ISSN: 0074-7246

INTERNATIONAL PACIFIC HALIBUT COMMISSION

Established by a Convention Between
Canada and the United States of America

Technical Report No. 52

Diet of Pacific halibut (*Hippoglossus stenolepis*) in the northwestern Pacific Ocean

by

I. N. Moukhametov[1], A. M. Orlov[2], and B. M. Leaman[3]

[1] Sakhalin Research Institute of Fisheries & Oceanography (SakhNIRO), 196, Komsomol'skaya, Yuzhno-Sakhalinsk, 693016, Russia

[2] Russian Federal Research Institute of Fisheries & Oceanography (VNIRO), 17, V. Krasnosel'skaya, Moscow, 107140, Russia

[3] International Pacific Halibut Commission, P.O. Box 95009 Seattle WA 98145-2009, USA

SEATTLE, WASHINGTON
2008

The International Pacific Halibut Commission has three publications: Annual Reports (U.S. 0074-7238), Scientific Reports, and Technical Reports (U.S. ISSN 0579-3920). Until 1969, only one series was published (U.S. ISSN 0074-7246). The numbering of the original series has been continued with the Scientific Reports.

INTERNATIONAL PACIFIC HALIBUT COMMISSION
P.O. BOX 95009
SEATTLE, WASHINGTON 98145-2009, U.S.A.
www.iphc.washington.edu

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Contents

Preface

This report has been produced through collaboration between Russian researchers and the International Pacific Halibut Commission (IPHC) staff. The existence of the Russian diet studies was brought to the attention of the IPHC during a period when Commission staff was examining changes in the growth rate of Pacific halibut in the eastern Pacific Ocean. It therefore was appropriate for the Commission to make the these results more broadly available. The third author worked with his Russian colleagues to enhance the presentation and analysis, and to format the report to IPHC standards. The third author expresses his appreciation for the patience of the Russian scientists during this process. Internal reviews by IPHC staff were also helpful in improving the quality of the presentation.

Abstract

The diet of Pacific halibut (*Hippoglossus stenolepis*) inhabiting the western Bering Sea, the Pacific Ocean waters off the northern Kuril Islands, southeastern Kamchatka, and the waters around the southern Kuril Islands was examined. The diet of the species consisted mostly of fishes, cephalopods, and smaller invertebrates. Consumption of fishery offal by Pacific halibut in the western Bering Sea was associated with major commercial fisheries in this area. We examined the diet of the species among study areas, depths, and sexes and found that the ontogenetic and bathymetric trends in the transition of prey noted elsewhere, from smaller invertebrates to fishes and larger cephalopods, also appear in the western Pacific Ocean. Differences in diet among areas mainly reflect faunistic differences in available prey and the presence of commercial fish processing operations.

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Introduction

Pacific halibut (*Hippoglossus stenolepis*) is an important target of the groundfish fishery in the north Pacific Ocean (Eschmeyer et al. 1983, Fadeev 1984, Kramer et al. 1995) with annual harvests during the past five years ranging from 39.3-43.6 thousand metric tons. Pacific halibut consume other abundant or commercially important species such as walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), saffron cod (*Eleginus gracilis*), Pacific herring (*Clupea pallasi*), Japanese sardine (*Sardinops melanostictus*), capelin (*Mallotus villosus*), Pacific sandlance (*Ammodytes hexapterus*), Atka mackerel (*Pleurogrammus monopterygius*), sandfish (*Trichodon trichodon*), arrowtooth flounder (*Atheresthes stomias*), yellowfin sole (*Limanda aspera*), sculpins (Cottidae), salmon (*Oncorhynchus* spp.), eelpouts (*Lycodes* spp.), snailfishes (*Liparis* spp.), crabs, shrimps, squids, and octopi (Moiseev 1953, Novikov 1963, Mito 1974, Tsuji 1974, Fadeev 1971, 1984, 1986; Best and St-Pierre, 1986 Brodeur and Livingston 1988, Livingston et al. 1993, Yang 1993, 1996, 2003; Yang and Nelson 2000, St-Pierre and Trumble 2000). Halibut plays an important trophic role in ecosystems of the north Pacific basin. The trophic ecology of halibut inhabiting the western Bering Sea, the Pacific waters off the northern Kuril Islands and southeastern Kamchatka, and especially waters around the southern Kuril Islands, has been poorly studied (Vernidub 1936, Gordeeva 1954, Novikov 1964, 1974). More recent studies have investigated the feeding ecology of halibut in the western Bering Sea, dealing mainly with ration size and seasonal changes in feeding intensity (Napazakov and Chuchukalo 2001), or with brief descriptions of halibut diet (Chikilev and Palm 1999, 2000). In the Kuril-Kamchatka area, Novikov (1974), Orlov (1997a, 1997b, 1998, 1999a, 1999b, 2000), and Moukhametov (2002a) have investigated frequency of occurrence of prey and ration size. Only a few papers contain information on the diet of Pacific halibut off the southern Kuril Islands (Mikulich 1954, Moukhametov, 2002b) and the presentations in these papers involve limited sampling and are primarily descriptive. No quantitative studies dealing with the diet of Pacific halibut in the northwestern Pacific have been conducted.

This paper describes Pacific halibut diets in various regions of the northwestern Pacific Ocean (western Bering Sea, Pacific Ocean waters off the northern Kuril Islands and southeastern Kamchatka, and the waters around southern Kuril Islands) and examines dietary changes associated with fish size and sex, as well as capture depth.

Materials and methods

In this study, the stomach contents of Pacific halibut sampled aboard the Japanese trawlers F/V *Kayo Maru No. 28* and F/V *Tomi Maru No. 82* during summer-autumn 1997, and aboard the Russian R/V *Professor Levanidov* during autumn 2000 were analyzed. The study took place in the western Bering Sea (BS) between 168°00′ E and 177°30′ W, in the Pacific Ocean waters off the northern Kuril Islands and southeastern Kamchatka (NK) between 48°10′ N and 51°30′ N, and in the waters off the southern Kuril Islands (SK) between 44°00′ N and 45°30′ N (Fig. 1). Samples for analysis were taken from bottom trawl catches. The trawls were equipped with a soft ground rope; the vertical and horizontal openings of the trawl nets were approximately five and 25 m, respectively on the Japanese vessels and approximately 14 m on the Russian vessel.

