FOOD HABITS AND DIET OVERLAP OF TWO CONGENERIC SPECIES, *ATHERESTHES STOMIAS* and *ATHERESTHES EVERMANNI*, IN THE EASTERN BERING SEA

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ABSTRACT

Stomachs of 196 arrowtooth flounder, *Atheresthes stomias*, and 152 Kamchatka flounder, *A. evermanni*, collected from the same area of the eastern Bering Sea in summer 1983 were examined. Each species was divided into four fork-length groups: less than 201 mm, 201-300 mm, 301-400 mm, and greater than 400 mm. The principle diet of both species was comprised of walleye pollock, *Theragra chalcogramma*, shrimp (mostly Crangonidae), and euphausiids. Pollock was the most important prey item for both species in all four size groups, ranging from 56 to 86% and 66 to 88% of the total stomach content weight of Kamchatka flounder and arrowtooth flounder, respectively. Schoener's indices of diet overlap were calculated between the two species for each size group. The high value of the indices (ranging from 0.67 to 0.90) indicate that these two congeneric species basically consume the same resources.

The genus *Atheresthes* of the family Pleuronectidae has two species: Kamchatka flounder, *A. evermanni* (Jordan and Starks), and arrowtooth flounder (Norman, 1934), *A. stomias* (Jordan and Gilbert). *Atheresthes evermanni* is distributed from northern Japan (Hokkaido) through the Sea of Okhotsk to the western Bering Sea north to Anadyr Gulf (Willimovsky et al. 1967). *Atheresthes stomias* is distributed from Central California to the eastern Bering Sea. In the Bering Sea, it meets about on a line with Saint Matthew Island, overlaps with, and is replaced by *A. evermanni* (Hart 1973).

Because the morphological differences between *A. evermanni* and *A. stomias* are subtle, they have been recorded as one species, *A. stomias*, in the eastern Bering Sea resource assessment surveys of the Northwest and Alaska Fisheries Center (NWAFC) (Smith and Bakkala 1982). Food habits of *A. stomias* have been studied by some researchers (Gotshall 1969; Kabata and Forrester 1974; Smith et al. 1978), but none of those studies covered the food habits of *A. evermanni*. Shuntov (1970) studied the feeding intensity of the two *Atheresthes* species, but he did not compare the diets of these species.

Using electrophoretic examination, Ranck et al. (1986) have confirmed that these two types of *Atheresthes* are separate species. The purpose of this study is to analyze stomach samples of these two congeneric species collected in the area of their distributional overlap in the eastern Bering Sea and compare the diets of both fish species to calculate the degree of diet similarity to determine whether the two species can be considered trophically equivalent.

COLLECTION AND PROCESSING OF SAMPLES

Specimens were collected from 6 July to 16 July 1983 in the eastern Bering Sea aboard the *Alaska*, a research vessel participating in the annual summer resource assessment survey conducted by the Resource Assessment and Conservation Engineering (RACE) division of the NWAFC in Seattle, WA. Stomachs of arrowtooth flounder and Kamchatka flounder were taken at standard resource assessment stations where half-hour tows were made using an 83-112 Eastern bottom trawl net with an estimated 2.3 m vertical and 16.4 m horizontal mouth opening.

The samples were collected in an area around and to the northwest of the Pribilof Islands at bottom depths ranging from 71 to 137 m (Fig. 1, Table 1). A random subsample of individuals of both arrowtooth flounder and Kamchatka flounder was obtained at each station with a total collection of 348 stomachs from 19 stations.

Individual fish were first checked for signs of regurgitation, i.e., food items in mouth or gill plates or flaccid stomach, and were discarded if any such signs were noted. Stomachs from the remaining fish

