



NOAA Technical Memorandum NMFS-AFSC-177

# **Food Habits and Diet Overlap of Seven Skate Species in the Aleutian Islands**

by  
M-S. Yang

**U.S. DEPARTMENT OF COMMERCE**  
National Oceanic and Atmospheric Administration  
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**ABSTRACT**

In the Aleutian Islands ecosystem, food habits of many non-commercial species such as skates have not been studied. This study provides the basic information on food habits and diet overlap of 7 skate species found in the Aleutian Islands area. These species include the Aleutian skate (*Bathyraja aleutica*), big skate (*Raja binoculata*), Bering skate (*B. interrupta*), Alaska skate (*B. parmifera*), black skate (*B. trachura*), mud skate (*B. taranetzi*), and whiteblotched skate (*B. maculata*).

Small skates (black skates, Bering skates, and mud skates) ate mainly polychaetes, mysids, isopods, and gammarid amphipods. Larger skates (big skates, Aleutian skates, whiteblotched skates, and Alaska skates) fed primarily on Atka mackerel, walleye pollock, other miscellaneous fish, crabs, and shrimp.





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## INTRODUCTION

In the North Pacific, skates (family Rajidae) have been managed under the "other species" category within the Bering Sea Aleutian Islands (BSAI) groundfish fishery management plan. There is no directed fishery for skates at present in the BSAI area although a directed skate fishery developed in the Gulf of Alaska in 2003 (Gaichas et al. 2004). As a result, there has been an interest in skates as a potential target fishery in the BSAI. Presently, skates are taken only as bycatch in fisheries directed at target species in the BSAI area. The recent average catch of all skates was 18,645 t (Gaichas et al. 2004).

There are about 13 skate species in three genera, *Amblyraja*, *Raja* and *Bathyraja*, in the eastern North Pacific (Mecklenburg et al. 2002, Stevenson and Orr 2005). Previous studies on skates (e.g., Brodeur and Livingston 1988, Livingston and deReynier 1996, Orlov 1998, Dolganov 1999, Hoff 2002, Orlov 2003, Stevenson et al. 2004, Ebert 2005) have covered the fields of taxonomy, reproductive biology, diets of different skate species in the eastern Bering Sea (both shelf and slope), western Bering Sea, northern California, northern Kuril Islands, and southern Kamchatka areas.

While predator-prey relationships among the commercially important groundfish species has been reported for the Aleutian Islands ecosystem (Yang 2003), food habits of many non-commercial species such as skates have not been studied. This study describes the food habits of seven skate species found in the Aleutian Islands area. These species include the Aleutian skate (*Bathyraja aleutica*), big skate (*Raja binoculata*), Bering skate (*B. interrupta*), Alaska skate (*B. parmifera*), black skate (*B. trachura*), mud skate (*B. taranetzi*), and whiteblotched skate (*B. maculata*).

#### **METHODS**

The study area covered the southeastern Bering Sea, from Unimak Pass (165°W long.) to the Islands of Four Mountains (170° W) and the Aleutian Islands from long. 170° W to Stalemate Bank (170° E).

Scientists on board chartered bottom trawl vessels collected stomachs from skates captured during Alaska Fisheries Science Center (AFSC) trawl surveys in 1994, 1997, 2000, and 2002. All surveys were conducted during the summer using the Resource Assessment and Conservation Engineering (RACE) Division's Poly-Nor'eastern, hard bottom,

high-opening bottom trawl. The trawls were constructed of 12.7 cm (5 in) stretched mesh polyethylene web with a 3.2 cm (1-1/4 in) stretched mesh nylon liner in the codend to retain smaller specimens. The complete gear specifications are given in Zenger (2002).

The disc width (wing-tip to wing-tip) of skates was measured. All stomach samples were preserved in 10% formalin and transferred into 70% ethanol before being analyzed. At the AFSC, each prey item was classified to the lowest practical taxonomic level. Prey items from all skates were weighed. Fish prey were identified as fishery offal if the parts (usually heads or tails) had an evident cut. All fish prey were measured to standard length (SL). Carapace width was measured for Tanner crabs and carapace length was measured for pandalid shrimp. The detailed methodology of stomach collection and stomach contents analysis are given in Yang (2003).

The general diet of each species was summarized to show the mean percent frequency of occurrence, and the mean percent of the total weight of each prey item found in the stomach. These values were calculated as the average of the values of each haul.

Change in diet by predator size in terms of percent by weight of main prey items was examined for different size

groups (when data were available). The prey size data of commercially important fish, crabs, and shrimp, and some forage fish were also summarized.

Diet overlaps (in terms of the percent similarity index (PSI) by weight of the main prey items) among the seven skate species were compared. Because of the small sample sizes for some of the skate species, diet overlaps were not compared by different size groups.

## **RESULTS**

A total of 346 skate stomachs were collected and analyzed for the Aleutian Islands area. The general diet, diet variations by predator size, and prey size are described below for each species.

### **Aleutian Skate**

#### **General Diets**

The Aleutian skate is a large skate reaching 150 cm total length (TL) (Mecklenburg et al. 2002). The sampling locations are shown in Figure 1. The depth range of the haul locations ( $n = 16$ ) was 96–471 m with a mean and standard deviation ( $\pm$ SD) of 228.2 ( $\pm$  111.3) m. Only 23 (19 with food) stomachs were collected from 1994 to 2002

(Table 1). Because of the small sample size, stomach contents were pooled together for data analysis. Stomachs from specimens ranging from 31 to 101 cm disc width were examined. Walleye pollock and Atka mackerel were the most important prey fish of Aleutian skate. In terms of weight, they made up 25% and 14% of the total stomach contents, respectively.

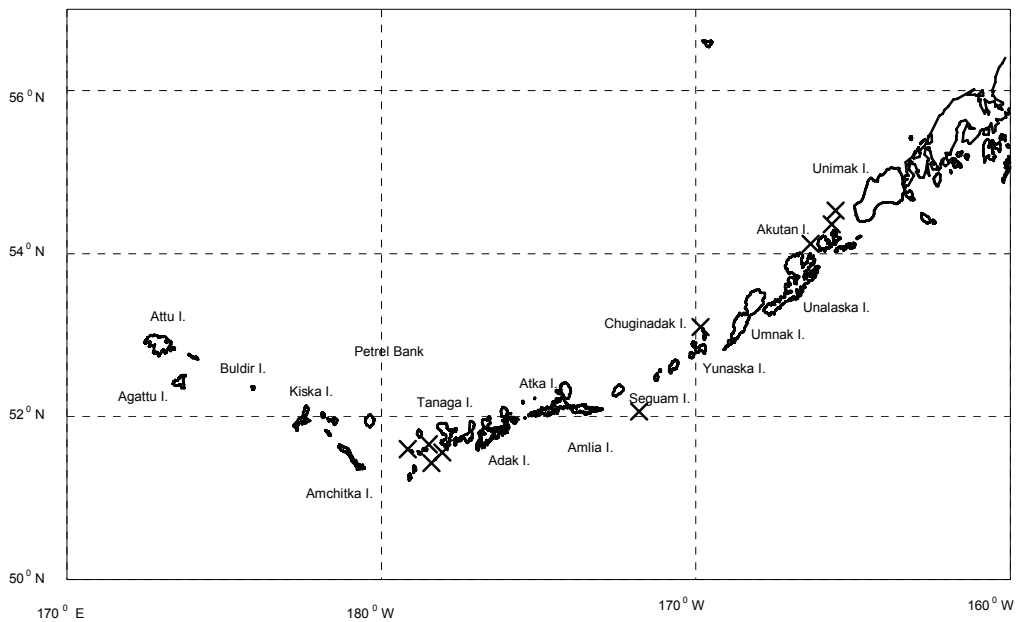


Figure 1. -- Collection locations (x) of Aleutian skate stomachs in the Aleutian Islands area.

Sculpins, arrowtooth flounder, and fishery offal were also consumed by Aleutian skates. Shrimp, mainly *Pandalus* spp., were the most important invertebrate prey. They comprised 21% of the total stomach contents weight. The Aleutian

skate diet also included 10% cephalopods (squid and octopus), 2% mysids, and 4% gammarids.

Atka mackerel consumed by Aleutian skates had a mean standard length ( $\pm$ SD) of 185 ( $\pm$  80.6) mm with a range 110-294 mm SL. The average size of walleye pollock consumed by Aleutian skates was 337 ( $\pm$  104.8) mm SL with a range of 191-471 mm SL.

