The trophic role of Atka mackerel, *Pleurogrammus monopterygius*, in the Aleutian Islands area

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Atka mackerel (*Pleurogrammus monopterygius*) is presently the most abundant marine fish species in the Aleutian Islands. Its exploitable biomass in 1998 was estimated to be 535,500 metric tons (t) (Lowe and Fritz[1]). The commercial catch of Atka mackerel increased from 26,740 t in 1991 to 104,000 t in 1996 (Lowe and Fritz[1]). Atka mackerel has been identified as food for other marine fishes, i.e. Pacific cod (*Gadus macrocephalus*) (Andriyashev, 1937), coho salmon (*Oncorhynchus kisutch*) (Wing, 1985; Volkov et al., 1995; Davis[2]), arrowtooth flounder (*Atheresthes stomias*) (Mito, 1974); sea birds such as thick-billed murres (*Uria lomvia*) (Ogi, 1980); and marine mammals such as Steller sea lions (*Eumetopias jubatus*) (Merrick et al., 1997). The western stock of Steller sea lions has recently been listed as endangered. A connection between the observed decline in Steller sea lions and the sea lion's dependence on commercially exploited fish species such as Atka mackerel as prey has been suggested (Merrick et al., 1997). Because of the great abundance of Atka mackerel and its important role as food for marine fish and marine mammals, it is essential to understand the trophic role of Atka mackerel in the Aleutian Islands area. The objective of this study was to describe the role of Atka mackerel as prey and as predator in the Aleutian Islands ecosystem.

Methods

Study area

From July to September 1991, the Resource Assessment and Conservation Engineering (RACE) Division at the Alaska Fisheries Science Center (AFSC), Seattle, Washington, conducted a groundfish resources trawl survey in the Aleutian Islands region. This area (Fig. 1) was divided into four major geographical units: southeastern Bering Sea area (from long. 165°W to 170°W, 42,604 km^2); eastern Aleutian area (long. 170°W to 177°W, 338,818 km^2); central Aleutian area (long. 177°W to 177°E, 322,234 km^2); and western Aleutian area (long. 177°E to 170°E, an area of 343,083 km^2). Two chartered fishing vessels, *Ocean Hope* and *Green Hope*, were used. Both vessels used standard RACE Division Poly-Nor'eastern, hard bottom, high-opening bottom trawls constructed of 12.7-cm (5-inch) stretched-mesh polyethylene web, with a 3.2-cm (1-1/4 inch) stretched-mesh nylon liner in the codend to retain smaller specimens (Harrison, 1993). Trawls were towed at 3 knots for 30 minutes. Scientists from the Resource Ecology and Fisheries Management (REFM) Division, Resource Ecology and Ecosystem Modeling Task, collected fish stomach samples during this survey.

Sample collection

Fish stomach samples were collected during trawling operations by scientists aboard the charter vessel *Green Hope*. Both Atka mackerel and their potential fish predators were sampled and measured, and stomach samples were collected. Because of the previously demonstrated high similarity (>60%) in diet between arrowtooth flounder and Kamchatka flounder (Yang and Livingston, 1986), no stomach samples of Kamchatka flounder were collected. Before excising a stomach, fish were examined for evidence of regurgitation or net feeding. If a fish had food in its mouth or around the gills, or if its stomach was everted or flaccid, the fish was categorized as having regurgitated food and the specimen was discarded. If a predator had fresh food (usually fish) sticking out of its mouth or throat, it was categorized as a net-feeding fish and was also discarded. When a sampled stomach was retained, it was put into a cloth stomach bag. A field tag with the species name, fork length (FL), and haul data (vessel, cruise, haul number, and specimen number) was also put into the bag. All of the samples collected were then preserved in buckets containing a 10% buffered formalin solution. When

[1] Lowe, S. A., and L.W. Fritz. 1997. Atka mackerel. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions as projected for November 1997, compiled by the plan team for the groundfish fisheries of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.

[2] Davis, N. D. 1990. U.S.-Japan cooperative high seas salmonid research in 1990: summary of research aboard the Japanese research vessel *Hokuho maru*, 4 June to 19 July. (INPFC Doc. 3508) FRI-UW-9010. Fish. Res. Inst., Univ. Washington, Seattle, WA 98195, 24 p.

Manuscript accepted 11 December 1998.
Fish. Bull. 97(4):1047–1057 (1999).