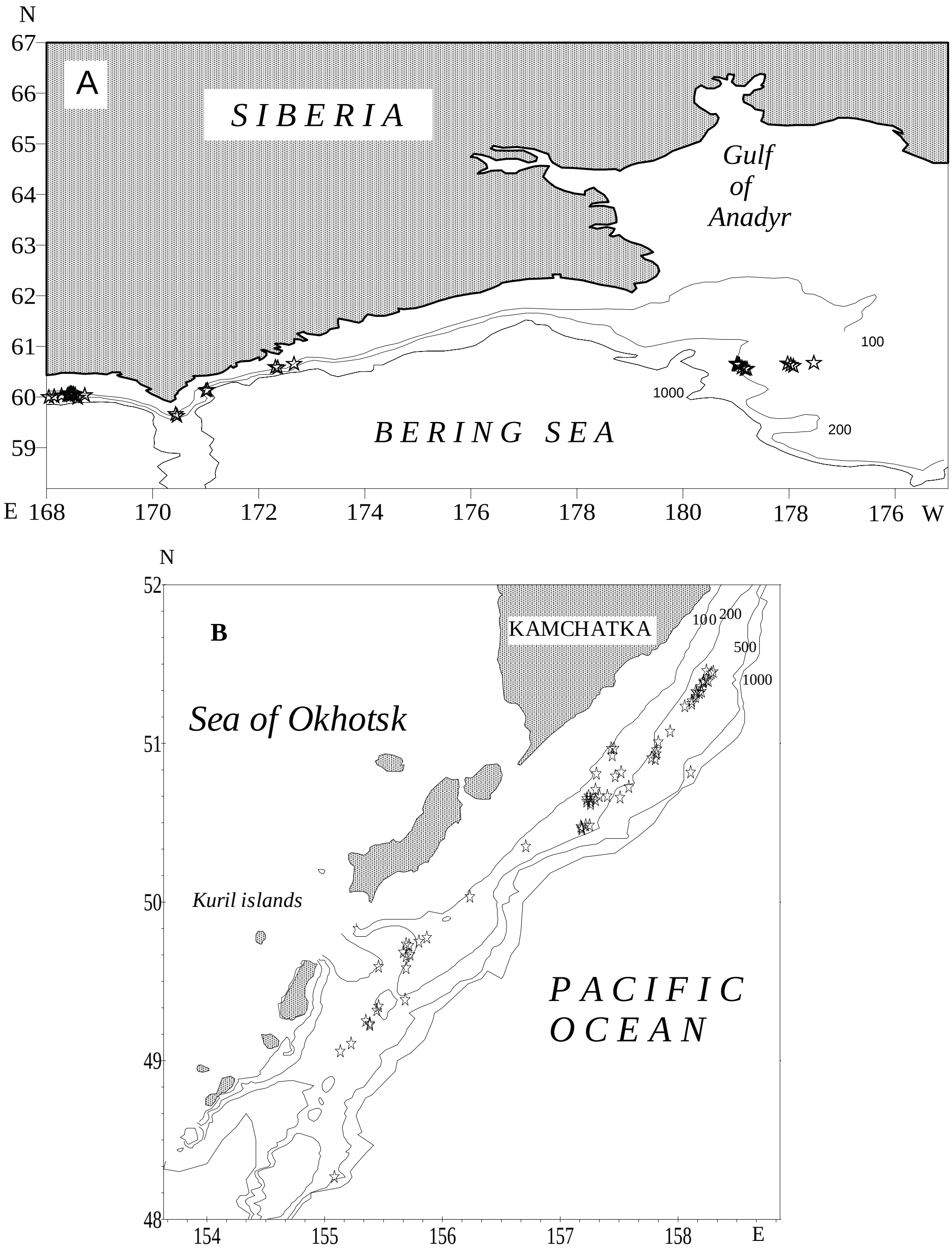

Figure 1. Map of the study area, showing bottom trawl stations (hollow stars), at which stomachs of Pacific halibut were sampled. A – western Bering Sea, B – northern Kuril Islands/southeast Kamchatka, C - southern Kuril Islands. Lines and numbers show isobaths (m).

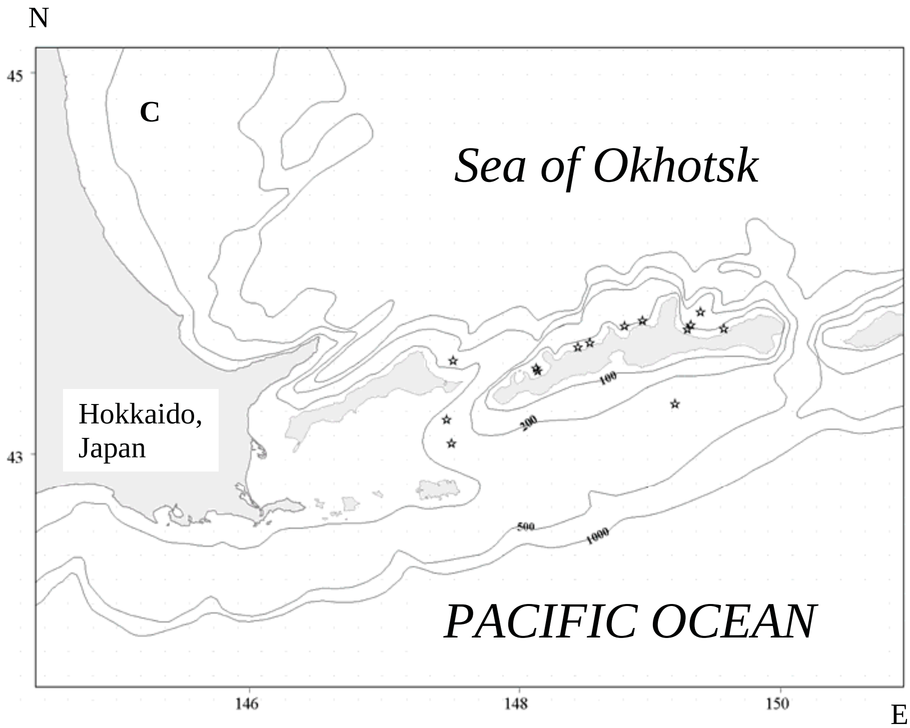

Figure 1. Continued.

The mesh size of codends on the nets used by the Japanese trawlers was 110 mm, while that of nets used on the Russian vessel was 30 mm. The depths of halibut capture varied by area: 251-500 m, 101-300 m, and 50-150 m in the BS, NK, and SK, respectively. Fishing was conducted throughout the 24-h daily period during the six-month study, although temporal differences are not examined in this report. Collections from the BS and NK were obtained in the summer-autumn of 1997, while collections from the SK were made in the autumn of 2000.

Halibut stomach contents were sorted, identified to the lowest possible taxonomic level, and weighed. The weight of each prey taxon was recorded to the nearest 0.1 g. Prey groups were described in terms of percent of total stomach content weight (% W) and percent occurrence (% O). The percent occurrence was calculated as the number of stomachs that contained that prey group divided by the total number of stomachs that contained food, however this paper examines only the contributions of diet items by weight. Fishes showing signs of regurgitation (digested food items in the mouth or gill cavity, or a flaccid or water-filled stomach) or net-feeding (freshly consumed prey items in the mouth or throat) were excluded from the analysis.

Fork lengths (tip of snout to the end of the middle rays of tail) were measured (cm) for all halibut from which stomachs were collected.

Results

The total sample sizes, and those for fish whose stomachs contained food, were: 262 and 206 in the BS, 386 and 270 in the NK, and 102 and 82 in the SK.

General description of diets

The diet of Pacific halibut examined in this study consisted of a wide spectrum of prey (Table 1, Figs. 2-4). The total number of identified organisms (excluding fishery offal) in halibut

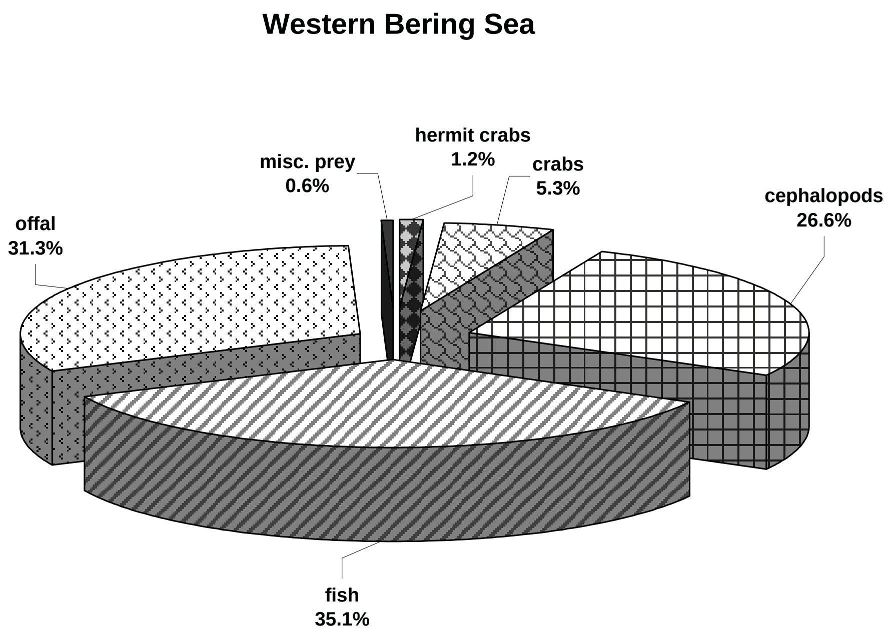

Figure 2. Diets of Pacific halibut in the western Bering Sea, categorized by percent by weight of main food items.

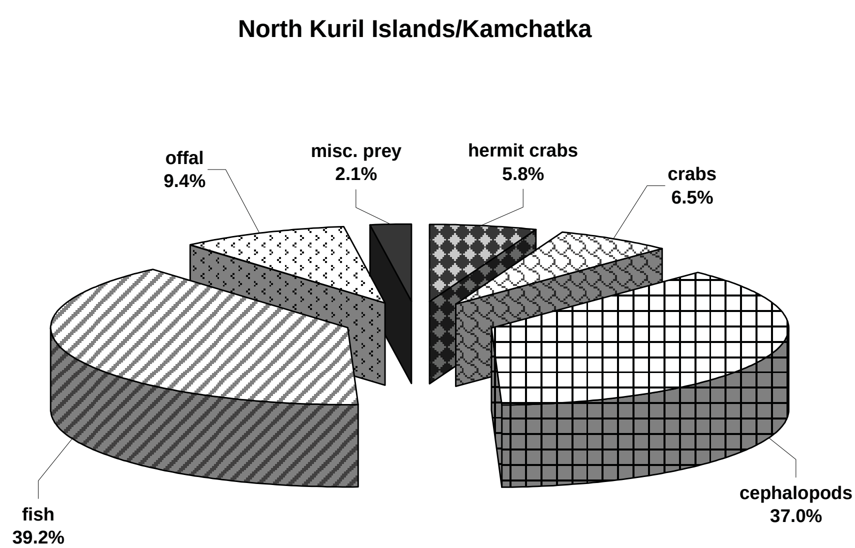

Figure 3. Diets of Pacific halibut in the northern Kuril Islands/southeast Kamchatka, categorized by percent by weight of main food items.

