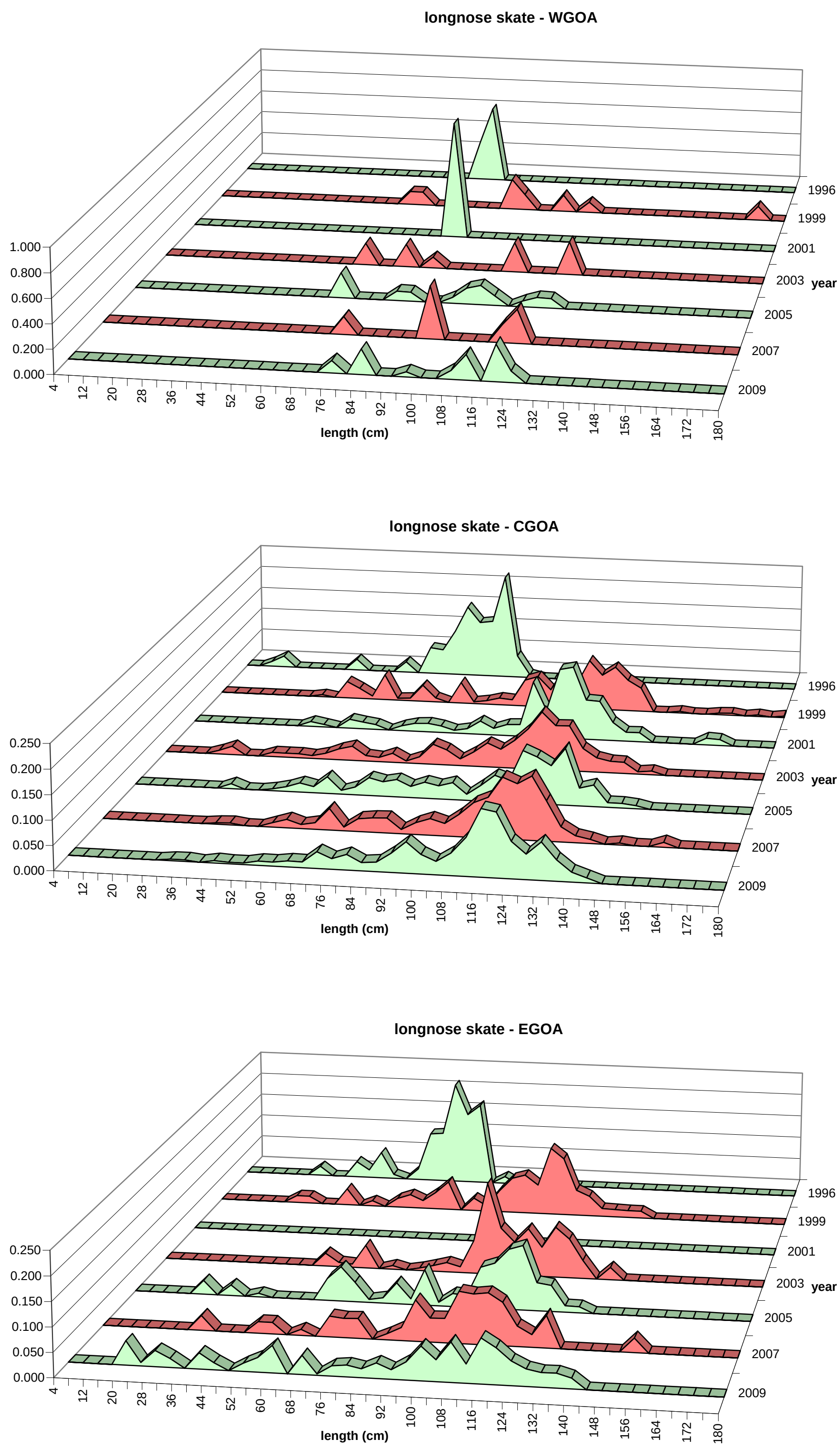


Figure 17. Longnose skate trawl survey length composition by regulatory area, 1996-2009.