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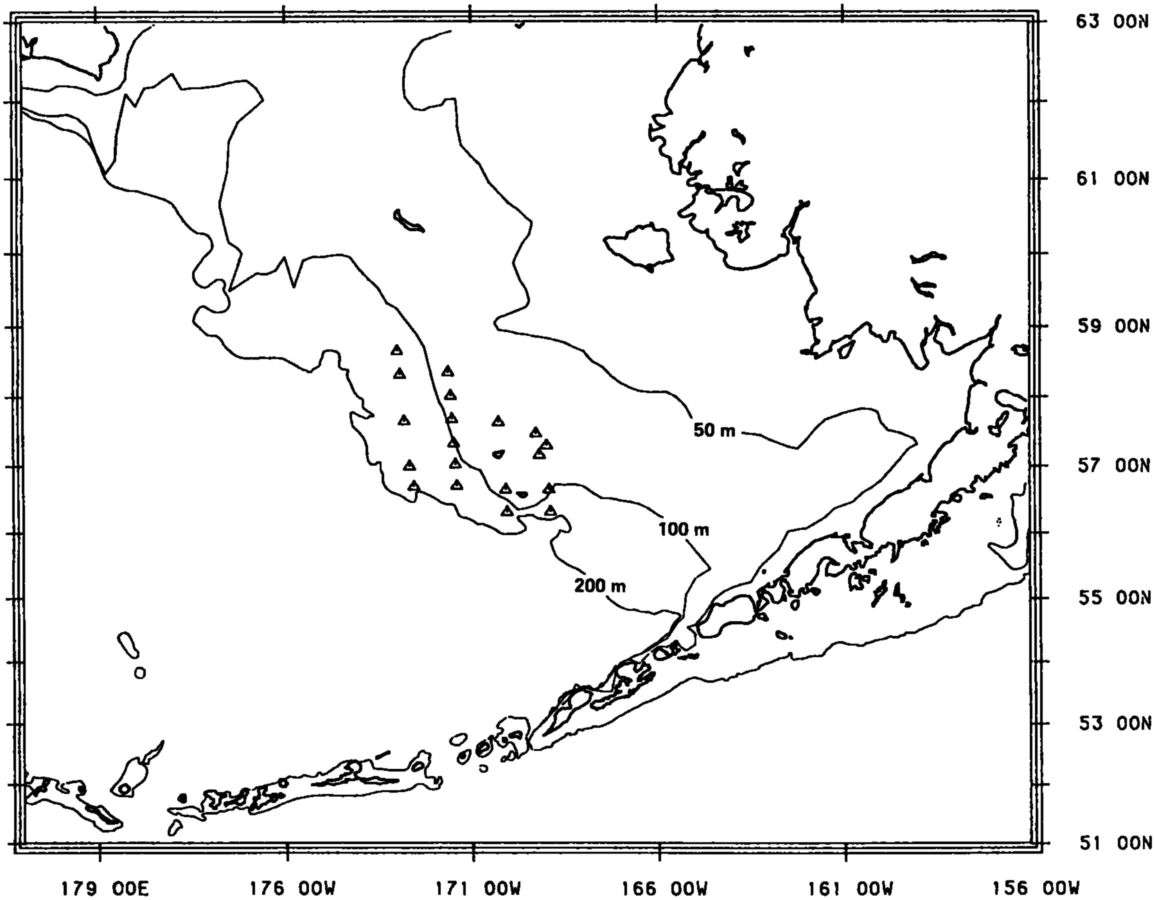

FIGURE 1.—Sampling locations for arrowtooth flounder, *Atheresthes stomias*, and Kamchatka flounder, *A. evermanni*, in summer 1983 in the eastern Bering Sea.

were excised along with the anterior portion of the body (including head, stomach, and intestines), and these samples were sent to the laboratory for species identification. Each specimen was placed in a muslin bag with a specimen label bearing fork length, sex, and station information. All samples were preserved in 10% Formalin[3].

In the laboratory, two characters were used for species identification: the position of the left eye relative to the dorsal profile and gill rakers. Kamchatka flounder has the upper eye completely on the right side of the head and 13 or fewer gill rakers on the first arch. Arrowtooth flounder has an upper eye which interrupts the dorsal profile of the head and 15 or more gill rakers on the first arch (Norman 1934; Willimovsky et al. 1967).

[3]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Stomachs were analyzed individually. Prey items were identified to the lowest taxonomic level practical, counted, and weighed damp to the nearest milligram. The standard length of fish prey were also measured.

DATA ANALYSIS

Specimens of *A. stomias* and *A. evermanni* were divided into 100 mm fork-length groups for data analysis: <201 mm, 201-300 mm, 301-400 mm, and >400 mm. Percent of frequency of occurrence (% FO), percentage of total stomach content weight (% W), percentage of total prey number (% N) and the Index of Relative Importance [IRI = % FO (% N + % W)] (Pinkas et al. 1971) were calculated for major categories of prey items in the 100 mm size groupings of *A. stomias* and *A. evermanni*.

Based on a review of dietary overlap measures

TABLE 1.—Station information and number of stomachs collected at each station of arrowtooth flounder (ATF) and Kamchatka flounder (KF) in the eastern Bering Sea for the summer 1983.

