Feeding Interactions of Juvenile Pacific Salmon and Other Fish Species in the Coastal Epipelagic Zone of Kamchatka

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This study was based on data collected from trawl surveys conducted on board the RV *MRTK-316* (ship-owner: KamchatNIRO) from June to July 2005-2011 in the coastal waters of Southwest Kamchatka and in August 2007 and 2010 in the Kamchatsky Gulf (East Kamchatka; Fig. 1).

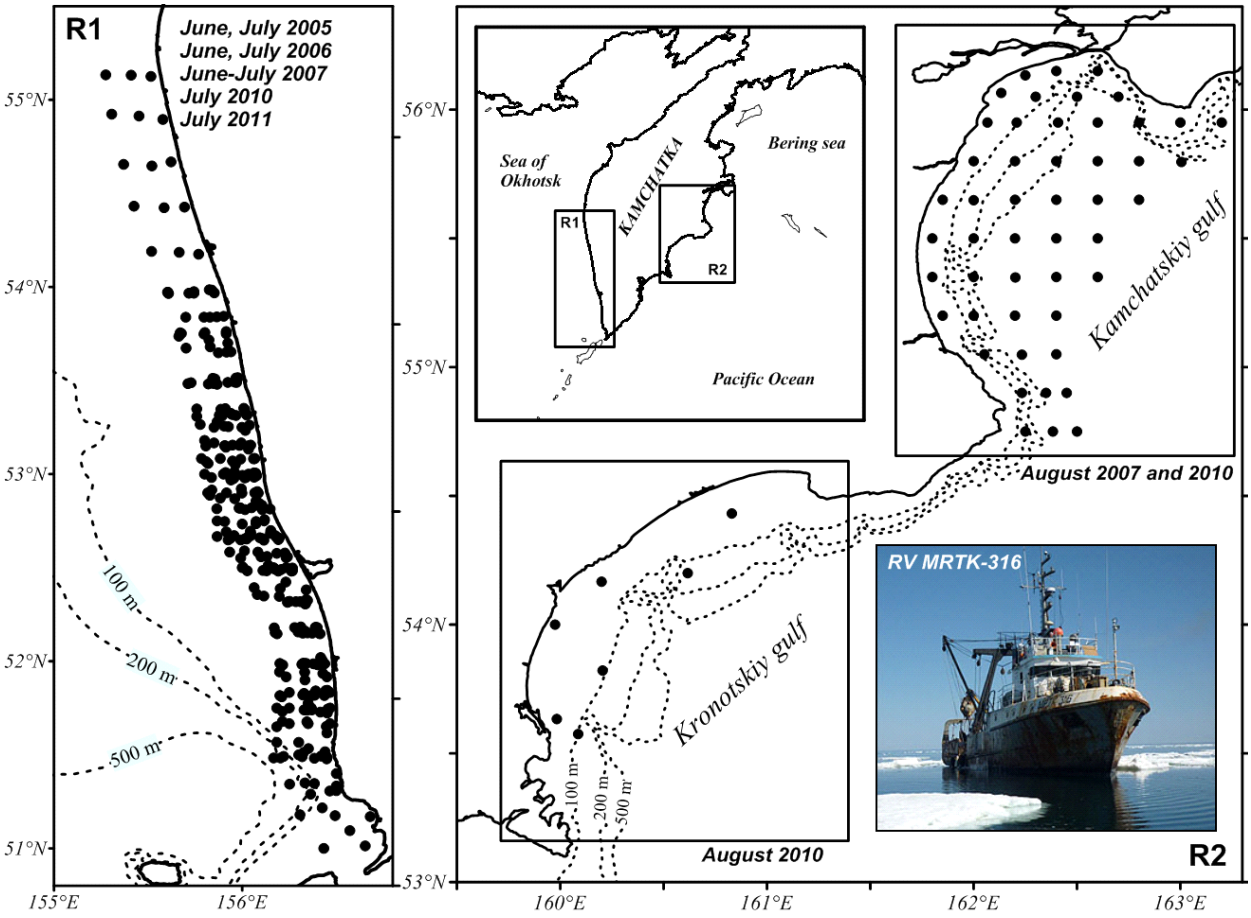

Fig. 1. The scheme of trawl stations used by researchers aboard the R/V *MRTK-316* in the coastal waters of West and East Kamchatka from June to August, 2005-2011.

Pacific salmon and up to 25 other fish species were recorded in the summer trawl catches for the period 2005-2011 in the coastal waters of West Kamchatka as permanent inhabitants of the pelagic zone and members of coastal biocenotic communities. Pacific sand lance, capelin, sandfish, yellowfin sole, starry flounder, and juvenile greenlings were distributed in the survey area. High abundance was typical for Pacific sand lance, capelin and sandfish. In contrast, the most frequently caught species in surveys off East Kamchatka was Pacific herring (Koval et al. 2011).

