16. Gulf of Alaska Skates

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Executive Summary

Summary of Major Changes

Changes in the input data:

1. Total catch weight for GOA skates is updated with 2004 and partial 2005 data.
2. Biomass estimates from the 2005 GOA bottom trawl survey are incorporated.
3. Life history information has been updated with recent research results.
4. Information on the position of skates within the GOA ecosystem and the potential ecosystem effects of skate removals are included.

Changes in assessment methodology: There are no changes to the Tier 5 assessment methodology.

Changes in assessment results:
No directed fishing for skates in the GOA is recommended, due to high incidental catch in groundfish and halibut fisheries. Skate biomass changed between the last NMFS GOA trawl survey in 2003 and the most recent survey in 2005, which changes the Tier 5 assessment results based on survey biomass. The recommendations for 2005 based on the three most recent survey biomass estimates for skates and M=0.10 are:

		Western GOA (610)	**Central GOA (620, 630)**	**Eastern GOA (640, 650)**
Big skate	**ABC**	695	2,250	599
	OFL	927	3,001	798
Longnose skate	**ABC**	65	1,969	861
	OFL	87	2,625	1,148

***Bathyraja* skates**	**Gulfwide**
ABC	1,617
OFL	2,156

Responses to SSC Comments

SSC comments specific to the GOA Skates assessment:
From the December, 2004 SSC minutes: *The SSC is grateful to samplers with ADF&G who collected catch data and biological samples for Kodiak landings. We encourage similar sampling of Homer landings. However, the SSC reiterates its recommendation from the December 2003 minutes:*

"that no directed fishery be allowed for skates until a data collection plan is submitted by the industry and approved by the Council. The primary data collection need is the collection of accurate skate species composition data so that harvests of big skate, longnose skate, and Bathyraja-species complex can be monitored relative to their individual biomass levels. Means to collect these data could include onboard observers, video recording of longline catches (perhaps using systems similar to those developed in British Columbia), logbooks, dockside sampling, or some combination of these. Also, an ability to collect representative samples of age, weight, length, and sex data is important to characterize the fishery removals from the stocks. These recommended data-collection requirements are necessary owing to the significant portion of the skate catch that is unobserved. A directed skate fishery should be allowed only if such a data collection program is approved and provided that annual bycatch needs of other fisheries have been safely accommodated."

We agree with both the December 2004 comment and the December 2003 SSC recommendation. No directed fishery for skates is recommended in this year's assessment. However, a prohibition on directed fishing does not prevent landing and processing of incidental skate catch within the TAC, so big, longnose, and other skates continue to be captured and delivered, and obtaining basic fishery data (including catch by species) from sectors with little to no observer coverage continues to present a problem for this stock assessment.

This year, we have attempted to address this SSC recommendation with the following actions:

1. Coordinating age and growth collection and research between agencies and academic institutions
2. Requesting an observer special project to collect skate lengths in observed GOA plants
3. Requesting continuation of assistance from ADF&G port samplers in Kodiak
4. Requesting assistance from ADF&G staff in Homer

Results of preliminary age and growth investigations on big and longnose skates are reported in this assessment and coordination of data collection and research between ADF&G, NMFS, University of Washington, and Moss Landing Marine Laboratory (CA) are ongoing. Our request for an observer special project to collect skate lengths in GOA plants in 2006 has been approved. However, we realize that this does nothing to address skate deliveries to unobserved plants. Our requests for assistance with port sampling in federally unobserved plants from ADF&G port samplers in Kodiak and Homer have been graciously approved, but these port samplers cannot prioritize sampling of landings from federal waters skate fisheries without dedicated funding, and it is our understanding that there are no additional NMFS funds this year to devote to skate sampling. Unfunded port sampling will continue only as lowest priority after other ADF&G priorities have been achieved. The difference in data available for stock assessment based on availability of funds is obvious when comparing the 2004 (1 month funded) and 2005 (3 months funded) ADF&G Kodiak port sampling results in this assessment.

We assume that the SSC reiterated their 2003 comment because they, like us, continue to recognize the failure of the current federal data collection system to provide adequate stock assessment information to manage the fishery for big and longnose skates. While we are taking the steps available to us to improve this situation, this year we find that even continuing our rudimentary attempts at cooperative port sampling via ADF&G is hampered by a lack of internal funding. The SSC-recommended placement of onboard observers, video recording systems, logbooks, or port samplers to collect representative samples of catch in the unobserved portion of the skate fishery would represent an immense improvement in the data available for this assessment, and would certainly benefit any other assessments where a significant portion of catch comes from unobserved fisheries. These technologies could also assist in estimating the magnitude of skate bycatch in fisheries directed at Pacific halibut, which is more significant than originally estimated in 2003. However, it seems clear that achieving these improvements in fishery monitoring requires Council initiative and action, as well as more formal cooperation between agencies. This SSC comment cannot be further addressed within a SAFE document; we strongly agree with the recommendations and request that the SSC recommend these changes to the federal data collection system for action at the Council level.

<u>SSC comments on assessments in general:</u>
From the December, 2004 SSC minutes: *In its review of the SAFE chapter, the SSC noted that there is variation in the information presented. Several years ago, the SSC developed a list of items that should be included in the document. The SSC requests that stock assessment authors exert more effort to address each item contained in the list. Items contained in the list are considered critical to the SSC's ability to formulate advice to the Council. The SSC will review the contents of this list at its February meeting.*

This year, an Ecosystem Considerations section for GOA skates was added to the assessment. All other required SAFE sections have been addressed as information permits for GOA skates.

Introduction

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

Skates (family Rajidae) are cartilaginous fishes which are 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). Within the family Rajidae, there are two genera, *Raja* and *Bathyraja*, with 7 and 13+ species respectively in the northeast Pacific (Love et al 2005). 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. At least 15 species of skates (3 *Raja* and 12 *Bathyraja*) are found in Alaskan waters and are common from shallow inshore waters to very deep benthic habitats (Eschmeyer et al., 1983). Table 16-1 lists the species found in Alaska, some life history characteristics (which are outlined in more detail below), and the depth distribution of each skate species found in Alaska.

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 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 (see below). One deep-dwelling Raja species, the roughshoulder skate *R. badia*, ranges throughout the north Pacific from Japan to Baja California 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). Within the genus *Bathyraja*, only two of the 13+ north Pacific species are not found in Alaska. Of the remaining 11+, more are found in the Aleutian Islands and Bering sea than the Gulf of Alaska, with the exception of Aleutian, Alaska, and Bering skates. The Aleutian skate ranges throughout the north Pacific, but 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 20 to 1425 m (Love et al 2005). 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 Bering Sea to southern California (D. Stevenson and J.Orr, AFSC, pers comm., Love et al 2005).

The species within this complex 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, *Raja binoculata* (Figure 16-2). In continental shelf waters from 100-200 m depth, longnose skates *R. rhina* dominate skate biomass, and *Bathyraja* skate species are dominant in the deeper waters extending from 200 to 1000 m or more in depth. 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 16-2).

<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. Catch within this category has historically been 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 16-3). 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. Although the composition of this category has varied over the course of FMP management, the configuration of sharks, skates, sculpins, squid, and octopus 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 other species 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 despite efforts to limit directed fisheries and develop more protective management within this category. 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 (see below). The remaining species in the GOA Other species category continue to be managed under an aggregate TAC set at 5% of the sum of all target species TACs. The NPFMC has appointed a committee to address management of nontarget species and species complexes.

Skate management units have continued to evolve in 2004 and 2005 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. In 2005, big skates were managed as a single species group throughout the GOA, as were longnose skates. Furthermore, to address concerns about disproportionate harvest of skates, big skate and longnose skate TACs were managed separately for the Western, Central, and Eastern GOA. The remaining skates (in the genus *Bathyraja*) were managed as a gulfwide species complex in 2005 because they were not the targets of the fishery and they are more difficult to identify. The remaining nontarget skates in the GOA are managed as "Other skates," but we also use the term "*Bathyraja* skates" interchangeably in this assessment.

<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 *Raja batis* has been extirpated from the Irish Sea (Brander, 1981) and much of the North Sea (Walker and Hislop, 1998) and the barndoor skate *Raja laevis* has disappeared from much of its range off New England (Casey and Myers, 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 relatively information 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 *Raja 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.”

To summarize, there are clear implications for sustainable management of skates even though their populations and life histories have not been studied in as much detail as other exploited marine species. After an extensive review of population information for many elasmobranch species, Frisk et al (2001, p. 980) recommended that precautionary management be implemented especially for the conservation of large species:

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

Life history and stock structure (Alaska-specific)

Information on fecundity in North Pacific skate species is extremely limited. There are one to seven embryos per egg case in 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 BSAI skate SAFE, Gaichas et al 2005).

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 *Raja batis* and the barndoor skate *Raja 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 (Table 16-4).

Currently there is little life history information available for skate species in the eastern North Pacific, but recent research results are improving this situation. Vertebrae were collected from the Gulf of Alaska in 2003, 2004, and 2005 from commercial fisheries and during ADF&G and NMFS trawl surveys, and a method for ageing *Raja* species is in development in British Columbia, Canada (King and McFarlane 2002), as well as at the AFSC age and growth lab. Before these collections were available, the only age and growth information available was from a study completed off the U.S. West Coast which was limited to a size range of skates smaller than that observed off British Columbia (King and McFarlane 2002) or in Alaska. According to that study, Californian female big skates mature at 12 years (1.3-1.4m), and males mature at 7-8 years (1-1.1 m), but the maximum sizes estimated were only 170 cm for females and 140 cm for males (Zeiner and Wolf, 1993). Maximum size from fisheries off California is reported to be 2.4 m, with 1.8m and 90 kg common (Martin and Zorzi, 1993). The longnose skate, *Raja rhina*, achieves a smaller maximum length of about 1.4 m in California, and matures between ages 6 (males) and 9 (females). Maximum age reported for the longnose skate was 13 years, but again the maximum estimated size seemed small at 107 cm for females and 95 cm for males (Zeiner and Wolf, 1993). Preliminary results from age and growth research at AFSC suggest that maximum age for the longnose skate *Raja rhina* may be higher than that found by Zeiner and Wolf; in a sample of 127 individuals ages up to 17 years were observed (C. Gburski AFSC 2005 pers. comm.). In the same study, 146 big skates *Raja binoculata* were aged with the highest observed age being 13 years, closer to the results for California big skates. We expect to incorporate this Alaska specific longevity information within the stock assessment as soon as the study is finalized; likely in time for the next biennial GOA skate assessment in 2007.

In the 2003 assessment, we reported that there was no information on life history for any *Bathyraja* species, but considerable research has been directed at skates in both the Gulf of Alaska and the Bering Sea over the past two years. Initial age and growth investigations for the Aleutian (*B. aleutica*) and Bering (*B. interrupta*) skates from the GOA have begun at AFSC, and life history information for other species in the GOA *Bathyraja* complex are ongoing as student projects at Moss Landing Marine Labs in California. Age, growth, maturity, and nursery habitat studies of the predominant *Bathyraja* species in the Bering Sea, the Alaska skate *B. parmifera*, were initiated in 2003, and may provide information helpful to management of GOA species in the future. Preliminary results from these projects are reported in the BSAI skate SAFE (Gaichas et al. 2005), and are summarized in Table 16-1.

Fishery

Directed fishery, bycatch, and discards 2003-present

Until 2003, skates were primarily caught as bycatch in both longline and trawl fisheries directed at 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 (Other species) target fishery, even though directed fishing for cod was seasonally closed. The result was a dramatic increase in skate landings (Figure 16-3).

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. These vessels deliver skates to plants that process monthly volumes of catch that are also too low to require observer coverage. Therefore, this multispecies fishery developed (and largely continues) without the appropriate monitoring established for federal groundfish management in Alaska. In the rest of this section, we use available information to estimate both total skate catch and catch by species in the GOA for 2003 through 2005, and comment on catch estimation.

Catch estimates for skates in the GOA in 2003 are somewhat uncertain given the difficulties with the reporting system, which was not designed to report skates separately from the Other species complex at that time. In addition, the reporting system changed from the "Blend" system used from 1991 to 2002 to a new Catch Accounting System (CAS) in 2003. While this change represents a significant improvement in catch reporting overall, the transfer rendered the methods of nontarget species catch estimation used to estimate skate catch between 1997 and 2002 (see below) obsolete. Three sources were used to estimate skate catch in 2003: the ADF&G fish ticket database, NMFS groundfish observer data, and IPHC survey and fishery data. In a previous assessment (Gaichas et al 2003), we used the difference between the average catch reported on ADF&G fish tickets by area 1997-2002 and the catch reported for 2003, to approximate the catch in the new target skate fishery. This method suggested that a total of 2,629 t of skates were taken in the directed fishery, with 2,498 t (95%) coming from the Central GOA. We also attempted to distinguish 2003 directed skate catch from skate catch landed as bycatch by using information on Maximum Retainable Allowances (MRAs) contained in fish tickets. We assumed that those fish tickets where skates were over the MRA of 20% could be considered the directed skate fishery, whereas those listed in the Pacific cod target with retention of skates at 20% or less of cod catch could be considered landed bycatch of skates. Gulfwide target fishery skate catch estimated by this method was 2,743 t, very similar to that estimated by the alternative method above. These estimates of catch from the ADF&G fish ticket database likely underestimate total catch as this method probably underestimates at-sea discards.

The distinction between skate species was not recorded on fish tickets, especially because there were not species codes for one of the major species landed in the fishery (big skates) until 2005. However, there was some evidence for preferential retention of *Raja* species and at sea discard of *Bathyraja* species if they could be distinguished (Rob Swanson, July 2003 skipper and crew interviews dockside in Kodiak). Species composition of landed skate catch comes from dockside sampling by ADF&G and NMFS staff in Kodiak. The early fishery in February and March was sampled by ADF&G port samplers. Based on this sampling, the directed skate fishery was landing approximately 79% big skates (of which 78% were female), and 21% longnose skates (which were 52% female). Sampling later in the year by NMFS staff in

Kodiak resulted in similar, if not more extreme species and sex compositions. Sampling indicated that 95% of hook and line landings and 92% of trawl landings were big skates (of which 80% and 90% were female, respectively). Longnose skates composed 4 and 6% of hook and line and trawl landings, respectively, and landings for this species were 53% and 35% female by gear type. It seems clear from these samples that the directed skate fishery seeks large individuals, which are predominantly female big skates. Size sampling of the delivered hook and line catches in conjunction with two at sea observer samples of trawl skate catch appears to corroborate this conclusion (see Figure 14). Applying the species compositions estimated from dockside sampling to an approximate estimate of 2,700 t total skate catch in the 2003 directed fishery (see above), directed catch of big skates in 2003 would be between 2,160 t (80%) and 2,430 t (90% of catch), catch of longnose skates would be between 135 and 340 t, and *Bathyraja* species catch would be the remainder, up to 135 tons. The Catch Accounting System estimated that an additional 1,325 t of skates were caught incidentally in 2003 groundfish fisheries, for a total skate catch estimate of 4,025 t (Table 16-3).

