# Gulf of Alaska Skate and Octopus Directed Fishery Considerations

Council staff discussion paper
November 2013



## 1 Introduction

In June 2013, the Council requested a discussion paper on the potential for a directed octopus fishery in the Gulf of Alaska (GOA) in 2014. The Council had also previously requested information for consideration of opening a directed fishery for skates in the EGOA. Per this request, information is assembled below in order to best inform the Council of the available stock assessment and management information as well as the process by which the Council could consider recommending a directed octopus fishery in the GOA. The Council will receive the GOA Plan Team comments in December and take further action at that time as needed.

## 2 Stock assessment overview

*Skates:*
In the Gulf of Alaska (GOA), the most common skate species are two *Raja* species, the big skate *R. binoculata* and the longnose skate *R. rhina*, and three *Bathyraja* species, the Aleutian skate, *B. aleutica*, the Bering skate *B. interrupta*, and the Alaska skate *B. parmifera*. In the GOA separate specifications are established for big skates and longnose skates with species-specific gulf-wide OFLs, and species and area-specific ABCs. *Bathyraja* skates are managed as a complex under a single gulfwide OFL and ABC.

*Octopus:*
At least seven species of octopus are found in the GOA. While the species composition of the natural community and the commercial harvest are not well documented, research indicates that the Giant Pacific octopus *Enteroctopus dofleini* is the most abundant species in shelf waters and comprises the majority of the catch in commercial fisheries (Conners et al., 2012). Octopus are currently grouped into a single assemblage and managed as a complex.

### 2.1 Life History and Stock Structure

*Skates:*
The following section has been excerpted from the 2011 GOA skate stock assessment (Ormseth, 2011). This represents the last ‘full’ assessment for GOA skate species due to the government shut-down in October 2013.

> Skate life cycles are similar to sharks, with relatively low fecundity, slow growth to large body sizes, and dependence of population stability on high survival rates of a few well developed

offspring (Moyle and Cech 1996). Sharks and skates in general have been classified as "equilibrium" life history strategists, with very low intrinsic rates of population increase implying that sustainable harvest is possible only at very low to moderate fishing mortality rates (King and McFarlane 2003). Within this general equilibrium life history strategy, there can still be considerable variability between skate species in terms of life history parameters (Walker and Hislop 1998). While smaller-sized species have been observed to be somewhat more productive, large skate species with late maturation (11+ years) are most vulnerable to heavy fishing pressure (Walker and Hislop 1998; Frisk et al 2001; Frisk et al 2002). The most extreme cases of overexploitation have been reported in the North Atlantic, where the now ironically named common skate Dipturus batis has been extirpated from the Irish Sea (Brander 1981) and much of the North Sea (Walker and Hislop 1998). The mixture of life history traits between smaller and larger skate species has led to apparent population stability for the aggregated "skate" group in many areas where fisheries occur, and this combined with the common practice of managing skate species within aggregate complexes has masked the decline of individual skate species in European fisheries (Dulvy et al 2000). Similarly, in the Atlantic off New England, declines in barndoor skate abundance were concurrent with an increase in the biomass of skates as a group (Sosebee 1998).

Several recent studies have explored the effects of fishing on a variety of skate species in order to determine which life history traits might indicate the most effective management measures for each species. While full age-structured modeling is difficult for many of these data-poor species, Leslie matrix models parameterized with information on fecundity, age/size at maturity, and longevity have been applied to identify the life stages most important to population stability. Major life stages include the egg, juvenile, and adult stages (summarized here based on Frisk et al 2002). All skate species are oviparous (egg-laying), investing considerably more energy per large, well-protected embryo than commercially exploited groundfish. The large, leathery egg cases incubate for extended periods (months to a year) in benthic habitats, exposed to some level of predation and physical damage, until the fully formed juveniles hatch. The juvenile stage lasts from hatching through maturity, several years to over a decade depending on the species. The reproductive adult stage may last several more years to decades depending on the species.

Age and size at maturity and adult size/longevity appear to be more important predictors of resilience to fishing pressure than fecundity or egg survival in the skate populations studied to date. Frisk et al (2002) estimated that although annual fecundity per female may be on the order of less than 50 eggs per year (extremely low compared with teleost groundfish), there is relatively high survival of eggs due to the high parental investment, and therefore egg survival did not appear to be the most important life history stage contributing to population stability under fishing pressure. Juvenile survival appears to be most important to population stability for most North Sea species studied (Walker and Hilsop 1998), and for the small and intermediate sized skates from New England (Frisk et al 2002). For the large and long-lived barndoor skates, adult survival was the most important contributor to population stability (Frisk et al 2002). In all cases, skate species with the largest adult body sizes (and the empirically related large size/age at maturity, Frisk et al 2001) were least resilient to high fishing mortality rates. This is most often attributed to the long juvenile stage during which relatively large yet immature skates are exposed to fishing mortality, and also explains the mechanism for the shift in species composition to smaller skate species in heavily fished areas. Comparisons of length frequencies for surveyed North Sea skates from the mid- and late-1900s led Walker and Hilsop (1998, p. 399) to the conclusion that "all the breeding females, and a large majority of the juveniles, of Dipturus batis, R. fullonica and R. clavata have disappeared, whilst the other species have lost only the very largest individuals." Although juvenile and adult survival may have different importance by skate species, all studies found that one metric, adult size, reflected their overall sensitivity to fishing.

After modeling several New England skate populations, Frisk et al (2002, p. 582) found "a significant negative, nonlinear association between species total allowable mortality, and species maximum size."

There are clear implications of these results for sustainable management of skates in Alaska. After an extensive review of population information for many elasmobranch species, Frisk et al ((2001, p. 980) recommended that precautionary management be implemented especially for the conservation of large species:
"(i) size based fishery limits should be implemented for species with either a large size at maturation or late maturation, (ii) large species (>100 cm) should be monitored with increased interest and conservative fishing limits implemented, (iii) adult stocks should be maintained, as has been recommended for other equilibrium strategists (Winemiller and Rose 1992)."

Life history and stock structure (Alaska-specific)

Information on fecundity in North Pacific skate species is extremely limited. There are one to seven embryos per egg case in locally occurring *Raja* species (Eschmeyer et al 1983), but little is known about frequency of breeding or egg deposition for any of the local species. Similarly, information related to breeding or spawning habitat, egg survival, hatching success, or other early life history characteristics is extremely sparse for Gulf of Alaska skates (although current research is addressing these issues for Alaska skates in the Eastern Bering sea; J. Hoff, AFSC, pers. comm.; see also the 2009 BSAI skate SAFE, Ormseth and Matta 2009).

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

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

Some additional information was provided during the Plan Team meeting in November regarding the potential biological concerns with a directed skate fishery in the EGOA. There remains considerable uncertainty in estimation of life-history parameters such as natural mortality. There is also uncertainty in population structure and movement. A recent CIE review also noted that there is some evidence that the use of *M* as a proxy for $F_{OFL}$ may not apply to long-lived, late-maturing species.