Haul	Date	Alaska daylight time	Haul depth (m)	Bottom temp. (°C)	Latitude N	Longitude W	No. ATF[1] stomachs collected	No. KF[1] stomachs collected
100	7/6	1000	71.3	3.1	56°29.46′	169°15.61′	14 (6)	19 (17)
101	7/6	1200	71.3	3.1	57°19.25′	168°59.13′	4 (5)	2 (1)
102	7/6	1400	76.8	2.6	57°10.87′	169°10.22′	14 (6)	7 (6)
105	7/7	0800	102.4	2.7	56°39.96′	168°55.22′	18 (9)	7 (4)
106	7/7	1100	133.5	3.8	56°20.18′	168°53.24′	11 (2)	10 (3)
107	7/7	1600	111.6	3.5	58°20.01′	170°02.15′	12 (0)	12 (1)
108	7/8	0800	96.9	3.8	56°40.00′	170°04.47′	5 (1)	3 (1)
114	7/9	1400	75.0	2.7	57°39.23′	170°16.12′	13 (1)	2 (0)
135	7/13	1900	96.9	1.5	58°22.09′	171°37.39′	6 (1)	0 (0)
136	7/14	0700	100.6	2.8	58°01.90′	171°33.37′	5 (0)	1 (0)
137	7/14	1000	100.6	3.0	57°41.94′	171°31.16′	7 (0)	0 (1)
138	7/14	1300	102.4	3.7	57°21.05′	171°28.26′	8 (3)	6 (1)
139	7/14	1500	109.7	3.9	57°02.54′	171°25.63′	11 (0)	6 (1)
140	7/14	1800	120.7	3.7	56°43.42′	171°23.38′	6 (0)	9 (0)
141	7/15	0700	137.2	4.0	56°42.72′	172°32.33′	2 (6)	7 (2)
142	7/15	0900	124.4	3.6	57°00.84′	172°39.37′	5 (6)	7 (2)
144	7/15	1500	122.5	3.7	57°40.10′	172°47.92′	3 (1)	2 (0)
146	7/16	0600	111.6	2.6	58°20.10′	172°55.00′	2 (2)	9 (0)
147	7/16	0900	115.2	2.6	58°40.07′	172°59.18′	3 (0)	3 (0)
Total							149 (47)	112 (40)

[1]Stomachs containing food, number of empties in parentheses.

(Cailliet and Barry 1979; Linton et al. 1981), Schoener's (1970) index was chosen because it was found to measure overlap accurately over most of the range of potential overlap (Linton et al. 1981). Schoener's index, Cxy, is calculated as

$$Cxy = 1.0 - 0.5\left(\sum\left|p_{x,i} - p_{y,i}\right|\right)$$

where $p_{x,i}$ and $p_{y,i}$ are the estimated proportions by weight of prey i in the diets of species x and y, respectively (the percentage by weight of prey items in Table 2). The index ranges from 0 which indicates no dietary overlap to a maximum overlap of 1 when all prey items are found in equal proportions.

RESULTS

General Feeding Trends

A total of 348 stomachs were analyzed; 87 stomachs (25%) were empty. Table 2 shows the percentages by weight of all prey items found in the stomachs of both flounder species by size group. In general, both species consumed the same prey species or groups: euphausiids, pandalid and crangonid shrimps, and walleye pollock (Fig. 2). *Thysanoessa inermis* and *T. raschii* were the dominant euphausiids consumed. Some pandalid shrimps were eaten by smaller (<301 mm) flounders of both species, but crangonid shrimps, mainly *Crangon communis*, were the dominant shrimp consumed. Walleye pollock constituted the highest proportion of the diet for all size groups of flounder, ranging from 56% by weight of the diet for Kamchatka flounders 301-400 mm long to about 88% by weight for arrowtooth flounders >400 mm long. Miscellaneous food items consumed included polychaetes, copepods, cumaceans, hippolytid shrimps, ophiuroids, and various fish species.

Mean stomach content weight of those stomachs with food was similar between arrowtooth flounder and Kamchatka flounder for all but the largest size group. The mean stomach content weight ranged from about 1.4 g for the small flounders to over 20 g for the largest size group.

Diet Comparisons Within Size Groups

The principle diet of both *Atheresthes* species in the ≤200 mm size group was comprised of walleye pollock, euphausiids, and shrimps (Fig. 3). Walleye pollock comprised 58% and 65.5% by weight of the diet of Kamchatka flounder and arrowtooth flounder, respectively. Euphausiids comprised the highest percentage by numbers of the diet of both species, 53% for Kamchatka flounder and 69.4% for arrowtooth flounder. Shrimps, including *Crangon communis*, *Pandalus goniurus*, *Pandalus tridens*, and *Eualus avinus*, constituted 17.1% and 7.2% by weight of the diet of Kamchatka flounder and arrowtooth flounder, respectively. Other less important

TABLE 2.—Percentage by weight of prey items in the stomachs of arrowtooth flounder (ATF) and Kamchatka flounder (KF) by 100 mm FL categories; and Schoener's indices (*Cxy*) of diet overlap between the two species.