Table 1.-- Prey items (expressed in mean percent frequency of occurrence, and mean percent total weight) of *Bathyrja aleutica* (Aleutian skate) collected in the Aleutian Islands area. (prey name arranged by phylogenetic order)

Prey name	Percent frequency	Percent weight
Anthozoa (anemome)	7.14	0.05
Cephalopoda (squid and octopus)	10.71	2.36
Teuthida (squid)	3.57	0.34
Octopoda (octopus)	14.29	7.20
Mysidae (mysid)	25.00	1.58
Isopoda (isopod)	14.29	3.92
Gammaridea (amphipod)	14.29	0.70
Caridea (shrimp)	8.93	0.41
Hippolytidae (shrimp)	14.29	3.81
<i>Pandalus</i> spp. (shrimp)	21.43	20.95
<i>Metacrangon variabilis</i> (deepsea spinyhead)	3.57	0.66
Reptantia (crab)	7.14	0.03
<i>Chionoecetes bairdi</i> (Tanner crab)	1.79	0.07
Teleostei (fish)	7.14	1.79
Non-gadoid fish remains	12.50	6.35
<i>Gadus macrocephalus</i> (Pacific cod)	1.79	0.13
<i>Theragra chalcogramma</i> (walleye pollock)	25.00	25.04
<i>Pleurogrammus monopterygius</i> (Atka mackerel)	21.43	14.18
<i>Hemilepidotus</i> sp. (sculpin)	1.79	2.51
Pleuronectoidei (flatfish)	1.79	0.02
<i>Atheresthes stomias</i> (arrowtooth flounder)	1.79	0.75
Fishery offal	7.14	7.14
Total non-empty stomachs = 19		
Total prey weight = 3280.2 g		
Total empty stomachs = 4		
Number of hauls = 14		



### Variation of Diet Based on Predator Size

The diet of Aleutian skate varied by predator size (Fig. 2). Smaller-sized (< 40 cm width) Aleutian skates consumed high percentages of cephalopods (16%), mysids (11%), and isopods (27%). Aleutian skates 40-59 cm consumed a high percentage of shrimp (81%), whereas skates 60-79 cm consumed 66% fish (33% of both pollock and Pacific cod, respectively). The largest size group ( $\geq$  80 cm) consumed high percentages of pollock (31%), Atka mackerel (25%), and miscellaneous fish (18%).

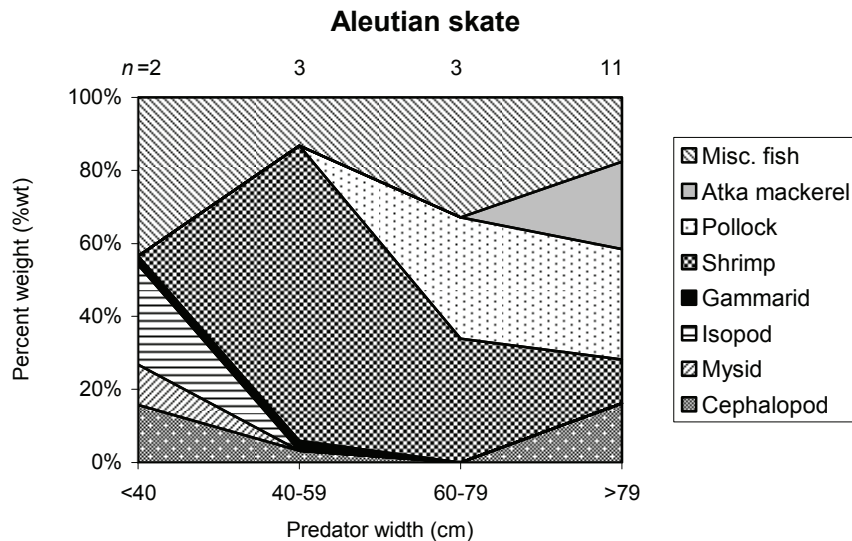


Figure 2.--Variations in the main food items of Aleutian skate (*Bathyraja aleutica*), by predator size, in the Aleutian Islands.  $n$  = sample size.

### **Diet Variation by Depth**

More smaller-sized Aleutian skates were found with increasing depth, and less prey fish were found in smaller-sized skates in the deeper area. In this study, we found that the stomach contents of Aleutian skates, collected in the area less than 200 m deep, comprised 85% (by weight) of fish, whereas the stomach contents of the Aleutian skate collected from deep area (200-470 m) comprised only 30% of fish. Instead, shrimp (mainly *Pandalus* spp.) and cephalopods comprised 37% and 20%, by weight of the total stomach contents, respectively.

### **Big Skate**

#### **General Diets**

Big skate is the largest skate in the Aleutian Islands area. They can reach 244 cm TL, but are rarely over 183 cm TL (Mecklenburg et al. 2002). The sampling locations were shown in Figure 3. The depth range of the haul locations ( $n = 2$ ) was 80-117 m with a mean and standard deviation ( $\pm$ SD) of 98.5 ( $\pm$  26.2) m. Stomachs from the two specimens collected in 2002 (79 and 91 cm disc width, respectively) were examined. Flatfish and Tanner crabs were the most important prey, comprising 56% and 43%, respectively, of

the total stomach contents weight of big skates (Table 2). Big skates also consumed small amount (1% by weight) of shrimp.

Due to the small sample size, depth and predator size variations were not analyzed. According to Stevenson et al. (in prep), big skates are only found in the eastern end of the Aleutian Islands. They also note that the big skate is most abundant at depths less than 100 m in the Gulf of Alaska.

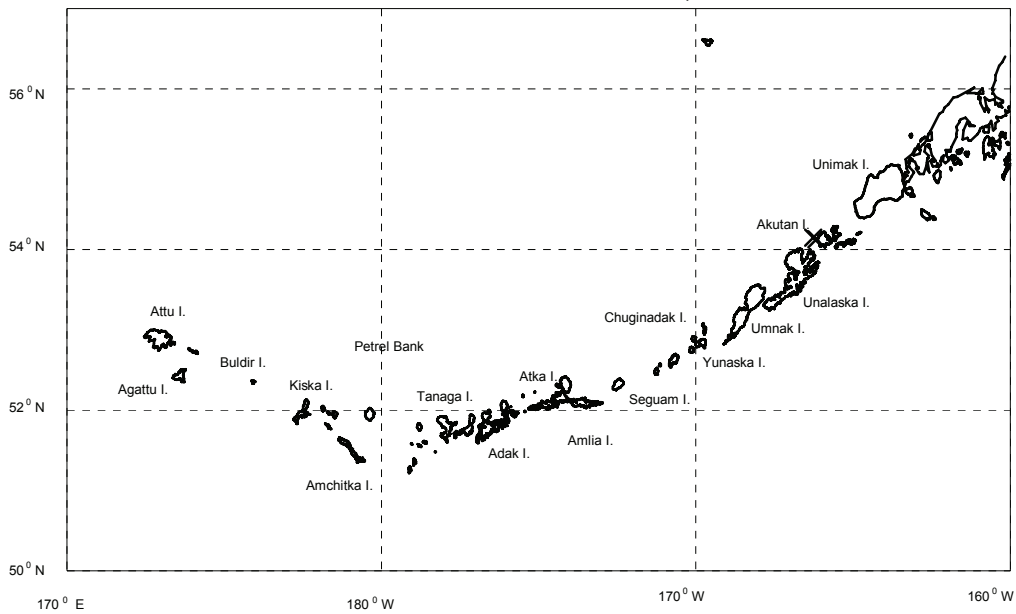


Figure 3. -- Collection locations (x) of big skate stomachs in the Aleutian Islands area.

Table 2.-- Prey items (expressed in mean percent frequency of occurrence, and mean percent total weight) of *Raja binoculata* (big skate) collected in the Aleutian Islands area. (prey name arranged by phylogenetic order).

Prey name	Percent frequency	Percent weight
Natantia (shrimp)	50.00	0.88
<i>Chionoecetes bairdi</i> (Tanner crab)	50.00	43.18
Pleuronectidae (flatfish)	100.00	55.94
Total non-empty stomachs = 2		
Total prey weight = 55.16 g		
Total empty stomachs = 0		
Number of hauls = 2		

## Bering Skate

### General Diets

The Bering skate is a relatively small skate, with the largest reaching about 86 cm TL (Mecklenburg et al. 2002). The sampling locations of the four Bering skate collected from the Aleutian Islands are shown in Figure 4. The depth of the haul locations ( $n = 3$ ) ranged from 191 to 461 m with a mean and standard deviation ( $\pm$ SD) of 303 ( $\pm$  140.8) m. For the four specimens which ranged between 32 and 50 cm disc width, Tanner crab, lyre crab (*Hyas lyratus*), and polychaetes were the most important prey; they comprised 31%, 27%, and 25%, respectively, of the total stomach contents weight. Bering skates also consumed some shrimp (6%), isopods (4%), and gammarid amphipods (2%) (Table 3).

