16. Bering Sea and Aleutian Islands Skates

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Executive Summary

Summary of Major Changes

Changes in the input data:

1. Total catch (t) for BSAI skates is updated with 2005 and partial 2006 data.
2. Biomass estimates from the 2006 EBS shelf and AI bottom trawl surveys are incorporated.
3. Distribution maps for each species have been included.
4. Life history information has been updated with recent research results.
5. Alaska skate length frequencies from survey data are presented.
6. Retention of the observed skate catch is noted by species and region.

Changes in assessment methodology:

This year, in addition to formatting the assessment as a stand-alone sub-section of the BSAI Squid and Other species SAFE chapter (to support more effective management of BSAI skates), we have presented our recommendations by splitting the BSAI Skates assemblage into two categories: Alaska skate (*Bathyraja parmifera*), and all other skate species ("Other Skates"). The goal of these separate recommendations is to provide increased protection to rare and endemic skate species.

Changes in assessment results:

We recommend applying Tier 5 criteria to the Alaska skate (*Bathyraja parmifera*) and the "Other Skates" complex separately, using the default natural mortality rate of M=0.10 and the average of survey biomass estimates since 1999, when species identification became reliable (past 8 years). Therefore, we recommend:

	Alaska skate	**Other Skates**
1999-2006 avg survey biomass (t)	407,939	84,412
M	0.10	0.10
ABC	30,595	6,331
OFL	40,794	8,441

The proposed FMP amendment to split the Other species complex into groups so that skates can be managed separately has not yet been implemented. Therefore, as in past years, these recommendations for Tier 5 management of BSAI skates are presented so that the BSAI Plan Team and NPFMC SSC can use this information combined with information for sharks, sculpins, and octopus to best manage the Other species complex in the interim.

Responses to SSC Comments

SSC comments specific to the BSAI Skates assessment:

There were no specific BSAI skate comments.

<u>SSC comments on assessments in general:</u>
From the December 2005 SSC minutes:

> *The SAFEs have been improved overall by expanded sections on ecosystem considerations to include discussion of predator-prey interactions. To this end, tables and figures have been added from ECOPATH models. One problem that has arisen is that there is some confusion about whether the information presented is stomach contents data, output from a single-species model, or output from an ECOPATH model. Figures and tables should more explicitly describe the source of the information presented. To avoid confusion between statistically-driven single species models and manually-adjusted ECOPATH models, the word "estimate" should be reserved for output from single-species models. In the absence of a statistical fitting procedure, outputs from ECOPATH/ECOSIM models should be referred to as adjusted parameters or just outputs. When ECOPATH/ECOSIM parameters are assumed to take on particular values, such assumptions should be stated explicitly. Care should be taken to avoid mixing results from different model structures.*

The Ecosystem Considerations figures have been updated with short descriptions of the data sources and the methods used.

Introduction

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

Skates (family Rajidae) are cartilaginous fishes which are related to sharks. They are dorso-ventrally depressed animals with large pectoral "wings" attached to the sides of the head, and long, narrow whiplike tails (Figure 16.3-1). At least 15 species of skates in three genera, *Raja*, *Bathyraja*, and *Amblyraja,* are distributed throughout the eastern North Pacific and are common from shallow inshore waters to very deep benthic habitats (Eschmeyer et al. 1983, Stevenson et al. 2006). Table 16.3-1 lists the species found in Alaskan waters, with their depth distributions and selected life history characteristics (which are outlined in more detail below).

The species within the skate assemblage occupy different habitats and regions within the BSAI FMP area (Figure 16.3-2). Within the Eastern Bering Sea (EBS), the skate species composition varies by depth, and species diversity is generally greatest on the upper continental slope (250 to 500 m depth) (Stevenson et al. 2006) (Figure 16.3-3). In this assessment, we distinguish three habitat areas: the EBS shelf (0 to 200 m depth), the EBS slope (>200 m depth), and the Aleutian Islands (AI) region (all depths). The EBS shelf skate complex is dominated by a single species, the Alaska skate (*Bathyraja parmifera*) (Table 16.3-2). This species is distributed throughout the shelf, and is most commonly found at depths of 50 to 200 m (Stevenson 2004) (Figure 16.3-4). The Bering or sandpaper skate (*Bathyraja interrupta*) is the next most common species on the EBS shelf, and is distributed on the outer continental shelf (Figure 16.3-5). While skate biomass is somewhat lower on the EBS slope than on the shelf, skate diversity is substantially higher on the slope (Figure 16.3-6). The Aleutian skate (*Bathyraja aleutica*) is found occasionally on the outer EBS shelf but comprises almost half of the EBS slope skate biomass, with Bering and Alaska skates still quite common. A number of other species are found on the EBS slope in substantial numbers, including the Commander skate (*B. lindbergi*), whiteblotched skate (*B. maculata*), whitebrow skate (*B. minispinosa*), and roughtail skate (*B. trachura*) (Table 16.3-2). Two rare species, the deepsea skate (*B. abyssicola*) and roughshoulder skate (*Amblyraja badia*), were only recently reported from EBS slope bottom trawl surveys (Stevenson and Orr 2005).

The skate complex in the AI is quite distinct from the EBS shelf and slope complexes, with different species dominating the biomass, as well as at least one endemic species, the recently described butterfly skate, *Bathyraja mariposa* (Stevenson et al. 2004). In the AI, the most abundant species is the whiteblotched skate, *Bathyraja maculata* (Table 16.3-2). The whiteblotched skate is found primarily in the eastern and far western Aleutian Islands (Figure 16.3-7). Aleutian skates are also common in the AI. The mud skate, *Bathyraja taranetzi*, is relatively common in the AI but represents a lower proportion of total biomass because of its smaller body size. We note that the common species formerly known as the Alaska skate in the western Aleutians looks very different from the Alaska skate found on the EBS shelf (Figure 16.3-8). The Aleutian Islands type, or "leopard skate", has been confirmed to be a separate species (J. Orr pers. comm.).

Management units

In the North Pacific, skate species are part of the "Other species" management category within the Bering Sea Aleutian Islands (BSAI) Fishery Management Plan (FMP). This means that their catch is reported as "Other" in aggregate with the catch of sharks, sculpins, and octopus. Because catch is officially reported within the Other species complex, estimates of skate catch must be made independently (see Bycatch and discards, below).

In the BSAI, catch of Other species is limited by a Total Allowable Catch (TAC) which is based on an Allowable Biological Catch (ABC) estimated by the NPFMC Scientific and Statistical Committee (SSC). Right now, skates are taken only as bycatch in fisheries directed at target species in the BSAI, so future catches of skates are more dependent on the distribution and limitations placed on target fisheries than on any harvest level established for this category. An FMP amendment was initiated by the NPFMC in 1999 to remove both skates and sharks from the Other species category to increase the level of management attention and control for these potentially vulnerable species groups; this action is still in the process of revision and review. In response to a developing fishery in the GOA, the GOA FMP was amended to remove skates from the Other species category. FMP amendments are being proposed to split the Other species category into component groups in both the BSAI and GOA, and this assessment is written as a stand-alone skate assessment in support of this effort to improve Other species management.

Life history and stock structure (general)

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 (Winemiller and Rose 1992), with very low intrinsic rates of population increase implying that sustainable harvest is possible only at very low to moderate fishing mortality rates (King and McFarlane, 2003). Within this general equilibrium life history strategy, there can still be considerable variability between skate species in terms of life history parameters (Walker and Hislop 1998). 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 "common" skate *Dipturus batis* has been extirpated from the Irish Sea (Brander 1981) and much of the North Sea (Walker and Hislop 1998), and the barndoor skate *Dipturus 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 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 most commercially exploited teleost groundfish. The large, leathery egg cases incubate for extended periods (several months to over 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 Hislop 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). Comparisons of length frequencies for surveyed North Sea skates from the mid and late 1900s led Walker and Hislop (1998, p. 399) to the conclusion that after years of very heavy exploitation "all the breeding females, and a large majority of the juveniles, of *Dipturus batis*, *Leucoraja 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." This may be an oversimplification of the potential response of skate populations to fishing; in reality it is the interaction of natural mortality, age at maturity, and the selectivity of fisheries which determines a given species' sensitivity to fishing and therefore the total allowable mortality (ABC). While we strive to collect information on age at maturity, longevity, and size composition of catch for each skate species in the BSAI to apply it in future assessments, at present we are falling back on the general relationship of total mortality to total biomass (Tier 5), so Frisk's caution is warranted.

Life history and stock structure (Alaska-specific)

Currently there is little published life history information available for skate species in the eastern North Pacific, but recent research results are changing this situation. Known life history parameters of Alaskan skate species are presented in Table 16.3-1. Zeiner and Wolf (1993) determined age at maturity and maximum age for big skates (*Raja binoculata*) and longnose skates (*R. rhina*) from Monterey Bay, CA. The maximum age of CA big skates was 11-12 years, with maturity occurring at 8-11 years; estimates of maximum age for CA longnose skates were 12-13 years, with maturity occurring at 6-9 years. McFarlane and King (2006) recently completed a study of age, growth, and maturation of big and longnose skates in the waters off British Columbia (BC), finding maximum ages of 26 years for both species, much older than the estimates of Zeiner and Wolf. Age at 50% maturity occurs at 6-8 years in BC big skates, and at 7-10 years in BC longnose skates. However, these parameter values may not apply to Alaskan stocks. The AFSC Age and Growth Program has recently reported a maximum observed age of 25 years for the longnose skate in the GOA, significantly higher than that found by Zeiner and Wolf but close to that observed by McFarlane and King (Gburski et al. in review). In the same study, the maximum observed age for GOA big skates was 15 years, closer to Zeiner and Wolf's results for California big skates. The life histories of these two species are reported in more detail in the GOA skate SAFE (Gaichas et al. 2005).

Considerable research has been directed at skates in the Bering Sea over the past few years. Graduate students at the University of Washington and California State University (Moss Landing Marine Laboratories) have begun projects detailing aspects of life history and population dynamics of several Bering Sea species. A comprehensive study on the age, growth, and reproductive biology of the Alaska skate, the most common skate species on the eastern Bering Sea shelf, was recently completed (Matta 2006). Life history aspects examined in this study include estimates of maximum age, instantaneous rate of natural mortality (M), length and age at maturity, growth parameters, annual fecundity, and seasonal reproductive timing. Age and size at 50% maturity were 9 years and 92 cm TL for males and 10 years and 93 cm TL for females (Table 16.3-1). Von Bertalanffy growth parameters were estimated for males (L_∞ = 126.29 cm TL, k = 0.120 year^{-1}, t_0 = -1.39 year) and females (L_∞ = 144.62 cm TL, k = 0.087 year^{-1}, t_0 = -1.75 year), although length-at-age data were fit slightly better by a Gompertz growth function for both sexes. Based on seasonal reproductive data, including ova diameter, gonadosomatic index (GSI), and egg cases, the Alaska skate appears to be reproductively active throughout the year. A reproductive resting phase (e.g. 'spent' gonads) was never observed in either large males or females, and females containing egg cases were encountered during each month of collection. Annual fecundity was estimated to average 21 to 37 eggs per year, based on the relationship between annual reproductive effort and natural mortality (Gunderson 1997). While the fecundity estimate should be validated using direct methods, fecundity is still likely to be low for the Alaska skate, as is typical for most elasmobranchs.

Gerald Hoff (AFSC/UW) is working on a project which will be completed this winter, examining skate reproduction and skate nursery habitat of the Alaska skate and the Aleutian skate from the eastern Bering Sea. Project goals are to determine the relationships between successful skate reproduction and selected nursery grounds. Questions such as vulnerability sources, reproductive cycles, habitat selection criteria, and physical factors controlling reproduction are being addressed. To date, six nursery sites for three different skate species have been described in the eastern Bering Sea (Figure 16.3-9), and there is ample evidence that additional nursery areas exist. All sites are located along the shelf-slope interface in approximately 140-360 m of water. Two sites, those of the Alaska and Aleutian skates, have been studied in detail through seasonal monitoring. An index location at each nursery site was re-sampled approximately once every 60 days from June 2004 through July 2005 for a total of eight sampling periods. During each sampling period data on mortality, reproductive cycles, embryo developmental, species utilization and adult reproductive states were examined. Field sampling has been completed and data collection from preserved samples is underway.

The Alaska skate nursery is located in 149 meters of water near the shelf-slope interface in a highly productive area of the eastern Bering Sea. The nursery is small in area (< 2 nautical miles), persistent, and highly productive. Density estimates from trawling showed the most active part of the nursery contained >100,000 eggs/km^2. Preliminary analysis suggests two peak reproductive periods during summer and winter in the Alaska skate nursery. During each active period the nursery showed high densities of mature reproductive adults and high numbers of newly deposited egg cases. Although there are peak reproductive periods at any single sampling time, the nursery contained embryos in all stages of development, and specific cohorts were easily discernable from frequency stage monitoring. The Oregon triton *Fusitriton oregonensis* was the most likely predator on newly deposited egg cases and mortality rate was estimated at 3.64%. After hatching, young skates were vulnerable to predation by Pacific cod, *Gadus macrocephalus* and Pacific halibut, *Hippoglossus stenolepis*. Predation by these two large fish species peaked during the summer and winter periods and was highly correlated with hatching events. The Alaska skate nursery site was occupied by mature male and female skates throughout the year, with juvenile and newly hatched individuals extremely rare. Evidence suggests that newly hatched skates quickly move out of the nursery site and immature skates are infrequent visitors to nursery sites. The nursery is located in a highly fished area and is vulnerable to disturbances due to continuous use of the nursery grounds by skates throughout the year. Some degree of intra-species habitat partitioning is evident and is being examined for the Alaska skate throughout the eastern Bering Sea shelf environment.

Researchers at the Pacific Shark Research Center (PSRC), Moss Landing Marine Laboratories (MLML) are currently conducting investigations into aspects of the age, growth, reproduction, demography, and diet of several Alaskan skates. In cooperation with the Alaska Department of Fish and Game and the AFSC, they have examined more than 5,000 specimens comprising 13 species Aleutian skate, Commander skate, whiteblotched skate, whitebrow skate, Alaska skate, roughtail skate, Bering skate, and mud skate (Ebert, 2005). Currently, four graduate students are working towards their Masters degrees with thesis projects on Alaskan skate species. In addition, two other students, Chante Davis (2006) and Heather Robinson (2006), have recently completed their respective thesis research on two skate species (roughtail skate and longnose skate) that occur in Alaskan waters. Although their studies were conducted outside of Alaskan waters, their findings represent new and original information on the life history of these two skate species.

Age determination and validation studies are currently ongoing at the PSRC to obtain essential information on the age at maturity, growth rates and longevity of seven Alaskan skate species: Aleutian skate, Commander skate*,* whiteblotched skate, whitebrow skate, roughtail skate, Bering skate, and mud skate. Theoretical longevity and indirect estimates of natural morality will be calculated from the resulting growth parameters. Additionally, the suitability of caudal thorns as an alternative ageing structure is being investigated, potentially providing a valuable, non-lethal ageing technique for this group. Age and growth studies are currently being conducted by Diane Haas (Aleutian skate), Jasmine Fry (mud skate), and Shaara Ainsley (whitebrow skate and Bering skate) for their thesis research. Results for Aleutian skate and Bering skate should be available in 2007.

Reproductive studies are also currently ongoing at the PSRC to obtain information on the size at maturity, seasonality, and fecundity of nine Alaskan skate species: Aleutian skate, Commander skate, whiteblotched skate, whitebrow skate, roughtail skate, Bering skate, mud skate, big skate, and longnose skate. Estimates of maturity based on visual and histological methods are being compared for these species. The reproductive biology of Aleutian skate, Bering skate, big skate, and longnose skate is being investigated as part of a NPRB funded study to assess life history characteristics of Alaskan skate species. Reproductive studies are currently being conducted by PSRC staff (big and longnose skates) and three graduate students: Diane Haas (Aleutian skate), Jasmine Fry (mud skate), and Shaara Ainsley (whitebrow skate and Bering skate) as a component of their thesis research. The reproductive biology of an additional species, roughtail skate, was recently completed as a Masters thesis by Chante Davis (2006). Although her study was conducted outside of Alaska, the findings provide previously unavailable information on the maturity of another skate species known from Alaskan waters. Results for Aleutian, Bering, big, and longnose skates should be available in 2007, with results for most of the other species available in 2008.