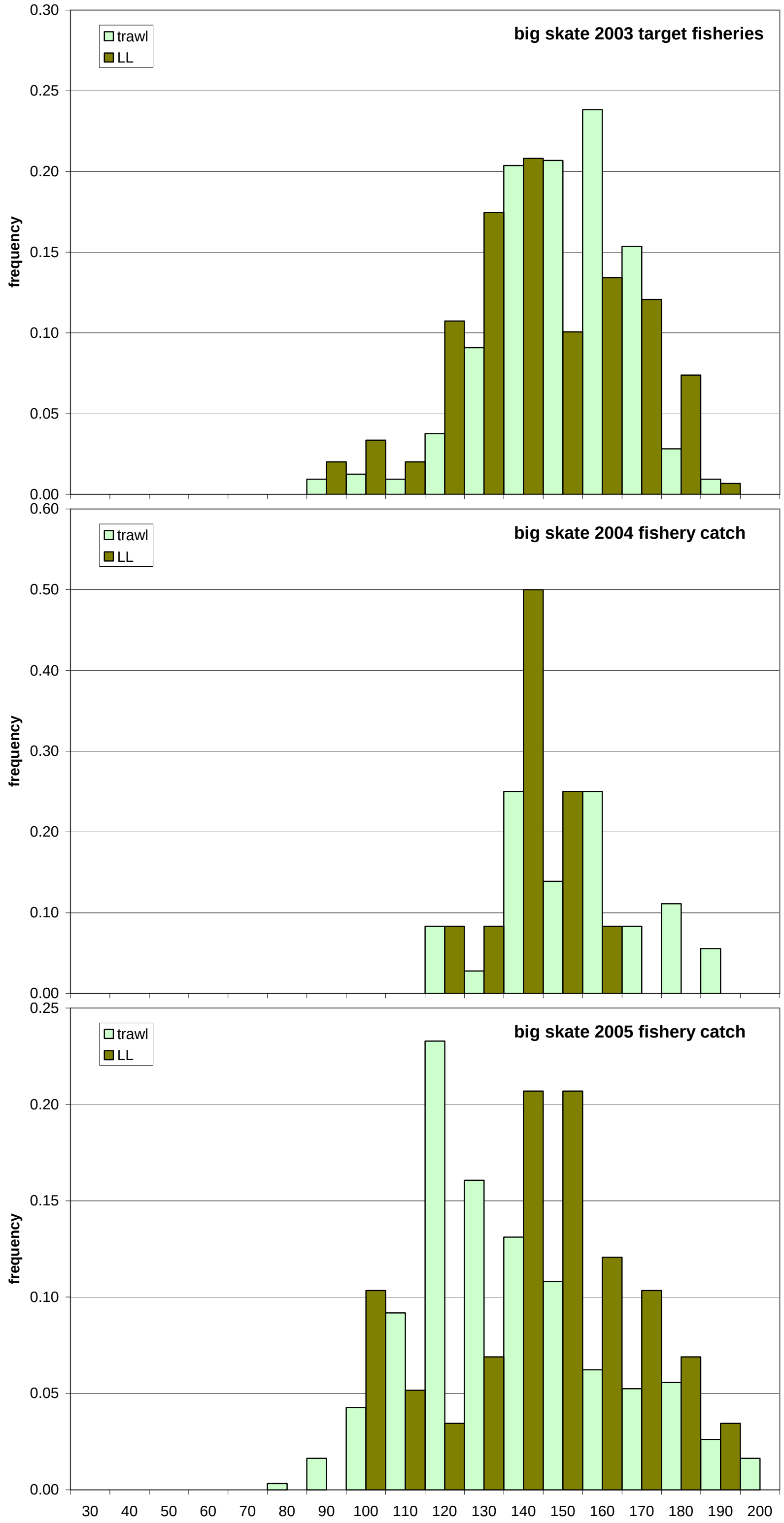


Figure 18. Big skate fishery length compositions, 2003-2005. LL = longline. 2003 *N*: trawl 319, LL 149; 2004 *N*: trawl 36, LL 12; 2005 *N*: trawl 305, LL 58.

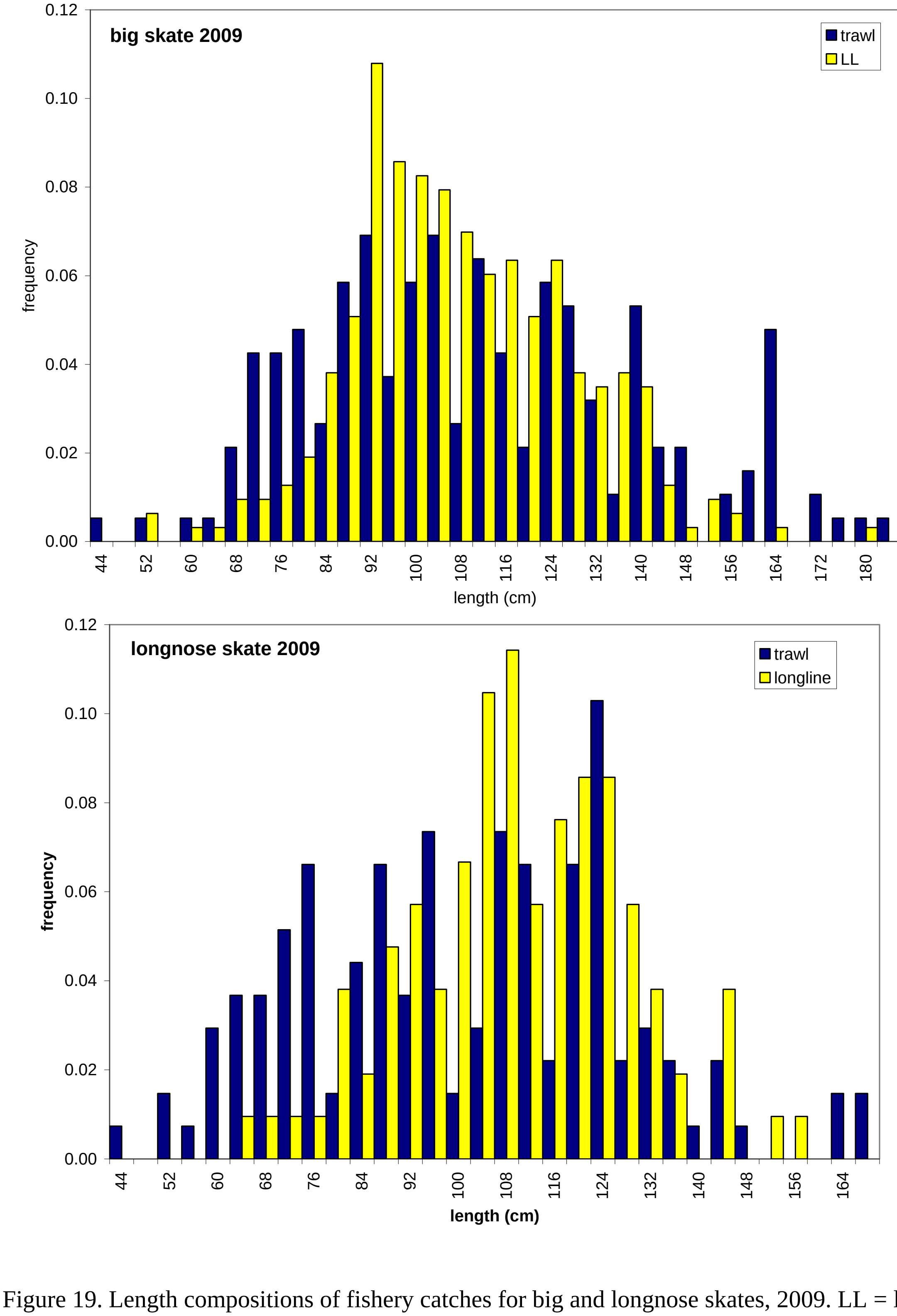


Figure 19. Length compositions of fishery catches for big and longnose skates, 2009. LL = longline. Big skate *N*: trawl 188, LL 316; longnose skate *N*: trawl 136, LL 205.

