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U.S. DEPARTMENTOF COMMERCE
National Oceanic and Atmospheric Administration
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Alaska Fisheries Science Center

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ABSTRACT

Variations in mean stomach contentweights (as-percentage of body weight) of walleye pollock, Theraqra chalcosramma, collected in the eastern Bering Sea from 1981 to 1987 were analyzed. The, results of a one-way analysis of variance (ANOVA) showed that bottom depth and prey type explained the highest proportions of the total variation in stomach content weights (5.7% and 4.6.% respectively), followed by season and year with 3.8% and 2.8%. of the total variation, respectively.. Time of day and predator length were not important factors., They explained only 1% and 0.04% of the total variation, respectively.

In general, the mean stomach content weights were low in the continental slope area and high in the continental shelf area., Because this phenomenon does not reflect the abundance of zooplankton, and because the percentage of empty stomachs increases as the bottom depth increases, it is suggested that undetected regurgitation played an important role in the variation of the stomach content weights.

Walleye pollock that ate both fish and invertebrates had significantly higher stomach content weights than those that ate only invertebrates. Prey type or size, therefore, is probably one of the determinant-s of the gastric evacuation rate.

CONTENTS

INTRODUCTION

The weight of stomach contents for marine fish is an important variable in the calculation of daily ration models. Generally, these daily ration models use estimates of stomach content weights from field-collected fish in conjunction with laboratory-estimated gastric evacuation rates (Livingston et al. 1986, Ney 1990). Gastric evacuation rates may be influenced by many variables including temperature, predator size, and prey type. Stomach content weights of field-collected fish may reflect changes in these variables in addition to changes in food abundance. For example, seasonal or interannual variation in mean stomach content weight may be due to seasonal changes in water temperature or prey availability. Geographic differences in stomach weights could also reflect localized differences in food abundance.' The analysis of the potential sources of variation in stomach content weight may help us understand which factors influence food intake of fishes and allow us to properly stratify daily ration estimates by area, season, and year. The objective of this study was to identify the main factors that were associated with the observed variation in the mean stomach content weights of walleye pollock, *Therasra chalcoqramma*, in the eastern Bering Sea.

METHODS

Data Collection

For our analysis, we used the food habits database of the Resource Ecology and Fisheries Management Division of the Alaska

Fisheries Science Center, which includes food habits data on several commercially important groundfish species in the eastern Bering Sea collected from 1981 to 1987. Stomach samples were collected by the scientists on board research vessels or charter boats, during the bottom trawl surveys conducted by the Alaska Fisheries Science Center or were collected by the observers on board the commercial fishing vessels. Before excising the stomach, regurgitation and net feeding were checked. If a fish had food in its mouth or around the gills, or if the stomach was inverted or flaccid, it was categorized as a regurgitated fish, and this specimen was discarded., If a predator had fresh food (usually fish) sticking out of the mouth, or the throat, it was categorized as a net-feeding fish, and was also discarded. When a qualified stomach was excised from the fish, it was put in a cloth stomach bag. A field tag with the species name, fork length of the fish; and haul data (vessel, cruise, haul number,. specimen number) was also put in the bag. All of the samples collected were then preserved in the buckets containing a l0% formalin solution. When the samples arrived in the laboratory, they were transferred to 76% ethanol alcohol before stomach contents analysis. In the laboratory, the stomach contents were first blotted with paper towel and the wet weight was then, recorded to the nearest one tenth of a gram. After obtaining the total stomach contents weight, the contents were placed on a petri-dish and examined under the microscope. Details of walleye pollock stomach collection in the field and the stomach content analysis in the laboratory are described by Dwyer et al. (1987).

Data Analysis

An analysis of variance (ANOVA) procedure was used to examine the variation in stomach content weights for pollock. Theoretically, this procedure assumes that the samples are normally distributed and that there is an homogeneity of variances. These two assumptions were not met in this study, even when data transformations (natural logarithms and arcsin) were used. However, according to Zar (1974), the ANOVA is fairly robust even with considerable heterogeneity of variances and nonnormality of the distribution. Therefore, the ANOVA was considered appropriate for the untransformed data set.

One-way ANOVAs of walleye pollock stomach content weight as percentage of body weight (%BW) were performed separately on fish with stomachs containing food for each of the following factors: prey type; year, season, bottom depth, predator length, and time of day. For analysis, the level of significance was set at $P > 0.05$. A one-way ANOVA rather than a multiway ANOVA was used (Zar 1974) because empty cells could not be included in the multiway tests, and empty cells occurred in some years, seasons, and bottom depths-. The prey type factor had two levels: Type 1 if the stomach contained some fish and Type 0 if the stomach contained only invertebrates. The sampling area (Fig. 1) was divided into three subareas based on bottom depth: Depth 1 (<l00 m), Depth 2 (100-200 m), and Depth 3 (>200 m). Five years (1981, 1982, 1983, 1985; 1987) of data were included in this analysis. The four seasons were assigned as: spring (15 March-14 June), summer (15 June-14 September), fall (15 September-

