FOOD OF WALLEYE POLLOCK, *THERAGRA CHALCOGRAMMA*, IN AN EMBAYMENT OF SOUTHEASTERN ALASKA

The walleye pollock, *Theragra chalcogramma* Pallas, is commercially and ecologically one of the most important fishes in Alaskan waters. In recent years, it has predominated by weight in the catches of commercial groundfish and in demersal trawling surveys of the Bering Sea and the Gulf of Alaska (North Pacific Fishery Management Council 1979a, b; Pereyra et al. 1976[1]; Ronholt et al. 1978[2]). It is similarly abundant in the inside waters of southeastern Alaska (Carlson et al. 1977[3]), where recent attempts have been made to establish a commercial fishery for walleye pollock. Walleye pollock are also an important component of the food web, primarily as forage for seabirds, marine mammals, and fish. In the eastern Bering Sea, walleye pollock is the most important species in the diet of many seabirds (Hunt et al. 1981) and is a major food of seals, *Phoca* spp. (Lowry and Frost 1981); whales (Frost and Lowry 1981); and northern fur seals, *Callorhinus ursinus* (Harry and Hartley 1981). In southeastern Alaska, juvenile walleye pollock are one of the most common foods of troll-caught Pacific salmon, *Oncorhynchus* spp. (Wing 1977).

Despite the importance of walleye pollock, their diet has been little studied. The food of adults and juveniles from the eastern Bering Sea has been investigated during the spring, summer, or fall (Takahashi and Yamaguchi 1972; Mito 1974; Bailey and Dunn 1979), but no single study covered more than one season in a given area. There are no published data on the food of walleye pollock in the eastern North Pacific Ocean south of the Bering Sea except for one report of their feeding upon salmon fry in southeastern Alaska (Armstrong and Winslow 1968). In this report, I document the foods and seasonal changes in the diet of walleye pollock for 1 yr in an area of the inside waters of southeastern Alaska.

Methods

During each of the four seasons, stomachs were collected from walleye pollock in two adjacent bays, Auke Bay and Fritz Cove, near Juneau, Alaska (Table 1; Fig. 1). The two bays make up a larger embayment of Stephens Passage, a prominent fjord in the inside waters of southeastern Alaska. Depending upon the availability of research vessels, fish were caught with three types of bottom trawls: A 400-mesh (27 m) Eastern otter trawl, a standard 40-ft (12 m) Gulf shrimp trawl, and a 12-ft (3.7 m) balloon-type otter trawl. All trawling was done during daylight. The trawls were dragged from deeper to shallower water during each haul, so the exact depth at which fish were captured could not be determined. Trawling depths averaged 46 m (range 16-60 m) in Auke Bay and 90 m (range 55-110 m) in Fritz Cove. It was necessary to collect walleye pollock from both bays to obtain a broad size range of fish in each season. When a single tow produced large numbers of walleye pollock, the catch was arbitrarily sampled to obtain about 40 fish in each 100 mm size category; otherwise, all walleye pollock were retained. Standard length (SL) of each retained fish was measured, sex determined when possible, and stomachs removed and preserved in 5% buffered Formalin[4]. Walleye pollock used for the stomach samples were mostly between 150 and 450 mm SL, and ranged from 106 to 585 mm SL. Most of these fish were probably juveniles or young adults because walleye pollock mature at lengths between 290 and 350 mm FL (fork length) (Hughes and Hirschhorn 1979).

A number of authors have discussed various techniques for analyzing stomach contents of fish (see Windell 1971), and it appears that any single method

[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. Processed rep., 619 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard E., Seattle, WA 98112.

[2]Ronholt, L. L., H. H. Shippen, and E. S. Brown. 1978. Demersal fish and shellfish resources of the Gulf of Alaska from Cape Spencer to Unimak Pass 1948-1976, a historical review. Processed rep., 4 vols., 955 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard E., Seattle, WA 98112.

[3]Carlson, H. R., R. E. Haight, and K. J. Krieger. 1977. Species composition and relative abundance of demersal marine life in waters of southeastern Alaska, 1969-77. Processed rep., 69 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, 2725 Montlake Boulevard E., Seattle, WA 98112.