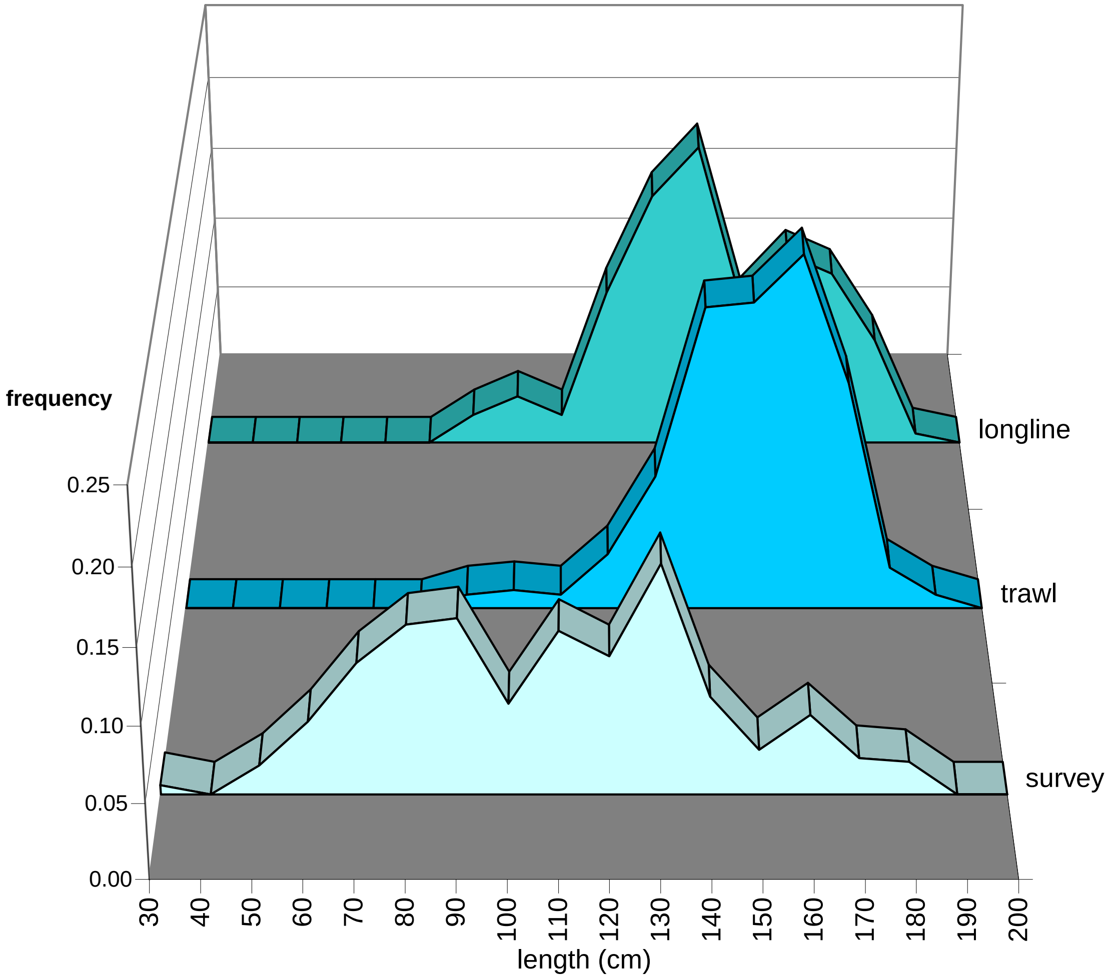


Figure 20. Comparison of big skate trawl survey and fishery length compositions in 2003.

