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Food habits and trophic position of Pacific salmon in the Bering Sea epipelagic communities in autumn 2000–2004

by

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Abstract

Food habits of Pacific salmon were studied using data collected during four comprehensive expeditions of TINRO-Centre into the northwestern Bering Sea and using data obtained in the central and eastern Bering Sea under an international program “BASIS” during autumn in 2000-2004. Daily food rations of different Pacific salmon species were associated with prey organisms available in forage areas. Consumption rates were estimated for Pacific salmon. Salmon consumed as much as 963,559 thousand tons of forage organisms in autumn 2002-2004, which appeared two-four times larger than in 1986, 1987 and 1990.

Introduction

Pacific salmon species migrate in large quantities in the northwestern Bering Sea in autumn: mature, smolts and immature fish intensively feed on a variety of prey organisms. The importance of Pacific salmon for epipelagic trophic structure has changed due to their recent rise in abundance, particularly, due to high abundance of artificial stocks. Our main objectives were to analyze changes in various parameters of salmon feeding activity that had happened in association with changes of forage base composition, to assess the amount of prey organisms consumed by salmon in autumn and to compare our data with analogous data obtained in the 1980s.

Methods

In this study, we used data obtained from stomach contents of Pacific salmon species along with information on the abundance and biomass of Pacific salmon collected during TINRO-Centre epipelagic trawl surveys in autumn 2000-2004 in the western Bering Sea. We compared our data with data collected in the central and eastern Bering Sea during epipelagic trawl surveys in autumn 2003 and 2004 under an international “BASIS” program on board research vessels «Sea Storm» and «Kaiyo-Maru». All available data were averaged by standard biostatistical regions, which had been distinguished based on water circulation pattern and water mass distribution (Shuntov et al., 1988a, b; Volkov et al., 2004) (Figure 1).

Food samples from Pacific salmon stomachs were collected and processed following express-method that had been developed in TINRO-Centre (Chuchukalo, Volkov, 1986). For each salmon species, we pooled together stomach contents from fish of the same size. Then we identified prey organisms, and determined weight of consumed food and weights of food components.

Daily food rations for fish species were determined following a method of A.V. Kogan (1963) and N.S. Novikova (1949), that is, a ration of a predator was determined as the total amount of food consumed within a given period.

We calculated the amount of food consumed by a species during a day and a season in order to assess its trophic significance for a community. The amount of forage organisms consumed by a species was calculated using the following equation:

$$B=b*R*n,$$

where B = biomass of forage organisms consumed by a predator, tons; b = biomass of a predator, tons; R = daily ration of a predator, %; n = number of days.

We also considered size-age related, seasonal, annual and regional food habits of salmon species, as well as their number and biomass in calculations of prey consumption rates (Table 1).

Table 1. Biomass (thousand tons) of Pacific salmon in the Russian Economic Zone of the Bering Sea in September-November 2000-2004, based on epipelagic trawl surveys (Temnykh, 2005)

Year	2000	2002	2003	2004
Chum				
Juvenile	0.092	2.215	3.070	1.631
Mature	11.848	316.754	246.29	132.773
Immature	0.440	15.941	10.820	11.320
Total	12.380	334.999	260.180	145.724
Sockeye				
Juvenile	0.288	2.110	1.940	2.080
Immature	30.120	175.420	90.600	103.950
Total	30.408	177.53	92.540	106.040
Pink				
Juvenile	3.955	26.4	15.53	20.13
Chinook				
Juvenile	0.439	0.729	2.02	2.04
Immature	0.587	19.235	24.76	9.61
Total	1.026	19.964	26.78	11.65
Coho				
Juvenile	0.97	2.15	4.26	1.51
Mature		0.2		+
Total	0.97	2.35	4.26	1.51
Research area, thousand km^2	356.219	624.360	624.360	524.380

Results

Food habits of Pacific salmon

Chum salmon. Post-catadromous juvenile chum salmon originated from Olutorskyi-Navarin and Anadyr reproductive areas, immature individuals of the second and third years of life in the sea and mature individuals of the autumn-spawning run, all forage in the western Bering Sea in autumn.

Data collected in 2000-2004 suggest that in the western Bering Sea, chum yearlings and fish smaller than 50 cm consumed primarily zooplankton, particularly, amphipods (hyperiids of the genus *Themisto*), pteropods and euphausiids (Efimkin, 2003; Efimkin et al., 2004; Volkov et al., in press). Yearlings preyed mostly on hyperiids, which share in stomach contents was low only in the southeastern Anadyr Bay (area 3) (Figures 2 and 3). Usually, *Themisto pacifica* were predominant prey hyperiids. However, another species *T. libellula* accounted for 99.8% of food consumed by chum in the eastern Anadyr Bay (area 4) in autumn 2002 (Efimkin, 2003). The proportion of pteropods (mainly *Limacina helicina*) in chum diet was the highest in the Commander Basin and in adjoining slope zone of the Olutorskyi Bay (area 9), whereas in area 3, this group accounted for 59.7% and 63.5% of chum food in 2002 and 2004 (Figure 3). Larger fish (31-50 cm and >50 cm) preyed more intensively on euphausiids than yearlings, and euphausiids occurred more frequently in stomachs of fish from the Aleutian Basin (area 8) than in fish from other areas (Figures 2 and 3). As chum grow, they start preying more intensively on fish such as lanternfishes, young walleye pollock, atka mackerel, sand lance and capelin, depending on a forage area. Cephalopods were of minor importance for chum as prey organisms. Of pteropods, *Clione limacina* served as prey for large-sized chum. Young chum preyed more intensively than large fish: daily ration was 7-7.9% of body weight for yearlings, 2.1-4.6% for fish 31-50 cm long, and 3.2-4.9% for larger fish in 2002-2004 (Efimkin, 2003; Efimkin et al., 2004; Shuntov, Temnykh, 2005). Large-sized zooplankton (hyperiids, pteropods, euphausiids and hydroid jellyfish *Aglantha digitale*) dominated among food items in chum of all size classes, and stomach fullness indices were low in the central Bering Sea in autumn 2003 (Table 2).

Chum of all size classes preyed primarily on larvae and juveniles of pollock, larvae of crabs and on coelenterates in the eastern Bering Sea in autumn 2003-2004 (Table 3) (Volkov et al., in press). Chum preyed more intensively in the eastern, than in the central Bering Sea, and indices of stomach fullness there ranged from 103-271$^{o}/_{ooo}$ in yearlings and from 20-199$^{o}/_{ooo}$ in fish of other size classes.

Having considered size-age and regional food habits, biomass (Table 1) and time of forage activity of chum, we calculated the amount of forage organisms consumed by chum during autumn within the surveyed area of the western Bering Sea. In 2002, the amount of food consumed by chum was the highest, of 873.421 thousand tons, of which 72.8% or 636.271 thousand tons were due to zooplankton (Figures 4 and 5). In 2003, when abundance, biomass and rations of chum were lower, these salmon consumed 614.623 thousand tons of forage organisms, and zooplankton accounted for 576.698 thousand tons or 93.8% of the total amount of consumed food. In 2004, the amount of food consumed by chum was the lowest, of 203.815 thousand tons, which was associated with low chum abundance and feeding activity. At that time, chum consumed larger quantities of nekton and were less dependent upon zooplankton, which accounted for 132.712 thousand tons or only 65.1% of all food consumed by chum. Chum yearlings (even when their daily rations were high) consumed no more than 1.3-4.2% of all food consumed by chum. Yearlings preyed more intensively in deep-sea areas than in coastal and shelf areas (Figure 6). At low abundance and with low daily rations, mature chum consumed 2.5-7.8% of food at most, while immature chum occurred at great numbers and was intensively foraging, and as a result, accounted for 88-96.2% of all food consumed by these salmon.

Sockeye salmon. Post-catadromous and immature individuals of sockeye are widely distributed over deep areas in the western Bering Sea in autumn (Shuntov, 1988a; Starovoitov et al., 2004). Biomass of sockeye varied from 30.408 to 177.53 thousand tons in 2000-2004 (Table 1). In 2002, abundance of smolts and immature sockeye was the highest on record in the Bering Sea (Starovoitov et al., 2004).

Smolts and immature sockeye actively forage in autumn. Fish smaller than 50 cm preyed predominantly upon hyperiids, euphausiids, pteropods and juvenile squid, while larger fish preyed more intensively on nektonic animals (Efimkin, 2003; Efimkin et al., 2004; Volkov et al., in press). Like in chum, food composition in sockeye stomachs varied depending on a region (Figures 7 and 8). Sockeye of all size classes preyed mainly on euphausiids (which accounted for 76.0-91.5% of consumed food) in the Aleutian Basin and Koryak slope, while pteropods more frequently occurred in sockeye stomachs in the Commander Basin, southeastern Anadyr Bay (area 3) and Navarin region (area 5). Copepods were present in sockeye stomachs in deep-sea regions (areas 8-12). Of nektonic animals, sockeye preyed mainly on lanternfishes, and less frequently on pollock and capelin. In deep areas (8-12), sockeye consumed large quantities of juvenile squid, which accounted for 27.2-63.4% of all food consumed by these salmon (Figures 7 and 8).

In the central Bering Sea, zooplankton organisms, such as pteropods, amphipods, euphausiids and copepods were predominant food for sockeye. Small squid were plentiful in fish stomachs, while fish accounted for only a small portion of sockeye food of nektonic origin (Table 2) (Volkov et al., in press).

In the eastern Bering Sea, plankton occurred in rather low quantities in sockeye stomachs. Planktonic animals were more common sockeye prey only in Nunivak region. They accounted for 25.4-41.4% of all food consumed by sockeye there, and were represented mainly by crab larvae in 2003, and by crab larvae, euphausiids and hyperiids in 2004 (Table 3). The following nektonic animals dominated (53-100%) in stomach contents of sockeye: larvae and juveniles of walleye pollock, capelin, sand lance, flounders and rockfishes (Volkov et al., in press).

Indices of stomach fullness for smolts and immature sockeye were lower than for chum. Daily rations were 4.1-6.0% of body weight in smolts, 1.8-5.4% in fish 31-50 cm long and 1.0-4.0% in fish larger than 51 cm (Efimkin, 2003; Efimkin et al., 2004; Shuntov, Temnykh, 2005).

The amount of forage organisms consumed by sockeye in the Bering Sea in autumn was the highest, of 302.552 thousand tons, in 2003. At that time, daily rations of sockeye were high. However, the largest amount of zooplankton organisms, 198.422 thousand tons, has been consumed by sockeye in autumn 2004 (Figures 4 and 5). In common with chum, immature individuals were responsible for the major portion (96.8-97.8%) of food consumed by sockeye. Smolts of sockeye consumed only 6.049-7.613 thousand tons of forage organisms during autumn.

Pink salmon. Yearlings of pink salmon migrate downstream from rivers of Kamchatka Peninsula into the Bering Sea during autumn. Having entered the sea, pink smolts immediately migrate offshore and further into the ocean through Kuril passes (Shuntov, 1989, 1994; Starovoitov et al., 2004). In September and early October, dense aggregations of pink yearlings were observed over deep areas, and later they were encountered close to Commander passes. Biomass of pink yearlings varied from 3.955 to 26.4 thousand tons depending on time of survey and area of research (Table 1).

In common with young stages of other salmon species, pink yearlings preyed intensively upon a variety of forage organisms, as demonstrated by great indices of stomach fullness, which peaked at 487-533$^{o}/_{ooo}$, and by high daily rations, of 7.6-7.8% (Efimkin, 2003; Chuchukalo, Kuznetsova, in press).

In the western Bering Sea in autumn 2000-2004, pink yearlings preyed primarily upon amphipods (*T. pacifica*). These crustaceans accounted for 27.2-100% of daily rations (depending on a region) in fish smaller than 20 cm and 19.9-99% in larger fish, of 21-30 cm long. In addition to amphipods, euphausiids were registered as food items, accounting for 14.9-54.3% of prey organisms consumed by pink yearlings in the Aleutian Basin. Besides, copepods were preyed upon as well, accounting for 8.5-23.4% of the diet of pink yearlings in 2003. Pteropods occasionally accounted for up to 43.5-54.7% of food consumed by pink yearlings in the Commander Basin. Young pink also preyed on pteropods in coastal regions (areas 3 and 5). Pink yearlings also preyed on nektonic organisms, such as juvenile fish and squid (Efimkin, 2003; Efimkin et al., 2004).

Larval plankton (larvae and juveniles of fish, larvae of crabs) were predominant food items for pink yearlings in the eastern Bering Sea in autumn 2003 and 2004 (Table 4) (Volkov et al., in press).

Having considered fluctuations in stock abundance, pink yearlings consumed from 18.818 to 124.374 thousand tons of forage organisms in 2000-2004 (Figures 4 and 5).