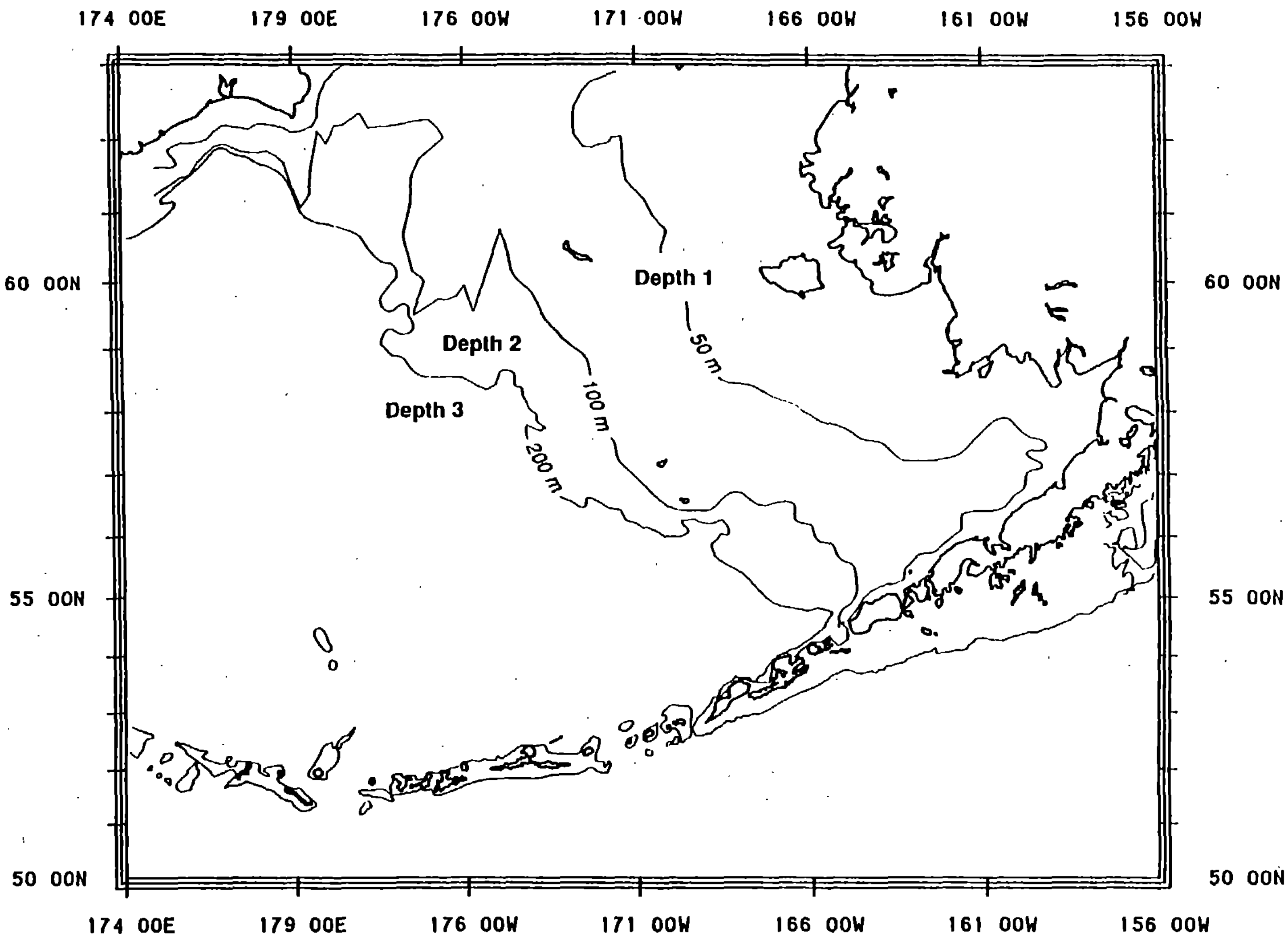

Figure 1. The general sampling subareas by bottom depth: Depth 1 (<100 m), Depth 2 (100-200 m), and Depth 3 (>200 m) of walleye pollock stomachs in the eastern Bering Sea.

14 December), and winter (15 December-14 March). Two predator fork length (FL) groups (<40 cm FL and >40 cm FL) were used in this study based on previous studies (Dwyer et al. 1987, Livingston et al. 1986), which showed that walleye pollock gradually shift their diet from zooplankton to fish beginning at approximately. 40 cm FL. Time of day was separated into eight time intervals of 3 hours each The proportion of the total variance (the coefficient of determination, r) explained by each of the main factors was calculated by dividing the sum of squares of the between groups by the total sum of squares from the output of the one-way ANOVA.

A multiway ANOVA was used to test differences of mean -stomach content weights in 1982 by the following four factors: bottom depth, prey type, season, and predator length (time was excluded as a factor to eliminate empty cells and to provide a better sample size for each cell). Only three seasons (spring, summer, fall) in 1982 contained data for all of the three depth areas and for both of the two predator- size groups. Data from the other years either contained less than three seasons data or did not have a complete data set for all' three areas within one season (see Appendix). Therefore, only comparable data sets with no empty cells were used for the multiway ANOVA test to examine the sources of variationand their interactions.

A multiway ANOVA was also used to test for variation in stomach content during the same season in differant years. Year, prey type, and sampling depth were used as factors. When there was insufficient data (i.e., the presence of empty cells) to include all of the factors in a multiway ANOVA test, fewer factors were used. If the results of the ANOVA (one-way or multiway) revealed a significant difference between levels of a factor having more than two levels, Tukey's multiple-range test was used to determine differences between specific levels at P = 0.05.

RESULTS

General Description

Data from 3,422 walleye pollock whose stomachs contained food were included in this study. Walleye pollock lengths ranged from 16 cm to 78 cm FL (mean =.43 cm FL, S.E. = 0.182). The mean, stomach content weight as a percentage of body weight (%BW) and the sample sizes by sampling year, season, bottom depth, and prey type are listed in the Appendix.

The results of a one-way ANOVA for the entire data set (Table 1) indicated that depth and prey type described the highest proportion of the total variation in stomach content weights (5.7% and 4.6%, respectively), followed by season and year (3.8.% and 2.8% of the total variation, respectively). Time of day explained 1% of the-total variation. No specific trend in %BW was observed for the different time periods (Fig. 2) except during the time interval 0300-0600, which had the lowest %BW value (0..49). The remaining seven time groups were not significantly different from each other based on Tukey's multiple-range test. Predator length explained only 0.04% of the total variation and mean stomach- content weights between the two size groups were not significantly different (P =0.2378).

Table 1. --Sources of variation in the mean stomach- content weights as percent of body weight in walleye pollock, Therasra chalcogramma, collected in the eastern Bering Sea from 1981-83, 1985, and 1987. (Total sample size = 3,422)

Source of variation	Percentage (%)
Between-cells	
Depth	5.7
Prey type	4.6
Season	3.8
Year	2.8
Time of day	1.0
Predator length	<0.1
Within cells	82.1

Depth Effect

Figure 3 shows the mean walleye pollock stomach content weights for each year and season by bottom depth. In general, walleye, pollock in continental shelf areas (<200 m) had higher stomach content weights than walleye pollock in continental slope areas with bottom depths greater than 200 m. The mean stomach content weights for walleye pollock collected in the continental slope area were all less than 1% of the body weight. Also, most walleye pollock from areas with bottom depths of less than 100 m had higher mean stomach content weights than those from bottom depths 100-200 m.

Prey Type Effect

The mean stomach content weights of the walleye pollock that had fish (mainly juvenile pollock) in their stomachs were generally higher than those that only ate invertebrates (Fig. 4).