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

TABLE 1.—Summary of walleye pollock stomach samples collected each season, by date and location of collection, Auke Bay and Fritz Cove, southeastern Alaska, 1979-80.

Season	Dates of collection	Number of trawl hauls	Number of stomachs collected: Auke Bay	Fritz Cove	Total
Summer	July, August 1979	11	105	62	167
Fall	October, November 1979	6	64	113	177
Winter	January 1980	4	81	67	148
Spring	April 1980	2	39	46	85
Totals			289	288	577

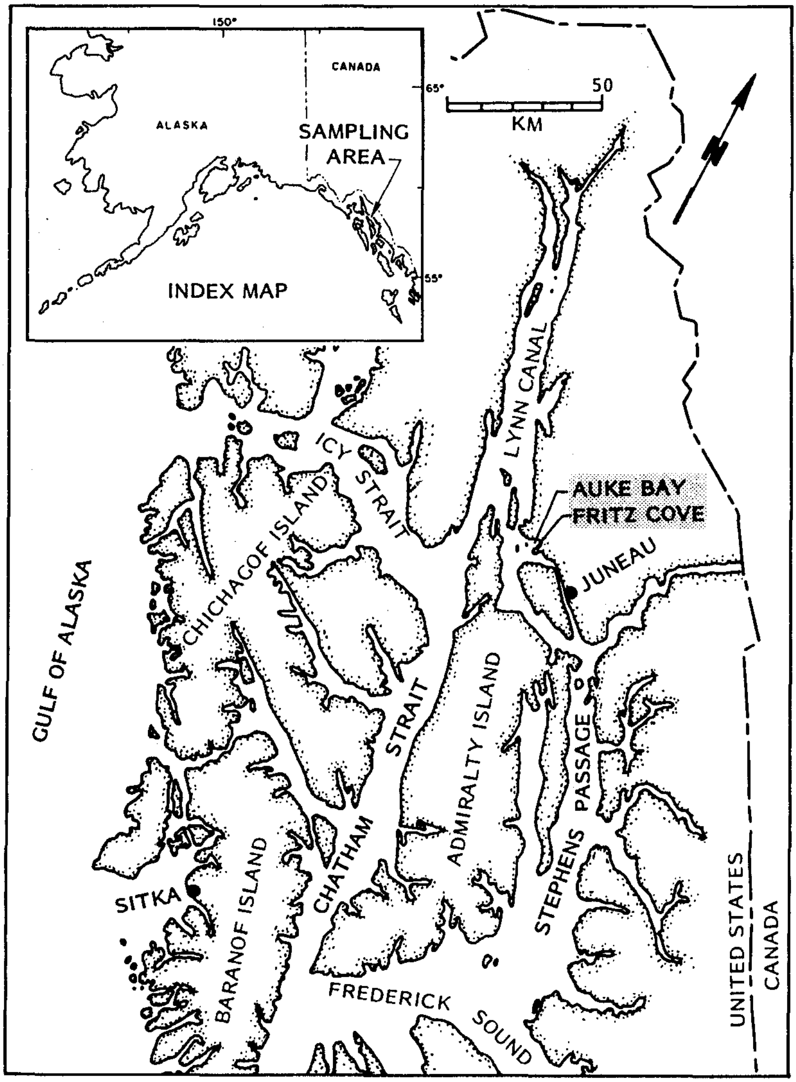

FIGURE 1.—Location of Auke Bay and Fritz Cove, southeastern Alaska, where stomachs were collected from walleye pollock in 1979-80.

has its biases. Therefore, I chose to analyze the stomach contents of walleye pollock in two ways: 1) Percent by volume of major food categories to show the contribution in biomass of the foods, and 2) percent frequency of occurrence to show the diversity of foods at lower taxonomic levels.

To determine percent by volume, I either measured or estimated the volume of major food categories (e.g., mysids, shrimp, or fish) in each stomach, depending upon the amount of food present. In walleye pollock with stomach contents about ≥ 0.5 ml, the displacement volume of food in each major category was measured in a graduated cylinder and then expressed as a percentage of the total volume of the stomach contents. In fish with stomach contents <0.5 ml, food was divided by categories into piles of uniform height in a petri dish and placed over a grid. The number of grid squares covered by each pile was used to estimate the volume percentage of each food category. I then pooled percent-volume measurements and estimates for all fish and calculated mean percentages for each food category. Walleye pollock with empty stomachs or with stomachs containing only a trace of food were excluded from these calculations. Many stomachs contained a large percentage of flocculent, digested matter or an indistinguishable mixture of crustacean parts; these items were termed "unidentified digested matter" and "unidentified crustacean fragments," respectively.