Chinook salmon. Chinook salmon are found in low numbers in the western Bering Sea. Most of these fish are immature foraging individuals distributed over the entire area, and smolts migrating offshore from coastal areas (Starovoitov et al., 2004). Migrations of smolts from the inner shelf seaward continue over a long period and stop only in the late October (Glebov, 2000).

Chinook, being an active predator, preyed upon juvenile squid, larvae and juveniles of capelin, atka mackerel, pollock and sand lance. Nektonic animals were among predominant food items of large-sized chinook. Large fish consumed squid in Navarin (area 5) and deep-sea regions of the Aleutian and Commander basins (areas 8 and 12), and preyed almost exclusively upon fish on the shelf of Chukotka peninsula (Efimkin et al., 2004; Volkov et al., 2005 in press). Planktonic animals accounted at most for 25.2-31.3% of food consumed by smolts and 3.2% by large individuals, and were represented mainly by large crab larvae and rarely by large mature euphausiids (*Th. longipes*). The following planktonic organisms were registered in stomach contents of chinook smolts in the Commander Basin in 2003: pteropods (*L. helicina*, which accounted for 7.8% of the fish diet), opossum shrimps (3.8%), amphipods (*Hyperia galba*, 1.4%) and copepods. Opossum shrimps accounted for up to 100% of the diet of immature chinook 31-40 cm long in area 3 (Efimkin et al., 2004; Volkov et al., in press).

Chinook of all size classes preyed predominantly upon fish in the eastern Bering Sea in autumn 2003, and large individuals preyed almost exclusively on squid, which accounted for 97.2% of the fish diet in the Bristol Bay in autumn 2004. Among planktonic forage animals, the chinook preyed exclusively on megalops of crabs in Nunivak region and on bottom opossum shrimps in the Bristol Bay (Table 5) (Volkov et al., in press).

Mean indices of stomach fullness appeared rather high, of 95-209 $^{o}/_{ooo}$, for most size classes of chinook during our research period and were similar to those observed in 1986 and 1987, of 84-219 $^{o}/_{ooo}$, when daily rations were 3.8-4.5%. During autumn forage period, chinook (considering estimated species abundance in the surveyed area) consumed 2.128-75.381 thousand tons of forage organisms, of which zooplankton accounted for only 0.152-1.207 thousand tons (Figures 4 and 5).

Coho salmon. Abundance of coho salmon was the lowest of all Pacific salmon species during research period. In the northwestern Bering Sea in autumn, young and adult coho were observed. Juvenile fish migrated from shelf areas offshore rather early. Adult individuals forage in the area until October, because they begin prespawning migrations later than other Pacific salmon (Glebov, 2000; Ogura, 1994; Starovoitov et al., 2004).

Coho preyed predominantly upon nektonic organisms. Small-sized individuals consumed mainly fish larvae and young squid, while large coho preyed mainly on young pollock, sand lance and lanternfishes (Karpenko, 1998; Efimkin, 2003; Efimkin et al., 2004; Volkov et al., in press). Squid may serve as the main prey for young coho in some years. For example, squid accounted for 82.5-100% of food consumed by coho in autumn 2003, and 41.2% of coho prey in the Aleutian Bain in 2004. Planktonic organisms (mainly amphipods, euphausiids, pteropods and decapod larvae) were of minor importance as prey organisms for coho. However, amphipods accounted for 87.1% and euphausiids 12.9% of prey consumed by large-sized coho in the Commander Basin in 2002. In the eastern Bering Sea, coho preyed predominantly upon nektonic animals and crab larvae (megalops stage) (Table 6) (Volkov et al., 2005 in press).

Mean indices of stomach fullness for fish of various size classes ranged from 83-359$^{o}/_{ooo}$ during research period. Similar rates of forage activity and rations were characteristic for coho in the northern Okhotsk Sea, where daily ration of young fish averaged 5% of the fish body weight (Kuznetsova, 2004). Estimated amount of forage organisms consumed by coho during autumn feeding period varied from 1.504-11.183 thousand tons, of which 0.304-0.428 thousand tons were due to zooplankton (Figures 4 and 5).

Consumption of prey organisms by Pacific salmon

Having considered abundance, biomass, forage activity and time of residence of Pacific salmon species in the northwestern Bering Sea during autumn, the estimated total amount of forage organisms consumed by these fish ranged from 121.256 thousand tons in 2000 (when only a portion of the vast area has been covered by surveys) to 572.375-1,336.873 thousand tons in 2002-2004. Salmon consumed 424.822-963.559 thousand tons of zooplankton, accounting for 10-11% of total amount of zooplankton consumed by all considered highly abundant fish species. In 1986, 1987 and 1990, the amount of zooplankton preyed on by salmon was much smaller and ranged from 234.435-302.039 thousand tons (Figure 9).

For abundant fish species encountered in the northwestern Bering Sea epipelagic zone it is walleye pollock that typically consumed much of the forage base in all years of observations. Also, high consumption rates were demonstrated occasionally by such predators as atka mackerel, capelin, herring and mesopelagic fishes (Shuntov et al., 2000; Temnykh et al., 2004) (Figure 9). At high stock abundance, these species may cause intensification of trophic interactions with salmon in forage areas shared by these fish through changing the proportions between existing and required food resources (Chuchukalo, Kuznetsova, in press). However, food competition between salmon and other abundant fish is somewhat loosened through diversification of their food preferences and by the fact that salmon forage predominantly in the upper epipelagic layers and prey mainly upon those zooplankton that are found in these upper water strata (Volkov et al., in press). Salmon are also known for their trophic plasticity, which enables them to choose those favorable forage organisms that are most abundant.

During research activity it appeared that pteropods were more abundant and were of more importance as prey for salmon in the southeastern Anadyr Bay (area 3), Navarin shelf (area 5), Olutorskyi slope (area 9) and Commander Basin (area 12) than in other areas (Figures 2, 3, 7, 8, 10-12, 13-15, 16). In the Commander Basin and off Karaginskyi Island decapods were important components of plankton communities and prey items for salmon (Figures 13-15, 17), while salmon preyed more intensively on euphausiids in the Aleutian Basin (data averaged over 2002-2004) than in the Commander Basin (Figure 13-15).

In the central Bering Sea, plankton communities were dominated by large-sized (>3.3-3.5 mm) zooplankton: hyperiids, pteropods, euphausiids and hydroids (*Aglantha digitale*), and these planktonic organisms were predominant prey items in the diet of Pacific salmon species (Volkov et al., in press). In the eastern Bering Sea, contrary to its western and central parts, zooplankton communities were dominated by small-sized copepods and chaetognaths, and these should probably be considered as an additional food reserve for chum. Large-sized zooplankton were represented mainly by coelenterates, particularly, small hydroid jellyfish. At the same time, there were plenty of ichthyoplankton and meroplankton (primarily, larvae and juveniles of pollock and larvae of crabs) in the eastern Bering Sea, and all these organisms dominated in salmon diet (Volkov et al., in press).

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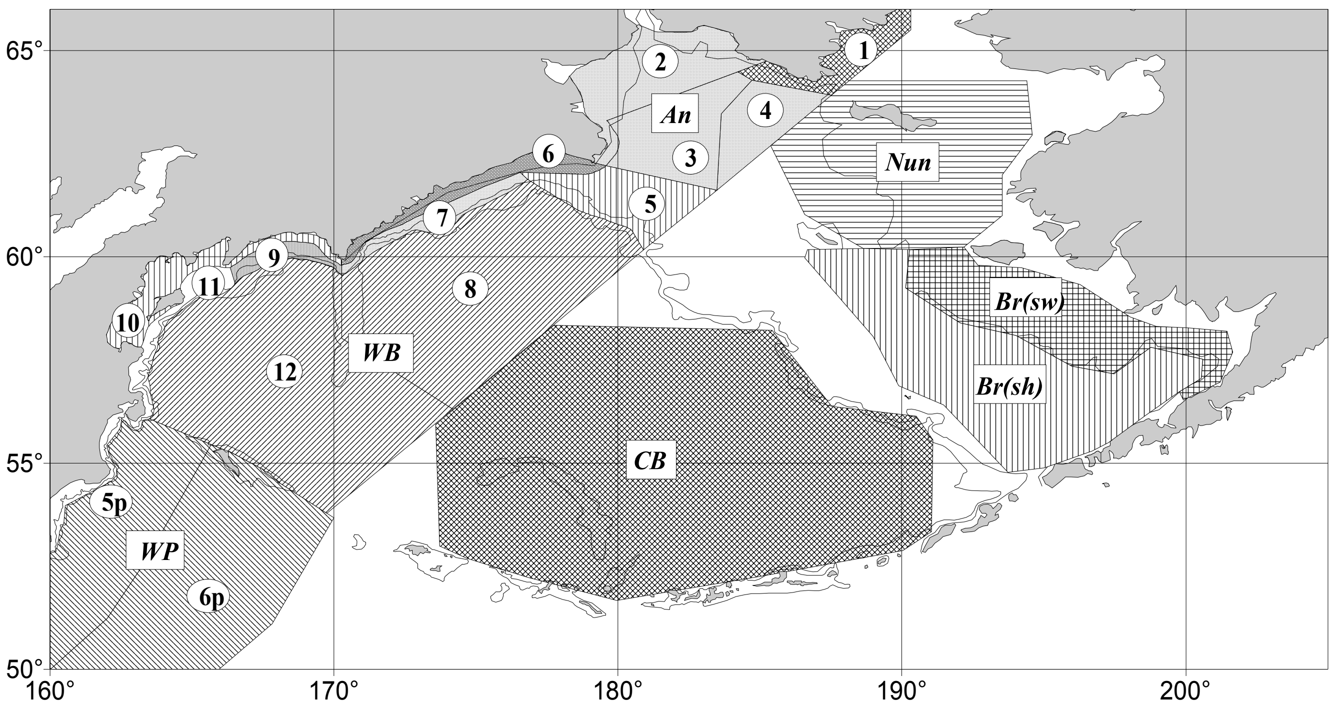


Fig. 1. Biostatistical regions of data averaging in the Bering Sea. Figures indicate standard biostatistical regions of the Russian Economic Zone (Shuntov et al., 1988a, b). Areas of data averaging based on BASIS expeditions are shaded (Volkov, 2004). Full names of the regions: 1 – Bering Strait, 2 – northwestern Anadyr Bay, 3 – southeastern Anadyr Bay, 5 – Navarin region, 6 – Koryak shelf, 7 – Koryak slope, 8 – western Aleutian Basin, 9 – Olutorskyi slope, 10 – shelf of Karaginskyi and Olutorskyi bays, 11 – Karaginskyi slope, 12 – Commander Basin, 5p – Kamchatka Trench, 6p – oceanic waters off Kamchatka and Commander Islands, An – Anadyr Bay, WB – western Bering Sea basins, WP – oceanic waters near Commander Islands, CB – central deep Bering Sea, Nun – Nunivak region, Brsw – shallow area of Bristol Bay (<50 m), Brsh – shelf zone of the Bristol Bay (>50 m).