The three Tanner crabs consumed by Bering skates had a mean carapace width ( $\pm$ SD) of 42.0 ( $\pm$  16.8) mm with a range

of 24-58 mm. One sculpin consumed by a Bering skate was 43 mm SL.

Because of the small sample size of Bering skates, an analysis of diet variation between different size groups or depth groups was not done.

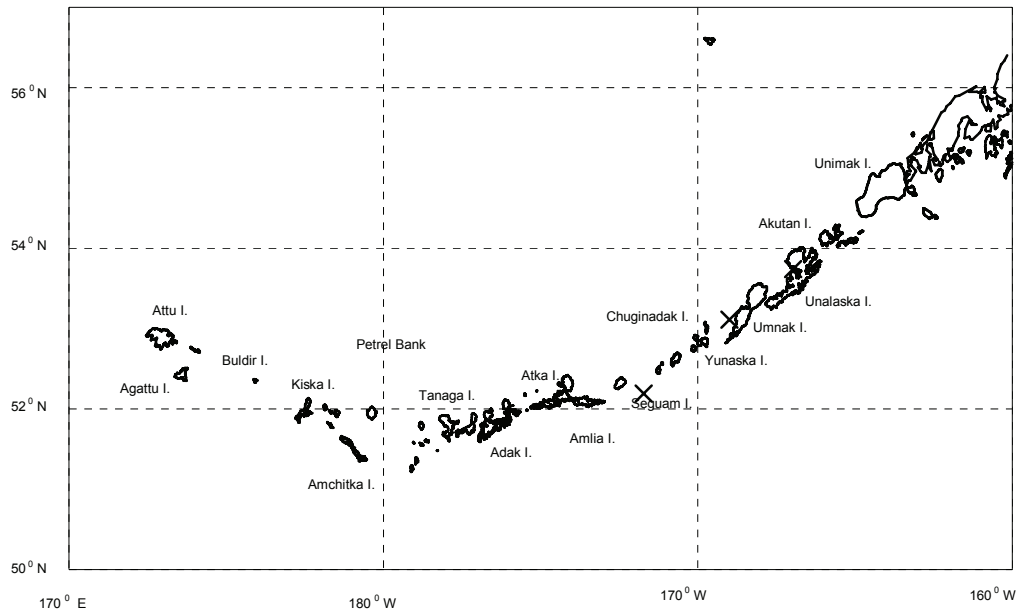


Figure 4. -- Collection locations (x) of Bering skate stomachs in the Aleutian Islands area.

Table 3.-- Prey items (expressed in mean percent frequency of occurrence, and mean percent total weight) of *Bathyraja interrupta* (Bering skate) collected in the Aleutian Islands area. (prey name arranged by phylogenetic order).

Prey name	Percent frequency	Percent weight
Polychaeta (worm)	66.67	23.82
Polynoidae (polychaete)	33.33	0.93
Gastropoda (snail)	33.33	0.85
Cephalopoda (squid and octopus)	33.33	0.19
Mysidae (mysid)	33.33	0.34
Isopoda (isopod)	33.33	4.40
Gammaridea (amphipod)	33.33	1.92
<i>Spirontocaris arcuata</i> (shrimp)	33.33	0.30
Pandalidae (shrimp)	50.00	3.25
<i>Pandalus montagui tridens</i> (shrimp)	33.33	0.22
Crangonidae (shrimp)	16.67	1.55
<i>Metacrangon variabilis</i> (deepsea spinyhead)	33.33	0.21
Reptantia (crab)	33.33	2.92
<i>Hyas lyratus</i> (lyre crab)	33.33	26.92
<i>Chionoecetes bairdi</i> (Tanner crab)	33.33	31.44
Non-gadoid fish remains	33.33	0.18
Agonidae (poacher)	33.33	0.57
Total non-empty stomachs = 4		
Total prey weight = 83.001 g		
Total empty stomachs = 0		
Number of hauls = 3		

## **Alaska Skate**

### **General Diets**

The Alaska skate is a large skate reaching to 107 cm TL (Mecklenburg 2002). A total of 127 Alaska skate were collected at sampling locations in the Aleutian Islands area (Fig. 5). The depth range of the haul locations ( $n = 55$ ) ranged from 56 to 260 m with a mean and standard deviation (SD) of 147.4 ( $\pm 45.7$ ) m. Specimens analyzed ranged from 11 to 122 cm disc width. Of 127 stomachs analyzed, 109 contained food (Table 4). Atka mackerel was the most important prey fish of Alaska skate in terms of weight comprising 51% of the total stomach contents. Walleye pollock comprised 6% of the total stomach contents. Miscellaneous fish (e.g., eelpouts, rockfish, sculpins, snailfish, searchers, stichaeids, sand lance, Pacific halibut) made up 21% of the total stomach contents weight. Crabs (mainly hermit crabs and Tanner crabs) and gammarid amphipods were the most important invertebrate prey of Alaska skate. They made up 8% and 5% of the total stomach contents weight, respectively.

Atka mackerel consumed by Alaska skates had a mean standard length ( $\pm$ SD) of 243 ( $\pm 74.2$ ) mm with a range of 36-400 mm. The average size of walleye pollock consumed by

Alaska skates was 422 ( $\pm$  111.9) mm SL with a range 296-510 mm SL.

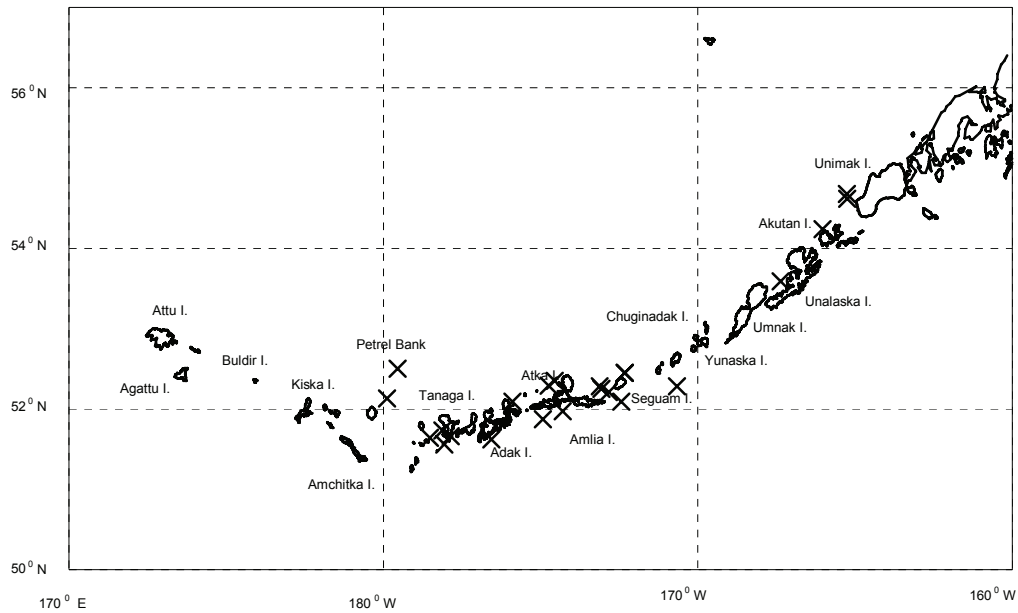


Figure 5. -- Collection locations (x) of Alaska skate stomachs in the Aleutian Islands area.



Table 4.-- Prey items (expressed in mean percent frequency of occurrence, and mean percent total weight) of *Bathyraja parmifera* (Alaska skate) collected in the Aleutian Islands area. (prey name arranged by phylogenetic order).

Prey name	Percent frequency	Percent weight
Polychaeta (worm)	0.96	0.04
Hirudinea (leech)	0.96	0.04
Teuthida (squid)	0.64	0.00
Octopoda (octopus)	0.96	0.00
<i>Gnathophausia</i> sp.	1.92	1.92
Mysidae (mysid)	1.92	0.19
Cumacea (cumacean)	1.92	0.19
Isopoda (isopod)	2.88	0.28
Gammaridea (amphipod)	8.33	4.82
Euphausiacea (euphausiid)	0.96	0.00
Natantia (shrimp)	0.64	0.00
Hippolytidae (shrimp)	0.96	0.01
Pandalidae (shrimp)	1.28	0.00
<i>Pandalus montagui tridens</i> (shrimp)	3.04	2.00
Crangonidae (shrimp)	2.88	0.44
Reptantia (crab)	2.96	0.44
Paguridae (hermit crab)	5.45	3.91
<i>Acantholithodes hispidus</i> (fussy crab)	0.48	0.08
<i>Placetron wosnessenskii</i> (scale crab)	2.16	0.18
Majidae (spider crab)	0.64	0.01
<i>Hyas</i> sp. (lyre crab)	2.56	0.08
<i>Chionoecetes bairdi</i> (Tanner crab)	2.88	3.08
Atelecyclidae (crab)	1.92	0.15
Ophiurida (brittle star)	0.64	0.00
Teleostei (fish)	2.16	0.07
Non-gadoid fish remains	2.40	0.25
Gadidae (gadid fish)	1.92	1.92
<i>Theragra chalcogramma</i> (walleye pollock)	6.41	6.30
Zoarcidae (eelpout)	0.64	0.24
<i>Sebastes</i> sp. (rockfish)	4.49	4.07
<i>Sebastes alutus</i> (Pacific ocean perch)	0.32	0.83
<i>Hexagrammos decagrammus</i> (kelp greenling)	0.96	0.74
<i>Pleurogrammus monopterygius</i> (Atka mackerel)	50.88	50.73
Cottoidei (sculpin)	2.40	0.98
Cottidae (sculpin)	1.60	1.84

Table 4.--Continued.