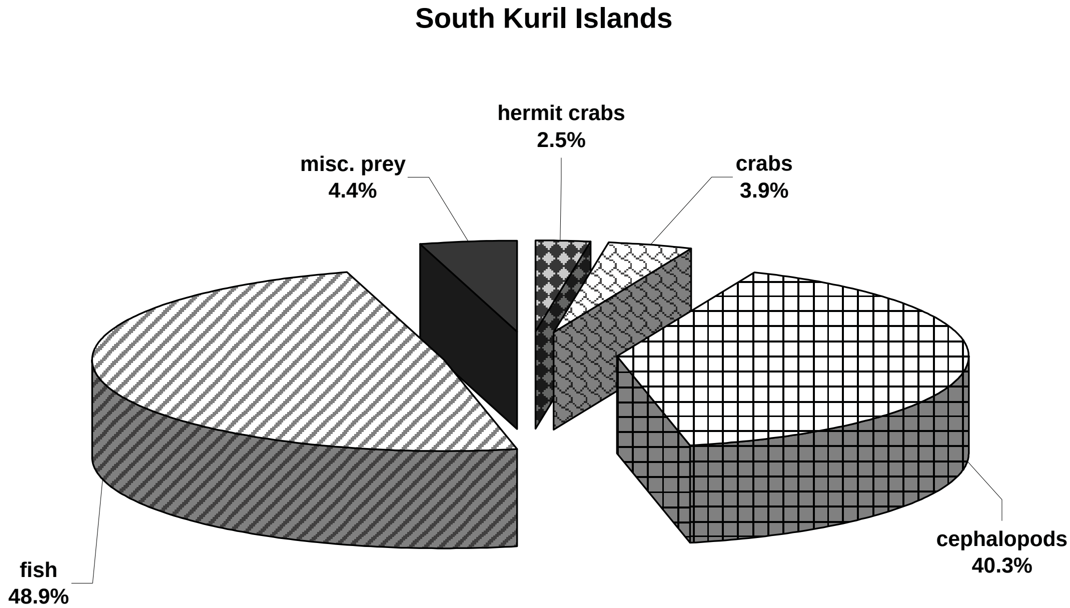

Figure 4. Diets of Pacific halibut in the southern Kuril Islands, categorized by percent by weight of main food items.

Table 1. Stomach contents of Pacific halibut (*Hippoglossus stenolepis*) expressed as frequency of occurrence (% O) and weight (% W) sampled in the western Bering Sea (BS), the Pacific Ocean waters off the northern Kuril Islands and southeastern Kamchatka (NK) during summer-autumn 1997, and off the southern Kuril Islands (SK), during autumn 2000.

Prey item	BS		NK		SK	
	% O	**% W**	**% O**	**% W**	**% O**	**% W**
ANNELIDA						
Polychaeta	-	-	0.4	<0.1	-	-
Echiurida	-	-	0.4	0.1	1.2	1.3
Sipunculida	-	-	1.9	0.3	1.2	0.4
CRUSTACEA						
Euphausiacea						
Euphausiidae gen sp.	-	-	-	-	1.2	0.1
Isopoda	-	-	3.7	0.3	-	-
Amphipoda						
Amphipoda gen. sp.	1.0	<0.1	0.7	<0.1	1.2	<0.1
Anonyx sp.	-	-	1.5	0.1	1.2	<0.1
Decapoda						
Pandalus goniurus	1.9	0.1	0.4	<0.1	-	-
Pandalus sp.	-	-	3.7	1.3	3.7	0.1
Sclerocrangon sp.	-	-	0.4	<0.1	25.6	1.7
Pagurus sp.	8.7	1.2	27.0	5.8	19.5	2.5
Hyas coarctatus	0.5	<0.1	-	-	-	-
Chionoecetes angulatus	5.8	2.1	-	-	-	-
C. bairdi	1.0	0.1	0.7	0.3	-	-
C. opilio	10.2	2.4	18.9	6.1	-	-
C. tanneri	1.5	0.6	-	-	-	-
Majidae gen. sp.	1.9	0.1	-	-	8.5	1.7
Telmessus chairagonus	-	-	-	-	4.9	1.0
Erimacrus issenbekii	-	-	-	-	2.4	1.2
Unidentified Decapoda	-	-	0.4	<0.1	-	-

Table 1. Continued

MOLLUSCA						
Gastropoda						
Buccinidae gen. sp.	3.4	0.5	0.7	<0.1	1.2	<0.1
Bivalvia						
Chlamys sp.	-	-	0.4	<0.1	-	-
Cephalopoda						
Berryteuthis magister	20.4	13.6	10.7	12.8	-	-
Todarodes pacificus	-	-	-	-	12.2	17.2
Galyteuthis phyllura	-	-	0.4	0.5	-	-
Octopus sp.	-	-	19.3	20.5	-	-
Benthoctopus sp.	-	-	1.5	3.0	-	-
Octopoda gen sp.	14.1	13.0	-	-	13.4	23.0
Unidentified Cephalopoda	-	-	3.0	0.5	-	-
ECHINODERMATA						
Asteriidae gen. sp.	-	-	-	-	2.4	0.6
Ophiuroidea gen. sp.	0.5	<0.1	0.4	<0.1	-	-
OSTEICHTHYES						
Clupea pallasii	15.5	12.9	-	-	-	-
Salmonidae gen sp.	-	-	0.4	2.0	-	-
Theragra chalcogramma	18.5	18.7	12.6	21.8	4.9	3.7
Albatrossia pectoralis	0.5	0.3	-	-	-	-
Coryphaenoides cinereus	0.5	0.2	-	-	-	-
Arctoscopus japonicus	-	-	-	-	1.2	1.9
Opisthocentrus sp.	-	-	-	-	2.4	0.3
Lycodes brevipes	0.5	0.2	-	-	-	-
L. brunneofasciatus	-	-	0.4	0.7	-	-
L concolor	0.5	0.3	-	-	-	-
L. diapterus	0.5	0.2	-	-	-	-
Sebastes sp. (fry)	-	-	-	-	7.3	0.3
Pleurogrammus azonus	-	-	-	-	6.1	33.0
P. monopterigius	-	-	1.9	4.5	-	-
Artediellus sp.	-	-	0.4	<0.1	-	-
Gymnocanthus detrisus	-	-	0.4	0.8	-	-
G. herzensteini	-	-	-	-	1.2	0.6
Taurocottus bergi	-	-	-	-	1.2	<0.1
Triglops scepticus	-	-	1.1	0.4	-	-
Triglops sp.	-	-	-	-	1.2	0.5
Cottidae gen. sp.	-	-	0.4	0.1	2.4	0.2
Malacocottus zonurus	1.5	0.3	-	-	-	-
Bathyagonus nigripinnis	1.0	0.2	-	-	-	-
Sarritor frenatus	-	-	1.5	0.4	-	-
Pallasina barbata	-	-	-	-	1.2	<0.1
Podothecus veternus	-	-	-	-	1.2	0.7
Elassodiscus tremebundus	1.0	0.4	-	-	-	-
Hippoglossoides elassodon	0.5	0.5	0.4	<0.1	-	-
Pleuronectidae gen. sp.	-	-	-	-	4.9	1.6
Unidentified Teleostei	4.9	0.9	15.9	8.2	31.7	6.2
Fishery offal	29.6	31.3	7.4	9.3	-	-
Number of stomachs analyzed	262		386		102	
Stomachs with food	206		270		82	
Halibut length range, cm	47-154		35-134		28.2-105.5	
Mean halibut length ± SE	73.92±0.76		61.40±1.00		50.3±1.44	
Halibut weight range, kg	1.05-56.00		0.33-33.00		0.24-15.90	
Mean halibut weight ± SE	5.250±0.271		4.001±0.253		2.020±0.244	

stomachs was 25 in the BS, 32 in the NK, and 28 in the SK. In all areas, the contribution of crabs in the diet was disproportionately higher as % O, than as % W. For almost all other diet items, the % O and the % W contributions were quite similar.

