FEEDING HABITS OF THE ARROWTOOTH FLOUNDER,

Atheresthes stomias, FROM THE NORTHEAST GULF OF ALASKA

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A

THESIS

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ABSTRACT

The feeding habits of *Atheresthes stomias* from the northeast Gulf of Alaska were studied. Analysis of 558 specimens indicated that fishes, shrimp, and euphausiids were the dominant prey items. Fishes occurred in 42% of the specimens found to be feeding and contributed nearly 90% of the total prey volume. Shrimp, primarily Pandalidae, contributed approximately 6% of the total prey volume and were found in 28% of the feeding specimens. Euphausiids occurred in nearly 26% of the feeding specimens, but contributed less than 3% of the total prey volume.

Feeding habits were influenced by the size of the flounder; larger specimens preyed more heavily on fishes than on crustaceans. Depth also affected the feeding habits of *A. stomias*. Flounders taken from depths of 150 m or less were feeding more intensively than those from deeper water. Marked differences in the diet of specimens from different sample locations were observed.

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INTRODUCTION

Atheresthes stomias, a member of the family Pleuronectidae, is known by many common names including arrowtoothed halibut, long-jaw flounder, turbot, and arrowtooth flounder. Arrowtooth flounder is the common name that has been officially adopted for the species (Hart 1973).

Atheresthes stomias is found in the waters off central California to the eastern Bering Sea (Hart 1973). In the Bering Sea, the range of *A. stomias* overlaps that of a closely allied species, *A. evermanni*, which is the more abundant of the two species in the western Bering Sea. The greatest numbers of arrowtooth flounders are found in the northern portions of its range, particularly in the northeastern Gulf of Alaska (NEGOA) and the seas just south of the Alaska Peninsula (Alverson et al. 1964). The arrowtooth flounder is primarily a deep-water fish, forming large concentrations on the outer continental shelf-upper continental slope area in depths of 100 to 400 m (Alverson et al. 1964).

From British Columbia to the south side of the Alaska Peninsula, *A. stomias* is the "most important flounder" (Alverson et al. 1964). In benthic trawl surveys from this portion of its range, the arrowtooth flounder accounts for 42% to 91% by weight of the total flounder catch in waters greater than 90 m in depth. Catch rates of 1,000 lbs/hr are reported for portions of the Gulf of Alaska (Alverson et al.

(1964). Arrowtooth flounder was the most numerous flatfish encountered in a demersal fish resource assessment study of NEGOA (Ronholt et al. 1976). *Atheresthes stomias* contributed 44% by weight of all flatfish taken, and 24% by weight of the total fish catch (Ronholt et al. 1976). Only one other species of fish, *Theragra chalcogramma*, was more abundant in the area surveyed. The estimated standing stock of *A. stomias* in NEGOA was 52,600 metric tons, or 144 million fish (Ronholt et al. 1976).

In the past, utilization of demersal fish species from Alaskan waters by American fishermen has been marginal. Korean, Japanese, and Russian fishing fleets have harvested various groundfish species from Alaskan waters for a number of years (Alverson et al. 1964; Kasahara 1960). The primary targets for these fleets have been pollock, yellowfin sole, and black cod; however, arrowtooth flounder has also been utilized (Kasahara 1962). The arrowtooth flounder has been used as mink food in the United States and Canada (Alverson et al. 1964), while the Japanese have used it as a source of fishmeal and oil (Kasahara 1960). It is marketed to a limited extent for human consumption in the United States, along with at least one other species of fish, under the name of "turbot."

At present, there is a growing interest in the development of a bottomfish industry in Alaskan waters (Cline 1978; Painter 1978). This is, in part, due to the extension of the United States' territorial limit to 200 miles offshore, and declining catches of shrimp and crab (Pennington 1978). Various state, federal, and private organizations are working together to develop this fishery. The enthusiasm shown by U.S. fishermen for the development of a bottomfish industry can be seen in the recent increase in production of boats designed for use in trawling operations in northern seas (Burgess 1978). The accessibility and abundance of the arrowtooth flounder may make it a prime target of the bottomfish industry.

The primary purpose of this study was to determine the food and feeding habits of *Atheresthes stomias* from the northeastern Gulf of Alaska. Both qualitative and quantitative aspects of the diet of this flounder were investigated, along with the influence of depth and of predator size on food and feeding habits.

This study was a part of a more comprehensive investigation of the food and feeding habits of the demersal fish communities of NEGOA and the southeastern Bering Sea (Smith et al. 1978), that was undertaken in order to obtain an understanding of the complex interrelationships of the members of the benthic community. The knowledge gained may be of use in the prediction of the impact of Alaskan outer continental shelf oil development and in the management of the developing bottomfish industry in Alaskan waters.

STUDY AREA

The area sampled was the continental shelf of the northeastern Gulf of Alaska (NEGOA), bounded on the east by Yakutat Bay and on the west by Cape Cleare, Montague Island. The locations of stations from which specimens of *Atheresthes stomias* were obtained for stomach analysis are presented in Table 1 and Figure 1. (For additional information about the study area, see Jewett and Feder 1976 and Ronholt et al. 1976.)