Upon completion of the PSRC age, growth, and reproductive studies, demographic analyses (Leslie matrix) will be completed to provide an improved understanding of the population dynamics and vulnerability of these species to fisheries exploitation. Key demographic parameters, including annual population growth rate (λ), rate of increase per generation (rT), generation time ($\bar{A}$), net reproductive rate (R_O), and population doubling time (t_{x2}) will be projected for Aleutian, Bering, big, and longnose skates. Variability and uncertainty in life history parameters will be accounted for by incorporating Monte Carlo simulation into these models. Completion of these analyses for the aforementioned four species will be in 2007, with analyses of the remaining species expected to be completed in 2008-09. Information generated from this project will be incorporated into a life history data matrix (LHDM) developed by the

PSRC for eastern North Pacific chondrichthyans; the most recent version of the LHDM is currently available via the worldwide web (http://psrc.mlml.calstate.edu/).

Fishery

Directed fishery

In the BSAI, there is no directed fishery for skates at present; however, skates support directed fisheries in other parts of the world (Agnew et al. 1999, NE stock assessment 1999, Martin and Zorzi 1993). A directed skate fishery developed in the Gulf of Alaska in 2003 (Gaichas et al. 2003). There has been interest in developing markets for skates in Alaska (J. Bang and S. Bolton, Alaska Fishworks Inc., 11 March 2002 personal communication), and the resource was economically valuable to the GOA participants in 2003, although the price apparently dropped in 2004. Nevertheless, we should expect continued interest in skates as a potential future target fishery in the BSAI as well as in the GOA.

Bycatch and discards

Skate catch in the BSAI is officially reported as “Other” in aggregate with the catch of sharks, sculpins, and octopus, and thus estimates of skate catch must be made independently for each year using observer data, shoreside processor landings data, and processor weekly production report data. In 2003 the Alaska Regional Office (AKRO) converted to the Catch Accounting System (CAS), an improvement over the previous “Blend” system. However, at present the CAS is only capable of reporting aggregate skate catch in the BSAI; species composition of the catch can only be inferred from the observed skate catch. It should be noted that the 2003-2005 catch estimates from the CAS have changed slightly since last year’s assessment; these data are continuously updated and checked for errors by AKRO. The latest CAS estimates reported here represent the best and most accurate data available.

Skates constitute the bulk of the Other species FMP category catches, accounting for between 51% and 75% of the estimated totals in 1992-2006 (Table 16.3-3). While skates are caught in almost all fisheries and areas of the Bering Sea shelf, most of the skate bycatch is in the hook and line fishery for Pacific cod, with trawl fisheries for pollock, rock sole, flathead sole, and yellowfin sole also catching significant amounts (Tables 16.3-4 and 16.3-5). (In this assessment, "bycatch" means incidental or unintentional catch regardless of the disposition of catch – it can be either retained or discarded. We do not use the Magnuson Act definition of "bycatch," which always implies discard.) When caught as bycatch, skates may be discarded (and may survive depending upon catch handling practices) although skates caught incidentally are sometimes retained and processed. Due to incomplete observer coverage, it is difficult to determine how many skates are actually retained. However, between 24% and 39% of the total observed skate catch was retained during the years 2003-2006 (Table 16.3-6). More skates were retained in the EBS than the AI, and it appears that large-bodied species (>100 cm TL) are more likely to be retained than smaller-bodied skates. For example, while the Aleutian skate, a large-bodied species, made up a relatively small portion of the total skate catch in 2005 (approximately 2%), 31% of the Aleutian skates caught were retained. However, Bering skates (a small-bodied species less than 100 cm TL) were retained less frequently (10% in 2005). Larger percentages of Alaska skates and *Raja* species (big and longnose skates) are also retained; all three are relatively large-bodied skates.

Until 2004, the Other species TAC had never been exceeded in the BSAI with the current composition of the category. In 2004, the BSAI open access TAC of 23,124 t was exceeded as of October 23, so all Other species, including skates, were put on prohibited status (meaning no further retention is allowed, but catch and discard can continue up to the Other species OFL of 81,150 t). In addition, the Other species CDQ reserve of 2,040 t was also exceeded as of November 4, 2004. We note that the TAC of Other species was reduced from the ABC recommended by the SSC in December 2003, likely to keep the total catch of groundfish in compliance with the BSAI Optimum Yield (OY) cap of 2 million metric tons (Table 16.3-

3). However, if interest continues in developing fisheries within this category, the lower aggregate TAC may restrict retention and utilization of the more valuable components of the Other species category (skates and octopus).

Historically, skates were almost always recorded as "skate unidentified", with very few exceptions between 1990 and 2002. However, due to improvements in species identification by fishery observers initiated by Dr. Duane Stevenson (AFSC) within the Observer program in 2003, we can estimate the species composition of observed skate catches 2004-2006 (Figure 16.3-10). Recent observer data indicates that only about 50% of skate catch is not identified to the species level. This is largely because most skates are caught in longline fisheries, and if the animal drops off the longline as unretained incidental catch, it cannot be identified to species by the observer (approximately 80% of longline-caught skates are unidentified, and longline catch accounts for the majority of observed skate catch).

In 2005, observers were encouraged to identify skates dropped off longlines to genus, which can be done without retaining the skate; hence in 2005 more than half of the unidentified skates were at least assigned to the genus *Bathyraja*. Of the identified skates, the majority (90%) were Alaska skates, as would be expected by their dominance in terms of overall skate biomass in the BSAI. The next most commonly identified species BSAI-wide was Aleutian skate, at 6.6% of identified catch, followed by Bering skates at 4.3 %, big skates at 3.6%, and whiteblotched at approximately 1.3% across the BSAI. It should be noted that the observed skate catch composition may not reflect the true catch composition, possibly due to selective retention of larger species or to a higher likelihood of identifying distinctive species. However, when viewed by area (EBS vs. AI), it is clear that the majority of identified Aleutian and whiteblotched skates are caught in AI fisheries, and that the species composition of the observed catch in the AI is very different from the EBS (Figure 16.3-10). Reporting areas encompassing the EBS outer shelf and upper continental slope experienced high catch rates during 2003-2005 (Fig 16.3-11). Longline fisheries targeting Pacific cod take much of the incidental skate catch, and they tend to operate on the outer EBS shelf and slope where skate species diversity is high and where Aleutian skates are more prevalent than Alaska skates. Therefore it is likely that the species composition of the catch is not in proportion to the overall species composition (from survey data) across the BSAI.

Survey Data

<u>Survey biomass in aggregate and by species</u>

The biomass of all skate species combined has shown an increasing trend from 1975-2005 (Table 16.3-7). Because skates as a group are found in nearly all habitats, the uncertainty (measured as the coefficient of variation, CV) in these aggregate biomass estimates is rather low, but that for individual species is more variable (see Table 16.3-2). Unfortunately, due to taxonomic uncertainty, we cannot evaluate individual species trends within the complex for surveys prior to 1999. Recent survey information is used to describe the variable species composition of the skate complex within each of three areas, the EBS shelf, the EBS slope, and the Aleutian Islands. The EBS shelf skate complex is dominated by a single species, the Alaska skate (Table 16.3-2). This species is distributed throughout the EBS shelf (Figure 16.3-4) where since 1999 it has accounted for between 91% and 97% of aggregate skate biomass estimates. The Bering skate is the next most common species on the EBS shelf, making up about 3% of aggregate skate biomass. It is distributed on the outer continental shelf (Figure 16.3-5). While skate biomass decreases somewhat on the EBS slope, skate diversity increases substantially (Figure 16.3-6). The Aleutian skate is found occasionally on the outer EBS shelf but comprises the majority of the EBS slope skate biomass, with Bering and Alaska skates still quite common.

The skate community in the AI appears to be different from that described for both the EBS shelf and slope (Figure 16.3-6). In the AI, the most abundant species is the whiteblotched skate (over 50% of aggregate biomass). The whiteblotched skate is found primarily in the eastern Aleutians, and also very far out west (Figure 16.3-7). Alaska and Aleutian skates are also common in the AI, composing about 25% and 12% of aggregate biomass, respectively. The mud skate is relatively common but represents a lower proportion of total biomass (~5%) because it is a smaller-bodied skate.

Length frequency

Total length (TL, mm) has been recorded for a number of different skate species during annual resource assessment bottom trawl surveys. Length frequencies from 2000-2006 survey data for the most abundant species in the BSAI, the Alaska skate, are shown in Figure 16.3-12. The length composition of this species differs greatly by habitat area. The full known size range of the Alaska skate (21 to 119 cm TL, Matta 2006) is found on the EBS shelf, while mostly only large individuals are found in the deeper waters of the EBS slope and in the AI.

Analytic Approach, Model Evaluation, and Results

Parameters Estimated Independently: M

An analysis was undertaken to explore alternative methods to estimate natural mortality (M) for skate species found in the BSAI. 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). Natural mortality was estimated using these methods applied to data for California big skate (*Raja binoculata*) and longnose skate (*R. rhina*), which are found in the GOA but are rare in the BSAI. Considering the uncertainty inherent in applying this method to skate species and stocks not found in the BSAI, we elected to use the lowest estimates of M derived from any of these methods (M=0.10, Table 16.3-8). Choosing the lowest estimate of M will result in conservative estimates of ABC and OFL under Tier 5. Until better information is available on the productivity of individual skate species in the BSAI, we recommend this strategy in the interim in order to promote skate conservation while still allowing for historical levels of incidental catch in target groundfish fisheries.

New biological information has become available for skates from Alaskan waters and has been used to generate new estimates of M. Recent results, including age and growth data for GOA big and longnose skates and age, growth, and maturity data for EBS Alaska skates (*Bathyraja parmifera*) are available and have been added to Table 16.3-8. These latest estimates of M have not been applied to this year's assessment since they have yet to undergo review by the SSC; however they have been included here to demonstrate their availability for next year's assessment. The new estimates of M are close to the estimate of M=0.10 derived from CA big and longnose skates, which has been accepted by the Plan Team and the SSC as a reasonable approximation of "aggregate skate" M.

Assemblage analysis and recommendations

Because skates represent a potentially valuable fishery resource as well as a potentially sensitive species group, we recommend that they be managed separately from the Other species complex. There is a reliable biomass time series for the skate assemblage as a whole in both the EBS and AI, and recently (since 1999) there are also reliable estimates of biomass for each species within the assemblage.

We further recommend splitting the Alaska skate (*Bathyraja parmifera*) from the BSAI skate assemblage to form two management groups: Alaska skate and 'Other Skates'. The purpose of separate recommendations is to provide increased protection to rare or endemic species in the EBS slope and AI habitat areas, since the Alaska skate constitutes the bulk of the biomass in the EBS shelf habitat area. We have shown that the distribution of species differs greatly by habitat areas within the BSAI, and that overall catch is not necessarily in proportion to BSAI-wide biomass due to the distribution of fishing effort. Because it would be difficult to manage skates by habitat area, managing Alaska skates and the Other Skates complex separately represents a reasonable compromise which increases protection to the species within each ecosystem but maintains a level of management simplicity appropriate to nontarget species complexes. In the event that target fisheries develop for individual skate species in the Other Skates complex, we would recommend that target skate species be further separated from the complex and managed individually. Furthermore, directed fishing for skates in the BSAI should only be allowed when sufficient life history information becomes available to make reasonable species-specific estimates of productivity.

Projections and Harvest Alternatives

Acceptable Biological Catch and Overfishing Limit

We recommend that a Tier 5 approach be applied to the Alaska skate and the Other Skate species complex if the catch remains incidental and no target fishery develops. Tier 5 is recommended because reliable estimates of biomass exists, and M =0.10 is considered a reasonable approximation of "aggregate 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. Biomass estimates were used from years when species identification aboard research surveys was considered most reliable (1999-2006). Tier 6 is not recommended because the catch history for skates is not considered reliable (reported as "Other species"), and average catch for untargeted species is likely to constrain target fisheries if used to specify harvest limits. For the Tier 5 estimate, we recommend using an 8 year average of skate biomass so that we may include multiple estimates from each of the trawl surveys, but capture recent biomass levels.

	Alaska skate			**Other Skates**		
Survey Year	EBS shelf	EBS slope	AI	EBS shelf	EBS slope	AI
1999	315,536			32,941		
2000	300,954		9,801	24,338		19,518
2001	402,909			17,405		
2002	347,873	35,932	10,662	18,441	33,344	23,752
2003	354,244			32,095		
2004	402,354	4,248	12,727	14,205	28,909	40,344
2005	461,067			20,127		
2006	424,511		13,484	18,045		40,726
average	**376,181**	**20,090**	**11,668**	**22,200**	**31,127**	**31,085**

Alaska skate ABC

Applying the M estimate of 0.10 to the 8 year average of bottom trawl survey biomass estimates, we calculate an ABC of 0.75 * 0.10 * (EBS shelf biomass of 376,181 + EBS slope biomass of 20,090 + AI biomass of 11,668) = 30,595 t.

Alaska skate OFL

Applying the M estimate of 0.10 to the 8 year average of bottom trawl survey biomass estimates, we calculate an OFL of 0.10 * (EBS shelf biomass of 376,181 + EBS slope biomass of 20,090 + AI biomass of 11,668) = 40,794 t.

Other Skates ABC
Applying the M estimate of 0.10 to the 8 year average of bottom trawl survey biomass estimates, we calculate an ABC of 0.75 * 0.10 * (EBS shelf biomass of 22,200 + EBS slope biomass of 31,127 + AI biomass of 31,085) = 6,331 t.

Other Skates OFL
Applying the M estimate of 0.10 to the 8 year average of bottom trawl survey biomass estimates, we calculate an OFL of 0.10 * (EBS shelf biomass of 22,200 + EBS slope biomass of 31,127 + AI biomass of 31,085) = 8,441 t.

Ecosystem Considerations

This section focuses on the Alaska skate in both the EBS and AI, with all other species found in each area summarized within in the group "Other skates." We also include supplemental information on the other biomass dominant species in the AI, the Aleutian and whiteblotched skates. This level of aggregation is necessary due to current data constraints, but improved species-specific information will be incorporated as it becomes available.

Skates are predators in the BSAI FMP area. Some species are piscivorous while others specialize in benthic invertebrates; additionally, at least three species, deepsea skate, roughtail skate, and longnose skate, are benthophagic during the juvenile stage but become piscivorous as they grow larger (Ebert 2003, Robinson 2006) (Table 16.3-1). Each skate species would occupy a slightly different position in EBS and AI food webs based upon its feeding habits, but in general skates as a group are predators at a relatively high trophic level. For simplicity, we show the food webs for all skate species combined in each system (Figure 16.3-13; EBS in upper panel, AI in lower panel). In the EBS food web, the skate biomass and therefore the general skate food web position is dominated by the Alaska skate, which eats primarily pollock (as do most other piscivorous animals in the EBS). The food web indicates that aside from sperm whales, most of the "predators" of EBS skates are fisheries, and that cod and halibut are both predators and prey of skates. The AI food web shows skates with different predators and prey than in the EBS, but still at the same moderately high trophic level. Relative to EBS skates, AI skates display more diet diversity (because the species complex is more diverse than in the Alaska skate-dominated EBS), and have more non-fishery predators including sharks and sea lions. These food webs were derived from mass balance ecosystem models assembling information on the food habits, biomass, productivity and consumption for all major living components in each system (Aydin et al. in review).