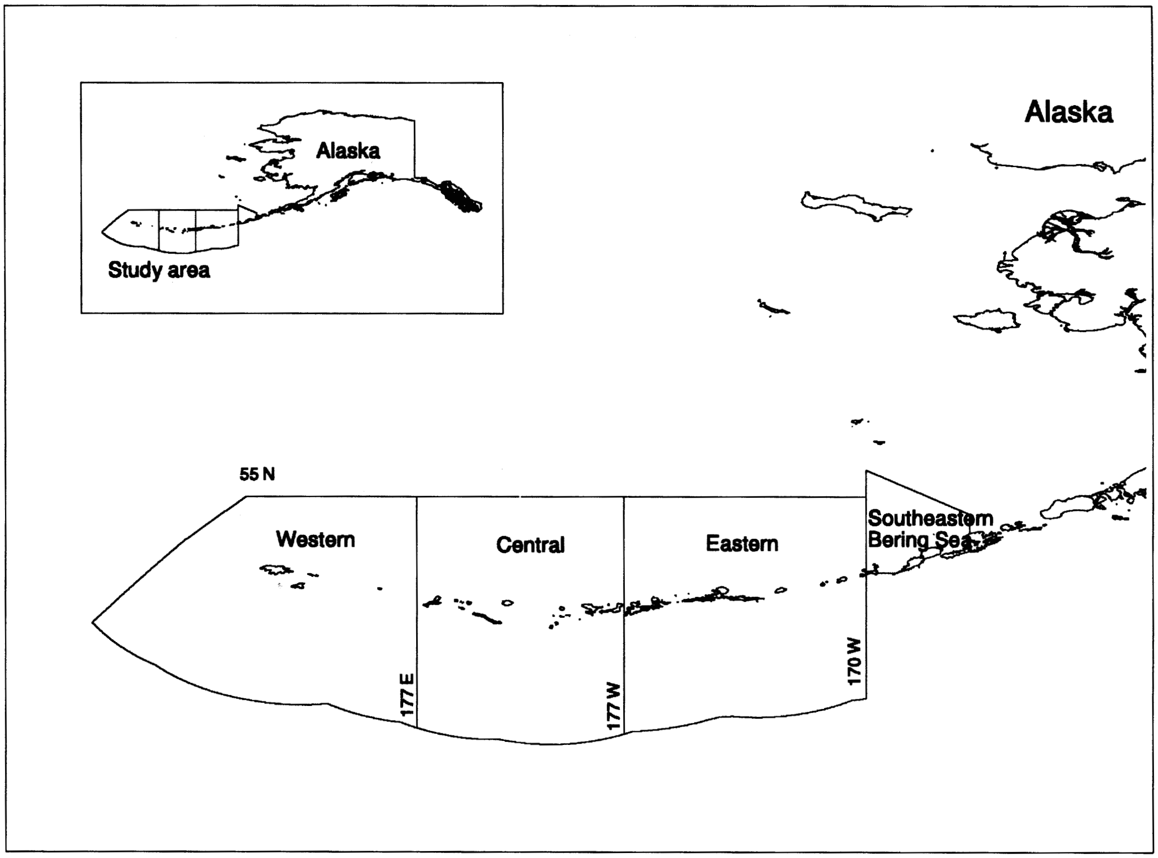

Figure 1
The subareas of the Aleutian Islands trawl survey area.

the samples arrived at the laboratory, they were transferred to 70% ethanol before the contents were analyzed.

Stomach content analysis

In the laboratory, stomach contents were first blotted with a paper towel and the wet weight recorded to the nearest one-tenth of a gram. After obtaining the total weight of the contents, these were placed in a petri dish and examined under a dissecting microscope. Each prey item was classified to the lowest practical taxonomic level. The numbers of noncommercially important prey were not counted; instead the percent total volume of these prey items in stomachs was visually estimated. Prey weights and numbers of commercially important crabs and fish were recorded. If walleye pollock otoliths were found, otolith lengths were measured and the pollock's standard length (SL) was derived through an otolith length-fish length regression table (from REFM's Ageing Task). Other fish otoliths were not treated as walleye pollock otoliths either because they were not found as frequently as walleye pollock or were difficult to identify to the species level. Standard lengths of prey fish, carapace widths (CW) of Tanner crabs (*Chionoecetes* spp.), and Korean horse-hair crabs (*Erimacrus isenbeckii*) were also recorded.

Data analysis

Atka mackerel as prey and predator The general diet of each species was analyzed to determine the overall percent total weight that each prey item represented in the stomach and to identify predators of Atka mackerel. Marine fishes that were mainly fish eaters were then selected for an analysis of population consumption of Atka mackerel. Stomach content analysis of Atka mackerel were performed to understand the role of Atka mackerel as a predator in the Aleutian Islands area.

Population level consumption of Atka mackerel by marine fish Following their identification as predators, the consumption of Atka mackerel by four marine fish species, Pacific cod, Pacific halibut, arrowtooth flounder, and Kamchatka flounder, was estimated. The amount of Atka mackerel consumed at the population level was calculated by using the following equation:

$$\sum C_i = DR_i \times D \times B_i \times P_i,$$

where C_i = the consumption (by weight) of Atka mackerel by size group i of a predator species;

DR_i = the daily ration (as a proportion of body weight per day) of predator size group i (Table 1);

D = the number of days when Atka mackerel were vulnerable to predation (from 1 May to 30 September in this study);

B_i = the biomass of the predator size group i (Table 2); and

P_i = the proportion by weight of prey Atka mackerel in the diet of predator size group i (Table 3).

Daily rations were calculated by using annual growth increments and conversion efficiencies (Brett and Groves, 1979). Predator biomass data were obtained from the RACE Division database at the AFSC. The percent by weight of prey Atka mackerel in the diet of predators (P_i) was calculated for arrowtooth flounder, Pacific cod, and Pacific halibut. Because of the high similarity (>60%) between the diets of Kamchatka flounder and arrowtooth flounder (Yang and Livingston, 1986), the percent by weight of Atka mackerel that arrowtooth flounder consumed was also used for Kamchatka flounder.

Table 1

Daily ration (Dr_i, in terms of proportion of body weight per day) of four groundfish predators in the Aleutian Islands area in 1991.