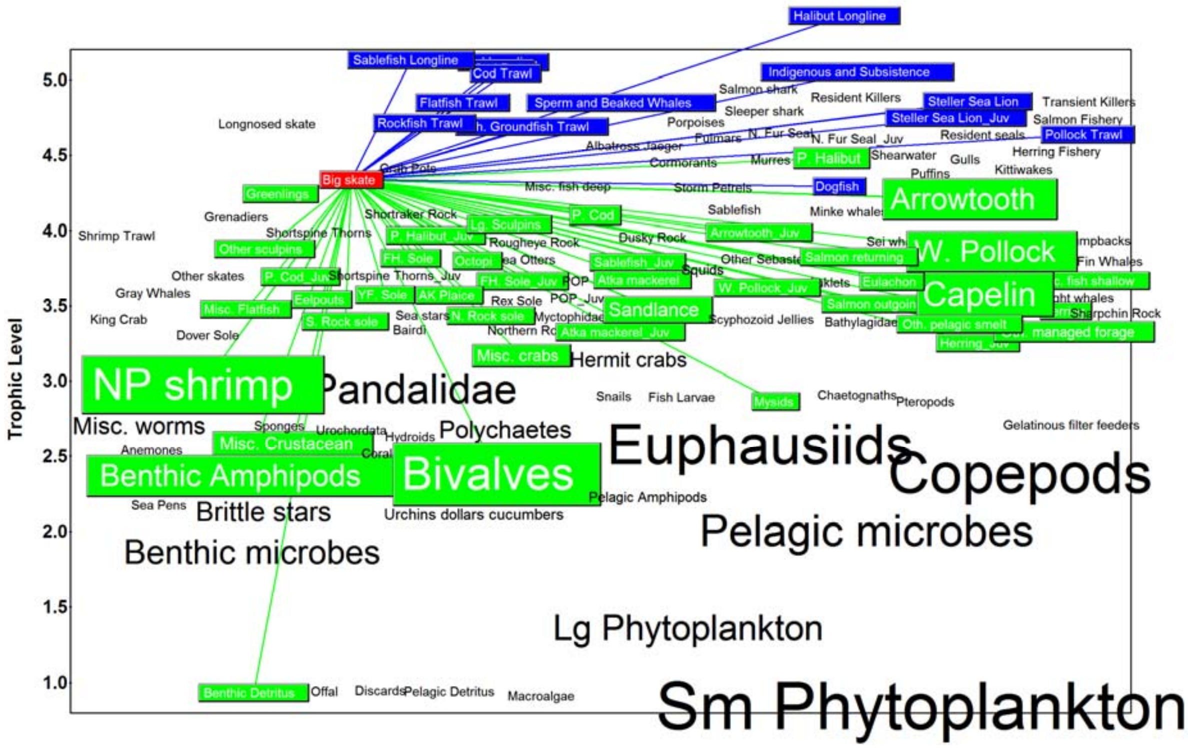


Figure 21. Food web for big skates in the GOA. (Source: K. Aydin, AFSC, code available upon request.)

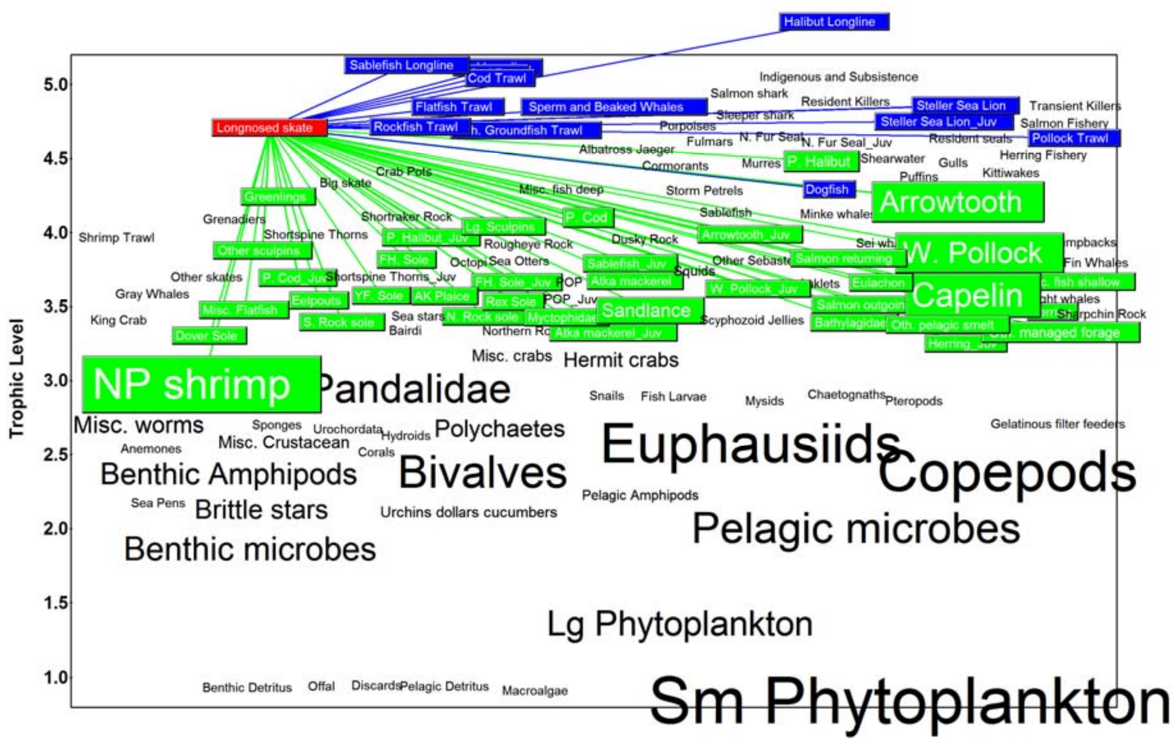


Figure 22. Food web for longnose skates in the GOA. (Source: K. Aydin, AFSC, code available upon request.)