Table 1. Stations where Samples of *Atheresthes stomias* were obtained

Station Number*	Tow Number**	Date	Time	Latitude	Longitude	Depth Fished (m)
070C	2	5/ 3/75	1345	59°33'	147°48'	102.0-113.0
070D	3	5/ 3	1740	59°27'	147°45'	103.7-111.0
076A	16	5/10	1335	60°12'	146°10'	105.5-107.3
074H	20	5/12	1150	59°24'	146°48'	151.0-158.3
086C	43	5/30	1440	59°45'	143°53'	116.4-127.4
092D	50	6/ 2	0825	59°39'	142°14'	222.0-225.6
094D	51	6/ 2	1200	59°27'	141°48'	123.7-127.4
100B	55	6/ 4	0820	59°27'	140°14'	220.2-222.2
100C	56	6/ 5	0915	59°21'	140°14'	158.3-161.9
094G	63	6/27	1150	59°22'	141°40'	182.0-182.0
098C	74	7/ 4	1350	59°28'	140°44'	287.5-291.0
070B	111	7/20	0630	59°40'	147°44'	109.2-116.5
071B	112	7/20	0910	59°44'	147°24'	109.2-111.0
073A	115	7/25	0655	60°10'	147°02'	262.1-263.1
073C	117	7/25	1330	59°57'	146°59'	142.0-149.2
074G	121	7/26	1705	59°32'	146°42'	113.0-115.0
075G	122	7/27	0735	59°36'	146°27'	95.0- 98.3
073H	123	7/27	1055	59°28'	146°57'	202.0-204.0
077I	125	7/28	0740	59°33'	145°59'	133.0-145.6
077E	128	7/28	1550	59°53'	146°03'	93.0- 97.0

*Jewett and Feder (1976).
**Ronholt et al. (1976).

Table 1. continued

Station Number*	Tow Number**	Date	Time	Latitude	Longitude	Depth Fished (m)
075A	132	8/ 1/75	0750	60°11'	146°27'	131.0-133.0
077B	133	8/ 1	1115	60°12'	146°02'	100.1-102.0
077A	134	8/ 1	1345	60°17'	145°29'	53.0- 54.6
079C	137	8/ 2	1150	60°00'	145°29'	100.1-104.0
081F	140	8/ 3	0935	59°35'	145°00'	173.0-178.4
083F	141	8/ 3	1450	59°39'	144°34'	137.0-140.1
083E	142	8/ 4	0800	59°43'	144°37'	129.2-131.0
081G	144	8/ 4	1510	59°27'	145°01'	208.0-220.2

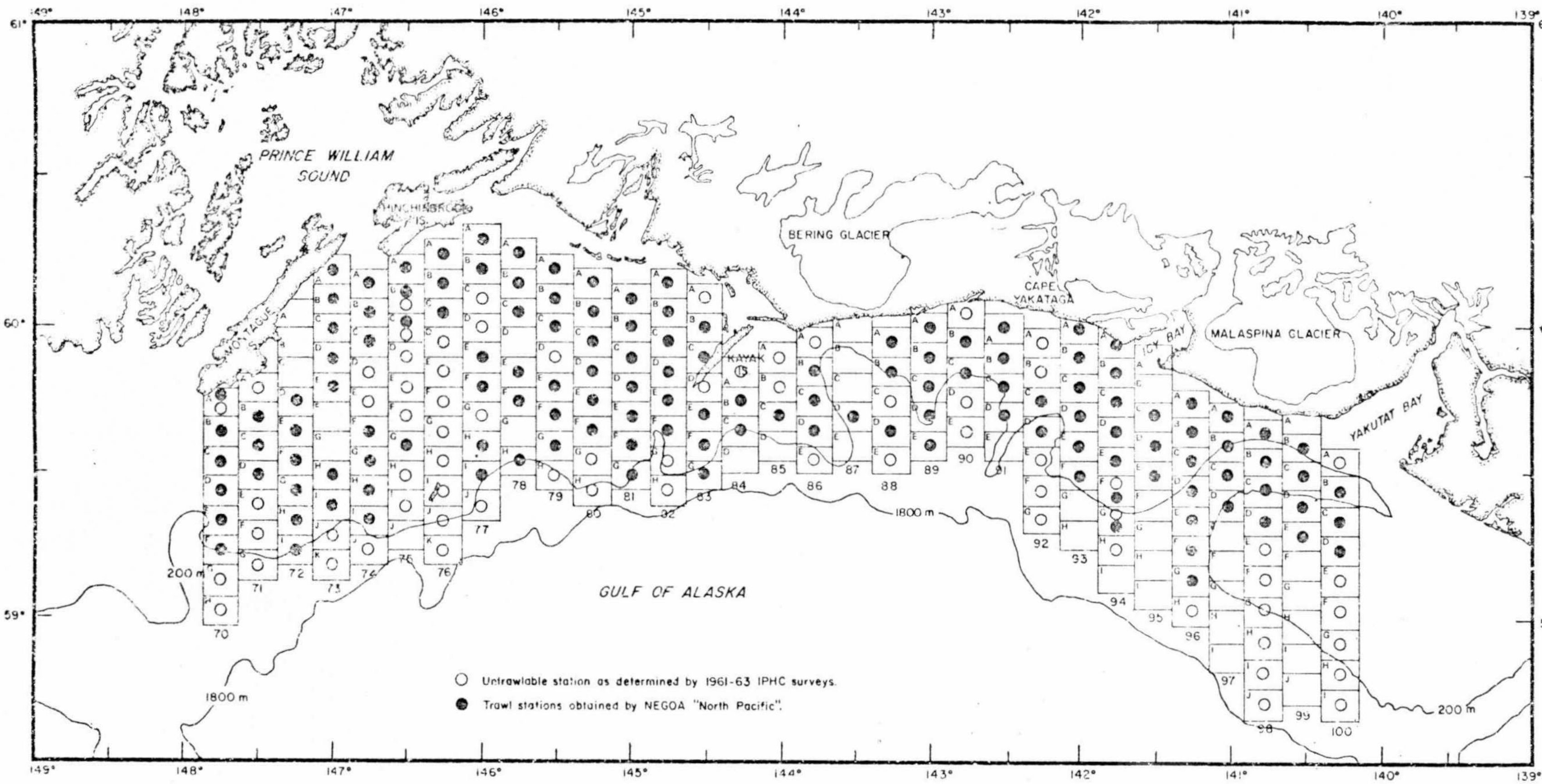

Figure 1. Map of the Northeastern Gulf of Alaska. Specimens were obtained from 28 of the stations located on the grid. (From Jewett and Feder 1976.)