The density and mortality patterns for skates also differ greatly between the EBS and AI ecosystems. The biomass density of Alaska skates is much higher in the EBS than in the AI (Figure 16.3-14 upper left panel) and we now know they are likely separate species between the areas as well. The density of Alaska skates in the EBS also far exceeds that of all other *Bathyraja* species in any area (Figure 16.3-14 upper right panel), but the density of other *Bathyraja* skates is highest in the AI. One simple way to evaluate ecosystem (predation) effects relative to fishing effects is to measure the proportions of overall mortality attributable to each source. The lower panels of Figure 16.3-14 distinguish predation from fishing mortality, and further distinguish these measured sources of mortality from sources that are not explained within the ecosystem models, which are based on early 1990s fishing and food habits information. While there are many uncertainties in estimating these mortality rates, the results suggest that (early 1990s) fishing mortality exceeded predation mortality for Alaska skates and for other skates in the EBS and AI (and for other skates in the GOA as well). Furthermore, predation mortality appeared to be higher for AI skates than for EBS skates, both for Alaska and other skate species in the early 1990s, suggesting that skates experience higher overall mortality in the AI relative to the EBS. One source of uncertainty in these results is that all skate species in all areas were assumed to have the same total mortality rate, which is an oversimplification, but one which is consistent with the assumptions regarding natural mortality rate (the same for all skate species) in this stock assessment. We expect to improve on these default assumptions as data on productivity and catch for the skate species in each area continue to improve.

In terms of annual tons removed, it is instructive to compare fishery catches with predator consumption of skates. We estimate that fisheries were annually removing about 13,000 and 1,000 tons of skates from the EBS and AI, respectively on average during the early 1990s (Fritz 1996, 1997). While estimates of predator consumption of skates are perhaps more uncertain than catch estimates, the ecosystem models incorporate uncertainty in partitioning estimated consumption of skates between their major predators in each system. The predators with the highest overall consumption of Alaska skates in the EBS are sperm whales, which account for less than 2% of total skate mortality and consumed between 500 and 2,500 tons of skates annually in the early 1990s. Consumption of EBS Alaska skates by Pacific halibut and cod are too small to be reliably estimated (Figure 16.3-15, left panels). Similarly, sperm whales account for less than 2% of other skate mortality in the EBS, but are still the primary predator of other skates there, consuming an estimated 50 to 400 tons annually. Pacific halibut consume very small amounts of other skates in the EBS, according to early 1990s information integrated in ecosystem models (Figure 16.3-15, right panels). The predators with the highest consumption of Alaska skates in the AI are also sperm whales, which account for less than 2% of total skate mortality and consumed between 20 and 120 tons of skates annually in the early 1990s. Pinnipeds (Steller sea lions) and sharks also contributed to Alaska skate mortality in the AI, averaging less than 50 tons annually (Figure 16.3-16, left panels). Similarly, sperm whales account for less than 2% of other skate mortality in the AI, but are still the primary predator of other skates there, consuming an estimated 20 to 150 tons annually. Pinnipeds and sharks consume very small amounts of other skates in the AI, according to early 1990s information (Figure 16.3-16, right panels). Gerald Hoff's research on skate nursery areas suggests that gastropod predation on skate egg cases may account for a significant portion of mortality during the embryonic stage, and Pacific cod and Pacific halibut consume substantial numbers of newly hatched juvenile skates within nursery areas. These sources of mortality may be included in the models once his work is completed.

Diets of skates are derived from food habits collections taken in conjunction with EBS and AI trawl surveys. Skate food habits information is more complete for the EBS than for the AI, but we present the best available data for both systems here. Over 40% of EBS Alaska skate diet measured in the early 1990s was adult pollock, and another 15% of the diet was fishery offal, suggesting that Alaska skates are opportunistic piscivores (Figure 16.3-17, upper left panel). Eelpouts, rock soles, sandlance, arrowtooth flounder, salmon, and sculpins made up another 25-30% of Alaska skates' diet, and invertebrate prey made up the remainder of their diet. This diet composition combined with estimated consumption rates and the high biomass of Alaska skates in the EBS results in an annual consumption estimate of 200,000 to 350,000 tons of pollock annually (Figure 16.3-17, lower left panel). EBS other skates also consume pollock (45% of combined diets), but their lower biomass results in consumption estimates ranging from 20,000 to 70,000 tons of pollock annually (Figure 16.3-17, right panels). Other skates tend to consume more invertebrates than Alaska skates in the EBS, so estimates of benthic epifaunal consumption due to other skates range up to 50,000 tons annually, higher than those for Alaska skates despite the disparity in biomass between the groups (Figure 16.3-17, lower panels). Because Alaska skates and all other skates are distributed differently in the EBS, with Alaska skates dominating the shallow shelf areas and the more diverse species complex located on the outer shelf and slope, we might expect different ecosystem relationships for skates in these habitats based on differences in food habits among the species. Similarly, in the AI the unique skate complex has different diet compositions and consumption estimates from those estimated for EBS skates. The skate in the AI formerly known as the Alaska skate is opportunistically piscivorous like its EBS relative, feeding on the common commercial forage fish, Atka mackerel (65% of diet) and pollock (14% of diet), as well as fishery offal (7% of diet; Figure 16.3-18 upper left panel).

Diets of other skates in the AI are more dominated by benthic invertebrates, especially shrimp (pandalid and non-pandalid total 42% of diet), but include more pelagic prey such as juvenile pollock, adult Atka mackerel, adult pollock and squids (totaling 45% of diet; Figure 16.3-18 upper right panel). Estimated annual consumption of Atka mackerel by AI (former) Alaska skates in the early 1990s ranged from 7,000 to 15,000 tons, while pollock consumption was below 5,000 tons (Figure 16.3-18 lower left panel). Shrimp consumption by AI other skates was estimated to range from 4,000 to 15,000 tons annually in the early 1990s, and consumption of pollock ranged from 2,000 to 10,000 tons (Figure 16.3-18 lower right panel). Atka mackerel consumption by AI other skates was estimated to be below 5,000 tons annually. The diet composition estimated for AI other skates is likely dominated by the biomass dominant species in that system, whiteblotched skate and Aleutian skate. We include updated summaries of food habits data for these important AI species in Figure 16.3-19; please note that their diet compositions have changed since last year's skate assessment. The diet compositions of both Aleutian and whiteblotched skates in the AI appear to be fairly diverse, and are described in further detail in Yang (in prep) along with the diets of big skate, Bering skate, Alaska skate, roughtail skate, and mud skate in the AI. In the future, we hope to use diet compositions to make separate consumption estimates for whiteblotched and Aleutian skates along with (former) Alaska skates in the AI.

Examining the trophic relationships of EBS and AI skates provides a context for assessing fishery interactions beyond the direct effect of bycatch mortality. In both areas, the biomass-dominant species of skates feed on commercially important fish species, so it is important for fisheries management to maintain the health of pollock and Atka mackerel stocks in particular to maintain the forage base for skates (as well as for other predators and for human commercial interests).

Data gaps and research priorities

Because skates are at a relatively high trophic level in the EBS and AI, predation mortality is less significant than fishing mortality. Therefore, the assessment of skate population dynamics and response to fishing should be continued and improved as fishing represents the largest explained source of mortality in the EBS and AI (especially since this mortality is not from targeted fishing, but from incidental catch). 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 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 EBS and AI, and some results have already become available. Such research 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 juveniles, with the completion of Gerald Hoff's research on skate nursery areas.

The PSRC (MLML) has recently received funding from the North Pacific Research Board (NPRB) to examine the feeding habits of Aleutian, Bering, big, and longnose skates. Simon Brown, a graduate student, is currently working on this project. Specific objectives are to: 1) determine the diets of Alaskan skate species through analysis of stomach contents, 2) examine temporal, ontogenetic, and intergender differences in diet for each species, 3) investigate aspects of foraging habitat and trophic relationships for each species, and 4) compare interspecific diets of these Alaskan skate species to determine degree of dietary overlap. The results of this study will provide basic biological information on skates for inclusion in multi-species and predator/prey models.

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 mostly 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 of skate nursery areas to evaluate their importance to population production.

We do not see any conflict at present between commercial fishing and skate foraging on pollock or Atka mackerel, 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 BSAI skates and the entire groundfish fishery where they are caught incidentally. Because there is no "skate fishery" in the EBS or AI 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 BSAI Skates ***(evaluating level of concern for skate populations)***

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

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

Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Skate catch	Varies from 12,000 to 23,000 tons annually	Largest portion of total mortality for skates	Possible concern
Forage availability	Skates have few predators, and skates are small proportion of diets for their predators	Fishery removal of skates has a small effect on predators	Probably no concern
Fishery concentration in space and time			
	Skate bycatch is spread throughout FMP areas, although higher proportion of skate bycatch occurs on outer continental shelf and upper slope	Potential impact to skate populations if fishery disturbs nursery or other important habitat, but small effect on skate predators	Possible concern for skates, probably no concern for skate predators
Fishery effects on amount of large size target fish			
	Size of bycaught skates not measured	Unknown	Unknown
Fishery contribution to discards and offal production			
	Skate discard a relatively high proportion of skate catch, some incidentally caught skates are retained and processed	Unclear whether discard of skates has ecosystem effect	Unknown
Fishery effects on age-at-maturity and fecundity			
	Skate age at maturity and fecundity are just now being described; fishery effects on them difficult to determine due to lack of unfished population to compare with	Unknown	Unknown

Summary

2006 Recommendations	Alaska skate	Other Skates
M	0.10	0.10
Tier	5	5
Biomass	407,939	84,412
F_{OFL}	0.10	0.10
Max F_{ABC}	0.075	0.075
Recommended F_{ABC}	0.075	0.075
OFL	40,794	8,441
Max ABC	30,595	6,331
Recommended ABC	30,595	6,331

Acknowledgements

Many thanks to the following for their valuable contributions to this document: Bob Lauth, Mark Wilkins, and others in the RACE program for providing new survey biomass estimates, the North Pacific Groundfish Observer Program for their hard work in the field and compiling data, and the Alaska Regional Office for making nontarget species catch estimates available for 2003-2006. We gratefully acknowledge Chris Gburski and Mei-Sun Yang (AFSC) and Wade Smith, Joe Bizzarro, and other members of the Pacific Shark Research Center (MLML/CSU) for generously contributing unpublished diet and life history research results. Lastly, we'd like to thank Dean Courtney for review of this assessment. Thank you!!

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Tables

Table 16.3-1. Life history and depth distribution information available for BSAI and GOA skate species, from Stevenson (2004) unless otherwise noted.

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

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

Table 16.3-2. Species composition of the EBS and AI skate complexes from the most recent AFSC bottom trawl surveys.

Skate species	**Common name**	**2006 EBS shelf**		**2004 EBS slope**		**2006 Aleutians**	
		bio (t)	**cv**	**bio (t)**	**cv**	**bio (t)**	**cv**
Bathyraja abyssicola	deepsea	0		164	0.73	0	
Bathyraja aleutica	Aleutian	5,568	0.41	14,987	0.14	6,684	0.23
Bathyraja interrupta	Bering	11,204	0.13	1,953	0.11	186	0.55
Bathyraja lindbergi	Commander	0		4,194	0.15	0	
Bathyraja maculata	whiteblotched	182	1.00	3,450	0.16	29,712	0.19
Bathyraja minispinosa	whitebrow	0		1,755	0.20	0	
Bathyraja parmifera	Alaska	424,511	0.05	4,248	0.33	13,484	0.19
Bathyraja taranetzi	mud	55	1.00	702	0.20	2,970	0.28
Bathyraja trachura	roughtail	0		1,677	0.12	0	
Bathyraja violacea	Okhotsk	0		8	1.00	0	
Raja binoculata	big	1,036	0.68	0		568	0.72
Raja rhina	longnose	0		0		0	
Rajidae unid	Unidentified skate species	0		19	0.54	605	0.41
Total skate complex		**442,556**	**0.05**	**33,156**	**0.08**	**54,210**	**0.12**

Table 16.3-3. Time series of BSAI Other species ABC, TAC, OFL and catch (t), with skate catch proportion. Other species catch includes squids.

Year	**Other species ABC**	**Other species TAC**	**Other species OFL**	**Other species catch**	**BSAI skate catch**	**Skate % of Other species catch**
1991	28,700	15,000		17,199		
1992	27,200	20,000	27,200	33,075	16,962	51%
1993		22,610		23,851	12,226	51%
1994	27,500	26,390	141,000	24,555	14,223	58%
1995	27,600	20,000	136,000	22,213	14,892	67%
1996	27,600	20,125	137,000	21,440	12,643	59%
1997	25,800	25,800		25,176	17,747	70%
1998	25,800	25,800	134,000	25,531	19,318	76%
1999	32,860	32,860	129,000	20,562	14,080	68%
2000	31,360	31,360	71,500	26,108	18,877	72%
2001	33,600	26,500	69,000	27,178	20,570	76%
2002	39,100	30,825	78,900	28,619	21,279	74%
2003	43,300	32,309	81,100	27,356	19,419	71%
2004	46,810	27,205	81,150	30,530	22,462	74%
2005	53,860	29,000	87,920	30,609	22,982	75%
2006	58,882	29,000	89,404	26,279*	18,478*	70%

Sources: Other species ABC, TAC, OFL and 1992-2002 Other species catch from AKRO website.
BSAI skate catch 1992-1996 from Fritz 1996, 1997, 1997-2002 from Gaichas et al. 2004.
BSAI Other species and skate catch 2003-2006 from AKRO CAS. CAS estimates have changed slightly since last year's assessment and represent the most accurate data available.
*2006 data complete as of October 22, 2006

Table 16.3-4. Estimated catch (t) of all skate species combined by target fishery, gear, and area, 1997-2002. Source: Gaichas AFSC.

Target fishery	gear	1997	1998	1999	2000	2001	2002
Arrowtooth	hook n line		0.65	9.72	1.31		0.49
	trawl	1.62	117.64	17.74	43.02	89.98	81.55
Arrowtooth Total		1.62	118.29	27.46	44.33	89.98	82.04
Atka mackerel	trawl	110.51	130.81	126.66	71.50	80.57	73.30
Flatheadsole	trawl	777.22	1,867.59	1,215.15	1,655.80	1,752.36	1,530.37
Other	hook n line		10.42	26.07	52.48	70.43	31.17
	trawl						8.82
Other Total			10.42	26.07	52.48	70.43	39.98
OtherFlats	trawl	39.18	103.15	69.22	115.16	20.09	58.48
Pacific cod	hook n line	13,298.81	13,534.64	9,651.09	12,975.65	14,116.58	14,059.10
	pot	1.50	0.01	0.11	0.06	0.10	0.00
	trawl	715.23	770.48	984.30	1,053.86	631.91	1,400.41
Pacific cod Total		14,015.53	14,305.12	10,635.50	14,029.56	14,748.59	15,459.51
Pollock	trawl	349.73	405.67	375.87	598.19	627.58	807.04
Rock sole	trawl	679.20	558.69	322.21	334.28	820.60	836.61
Rockfish	hook n line	110.27	6.73	0.69	1.70	4.42	0.84
	trawl	30.05	39.94	53.61	50.53	47.67	78.14
Rockfish Total		140.32	46.67	54.30	52.23	52.09	78.99
Sablefish	hook n line	266.00	110.10	109.54	115.86	194.11	233.13
	pot			0.09	0.01	0.06	0.01
	trawl		0.06			1.24	
Sablefish Total		266.00	110.16	109.63	115.87	195.41	233.14
Turbot	hook n line	140.82	280.84	319.92	317.36	187.07	120.80
	pot			1.22			
	trawl	16.13	18.67	17.34	23.92	16.66	7.76
Turbot Total		156.95	299.51	338.48	341.28	203.73	128.57
Unknown	hook n line	0.11	2.00	1.16	0.95	0.21	
	trawl		1.09		0.01	0.11	
Unknown Total		0.11	3.09	1.16	0.95	0.32	
Yellowfinsole	trawl	1,210.99	1,358.70	778.11	1,464.90	1,908.69	1,950.67
Grand Total		17,747.37	19,317.86	14,079.84	18,876.53	20,570.46	21,278.69

FMP area	area	1997	1998	1999	2000	2001	2002
AI	541	569.98	640.25	462.61	501.96	540.77	288.88
	542	200.87	369.17	239.96	608.31	422.64	217.74
	543	86.30	119.02	99.79	698.20	1,546.14	188.84
AI Total		857.15	1,128.45	802.36	1,808.47	2,509.56	695.46
EBS	509	1,920.87	2,317.12	2,033.62	2,830.27	3,092.09	3,112.51
	512	0.92		14.33		91.68	132.82
	513	2,572.53	2,605.18	1,993.53	2,641.56	2,726.15	4,036.76
	514	134.61	40.86	203.65	101.55	83.42	223.02
	516	74.26	73.35	199.06	122.64	249.95	336.13
	517	3,499.07	4,820.64	3,514.42	4,910.51	4,378.18	4,394.10
	518	49.00	82.65	80.14	52.09	101.80	65.00
	519	42.69	106.07	57.86	83.01	96.52	68.93
	521	7,066.94	7,205.81	4,420.95	5,724.41	6,517.25	7,327.22
	523	548.85	455.37	404.81	284.01	324.73	314.50
	524	980.48	482.36	355.11	318.01	399.14	572.23
EBS Total		16,890.22	18,189.41	13,277.48	17,068.06	18,060.90	20,583.23
BSAI Total		17,747.37	19,317.86	14,079.84	18,876.53	20,570.46	21,278.69

Table 16.3-5. Estimated catch (t) of all skate species combined by target fishery, gear, and region 2003-2006. Source: AKRO CAS. CAS estimates have changed slightly since last year's assessment and represent the most accurate data available *2006 data complete as of October 22, 2006.