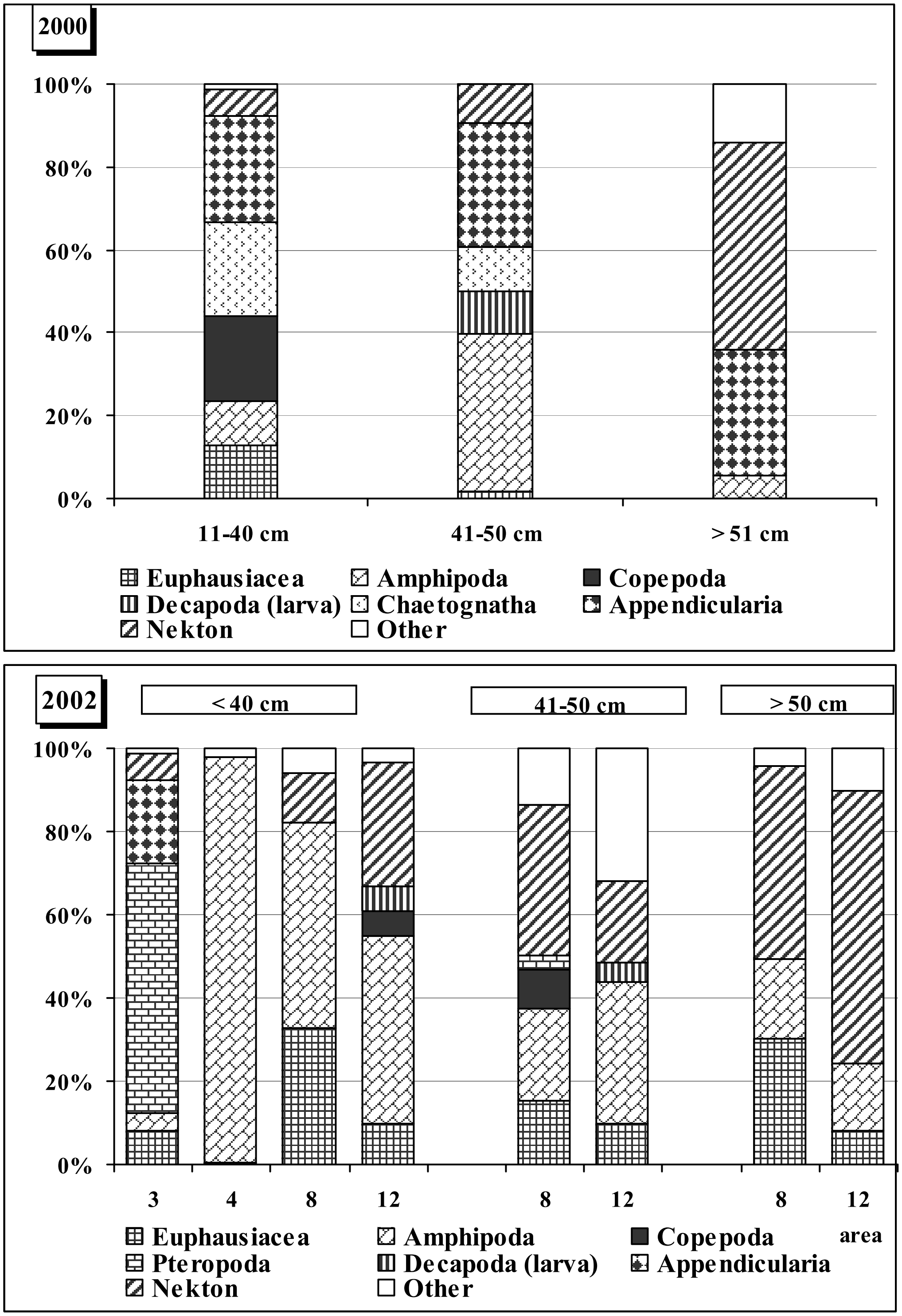


Fig. 2. Chum diet (%) in the epipelagic northwestern Bering Sea in autumn 2000 and 2002

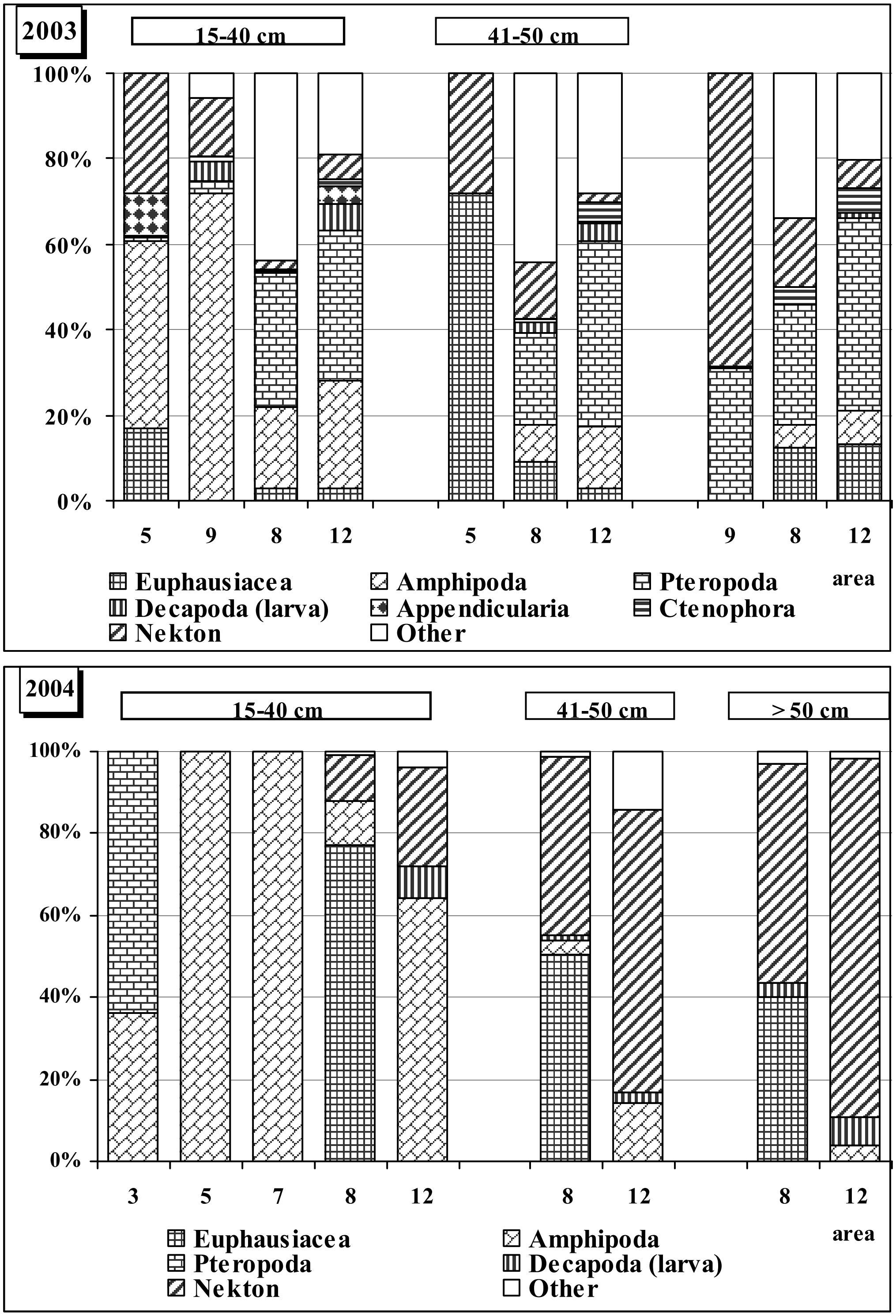


Fig. 3. Chum diet (%) in the epipelagic northwestern Bering Sea in autumn 2003 and 2004

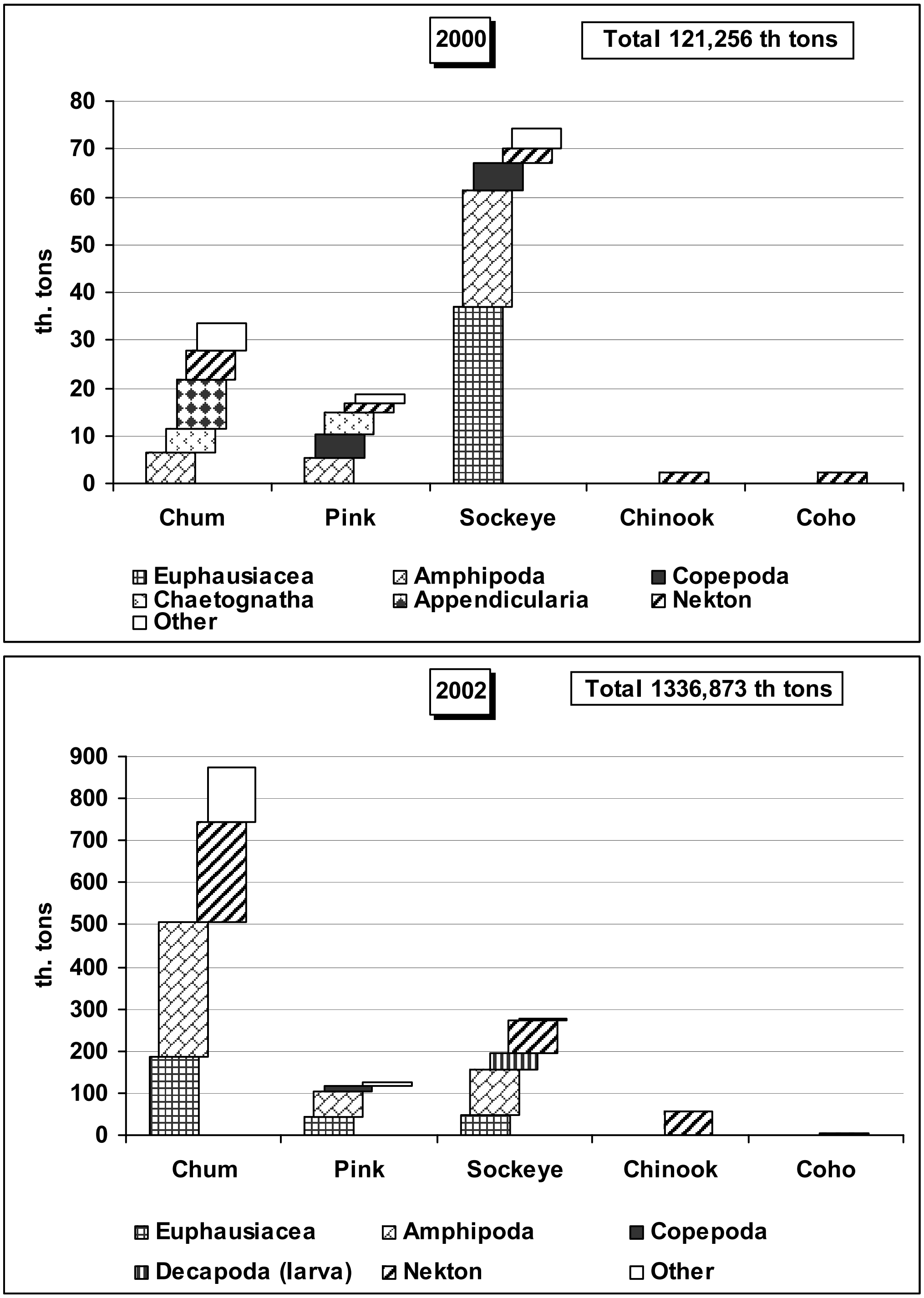


Fig. 4. Amount of forage organisms (thousand tons) consumed by Pacific salmon in the epipelagic northwestern Bering Sea in September-November 2000-2002

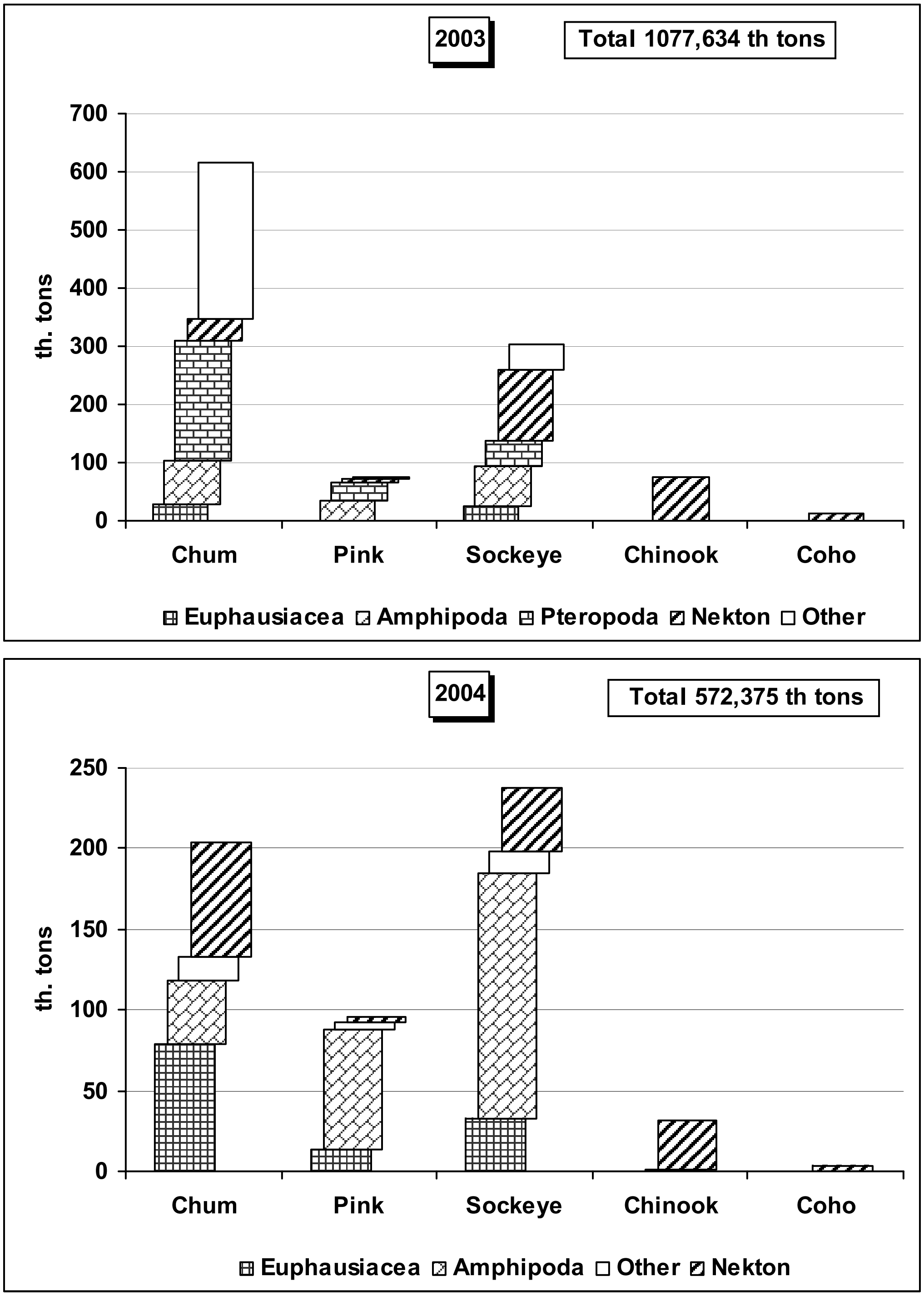


Fig. 5. Amount of forage organisms (thousand tons) consumed by Pacific salmon in the epipelagic northwestern Bering Sea in September-November 2003-2004