	Predator size group (mm)							
	≤200		201-300		301-400		>400	
Prey item	KF	ATF	KF	ATF	KF	ATF	KF	ATF
Invertebrates								
Polychaeta	—	—	—	0.28	—	—	—	—
Copepoda	—	0.01	—	—	—	—	—	—
Mysidacea	0.45	0.34	0.12	—	—	—	—	—
Cumacea	—	—	0.01	—	—	—	—	—
Amphipoda	0.22	—	0.52	—	0.07	—	—	—
Euphausiiacea								
Unidentified	5.64	8.99	0.23	9.10	0.54	3.86	—	0.22
Thysanoessa rachii	—	2.76	—	1.35	—	2.32	—	—
T. inermis	4.28	10.67	3.55	9.33	7.40	10.03	4.09	6.55
Caridea								
Unidentified	1.05	1.31	—	—	—	0.08	—	—
Hippolytidae								
Eualus avinus	0.88	—	—	0.05	—	—	—	—
Pandalidae								
Unidentified	—	1.08	—	—	—	—	—	—
Pandalus goniurus	3.89	—	—	—	—	—	—	—
Pandalus tridens	4.77	—	—	—	—	—	—	—
Pandalus sp.	0.54	0.37	0.24	—	—	—	—	—
Crangonidae								
Unidentified	0.34	2.98	2.15	0.10	—	—	0.07	—
Crangon dalli	—	—	0.85	0.61	—	—	—	—
C. communis	5.67	1.43	5.53	0.70	0.31	0.15	—	0.22
Paguridae	—	0.01	—	—	0.58	—	—	—
Ophiuroidea	—	0.19	—	—	0.03	—	—	—
Chaetognatha								
Sagitta sp.	—	0.03	—	0.01	—	—	—	—
Pisces								
Gadidae								
Unidentified	—	—	5.40	4.62	2.70	5.65	8.20	—
Theragra chalcogramma	58.03	65.51	81.55	71.69	55.78	76.99	85.87	87.96
Zoarcidae								
Unidentified	—	—	—	—	5.55	—	—	5.06
Lycodes brevipes	—	—	—	—	8.20	—	—	—
Cottidae	—	1.15	—	—	—	—	—	—
Stichaeidae								
Unidentified	3.00	—	—	—	—	—	—	—
Lumpenus maculatus	—	3.16	—	1.97	9.47	—	—	—
Pleuronectidae								
Unidentified	7.50	—	—	—	9.36	—	1.77	—
Atheresthes sp.	3.73	—	—	—	—	—	—	—
Unidentified organic material	—	—	0.05	0.19	—	0.92	—	—
No. of stomachs with food	32	40	43	53	20	40	19	14
Total weight of stomach content (g)	46.96	57.24	93.29	167.66	181.89	291.43	383.32	467.91
Mean stomach content weight (g)	1.47	1.43	2.17	3.16	9.09	7.29	20.17	33.42
Mean fish length (mm)	187.80	184.60	250.10	260.70	350.50	341.30	441.10	450.00
Cxy	0.72		0.82		0.67		0.90	

food items were stichaeids, pleuronectids, cottids, mysids, and amphipods.

Walleye pollock, the dominant food of both *Atheresthes* species in the 201-300 mm size group (Fig. 3), constituted 81.6% and 71.7% by weight of the diet of Kamchatka flounder and arrowtooth flounder, respectively. Euphausiids comprised 20% by weight of the diet of arrowtooth flounder. However, euphausiids only comprised 3.8% by weight (39.9% by number) of the diet of Kamchatka flounder. Shrimps (Crangonidae, Pandalidae) were more important food for Kamchatka flounder (8.8% by weight) than for arrowtooth (1.4% by weight). Unidentified gadoids comprised 5.4% and 4.6% by weight of the diet of Kamchatka flounder and arrowtooth flounder, respectively. Other less important food items were polychaetes, mysids, amphipods, and the stichaeid *Lumpenus maculatus*; they were

