# 18. Bering Sea and Aleutian Islands skates

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## Executive Summary

The Bering Sea and Aleutian Islands (BSAI) skate complex is managed in aggregate, with a single set of harvest specifications applied to the entire complex. Beginning with the 2008 assessment, harvest recommendations for Alaska skate (*Bathyraja parmifera*), the most abundant skate species in the BSAI, are made using the results of an age structured model and Tier 3. The remaining species ("other skates") are managed under Tier 5 due to a lack of data. The Tier 3 and Tier 5 recommendations are combined to generate recommendations for the complex as a whole. In 2010, the North Pacific Fishery Management Council passed amendment 95 to the BSAI Fishery Management Plan, which removed skates from the Other Species complex and into the target category. Amendment 96 eliminated the Other Species complex and requires separate annual catch limits for its constituent species groups. Thus, BSAI skates are now managed as an independent complex with its own harvest specifications.

### *Summary of Major Changes*

Changes in the input data:

- Total catch (t) for the BSAI skate assemblage has been updated through November 3, 2011.
- Biomass estimates from the 2011 EBS shelf survey were added for all species.
- Fishery and survey length composition data have been updated.
- An appendix has been added containing data regarding non-commercial catches and catches in the halibut IFQ fishery.

Changes in assessment methodology:

- No changes were made to the assessment methodology.

### *Summary of results*

The ABC and OFL recommendations for Alaska skates and Other Skates are slightly higher in the 2011 assessment than in 2010. The model estimate of total and spawning biomass was up slightly relative to 2010, although the allowable *F*s were smaller. For Other Skates, a slight decrease in the 2011 biomass estimate reduced the 3-survey-average and the resulting harvest recommendations. The 2011 survey and 2010 fishery length compositions were similar to those in the previous year, although fewer large skates were apparently captured in the longline fishery.

*(Harvest recommendations are on the following page.)*

## Alaska skate harvest recommendations

| Quantity | As estimated or *specified last* year for: 2011 | 2012 | As estimated or *recommended this* year for: 2012 | 2013 |
|---|---|---|---|---|
| *M* (natural mortality rate) | 0.13 | 0.13 | 0.13 | 0.13 |
| Tier | 3a | 3a | 3a | 3a |
| Projected total (age 0+) biomass (t) | 517,384 | 502,627 | 550,912 | 534,449 |
| Female spawning biomass (t) | | | | |
| Projected | 53,188 | 52,692 | 55,139 | 54,319 |
| $B_{100\%}$ | 88,637 | 88,637 | 92,117 | 92,117 |
| $B_{40\%}$ | 35,455 | 35,455 | 36,846 | 36,846 |
| $B_{35\%}$ | 31,023 | 31,023 | 32,241 | 32,241 |
| $F_{OFL}$ | 0.09 | 0.09 | 0.087 | 0.087 |
| $maxF_{ABC}$ | 0.077 | 0.077 | 0.075 | 0.075 |
| $F_{ABC}$ | 0.077 | 0.077 | 0.075 | 0.075 |
| OFL (t) | 28,348 | 27,700 | 29,669 | 28,918 |
| maxABC (t) | 24,421 | 23,864 | 25,565 | 24,918 |
| ABC (t) | 24,421 | 23,864 | 25,565 | 24,918 |
| **Status** | As determined *last* year for: 2009 | 2010 | As determined *this* year for: 2010 | 2011 |
| Overfishing | No | n/a | No | n/a |
| Overfished | n/a | No | n/a | No |
| Approaching overfished | n/a | No | n/a | No |

## other skate harvest recommendations

| Quantity | As estimated or *specified last* year for: 2011 | 2012 | As estimated or *recommended this* year for: 2012 | 2013 |
|---|---|---|---|---|
| *M* (natural mortality rate) | 0.1 | 0.1 | 0.1 | 0.1 |
| Tier | 5 | 5 | 5 | 5 |
| Biomass (t) | 94,690 | 94,690 | 94,075 | 94,075 |
| $F_{OFL}$ | 0.1 | 0.1 | 0.1 | 0.1 |
| $maxF_{ABC}$ | 0.075 | 0.075 | 0.075 | 0.075 |
| $F_{ABC}$ | 0.075 | 0.075 | 0.075 | 0.075 |
| OFL (t) | 9,469 | 9,469 | 9,408 | 9,408 |
| maxABC (t) | 7,102 | 7,102 | 7,056 | 7,056 |
| ABC (t) | 7,102 | 7,102 | 7,056 | 7,056 |
| **Status** | As determined *last* year for: 2009 | 2010 | As determined *this* year for: 2010 | 2011 |
| Overfishing | No | n/a | No | n/a |

## aggregate harvest recommendations for the BSAI complex

| Quantity | As estimated or *specified last* year for: 2011 | 2012 | As estimated or *recommended this* year for: 2012 | 2013 |
|---|---|---|---|---|
| OFL (t) | 37,817 | 37,169 | 39,077 | 38,326 |
| ABC (t) | 31,523 | 30,966 | 32,621 | 31,974 |

# General Introduction

## Contents of this report

Because two different assessment methodologies are used for skates, this report deviates somewhat from the format of other SAFE documents. The report contains the following sections:

1) General introduction for all BSAI skates
2) Description of the Tier 3 assessment for the Alaska skates
3) Description of the Tier 5 assessment for Other Skates
4) Harvest recommendations for all BSAI skates
5) Ecosystem considerations
6) Tables & Figures
7) Appendix containing supplementary catch information

## Description, scientific names, and general distribution

Skates (family Rajidae) are cartilaginous fishes 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 (Fig. 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 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 (Fig. 2). In this assessment, we distinguish three habitat areas: the EBS shelf (< 200 m depth), the EBS slope (> 200 m depth), and the Aleutian Islands (AI) region (all depths) (Fig. 3). Within the Eastern Bering Sea (EBS), the skate species composition varies by depth, and species diversity is generally greatest on the upper continental slope at 250 to 500 m depth (Fig. 4; Stevenson et al. 2006). The EBS shelf skate complex is dominated by a single species, the Alaska skate (*Bathyraja parmifera*) (Table 2 & Fig. 3). The Alaska skate is distributed throughout the EBS shelf habitat area (Fig. 6), most commonly at depths of 50 to 200 m (Stevenson 2004), and has accounted for between 91% and 97% of aggregate skate biomass estimates since species identification became reliable in 1999. The Bering or sandpaper skate (*B. interrupta*) is the next most common species on the EBS shelf, and is distributed on the outer continental shelf (Fig. 2).

While skate biomass is much higher on the EBS shelf than on the slope, skate diversity is substantially greater on the EBS slope (Fig. 3). The dominant species on the EBS slope is the Aleutian skate (*B. aleutica*) (Table 2 & Fig. 3). A number of other species are found on the EBS slope in significant numbers, including the Alaska skate, Commander skate (*B. lindbergi*), whiteblotched skate (*B. maculata*), whitebrow skate (*B. minispinosa*), roughtail skate (*B. trachura*), and mud skate (*B. taranetzi*) (Table 2). Two rare species, the deepsea skate (*B. abyssicola*) and roughshoulder skate (*Amblyraja badia*), have only recently been reported from EBS slope bottom trawl surveys (Stevenson and Orr 2005). The Okhotsk skate (*B. violacea*) is also occasionally found on the EBS slope.

The skate complex in the AI is quite distinct from the EBS shelf and slope complexes, with different species dominating the biomass, as well as 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, *B. maculata* (Table 2 & Fig. 3). The whiteblotched skate is found primarily in the eastern and far western Aleutian Islands (Fig. 2). Aleutian and Alaska skates are also common in the AI. The mud skate (*B. 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 (Fig. 8). The Aleutian Islands type or "leopard skate" (*Bathyraja* sp. cf. *parmifera*) has been confirmed to be a separate species (J. Orr pers. comm.).

## Management units

In the North Pacific, skate species were originally managed as part of the "Other Species" management category within the BSAI Fishery Management Plan (FMP). In October 2009 the NPFMC approved amendment 95 to the BSAI FMP, which separated skates from the BSAI Other Species complex. Beginning in 2011, skates are managed as a single complex with skate-specific ABC and OFL. Currently skates are taken only as bycatch in fisheries directed at target species in the BSAI, so future catches of skates are more dependent on the distribution and limitations placed on target fisheries than on any harvest level established for this category.

## 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* disappeared from much of its range off New England (Casey and Myers 1998). The relative difference in 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). A similar situation has occurred off the northeast coast of the United States, where skates are managed as a complex and are the subject of skate wing and lobster bait target fisheries; skates are also taken incidentally in other fisheries (NEFSC 2007). Aggregate skate biomass was relatively stable in the 1970s, but has fluctuated since the early 1980s, with apparent shifts in the relative abundance of individual species (NEFSC 2007). Declines in barndoor skate abundance were concurrent with an increase in the biomass of skates as a group (Sosebee 1998). While barndoor skate biomass is now above minimum threshold levels, winter skates (*Leucoraja ocellata*) and thorny skates (*Amblyraja radiata*) have become overfished, and smooth skates (*Malacoraja senta*) and little skates (*Leucoraja erinacea*) are in danger of becoming overfished according to the New England Fishery Management Council's definitions, requiring immediate action to reduce mortality and initiate rebuilding of overfished stocks (NEFSC 2007 and http://www.nefmc.org/skates/index.html).

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 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 skate, 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).

## Life history and stock structure (Alaska-specific)

Known life history parameters of Alaskan skate species are presented in Table 1. Zeiner and Wolf (1993) determined age at maturity and maximum age for big 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. 2007). In the same study, the maximum observed age for GOA big skates was 15 years, closer to Zeiner and Wolf's results for California big skates. The life histories of these two species are reported in more detail in the GOA skate SAFE (Ormseth and Matta 2007).

Considerable research has been directed at skates in the Bering Sea within the past few years. Graduate students at the University of Washington and California State University (Moss Landing Marine Laboratories) have begun or completed 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 1). Von Bertalanffy growth parameters were estimated for males ($L_\infty$ = 126.29 cm TL, $k$ = 0.120 year$^{-1}$, $t_0$ = -1.39 year) and females ($L_\infty$ = 144.62 cm TL, $k$ = 0.087 year$^{-1}$, $t_0$ = -1.75 year), although length-at-age data were fit slightly better by a Gompertz growth function for both sexes. Based on seasonal reproductive data, including ova diameter, gonadosomatic index (GSI), and the presence of egg cases, the Alaska skate appears to be reproductively active throughout the year. A reproductive resting phase (e.g. 'spent' gonads) was never observed in either large males or females, and females containing egg cases were encountered during each month of collection. Annual fecundity was estimated to average 21 to 37 eggs per year, based on the relationship between annual reproductive effort and natural mortality (Gunderson 1997). While the fecundity estimate needs to be validated using direct methods, fecundity is still likely to be low for the Alaska skate, as is typical for most elasmobranchs.

Hoff (2007) examined skate reproduction and skate nursery habitat of the Alaska skate and the Aleutian skate from the eastern Bering Sea. The relationships between successful skate reproduction and selected nursery grounds were examined. Vulnerability sources, reproductive cycles, habitat selection criteria, and physical factors controlling reproduction were addressed. To date, six nursery sites for three different skate species have been described in the eastern Bering Sea (Fig. 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.

The Alaska skate nursery in Bering Canyon is located in 149 meters of water near the shelf-slope interface in a highly productive area of the eastern Bering Sea. The nursery is small in area (< 2 nautical miles), persistent, and highly productive. Density estimates from trawling showed the most active part of the nursery contained >100,000 eggs/km$^2$. Two peak reproductive periods during summer and winter were evident in the Alaska skate nursery. During each active period the nursery showed high densities of mature reproductive adults and high numbers of newly deposited egg cases. Although there are peak reproductive periods at any single sampling time, the nursery contained embryos in all stages of development, and specific cohorts were easily discernable from frequency stage monitoring. Cohort analysis based on embryo lengths measured at an Alaska skate nursery site in the EBS suggested that the Alaska skate has an eggcase development time of over 3 years, possibly due to the cold ocean temperatures in the EBS (Fig. 10; Hoff 2007). Captive studies are currently underway at the Alaska Sealife Center (Seward, AK) to validate this finding, but the field observations are consistent with development times observed in other skate species (Fig. 11; Hoff 2007). For example, thorny skate (*Raja radiata*) embryos spend approximately 2.5 years in the eggcase development stage at warmer temperatures than those found in the EBS (Berestovskii 1994 in Hoff 2007).

The Oregon triton *Fusitriton oregonensis* was the most likely predator on newly deposited egg cases and mortality rate was estimated at 3.64% per year (Hoff 2007). After hatching, young skates were vulnerable to predation by Pacific cod, *Gadus macrocephalus* and Pacific halibut, *Hippoglossus stenolepis*. Predation by these two large fish species peaked during the summer and winter periods and was highly correlated with hatching events. The Alaska skate nursery site was occupied by mature male and female skates throughout the year, with juvenile and newly hatched individuals extremely rare. Evidence suggests that newly hatched skates quickly move out of the nursery site and immature skates are infrequent visitors to nursery sites. 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, including 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. Preliminary estimates of maximum ages for Aleutian and Bering skates are 17 and 13 years, respectively (Ebert et al. 2007). Age validation remains to be completed for these species (D. Ebert, PSRC, pers. comm.). Additional age and growth studies are currently being conducted by Jasmine Fry (mud skate), and Shaara Ainsley (whitebrow skate) for their thesis research.

Reproductive studies are also currently ongoing at the PSRC to obtain information on the size at maturity, seasonality, and fecundity of several Alaskan skate species. The reproductive biology of the Aleutian skate, Bering skate, big skate, and longnose skate has been investigated as part of a NPRB funded study to assess life history characteristics of Alaskan skate species (Ebert et al. 2007). Median length at maturity (cm TL) was estimated to be 124.4 for the Aleutian skate, 70.2 for the Bering skate, 148.6 for the big skate, and 113.1 for the longnose skate (Ebert et al. 2007). Reproductive studies are also being conducted on mud and whitebrow skates by graduate students affiliated with the PSRC.

The PSRC has also conducted demographic analyses to improve understanding of the population dynamics and vulnerability of these species to fisheries exploitation. Preliminary estimates of annual population growth rates are 25% for the Aleutian skate, 36% for the Bering skate, 33% for the big skate, and 20% for the longnose skate (Ebert et al. 2007). Other demographic parameters have also been estimated for these species (Ebert et al. 2007). 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 pers. comm.), 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

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 only reports species-specific catch for big (*Raja binoculata*) and longnose (*Raja rhina*) skates. All remaining skate species are reported as "other". Big and longnose skates make up only a small fraction of BSAI skate biomass, which is dominated by the Alaska skate. The fraction of Alaska skate catch in the total "other skates" is estimated by applying the average species composition encountered during trawl surveys (see Data section below).

Skates are caught in almost all fisheries and areas of the Bering Sea shelf, but most of the skate bycatch is in the hook and line fishery for Pacific cod. Trawl fisheries for pollock, rock sole, flathead sole, and yellowfin sole also catch significant amounts (Tables 4 & 5). The catch of skates in pollock fisheries has increased in recent years, possibly because the fisheries are targeting pollock closer to the bottom. In this assessment, "bycatch" is interpreted as 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 6). More skates were retained in the EBS than the AI, and it appears that species that grow to a larger maximum size (>100 cm TL) are more likely to be retained than smaller-bodied species. For example, while the Aleutian skate, a large-bodied species, made up a relatively small portion of the observed 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 are also retained; all three are relatively large-bodied skates.

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 (Fig. 12). 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). Changes made to the observer manual at the author's request have resulted in a large increase in skate length measurements beginning in 2008.

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 (Fig. 12).

Reporting areas encompassing the EBS outer shelf and upper continental slope experienced high catch rates during 2003-2006 (Fig. 13). 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 possible that the species composition of the catch is not in proportion to the overall species composition (from survey data) across the BSAI. However, depth analysis of the observed catch demonstrates that most of the skate catch occurs <200m (98%). More work is needed to determine the actual species composition of the catch.

# ALASKA SKATE – Tier 3 assessment

### *Overview*

The model presented here begins in 1992. In the 2007 assessment, we included an alternative model starting in 1958 that included historical catch data and survey biomass estimates from 1982. The alternative model was eliminated from the 2008 assessment due to uncertainty in catch and survey data prior to 1992, as well as a short history of fishery length composition data. For these reasons, the population is modeled during the "modern era" for skates in the BSAI, where the biomass has remained relatively stable and available data are substantially more complete and reliable.

This assessment model resembles teleost groundfish models in many ways, but we made some changes to incorporate life history features unique to elasmobranchs. As previously discussed, all skate species have an extended embryonic period during which they develop within protective eggcases on the seafloor. Alaska skates do not appear to form visible annual growth marks in their vertebrae during embryonic development. However, cohort analysis based on embryo lengths measured at an Alaska skate nursery site in the EBS suggested that the Alaska skate has an eggcase development time of approximately 3.6 years, possibly due to the cold ocean temperatures in the EBS (Hoff 2007; Fig. 10). Captive studies are currently underway at the Alaska Sealife Center (Seward, AK) to validate this finding, but the field observations are consistent with development times observed in other skate species (Fig. 11; Hoff 2007). For example, thorny skate (*Raja radiata*) embryos spend approximately 2.5 years in the eggcase development stage at warmer temperatures than those found in the EBS (Berestovskii 1994 in Hoff 2007). Incorporating this information in the model is complicated by the possibility that embryo development times may be temperature-dependent (G. Hoff, pers. comm.).

The timing of *B. parmifera* reproduction is also uncertain. While most females appear to deposit eggcases during the summer, with emergence of young skates occurring during the winter, some level of skate reproduction seems to occur year-round. We assigned the first three age classes of Alaska skates (0-2) to an embryonic period where growth differed from older age classes and individuals were not available to either the fishery or survey. Thus, free-swimming skates in their first year were considered to be 3½ years old. In addition, we adjusted parameters of the length model and age selectivity to accommodate the developmental delay and the uncertainty in its duration. This approach allowed us to more accurately model skate population dynamics and ensured that characteristics of the spawning population would correspond to the appropriate year class. In addition, we considered the equilibrium life history strategy in specifying recruitment parameters and evaluating our model results.

We present a base model that we determined to provide the best description of Alaska skate population dynamics given the data and the limitations of the modeling software. The alternative model presented in the 2008 assessment is not included in the 2009 assessment.

# Data

Survey biomass

Three bottom trawl surveys are conducted in the BSAI region: EBS shelf, EBS slope, and the Aleutian Islands. Because the Alaska skate population is concentrated on the EBS shelf, and the EBS shelf survey provides yearly estimates of biomass, we used biomass data from only the EBS shelf survey in this assessment. Recent (1999-2011) survey information on species composition was used to describe the relative proportion (0.95) of the Alaska skate to all other skate species ("Other Skates") within the EBS shelf area (Table 7 & Fig. 14). Biomass estimates from 1992 through 2010 were utilized in the Alaska skate model. For each survey prior to 1999, total skate biomass estimates were partitioned into Alaska skate and Other Skates based on the average proportion of each group in the 1999-2011 surveys (Table 7). The model employs the coefficient of variation (CV) as the standard deviation (*s*) associated with each estimate. For the estimates prior to 1999, a value of *s* was chosen that was intermediate to recent values and a high *s* observed in 1999 (Table 7).

Survey length composition

Total length (TL) data from the EBS shelf survey were available from 2000-2011 (Table 8). The survey takes length measurements for every skate in each haul. An N of 100 for each length composition was used in the model.

*Binning*: Discussions with staff from the Resource Assessment and Conservation Engineering (RACE) division at the AFSC during summer 2008 indicated that there may be a slight bias in the length measurements of skates in the EBS shelf survey towards odd-numbered sizes. This is likely due to the design of the length measuring boards, which display the odd sizes along the edge closest to the biologists, and the general difficulty of measuring a disc-shaped animal like a skate. This bias might be important when 5-cm length bins are used, as the bins contain different proportions of odd and even sizes. To ameliorate this problem, in 2008 the length composition bins were changed to a 4-cm width that includes equal numbers of odd and even sizes.

Total catch

Commercial catches of BSAI skates are reported FMP area-wide in aggregate with sculpins, octopus, and squid. Independent estimates of BSAI skate catch from 1992-2011 were made by the Blend system and AKRO CAS as described in the 2007 BSAI skate assessment. Catches were broken down by habitat area (EBS shelf, EBS slope, and AI) and by fishery gear type from 1992-2011 (Table 9). Total skate catch estimates for the EBS and AI are available since 1997; the average proportion of the skate catch in both of these areas (94% EBS and 6% AI) was assumed to remain constant prior to 1997 in order to reconstruct the area-specific catch. Catch is not estimated separately for the EBS shelf and EBS slope habitat areas by Blend or CAS; therefore a proxy based on fishery observer depth data was developed. The observed total skate catch from 2003-2009 in the EBS was partitioned by depth in order to approximate the proportion of the catch occurring in each of the two EBS habitat areas; catches less than 200 m were considered to occur on the EBS shelf (about 98%) and catches deeper than 200 m were considered to occur on the EBS slope (about 2%).

The average area-specific species compositions from the 1999-2011 bottom trawl surveys (Fig. 14) were utilized to further partition the catch into Alaska skates and Other Skates. Two major fishery gear types with different size selectivities for skates operate in the BSAI management area: trawlers and longliners. (Pot gear accounts for a minor portion of the skate catch (<0.1%) and was considered negligible for the

purposes of this assessment.) The proportion of the catch by each fishery gear type differs by habitat area; for years without gear type data, the average proportion of each gear type from 2003 to 2005 was applied. The results were then totaled to obtain the total Alaska skate catch for each fishery across the entire BSAI management area, which was incorporated into the model (Table 9 and Fig. 15).

Catch length composition

Length data for the Alaska skate were collected as a special project by fishery observers aboard trawl and longline vessels operating in the EBS in 2007. In 2008, the observer manual was changed to require collection of skate lengths on every haul where they were present in the target fisheries for Pacific cod and flatfishes. Fishery length composition varies by season, with larger skates caught later in the year (Figure 15). Fishery length data from 2007-2010 was included for both gear types. The number of hauls sampled for the fishery length data is much higher than in the survey because observers take a small number of length measurements from a large number of hauls, and an N of 100 (identical to the survey data) was applied to each fishery length composition. Length data were aggregated into 4-cm bins as for the survey data (Table 10).

Length at age

Mean length at age data were obtained from Matta (2006) and from production ageing at the AFSC. Age was determined through examination of annual growth rings which begin to form in vertebral thin sections following hatching from the eggcase. Skate age determination is inherently difficult due to the typically faint appearance of growth zones, and CVs associated with many skate ageing studies tend to be high. However, Matta (2006) was able to corroborate ages generated from two different ageing structures in the Alaska skate, vertebrae and caudal thorns, as well as to verify the annual periodicity of vertebral growth ring formation through marginal increment analysis. Three sample sets were included in the model; one from the 2003 EBS shelf survey (n=182; Fig. 16), one from the 2005 longline fishery (n=208; Fig. 17), and one from the 2007 EBS shelf survey (n=243).

Weight at length

Parameters from the allometric length-weight relationship ($W = aTL^b$, where W is weight in kg and TL is total length in cm) were obtained from Matta (2006) for the Alaska skate. For sexes combined, *a* was estimated as $4.01*10^{-6}$ and *b* was estimated as 3.149 (n = 526; Fig. 18).

## Analytic Approach

Model structure

The Stock Synthesis 2 (SS2) assessment program[1] (Methot 2005, 2007) was used to develop an age-structured population model of Alaska skates. SS2 allows the flexibility to incorporate both age-and size-structured information in the model. In the model described here, natural mortality is the only parameter that is explicitly age-based; selectivity, maturity, and mean body weight are length-based parameters. Length-at-age data and estimates of ageing error are used by SS2 to convert the size-based information into age-specific values that can be used to model the population through time.

SS2 is comprised of three submodels. A population submodel captures the dynamics of an age-structured population and an observation model specifies likelihood components for comparing model predictions to observed data. A statistical model incorporates those components and others into an objective function that SS2 uses to maximize the overall likelihood by altering the parameters that govern the population dynamics model. SS2 also contains a forecasting routine that specifies fishery management targets and

[1] NOAA Fisheries Toolbox Version 2.10, 2006. Stock Synthesis 2, Version 2.00g, Richard Methot, Northwest Fisheries Science Center, Seattle, WA. [Internet address: http://nft/nefsc.noaa.gov]

projects the population into the future, but we used an alternative projection model that was designed exclusively for use in Alaska fisheries by Jim Ianelli (AFSC, NMFS). The structure of SS2 is explained in detail elsewhere (Methot 1990, 2005, 2007), and we offer here only a limited explanation of the model structure.

The population dynamics model is depicted schematically in Fig. 19. Briefly, unfished recruitment and *M* determine the age structure of an unfished population. The unfished age structure is then modified by *M* and equilibrium catch to produce an initial age structure. For each subsequent year in the model, individuals are added through recruitment and subtracted through *M* and catch. The expected level of recruitment in each year results from estimates of spawning biomass in the previous year and the parameters of the Beverton-Holt stock-recruit curve. Model estimates of recruitment deviate from the expected level according to the standard deviation of log recruitment ($\sigma_R$), which can be fixed or estimated within the model. In all cases, catch is modified by fishery age and length selectivity. For Alaska skates, the observation submodel includes three likelihood components based on model fits to observed data: EBS shelf survey biomass, length compositions from the shelf survey and each of the fisheries, and mean length at age. An additional likelihood component compares the deviations in recruitment to the value of $\sigma_R$. The objective function combines these four components to calculate overall likelihood. All likelihood components were weighted equally in the model.

This assessment model included a number of simplifications and assumptions. The entire BSAI was treated as one homogenous area. Because growth and maturity patterns are similar for males and females, we specified only one sex. Spawning was assumed to occur at the midpoint of the year. No informative priors were used. We also assumed that parameters did not vary with season or year and were not influenced by environmental conditions. All parameters used in the base model are listed in Table 11 and described in more detail below.

<u>Parameters estimated independently:</u>

*Natural mortality (M)*

In 2007, a conservative value of 0.13 was chosen from a set of *M* values estimated using different life history parameters (Matta 2006; Table 12): growth parameters (Alverson and Carney 1975, Pauly 1980, Charnov 1993), longevity (Hoenig 1983), reproductive potential (Rikhter and Efanov 1976, Roff 1986), von Bertlanffy k (Jensen 1996, Gunderson 2003), and age at maturity (Jensen 1996). Previous runs of the model have demonstrated that this value of *M* provides the best model fit, so *M* in the model contionues to be fixed at 0.13.

*Length at maturity*

SS2 incorporates female maturity parameters into the model using the following equation:

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

where $L_{50}$ is the length at 50% maturity and *b* is a slope parameter. Maturity parameters were obtained from Matta (2006), where $b$ = -0.548 and $L_{50}$ = 93.28 cm TL (Table 11 & Fig. 20). Maturity was estimated directly from paired length and maturity stage data; maturity stage was easily assessed through macroscopic examination of the reproductive organs.

*Ageing error*

Each vertebra was aged three independent times by a primary age reader without knowledge of the specimen's biological information. For each true age, the standard deviation of the estimated age was

calculated from the three reads of each vertebra and incorporated into the model to account for variability in age determination.