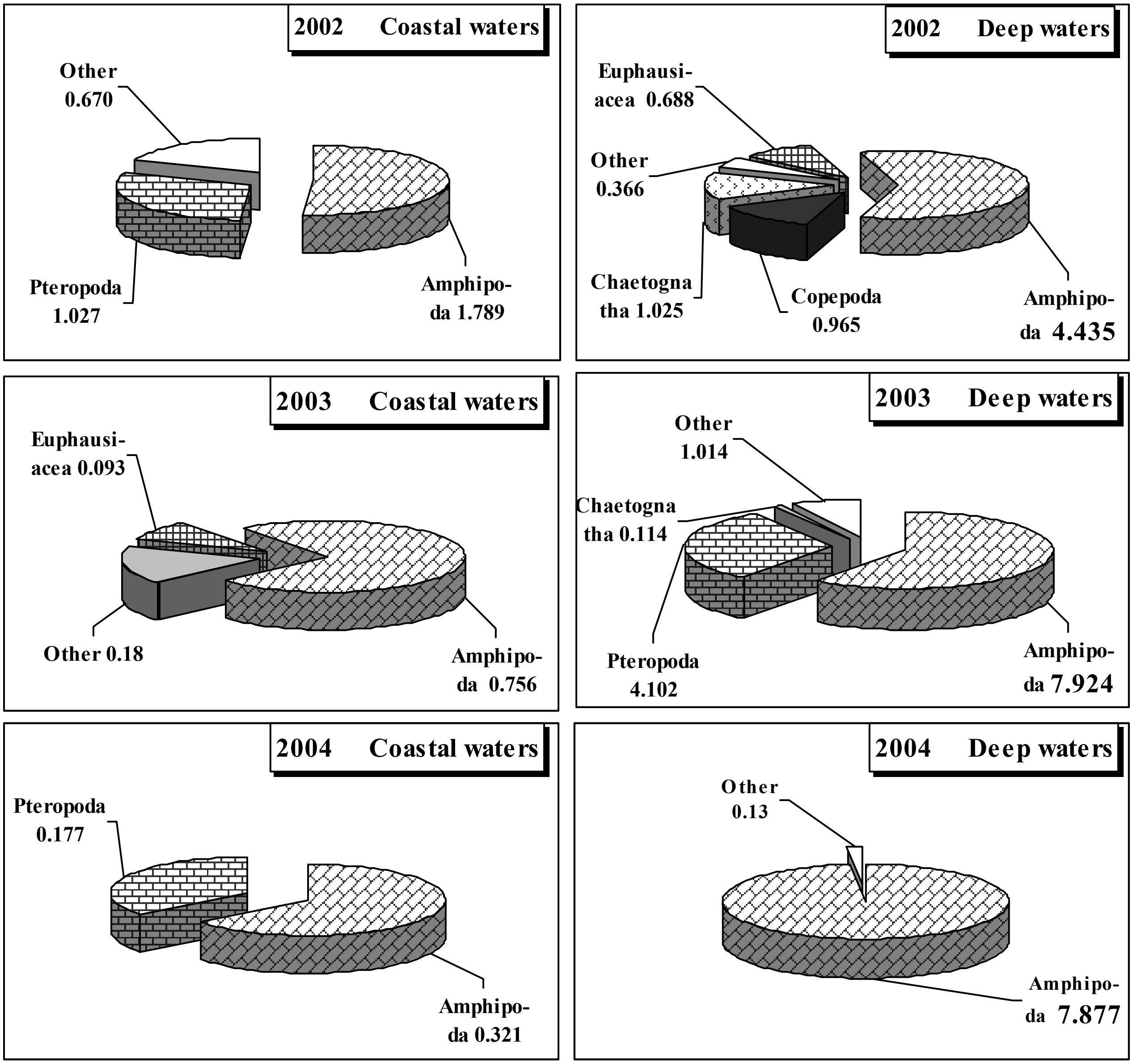


Fig. 6. Amount of forage organisms (thousand tons) consumed by small-sized chum in the epipelagic northwestern Bering Sea in September-November 2002-2004

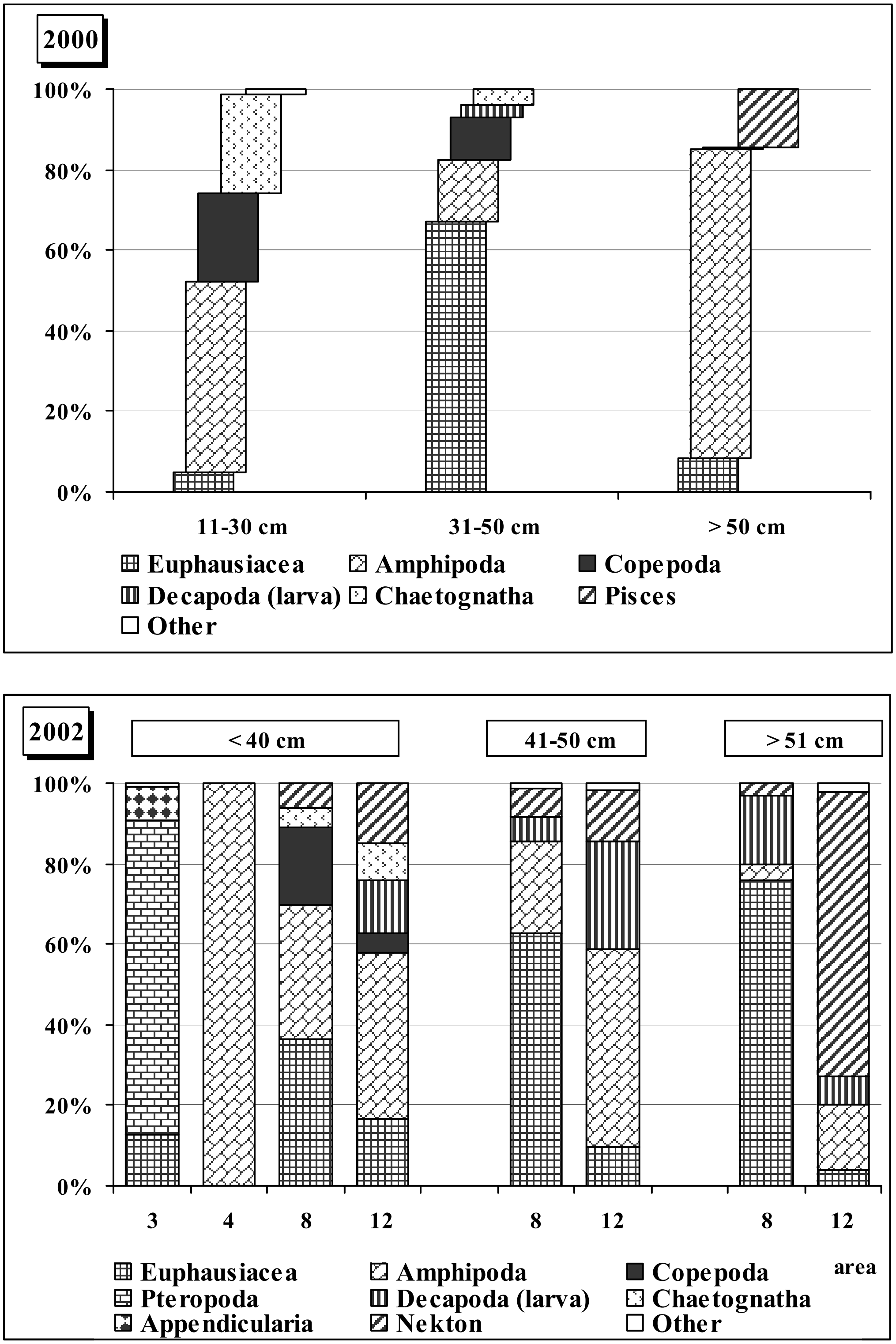


Fig. 7. Sockeye diet (%) in the epipelagic northwestern Bering Sea in autumn 2000 and 2002

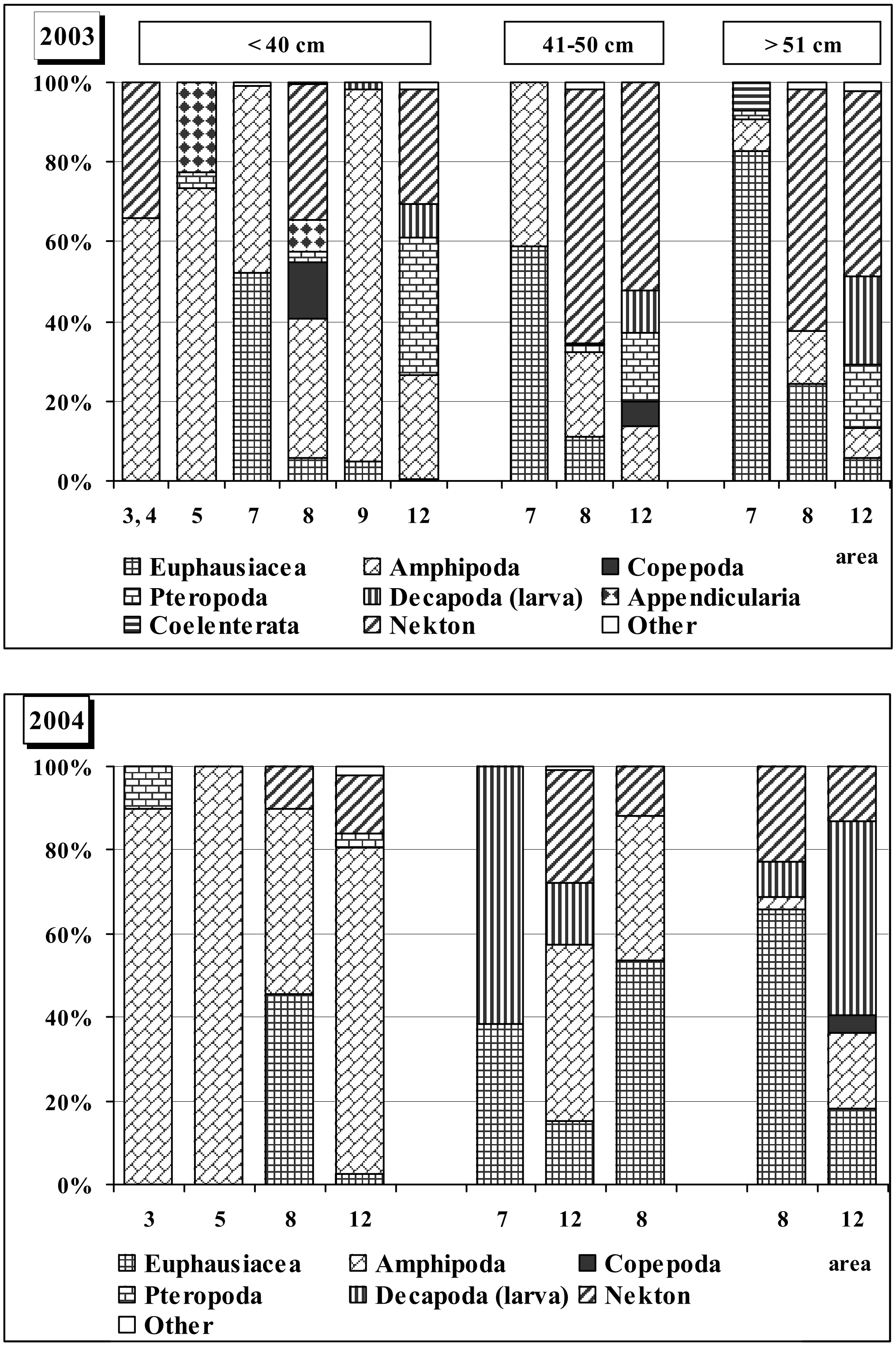


Fig. 8. Sockeye diet (%) in the epipelagic northwestern Bering Sea in autumn 2003 and 2004