Target Fishery	Gear	2003	2004	2005	2006*
Atka mackerel	trawl	93.97	143.04	139.98	131.00
Pacific cod	hook & line	13,629.99	16,901.39	18,625.92	12,031.05
	pot	0.05	0.00	0.01	0.11
	trawl	1,524.13	1,584.66	755.76	1,627.00
	all gear types	15,154.17	18,486.05	19,381.69	13,658.16
Arrowtooth	hook & line	0.13	0	1.19	65.10
	trawl	106.03	65.09	127.97	174.78
	all gear types	106.17	65.09	129.16	239.88
Flathead sole	trawl	628.34	1,207.01	847.24	806.18
Halibut	hook & line	265.10	269.53	92.59	59.29
Rock sole	trawl	551.12	508.64	423.14	891.43
Turbot	hook & line	208.46	127.88	166.86	135.62
	trawl	12.57	7.90	1.21	0
	all gear types	221.03	135.78	168.07	135.62
Yellowfin sole	trawl	1,539.94	595.76	942.31	1,114.47
Other flatfish	trawl	26.64	78.27	43.40	6.97
Pollock	hook & line	0	0.01	0.13	2.14
	trawl	471.00	842.52	731.30	1,207.88
	all gear types	471.00	842.53	731.42	1,209.42
Rockfish	hook & line	7.69	0.91	4.13	1.26
	trawl	65.07	20.64	25.37	23.47
	all gear types	72.75	21.55	29.49	24.73
Sablefish	hook & line	57.12	10.20	25.76	84.93
	pot	0.25	0.09	0.39	0.04
	trawl	0	0.30	0	0
	all gear types	57.36	10.59	26.15	84.97
Unknown Target	all gear types	231.05	97.85	27.73	115.07
BSAI Total	all gear types	19,418.62	22,461.68	22,982.37	18,478.18

Region	Area	2003	2004	2005	2006*
AI	541	302.19	471.54	471.54	527.03
	542	234.39	259.77	123.68	273.85
	543	118.10	139.45	81.69	60.65
AI Total		**654.67**	**870.76**	**676.90**	**861.54**
EBS	508	0	0.06	0	0
	509	2,008.63	2,169.97	3,226.06	3,276.93
	512	24.76	204.80	14.70	0
	513	2,784.91	2,882.64	4,007.19	2,531.80
	514	280.77	66.96	196.19	201.06
	516	132.24	417.22	239.20	250.78
	517	3,037.93	3,046.30	3,656.32	2,026.06
	518	24.73	6.56	2.90	6.65
	519	199.11	138.62	102.76	59.38
	521	8,948.13	10,309.93	8,466.98	7,732.10
	523	306.71	322.85	243.85	206.79
	524	1,016.04	2,025.01	2,149.34	1,325.11
EBS Total		**18,763.95**	**21,590.92**	**22,305.47**	**17,616.64**
BSAI Total		**19,418.62**	**22,461.68**	**22,982.37**	**18,478.18**

Table 16.3-6. Observed skate catch and observed skate retention by species, and by region, 2003-2006. *2006 reported as of September 2006 (not a complete year). Source: North Pacific Groundfish Observer Program database.

Species	2003 Observed Catch (t)	2003 Observed Retained (t)	2003 Percent Retained	2004 Observed Catch (t)	2004 Observed Retained (t)	2004 Percent Retained	2005 Observed Catch (t)	2005 Observed Retained (t)	2005 Percent Retained	2006* Observed Catch (t)	2006* Observed Retained (t)	2006* Percent Retained
Aleutian	70.80	19.68	28 %	264.19	95.03	36%	303.92	93.94	31%	78.55	31.17	40 %
Alaska	1,178.73	582.25	49 %	4,373.09	1,562.07	36%	4,124.94	1,590.14	39%	3,315.89	941.57	28 %
Roughtail	0.21	0	0 %	4.96	0.39	8%	1.60	0.03	2%	2.30	0.05	2 %
Deepsea				0.04	0	0%						
Bering	43.39	11.64	27 %	232.51	27.20	12%	197.21	20.57	10%	62.79	8.65	14 %
Sandpaper				0.02	0	0%						
Whitebrow	0.38	0	0 %	5.25	1.65	31%	6.72	0.49	7%	3.14	0.53	17 %
Commander	2.11	0.02	1 %	14.87	2.67	18%	26.09	1.34	5%	6.41	0.29	4 %
White-blotched	9.12	0.05	1 %	153.18	32.33	21%	58.26	13.86	24%	44.10	9.72	22 %
Mud	0.67	0.01	2 %	28.64	1.97	7%	22.04	0.83	4%	4.57	0.99	22 %
Okhotsk	0.76	0.02	3 %	0.03	0.01	25%						
Butterfly							0.01	0.01	100%			
Bathyraja unID	57.84	44.25	77 %	77.42	6.41	8%	6,318.64	2,338.69	37%	2,581.72	528.19	20 %
Big	25.83	15.51	60 %	130.77	35.24	27%	165.26	31.51	19%	146.48	37.72	26 %
Longnose	1.34	0.43	32 %	15.17	6.43	42%	5.08	2.24	44%	0.82	0.09	10 %
Starry										0.01	0.01	100 %
Raja unID				0.32	0	0%	9.94	0.38	4%	0.15	0.10	68 %
Skate unID	13,024.37	4,901.10	38 %	8,822.19	2,411.38	27%	3,852.59	1,089.45	28%	1,316.11	263.97	20 %
All BSAI skates	**14,415.55**	**5,574.97**	**39 %**	**14,122.64**	**4,182.79**	**30%**	**15,092.30**	**5,183.49**	**34%**	**7,563.03**	**1,823.04**	**24 %**

Region	2003 Observed Catch (t)	2003 Observed Retained (t)	2003 Percent Retained	2004 Observed Catch (t)	2004 Observed Retained (t)	2004 Percent Retained	2005 Observed Catch (t)	2005 Observed Retained (t)	2005 Percent Retained	2006* Observed Catch (t)	2006* Observed Retained (t)	2006* Percent Retained
AI	437.08	79.05	18%	589.73	122.92	21%	463.29	76.58	17%	462.77	64.88	14%
EBS	13,978.47	5,495.92	39%	13,532.91	4,059.87	30%	14,629.02	5,106.91	35%	7,100.26	1,756.16	25%
All BSAI skates	**14,415.55**	**5,574.97**	**39%**	**14,122.64**	**4,182.79**	**30%**	**15,092.30**	**5,183.49**	**34%**	**7,563.03**	**1823.04**	**24%**

Table 16.3-7. Skate biomass (metric tons) with coefficient of variation (cv) from bottom trawl surveys of the Eastern Bering Sea (EBS) shelf, EBS slope, and Aleutian Islands (AI), 1975-2006.

Year	EBS shelf		EBS slope		AI	
	biomass	cv	biomass	cv	biomass	cv
1975	24,349	0.19				
1976						
1977						
1978						
1979	58,147	0.14	3,056	0.26		
1980					4,257	0.25
1981			2,743	0.12		
1982	164,084	0.10	2,723	0.10		
1983	161,329	0.09			9,683	0.12
1984	186,976	0.09				
1985	149,573	0.11	3,329	0.10		
1986	251,296	0.15			15,436	0.19
1987	346,679	0.10				
1988	408,242	0.11	3,271	0.21		
1989	406,007	0.08				
1990	533,837	0.11				
1991	448,054	0.09	4,031	0.25	14,967	0.17
1992	390,294	0.09				
1993	374,882	0.07				
1994	414,054	0.08			25,014	0.10
1995	391,537	0.08				
1996	403,521	0.06				
1997	391,032	0.07			28,922	0.14
1998	354,000	0.05				
1999	348,477	0.16				
2000	325,292	0.06			29,320	0.09
2001	420,313	0.06				
2002	366,315	0.07	69,275	0.50	34,413	0.11
2003	386,339	0.05				
2004	416,559	0.05	33,156	0.08	53,071	0.16
2005	481,194	0.05				
2006	442,556	0.05			54,210	0.12

Table 16.3-8. Estimates of M based on life history for skate species. "Age mature" was given a range for M estimates by the Rikhter and Efanov method to account for uncertainty in this parameter. Study areas are indicated as CA (California), GOA (Gulf of Alaska), BC (British Columbia), and EBS (Eastern Bering Sea). Life history parameter sources: Zeiner and Wolf 1993, Gburski et al. in review, McFarlane and King 2006, Matta 2006.

Species	Area	Sex	Hoenig	Age mature	Rikhter & Efanov	Alverson & Carney	Charnov	Roff
Big skate	CA	*males*	0.38					
	CA	*females*	0.35					
	CA	*both*		8	0.19			
	CA			9	0.16			
	CA			10	0.13			
	CA			11	0.12			
	CA			12	**0.10**			
Longnose skate	CA	*males*	0.32			0.31	0.44	0.23
	CA	*females*	0.35			0.45	0.29	0.03
	CA	*both*		7	0.22		0.31	
	CA			8	0.19			
	CA			9	0.16			
	CA			10	0.13			
Big skate	GOA	*males*	0.28			0.33	0.28	
	GOA	*females*	0.30			0.45	0.15	
Longnose skate	GOA	*males*	0.17			0.24	0.11	
	GOA	*females*	0.17			0.28	0.07	
Big skate	BC	*males*	0.17			0.25	0.10	0.34
	BC	*females*	0.16			0.25	0.08	0.27
	BC	*both*		5	0.32			
	BC			6	0.26			
	BC			7	0.22			
	BC			8	0.19			
Longnose skate	BC	*males*	0.18			0.25	0.13	0.21
	BC	*females*	0.16			0.22	0.11	0.12
	BC	*both*		6	0.26			
	BC			7	0.22			
	BC			8	0.19			
	BC			9	0.16			
	BC			10	0.13			
Alaska skate	EBS	*males*	0.28			0.37	0.22	0.13
	EBS	*females*	0.25			0.35	0.16	0.15
	EBS	*both*		8	0.19			
	EBS			9	0.16			
	EBS			10	0.13			

Figures

Figure 16.3-1 Skate diversity on the Bering Sea slope: five species of skate captured in a single trawl haul on the NMFS Bering sea slope survey, 2002. Species pictured include *Bathyraja minispinosa* (whitebrow), *B. taranetzi* (mud), *B. maculata* (whiteblotched), *B. aleutica* (Aleutian), and *B. lindbergi* (Commander). Photo credit: Gerald Hoff.

The following maps show the range of each skate species encountered in the BSAI FMP area. These maps were created primarily using survey data, although observer records were included whenever positive species identification was possible (through voucher specimens or photographs).

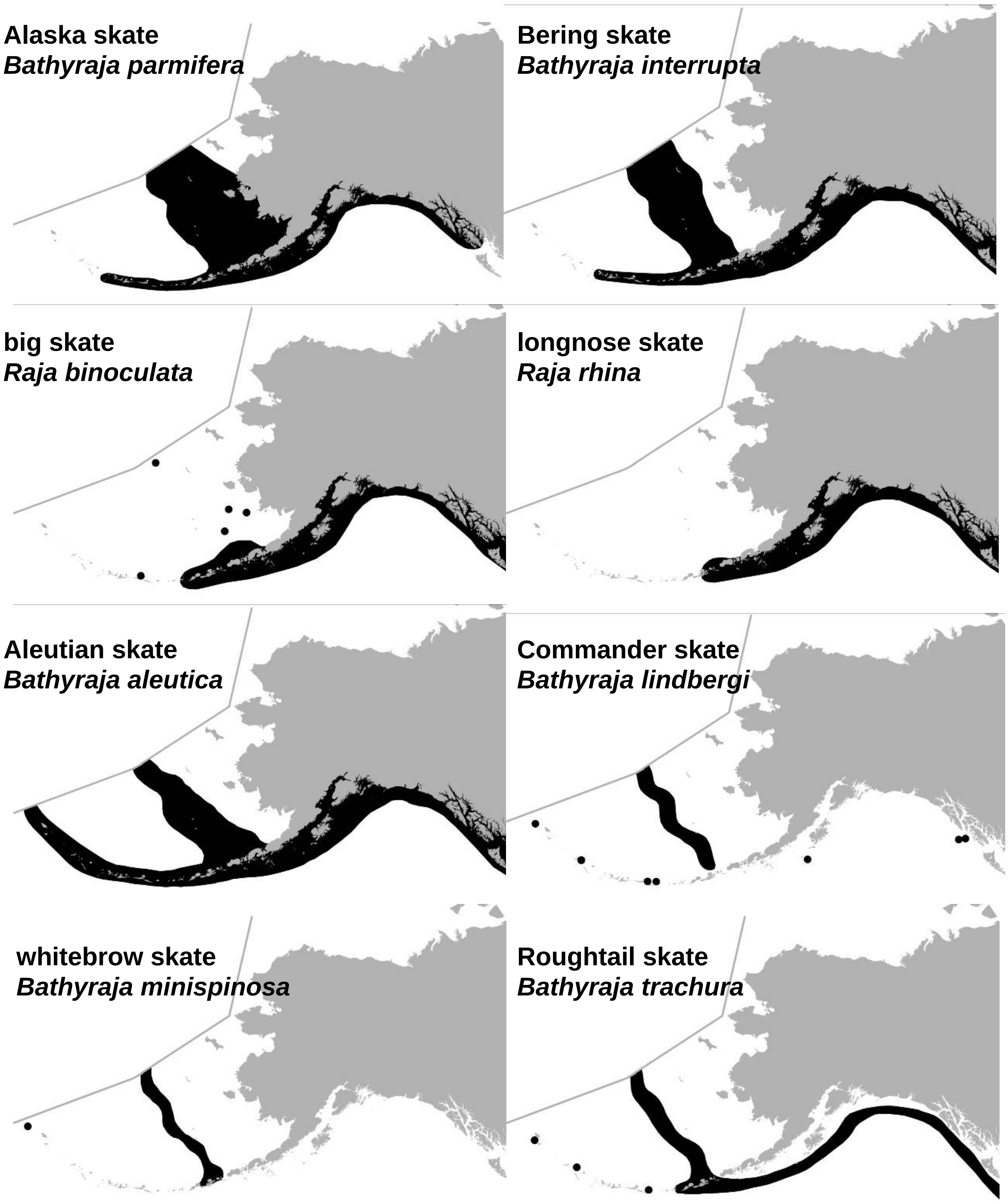


Figure 16.3-2. Distribution of skate species in Alaskan waters. (Source: Stevenson et al. in press.)