*Survey catchability*
Empirical evidence suggests that the capture probability of a combined *Bathyraja* species group in the shelf bottom survey is highly length-dependent with a maximum value of 0.846 for the largest skates (Kotwicki and Weinberg 2005; Fig. 21). To incorporate this capture probability data into the model, we assumed a catchability of 1.0 and fixed the survey length selectivity parameters according to parameters of the logistic equation given in Kotwicki and Weinberg (2005; see below). In addition, we did not adjust catchability for the segments of the Alaska skate population (AI and EBS slope) that are not observed by the EBS shelf survey. Over 96% of the Alaska skate population is on the shelf, surveys from the other areas are infrequent, and the AI survey has not been conducted since 2006. We felt it was a precautionary measure not to account for the small amount of Alaska skate biomass on the slope and in the AI.

*Length selectivity*
A logistic selectivity pattern was specified for the EBS shelf survey. Parameters of the logistic function given in Kotwicki and Weinberg (2005) were adapted for the form of the function used in SS2, and both parameters were fixed (Table 11). Fishery length selectivity was governed by a double-normal function defined by six parameters for each fishery or survey, where p1 was the peak or ascending inflection size, p2 was the width of the plateau, p3 was the ascending width, p4 was the descending width, p5 was the selectivity at the first length bin, and p6 was the selectivity at the last length bin. Selectivity parameters are summarized in Table 11. For each fishery, p6 was fixed so that selectivity was asymptotic and all other parameters were estimated within the model. With the exception of p1, all bounds were the default values specified in the SS2 documentation. Bounds for p1 were taken from an SS2 model for longnose skates in the Pacific Northwest (Gertseva et al. 2007).

*Age selectivity*
The uncertainty surrounding the embryonic development period for the Alaska skate posed some problems in this assessment, and age selectivity was used to partially offset these problems. The best estimate of embryo development times is approximately 3.6 years (Hoff 2007), and the majority of young skates appear to emerge during the winter. Therefore, surveys conducted during the following summer would be catching age-4 skates. A logistic age selectivity function was used for the survey and both fisheries. In all cases, the age at 50% selection was fixed and the width of the selectivity curve was estimated within the model. Age at 50% selectivity was set at age 3.5 for the trawl fishery and age 6 for the longline fishery (based on the lack of earlier ages in the length-at-age data available for the longline fishery). An age of 4 was specified for the trawl survey; a likelihood-profile analysis of this specification is discussed in the model evaluation section.

<u>Parameters estimated conditionally:</u>
*Growth parameters*
The form of the von Bertalanffy growth equation (LVB) used in SS2 is:

$$L_A = L_\infty + (L_1 - L_\infty)e^{-k(A-A_1)},$$

where $L_A$ is the mean length at age $A$, $A_1$ is a reference age near the youngest age well represented in the data, $L_1$ is the mean length at age $A_1$, $k$ is the von Bertalanffy growth coefficient, and $L_\infty$ is the mean asymptotic length, calculated from the equation:

$$L_\infty = L_1 + \frac{L_2 - L_1}{1 - e^{-k(A_2 - A_1)}},$$

where $A_2$ is a reference age near the oldest age well represented in the data, and $L_2$ is the mean length at age $A_2$. The reference ages $A_1$ and $A_2$ were set to 3.5 and 20 years, respectively, because these ages were frequently observed and represented nearly the entire age range of the Alaska skate. $L_1$, $L_2$ and $k$ were estimated within the model.

*Spawner-recruit parameters*
SS2 uses a Beverton-Holt function to describe the spawner-recruit relationship of the Alaska skate (Table 11). The steepness of this function was fixed at 1.0 in the Alaska skate model, so recruitment is effectively treated as a mean value from which recruitment estimates are allowed to deviate. This value was chosen because there is very little contrast in SSB for the modeling time period and the data are thus uninformative regarding steepness. The unfished level of recruitment ($R_0$) was freely estimated within the model. Recruitment deviations were included in the model, and the standard deviation of log recruitment ($\sigma^R$) was fixed at 0.4. A likelihood-profile analysis and discussion of this specification are discussed in the model evaluation section.

*Initial fishing mortality*
Initial fishing mortality was estimated within the model for each of the two fisheries.

# Results

## *Model Evaluation*

Because the new input data (survey biomass estimate, catch, length compositions) and the model results were very similar to those used for the 2010 assessment, some of the model evaluation procedures (e.g. likelihood profiles) were not conducted for the 2011 assessment.

### Model evaluation criteria

Likelihood values are given in Table 13. We evaluated the model based on the following criteria:

1) Model fit to survey biomass estimates.
2) Model fit to length compositions.
3) Model fit to length-at-age data.
4) Reasonable estimates of fishery length selectivity parameters.
5) Reasonable estimates of unfished recruitment and recruitment variability.

### Evaluation of the model

1) The expected survey biomass produced by the model provided a good fit to the observed biomass (Fig. 22). The expected survey biomass is within the confidence interval of all but 3 of the observed biomass estimates. The model fit is relatively flat, although it shows more of an increase than in previous years.

2) The model continues to provide good fits to the length composition data from the EBS shelf survey (Fig. 23) and both fisheries (Fig. 24). The model is unable to capture the spikes in large skates observed in the 2003 and 2004 surveys, but it does fit the two modes observed in the survey length composition data. The fit to the fishery data is very good.

3) The model fit the observed length-at-age data from the survey (Fig. 25) and longline fishery (Fig. 26) reasonably well, except for older skates. These fits are unchanged from previous years. Fig.

27 shows the fit of the population growth estimate (in contrast to the observed estimate) to the three length-at-age datasets.

The model continues to underestimate length for skates older than 13 years. The lack of a better fit may be partially due to the limitations of the von Bertalanffy growth model employed in SS2. In future assessments we anticipate moving to a new version of Stock Synthesis that has more flexibility in modeling growth.

An alternative explanation is that the length-at-age data do not accurately reflect skate growth. In the survey length compositions, a single length bin (96-99 cm) consistently has the highest proportion of skates throughout the 9-year time series. The magnitude of this length bin proportion declined from 2002 onwards, presumably as members of that size class were removed by natural mortality. The observation that the length-bin position of this size class did not move suggests that for most skates, growth stops when they reach approximately 100 cm in length (approximately 13 years of age). This is approximately the age of maturation, and a cessation of growth after reaching maturity has been hypothesized for some elasmobranch species. A possible contradiction is that the mean length of older skates is higher than 100 cm. However, these may be exceptional cases. If the growth of most skates ceases, growth in the vertebrae that are used for aging likely ceases as well. Thus, there may be 23-year-old skates 100 cm in length that are misidentified as younger skates. Because the collection of skate vertebrae is length-stratified, it may be that skates with extended growth are preferentially selected. This is supported by the observation that sample size for length-at-age drops considerably after 14-15 years of age. Although the model may underestimate spawning biomass due to the lack of fit of the length-at-age data, the error is in a precautionary direction.

4) Estimates of selectivity parameters (Table 11) and selectivity at length (Fig. 28) for the longline and trawl fisheries were reasonable. Longline fisheries displayed high selectivity for larger skates, which is consistent with the length composition data. This selectivity may be due in part to the emergence of large skates from the nursery grounds during the third quarter of the year, when the longline catch of large skates is particularly high (Fig. 15). The estimate of trawl selectivity also seems reasonable, as the increased selectivity on smaller skates (relative to longline) is likely due to the concentration of trawl fisheries in areas where small skates are less abundant.

5) The base model estimate of unfished recruitment was consistent with the amount of spawning biomass and our limited knowledge of skate fecundity. Evaluating recruitment variability is difficult because little is known about recruitment of equilibrium strategists. The estimated levels of recruitment variability (Figs. 29 & 30) were higher than expected but still seem reasonable for this population.

### *Time series results*

Results presented below are from the base model.

Definitions

Biomass is shown as total (age 0+) biomass (metric tons; t) of all Alaska skates in the population, and as female spawning biomass (t). Recruitment is reported as the number (in thousands) of Alaska skates at age 0. As described above, this corresponds to the number of viable embryos deposited in egg cases.

Biomass time series

Time series of total biomass and spawning biomass estimates from 1992-2011 are reported in Table 14 and in Fig. 31, respectively. These estimates suggest that total skate biomass has been increasing slightly

since the model start year of 1992, and that spawning biomass has increased to a lesser extent during the same period.

Recruitment

Time series of age 0 recruitment are reported in Table 14 and Fig. 29, and the relationship between spawning biomass and recruitment is shown in Fig. 30. The model suggests that recruitment has been relatively low in recent years after being above average during the late 1990s and early 2000s.

Exploitation rate

A time series of exploitation (catch/total biomass) is given in Table 15. The exploitation rates estimated in the 2011 assessment are similar to those of previous years.

# OTHER SKATES – Tier 5 assessment

## Data

Survey biomass

The biomass of the skate assemblage as a whole has increased since the early 1980s (Table 16, Fig. 32). Because skates as a group are contiguous and found in nearly all habitats, the uncertainty (measured as the coefficient of variation, CV) in aggregate skate biomass estimates is rather low, but the uncertainty for individual species is greater (Table 2). Survey species identifications are considered reliable after 1998. Unfortunately, due to taxonomic uncertainty, we cannot evaluate individual species trends within the complex for surveys prior to 1999. Recent surveys demonstrate the variable species composition of the skate complex within each of the three habitat areas, the EBS shelf, the EBS slope, and the Aleutian Islands (Figure 3). The Alaska skate (*B. parmifera*) is dominant and highly abundant on the EBS shelf, while in each of the other two habitat areas, the skate species composition is far more diverse, especially on the EBS slope (Table 2). To generate harvest recommendations, we used the 3 most recent survey biomass estimates for each area to calculate average biomass.

## Analytic Approach

Parameters estimated independently: *M*

As in previous years, *M* was estimated based on other life history parameters. 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 life history parameters from California big skate (*Raja binoculata*) and longnose skate (*R. rhina*) (Zeiner and Wolf 1993), which are found in the GOA but are rare in the BSAI. We also estimated *M* for big and longnose skates from British Columbia and the Gulf of Alaska based on two life history studies (McFarlane and King 2006, Gburski et al. 2007). These 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* for the Other Skates group. Considering the uncertainty inherent in applying this method to the multi-species Other Skates group, we elected to use the lowest estimate of *M* (*M*=0.10, Table 17), which results in conservative estimates of ABC and OFL under Tier 5 criteria. Until better information is available on the productivity of individual skate species in the BSAI Other Skates group, 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.

We recommend that a Tier 5 approach be applied to the Other Skate species complex if the catch remains incidental and no target fishery develops. Tier 5 is recommended because reliable estimates of biomass exist, and *M* =0.10 is considered a reasonable approximation of "aggregate skate" *M* by the Plan Team and SSC. We note that though the proxy *M* was applied to all species, it was based on relatively sensitive skate species. Therefore it is likely an underestimate of *M* for more productive species, which results in conservative specifications. We recommend using an average of the last 3 surveys in each BSAI subregion so that we may include multiple estimates from each of the trawl surveys, while capturing recent biomass levels.

## *Projections and Harvest Alternatives – entire BSAI skate complex*

Reference points and tier assignment – Alaska skate

This assessment using the base model provides reliable estimates of $B_0$, $B_{40\%}$, and the fishing mortality rates corresponding to $F_{40\%}$ and $F_{35\%}$. Therefore, management recommendations are made under Tier 3 of the BSAI Groundfish Fishery Management Plan. Using Tier 3, ABC and OFL are set according to the following criteria:

3a) Stock status: $B/B_{40\%} > 1$

$F_{OFL} = F_{35\%}$

$F_{ABC} \leq F_{40\%}$

3b) Stock status: $0.05 < B/B_{40\%} < 1$

$F_{OFL} = F_{35\%}\ H\ (B/B_{40\%} - 0.05) \times 1/0.95$

$F_{ABC} < F_{40\%}\ H\ (B/B_{40\%} - 0.05) \times 1/0.95$

3c) Stock status: B/B40% < 0.05

$F_{OFL} = 0$

$F_{ABC} = 0$

Specification of OFL and ABC – Alaska skate

The 2010 estimate of female spawning biomass for BSAI Alaska skates is 55,755 t. The estimate of $B_{40\%}$ is 36,846 t, so $B/B_{40\%}$ is 1.51 and 2012-2013 Alaska skate harvest levels can be assigned according to subtier 3a. Therefore, $F_{OFL}= F_{35\%} = 0.087$ and maximum $F_{ABC}= F_{40\%} = 0.075$. The corresponding 2012 OFL is 29,669 t and maximum allowable ABC is 25,565 t. For 2013, OFL is projected to be 28,918 t and maximum allowable ABC is 24,918 t.

Specification of OFL and ABC – Other Skates

| other skates biomass estimates | | | |
|---|---|---|---|
| | EBS shelf | AI | EBS slope |
| 2004 | | 40,344 | 28,908 |
| 2005 | | | |
| 2006 | | 40,726 | |
| 2007 | | | |
| 2008 | | | 33,033 |
| 2009 | 20,162 | | |
| 2010 | 18,902 | 48,342 | 33,956 |
| 2011 | 17,771 | | |
| 3-survey average biomass | 18,945 | 43,137 | 31,992 |
| total BSAI other skates average biomass | | | 94,075 |

Applying the *M* estimate of 0.10 to the 3-survey average of survey biomass estimates, we calculate an ABC of 0.75 * 0.10 * (total BSAI biomass of 94,075 t) = 0.075 * 94,075 t = 7**,056 t**. Applying the *M* estimate of 0.10 to the 3-survey average of survey biomass estimates, we calculate an OFL of 0.10 * (total BSAI biomass of 94,075 t) = 0.1 * 94,075 t = **9,408 t**.

Assemblage analysis and recommendations

Because the incidental skate catch in the BSAI is already high relative to ABC, we recommend that no directed fishing be allowed for skates in the BSAI.

# Ecosystem Considerations

This section focuses on the Alaska skate in both the EBS and AI, with all other species found in each area summarized within the group "Other Skates." We also include supplemental information on the other biomass dominant species in the AI, the Aleutian and whiteblotched skates. 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 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 33; EBS in upper panel, AI in lower panel). In the EBS food web, the skate biomass and therefore the general skate food web position is dominated by the Alaska skate, which eats primarily pollock (as do most other piscivorous animals in the EBS). The food web indicates that aside from sperm whales, most of the "predators" of EBS skates are fisheries, and that cod and halibut are both predators and prey of skates. The AI food web shows skates with different predators and prey than in the EBS, but still at the same moderately high trophic level. Relative to EBS skates, AI skates display more diet diversity (because the species complex is more diverse than in the Alaska skate-dominated EBS), and have more non-fishery predators including sharks and sea lions. These food webs were derived from mass balance ecosystem models assembling information on the food habits, biomass, productivity and consumption for all major living components in each system (Aydin et al. 2007).

The density and mortality patterns for skates also differ greatly between the EBS and AI ecosystems. The biomass density of Alaska skates is much higher in the EBS than in the AI (Fig. 34 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 (Fig. 34 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 Fig. 34 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 (Fig. 35, 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 (Fig. 35, 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 (Fig. 36, 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 (Fig. 36, right panels). Gerald Hoff's research on skate nursery areas suggests that gastropod predation on skate egg cases may account for a significant portion of mortality during the embryonic stage, and Pacific cod and Pacific halibut consume substantial numbers of newly hatched juvenile skates within nursery areas. These sources of mortality may be included in future stock assessments.

Diets of skates are derived from food habits collections taken in conjunction with EBS and AI trawl surveys. Skate food habits information is more complete for the EBS than for the AI, but we present the best available data for both systems here. Over 40% of EBS Alaska skate diet measured in the early 1990s was adult pollock, and another 15% of the diet was fishery offal, suggesting that Alaska skates are opportunistic piscivores (Fig. 37, 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 (Fig. 37, 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 (Fig. 37, 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 (Fig. 37, 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; Fig. 38 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; Fig. 38 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 (Fig. 38 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 (Fig. 38 lower right panel). Atka mackerel consumption by AI Other Skates was estimated to be below 5,000 tons annually. The diet composition estimated for AI Other Skates is likely dominated by the biomass dominant species in that system, whiteblotched skate and Aleutian skate. The diet compositions of both Aleutian and whiteblotched skates in the AI appear to be fairly diverse (Fig. 39), and are

described in further detail in Yang (2007) along with the diets of big skate, Bering skate, Alaska skate, roughtail skate, and mud skate in the AI. In the future, we hope to use diet compositions to make separate consumption estimates for whiteblotched and Aleutian skates along with (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).

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

In the following tables, we summarize ecosystem considerations for BSAI skates and the entire groundfish fishery where they are caught incidentally. 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 | Currently declining from high biomass levels | Probably still adequate forage available for piscivorous skates | Probably no concern |
| Atka mackerel | Cyclically varying population with slight upward trend overall 1977-2005 | Adequate forage available for piscivorous skates | No concern |
| Shrimp/ Benthic invertebrates | Trends are not currently measured directly, only short time series of food habits data exist for potential retrospective measurement | Unknown | Unknown |
| *Predator population trends* | | | |
| Sperm whales | Populations recovering from whaling? | Possibly higher mortality on skates? But still a very small proportion of mortality | No concern |
| Steller sea lions | Declined from 1960s, low but level recently | Lower mortality on skates? | No concern |
| Sharks | Population trends unknown | Unknown | Unknown |
| *Changes in habitat quality* | | | |
| Benthic ranging from shallow shelf to deep slope, isolated nursery areas in specific locations | Skate habitat is only beginning to be described in detail. Adults appear adaptable and mobile in response to habitat changes. Eggs are limited to isolated nursery grounds and juveniles use different habitats than adults. Changes in these habitats have not been monitored historically, so assessments of habitat quality and its trends are not currently available. | Continue study on small nursery areas to evaluate importance to population production | Possible concern if nursery grounds are disturbed or degraded. |

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

| Indicator | Observation | Interpretation | Evaluation |
|---|---|---|---|
| *Fishery contribution to bycatch* | | | |
| Skate catch | Has varied from 12,226 t to 22,982 t from 1992-2007 | Largest portion of total mortality for skates | Possible concern |
| Forage availability | Skates have few predators, and skates are small proportion of diets for their predators | Fishery removal of skates has a small effect on predators | Probably no concern |
| *Fishery concentration in space and time* | | | |
| | Skate bycatch is spread throughout FMP areas, although higher proportion of skate bycatch occurs on outer continental shelf and upper slope | Potential impact to skate populations if fishery disturbs nursery or other important habitat, but small effect on skate predators | Possible concern for skates, probably no concern for skate predators |
| *Fishery effects on amount of large size target fish* | | | |
| | Survey length compositions (2000-2007) suggest that large size classes of Alaska skates appear to be stable | Fishery removals do not appear to have an effect on size structure | Probably no concern |
| *Fishery contribution to discards and offal production* | | | |
| | Skate discard is a relatively high proportion of skate catch, some incidentally caught skates are retained and processed | Unclear whether discard of skates has ecosystem effect | Unknown |
| *Fishery effects on age-at-maturity and fecundity* | | | |
| | Skate age at maturity and fecundity are just now being described; fishery effects on them difficult to determine due to lack of unfished population to compare with | Unknown | Unknown |

## Data gaps and research priorities

Aggregate skate and Alaska skate catches have been estimated using several different methods each with a number of inherent assumptions. We used species composition from recent surveys to partition the Alaska skate catch; however there are two caveats involved with this approach: 1) we assume species composition has remained constant prior to 1999, and 2) we assume that survey species composition is representative of the catch species composition. Also, aggregate skate catch records can mask shifts in species composition, and fishing gear may be more selective for larger-bodied species. Species identification by fishery observers has vastly improved in recent years; however it is still difficult to make accurate identifications in the longline fishery, as many skates are dropped off the line without being brought on board. Mounted video camera systems may be a cost-effective way to determine the species composition of the catch in the future.

In the Alaska skate model, we assumed a catch rate with 100% mortality. In reality, skate mortality is dependent upon the time spent out of water, the type of gear, and handling practices after capture. From fishery observer data, approximately 30% of skates are retained; however we currently have no information regarding the survival of skates that are discarded at sea.

Very few biomass indices are available from the Bering Sea slope survey. The Bering Sea slope habitat area has very high skate species diversity, yet there are only two years of survey data from this area where species identification can be considered reliable (2002 and 2004). Continuation of the Bering Sea slope survey, at least in alternate years, would help to identify overall trends in skate abundance as well as potential shifts in the relative species composition there.

We have initiated a tagging program to gather information regarding movement, distribution patterns, and growth of the Alaska skate. In 2008, approximately 1,200 skates were tagged and released during the shelf and slope surveys. The vast majority of these releases occurred during the shelf survey, and releases were distributed over the entire shelf survey area. As of October 2008, two of these tags had already been recovered through the commercial longline fishery. We expect to deploy additional tags during future trawl surveys and other research cruises.

Fecundity is a very difficult quantity to measure in skates, as individuals of some species may reproduce throughout the year and thus the number of mature or maturing eggs present in the ovary may represent only a fraction of the annual reproductive output. Matta (2006) estimated the average fecundity of the Alaska skate to range between 21 and 37 eggs per female per year, based on the assumed relationship between reproductive potential and *M* (Gunderson 1997). However, due to the uncertainty involved with this parameter, fecundity estimates were not included in the stock assessment model. Fecundity estimates for other skate species range from 48 to 150 young per year (Holden et al. 1971; Holden 1975; Luer & Gilbert 1985; Ellis & Shackley 1995), and it is conceivable that the Alaska skate also has very low annual fecundity. Additional work, such as laboratory rearing experiments, is needed to validate these estimates.

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.

Because skates are at a relatively high trophic level in the EBS and AI, predation mortality is less significant than fishing mortality for adult skates. 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. 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.

Juvenile skates and skate egg cases are likely to be much more vulnerable to predation and disturbance than adults. Gerald Hoff's (AFSC) work on skate nursery areas, described in the life history section of this assessment, suggests that the egg case and neonate life history stages are susceptible to predation by snails and some groundfish. Differences between life history stages in terms of predation and effects of trawling on nursery areas have not been examined in population or ecosystem models.

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.

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.

## Acknowledgements

Many thanks to the following for their valuable contributions to this document: Bob Lauth, Mark Wilkins, and others in the AFSC RACE program for providing survey biomass estimates, the AFSC's Age and Growth Program for providing skate ages, the AFSC's Fishery Monitoring and Analysis program for their hard work in the field and compiling data, and the Alaska Regional Office for making nontarget species catch estimates available. Jim Ianelli provided the projection model. Rick Methot, Grant Thompson, Anne Hollowed, Vladlena Gertseva, and Martin Dorn provided valuable advice regarding the age-structured model.

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# Tables

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

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

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

Table 2. Species composition of the EBS and AI skate complexes from 2010, the most recent year in which all 3 surveys were conducted in the same year.

| species | 2010 shelf | | 2010 slope | | 2010 AI | |
|---|---|---|---|---|---|---|
| | biomass | CV | biomass | CV | biomass | CV |
| Alaska | 366,116 | 0.06 | 1,296 | 0.32 | 3,663 | 0.20 |
| Bering | 11,992 | 0.14 | 2,780 | 0.16 | 56 | 0.45 |
| big | 3,445 | 0.66 | 0 | - | 640 | 0.83 |
| Aleutian | 3,332 | 0.35 | 18,721 | 0.22 | 8,711 | 0.21 |
| whiteblotched | 133 | 1 | 4,055 | 0.14 | 24,179 | 0.20 |
| skate unidentified | 0 | - | 0 | - | 13,245 | 0.21 |
| *Bathyraja* sp | 0 | - | 0.84 | 1.00 | 0 | - |
| deepsea | 0 | - | 345 | 0.64 | 0 | - |
| mud | 0 | - | 576 | 0.25 | 1,511 | 0.23 |
| roughtail | 0 | - | 2,103 | 0.16 | 0 | - |
| commander | 0 | - | 3,393 | 0.15 | 0 | - |
| whitebrow | 0 | - | 1,908 | 0.19 | 0 | - |

Table 3. Time series of BSAI Other Species ABC, TAC, OFL and catch (t), with skate catch proportion.

| 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 | 25,728 | 19,156 | 74% |
| 2004 | 46,810 | 27,205 | 81,150 | 29,478 | 22,300 | 76% |
| 2005 | 53,860 | 29,000 | 87,920 | 29,575 | 23,084 | 78% |
| 2006 | 58,882 | 29,000 | 89,404 | 27,107 | 20,249 | 75% |
| 2007 | 68,800 | 37,355 | 91,700 | 26,648 | 18,615 | 70% |
| 2008 | 78,100 | 50,000 | 104,000 | 29,630 | 21,614 | 73% |
| 2009 | 63,700 | 50,000 | 80,800 | 27,992 | 20,598 | 74% |
| 2010 | 61,100 | 50,000 | 88,200 | 19,402 | 14,445 | 74% |

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: 2003-2010 Other Species and BSAI skate catch from AKRO CAS.