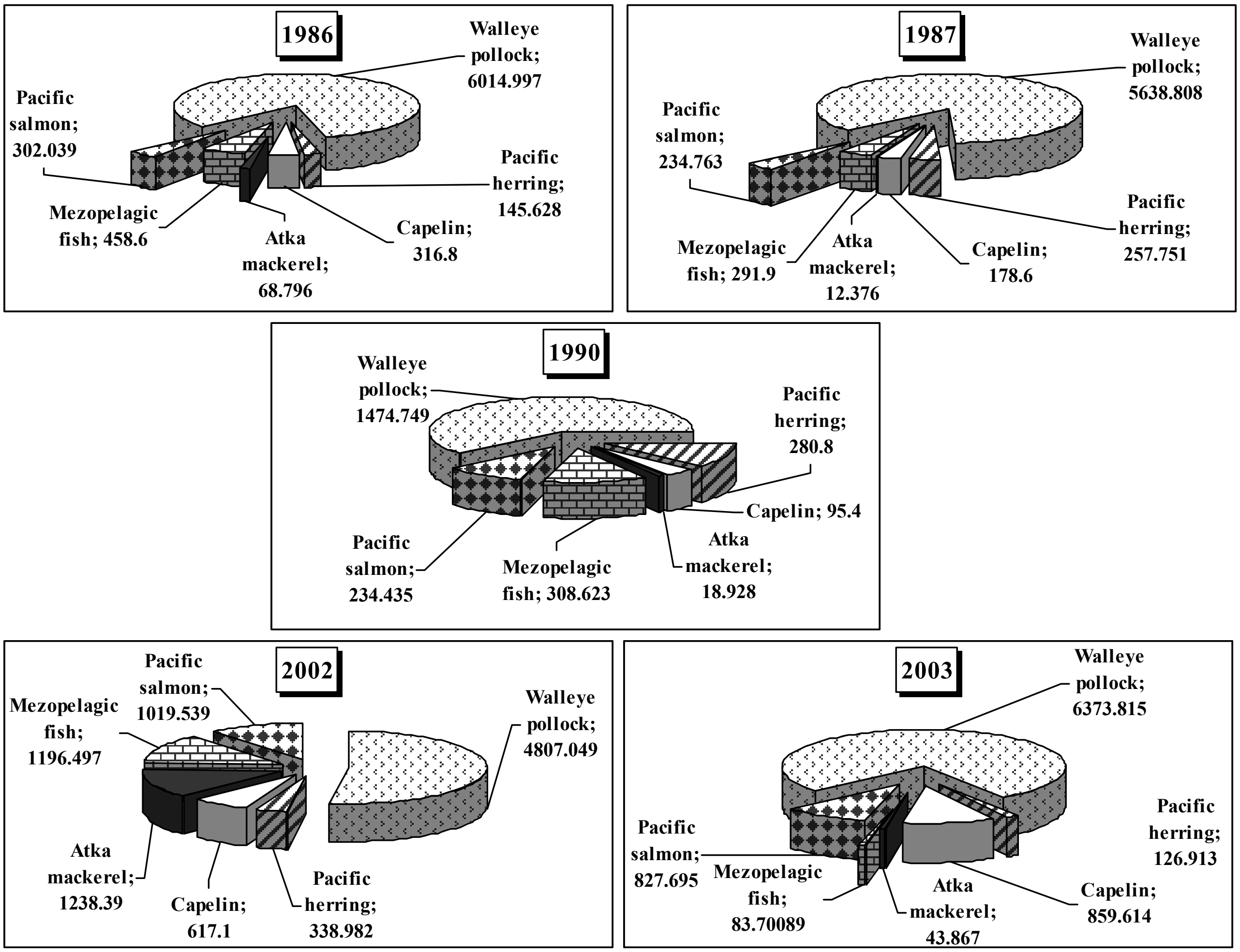
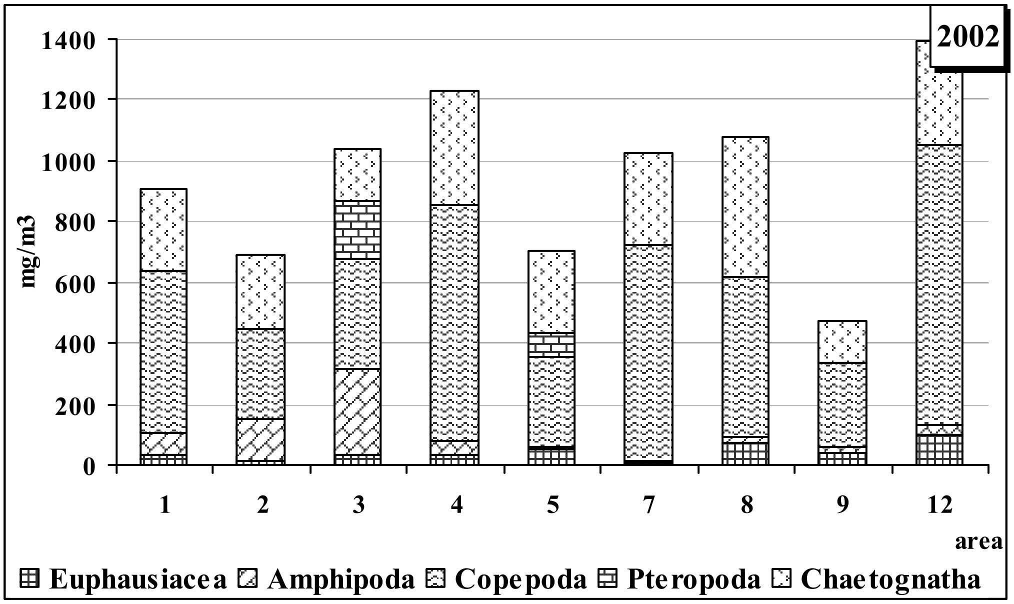


Fig. 9. Amount of forage organisms (thousand tons) consumed by abundant fish species in the epipelagic northwestern Bering Sea in autumn in 1986, 1987, 1990, 2002 and 2003



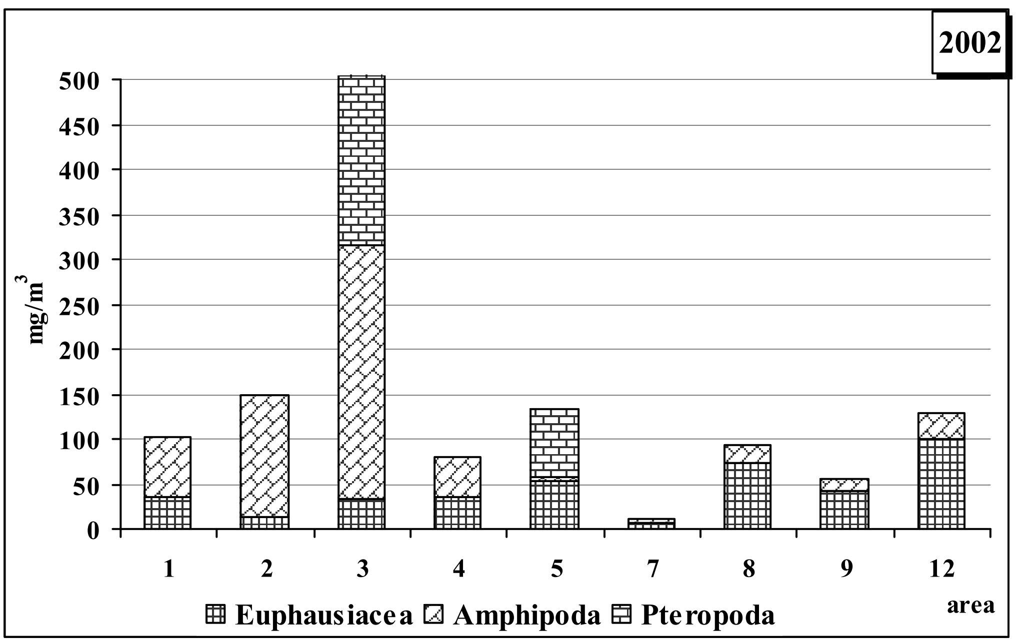


Fig. 10. Biomass (mg/m^3) of some groups of zooplankton in the epipelagic (0-50 m) northwestern Bering Sea in autumn 2002

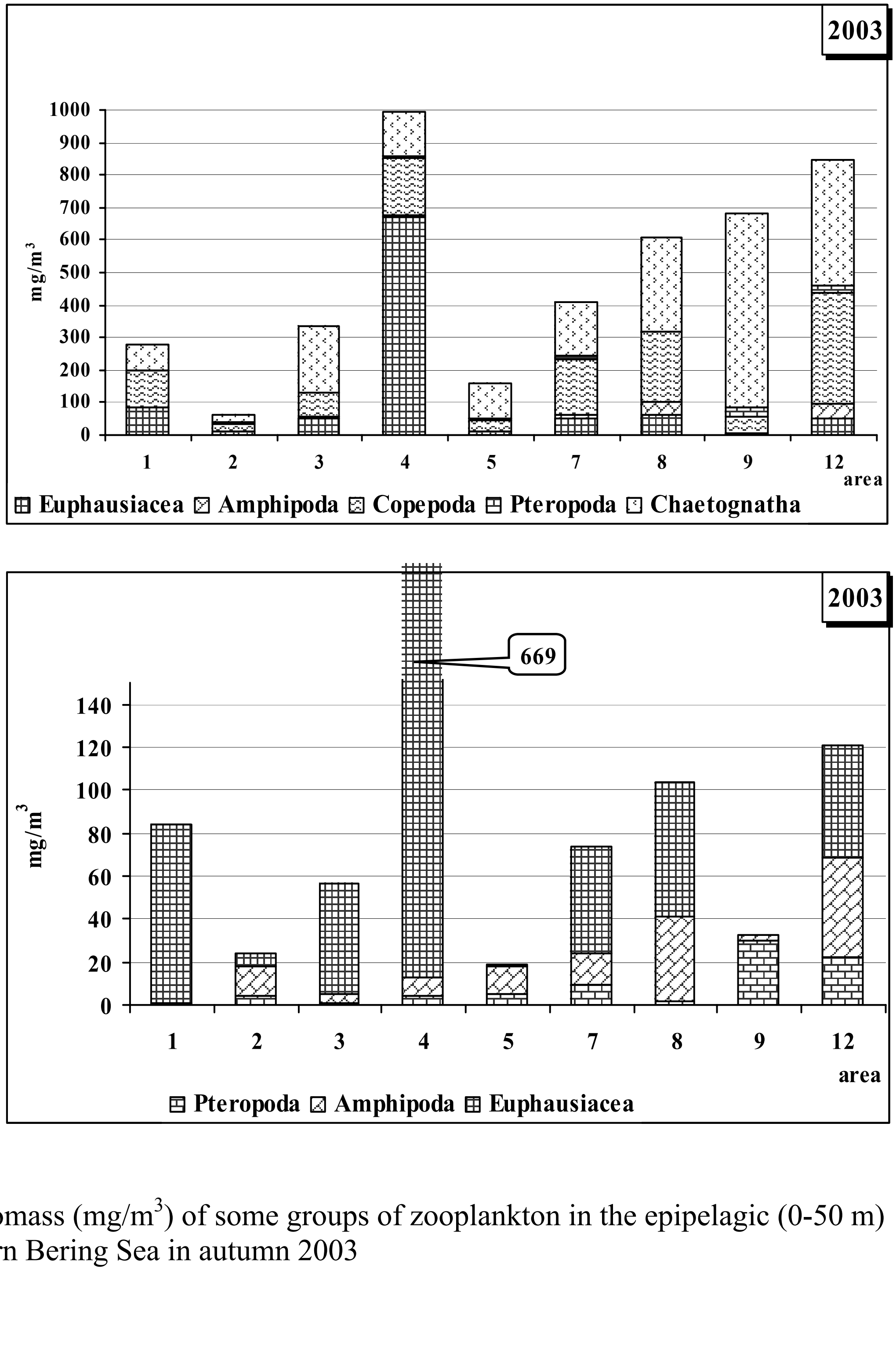
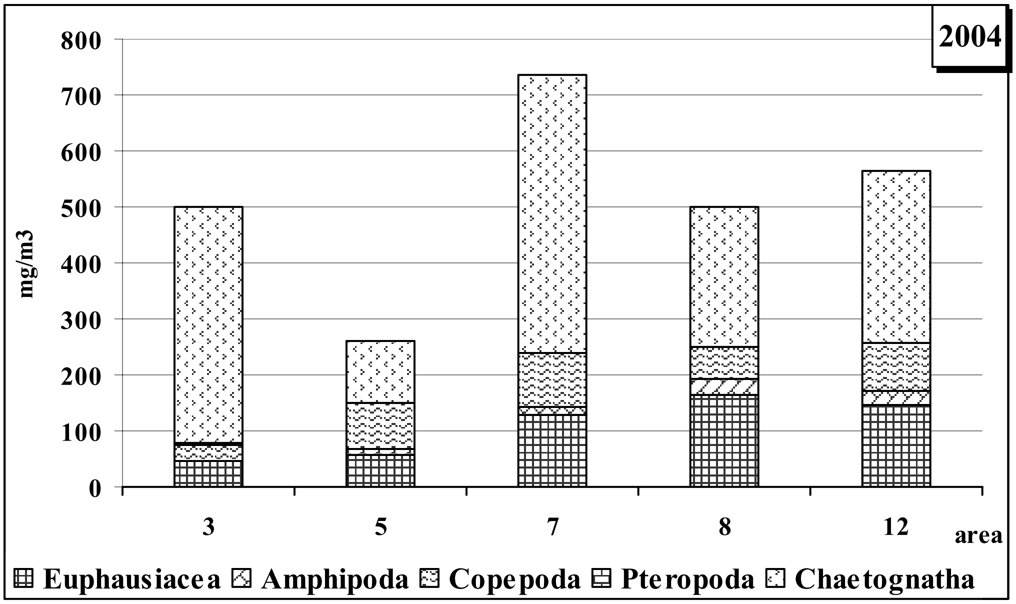