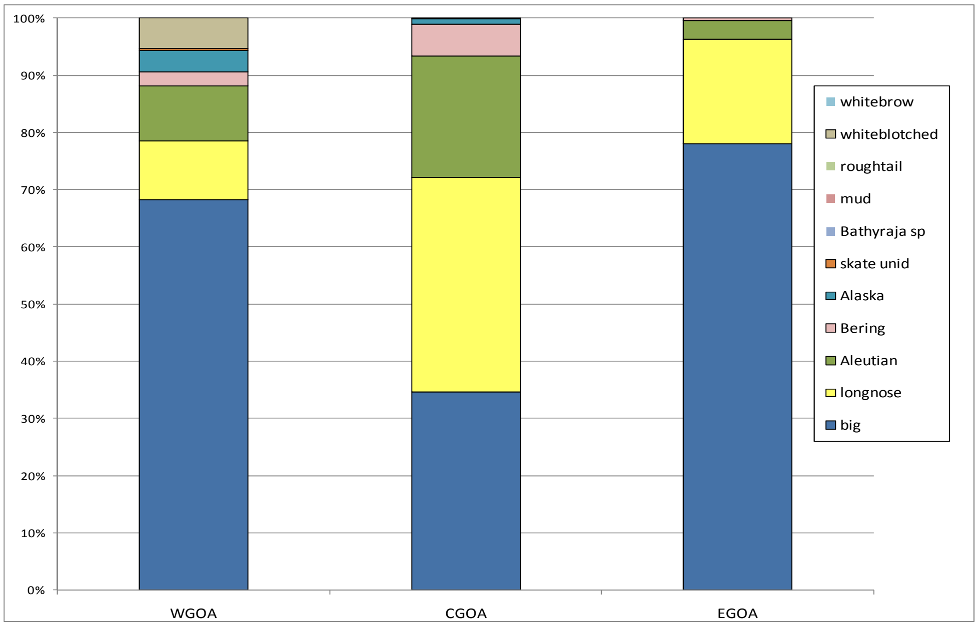


Figure 1 2011 Survey biomass by skate species by management area.

Big skates comprise the majority of the 2011 biomass in the EGOA with longnose skates as the next largest component (Figure 1). During the Plan Team meeting, the stock assessment author noted the size composition differences among GOA regulatory areas for big and longnose skates (Figure **2**). Big skates in the EGOA in particular tend to be smaller and are likely immature.

Previous skate stock assessments have recommended area-specific ABCs and OFLs for big and longnose skates noting that these species display sensitive life history traits (large size, late maturity, and low fecundity), and retention of skates is extremely localized (Ormseth and Matta, 2009). However the Plan Team and SSC have yet to recommend area-specific OFLs. In continuing to recommend GOA-wide OFLs for big and longnose skates the SSC concurred with the GOA Plan Team's rationale "that a single OFL provides adequate precaution given the bycatch-only status of the current catches."(SSC minutes 2009).

The Team requested that for September 2014 the authors provide the stock structure template for skate species in the GOA and any other information that would assist in determining whether there is a conservation concern under current harvest levels. More information is included in the incidental catch section of this report.

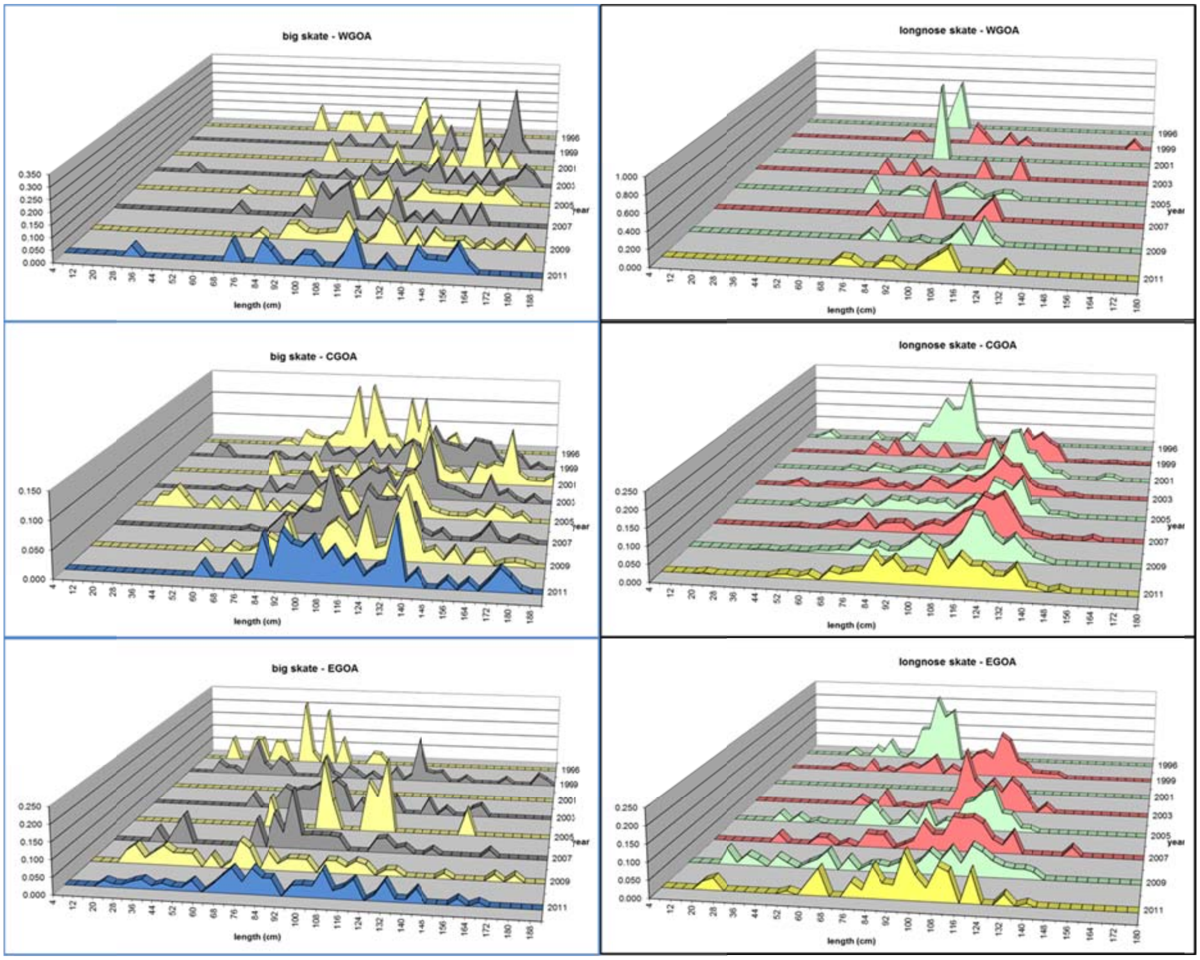


Figure 2 Length-frequency of big and longnose skates by regulatory area from survey data (Ormseth, pers. Comm.)

*Octopus:*
The following section has been excerpted from the 2012 GOA Octopus stock assessment (Conners et al., 2012):

> In general, octopuses are fast growing with a life span generally less than 5 years. Life histories of seven of the eight species in the Gulf of Alaska are largely unknown. *Enteroctopus dofleini* has been studied extensively in Alaskan, Japanese and Canadian waters and its life history will be reviewed here; generalities on the life histories of the other seven species will be inferred from what is known about other members of the genus.
>
> *Enteroctopus dofleini* within the Gulf of Alaska have been found to mature between 10 to 20 kg with 50% maturity values of 13.7 kg (95% CI 12.5-15.5 kg) for females and 14.5 kg (95% CI = 12.5-16.3 kg) for males (Conrath and Conners, in press). *Enteroctopus dofleini* are problematic to age due to soft chalky statoliths (Robinson and Hartwick 1986). Therefore the determination of age at maturity is difficult for this species. In Japan, this species is estimated to mature at 1.5 to 3 years and at similar but smaller size ranges (Kanamaru and Yamashita 1967, Mottet 1975). Within the Gulf of Alaska this species has a protracted reproductive cycle with a peak in spawning in the winter to early spring months. Due to differences in the timing of peak gonad development between males and females it is likely that females have the capability to store

sperm. This phenomenon has been documented in an aquarium study of octopus in Alaska (Jared Gutheridge pers com) and British Columbia (Gabe 1975). Fecundity for this species ranges from 40,000 to 240,000 eggs per female with an average fecundity of 106,800 eggs per female. Fecundity is significantly and positively related to the size of the female. The fecundity of *E. dofleini* within this region is higher than that reported for other regions. The fecundity of this species in Japanese waters has been estimated at 30,000 to 100,000 eggs per female (Kanamaru 1964, Mottet 1975, Sato 1996). Gabe (1975) estimated a female in captivity in British Columbia laid 35,000 eggs. Hatchlings are approximately 3.5 mm. Mottet (1975) estimated survival to 6 mm at 4% while survival to 10 mm was estimated to be 1%; mortality at the 1 to 2 year stage is also estimated to be high (Hartwick, 1983). Since the highest mortality occurs during the larval stage, it is probable that ocean conditions have a large impact on numbers of *E. dofleini* in the GOA and large fluctuations in numbers of *E. dofleini* should be expected.