MATERIALS AND METHODS

All specimens were collected by 400 mesh eastern otter trawl during benthic trawl studies conducted from the chartered fishing vessel North Pacific. The majority of the specimens were collected between May 3, 1975, and June 27, 1975. Additional specimens were taken between July 4, 1975, and August 8, 1975.

Whole fish with the abdominal cavity slit, or the anterior halves of larger specimens, were placed in 5 gallon plastic buckets containing 10% formalin buffered with hexamethylenetetramine.

In the laboratory, whole fish were measured for standard length and head length (tip of lower jaw to the posterior edge of the opercular bone). Sex and state of maturity were also recorded. The head length of those specimens that were cut in half was taken, and their standard length calculated by linear regression using the ratio of head length to standard length obtained from the whole specimens.

Stomach contents were sorted and prey items identified to the lowest possible taxon. Counts and volumes of all prey items were made. Volumes to the nearest 0.1 ml were determined by water displacement.

The percent frequency of occurrence (F), percent contribution by number (N), and percent contribution to prey volume (V) was calculated for each prey taxon from each sample station and for all stations combined. Percent frequency of occurrence as used here is defined as the number of fish a given food item is found in divided by the total number of feeding fish examined. Similarly, a percent contribution by number was calculated by dividing the count of a particular prey species by the total number of all prey items. Percent contribution by volume was calculated by dividing the volume of a prey species by the total prey volume. An index of relative importance (IRI) (Pinkas et al. 1971), calculated by F(N+V) = IRI, was also determined for each prey taxon at each station and for all stations combined.

Predator stomach fullness was subjectively determined for each specimen and recorded in the following manner: 0 = no information; 1 = empty; 2 = trace; 3 = 25% full; 4 = 50% full; 5 = 75% full; 6 = 100% full; and 7 = distended. The mean fullness of predator stomachs was calculated for each prey taxon at a station, for all prey taxa at a station, for each prey taxon over all stations, and for all taxa over all stations. Calculations of mean predator length for each prey taxon and all prey taxa were made in the same manner.

Food habits relative to predator length were determined by dividing the sample into five length categories. All of the calculations mentioned above were then applied to each predator length interval.

Feeding habits with regard to sex and maturity were not examined. Data on sex and maturity of *A. stomias* from NEGOA were gathered by

Ronholt et al. (1976) concomitantly with the collection of the specimens used in this study. Those data indicated that spawning apparently occurred just prior to the survey (April-August 1975).

RESULTS

The stomachs of 558 *Atheresthes stomias* were examined, of which 236 contained prey items. A wide variety of prey were found among the stomach contents (Table 2). Fishes occurred in 42.8% of the flounders, and contributed nearly 90% of the prey volume. Crustaceans, primarily shrimp and euphausiids, contributed 9% of the total prey volume and occurred in 53.8% of the stomachs examined (Table 3).

Of the identifiable fish remains, members of the families Osmeridae, Gadidae, and Zoarcidae, in decreasing order of percent frequency of occurrence, were the most important. Species from the families Clupeidae, Cottidae, Stichaeidae, and Pleuronectidae were also found among the stomach contents (Table 2). The crustaceans occurring in the diet were primarily decapods and euphausiids (Table 2). The latter two groups occurred with almost the same frequency; however, decapods contributed a greater percentage of the prey volume than did the euphausiids (Table 3). The importance of euphausiids in the diet, as indicated by their high IRI value, was due primarily to their contribution to the total prey count (Table 3). The decapods in the diet of the arrowtooth flounder were exclusively shrimp, primarily pandalids (Table 2).

In order to determine if *Atheresthes stomias* undergoes a change in feeding habits with increased size, five length intervals were examined (Table 4). The results of the analysis of feeding habits by

Table 2. Individual Prey Items of 236 *Atheresthes stomias* from the Northeastern Gulf of Alaska, May-August 1975*

Prey Taxon	Percent Frequency of Occurrence	Percent by Number	Percent by Volume	Index of Relative Importance
Teleostei (unidentified)	30.08	10.18	50.87	1836.4
Euphausiacea	25.85	46.51	2.64	1270.5
Decapoda (unidentified)	13.56	24.85	2.02	364.4
Mallotus villosus	5.51	3.79	5.77	52.7
Pandalidae	4.66	1.66	0.57	10.4
Pandalus borealis	2.97	1.18	2.42	10.7
Crangonidae	2.54	0.71	0.09	2.0
Zoarcidae	2.12	0.71	0.96	3.5
Theragra chalcogramma	1.27	0.36	21.73	28.1
Pandalus spp.	0.85	0.36	0.16	0.4
Eualus sp.	0.85	0.24	0.08	0.3
Osmeridae	0.85	0.36	0.50	0.7
Polychaeta	0.42	0.12	0.01	0.1
Pelecypoda	0.42	0.12	0.00	0.1
Cephalopoda	0.42	0.12	0.73	0.4
Isopoda	0.42	2.25	0.13	1.0
Pandalus jordani	0.42	0.12	0.15	0.1

*Listed in descending order of frequency of occurrence.