To determine the frequency of occurrence of foods, each item present in a stomach was identified to the lowest practical taxon. Percent frequency of occurrence for the food item was calculated by dividing the number of stomachs that contained the item by the total number of walleye pollock stomachs. Stomachs with a trace of food were included in this analysis, but empty stomachs were not.

The volumetric data were categorized by size and sex of walleye pollock and by season of year (for dates, see Table 1) to determine if these factors influenced the diet. To compare types of food eaten by different sizes of walleye pollock, the fish were arbitrarily divided into three length groups: Small, <250 mm; intermediate, 250-349 mm; and large, >349 mm SL. The percent of empty stomachs was also calculated for each season and size category as an indicator of seasonal feeding activity. Because the size of walleye pollock was generally different in each bay during the same season, the foods of the fish in the two bays could not be compared. Consequently, data for the two bays were pooled for all analyses. Differences in feeding at different depths also could not be analyzed because, as previously noted, the precise depth where fish were caught was unknown.

Results and Discussion

When data from all samples of walleye pollock were combined (regardless of size, sex, or season), crustaceans were the major food. Of the crustaceans, euphausiids and mysids had the highest percent volumes and frequencies of occurrence (Tables 2, 3). *Thysanoessa raschii* was the most frequently eaten euphausiid; *Acanthomysis pseudomacropsis* and *Neomysis kadiakensis* were the most frequently eaten mysids. The percent volume of shrimp was nearly as high as the percent volume of euphausiids and mysids; however, shrimp were eaten less frequently. Most of the shrimp were either *Crangon* spp. (Crangonidae) or Pandalidae. Copepods, hyperiid and gammarid amphipods, and cumaceans were found in many of the stomachs (>20%), but their percent volumes were small (<3%). Often stomachs contained only one or two individuals that comprised a minute fraction of the contents. Copepods were mostly *Metridia* sp. and *Calanus* sp.; cumaceans were mostly *Eudorella* sp. Amphipods were generally not identified to species.

Fish and, to a lesser degree, polychaetes were the only other foods present in amounts greater than a trace. They were found less frequently than crustaceans and were usually identifiable only to class. However, compared with crustaceans, fish found in the stomachs were relatively large and usually composed most of the volume of food in the stomachs, when they occurred.

The common food organisms in all of the studies of walleye pollock have been crustaceans and fish. In the eastern Bering Sea in summer 1970, walleye pollock fed almost exclusively on euphausiids, copepods, and fish (Takahashi and Yamaguchi 1972). In fall 1972, walleye pollock there ate euphausiids and fish (Mito 1974); and in summer 1974 and spring 1977, they ate mostly euphausiids, copepods, fish, and amphipods (Bailey and Dunn 1979). In southeastern Alaska in 1979-80 (my study),

TABLE 2.—Mean percent volume of major categories of food in walleye pollock stomachs from Auke Bay and Fritz Cove, southeastern Alaska, 1979-80. (Table does not include empty stomachs or those with only a trace of food.)

Food category	All fish (%)	By length (SL) category of fish: <250 mm (%)	250-349 mm (%)	>349 mm (%)	By sex of fish[1]: Males (%)	Females (%)
Euphausiids	17.1	16.6	21.4	8.5	19.3	18.8
Mysids	14.8	21.4	9.9	6.5	11.7	10.2
Shrimp:	14.3	7.7	13.8	35.6	15.5	18.3
Pandalids	7.3	1.7	7.1	25.2	8.7	9.6
Crangonids	5.3	4.7	5.0	7.6	4.0	7.0
Hippolytids	0.6	0.9	0.5	0.1	0.2	1.3
Unidentified shrimp	1.1	0.4	1.2	2.7	2.6	0.4
Fish	5.7	3.7	4.6	14.7	5.7	6.7
Cumaceans	2.8	3.8	2.4	0.8	2.2	1.5
Polychaetes	2.4	0.7	4.5	2.5	3.0	3.1
Copepods	2.2	4.0	0.6	0.5	0.3	1.4
Gammarid amphipods	1.6	1.9	1.3	1.4	1.9	1.3
Hyperiid amphipods	1.2	1.2	1.3	0.9	1.8	0.8
Unidentified crustacean fragments	9.7	10.6	8.8	9.3	9.0	7.2
Other foods	2.0	2.0	0.9	4.5	1.0	2.6
Unidentified digested matter	26.2	26.4	30.5	14.8	28.6	28.2
Mean length of pollock (mm)	261.3	193.9	292.0	394.9	283.8	283.2
Number of samples	431	204	161	66	150	190