*Enteroctopus dofleini* is found throughout the northern Pacific Ocean from northern Japanese waters, throughout the Aleutian Islands, the Bering Sea and the Gulf of Alaska and as far south down the Pacific coast as southern California (Kubodera, 1991).The stock structure and phylogenetic relationships of this species throughout its range have not been well studied. Three sub-species have been identified based on large geographic ranges and morphological characteristics including *E. dofleini dofleini* (far western North Pacific), *E. dofleini apollyon* (waters near Japan, Bering Sea, Gulf of Alaska), and *E. dofleini martini* (eastern part of their range, Pickford 1964). A recent genetic study (Toussaint et al. 2012) indicate the presence of a cryptic species of *E. dofleini* in Prince William Sound, Alaska and raises questions about the stock structure of this species. There is little information available about the migration and movements of this species in Alaska waters. Kanamaru (1964) proposed that *E. dofleini* move to deeper waters to mate during July through October and then move to shallower waters to spawn during October through January in waters off of the coast of Hokkaido, Japan. Studies of movement in British Columbia (Hartwick et al. 1984) and south central Alaska (Scheel and Bisson 2012) found no evidence of a seasonal or directed migration for this species, but longer term tagging studies may be necessary to obtain a complete understanding of the migratory patterns of this species. Additional genetic and/or tagging studies are needed to clarify the stock structure of this species in Alaska waters.

*Octopus californicusis* a medium-sized octopus with a maximum total length of approximately 40 cm. Very little is known about this species of octopus. It is collected between 100 to 1,000 m depth in Alaska and has been reported in even deeper waters off the coast of California (Smith and Mackenzie 1948). It is believed to spawn 100 to 500 eggs. Hatchlings are likely benthic; hatchling size is unknown. The female likely broods the eggs and dies after hatching.

*Octopus rubescens* has been reported from Prince William Sound in the central GOA, but has not been verified in survey collections. *Octopus rubescens* appears to have a two year life cycle with egg laying occurring in July through September and hatching occurring 5 to 10 months later in February through March. Females of this species are terminal spawners estimated to lay approximately 3,000 eggs (Dorsey 1976). *Octopus rubescens* has a planktonic larval stage.

*Octopus sp. A* is a small-sized species with a maximum total length < 10 cm. This species has only recently been identified in the GOA and its full taxonomy has not been determined. *Octopussp. A* is likely a terminal spawner with a life-span of 12 to 18 months. The eggs of *Octopussp. A* are likely much larger than those of *O. rubescens*, as they appear to have larger benthic larvae. Females of *Octopus sp. A* lay between 80 to 90 eggs that take up to six months or more to hatch.

*Benthoctopus leioderma* is a medium sized species; its maximum total length is approximately 60 cm. Its life span is unknown. It occurs from 250 to 1400 m and is found throughout the shelf break region. It is a common octopus and often occurs in the same areas where *E. dofleini* are found. The eggs are brooded by the female but mating and spawning times are unknown. Members of this genus in the North Pacific Ocean have been found to attach their eggs to hard substrate under rock ledges and crevices (Voight and Grehan 2000). *Benthoctopus* tend to have small numbers of eggs (<200) that develop into benthic hatchlings.

*Opisthoteuthis californiana* is a cirrate octopus; it has fins and cirri (on the arms). It is common in the GOA but is not likely to be confused with *E. dofleini*. It is found from 300 to 1,100 m and is likely common over the abyssal plain. *Opisthoteuthis californiana* in the northwestern Bering Sea have been found to have a protracted spawning period with multiple small batch spawning events. Potential fecundity of this species was found to range from 1,200 to 2,400 oocytes (Laptikhovsky 1999). There is evidence that *Opisthoteuthis species* in the Atlantic undergo 'continuous spawning' with a single, extended period of egg maturation and a protracted period of spawning (Villanueva 1992). Other details of its life history remain unknown.

*Japetella diaphana* is a small pelagic octopus. Little is known about members of this family. In Hawaiian waters gravid females are found near 1,000 m depth and brooding females near 800 m depth. Hatchlings have been observed to be about 3 mm mantle length (Young 2008). This is not a common octopus in the GOA and not likely to be confused with *E. dofleini*.

*Vampyroteuthis infernalisis* a cirrate octopus. It is not common in the GOA and is easily distinguishable from other species of octopus by its black coloration. Very little is known about its reproduction or early life history. An 8 mm ML hatchling with yolk was captured near the Hawaiian Islands indicating an egg size of around 8 mm for this species (Young and Vecchione 1999).

In summary, there are at least seven species of octopus present in the GOA, and the species composition both of natural communities and commercial harvest is unknown. At depths less than 200 meters, *E. dofleini* appears to have the highest biomass, but the abundances of *Octopus sp. A* and *B. leioderma* are also very high. The greatest difference in species composition between the Bering Sea Aleutian Islands (BSAI) and the GOA is the presence of *O. californicus* and the small *Octopus sp. A*.

The GOA trawl surveys produce estimates of biomass for octopus, but these estimates are highly variable and may not reflect the same size octopus caught by industry (Connors et al., 2012). Octopus are taken in trawl, longline and pot fisheries in the GOA with the highest catch rates from the Pacific cod pot fisheries in the central and western GOA. A portion of the catch is retained or sold for human consumption or bait.

Data are currently insufficient to support a model-based assessment for GOA octopus. The SSC has determined that GOA octopus are in Tier 6 due to inadequate data to reliably estimate biological parameters for Tier 5. There are no historical records of directed fishing for octopus, thus catch estimates are for incidental catch in groundfish fisheries (Connors et al., 2012). This complicates the ability to set an average catch-based OFL and ABC. A modified Tier 6 approach has been considered using the maximum incidental catch from 1997-2006 to set the OFL with ABC = 75% of the OFL. However since 2010 the GOA PT and the SSC have recommended using an average of the last three survey biomass estimates and applying a Tier 5 calculation to obtain an OFL. This modified Tier 6 approach includes a conservative estimate of natural mortality of 0.53 and a minimum biomass estimate using the average of the last three surveys. Using a Tier 5-like calculation of OFL, average minimum B×M (3,662 t × 0.53 = 1,941 t) and the ABC equal to 0.75 × OFL (1,455 t) is estimated. This approach recognizes that the catch history is not appropriate for Tier 6 management and that the biomass estimates and M estimates are not sufficient for a Tier 5 approach. The OFL and ABC for the complex have been managed gulf-wide.

The stock assessment author currently does not recommend a directed fishery without further information being available on an appropriate index for octopus. However the author has indicated that a small experimental fishery which would provide more biological information and further develop octopus-specific index survey gear could be useful. The GOA Plan Team did not comment on the extent to which a directed fishery would be recommended, but did note that should a directed fishery be considered that the ABC should be apportioned by area and consideration given to appropriate size restrictions. The GOA Plan Team area apportionment recommendation approach is listed in section 3.