Skate catch in the target fishery dropped off considerably in 2004 and 2005 (Figures 16-4 and 16-5, Table 16-3), reportedly due to changed market conditions (lower ex-vessel prices); however at least one participant in the 2003 fishery also reported a substantial drop in CPUE when attempting to target skates in 2004 (T. Pearson, NMFS AKRO, pers comm.). It is still difficult to estimate what proportion of skate catch was taken in target fisheries versus as bycatch, but some distinction by species is now possible because species codes for big and longnose skates were created. In 2004, catch of 1,527 t of combined big and longnose skates for the Central GOA were reported in the catch accounting system. The remaining skate species from the CGOA plus all skate species in the rest of the GOA amounted to 1,399 t, for a total skate catch of 2,926 t. Port sampling was extremely limited in 2004 due to lack of funding, so only 134 skates were identified and measured during that year. Based on this small sample, we estimate that 87% by weight of the Central GOA big and longnose catch was big skates, and the remaining 13% was longnose skates. Therefore, the catch in the Central GOA was estimated to be 1,323 t big skate and 204 t longnose skate. Because port sampling was only conducted in the CGOA (Kodiak), we cannot determine the species composition of the remaining 1,399 t of skates caught in the GOA in 2004 unless we assume it reflects historical patterns of bycatch (see below).

In 2005, separate species codes and reporting for big and longnose skates were implemented Gulfwide to support the area specific TACs for the Western, Central, and Eastern GOA (Table 16-3). The catches to date (as of October 21, 2005) reported in the CAS total to 845 t big skates, 1,093 t longnose skates, and 657 t other skates Gulfwide (area breakdowns are reported in Table 16-3). However, the 2005 species composition from port sampled skate catch in the Kodiak area indicated a predominance of big skates in the catch not reflected in the official catch estimates for the CGOA. Port sampling was conducted for three months in 2005, triple the effort funded in 2004, so that a total of 832 skates were identified to species and measured for length. Port sampled skate landings were 65% big skates by weight, 31% longnose, and 5% all other skates combined. The reason for the discrepancy between the species composition from port sampling and that from the CAS which suggests 33% big skates, 42% longnose skates, and 25% other skates Gulfwide appears to be the erroneous use of species codes for reporting catch on fish tickets. For the 19 sampled landings where both port sampled species compositions and fish ticket information were available, 15 of 19 fish tickets reported all retained skates as longnose skates (despite the fact that the majority of these catches were of big skates), and all discarded skates as unidentified skates. The remaining 4 fish tickets that did report retained catch of big and longnose skates accurately always reported discarded catch as unidentified skates, regardless of the composition of discarded skates. Given that the species code for big skates, 702, is a new species code for 2005 and the code for longnose skates, 701, was the only code to identify skates in the past (aside from 700 for unidentified skates), this mistaken reporting is not surprising. However, it is important that catch and discard be reported accurately by species for proper inseason management and assessment of skates. There is no way to validate the skate species reported on fish tickets without continued port sampling.

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 2004 are for the Other species complex in the GOA. In this section, we outline several methods for estimating historical skate catch prior to the development of the skate fishery in 2003.

Incidental catch of skates (all species in aggregate) in federal groundfish fisheries between 1997-2002 (Table 16-5) was estimated as follows (this is the same method which has been used to estimate catch of all nontarget species in both the GOA and the BSAI). Because annual nontarget species catches are either reported in aggregate in the official Blend catch database or are not reported at all, catches by species group or individual species must be estimated using data reported by fishery observers. Catches for all non-target species were estimated at the lowest practical taxonomic level for the recent domestic fishery, 1997 - 2002, by simulating the Regional Office's blend catch estimation system as follows. Target fisheries were assigned to each vessel / gear / management area / week combination based upon retained catch of allocated species, according to the same algorithm used by the Regional Office. Observed catches of other species (as well as forage and non-specified species) were then summed for each year by target fishery, gear type, and management area. The ratio of observed other species group catch to observed target species catch was multiplied by the blend-estimated target species catch within that area, gear, and target fishery.

Estimation of individual species catches within the other species complex depends on the level of identification of those species in the catch. Skates were almost always recorded as "skate unidentified", with very few exceptions between 1990 and 2002. At that time, Observers were instructed to devote resources to higher-priority target species and prohibited species data collection. However, the Observer Program initiated a skate species identification special project in 2003 (Stevenson 2004). Based on the success of this project, all observers have been instructed to identify skates to species since 2004. This represents a major improvement to data available for stock assessment.

The accuracy of catch estimates for groups or species within the other species complex also depends on the level of observer coverage in a given fishery (no observers, no catch estimates). Observer coverage requirements are based upon vessel size, such that vessels greater than 125 ft in length carry an observer on all fishing days, vessels 60-125 ft in length carry an observer for 30% of fishing days, and vessels under 60 ft in length are not required to carry observers. In general, larger vessels fish in the Bering Sea, so observer coverage levels in some Bering sea fisheries approach 100%. Our calculations for 1997-2001 suggest that the BSAI region has approximately 70-80% observer coverage overall. Due to the size distribution of vessels fishing in the Gulf of Alaska, approximately 20-25% of groundfish fishery operations (not including Pacific halibut) are observed. Some GOA target fisheries (ie. rockfish) are prosecuted on larger vessels with 100% observer coverage. Therefore, in making these catch estimates, we are assuming that other species catch in general and skate catch aboard observed vessels is representative of other species catch aboard unobserved vessels throughout Alaska. Because observer assignment to vessels in the 30% coverage class is nonrandom, there is a possibility that this assumption is incorrect.

Spatial estimation of species specific skate bycatch and discards in groundfish fisheries, 1997-2002

The observed catch and landings of skates have shown consistent spatial patterns between 1997 and 2002, suggesting that skates are associated with certain areas and or habitats in the GOA and may be found there predictably, especially since there was little to no targeting of skates in those years. The overall implication of skate bycatch maps shown in the 2003 assessment (Gaichas et al 2003) is that skate catch has occurred consistently in “hotspots.” This suggests that the species distributions may be constant over time and space and that survey distributions might be useful to predict fishery catch by species. This also implies that catch is concentrated in space, so the potential for localized depletion is high. While the degree of mixing among these areas is unknown, it seems prudent to have management measures that sustain these concentrations until more is known about stock structure.

Although there are no direct estimates of skate bycatch by species in any fisheries 1997-2002, aggregated skate catch can be proportioned to species by fishery using spatial information combined with survey estimates, as follows (a full discussion of survey information is found below, under “Resource surveys”). Observed hauls with skate catch were assigned to GOA trawl survey strata according to the latitude and longitude of trawl haul or fixed gear set retrieval. Then, all catch that was identified as “skate unidentified” was proportioned to species using the average (1999-2003 surveys) skate species proportions for that survey strata. These survey years were selected because we are most confident in skate species identification for surveys conducted since 1999, and because survey distributions up to 2003 presumably did not reflect any targeting of skates by the fishery. Skate species composition estimates for survey strata in the Western and Central GOA down to 500 m depth were based on three surveys (1999, 2001, and 2003), while the Eastern GOA and strata deeper than 500 m were based only on the 1999 and 2003 surveys. The total skate catch estimates reported by gear and area in Table 16-5 were apportioned to species by the skate species composition estimated for the observed skate catch by survey strata. This method assumes that skate species composition by survey strata has remained constant over the late 1990s, that summer survey distributions are representative of skate species distributions throughout the year, and that observed skate catch is representative of unobserved skate catch by gear type and area. The resulting catch estimates by skate species should be considered rough approximations subject to numerous assumptions, but nevertheless are the best available information on skate catch by species (Table 16-6). This estimation method suggests that approximately 44% of historical GOA skate bycatch on average has been longnose skates, about 26% has been big skates, and the remaining 30% has been *Bathyraja* species.

Bycatch and discards of skates in halibut fisheries, 1997-2004

In 2003, the NPFMC requested that this assessment account for skate bycatch in directed Pacific halibut fisheries. There is no observation of these fisheries at sea, so the IPHC provided estimates of skate bycatch in the fisheries based on skate bycatch observed during IPHC longline surveys for halibut (Table 16-7). Figure 16-6 shows how IPHC areas correspond to NPFMC management areas. In general, it appears that directed fisheries for Pacific halibut take a substantial amount of skates annually as bycatch, on the order of 5,000 metric tons or more per year in the GOA. Steps should be taken to quantify this bycatch to species, as it is more than double the magnitude of groundfish skate bycatch (shown in Table 16-5). The species composition of skate bycatch in halibut fisheries is also unknown, but if it is similar to survey species compositions it can be estimated similarly to total skate bycatch. In 2004, IPHC surveys used the same skate identification key used in NMFS groundfish surveys, so species composition was estimated from the 2004 survey and extrapolated to the 2004 skate bycatch estimates (Table 16-8).

Fishery summary

Skates are caught incidentally by groundfish and halibut fisheries in the GOA, and since 2003 increased market prices for skates have both triggered a directed fishery for skates and have increased retention and deliveries of incidentally caught skates. While all of the catch estimates were derived from different sources and have some uncertainties associated with them, they represent the best available information on skate removals by fisheries in the Gulf of Alaska. Combining information sources (Table 16-9) suggests that skate catch in the Gulf of Alaska from all sources ranges from 6,000 to 10,000 or more tons annually, and perhaps has increased in recent years. Limited species composition sampling information suggests that historical incidental catch in both groundfish and halibut fisheries has been dominated by longnose skates, and port sampling indicates that the proportion of big skates in the catch has increased since the target fishery began in 2003.

Survey Data

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. Unfortunately, the sablefish longline survey conducted by the NMFS Auke Bay lab does not identify skates to species at present and is therefore of limited use for stock assessment. 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 1984-2005 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. Preliminary work on skate escapement under bottom trawl footropes was initiated this year in the EBS, and results should be available soon to evaluate the assumptions about survey catchability for skates (here assumed to equal 1).

Survey trends by species between 1984 and 2005 are displayed in Figure 16-7 for the entire GOA. A breakdown of biomass estimates for the Eastern (management areas 640-650), Central (620-630) and Western (610) GOA for 1984-2005 are given in Table 16-10. 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. *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 16-8). 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, see the BSAI Other species SAFE.

Skate species composition also differs by area, as has been found in the North Sea (Walker and Hislop 1998). Figure 16-8 compares the Gulfwide skate biomass by species with species compositions specific to the Western, Central, and Eastern GOA from the 2005 GOA bottom trawl survey. We note that the center of abundance for big and longnose skates is in the Central GOA, with somewhat lower biomass estimated for the Eastern GOA and much lower biomass for the Western GOA (Table 16-10). *Bathyraja* species abundance increases from East to West in the GOA. The Central GOA is not only the center of skate abundance, but also diversity according to the 2005 survey. However, we note that the species compostion shifted in all areas between 2003 and 2005, with more dominance of longnose skates in each area, and proportionally lower big skates throughout the GOA (Figure 16-8 compared with 16-9).

Figure 16-10 illustrates survey size compositions for big skates *Raja binoculata* from GOA bottom trawl surveys 1999-2005. It is apparent that female big skates attain much larger sizes (190-200 cm) than males of the same species (150-160 cm). Figure 16-11 compares the big skate length frequency from the 2003 summer trawl survey with some limited data collected during the same time period from skate fisheries. It is apparent that both longline catches and trawl catches of big skate were disproportionately of large animals, and were dominated by large females as data presented above for the target fishery suggested. This pattern remained in fishery length samples from 2004 and 2005 (Figure 16-12), although trawl fishery catch in 2005 appears to have captured smaller skates. This could reflect either retention and delivery of incidentally caught skates, or less availability of larger skates to the fishery, or both.

Analytic Approach, Model Evaluation, and Results

At present, the available data do not support population modeling for skates in the GOA, so none of these stock assessment sections are relevant, except for one:

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 (Table 16-4). 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, *Raja batis* and *R. 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 natural mortality (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. We expect the results of AFSC big and longnose skate ageing to be available for use in the 2007 assessment.

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 16-11).

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 are also the biomass dominant skate species 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.

Projections and Harvest Alternatives

Acceptable Biological Catch and Overfishing Limit

While it appears that historical incidental catch of skates in groundfish and halibut fisheries did not represent heavy fishing pressure (stable to increasing survey trends between 1984-2003 support this assertion), the incidental catch combined with a directed skate fishery targeting the largest individuals of the largest species might result in excessive fishing mortality and negative population effects if improperly managed. We note that of all GOA skate species, big skate biomass was the only one not to remain stable or increase in the 2005 survey results. However, it is difficult to determine if the observed decline in big skate survey biomass is directly attributable to increased fishery catch of large adult females since 2003. The spatial concentration of the directed fishery in particular suggests that management should guard against localized depletion of skates, especially when little is known of migratory habits or population structure for any Alaskan skate species.

We recommend the following management measures be applied to GOA skates in 2006:

- Continued individual species ABC and OFL for the two current target species of the skate fishery, the big skate (*Raja binoculata*) and the longnose skate (*Raja rhina*).
- Area specific ABC and OFL for *Raja binoculata* and *Raja rhina.* These species display sensitive life history traits (large size, late maturity, and low fecundity), and the directed fishery is extremely localized, so management measures should follow suit to the extent possible.
- Continued genus level ABC and OFL (Gulfwide) for the *Bathyraja* species complex pending the collection of further information. These species are not yet the targets of directed fishing.

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 three GOA trawl surveys in 2001, 2003 and 2005. Tier 5 is recommended because a reliable estimate of biomass exists for big, longnose, and the *Bathyraja* complex, and the M =0.10 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. Tier 6 is not recommended because the catch history for skates is not considered reliable (reported as "Other"), and average catch for untargeted species is likely to constrain target fisheries if used to specify harvest limits.