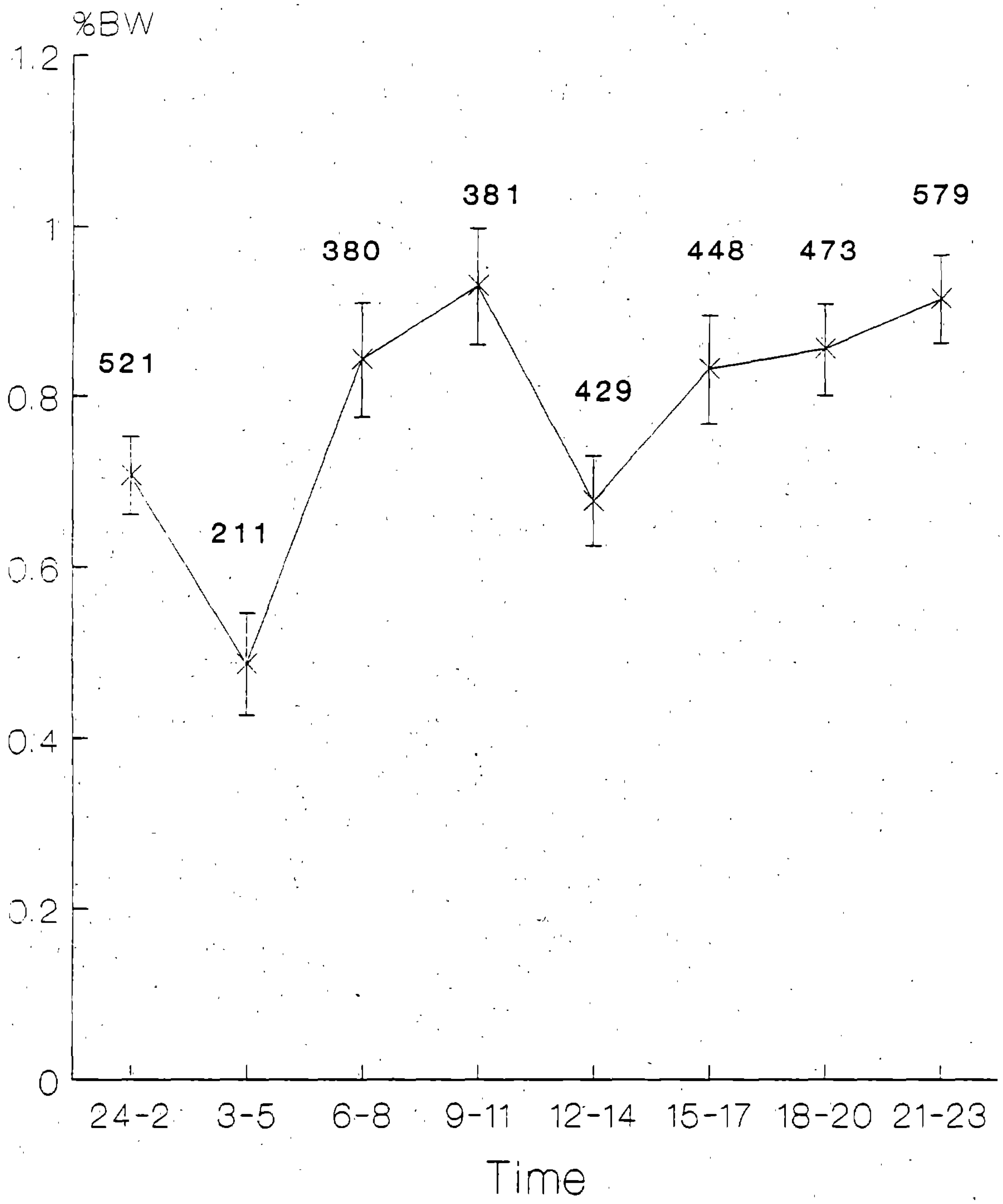

Figure 2. Variations in mean stomach content weight (as percent of body weight, %BW) of walleye pollock, by 3-hour time intervals, in the eastern Bering Sea. Each data point is the. %BW + S.E. The number above each data point is the sample size.

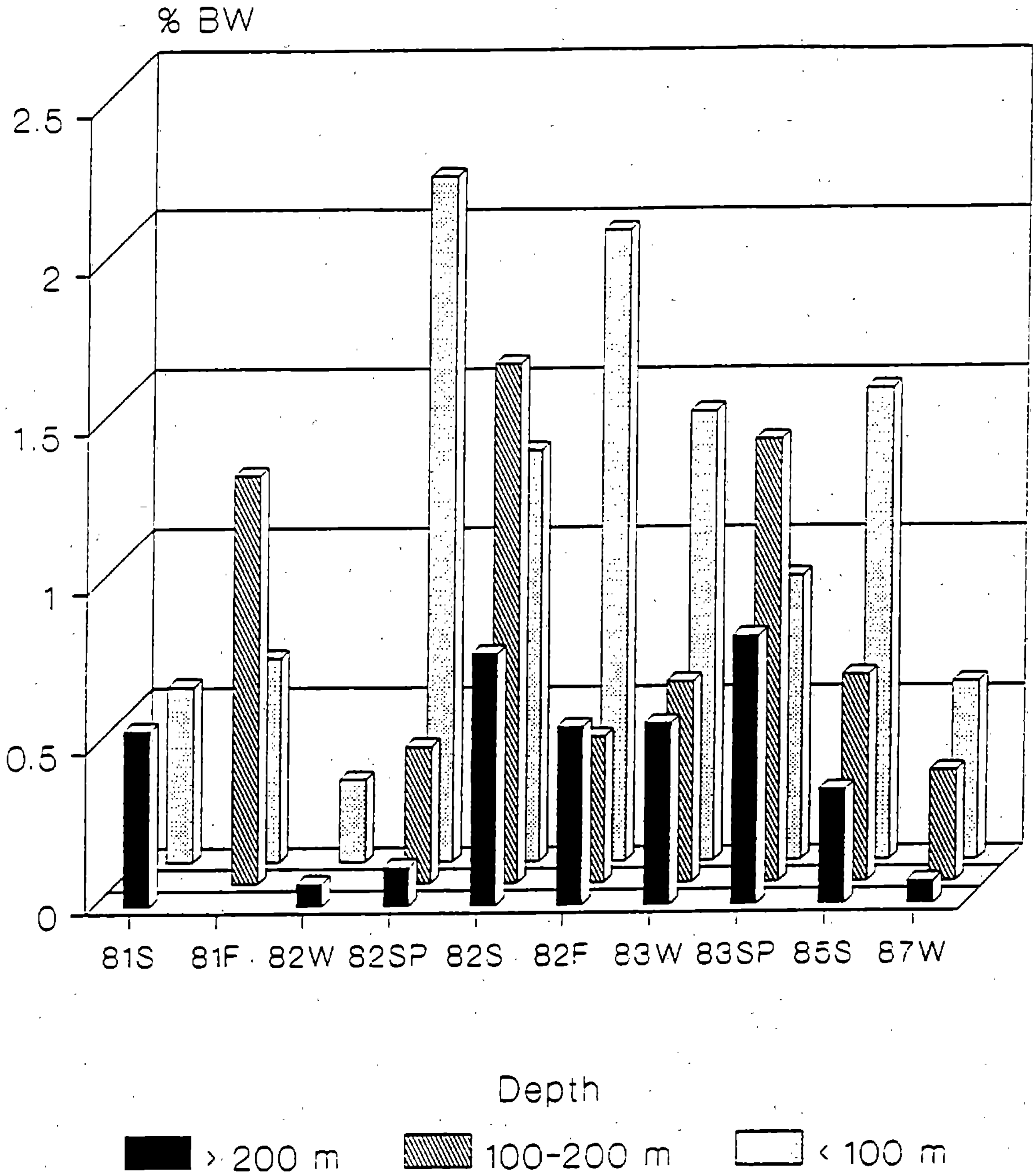

Figure 3. Variations in mean stomach content weight (as percent of body weight, %BW) of walleye pollock in the eastern Bering Sea. Each bar represents the mean of the sample collected from the same year, season (SP= spring, S = summer, F = fall, W = winter) and samping depth.

