DIFFERENCES IN THE WEIGHT AND COMPOSITION OF STOMACH CONTENT OF POLLOCK BETWEEN AREAS IN THE BERING SEA

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ABSTRACT

Differences in the weight and composition of stomach content of pollock were determined in five areas: the southern and northern continental shelf of the eastern Bering Sea, Aleutian Islands region, and the southern and northern Aleutian Basin. The proportion of stomach content weight against the body weight was particularly high in the northern continental shelf of the eastern Bering Sea. In the composition of the stomach contents, cannibalism was observed remarkably in the southern and northern continental shelf of the eastern Bering Sea, but was scarcely observed in other areas. These differences were considered to be caused that the rate of growth of pollock on the continental shelf of the eastern Bering Sea was faster than that of pollock in the Aleutian Basin.
1. **Introduction**

Pollock in the Bering Sea account for the predominant portion of the catch and estimated biomass of the fish. Therefore, pollock in the Bering Sea is anticipated to play an important part in the ecosystem of the Bering Sea. In order to determine the role of each component in the ecosystem, we have to determine the food chain, and the analysis of stomach content is the first step for this purpose.

The studies which determined the stomach content composition of pollock in the Bering Sea were as follows: Bailey and Dunn (1979), Dwyer et al. (1987), Kachina and Savicheva (1987), Livingston et al. (1986), Maeda (1971), Mito (1974 and 1988), Takahashi and Yamaguchi (1972), and Wakabayashi (1986), etc. The above scientists concentrated mainly on pollock from the continental shelf of the eastern Bering Sea, whereas few of the studies concentrated on pollock from the continental shelf of the western Bering Sea or Aleutian Basin.

Pollock in the Bering Sea were distributed extensively throughout areas from the continental shelf to the Aleutian Basin. It has recently been determined that there are differences in the life history patterns such as spawning and growth between pollock which live on the continental shelf and in the Aleutian Basin (Hincley 1987, Okada and Yamaguchi 1985, Stepanenko 1989, Teshima et al. 1989, Traynor and Nelson 1985). This is considered as an indication that there are also some differences in the feeding behaviour of pollock which live in both areas. However, the present situation is that the studies which compare the feeding behaviour of pollock which live in both areas are seldom undertaken, and there is just one study which compared the stomach contents of pollock on the continental shelf of the eastern Bering Sea with that in the Aleutian Basin (Dwyer et al. 1987), but even their study, the number of samples of pollock in the Aleutian Basin is not sufficient.

The analysis of stomach contents of pollock, Pacific cod, and yellowfin sole, etc. have been made since 1970 by the National Research Institute of Far Seas Fisheries. In addition, the author analyzed the stomach contents of pollock, Pacific cod, flathead sole, and Pacific ocean perch, etc. at the Faculty of Fisheries of the Hokkaido University. In the "Ecosystem Modelling Project in the Bering Sea" which was conducted from 1985 to 1988, the major results obtained from these analyses were input into the computer and used as a database. The author used this database and additional data obtained later and determined the difference by area of the weight and composition of the stomach content of pollock.

2. **Materials and Method**

The number of stomach samples of pollock analyzed by the National Research Institute of Far Seas Fisheries and me at the Hokkaido University are shown in Table 1 by research vessel and commercial fishing vessel. The number of individuals analyzed was 35,864 fish and of those, 32,344 fish were used.
for calculation. Data analyzed after input into the computer were also included. Samples were collected from almost all areas of the Bering Sea, except from the 200 miles zone of the U.S.S.R. (Fig. 1).

These samples were divided into the following five areas and summed (Fig. 2).

Area A: southern continental shelf and continental slope of the eastern Bering Sea
Area B: northern continental shelf and continental slope of the eastern Bering Sea
Area C: Aleutian Islands region
Area D: southern Aleutian Basin
Area E: northern Aleutian Basin

Further, the sampling period was divided into winter (January to March), spring (April to June), summer (July to September), and autumn (October to December). In addition, the range of length of pollock was divided into 6 groups at 100 mm interval. The number of samples are shown in Table 2 by area, by season, and by size.

The analysis of stomach contents was conducted by the scientists of the North Pacific Groundfish Section, National Research Institute of Far Seas Fisheries or by the author at the Hokkaido University. The condition of samples at the time of analysis was either thawed frozen samples, samples preserved with formalin on board the vessel, or previously frozen samples preserved with formalin at the laboratory. Stomach samples were cut open, stomach contents were taken out, and wet weight of sorted species group of prey items were measured. When I analyzed the sample at the Hokkaido University, prey items from several or tens of small pollock of the same length range were combined to measure wet weight. The classification stages of prey items were from order to species and they varied with the scientist and with the degree of digestion. When possible the length of large prey items such as fish were measured. In addition, for pollock, head length and otolith length were also measured when possible, and these measurements were converted to fork length with the following equations:

\[
\begin{align*}
    FL &= 4.250 \times HL - 2.6 \\
    FL &= 26.75 \times OL - 45.8
\end{align*}
\]

where,  
FL : fork length (mm)  
HL : head length (mm)  
OL : otolith length (mm)