		Western GOA (610)	Central GOA (620, 630)	Eastern GOA (640, 650)
Big skate	**ABC**	695	2,250	599
	OFL	927	3,001	798
Longnose skate	**ABC**	65	1,969	861
	OFL	87	2,625	1,148

***Bathyraja* skates**	**Gulfwide**
ABC	1,617
OFL	2,156

Given the updated information suggesting that bycatch of skates in Pacific halibut fisheries may be more than double that estimated in groundfish fisheries prior to 2003, we recommend that direct observation of these fisheries be initiated to monitor this substantial bycatch. The combination of incidental catch in groundfish and halibut fisheries appears to be enough to take the entire allowable catch of big, longnose, and other skates in the GOA, and possibly to exceed 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 16-1). 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 16-13, 16-14, and 16-15). 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 16-2), where they feed on both pelagic and demersal fish and bivalves, benthic amphipods and other benthic crustaceans, and even some benthic detritus (Figure 16-13). Longnose skates are distributed throughout all depths, but are dominant in deeper continental shelf habitats from 100-200 m depth (Figure 16-2), and feed almost exclusively on fish above trophic level 3 as well as non-pandalid (NP) shrimp (Figure 16-14). Other skates are also found in all depth ranges, but are dominant in depths greater than 200 m (Figure 16-2) 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 16-15). 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 in review).

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 16-16 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 1990’s 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 16-17, 16-18, and 16-19), so a full range of incidental fishing effects were 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, Gaichas et al 2005). Therefore, the information presented on skate mortality sources in Figures 16-17, 16-18 and 16-19 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 1990's (Table 16-3), and limited information suggests that halibut fisheries removed up to another 5,000 + tons per year. 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 16-17). 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 16-17). 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 16.-8), 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 16.-8). 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 16-19). 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 the 2007 assessment.

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 16-20). 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 16-20). 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 16-21). 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 16-22). 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 both 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.

Data gaps and research priorities

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

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 1960's, 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

Summary

2006 and 2007 Recommendations	WGOA big skates	CGOA big skates	EGOA big skates	WGOA longnose skates	CGOA longnose skates	EGOA longnose skates	Gulfwide Other skates
M	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Tier	5	5	5	5	5	5	5
Biomass	9,273	30,005	7,982	868	26,255	11,478	21,564
F OFL	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Max F ABC	0.075	0.075	0.075	0.075	0.075	0.075	0.075
Recommended F ABC	0.075	0.075	0.075	0.075	0.075	0.075	0.075
OFL	0	0	0	0	0	0	0
Max ABC	0	0	0	0	0	0	0
Recommended ABC	0	0	0	0	0	0	0

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- The AFSC Age and Growth group has taken on the additional task of developing ageing methods for skate vertebrae and will be providing final age and growth estimates for big and longnose skates in the 2007 assessment.

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Tables

Table 16-1. Life history and depth distribution information available for BSAI and GOA skate species, from Stevenson (2004) unless otherwise noted.

Species	Common	Max Length (cm)	Highest Observed Age	Age Mature, Length Mature[2]	Feeding mode[3]	N embryos / egg case[1]	Depth range (m)	Natural Mortality estimate[6]
Bathyraja abyssicola	deepsea skate	140	?	?	?	?	362-2940	0.10
Bathyraja aleutica	Aleutian skate	150	14[8]	?	predatory	1	29-950	0.10
Bathyraja interrupta	Bering skate (complex?)	80	19[8]	?	benthophagic	1	37-1372	0.10
Bathyraja lindberghi	Commander skate	93	?	?	?	1	160-1193	0.10
Bathyraja maculata	whiteblotched skate	120	?	?	predatory	1	84-1193	0.10
Bathyraja mariposa[4]	butterfly skate	76	?	?	?	1	90-448	0.10
Bathyraja minispinosa	whitebrow skate	82	?	?	benthophagic	1	160-1420	0.10
Bathyraja parmifera	Alaska skate	113 (M) 122 (F)[7]	17 (M) 19 (F)[7]	94 cm (F) 90 cm (M)[7]	predatory	1	17-600	0.10
Bathyraja sp, cf parmifera	"Leopard" parmifera	133 (M) 139 (F)	?	?	predatory	?	48-251	0.10
Bathyraja tanaretzi	mud skate	70	?	?	?	1	58-1054	0.10
Bathyraja trachura	black skate	85	?	?	?	1	213-1504	0.10
Bathyraja violacea	Okhotsk skate	73	?	?	benthophagic	1	47-520	0.10
Raja badia	roughshoulder skate	98	?	?	?	?	1280-2322	0.10
Raja binoculata	big skate	244	13[8]	8-12 yrs, 109-130 cm	predatory[9]	1-7	16-800	0.10
Raja rhina	longnose skate	180	17[8]	7-10 yrs, 74-100 cm	predatory[9]	1	25-675[5]	0.10

[1]Eschemeyer, 1983. [2]Zeiner and Wolf, 1993. [3]Orlov, 1998 & 1999 (benthophagic eats mainly amphipods, worms. Predatory diet primarily fish, cephalopods). [4]Stevenson et al 2004. [5]Allen and Smith, 1988. [6]Gaichas et al, 1999. [7]Preliminary results from Matta, 2005, unpublished data. [8]Gburski (AFSC), pers omm.. [9]Wakefield 1984.

Table 16-2. Biomass of skate species from recent complete GOA bottom trawl surveys, 1999-2005.

GOA skates Gulfwide survey biomass (t)		**1999**	**2003**	**2005**
big skate	*Raja binoculata*	54,650	55,397	39,320
longnose skate	*R. rhina*	39,333	39,603	41,449
Aleutian skate	*Bathyraja aleutica*	11,293	15,813	24,253
Bering skate	*B. interrupta*	3,818	3,701	4,337
Alaska skate	*B. parmifera*	1,569	1,908	700
whiteblotched skate	*B. maculata*	1,469	264	502
roughtail skate	*B. trachura*	677	0	139
skate unident.	*Rajidae*	74	37	129
whitebrow skate	*B. minispinosa*	0	52	0
mud skate	*B. taranetzi*	46	0	0

Table 16-3. Time series of ABC, TAC, and catch for GOA other species, with estimated skate catch.

Year	ABC	TAC	Other species catch*	Estimated Skate catch*	Management method
1992	N/A	13,432	12,313	1,835	Other species TAC (included Atka)
1993	N/A	14,602	6,867	3,882	Other species TAC (included Atka)
1994	N/A	14,505	2,721	1,770	Other species TAC
1995	N/A	13,308	3,421	1,273	Other species TAC
1996	N/A	12,390	4,480	1,868	Other species TAC
1997	N/A	13,470	5,439	3,120	Other species TAC
1998	N/A	15,570	3,748	4,476	Other species TAC
1999	N/A	14,600	3,858	2,000	Other species TAC
2000	N/A	14,215	5,649	3,238	Other species TAC
2001	N/A	13,619	4,801	1,828	Other species TAC
2002	N/A	11,330	3,748	6,484	Other species TAC
2003	N/A	11,260	6,371	4,025	Other species TAC
2004	4,435	3,284		1,527	Big/Longnose CGOA
	3,709	3,709		1,399	Other skates Gulfwide + Big/Longnose W/E
2005	727 / 2,463 / 809	727 / 2,463 / 809		26 / 759 / 60**	Big W/C/E
	66 / 1,972 / 780	66 / 1,972 / 780		15 / 944 / 134**	Longnose W/C/E
	1,327	1,327		657**	Other skates Gulfwide

*Does not include catch of skates in Pacific halibut fisheries
**2005 catches estimated as of October 21, 2005

Sources: ABC, 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 16-5 in this assessment). Estimated skate catch 2003-2005 from AKRO Catch Accounting System (CAS). Port sampling indicates that more of the catch in 2005 is 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 16-6 for additional estimated skate catch from Pacific halibut fisheries.

Table 16-4. Length at maturity (mm) for each species equals max length times 0.71 plus 5.17 and the regression r squared was 0.89 (Frisk et al 2001). Max length (mm) is reported from NMFS GOA bottom trawl survey sampling between 1999 and 2005 (the years of best species identification).

GOA skates		Max length (mm) from GOA trawl survey				Max	Frisk et al
		1999	2001	2003	2005	observed	L maturity
Alaska skate	*B. parmifera*	1270	1350	1290	1000	1350	964
Aleutian skate	*B aleutica*	1490	1500	1450	1540	1540	1099
Bering skate	*B. interrupta*	860	840	840	830	860	616
big skate	*R. binoculata*	1890	1920	1870	1800	1920	1368
longnose skate	*R. rhina*	1800	1670	1550	1490	1800	1283
whiteblotched skate	*B. maculata*			1210	1140	1210	864

Table 16-5. Estimated total weight (tons) of skates caught in GOA fisheries targeting groundfish, by target fishery, gear, and area, 1997-2002.

Target	Gear	1997	1998	1999	2000	2001	2002
Arrowtooth	trawl	133	21	49	182	48	174
Deepflats	trawl	42	31	17	5	7	14
Flathead sole	trawl	139	130		2	26	102
Rexsole	trawl	489	172	331	142	107	230
Shallowflats	trawl	427	186	70	275	171	400
Flatfish Total		1,229	540	467	607	359	920
Pacific cod	hook n line	478	461	789	1,823	617	5,005
	pot	1	0	0	0	0	0
	trawl	476	411	385	219	272	120
Pacific cod Total		954	873	1,174	2,042	889	5,125
Pollock	trawl	31	52	24	87	53	10
Rockfish	hook n line	223		22	75	75	4
	trawl	70	39	71	77	126	113
Rockfish Total		293	39	92	151	201	117
Sablefish	hook n line	166	2,834	243	336	262	305
	trawl				0	1	0
Sablefish Total		166	2,834	243	336	263	305
Unknown Target		446	138	0	14	63	7
Grand Total		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			
Grand Total	3,120	4,476	2,000	3,238	1,828	6,484

Table 16-6. Spatially-estimated species composition of skates caught in GOA fisheries targeting groundfish by area, 1997-2002.

	1997	1998	1999	2000	2001	2002
annual total catch	3,120	4,476	2,000	3,238	1,828	6,484
Central GOA						
big	712	391	255	579	408	2,018
longnose	1,149	651	554	1,221	672	2,734
Eastern GOA						
big	48	234	13	10	11	21
longnose	164	1,718	65	153	67	54
Western GOA						
big	100	85	271	100	103	236
longnose	19	16	26	23	18	38
Gulfwide						
all bathyraja	927	1,380	815	1,152	550	1,383

Table 16-7. Estimated numbers and total weight (tons) of skates caught in GOA fisheries targeting Pacific halibut, 1997-2004 by IPHC area (see Figure 16-6). These estimates apply IPHC survey skate catch rates in each area and year to the number of commercial hooks retrieved in halibut fisheries in each area and year to estimate the total numbers of individual skates (upper table). To estimate weight of skate catch we apply the general species composition of skates observed on IPHC surveys (relatively stable at 50% longnose, 20% big, and 30% other by numbers throughout the survey years) combined with average weights for skates in each species group sampled at sea by groundfish observers to convert numbers to tons.

Note: these numbers differ from those presented in the 2003 GOA skate SAFE because a mathematical error in the 2003 estimates has been corrected.

Estimated numbers of individual skates (all species combined) caught in Pacific halibut fisheries

	3B	3A	2C	Total GOA
1997	68,903	256,106	94,227	419,236
1998	58,967	206,413	99,862	365,241
1999	102,204	242,582	95,655	440,442
2000	132,899	257,504	127,870	518,273
2001	120,024	273,786	121,672	515,482
2002	120,849	296,567	79,817	497,233
2003	166,334	253,884	85,530	505,749
2004	214,546	401,314	62,635	678,496

Estimated tons of skates (all species combined) caught in Pacific halibut fisheries

	3B	3A	2C	Total GOA
1997	947	3,520	1,295	5,762
1998	810	2,837	1,373	5,020
1999	1,405	3,334	1,315	6,054
2000	1,827	3,539	1,758	7,124
2001	1,650	3,763	1,672	7,085
2002	1,661	4,076	1,097	6,834
2003	2,286	3,490	1,176	6,951
2004	2,846	5,800	753	9,398

Sources: skate catch rates from IPHC longline surveys 1997-2004
commercial hooks retrieved in halibut fisheries 1997-2004 from logbooks, data provided by IPHC
aggregate skate species composition from IPHC surveys: 50% longnose, 20% big, 30% other skates
average skate weights by species from groundfish observer sampling in GOA

Table 16-8. Estimated species composition of 2004 skate catch in fisheries targeting Pacific halibut, from IPHC survey species composition.

Estimated numbers and tons of skates for 2004 by NPFMC species group

	numbers			tons		
	3B	3A	2C	3B	3A	2C
Big skate	58,328	60,566	2,815	1,483	1,540	72
Longnose skate	50,213	295,446	42,226	674	3,965	567
All other skates	106,005	45,302	17,594	689	294	114

Table 16-9. Summary of GOA skate catch. Groundfish fishery estimates from 1997-2002 are summed from spatially derived species estimates in Table 16-6. Groundfish fishery estimates for 2003, 2004, and 2005 are recalculated to reflect port sampling species compositions in the target fishery combined with incidental catches; in 2005 this results in different species estimates from the CAS. Halibut fishery estimates assume skate catch in numbers was 20% big skate, 50% longnose skate, and 30% other skates for 1997-2003, which reflects average species composition in those survey years with some portion of the catch identified. In 2004, halibut fishery estimates use IPHC survey species composition for that year. Average weights by species are averaged from GOA observer at-sea collections. Catch by area is not comparable between groundfish and halibut fishery estimates.

Year	Groundfish Big skate	Groundfish Longnose skate	Groundfish All other skates	**Groundfish fishery skate catch**
1997	860	1,333	927	3,120
1998	710	2,386	1,380	4,476
1999	539	646	815	2,000
2000	689	1,397	1,152	3,238
2001	522	757	550	1,828
2002	2,275	2,825	1,383	6,484
2003	2,646	936	443	4,025
2004	1,693	822	411	2,926
2005	1,241	697	657	2,595

Year	Halibut fishery Big skate	Halibut fishery Longnose skate	Halibut fishery All other skates	**Halibut fishery skate catch**	**Gulfwide, Fisherywide Total estimated skate catch**
1997	2,132	2,813	817	5,762	8,882
1998	1,857	2,451	712	5,020	9,496
1999	2,240	2,956	858	6,054	8,054
2000	2,636	3,478	1,010	7,124	10,362
2001	2,622	3,459	1,004	7,085	8,914
2002	2,529	3,337	969	6,834	13,318
2003	2,572	3,394	985	6,951	10,976
2004	3,095	5,206	1,097	9,398	12,324
2005	*	*	*	*	*

Table 16-10. Survey biomass estimates for skates in each GOA area, 1984-2005.