Predator species	Predator size (cm)	Daily ration
Arrowtooth flounder and Kamchatka flounder	<20	0.009
	20–39	0.005
	≥40	0.008
Pacific cod	<30	0.011
	30–59	0.011
	≥60	0.008
Pacific halibut	50–79	0.004
	≥80	0.007

Results

Atka mackerel as prey of marine fishes

Eleven commercially important groundfish species were collected: Pacific cod, *Gadus macrocephalus*; walleye pollock, *Theragra chalcogramma*; Pacific halibut, *Hippoglossus stenolepis*; arrowtooth flounder, *Atheresthes stomias*; Greenland turbot, *Reinhardtius hippoglossoides*; Atka mackerel, *Pleurogrammus monopterygius*; Pacific ocean perch, *Sebastes alutus*; northern rockfish, *S. aleutianus*; shortraker rockfish, *S. borealis*; and shortspine thornyhead, *Sebastolobus alascanus*. According to stomach content data, Atka mackerel (mostly juveniles) were found in the stomachs of Pacific cod, Pacific halibut, and arrowtooth flounder. The detailed food habits of these species were previously reported (Yang, 1996). The mean percent weights of Atka mackerel consumed by the predators are given in Table 3 by predator size and subarea. Arrowtooth flounder >40 cm FL consumed large amounts (36.6% by weight) of Atka mackerel in the western Aleutian area, whereas Pacific cod >60 cm FL and Pacific halibut (especially fish >80 cm FL) both consumed great amounts of Atka mackerel in the central Aleutian area (42% and 72.9% by weight, respectively).

Atka mackerel as predator

A total of 238 Atka mackerel stomachs were analyzed, 231 (97%) of which contained food. Atka mackerel ranged from 22 to 44 cm FL, with a mean and SD of 33.5 cm and ±4.5 cm, respectively. Table 4 lists the percent by weight of the prey found in Atka mackerel stomachs. More than 90% of the total weight of stomach contents was invertebrates and less than 5% was fish. Euphausiids (mainly *Thysanoessa inermis*) were the most important prey, representing more than 28% of the total stomach contents. Calanoid copepods were another important prey of Atka mackerel, representing approximately 23% of the total stomach content weight. Larvaceans and *Themisto* sp., a hyperiid amphipod, occurred frequently but each represented less than 10% of the total weight of stomach contents. Squid were another invertebrate prey of Atka mackerel; they represented 5% of the total weight of stomach contents.

Several fish species were preyed on by Atka mackerel. Walleye pollock represented 2.4% by weight of the total stomach contents. Myctophids, bathylagids, zoarcids, stichaeids, and pleuronectids were also found. However, each of them represented less than 1% of the total weight of stomach contents. Cannibalism of eggs was also observed in Atka mackerel stomachs, and eggs represented 5.5% of the total weight of stomach contents.

Figure 2 shows the percentage by weight of the main prey items for different Atka mackerel size

Table 2

Biomass (B_i ; in tons) of predators of Atka mackerel by size groups in three subareas (W, C, E) around the Aleutian Islands and southeastern Bering Sea (SBS) in 1991. ATF = arrowtooth flounder; PCOD = Pacific cod; PH = Pacific halibut; ATKA = Atka mackerel; KF = Kamchatka flounder; W = western Aleutian; C = central Aleutian; E =eastern Aleutian.

Species (cm)	W	C	E	SBS	Total
ATF					
<20	1.9	0.6	29.4	37.6	
20–39	947.8	728.1	2162.1	4276.3	
≥40	3796.2	1571.1	4733.5	8315.8	
Total	4745.9	2299.8	6925.0	12,629.8	26,601
PCOD					
<30	12.5	153.7	138.6	151.6	
30–59	5507.2	9791.5	15,010.9	3886.2	
≥60	57,847.8	28,355.0	46,159.4	7448.3	
Total	63,367.6	38,300.2	61,308.8	11,486.1	174,463
PH					
<50	0	157.5	204.5	1857.8	
50–79	560.1	1795.1	6813.4	2891.8	
≥80	4745.9	5267.2	11,123.4	4207.9	
Total	5306.0	7219.8	18,141.3	8957.7	39,625
ATKA					
≤25	2537.9	2267.6	2000.0	0	
26–35	142,607.1	86,328.5	65,407.6	0	
>35	175,047.2	185,358.4	2629.7	0	
Total	320,192.3	273,954.5	70,037.4	0	664,184
KF					
<20	0	0	9.3	0	
20–39	280.9	251	442.2	4.8	
≥40	5281.5	9028.7	1114.6	881.7	
Total	5562.4	9279.7	1566.1	886.6	17,295

Table 3

Mean percent weight (P_i) of Atka mackerel consumed by marine fish in three subareas (W, C, E) around the Aleutian Islands and southeastern Bering Sea (SBS) in 1991. (—) indicates no sample. Values in parentheses are sample sizes. ATF = arrowtooth flounder; PCOD = Pacific cod; PH = Pacific halibut. W = western Aleutian; C = central Aleutian; E = eastern Aleutian.

Species (cm)		W	C	E	SBS
ATF	<20	—	—	0 (1)	0 (6)
	20–39	0 (20)	0 (9)	0 (56)	0 (36)
	≥40	36.6 (19)	0 (3)	0 (28)	14.3 (16)
	Total	32.1 (39)	0 (12)	0 (85)	7.1 (58)
PCOD	<30	—	—	0 (3)	0 (31)
	30–59	5.0 (78)	14.5 (44)	0 (68)	0 (28)
	≥60	25.3 (117)	41.7 (23)	5.6 (145)	0 (14)
	Total	24.1 (195)	40.2 (67)	3.6 (316)	0 (73)
PH	<50	0 (3)	0 (6)	0 (5)	0 (47)
	50–79	4.0 (10)	36.0 (7)	0 (39)	9.8 (33)
	≥80	38.5 (9)	72.9 (5)	0.2 (10)	0 (6)
	Total	28.2 (22)	33.8 (18)	0.1 (54)	4.0 (86)

groups. The most important food of the smallest (≤25 cm) size group of Atka mackerel were calanoid copepods (35% by weight) and larvaceans (33%). The most important prey of Atka mackerel between 26 and 35 cm FL were calanoid copepods (35%) and euphausiids (29%). The largest size group (>35 cm) of Atka mackerel consumed a substantial amount of calanoid copepods (18%), in addition to euphausiids (22%). Miscellaneous fish (walleye pollock, cottids, myctophids, and zoarcids) represented approximately 9% of the total weight of stomach contents of the largest size group of Atka mackerel. Atka mackerel eggs (as evidence of cannibalism) were found almost exclusively in the largest size group, representing 11% of total weight of stomach contents.

