rhessodon and, therefore, is not useful in distinguishing it from other species.

Acknowledgments

For their advice and instruction, I thank Robert J. Lavenberg and H. Geoffrey Moser. Gary D. Brewer and Gerald E. McGowen gave advice and field and laboratory assistance, and provided specimens. Brian White, Marty Meisler, Marianne Ninos, Layne Nordgren, A. Kubo, Delaine Winkler, Sarah Swank, Scott Ralston, and Tina Behrents assisted in the field collection of eggs, larvae, and adult clingfishes. Michael H. Horn, Robert J. Lavenberg, H. Geoffrey Moser, and Sally L. Richardson greatly enhanced the manuscript through their critical reviews.

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SPRING AND SUMMER FOODS OF WALLEYE POLLOCK, *THERAGRA CHALCOGRAMMA*, IN THE EASTERN BERING SEA

The walleye (Alaska) pollock, *Theragra chalcogramma* (Pallas 1811), is the most abundant commercial fish species in the eastern Bering Sea (Pereyra et al.[1]) and plays an important role in ecosystem trophodynamics of the region. To obtain better knowledge of the role of the pollock as a predator, we have studied the stomach contents of pollock from the eastern Bering Sea collected on U.S. research vessels in the summer of 1974 and on Soviet and Japanese fishing vessels in the spring of 1977.

Results from this study contribute to our understanding of feeding habits; information on seasonal and size-dependent changes in feeding behavior are used to model interactions between species (trophodynamics), and to predict the influence of commercial fisheries on the abundance of populations in the eastern Bering Sea (Laevastu and Favorite[2,3]).

Methods

Pollock stomachs were collected by U.S. fisheries observers, on an opportunistic basis, aboard Soviet and Japanese motherships in the eastern Bering Sea. Samples were collected in the region of the continental shelf break in April and May 1977 (Figure 1, Table 1). The stomachs were removed, tied in cheesecloth, and preserved in dilute Formalin[4] (ca. 5%) and sent to the Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, Seattle, Wash., for analysis. Identifiable matter was separated by major taxa. Wet weight for each taxa was determined after blotting with paper towels. Uniden-

[1]Pereyra, W. T., J. E. Reeves, and R. G. Bakkala. 1976. Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1975. Unpubl. manuscr., vol. 1, 619 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

[2]Laevastu, T., and F. Favorite. 1976. Evaluation of standing stocks of marine resources in the eastern Bering Sea. Unpubl. manuscr., 35 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

[3]Laevastu, T., and F. Favorite. 1976. Dynamics of pollock and herring biomasses in the eastern Bering Sea. Unpubl. manuscr., 50 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