Table 2. Continued

Prey Taxon	Percent Frequency of Occurrence	Percent by Number	Percent by Volume	Index of Relative Importance
P. platyceros	0.42	0.12	0.02	0.1
Pandalopsis sp.	0.42	--	--	--
P. dispar	0.42	0.24	0.75	0.4
P. ampla	0.42	0.24	--	--
Crangon communis	0.42	0.12	0.03	0.1
Sclerocrangon sp.	0.42	0.12	0.02	0.1
Ophiuroidea	0.42	0.12	0.01	0.1
Clupeidae	0.42	0.36	0.49	0.4
Clupea pallasii	0.42	0.12	8.63	3.7
Salmoniformes	0.42	0.12	0.15	0.1
Thaleichthys pacificus	0.42	0.12	--	--
Gadidae	0.42	0.12	--	--
Cottidae	0.42	0.12	0.13	0.1
Stichaeidae	0.42	0.12	0.14	0.1
Lumpenus sp.	0.42	0.36	0.15	0.2
Pleuronectidae	0.42	0.12	0.20	0.1
Atheresthes stomias	0.42	0.12	0.14	0.1
Glyptocephalus zachirus	0.42	0.12	0.13	0.1
Unidentified animal material	7.63	--	0.18	--

Table 3. Summary of Prey by Higher Taxa for *Atheresthes stomias* from the Northeastern Gulf of Alaska, May-August 1975

Prey Taxon	Percent Frequency of Occurrence	Percent by Number	Percent by Volume	Index of Relative Importance
Teleostei	42.80	17.16	89.99	4586.0
Decapoda	27.97	29.94	6.31	1013.9
Euphausiacea	25.85	46.51	2.64	1270.5
Mollusca	0.85	0.24	0.73	0.8
Annelida	0.42	0.12	0.01	0.1
Echinodermata	0.42	0.12	0.01	0.1

Table 4. Sample Size, Total Prey Volume, and Mean Specimen Length of the Predator Size Categories of *Atheresthes stomias* from the Northeastern Gulf of Alaska, May-August 1975

Length Category (mm)	Number of Fish	Mean Length of Fish (mm)	Number Feeding	Number Empty	Total Volume of Stomach Contents
0-150	7	106	5	2	6.3 ml
151-250	217	214	120	97	231.7 ml
251-350	252	292	90	162	355.7 ml
351-450	39	381	8	31	288.7 ml
≥451	43	553	13	30	1621.3 ml

predator length are shown in Tables 5 and 6. Although the differences in sample sizes between length categories do not allow for meaningful statistical comparison, several trends are suggested. On the basis of IRI values, it appears that fishes become more important in the diet with increased predator size. Decapods also gain importance in the diet of fish up to 450 mm long, but they are no longer present in the diet of larger individuals. Euphausiids, which are small prey items, decline in importance with increased predator length. Euphausiids are absent from the diet of fishes larger than 350 mm. The stomachs of feeding specimens over 450 mm long contained only fishes; feeding specimens under 151 mm long appeared to contain only crustaceans.

The greatest variety of prey was taken by specimens from 151 mm to 250 mm long. As the specimens increased in length, the variety of prey taken decreased (Table 6).

The composition of the diet of NEGOA arrowtooth flounders varied, in some respects, with the depth of capture (Tables 7 and 8). Decapod crustaceans were more important in the diet of arrowtooth flounders from the shallower waters (<150 m) than from the greater depths, as evidenced by their percent frequency of occurrence, percent by number, and percent by volume (Table 7). Fishes were more important in the diet of arrowtooth flounders taken from depths of 150 m or greater. This is most evident in their contribution to the total prey volume (Table 8).

Table 5. Summary of Higher Prey Taxa by Length Categories of *Atheresthes stomias* from the Northeastern Gulf of Alaska, May-August 1975

Length Category	Prey Taxon	Percent Frequency of Occurrence	Percent by Number	Percent by Volume	Index of Relative Importance
0-150 mm	Euphausiacea	40.00	97.78	71.43	6768.0
	Decapoda	20.00	2.22	1.59	76.0
	Unidentified animal matter	40.00	--	26.98	--
151-250 mm	Annelida	0.83	0.26	0.08	0.3
	Mollusca	0.83	0.26	0.00	--
	Euphausiacea	32.50	52.62	12.77	2125.2
	Decapoda	30.83	21.99	20.02	1330.5
	Echinodermata	0.83	0.26	0.08	0.3
	Teleostei	40.00	14.66	65.11	3190.8
	Unidentified animal matter	5.00	--	0.56	--
251-350 mm	Mollusca	1.11	0.26	5.14	6.0
	Euphausiacea	22.22	37.85	9.00	1041.0
	Decapoda	25.56	41.18	16.28	1468.7
	Teleostei	46.67	19.18	69.18	4123.8
	Unidentified animal matter	7.78	--	0.39	--
351-450 mm	Decapoda	62.50	38.89	18.57	3591.0
	Teleostei	37.50	33.33	81.36	4301.0
	Unidentified animal matter	12.50	--	0.07	--
≥451 mm	Teleostei	100.00	100.00	100.00	20000.0

Table 6. Summary of Individual Prey Taxa by Length Categories of *Atheresthes stomias* from the Northeastern Gulf of Alaska, May-August 1975