[1]91 additional fish were examined for which sex could not be determined.

TABLE 3.—Frequency of occurrence of food items found in at least 1% of stomachs of 541 walleye pollock from Auke Bay and Fritz Cove, southeastern Alaska, 1979-80[1]. (Table does not include an additional 36 stomachs that were empty.)

Food item	Frequency of occurrence (%)
Mysids	54
Acanthomysis pseudomacropsis	19
Acanthomysis nephrophthalma	5
Neomysis kadiakensis	18
Neomysis rayii	3
Neomysis sp.	1
Pseudomma truncatum	7
Unidentified mysids	9
Euphausiids	47
Thysanoessa raschii	31
Thysanoessa spinifera	1
Thysanoessa longipes	1
Unidentified euphausiids	17
Copepods	42
Metridia sp.	20
Calanus sp.	15
Euchaeta elongata	6
Aetidius sp.	6
Centropages abdominalis	2
Unidentified copepods	6
Hyperiid amphipods	29
Parathemisto sp.	6
Unidentified hyperiids	23
Shrimp	28
Pandalid shrimp	11
Pandalus borealis	3
Pandalus tridens	1
Unidentified pandalids	9
Crangonid shrimp	14
Crangon communis	2
Crangon dalli	2
Crangon franciscorum	1
Crangon sp.	6
Unidentified crangonids	4
Hippolytid shrimp	4
Eualus avinus	1
Unidentified hippolytids	3
Unidentified shrimp	5
Gammarid amphipods	25
Oetocerotidae	4
Cyphocaris challengeri	1
Unidentified gammarids	21
Cumaceans	21
Eudorella sp.	16
Leucon sp.	2
Unidentified cumaceans	3
Polychaetes (unidentified)	12
Fish	10
Theragra chalcogramma	1
Unidentified fish	8
Cephalopods	1
Pelecypods	1
Isopods	1
Larval shrimp	1
Larval brachyuran crab	1
Larval anomuran crab	1

[1]Also present at frequencies <1%: Mysids—*Pseudomma berkeleyi, Meterythrops* sp., *Holmesiella anomula, Stilomysis grandis*; pandalid shrimp—*Pandalopsis dispar*; crangonid shrimp—*Crangon alaskensis, Argis crassa*; fish—*Clupea harengus pallasi*, Osmeridae, Pleuronectidae, Stichaeidae; cumaceans—*Cumella* sp.; copepods—*Calanus cristatus, Pseudocalanus* sp.; hyperiid amphipod—*Primno macropa*; cephalopod—*Octopus* sp.; unidentified gastropods; Paguridae—*Pagurus ochotensis*; brachyuran crab; barnacle cyprid; larval fish—*Thaleichthys pacificus*; Holothuroidea—*Molpadia intermedia*; algae.

walleye pollock consumed primarily euphausiids, mysids, shrimp, and fish. Thus, of the crustaceans, euphausiids were a major food in all studies, whereas the types of other crustaceans varied among the investigations. Shrimp, an important food for walleye pollock both in my study and near Kodiak Island[5], were found only in very small amounts in Bering Sea fish. In all studies, organisms that are strictly benthic (e.g., clams and crabs) were conspicuously scarce in the diet.