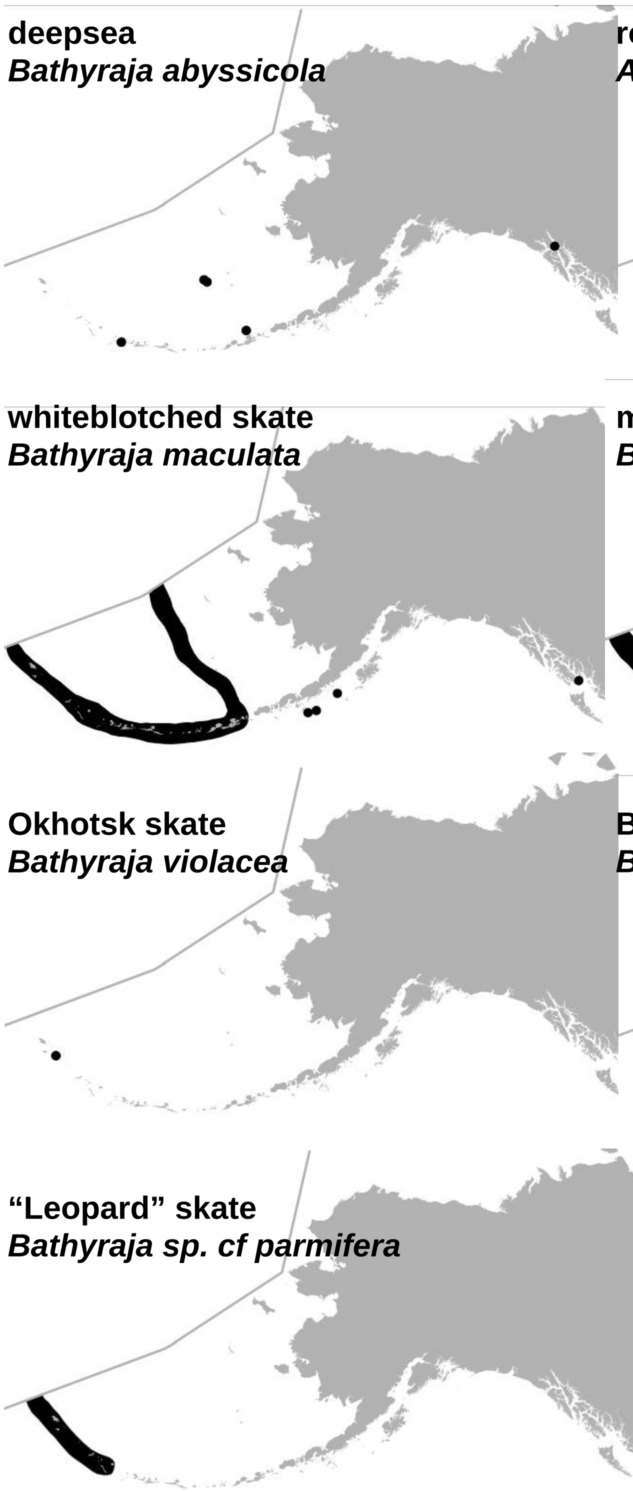


Figure 16.3-2(continued). Distribution of skate species in Alaskan waters (Source: Stevenson et al. in press.)

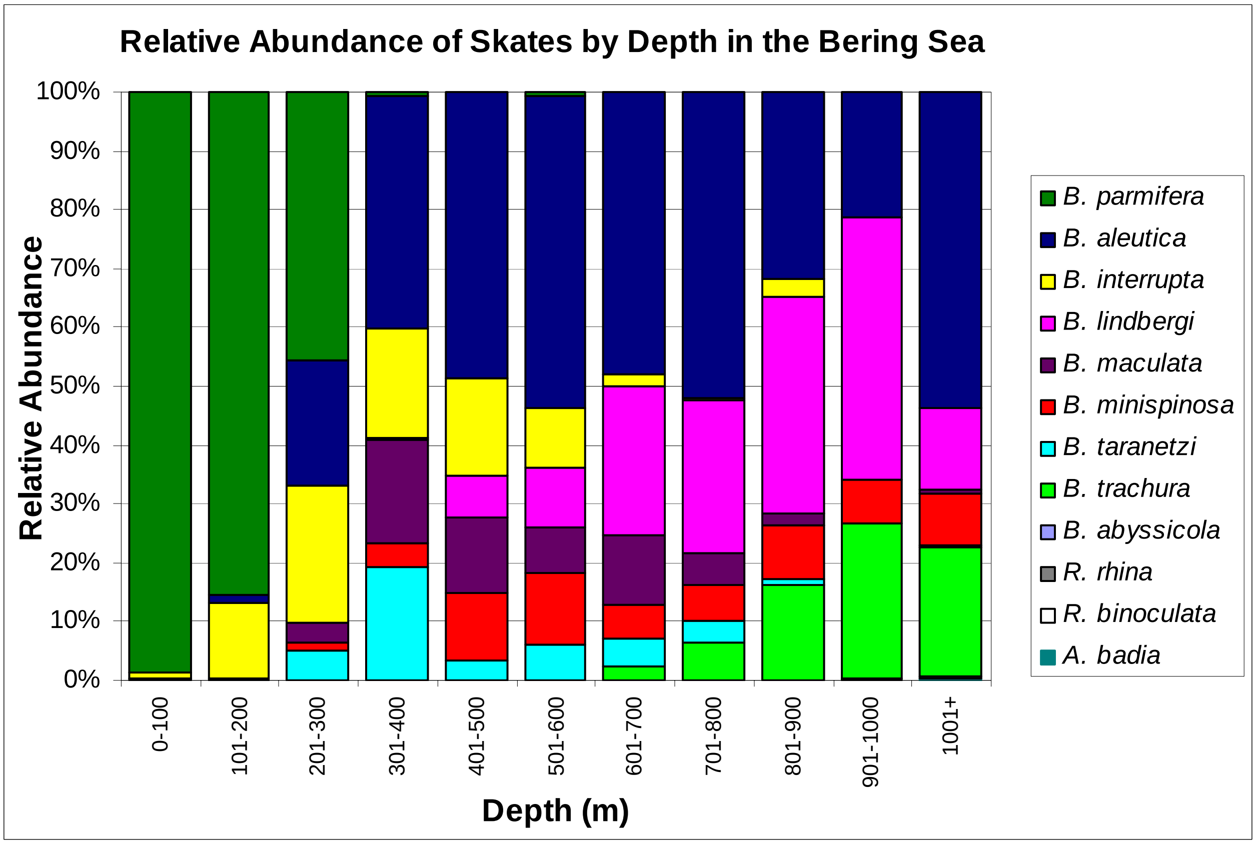


Figure 16.3-3. Relative abundance of skate species in the EBS by depth. Source: Stevenson et al. 2006.

The following CPUE maps were created using data from RACE Bering Sea Groundfish Surveys, 2001-2004. The data shown is the average CPUE (kg/ha) for each station, and the scale changes appropriately for each species.

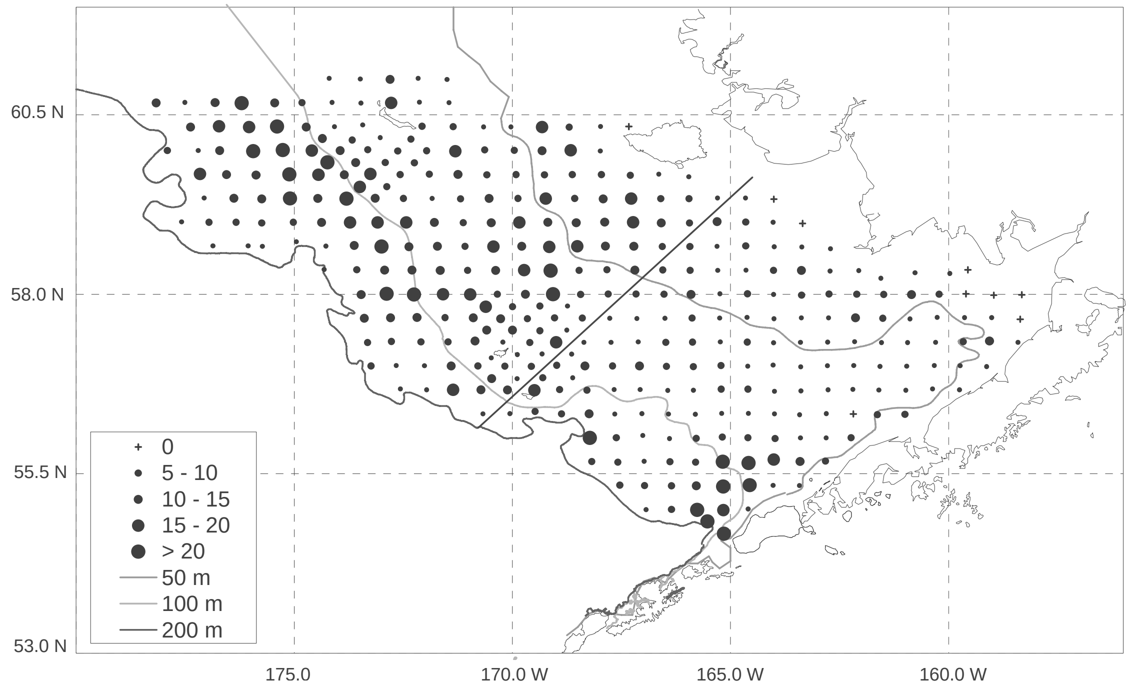


Figure 16.3-4. Average survey CPUE, Alaska skate (*Bathyraja parmifera*), 2001-2004.

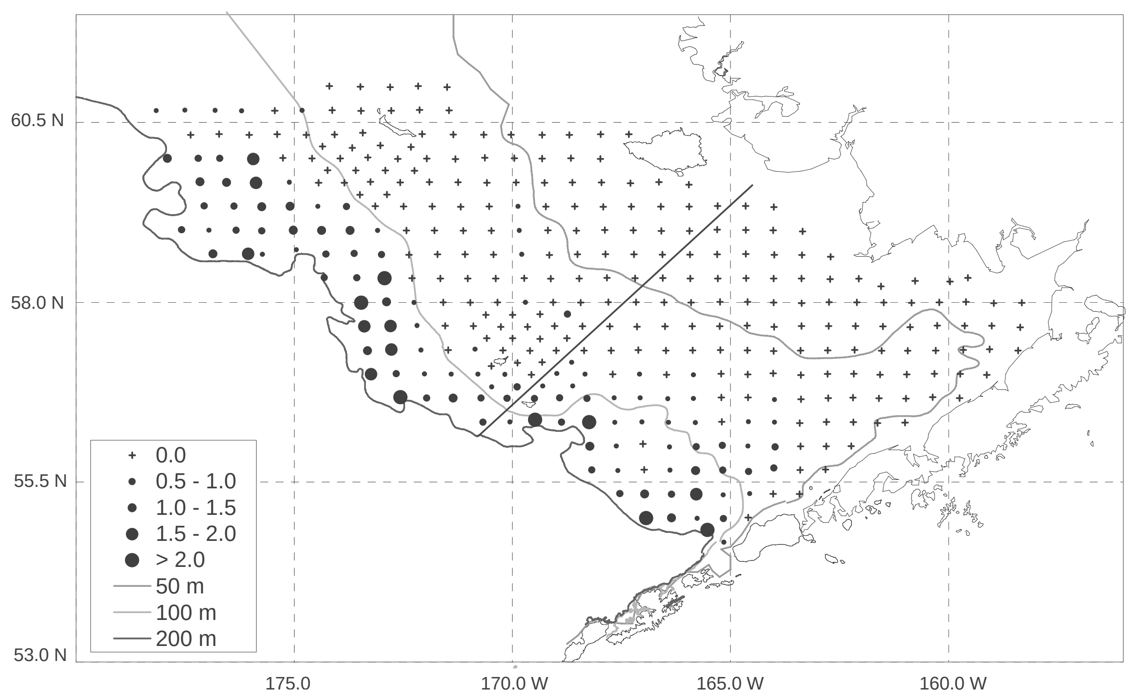


Figure 16.3-5. Average survey CPUE, Bering skate (*Bathyraja interrupta*), 2001-2004.

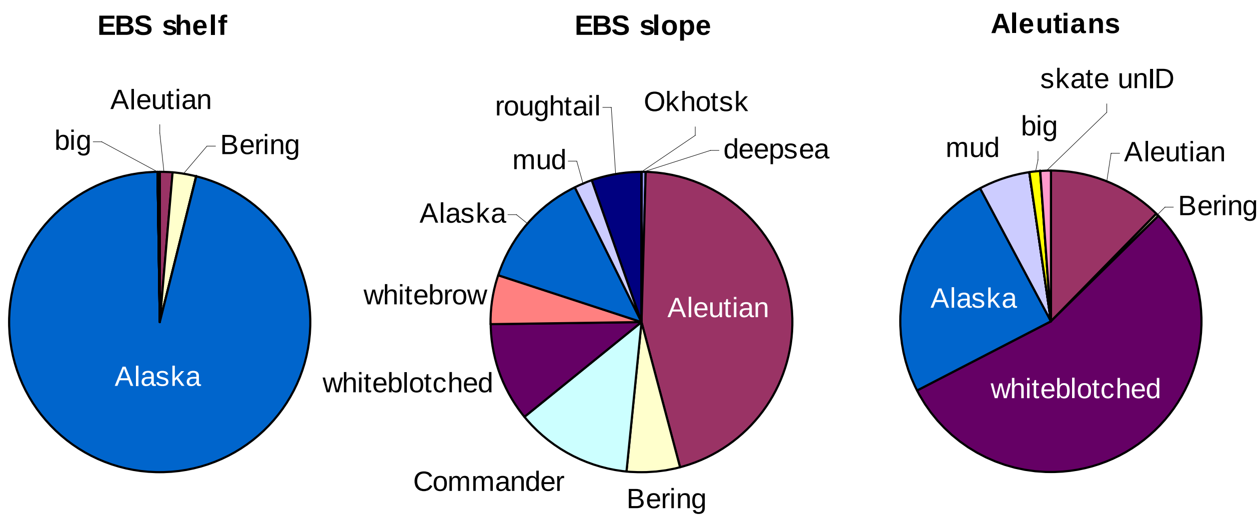


Figure 16.3-6. Skate species composition by area, EBS shelf (left), EBS slope (center), and AI (right). EBS shelf and AI data are from 2006 bottom trawl surveys, EBS slope data are from 2004 bottom trawl survey.