The diet of Pacific halibut in the BS samples was comprised primarily of fishes (35.1% W), fishery offal (31.3% W) and cephalopods (26.6% W) (Fig. 2). Walleye pollock represented the majority of fish consumed (18.7% W), followed by Pacific herring (12.9% W). Red squid (*Berryteuthis magister*) (13.6% W) and octopi (13.0% W) were the most important cephalopod prey items (Table 1, Fig. 2).

In the NK samples, Pacific halibut consumed mainly fishes (39.2% W) and cephalopods (37.0% W) (Fig. 3). Fishery offal in the diet of halibut here was of lesser importance than in the BS (9.4% W). Similar to the BS area, walleye pollock (21.8% W) was the most important prey item among fishes and octopi were the most important cephalopod prey (23.5% W) (Table 1, Fig. 3).

Fish was the largest dietary component (48.9% W) for halibut from the SK study area , where the most important prey was arabesque greenling (*Pleurogrammus azonus,* 33.0% W) (Table 1, Fig. 4). The role of cephalopods in the halibut diet in the SK was also the highest among the study areas (40.3% W). The primary cephalopod species were unidentified octopi (23.0% W) and the Japanese common squid (*Todarodes pacificus*) (17.2% W).

Diet vs. size of halibut

Considerable differences in Pacific halibut diet composition with increasing size were common among the three study areas. In the BS, increasing size of Pacific halibut was accompanied by an increased consumption of fishes and decreased consumption of fishery offal (Fig. 5). The proportion of cephalopods was approximately equal in diets of various length categories, although larger halibut had increased occurrence of red squid and decreased occurrence of octopi, compared with smaller halibut.

In the NK area, the variation in the diet of Pacific halibut by length was the greatest among all areas. Small fish (<50 cm) ate mostly hermit crabs, small crustaceans (isopods and amphipods), spider crabs, shrimps, and fishes (Fig. 6). The role of hermit crabs in halibut diet decreased with increasing halibut length and became relatively unimportant after halibut attained 60 cm. Spider crabs were common in halibut diet within all analyzed length categories, although their average proportion comprised only about 2% W of stomach contents for fish larger than 70 cm. The role of cephalopods, fishes, and fishery offal rose with increasing halibut size but the largest individuals in the NK area ate fish almost exclusively.

The smallest individual halibut were observed in the SK area. Individuals < 55 cm consumed a variety of prey, of which fishes, cephalopods, and crabs were most important (24.0-34.2% W of the diet was comprised of echiurid worms, shrimps, hermit crabs and crabs of the families Atelecyclidae and Majidae) (Fig. 7). Larger halibut fed mainly on fishes and cephalopods.

Diet vs. capture depth of halibut

Considerable differences in diet composition were associated with the depth of capture. Stomach contents of BS Pacific halibut caught at shallower depths consisted mostly of fishery offal and fish (mainly of walleye pollock) (Fig. 8). With increasing depth, the role of fishery offal decreased from 63.8% W at 251-300 m to 17.5% W at 401-450 m, while that of cephalopods conversely increased from 9.1% W to 47.5% W. The percentage of fishes in the halibut diet increased from 23.5% W at 251-300 m to 56.8% W at 351-400 m and subsequently reduced to 9.4% W at the greatest depths of capture.

In the NK increasing depth was accompanied by a decreasing proportion of fish in the halibut diet, while the importance of cephalopods increased (Fig. 9). Fishery offal comprised

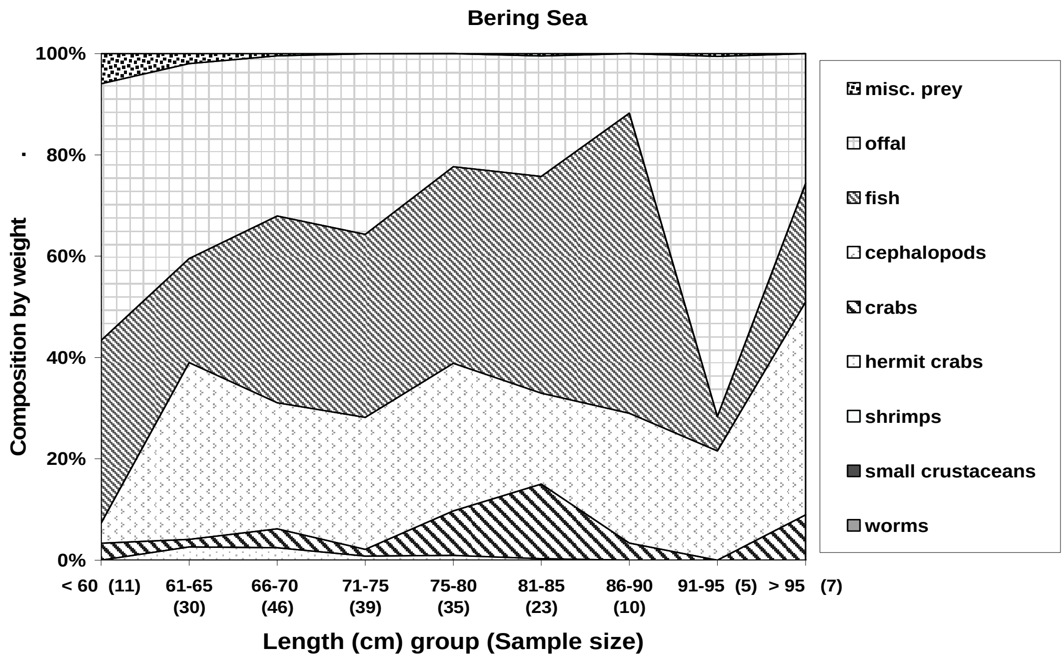

Figure 5. Variations in the main food items of Pacific halibut collected in the western Bering Sea, by halibut size (sample size is shown in parentheses).

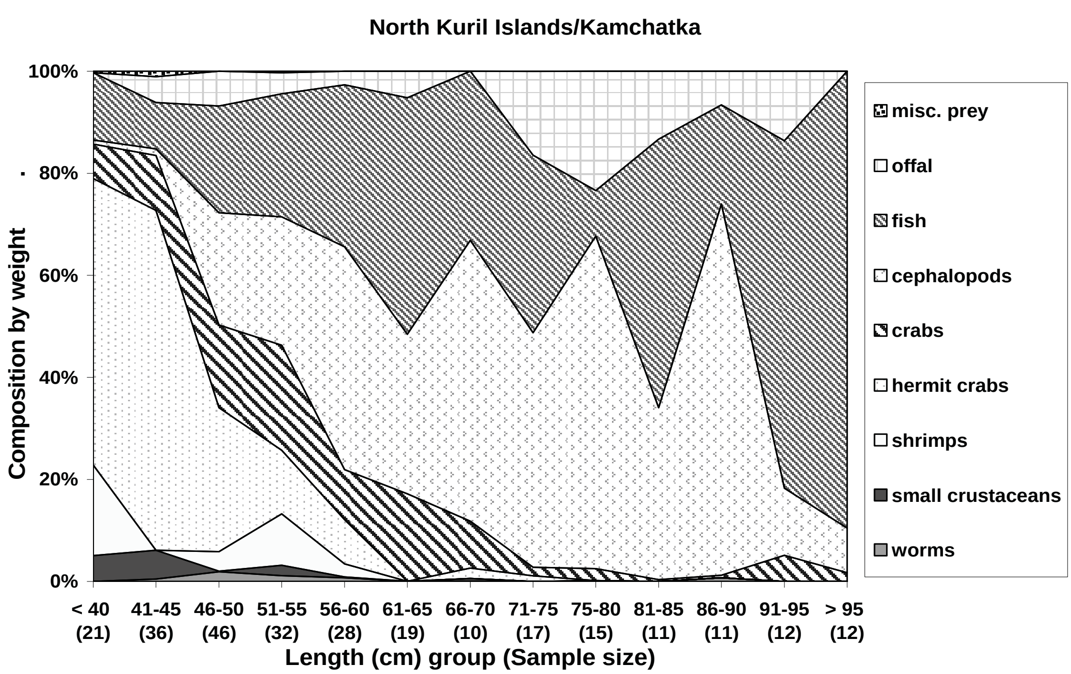

Figure 6. Variations in the main food items of Pacific halibut collected in the northern Kuril Islands/southeast Kamchatka, by halibut size (sample size is shown in parentheses)