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Mechanisms allow predators to feed maximally on the forage base within an area and to minimize competition among species. These mechanisms are spatial separation of predators and divergence in the spectrum of forage organisms (size and species composition) consumed by the predator. Our analysis revealed that both mechanisms are operating, even from the very early period of Pacific salmon residence in marine waters.

In the waters of West Kamchatka, the maximum similarity in prey composition was observed in predators, including juvenile coho, Chinook, and masu salmon, and adult Pacific sandfish (Fig. 2). Nevertheless, the ration of these predators was different. Juvenile coho salmon typically consumed juvenile walleye pollock, adult capelin, and sand lance. Chinook salmon consumed juvenile sand lance, sculpins, or pricklebacks. Moreover, coho salmon migrated during summer and autumn to the outer edge of the shelf zone to feed on juvenile walleye pollock aggregations—the most preferable forage for coho salmon (Erokhin 1987). Chinook salmon and Pacific sandfish remained on the inner shelf illustrating a spatial divergence from coho salmon. The most abundant group of plankton-eating fish species included juvenile chum, pink, and sockeye salmon, Pacific sandlance, capelin, juvenile Pacific sandfish, and walleye pollock. However, similarity in the prey composition of these fish species was low. The ration generally consisted of organisms of the neritic complex—coastal species of copepods (*Epilabidocera amphitrites*), euphausiids (*Thysanoessa raschii, Th. inermis*), mysids, and others. By the end of summer, exploitation of the food web in coastal areas became less intense because pink and chum salmon left these waters, thereby creating spatial divergence among these predators. A characteristic of the West Kamchatka shelf is that typical plankton consumers, such as pink, chum, and sockeye salmon, often consume juvenile and larval fish (> 50 % of prey weight). This can be explained by the mass emergence and early feeding of larval fish of the neritic species complex in summer.

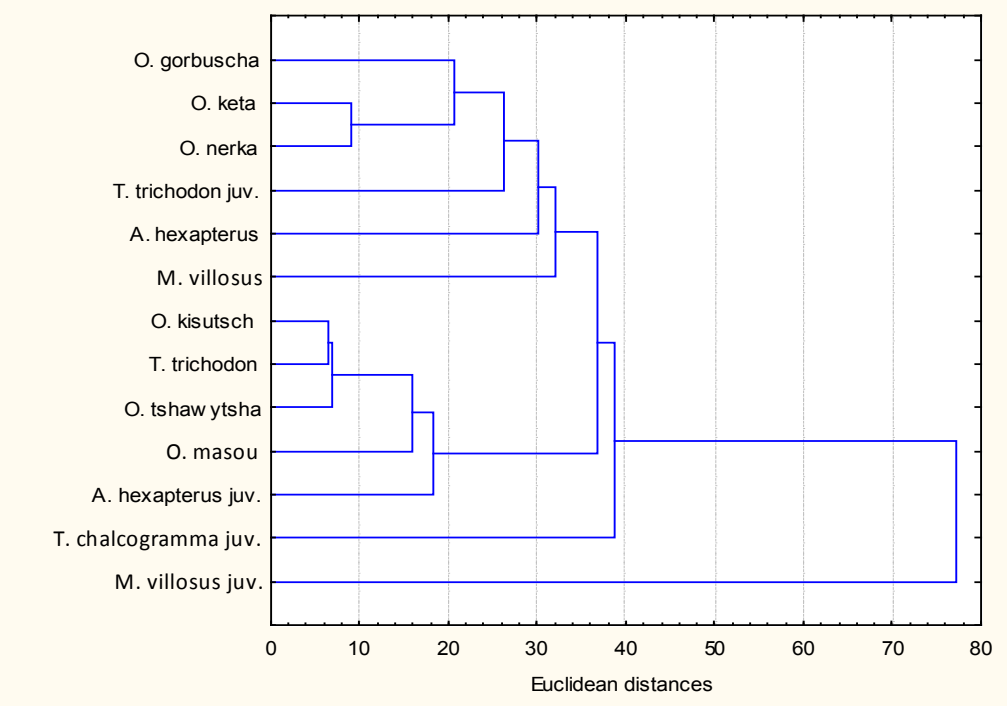

Fig. 2. Food similarity (Euclidean distance) among juvenile Pacific salmon and the other fish species collected in the coastal waters of West Kamchatka in June-July, 2005-2007 and 2010-2011 (all data combined).