Table 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 5a. Estimated catch (t) of all skate species combined by target fishery, 2003-2011. Source: AKRO CAS. *2011 data incomplete; reported as of November 3, 2011

| **target fishery** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | ***2011**** |
|---|---|---|---|---|---|---|---|---|---|
| AK plaice | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 5 | *36* |
| arrowtooth | 103 | 64 | 127 | 281 | 81 | 297 | 193 | 179 | *122* |
| Atka mackerel | 91 | 143 | 140 | 141 | 153 | 179 | 185 | 246 | *262* |
| flathead sole | 627 | 1,184 | 844 | 851 | 769 | 664 | 362 | 301 | *112* |
| Grnlnd turbot | 221 | 136 | 168 | 121 | 174 | 69 | 209 | 359 | *360* |
| IFQ halibut | 265 | 282 | 130 | 84 | 18 | 1,364 | 25 | 38 | *12* |
| Kamchatka | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *71* |
| other flatfish | 26 | 78 | 43 | 7 | 64 | 2 | 14 | 2 | *3* |
| other target | 228 | 95 | 28 | 115 | 70 | 63 | 33 | 10 | *18* |
| Pacific cod | 14,950 | 18,336 | 19,450 | 15,109 | 13,459 | 14,309 | 12,704 | 11,442 | *14,259* |
| rock sole | 530 | 509 | 423 | 931 | 1,000 | 559 | 944 | 1,208 | *709* |
| rockfish | 73 | 23 | 30 | 37 | 72 | 64 | 96 | 53 | *79* |
| sablefish | 57 | 13 | 26 | 123 | 61 | 40 | 99 | 76 | *142* |
| yellowfin | 1,513 | 596 | 942 | 1,133 | 1,405 | 1,301 | 1,802 | 1,915 | *1,690* |
| pollock | 471 | 841 | 732 | 1,308 | 1,287 | 2,758 | 3,856 | 1,879 | *2,322* |
| **BSAI total** | **19,156** | **22,300** | **23,084** | **20,249** | **18,615** | **21,670** | **20,602** | **17,713** | ***20,198*** |

Table 5b. Estimated catch (t) of all skate species combined by reporting area, 2003-2011. Source: AKRO CAS. *2011 data incomplete; reported as of November 3, 2011.

| region | rep. area | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | *2011** |
|---|---|---|---|---|---|---|---|---|---|---|
| EBS | 508 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *6* |
| | 509 | 1,968 | 2,160 | 3,267 | 3,537 | 3,577 | 4,037 | 5,007 | 2,793 | *5,630* |
| | 512 | 25 | 205 | 15 | 0 | 0 | 29 | 16 | 13 | *7* |
| | 513 | 2,757 | 2,821 | 4,010 | 2,667 | 2,360 | 2,069 | 2,541 | 1,887 | *2,341* |
| | 514 | 279 | 67 | 196 | 221 | 445 | 86 | 134 | 79 | *146* |
| | 516 | 132 | 408 | 239 | 253 | 398 | 488 | 573 | 660 | *243* |
| | 517 | 2,863 | 2,946 | 3,669 | 2,399 | 2,139 | 2,452 | 3,166 | 2,805 | *2,202* |
| | 518 | 25 | 6 | 16 | 11 | 5 | 480 | 56 | 41 | *11* |
| | 519 | 184 | 139 | 104 | 69 | 109 | 185 | 55 | 80 | *92* |
| | 521 | 8,946 | 10,313 | 8,478 | 8,351 | 7,105 | 7,616 | 6,184 | 6,595 | *7,562* |
| | 523 | 306 | 325 | 243 | 283 | 334 | 242 | 263 | 405 | *266* |
| | 524 | 1,016 | 2,025 | 2,151 | 1,493 | 1,137 | 2,568 | 1,399 | 1,019 | *971* |
| | 530 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | *0* |
| | **EBS total** | **18,501** | **21,415** | **22,388** | **19,283** | **17,608** | **20,251** | **19,396** | **16,376** | ***19,476*** |
| AI | 541 | 302 | 466 | 487 | 563 | 337 | 497 | 452 | 465 | *475* |
| | 542 | 234 | 278 | 126 | 336 | 394 | 577 | 334 | 445 | *217* |
| | 543 | 118 | 141 | 83 | 67 | 276 | 345 | 420 | 428 | *30* |
| | **AI total** | **655** | **885** | **696** | **966** | **1,007** | **1,419** | **1,206** | **1,337** | ***722*** |

Table 6. Observed skate catch and percent retained by species, and by region, 2003-2007. *2007 reported as of October 15, 2007 (not a complete year). Source: North Pacific Groundfish Observer Program database.

| | 2003 | | 2004 | | 2005 | | 2006 | | 2007 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Obs Catch (t)** | **% Retained** | **Obs Catch (t)** | **% Retained** | **Obs Catch (t)** | **% Retained** | **Obs Catch (t)** | **% Retained** | **Obs Catch (t)** | **% Retained** |
| **Alaska** | 1,179 | 49% | 4,373 | 36% | 4,125 | 39% | 4,956 | 36% | 4,076 | 32% |
| **Aleutian** | 71 | 28% | 264 | 36% | 304 | 31% | 154 | 43% | 119 | 28% |
| **Bathyraja UnID** | 58 | 77% | 77 | 8% | 6,319 | 37% | 4,586 | 29% | 3,233 | 23% |
| **Bering** | 43 | 27% | 233 | 12% | 197 | 10% | 128 | 17% | 79 | 21% |
| **Big** | 26 | 60% | 131 | 27% | 165 | 19% | 179 | 27% | 84 | 46% |
| **Commander** | 2 | 1% | 15 | 18% | 26 | 5% | 16 | 5% | 21 | 16% |
| **Longnose** | 1 | 32% | 15 | 42% | 5 | 44% | 2 | 48% | | 0% |
| **Mud** | | | 29 | 7% | 22 | 4% | 6 | 20% | 13 | 7% |
| **Raja UnID** | | | | | 10 | 4% | | | | 0% |
| **Roughtail** | | | 5 | 8% | 2 | 2% | 5 | 12% | 2 | 3% |
| **Skate UnID** | 13,024 | 38% | 8,822 | 27% | 3,853 | 28% | 2,819 | 26% | 510 | 14% |
| **Whiteblotched** | 9 | 1% | 153 | 21% | 58 | 24% | 92 | 28% | 39 | 28% |
| **Whitebrow** | | | 5 | 31% | 7 | 7% | 3 | 22% | 2 | 21% |
| **Other** | 2 | 1% | 0 | 2% | 0 | 100% | 0 | 67% | 2 | 14% |
| **Total** | **14,416** | **39%** | **14,123** | **30%** | **15,092** | **34%** | **12,947** | **31%** | **8,181** | **27%** |

| | 2003 | | 2004 | | 2005 | | 2006 | | 2007 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Region** | **Obs Catch (t)** | **% Retained** | **Obs Catch (t)** | **% Retained** | **Obs Catch (t)** | **% Retained** | **Obs Catch (t)** | **% Retained** | **Obs Catch (t)** | **% Retained** |
| **AI** | 437 | 18% | 590 | 21% | 463 | 17% | 690 | 21% | 406 | 34% |
| **EBS** | 13,978 | 39% | 13,533 | 30% | 14,629 | 35% | 12,258 | 32% | 7,775 | 27% |
| **Total** | 14,416 | 39% | 14,123 | 30% | 15,092 | 34% | 12,947 | 31% | 8,181 | 27% |

Table 7. EBS shelf bottom trawl survey estimates of Alaska skate (*Bathyraja parmifera*) biomass (metric tons). Line indicates the start year of the model. Estimates and CVs in bold (1999-2011) were obtained directly from trawl survey data when species identification was reliable. Estimates and CVs prior to 1999 were partitioned using species composition data from 1999-2011.

| year | biomass | CV |
|---|---|---|
| 1982 | 167,826 | 0.10 |
| 1983 | 163,970 | 0.10 |
| 1984 | 190,037 | 0.10 |
| 1985 | | |
| 1986 | 255,409 | 0.10 |
| 1987 | 334,132 | 0.10 |
| 1988 | 392,645 | 0.10 |
| 1989 | 395,370 | 0.10 |
| 1990 | 513,751 | 0.10 |
| 1991 | 433,529 | 0.10 |
| 1992 | 379,682 | 0.10 |
| 1993 | 370,356 | 0.10 |
| 1994 | 412,663 | 0.10 |
| 1995 | 385,126 | 0.10 |
| 1996 | 426,649 | 0.10 |
| 1997 | 402,720 | 0.10 |
| 1998 | 352,101 | 0.10 |
| **1999** | **349,571** | **0.16** |
| **2000** | **311,970** | **0.06** |
| **2001** | **414,539** | **0.06** |
| **2002** | **410,016** | **0.06** |
| **2003** | **372,257** | **0.05** |
| **2004** | **433,660** | **0.05** |
| **2005** | **547,031** | **0.05** |
| **2006** | **437,737** | **0.05** |
| **2007** | **478,872** | **0.07** |
| **2008** | **361,298** | **0.06** |
| **2009** | **350,233** | **0.06** |
| **2010** | **366,116** | **0.06** |
| **2011** | **410,340** | **0.05** |

Table 8. Alaska skate EBS shelf survey length compositions, 2000-2011. Bin number is the lower limit of each 4 cm length bin; data are proportions of each bin. N = number of hauls.

| | year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| bin | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** |
| **4** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.002 | 0 | 0 |
| **8** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **12** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **16** | 0 | 0 | 0.001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.001 | 0 |
| **20** | 0.007 | 0.01 | 0.01 | 0.006 | 0.006 | 0.004 | 0.003 | 0.007 | 0.004 | 0.008 | 0.003 | 0.004 |
| **24** | 0.037 | 0.039 | 0.023 | 0.033 | 0.016 | 0.019 | 0.024 | 0.017 | 0.017 | 0.019 | 0.015 | 0.015 |
| **28** | 0.047 | 0.056 | 0.031 | 0.031 | 0.03 | 0.025 | 0.026 | 0.019 | 0.02 | 0.019 | 0.018 | 0.021 |
| **32** | 0.047 | 0.058 | 0.037 | 0.047 | 0.032 | 0.033 | 0.031 | 0.028 | 0.027 | 0.03 | 0.017 | 0.025 |
| **36** | 0.052 | 0.048 | 0.044 | 0.053 | 0.032 | 0.041 | 0.036 | 0.042 | 0.038 | 0.043 | 0.028 | 0.028 |
| **40** | 0.051 | 0.048 | 0.042 | 0.048 | 0.049 | 0.047 | 0.045 | 0.051 | 0.052 | 0.051 | 0.04 | 0.042 |
| **44** | 0.046 | 0.051 | 0.044 | 0.052 | 0.051 | 0.061 | 0.052 | 0.052 | 0.061 | 0.054 | 0.048 | 0.057 |
| **48** | 0.052 | 0.044 | 0.041 | 0.053 | 0.058 | 0.057 | 0.057 | 0.062 | 0.061 | 0.053 | 0.042 | 0.064 |
| **52** | 0.056 | 0.049 | 0.045 | 0.041 | 0.062 | 0.054 | 0.051 | 0.052 | 0.065 | 0.06 | 0.05 | 0.064 |
| **56** | 0.052 | 0.043 | 0.037 | 0.036 | 0.051 | 0.057 | 0.057 | 0.055 | 0.062 | 0.063 | 0.053 | 0.062 |
| **60** | 0.055 | 0.051 | 0.035 | 0.041 | 0.047 | 0.064 | 0.055 | 0.05 | 0.059 | 0.064 | 0.051 | 0.064 |
| **64** | 0.045 | 0.043 | 0.033 | 0.039 | 0.042 | 0.053 | 0.053 | 0.06 | 0.06 | 0.059 | 0.059 | 0.064 |
| **68** | 0.035 | 0.047 | 0.041 | 0.043 | 0.049 | 0.046 | 0.048 | 0.055 | 0.046 | 0.052 | 0.061 | 0.059 |
| **72** | 0.038 | 0.046 | 0.035 | 0.041 | 0.043 | 0.048 | 0.049 | 0.053 | 0.051 | 0.054 | 0.057 | 0.060 |
| **76** | 0.03 | 0.035 | 0.041 | 0.042 | 0.047 | 0.04 | 0.048 | 0.046 | 0.049 | 0.049 | 0.054 | 0.050 |
| **80** | 0.04 | 0.03 | 0.035 | 0.047 | 0.038 | 0.04 | 0.037 | 0.041 | 0.043 | 0.05 | 0.056 | 0.046 |
| **84** | 0.03 | 0.026 | 0.046 | 0.037 | 0.043 | 0.039 | 0.044 | 0.04 | 0.04 | 0.045 | 0.058 | 0.047 |
| **88** | 0.034 | 0.033 | 0.069 | 0.044 | 0.044 | 0.052 | 0.038 | 0.045 | 0.043 | 0.049 | 0.063 | 0.048 |
| **92** | 0.051 | 0.06 | 0.092 | 0.056 | 0.062 | 0.048 | 0.062 | 0.058 | 0.055 | 0.049 | 0.076 | 0.052 |
| **96** | 0.07 | 0.071 | 0.094 | 0.088 | 0.081 | 0.062 | 0.068 | 0.063 | 0.057 | 0.056 | 0.069 | 0.058 |
| **100** | 0.066 | 0.069 | 0.076 | 0.065 | 0.072 | 0.059 | 0.064 | 0.06 | 0.055 | 0.045 | 0.047 | 0.045 |
| **104** | 0.043 | 0.031 | 0.037 | 0.043 | 0.034 | 0.035 | 0.038 | 0.028 | 0.026 | 0.02 | 0.025 | 0.017 |
| **108** | 0.014 | 0.011 | 0.01 | 0.013 | 0.01 | 0.011 | 0.012 | 0.011 | 0.009 | 0.006 | 0.008 | 0.006 |
| **112** | 0.002 | 0.002 | 0.003 | 0.002 | 0.003 | 0.002 | 0.002 | 0.003 | 0.001 | 0 | 0.001 | 0.001 |
| **116** | 0 | 0 | 0 | 0 | 0 | 0.001 | 0 | 0.001 | 0 | 0 | 0 | 0 |
| **120** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **124** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **128** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **132** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **N** | 316 | 354 | 333 | 332 | 380 | 370 | 352 | 362 | 346 | 363 | 361 | 361 |

Table 9. Partitioned Alaska skate catch estimates (metric tons) based on observed catch data and survey species composition. Total BSAI catch estimates for each fishery (right-most column) were used in the SS2 base model. 2011 catch is as reported through November 3, 2011.

| year | EBS shelf longline | EBS shelf trawl | EBS slope longline | EBS slope trawl | AI longline | AI trawl | BSAI longline | BSAI trawl |
|---|---|---|---|---|---|---|---|---|
| 1992 | 12,204 | 2,690 | 23 | 8 | 169 | 94 | 12,396 | 2,792 |
| 1993 | 8,797 | 1,939 | 16 | 6 | 122 | 68 | 8,935 | 2,013 |
| 1994 | 10,234 | 2,256 | 19 | 7 | 142 | 79 | 10,394 | 2,341 |
| 1995 | 10,715 | 2,362 | 20 | 7 | 148 | 83 | 10,883 | 2,451 |
| 1996 | 9,097 | 2,005 | 17 | 6 | 126 | 70 | 9,240 | 2,081 |
| 1997 | 12,885 | 2,840 | 24 | 8 | 150 | 84 | 13,059 | 2,932 |
| 1998 | 13,876 | 3,059 | 26 | 9 | 198 | 110 | 14,100 | 3,178 |
| 1999 | 10,129 | 2,233 | 19 | 7 | 141 | 78 | 10,288 | 2,318 |
| 2000 | 13,020 | 2,870 | 24 | 9 | 317 | 177 | 13,362 | 3,055 |
| 2001 | 13,778 | 3,037 | 26 | 9 | 440 | 245 | 14,244 | 3,291 |
| 2002 | 15,702 | 3,461 | 119 | 42 | 122 | 68 | 15,943 | 3,571 |
| 2003 | 13,944 | 3,271 | 30 | 7 | 115 | 64 | 14,088 | 3,342 |
| 2004 | 16,104 | 3,777 | 26 | 22 | 155 | 86 | 16,285 | 3,886 |
| 2005 | 17,498 | 3,333 | 40 | 4 | 122 | 68 | 17,660 | 3,405 |
| 2006 | 14,710 | 3,243 | 27 | 10 | 169 | 94 | 14,907 | 3,346 |
| 2007 | 13,432 | 2,961 | 25 | 9 | 177 | 98 | 13,634 | 3,068 |
| 2008 | 15,449 | 3,405 | 29 | 10 | 249 | 139 | 15,726 | 3,554 |
| 2009 | 14,796 | 3,262 | 28 | 10 | 211 | 118 | 15,035 | 3,389 |
| 2010 | 12,493 | 2,754 | 23 | 8 | 234 | 131 | 12,750 | 2,892 |
| 2011 | 14,857 | 3,275 | 28 | 10 | 127 | 70 | 15,012 | 3,355 |

Table 10. Alaska skate length compositions from the BSAI longline and trawl fisheries, 2007-2010. Bin number is the lower limit of each 4 cm length interval.

| | 2007 | | 2008 | | 2009 | | 2010 | |
|---|---|---|---|---|---|---|---|---|
| **bin** | **longline** | **trawl** | **longline** | **trawl** | **longline** | **trawl** | **longline** | **trawl** |
| **4** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **8** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **12** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| **16** | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.002 |
| **20** | 0.000 | 0.008 | 0.000 | 0.004 | 0.000 | 0.003 | 0.000 | 0.003 |
| **24** | 0.000 | 0.017 | 0.000 | 0.022 | 0.000 | 0.011 | 0.000 | 0.010 |
| **28** | 0.000 | 0.013 | 0.000 | 0.035 | 0.000 | 0.024 | 0.000 | 0.018 |
| **32** | 0.000 | 0.023 | 0.000 | 0.043 | 0.001 | 0.035 | 0.001 | 0.031 |
| **36** | 0.000 | 0.030 | 0.001 | 0.062 | 0.001 | 0.053 | 0.001 | 0.037 |
| **40** | 0.002 | 0.040 | 0.002 | 0.056 | 0.002 | 0.065 | 0.002 | 0.054 |
| **44** | 0.005 | 0.054 | 0.004 | 0.047 | 0.005 | 0.066 | 0.006 | 0.055 |
| **48** | 0.006 | 0.061 | 0.014 | 0.049 | 0.009 | 0.056 | 0.014 | 0.051 |
| **52** | 0.016 | 0.053 | 0.020 | 0.046 | 0.017 | 0.051 | 0.024 | 0.042 |
| **56** | 0.027 | 0.046 | 0.027 | 0.037 | 0.023 | 0.044 | 0.032 | 0.041 |
| **60** | 0.046 | 0.061 | 0.030 | 0.039 | 0.032 | 0.041 | 0.045 | 0.043 |
| **64** | 0.062 | 0.067 | 0.053 | 0.037 | 0.043 | 0.048 | 0.056 | 0.048 |
| **68** | 0.054 | 0.049 | 0.074 | 0.038 | 0.058 | 0.048 | 0.068 | 0.057 |
| **72** | 0.072 | 0.053 | 0.062 | 0.039 | 0.063 | 0.048 | 0.070 | 0.054 |
| **76** | 0.055 | 0.059 | 0.072 | 0.037 | 0.069 | 0.040 | 0.062 | 0.050 |
| **80** | 0.059 | 0.045 | 0.072 | 0.041 | 0.069 | 0.054 | 0.071 | 0.054 |
| **84** | 0.060 | 0.048 | 0.073 | 0.044 | 0.069 | 0.045 | 0.067 | 0.054 |
| **88** | 0.065 | 0.059 | 0.078 | 0.052 | 0.083 | 0.061 | 0.072 | 0.055 |
| **92** | 0.089 | 0.052 | 0.082 | 0.056 | 0.098 | 0.061 | 0.091 | 0.069 |
| **96** | 0.117 | 0.060 | 0.110 | 0.075 | 0.129 | 0.058 | 0.103 | 0.068 |
| **100** | 0.137 | 0.051 | 0.132 | 0.075 | 0.124 | 0.050 | 0.104 | 0.054 |
| **104** | 0.080 | 0.025 | 0.063 | 0.040 | 0.068 | 0.027 | 0.057 | 0.028 |
| **108** | 0.031 | 0.013 | 0.029 | 0.014 | 0.028 | 0.007 | 0.028 | 0.012 |
| **112** | 0.010 | 0.008 | 0.001 | 0.006 | 0.006 | 0.002 | 0.013 | 0.004 |
| **116** | 0.006 | 0.004 | 0.001 | 0.002 | 0.002 | 0.000 | 0.006 | 0.003 |
| **120** | 0.002 | 0.001 | 0.000 | 0.001 | 0.001 | 0.000 | 0.004 | 0.001 |
| **124** | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 |
| **128** | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| **132** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **N** | 2,911 | 858 | 1,369 | 2,930 | 18,081 | 8,174 | 17,168 | 9,545 |

Table 11. Final parameter values of the base model. Where parameters were estimated freely within the model, minimum and maximum bounds are shown.

| parameter | | value | min | max | fix? |
|---|---|---|---|---|---|
| **growth and natural mortality** | natural mortality (M) | 0.13 | | | X |
| | length at A1 (L1) | 20.0 | 10 | 30 | |
| | length at A2 (L2) | 101.5 | 70 | 120 | |
| | von Bertalanffy coefficient (k) | 0.145 | 0.05 | 0.2 | |
| | CV of L1 | 0.366 | 0 | 0.5 | |
| | ln CV of L2 | -1.82 | -3 | 1 | |
| **length-weight relationship** | coefficient (a) | $4.0 \times 10^{-6}$ | | | X |
| | exponent (b) | 3.149 | | | X |
| **length at maturity** | length at 50% maturity (a) | 93.28 | | | X |
| | slope (b) | -0.548 | | | X |
| **weight-fecundity relationship** | coefficient (a) | 0.5 | | | X |
| | exponent (b) | 0 | | | X |
| **stock-recruit relationship** | ln virgin recruitment level (R0) | 10.60 | 5 | 15 | |
| | steepness (h) | 1 | | | X |
| | SD of R0 (σR) | 0.4 | | | X |
| **EBS shelf survey catchability** | ln catchability (Q) | 0 | | | X |
| **longline length selectivity** | peak (p1) | 102.1 | 7.6 | 126 | |
| | top (p2) | 1.97 | -6 | 4 | |
| | ascending width (p3) | 3.94 | -1 | 9 | |
| | descending width (p4) | 5.06 | -1 | 9 | |
| | selectivity at first size bin (p5) | -0.50 | -5 | 9 | |
| | selectivity at last size bin (p6) | 9.0 | | | X |
| **trawl length selectivity** | peak (p1) | 41.7 | 7.6 | 126.2 | |
| | top (p2) | -2.96 | -6 | 4 | |
| | ascending width (p3) | 5.66 | -1 | 9 | |
| | descending width (p4) | 0.55 | -1 | 9 | |
| | selectivity at first size bin (p5) | -5 | -5 | 9 | |
| | selectivity at last size bin (p6) | 9 | -5 | 9 | X |
| **survey length selectivity (logistic)** | (p1) | -32.99 | | | X |
| | (p2) | 285.9 | | | X |
| **longline age selectivity (logistic)** | (p1) | 6.5 | | | X |
| | (p2) | 0.438 | 0 | 30 | |
| **trawl age selectivity (logistic)** | (p1) | 3.5 | | | X |
| | (p2) | 0.072 | 0 | 30 | |
| **survey age selectivity (logistic)** | (p1) | 4 | | | X |
| | (p2) | 0.170 | 0 | 30 | |
| **initial fishing mortality** | longline fishery F | 0.037 | 0.001 | 1 | |
| | trawl fishery F | 0.005 | 0.0004 | 1 | |

Table 12. Estimates of M based on Alaska skate life history parameters from Matta (2006). "Age mature" ($T_{mat}$) was given a range to estimate M by the Rikhter and Efanov method to account for uncertainty in this parameter.

| Sex | Hoenig | $T_{mat}$ | Rikhter & Efanov | Alverson & Carney | Charnov | Roff | Jensen k | Jensen $T_{50}$ |
|---|---|---|---|---|---|---|---|---|
| *males* | 0.28 | | | 0.37 | 0.22 | **0.13** | 0.19 | 0.18 |
| *females* | 0.25 | | | 0.35 | 0.16 | 0.15 | 0.14 | 0.17 |
| *both* | | 8 | 0.19 | | | | | |
| | | 9 | 0.16 | | | | | |
| | | 10 | **0.13** | | | | | |

Table 13. Overall and component likelihoods.

| **overall likelihood** | **185.407** |
|---|---|
| survey | -19.113 |
| length compositions | 91.7063 |
| length at age | 159.254 |
| equilibrium catch | 0.00063 |
| recruitment | -35.446 |
| forecast recruitment | -10.996 |

Table 14. Time series of total (age 0+) biomass (metric tons), spawning biomass (metric tons) and the number of age 0 recruits (thousands of fish) predicted by the base model.

| | **total biomass (t)** | **female spawning biomass (t)** | **recruits (1000s)** |
|---|---|---|---|
| **1992** | 464,847 | 108,413 | 30,049 |
| **1993** | 466,671 | 106,477 | 33,629 |
| **1994** | 473,476 | 106,001 | 42,761 |
| **1995** | 478,701 | 105,338 | 45,632 |
| **1996** | 482,683 | 105,219 | 50,837 |
| **1997** | 487,456 | 106,000 | 50,328 |
| **1998** | 487,259 | 105,950 | 47,325 |
| **1999** | 486,532 | 106,109 | 52,994 |
| **2000** | 491,827 | 108,529 | 37,711 |
| **2001** | 495,731 | 109,341 | 39,386 |
| **2002** | 500,710 | 109,723 | 36,985 |
| **2003** | 505,610 | 108,945 | 38,809 |
| **2004** | 513,550 | 108,048 | 52,406 |
| **2005** | 518,436 | 106,553 | 36,652 |
| **2006** | 521,413 | 105,844 | 33,090 |
| **2007** | 525,504 | 106,544 | 33,011 |
| **2008** | 530,015 | 108,673 | 36,054 |
| **2009** | 531,650 | 110,557 | 36,054 |
| **2010** | 532,837 | 112,660 | 36,054 |
| **2011** | 534,824 | 116,435 | 36,054 |

Table 15. Time series of exploitation rates (catch/total biomass) as estimated by the model.

| year | longline | trawl | total |
|---|---|---|---|
| 1992 | 0.043 | 0.006 | 0.049 |
| 1993 | 0.031 | 0.004 | 0.035 |
| 1994 | 0.036 | 0.005 | 0.040 |
| 1995 | 0.037 | 0.005 | 0.042 |
| 1996 | 0.031 | 0.004 | 0.035 |
| 1997 | 0.043 | 0.006 | 0.049 |
| 1998 | 0.047 | 0.006 | 0.053 |
| 1999 | 0.034 | 0.005 | 0.039 |
| 2000 | 0.044 | 0.006 | 0.051 |
| 2001 | 0.047 | 0.007 | 0.054 |
| 2002 | 0.053 | 0.007 | 0.060 |
| 2003 | 0.046 | 0.007 | 0.053 |
| 2004 | 0.053 | 0.007 | 0.060 |
| 2005 | 0.057 | 0.006 | 0.063 |
| 2006 | 0.047 | 0.006 | 0.054 |
| 2007 | 0.043 | 0.006 | 0.049 |
| 2008 | 0.049 | 0.007 | 0.056 |
| 2009 | 0.047 | 0.006 | 0.053 |
| 2010 | 0.040 | 0.005 | 0.045 |
| 2011 | 0.046 | 0.006 | 0.052 |

Table 16. Total 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), 1975-2011.

| 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 | 175,643 | 0.09 | 2,723 | 0.10 | | |
| 1983 | 171,607 | 0.08 | | | 9,683 | 0.12 |
| 1984 | 198,888 | 0.09 | | | | |
| 1985 | | | 3,329 | 0.10 | | |
| 1986 | 267,306 | 0.15 | | | 15,436 | 0.19 |
| 1987 | 356,519 | 0.09 | | | | |
| 1988 | 416,029 | 0.11 | 3,271 | 0.21 | | |
| 1989 | 413,909 | 0.08 | | | | |
| 1990 | 540,502 | 0.11 | | | | |
| 1991 | 448,054 | 0.09 | 4,031 | 0.25 | 14,967 | 0.17 |
| 1992 | 399,358 | 0.09 | | | | |
| 1993 | 388,950 | 0.07 | | | | |
| 1994 | 414,054 | 0.08 | | | 25,014 | 0.10 |
| 1995 | 404,460 | 0.08 | | | | |
| 1996 | 446,036 | 0.06 | | | | |
| 1997 | 422,974 | 0.07 | | | 28,922 | 0.14 |
| 1998 | 369,330 | 0.05 | | | | |
| 1999 | 382,446 | 0.15 | | | | |
| 2000 | 336,713 | 0.05 | | | 29,320 | 0.09 |
| 2001 | 428,591 | 0.06 | | | | |
| 2002 | 428,664 | 0.06 | 69,275 | 0.50 | 34,413 | 0.11 |
| 2003 | 404,639 | 0.05 | | | | |
| 2004 | 448,316 | 0.05 | 33,156 | 0.08 | 53,071 | 0.16 |
| 2005 | 563,846 | 0.05 | | | | |
| 2006 | 452,685 | 0.05 | | | 54,210 | 0.12 |
| 2007 | 496,108 | 0.07 | | | | |
| 2008 | 380,915 | 0.05 | 37,548 | 0.08 | | |
| 2009 | 370,395 | 0.06 | | | | |
| 2010 | 385,018 | 0.06 | 35,251 | 0.08 | 52,005 | 0.13 |
| 2011 | 428,111 | 0.05 | | | | |

Table 17. Estimates of M for the Other Skates group based on *Raja* sp. life history parameters. "Age mature" ($T_{mat}$) was given a range for M estimates by the Rikhter and Efanov method to account for uncertainty in this parameter. Study areas are indicated as CA (California), GOA (Gulf of Alaska), and BC (British Columbia. Life history parameter sources: Zeiner and Wolf 1993, Gburski et al. 2007, McFarlane and King 2006.