Prey name	Percent frequency	Percent weight
Cyclopteridae (snailfish)	1.60	0.26
<i>Bathymaster signatus</i> (searcher)	1.44	0.78
Stichaeidae (prickleback)	0.48	0.16
<i>Ammodytes</i> sp. (sand lance)	1.92	1.48
<i>Ammodytes hexapterus</i> (Pacific sand lance)	3.21	1.92
<i>Hippoglossus stenolepis</i> (Pacific halibut)	0.96	0.06
Unidentified organic material	1.92	1.92
Fishery offal	5.05	5.64
Overboard material (non-fishery)	1.92	1.92
Total non-empty stomachs = 108		
Total prey weight = 15190.347 g		
Total empty stomachs = 19		
Number of hauls = 52		

### Variation of Diet Based on Predator Size

The diet of Alaska skate varied with predator size (Fig. 6). Smaller (< 40 cm width) Alaska skate consumed high percentages of gammarid amphipods (45%), and hermit crabs (25%). Alaska skates 40–59 cm consumed high percentages of spider crab (33%), Pacific sand lance (26%), and gammarid amphipods (24%), whereas the diet of skates 60–79 cm was made up of 92% fish (61% Atka mackerel, 9% walleye pollock, 3% Pacific sand lance, and 6% rockfish). The largest size group ( $\geq$  80 cm) consumed high percentage of Atka mackerel (56%), and some miscellaneous fish (walleye pollock, sculpins, Pacific sand lance, and searcher). The diet of this group was also made up of 11% crab and 7% shrimp.

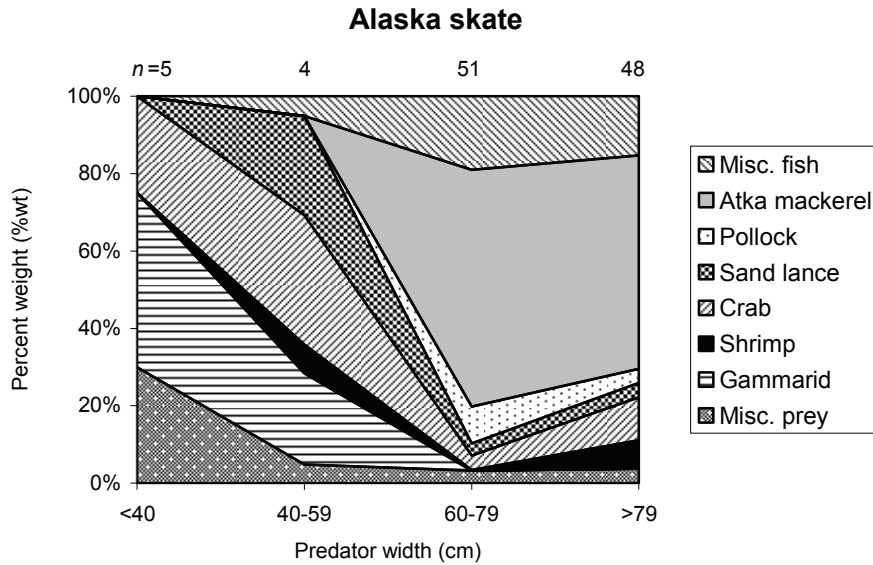


Figure 6.--Variations in the main food items of Alaska skate (*Bathyraja parmifera*), by predator size, in the Aleutian Islands. *n* = sample size.

### Diet Variation by Depth

According to Stevenson et al. (in prep), Alaska skate is the most common skate in the shallow waters of the Bering Sea continental shelf accounting for more than 90% of the skate catch. They also note that Alaska skate is one of the three dominant species (the other two are whiteblotched skate and mud skate) in the Aleutian Islands. All Alaska skate stomachs were collected from depths no deeper than 260 m. The diets of Alaska skate collected from

three different depths (< 100 m, 100-199 m, and  $\geq$  200 m) were very similar. They were all comprised 75% to 82% of fish (mainly Atka mackerel), 2% to 9% of crabs, and 4% to 9% of gammarid amphipods. Within each depth group, the diet of all larger-sized fish ( $\geq$  60 cm disc width) was made up of more than 75% of miscellaneous fish.

## **Black Skate**

### **General Diets**

The black skate is another small skate reaching only 89 cm TL (Mecklenburg 2002). Four black skates were sampled during one haul (Fig. 7). The depth of the haul location was 461 m. Stomachs were collected from four fish ranging from 26 to 44 cm disc width. Polychaetes were the most important prey; they comprised 57% of the total stomach contents weight of black skates. Black skates also consumed some fish (15%, mainly myctophids), cephalopods (8%), pandalid shrimp (5%), mysids (4%) and isopods (4%) (Table 5). One myctophid consumed by a 34 cm black skate was 31 mm SL.

Because of the small sample size of Bering skate stomachs, an analysis of diet variation between different size groups or different depth groups was not done.

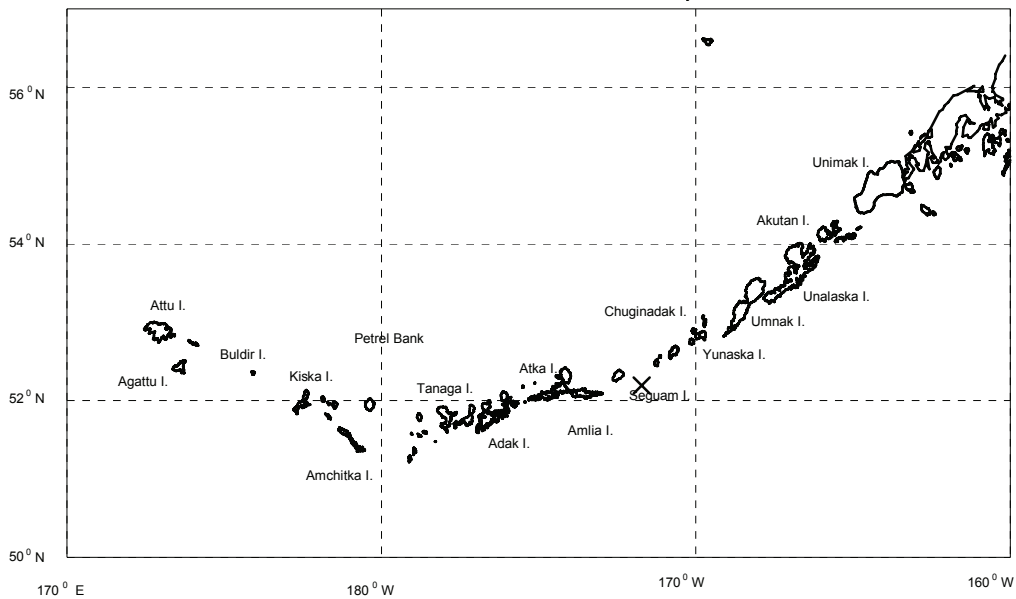


Figure 7. -- Collection locations (x) of black skate stomachs in the Aleutian Islands area.

Table 5.-- Prey items (expressed in mean percent frequency of occurrence, and mean percent total weight) of *Bathyraja trachura* (black skate) collected in the Aleutian Islands area.