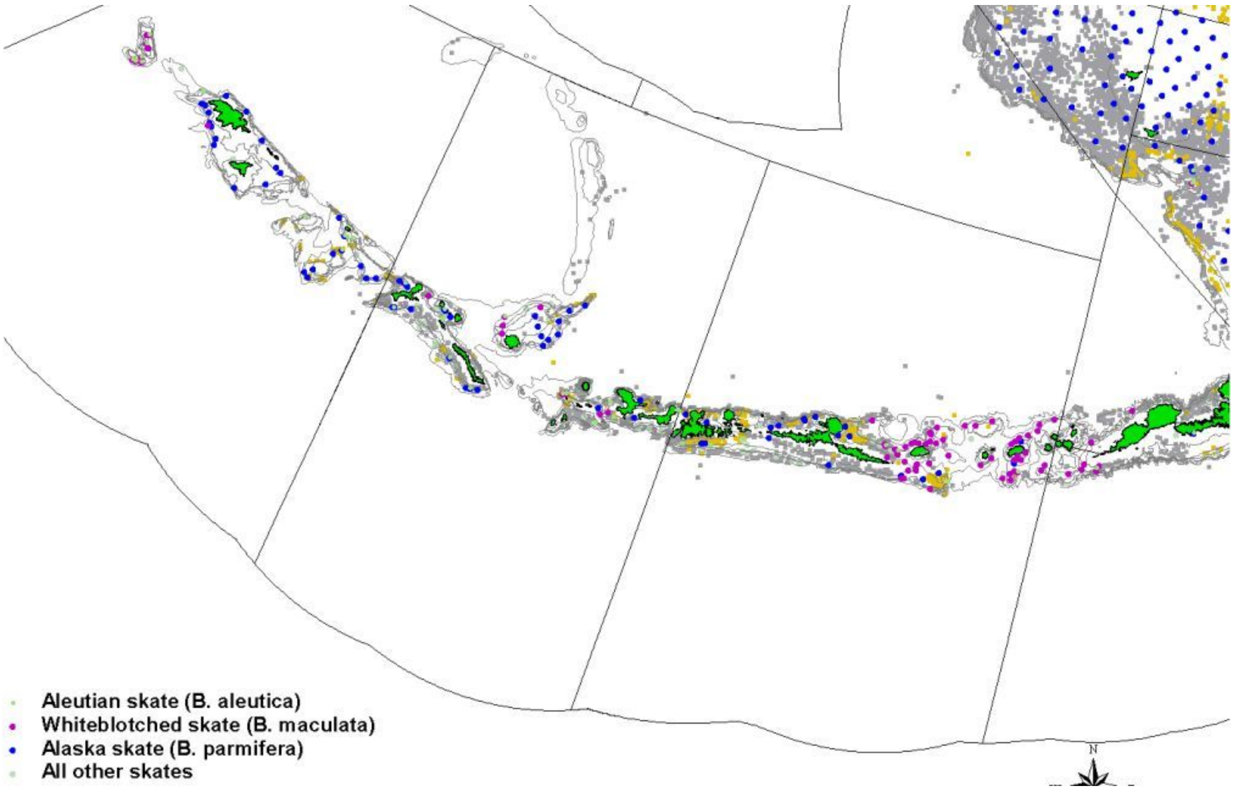


Figure 16.3-7. Skate distribution in the AI from NMFS bottom trawl surveys. Specimens of *B. parmifera* in the western AI have now been described as a new species (see below).

Figure 16.3-8. Skate diversity in the Aleutians: a new species, the leopard skate, from the Aleutian Islands (left) formerly thought to be the same species as the extremely common Alaska skate, *B. parmifera* (from the EBS, right). Photo credits: leopard skate, Richard MacIntosh; Alaska skate, Beth Matta.

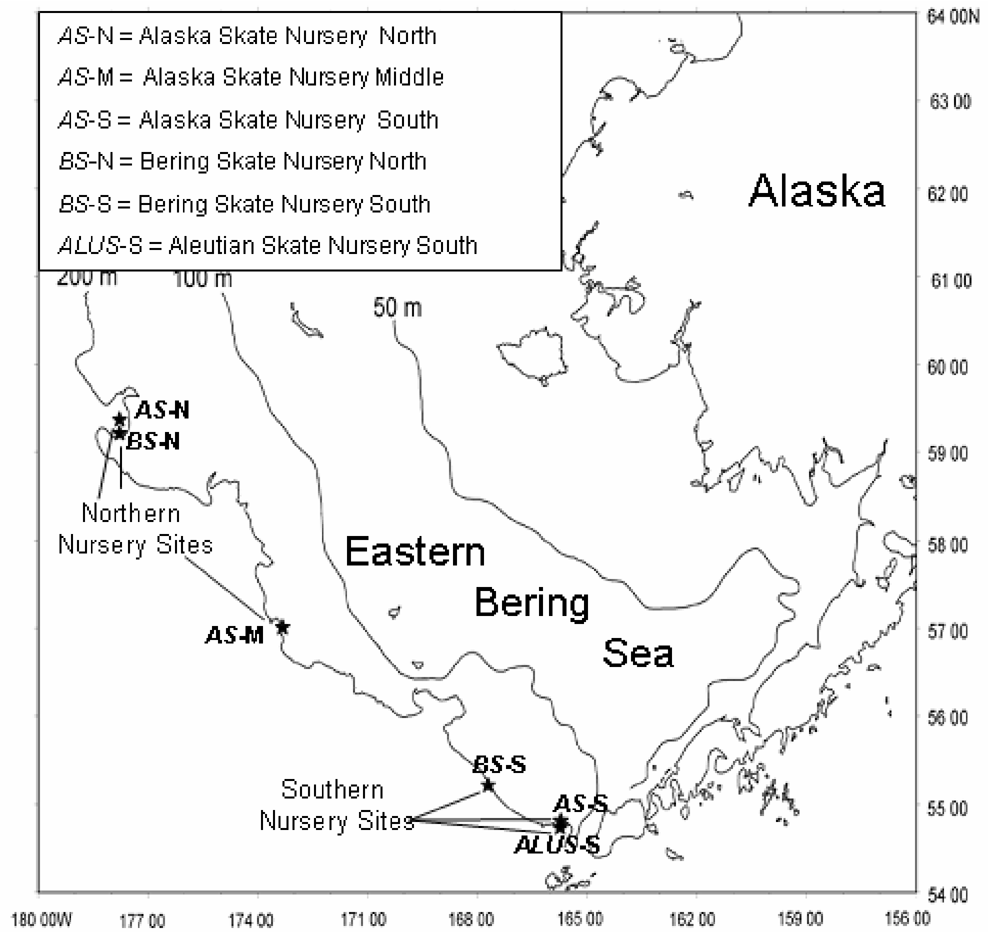


Figure 16.3-9. Map of the eastern Bering Sea with the six known skate nursery site locations and designations as a northern or southern nursery site. (See the legend for nursery site designation.) Source: Gerald Hoff, AFSC, unpublished data.

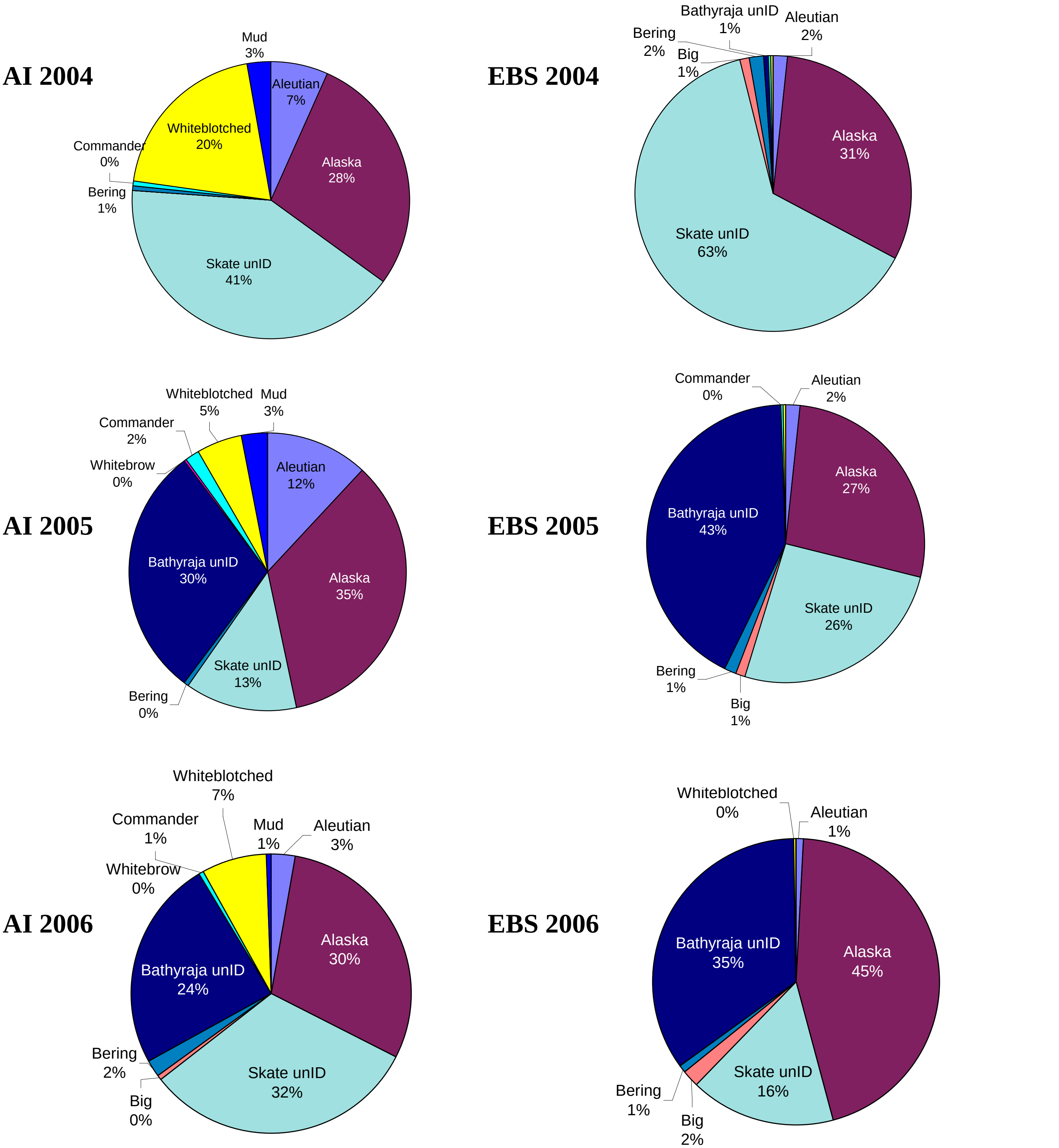


Figure 16.3-10. Identification of observed incidentally caught skates in AI (left) and EBS (right) groundfish fisheries, 2004 (top), 2005 (middle), and 2006 (bottom). Source: North Pacific Groundfish Observer Program database. 2006 data are reported through September 2006.

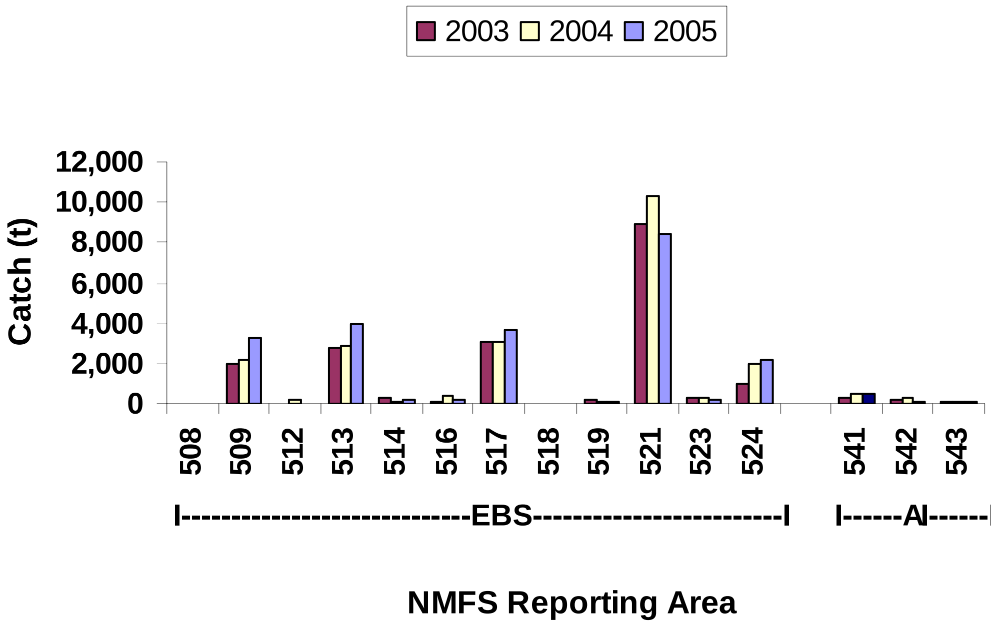
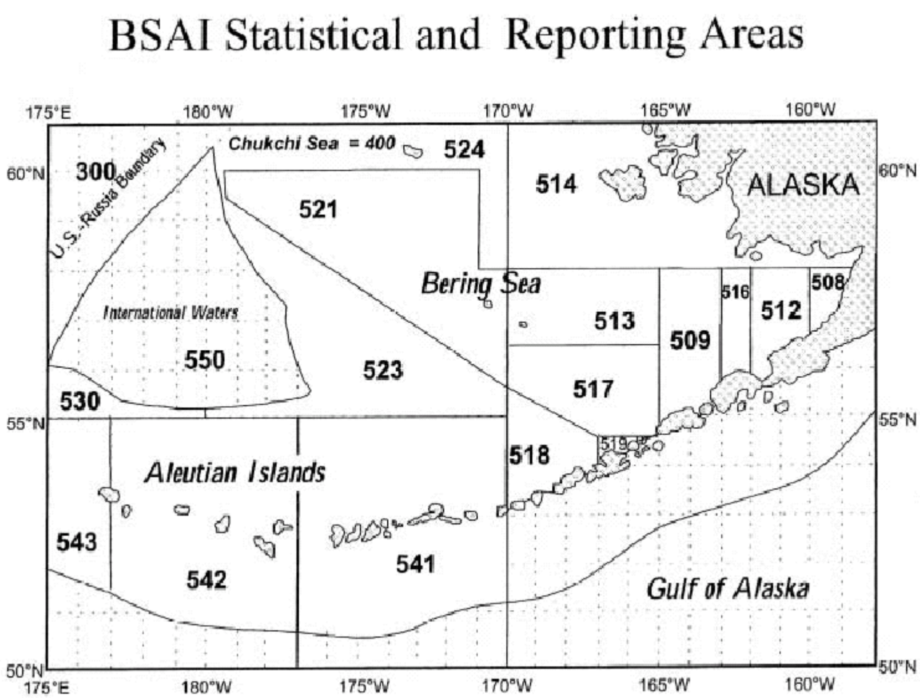
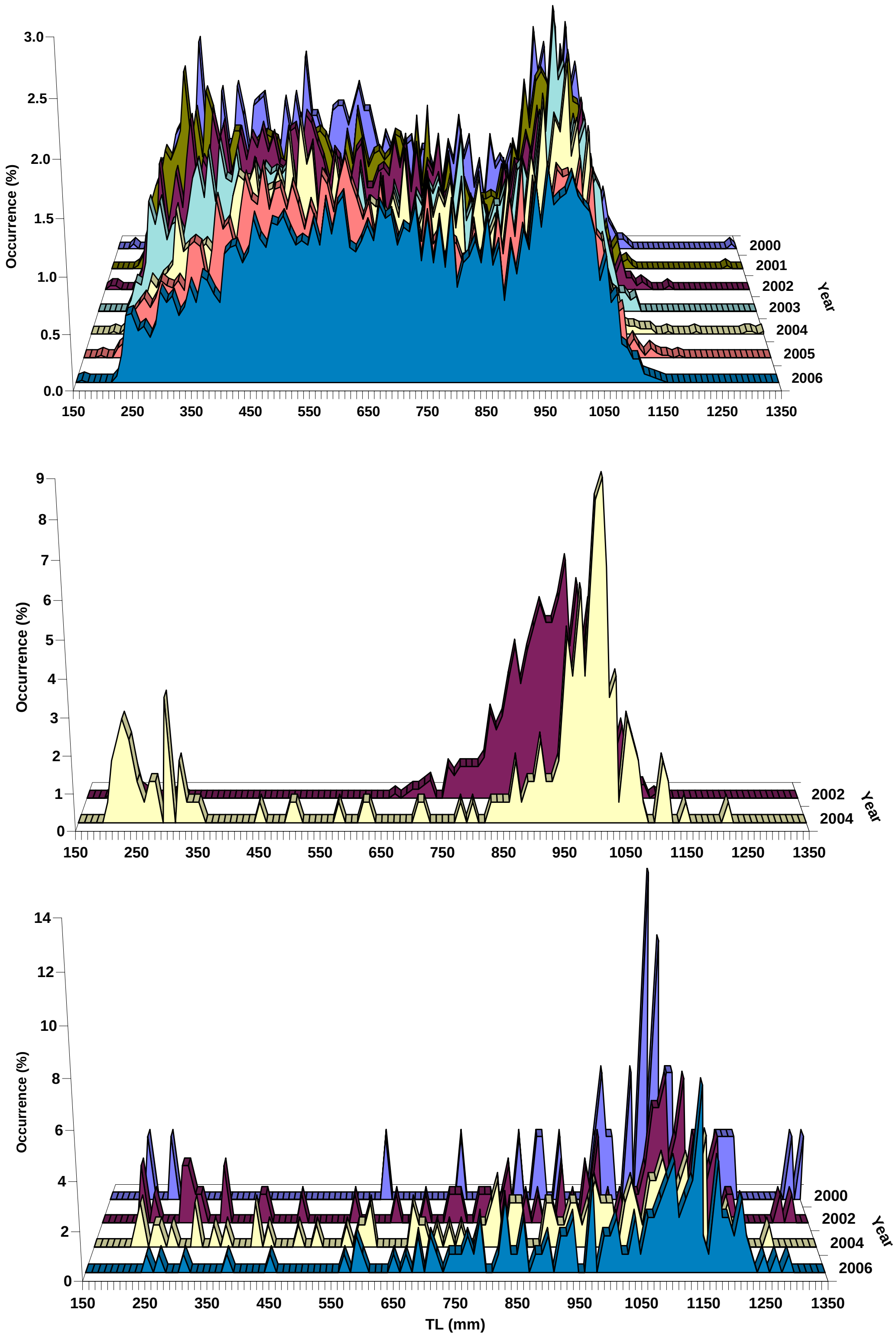


Figure 16.3-11. Total skate catch (all species combined) by FMP reporting area for both the EBS and the AI, 2003-2005. Source: AKRO CAS.