Length Category	Prey Taxon	Percent Frequency of Occurrence	Percent by Number	Percent by Volume	Index of Relative Importance
0-150 mm	Euphausiacea	40.00	97.78	5.14	6768.2
	Decapoda (unidentified)	20.00	2.22	1.59	76.2
	Unidentified animal matter	40.00	--	26.98	--
151-250 mm	Polychaeta	0.83	0.26	0.08	--
	Pelecypoda	0.83	0.26	--	--
	Isopoda	0.83	4.97	1.51	5.4
	Euphausiacea	32.50	52.62	12.77	2125.2
	Decapoda (unidentified)	15.83	15.71	6.39	349.8
	Pandalidae	5.00	2.36	1.33	18.5
	Pandalus spp.	0.83	0.52	0.52	0.9
	P. borealis	4.17	1.57	9.19	44.9
	P. jordani	0.83	0.26	1.64	1.6
	P. platyceros	0.83	0.26	0.26	0.43
	Eualus spp.	0.83	0.26	--	--
	Crangonidae	2.50	0.79	0.39	3.0
	Crangon communis	0.83	0.26	0.30	0.5
	Ophiuroidea	0.83	0.26	0.08	0.3
	Teleostei (unidentified)	27.50	9.42	30.12	1087.4

Table 6. Continued

Length Category	Prey Taxon	Percent Frequency of Occurrence	Percent by Number	Percent by Volume	Index of Relative Importance
151-250 mm (continued)	Salmoniformes	0.83	0.26	1.64	1.6
	Osmeridae	1.67	0.79	5.39	10.3
	Mallotus villosus	4.17	1.57	10.23	49.2
	Theragra chalcogramma	0.83	0.26	7.25	6.2
	Zoarcidae	1.67	0.52	2.20	4.5
	Cottidae	0.82	0.26	1.38	1.4
	Stichaeidae	0.83	0.26	1.51	1.5
	Lumpenus sp.	0.83	0.79	1.64	2.0
	Pleuronectidae	0.83	0.26	2.20	2.0
	Atheresthes stomias	0.83	0.26	1.47	1.4
	Unidentified animal matter	5.00	2.09	0.56	13.3
251-350 mm	Cephalopoda	1.11	0.26	5.14	6.0
	Euphausiacea	22.22	37.85	9.00	1041.0
	Decapoda (unidentified)	11.11	37.60	9.98	528.6
	Pandalidae	5.56	1.28	3.12	24.5
	Pandalus sp.	1.11	0.26	0.82	1.2
	P. borealis	1.11	0.26	1.32	1.8
	Pandalopsis ampla	1.11	0.51	--	--

Table 6. Continued

Length Category	Prey Taxon	Percent Frequency of Occurrence	Percent by Number	Percent by Volume	Index of Relative Importance
251-350 mm (continued)	*Eualus* sp.	1.11	0.26	0.53	0.9
	Crangonidae	3.33	0.77	0.37	3.8
	Sclerocrangon sp.	1.11	0.26	0.14	0.4
	Teleostei (unidentified)	35.56	11.25	30.44	1482.5
	Clupeidae	1.11	0.77	3.46	4.7
	Mallotus villosus	7.78	5.88	30.19	280.6
	Theragra chalcogramma	1.11	0.26	--	--
	Zoarcidae	2.22	0.77	4.19	11.0
	Glyptocephalus zachirus	1.11	0.26	0.90	1.3
	Unidentified animal matter	7.78	1.53	0.39	14.9
351-450 mm	Decapoda (unidentified)	25.00	11.11	0.10	280.4
	Pandalus borealis	12.50	16.67	11.98	358.1
	Pandalopsis sp.	12.50	--	--	--
	P. dispar	12.50	11.11	6.48	219.9
	Teleostei (unidentified)	25.00	11.11	1.94	326.3

Table 6. Continued

Length Category	Prey Taxon	Percent Frequency of Occurrence	Percent by Number	Percent by Volume	Index of Relative Importance
351-450 mm (continued)	*Clupea pallasii*	12.50	5.56	74.82	1004.7
	Mallotus villosus	12.50	16.67	4.61	265.9
	Unidentified animal matter	12.50	27.78	0.07	348.1
≥451 mm	Teleostei (unidentified)	40.00	50.00	67.23	4689.2
	Thaleichthys pacificus	10.00	12.50	--	--
	Gadidae	10.00	12.50	--	--
	Theragra chalcogramma	10.00	12.50	32.52	450.2
	Zoarcidae	10.00	12.50	0.25	127.5
	Unidentified animal matter	10.00	--	--	--

Table 7. Individual Prey Items of *Atheresthes stomias* from the Northeastern Gulf of Alaska, May-August 1975, Taken from Depths of Less than 150 Meters

Taxon	Percent Frequency of Occurrence	Percent by Number	Percent by Volume	Index to Relative Importance
Polychaeta	0.6	0.1	0.0	0.1
Pelecypoda	0.6	0.1	0.1	0.1
Isopoda	0.6	2.8	0.5	2.0
Euphausiacea	27.6	45.8	6.6	1446.2
Decapoda (unidentified)	17.2	30.4	6.0	626.1
Pandalidae	3.7	1.3	0.9	8.1
Pandalus sp.	1.2	0.4	0.5	1.1
P. borealis	3.7	1.3	7.7	33.3
Crangonidae	3.1	0.7	0.2	2.8
Crangon communis	0.6	0.1	0.1	0.1
Ophiuroidea	0.6	0.1	0.0	0.0
Teleostei (unidentified)	30.1	9.1	19.5	860.9
Clupeidae	0.6	0.4	1.6	1.2
Clupea pallasii	0.6	0.1	28.9	17.4
Salmoniformes	0.6	0.1	0.5	0.4
Osmeridae	1.2	0.4	1.5	2.3
Mallotus villosus	8.0	4.7	19.3	192.0
Theragra chalcogramma	1.2	0.3	2.2	3.0
Zoarcidae	1.8	0.4	1.2	2.9