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

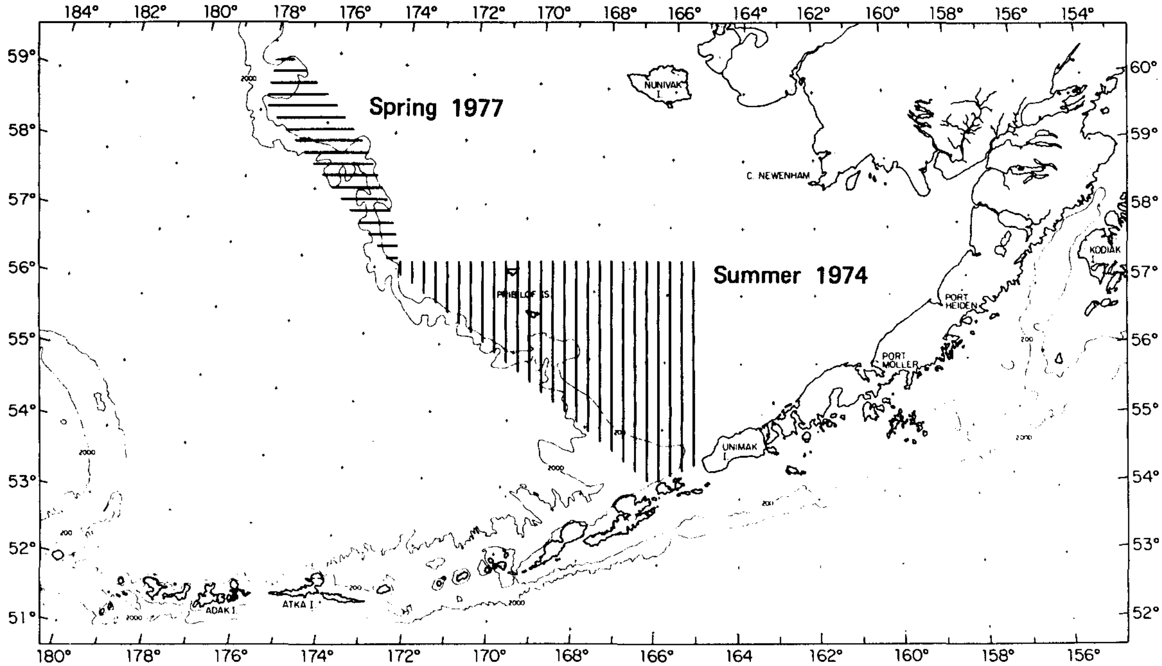

FIGURE 1.—Location sites where walleye pollock stomach samples were collected in the eastern Bering Sea.

TABLE 1.—Summary of walleye pollock stomach samples collected in the eastern Bering Sea.

Vessel	Sampling period	No. of stomachs collected	Depth range (m) of bottom	Average depth (m)
Oregon (U.S.)	July 1974	352	71-132	99
Chikubu Maru (Jpn.)	Apr. 1977	180	124-210	194
Tiraspol (U.S.S.R.)	Apr. 1977	225	128-256	167
Tenyo Maru #3 (Jpn.)	Apr.-May 1977	92	110-165	132
	Total	849		

tifiable matter was classed as "digested material" and also weighed. Percentage of food weight for each major food category, by fish-length group, was calculated as was the weight for each major food category per fish for each length group. Empty stomachs were not included in the analysis.

Detailed length data from foreign fishing vessels were available only from the Japanese fishing vessel *Tenyo Maru*. These data were analyzed by 10-cm fork length classes. Fish lengths from the Japanese fishing vessel *Chikubu Maru* and the Soviet fishing vessel *Tiraspol* were recorded only as greater or less than 35 cm (the approximate length at sexual maturity). This is also the size at which pollock become markedly cannibalistic (Takahashi and Yamaguchi 1972). Data from all three observer cruises were combined using these two major size categories to obtain sufficient sample sizes for comparison with the data collected in 1974.

Data collected in 1974 (RV *Oregon*) were examined by 5-cm length classes. The larger number of stomach samples collected during this cruise allowed a finer analysis of size-related changes in feeding habits. The methods used for processing samples from this cruise were approximately the same as for samples from the foreign vessels.

Results

An examination of stomach content weight by fish-length group provided evidence of related shifts in principal food categories in the diet of pollock (Figures 2, 3). In both spring 1977 and summer 1974, the percentage of copepods as food biomass tended to decrease with increasing size of pollock. The percentage of fish in pollock stomachs tended to increase with the size of pollock. Euphausiids were important food components in most length classes in both sampling periods. Amphipods, however, were only abundant in