Walleye pollock were the most common fish species in the Atka mackerel diet. The size of walleye pollock consumed ranged from 49 to 63 mm SL with a mean and SD of 56.2 mm and ±4.8 mm, respectively. The cottids consumed by Atka mackerel ranged from 12 to 21 mm SL with mean and SD of 15.9 mm and ±3.1 mm, respectively. In addition, Atka mackerel stomach samples contained one bathylagid

Table 4

Mean percent total weight (%W) and mean percent of frequency of occurrence (%FO) of the prey items of Atka mackerel (*Pleurogrammus monoptgerygius*) collected in the Aleutian Islands area in 1991.

Prey name	%W	%FO	Prey name	%W	%FO
Polychaeta (worm)	0.62	2.59	Caridea (shrimp unidentified)	0.11	15.45
Gastropoda (snail)	0.88	34.86	Hippolytidae (shrimp)	0	0.48
Pteropoda	0.03	3.89	Pandalidae (shrimp)	0.12	0.32
Cephalopoda (squid and octopus)	0.07	5.29	Paguridae (hermit crab)	0	2.06
Teuthoidea (squid)	4.67	27.26	Majidae (spider crab)	0.06	3.81
Octopoda (octopus)	0.09	1.27	*Hyas* sp. (lyre crab)	0.02	3.66
Crustacea (unidentified)	4.89	6.98	*Chionoecetes* sp. (snow and Tanner crab)	0.06	6.72
Ostracoda (unidentified)	0.04	12.79	*Erimacrus isenbeckii* (Korean horse-hair crab)	0	0.32
Calanoida (copepod unidentified)	22.68	61.12	Cancridae (crab)	0.03	0.32
Eucalanidae (copepod)	0.23	5.49	Ectoprocta (bryozoan)	0.02	1.98
Eucalanus sp. (copepod)	0.01	1.29	Chaetognatha (arrow worm)	0.79	23.71
Pseudocalanus sp. (copepod)	0	0.34	Larvacea Copelata	9.05	72.28
Candacia columbiae (copepod)	0.51	45.00	Chondrichthyes	0.01	1.66
Mysidacea (mysid unidentified)	0.01	1.59	Osteichthyes Teleostei (bony fish unidentified)	0.1	1.27
Mysidacea Mysida (mysid)	0.01	0.63	Bathylagidae (deepsea smelts)	0	0.48
Acanthomysis pseudomacropsis (mysid)	0	0.48	Myctophidae (lanternfish)	0.75	0.95
Cumacea (cumacean unidentified)	0.02	5.29	*Theragra chalcogramma* (walleye pollock)	2.4	2.06
Amphipoda (amphipod unidentified)	0.02	1.82	Zoarcidae (eelpout)	0.67	0.32
Gammaridea (amphipod)	0.84	16.36	Atka mackerel eggs	5.52	6.67
Themisto sp. (amphipod)	2.41	59.16	Stichaeidae (prickleback)	0.01	0.32
Caprellidea (amphipod)	0.02	2.45	Pleuronectidae (flatfish)	0.01	0.32
Euphausiacea (euphausiid unidentified)	27.46	60.08	Unidentified organic material	10.39	28.49
Euphausia sp. (euphausiid)	0.03	0.48	Fishery discards	0.58	0.32
Euphausia pacifica (euphausiid)	0.02	0.48			
Thysanoessa inermis (euphausiid)	0.75	0.48	Total prey weight	700.55 g	
Thysanoessa inspinata (euphausiid)	0.14	0.32	Total nonempty stomachs	231	
Thysanoessa longipes (euphausiid)	0.1	0.48	Total empty stomachs	7	
Thysanoessa spinifera (euphausiid)	0.19	0.95	Total hauls	21	

(11 mm SL), one zoarcid (61.4 mm SL), one myctophid (59 mm SL), and one stichaeid (29 mm SL).

Consumption of Atka mackerel at the population level

The dominant predator species, Pacific cod and Pacific halibut, consumed large amounts of Atka mackerel (Table 5). The estimated amount of Atka mackerel consumed by each species varied by predator size as well as by the location where the predator was collected. For Pacific cod, large fish (≥60 cm) in the western and central Aleutian areas consumed between 14,000 and 18,000 t of Atka mackerel. For Pacific halibut, large fish (≥80 cm) consumed between 2000 and 4000 t in the western and central Aleutian Islands areas. Consumption of Atka mackerel by arrowtooth flounder was found in samples

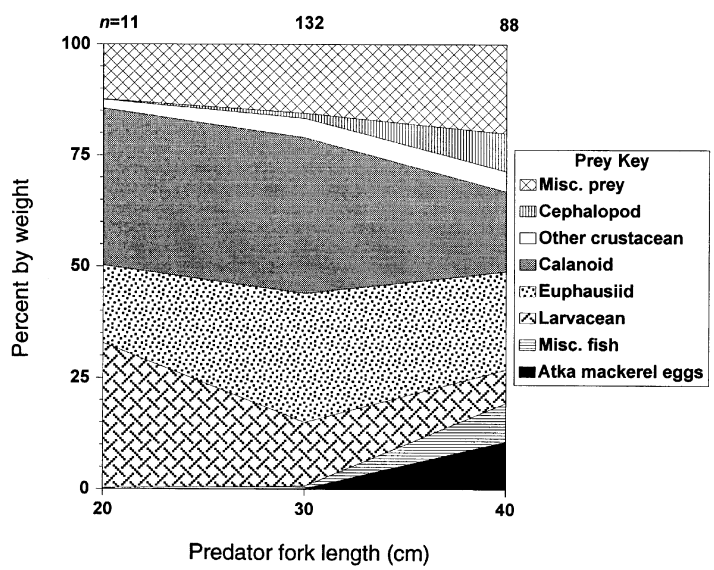

Figure 2

Variation in the main food items of Atka mackerel, by predator size, in the Aleutian Islands area in 1991. *n* = sample size.