# 3 Catch and in-season management

## 3.1 Incidental catch information

*Skates:*
Catches of big and longnose skates by management area and target fishery as reported in the 2013 assessment are given in Table 1through Table 4. Considered GOA-wide, incidental catch of big skates is highest in the arrowtooth flounder target, the Pacific cod target and the IFQ halibut fisheries. For longnose skates GOA-wide, the IFQ halibut fishery has the highest catches followed by Pacific cod target and arrowtooth flounder target. Reported catches in the IFQ halibut fishery are notably higher in 2013 than the estimates indicated in previous years. 2013 is the first year that observer coverage included the IFQ halibut fishery under the restructured program.

Table 1 Time series of ABC, OFL and catch (t) for skates, beginning in 2004 when they were first managed outside of the 'other species' category. Outlined cells in bold indicate years/areas where the catch exceeded the ABC. 2013 catch data are incomplete; retrieved September 18, and EGOA catches include statistical areas 649 and 659.

| | ABC | | | OFL | estimated skate catch | | | management method |
|---|---|---|---|---|---|---|---|---|
| | W | C | E | | W | C | E | |
| **2004** | | 4,435 | | 10,859 | | 1,569 | | big/longnose CGOA |
| | | 3,709 | | | | 1,451 | | o.skates GW, big/longnose W/E |
| **2005** | 727 | 2,463 | 809 | 5,332 | 26 | 811 | 67 | big (ABC by area) |
| | 66 | 1,972 | 780 | 3,757 | 37 | 993 | 173 | longnose (ABC by area) |
| | | 1,327 | | 1,769 | | 719 | | other skates gulfwide |
| **2006** | 695 | 2,250 | 599 | 4,726 | 72 | 1,268 | 359 | big (ABC by area) |
| | 65 | 1,969 | 861 | 3,860 | 57 | 679 | 240 | longnose (ABC by area) |
| | | 1,617 | | 2,156 | | 1,402 | | other skates gulfwide |
| **2007** | 695 | 2,250 | 599 | 4,726 | 69 | 1,517 | 9 | big (ABC by area) |
| | 65 | 1,969 | 861 | 3,860 | 76 | 966 | 335 | longnose (ABC by area) |
| | | 1,617 | | 2,156 | | 1,241 | | other skates gulfwide |
| **2008** | 632 | 2,065 | 633 | 4,439 | 132 | 1,241 | 48 | big (ABC by area) |
| | 78 | 2,041 | 768 | 3,849 | 34 | 965 | 115 | longnose (ABC by area) |
| | | 2,104 | | 2,806 | | 1,403 | | other skates gulfwide |
| **2009** | 632 | 2,065 | 633 | 4,439 | 73 | 1,827 | 128 | big (ABC by area) |
| | 78 | 2,041 | 768 | 3,849 | 77 | 1,037 | 277 | longnose (ABC by area) |
| | | 2,104 | | 2,806 | | 1,341 | | other skates gulfwide |
| **2010** | 598 | 2,049 | 681 | 4,438 | 146 | **2,220** | 172 | big (ABC by area) |
| | 81 | 2,009 | 762 | 3,803 | 104 | 843 | 181 | longnose (ABC by area) |
| | | 2,093 | | 2,791 | | 1,488 | | other skates gulfwide |
| **2011** | 598 | 2,049 | 681 | 4,438 | 94 | **2,075** | 126 | big (ABC by area) |
| | 81 | 2,009 | 762 | 3,803 | 62 | 863 | 106 | longnose (ABC by area) |
| | | 2,093 | | 2,791 | | 1,211 | | other skates gulfwide |
| **2012** | 469 | 1,793 | 1,505 | 5,023 | 66 | **1,894** | 59 | big (ABC by area) |
| | 70 | 1,879 | 676 | 3,500 | 38 | 771 | 104 | longnose (ABC by area) |
| | | 2,030 | | 2,706 | | 1,228 | | other skates gulfwide |
| ***2013**** | 469 | 1,793 | 1,505 | 5,023 | *83* | ***1,853*** | *167* | big (ABC by area) |
| | 70 | 1,879 | 676 | 3,500 | *43* | *995* | *724* | longnose (ABC by area) |
| | | 2,030 | | 2,706 | | *1,572* | | other skates gulfwide |

Table 2 Catches (t) of Big skates in the GOA by target fishery, 2003-2013. Data are from the Alaska Regional Office Catch Accounting System. The 2013 data are incomplete; retrieved September 18, 2013. ATF = arrowtooth flounder, FHS = flathead sole.

| big skate | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013* |
| ATF | | 140 | 225 | 163 | 299 | 219 | 433 | 478 | 812 | 677 | 918 |
| Pacific cod | | 331 | 222 | 417 | 537 | 586 | 550 | 940 | 919 | 755 | 548 |
| IFQ halibut | | 24 | 37 | 577 | 11 | 36 | 90 | 43 | 132 | 38 | 298 |
| rex sole | | 31 | 49 | 99 | 74 | 70 | 264 | 172 | 106 | 140 | 145 |
| pollock | | 1 | 2 | 23 | 38 | 22 | 34 | 47 | 93 | 48 | 127 |
| shallow flat | | 237 | 251 | 350 | 608 | 413 | 535 | 707 | 190 | 288 | 44 |
| FHS | | 38 | 21 | 30 | 23 | 66 | 53 | 112 | 31 | 57 | 15 |
| sablefish | | 6 | 24 | 9 | 6 | 3 | 5 | 11 | 3 | 3 | 5 |
| rockfish | | 16 | 19 | 4 | 0 | 4 | 4 | 14 | 8 | 13 | 2 |
| other | | 376 | 56 | 27 | 0 | 2 | 60 | 14 | 1 | 0 | 1 |
| deep flat | | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| **GOA total** | | **1,204** | **904** | **1,699** | **1,595** | **1,421** | **2,028** | **2,539** | **2,295** | **2,020** | **2,103** |

Table 3 Catches (t) of Longnose skates in the GOA by target fishery, 2003-2013. Data are from the Alaska Regional Office Catch Accounting System. The 2013 data are incomplete; retrieved September 18, 2013. ATF = arrowtooth flounder, FHS = flathead sole.

| longnose skate | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013* |
| IFQ halibut | 1 | 35 | 106 | 197 | 394 | 109 | 379 | 115 | 171 | 88 | 904 |
| Pacific cod | 10 | 83 | 139 | 165 | 306 | 361 | 325 | 425 | 346 | 329 | 347 |
| ATF | 14 | 63 | 373 | 135 | 165 | 212 | 152 | 166 | 238 | 181 | 212 |
| sablefish | 16 | 121 | 113 | 306 | 264 | 123 | 79 | 98 | 77 | 111 | 152 |
| rex sole | 0 | 13 | 19 | 29 | 24 | 36 | 82 | 52 | 44 | 45 | 54 |
| shallow flat | 3 | 26 | 278 | 97 | 168 | 227 | 239 | 173 | 78 | 65 | 45 |
| pollock | 0 | 0 | 5 | 13 | 27 | 24 | 35 | 10 | 35 | 9 | 22 |
| rockfish | 1 | 32 | 20 | 21 | 17 | 12 | 17 | 12 | 25 | 23 | 18 |
| FHS | 9 | 7 | 11 | 11 | 13 | 11 | 24 | 30 | 17 | 60 | 8 |
| other | 0 | 155 | 137 | 2 | 0 | 0 | 61 | 47 | 0 | 0 | 1 |
| deep flat | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **GOA total** | **53** | **539** | **1,202** | **976** | **1,377** | **1,114** | **1,392** | **1,129** | **1,032** | **912** | **1,762** |