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

## Figures

Figure 1. 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 whitebrow skate (*B. minispinosa*), mud skate (*B. taranetzi*), whiteblotched skate (*B. maculata*), Aleutian skate (*B. aleutica*), and Commander skate (*B. lindbergi*). Photo credit: Gerald Hoff.

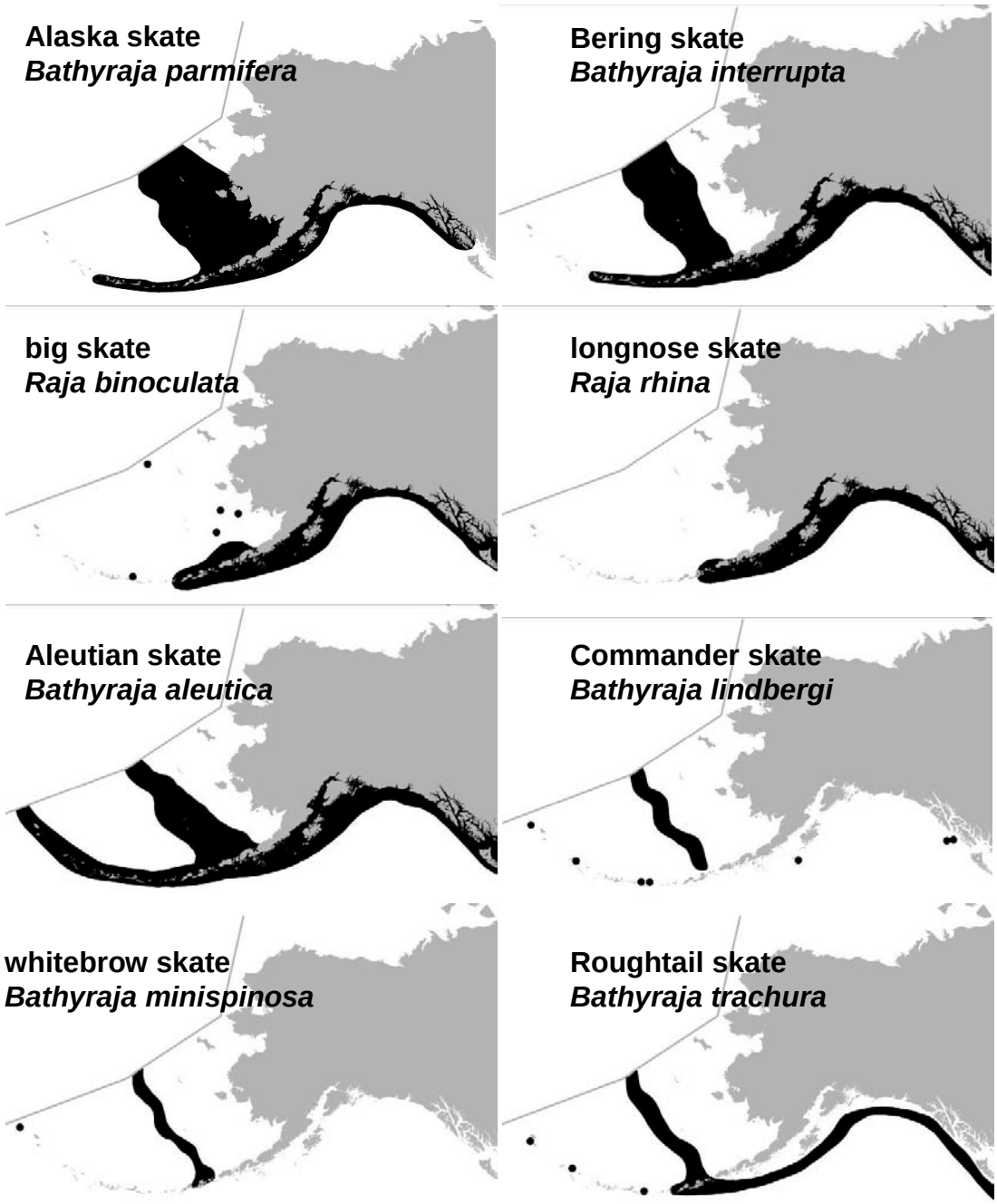



Figure 2. Distribution of skate species in Alaskan waters. These maps were created primarily using survey data, although observer records were included whenever positive species identification was possible (through voucher specimens or photographs). ***(Source: Stevenson et al. 2007)***

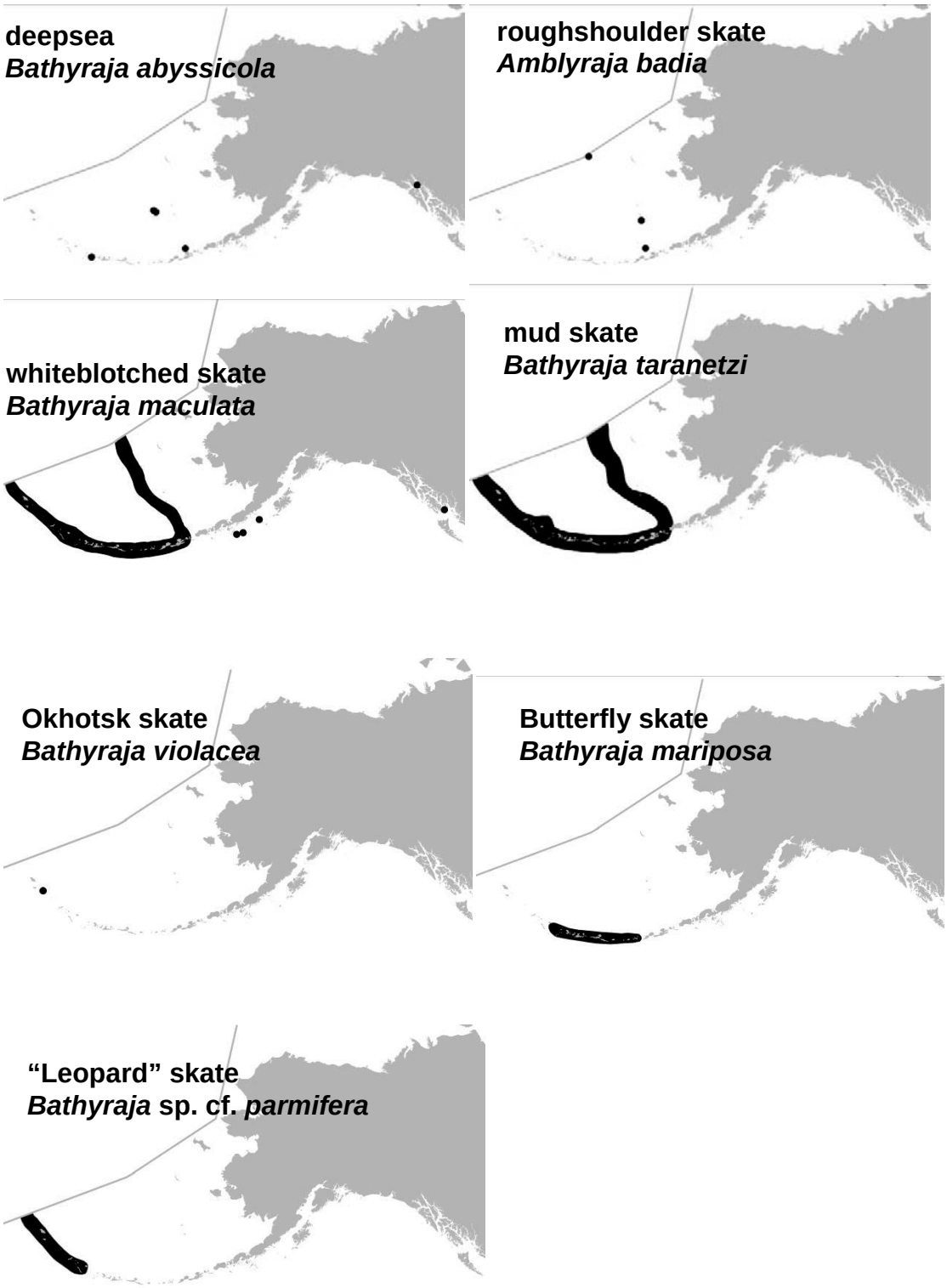



Figure 2 continued. Distribution of skate species in Alaskan waters. (Source: Stevenson et al. 2007)

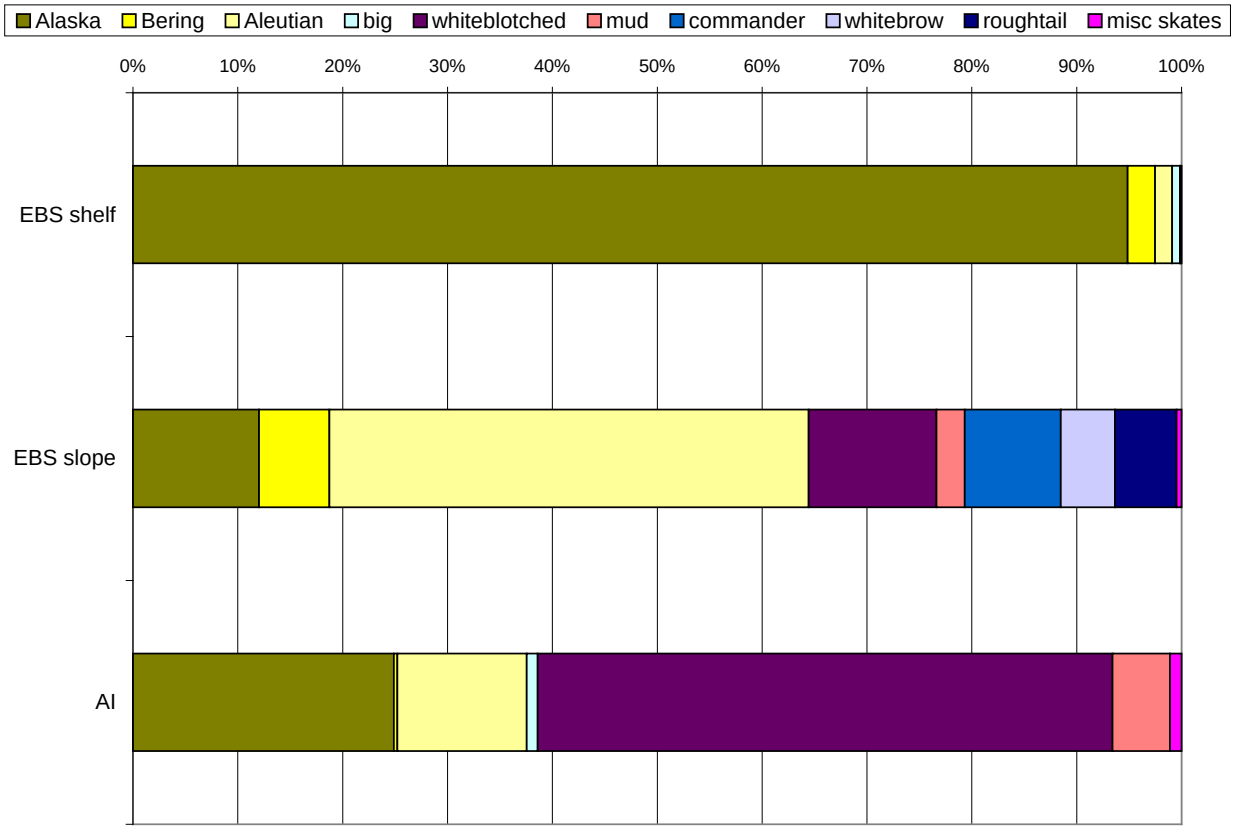



Figure 3. Skate species composition (by weight) by BSAI subregion, from surveys conducted in each region in 2010. “Misc skates” contains longnose, deepsea, and unidentified skates.

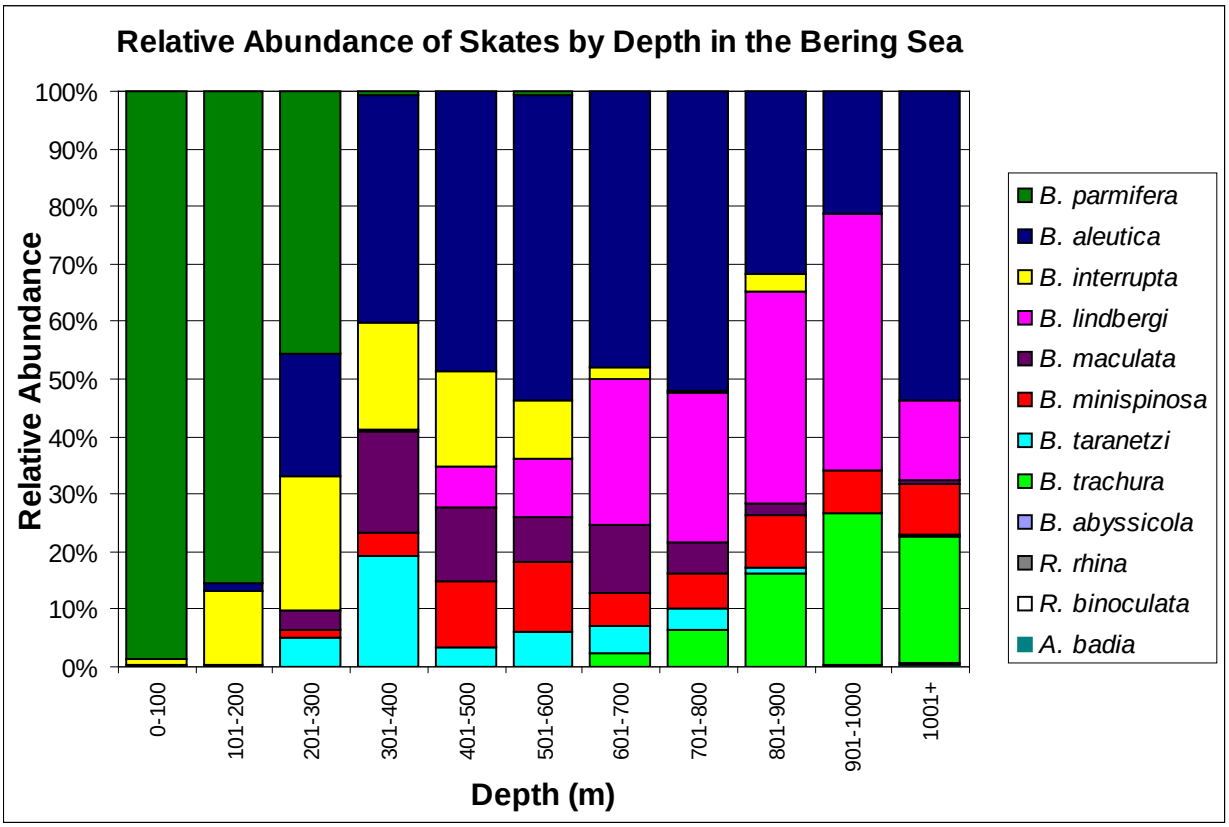
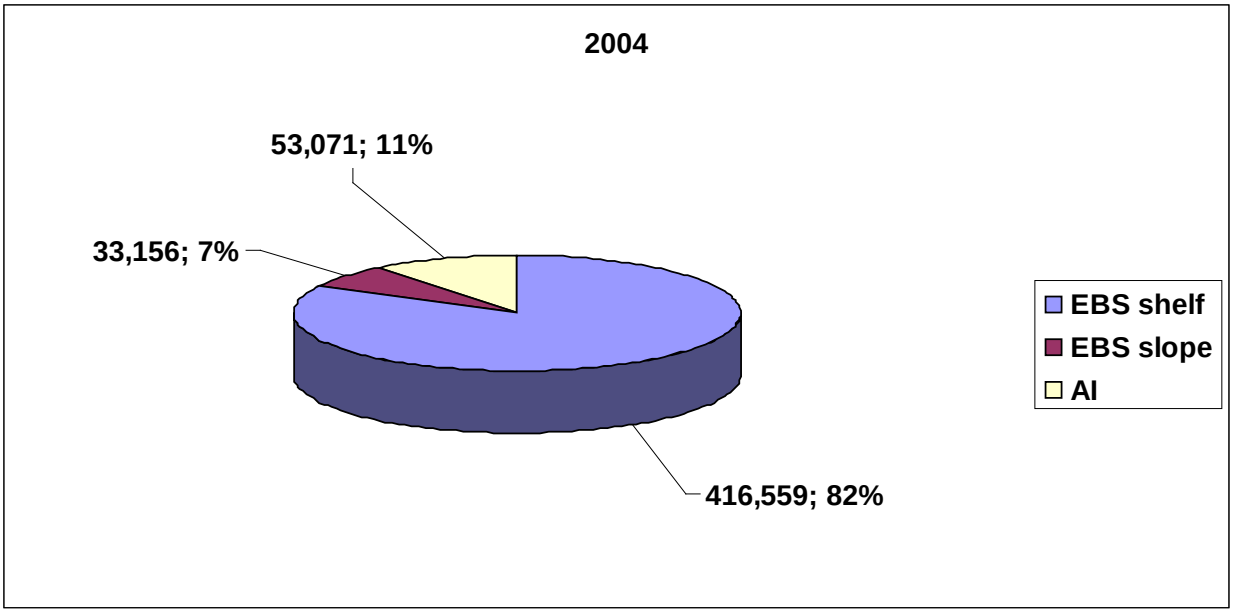



Figure 4. Relative abundance of skate species in the EBS by depth. (Source: Stevenson et al. 2006.)



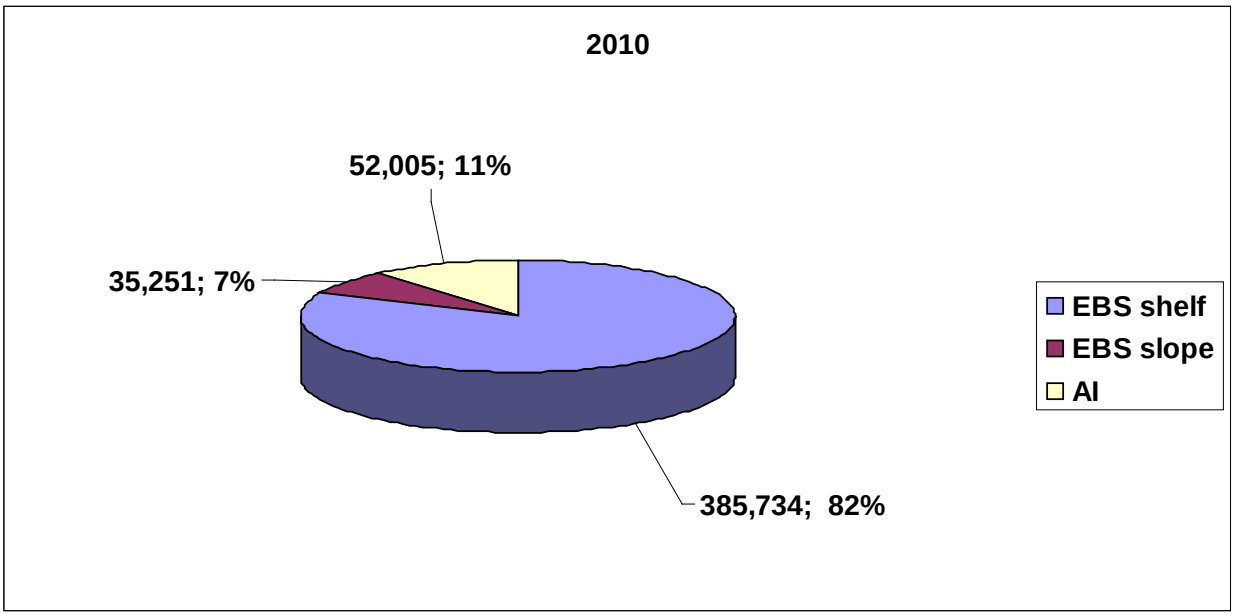




Figure 5. Distribution of skate biomass in the 3 subregions of the BSAI, 2004 and 2010. Data are biomass estimates from AFSC groundfish surveys.

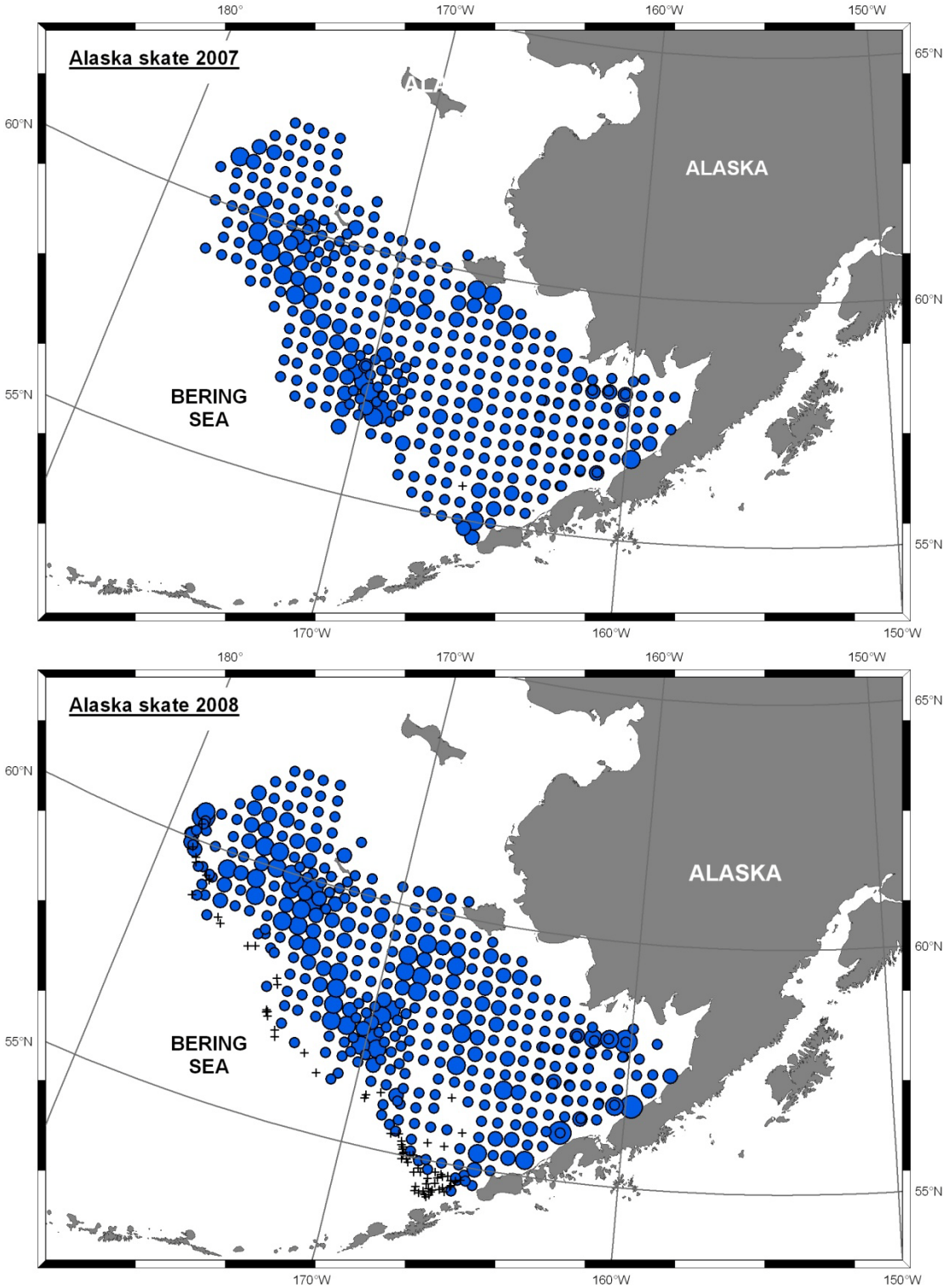



Figure 6. AFSC bottom trawl survey catches of Alaska skate in 2007 & 2008. Symbol size is proportional to total catch at each survey station. Data from 2008 include the 2008 slope survey. Crosses indicate no catch of Alaska skate at that station.

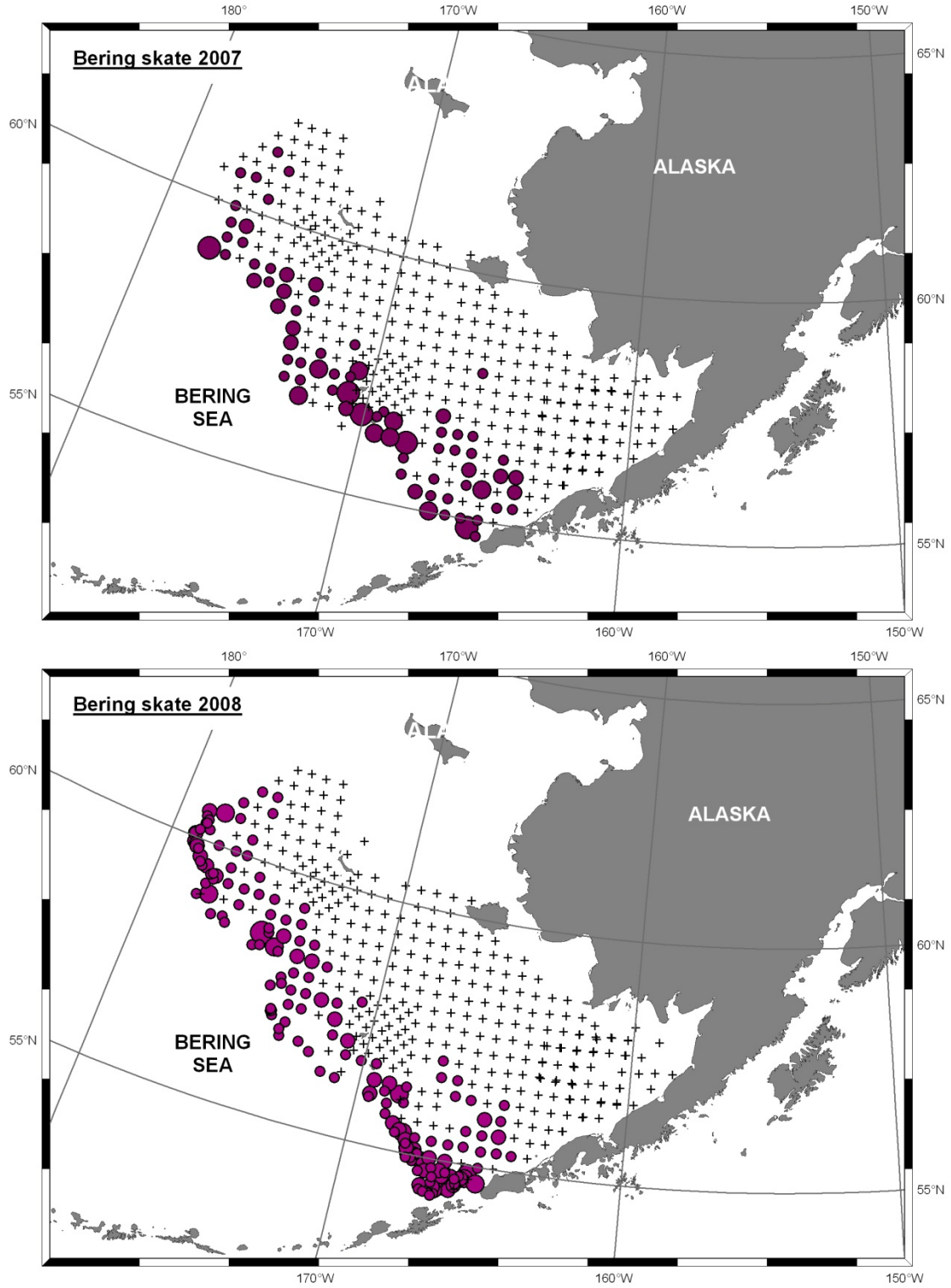



Figure 7. AFSC bottom trawl survey catches of Bering skate in 2007 & 2008. Symbol size is proportional to total catch at each survey station. Data from 2008 include the 2008 slope survey. Crosses indicate no catch of Bering skate at that station.

