Trophic Relationship of Age-0 and Age-1 Walleye Pollock *Theragra chalcogramma* Collected Together in the Eastern Bering Sea*

Jill J. Grover
College of Oceanography, Oregon State University
Hatfield Marine Science Center, Newport, Oregon 97365

Walleye pollock *Theragra chalcogramma* a gadid endemic to the north Pacific, is one of the most important components of the Bering Sea food web (Smith 1981) and supports the largest single-species commercial fishery in the world (Megrey 1989). Although a number of studies have documented the food habits of larval (e.g., Kamba 1977, Cooney et al. 1980, Clarke 1978 and 1984, Kendall et al. 1987, Grover 1990), juvenile (e.g., Kamba 1977, Bailey and Dunn 1979, Cooney et al. 1980, Lee 1985, Grover 1990), and adult walleye pollock (e.g., Takahashi and Yamaguchi 1971, Bailey and Dunn 1979, Livingston et al. 1986, Dwyer et al. 1987, Bailey 1989), previous studies have generally pooled samples either over time or space. While pooled data adequately characterize large-scale patterns of prey utilization, small-scale patterns of between-year-class trophic relationships are best defined by fish that were collected together.

This study examined the trophic relationship of age-0 and age-1 pollock that were collected in a single haul in the southeastern Bering Sea. As pollock are known to be highly cannibalistic (Takahashi and Yamaguchi 1971, Bailey and Dunn 1979, Livingston et al. 1986, Dwyer et al. 1987, Bailey 1989), this study looked for evidence of cannibalism, as well as defined the size and taxa of prey that were ingested by the two year-classes.

Methods

Juvenile pollock were collected as one aspect of a survey of groundfish in the eastern Bering Sea in 1985 by the *Morning Star*, using a Marinovich midwater trawl (Walters et al. 1988). An examination of length-frequency distributions from these trawls, which principally targeted age-0 fish, revealed that age-0 (zeros) and age-1 fish (ones) were rarely collected together (Jim Traynor, NMFS Alaska Fish. Sci. Cent., Seattle, unpubl. data). Among stations where zeros and ones occurred in the same haul, comparable numbers of both year-classes were obtained at only one station. Coincidentally, although not all of the ones were saved, this was the only station where both ones and zeros were preserved. This collection was made from 0900 to 0920 hours on 3 August 1985, at station 95 (56° 11.17′N, 162°18.36′W), in the southeast shelf region. Gear depth averaged 20 m, and water temperature was 6.5°C. The fish were frozen at sea. In the laboratory, they were defrosted in 10% formalin to facilitate the simultaneous separation and fixation of the specimens. All the preserved specimens from this collection were analyzed.

This study examined the diet of 52 age-0 and 22 age-1 fish. Age groups were determined based on length, using the categories of Dwyer et al. (1987)—age 0, 1–130 mm; age 1, 131–220 mm, which were based on Smith's (1981) Bering Sea data. For each fish, total length was recorded and the stomach was removed. Stomach contents were dissected out and identified. Due to prey condition, only copepods could be consistently identified to species. Extremely well-digested copepods were identified largely by their size and shape. No distinction was made between copepodite and adult stages. Copepods eggs, *Calanus marshallae*, *Pseudocalanus* sp., *Centropages abdominalis*, *Metridia* sp., *Acartia* sp., and *Tortanus discaudatus* were identified. *Calanus marshallae* and *Metridia* sp. were >2 mm in length. All other copepod species were <2 mm. Other prey were identified as amphipods, euphausiid furcilia/juveniles, mysids, decapod larvae, and fish scales. Well-digested euphausiids were enumerated based on eye counts.

Food particle-size selection was examined by measuring widths of all prey items that were not severely digested or broken. Widths were recorded from a total of 7291 prey items.

Diet was analyzed in terms of numerical percent composition (%N), volumetric percent composition (%VOL), frequency of occurrence (%FO), and the index of relative importance (IRI = [%N + %VOL] × %FO) (Pinkas et al. 1971). Volumes were calculated from prey dimensions for zeros (Grover and Olla 1987), and were measured directly for ones.