Fig. 11. Biomass (mg/m^3) of some groups of zooplankton in the epipelagic (0-50 m) northwestern Bering Sea in autumn 2003



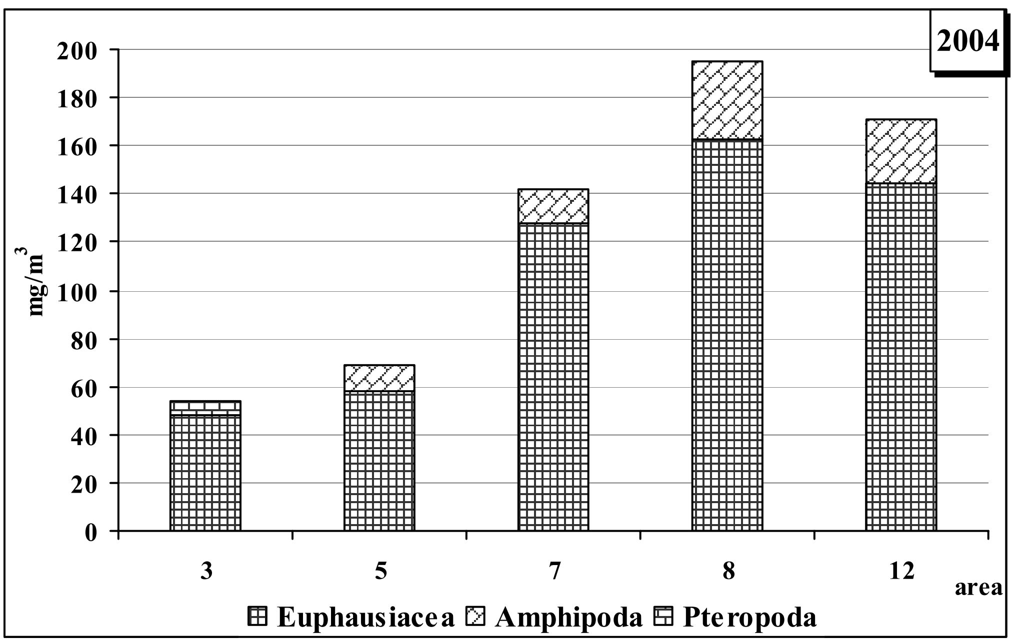
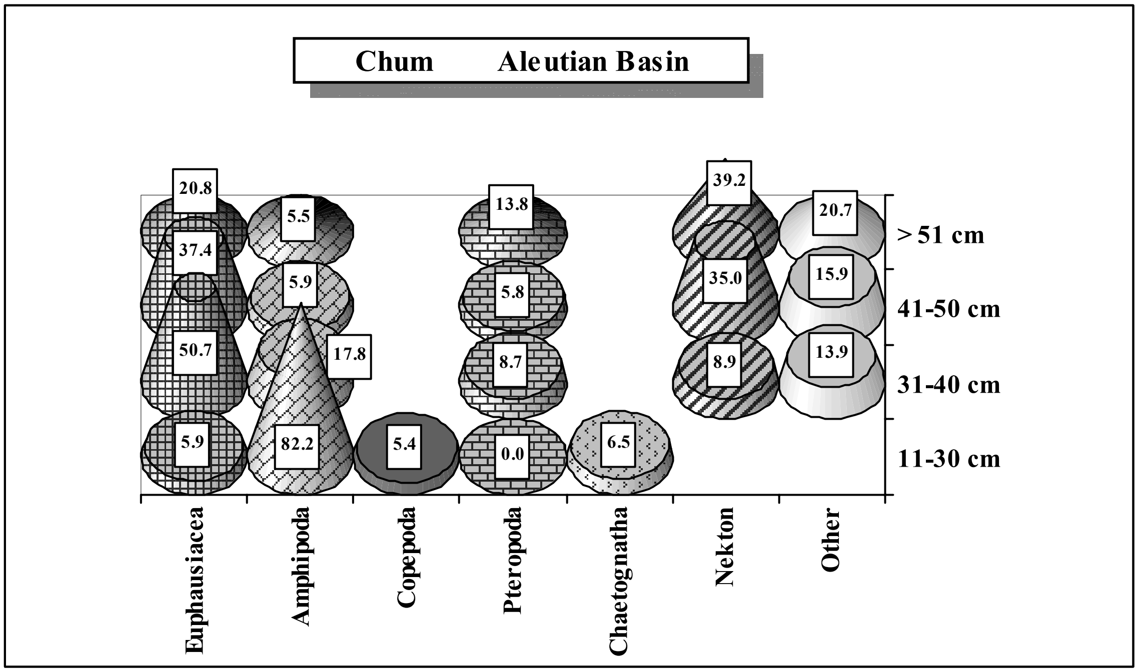


Fig. 12. Biomass (mg/m^3) of some groups of zooplankton in the epipelagic (0-50 m) northwestern Bering Sea in autumn 2004



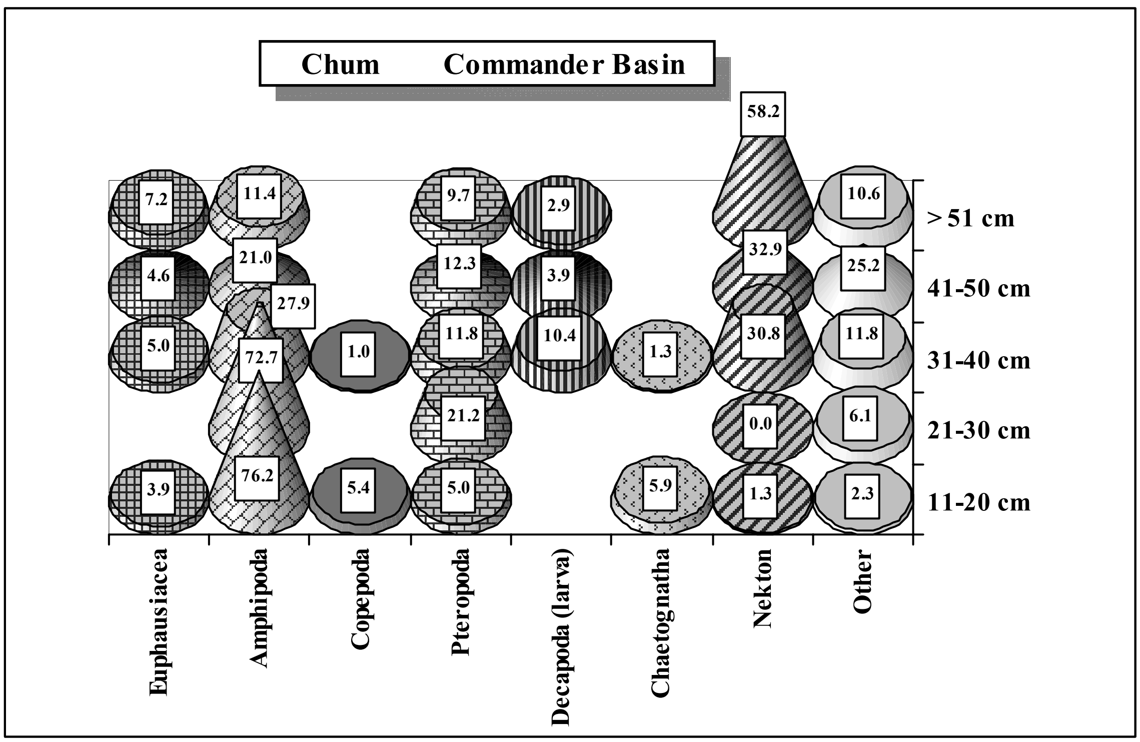
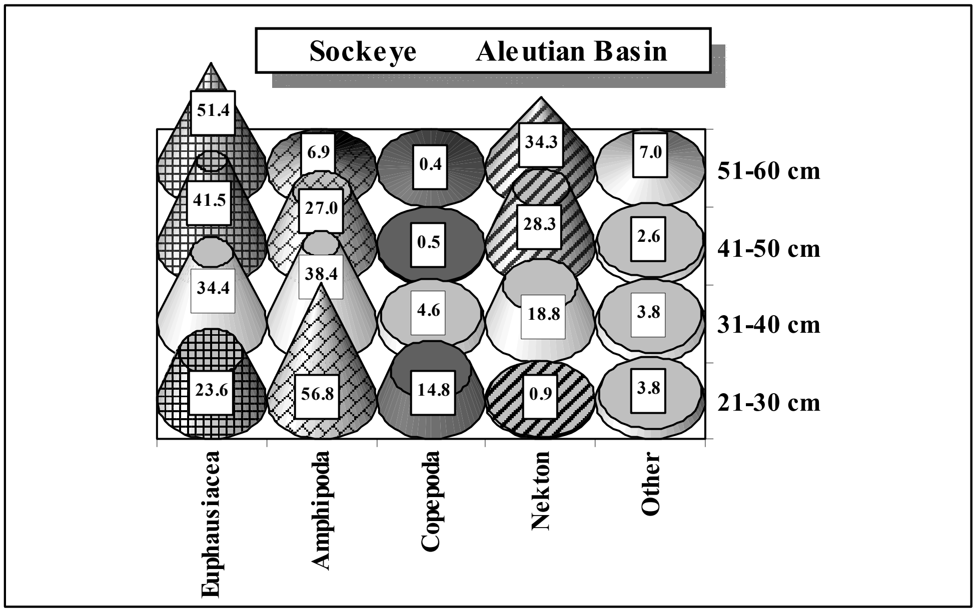


Fig. 13. Chum diet (%) in the epipelagic zone of Aleutian and Commander basins in the northwestern Bering Sea based on data averaged over 2002-2004