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

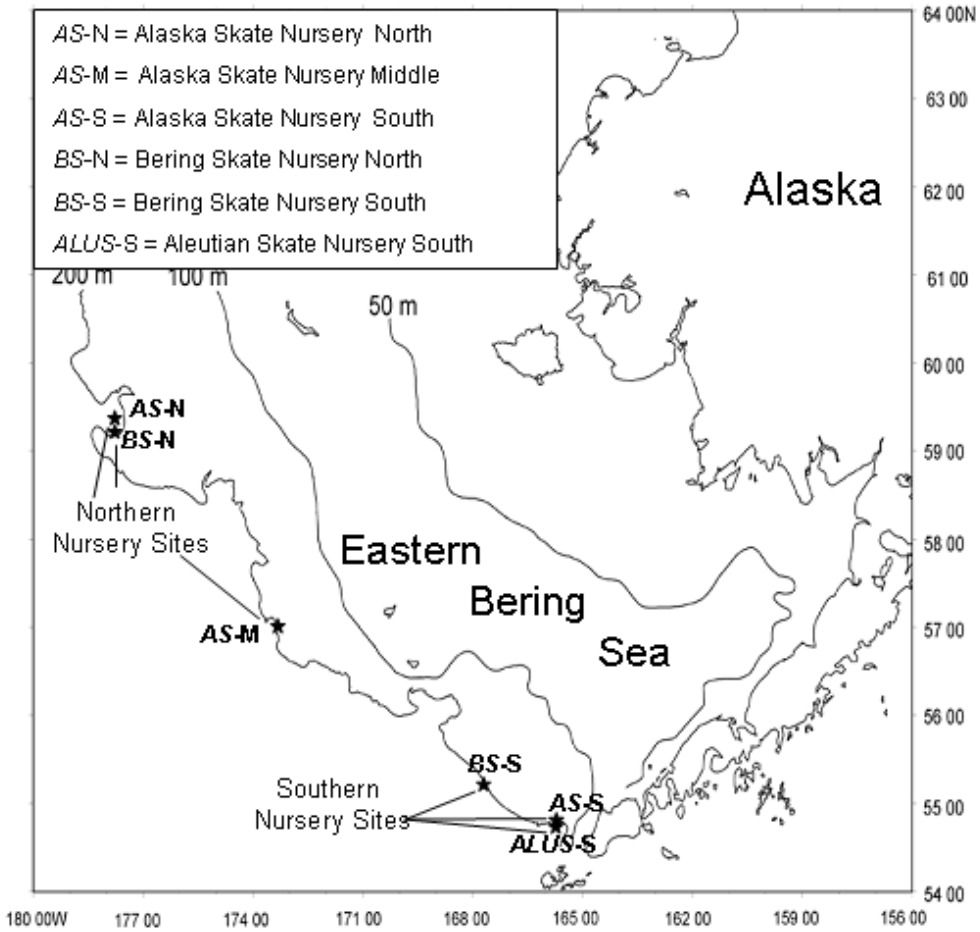



Figure 9. Map of the eastern Bering Sea with the six known skate nursery site locations and designations as a northern or southern nursery site. (See the legend for nursery site designation.) Source: Gerald Hoff, AFSC, unpublished data.

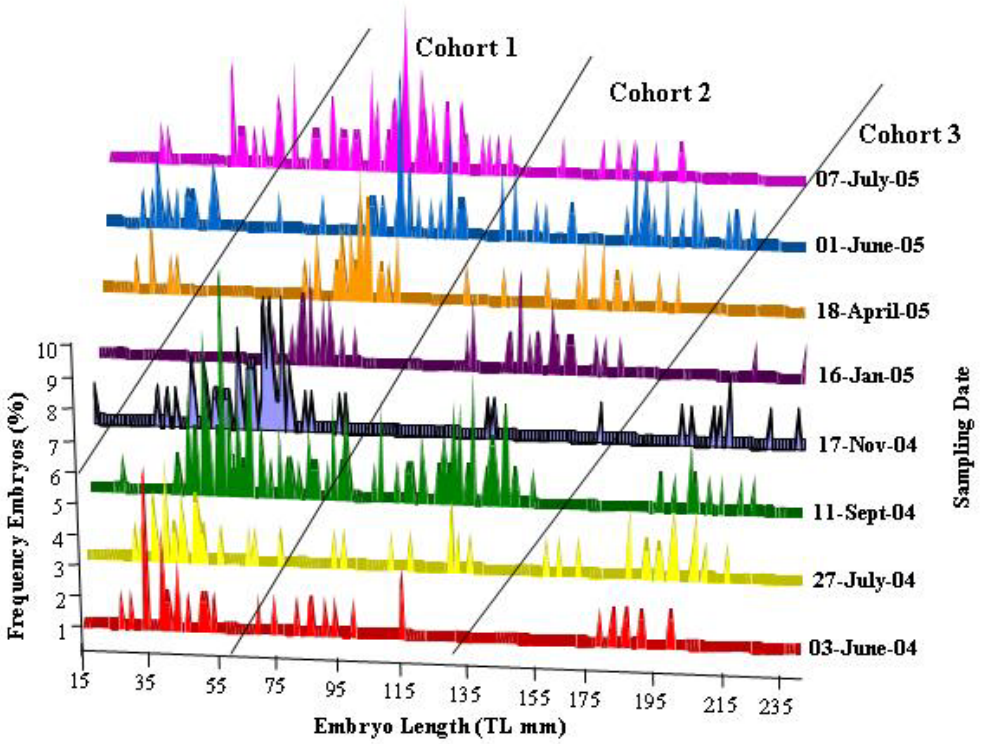



Figure 10. Embryo length composition data used in a cohort analysis of embryo development time. Figure is from G. Hoff (pers. comm.).

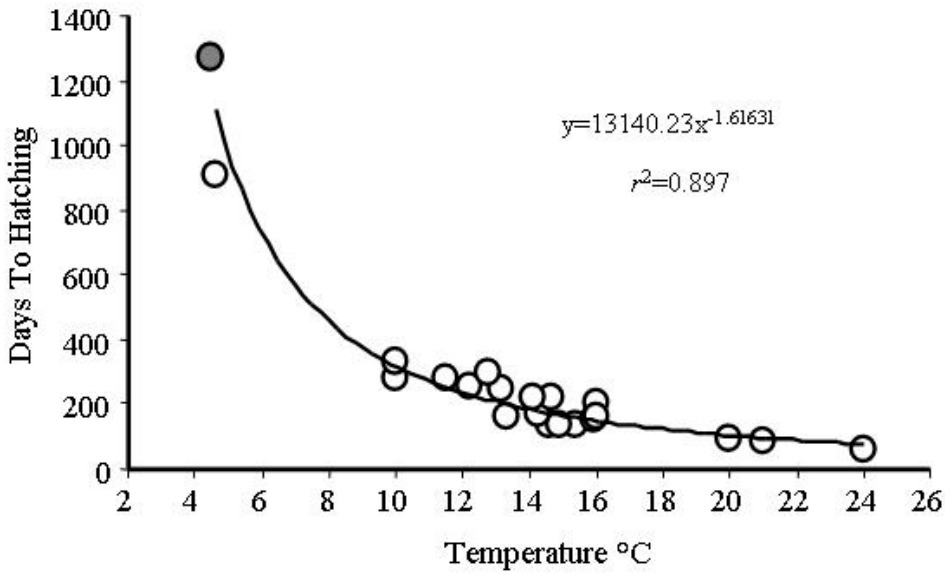



Figure 11. Ocean temperature versus embryo development time for 21 skate species. Dark grey circle is the Alaska skate. Equation and $R^2$ are the values of the fitted relationship. Figure is from G. Hoff, AFSC, pers. comm.

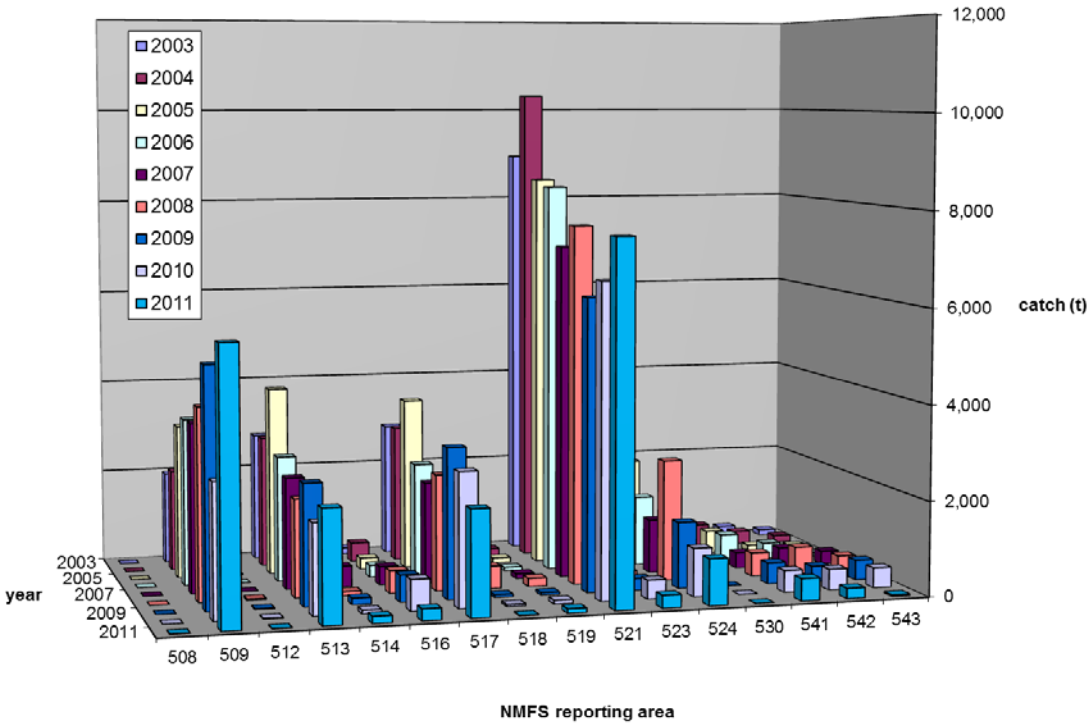



Figure 12. Total skate catch (all species combined) by FMP reporting area for both the EBS and the AI, 2003-2011. Source: AKRO CAS. 2011 data incomplete; reported as of November 3, 2011.

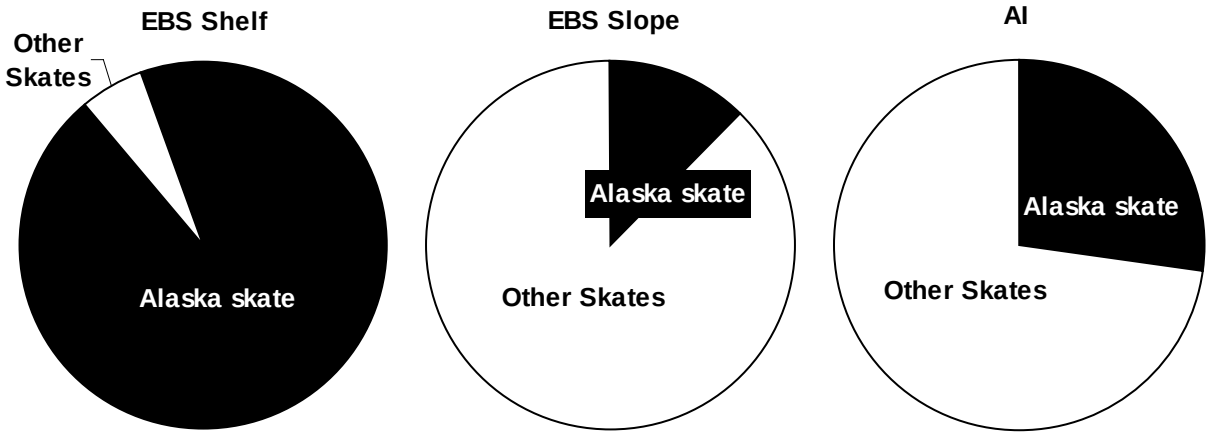



Figure 13. Relative proportion of Alaska skates and Other Skates in each habitat area. Graphs represent weighted averages from 1999-2011 trawl survey biomass estimates. These data were used to reconstruct catch data for the Alaska skate for use in the assessment model.

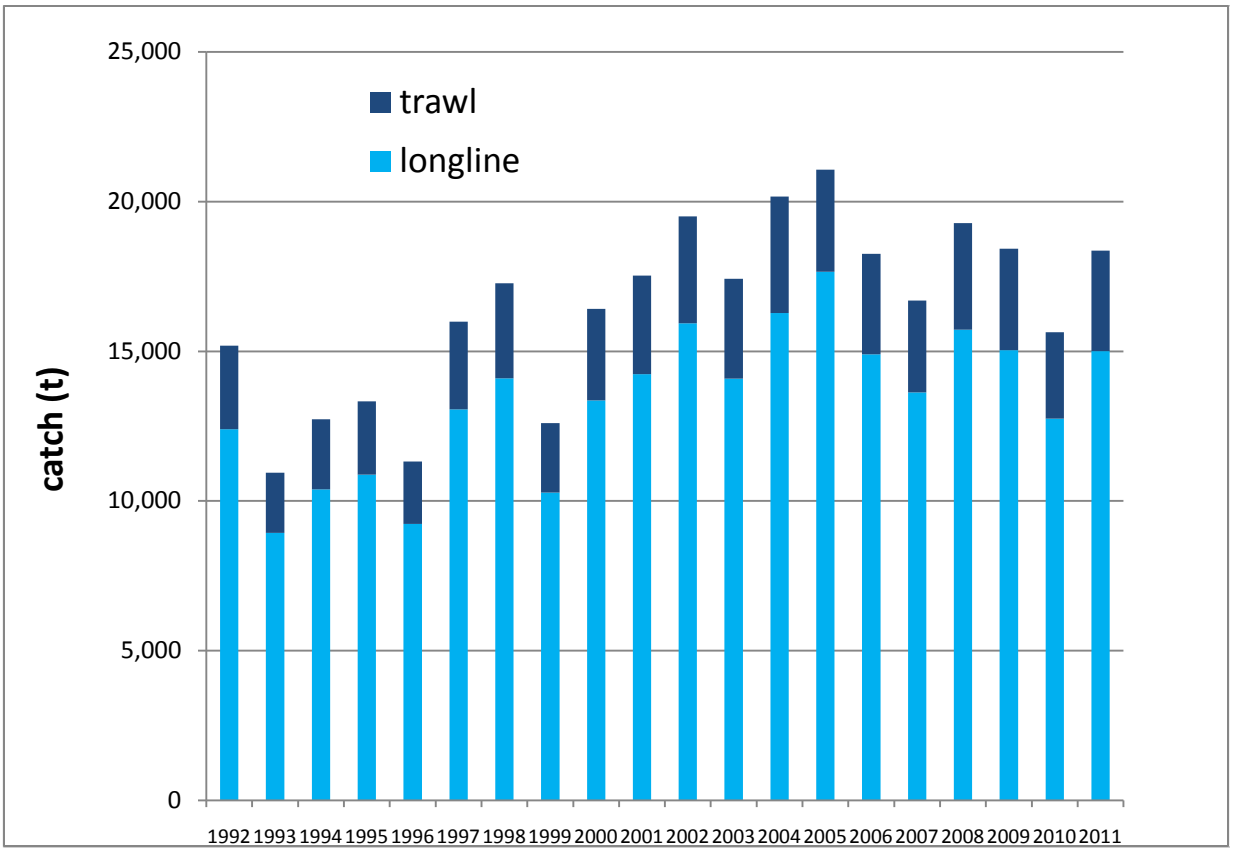
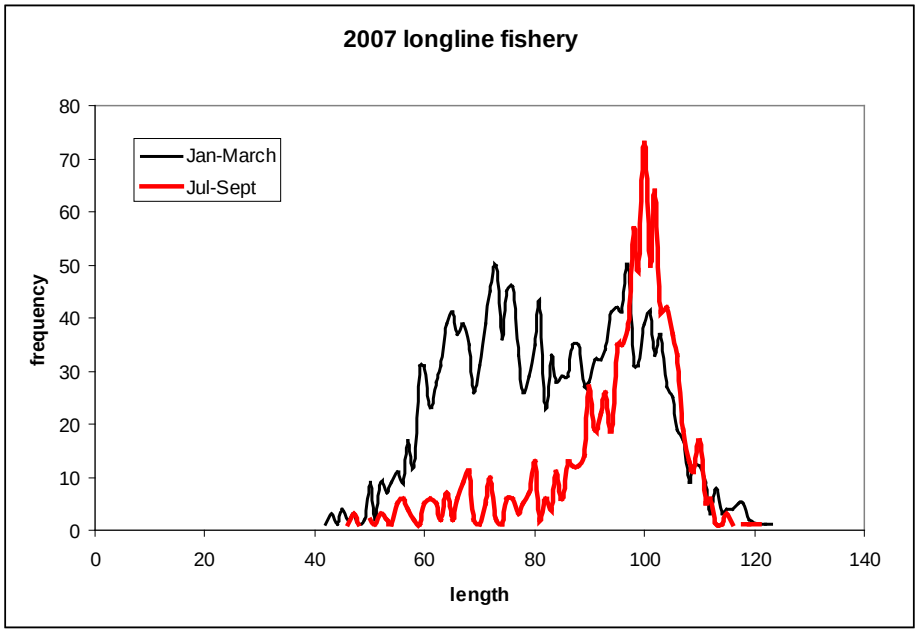



Figure 14. Estimated catch of Alaska skates (t) in the BSAI used in the model, 1992 to 2011. Data were obtained from the Blend system and AKRO CAS. 2011 catch is as reported through November 3, 2011.



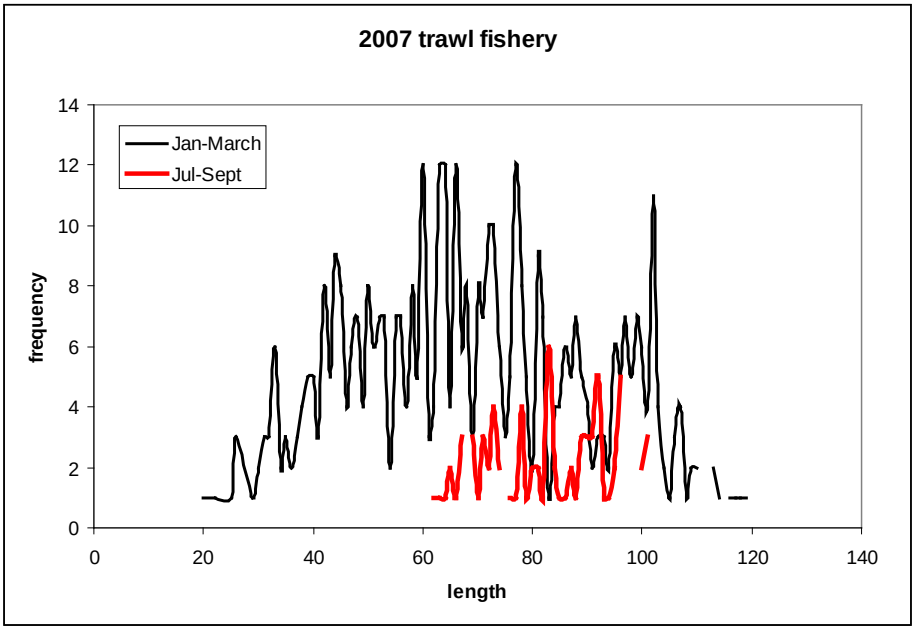




Fig. 15. Fishery length compositions by quarter (unbinned data) for Alaska skates during 2007.

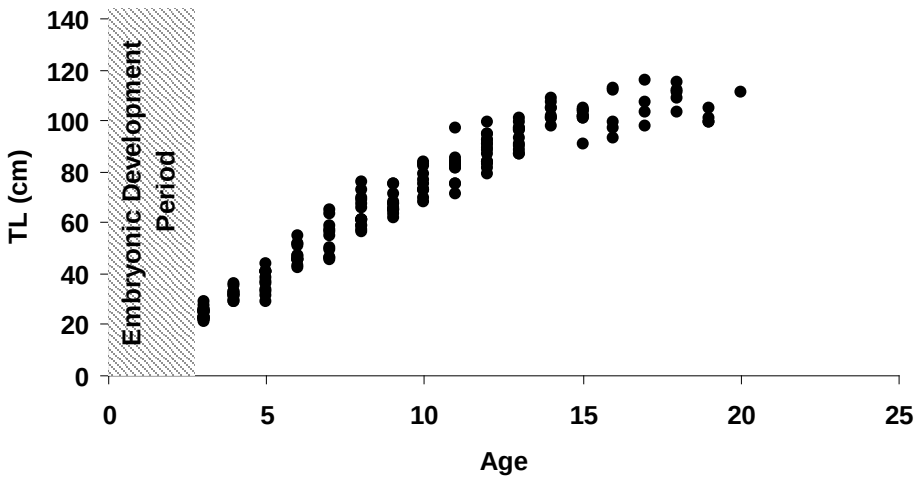



Figure 16. Observed size at age data from Alaska skates collected in the 2003 EBS shelf trawl survey, sexes combined (n=182). The three year embryonic development period included in the base model is represented by the shaded area.

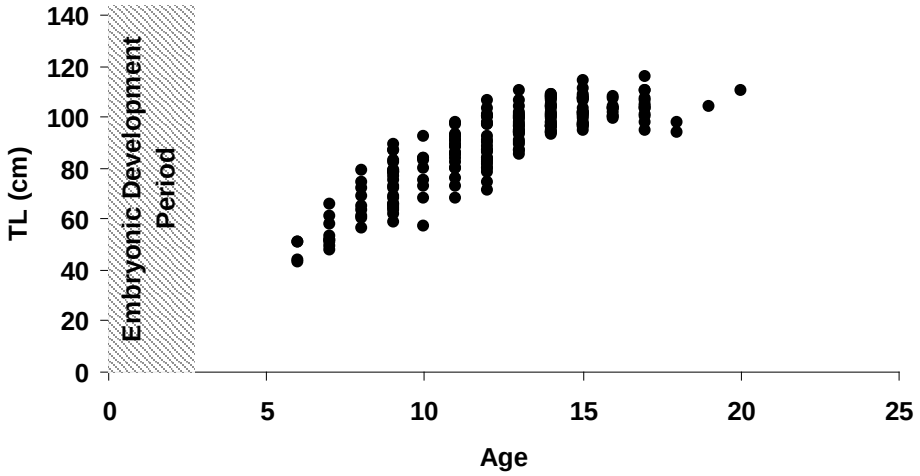



Figure 17. Observed size at age data from Alaska skates collected in the 2005 longline fishery, sexes combined (n=208). The three year embryonic development period included in the base model is represented by the shaded area.

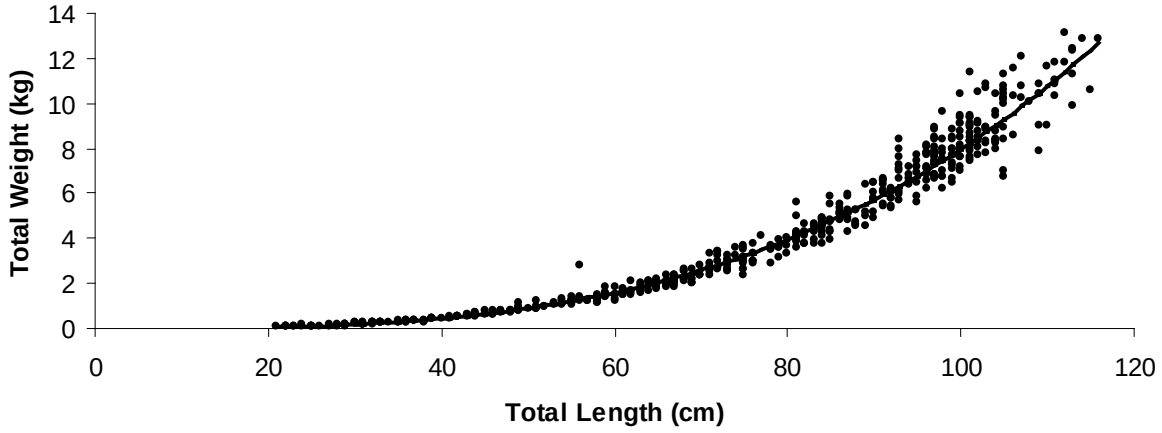



Figure 18. The relationship between total length (TL) and total body weight (W) for the Alaska skate, both sexes combined (n=526).