Table 7. Continued

Taxon	Percent Frequency of Occurrence	Percent by Number	Percent by Volume	Index fo Relative Importance
Stichaeidae	0.6	0.1	0.5	0.4
Lumpenus sp.	0.6	0.4	0.5	0.5
Pleuronectidae	0.6	0.1	0.7	0.5
Atheresthes stomias	0.6	0.1	0.5	0.4
Unidentified animal matter	6.1	--	0.4	--

Table 8. Individual Prey Items of *Atheresthes stomias* from the Northeastern Gulf of Alaska, May-August 1975, Taken from Depths of 150 Meters or Greater

Taxon	Percent Frequency of Occurrence	Percent by Number	Percent by Volume	Index of Relative Importance
Cephalopoda	1.4	0.8	1.1	2.7
Crustacea	1.4	9.6	0.1	13.6
Euphausiacea	20.8	55.2	0.7	1162.7
Decapoda (unidentified)	5.6	2.4	0.2	14.6
Pandalidae	6.9	4.0	0.4	30.4
Pandalus borealis	1.4	0.8	0.2	1.4
P. jordani	1.4	0.8	0.2	1.4
P. platyceros	1.4	0.8	0.0	1.1
Pandalopsis sp.	1.4	0.8	--	--
P. ampla	1.4	1.6	--	--
P. dispar	1.4	1.6	1.1	3.8
Eualus sp.	2.8	1.6	0.1	4.8
Crangonidae	1.4	0.8	0.0	1.1
Sclerocrangon sp.	1.4	0.8	0.0	1.1
Teleostei (unidentified)	27.8	13.6	64.9	2182.3
Thaleichthys pacificus	1.4	0.8	--	--
Gadidae	1.4	0.8	--	--
Theragra chalcogramma	1.4	0.8	30.3	43.5
Zoarcidae	1.4	0.8	0.2	1.4

Table 8. Continued

Taxon	Percent Frequency of Occurrence	Percent by Number	Percent by Volume	Index of Relative Importance
Cottidae	1.4	0.8	0.1	1.3
Glyptocephalus zachirus	1.4	0.8	0.1	1.3
Unidentified animal matter	5.6	--	0.0	--

Specimens from the shallower waters (<150 m) averaged 249 mm, while those from the deeper water averaged 332 mm. The difference between the two means was significant at $\alpha = 0.05$.

The intensity of feeding was greater among flounders taken from depths of less than 150 m as compared to those from deeper water (Table 9). In May and June, only 29% of the arrowtooth flounders captured at depths of 150 m or greater were feeding. In contrast, 54% of those flounders from water less than 150 m were found to be feeding. A mean fullness of 21% was observed in the feeding specimens from the deeper water while the specimens from shallow water exhibited a mean fullness of 35% (Table 9). A similar trend was observed in the specimens collected in July and August (Table 9).

Differences in prey composition between sampling stations were sometimes pronounced, suggesting that opportunistic feeding is probably characteristic of the arrowtooth flounder. Specimens collected at stations 71B, 74H, and 75G were feeding primarily on pandalid shrimp, including *Pandalus borealis* and *Pandalopsis dispar*. These stations were located adjacent to areas recognized as untrawlable by the International Pacific Halibut Commission due to bottom characteristics (Figure 1). Stomachs from specimens taken at station 100B contained only fishes, primarily *Thaleichthys pacificus* and *Theragra chalcogramma*. Station 100B, located just outside of Yakutat Bay, was one of the deepest stations sampled. Stations located in nearshore areas of Montague, Hinchinbrook, and

Table 9. Numbers of Feeding and Non-Feeding Specimens of *Atheresthes stomias* by Station and Depth from the Northeastern Gulf of Alaska, May-August 1975

Stations < 150 m in Depth			Stations ≥ 150 m in Depth		
Station Number	Number of Feeding Fish	Number of Non-Feeding Fish	Station Number	Number of Feeding Fish	Number of Non-Feeding Fish
		MAY-JUNE 1975			
070C	21	24	074H	26	44
070D	33	14	092D	6	26
076A	21	17	100B	13	36
086C	20	45	100C	15	15
094D	34	10	094G	9	46
Total	129	110	Total	69	167
Mean fullness of feeding fish:		35%	Mean fullness of feeding fish:		21%
		JULY-AUGUST 1975			
070B	5	1	098C	2	10
071B	6	3	073A	0	5
073C	3	3	073H	1	2
074G	1	4	081F	0	3
075G	3	1	081G	0	2
077I	2	0	Total	3	22
077E	1	4	Mean fullness of feeding fish:		18%
075A	1	0			
077B	1	2			
077A	3	0			
079C	4	0			
083F	2	3			
083E	2	2			
Total	34	23			
Mean fullness of feeding fish:		58%			

Kayak islands (stations 70B, 76A, 77A, and 83E) yielded specimens that were feeding on *Mallotus villosus*, unidentified osmerids, and clupeids. Many of the *M. villosus* found among the stomach contents were ripe females. The majority of the euphausiids taken as prey were consumed at stations 86C, 94D, and 100C in late May and early June.

During the examination of the stomachs of *A. stomias*, it was noted that 77.5% of the feeding specimens had ingested only one taxon of prey. The greatest variety of prey found in one stomach was three different prey taxa, with two prey taxa in an individual stomach occurring with a little greater frequency.