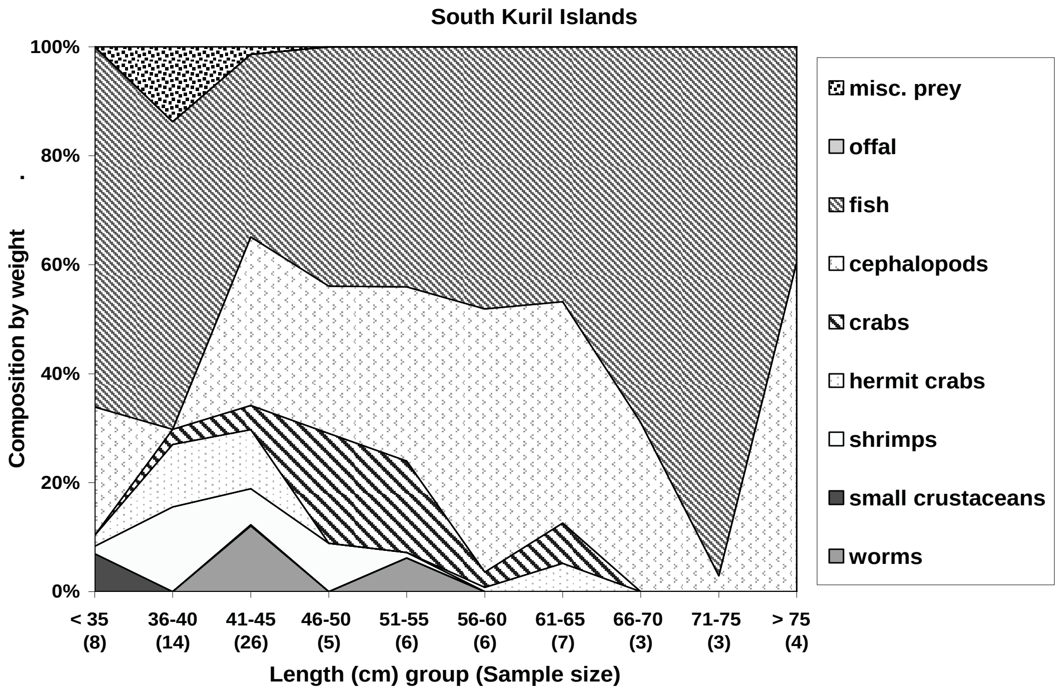

Figure 7. Variations in the main food items of Pacific halibut collected in the southern Kuril Islands, by halibut size (sample size is shown in parentheses).

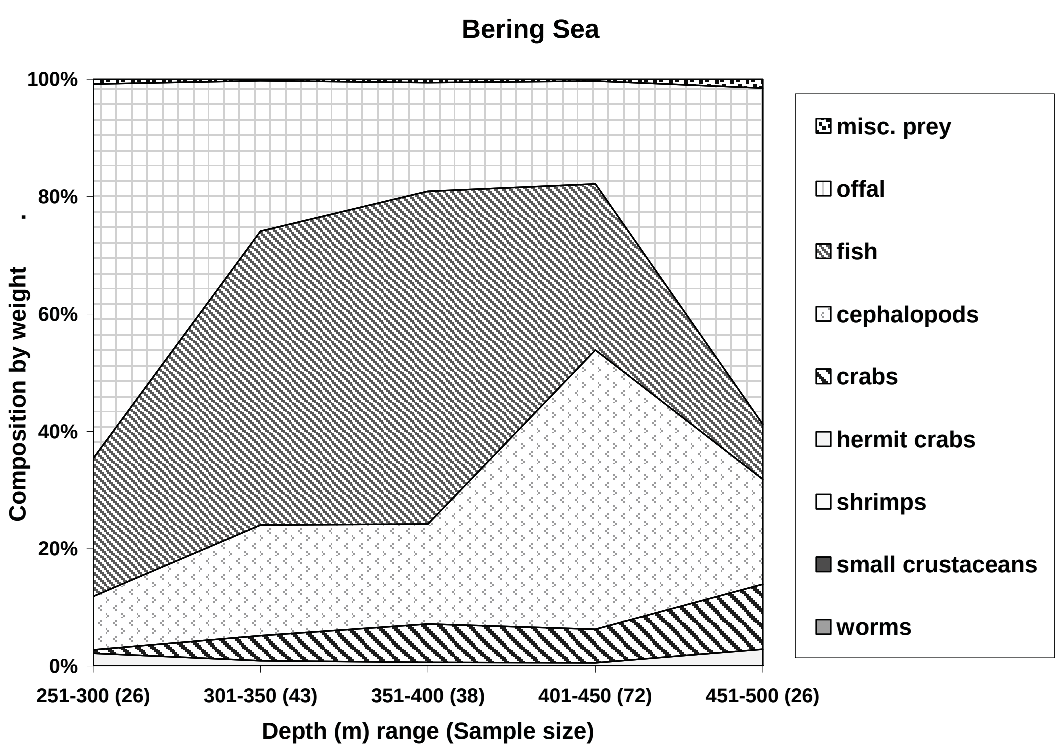

Figure 8. Variations in the main food items of Pacific halibut collected in the western Bering Sea, by capture depth (sample size is shown in parentheses).

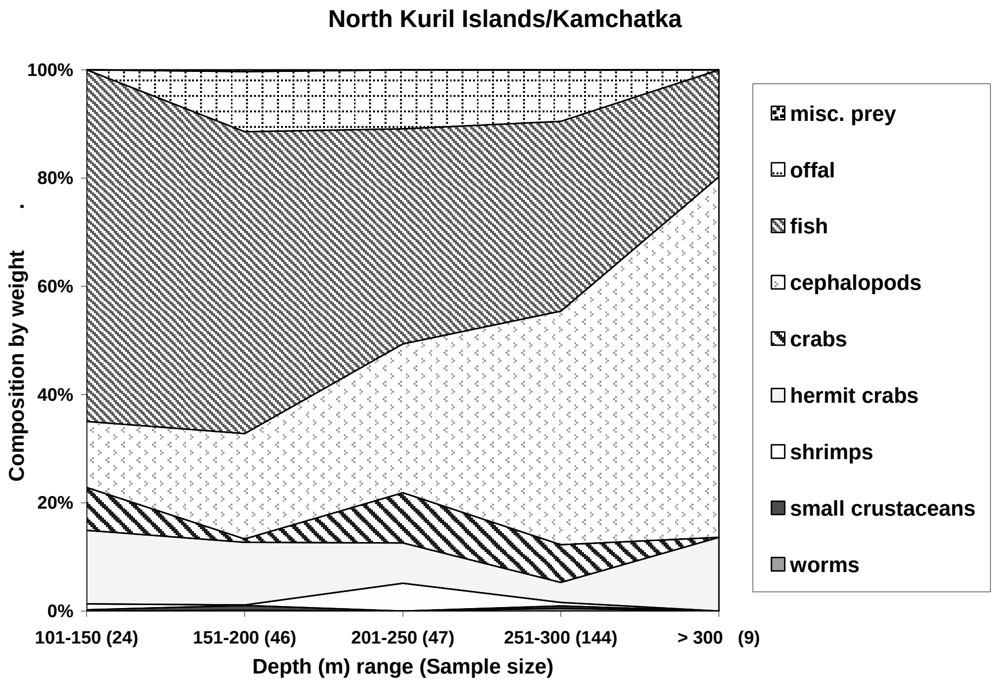

Figure 9. Variations in the main food items of Pacific halibut collected in the northern Kuril Islands/southeast Kamchatka, by capture depth (sample size is shown in parentheses).

9.5-11.1% W of stomach contents at 151-300 m. The presence of hermit crabs was notable within all investigated depth ranges (3.7-13.6% W).

In the SK area, the samples were taken at the shallowest depths among study areas (Fig. 10). With the exception of a single specimen caught at 342 m, all fish were caught shallower than 120 m, therefore this single specimen was excluded from analysis. Pacific halibut in this area fed mainly on cephalopods and fish. With increasing depth, the share of cephalopods declined from 49.7% W to 25.6% W, while that of fishes rose from 39.5% W to 68.3% W. Arabesque greenling was the dominant fish prey at shallower depths while the importance of walleye pollock in the diet rose with increasing depth.

Since the data show differences in the diet of halibut with fish size, any examination of the effects of depth on the diet of halibut should also consider whether the fish size distribution also varies with depth (Figs. 11-13). In the BS area, there was no apparent shift in the size distribution of halibut over the depths examined, although the depth range (approximately 270-450 m) did not include shallower depths where smaller halibut are more common (Fig. 11). Samples from the NK area spanned a more extensive depth range of approximately 120-320 m and while a slight relationship of increasing size with depth was noted, the sizes of halibut at comparable depth ranges with the other two areas were similar (Fig. 12). Samples from the SK area were obtained almost exclusively in shallow (< 150 m) water (with only a single male caught deeper than 150 m) and showed only a slightly increasing size of both males and females with depth (Fig. 13). For both the NK and SK areas, the smallest males and females occurred in the shallowest depths.