Table 5

Biomass (t) of Atka mackerel population consumed by marine fishes in three subareas (W, C, E) around the Aleutian Islands and the southeastern Bering Sea (SBS) area in 1991. (—) indicates no sample. Values in parentheses are % total biomass. ATF = arrowtooth flounder; PCOD = Pacific cod; PH = Pacific halibut; KF = Kamchatka flounder. W = western Aleutian; C = central Aleutian; E = eastern Aleutian.

Species (cm)		W	C	E	SBS	Total
ATF	<20	—	—	0	0	0
	20–39	0	0	0	0	0
	>40	1702 (3.5)	0	0	1455 (3.0)	3157 (6.5)
	Total	1702 (3.5)	0	0	1455 (3.0)	3157 (6.5)
PCOD	<30	—	—	0	0	0
	30–59	460 (1.0)	2394 (4.9)	0	0	2854 (5.9)
	≥60	17,914 (36.9)	14,487 (29.9)	3170 (6.5)	0	35,570 (73.3)
	Total	18,374 (37.9)	16,881 (34.8)	3170 (6.5)	0	38,424 (79.2)
PH	<50	0	0	0	0	0
	50–79	14 (0.1)	395 (0.8)	0	173 (0.4)	582 (1.2)
	≥80	1958 (4.0)	4114 (8.5)	19 (0.1)	0	6091 (12.6)
	Total	1972 (4.1)	4509 (9.3)	19 (0.1)	173 (0.4)	6673 (13.8)
KF	<20	—	—	0	0	0
	20-39	0	0	0	0	0
	≥40	126 (0.3)	0	0	154 (0.3)	280 (0.6)
	Total	126 (0.3)	0	0	154 (0.3)	280 (0.6)
	All species	22,173 (45.6)	21,390 (44.1)	3189 (6.6)	1782 (3.7)	48,534

from the western Aleutian and southeastern Bering Sea areas. Because the diet of arrowtooth flounder and Kamchatka flounder are very similar (Yang and Livingston, 1986), the daily ration values (Table 1) and the values of the mean percent of the Atka mackerel consumed by arrowtooth flounder (Table 3) were used for the calculation of the consumption of Atka mackerel by Kamchatka flounder. The total biomass of Atka mackerel consumed by the main marine fishes in the Aleutian Islands areas was 48,534 t (Table 5).

The number of Atka mackerel consumed by marine fishes was also estimated from the biomass consumed (Table 5) and the prey length recorded from stomach content analysis. The total number of Atka mackerel consumed by marine fishes in the Aleutian Islands area was about 284 million (Table 6), 84% of which were consumed by Pacific cod. The size and age composition of Atka mackerel consumed by groundfishes is listed in Table 7. Age-2 fish represented about 40% of the total numbers of Atka mackerel consumed by groundfishes, including predators of all sizes from different areas. Age-1 and age-3 fish accounted for 30% and 22% of the total numbers consumed, respectively. Age-0 Atka mackerel (4%) were consumed only by Pacific cod ≥60 cm FL in the central Aleutian area. Some age-4 and age-6 Atka mackerel were also found in marine fish stomachs, but they accounted for only about 4% of the total number consumed compared with about 25% of the Atka mackerel that were age 3. In terms of biomass, the age 2+ Atka mackerel consumed by marine fishes (41,071 t) represented about 3.2% of the estimated Atka mackerel population biomass (age 2+) (Lowe and Fritz[1]).

Discussion

Atka mackerel as prey of marine fishes

In addition to groundfish, such as Pacific halibut, Pacific cod, arrowtooth flounder, and Kamchatka flounder that feed on Atka mackerel, other marine fishes also consume Atka mackerel. Several authors have reported that pelagic salmonids prey on Atka mackerel. Davis[2] found that coho salmon (*Oncorhynchus kisutch*) ate Atka mackerel in the North Pacific Ocean. Volkov et al. (1995) found that Atka mackerel represented 30% and 13% of the food composition of coho salmon in the Sea of Okhotsk and the western Kamchatka areas, respectively. Gorbunova (1970) stated that 25–30 mm long larvae of Atka mackerel were found frequently in the stomachs of salmon caught in the open sea. In this study, no larval Atka mackerel were found in the stomachs of marine fishes, only juveniles or adults.

Table 6

Numbers (thousand) of Atka mackerel population consumed by marine fishes in three subareas (W, C, E) around the Aleutian Islands and the southeastern Bering Sea (SBS) in 1991. (—) indicates no data. Values in parentheses are % total numbers. ATF = arrowtooth flounder; PCOD = Pacific cod; PH = Pacific halibut; KF = Kamchatka flounder; W = western; C = central; E = eastern.