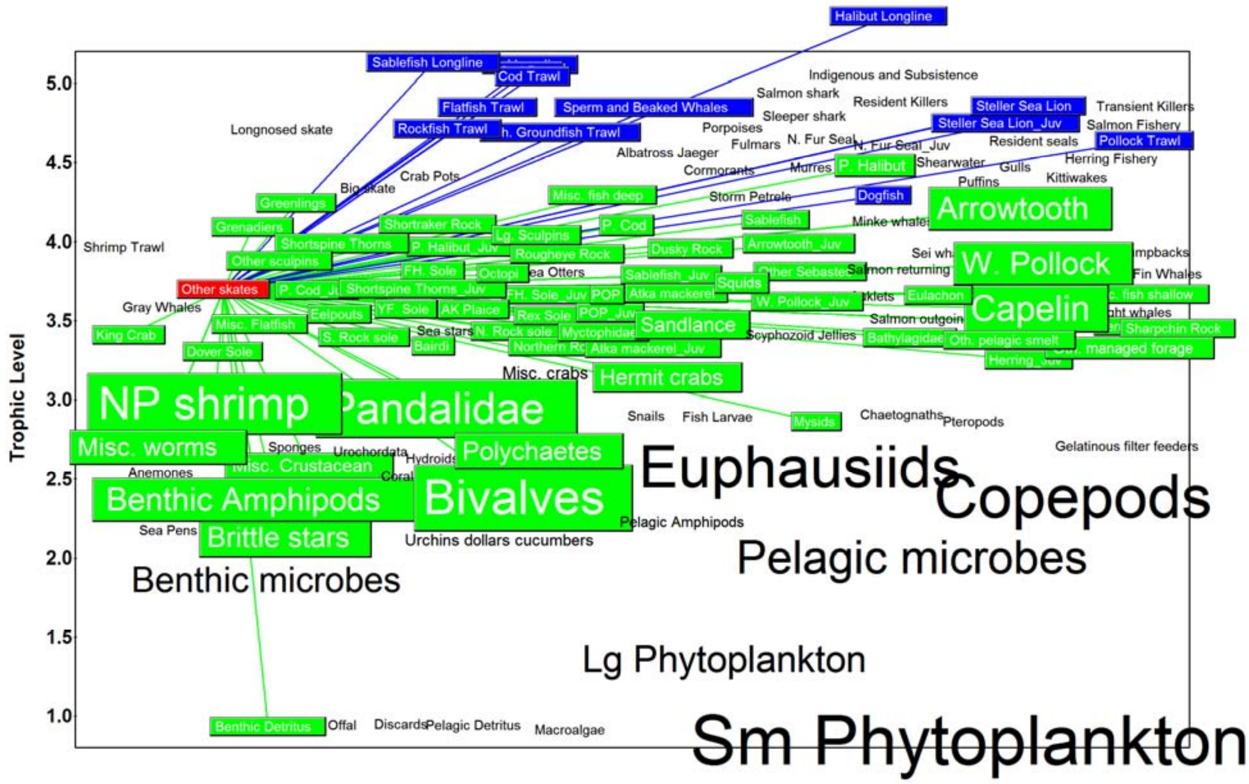


Figure 23. Food web for Other skates in the GOA. (Source: K. Aydin, AFSC, code available upon request.)

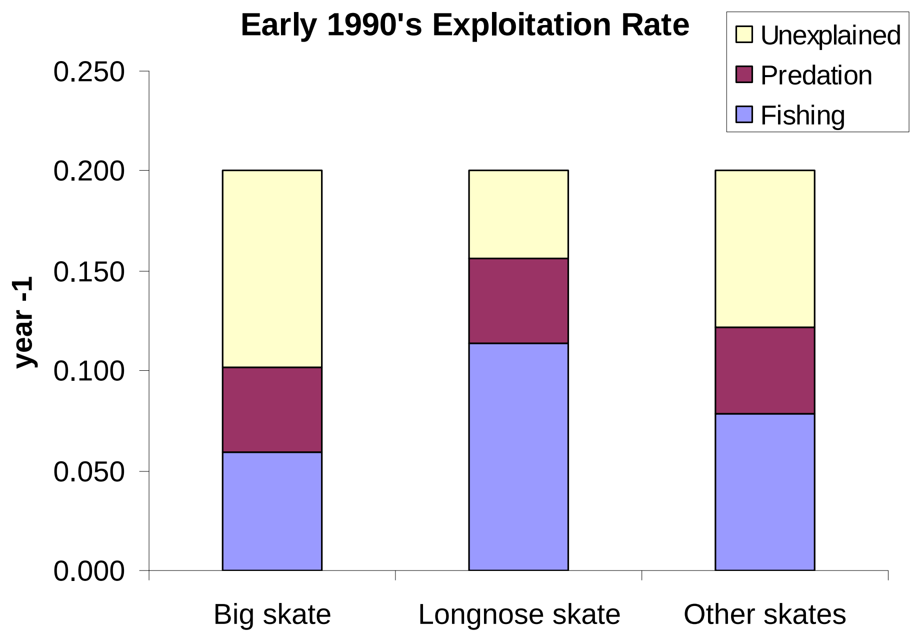


Figure 24. Mortality rates from predation and fishing for Other skates, longnose skates, and big skates in the GOA (early 1990s prior to target fishery developing for big skates). Total mortality (fishing + predation + unexplained) is assumed to equal the production rate for skate populations at equilibrium (here, 0.2 as approximated from Frisk et al. 2001). Total mortality is apportioned between estimates of predation mortality (from AFSC ecosystem modeling) and fishing mortality (exploitation rate: catch/biomass), and the remaining fraction of mortality is attributed to unknown sources.