Prey name	Percent frequency	Percent weight
Polychaeta (worm)	100.00	57.38
Cephalopoda (squid and octopus)	25.00	2.28
Teuthida (squid)	25.00	5.74
Calanoida (copepod)	25.00	0.22
Mysidae (mysid)	75.00	4.38
Isopoda (isopod)	75.00	4.26
Gammaridea (amphipod)	75.00	2.87
Euphausiacea (euphausiid)	25.00	0.59
Caridea (shrimp)	25.00	0.99
Hippolytidae (shrimp)	25.00	1.11
Pandalidae (shrimp)	50.00	4.88
Teleostei (fish)	50.00	13.08
Myctophidae (lanternfish)	25.00	2.22
Total non-empty stomachs = 4		
Total prey weight = 16.2 g		
Total empty stomachs = 0		
Number of hauls = 1		

## Mud Skate

### General Diets

The mud skate is another small to medium-sized skate. They can reach to 70 cm TL (Mecklenburg 2002). The depth range of the haul locations ( $n = 24$ ) was 150–471 m with a mean and standard deviation (SD) of 309.5 ( $\pm 80.5$ ) m. The sampling locations of the mud skate were shown in Figure 8. Stomachs were collected from 116 mud skates ranging from 6 to 72 cm disc width. A total of 113 stomachs contained food (Table 6). Gammarid amphipods were the most important prey of mud skate comprising 44% of the total stomach contents weight. Polychaetes were the second most important prey of mud skates comprising 17% of the total stomach contents weight. Shrimp (mainly pandalids) made up 15% of the total stomach contents weight. Fish were not important prey of mud skates, comprising only 5% of the total stomach contents weight. Mud skates also consumed crabs (6%), isopods (5%), mysids (2%), and squid (2%).

The *Pandalus* spp. consumed by mud skates had a mean carapace length ( $\pm$ SD) of 10.9 ( $\pm 4.3$ ) mm with a range of 6–23 mm. The average size of myctophids consumed by mud skates was 29.5 ( $\pm 4.9$ ) mm SL with a range of 26–33 mm SL.

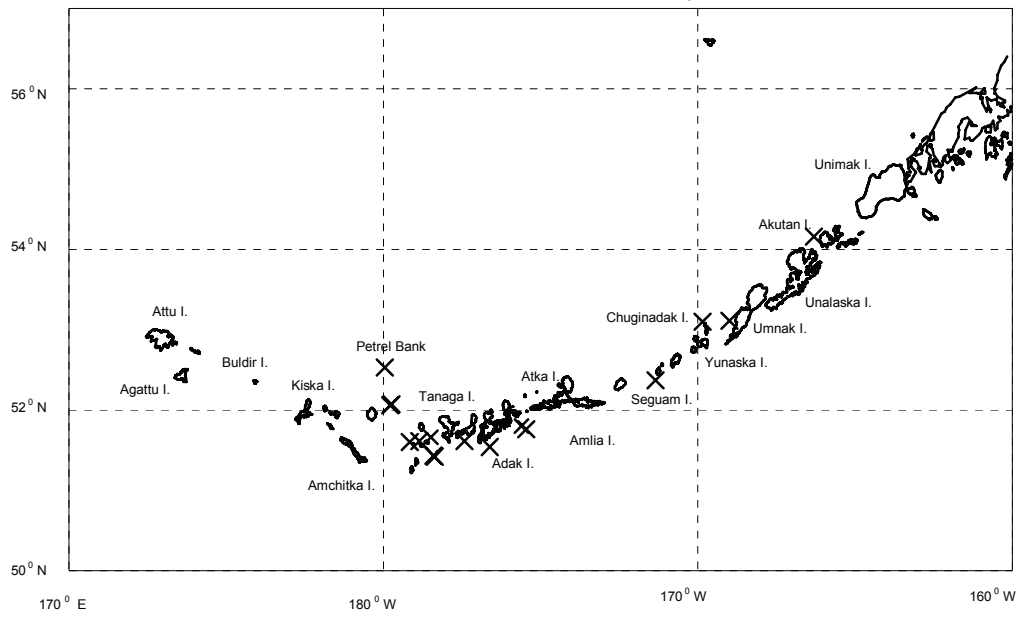


Figure 8. -- Collection locations (x) of mud skate stomachs in the Aleutian Islands area.

Table 6.-- Prey items (expressed in mean percent frequency of occurrence, and mean percent total weight) of *Bathyraja taranetzi* (mud skate) collected in the Aleutian Islands area. (prey name arranged by phylogenetic order).

Prey name	Percent frequency	Percent weight
Polychaeta (worm)	77.92	16.81
Polynoidae (polychaete)	4.17	0.24
Hirudinea (leech)	0.42	0.00
Bivalvia (clam)	4.17	0.52
Cephalopoda (squid and octopus)	0.42	0.02
Teuthida (squid)	7.42	1.93
Octopoda (octopus)	0.60	0.17
Calanoida (copepod)	4.31	0.08
Malacostraca Leptostraca	0.42	0.00
<i>Gnathophausia gigas</i> (mysid)	0.42	0.01
Eucopiidae	2.08	0.03
Mysidae (mysid)	28.38	2.01
<i>Holmesiella anomala</i> (mysid)	0.60	0.05
<i>Pseudomma truncatum</i> (mysid)	2.62	0.08
Cumacea (cumacean)	7.45	0.11
Isopoda (isopod)	35.63	5.05
<i>Arcturus longispinus</i> (isopod)	2.08	0.10
Idoteidae (isopod)	1.67	0.48
Gammaridea (amphipod)	93.60	43.61
Ampeliscidae (amphipod)	0.83	0.02
<i>Themisto</i> sp. (amphipod)	0.42	0.01
Caprellidea (amphipod)	11.85	0.43
Euphausiacea (euphausiid)	8.69	0.32
Euphausiidae (euphausiid)	3.10	0.27
<i>Thysanoessa</i> sp. (euphausiid)	2.92	0.43
Natantia (shrimp)	4.17	0.59
Caridea (shrimp)	10.12	1.83
Hippolytidae (shrimp)	23.85	2.83
<i>Spirontocaris arcuata</i> (shrimp)	4.17	1.25
<i>Eualus</i> spp. (shrimp)	1.39	0.15
Pandalidae (shrimp)	4.72	0.96
<i>Pandalus</i> sp. (shrimp)	14.58	3.32
<i>Pandalus borealis</i> (shrimp)	0.60	0.55
<i>Pandalus goniurus</i> (shrimp)	1.25	1.18
<i>Pandalus montagui tridens</i> (shrimp)	4.17	0.17



Table 6.--Continued.

Prey name	Percent frequency	Percent weight
Crangonidae (shrimp)	4.52	0.37
<i>Argis</i> sp. (shrimp)	2.78	1.31
<i>Argis lar</i> (shrimp)	0.69	0.08
Reptantia (crab)	0.42	0.02
Paguridae (hermit crab)	2.92	0.20
<i>Munida quadrispina</i> (pinch bug)	8.75	1.69
<i>Hyas lyratus</i> (lyre crab)	4.17	3.73
Ectoprocta (bryozoan)	0.60	0.00
Copelata (larvacea)	0.42	0.03
Teleostei (fish)	8.27	0.85
Non-gadoid fish remains	0.42	0.01
Bathylagidae (deepsea smelts)	0.42	0.13
Myctophidae (lanternfish)	1.81	0.27
Cottoidei (sculpin)	2.08	3.81
Unidentified organic material	2.68	0.13
Unidentified worm-like organism	0.42	0.02
Fishery offal	1.67	1.76
Total non-empty stomachs = 113		
Total prey weight = 733.194 g		
Total empty stomachs = 3		
Number of hauls = 24		

### Variation of Diet Based on Predator Size

Figure 9 shows the variations of the diet of mud skates by predator size. Smaller (< 20 cm width) mud skates consumed high percentages of gammarid amphipods (65%), polychaetes (16%), and isopods (11%). Mud skates 20–39 cm consumed high percentages of gammarid amphipods (46%), shrimp (26%), and polychaetes (17%), whereas skates 40–59 cm consumed 28% of fish (17% sculpins, 9% fish offal). Mud skates > 59 cm consumed 28% of fish (17% sculpins, 9% fish offal).

The diet of skates (> 59 cm) was made up of a high percentage of cephalopods (66%), and unknown fish (33%). Their diet also included small amounts of mysids and isopods.

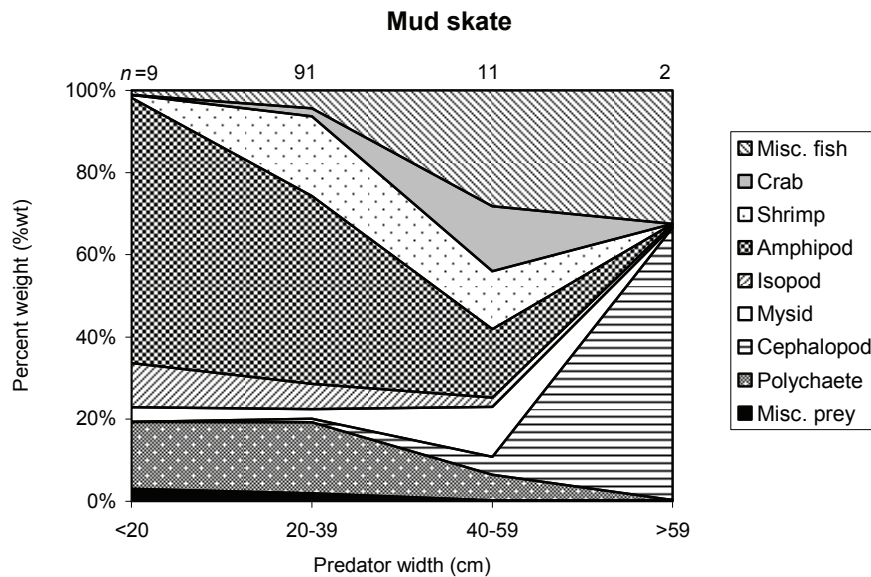


Figure 9.--Variations in the main food items of mud skate (*Bathyraja taranetzi*), by predator size, in the Aleutian Islands. *n* = sample size.