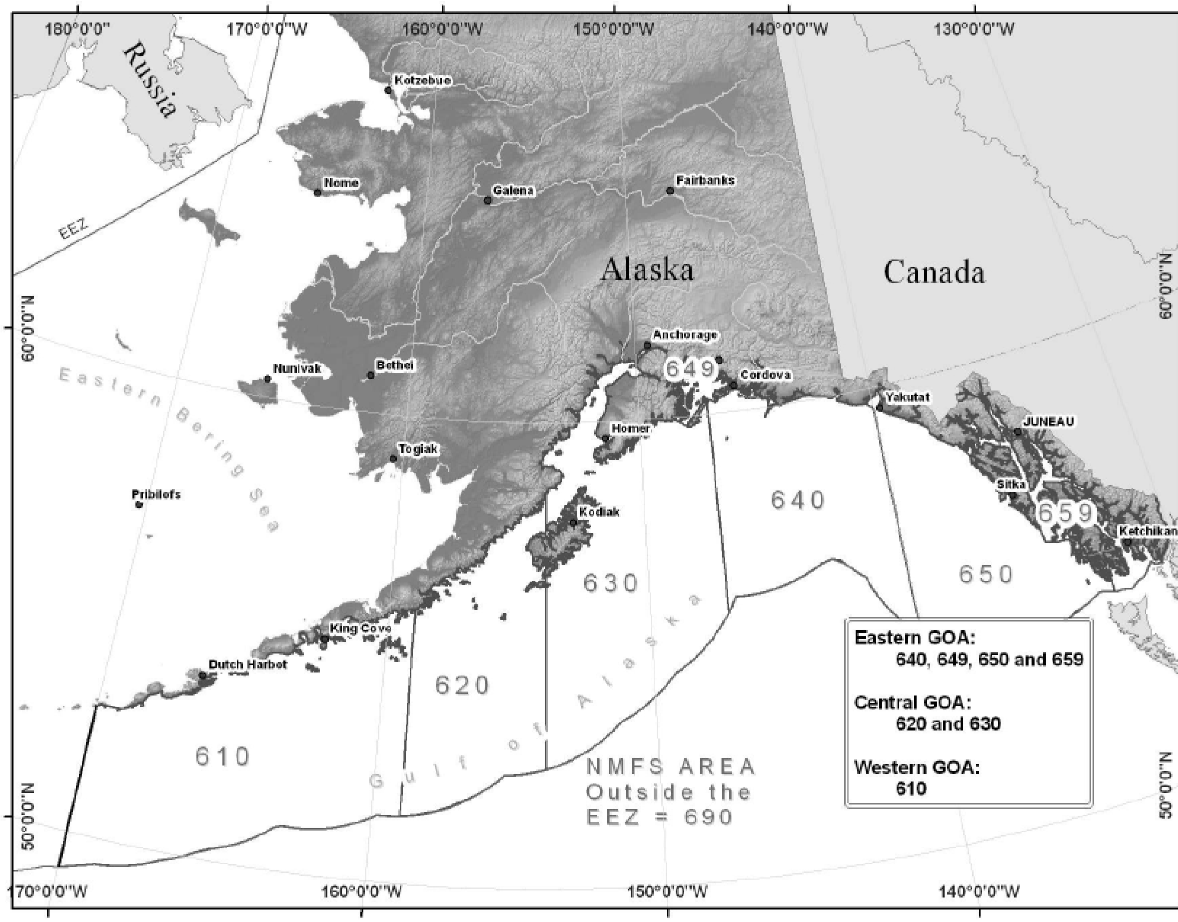


Figure 3 GOA management areas. Note that EGOA includes 649 and 659.

One issue that has been raised to the GOA Plan Team by NMFS RO staff this year is the relative catch in EGOA areas 649 (Prince William Sound) and 659 (Southeast; Figure 3). Currently, skates are a federally managed species. In state waters, federal fisheries catches are included in the Catch Accounting System (CAS) but do not currently accrue towards the federal TAC. This issue is reflected in the GOA Plan Team report as a general issue for multiple stocks, but given the increase in catch estimation in 2013 (presumably under increased observations on federally fishing smaller vessels) this is of particular note for skates. Incidental catch in 2013 by target and management area, including areas 649 and 659, is shown in Table 4. While the ABC has been exceeded in the central GOA for big skates for multiple years (Table 1), when 649/659 catches are included in estimates for EGOA the ABC for longnose is also exceeded. This raises concerns about the potential for directed fishing on skates in the EGOA.

Retention rates have been fairly high in recent years indicating that skates are being retained and processed as bycatch in other directed fisheries (Table 5).

Table 4 Incidentally caught skate species in 2013 by target and management area in GOA.

**Longnose skate**

| | bot_pol | P cod | shal_flat | IFQ halibut | rockfish | FHS | other | pel_pol | sablefish | ATF | rex |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 610 | 0 | 12 | 0 | 61 | 0 | 1 | 0 | 0 | 7 | 0 | 1 |
| 620 | 13 | 54 | 14 | 106 | 5 | 0 | 0 | 4 | 4 | 12 | 42 |
| 630 | 8 | 221 | 49 | 241 | 18 | 7 | 1 | 0 | 171 | 209 | 11 |
| 640 | 0 | 15 | 0 | 181 | 0 | 0 | 0 | 0 | 73 | 0 | 0 |
| 649 | 0 | 70 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 650 | 0 | 0 | 0 | 86 | 0 | 0 | 0 | 0 | 39 | 0 | 0 |
| 659 | 0 | 2 | 0 | 277 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| Grand Total | 21 | 374 | 64 | 960 | 23 | 8 | 1 | 4 | 299 | 221 | 54 |

**Big skate**

| | bot_pol | P cod | shal_flat | IFQ halibut | rockfish | FHS | other | pel_pol | sablefish | ATF | rex |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 610 | 1 | 32 | 0 | 70 | 0 | 6 | 0 | 0 | 2 | 0 | 1 |
| 620 | 62 | 135 | 19 | 148 | 1 | 0 | 0 | 11 | 0 | 65 | 115 |
| 630 | 141 | 337 | 95 | 137 | 0 | 8 | 1 | 0 | 2 | 879 | 30 |
| 640 | 0 | 16 | 0 | 25 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 649 | 0 | 29 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 650 | 0 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 659 | 0 | 1 | 0 | 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grand Total | 204 | 550 | 113 | 501 | 2 | 15 | 1 | 11 | 8 | 944 | 145 |

Table 5 Retention rates of skates since 2007 in GOA. Data are from the Alaska Regional Office discard and retention reports. 2013 data are incomplete; retrieved October 28.

| | other skates | big skate | longnose skate |
|---|---|---|---|
| 2007 | 27% | 46% | 28% |
| 2008 | 17% | 70% | 64% |
| 2009 | 18% | 76% | 51% |
| 2010 | 15% | 72% | 64% |
| 2011 | 19% | 81% | 65% |
| 2012 | 13% | 93% | 74% |
| *2013** | *1%* | *68%* | *36%* |

*Octopus:*
Catch specifications and catch in recent years are shown below. As noted the incidental catch is primarily in the Pacific cod pot fisheries in the western and central GOA.

| Year | OFL | ABC | TAC | Catch |
|---|---|---|---|---|
| 2011 | 1,272 | 954 | 954 | 917 |
| 2012 | 1.941 | 1,455 | 1,455 | 421 |
| 2013 (through 9/18) | 1,941 | 1,455 | 1,455 | 214 |

In 2012, 23% of the catch was discarded while in 2013 to date 56% has been discarded. Discard mortality rate estimation analyses are underway by the stock assessment author but are not currently employed in management thus mortality is assumed to be 100% for purposes of accrual against the TAC.