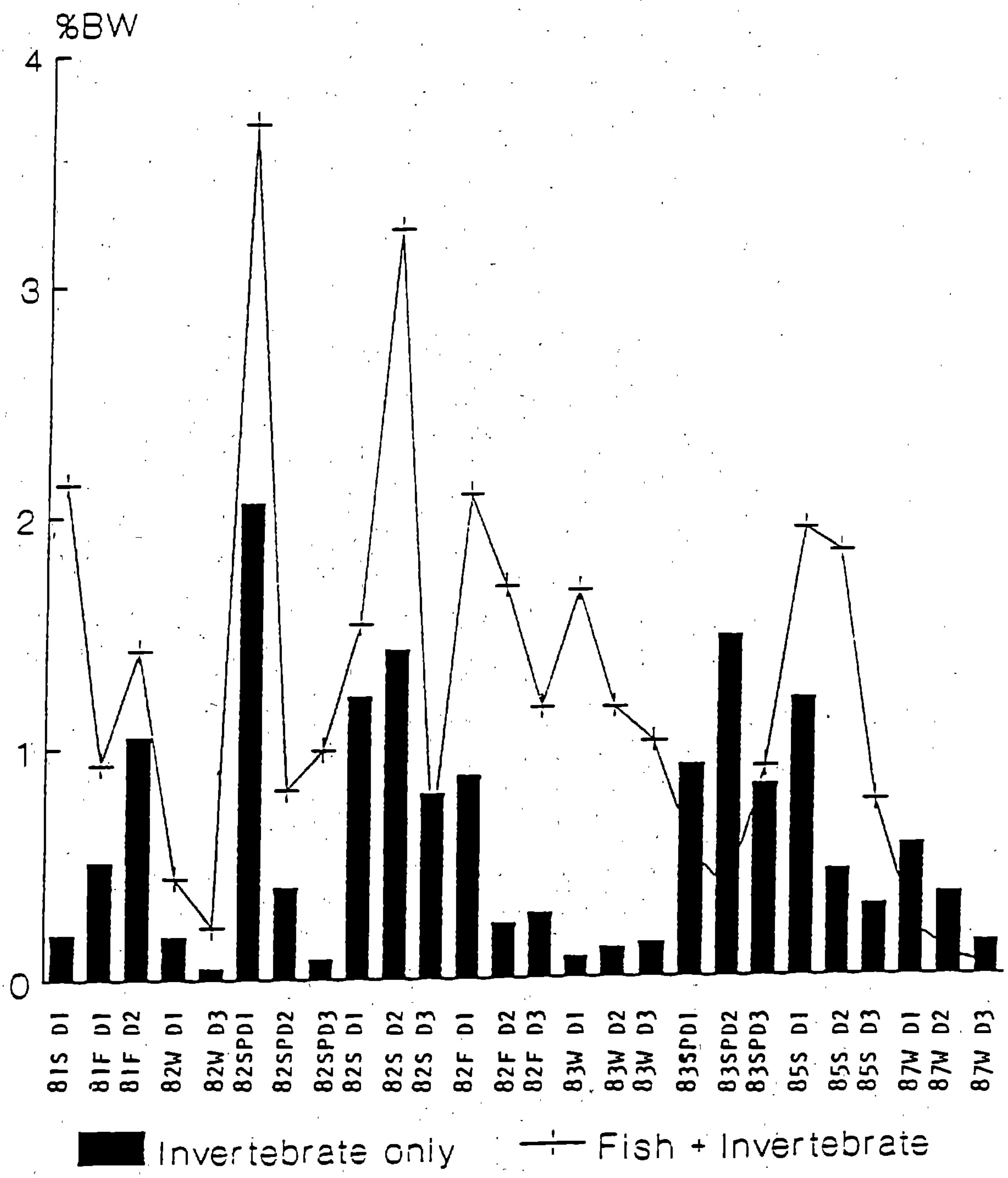

Figure 4: Differences in the mean stomach content weight (as percent of body-weight, %BW) of walleye pollock that had. fish in their diet versus those that only ate invertebrates. Each data point, is the sample from same year, season (SP = spring, S = summer, F = fall, W = winter:, and bottom depth (Dl =<lOO m, D2 = l00-200 m, D3 = >200 m); for example, 81-S D1 means sample collected from depth <l00 m in summer 1981.

(Each data point is the mean stomach content weight from a sample collected from the same year, same season, same depth). When a one-way ANOVA was performed separately by year, season, depth, and predator size, pollock that ate fish in conjunction with invertebrates showed higher mean stomach content weights than those that only ate invertebrates (Fig. 5). The data points (fish + invertebrates versus invertebrates) were all significantly different ($P < 0.01$) from each other except for the spring data (they were barely non-significant, $P = 0.0553$).

Multiway Analysis of Variance of the 1982 Samples

The results of the multiway ANOVA test on the 1982 samples were similar to those of the one-way ANOVA tests on the entire sample. Bottom depth,-prey type, and season described ll%, 6%, and 5% of the total variation, respectively (Table 2). Even though predator fork length was .a significant factor ($P = 0.042$, Table 2), it only explained 0.3% of the total variation. Interactions between different factors are presented in Table 2. Within the two-way interactions, only the interaction of "season by depth" (9% of the total variation) played animportant role in explaining variation of pollock stomach content weights. Each of the remaining interaction effects (two-way, three-way, and four-way) described less than 2% of the total variation, even though some of these interactions are significant.

Tukey's multiple-range test was applied to examine the differences between specific levels of the depth and season factors (Tables 3-8). During spring and fall in areas less than 100 m in depth, pollock contained more food (2.15% and 1.98 %BW,

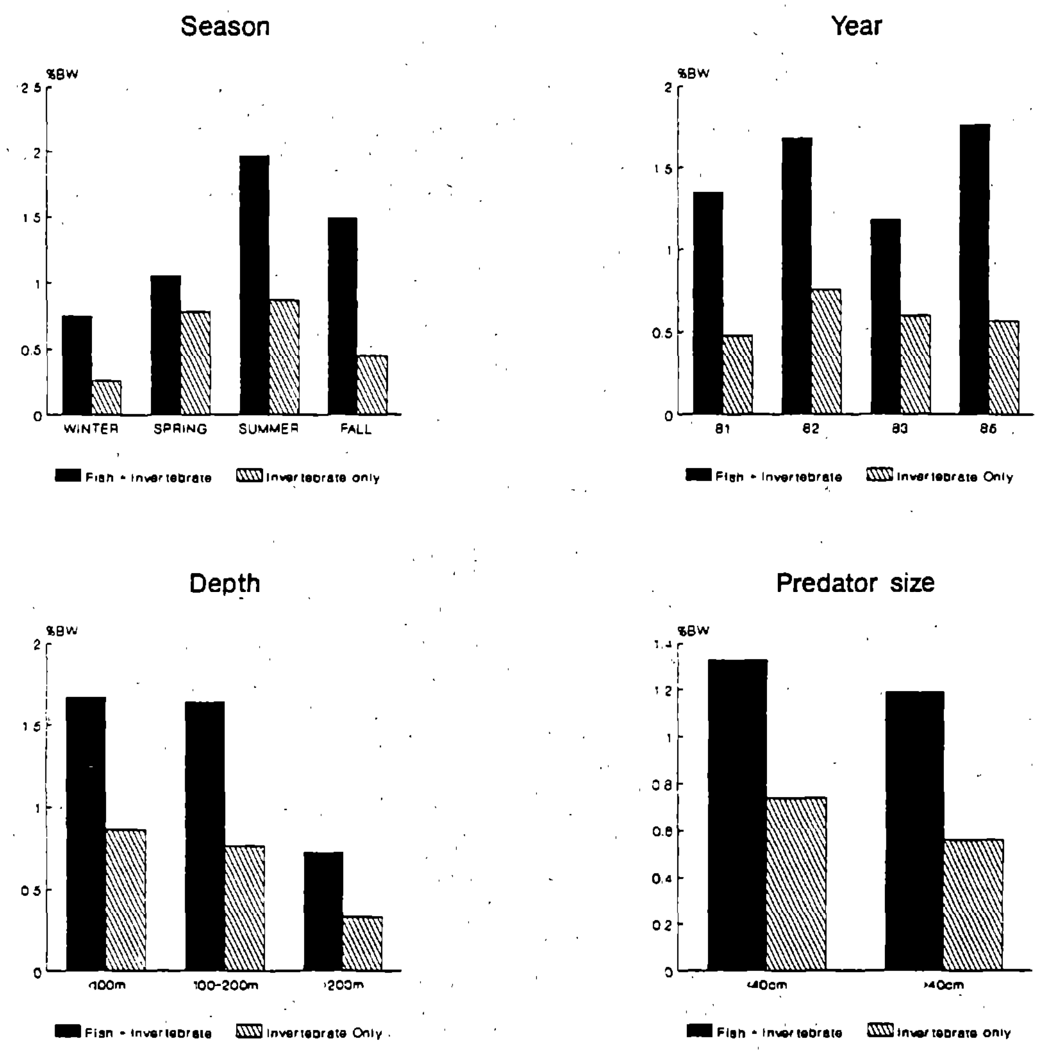

Figure 5. Differences in the mean stomach content weight '(as percent of body weight, %BW) of walleye pollock between those that ate fish plus invertebrates from those that ate invertebrates only by using different factors to group the data: Season/Depth, Year, and Predator Size.