Results

Little overlap was seen in the size of prey that were ingested by age-0 pollock, which ranged from 26 to 64 mm TL ($\bar{x}$ 49.4 mm, SD 9.6), and

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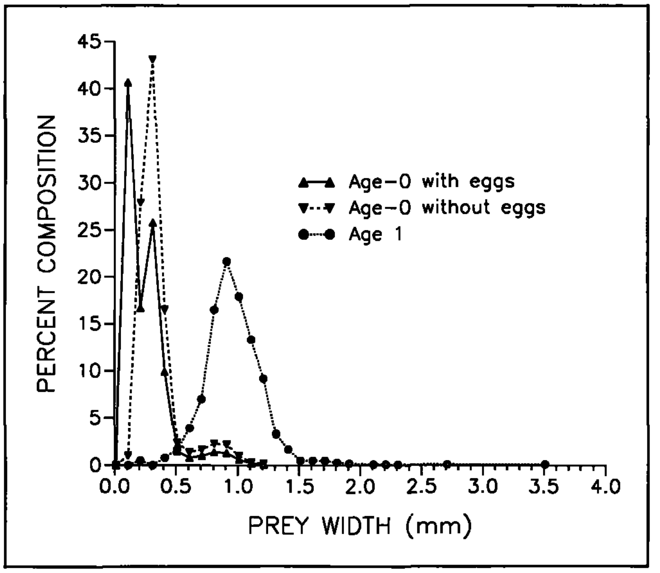

Figure 1
Size of prey ingested by age-0 and age-1 walleye pollock at station 95 (56°11.17′N, 162°18.36′W), in the southeastern shelf region of the Bering Sea, 3 August 1985. Age-0 data are plotted, including and excluding copepod eggs. Prey widths (in mm) were as follows: copepod eggs 0.11–0.20, *Calanus marshallae* 0.61–1.70, *Pseudocalanus* sp. 0.11–0.70, *Centropages abdominalis* 0.31–0.60, *Metridia* sp. 0.51–0.60, *Acartia* sp. 0.21–0.40, *Tortanus discaudatus* 0.31–0.50, amphipods 0.21–1.8, euphausiid furcilia/juveniles 0.21–3.50, mysids 0.41–0.50, decapod larvae 0.21–0.90. Fish scales were not included in this analysis, as their ingestion was deemed incidental.

by age-1 pollock, which ranged from 137 to 212 mm TL ($\bar{x}$ 162.8 mm, SD 16.32) (Fig. 1). Prey-size distributions were significantly different regardless of whether copepod eggs were included ($P<0.001$, Kolmogorov-Smirnov test; Conover 1980). Taxa of prey ingested by the two age-classes also differed (Table 1). Small copepods (0.21–0.50 mm width) and copepod eggs (0.11–0.20 mm width) comprised the bulk of the prey ingested by age-0 fish, while larger copepods and euphausiid furcilia (0.71–1.30 mm width) comprised the bulk of the prey ingested by age-1 fish.

Although euphausiid furcilia and juveniles made a substantial contribution to the diet of both age-classes, age-0 fish ingested smaller and/or earlier furcilia stages than did age-1 fish. Copepods comprised a major por-

Table 1
Composition of the diet of age-0 and age-1 walleye pollock *Theragra chalcogramma* in terms of index of relative importance (%IRI) and its components (%N, %VOL, and %FO). Values in parentheses exclude copepod eggs.

	Age-0				Age-1			
	%N	%VOL	%FO	%IRI	%N	%VOL	%FO	%IRI
Copepods								
Eggs	32.8	0.4	92.3	18.4				
Calanus marshallae	0.1 (0.2)	2.2 (2.2)	9.6	0.1 (0.1)	63.1	48.8	100.0	56.6
Pseudocalanus sp.	61.3 (91.3)	47.6 (47.8)	98.1	64.2 (81.8)	0.2	<0.1	13.6	<0.1
Centropages abdominalis	<0.1 (<0.1)	<0.1 (0.1)	3.8	<0.1 (<0.1)				
Metridia sp.	<0.1 (<0.1)	0.1 (0.1)	1.9	<0.1 (<0.1)				
Acartia sp.	0.1 (0.1)	<0.1 (<0.1)	5.8	<0.1 (<0.1)				
Tortanus discaudatus	<0.1 (<0.1)	<0.1 (0.01)	3.8	<0.1 (<0.1)				
Amphipods	<0.1 (<0.1)	<0.1 (<0.1)	3.8	<0.1 (<0.1	1.1	2.6	63.6	1.2
Euphausiid furcilia/juveniles	5.5 (8.2)	49.5 (49.7)	51.9	17.2 (18.0)	35.0	48.1	100.0	42.0
Mysids					<0.1	<0.1	4.5	<0.1
Decapod larvae					0.4	0.4	31.8	0.1
Fish scales					0.2	<0.1	27.3	<0.1

tion of the diet for both age groups, however age-0 fish primarily ingested small (<2 mm in length) *Pseudocalanus* sp., while age-1 fish primarily ingested larger (>3 mm) *Calanus marshallae* (Table 1).