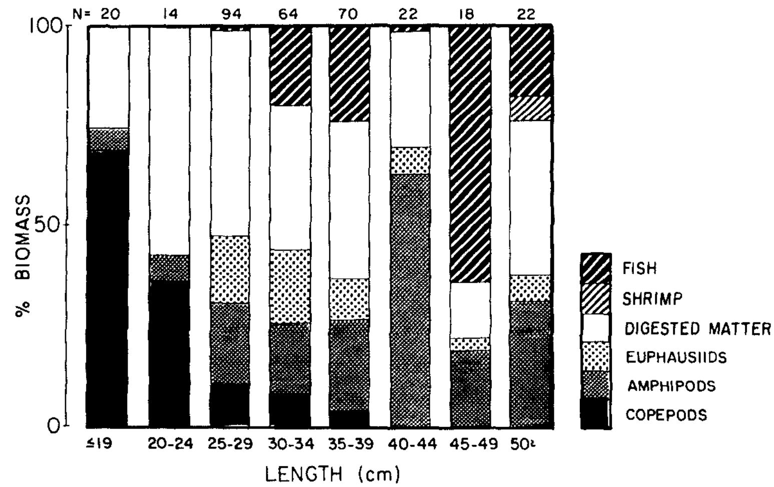

FIGURE 2.—Percent biomass of stomach contents by taxa per 5-cm length group of Bering Sea walleye pollock, summer 1974.

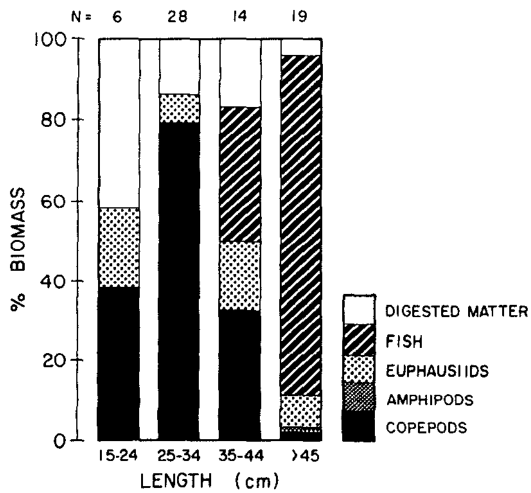

FIGURE 3.—Percent biomass of stomach contents by taxa per 10-cm length group of Bering Sea walleye pollock, spring 1977.

TABLE 2.—Proportion of taxa observed in walleye pollock stomachs in the eastern Bering Sea.

Taxa	Observer cruises, spring 1977		*Oregon* cruise, summer 1977	
	Weight (g)	% biomass	Weight (g)	% biomass
Fish	277.07	28.53	223.21	25.94
Copepods	349.81	36.02	44.60	5.18
Euphausiids	210.02	21.62	81.70	9.49
Amphipods	2.15	0.22	235.63	27.38
Chaetognaths	0.47	0.05	17.77	2.07
Cephalopods	0.30	0.03	—	—
Mollusks	0.15	0.02	0.89	0.10
Ostracods	0.02	—	—	—
Larvaceans	0.08	0.01	0.08	0.01
Annelids	3.99	0.42	3.40	0.40
Shrimp	12.91	1.33	9.79	1.14
Cumacean	—	—	0.01	—
Nemerteans	—	—	0.92	0.11
Mysids	—	—	0.55	0.06
Crab	—	—	4.56	0.53
Unidentified	—	—	1.64	0.19
Digested	114.09	11.75	235.83	27.40
Total	971.06	100.00	860.58	100.00

TABLE 3.—Grams of food organisms per fish (not including fish with empty stomachs) in each size class, *Tenyo Maru*, spring 1977.

Item	Fork length (cm) of pollock			
	15-24	25-34	35-44	>45
Grams copepods/fish	0.08	0.97	0.66	0.14
Grams euphausiids/fish	0.04	0.09	0.35	0.82
Grams fish/fish	—	—	0.69	5.28
Grams total food/fish	0.20	1.22	2.04	6.50
No. of fish with food	6	28	14	19
Percentage of fish with empty stomachs	57	26	18	17

stomachs collected in summer 1974, and the percentage of amiphods as food biomass tended to increase with increasing pollock size. Other food organisms that appeared in the diet are listed in Table 2.

The analysis of stomach contents by weight-percentage masks the behavioral aspects of pollock feeding due to size differences in food organisms. More information can be obtained from the data when analyzed as grams of food organisms per fish for each length class (Tables 3, 4). From this analysis it appears that larger pollock tended to exclude smaller food items from their diet. As the pollock grew larger they fed more on euphausiids, amphipods, and fish.