Table 2.--Test of significance for stomach content weights as percent of body weights (%BW) of walleye pollock, _Therasra chalcogramma_, collected in spring, summer, and fall in 1982 in the eastern Bering Sea.

Source of variation	Sum of squares	Degrees of freedom	P
Between cells			
Season	118.79	2	<0.001
Prey type	130.56	1	<0.001
Depth	252.84	2	<0.001
Predator length	4.58	1	0.042
Interactions			
Season by depth	205.03	4	<0.001
Season by prey type	1.24	2	0.569 NS
Season by predator length	0.60	2	0.761 NS
Depth by prey type	21.06	2	<0.001
Depth by predator length	0.35	2	0.851 NS
Prey type by predator length	0.16	1	0.699 NS
Season by depth by prey type	31.14	4	<0.001
Season by depth by predator length	20.86	4	0.001
Season by prey type by predator length	19.43	2	<0.001
Depth by prey type by predator length	8.28	2	0.024
Season by depth by prey type by predator length	7.33	3	0.084 NS
Within cells	1,455.38	1,322	
Total	2,277.64		
r^2 =0.361			

NS means not significant at P > 0.05

Table 3.--Tukey's multiple-range test on the variations of the. mean stomach. content weights of pollock,, *Therasra chalcogramma*, from samples collected in three depths area in spring 1982. (*) denotes pairs of means that are significantly different at the '0.05 level.

Count	Mean (%BW)	Group	Depth 3	Depth 2	Depth 1
132	0.12	Depth 3			
234	0.43	Depth 2	*		
96	2.15	Depth 1	*	*	

Table 4.--Tukey's multiple-range test on the variations of the mean stomach content weights of pollock, *Theragra chalcogramma*, from samples collected in three depths area in summer 1982. (*) denotes pairs of means that are significantly different at the 0.05 level.

Count	Mean (%BW)	Group	Depth 3	Depth 1	Depth 2
82	0.79	Depth 3			
173	1.29	Depth 1	*		
263	1.63	Depth 2	*		

Table 5.--Tukey's multiple-range test on the variations of the mean stomach content weights of pollock, *Theragra chalcogramma*, from samples collected in three depths area in fall 1982. (*) denotes pairs of means that are significantly different at the 0.05 level.

Count	Mean (%BW)	Group	Depth 2	Depth 3	Depth 1
61	0.45	Depth 2			
215	0.56	Depth 3			
101	1.98	Depth 1	*	*	

Table 6.--Tukey's multiple-range test on the variations of the mean stomach content weights of pollock, Therasra chalcosramma, from samples collected in Depth 1 (<l00 m) in spring, summer, fall of 1982. (*) denotes pairs of means that are significantly different at the 0.05 level.

Count	Mean(%BW)	Group	Summer	Fall	Spring
173	1.29	Summer			
101	1.98	Fall	*		
96	2.15	Spring	*		

Table 7.--Tukey's multiple-range test on the variations of the mean stomach content weights of pollock, Therasra chalcoqramma, from samples collected in Depth 2 (100-200 m) in spring, summer, fall of 1982. (,f) denotes pairs of means that are significantly different at the 0.05 level.

Count	Mean(%BW)	Group	Spring	Fall	Summer
234	0.43	Spring			
61	0.45	Fall			
263	1.63	Summer,	*	*	

Table 8.--Tukey's multiple-range test on the variations of the mean stomach content weights of pollock, Therasra chalcoqramma, from samples collected in Depth 3 (>200 m) in spring, summer, fall of 1982. (*)-denotes pairs of means that are significantly different at the 6.05 level.

Count	Mean(%BW)	Group	Spring	Fall	Summer
132	0.12	Spring			
215	0.56	Fall	*		
82	0.79	Summer	*		

respectively) than fish from the two deeper zones. In summer, walleye pollock in the two areas less than 200 m deep contained more food (1.63 and 1.29 %BW, respectively) than fish in the areas greater than 200 m (0.79 %BW).

Interannual Variations

Since the one-way ANOVA results indicated that time and predator fork length described only a small amount of the variation in stomach content weight (1.0% and 0.04%, respectively), the data used in the following comparisons were not subdivided into size and time groups for analysis.

The results of a three-way ANOVA (Table 9, Fig. 6) show that stomach content weights were significantly different between winter 1983 and winter 1987. They also show significant differences between the spring-samples of 1982 and 1983 and the summer samples of 1982 and 1985. A three-way ANOVA was not applied to the fall data of 1981 and 1982 since we did not -have samples collected from the Depth 3 area in 1981 (Appendix).

Even though the three-way ANOVA tests demonstrate that year was a significant factor explaining variation in stomach content weights, its contribution to the total variation was not a's, important, as the depth or prey type factors (Table 9).

DISCUSSION

Feeding behavior is affected by both biotic and abiotic factors. Biotic. factors include availability of food, competition with other predators, metabolic rate, spawning condition, and migratory behavior (vertical and seasonal).

Table 9.--Three-way ANOVA of the mean stomach content weights (%BW) of walleye pollock, Therasra chalcocramma, of different seasons by the factors of year, prey-type, and depth.

Source of variation	Sum of square	Degrees of freedom	P
Winter 1983, 1987			
Within cells	939.11		
Prey type	52.64	1, 847	<0.001
Year	43.59	1, 847	<0.001
Depth	60.86	2, 847	<0.001
Interaction			
Prey type by year	42.68	1, 847	<0.001
Year by depth	9.18	1, 847	0.016
Depth by prey type	2.41	1, 847	0.338 NS
Year by depth by prey type	3.11	2, 847	0.246 NS
Total	1,153.59		
r^2 =0.222			
Spring 1982, 1983			
Within cells	576.35		
Prey type	3.89	1, 698	0.030
Year	14.21	1, 698	<0.001
Depth	204.99	2, 698	<0.001
Interaction			
Prey type by year	10.17	1, 698	<0.001
Year by depth	71.07	2, 698	<0.001
Depth by prey type	9.46	2, 698	0.003
Year by depth by prey type	1.60	2, 698	0.380 NS
Total	891.74		
r^2 =0.354			
Summer 1982, 1985			
Within cells	997.61		
Prey type	121.16	1, 913	<0.001
Year	77.76	1, 913	<0.001
Depth	4.27	2, 913	<0.001
Interaction			
Prey type by year	0.20	1, 913	0.667 NS
Year by depth	45.62	2, 913	<0.001
Depth by prey type	41.07	2, 913	<0.001
Year by depth by prey type	6.17	2, 913	0.060 NS
Total	1,343.86		
r^2 =0.258			