Table 6 Estimated state and federal catch (t) of all octopus species combined, by target fishery. Catch for 1997-2002 estimated from blend data. Catch for 2003-2013 data from AK region catch accounting. *Data for 2013 are as of September18, 2013; catch figures for flatfish targets have been revised to include the IFQ Halibut fishery.

| | Target Fishery | | | | | | |
|---|---|---|---|---|---|---|---|
| **Year** | **Pacific cod** | **Pollock** | **Flatfish*** | **Rockfish** | **Sablefish** | **Other** | **Total** |
| 1997 | 193.8 | 0.7 | 1.3 | 2.3 | 22.4 | | 232 |
| 1998 | 99.7 | 3.5 | 4.3 | 0.8 | 0.3 | | 112 |
| 1999 | 163.2 | 0 | 2.4 | 0.5 | 0.2 | | 166 |
| 2000 | 153.5 | - | 0.7 | 0.2 | 0.5 | | 156 |
| 2001 | 72.1 | 0.2 | 0.8 | 0 | 2 | | 88 |
| 2002 | 265.4 | 0 | 17.2 | 0.7 | 1 | | 298 |
| 2003 | 188.9 | - | 17.2 | 0.6 | 2.9 | 0.1 | 210 |
| 2004 | 249.8 | 0.0 | 2.8 | 0.4 | 0.1 | 16.5 | 270 |
| 2005 | 138.6 | 0.1 | 8.7 | 0.2 | 0.2 | 1.7 | 149 |
| 2006 | 151.0 | 3.4 | 10.7 | 0.5 | 0.3 | 0.2 | 166 |
| 2007 | 242.0 | 1.5 | 12.1 | 0.1 | 1.8 | - | 257 |
| 2008 | 326.0 | 0.0 | 9.5 | 2.9 | 0.2 | 0.1 | 339 |
| 2009 | 296.7 | 0.1 | 10.4 | 1.2 | 2.3 | 0.9 | 312 |
| 2010 | 265.2 | 0.8 | 16.6 | 3.7 | 1.1 | 41.9 | 329 |
| 2011 | 859.6 | 2.3 | 53.2 | 0.9 | 0.8 | 1.1 | 918 |
| 2012 | 413.9 | 0.4 | 4.6 | 0.9 | 0.8 | - | 421 |
| 2013* | 122.9 | 0.2 | 75.6 | 1.4 | 13.5 | 0.0 | 214 |

Per Council request, the GOA Plan Team discussed how to apportion octopus across management areas. The Team considered two different approaches, incidental catch by region (Table 7) or survey biomass by region (Table 8). The Team recommended that should a directed fishery be considered that the ABC should be apportioned by area. The Team recommended an apportionment based on the average biomass proportions from most recent 3 survey years: Western 35%, Central 63%, East 2%.

Table 7 Distribution of Octopus catch data for GOA regions, 2003 – 2013 (*2013 data through Sept, 2013).

| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Western | 69% | 69% | 39% | 23% | 25% | 37% | 45% | 43% | 61% | 42% | 32% |
| Central | 29% | 30% | 61% | 77% | 75% | 63% | 55% | 57% | 38% | 58% | 58% |
| Eastern | 1.1% | 0.2% | 0.0% | 0.3% | 0.1% | 0.0% | 0.2% | 0.1% | 0.3% | 0.0% | 9.2% |
| Total Catch (t) | 210 | 270 | 149 | 166 | 257 | 339 | 312 | 329 | 918 | 421 | 214 |

Table 8 Estimated biomass from three most recent AFSC trawl surveys.

| | Western | Central | Eastern |
|---|---|---|---|
| 2009 Survey Biomass | 46% | 52% | 1.9% |
| 2011 Survey Biomass | 25% | 73% | 1.6% |
| 2013 Survey Biomass | 35% | 61% | 4.5% |
| 3 Survey Average | 35% | 63% | 2.4% |

### 3.2 State waters catch

*Skates:*
A state fishery existed in Prince William Sound for Big and Longnose skates in 2009 and 2010. The following description of the fishery and fisheries management was provided by the ADF&G regarding that fishery:

The Prince William Sound (PWS) directed skate fishery, targeting big *Raja binoculata* and longnose *Raja rhina* skates, began in 2009 following receipt of a $50K capital budget increment. Fisheries occurred in 2009 and 2010 and were managed under a commissioner's permit described in regulation 5 AAC 28.083. The permit stipulated species, season, fishing area, logbooks, catch reporting, prior notice of departure and landing, and accommodation of a department observer. In 2010, the permit also stipulated a big skate trip limit of 2,500 lb per two-day period due to overharvest in 2009. Harvest levels for the fishery were set for the PWS Inside and Outside districts (Figure 4).

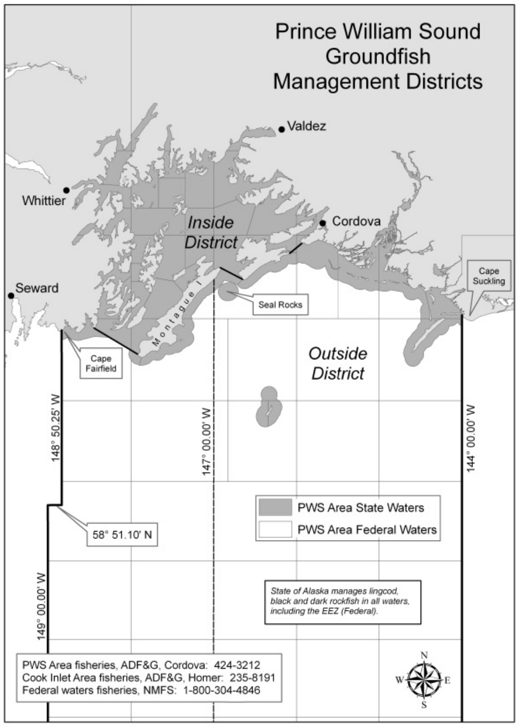


Figure 4 State of Alaska Prince William Sound groundfish fishing districts

Using estimates of skate abundance derived from PWS Inside District trawl survey data and applying a harvest rate for longnose skate of 0.034% and 0.045% in 2009 and 2010 respectively (identical to federal BSAI rates and refers to most recent 5-year average). For big skate, the lower 0.034% harvest rate from 2009 was used for both years, due to overharvesting in 2009. Applying described harvest rates resulted in Inside District guideline harvest levels (GHL) of 20,000 lb and 100,000 lb (110K in 2010) for big and longnose skates respectively. Lacking survey data for the Outside District, big and longnose skate GHLs were set at 30,000 lb and 150,000 (155K in 2010) based upon a fishing area approximately 50% larger than the Inside District. Total skate harvest including bycatch is shown in Table 9.