EBS shelf	
Year	n
2000	2,140
2001	3,236
2002	2,678
2003	2,823
2004	4,210
2005	4,589
2006	5,208

EBS slope	
Year	n
2002	802
2004	180

Aleutians	
Year	n
2000	37
2002	83
2004	109
2006	134

Figure 16.3-12. Length frequencies of Alaska skate (*Bathyraja parmifera*) from trawl survey data in the EBS shelf (top), EBS slope (middle), and AI (bottom) habitat areas. Sample sizes of individuals measured during surveys are shown to the right of each figure. Individuals collected in the western AI were not included in the analysis as they are likely a different species (leopard skate).

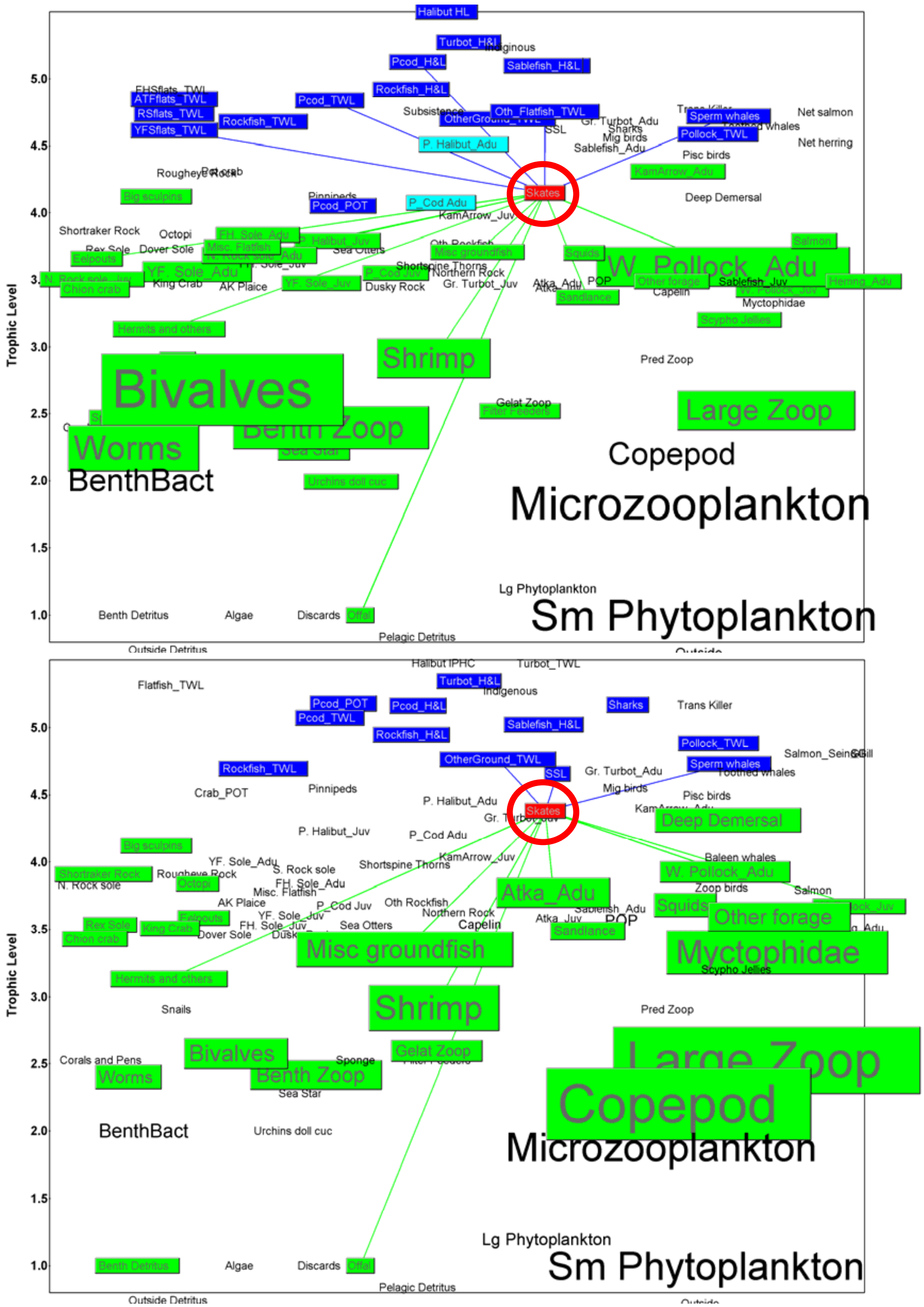


Figure 16.3-13. EBS (upper panel) and AI (lower panel) skate food webs derived from mass balance ecosystem models, with skate species aggregated in each area. (Source: K. Aydin, AFSC, code available upon request.)

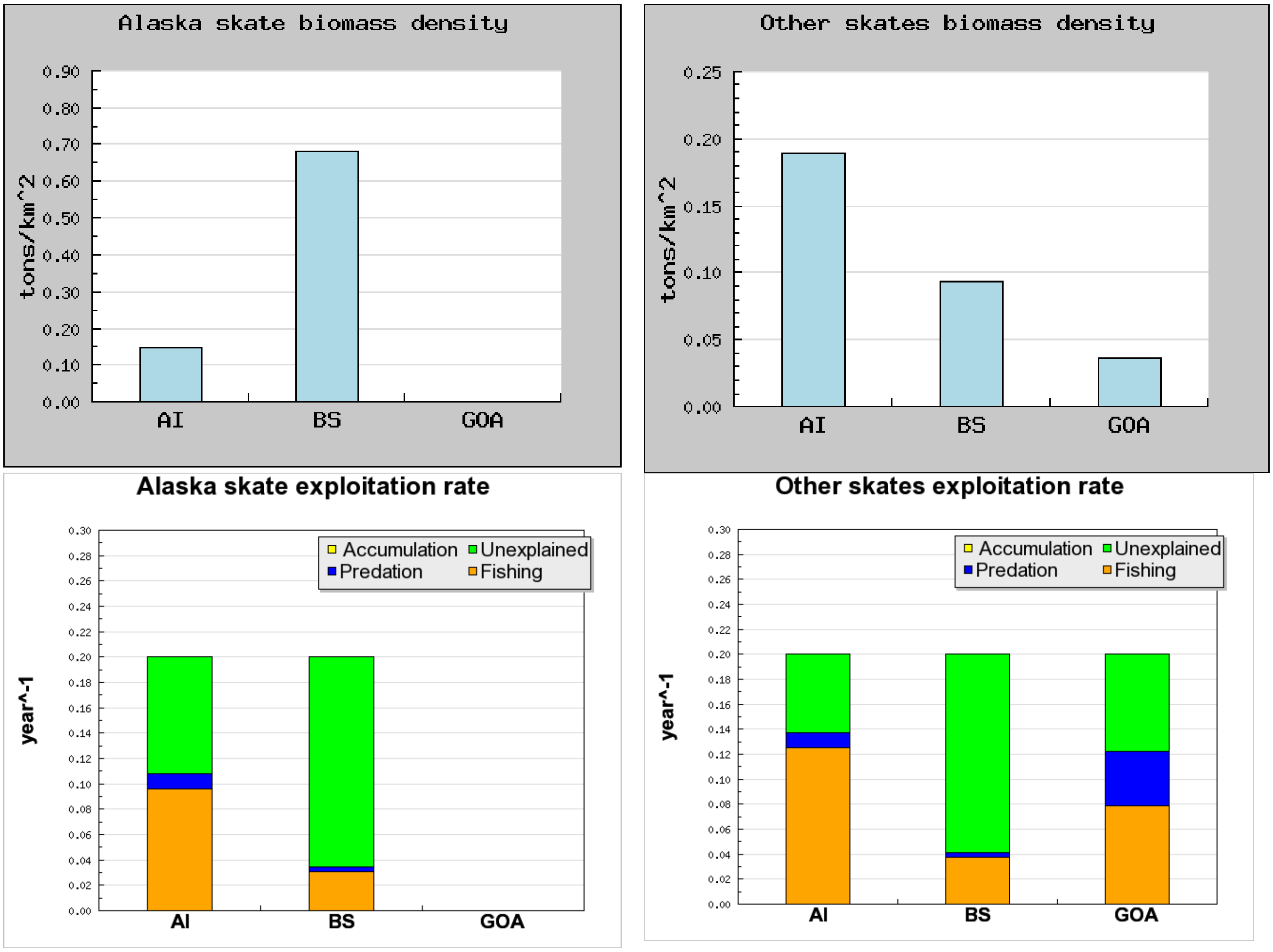


Figure 16.3-14. Comparative density (upper panels) and exploitation rate (lower panels) of Alaska (left panels) and all other *Bathyraja* (right panels) skates in the AI, EBS, and GOA (early 1990s, before fishery in GOA). (Alaska skates are a very small component of skate biomass in the GOA, and are therefore not modeled separately.) Note that the GOA Other skates plot does not include the most common species in that region, the big skate and longnose skate—see the GOA skate SAFE for information on those skates. Biomass density plots are from trawl survey data; exploitation rate plots are derived from catch and biomass estimates and from assumed estimates of skate productivity (approximated from Frisk et al. 2001).

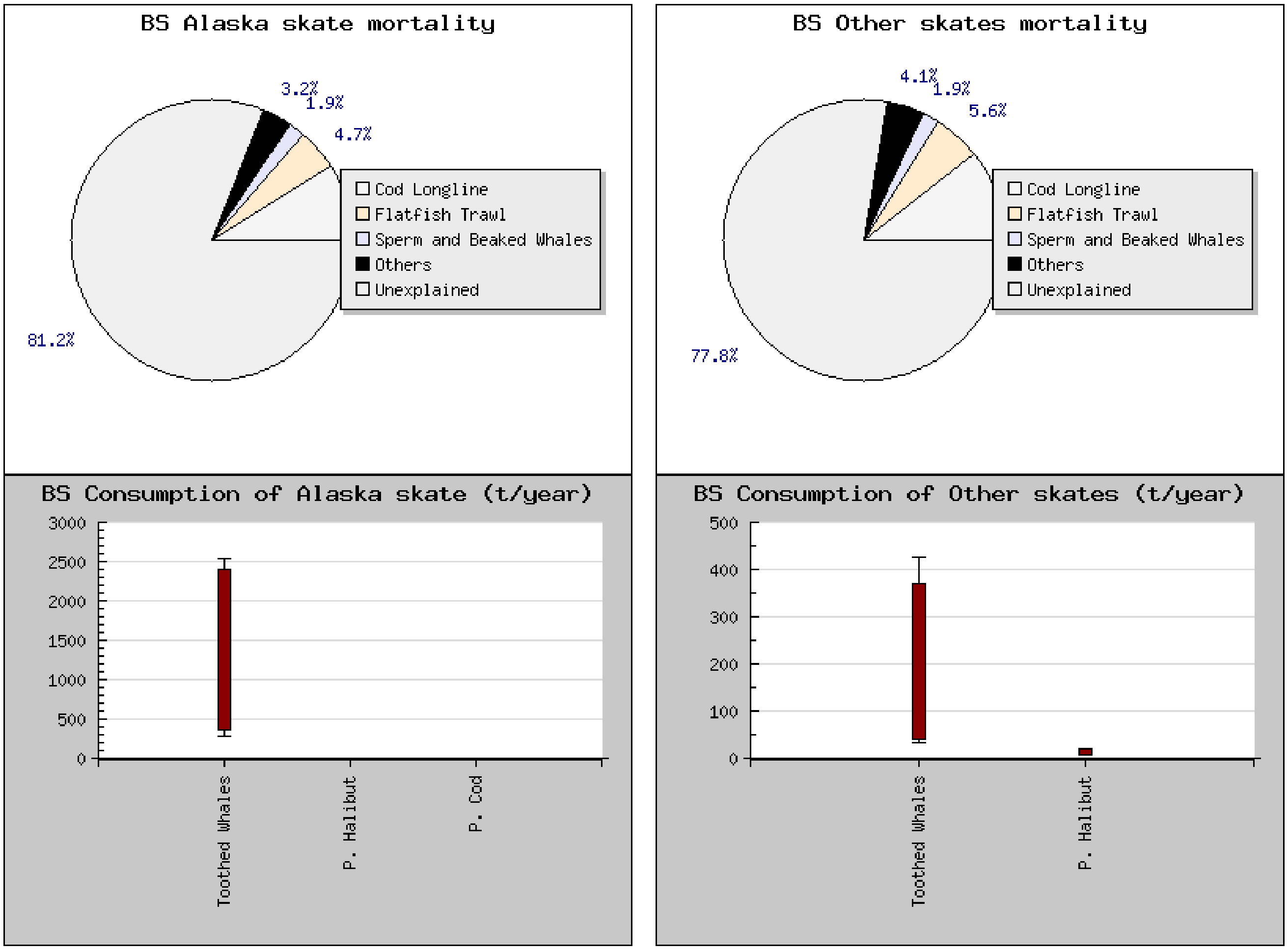


Figure 16.3-15. Mortality sources and consumption of skates in the EBS—mortality pie (upper panels) and estimates of annual consumption by predators (lower panels) for EBS Alaska skates (left panels) and all other EBS skates (right panels). Model outputs were derived from diet compositions, production rates, and consumption rates of skate predators, and from skate catch data.