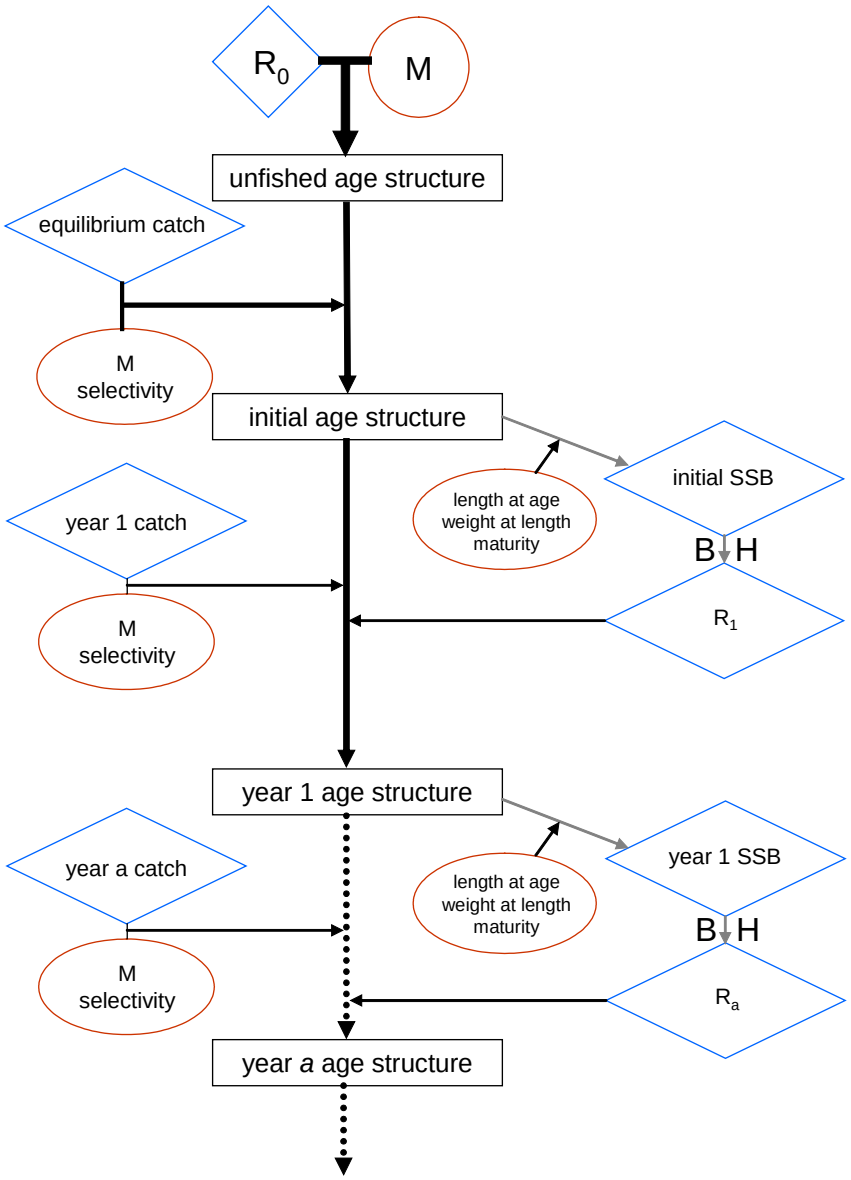



Figure 19. Simplified schematic depiction of population dynamics model used in the Alaska skate assessment. Blue diamonds indicate physical quantities, red circles indicate rates. $R_a$ = recruitment in year a, M = natural mortality, SSB = spawning biomass, BH indicates that a Beverton-Holt stock-recruit relationship is applied to SSB to estimate recruitment.

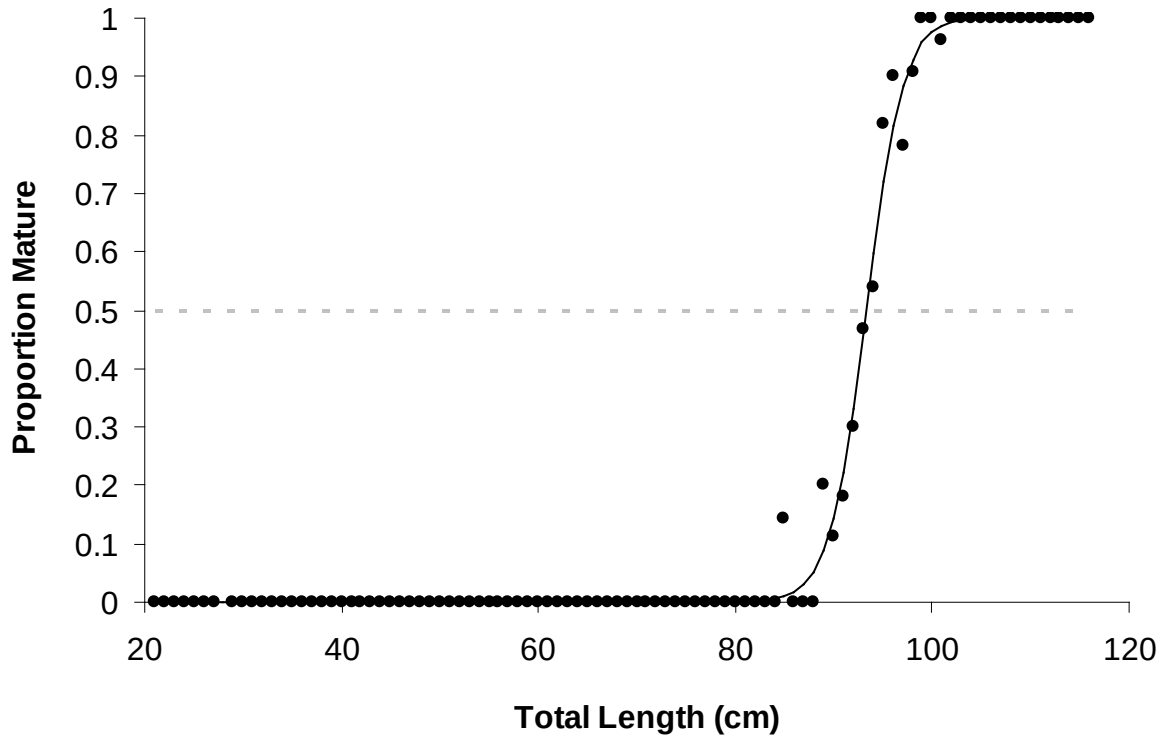



Figure 20. Female Alaska skate maturity-at-length data shown with fitted logistic curve from Matta (2006) (n=642).

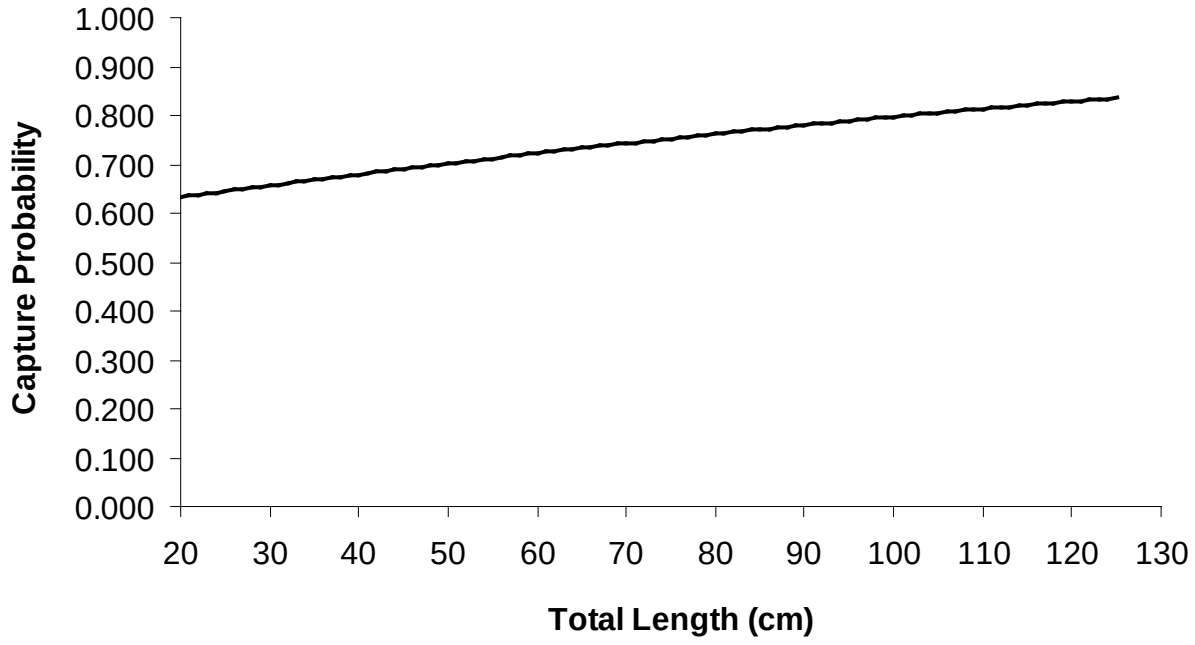



Figure 21. Length-based capture probability for skates (*Bathyraja* spp.) in the EBS shelf bottom trawl survey, based on data from Kotwicki and Weinberg (2005).

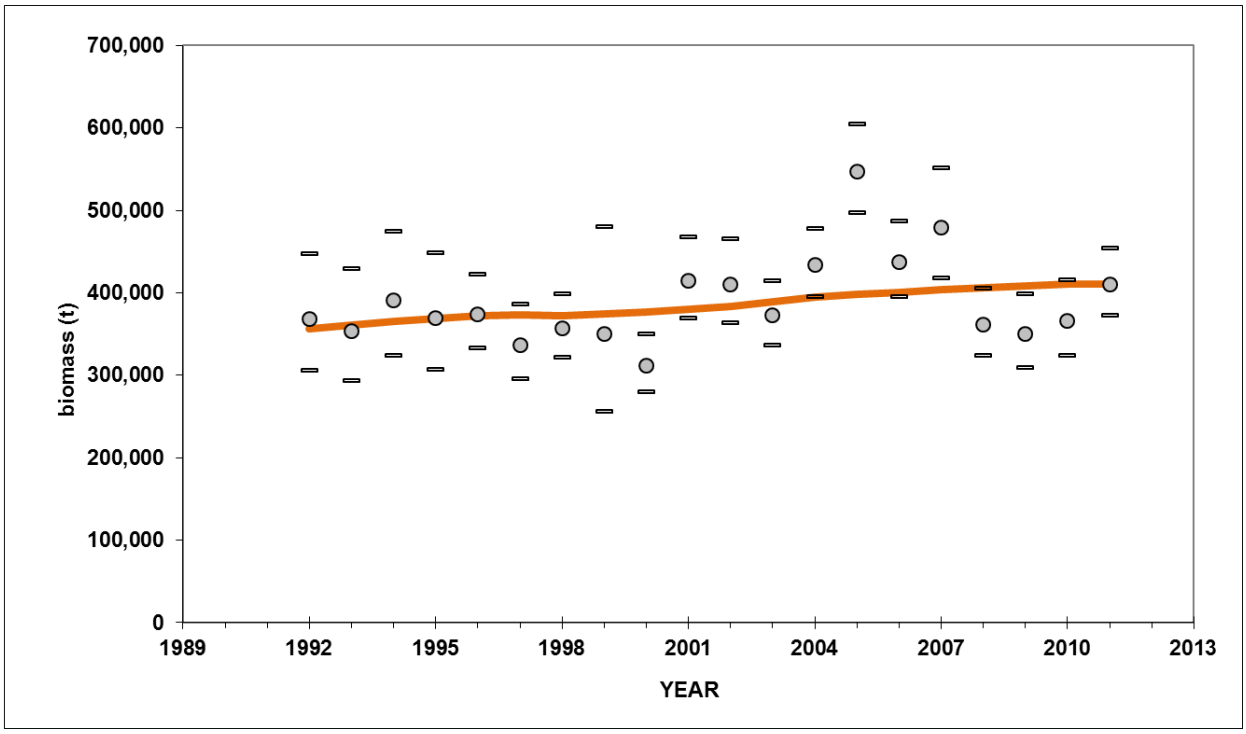



Figure 22. Observed biomass (circles) from EBS shelf surveys 1992-2011, with approximate confidence intervals (± 2 SE), and predicted survey biomass from the model (orange line).

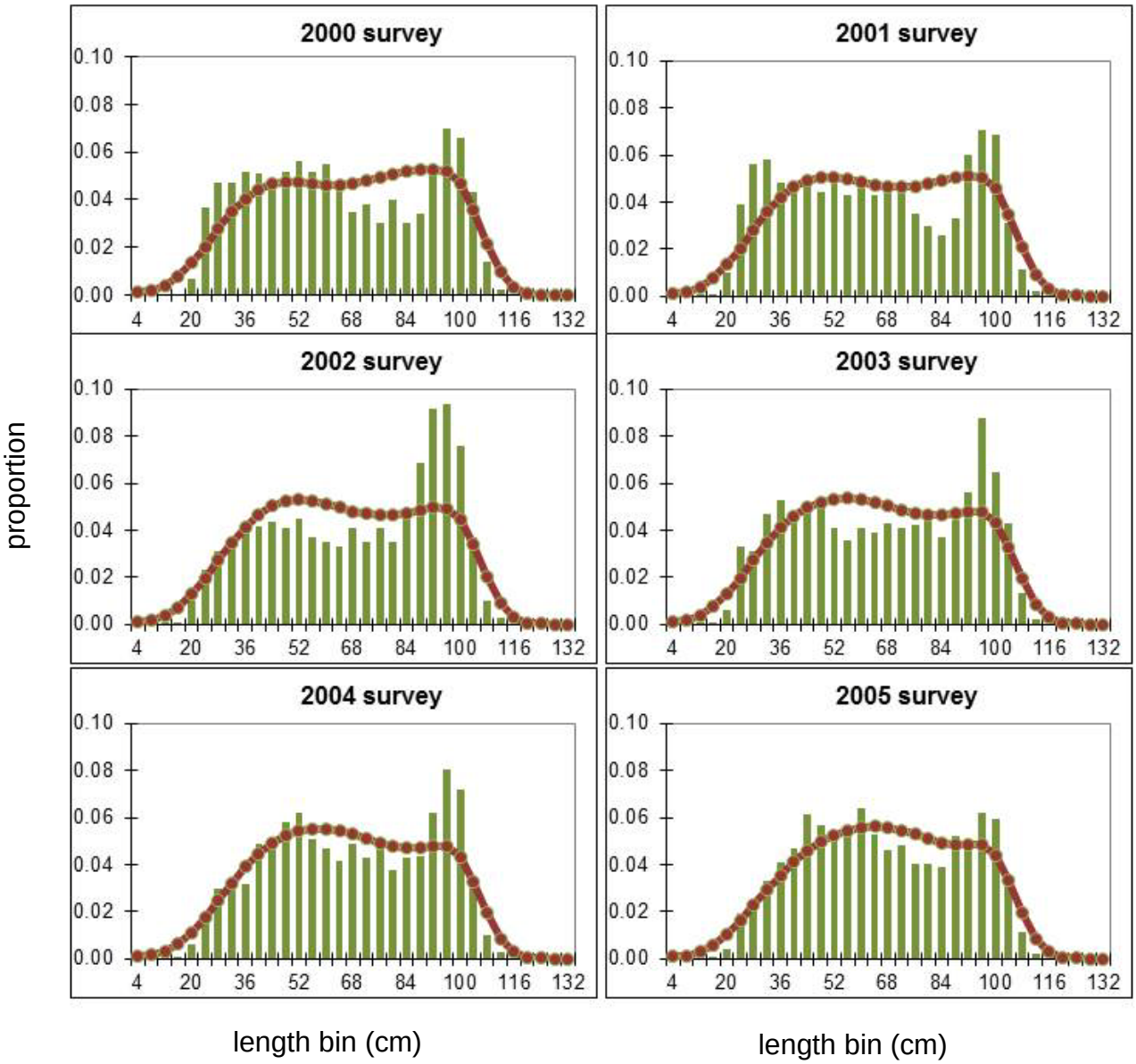



Figure 23. EBS shelf survey length compositions from 2000-2011. Green bars = observed proportions; orange line with circles = model predictions.

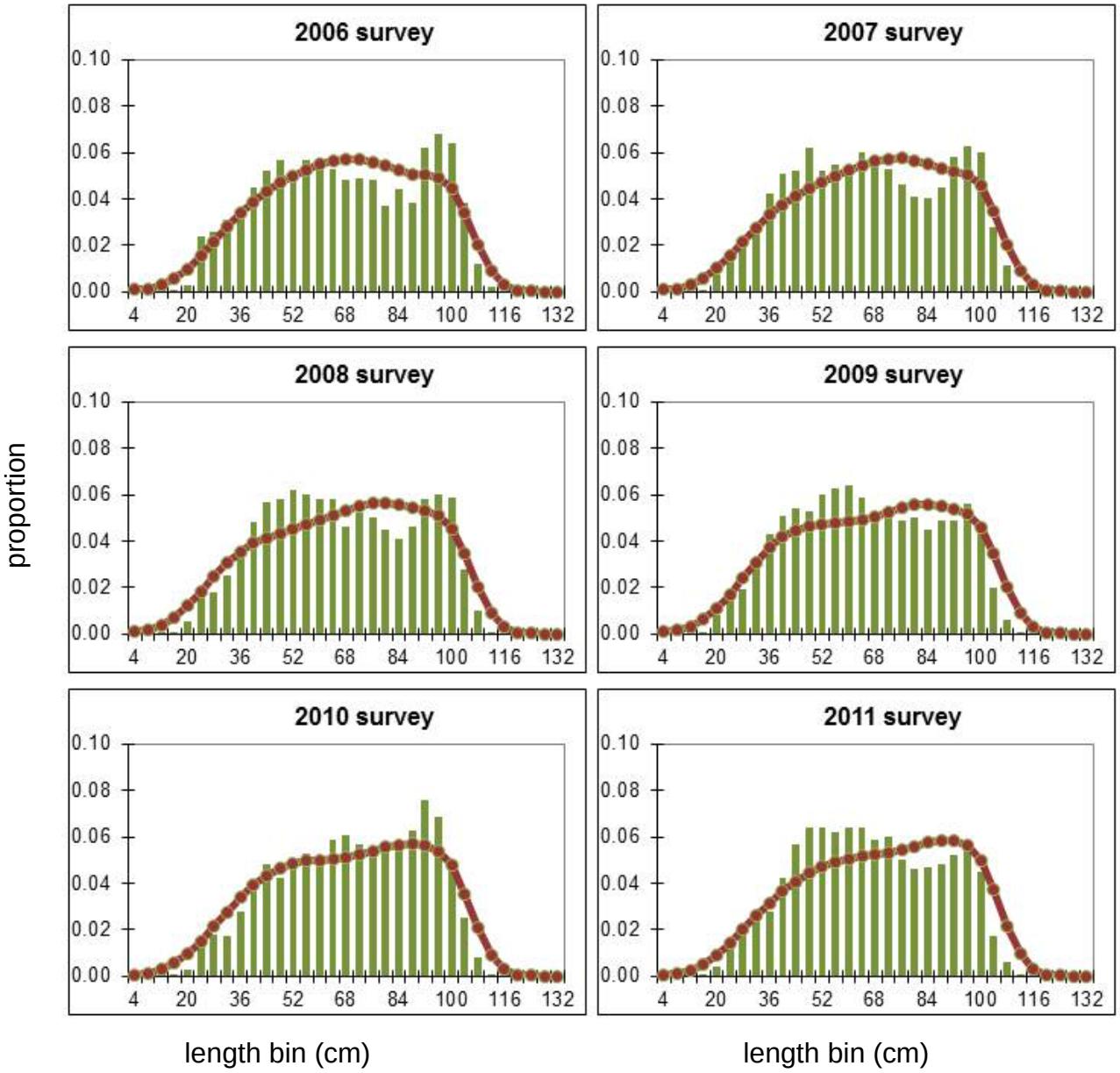



Figure 23 continued. EBS shelf survey length compositions from 2000-2011. Green bars = observed proportions; orange line with circles = model predictions.

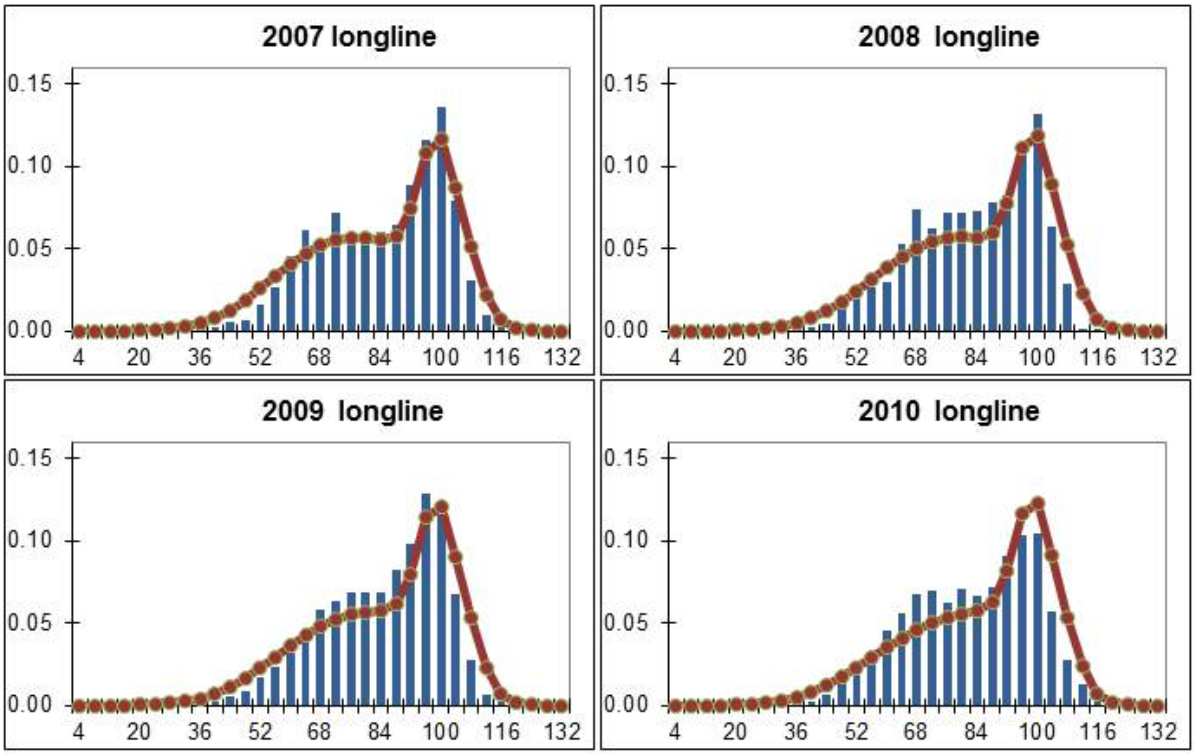



Figure 24a. Observed and model-predicted length compositions from the 2007-2010 longline fisheries, with model predictions. Blue bars = observed values, orange line with circles = predicted values

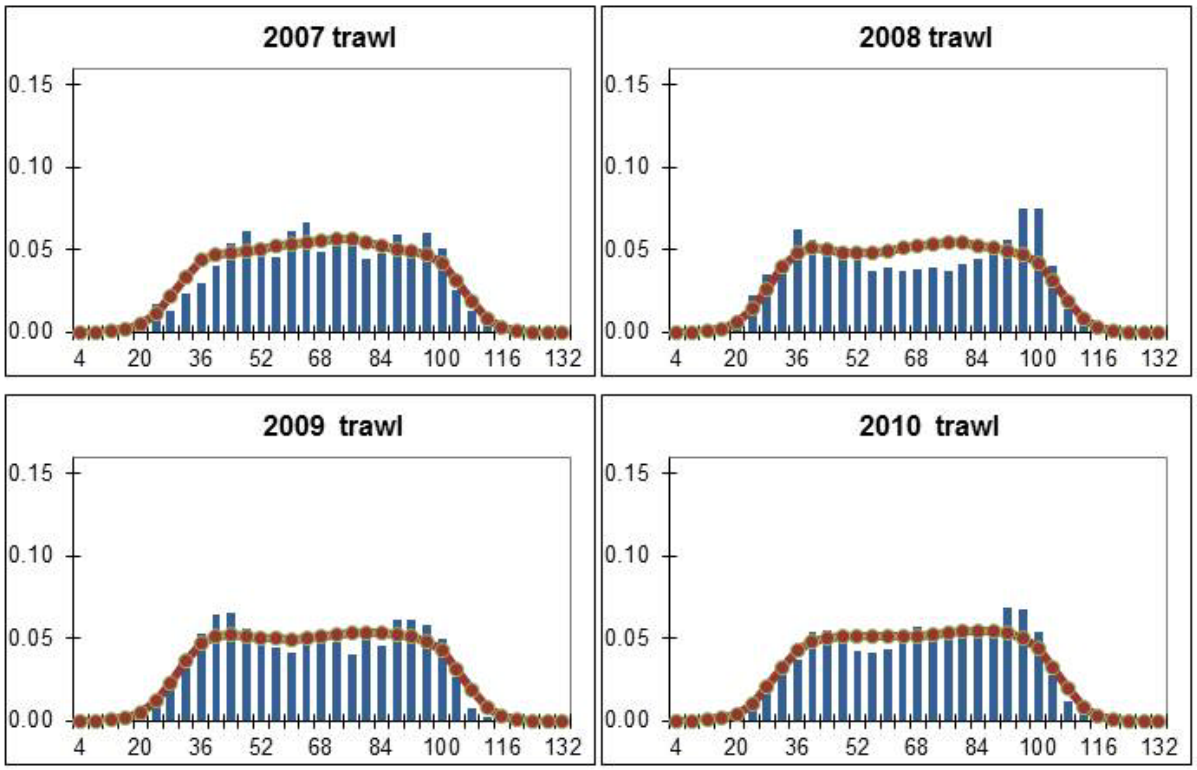
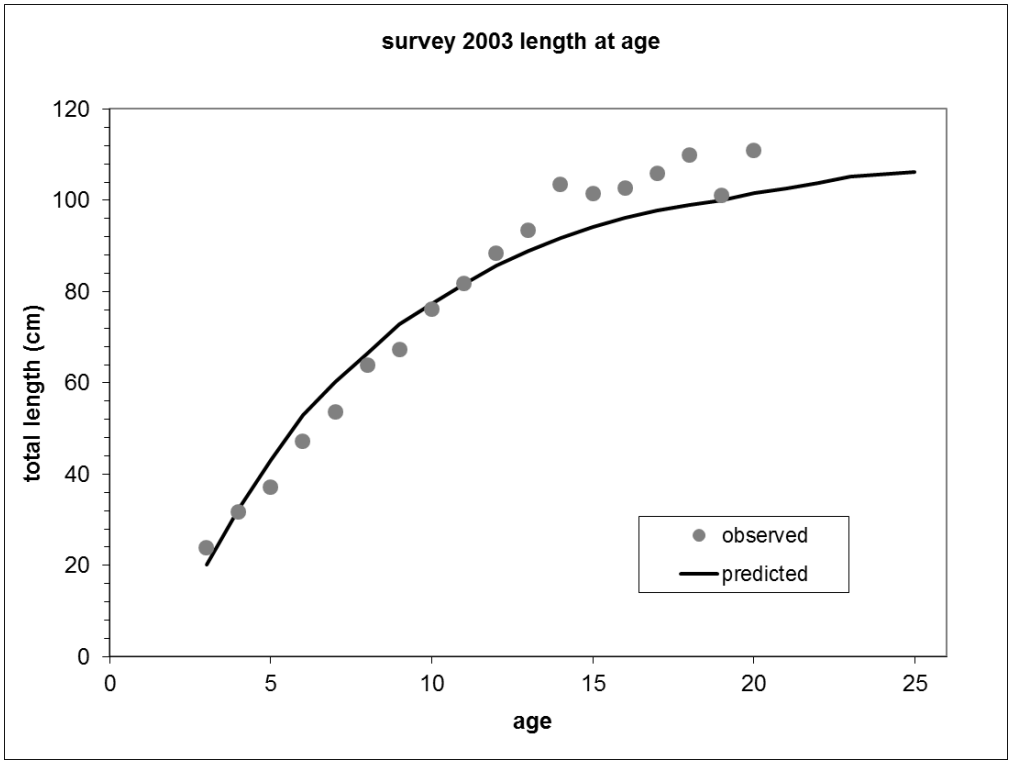



Figure 24b. Observed and model-predicted length compositions from the 2007-2009 trawl fisheries, with model predictions. . Blue bars = observed values, orange line with circles = predicted values.