DISCUSSION

Although *Atheresthes stomias* is rather widely distributed and quite abundant, little work is available on the biology and ecology of the species. Information concerning the feeding habits of this flounder is sparse. Nikolsky (1961) reported that *A. stomias* and *A. evermanni* from the Bering Sea fed upon pollock, herring, squid, and other flounders. In a feeding habits study of arrowtooth flounders from northern California, Gotshall (1969) found that crustaceans, especially *Pandalus jordani* and euphausiids, accounted for 45.7% of the total prey volume and were the most frequently occurring prey items. In the same study, fishes, primarily other flounders, contributed 46.7% of the prey volume, but occurred with less frequency.

Some similarities in the food of *A. stomias* from the waters of northern California and NEGOA are apparent. The crustacean prey is primarily pandalid shrimp and euphausiids; teleostean prey includes osmerids, pleuronectids, zoarcids, and gadids. However, the proportions in which crustaceans and fishes occur in the diet of the arrowtooth flounders from the two regions are quite disparate. Volumetrically, fishes are much more important in the diet of NEGOA *A. stomias* than in the diet of northern California conspecifics. The composition of the teleost prey species is also quite different between the two regions; northern California arrowtooth flounders consumed mainly other flounders, while NEGOA arrowtooths took osmerids and gadids.

The greatest difference in the feeding habits of *A. stomias* between the two areas was in the consumption of crustaceans. In NEGOA, less than 10% of the total prey volume was contributed by crustaceans, while in northern California, crustaceans contributed 53% of the total prey volume.

One relatively minor difference in the food habits of NEGOA and Californian *A. stomias* was the presence of *Cancer magister* in the diet of northern California specimens (Gotshall 1969). No crabs were found among the stomach contents examined from NEGOA. Other species of fishes taken from the same locations as the *A. stomias* used in the present study were found to be preying upon crabs, primarily *Chionoecetes bairdi* (Smith et al. 1978). *Cancer magister* was not very abundant or widely distributed in the portion of NEGOA from which the specimens for this study were collected (Ronholt et al. 1976).

Gotshall (1969) suggests that the arrowtooth flounder is an opportunistic feeder. Based on the NEGOA data, it appears that within certain limits, *A. stomias* is an opportunistic predator. The great variety in the diet of these flounders between sampling stations supports this hypothesis. Shrimp, euphausiids, and fishes are the major components of the diet of arrowtooth flounders from northern California and NEGOA. The opportunism of *A. stomias* is probably limited to these prey groups.

The presence of euphausiids in the diet of northern California *A. stomias* prompted speculation that these flounders may swim up into the water column at times in search of prey (Gotshall 1969). Evidence exists for this type of behavior in a morphologically similar species, *Reinhardtius hippoglossoides* (De Groot 1970). The presence of both euphausiids and capelin (*Mallotus villosus*) in the diet of NEGOA arrowtooth flounders is also suggestive of this type of behavior. However, the presence of these prey items in the diet is not conclusive evidence. The more widespread and numerically abundant species of euphausiids found in NEGOA inhabit the 0.0 m to 100 m depth zone, but frequently descend to greater depths (Brinton 1962). The larger members of many species live permanently below 200 m, and do not ascend and descend diurnally as do their younger, smaller conspecifics (Ponomareva 1963). It has also been found that the euphausiid species *Thysanoëssa inermis* and *T. raschii* from Russian waters do not descend to the benthopelagic layers as they do elsewhere during their diurnal migrations (Ponomareva 1963). This is apparently a predator avoidance response freeing them from predation by demersal fishes. The varying behavior of euphausiids makes it difficult to prove, on a basis of presence in the diet, whether or not *A. stomias* leaves the bottom to feed. Skalkin (1963) recorded the presence of euphausiids in the diet of Bering Sea yellowfin sole and suggested that those flounders obtained these crustaceans on the bottom. It may also be possible for arrowtooth flounders to obtain these crustaceans on or very near the bottom.

Likewise, the presence of capelin in the diet of the arrowtooth flounder cannot be taken as proof that the flounder feeds far off the bottom. Though capelin are pelagic much of the time, spawning takes place in nearshore waters with sandy substrate (Jangaard 1974). Many of the capelin found among the stomach contents of NEGOA arrowtooth flounders were ripe females that may have been taken on or near the bottom during spawning.

Changes in the composition of the diet as a function of predator size have been reported for several species of fishes from NEGOA. Pollock, flathead sole, and rex sole all exhibit changes in their diet as they grow (Smith et al. 1978). Shuntov (1970) states that Bering Sea halibuts (*Reinhardtius hippoglossoides*, *Atheresthes stomias*, and *A. evermanni*) prey upon benthic invertebrates when young and depend more upon other fishes when older and larger. *Reinhardtius hippoglossoides* from the Atlantic Ocean feeds upon crustaceans when young, and increases its consumption of fish as it grows larger (De Groot 1970). The Pacific halibut, *Hippoglossus stenolepis*, undergoes similar changes in its diet as it grows (Novikov 1968).

Very small specimens of *A. stomias* (10-19 mm) were found to be feeding on copepods (Barraclough 1968). The smallest length category of *A. stomias* (0-150 mm) examined in this study were feeding on small decapods and euphausiids (Table 6). The specimens of *A. stomias* examined in this study exhibited similar feeding habits to those of *Reinhardtius* and *Hippoglossus*; i.e., increased piscivory with greater predator size.