Data on the species composition of fish in pollock stomachs were available from the summer cruise of 1974 (*Oregon*). Fish ingested were identified from the stomachs of 27 pollock ranging in fork length from 26 to 57 cm (mean = 40 cm). Of the fish ingested, 89% by weight and 39% by number were

TABLE 4.—Grams of food organisms per fish (not including fish with empty stomachs) in each size class, *Oregon*, summer 1974.

Item	Fork length (cm) of pollock							
	<20	20-24	25-29	30-34	35-39	40-44	45-49	>49
Grams copepods/fish	0.42	0.26	0.14	0.16	0.13	0.02	—	—
Grams amphipods/fish	0.04	0.04	0.27	0.33	0.80	2.90	2.20	1.23
Grams euphausiids/fish	—	—	0.20	0.38	0.30	0.25	0.31	0.31
Grams shrimp/fish	—	—	—	—	0.01	—	—	0.40
Grams fish/fish	—	—	0.01	0.40	0.73	0.02	7.18	0.71
Grams total food/fish	0.62	0.70	1.27	1.97	2.91	4.57	11.24	4.00
No. of fish with food	20	14	94	64	70	22	18	22
Percentage of fish with empty stomachs	35	0	7	2	4	8	14	4

pollock. Other fishes identified included gadids, cottids, hexagrammids, and zoarcids.

Pollock food composition in summer 1974 and spring 1977 can be compared although geographic locations of stomachs collected varied (Figure 4). Pollock were observed with more copepods as a percentage of food biomass in spring 1974 than in summer 1977. Amphipods were nearly absent from stomachs collected in spring 1974 but were an important food component in summer 1977.

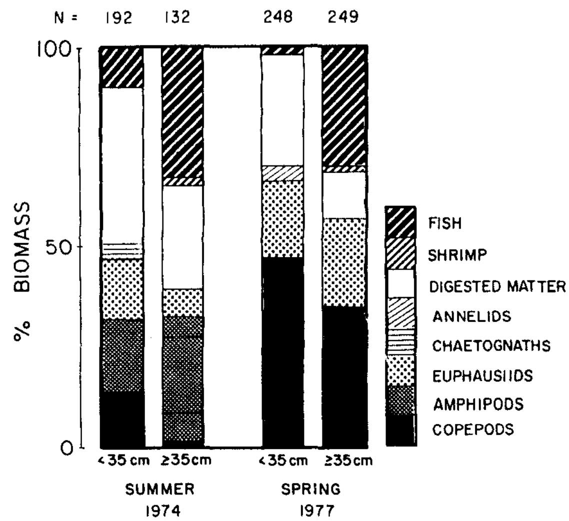

FIGURE 4.—Percent biomass of stomach contents by taxa for adult and juvenile walleye pollock in summer 1974 and spring 1977 in the Bering Sea.

Discussion

Previous studies on the food of the walleye pollock in the eastern Bering Sea indicated that in winter 1972, juvenile pollock fed mainly on euphausiids, while adult pollock fed on euphausiids, small pollock, and other fish (Mito 1974). In summer 1970, juvenile pollock fed on copepods and euphausiids, while adult pollock fed on euphausiids, small pollock, and other fish (Takahashi and Yamaguchi 1972). Our study indicates that in summer 1974 juveniles fed mostly on copepods, euphausiids, and amphipods, while adults fed on euphausiids, amphipods, and fish. In spring 1977, juvenile pollock fed mostly on copepods and euphausiids, while adult pollock fed on copepods, euphausiids, and fish. The results of these studies indicated that euphausiids are an important year-round food source of both juvenile and adult pollock. Fish appear to be an important year-round resource to adult pollock. The relative importance of other prey organisms in the diet of pollock seems to fluctuate between the studies.