Area	COMMON_NAME	SPECIES_NAME	1984	1987	1990	1993	1996	1999	2001	2003	2005
Western	big skate	*Raja binoculata*	3,339	4,313	1,745	2,287	13,130	11,038	8,425	9,602	9,792
	longnose skate	*Raja rhina*	0	41	1,045	105	278	1,747	104	782	1,719
	Aleutian skate	*Bathyraja aleutica*	358	112	139	292	82	1,928	1,858	4,401	1,453
	Bering skate	*Bathyraja interrupta*	45	20	28	0	52	218	170	39	86
	Alaska skate	*Bathyraja parmifera*	0	0	0	0	119	220	1,213	265	211
	whiteblotched skate	*Bathyraja maculata*	0	0	0	0	0	544	0	173	502
	roughtail skate	*Bathyraja trachura*	0	0	0	0	43	0	0	0	0
	skate unident.	*Rajidae unident.*	325	259	0	12	13	1	3	1	38
	whitebrow skate	*Bathyraja minispinosa*	0	0	0	0	0	0	0	0	0
	mud skate	*Bathyraja taranetzi*	0	0	0	0	0	46	0	0	0
	all others	*Bathyraja sp.*	0	91	0	651	453	0	0	0	0
Western Total			4,067	4,837	2,956	3,348	14,168	15,741	11,774	15,264	13,799
Central	big skate	*Raja binoculata*	17,635	20,855	9,071	21,586	26,544	34,007	30,658	33,814	25,544
	longnose skate	*Raja rhina*	2,280	2,667	8,708	14,158	20,328	29,872	23,171	25,741	29,853
	Aleutian skate	*Bathyraja aleutica*	1,235	601	896	60	5,681	8,055	4,734	10,772	22,395
	Bering skate	*Bathyraja interrupta*	230	519	1,861	107	1,492	3,371	2,423	3,526	3,910
	Alaska skate	*Bathyraja parmifera*	0	14	771	0	810	1,272	2,422	1,579	489
	whiteblotched skate	*Bathyraja maculata*	0	0	0	0	0	925	0	0	0
	roughtail skate	*Bathyraja trachura*	51	182	0	0	0	614	0	0	139
	skate unident.	*Rajidae unident.*	2,108	1,241	9,618	30	126	32	19	32	55
	whitebrow skate	*Bathyraja minispinosa*	8	0	0	0	0	0	0	0	0
	mud skate	*Bathyraja taranetzi*	0	0	0	0	0	0	0	0	0
	all others	*Bathyraja sp.*	0	32	0	3,572	1,566	0	14	1	0
Central Total			23,548	26,112	30,924	39,513	56,546	78,148	63,440	75,465	82,386
Eastern	big skate	*Raja binoculata*	6,566	2,925	11,501	15,836	3,391	9,606		11,981	3,984
	longnose skate	*Raja rhina*	6,722	3,923	2,242	3,539	5,620	7,714		13,081	9,876
	Aleutian skate	*Bathyraja aleutica*	0	25	216	0	796	1,310		640	406
	Bering skate	*Bathyraja interrupta*	187	68	159	119	673	229		136	341
	Alaska skate	*Bathyraja parmifera*	4	0	107	0	0	76		63	0
	whiteblotched skate	*Bathyraja maculata*	0	0	0	0	0	0		91	0
	roughtail skate	*Bathyraja trachura*	0	0	0	0	0	63		0	0
	skate unident.	*Rajidae unident.*	96	173	143	877	5	42		3	19
	whitebrow skate	*Bathyraja minispinosa*	0	0	0	0	0	0		52	0
	mud skate	*Bathyraja taranetzi*	0	0	0	0	0	0		0	0
	all others	*Bathyraja sp.*	0	0	0	470	3	0		0	17
Eastern Total			13,575	7,114	14,367	20,841	10,487	19,040		26,046	14,643
Grand Total			41,189	38,063	48,248	63,702	81,201	112,929	75,214	116,775	110,828

Table 16-11. Alternative methods for estimating M based on life history using information for California big and longnose skates (see text for methods and references). "Age mature" was given a range for M estimates by the Rikhter and Efanov method to account for uncertainty in this parameter.

Species	Area	Sex	Hoenig	Age mature	Rikhter & Efanov	Alverson & Carney	Charnov	Roff
Big skate	CA	*males*	0.38					
	CA	*females*	0.35					
	CA			8	0.19			
	CA			9	0.16			
	CA			10	0.13			
	CA			11	0.12			
	CA			12	0.10			
Longnose skate	CA	*males*	0.32			0.31	0.44	0.23
	CA	*females*	0.35			0.45	0.29	0.03
	CA	*both*					0.31	
	CA			7	0.22			
	CA			8	0.19			
	CA			9	0.16			
	CA			10	0.13			

Figures

Figure 16.1. Big skate, *Raja binoculata*, with stock assessment author for scale.

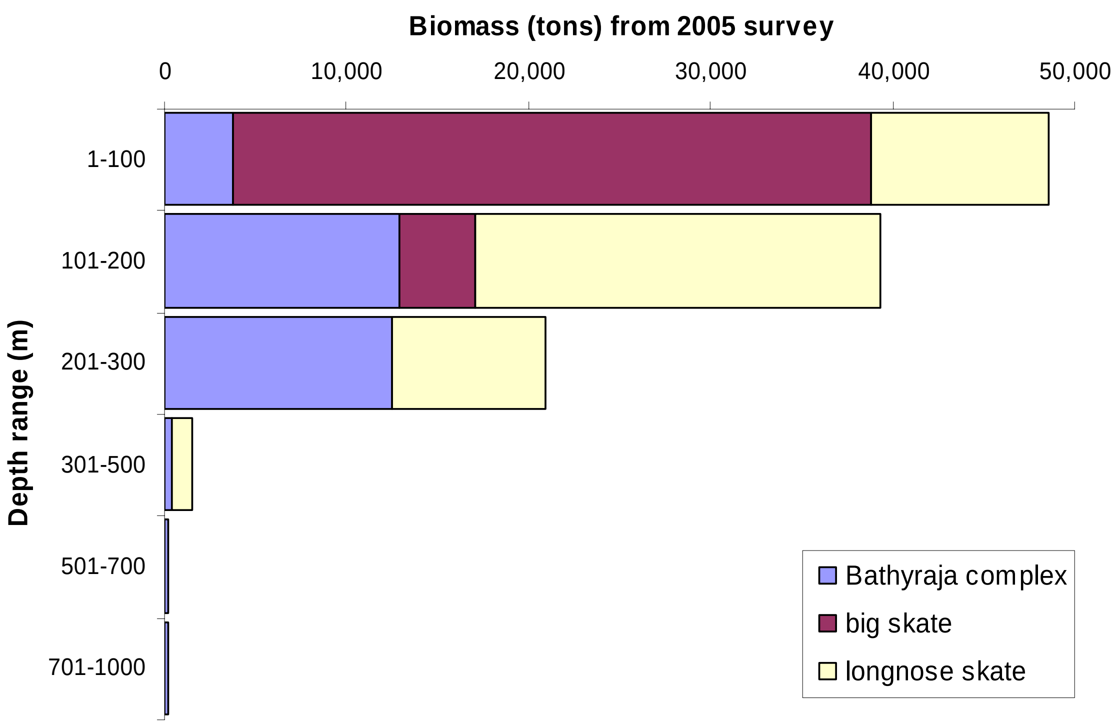


Figure 16.2. Biomass at depth for major GOA skate species, big, longnose, and *Bathyraja* sp.

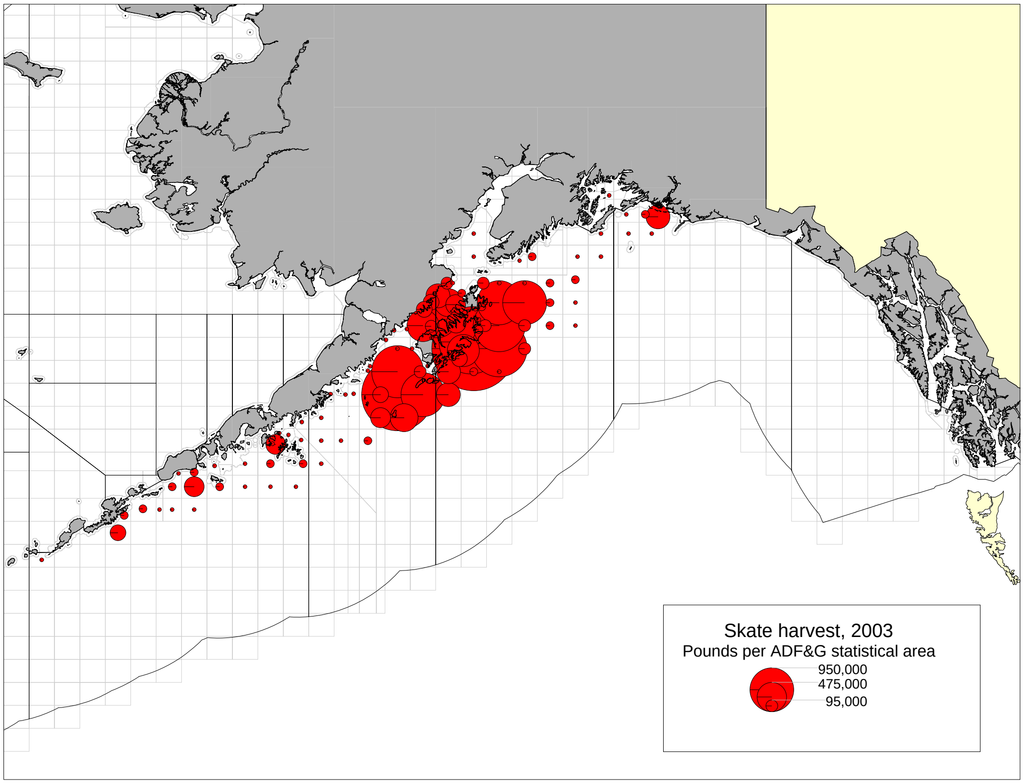


Figure 16.3. Skate catch from fish ticket database in 2003.

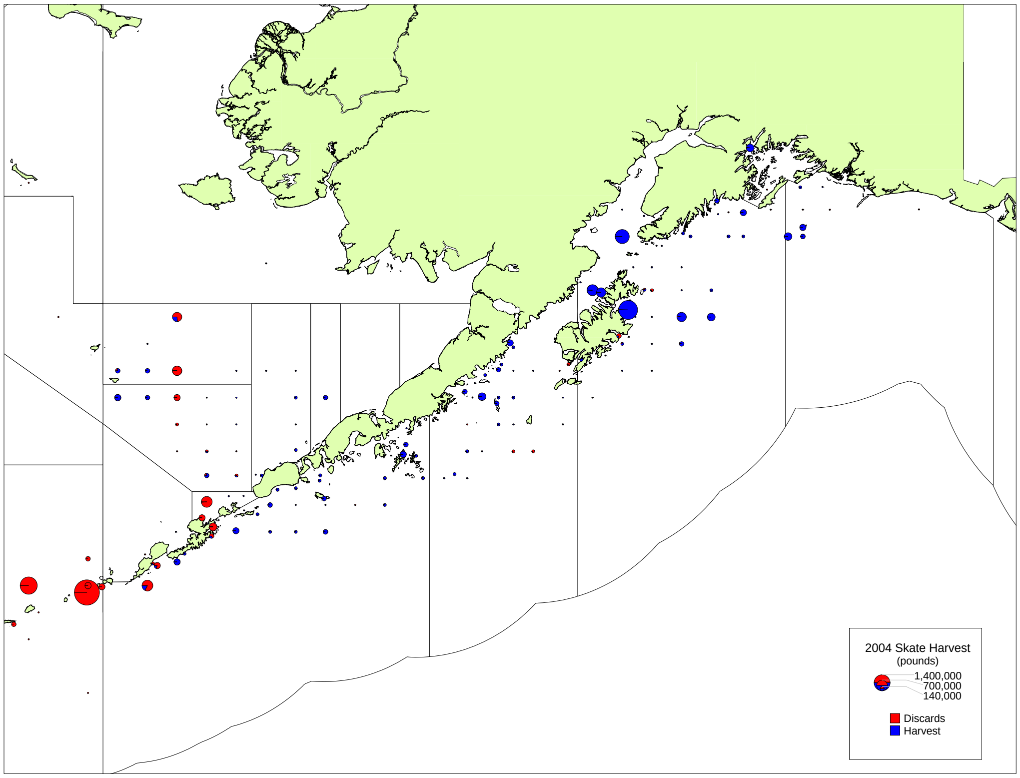


Figure 16.4. Skate catch from fish ticket database in 2004.

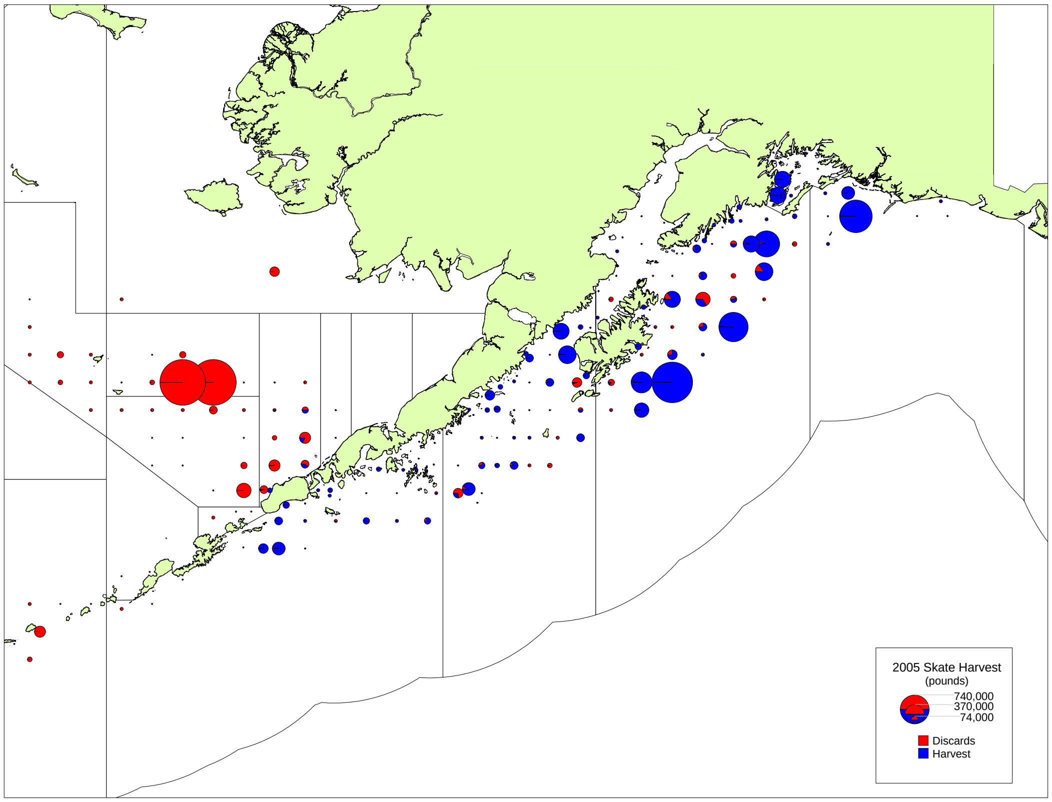


Figure 16.5. Skate catch from fish ticket database in 2005 (current as of September 30 2005).