In fishes, the size of prey generally increases as the size of predators increases (Nikolsky 1963), and this appears to be true in walleye pollock. In my study, small walleye pollock ate mostly planktonic crustaceans, particularly euphausiids, mysids, and copepods; large walleye pollock generally ate larger prey, such as shrimp and fish (Table 2). Intermediate-sized walleye pollock were transitional in their diet and ate a combination of large and small foods. In the Bering Sea, juvenile walleye pollock (<350 mm) also ate mostly euphausiids or copepods, whereas larger walleye pollock ate larger foods, primarily fish (Takahashi and Yamaguchi 1972; Mito 1974; Bailey and Dunn 1979). Walleye pollock became increasingly cannibalistic with increase in size in the Bering Sea: More than half the food of fish >550 mm FL was smaller walleye pollock (Takahashi and Yamaguchi 1972). In my study, cannibalism was observed in only 1% of the stomachs (Table 3); however, few walleye pollock >450 mm SL were examined.

Sex of the fish had little effect on their diet (Table 2). The diets of male and female walleye pollock were nearly identical in percent volume of each food category.

Walleye pollock apparently fed year-round (Table 4): In any one season only 4-8% of all fish had empty stomachs. In any one size group, no more than 14% of the fish had empty stomachs in any season. In con-

[5]P. Livingston, Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112, unpubl. data.

TABLE 4.—Seasonal feeding activity of walleye pollock shown by percent of fish with empty stomachs, Auke Bay and Fritz Cove, southeastern Alaska, 1979-80.

Size	Stomachs examined	Spring	Summer	Fall	Winter
All sizes	Total (no.)	85	167	177	148
	With food (no.)	82	158	162	139
	Empty (%)	4	5	8	6
<250 mm SL	Total (no.)	14	91	99	83
	With food (no.)	14	84	92	76
	Empty (%)	0	8	7	8
250-349 mm SL	Total (no.)	51	36	57	53
	With food (no.)	48	35	52	51
	Empty (%)	6	3	9	4
>349 mm SL	Total (no.)	20	40	21	12
	With food (no.)	20	39	18	12
	Empty (%)	0	3	14	0

trast, in a seasonal 1-yr study of food of adult walleye pollock off Hokkaido Island, Japan, the rate was much higher, particularly during the winter months when up to 80% of the stomachs were empty (Maeda et al. 1981). In an eastern Bering Sea study (Bailey and Dunn 1979), generally few walleye pollock had empty stomachs in summer 1974 (results similar to those of my study); however, a much higher percentage of fish had empty stomachs there in spring 1977 than in my study.

The diet of small walleye pollock varied widely from season to season in the percent volume of each food type (Fig. 2). Euphausiids were the predominant food of small walleye pollock in winter and spring (34% and 78%, by volume, respectively) but constituted <7% of the stomach contents in the summer and fall. Conversely, mysids were the predominant food in the summer and fall diets (36% and 22%, by volume, respectively) but were much less important in the winter and spring (<5%, by volume). Copepods were also an important food (11%, by volume) in the summer but were insignificant (<1%) in other seasons.