These data were stored in a computer during the work of the "Ecosystem Modelling Project in the Bering Sea" (Fisheries Agency of Japan 1986, 1987 and 1988). This study used this data file and followed the above standards. The compilation of data was executed by Fuyo Data Processing & Systems Development Ltd. Because the classification stages of prey items varies, prey items other than fish were classified by class or order and fish were classified by family or species.
3. Results

(1) Stomach Content Weight

Stomach content weight and percentage of weight (%BW: percentage against body weight) per individual of pollock are shown in Table 3 and Fig. 3 by area. These are combined all years scaled. Based on the evidence throughout the areas, the percentage of weight had a tendency to be high from spring to summer and low in winter. That is, the percentage of weight ranged from 0.6% to 4.2% in spring and summer, but was mostly less than 0.3% in winter. Although the season in which the percentage of weight was highest varied by area, judging from the seasonal change by area, the season in which the percentage of weight was low was mostly in winter in all areas. The season in which the percentage of weight was highest in each area was mainly summer in Area A, spring in Area B, and in Area D, the highest season was summer, likewise summer in Area A, but the percentage of weight of pollock ranged from 301 mm to 400 mm in body length was highest in autumn. By size of fish body, the percentage of weight of large-sized fish had a tendency to be low, however, in Area A, the group of 301 mm to 400 mm in length was lowest, and the group of more than 400 mm in length was slightly higher. Judging from the percentage of weight by area for all seasons, it was highest in Area B, and was almost the same value in Area A and Area D. Although the season was limited in Area C and Area E, when they were compared with the same season in Area D, Area C was the same level with Area D, and Area E was higher than that in Area D.

(2) Stomach Contents Composition

Weight composition of stomach contents was shown by combining into eight prey items such as Copepoda, Amphipoda (only Hyperiidea), euphausiids, shrimp, squid, other invertebrates, pollock and other fish by area (Table 4 and Fig. 4). By season, fishes such as pollock were abundant in winter, Copepoda were abundant in spring and summer, and euphausiids were abundant in the autumn. As the fish body became larger, the proportion of major prey items changed from Copepoda, euphausiids to fish such as pollock, and mainly larger prey items were taken. In comparison with Area A and Area B, euphausiids were consumed more, and Copepoda and pollock were consumed less in Area A. In Area C, euphausiids were mainly consumed and in Area D and Area E, Copepoda were mainly taken, and in these three areas, few pollock were consumed.

Age composition of pollock consumed by pollock is shown in Fig. 5. Age of pollock eaten was determined by corresponding to the length composition of catch by season and by area. Then, the ages converted as of the first of January. Since pollock were rarely eaten in Areas C, D, and E, it was shown only for Areas A and B. By season, there was a tendency for the proportion of age 2 fish in winter, age 1 fish in spring, and age 0 fish in summer and autumn were higher. As the predator grows, a greater proportion of older pollock were apt to be consumed. The difference of age composition by area was not remarkable. Age 3 pollock were consumed by pollock of 501 mm and
larger in Area A in spring. A fair amount of aged 2 fish were consumed by pollock of 301 to 400 mm in winter and spring. The body-length modes of aged 2 pollock in the catch during these periods ranged from 21 cm to 24 cm, but most of the pollock occurring as food items in the stomachs were smaller than those body-length modes. These are the highest value in the proportion of body-length of food items against the body-length of the predator, and it is considered to indicate the largest size of food item that pollock are able to consume. That is, it is considered possible that pollock may consume even pollock in size of about 55% of their own body-length.

4. Discussion

I compared my results with the other studies on the composition of stomach contents of pollock. In this study, in the eastern Bering Sea, pollock tended to consume mainly Copepoda in spring and summer, euphausiids in autumn, and pollock in winter. In accordance with pollock growth their main prey items will change from Copepoda to euphausiids and then to pollock, and when pollock became larger they consume more larger-sized prey items. Furthermore, pollock tended to consume euphausiids in the southern areas and Copepoda and pollock in the northern areas. The results obtained from the study of Takahashi and Yamaguchi (1972) which determined stomach content composition during July and August in 1970, were in accordance with the results obtained from this study with the change of prey items by body-length and that pollock were mainly consumed in the northern areas. In comparison with the results obtained from the studies by Dwyer et al. (1987) which determined the composition of the stomach contents from 1981 to 1983, it was not in accordance with the fact that euphausiids were mainly consumed in spring and many cannibalisms occurred in autumn. Although the causes of these disagreements were not obvious, it is considered to result from the differences of sampling sites in each season and differences of sampling years, etc. In my study, in the Aleutian Basin, euphausiids, Copepoda, squid and fish were mainly consumed by pollock in winter, and no prey items were observed to be particularly dominant. Copepoda occurred the most frequently in spring, Copepoda and euphausiids were dominant in summer, and euphausiids occurred most often in the autumn. According to Dwyer et al. (1987), fish and euphausiids were dominant in winter, Appendiculata were dominant in spring, and Copepoda occurred most often in summer, and their results were different from this study. From the stomach content of pollock collected in June, 1979, Okada and Yamaguchi (1985) indicated that Copepoda accounted for most of the food. For pollock in the western Bering Sea, an area not covered in this study, Kachina and Savicheva (1987) determined that small-sized pollock consumed mainly Copepoda and euphausiids, and large-sized pollock consumed mainly pollock and shrimp. As compared with the results obtained from this study for the eastern Bering Sea, it was observed that the amount of consumption of euphausiids was lower, and shrimp was more than my study.

