Diurnal Feeding Rhythm of Plankton-Eating Salmon Juveniles in the Kamchatkan Waters of the Bering and Okhotsk Seas

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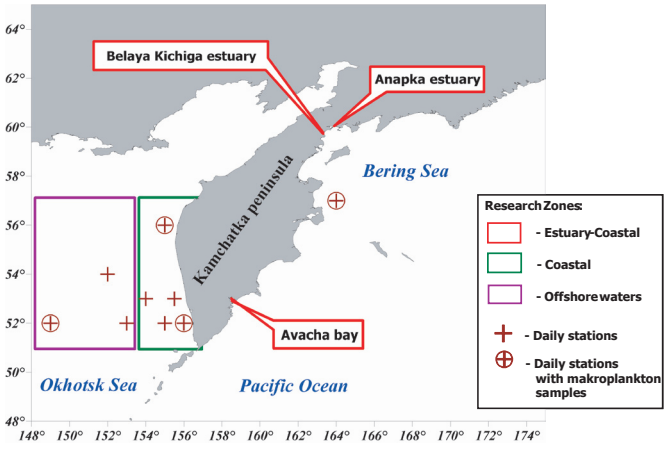
For estimation of food requirements of salmon juveniles was provided with regular 24-hour stations during coastal surveys to carry out from 1970s, and also with surveys in the offshore of the Bering and Okhotsk Seas from 1990s (Karpenko 1982, 1998). For the period mentioned there were accomplished more than 30 diurnal (24 hour) stations; the results more of half of this number have been used in this work (Fig. 1). The surveys were accomplished in the estuary-coastal zone (12 stations) and in the coastal-offshore waters (7 stations). Diurnal feeding by three Pacific salmon species (pink, chum and sockeye salmon) and the basis of food spectrum of these species, consisting of plankton organisms, was studied. To provide a comparison of feeding dynamics we also used results of studying food composition of the species mentioned, obtained in the course of standard juvenile trawl surveys. Stomachs of several thousand fishes of each species and also the composition of plankton in several 24-hour stations of some surveys were examined. We also used the data on the diurnal feeding rhythm of salmon juveniles in the other regions of Far East.

Fig. 1. Area of investigation.



In the estuary-coastal zone of the Bering Sea the principle food of juvenile salmon (chum salmon) were *Lamprops korroensis* (24%), larval and juvenile fish (capelin, herring, sand lance, flounders; up to 36%) and also larval and imago insects (23%) emerged from the rivers. The part of the other organisms, including copepods, Harpacticoidae, mysids and etc., was small due to the substantial desalinization and dynamism of the coastal water zone. For 24 hours usually two (sometime three) maxima (morning and evening) and one minimum (night) of food consumption have been observed. In pink salmon the part of Harpacticoidae was usually higher, being compared to that in chum salmon, but the character of the diurnal dynamics of the amount of food in stomach was similar. The dynamics of the food composition and of the amount of food in stomach is determined by the high-low tide cycle, and it also relates to the density of fish stocks in the coastal zone. Salmon juveniles feed actively and fishes with empty stomachs were very rare. Similar food spectrum and diurnal feeding rhythm of salmon juveniles has been revealed in the other regions, including the estuary of the Bolshaya River, Avacha Bay and South-West Sakhalin (Ivankov et. al. 1999; Karpenko 1979; Shershnev 1975).

In the offshore waters of the Bering Sea in September the basis of juvenile salmon food spectrum consisted of *Themisto japonica*, euphausiids (both mentioned organisms for pink and chum salmons) and larval crabs (sockeye salmon), which in particular cases got substantially over 50% of food weight (Fig. 2). The food spectrum of chum salmon juvenile was the widest, and that of sockeye salmon juvenile, the narrowest; pink salmon took intermediate position. Chum salmon also consumed a high number of Oikopleura (up to 50%) and Chaetognatha (up to 15% of food weight). In this zone one maximum (over 200 $^{o}/_{ooo}$) (in the evening) and minimum (10 times less) (midnight) of food consumption can be observed.