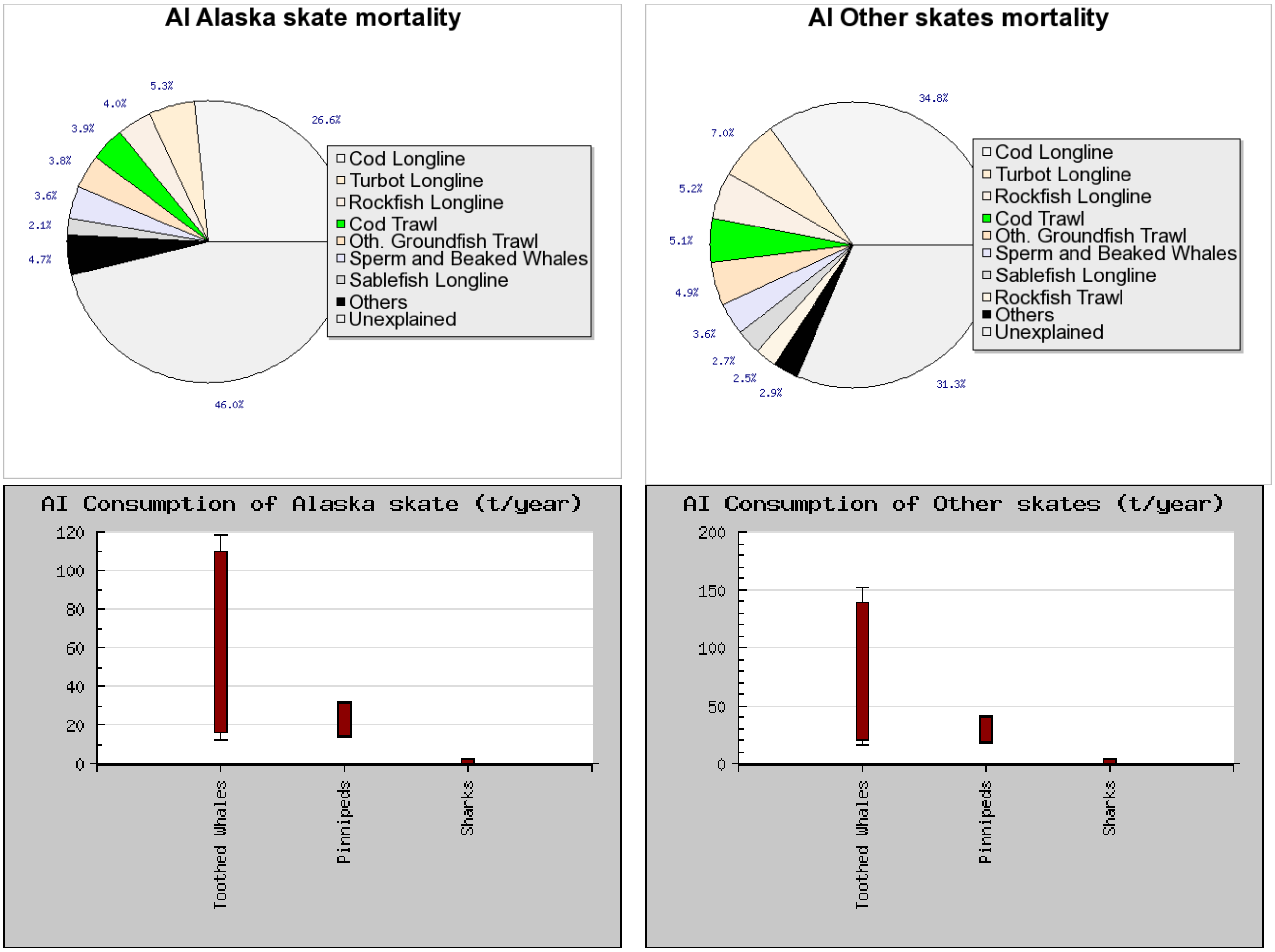


Figure 16.3-16. Mortality sources and consumption of skates in the AI—mortality pie (upper panels) and estimates of annual consumption by predators (lower panels) for AI (former) Alaska skate (left panels) and AI other skates (right panels). Model outputs were derived from diet compositions, production rates, and consumption rates of skate predators, and from skate catch data.

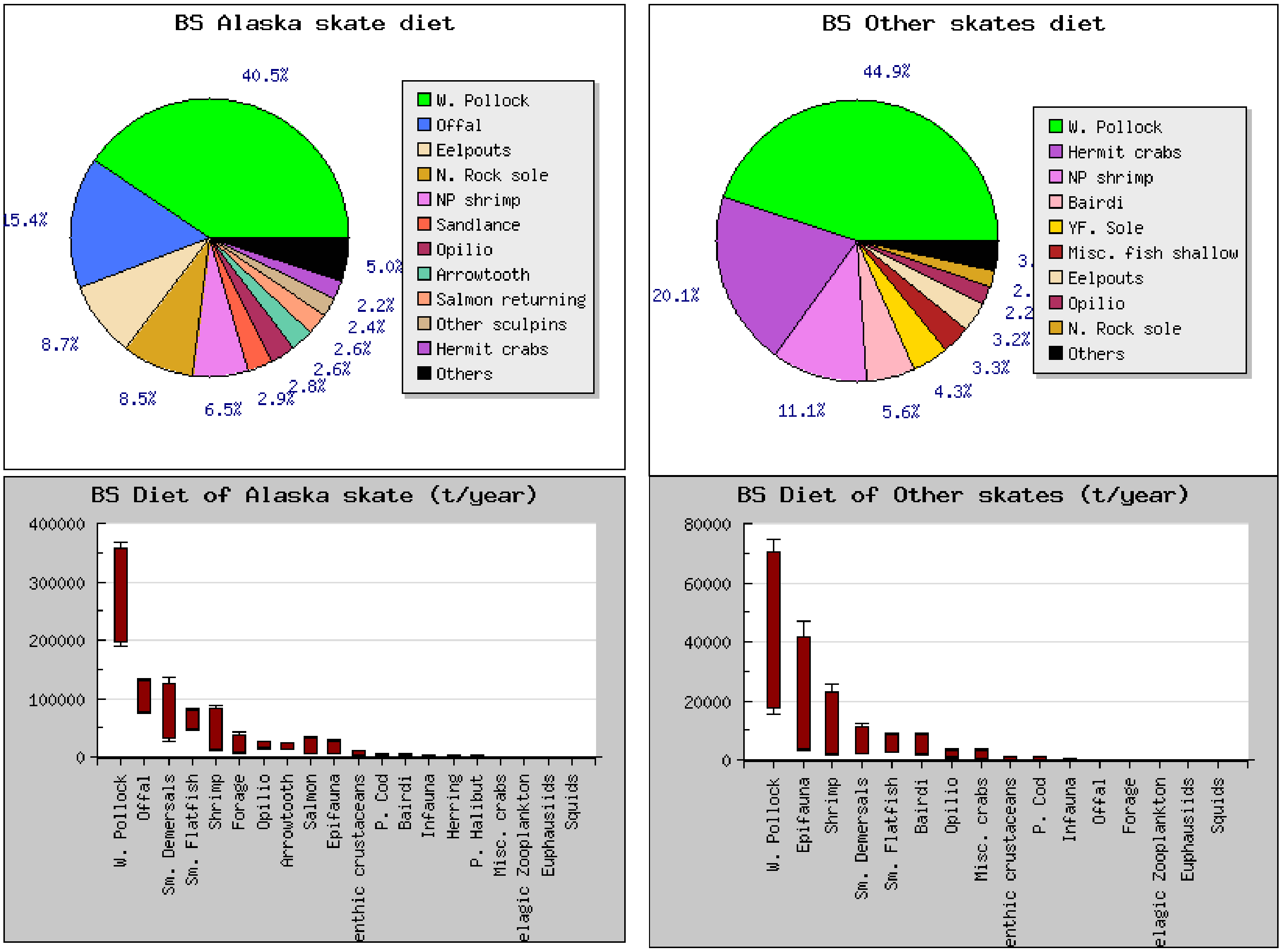


Figure 16.3-17. Diet composition (upper panels) and annual estimated prey consumption by skates (lower panels) for EBS Alaska skates (left panels) and Other Skates (right panels). Results were generated from stomach content collections occurring during RACE trawl surveys.

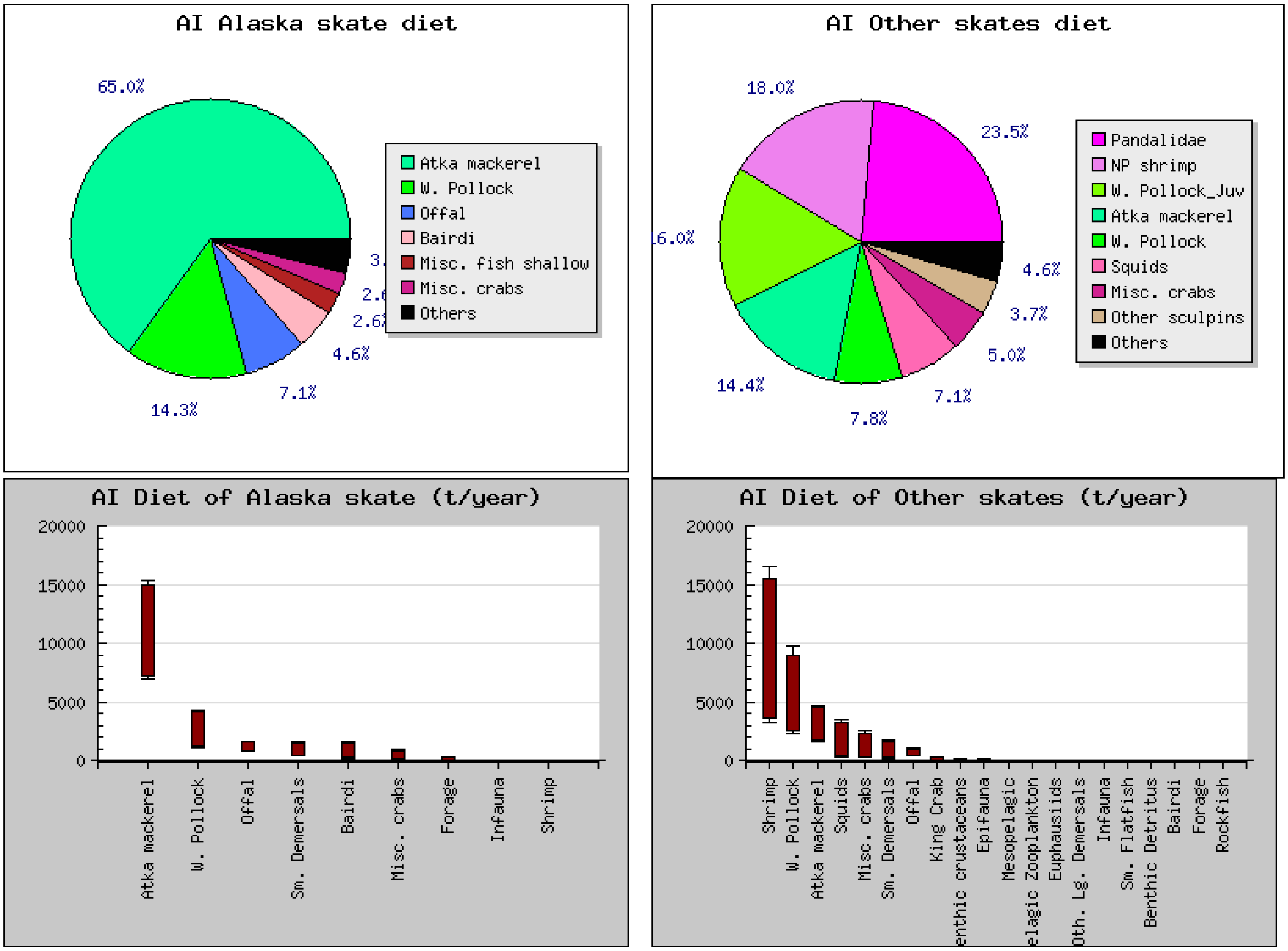


Figure 16.3-18. Diet composition (upper panels) and annual estimated prey consumption by skates (lower panels) for AI Alaska skates (left panels) and Other skates (right panels). Consumption rates were estimated using published diet data from the Kuril Islands (Orlov 1998, 1999) and estimated prey densities.

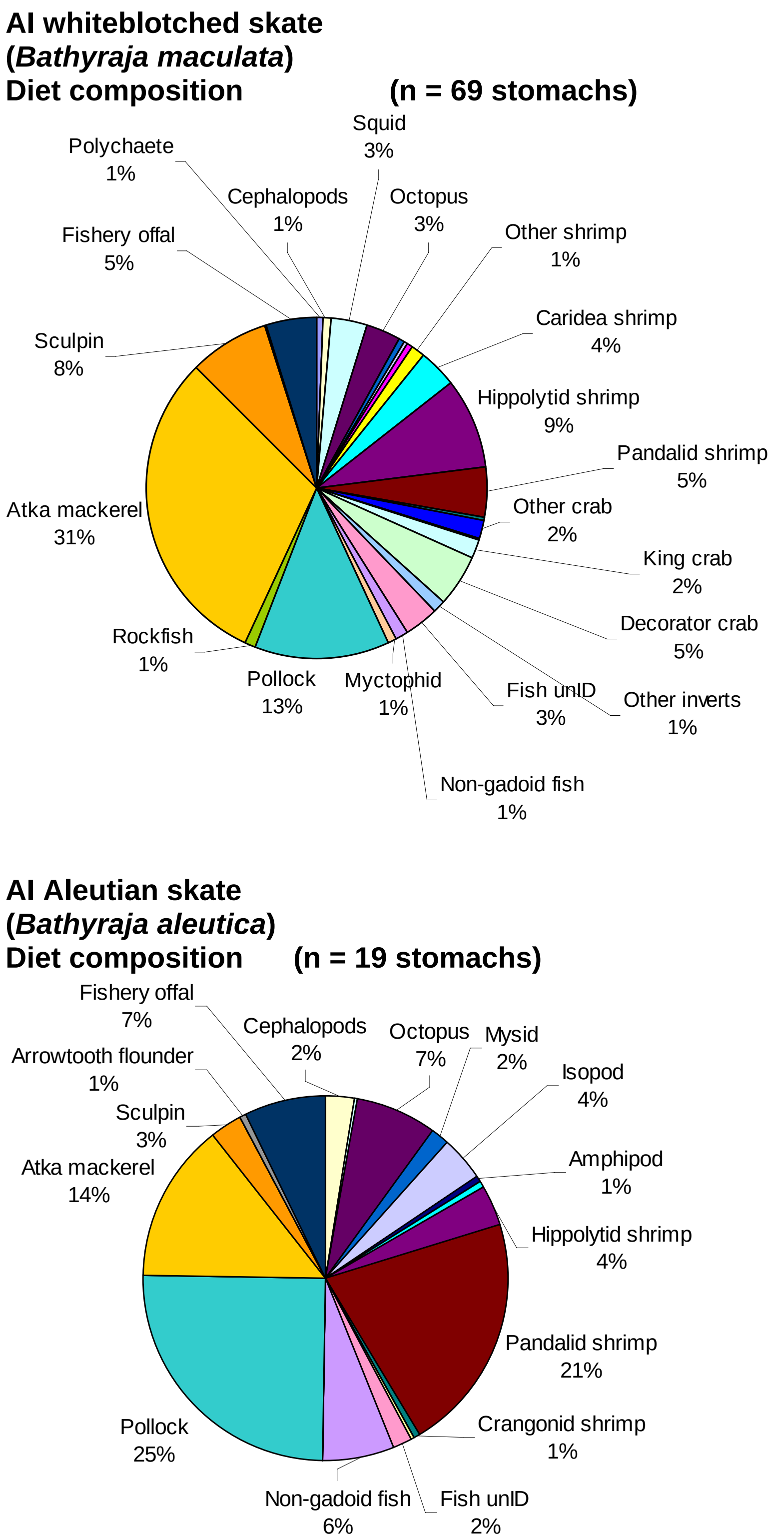


Figure 16.3-19. Diet composition (by weight) for the other two biomass-dominant skate species in the Aleutian Islands (which are included in the "Other Skates" group in the previous figure): whiteblotched skate (top) and Aleutian skate (bottom). Results were generated from stomach content collections occurring during trawl surveys, and are described in more detail in Yang (in prep).

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