In general, the changes noted above in the diet of fish with increasing depth in the area of the Kuril Islands (both NK and SK) are also associated with increasing size of fish. In contrast, the BS samples showed strong depth-associated changes in diet with little change in size frequency of halibut.

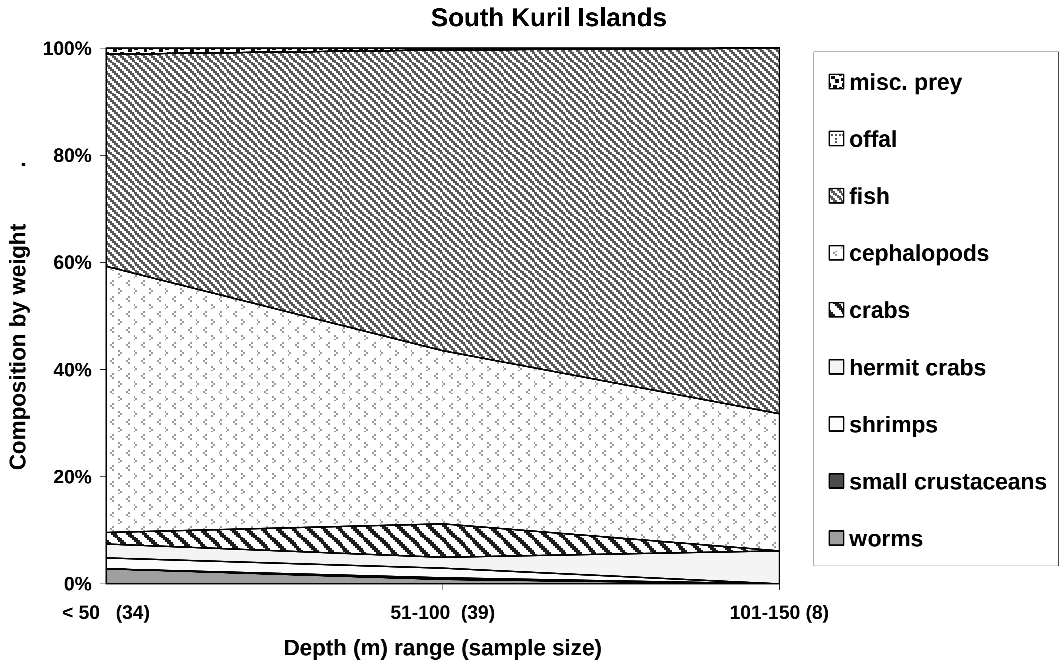

Figure 10. Variations in the main food items of Pacific halibut collected in the southern Kuril Islands, by capture depth (sample size is shown in parentheses).

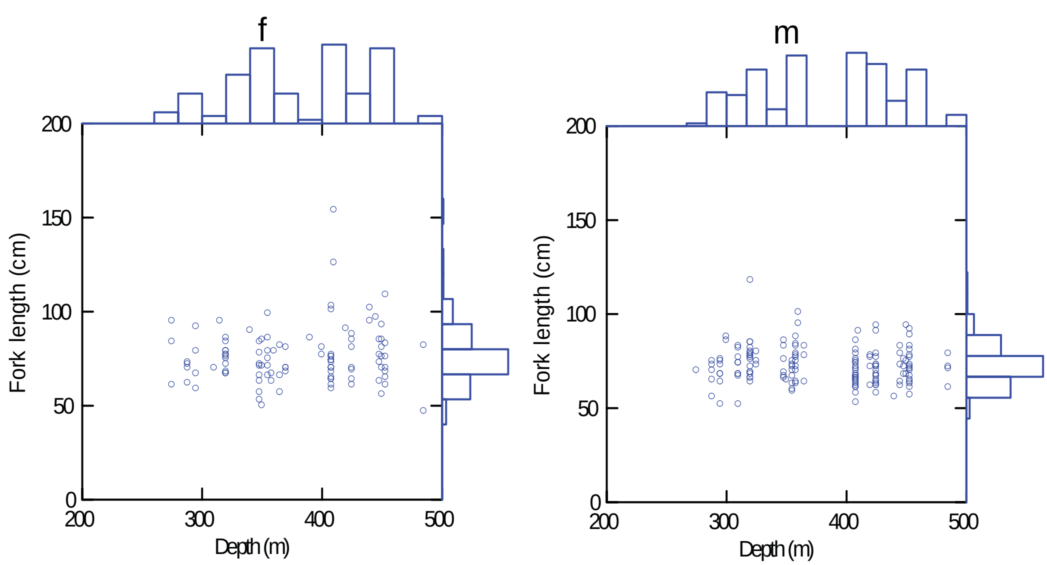

Figure 11. Halibut length by sex (f = female, m = male) and depth for the western Bering Sea samples. Histograms of observation frequencies border each axis.

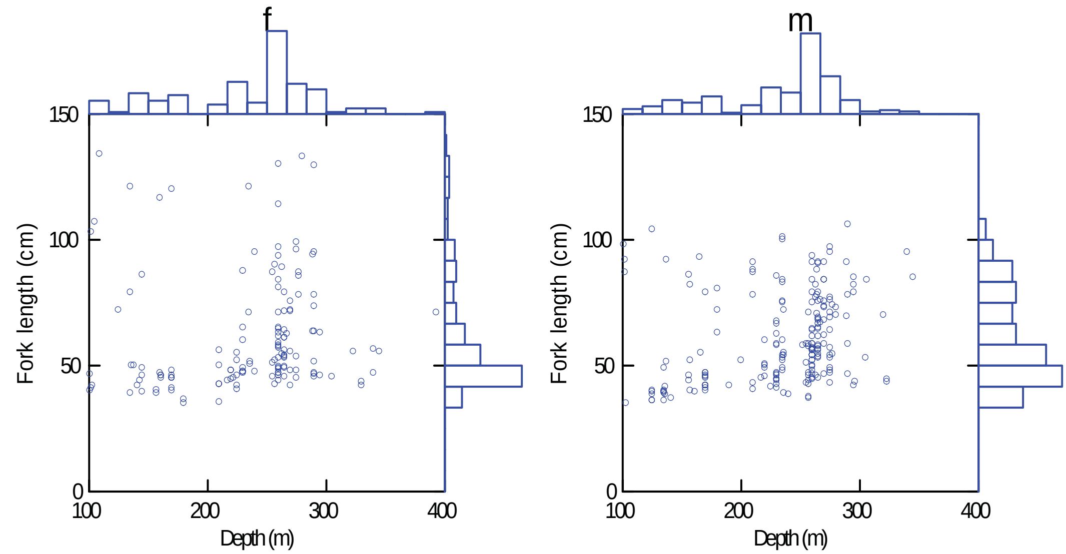

Figure 12. Halibut length by sex (f = female, m = male) and depth for the northern Kuril Islands/southeast Kamchatka samples. Histograms of observation frequencies border each axis.

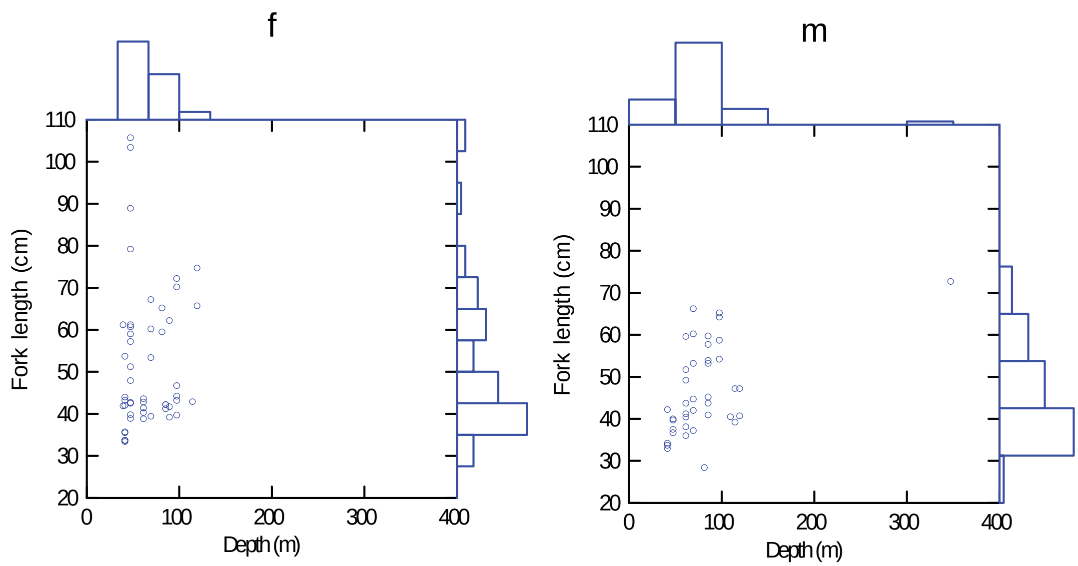

Figure 13. Halibut length by sex (f = female, m = male) and depth for the southern Kuril Islands samples. Histograms of observation frequencies border each axis.