It is possible that the differences in percentage of stomach content weight reflects differences of biomass of prey items in the environment. There are quite a few studies on the seasonal changes of zooplankton density.
by area which is a main food item for pollock. Therefore, it is considered to be possible to estimate the relative abundance of food items from the results of studying the stomach contents. That is, it is considered that density of prey items on the northern continental shelf of the eastern Bering Sea in spring is fairly high, as compared with that in the other areas. Although this high density is mainly attributable to Copepoda, it is assumed that the density of young pollock is also high. Density of prey items is considered to be high on the southern continental shelf of the eastern Bering Sea in summer, and it appears that it results mainly from euphausiids. Density of prey items tends to be high in the Aleutian Basin in autumn, and it appears that it results mainly from euphausiids. In addition, it is considered that density of young pollock is high in the northern continental shelf of the eastern Bering Sea. Although the density of prey items is considered to be low throughout areas in winter, it appears that the density of young pollock is not so low on the northern continental shelf of the eastern Bering Sea.

Okada and Yamaguchi (1985) and Traynor and Nelson (1985) determined the growth of pollock which live in the Aleutian Basin, and indicated that the growth rate at older ages was slower than that of pollock which live on the continental shelf of the eastern Bering Sea. Differences in growth by area are considered to have a close relationship with the intake of food (on the assumption that the intake is proportional to the stomach content weight). The proportion of stomach content weight of pollock on the northern continental shelf of the eastern Bering Sea against their body-weights was shown here to be fairly high. However, the individuals which grow fast were distributed on the southern continental shelf of the eastern Bering Sea, as compared with the northern continental shelf in spring (Sasaki and Yoshimura 1988). Then, the differences of body-length of age 5 and older fish among both areas disappear from spring through summer, but the differences of body-length among fish of ages 1 to 3 are shown to remain from May to October (Sasaki and Yoshimura 1988). In terms of stomach content weight, it was anticipated that density of prey items centering around Copepoda was higher in the northern area in spring. The main habitat of young pollock is in the northern area, and the stomach content weight of small-sized fish in the northern areas was generally heavier than that of small-sized fish in the southern areas in spring. However, pollock in the northern areas were smaller than those in the southern areas even in summer, and the amount of intake is not considered to be linked with growth. This is considered to result from the lower calorific value of Copepoda, which are consumed mainly in the northern areas, than that of euphausiids, which are mainly consumed in the southern areas. In comparison with pollock on the continental shelf of the eastern Bering Sea and in the Aleutian Basin, the ratio of stomach content weight of older fish against their body-weight, was lower for the Aleutian Basin than that of pollock on the continental shelf of the eastern Bering Sea. In particular, the difference was large in winter. The following are considered to be the cause of this difference, that is, although the biomass of prey items such as zooplankton decreases in both areas in winter, the young pollock distribute on the continental shelf of the eastern Bering Sea and the large-sized pollock mainly consume these young pollock. Therefore, the large-
sized pollock on the continental shelf continue to grow even in winter, and to become larger, as compared with pollock in the Aleutian Basin.

Like this, pollock on the continental shelf can grow to be larger by cannibalism. Judging whether this works profitably for an increase of pollock stock or not may be possible by quantitative analysis. For this purpose, it is necessary to determine the parameter such as the relation between the needed intake and growth by forming models which incorporate the predator-prey relation. At this time, we can just indicate that cannibalism of pollock is not necessarily disadvantageous for an increase of pollock stock. It is not too much to say that a noticeable cannibalistic phenomenon is a reflection of the significant dominance of pollock in the Bering Sea.

Pollock consume zooplankton at low trophic level in the Bering Sea ecosystem, young fish are cannibalized by the large-sized fish, and as a species, pollock are straddling over two trophic levels. Since biomass is dominant, it is considered that pollock play an important role for energy transfer in the ecosystem. In the future, it is necessary to determine the role of pollock more concretely by quantifying energy volume transferred.

Reference, Figs. 1 to 5 and Tables 1 to 4 are in English in the Japanese document.