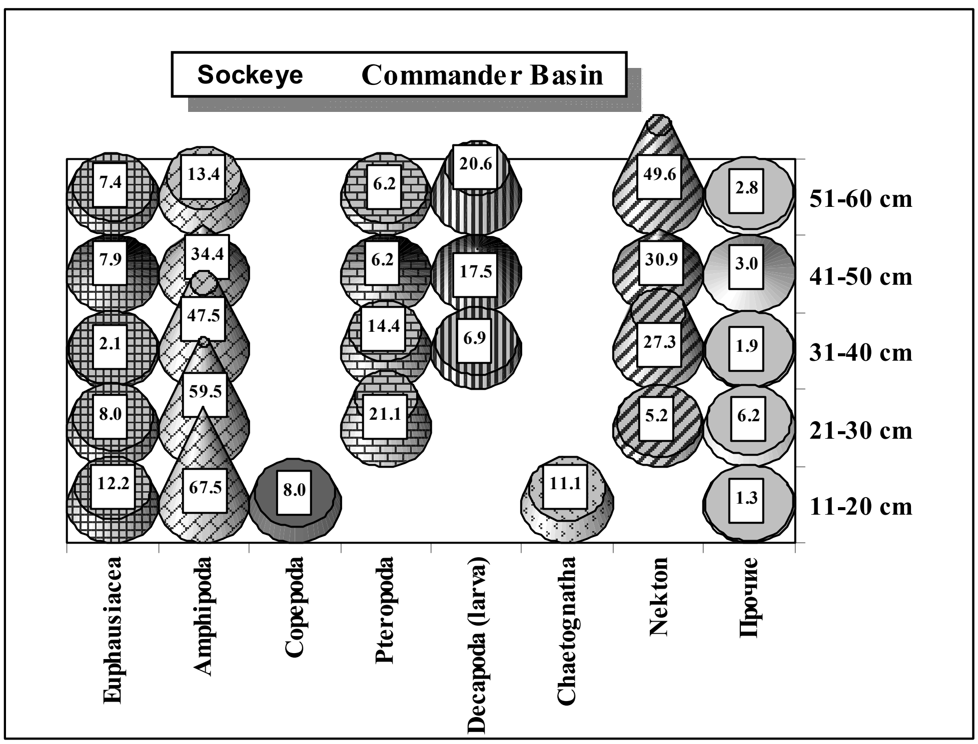


Fig. 14. Sockeye diet (%) in the epipelagic zone of Aleutian and Commander basins in the northwestern Bering Sea based on data averaged over 2002-2004

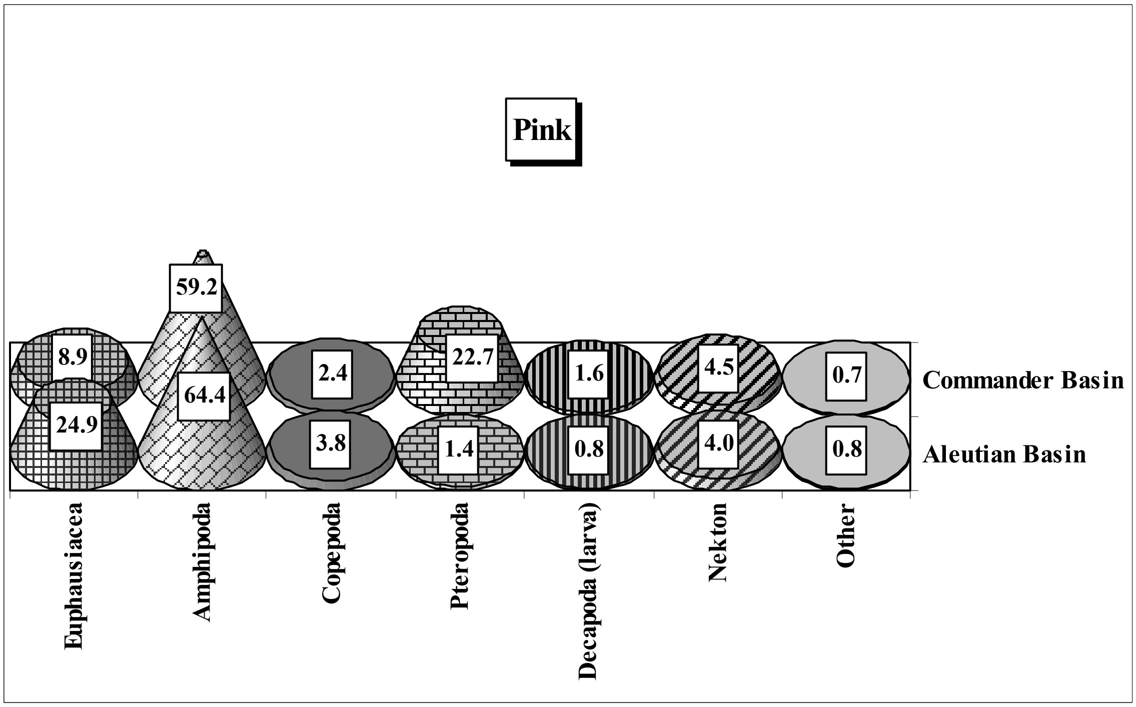


Fig. 15. Pink yearlings' diet (%) in the epipelagic zone of Aleutian and Commander basins in the northwestern Bering Sea in autumn, based on data averaged over 2002-2004

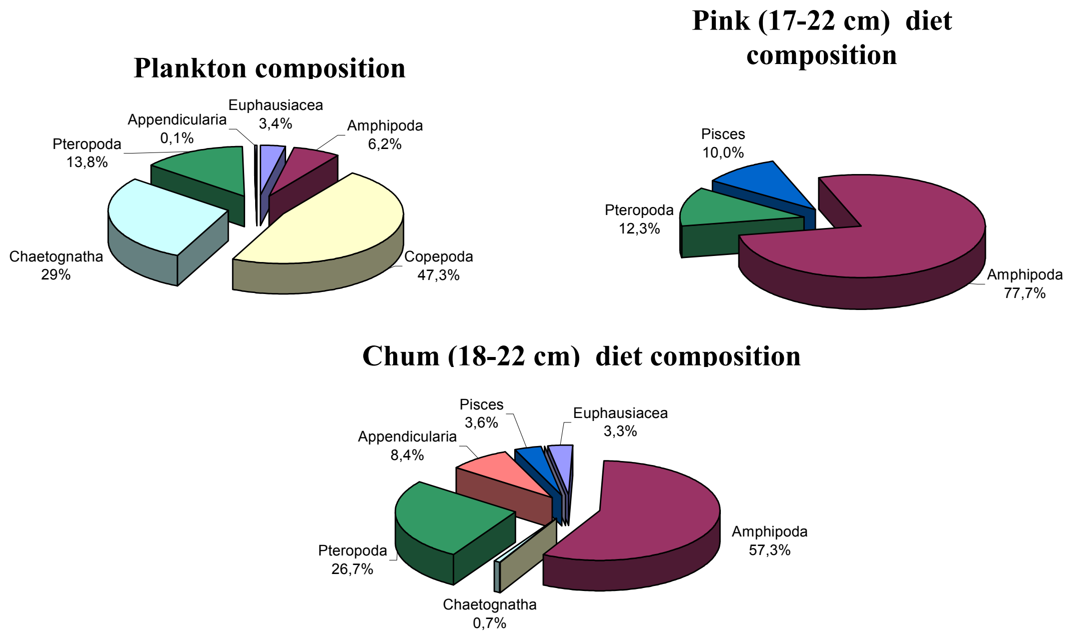


Fig. 16. Composition of plankton communities and diet (%) of juvenile pink and chum in the southeastern Anadyr Bay in September, 2002 (Efimkin, 2003)

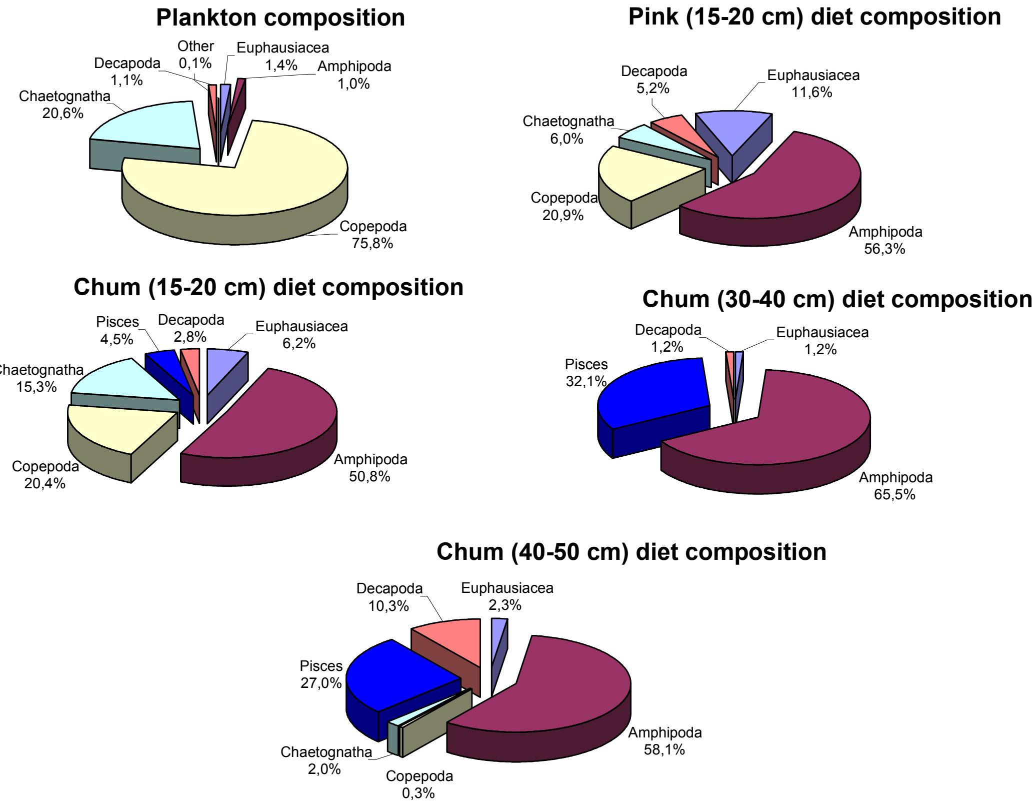


Fig. 17. Composition of plankton communities and diet (%) of juvenile pink and chum in the southern Karaginskyi Bay in September, 2002 (Efimkin, 2003)

Table 2. Diet (%) of chum and sockeye in the central Bering Sea in autumn 2003 (Volkov et al., in press)

Diet composition	Chum			Sockeye		
	Size group, cm					
	30-40	40-50	50-60	30-40	40-50	50-55
Neocalanus cristatus	0.1	0	0	0.1	0	0
Neocalanus plumchrus	0	0	0	0	**20.6**	0
Eucalanus bungii	0	0	0	0	1.5	0
Thysanoessa longipes	**10.5**	2.6	0.8	**16.6**	**11.2**	**57.8**
Themisto pacifica	8.9	4.2	5.7	5.0	**21.8**	**21.9**
Hyperia galba	0	0	0	0.3	0.2	0
Primno macropa	0	0	0	0	0	0
Decapoda	3.7	3.7	7.3	3.9	1.0	7.0
Oikopleura vanhoeffeni	8.8	5.1	1.7	0	0	0
Clione limacina	0.5	**8.8**	6.3	0	0	0
Limacina helicina	**11.8**	**9.7**	2.7	**28.7**	**29.2**	0
Sagitta elegans	1.0	0.1	3.1	0	0	0
Adlantha digitale	**31.3**	**36.7**	**51.9**	0	0	0
Beroe cucumis	0	0	0	0	0	0
Polychaeta	0	0.1	0.4	0	0	0
Cephalopoda	0.7	6.7	2.8	**29.4**	**10.0**	**10.3**
Liparidae	0	0.3	0.1	0	0	0
Mallotus villosus 2-3 cm	0	0	0	0	0	0
Pleurogrammus monopterigius	0	2.4	0.5	0	0	0
Pleuronectidae, lar. <2 cm	0	0	0	0	0	0
Stenobrachius sp.	6.7	4.3	1.0	0	0.6	0
Theragra chalcogramma	0	0	0	0	0.6	0
Cottidae, lar.<2 cm	0	0	0	0	0	0
Pandalus goniurus	0.2	2.1	0.6	0	0.3	0
Digestes food	15.8	13.2	15.1	16.0	3.0	3.0
Index of stomach fullness $^{o}/_{ooo}$	38	46	26	22	35	76
Plankton	76.5	71.1	79.9	54.6	85.6	86.8
Hekton	23.5	28.9	20.1	45.4	14.4	13.2
Number of stations	17	21	7	6	13	4
Number of stomachs processed	342	321	140	128	289	46

Table 3. Diet (%) of chum and sockeye in the eastern Bering sea in autumn 2003 and 2004 (Volkov et al., in press)