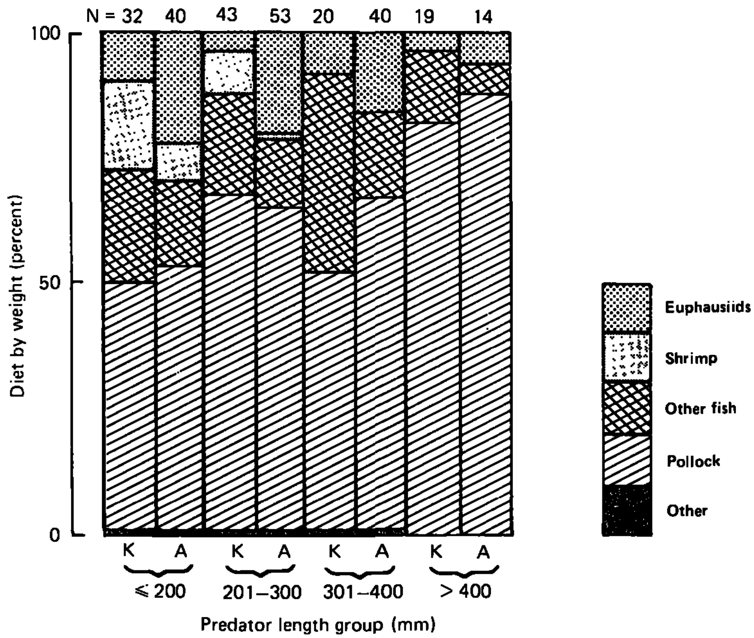

FIGURE 2.—Percentage by weight of major prey categories in the diet of arrowtooth flounder (A), *Atheresthes stomias*, and Kamchatka flounder (K), *A. evermanni*, for different length groups of fish collected from the eastern Bering Sea in summer 1983.

all <5% by weight of the diet of both *Atheresthes* species.

The principle diet by weight of Kamchatka flounder in the 301-400 mm size group was comprised of 55.8% walleye pollock, 13.8% zoarcids, 9.4% pleuronectids, 9.5% stichaeids, and 7.9% euphausiids (Table 2, Fig. 3). Walleye pollock also dominated the diet of arrowtooth flounder (77% by weight). The other two main items of arrowtooth flounder were euphausiids (16.2% by weight) and unidentified gadoids (5.7% by weight). Shrimps were not important food for either *Atheresthes* species of this size; they contributed <1% by weight of the diet. Other less important prey items were ophiuroids and pagurids. Numerically, euphausiids dominated the food for both species (90.7% for Kamchatka flounder, 96.0% for arrowtooth flounder).

Walleye pollock dominated the food of the two *Atheresthes* species in the >400 mm size group (Fig. 3). It constituted 85.9% and 88.0% by weight of the diet of Kamchatka flounder and arrowtooth flounder, respectively (Table 2). Though euphausiids dominated the food by number (91.5% for Kamchatka flounder, 97.0% for arrowtooth flounder), they only contributed 4.1% and 6.8% by weight of the diet of Kamchatka flounder and arrowtooth flounder, respectively. In addition to walleye pollock, unidentified gadoids comprised 8.2% and pleuronectids comprised 1.8% by weight of the diet of Kamchatka flounder. Zoarcids comprised 5.1% by weight of the diet of arrowtooth flounder. Shrimps played a less important role in the food of both *Atheresthes* species (<1% by weight).

Diet Comparison Among Size Groups

There was not much difference in diets among size groups in the proportion by weight of the prey categories such as euphausiids and fish (Fig. 2). However, shrimps disappeared from the diets of flounders in the two larger size groups. The number of different species in the diet also changes with size. The ≤200 mm size group of flounders consumed about 11 or 12 different prey categories while the >400 mm size groups consumed only 3 or 4 different prey types (see Table 2).

Even though the proportion by weight of fish in the diet remained fairly constant over flounder size groups, the size of individual fish consumed did change with flounder length. Figure 4 shows the frequency distribution of fish prey lengths found in the stomachs of different size *A. evermanni*. Most of the prey fish were age-0 juvenile pollock (<100 mm) for the two smaller size groups and age-1 juvenile