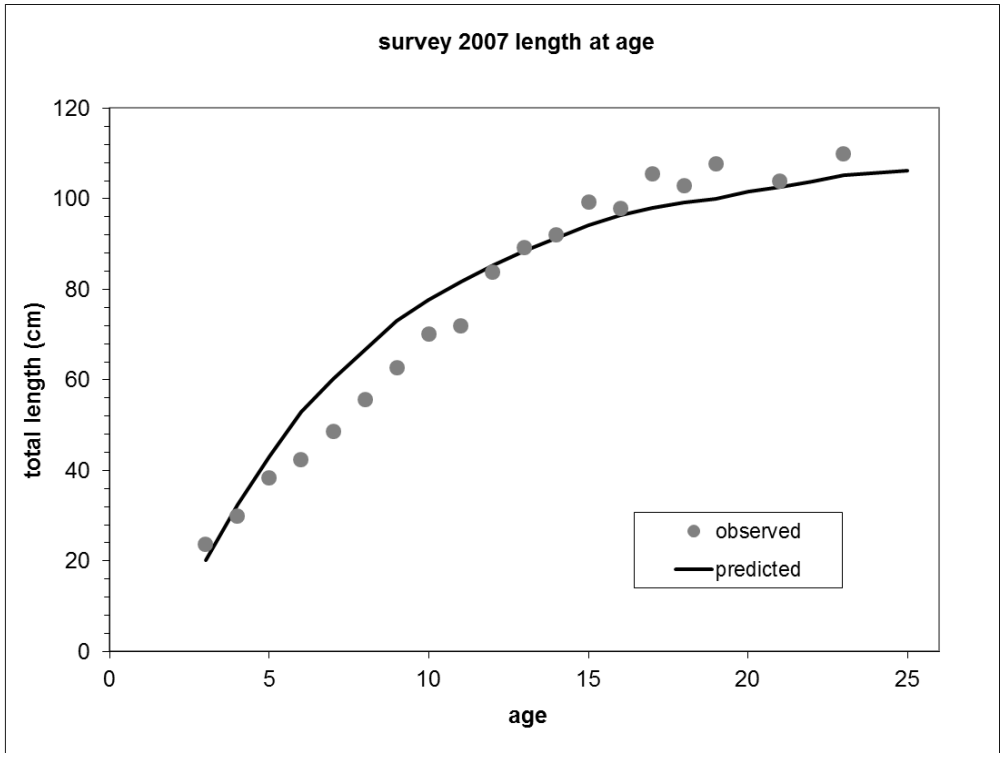




Figure 25. Observed and model-predicted length-at-age from the 2003 (upper panel) and 2007 (lower panel EBS shelf survey.

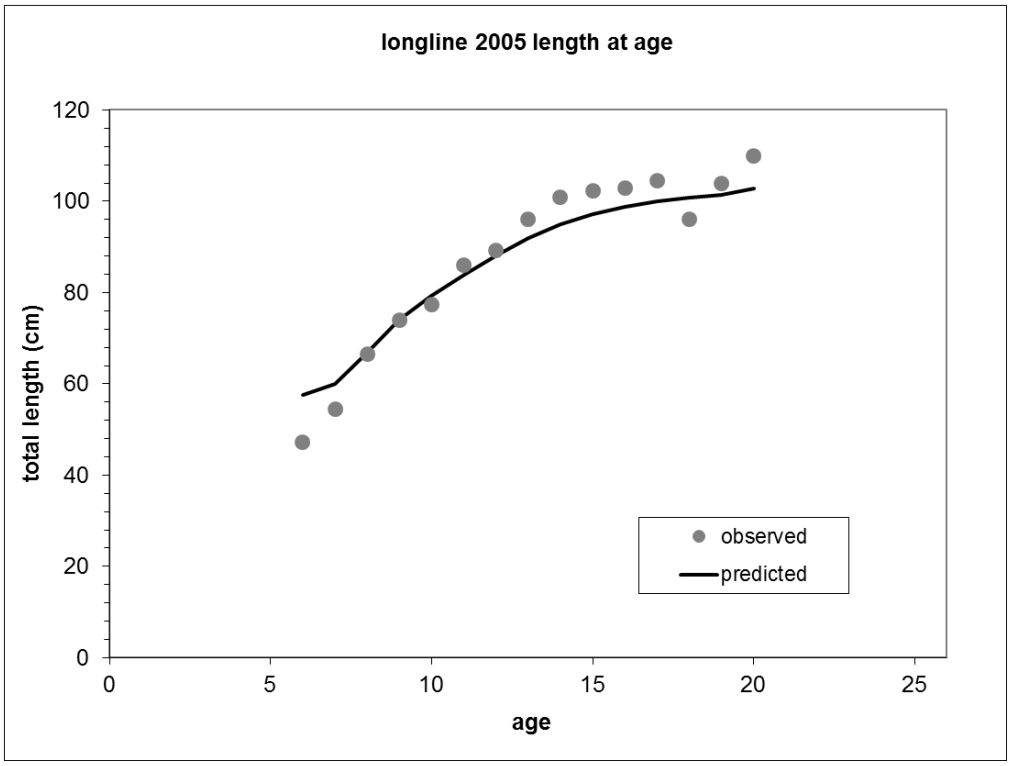



Figure 26. Observed and model-predicted length-at-age from the 2005 longline fishery.

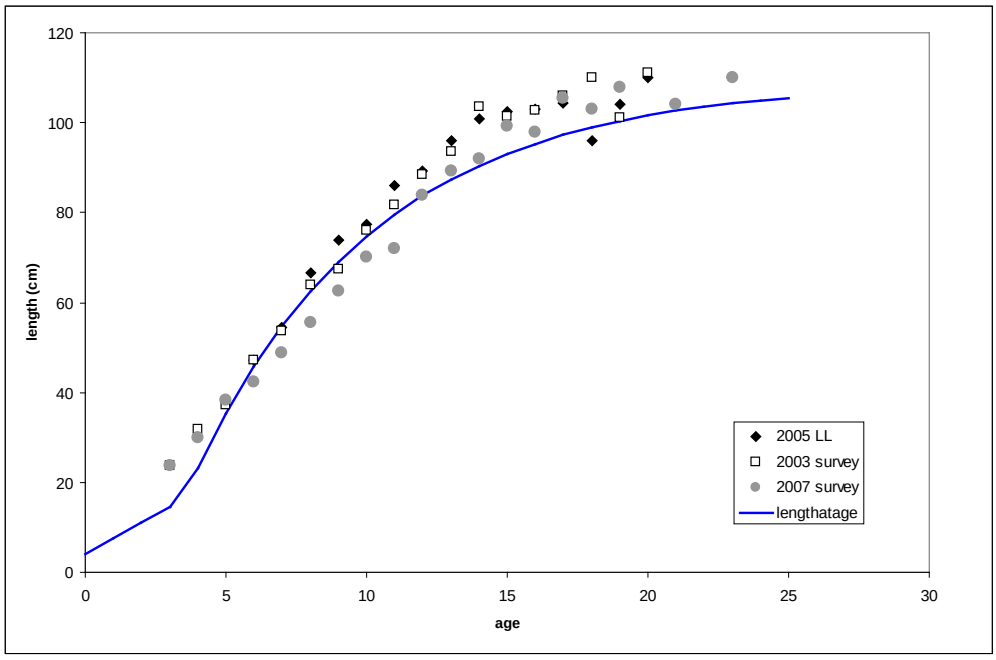



Figure 27. Observed length-at-age from the three datasets used in the model, with the population estimate of length-at-age (blue line) superimposed.

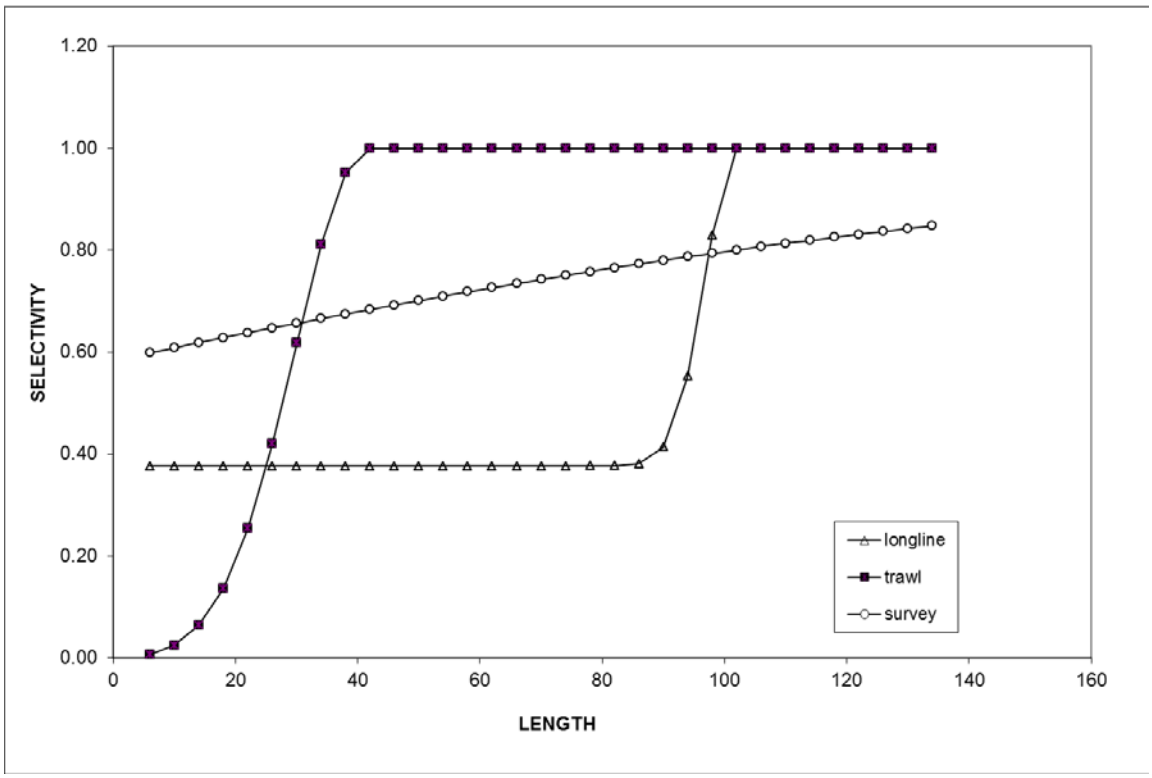



Figure 28. Length selectivities of the longline fishery, trawl fishery, and EBS shelf trawl survey.

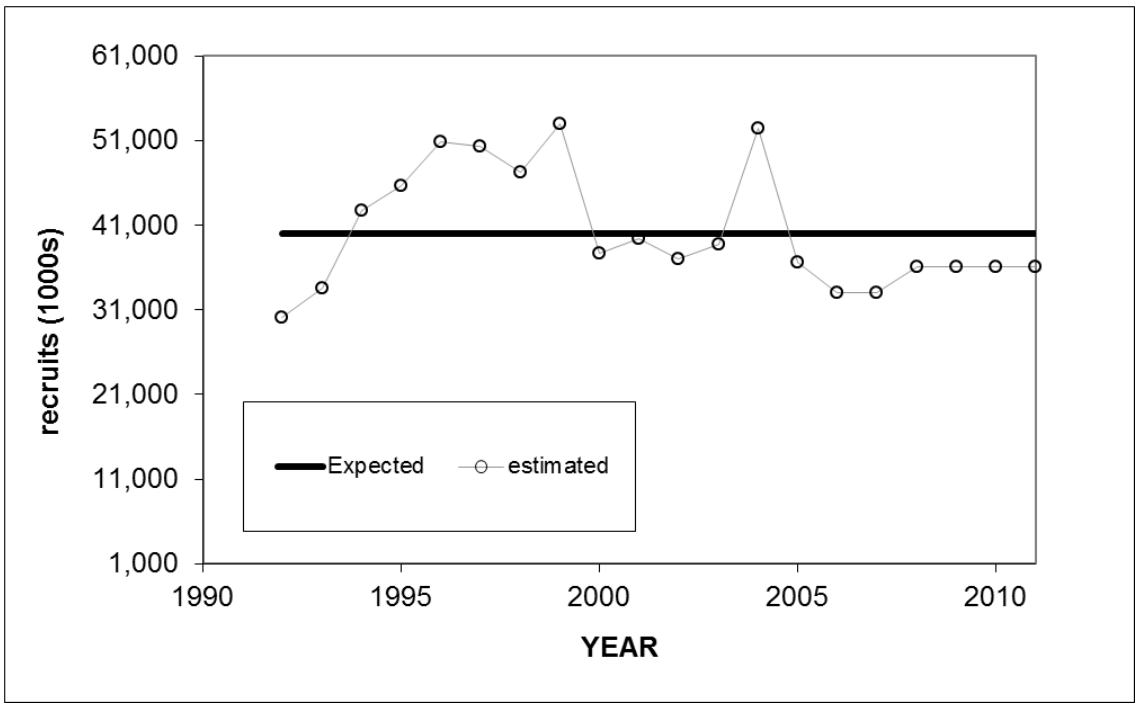



Figure 29. Time series of expected recruitment (in thousands of age 0 fish), with the time series of individual year class estimates predicted by the model and the expected Beverton-Holt stock-recruit relationship with a steepness of 1.0.

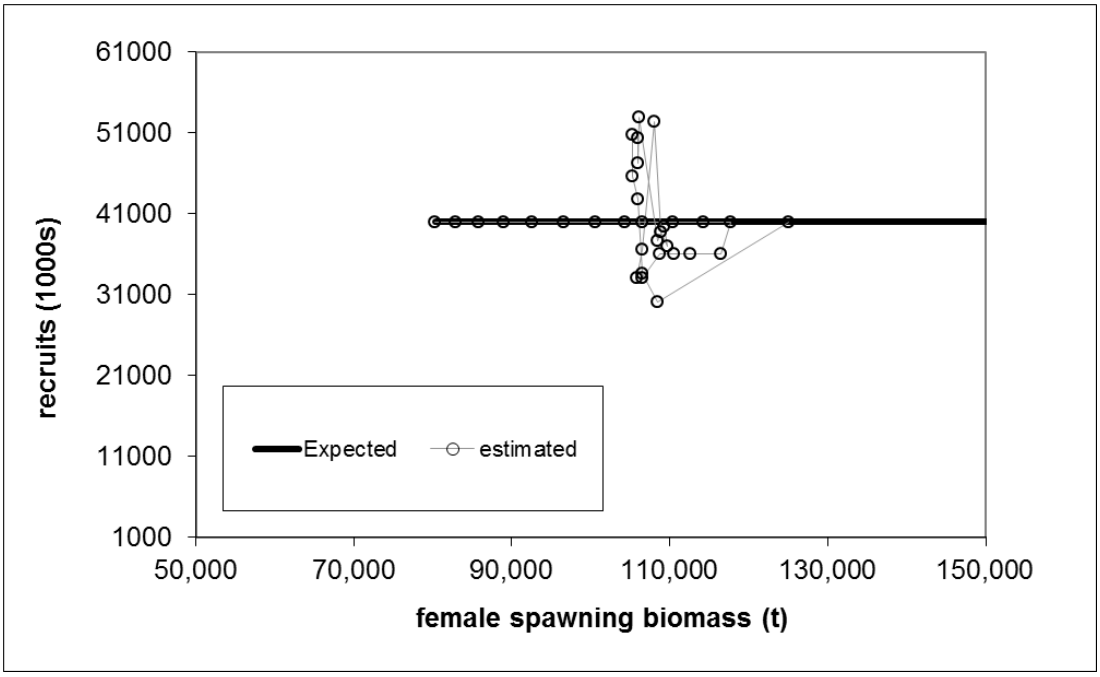



Figure 30. Relationship between female spawning biomass (t) and the number of age 0 recruits (in thousands of fish). Time series of individual year class estimates from SS2 is shown with a Beverton-Holt stock-recruit relationship with a steepness of 1.0.

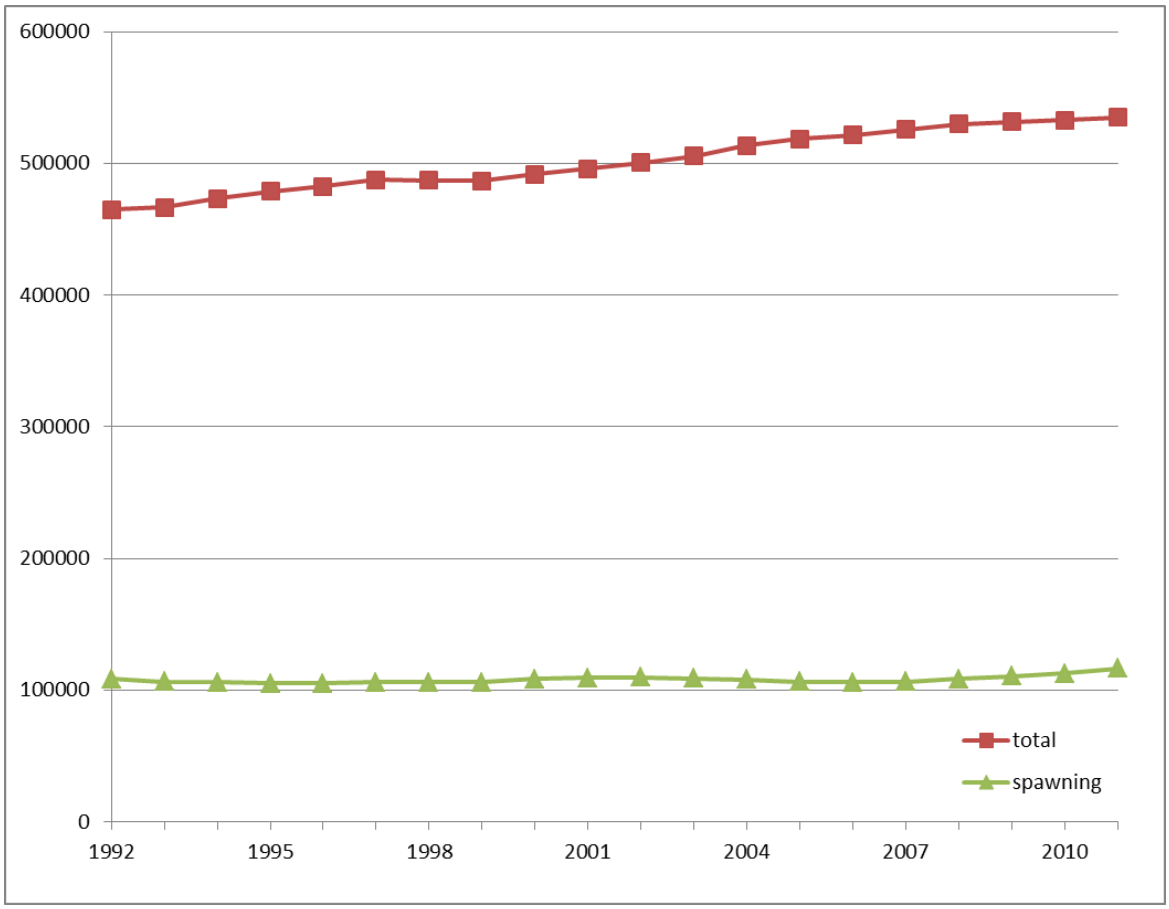



Figure 31. Time series of model estimates for total (age 0+) biomass (t) and female spawning biomass (t).

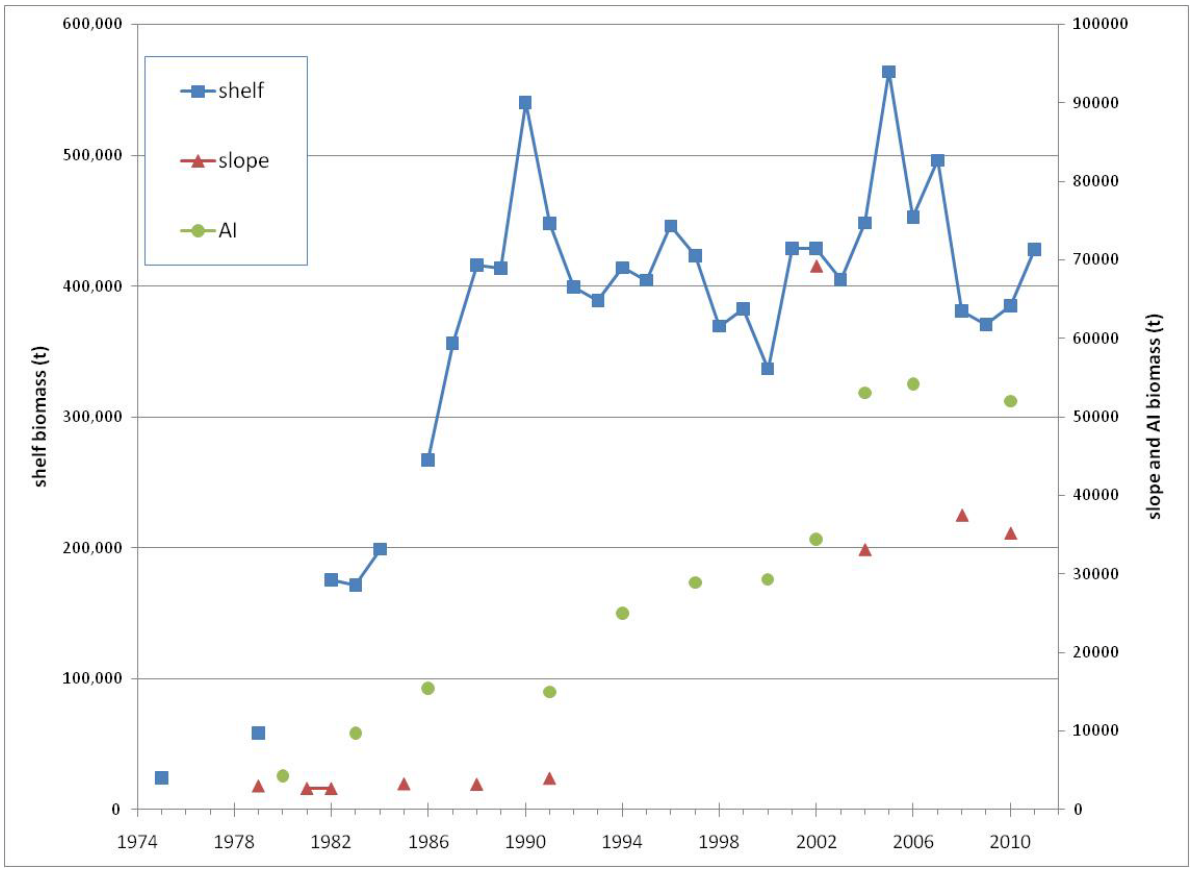



Figure 32. Aggregated skate biomass (metric tons) estimated from RACE bottom trawl surveys in each of the three major habitat areas (1975 – 2011). Note that slope and AI estimates are much smaller and pertain to the secondary y-axis.

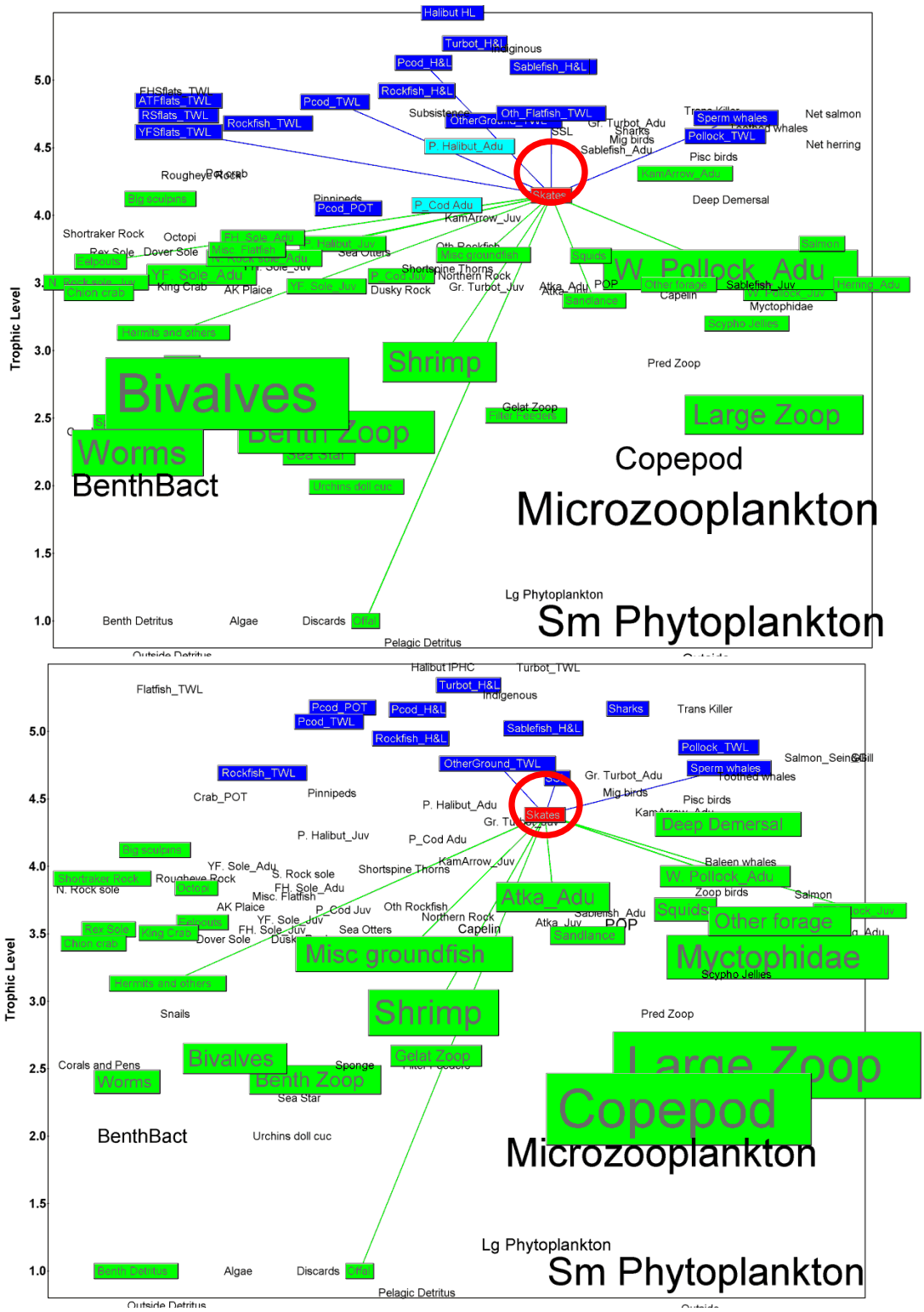



Figure 33. EBS (upper panel) and AI (lower panel) skate food webs derived from mass balance ecosystem models, with skate species aggregated in each area. (Source: K. Aydin, AFSC, code available upon request.)