### **Diet Variation by Depth**

No mud skates were collected from the area shallower than 150 m. Mud skate consumed more prey fish (> 12% by weight) in the deeper area ( $\geq$  300 m) than in the depth less than 300 m (< 1% by weight). On the other hand, more crabs (46% by weight) were consumed in shallower (< 200 m) water than in the deeper ( $\geq$  200 m) water. Amphipod made up a high percentage (21% to 54%) in the total stomach contents weight in all four different depth (100-199 m, 200-299 m, 300-399 m, and  $\geq$  400 m) areas.

### **Whiteblotched Skate**

#### **General Diets**

Whiteblotched skate is another large skate. They can reach up to 120 cm TL (Mecklenburg 2002). The sampling locations of the mud skate are shown in Figure 10. The depth range of the haul locations ( $n = 24$ ) was 120-461 m with a mean and standard deviation (SD) of 225.5 ( $\pm$  90.8) m. Specimens ranged from 15 to 76 cm disc width. A total of 70 stomachs were analyzed, of which 69 contained food (Table 7). Atka mackerel were the most important prey of whiteblotched skates comprising 30% of the total stomach contents weight. Shrimp (mainly pandalids) were the second most important prey of whiteblotched skates, comprising 19%

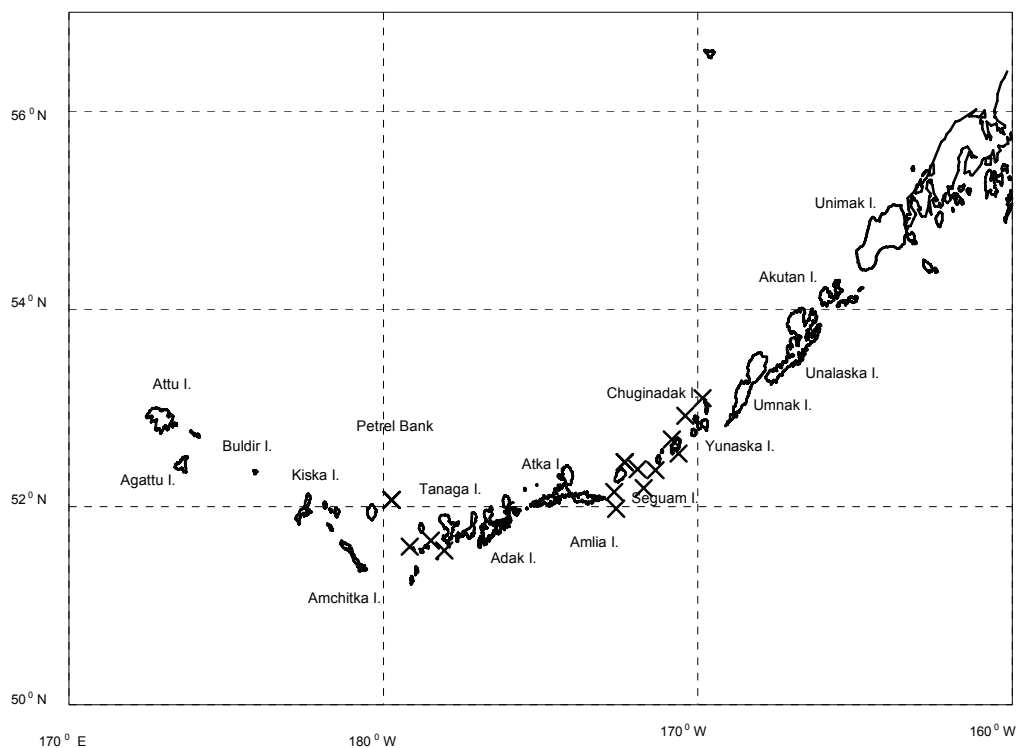


Figure 10. -- Collection locations (x) of whiteblotched skate stomachs in the Aleutian Islands area.

of the total stomach contents weight. Walleye pollock, crabs, and cephalopods comprised 13%, 9%, and 7% of the total stomach contents weight, respectively. Polychaetes made up less than 1% of the total stomach contents weight.

Atka mackerel consumed by whiteblotched skates had a mean standard length ( $\pm$ SD) of 220 ( $\pm$  70.9) mm with a range of 106–360 mm. The average size of walleye pollock consumed by whiteblotched skates was 190 ( $\pm$  226.3) mm SL with a range of 30–350 mm SL. The *Pandalus* spp. consumed by whiteblotched skates had a mean carapace length ( $\pm$ SD) of 19.1 ( $\pm$  5.8) mm with a range of 8–26 mm. The average size

of myctophids consumed by whiteblotched skates was

38 ( $\pm$  22.6) mm SL with a range of 22–54 mm SL.

Table 7.-- Prey items (expressed in mean percent frequency of occurrence, and mean percent total weight) of *Bathyraja maculata* (whiteblotched skate) collected in the Aleutian Islands area. (prey name arranged by phylogenetic order).

Prey name	Percent frequency	Percent weight
Polychaeta (worm)	7.02	0.64
Cephalopoda (squid and octopus)	7.25	0.67
Teuthida (squid)	15.60	3.32
Octopoda (octopus)	15.75	3.49
<i>Eucalanus bungii</i> (copepod)	0.62	0.00
<i>Gnathophausia</i> sp.	4.83	0.09
Mysidae (mysid)	7.61	0.39
Isopoda (isopod)	5.92	0.39
Gammaridea (amphipod)	7.02	0.17
Caprellidea (amphipod)	0.62	0.00
Euphausiacea (euphausiid)	5.22	0.04
Euphausiidae (euphausiid)	7.73	0.38
Natantia (shrimp)	2.17	0.13
Caridea (shrimp)	8.70	3.66
Hippolytidae (shrimp)	10.27	8.63
<i>Lebbeus groenlandicus</i> (shrimp)	1.45	1.28
Pandalidae (shrimp)	21.14	3.27
<i>Pandalus</i> spp. (shrimp)	3.26	0.29
<i>Pandalus borealis</i> (shrimp)	0.72	0.76
<i>Pandalus montagui tridens</i> (shrimp)	1.09	0.39
Crangonidae (shrimp)	0.72	0.13
<i>Argis</i> sp. (shrimp)	0.72	0.07
<i>Metacrangon variabilis</i> (deepsea spinyhead)	0.72	0.00
Reptantia (crab)	1.09	0.05
Paguridae (hermit crab)	3.79	0.37
Lithodidae (king crab)	2.17	1.48
<i>Placetron wosnessenskii</i> (scale crab)	1.71	0.44
<i>Lithodes couesi</i> (couesi king crab)	0.87	0.07
<i>Oregonia</i> sp. (decorator crab)	11.45	4.95
<i>Hyas lyratus</i> (lyre crab)	0.48	0.06
<i>Chorilia longipes</i> (decorator crab)	0.48	0.14
<i>Erimacrus isenbeckii</i> (Korean horse-hair crab)	2.17	1.12
Euryalina (basket star)	0.48	0.03
Urochordata (tunicate)	2.17	1.03
Copelata (larvacea)	0.62	0.00

Table 7.--Continued.

Prey name	Percent frequency	Percent weight
Teleostei (fish)	14.15	3.36
Non-gadoid fish remains	5.58	1.17
Myctophidae (lanternfish)	6.52	0.59
<i>Theragra chalcogramma</i> (walleye pollock)	13.54	12.97
<i>Sebastes</i> sp. (rockfish)	0.72	1.06
<i>Pleurogrammus monopterygius</i> (Atka mackerel)	30.42	30.46
Cottoidei (sculpin)	6.52	5.29
<i>Cottidae</i> (sculpin)	4.06	2.23
<i>Triglops ssepticus</i> (spectacled sculpin)	0.87	0.04
<i>Hypsagonus quadricornis</i> (4-horn poacher)	0.87	0.01
<i>Eumicrotremus</i> sp. (lumpsuckers)	4.35	0.12
Fishery offal	3.04	4.74
Total non-empty stomachs = 69		
Total prey weight = 4223.384 g		
Total empty stomachs = 1		
Number of hauls = 23		

### Variation of Diet Based on Predator Size

The diet of whiteblotched skates varied with predator size (Fig. 11). Smaller (< 20 cm width) whiteblotched skates consumed high percentages of miscellaneous prey (50% larvacean, 9% polychaetes, and 4% copepods), 21% amphipods, and 16% walleye pollock. Whiteblotched skates of 20–39 cm consumed high percentages of cephalopods (46%), isopods (23%), mysids (17%), and gammarid amphipods (12%), whereas skates of 40–59 cm consumed 40% shrimp, 16% crabs, 16% cephalopods, and 12% walleye pollock. The largest size group (> 59 cm) consumed high percentages of Atka mackerel (44%), and miscellaneous fish (27%). They also consumed some shrimp (10%) and crab (4%).