Annual migratory cycles, with associated changes in diet, have been observed in *Limanda aspera*, *Lepidopsetta bilineata*, *Hippoglossoides elassodon*, and *Pleuronectes quadrituberculatus* from the southeastern Bering Sea (Skalkin 1963). These migrations are primarily vertical, although some horizontal movement also occurs. During these migrations fishes move into the shallow waters for feeding and spawning with the coming of the warmer months. Kasahara (1962) grouped various genera of pleuronectids into three categories according to morphological characteristics: Small-mouthed flounders (*Limanda*, *Lepidopsetta*, *Glyptocephalus*, and *Platichthys*); Large-mouthed flounders (*Hippoglossoides*, *Eopsetta*, and *Cleisthenes*); and the halibuts (*Hippoglossus*, *Reinhardtius*, and *Atheresthes*). The behavior and feeding habits of these three groups were then examined. Small-mouthed flounders were found to exhibit the most noticeable seasonal variation in food habits and were more likely to undergo periods of starvation during the cold months, when they inhabited the deepest portions of their range. The large-mouthed flounders reduced their feeding intensity during the cold months and exhibited, to a lesser degree, variation in diet with the seasons. Halibuts displayed only a weak variation in food and feeding habits seasonally. Seasonal variation in the diet of pleuronectids is suggested to be a function of the change in depths at which the fishes are found during their migrations (Skalkin 1963; Smith et al. 1978). In contrast to other species of flatfishes, *A. stomias* was found to take part in relatively limited vertical migrations, with the younger, smaller members of the species exhibiting the greatest mobility (Shuntov 1970).

In this study, some variation in the diet as a function of depth was observed. The influence of depth on diet may only be apparent, however, since the mean length of specimens also varied with depth. The mean length of the arrowtooth flounders from depths greater than 150 m exceeded that of the specimens taken from shallower water by 83 mm. Other investigators (Alverson et al. 1964; Ronholt et al. 1976; Shuntov 1970) have reported that the mean length of *A. stomias* increases with increasing depth of capture. It is probable that the influence of depth on food habits of NEGOA arrowtooth flounders is actually due to the increase in the size of flounders with depth. It must be noted, however, that the specimens examined in this study were taken from a relatively limited depth range. Obtaining and examining specimens from a wider range of depths, especially the deeper portions of the flounder's range, would give a more complete picture of the food and feeding habits of *A. stomias*.

The information gathered in this study indicates that the feeding intensity of arrowtooth flounders in NEGOA is significantly greater in fishes taken from shallow waters and that feeding intensity increases throughout the warm months. This behavior has also been noted for *Hippoglossoides elassodon* from NEGOA (Smith et al. 1978), and is characteristic of several species of pleuronectids (Skalkin

1963; Shuntov 1970). Data on feeding intensity of Bering Sea arrowtooth flounders has been presented by Shuntov (1970). It was found that the flounders there also increased the rate of feeding (percent of fish feeding) from spring through summer, and decreased the rate from autumn through winter. Gotshall (1969) also found a similar cycle of feeding intensity in arrowtooth flounders from northern California. Although autumn and winter feeding data are not available for NEGOA arrowtooth flounders, the spring and summer information from this area suggests the same trends that were found in the Bering Sea and northern California.

Though marked seasonal fluctuations in the type of prey consumed do not seem to be characteristic of the food habits of *A. stomias*, some variation may be present. Gotshall (1969) suggests that fishes, although present as prey throughout the year, may be the more important prey of *A. stomias* during the winter months. In NEGOA arrowtooth flounders examined in this study, euphausiids were consumed throughout the study period, but were more important in late May and early June. More seasonal data is necessary in order to determine whether or not there is a significant variation in the qualitative aspect of the diet of *A. stomias* in NEGOA.

SUMMARY

The results of stomach analysis of *Atheresthes stomias* from the northeastern Gulf of Alaska have shown that fish, shrimp, and euphausiids are the most important prey of this flounder. Fish, especially osmerids, are the most important prey group, comprising close to 90% of the prey volume. Shrimps and euphausiids contributed approximately 9% of the prey volume.

The NEGOA arrowtooth flounders depended much more on fish as prey than did conspecifics from northern California, where crustaceans, primarily pandalid shrimp, were the most important prey.

Although the food habits of the NEGOA and northern California arrowtooth flounders differed quantitatively, from a qualitative aspect they were quite similar. It is probable that *A. stomias* is an opportunistic predator throughout its range, although preferring shrimp and fish.

The food and feeding habits of NEGOA *A. stomias* also appear to change as this fish grows. Small crustaceans are utilized less as the fish grows larger, and fishes become more important as prey items. Consumption of larger crustaceans, such as shrimp, increases with increasing predator size also. However, after the flounder attains a length of 450 mm, shrimp may no longer be utilized. A large sample size of large *A. stomias* from NEGOA is needed in order to better determine the importance of shrimp in the diet.

The composition of the diet of NEGOA arrowtooth flounders does not seem to vary throughout spring and summer, with the possible exception of euphausiids. Euphausiids may be taken more frequently in the spring than in late summer, but more information is needed in order to test this hypothesis. *Atheresthes stomias*, like other pleuronectids, increases the intensity of feeding as spring and summer progress, and also feeds more intensively in shallower waters.

Depth did not appear to have an effect on the food habits of NEGOA arrowtooth flounders. Differences in diet were noticeable between geographical locations, indicating that *A. stomias* may take the prey that is most accessible at a particular place and time. The examination of specimens from a greater range of depths would be helpful in determining if the diet of arrowtooth flounders is influenced by depth.

The question of whether or not *A. stomias* leaves the bottom and swims up into the water column seeking prey is left unresolved by this study. Although the presence of euphausiids and capelin in the diet suggest this to be true, both of these prey items may be taken on or near the bottom. The use of stomach content analysis alone is probably not sufficient to prove that the arrowtooth flounder feeds at any great distance from the bottom.

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