Diet vs. sex of halibut

Some differences between male and female halibut diets were detected, although the differences are small (Fig. 14). Male and female Pacific halibut (m/f) in the BS had similar composition of dominant diet items by weight: fishery offal (27.2%/36.9%), fish (38.0%/31.2%) and cephalopods (26.2%/27.1%). However, males consumed a wider spectrum of fish prey (nine species) compared with females (only four recognizable species). The most important identifiable species in the diet for both sexes were walleye pollock (18.2% W and 19.5% W for male and female, respectively), and Pacific herring (15.2% W and 9.8% W for male and female, respectively). Differences in proportions of red squid and octopi in male and female diets were also observed. Pacific halibut males consumed more red squid than octopi (16.1% W vs. 10.1% W, respectively) while the opposite occurred in female diets (16.8% W vs. 10.2% W, respectively).

In the NK area, the diet of Pacific halibut females consisted primarily of cephalopods (42.5% W), fish (31.2% W), and fishery offal (10.8% W), while males ate larger amounts of fish (45.1% W) than cephalopods (33.3% W). Similar to the BS region, the list of fish prey found in stomachs of halibut males was broader but the main dietary item of both sexes remained walleye pollock.

Different proportions of cephalopod and crab consumption by male and female Pacific halibut in the SK area were found. Cephalopods and crabs comprised, respectively, 43.0% W and 3.3% W of female diets and 30.6% W and 17.3% W of male diets. Proportions of octopi in male and female diets were almost equal (22.1% W and 23.3% W, respectively) though differences in squid consumption (8.5% W and 19.7% W by male and female, respectively) were observed.

Diet vs. area

Some regional differences in diet of Pacific halibut within the BS and NK areas were detected but the narrow geographic range of samples in the SK area renders any comparison of limited value and the data by category are highly variable across regions (Fig. 15). Neither these regional differences in proportional diet category contributions, nor the corresponding differences for the broader geographic areas (Fig. 16) are significantly different (ANOVA, $p > 0.98$ and $p > 0.99$, respectively), as a result of this variability. However, the presence of a high percentage (67.9% W) fish offal in the diet of halibut in the western Bering Sea and to a lesser extent in the north Kuril Is., is a singularly notable difference among the areas.

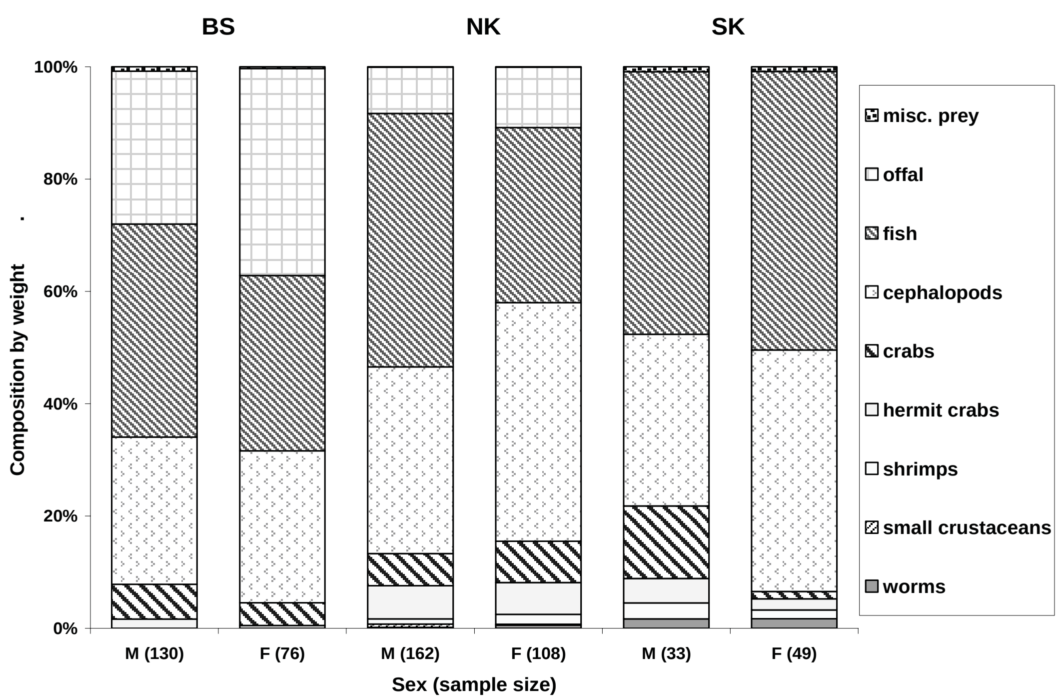

Figure 14. Variations in the main food items of Pacific halibut, by sex. BS – western Bering Sea, NK - northern Kuril Islands/southeast Kamchatka, SK - southern Kuril Islands; M – males, F – females (sample size is shown in parentheses).

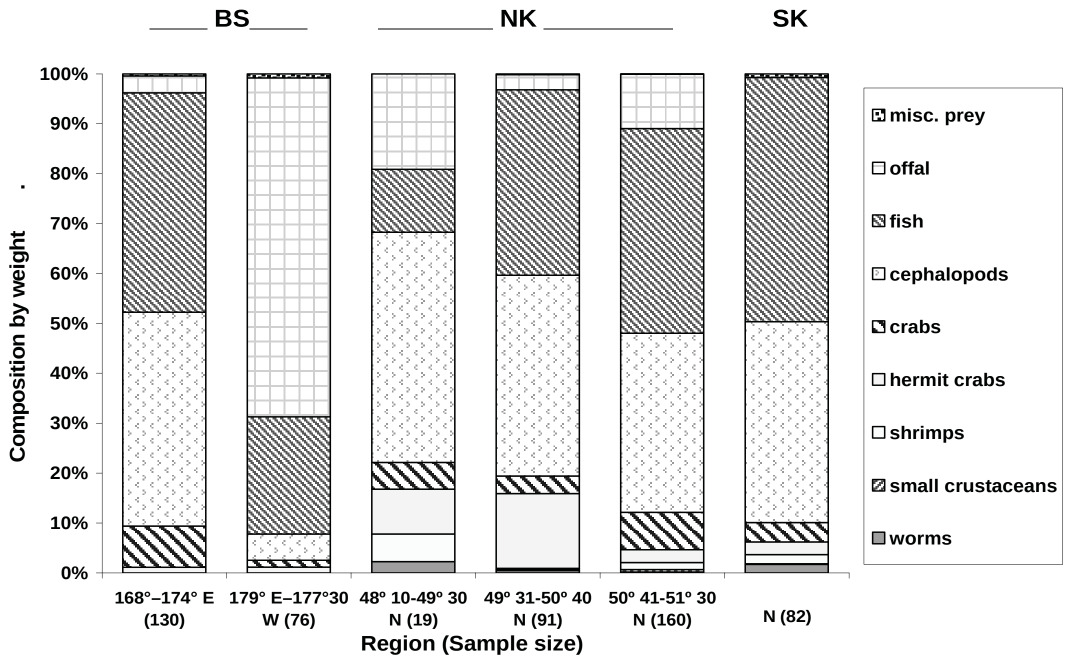

Figure 15. Variations in the main food items of Pacific halibut, by study area (sample size is shown in parentheses): BS – western Bering Sea, NK – northern Kuril Islands/southeast Kamchatka, SK – southern Kuril Islands.