Adult pollock tend to obtain a greater percentage of their food biomass from larger prey organisms than juvenile pollock, by ingesting more fish, euphausiids, and amphipods as they grow larger (Figures 2, 3). Additionally, larger pollock tend to exclude copepods from their diet (Tables 3, 4). These observations could result from an active process, based on preference or capture efficiency, or a passive process, resulting from spatial distribution.

Additional information is needed to understand the complexities of pollock feeding behavior, including: 1) seasonal variations in feeding behavior, 2) geographical variations, and 3) effects of alternate prey on cannibalism and grazing on other fish. This information would be useful in ecosystem modelling to understand the natural competitive and predatory interactions between fish populations and the potential effects of heavy exploitation.

Acknowledgments

We thank the following persons at the Northwest and Alaska Fisheries Center: Donald Day for collecting and making preliminary analysis of 1974 data, Robert French for arranging the collection, and Beverly Vinter and Jay Clark for iden-

tifying the contents of fish stomachs collected in 1977.

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FECUNDITY OF THE ATLANTIC MENHADEN, *BREVOORTIA TYRANNUS*

Although some work has been done to determine the time and place of spawning, age of spawning, and fecundity of Atlantic menhaden, *Brevoortia tyrannus* (Higham and Nicholson 1964), no attempt has been made to relate fecundity and age. In this study, I 1) examined the ovaries of fish 1 to 5 yr old collected during autumn 1970, in the vicinity of Beaufort, N.C.; 2) estimated the number of ripening ova in sexually mature fish; 3) calculated the mean number of ova spawned by fish of each age; and 4) determined the reproductive potential and the net reproductive rates for the 1954-63 year classes.

Atlantic menahden, family Clupeidae, constitute a single biological population (Nicholson 1972, 1978; Dryfoos et al. 1973) inhabitating coastal waters from Florida to the Gulf of Maine. It is subjected to an intensive purse seine fishery from Florida to New England. Fish are landed daily at reduction plants and processed into meal, oil, and solubles. Fishing begins in Florida and North Carolina in late April, in New Jersey coastal waters in early June, and in New England waters in late June. Fishing usually ends in mid to late November, except in the vicinity of Beaufort where schools of migrating fish of all ages from northern areas provide an intensive fishery from November to late December or early January.

Atlantic menhaden make extensive coastal movements and during the fishing season are stratified along the coast by age and size. In autumn most fish north of Virginia move southward and by January are concentrated in offshore waters from Cape Hatteras to northern Florida. About mid-March they begin a northward movement and by mid-June are stratified in coastal waters by age and size, the younger and smaller farther south and the older and larger farther north (Nicholson 1971). South of Cape Hatteras and in Chesapeake Bay most fish are ages 1 and 2. Age-2 fish dominate in coastal waters off New Jersey, ages 3 and 4 in Long Island Sound, and age 4 and older north of Cape Cod. Although they may live to age 9, few older than age 6 are caught.

Menhaden spawn in offshore coastal waters where the eggs hatch in 36 to 48 h (Reintjes 1962). Larvae, carried inshore by ocean currents, enter estuaries where they metamorphose to the adult form at about 35 mm total length. Although some spawning occurs in summer and early autumn in Long Island Sound and New England waters—the only areas where fish of spawning age are found during that time — most spawning occurs in the South Atlantic area from January to March and in the Middle Atlantic area from October to December and March to May. Although there appears to be only one spawning cycle each year, evidence is uncertain as to whether Atlantic menhaden are fractional spawners (Higham and Nicholson 1964).

As the population size decreased in the 1960's age structure also changed. Fish older than age 3 became extremely scarce, and most plants in the northern areas that were dependent on older fish closed. By 1969 few fish older than age 4 were landed, even in the North Carolina fall fishery. which traditionally had been dependent on older fish (Nicholson 1975).

Collection and Preparation of Ovaries

Ovaries were collected from 17 November to 29 December 1970 during the North Carolina fall fishery at the same time catches were being sampled routinely for age and size (June and Reintjes 1959). Sampling personnel measured and weighed the fish, removed scales for aging, and removed the ovaries. Only ripening ovaries fitting the