Diet composition	2003, chum								2004, chum								2003, sockeye					2004, sockeye						
	Br (sw, sh)					Nun			Br (ew, sh)				Nun				Br (sw, sh)			Nun		Br (sw, sh)				Nun		
	15-20	30-40	40-50	50-70	70-80	15-20	30-40	50-60	10-20	20-30	40-60	60-80	10-20	20-30	40-60	60-80	15-20	20-30	30-40	20-30	30-40	10-20	20-30	30-40	40-60	10-20	20-30	30-40
Neocalanus cristatus	0	0	0	0	2.0	0.1	0	0	0	0	0.2	0	0	0	0	0	0.1	0	0	0	0	0	5.4	2.5	0.7	0	0	0
Epilabidocera amphitrites	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0.2	0	0	1.3	0.5	0	0	0	0	0	0	0	0.5	3.6	0
Thysanoessa longipes	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	1.1	0	0	0	2.7	**13.6**	6.6	0	0	0
Th.raschii	0	0	0.7	0	1.4	1.3	0	0	6.3	0	0.2	0	7.0	0.4	0	0	6.4	3.4	0	0	0	7.0	0	2.0	1.2	**10.5**	2.7	0
Th. inermis	0	0	0	0	0	0	0	0	0	0	0	0	2.2	0	0	4.3	0	0	0.2	0	0	0	0	3	0.3	**10.5**	0	0
Th. sp.	0	0	0	0	0	0	0	0	0	0	0.2	0	2.8	0	0	0.9	0.2	0	0	0	0	0	0	0	0	3.5	0	0
Mysidacea	0.4	0	0	0	0	0.6	0	0	3.9	0	0	0	0.1	0	0	0	0	0	0	0	0	7.5	0	0	0	0	0	0
Themisto pacifica	0	0	0	0	0	0.5	0	0	0	0	0.4	0	7.0	0.4	0.1	0.3	0.9	8.3	0.9	0	0	0.1	0	0	5.7	**10.5**	2.2	0
Hyperia	0	0	0	0	0	2.6	0	0	0.8	0.7	0	1.1	3.4	4.1	0	0.8	0.1	0	0.1	0	0	0.2	0.1	0	0.3	0	1.2	0
Megalopa	0	**35.0**	2.3	0	0	8.5	0	0	0.1	0	0	0	6.8	**21.6**	0	6.2	6.9	0	5.3	**35.3**	**41.4**	0.5	0	0.7	0	0	**13.8**	0
Zoea	0	0	0	0	0	0	0	0	0.4	0	0.1	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0.1	0	0.6	0
Clione limacina	0	0	4.2	0	0	0.3	0	0	0	0	1.5	1.4	0	0	0	1.8	0	0	0	0	0	0	0	0	0	0	0	0
Limacina helicina	0	**15.0**	**29.9**	0	0	0.7	0	0	1.5	0	5.7	0	0.2	0	0	0	0.4	0	**32.2**	0	0	0.2	3.0	5.0	4.3	0	0	0
Oikopleura vanhoeffeni	0	0	0	0	0	4.2	0	3.8	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0
Sagitta elegans	0	0	0.4	0	0	0	0	0	0.4	0	0	0	2.8	0	0	0	1.0	0	0.1	0	0	0.3	0	0	0	0	1.4	0
Coelenterata	0	0	0.8	**17.3**	**15.7**	**31.8**	**55.5**	**50.6**	**13.0**	6.5	3.0	**12.8**	**39.6**	**23.2**	**31.9**	**44.2**	0	0.4	7.2	0	0	0.2	0	0	0	0	0.2	0
Ammodytes hexapterus	0	**50.0**	9.1	0	0	8.8	0	3.8	2.7	0	0	0	0	8.5	0	**23.3**	1.1	**10.4**	1.7	0	0	0.7	4.6	0	0	0	0	0
Mallotus villosus	0	0	0	0	0	0	0	**12.5**	0	0	0	0	0	0	0	0	**10.8**	2.4	0	0	**25.0**	0	0	0	0	0	0	0
Theragra chalcogramma	**42.0**	0	**51.8**	**61.0**	**53.7**	**22.8**	**44.5**	**24.3**	**42.8**	**92.8**	**87.4**	**82.2**	**13.1**	**29.2**	**56.3**	**15.0**	**58.6**	**69.0**	**34.8**	**64.7**	**32.4**	**51.8**	**77.8**	**65.6**	**80.7**	**64.5**	**73.6**	**82.8**
Larva pisces	**57.6**	0	0.4	0	0	9.3	0	0	**18.3**	0	0	0	**14.0**	**10.2**	0	0	0.8	0.4	2	0	0	**29.5**	5.9	0	0	0	1	0
Other food	0	0	0.4	2.1	0	0.1	0	0.6	4.4	0	0.5	0.4	0	0.3	0	0	6.4	0	0.3	0	0	1.3	0.5	0.3	0.1	0	0	0
Digestes food	0	0	0	19.6	27.2	8.4	0	4.4	5.4	0	0	2.1	0.6	1.9	11.7	3.2	4.8	5.2	14.1	0	1.2	0.6	0	7.3	0	0	0	17.2
Index of stomach fullness $^{0}/_{000}$	271	45	151	57	63	182	151	20	120	199	125	94	103	114	79	41	176	152	44	76	14	162	98	87	68	61	100	65
Plankton	0.4	50.0	38.3	19.3	19.0	50.8	55.5	55.0	26.5	7.2	12.1	15.3	72.3	50.0	32.0	58.5	18.3	12.7	47.0	35.3	41.4	16.3	11.2	26.8	19.1	35.5	25.7	0.0
Hekton	99.6	50.0	61.7	80.7	81.0	49.2	44.5	45.0	73.5	92.8	87.9	84.7	27.7	50.0	68.0	41.5	81.7	87.3	53.0	64.7	58.6	83.7	88.8	73.2	80.9	64.5	74.3	100.0
Number of stations	1	2	11	5	6	15	2	8	44	4	38	13	23	22	6	11	21	12	14	3	4	43	13	3	9	4	25	3
Number of stomachs processed	2	2	59	26	10	123	5	20	311	7	216	37	164	102	10	32	195	98	72	23	6	369	74	4	23	34	170	3

Table 4. Diet (%) of pink in the eastern Bering sea in 2003-2004 (Volkov et al., in press)

Diet composition	Autumn 2003		Autumn 2004			
	Br (sw, sh)	Nun	Br (sw, sh)			Nun
	Size group, cm					
	13-20	13-20	13-20	40-50	50-60	13-25
Neocalanus cristatus	0	0	0.5	0	0	0
N. plumchrus+flemingeri	0	0	0	0	0	0
Epilabidocera amphitrites	3.4	2.9	1.2	0	0	6.6
Thysanoessa longipes	0	0	0	0	0	6.9
Th.raschii	1.3	7.5	0	**14.0**	0.2	0.2
Th. inermis	0	0	0	0	0	2.3
Themisto pacifica	0	0	0	0	0.1	2.0
Th. libellula	0	0	0	0	0	0
Hyperia galba	0	2.4	1.2	0	0.2	1.5
Zoea Brachyura	0	0	2.5	0	0.6	0.8
Megalopa Brachyura	0	4.6	0.5	0	0	**33.4**
Larvae Pandalidae	0	0.0	0	0	0	0
Limacina helicina	0	0.4	0.6	0	5.5	0.2
Sagitta elegans	0	4.6	0.2	0	0	0.8
Berryteuthis anonychus	0	0	0	0	0	0
Gonatus kamtschaticus	0	0	0	0	0	0
Other Cephalopoda	0	0	0	0	0	0
Ammodytes hexapterus	0	5.5	0	0.6	**10.4**	8.6
Mallotus villosus	**37.2**	**28.0**	0	0	0	0
Pleurogrammus monopterigius	0	0	0	0	0	0
Theragra chalcogramma (<30 мм)	**53.7**	**42.2**	**59.5**	**85.4**	**81.7**	**18.5**
Sebastes sp. (<30-60 мм)	0	0	0	0	0	0
Stenobrachius sp.	0	0	0	0	0	0
Larva Pisces	4.0	1.3	**21.0**	0	0	**15.9**
Picses (*digested*)	0	0.6	0.1	0	0.2	1.8
Digestes food	0.4	0	12.7	0	1.0	0.5
Index of stomach fullness $^{o}/_{ooo}$	141	156	170	96	144	102
Plankton	5.2	22.3	10.3	14.0	7.4	55.0
Hekton	94.4	77.7	77.0	86.0	91.6	44.5
Number of stations	6	12	32	8	8	48
Number of stomachs processed	57	118	186	13	13	305

Table 5. Diet (%) of chinook in the eastern Bering sea in autumn 2003 and 2004 (Volkov et al., in press)

Diet composition	Autumn 2003			Autumn 2004									
	Br (sw, sh)		Nun	Br (sw, sh)					Nun				
	Size groups, cm												
	15-20	50-70	50-70	10-20	20-30	30-40	40-60	60-80	10-20	20-30	30-40	40-60	60-80
Thysanoessa longipes	0	0	0	0	0	0	0	0	0	0	0	0	0
Th. inermis	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphausia pacifica	0	0	0	0	0	0	0	0	0	0	0	0	0
Mysidacea	0	0	0	1.5	5.2	0	0	0	0	0	0	0	0
Megalopa Brachyura	0	0	0	0.4	0	0	0	0	**16.2**	6.9	9.4	9.3	0
Clione limacina	0	0	0	0	0	0	0	0	0	0	0	0	0
Limacina helicina	0	0	0	0	0	0	0	0	0	0	0	0	0
Cephalopoda	0	0	0	0	0	8.2	0	**97.2**	0	0	6.3	0	0
Ammodytes hexapterus	**84.0**	**64.3**	0	**36.8**	**54.5**	**19.2**	0	0	**25.0**	**28.0**	4.4	**79.2**	0.2
Bothrocarina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Clupea pallasi	0	0	**100**	0	0	0	0	0	16.2	14.6	0	0	**97.1**
Mallotus villosus	**16.0**	0	0	0	0	0	0	0	9.6	**22.1**	**77.4**	7.6	0
Osmerus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleurogrammus monopter.	0	0	0	0	0	0	0	0	0	0	0	0	0
Stenobrachius sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Sebastes sp. (30-60 мм)	0	0	0	0	0	0	0	0	0	0	0	0	0
Theragra chalcogramma	0	**35.7**	0	**37.1**	**33.9**	**23.3**	**100**	0	**30.5**	**26.0**	2.2	3.9	2.6
Larva pisces	0	0	0	**16.3**	4	**12.2**	0	0	0	0	0	0	0
Larva pandalus sp.	0	0	0	2.5	0	0	0	0	0	0	0	0	0
Digestes food	0	0	0	5.2	2	37.1	0	3	2.5	2.3	0.3	0	0
Index of stomach fullness $^{o}/_{ooo}$	360	86	0	113	145	30	81	11	137	175	138	42	123
Plankton	0	0	0	3.3	5.2	0	0	2.8	17.1	8.1	9.4	9.3	0
Hekton	100	100	100	96.7	94.8	100	100	97.2	82.9	91.9	90.6	90.7	100
Number of stations	1	3	2	14	11	7	2	3	9	29	13	6	8
Number of stomachs processed	10	4	3	107	24	9	3	3	53	85	22	13	10

Table 6. Diet (%) of coho in the eastern Bering Sea in autumn 2003 and 2004 (Volkov et al., in press)

Diet composition	Autumn 2003		Autumn 2004					
	Br (m, sh)		Br (m, sh)			Nyn		
	Size group, cm							
	30-40	40-70	20-30	30-40	50-80	20-30	30-40	50-80
Thysanoessa longipes	0	0	0	0	0	0	0	0
Mysidacea	0	0	0	0	0	0	0	0
Themisto pacifica	0	0	0	0	0	0	0	0
Hyperia galba	0	0	0	0	0	0	0	0
Megalopa Brachyura	0	**34.0**	0.4	0	0	**14.3**	**15.7**	0
Pandalus sp.	0	0	0	0	0	0	0	0
Gonatus kamtschaticus	0	0	0	0	0	0	0	0
Cephalopoda (squid)	2.4	0	0	0	0	0	0.6	0
Ammodytes hexapterus	**31.0**	3.0	**27.2**	2.1	3.3	**22.5**	9.9	0
Bothrocarina sp.	0	0	0	0	0	0	0	0
Clupea pallasi	0	0	0	0	0	**25.2**	3.1	**93**
Mallotus villosus	8.5	2.0	0	0	0	0	0	0
Osmerus sp.	0	0	0	0	0	0	**18.3**	0
Pleurogrammus monopterigius	0	0	0	0	0	0	0	0
Sebastes sp. (30-60 мм)	0	0	0	0	0	0	0	0
Stenobrachius sp.	0	0	0	0	0	0	0	0
Therragra chalcogramma	**54.1**	**61.0**	**66.7**	**95.8**	**96.4**	**29.8**	**50.4**	7.0
Juv. pisces	0	0	0	0	0	0	0	0
Larva pisces	0	0	2.1	0	0	0	0	0
Digestes pisces	4.0	0	0.1	0	0	1.1	0.1	0
Larva pandalus sp.	0	0	1.2	0	0	2.0	0.3	0
Other	0	0	2.3	2.1	0.2	5.1	1.6	0
Index of stomach fullness $^{o}/_{ooo}$	180	132	240	163	93	174	127	67
Plankton	0.0	34.0	2.6	0.0	0.1	15.7	17.0	0.0
Hekton	100	66.0	97.4	100	99.9	84.3	83.0	100
Number of stations	25	3	17	6	11	10	18	2
Number of stomachs processed	155	5	77	6	23	46	52	2