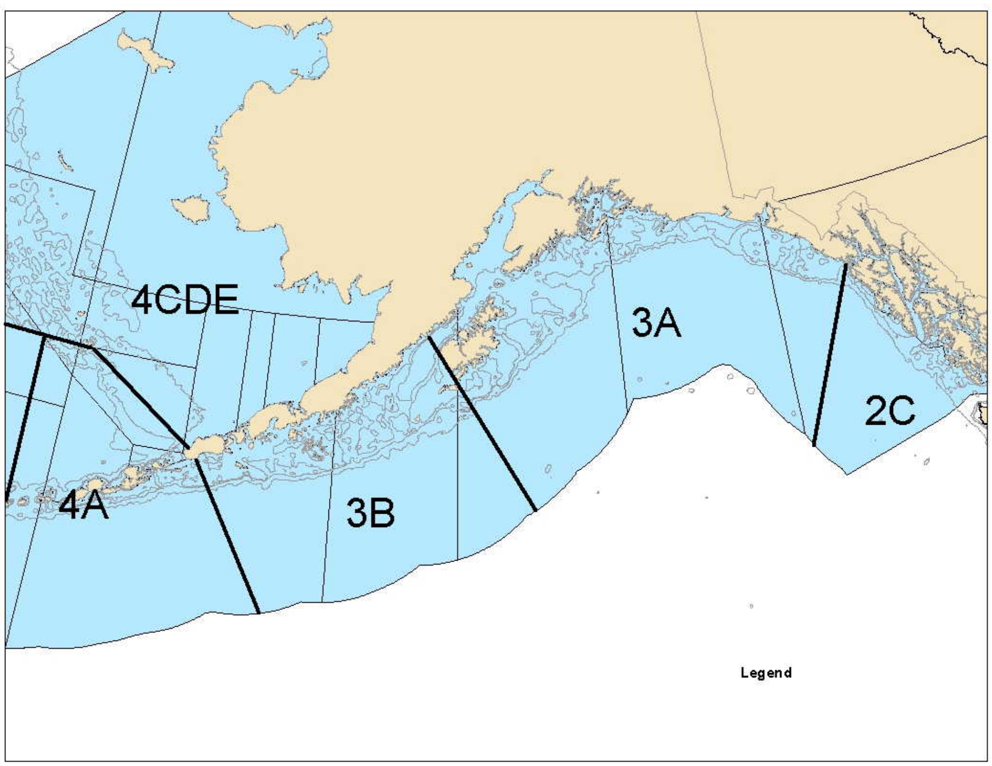


Figure 16-6. IPHC management areas overlaid on NPFMC management areas in Alaska.

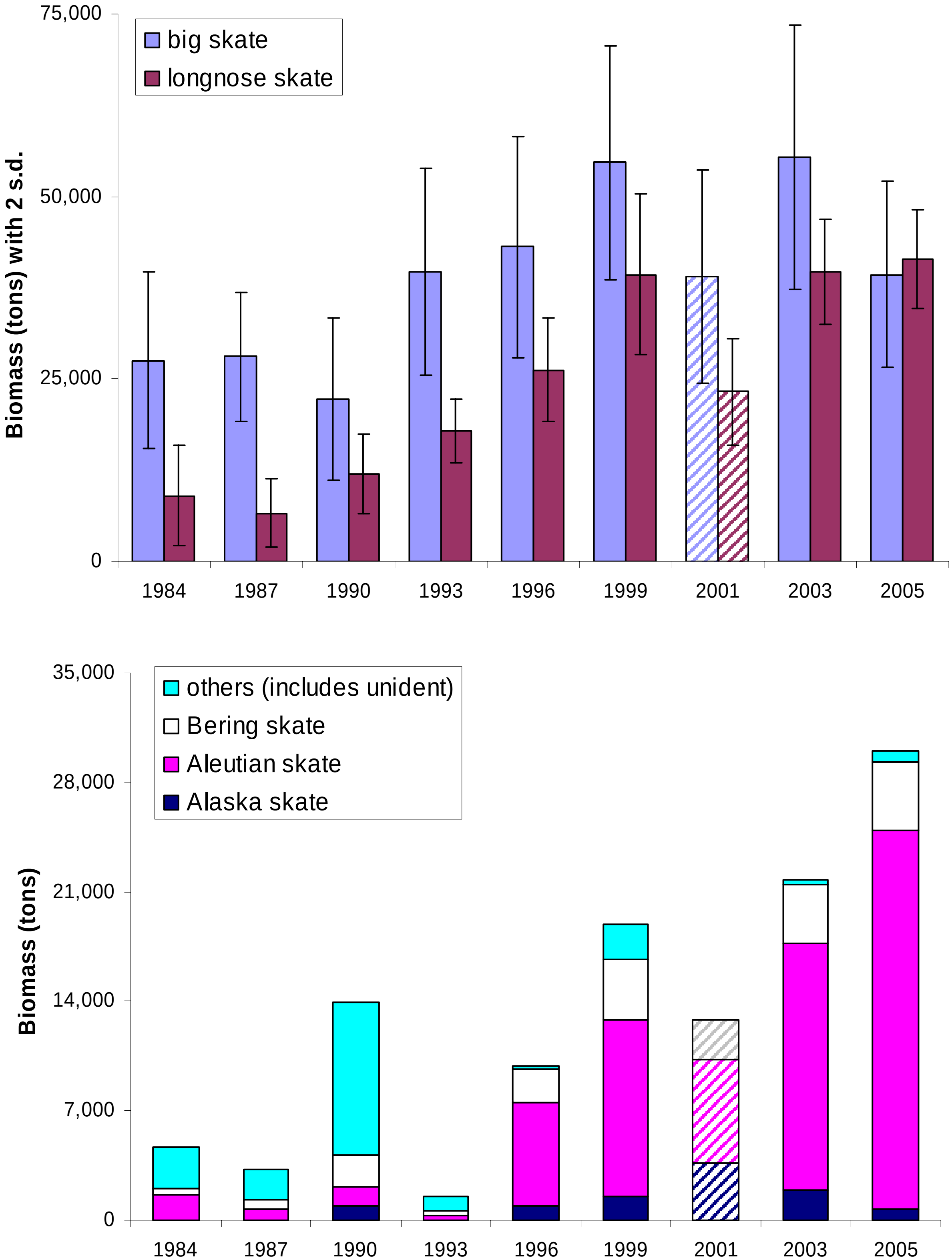
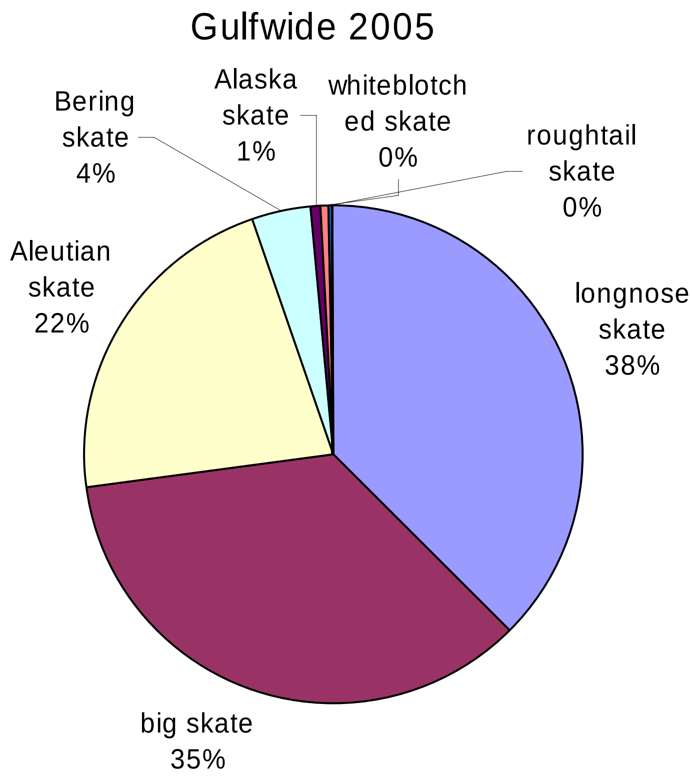


Figure 16.7. NMFS GOA bottom trawl survey biomass trends for major GOA skate species (2001 shaded to emphasize missing Eastern GOA, which is not a comparable survey to the rest of the time series).



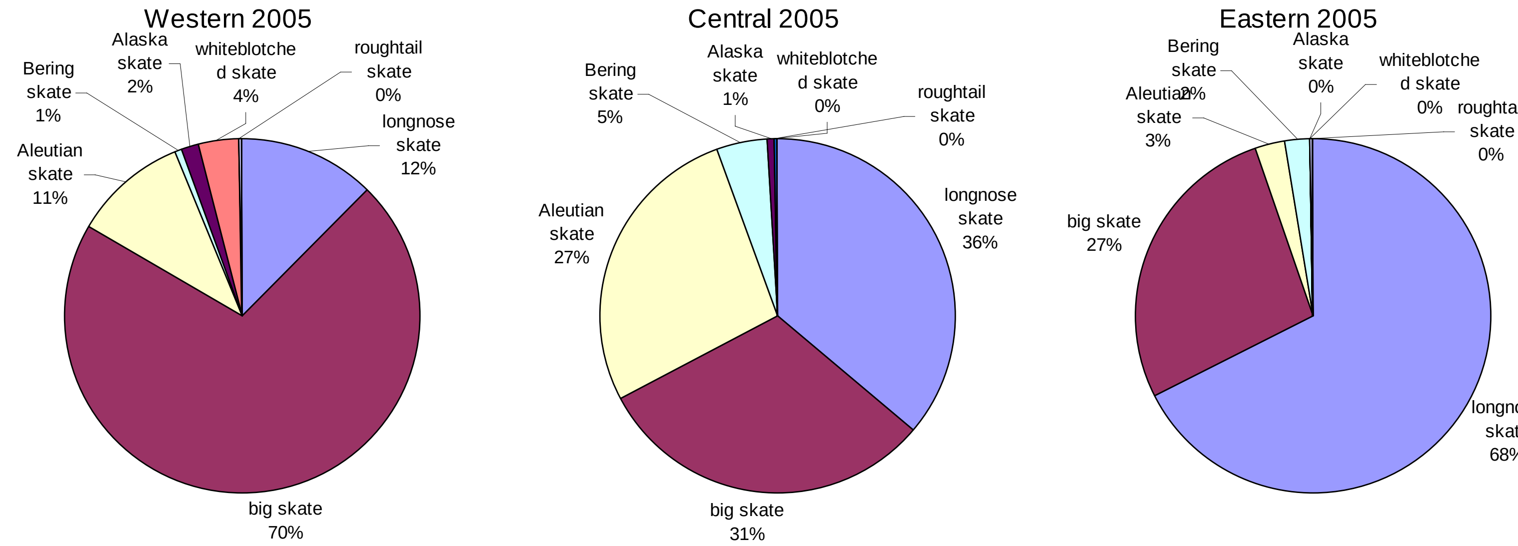


Figure 16.8. Distribution of skate biomass by species in 2005 gulfwide (top) and between areas (bottom).

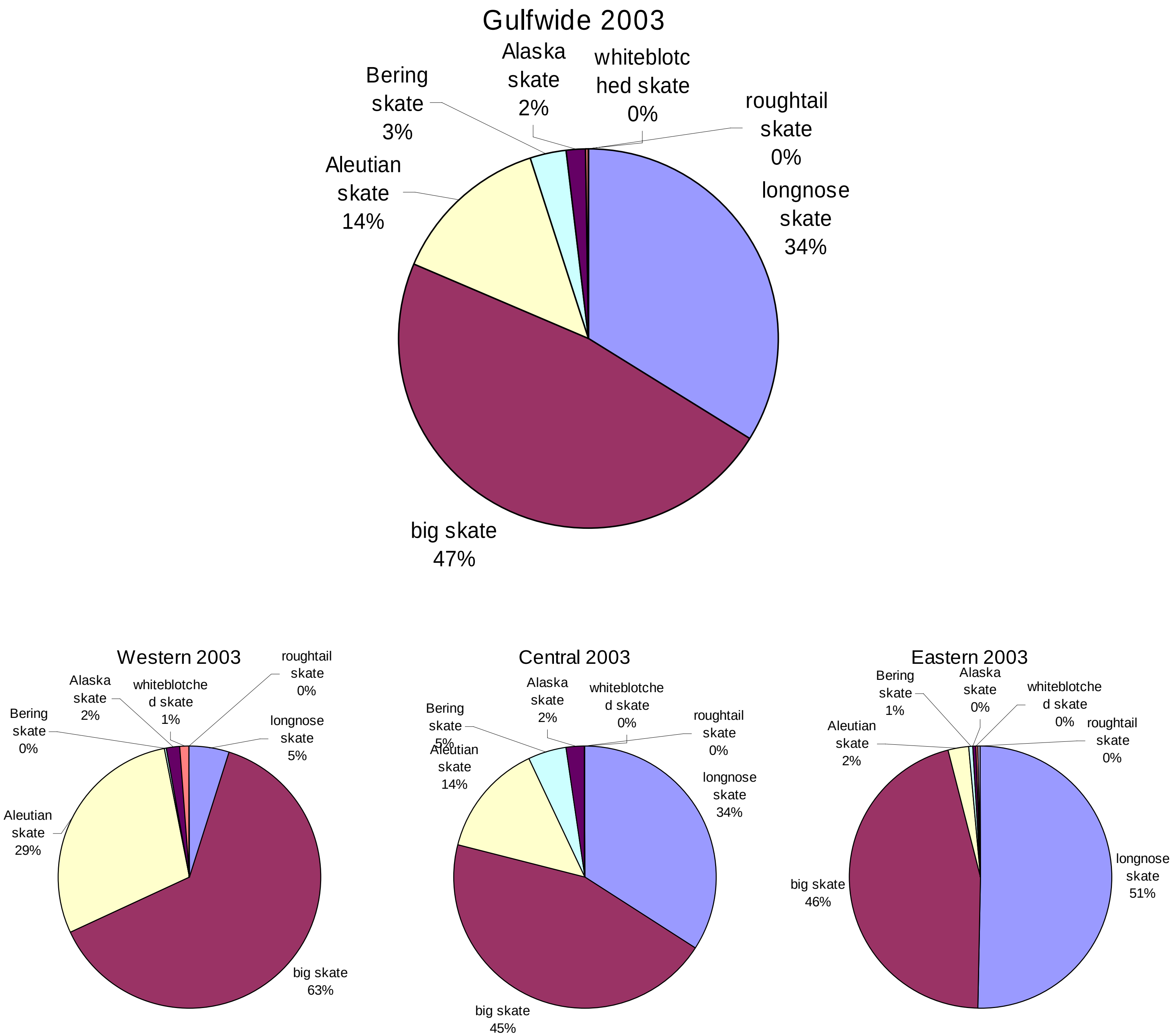


Figure 16.9. Distribution of skate biomass by species in 2003 gulfwide (top) and between areas (bottom).