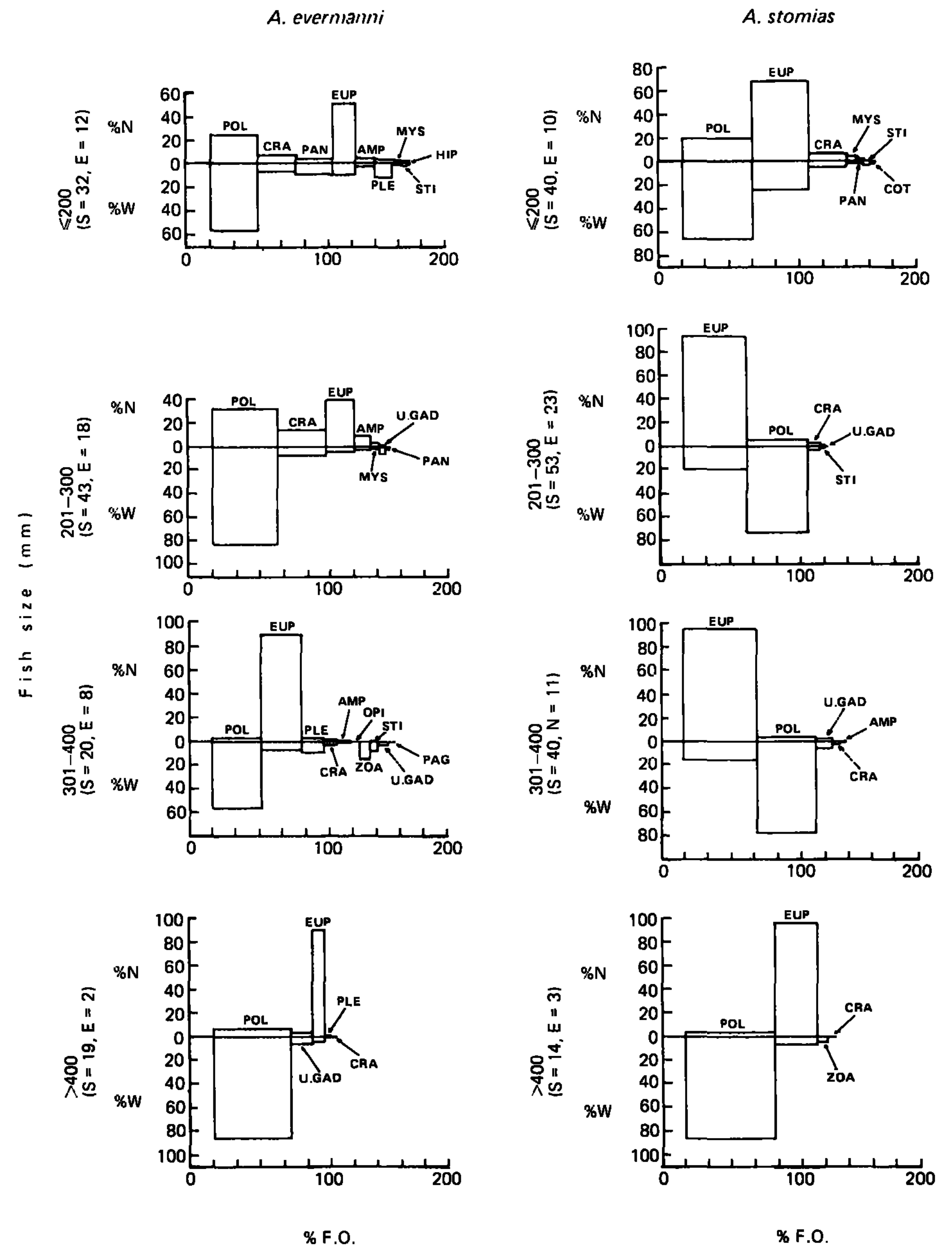

FIGURE 3.—Indices of Relative Importance of major prey items in the diets of *Atheresthes evermanni* and *A. stomias* of different size groups. % F.O., percent frequency of occurrence; % N, percentage of prey number; % W, percentage of total stomach content weight; POL, pollock; EUP, Euphausiacea; CRA, Crangonidae; PAN, Pandalidae; AMP, Amphipoda; PLE, Pleuronectidae; MYS, Mysidacea; STI, Stichaeidae; HIP, Hippolytidae; ZOA, Zoarcidae; U. GAD, Unidentified Gadidae; COT, Cottidae; S, number of stomachs containing food; E, number of empty stomachs.