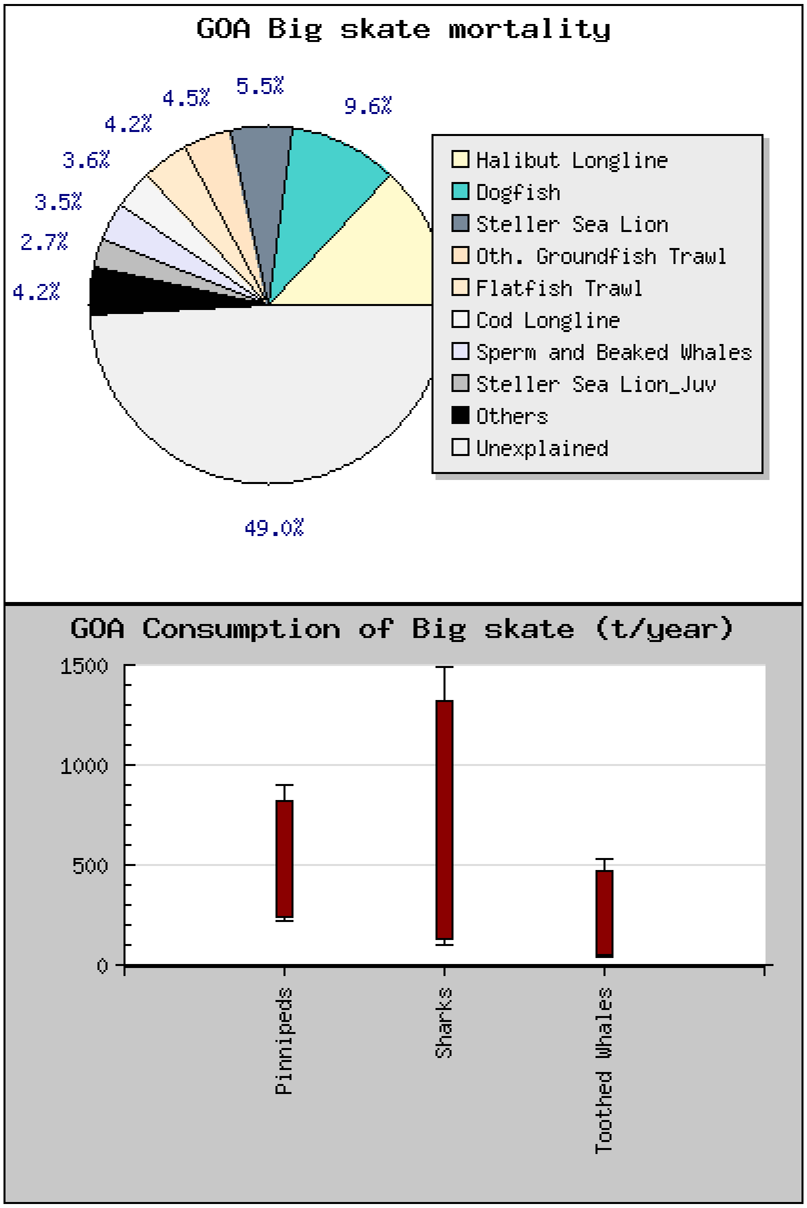


Figure 25. Mortality and consumption of big skates in the GOA. Model outputs were derived from diet compositions, production rates, and consumption rates of skate predators, and from skate catch data.

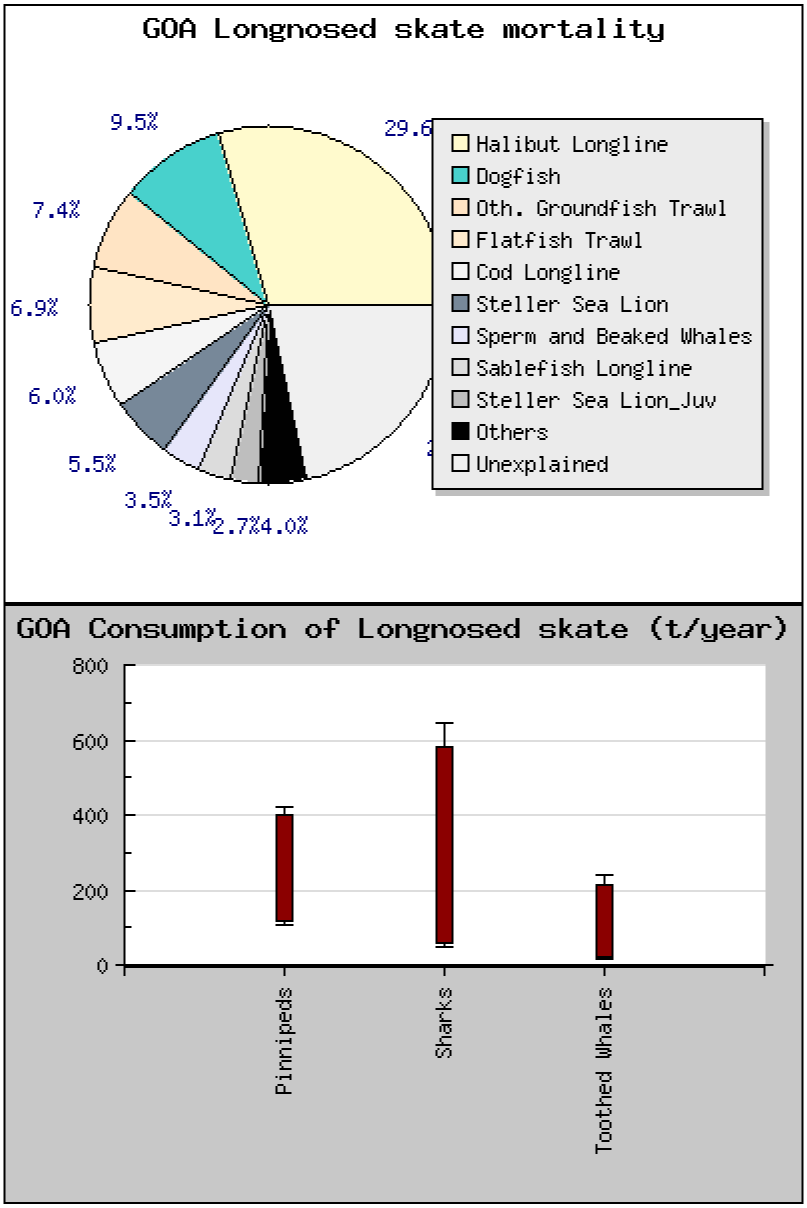


Figure 26. Mortality and consumption of longnose skates in the GOA. Model outputs were derived from diet compositions, production rates, and consumption rates of skate predators, and from skate catch data.