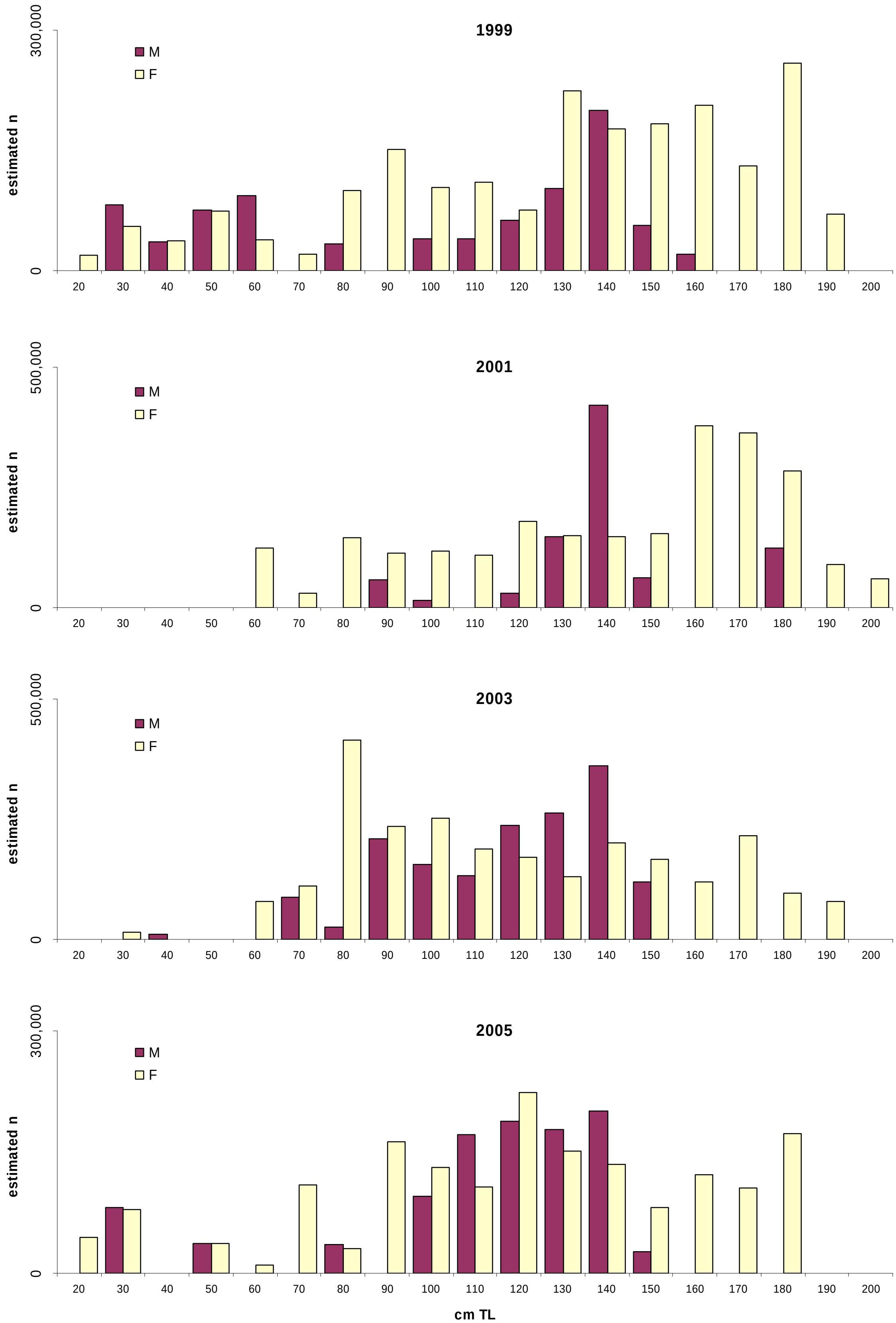
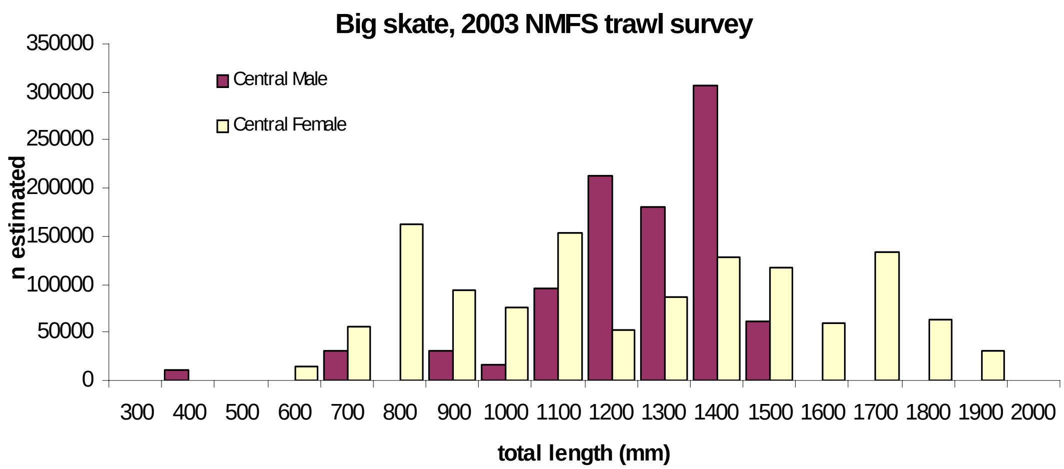
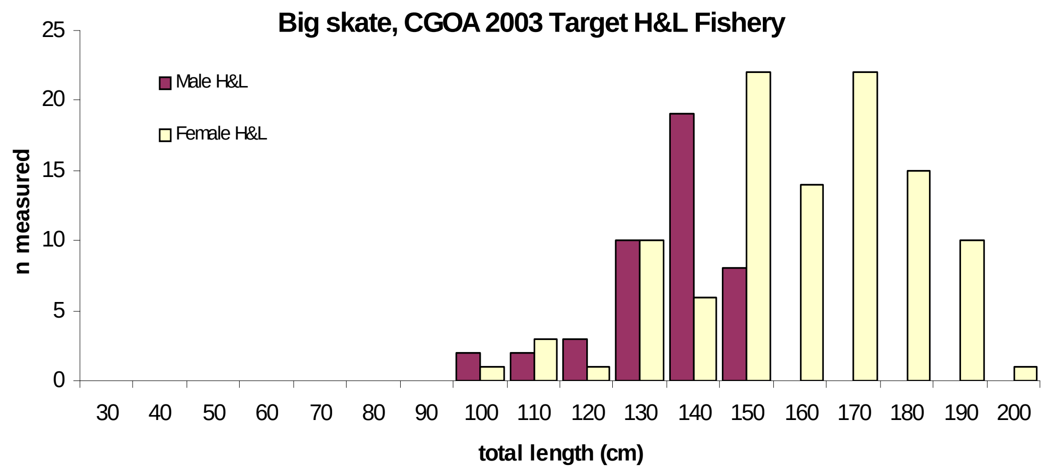


Figure 16-10. NMFS GOA trawl survey size composition for male and female big skates, 1999-2005





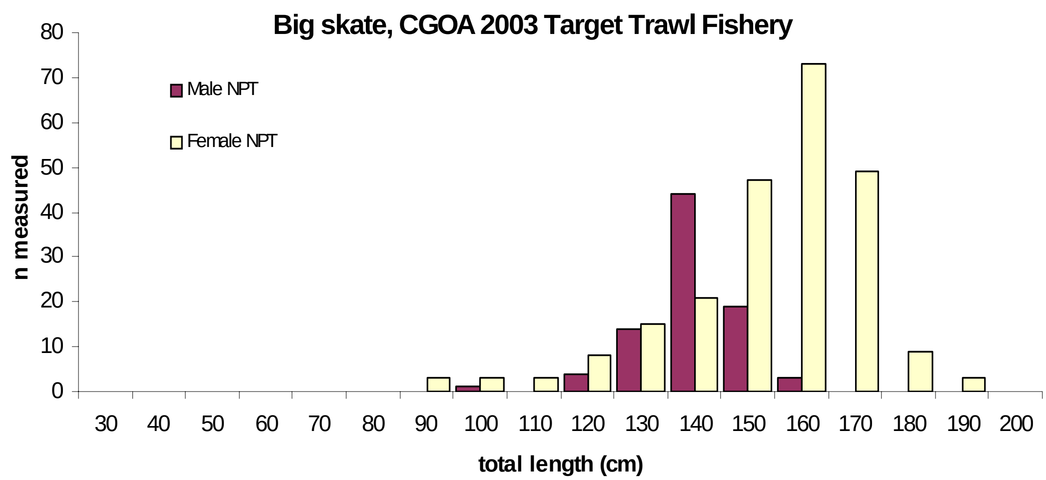


Figure 16-11. Comparison of estimated fishery catch at length for big skates with GOA trawl survey length composition for Central GOA big skates, 2003

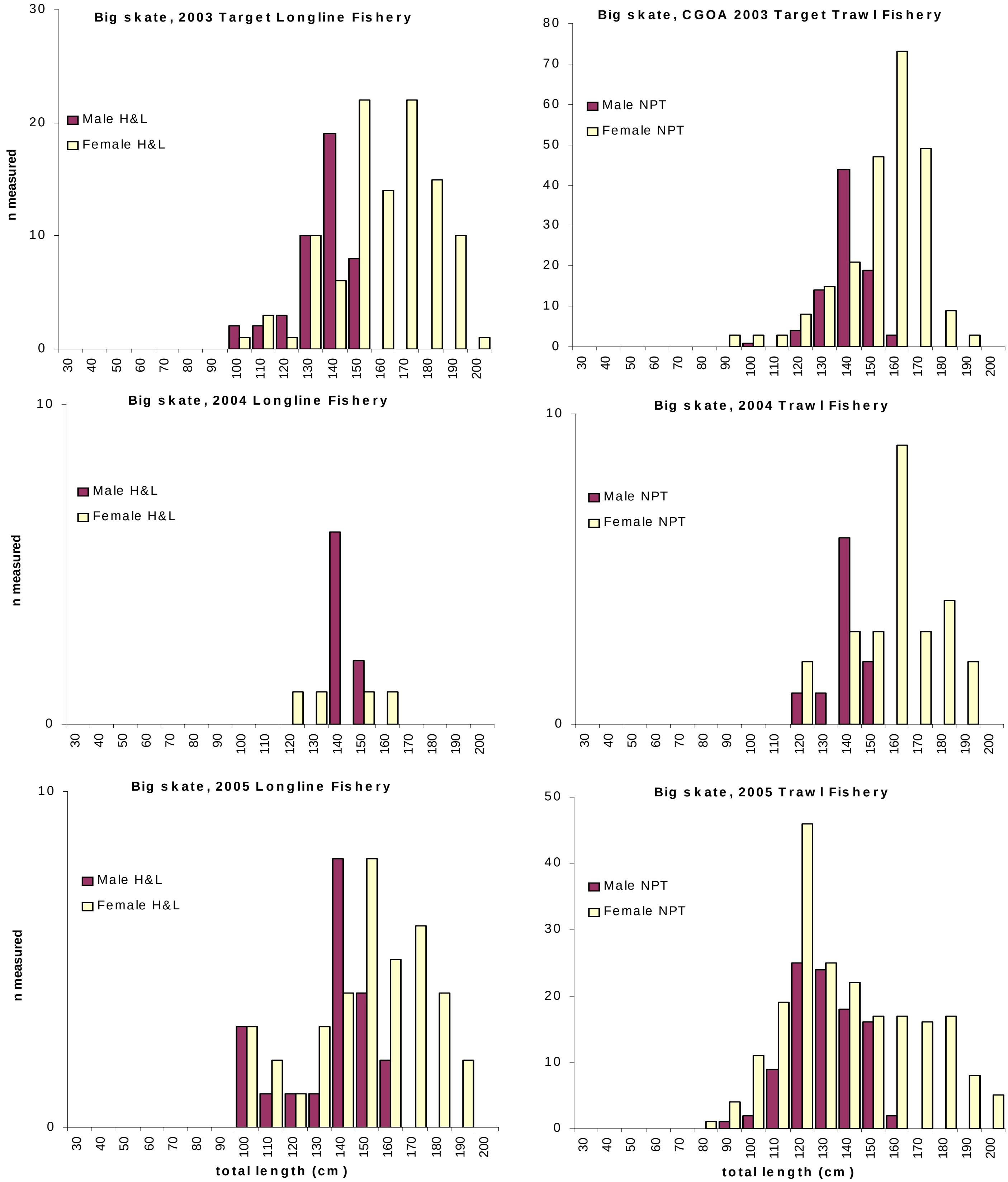


Figure 16-12. Comparison of big skate fishery length compositions by gear, 2003-2005.