Species (cm)		W	C	E	SBS	Total
ATF	<20	—	—	0	0	0
	20–39	0	0	0	0	0
	>40	7217 (2.5)	0	0	9419 (3.3)	16,639 (5.9)
	Total	7217 (2.5)	0	0	9419 (3.3)	16,636 (5.9)
PCOD	<30	—	—	0	0	0
	30–59	3668 (1.3)	47,081 (16.6)	0	0	50,749 (17.9)
	≥60	75,358 (26.5)	113,249 (39.9)	0	0	188,607 (66.4)
	Total	79,026 (27.8)	160,330 (56.5)	0	0	239,356 (84.3)
PH	<50	0	0	0	0	0
	50–79	0	3390 (1.2)	0	0	3390 (1.2)
	≥80	6856 (2.4)	16,242 (5.7)	0	0	23,098 (8.1)
	Total	6856 (2.4)	19,632 (6.9)	0	0	26,488 (9.3)
KF[1]	<20	—	—	0	0	0
	20–39	0	0	0	0	0
	≥40	534 (0.2)	0	0	999 (0.4)	1533 (0.5)
	Total	534 (0.2)	0	0	999 (0.4)	1533 (0.5)
	All species	93,633 (33.0)	179,962 (63.4)	0	10,418 (3.7)	284,013

[1] I used ATF stomach content data and KF biomass.

Table 7

Numbers (thousand) by age (yr) and size (mm) of Atka mackerel consumed by the marine fishes in the Aleutian Islands area in 1991. ATF = arrowtooth flounder; KF = Kamchatka flounder; PH = Pacific halibut; COD = Pacific cod; w = western Aleutian; c = central Aleutian; sbs = southeastern Bering Sea.

Predator	Age 0 <131	Age 1 131–206	Age 2 207–261	Age 3 262–302	Age 4 303–333	Age 5 334–354	Age 6 355–370	Total
ATF≥40cm-w	0	0	4811	0	2406	0	0	7217
ATF≥40cm-sbs	0	0	9419	0	0	0	0	9419
KF≥40cm-sbs	0	0	999	0	0	0	0	999
KF≥40cm-w	0	0	356	0	178	0	0	534
PH≥80cm-c	0	0	8121	8121	0	0	0	16,242
PH5079cm-c	0	1130	2260	0	0	0	0	3390
PH≥80cm-w	0	0	3428	1714	0	0	1714	6856
COD30–59cm-c	0	47,081	0	0	0	0	0	47,081
COD30–59cm-w	0	0	3668	0	0	0	0	3668
COD≥60cm-w	0	7536	22,607	37,679	7536	0	0	75,358
COD≥60cm-c	11,325	28,312	50,962	22,650	0	0	0	113,249
Total	11,325	84,059	106,631	70,164	10,120	0	1714	284,013

Atka mackerel as predator

Atka mackerel have been documented as predators of both planktonic invertebrates and teleosts in both the western and central North Pacific Ocean. Simenstad et al. (1977) found that planktonic crustaceans, hyperiid amphipods, calanoid copepods, and oikopleura (larvaceans) occurred frequently in Atka

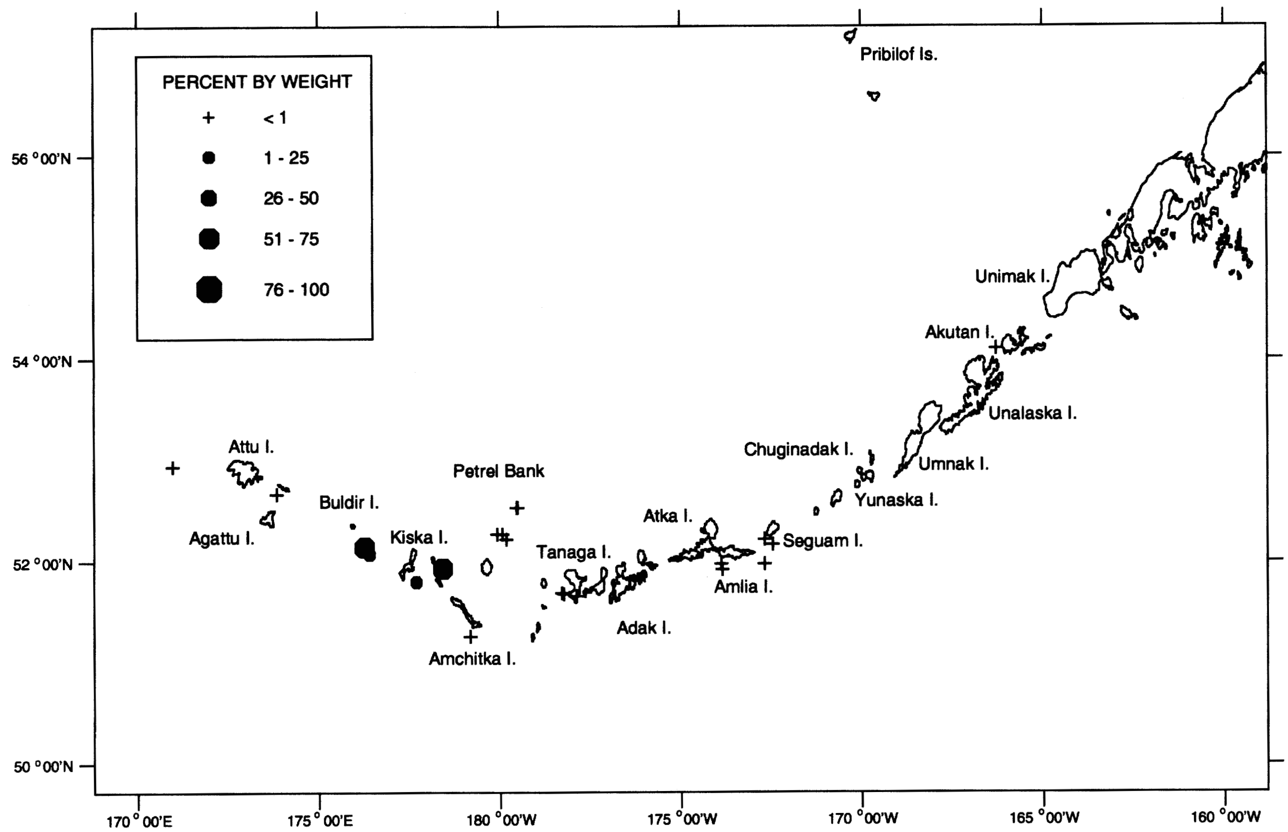

Figure 3

Geographic distribution of eggs cannibalized by Atka mackerel in the Aleutian Islands area in summer 1991.