In the Okhotsk Sea in September the food spectrum of juvenile salmon (plankton-eaters) normally includes less species of organisms, being compared to that in the Bering Sea. For example, in the coastal zone it was the narrowest and included mostly *Limacina helicina* and *Clione limacina*, their summary number usually taking over 80% of food weight (over 90% for chum salmon) (Fig. 3). Among the other organisms only juvenile fish (for chum and sockeye salmon), euphausiids and copepods (for pink salmon) played some role in feeding of salmon juveniles. Normally one (evening) food consumption maximum (over 150 $^{o}/_{ooo}$) and one (midnight) minimum (10

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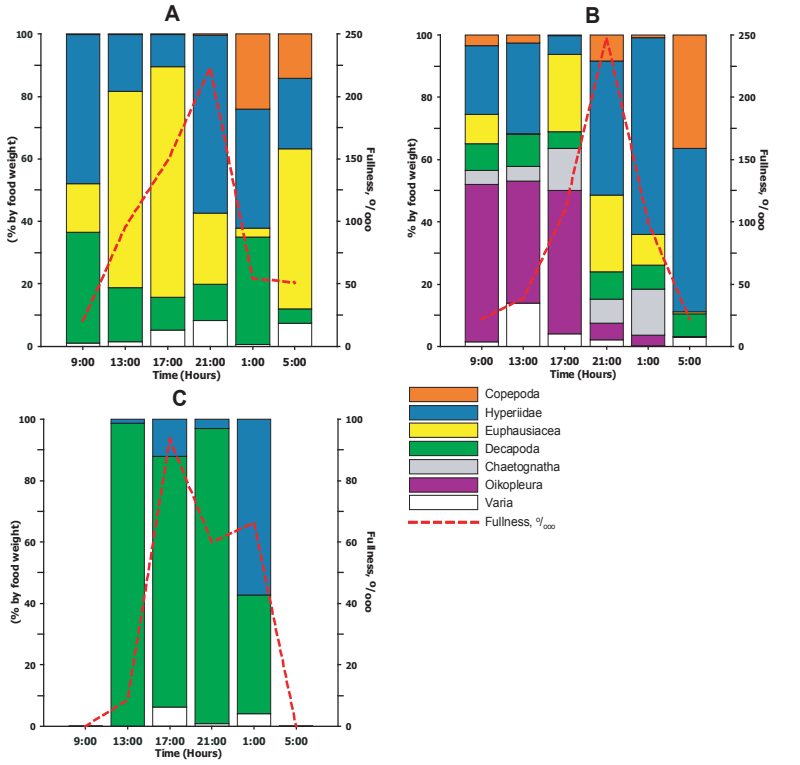
times less) were observed. In the offshore waters of the Okhotsk Sea in September the food spectrum of juvenile salmon (pink and chum salmon) got extending, but the basis of the spectrum still consisted of hyperiids, euphausiids and Oikopleura, the summary number of mentioned organisms being in some cases over 90% of food weight. Two (day and night) local maxima of food consumption (up to 200 $^{o}/_{ooo}$ and more) and one (morning) minimum (about 15 $^{o}/_{ooo}$) were demonstrated. A similar diurnal rhythm of feeding and food composition of juvenile pink salmon was observed in November 2003 in the Japan Sea, where the basis of food consisted of hyperiids, and the maximum amount of food in stomachs was observed in the evening (more than 300 $^{o}/_{ooo}$) (Chuchukalo in press).

Fig. 2. Diurnal feeding rhythm Pacific salmon juveniles, Offshore waters, Bering Sea, September 2002: A, pink salmon; B, chum salmon; C, sockeye salmon.



Plankton organisms undertake vertical migrations during 24 hours and create aggregations of different density, determining the removal by fish. The same vertical migrations are used by juvenile and adult salmons too. That creates a ground to determine the diurnal rhythm of feeding not only from daily surveys, but also from the by-catch of salmons in different time in the course of standard trawl surveys. Over the comparison of food composition and amount of food in stomach

Fig. 3. Diurnal feeding rhythm Pacific salmon juveniles, Okhotsk Sea, September 1999: Coastal waters: A, pink salmon; B, chum salmon; C, sockeye salmon; Offshore waters: D, pink salmon; E, chum salmon.