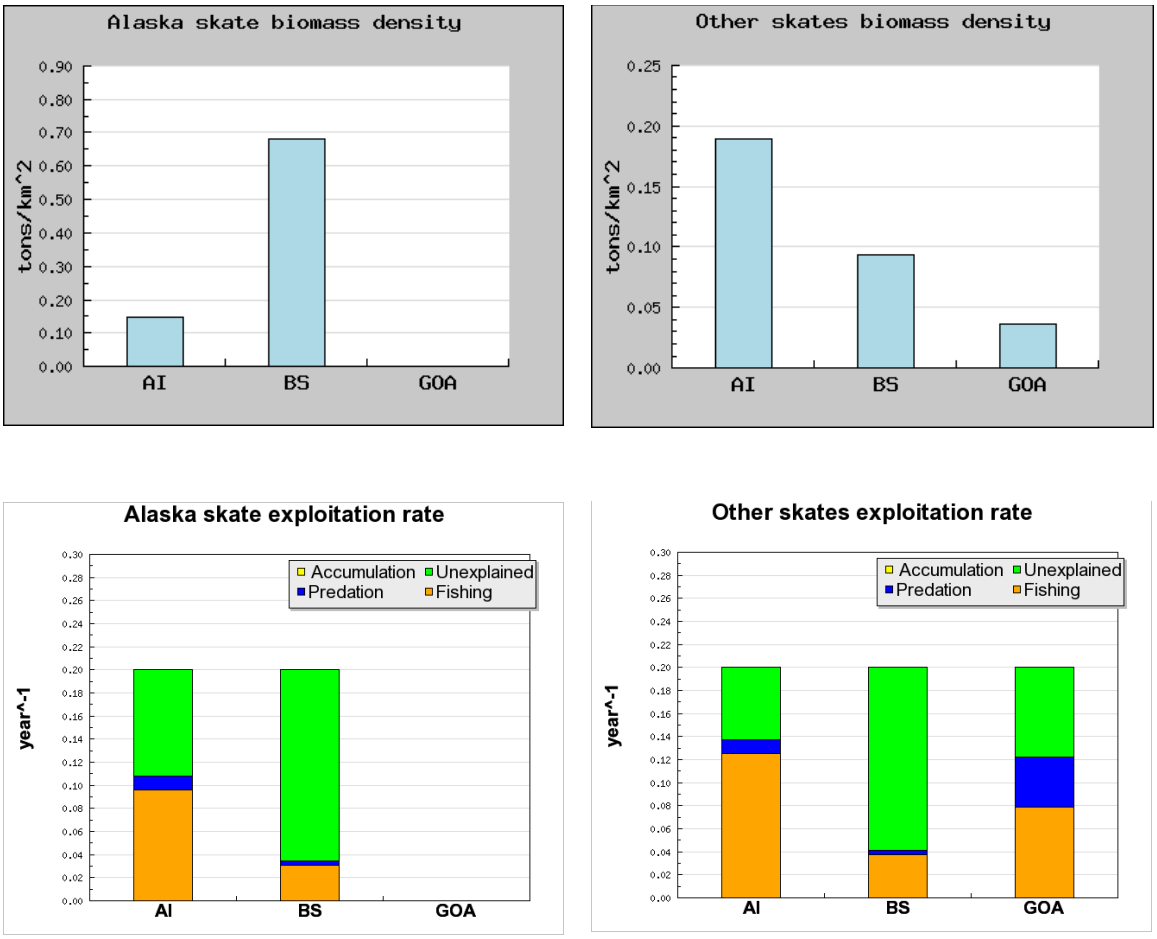



Figure 34. Comparative density (upper panels) and exploitation rate (lower panels) of Alaska (left panels) and all other *Bathyraja* (right panels) skates in the AI, EBS, and GOA (early 1990s, before fishery in GOA). (Alaska skates are a very small component of skate biomass in the GOA, and are therefore not modeled separately.) Note that the Other skates plot does not include the most common species in that region, the big skate and longnose skate—see the GOA skate SAFE for information on those skates. Biomass density plots are from trawl survey data; exploitation rate plots are derived from catch and biomass estimates and from assumed estimates of skate productivity (approximated from Frisk et al. 2001).

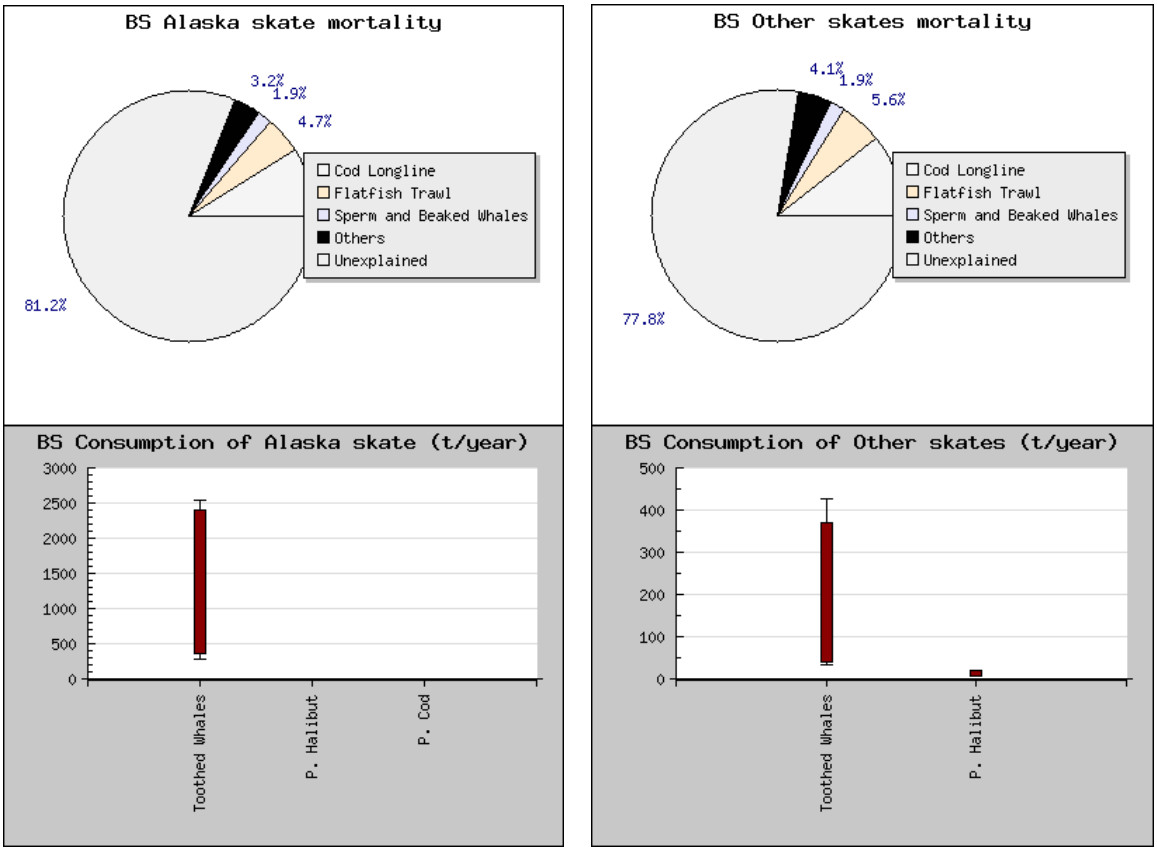



Figure 35. Mortality sources and consumption of skates in the EBS—mortality pie (upper panels) and estimates of annual consumption by predators (lower panels) for EBS Alaska skates (left panels) and all other EBS skates (right panels). Model outputs were derived from diet compositions, production rates, and consumption rates of skate predators, and from skate catch data.

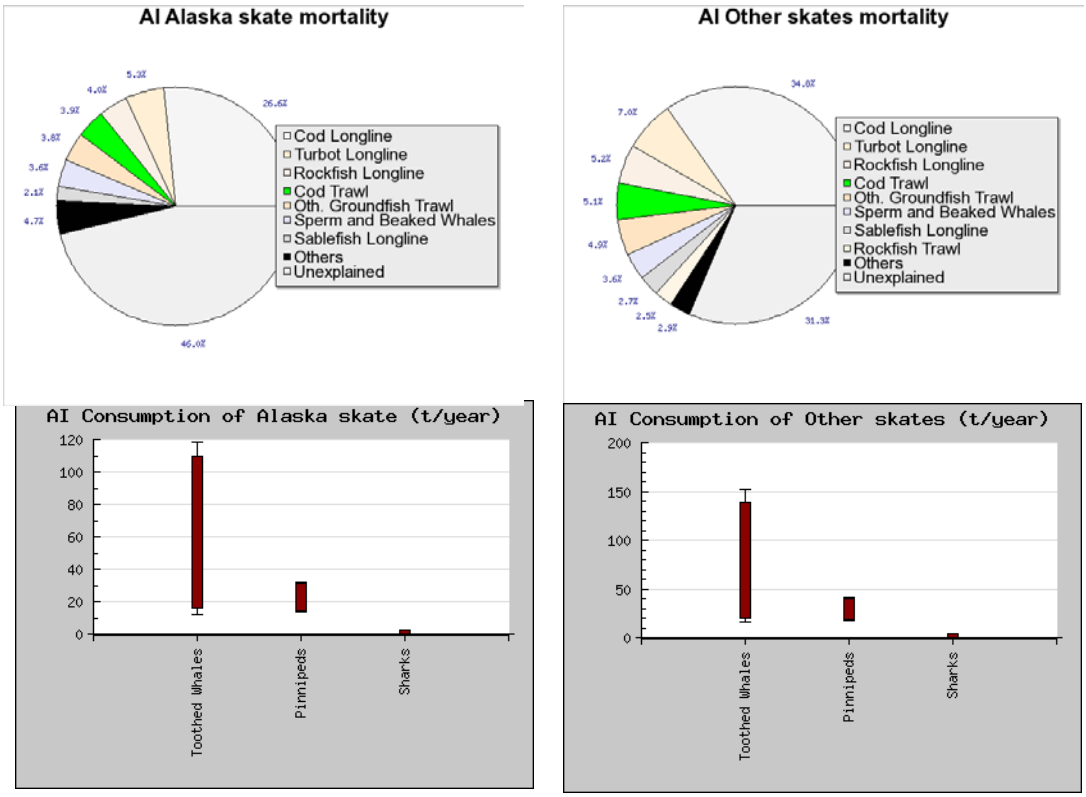



Figure 36. Mortality sources and consumption of skates in the AI—mortality pie (upper panels) and estimates of annual consumption by predators (lower panels) for AI (former) Alaska skate (left panels) and AI Other Skates (right panels). Model outputs were derived from diet compositions, production rates, and consumption rates of skate predators, and from skate catch data.

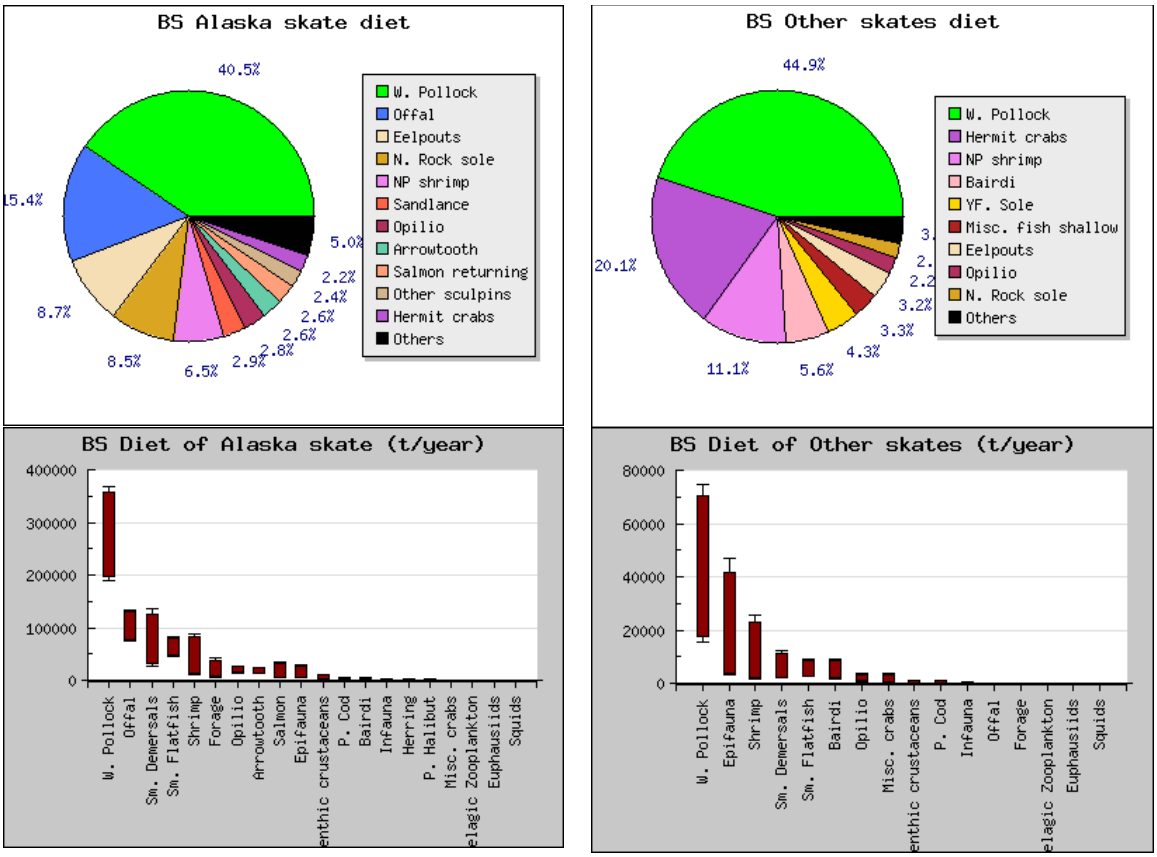



Figure 37. Diet composition (upper panels) and annual estimated prey consumption by skates (lower panels) for EBS Alaska skates (left panels) and Other Skates (right panels). Results were generated from stomach content collections occurring during RACE trawl surveys.

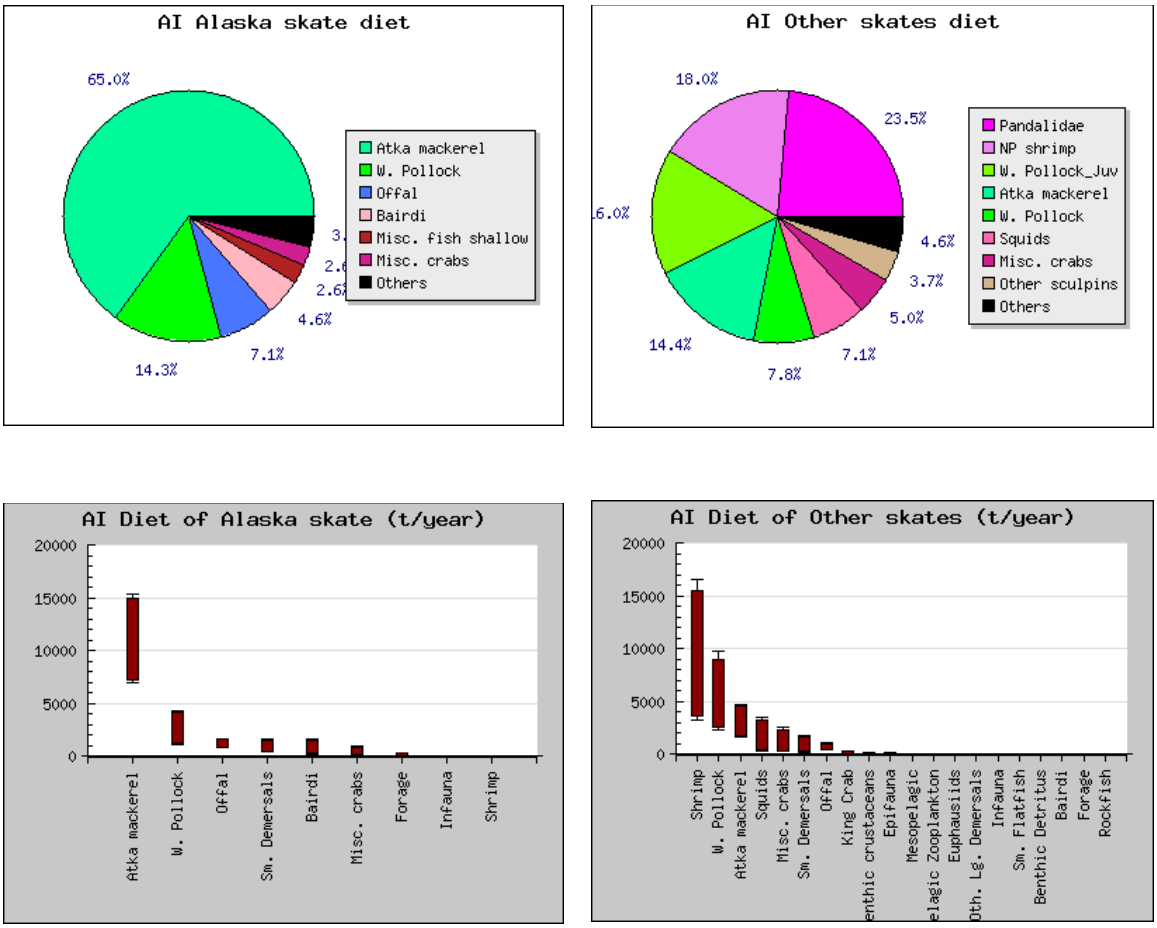
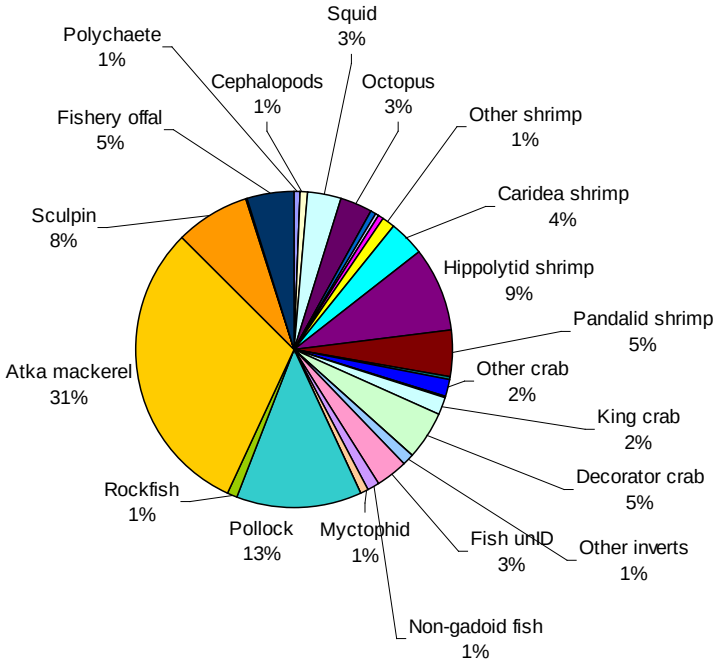



Figure 38. Diet composition (upper panels) and annual estimated prey consumption by skates (lower panels) for AI Alaska skates (left panels) and Other Skates (right panels). Consumption rates were estimated using published diet data from the Kuril Islands (Orlov 1998, 1999) and estimated prey densities.

**AI whiteblotched skate**
**(*Bathyraja maculata*)**
**Diet composition (n = 69 stomachs)**




**AI Aleutian skate**
**(*Bathyraja aleutica*)**
**Diet composition (n = 19 stomachs)**
**Skate**

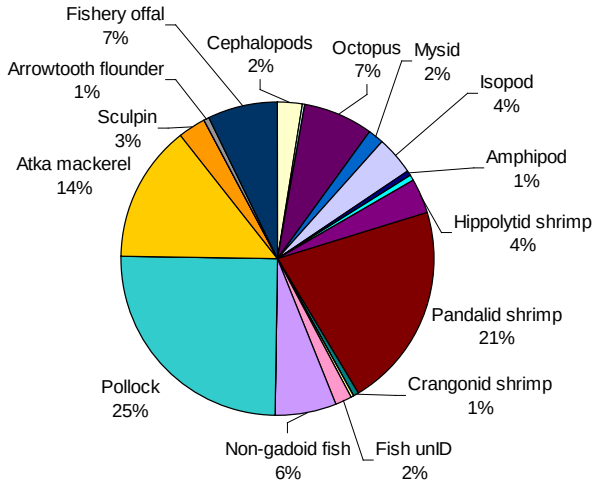



Figure 39. Diet composition (by weight) for the other two biomass-dominant skate species in the Aleutian Islands (which are included in the "Other Skates" group in the previous figure): whiteblotched skate (top) and Aleutian skate (bottom). Results were generated from stomach content collections occurring during trawl surveys, and are described in more detail in Yang (2007).

Appendix: Supplementary catch information

This section is provided to comply with the National Standard guidelines requirement for complete catch accounting. The information consists of three tables:

1) Total skate catches during research surveys conducted by the AFSC's Resource Assessment and Conservation Engineering (RACE) division
2) Total estimated research and sport fishery removals of skates in 2010
3) Estimated removals of skates in the IFQ halibut fishery

Table 1. Research and sport removals of BSAI skates in 2010.

| | total catch (kg) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2010 Aleutian Island Bottom Trawl Survey | 2010 Bering Sea Bottom Trawl Survey | 2010 Bering Sea Slope Survey | 2010 N Bering Sea Bottom Trawl Survey | blue king crab pot fishery | IPHC longline survey | ADF&G large-mesh trawl survey | NMFS longline survey |
| AK skate | 1,644 | 29,994 | 624 | 4,929 | 284 | 1,889 | 173 | |
| Other Skates | 6,030 | 1,125 | 8,943 | | | 40,087 | 59 | 11,024 |

Table 2. Estimated removals in the IFQ halibut fishery, 2001-2010.

| | AK skate | | Other Skates | | all skates | |
|---|---|---|---|---|---|---|
| year | kg | t | kg | t | kg | t |
| 2001 | 195,867 | 196 | 264,661 | 265 | 460,528 | 461 |
| 2002 | 165,387 | 165 | 1,016,180 | 1,016 | 1,181,567 | 1,182 |
| 2003 | 326,308 | 326 | 555,428 | 555 | 881,736 | 882 |
| 2004 | 330,524 | 331 | 895,341 | 895 | 1,225,864 | 1,226 |
| 2005 | 608,071 | 608 | 235,225 | 235 | 843,296 | 843 |
| 2006 | 229,253 | 229 | 637,261 | 637 | 866,514 | 867 |
| 2007 | 206,511 | 207 | 411,985 | 412 | 618,496 | 618 |
| 2008 | 321,420 | 321 | 816,419 | 816 | 1,137,840 | 1,138 |
| 2009 | 222,960 | 223 | 329,165 | 329 | 552,125 | 552 |
| 2010 | 100,030 | 100 | 545,590 | 546 | 645,621 | 646 |

Table 3. Catches of skates during RACE research surveys, 1963-2011. Catches are given in kilograms (kg) and metric tons (t).

| year | AK skate survey removals | | other skates survey removals | | all skates survey removals | |
|---|---|---|---|---|---|---|
| | kg | t | kg | t | kg | t |
| 1963 | n/a | n/a | 942 | 0.94 | 942 | 0.94 |
| 1964 | n/a | n/a | 5 | 0.01 | 5 | 0.01 |
| 1965 | n/a | n/a | 681 | 0.68 | 681 | 0.68 |
| 1966 | n/a | n/a | 219 | 0.22 | 219 | 0.22 |
| 1967 | n/a | n/a | 2,089 | 2.09 | 2,089 | 2.09 |
| 1968 | n/a | n/a | 37 | 0.04 | 37 | 0.04 |
| 1969 | n/a | n/a | 4 | 0.00 | 4 | 0.00 |
| 1970 | n/a | n/a | 245 | 0.24 | 245 | 0.24 |
| 1971 | n/a | n/a | 491 | 0.49 | 491 | 0.49 |
| 1972 | 62 | 0.06 | 37 | 0.04 | 98 | 0.10 |
| 1973 | 10 | 0.01 | 886 | 0.89 | 896 | 0.90 |
| 1974 | 49 | 0.05 | 2,189 | 2.19 | 2,238 | 2.24 |
| 1975 | n/a | n/a | 4,449 | 4.45 | 4,449 | 4.45 |
| 1976 | n/a | n/a | 5,236 | 5.24 | 5,236 | 5.24 |
| 1977 | n/a | n/a | 1,719 | 1.72 | 1,719 | 1.72 |
| 1978 | n/a | n/a | 2,481 | 2.48 | 2,481 | 2.48 |
| 1979 | n/a | n/a | 5,633 | 5.63 | 5,633 | 5.63 |
| 1980 | 120 | 0.12 | 10,400 | 10.40 | 10,519 | 10.52 |
| 1981 | 41 | 0.04 | 9,556 | 9.56 | 9,597 | 9.60 |
| 1982 | 21 | 0.02 | 16,981 | 16.98 | 17,003 | 17.00 |
| 1983 | 4,853 | 4.85 | 10,217 | 10.22 | 15,070 | 15.07 |
| 1984 | 3,498 | 3.50 | 4,515 | 4.51 | 8,013 | 8.01 |
| 1985 | 4,799 | 4.80 | 14,772 | 14.77 | 19,571 | 19.57 |
| 1986 | 1,898 | 1.90 | 15,085 | 15.08 | 16,983 | 16.98 |
| 1987 | 4,950 | 4.95 | 8,091 | 8.09 | 13,041 | 13.04 |
| 1988 | 7,861 | 7.86 | 13,394 | 13.39 | 21,255 | 21.26 |
| 1989 | 6,081 | 6.08 | 15,918 | 15.92 | 21,999 | 22.00 |
| 1990 | 8,236 | 8.24 | 15,193 | 15.19 | 23,429 | 23.43 |
| 1991 | 9,891 | 9.89 | 20,303 | 20.30 | 30,194 | 30.19 |
| 1992 | 595 | 0.59 | 11,338 | 11.34 | 11,933 | 11.93 |
| 1993 | n/a | n/a | 15,270 | 15.27 | 15,270 | 15.27 |
| 1994 | 1,693 | 1.69 | 20,421 | 20.42 | 22,114 | 22.11 |
| 1995 | 32 | 0.03 | 13,754 | 13.75 | 13,785 | 13.79 |
| 1996 | 12,983 | 12.98 | 2,326 | 2.33 | 15,308 | 15.31 |
| 1997 | 13,774 | 13.77 | 7,247 | 7.25 | 21,021 | 21.02 |
| 1998 | 13,669 | 13.67 | 426 | 0.43 | 14,095 | 14.10 |
| 1999 | 12,949 | 12.95 | 1,356 | 1.36 | 14,305 | 14.31 |
| 2000 | 13,947 | 13.95 | 9,124 | 9.12 | 23,071 | 23.07 |
| 2001 | 15,262 | 15.26 | 742 | 0.74 | 16,004 | 16.00 |
| 2002 | 19,420 | 19.42 | 10,109 | 10.11 | 29,529 | 29.53 |
| 2003 | 17,227 | 17.23 | 1,705 | 1.71 | 18,932 | 18.93 |
| 2004 | 19,411 | 19.41 | 14,310 | 14.31 | 33,721 | 33.72 |
| 2005 | 17,659 | 17.66 | 720 | 0.72 | 18,379 | 18.38 |
| 2006 | 19,910 | 19.91 | 5,956 | 5.96 | 25,867 | 25.87 |
| 2007 | 19,459 | 19.46 | 866 | 0.87 | 20,325 | 20.33 |
| 2008 | 15,728 | 15.73 | 8,576 | 8.58 | 24,304 | 24.30 |
| 2009 | 15,849 | 15.85 | 899 | 0.90 | 16,748 | 16.75 |
| 2010 | 18,595 | 18.60 | 17,654 | 17.65 | 36,249 | 36.25 |
| 2011 | 16,604 | 16.60 | 996 | 1.00 | 17,600 | 17.60 |