mackerel stomachs collected from the Amchitka Island area. By contrast, in this study, euphausiids were the most important food (28% by weight). Onishchik (1997) found that myctophids (57% by weight) were the most important food of Atka mackerel in the Kuril Range area even though calanoid copepods and euphausiids occurred more frequently in stomachs. Orlov's study (1997) also showed that Atka mackerel is mainly a planktivore. He found that in the Kuril Islands area, copepods were present in 51% of Atka mackerel stomachs.

Several studies (Takemura and Yamane, 1953; Zolotov and Medveditsyna, 1979; Zolotov and Tokranov, 1991) have shown that Atka mackerel eat their own eggs. I also found evidence of egg cannibalism at four locations near Kiska Island (Fig. 3). I compared the frequency of occurrence of Atka mackerel eggs found at these locations. In three out of four hauls, females cannibalized more eggs than did males. In four hauls, males (n=7–9) exhibited 13–43% frequency of occurrence, and females (n=6–8) exhibited 17–57% frequency of occurrence of egg cannibalism. This finding suggests that male egg-guarding behavior, a characteristic of the species (Zolotov and Tokranov, 1991), may have inhibited the males from feeding on their own eggs. Combining stomach-content data from these four hauls (Table 8) showed that males consumed more euphausiids (27%) and less calanoids (18%), whereas females consumed more calanoids (35%) and less euphausiids (6%) when egg cannibalism occurred. I analyzed the rest of the data (where no egg cannibalism occurred) and found that males and females fed on very similar percentage by weights of calanoids (mainly (*Neocalanus plumchrus*)), euphausiids (mainly *Thysanoessa* spp), and larvaceans (Table 9). On the basis of these data, I hypothesize that egg-guarding behavior may cause some variations in diet of male and female Atka mackerel. All cannibalism occurred in September at depths between 80 and 170 m, indicating that the Kiska Island area may be a spawning ground for Atka mackerel in September. Zolotov and Tokranov (1991) found that, during the spawning season (from August to September), Atka mackerel eggs were the main food of rock mackerel (*Hexagrammos lagocephalus*), Atka mackerel, yellow Irish lord (*Hemilepidotus jordani*), and the common Irish lord (*H. gilberti*).

Table 8

Mean percent total weight (%W) and mean percent of frequency of occurrence (%FO) of the main prey groups of Atka mackerel (*Pleurogrammus monopterygius*) where egg cannibalism occurred in the Aleutian Islands area in 1991.

	Male		Female		Total	
Prey name	%W	%FO	%W	%FO	%W	%FO
Gastropoda (snail)	2.66	42.46	1.50	40.77	1.59	41.67
Teuthoidea (squid)	2.05	34.13	1.52	38.69	1.11	36.67
Calanoida (copepod)	18.54	66.02	34.89	77.83	21.30	71.67
Candacia columbiae (copepod)	0.98	49.06	0.80	52.23	0.74	51.67
Gammaridea (amphipod)	4.40	42.11	2.97	37.05	3.79	40.00
Themisto sp. (amphipod)	2.34	63.34	2.93	74.40	1.89	68.33
Euphausiacea (euphausiid)	27.23	49.16	6.14	42.26	19.42	46.47
Caridea (shrimp)	0.05	2.78	0.27	14.43	0.12	8.33
Majidae (spider crab)	0.48	8.68	0	0	0.20	5.00
Chaetognatha (arrow worm)	0.86	12.95	0.05	3.57	0.25	8.33
Larvacea Copelata	11.07	89.73	9.25	89.14	8.76	90.00
Gnathostomata	0.01	3.57	0	0	0.01	1.67
Zoarcidae (eelpout)	5.24	2.78	0	0	3.51	1.67
Pleurogrammus monopterygius (Atka mackerel eggs)	16.66	28.77	32.79	41.67	28.96	35.00
Fishery discards	3.92	3.57	0	0	3.05	1.67
Total prey weight	52 g		25 g		78 g	
Total nonempty stomachs	32		28		60	
Total empty stomachs	0		0		0	
Total hauls	4		4		4	

Table 9

Mean percent total weight (%W) and mean percent of frequency of occurrence (%FO) of the main prey groups of the Atka mackerel (*Pleurogrammus monoptgerygius*) that had no egg cannibalism in the Aleutian Islands area in 1991.