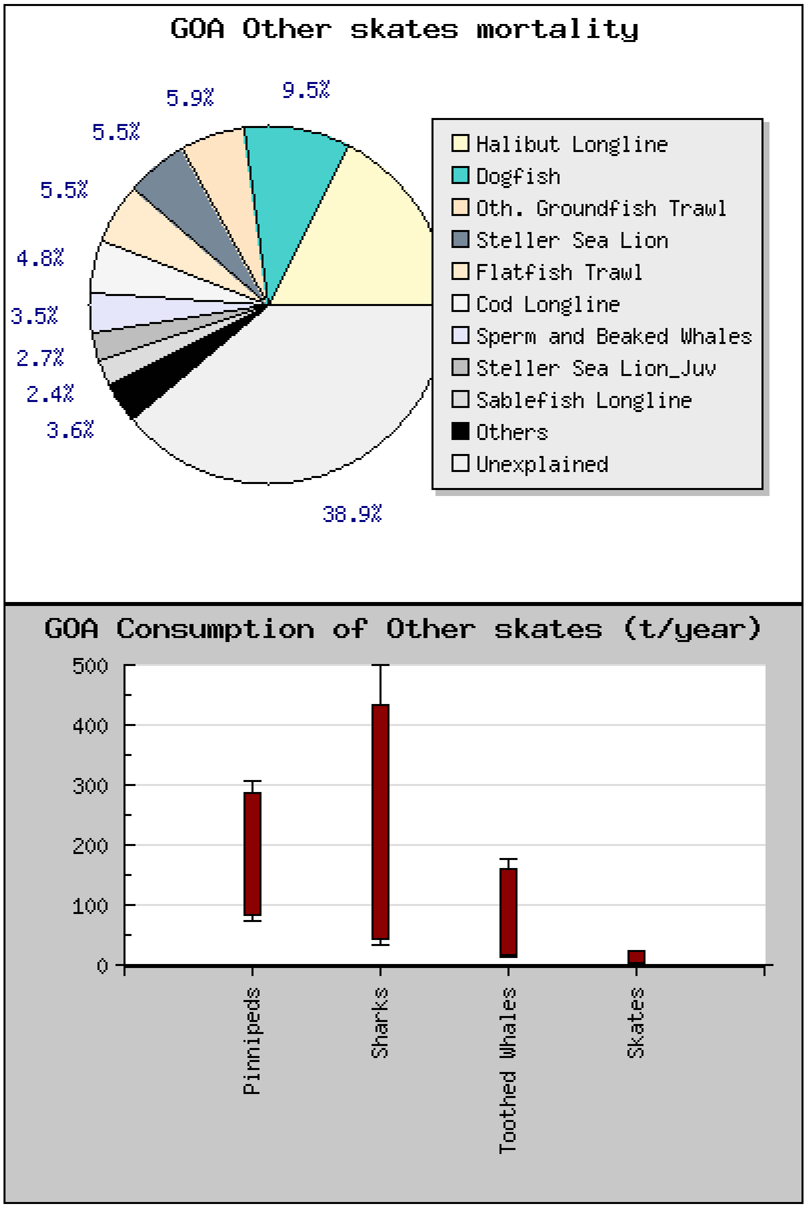


Figure 27. Mortality and consumption of Other skates in the GOA. Model outputs were derived from diet compositions, production rates, and consumption rates of skate predators, and from skate catch data.

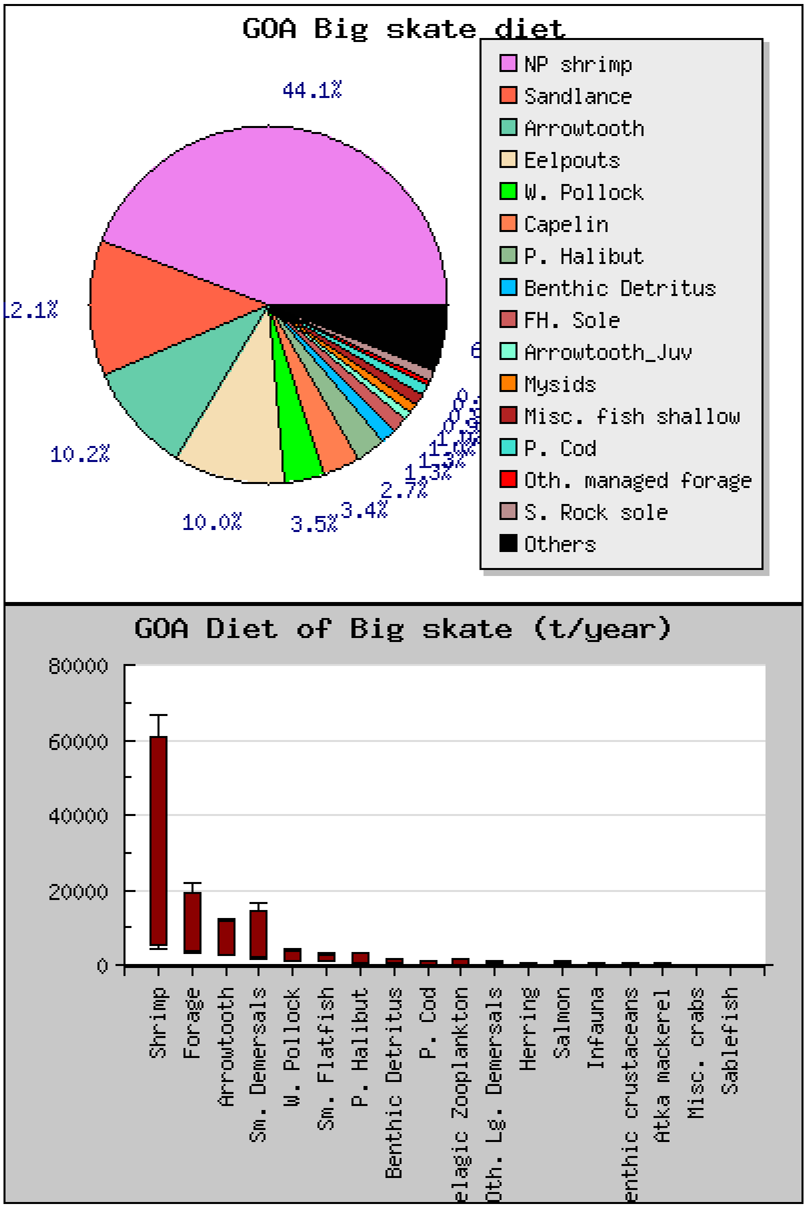


Figure 28. Diet composition and consumption of prey by big skates in the GOA. Results were generated from stomach content collections occurring during RACE trawl surveys.