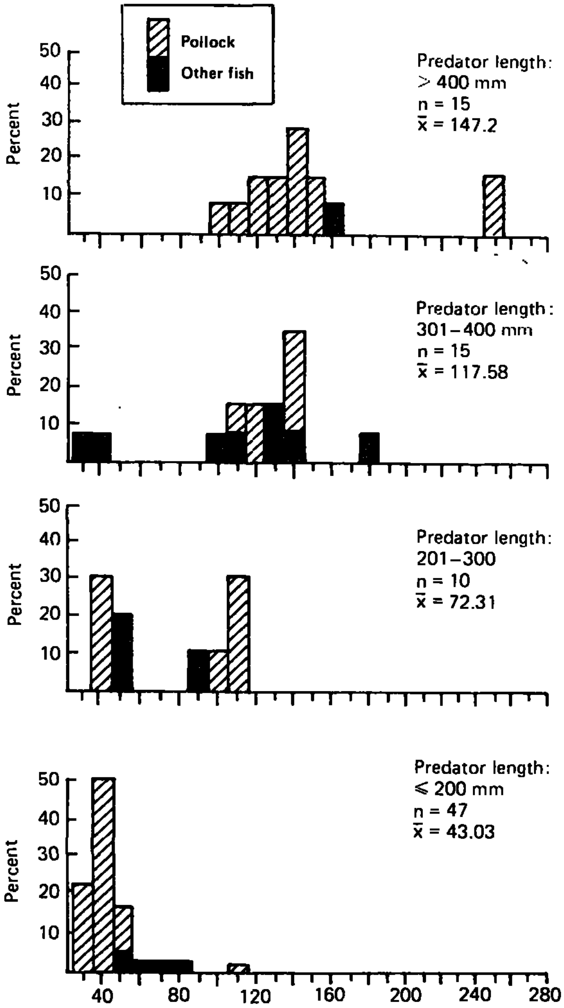

FIGURE 4.—Frequency distribution of standard lengths of prey fish found in the stomachs of *Atheresthes* species from the eastern Bering Sea in summer 1983.

pollock (100-200 mm) for the two larger size groups. The fish prey length was plotted against the predator length (Fig. 5). Fish prey size appears to increase linearly with increasing predator size.

Diet Overlap

Values for Schoener's (1970) index of dietary overlap were obtained from a comparison (by weight) between the diets of Kamchatka and arrowtooth flounder of the same size groups (Table 2). All the values obtained were >0.60, an indicator of high dietary overlap (Langton 1982). The ≤200 mm size group had an overlap value of 0.72 and the 201-300 mm size group had an overlap value 0.82. Within each of these two size groups, fairly similar proportions by weight of walleye pollock, euphausiids, and shrimps were consumed. The 301-400 mm size group had the lowest overlap value of 0.67. This is probably because Kamchatka flounder ate less walleye pollock by weight (56%) than did the arrowtooth flounder (77%). Most of the remainder of the diet for Kamchatka flounder in this size group was composed of different fish groups, such as zoarcids, stichaeids, and pleuronectids, which were almost totally absent from the arrowtooth's diet at this size. The largest size group of flounders (>400 mm) had the highest overlap value of 0.90. This size group ate very similar proportions by weight of walleye pollock and euphausiids.

DISCUSSION

From this study, it appears that both Kamchatka flounder and arrowtooth flounder are largely fish feeders. Walleye pollock was the most frequently observed prey and contributed the largest percentage by weight to the diets, followed by euphausiids and shrimps (Table 2, Fig. 3). Gotshall (1969) found that ocean shrimp, *Pandalus jordani*, was the most common food item of arrowtooth flounder (because the stomachs were collected on commercial shrimp grounds), followed by fishes and euphausiids. Pacific sanddabs, *Citharichthys sordidus*, were the most numerous prey fish found in his study. Kabata and Forrester (1974) examined 753 arrowtooth flounder collected off the west coast of Vancouver Island. Their study showed that euphausiids, followed by fish were the predominant foods taken by arrowtooth flounder. The most commonly found species of fish were eulachon, *Thaleichthys pacificus*, and Pacific herring, *Clupea pallasii*. Smith et al. (1978) found that fish constituted 41.09% and euphausiids 37.22% by volume of the food of 236 arrowtooth flounder collected from the northeast Gulf of Alaska. Walleye pollock were most commonly consumed fish prey. Moiseev (1953) found that Kamchatka flounder fed almost exclusively on pollock and only occasionally on herring and other fishes.

The type of prey eaten by a fish is strongly correlated with the morphology of the alimentary tract of the fish (De Groot 1971; Ebeling and Cailliet 1974; Allen 1982). Structure of the digestive tract of arrowtooth flounder and Kamchatka flounder are very similar. Both have a very large terminal mouth that is nearly symmetrical with a wide gape; teeth are arrow-shaped and well developed on both sides of the jaws; gill rakers are long and strongly dentate;