Observations of juvenile salmon food habits from the east coast of Kamchatka also demonstrated there are two feeding types: fish predators and plankton consumers (Fig. 3). In the Kamchatsky Gulf, salmon prey included not only neritic organisms, but a number of planktonic organisms (mostly Copepoda) brought into the gulf by water circulation. Thereby the ration of all fish, including fish predators that typically do not feed on zooplankton, can consists mostly of zooplankton (Morozova 2011). An important component of the stomach contents of plankton-eating juvenile salmon was oceanic copepods, *Eucalanus bungii* and *Neocalanus cristatus*. This relates to the narrow area of shallow water on the shelf. In some places in the northern gulf, the outer shelf and slope is as close as 5-10 miles from the shoreline. Therefore, the nearshore habitat of the Kamchatsky Gulf in East Kamchatka provides less stable feeding conditions as compared to conditions in the Okhotsk Sea. Another important characteristic of the northwestern area of the gulf is the run of Pacific herring to coastal

waters during the last half of August (Koval and Morozova 2012). This is probably one of the most important drivers of juvenile salmon early emigration from the Kamchatsky Gulf to the ocean. The herring run is important for juvenile sockeye, chum, and pink salmon because the prey of juvenile salmon is very similar to that of herring, and when juvenile salmon and herring are both present competition for the food increases (Koval et al. 2011).

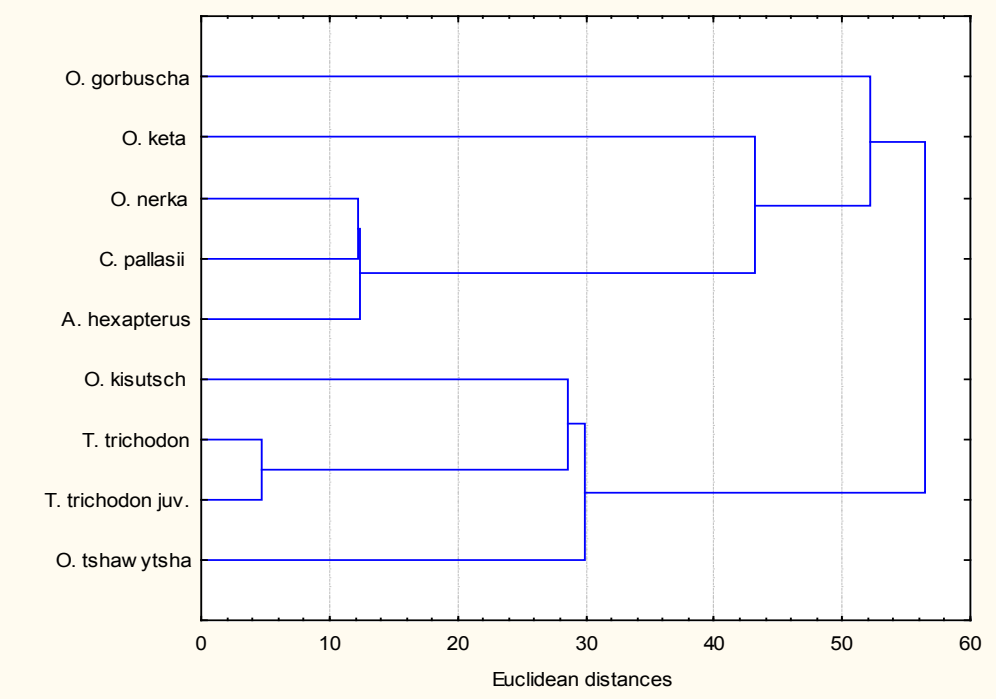

Fig. 3. Food similarity (Euclidean distance) among juvenile Pacific salmon and the other fish species collected in the Kamchatsky Gulf (East Kamchatka) in August 2007 and 2010 (all data combined).

Regarding the regional character of early marine feeding by juvenile salmon, the difference between East and West Kamchatka is the duration of juvenile salmon residence in near shore habitats. In the waters of West Kamchatka, species such as sockeye, Chinook, and coho salmon stay in the coastal waters until autumn (sockeye and Chinook salmon remain up to 5-7 months, coho salmon remain about two months). The duration of juvenile salmon residence in the Kamchatsky Gulf is 2.5-3 months. Juvenile salmon leave the rivers in June and July (when there is prolonged ice cover) and leave the gulf in late August.

West Kamchatka has a highly productive, developed shelf. In summer the coastal habitat provides a favorable environment for mass emergence of various fish larvae and for feeding during early ontogenesis. This feature of the habitat explains the presence of fish prey in the diet of all species of juvenile salmon. Forage resources in coastal habitats are more fully exploited by juvenile salmon because they remain in these habitats for a long feeding period.

The Kamchatsky Gulf has a narrow shelf and less forage production as compared to West Kamchatka. In late August, myriads of Pacific herring move into the gulf and compete for the same prey items as juvenile salmon. Therefore, young salmon strive to adapt and explore oceanic forage resources quickly and move relatively swiftly from the gulf to ocean feeding areas.

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