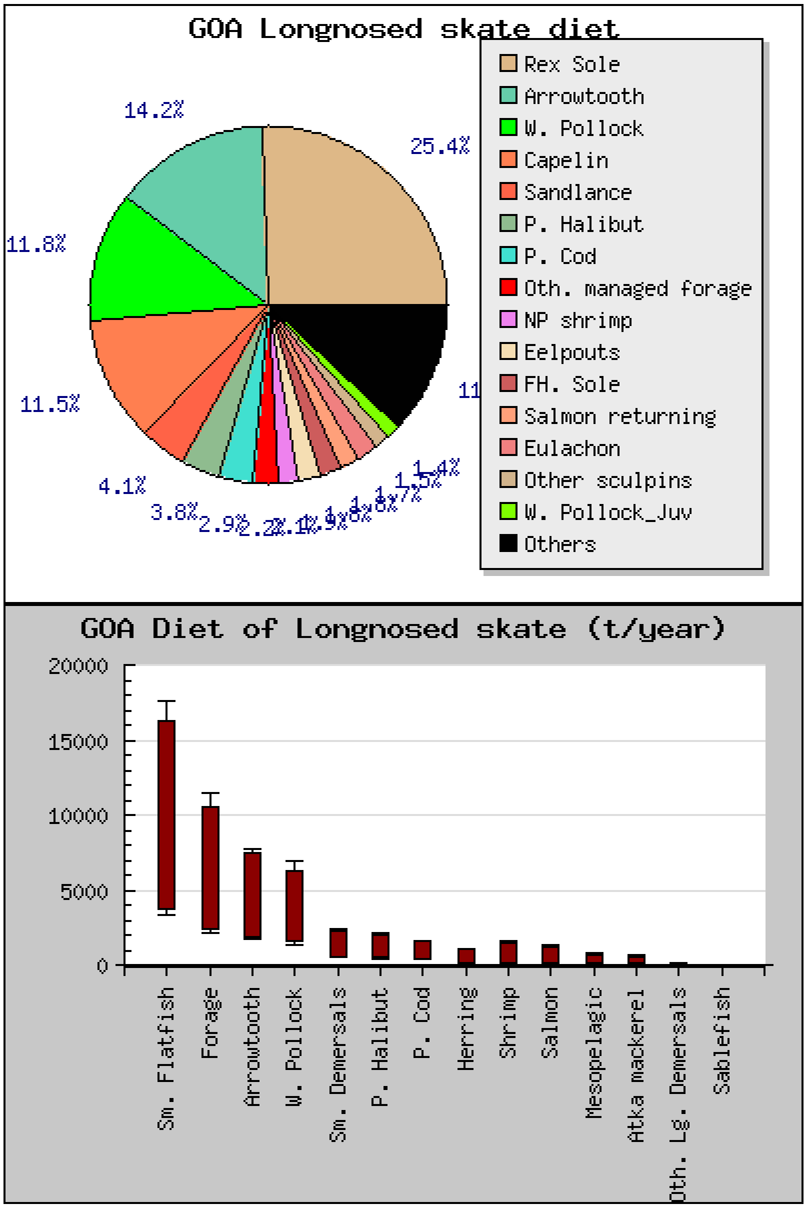


Figure 29. Diet composition and consumption of prey by longnose skates in the GOA. Results were generated from stomach content collections occurring during RACE trawl surveys.

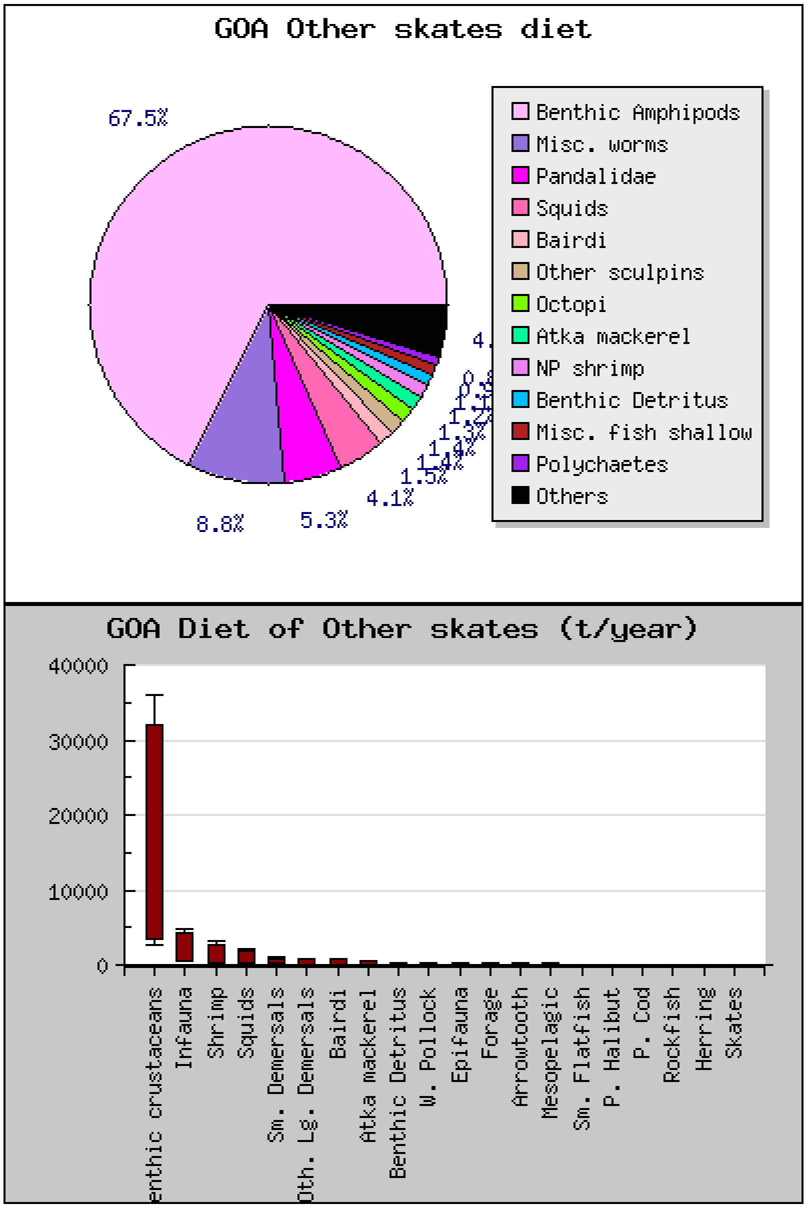


Figure 30. Diet composition and consumption of prey by Other skates in the GOA. Results were generated from stomach content collections occurring during RACE trawl surveys.