Table 9 Total skate harvest in PWS directed skate fishery (includes bycatch)

| Year | Skate Species | Inside District GHL (lb) | Inside District Harvest | Inside District Remaining | Outside District GHL (lb) | Outside District Harvest | Outside District Remaining |
|---|---|---|---|---|---|---|---|
| 2009 | Big | 20,000 | 47,220 | -27,220 | 30,000 | 82,793 | -52,793 |
| | Longnose | 100,000 | 68,828 | 31,172 | 150,000 | 59,538 | 90,462 |
| 2010 | Big | 20,000 | 20,382 | -382 | 30,000 | 6,190 | 23,810 |
| | Longnose | 110,000 | 68,681 | 41,319 | 155,000 | 9,257 | 145,743 |

Table 10Catch abundance and results of selected species and species groups from observed longline sets during the PWS pilot program directed skate fishery.

| Year | District | Big Skate | | Longnose Skate | | Other skate | | Pacific Halibut | | Rockfish | | Other species | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ret | Disc | Ret | Disc | Ret | Disc | Ret | Disc | Ret | Disc | Ret | Disc |
| **2009** | Inside | 0 | 567 | 777 | 7 | 0 | 182 | 0 | 598 | 49 | 0 | 1,012 | 319 |
| | Outside | 138 | 3 | 34 | 0 | 0 | 135 | 0 | 361 | 0 | 0 | 86 | 60 |
| | ***2009 Total*** | ***138*** | ***570*** | ***811*** | ***7*** | ***0*** | ***317*** | ***0*** | ***959*** | ***49*** | ***0*** | ***1,098*** | ***379*** |
| **2010** | Inside | 295 | 623 | 1,340 | 27 | 0 | 785 | 203 | 1,653 | 241 | 1 | 1,770 | 1,345 |
| | Outside | 194 | 391 | 382 | 6 | 0 | 93 | 0 | 572 | 0 | 0 | 500 | 398 |
| | ***2010 Total*** | ***489*** | ***1,014*** | ***1,722*** | ***33*** | ***0*** | ***878*** | ***203*** | ***2,225*** | ***241*** | ***1*** | ***2,270*** | ***1,743*** |
| ***Fishery Totals*** | | ***627*** | ***1,584*** | ***2,533*** | ***40*** | ***0*** | ***1,195*** | ***203*** | ***3,184*** | ***290*** | ***1*** | ***3,368*** | ***2,122*** |

*Note: Ret=Retained; Disc=Discarded*

The decision to not fish in 2011 involved consideration of the lack of comprehensive stock assessment data, relative catch and composition of skate species, bycatch, other skate harvest opportunities, and cost of management. Stock assessment limitations were twofold. The trawl survey, designed to assess Tanner crab, occurred only in PWS Inside District waters deeper than 50 fathoms. Big skates are known to inhabit shallower waters. The disparate GHLs for big and longnose skates were possibly attributable to the lack of survey data from shallower waters in the Inside District and the absence of survey data from predominantly shallow waters of the Outside District. Catch per unit effort declined slightly between years for big skate from 0.99 lb/hook to 0.79 lb/hook and for longnose skate from 0.66 lb/hook to 0.58 lb/hook. Catch composition differed between skate species with big skate catches comprised predominately of immature females and longnose skate catches comprised of mature males and females.

Although the observed abundance of each skate species was approximately equal, the biomass of big skates was greater. As a result, big skate GHLs in 2009, and trip limits in 2010, were quickly attained which resulted in high discards of big skate while trying to target longnose skates. Although skate discard mortality rates are unknown, there were observations of skate and halibut jaws being cut to release fish. Among observed sets in both years, halibut bycatch abundance exceeded the catch of either skate species and the catch ratio of halibut to both skate species combined was 0.7.

Other skate harvest opportunities were a factor in 2010 when vessels permitted to target Pacific cod in the federal EGOA opted to do so and with a skate bycatch allowance of 20% were able to retain more big skates than could be retained in the directed state waters fishery under trip limits. Also in 2010, the federal CGOA big skate TAC was achieved under a bycatch-only management regime. This strongly suggests that extant fisheries provide adequate opportunity to harvest skates at sustainable levels even under bycatch-only restrictions. Finally, cost was an important consideration. Given the observed levels of bycatch and the questions surrounding the appropriateness of GHLs and catch composition it would be important to continue observer coverage and maintain the close level of contact with the fleet. This is a costly approach and ADF&G lacks the funds for this level of management.

*Octopus:*
State fisheries exist in Cook Inlet and Prince William Sound. GHLs were established based on historical catches and are as follows: Cook Inlet is GHL 35,000 lb (15.3 t); Prince William Sound GHL is a range from 0-35,000 lb (15.3 t). The GHL was reached in Cook Inlet in 2013, and has been achieved or within

1,000 lbs. of the GHL for the past 7 years. PWS octopus harvest has been minimal since 2002. Catch from Cook Inlet and Prince William Sound fisheries are shown ion Table 11.

Table 11 Central Region Octopus Harvest 2002-2013

| | PWS Area | | | Cook Inlet Area | | |
|---|---|---|---|---|---|---|
| **Year** | **Vessel** | **Landings** | **Harvest** | **Vessel** | **Landings** | **Harvest** |
| 2002 | c | c | c | 11 | 166 | 38,522 |
| 2003 | c | c | c | 8 | 133 | 30,322 |
| 2004 | c | c | c | 11 | 127 | 35,981 |
| 2005 | c | c | c | 9 | 104 | 34,977 |
| 2006 | c | c | c | 8 | 108 | 30,558 |
| 2007 | | | | 7 | 85 | 36,017 |
| 2008 | c | c | c | 8 | 136 | 35,325 |
| 2009 | | | | 15 | 110 | 37,517 |
| 2010 | 4 | 24 | 939 | 13 | 107 | 33,595 |
| 2011 | | | | 15 | 104 | 37,606 |
| 2012 | 3 | 7 | 105 | 13 | 151 | 34,877 |
| 2013 | 9 | 50 | 1,095 | 15 | 135 | 35,731 |

- 'c' indicate confidential data.
- Data includes nominal amounts of octopus discarded at sea.
- Primary harvest occurs during pot fisheries.
- 2013 numbers are not final.

## 3.3 In-season management issues

Both skates and octopus are currently managed in the GOA on bycatch-only status. Separate area-specific ABCs and TACs are set for big and longnose skates. Thus, should the Council recommend and NMFS approve opening a directed fishery for skates in the EGOA for big and longnose skates, no modification to the current specifications process is needed. Octopus however, is managed under a gulfwide TAC and on bycatch-only status. Should the Council recommend (and NMFS approve) opening a directed fishery for octopus in the upcoming specifications cycle, the following process would need to occur:

1. GOA Plan Team recommended options for area-specific ABC break-outs to be included in the November assessment. (note the Plan Team provided their recommendation for an area apportionment should the SSC and Council decide to apportion octopus to allow for a directed fishery).
2. The November octopus stock assessment would need to include options (or sufficient information to calculate) ABC by area to be recommended by the GOA PT.[Note this information is provided in this paper as well as the introduction to the GOA SAFE report and GOA Plan Team minutes].
3. SSC would need to recommend area-specific ABCs in December. Council would then be able to establish TACs by area. These catch limits would not be effective until February/March absent NMFS revising the final 2013/14 harvest specifications for January 1, 2014. Thus opening a directed fishery would not occur until the 2014/15 harvest specifications are approved.

4. For catch accounting and fish tickets there is only one species code, 870. At least seven species are found in the GOA. The species composition both of the natural community and the commercial harvest is not well documented, but research indicates that the Giant Pacific octopus, *Enteroctopus dofleini*, is the most abundant octopus species in shelf waters and makes up the bulk of octopus catches in commercial fisheries. It may be necessary to have a separate species code for Giant Pacific octopus. This is a regulatory amendment (proposed and final rulemaking) for Table 2a FMP Species Codes and a Catch Accounting System programming change.
5. Species identification guides for industry (vessel and plant operators) may be needed. This would depend on how difficult octopus are to identify. Guides for rockfish and skates have been provided previously. As an alternative, retention of smaller octopus could be prohibited to limit harvest to *E. dofleini* (other species do not grow as large).
6. Maximum retainable amounts would be unchanged (http://alaskafisheries.noaa.gov/rr/tables/tabl10.pdf). If octopus were to open for directed fishing then retained octopus could be used as a basis species even though the species in the "other species" group are not open for directed fishing. However, if it was decided that octopuses needed to be separate from "other species" in 50 CFR 679, Table 10, then it is a regulatory amendment (proposed and final rulemaking).