NS means not significant at P > 0.05

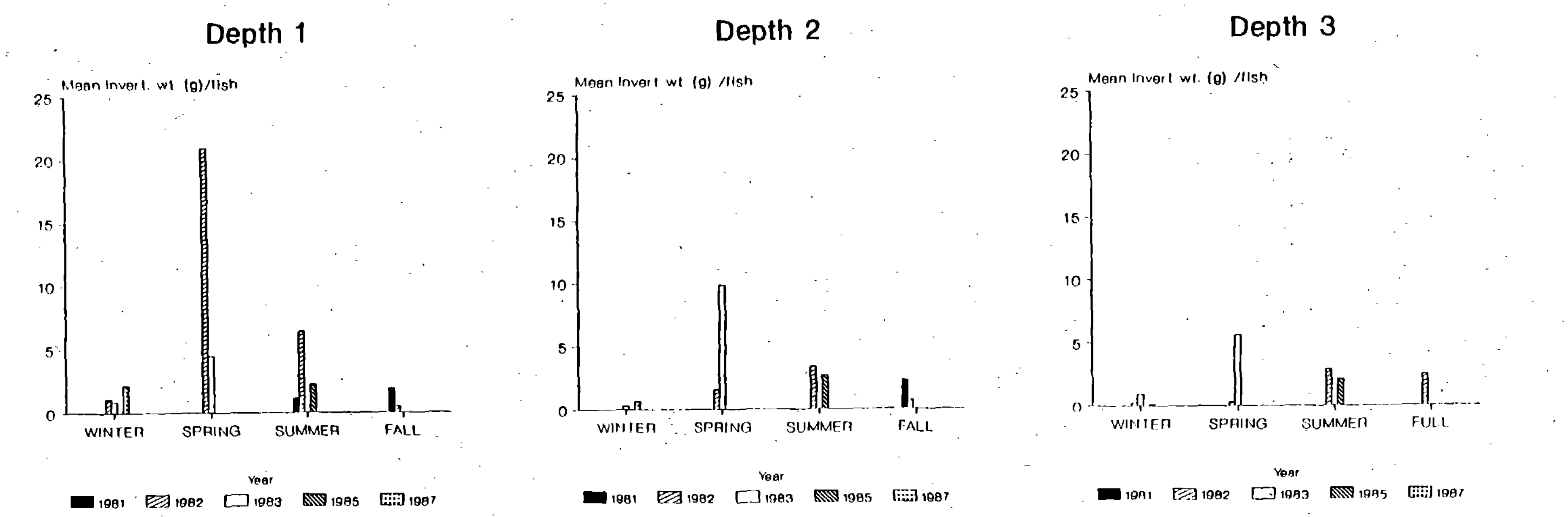

Figure 7. Mean weight of invertebrates (mainly zooplankton) per fish in the stomachs of walleye pollock in the eastern Bering Sea. Depth l (<l00 m); Depth 2 (100-200 m); Depth 3 (>200 m).

Abiotic factors include water temperature, currents, habitat, and other hydrographic and climatic factors. Because the diet of a fish is influenced by both these biotic and abiotic factors, it is not possible to quantitatively separate the effects of these factors without simultaneous measurement of each factor. The purpose of this study is not to explain how all these biotic and abiotic factors influence the feeding of pollock but to find some broad factors that might be used-to describe the variation in feeding behavior.

In this study, bottom depth and prey type were the main explained sources of variation in stomach content weights. The importance of other factors (predator fork length, sampling time, season, year) and the interactions of different factors were minor (even though some interactions were statistically significant) since they explained only a small portion of the total variation. However, even. the explained sources of variation only accounted for less than 40% of the variance, the within-cell variations (unexplained variations), were high due to the large range of stomach content weights (from 0.01 to 9.47 %BW). Bromley (1987) found that the last traces of- food (approximately 0.1% of body weight) are evacuated very slowly in turbot (Scophthalmus maximus L.) and he classified those stomachs with O.l% of body weight of food as empty. In our study, 1,121 out of 3,422 stomachs had content weights less than 0.1% of body weight. If these stomachs are excluded from the one-way ANOVA in this study, however, the unexplained variation is still very high (89%). Amundsen and Klemetsen (1986) studied the stomach content weights of Arctic char (Salvelinus aloinus L.) and found that, due to the large range in stomach content weights within each sample (3-hour time intervals), there were usually no significant differences between consecutive samples taken throughout each 24-hour period. Because of this, they believed that Elliott and Persson's (1978) model (based on the differences between consecutive samples) was not appropriate for. estimating the consumption rate of fish with no diel feeding pattern, and that the modified Bajkov (1935) model (based on the average stomach content weight for each 24-hour period) by Eggers (1979) should be regarded as the most appropriate method. They also noted that large variations in stomach content weights are common in published studies and that, at least in their study, these variations were not caused by small sample sizes but seemed to be biological. Though the within-haul variations were not included in our statistical analysis, they can be large (Table 10). Within-sample (haul) variations can sometimes be as high as 126-fold (6.30:0.05); This would seem to support Amundsen and Klemetsen's findings of large within-sample variations in fish stomach content weights.

These results point out that estimated mean stomach content weights of walleye pollock from field collected samples are probably biased downwards by undetected regurgitation. This suggests that walleye pollock daily ration values calculated from mean stomach content weights of field collected stomachs in conjunction with laboratory-estimated gastric evacuation rates are also biased downwards. This bias would be more pronounced

Table l0.--Example of within-sample (haul) variations of the stomach content weights of pollock, Therasra chalcogramma, collected in the area >200 m deep in winter 1983.

Total stomach, content weight (g)	Total body weight (g)	Stomach weight as % body weight
1.19	408.9	0.29
0.39	758.8	0.05
10.23	1,077.5	0.95
16.54	712.7	2.32
1.38	187.3	0.74
1.63	509.9	0.32
64.23	1,019.1	6.30
5.32	349.6	1.52
13.92	441.0	3.16
4.57	626.1	0.73
5.06	1,019.1	0.50
0.97	474.6	0.20

when using samples collected from waters deeper than 100 m, which is the main depth where most pollock can be found. Livingston et al. (1986) compared daily rations of Bering Sea groundfish estimated in -this fashion with daily rations calculated using a bioenergetic approach. They found that groundfish daily rations using field-collected stomach content weights were not only lower than those from the bioenergetic approach but were also insufficient to account for observed growth. This implies that daily rations should be calculated using a bioenergetic approach, especially for fish such as pollock that may have high undetected regurgitation rates. Because of the relative importance of the effect of bottom depth and prey type, the two factors are discussed separately.

Prey Type Effect

Prey type was one of the two mainfactors explaining variation in the stomach-content weights (4.6% for the entire sample and 5.7% for 1982 sample). Walleye pollock that ate fish in addition to. invertebrates had significantly higher stomach content weights than those that ate only invertebrates. Many studies have shown. that prey type or size is one of the determinants of the gastric evacuation rate; Jobling (1987) suggested that differences in surface-to-volume ratios between large and small food particles, and the friabilities of different food types are important in determining the pattern of emptying. He also noted that dietary energy content appeared to be an important factor. The surface-to-volume ratio of prey juvenile pollock is smaller than that of zooplankton, thereby increasing the effort required to complete digestion. Therefore, the evacuation rate for prey fish might be slower than for invertebrates. Thus, the observed mean stomach weights of pollock that ate fish would tend to be higher than-those that only ate invertebrates. Dos Santos and Jobling (1988) did experiments on Atlantic cod Gadus morhua) that consumed Atlantic herring, (Clupea harensus) and found that whole herring were digested and emptied from cod, stomachs much more slowly than minced herring, indicating that particle size is also an important factor controlling the emptying rate and thus the observed differences in stomach weight due to prey type.