Fish scales were observed in the stomachs of six age-1 fish. Only one scale was found in each stomach, and no other evidence of piscivory was observed. The scales were most likely ingested incidentally as a result of the collection process.

The mean number of prey ingested by age-0 fish was 134.8 (90.6 excluding copepod eggs), while age-1 fish ingested an average of 156.3 prey items. The incidence of feeding was 100% for both age groups.

Discussion

Based on two age and growth relationships (Nishimura and Yamada 1984, Yoklavich and Bailey 1989) and the timing of spawning in the southeast shelf region of the Bering Sea in 1985 (Mulligan et al. 1989), the age of age-0 pollock in this study was estimated to be 2–4 months. Assuming that the age-1 fish in this study were spawned as well as collected in the southeast shelf region, and then based on when spawning occurred in this region in 1984 (Hinckley 1987), the age of age-1 pollock was estimated to be 13–16 months.

At the time and place of this collection, diets of the two year-classes were divergent in terms of both prey size and taxa. Older, larger fish ingested larger prey. The importance of small copepods, notably *Pseudocalanus* sp., in the diet of age-0 pollock is consistent with previous studies (Kamba 1977, Cooney et al. 1980, Lee 1985, Grover 1990); however, one suborder of copepods, Cyclopoida, that was included in earlier dietary accounts was noticeably absent in the present study. Although, by most accounts, cyclopoids were not primary prey, Lee (1985) reported that for pollock between 20.0 and 24.9 mm TL and 45.0 and 49.9 mm TL, these copepods were either the foremost or secondmost important prey in the southeastern Bering Sea. Differences between studies may reflect temporal or spatial patchiness of prey.

Large numbers of copepod eggs have previously been reported in the diet of juvenile pollock (Cooney et al. 1980, Lee 1985, Grover 1990). The eggs were probably ingested incidentally, as the dominant copepod in the diet of age-0 pollock, *Pseudocalanus* sp., carries its eggs (Corkett and McLaren 1978).

The diet of age-1 pollock was dominated by a large copepod, *C. marshallae*, and euphausiid furcilia and juveniles. While previous dietary accounts have also illustrated the importance of large copepods, other specifics of diet apparently vary seasonally and spatially. Bailey and Dunn (1979) found that in the eastern Bering Sea, amphipods replaced euphausiids in the diet of pollock <24 cm in the summer of 1974. Dwyer et al. (1987) reported that copepods were the only prey ingested by pollock <30 cm in the southeastern Bering Sea during the summer, although in the northwestern Bering Sea euphausiids and larvaceans were also a part of the summer diet. The absence of copepod eggs from the diet of age-1 fish is consistent with the fact that *C. marshallae* females broadcast rather than carry eggs (Peterson 1980).

Another trophic relationship reported for these two year-classes is cannibalism (Livingston et al. 1986, Dwyer et al. 1987). While adult pollock cannibalize age-0 pollock to some extent during all seasons in the eastern and southeastern Bering Sea, age-1 pollock (<30 cm) have been observed to be cannibalistic only during autumn (Livingston et al. 1986, Dwyer et al. 1987). In the present study, based on a collection in summer, no conclusive evidence of piscivory or cannibalism was observed. Cannibalism has been shown to be highest when the vertical distribution patterns of juveniles and adults overlap (Bailey 1989). As this collection was not vertically discrete, the extent to which vertical distributions of age-0 and age-1 pollock overlapped at station 95 is unclear. However, based on the short duration and nature of this collection, i.e., that it targeted a hydroacoustic trace at a specific depth (Jim Traynor, NMFS Alaska Fish. Sci. Cent., Seattle, pers. commun. May 1991), then, minimally, vertical juxtaposition of the two year-classes is suggested. In which case, the present data indicate that when appropriate alternate prey are available, the juxtaposition of two juvenile year-classes can occur without cannibalism resulting. At station 95 in the eastern Bering Sea in August 1985, age-0 and age-1 pollock had a trophically neutral relationship: the food habits of each year-class did not impinge upon nor imperil the other.

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