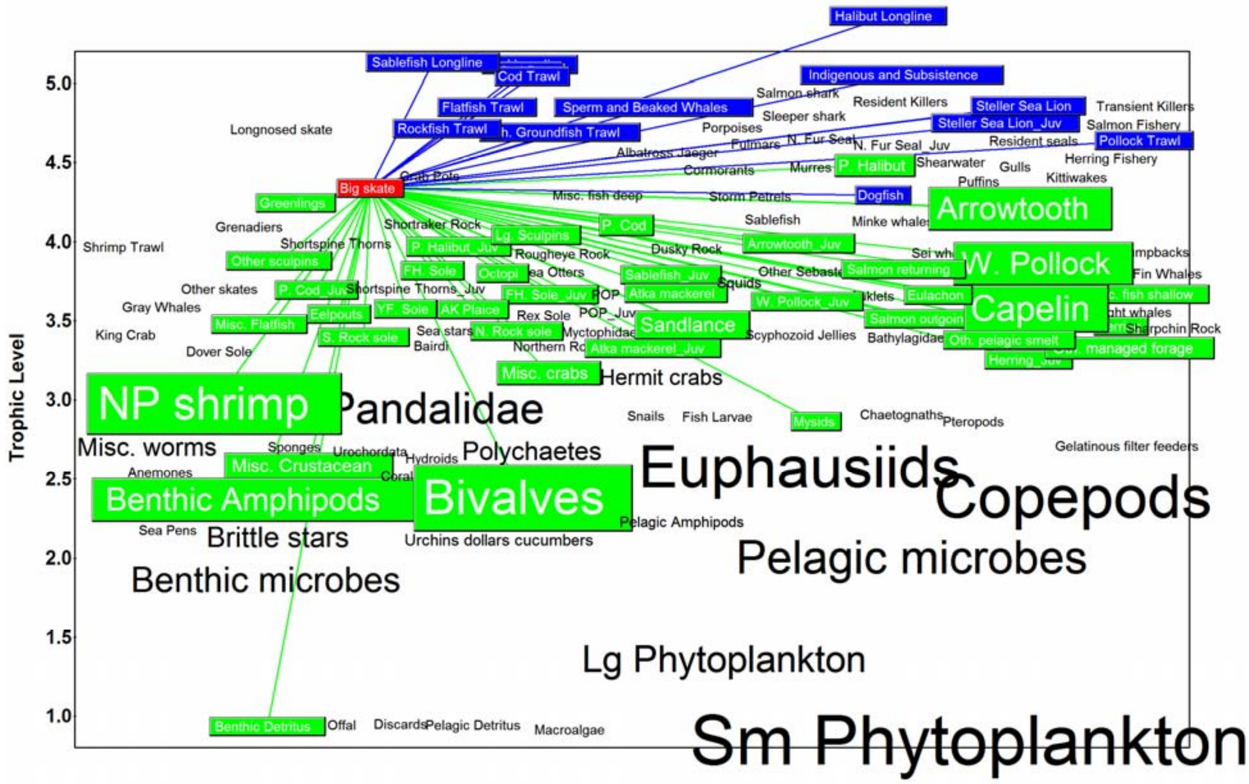


Figure 16-13. Food web for big skates in the GOA.

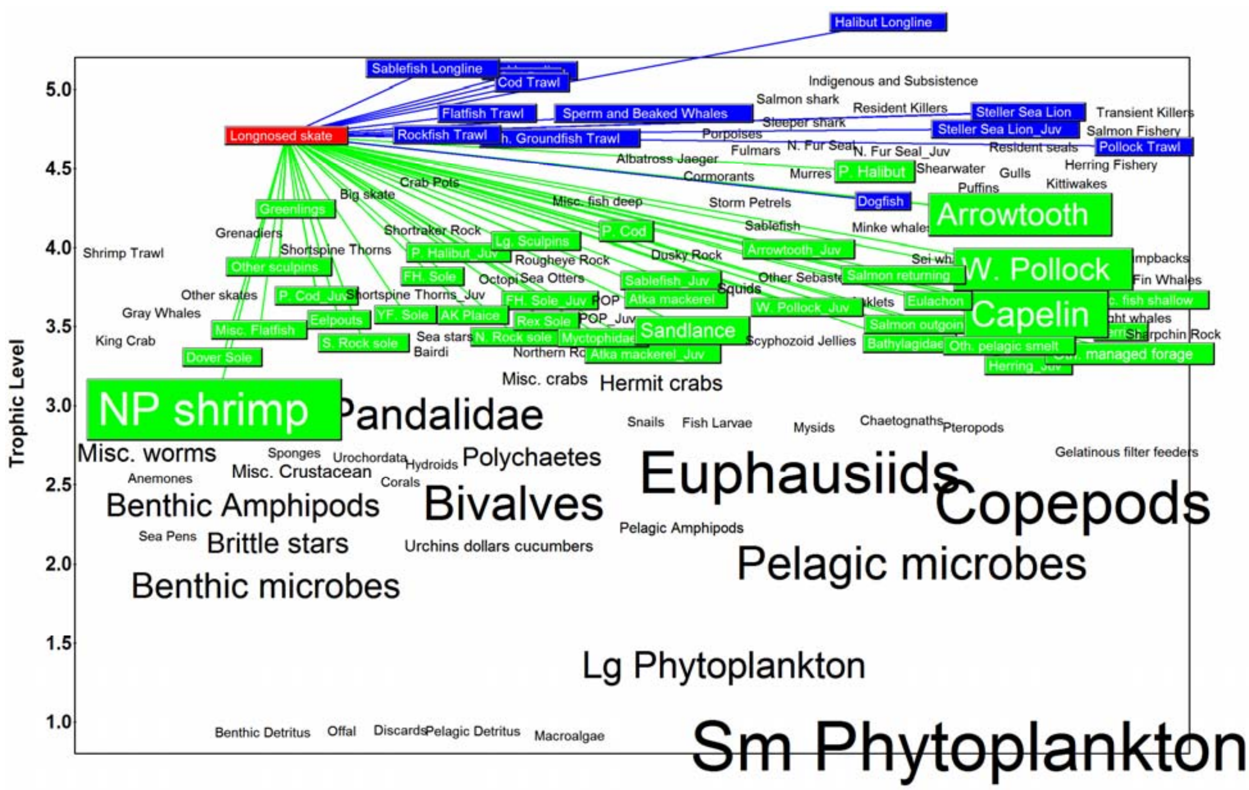


Figure 16-14. Food web for longnose skates in the GOA.

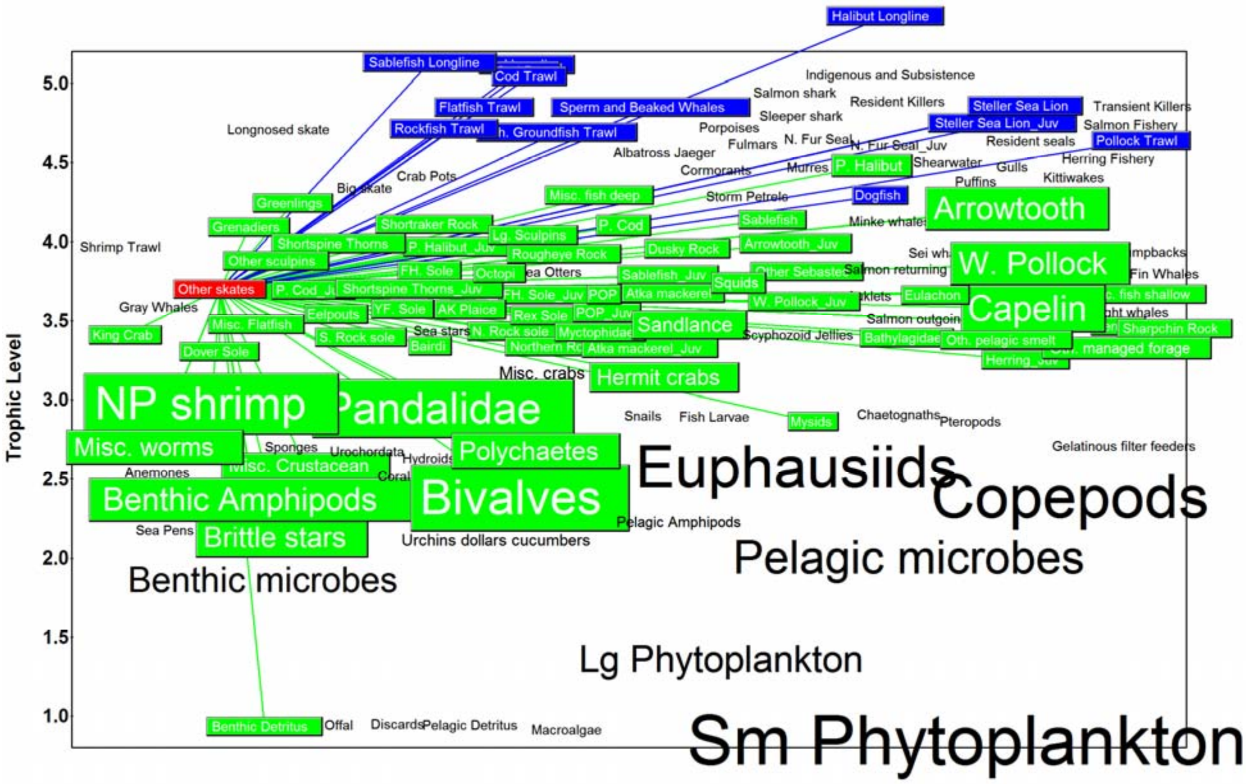


Figure 16-15. Food web for other skates in the GOA.

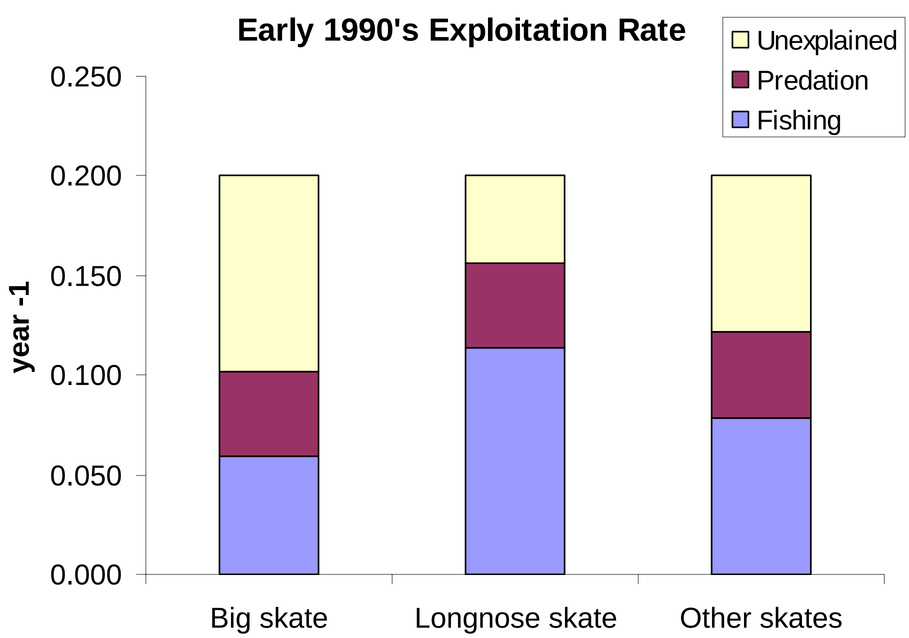


Figure 16-16. Mortality rates from predation and fishing for Other skates, Longnose skates, and Big skates in the GOA (early 1990's prior to target fishery developing for big skates).

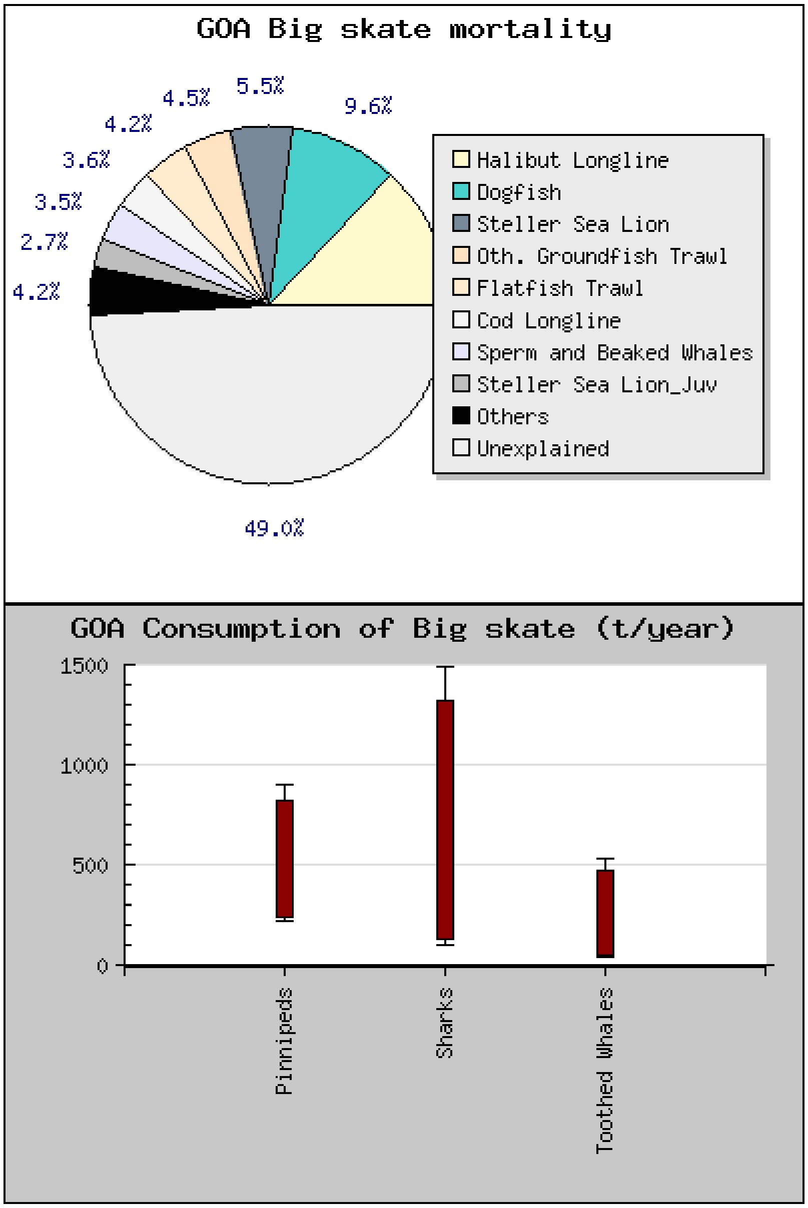


Figure 16-17. Mortality and consumption of big skates in the GOA.