Depth Effect

Geographic differences (i.e., bottom depth) explained the highest proportion (5.6% for the entire sample and 11.0% for 1982 sample) of variation in stomach content weight. The depth effect might be attributed to two factors. The first reflects the potential differences in food abundance across areas. The second is undetected regurgitation that might be expected to increase with capture in increasing water depth.

The zooplankton biomass in the continental slope and outer shelf area is much greater than that in the middle shelf area (Cooney 1981, Vidal and Smith 1986). According to Cooney (1981), the zooplankton production was about 13 gC/m /year in the oceanic region (>200 m), 8 gC/m /year in the mixed region (100-200 m), and between 2 and 6 gC/m /year in the middle shelf and coastal areas (cl00 m). The community over the outer shelf and slope is dominated by large copepods (mainly _Neocalanus_ spp. and _Eucalanus bunsii bunsii_). The middle shelf and coastal community is dominated by the small copepods _Acartia lonqiremis_ and _Pseudocalanus_ spp. and the euphausiid _Thvsanoessa raschii_. Smith and Vidal (1984) and Vidal and Smith (1986) described the relationship between temperature and the zooplankton communities in the Bering Sea.. They found that the sea surface temperatures on the slope and outer shelf area were higher than 3°C from late March until December; however, in the middle shelf, sea surface temperature was substantially lower until late May when sea surface temperature rose above 3°C. They noted that temperature was not, a good predictor of copepod abundance over the outer shelf and slope areas, but it was a relatively good predictor of their abundance over the middle shelf., We calculated the mean weight of invertebrates (mainly zooplankton) eaten by pollock to compare it with the zooplankton biomass in the Bering Sea. Within each depth area, pollock ate fewer invertebrates in winter and fall than in summer (Fig. 7). Figure 7 also shows large variations in the amount of invertebrates eaten by pollock in spring.Cooney (1981) found that the biomass of oceanic zooplankton is greatest in May and June and lowest in November in the outer shelf area. His observations concur with our findings that large amounts of zooplankton were available to be eaten by pollock in the outer shelf (Depth 2) -area in spring. These observations point out that abundance of available zooplankton, may explain, the variation in stomach content weights of pollock in different depth, areas;

The second possible explanation for decreasing stomach content weight with depth is undetected regurgitation. Some pollock stomachs may have been empty due to complete regurgitation and others with low stomach content weights might be the result of partial regurgitation. Bowman, (1981) noted that regurgitation is commonly observed in fish caught when bottom trawling in water deeper than 100 m. Bowman (1985) also noted that the percentage of detectable regurgitation for some fish species increases considerably with increasing trawl depths. He found that lower stomach content weights were often observed in the deeper areas even in those fish showing no signs of regurgitation. He attributed the low stomach content weights to-

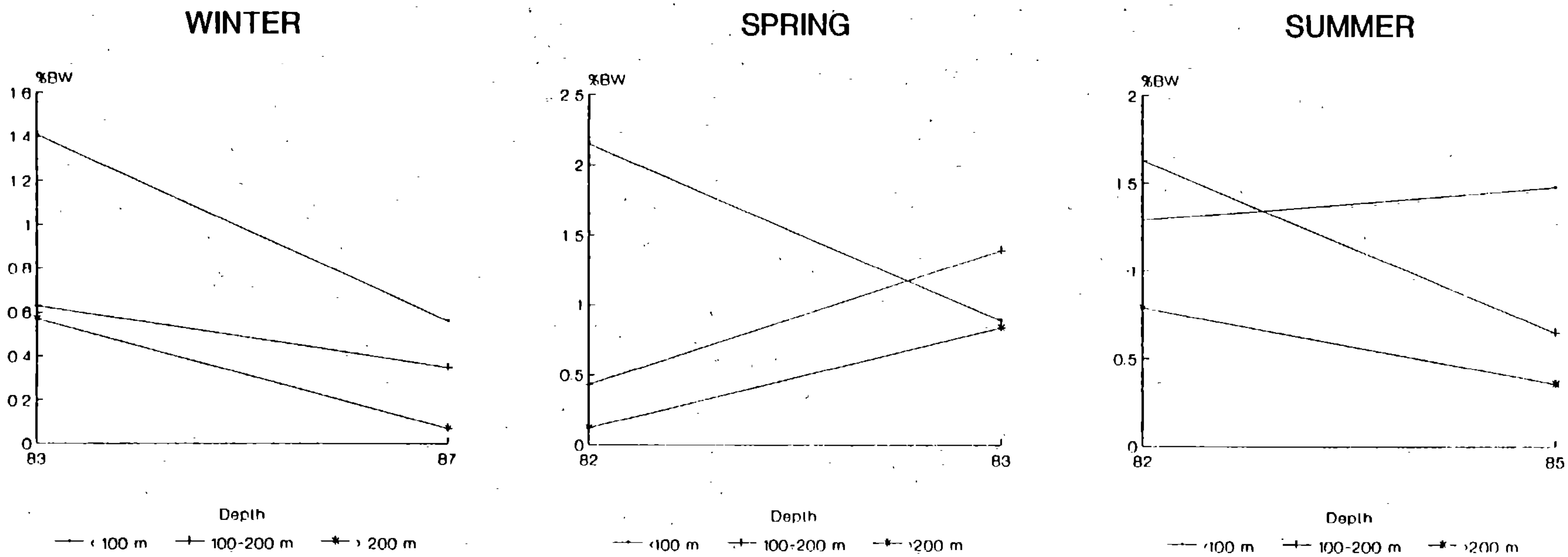

Figure 6. Interannual variations in mean stomach content weight (as percent of body weight, %BW) of walleye pollock in the eastern Bering Sea in winter, spring, and summer.