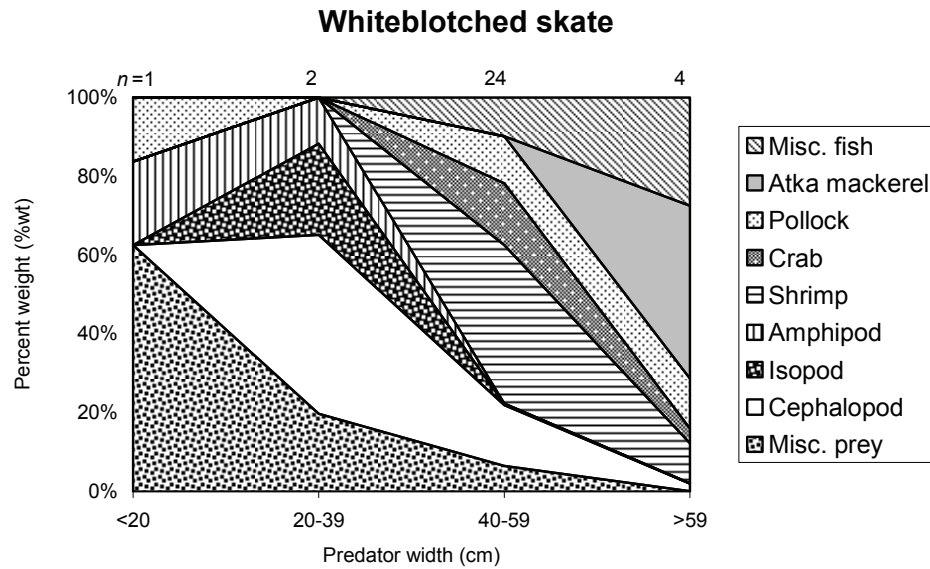


Figure 11.--Variations in the main food items of whiteblotched skate (*Bathyraja maculata*), by predator size, in the Aleutian Islands. *n* = sample size.

### Diet Variation by Depth

The diversity of the prey fish consumed by whiteblotched skate decreased when the depth increased. For example, in depth 100-199 m, there were seven prey fish species or groups (myctophid, walleye pollock, *Sebastes* sp., Atka mackerel, Spectacled sculpin (*Triglops scepticus*), four-horn poacher (*Hypsagonus quadricomis*), and *Eumicrotremus* sp.) in the diet of whiteblotched skate; whereas, in depth 200-299 m, there were only three fish species (walleye pollock, Atka mackerel, and non-gadid fish)

in the diet. The amount of fish consumed by whiteblotched skate also decreased when the depth increased (from 83% (by weight) in the 100-199 m depth interval to 52% in 200-299 m to 39% in 300-399 m). On the other hand, shrimp consumption by whiteblotched skate increased as the depth increased (from 6% to 21% to 45% in those three depth intervals).

### **Diet Overlap**

Table 8 lists the percent weight of the main prey items or prey groups for the seven skate species collected in the Aleutian Islands. There were nine main prey items or prey groups: polychaetes, cephalopods, mysids (including isopods and amphipods), shrimp, crabs, walleye pollock, Atka mackerel, miscellaneous fish, and miscellaneous prey (clams, snails, copepods, euphausiids, etc). The seven skate species can then be categorized into two groups: a smaller-sized group and a larger-sized group. The smaller-sized group includes black skate, Bering skate, and mud skate. The larger-sized group includes the big skate, Aleutian skate, whiteblotched skate, and Alaska skate. The smaller-sized skates mainly fed on polychaetes, mysids, isopods, amphipods, shrimp, and crabs, plus lesser amounts



Table 8. -- Percent weight of the main prey items of the skates collected in the Aleutian Islands. Ale, Aleutian skate; Big, big skate; Ber, Bering skate; Ala, Alaska skate; Bla, black skate; Mud, mud skate; Whi, whiteblotched skate.

Prey item	<b>Bla</b>	<b>Ber</b>	<b>Mud</b>	<b>Big</b>	<b>Ale</b>	<b>Whi</b>	<b>Ala</b>
Polychaetes	<b>57.4</b>	<b>24.8</b>	<b>16.8</b>	0.0	0.0	0.6	0.1
Cephalopods	<b>8.0</b>	<b>0.2</b>	<b>2.1</b>	0.0	9.9	7.5	0.0
Mysid, Isopod, Amphipod	<b>11.5</b>	<b>6.7</b>	<b>52.0</b>	0.0	6.2	1.0	7.4
Shrimp	<b>7.0</b>	<b>5.5</b>	<b>14.6</b>	0.9	25.8	18.6	2.5
Crabs	<b>0.0</b>	<b>61.3</b>	<b>5.6</b>	<b>43.2</b>	0.1	8.7	7.9
Walleye pollock	0.0	0.0	0.0	<b>0.0</b>	<b>25.1</b>	<b>13.0</b>	<b>6.3</b>
Atka mackerel	0.0	0.0	0.0	<b>0.0</b>	<b>14.2</b>	<b>30.5</b>	<b>50.7</b>
Miscellaneous fish	15.3	0.8	6.8	<b>55.9</b>	<b>18.7</b>	<b>18.6</b>	<b>21.2</b>
Miscellaneous prey	0.8	0.9	1.6	0.0	0.1	0.4	1.9
Stomachs with food	4.0	4.0	113.0	2.0	19.0	69.0	108.0
Empty stomachs	0.0	0.0	3.0	0.0	4.0	1.0	19.0
Mean width (cm)*	36.5	41.7	32.1	85.0	76.1	60.0	76.1
Standard deviation of mean*	8.2	9.6	10.1	0.7	20.5	12.9	17.4
Range of width (cm)*	26-44	32-52	6-72	79-91	31-101	15-76	11-122

\* data from stomachs with food only.

of fish, whereas the larger-sized skates fed mainly on walleye pollock, Atka mackerel, and miscellaneous fish (Table 8).

The percent similarity index (PSI) was calculated by using the proportions of the prey items in the stomachs (values in Table 8) to show diet overlap between skate species in the Aleutian Islands area.

The upper diagonal sections in Figure 12 shows the percent similarity values between different skate species. The lower diagonal section shows diet overlap between species by categorizing the percent similarities into low (< 34%), medium (34-66%), and high (> 66%) levels of dietary overlap.

The overlap values between the smaller-sized black skate, Bering skates, and mud skates were medium (34-66%) (Fig. 12), since they fed mainly on polychaetes, mysids, isopods, amphipods, some shrimp, and small amounts (< 15%) of miscellaneous fish (myctophids and sculpins). Within the larger-sized group, whiteblotched skates had high diet

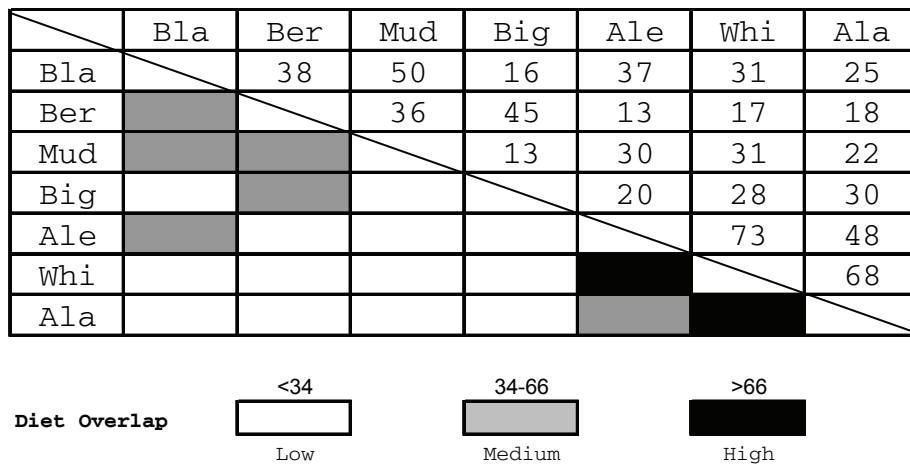


Figure 12.--Percent Similarity Index (%) of dietary overlap of the skates in the Aleutian Islands. Ala, Alaska skate; Ale, Aleutian skate; Ber, Bering skate; Big, big skate; Bla, black skate; Mud, mud skate; Whi, Whiteblotched skate.