For each season, the diet of intermediate-sized

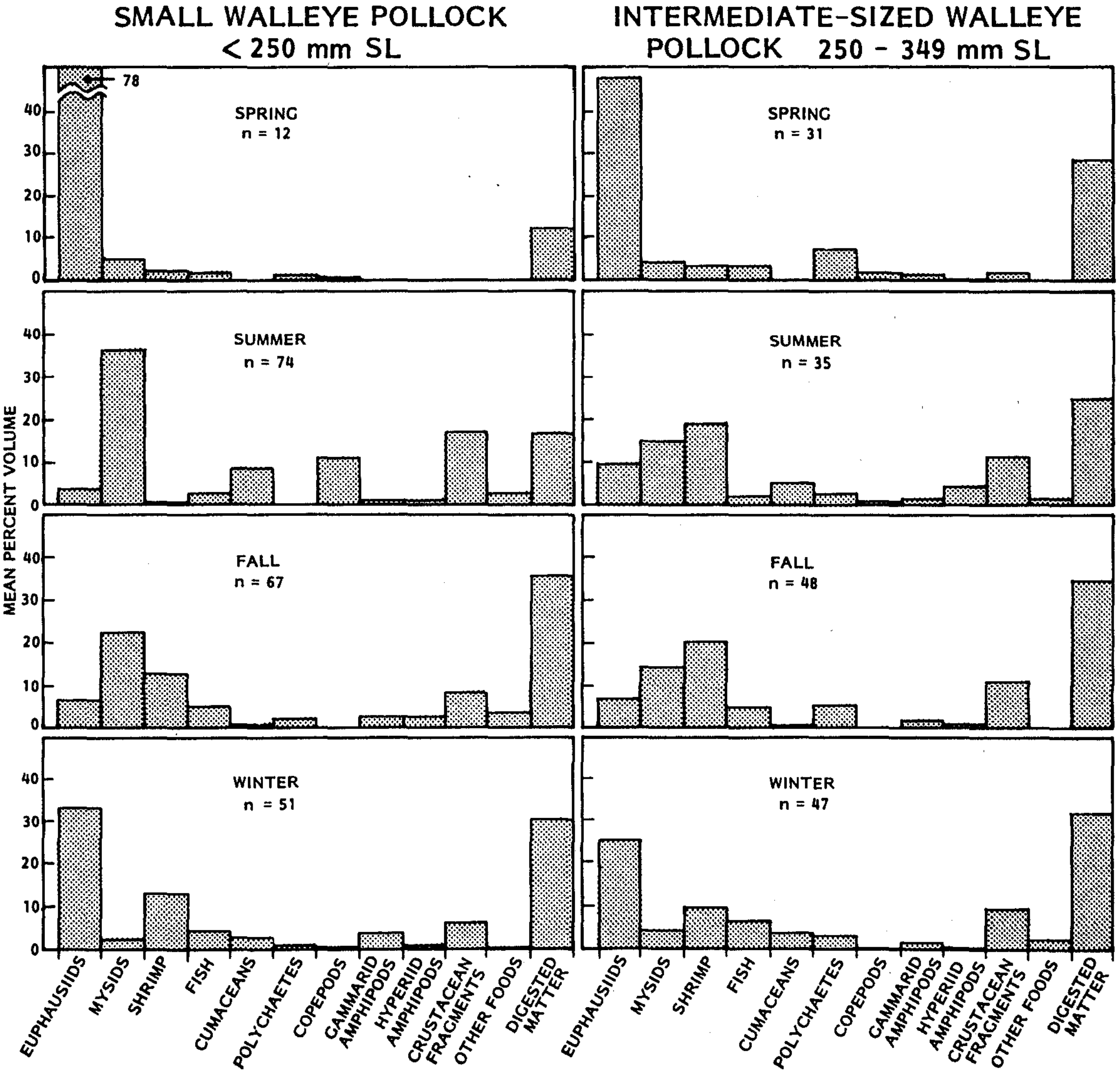

FIGURE 2.—Mean percent volume of major food categories in stomachs of small and intermediate-sized walleye pollock by season of year, Auke Bay and Fritz Cove, southeastern Alaska, 1979-80. (Figures do not include empty stomachs or those with only a trace of food.)

walleye pollock was similar to that of small walleye pollock (Fig. 2). Intermediate-sized fish also fed predominately on euphausiids in the winter and spring and more on mysids in the summer and fall. However, seasonal variability in diet was not as great as for small walleye pollock. Too few large walleye pollock were collected in three of the seasons to demonstrate seasonal changes in their foods.

Some of the seasonal differences found in foods of small walleye pollock may be explained by the availability of euphausiids and copepods. In two seasonal studies of zooplankton in the Auke Bay vicinity, 1962-64 (Wing and Reid 1972) and 1973-75 (Carlson 1980), euphausiids (excluding small larval forms) were least abundant and copepods were most abundant during the late spring and summer. Similar seasonal patterns were found in the foods of small walleye pollock: The percent volume of euphausiids was lowest in the summer, whereas copepods were a significant food only during the summer. However, results of the zooplankton studies also differ in some respects from my results: In 1973-75, euphausiids were most abundant in plankton in the fall (Carlson 1980), but in my 1979-80 study, they were relatively scarce in the stomach samples during the fall. Concurrent studies of walleye pollock foods and zooplankton abundance are needed to better understand the causes of seasonal variations in the diet of small walleye pollock.

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DAVID M. CLAUSEN

Northwest and Alaska Fisheries Center
Auke Bay Laboratory
National Marine Fisheries Service, NOAA
P.O. Box 155, Auke Bay, AK 99821