	Male		Female		Total	
Prey name	%W	%FO	%W	%FO	%W	%FO
Gastropoda (snail)	0.82	46.77	0.74	30.66	0.71	33.26
Teuthoidea (squid)	0.87	21.75	6.14	30.69	5.51	25.05
Calanoida (copepod)	30.02	60.81	22.08	60.20	23.01	58.63
Candacia columbiae (copepod)	0.32	41.52	0.53	48.36	0.46	43.43
Gammaridea (amphipod)	0.28	15.24	0.08	8.78	0.15	10.80
Themisto sp. (amphipod)	1.95	67.69	3.16	59.03	2.54	57.00
Euphausiacea (euphausiid)	26.78	63.40	31.81	68.63	30.86	63.24
Caridea (shrimp)	0.15	21.95	0.09	15.89	0.10	17.12
Majidae (spider crab)	0.03	4.04	0.05	4.37	0.03	3.53
Chaetognatha (arrow worm)	0.74	29.45	1.28	30.23	1.03	27.33
Larvacea Copelata	14.81	80.65	7.42	66.15	9.12	68.11
Gnathostomata	0.01	0.89	0.03	2.42	0.01	1.66
Myctophidae (lanternfish)	1.18	1.79	0.43	0.84	0.92	1.18
Theragra chalcogramma	2.79	2.81	4.12	2.86	2.96	2.55
Total prey weight	288 g		335 g		623 g	
Total nonempty stomachs	82		89		171	
Total empty stomachs	5		2		7	
Total hauls	14		17		17	

Atka mackerel as prey of marine mammals

Many marine mammals feed on Atka mackerel. Merrick (1995) found that Atka mackerel was the most common prey identified in Steller sea lion scats from the Aleutian Islands from 1990 to 1993. Nemoto (1957) found that Atka mackerel was the preferred food of humpback whales (*Megaptera novaeangliae*) in the waters west of the Attu Islands and the waters south of Amchitka Island. Kasamatsu and Tanaka (1992) stated that in the southwestern Hokkaido region, *Pleurogrammus azonus*, a congener distributed mainly in the northern part of the Sea of Japan, represented 80–100% of the diet of minke whale (*Balaenoptera acutorostrata*). Kenyon (1965) found that 85% (by volume) of the food of harbor seals (*Phoca vitulina*) in the Amchitka Islands area was Atka mackerel. Atka mackerel have also been found in the stomachs of sperm whales (*Physeter macrocephalus*) (Kawakami, 1980), killer whales (*Orcinus orca*) (Nishiwaki and Handa, 1958), fin whales (*Balaenoptera physalus*) (Nemoto, 1957), Dall's porpoise (*Phocoenoides dalli*) (Crawford, 1981; Perez and McAlister, 1993), minke whale (Perez and McAlister, 1993), harbor seal (Perez, 1990), northern fur seals (*Callorinus ursinus*) (Perez, 1990), and sea otters (*Enhydra lutris*) (Kenyon, 1969). Consumption of Atka mackerel at the population level by marine mammals was not estimated in this study because of insufficient data on their biomass, daily ration, and diet of marine mammals.

Atka mackerel as prey of seabirds

Seabirds are important predators in the Aleutian Islands marine ecosystem. Some seabirds feed on fish larvae or young juveniles, and some feed on zooplankton. Ogi (1980) analyzed the prey of 320 thick-billed murres (*Uria lomvia*) that drowned in Pacific salmon gill nets in the oceanic waters ranging from the Kuril Islands to a region east and south of the Aleutian Islands (160°W) and found that juvenile Atka mackerel and several species of lantern fish (Myctophidae) were important prey (17% of the total weight). Wehle (1983) found that Atka mackerel represented 42.3%, by occurrence, of the food of horned puffin (*Fratercula corniculata*), and it occurred in 6.3% of the stomachs of tufted puffin (*F. cirrhata*) at Buldir Island. Hatch and Sanger (1992) found only two Atka mackerel (138 and 139 mm) consumed by the tufted puffin, but Byrd et al.[3] found that Atka mackerel were important food of tufted puffin in 1990 at Buldir Island and Aiktak Island. Consumption of Atka mackerel at the population level by seabirds (like marine mammals) was not estimated in this study because of the lack of quantitative data on the biomass, daily ration, and diet of many seabirds in this area.

[3] Byrd, G. V., J. C. Williams, and R. Walder. 1992. Status and biology of the tufted puffin in the Aleutian Islands, Alaska, after a ban on salmon driftnets. U.S. Fish and Wildlife Service. Alaska Maritime National Wildlife Refuge. Aleutian Islands Unit, PSC 486, Box 5251, FPO AP 96506-5251, Adak, Alaska.

Summary

This study assessed the importance of Atka mackerel in the Aleutian Islands marine ecosystem. As a predator (mainly adults in this study), Atka mackerel were basically zooplanktivores. Calanoid copepods, euphausiids, planktonic tunicates, amphipods, and other crustaceans were principal food items. Atka mackerel also consumed some benthic fishes (cottids and young-of-the-year walleye pollock) and mesopelagic fishes (myctophids and bathylagids) and cannibalized its own eggs. As prey, about 48,500 t of Atka mackerel (mainly age 2+) were consumed by marine fishes. Table 7 indicates that about 26% of the consumed Atka mackerel were age-3 and older. Because of insufficient data, consumption of Atka mackerel at the population level by marine mammals and seabirds could not be estimated. Human beings also consumed a large amount of Atka mackerel. The total commercial catch of Atka mackerel was 26,740 t in 1991 (about 2.2% of the exploitable biomass [age 3+] in that year).

This study provides information about predator-prey relationships between Atka mackerel and their predators (marine fishes, marine mammals, and seabirds), and between Atka mackerel and their prey (zooplankton and other invertebrates) in the Aleutian Islands marine ecosystem. More information about the early life history (eggs, larvae, and juveniles) of Atka mackerel is needed to improve our understanding of their trophic role in the marine ecosystem.

Acknowledgments

I would like to thank Troy Buckley, Patricia Livingston, Susanne McDermott, and Thomas Wilderbuer for their reviews of this manuscript and many suggestions. Robin Harrison and Mike Martin (RACE) provided the survey biomass estimates and their help is appreciated. Thanks is also given to Doug Smith (REFM) for assisting with the computer programs and to Debbie Blood and Morgan Busby (RACE) for helping identify some juvenile fish, larvae, and eggs. I also want to thank three anonymous reviewers for their comments and suggestions.

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