overlap values with Aleutian skates and Alaska skates since they all fed on a high percentage of walleye pollock, Atka mackerel, and miscellaneous fish. The overlap value between Alaska skates and Aleutian skates was medium because Aleutian skates fed much more mysids, isopods, and amphipods (26%) than Alaska skates. On the other hand,

Alaska skates fed much more on Atka mackerel (51%) than did Aleutian skates. The big skates in the larger-sized group had low (< 34%) overlap values with all other larger-sized skates since the big skate had a high percentage (43%) of crabs in their diet, whereas only small amount of crabs (< 10%) were consumed by the other larger-sized skates. One notion need to keep in mind was the small sample size (2) of the big skates. The overlap values between the two size groups of skates were generally low (< 34%) or medium (34-66%). There was no high diet overlap between the skates of these two groups. Figure 12 shows that mud skates had low diet overlap values with all larger-sized skate species since mud skates fed on a great amount (52%) of mysids, isopods, and amphipods, whereas all larger-sized skates fed on large amounts ( $\geq$  56%) of fish. Black skates had medium dietary overlap value with Aleutian skates (37%) because they fed both on similar amounts of cephalopods, mysids, isopod, amphipods, shrimp, and miscellaneous fish. Figure 12 also shows that Bering skates had a medium diet overlap value with big skates (45%) since they both consumed large amounts ( $\geq$  43%) of crabs.

## DISCUSSION

### General Diet

The diets of seven skate species in the Aleutian Islands area were related to body size. Small skates (black skates, Bering skates, and mud skates) ate mainly polychaetes, mysids, isopods, and gammarid amphipods. Larger skates (big skates, Aleutian skates, whiteblotched skates, and Alaska skates) fed primarily on Atka mackerel, walleye pollock, other miscellaneous fish, crabs, and shrimp. The diets of whiteblotched skates and Alaska skates were more diverse than other species and included a high proportion of fish. Mud skates also had a diverse diet; however, it did not include a high proportion of fish.

Atka mackerel and walleye pollock are commercially important species in the Aleutian Islands. This study shows that they are the main prey of the larger-sized group of skates. In general, cephalopods were not an important prey of skates. Aleutian skates and whiteblotched skates fed on cephalopods in greater quantities than other species studied. The presence of Atka mackerel, walleye pollock, and cephalopods in the diets of Aleutian skates, whiteblotched skates, and Alaska skates suggest that they may feed in the water column.

Orlov (1998) categorized skates in the northern Kuril Islands and southeastern Kamchatka as predatory skates and benthophagic skates. In his study, predatory skates included the Alaska skate, whiteblotched skate, and *B. matsubarae* (a western Pacific species). Their diets consisted of large crustaceans, cephalopods, and multiple species of fishes. The benthophagic skates in Orlov's study included the Bering skate, Okhotsk skate (*B. violacea*), and whitebrow skate (*B. minispinosa*). They consumed mainly amphipods and worms.

#### **Distribution of Skates by Depth in Aleutian Islands**

The diets of the skates are related to the distribution and biomass of the skate species. Stevenson et al. (in prep.) found that whiteblotched skate, mud skate, and Alaska skate were the dominant skate species in the Aleutian Islands area. Aleutian skate was also common throughout the islands. Bering skate and big skate were found only in the eastern end of the archipelago.

Stevenson et al. (in prep) also note that skate diversity was highest on the western end of the Aleutian chain, near Stalemate Bank. Areas near some of the major passes in the central Aleutian Islands, such as Amukta Pass and Amchitka Pass, also exhibited moderate skate diversity.

They also note that skate abundance was highest in the far west, near Stalemate Bank, and in the central Aleutian Islands around Seguam Pass. Increases in abundance at greater depth are also correlated with decreases in size for most species, as neonates and juveniles are generally more abundant in the deeper portion of the bathymetric distribution than the mature adults (Stevenson et al. in prep.).

### **Diet Comparisons**

#### **Aleutian skate**

Stevenson et al. (in prep.) described that, in the Bering Sea slope, Aleutian skate was most common at depth 600-900 m. However, we don't have samples collected from this depth mainly due to the lack of deep trawling effort in the Aleutian Islands area.

Orlov (1998) found that pandalid shrimp were the most frequently occurring prey (24%) in the stomach contents of Aleutian skates. In comparison, we found that pandalid was important prey (21% by weight) of Aleutian skates.

Similarly, Orlov also found that Aleutian skates fed on walleye pollock, Atka mackerel, octopus, and miscellaneous sculpins.

**Big skate**

Big skates consumed a high (43%) percentage of Tanner crab in the Aleutian Islands area. In the Gulf of Alaska, Yang et al. (2006) found big skates also consumed high percentage of Tanner crab (46%). The difference was that big skate also consumed some flatfish in the Aleutian Islands area, whereas Pacific sand lance was important prey of big skates in the Gulf of Alaska. However, comparisons are limited by the small sample size ( $n = 2$ ) of big skates in the current study.

**Bering skate**

Orlov (1998) found that amphipods were the most frequently occurring (66%) prey and annelids were the second most important prey of Bering skates. Yang et al. (2006) found that in the Gulf of Alaska lyre crab (*Hyas lyratus*) was the most important prey of Bering skates. In this study, crabs and polychaetes were the most important prey of Bering skates collected from the Aleutian Islands area. Overall, Bering skates feed mainly on benthic and epibenthic prey.

**Alaska skate**

The Alaska skate appears to be mainly a fish eater. Fish comprised 78% of the total stomach contents weight of Alaska skates in the Aleutian Islands area. Atka mackerel and walleye pollock were the most important prey of Alaska skates. Brodeur and Livingston (1988) also found that in the eastern Bering Sea Alaska skates fed mainly on pollock (35%), *Chionoecetes* spp. (21%), and flatfishes (23%). Orlov (1998) found that Atka mackerel was the most frequently occurred (16%) prey fish of Alaska skates, followed by spectacled sculpin (*Triglops szepticus*) (11%), walleye pollock (5%), *Hemilepidotus gilberti* (sculpin), and snailfish (*Allocareproctus jordani*) (5%).

**Whiteblotched skate**

Orlov (1998) found that whiteblotched skates fed mainly on invertebrates (80% frequency of occurrence) and that miscellaneous fish occurred in less than 20% of the stomachs examined. Important invertebrate prey included amphipods, pandalid shrimp, *Chionoecetes opilio*, and *Berryteuthis magister*. The important prey fish included *Leuroglossus schmidti*, myctophids, pollock, and Atka mackerel. The difference between this study and Orlov's study was that more Atka mackerel and pollock (about 43% of



the total stomach contents weight) were in the diet of whiteblotched skate in the Aleutian Islands samples. Amphipods and squid (about 45% by frequency of occurrence) were more dominant prey of whiteblotched skates in the Kurils and southeastern Kamchatka.

### **Diet Variations by Predator Size**

Ontogenetic variation in diet within each skate species occurred. For example, the larger-sized skates all consumed high percentage of fish (> 75%) when they reached 80 cm disc width, whereas they consumed more mysids, isopods, gammarid amphipods, crabs, and shrimp (more than 50%) when they were less than 40 cm. This variation has also been reported in other skate diet studies (Ebert et al. 1991, Orlov 1998, Brickle et al. 2003).

### **Diet Overlap**

In this study, because of the small sample sizes for some skate species, diet overlap values were calculated by combining the data from all stomachs analyzed. The diet overlap values between different skate species were generally low (except the values between the Alaska skate, whiteblotched skate, and Aleutian skate). A number of factors, such as predator size, morphology of the digestive

system, and the abundance of prey and predators, could have contributed to the differences in feeding habits between predator species.

This study provides the food habits of skates in the Aleutian Islands ecosystem and improves the understanding of the predator-prey interrelationships. Skates are representatives of the benthic ichthyofauna; they fed mainly on benthic prey. However, in addition to Atka mackerel, walleye pollock, we also found myctophids, bathylagids, and squids in the stomachs. This means that skates also played an important role in the water column.

There are at least seven other species of skates, longnose skate (*R. rhina*), commander skate (*B. lindbergi*), deepsea skate (*B. abyssicola*), whitebrow skate (*B. minispinosa*), Okhotsk skate (*B. violacea*), *B. mariposa*, and *Amblyraja badia* that are known to occur in the BSAI area. Most of them are rare in the Aleutian Islands area or are found in deep water and were not collected from our survey (Stevenson and Orr 2005, Stevenson et al. 2004). It is important to examine the food habits of these species in the future studies.

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