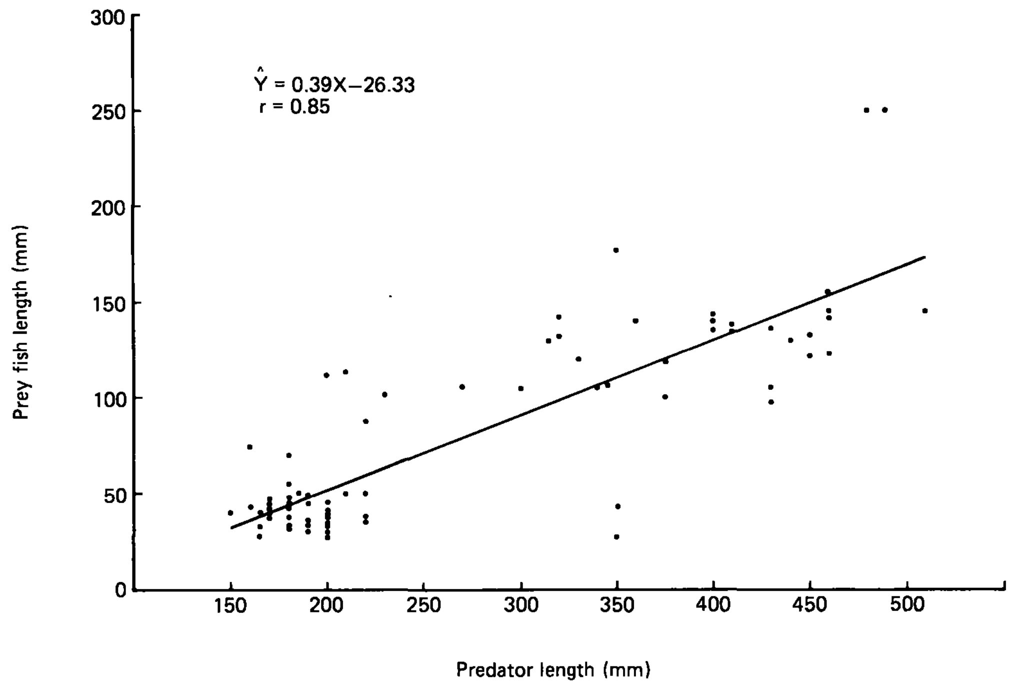

FIGURE 5.—Scatter plot of prey fish length consumed by *Atheresthes* species from the eastern Bering Sea in summer 1983.

and the esophagus and stomach are large with four large pyloric caeca and the intestine is a simple loop. All of these characteristics indicate that *Atheresthes* species are fish feeders as predicted by using De Groot's (1971) morphological criteria. He stated that large gill rakers with teeth are indispensable to fish feeders, since they prevent the prey, grasped alive, from struggling out of the mouth. The high percentages of fish in the diet of the two *Atheresthes* species obtained in this study would be expected on the basis of the similarities in the digestive tracts of the two species.

The results also indicate that *Atheresthes* species feed up in the water column. According to Allen (1982), flatfishes with large symmetrical mouths (*Atheresthes* species) probably use sight to locate prey. They are oriented up in the water column when foraging. The presence of pelagic fish (*T. chalcogramma*) and euphausiids or nektonic benthopelagic crustaceans such as shrimps in the diets of *Atheresthes* species supports Allen's generalizations concerning correlations between morphology and feeding behavior in flatfishes.

The trend of the feeding habits of *Atheresthes* species with regard to predator length is toward piscivory; that is, when the predators are bigger, they take more fish (by weight) as food. Specimens from the ≤200 mm size group were found to ingest the greatest variety of prey items in comparison to other size groups. Specimens >400 mm long preyed mainly on other fishes, primarily on pollock. However, euphausiids were of importance in the diet of all size groups. One 460 mm arrowtooth flounder was found to have 838 *Thysanoessa inermis* in its stomach. Smith et al. (1978) also noted a change in food habits with increasing length in the arrowtooth flounder. In their study, specimens over 450 mm long preyed exclusively on pollock and other gadoids. Euphausiids were important food of the arrowtooth flounder up to 350 mm long; however, none were found among the stomach contents of specimens larger than 350 mm.

Based on the results of this study and those of Smith et al. (1978) and Gotshall (1969), it appears that *Atheresthes* species are opportunistic feeders; they feed on those prey items that are most abundant—pollock and euphausiids in the Gulf of Alaska and eastern Bering Sea and ocean shrimp in northern California. In the eastern Bering Sea, the estimated abundance of age-0 pollock in 1982 is between 100 billion and 1,300 billion and, based on the results of the 1983 bottom trawl survey by NWAFC, this 1982 year class is the largest observed since the large 1978 year class (Traynor in press).

In spite of the high diet overlap between Kamchatka flounder and arrowtooth flounder, there is probably no competition for food between these two species because they are exploiting abundant food sources.

Finally, although Kamchatka founder and arrowtooth flounder are genetically distinct, they can be considered trophically equivalent on the basis of their similar diets and high diet overlap.

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