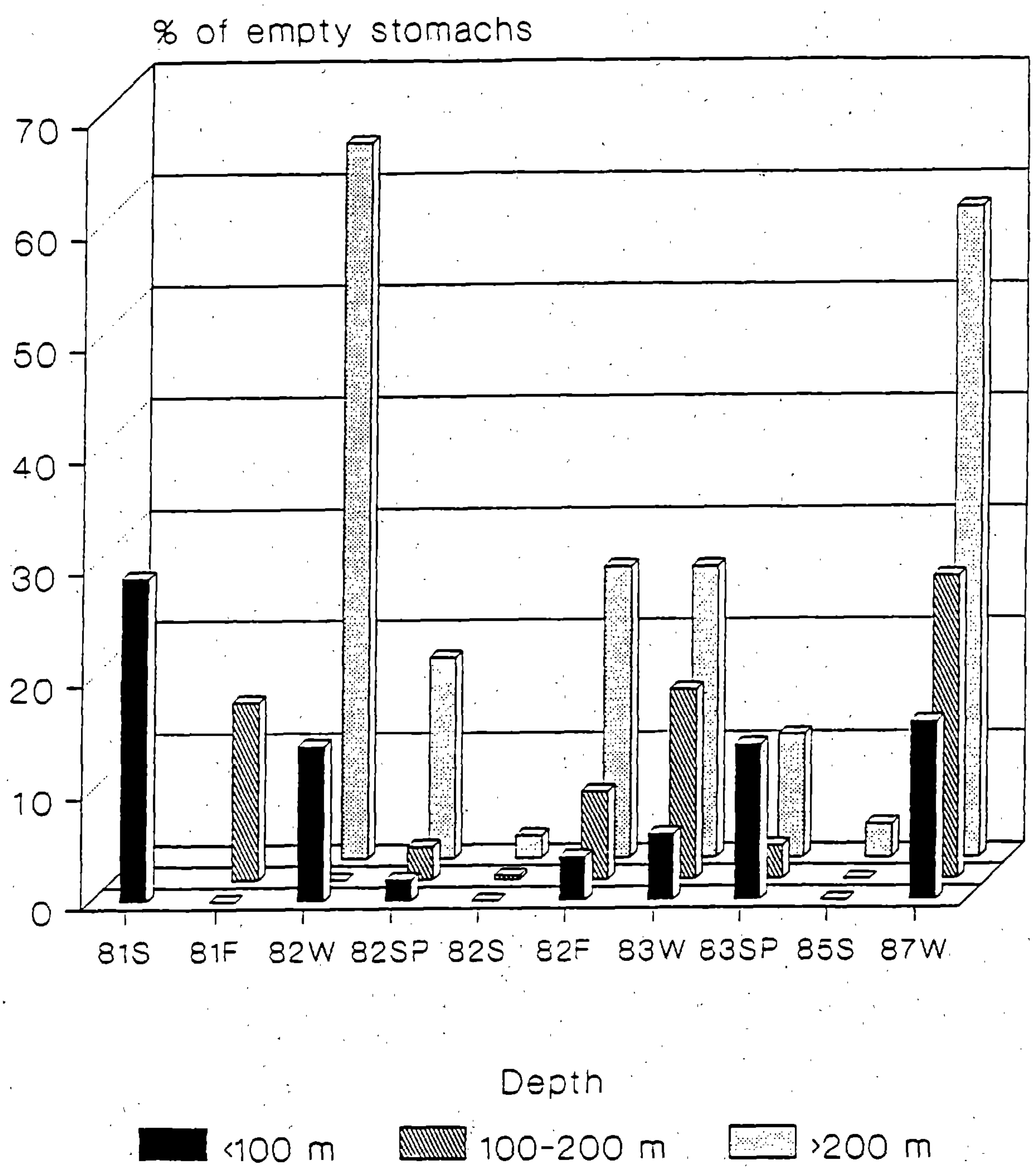

Figure 8. Percent of empty stomachs of walleye pollock collected in the eastern Bering Sea from 1981 to 1987. (SP = spring, S = summer, F = fall, W = winter)

undetected regurgitation. In our study, the high percentage of empty stomachs (Fig. 8) and the low stomach content weights in the deep area greater than 200 m (Fig. 3) strongly suggest that undetected regurgitation probably played an important role in the variation of the stomach content weights of pollock. Figure 8 shows the percent of empty stomachs of each subset sample by year, season, and depth. Except for the subset sample of Depth 1 in spring 1983 (with small sample size 27), the percentage of empty stomachs increases with depth, especially in the slope areas (>200 m).

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Appendix . List of the mean stomach content weights as percent of body weight (%BW) of walleye pollock, _Theragra chalcogramma_, in the eastern Bering Sea.

Year	Season	Bottom depth(m)	Prey type	%BW	Number of stomachs	Standard error of the mean
81	S	<100	Fish	2.14	22	0.55
81	S	<100	Invert	0.20	101	0.20
81	S	<100	Total	0.55	123	0.12
81	F	<100	Fish	0.93	54	0.14
81	F	<100	Invert	0.51	126	0.08
81	F	<100	Total	0.64	180	0.07
81	F	100-200	Fish	1.42	68	0.16
81	F	100-200	Invert	1.05	43	0.15
81	F	100-200	Total	1.28	111	0.11
82	W	<100	Fish	0.44	12	0.08
82	W	<100	Invert	0.19	31	0.04
82	W	<100	Total	0.26	43	0.04
82	W	>200	Fish	0.23	11	0.08
82	W	>200	Invert	0.05	83	0.02
82	W	>200	Total	0.07	94	0.02
82	SP	<100	Fish	3.70	5	0.49
82	SP	<100	Invert	2.06	91	0.17
82	SP	<100	Total	2.15	96	0.17
82	SP	100-200	Fish	0.82	16	0.17
82	SP	100-200	Invert	0.40	218	0.03
82	SP	100-200	Total	0.43	234	0.03
82	SP	>200	Fish	0.99	4	0.25
82	SP	>200	Invert	0.09	128	0.02
82	SP	>200	Total	0.12	132	0.03
82	S	<100	Fish	1.53	39	0.22
82	S	<100	Invert	1.22	134	0.09
82	S	<100	Total	1.29	173	0.08
82	S	100-200	Fish	3.24	30	0.45
82	S	100-200	Invert	1.42	233	0.07
82	S	100-200	Total	1.63	263	0.09
82	S	>200	Fish	0.62	6	0.24
82	S	>200	Invert	0.80	76	0.09
82	S	>200	Total	0.79	82	0.09
82	F	<100	Fish	2.09	92	0.20
82	F	<100	Invert	0.88	9	0.36
82	F	<100	Total	1.98	101	0.20
82	F	100-200	Fish	1.69	9	0.60
82	F	100-200	Invert	0.24	52	0.06
82	F	100-200	Total	0.46	61	0.12
82	F	>200	Fish	1.17	68	0.17
82	F	>200	Invert	0.28	147	0.04
82	F	>200	Total	0.56	215	0.07
83	W	<100	Fish	1.67	71	0.22

Appendix. Continued.

Year	Season	Bottom depth(m)	Prey. type	%BW	Number of stomachs	Standard error of the mean
83	W	<100	Invert	0.09	14	0.03
83	W	<100	Total	1.41	85	0.20
83	W	100-200	Fish	1.17	36	0.28
83	W	100-200	Invert	0.13	39	0.03
83	W	100-200	Total	0.63	75	0.15
83	W	>200	Fish	1.02	134	0.16
83	W	>200	Invert	0.15	145	0.03
83	W	>200	Total	0.57	279	0.08
83	SP	<100	Fish	0.55	2	0.53
83	SP	<100	Invert	0.92	21	0.16
83	SP	<100	Total	0.89	23	0.15
83	SP	100-200	Fish	0.36	5	0.16
83	SP	100-200	Invert	1.47	62	0.19
83	SP	100-200	Total	1.39	67	0.18
83	SP	>200	Fish	0.91	29	0.19
83	SP	>200	Invert	0.83	129	0.09
83	SP	>200	Total	0.84	158	0.08
85	S	<100	Fish	1.93	38	0.29
85	S	<100	Invert	1.20	60	0.13
85	S	<100	Total	1.48	98	0.14
85	S	100-200	Fish	1.83	32	0.31
85	S	100-200	Invert	0.46	200	0.03
85	S	100-200	Total	0.65	232	0.06
85	S	>200	Fish	0.76	9	0.28
85	S	>200	Invert	0.31	68	0.03
85	S	>200	Total	0.36	77	0.05
87	W	<100	Fish	0.23	6	0.16
87	W	<100	Invert	0.57	149	0.06
87	W	<100	Total	0.56	155	0.06
87	W	100-200	Fish	0.10	3	0.06
87	W	100-200	Invert	0.36	57	0.10
87	W	100-200	Total	0.35	60	0.10
87	W	>200	Fish	0.04	145	0.01
87	W	>200	Invert	0.15	60	0.06
87	W	>200	Total	0.07	205	0.02
Total				0.80	3,422	0.02