The following items apply equally to directed fishing for skates and octopus:

7. An assessment would need to be made if an octopus directed fishery or a skate directed fishery would increase incidental catch of groundfish or other PSC species.
8. An assessment of gear specifications may be needed. The EGOA is closed to trawling so it would be a fixed-gear only fishery. Octopus habitat pots are generally longlined, which is prohibited for crab pots. It is also possible to fish octopus with trawls and tangle hooks, or by scuba diving. Some kind of gear specifications would probably be needed.

# 4 References


Conners, M.E., Aydin, K., and C.L. Conrath. 2012. Assessment of the Octopus stock complex in the Gulf of Alaska. In Stock Assessment and Fishery Evaluation for the Gulf of Alaska Groundfish Fisheries. North Pacific Fishery Management Council, Anchorage, AK.

Conrath, C.L. and M. E. Conners. (Fishery Bulletin, in press) Aspects of the reproductive biology of the giant Pacific octopus *Enteroctopus dofleini*, in the Gulf of Alaska.

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

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

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

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

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

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

Hartwick, B. 1983. *Octopus dofleini*. In Cephalopod Life Cycles Vol. I. P.R. Boyle eds. 277-291.

Hartwick, E.B., R.F. Ambrose, and S.M.C. Robinson. 1984. Dynamics of shallow-water populations of *Octopus dofleini*. Mar.Biol. 82:65-72.

Hartwick, E.B, and I. Barriga (1989) *Octopus dofleini*: biology and fisheries in Canada (in) Lang, M. A. and F.G. Hochberg(eds.) (1997). Proceedings of the Workshop on the Fishery and market potential of octopus in California. Smithsonian Institutions: Washington. 192 p.

Jorgensen, E.M. 2009. Field guide to squids and octopods of the eastern North Pacific and Bering Sea. Alaska Sea Grant Pub.No. SG-ED-65, 100pp.

Kanamaru, S. 1964. The octopods off the coast of Rumoi and the biology of mizudako. Hokkaido Marine Research Centre Monthly Report 21(4&5):189-210.

Kanamaru, S. and Y. Yamashita. 1967. The octopus mizudako. Part 1, Ch. 12. Investigations of the marine resources of Hokkaido and developments of the fishing industry, 1961 – 1965.

King, J.R., and G.A. McFarlane, 2003. Marine fish life history strategies: applications to fishery

management. Fish. Man. And Ecology, 10: 249-264.

Kubodera, T. 1991. Distribution and abundance of the early life stages of octopus, *Octopus dofleini* Wulker, 1910 in the North Pacific. 49(1-2) 235-243.

Laptikhovsky, V.V. 1999. Fecundity and reproductive strategy of three species of octopods from the Northwest Bering Sea. Russian Journal of Marine Biology 25: 342-346.

Laptikhovsky, V. 2001. Fecundity, egg masses and hatchlings of *Benthoctopus* spp. (Octopodidae) in Falkland waters. J. Mar. Biol. Ass. U.K. 81: 267-270.

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

Mottet, M. G. 1975. The fishery biology of *Octopus dofleini*. Washington Department of Fisheries Technical Report No. 16, 39 pp. National Research Council. 1998. Improving fish stock assessments. National Academy Press, Washington, D.C.

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

Osako, M. and . Murata. 1983. Stock assessment of cephalopod resources in the northwestern Pacific. Pages55-144 *In* J.F. Caddy, ed. Advances in assessment of world cephalopod resources. FAO Fisheries Tech. Paper 231.

Paust, B.C. 1988. Fishing for octopus, a guide for commercial fishermen. Alaska Sea Grant Report No. 88-3, 48 pp.

Paust, B.C. (1997) *Octopus dofleini*: Commercial fishery in Alaska (in) Lang, M. A. and F.G. Hochberg (eds.) (1997). Proceedings of the Workshop on the Fishery and market potential of octopus in California. Smithsonian Institutions: Washington. 192 p.

Perry, R.I., C.J. Walters, and J.A. Boutillier. 1999. A framework for providing scientific advice for the management of new and developing invertebrate fisheries. Rev. Fish Biology and Fisheries 9:125-150.

Pickford, G.E. 1964. *Octopus dofleini* (Wulker), the giant octopus of the North Pacific. Bulleting of the Bingham Oceanographic Collection 19:1-70

Robinson, S.M.C. 1983.Growth of the Giant Pacific octopus, *Octopus dofleini martini* on the west coast of British Columbia. MSc thesis, Simon Fraser University.

Robinson, S.M.C. and E.B. Hartwick. 1986. Analysis of growth based on tag-recapture of the Giant Pacific octopus *Octopus dofleini martini*. Journal of Zoology 209: 559-572.

Rooper, C.F.E., M.J. Sweeny, and C.E. Nauen. 1984. FAO Species catalogue vol. 3 cephalopods of the world. FAO Fisheries Synopsis No. 125, Vol. 3.

Sato, K. 1996. Survey of sexual maturation in *Octopus dofleini* in the coastal waters off Cape Shiriya, Shimokita Peninsula, Aomori Prefecture. Nippon Suisan Gakkaishi 62(3): 355-360.

Sato, R. and H. Hatanaka. 1983. A review of assessment of Japanese distant-water fisheries for cephalopods. Pages 145-203 *In* J.F. Caddy, ed. Advances in assessment of world cephalopod resources. FAO Fisheries Tech. Paper 231.

Scheel, D. 2002 Characteristics of habitats used by *Enteroctopus dofleini* in Prince William Sound and Cook Inlet, Alaska. Marine Ecology 23(3):185-206.

Scheel, D. and L. Bisson. 2012. Movement patterns of giant Pacific octopuses, *Enteroctopus dofleini* (Wulker, 1910). Journal of Experimental and Marine Biology and Ecology 416-417: 21-31.

Sinclair, E.H. and T.K. Zeppelin. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*). J Mammology 83:973-990.

Smith, A.C., and G. Mackenzie, Jr. 1948. The marine mollusks and brachiopods of Monterey Bay, California and vicinity. Proceedings of the California Academy of Sciences 26: 147-245.

Sosebee, K., 1998. Skates. In Status of Fishery Resources off the Northeastern United States for 1998

(Stephen H. Clark, ed.), p. 114-115. NOAA Technical Memorandum NMFS-NE-115.

Toussaint, R.K., D. Scheel, G.K. Sage, and S.L. Talbot. 2012. Nuclear and mitochondrial markers reveal evidence for genetically segregated cryptic speciation in giant Pacific octopuses from Prince William Sound, Alaska. Conservation Genetics. Online First: DOI 10.1007/s10592-012-0392-4.

Villanueva, R. 1992. Continuous spawning in the cirrate octopods *Opisthoteuthis agassizii* and *O. vossi*: features of sexual maturation defining a reproductive strategy in cephalopods. Marine Biology 114: 265-275.

Wakabayashi, K, R.G. Bakkala, and M. S. Alton. 1985. Methods of the U.S.-Japan demersal trawl surveys (in) R.G. Bakkala and K. Wakabayashi (eds.), Results of cooperative U.S. - Japan groundfish investigations in the Bering Sea during May - August 1979. International North Pacific Fisheries Commission Bulletin 44.

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

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

Young, R.E. 2008. *Japetella diaphana* (Hoyle 1885). Version 28 April 2008 (under construction). http://tolweb.org/Japetella_diaphana/20224/2008.04.28 in the Tree of Life Web Project, http://tolweb.org/

Young, R.E., and M. Vecchione. 1999. Morphological observations on a hatchling and a paralarva of the vampire squid, *Vampyroteuthis infernalis* Chun (Mollusca: Cephalopoda). Proceedings of the Biological Society of Washington 112:661-666.

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