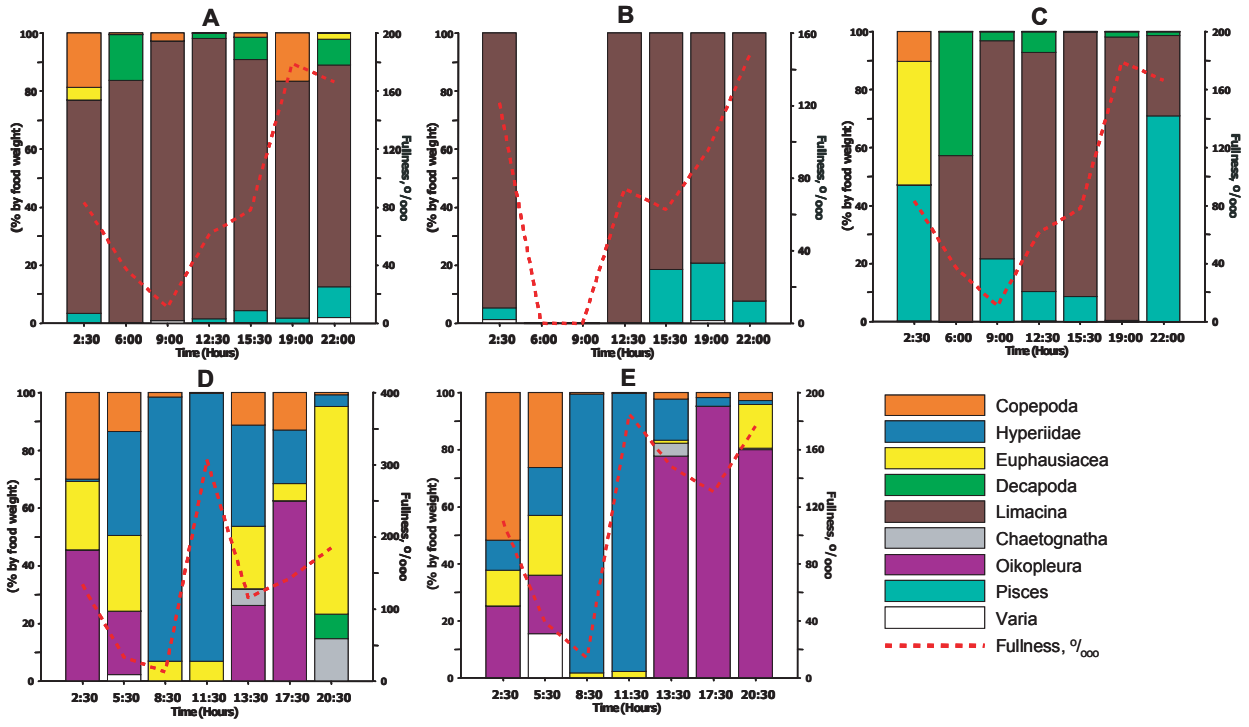


Table 1. Daily ration (% body weight) of plankton-eating juvenile salmon.

Area (species)	Year and month	Daily ration (% body weight)
Anapka estuary, Karaginsky Bay (chum)	1975–1993 mid July	6.7–16.5
Bering Sea (pink)	September 1998, 2002	6.5–9.3
Bering Sea (chum)	September 2002	5.9–6.8
Bering Sea (sockeye)	September 2002	7.0
Okhotsk Sea (pink)	September–October 1986–2001	5.9–13.2
Okhotsk Sea (chum)	September–October 1991–2001	4.9–10.5
Okhotsk Sea (sockeye)	September–October 1997–2001	6.0–7.7
Okhotsk Sea (pink)*	1985	5.5–7.2
	1994–2000	7.5–14.4
Okhotsk Sea (chum)*	1994–1998	6.8–7.3
Okhotsk Sea (sockeye)*	1994–2000	2.2–4.8

*Data from Chuchukalo (in press).

of juvenile salmon, the data collected with two methods—diurnal 24-hour surveys and regular juvenile surveys—demonstrated significant similarity characteristic for area of studies, what was observed both in the Bering Sea and in the Okhotsk Sea.

Different methods of studying of the diurnal rhythm of feeding allow assessing of food requirements of juvenile salmons directly or by inference, widely used by experts. The data from the daily rations of plankton-eating juvenile salmon make us to conclude, that on entering the sea the rations take 10–15% of juvenile body weight and go reducing gradually to 5–7% to the beginning of juvenile migration for wintering (Table 1). It also should be noted, that the daily ration of juvenile salmon with a short life cycle in the ocean (pink salmon) is usually higher, being compared to that of salmon, spending several years in the ocean (chum and sockeye salmon). Moreover, there are significant regional and seasonal variations of juvenile salmon food requirements by species.

The principle purpose of studying the diurnal rhythm of fish feeding consists in the estimation of food requirements, consumption and provision with food and also in the figuring out of the energy flows in the ocean communities with salmon membership. These all should be the principle directions either to use the data from the 24-hour survey stations.

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