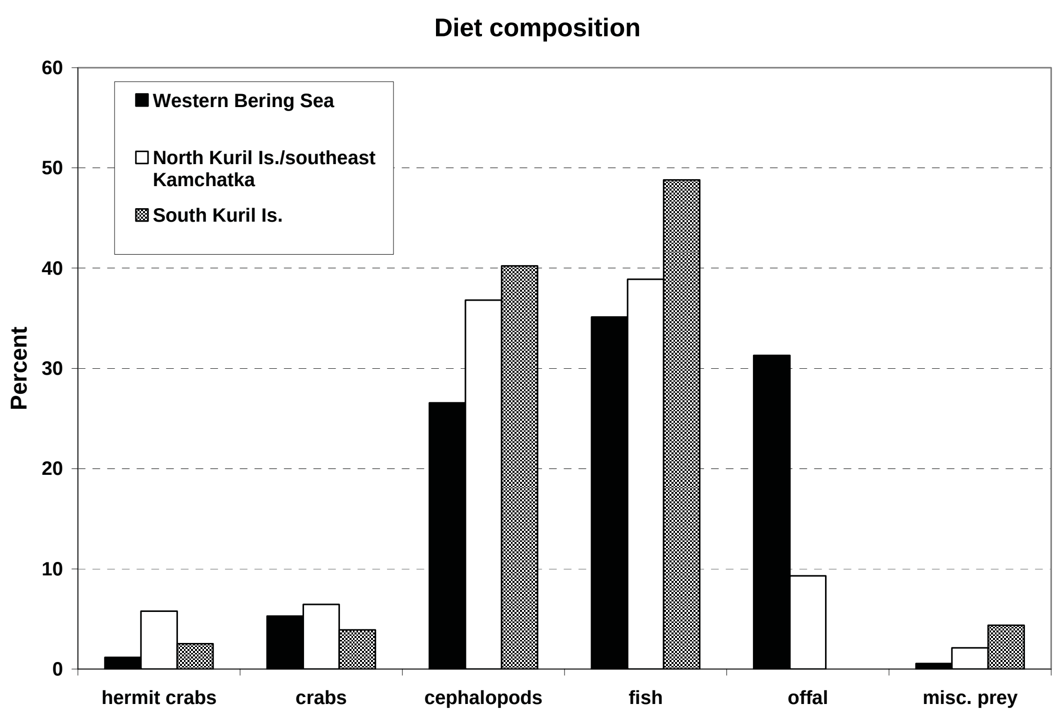

Figure 16. Diet composition of Pacific halibut, by geographic area.

Discussion

General description of diets

Previous research has demonstrated the dominant role of fishes in Pacific halibut diets in other areas of the north Pacific Ocean (Mito 1974, Tsuji 1974, Best and St-Pierre 1986, Brodeur and Livingston 1988, Livingston *et al*. 1993, Yang 1993, 1996, 2003, Yang and Nelson 2000). From the 1930s through the 1960s (Vernidub 1936, Gordeeva 1954, Novikov 1963, 1974) walleye pollock comprised the base of Pacific halibut diet in weight throughout the western Bering Sea, although Vernidub (1936) found crustaceans to be the most frequently occurring prey items in stomachs in her study. These authors found that the importance of cephalopods in halibut diet from the 1930s through the 1960s was minimal. Fishery offal was not found in stomachs because the Russian walleye pollock fishery had not yet developed (Shuntov *et al*. 1993). Differences in results among the present and the previous studies may be related, in part, to changes of prey abundance as well as to changes in intensity of fisheries in the study area.

In the NK area, a previous study had found the main food items of halibut to be fishes, spider crabs, and cephalopods (10.4 % O) (Novikov, 1974). However, recent studies (Orlov, 1997a, 1997b, 1999a, 1999b), based on frequency of occurrence, showed that the most important dietary components were fishes, followed by cephalopods and crustaceans. The most important prey items in the cephalopod group were octopi and red squid, while walleye pollock was the most important fish prey. Our study indicates the continued importance of fish in the diet of halibut.

Some data on diet composition of Pacific halibut inhabiting waters off the southern Kuril Islands were provided previously by Mikulich (1954), although only three specimens were analyzed in that study. One fish had an empty stomach and another two ate fishes (fry of Pacific cod (*Gadus macrocephalus*), flathead sole (*Hippoglossoides elassodon*), staghorn sculpin (*Gymnocanthus* sp.), and snakefish (*Lumpenus* sp.). Our results extend the knowledge of diet composition of Pacific halibut in the southern Kuril Islands waters considerably.

Diet vs. size

The changes in the diet composition of Pacific halibut with increasing fish size are common to fish inhabiting various parts of the north Pacific Ocean (Gordeeva 1954, Novikov 1964, Fadeev 1971, IPHC 1978, 1987, Yang 1993, 1996, 2003, Orlov 1997a, 1997b, 1999b, Yang and Nelson 2000, Napazakov and Chuchukalo, 2001). These changes have a common pattern: small fishes eat mostly crustaceans while large individuals consume mainly cephalopods and fishes.

For the western Bering Sea, size-dependent diet differences for Pacific halibut in terms of percent total stomach content weight have been described only recently (Napazakov and Chuchukalo 2001), though that examination grouped individuals by 20-cm intervals. Earlier, Novikov (1964) showed differences of occurrence of fishes and invertebrates in the diets of three halibut size groups: 30-60 cm, 60-90 cm and bigger than 90 cm.

Diet differences with halibut size in the Pacific Ocean waters off the northern Kuril Islands and southeastern Kamchatka have been reported previously by Orlov (1997a, 1997b, 1999b) and our study has confirmed these previous results. Similarly, the changes in diet compositions of Pacific halibut with increasing size in the waters off the southern Kuril Islands also confirm results of a previous study (Moukhametov 2002b).

Diet vs. capture depth

There have been no previous studies of depth-dependent changes halibut diet for the western Bering Sea or southern Kuril Islands. Orlov (1997a, 1997b, 1999b) recently conducted such research in the NK area, although those analyses were based only on occurrence of prey items in stomachs. The changes in diet composition with depth noted in our study are consistent with the changes of fish size with depth, for the common diet elements.

Diet vs. sex

Sex-dependent differences of male and female halibut diets in the BS area have not been reported previously. Such differences for Pacific halibut inhabiting the Pacific waters off the northern Kuril Islands and southeastern Kamchatka have been described in only a single previous paper (Orlov, 1997a). Since Orlov's study considered male and female diets only in terms of frequency of occurrence, our results present some differences. No comprehensive study of sex-dependent differences of Pacific halibut diet in the SK region has been reported previously.

Differences in Pacific halibut diet composition between males and females are consistent with essential distinctions in their sizes, expressed most clearly in the SK area, where mean lengths were 44.6 cm and 52.2 cm, for males and females, respectively. Although mean sizes were different in the other two study areas, the differences between the sexes were relatively minor. In the BS area, the mean length of males was 72.5 cm vs. 75.9 cm of females. In the NK area, the mean lengths of Pacific halibut were 59.9 cm vs. 62.3 cm for males and females, respectively.

Diet vs. area

Regional differences of Pacific halibut diet in the western Bering Sea were considered by Gordeeva (1954), although that study was based on limited data and prior to the development of the walleye pollock fishery in this area. Napazakov and Chuchukalo (2001) considered regional differences of Pacific halibut diet in the western Bering Sea. However, they combined data from areas east and west of 174° E, which we considered separately. Significantly, they did not report fishery offal among the dietary components of Pacific halibut.

The dominance of fishery offal in Pacific halibut diet in the eastern part of the BS area is probably related to intensive walleye pollock fisheries in that area. Feeding on fishery offal in the area considered in our study was also observed in other predators such as Greenland halibut (*Reinhardtius hippoglossoides matsuurae*), Kamchatka flounder (*Atheresthes evermanni*) (Orlov and Moukhametov 2002), and rougheye rockfish (*Sebastes aleutianus*) (Orlov 2002).

Differences in diet composition of Pacific halibut inhabiting various parts of the NK area may be explained both by essential distinctions of mean halibut size (52.7 vs. 54.9 vs. 65.2 cm in southern, middle and northern parts, respectively), and by latitudinal faunistic diversity in available prey.

Halibut diet in the western Pacific Ocean

The conclusions concerning depth, size, and sex effects on halibut diet presented here tend to confirm the general conclusions of ontogenetic changes in halibut diet observed elsewhere. It is of considerable interest that both this study and Yang (2003) note that fishery offal can be an important component of the diet of Pacific halibut – as high as 30% by weight in some areas. The long-term implications of such a diet component are not known, although Lang *et al*. (2003) note that most of the offal consumed in the eastern Bering Sea results from the at-sea processing of walleye pollock and may not represent a shift in the species-specific dietary dependence of halibut. This is also likely to be true in the western Bering Sea.

Acknowledgements

We would like to thank our friends and colleagues Dr. Sergei I. Moiseev (Russian Federal Research Institute of Fisheries and Oceanography, Moscow, Russia), Yuri N. Poltev and Alexei V. Berezov (Sakhalin Research Institute of Fisheries and Oceanography, Yuzhno-Sakhalinsk, Russia) who assisted us in the collection of stomachs during research cruises aboard the Japanese trawlers *Kayo Maru No. 28* and *Tomi Maru No. 82*in the summer of 1997, and the Russian vessel R/V *Professor Levanidov* in autumn 2000.

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