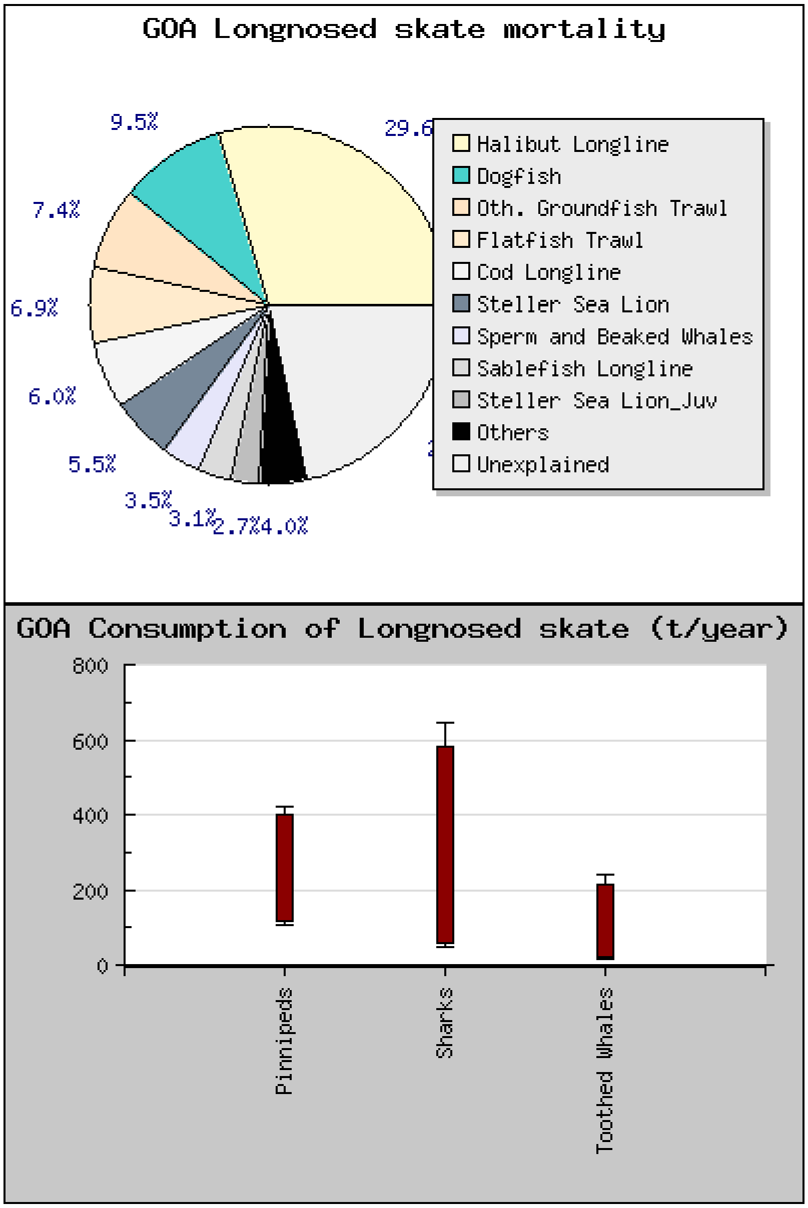


Figure 16-18. Mortality and consumption of longnose skates in the GOA.

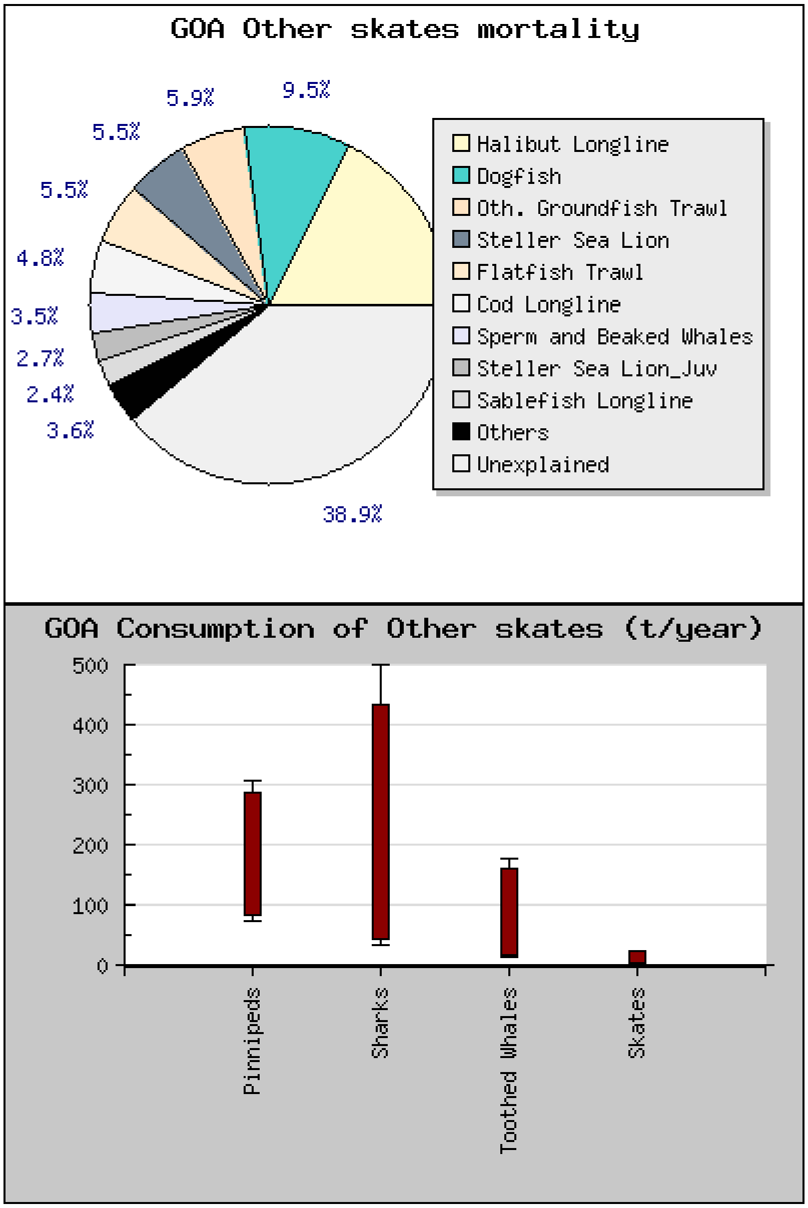


Figure 16-19. Mortality and consumption of other skates in the GOA.

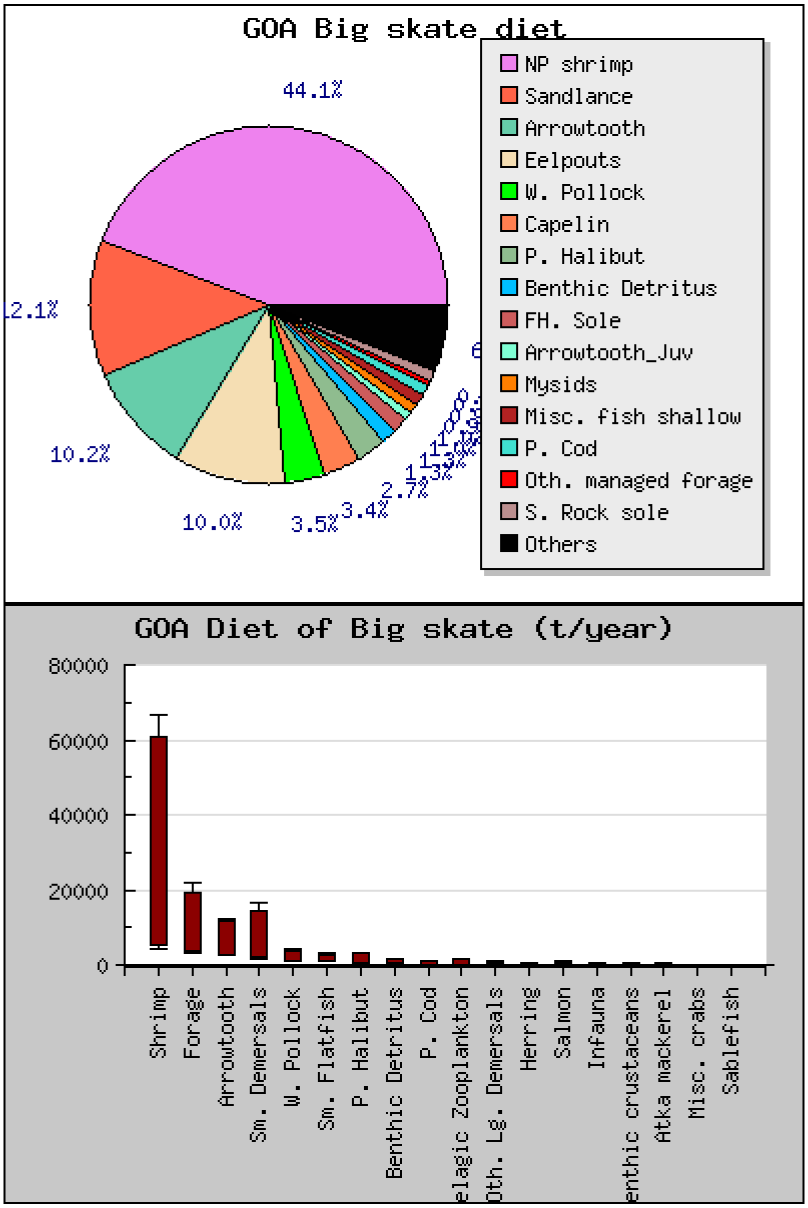


Figure 16-20. Diet composition and consumption of prey by big skates in the GOA.

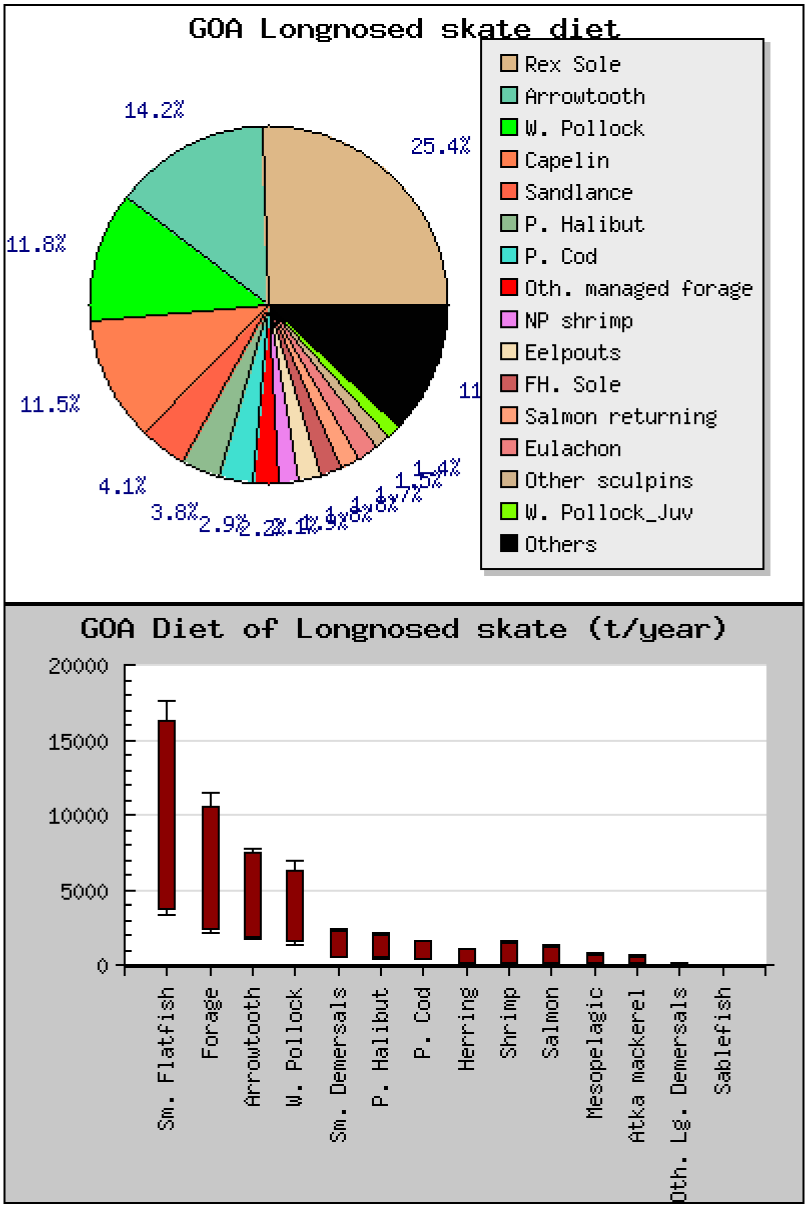


Figure 16-21. Diet composition and consumption of prey by longnose skates in the GOA.

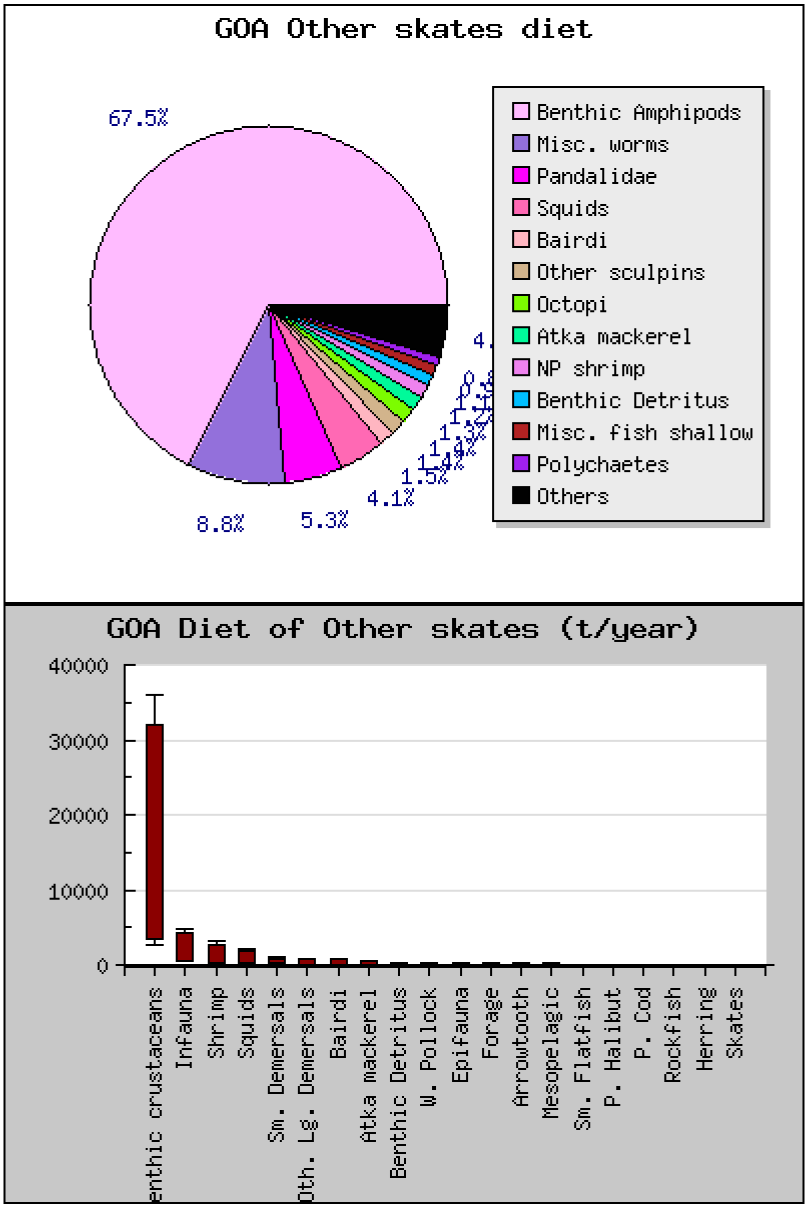


Figure 16-22. Diet composition and consumption of prey by other skates in the GOA.