

documented regime shifts and higher-frequency 4-10 year periodicities were detected in the herring data, and in biological (sedimentary hake scale record, diatoms) and physical factors (ALPI), as well as fishing intensity (historical landings).

From the ODP cores, a long-term relationship between primary and tertiary trophic levels does appear to be resolved in the Saanich record. Herring were among the first fish to colonize post-glacial Saanich Inlet.

Further research of this kind may help to provide testable hypotheses about patterns and causes of long-term variability. Data such as these may also prove invaluable to management of herring

stocks as a better understanding of the timescales of change may assist in planning for major regulatory changes at periods of low abundance.

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On relationship between crustacean zooplankton (Euphausiidae and Copepods) and Sakhalin-Hokkaido herring (Tatar Strait, Sea of Japan)

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Introduction

Sakhalin-Hokkaido herring is potentially the most abundant among all herring populations in the Far East. During the last several decades, the status of that population has been extremely low. A significant reduction in abundance began in 1940–50s and during the 1980–90s, the population appeared to be in a critical situation. The reasons for the decline were discussed widely (Svetovidov, 1952; Probatov, 1958; Hirano, 1961; Kondo, 1963; Motoda & Hirano, 1963; Birman, 1973; Pushnikova, 1981; 1996; Sokolovsky & Glebova, 1985). A majority of scientists considered that the main reason of this phenomenon was a change in ocean conditions such as the warming in the northern Sea of Japan and adjacent areas. Increasing commercial pressure on the Sakhalin-Hokkaido herring population is considered to be another important reason.

It is well known that the abundance of each generation depends on many factors, both biotic and abiotic. Prey abundance affects them to a considerable extent as well. In the Tatar Strait, the zooplankton community, feeding structure and other problems connected with herring feeding were studied actively. However, a question of the relationship between the biomass of the dominant zooplankton forms, the main components of herring feeding, and the number of Sakhalin-Hokkaido herring were not considered. The aim of our work was to determine the relationship between the biomass of one of the main components of feeding (crustacean zooplankton such as Euphausiidae), the number of Sakhalin-Hokkaido herring generations and the biomass of predatory zooplankton.

Materials and methods

In this work the dependencies between the abundance of Sakhalin-Hokkaido herring year-class at age 1+ (given as calculated data), biomass of small and large fractions of euphausiid, and biomass of the predatory zooplankton forms (*Sagitta elegans* is dominant among them) which feed on herring larvae, and small forms of the prey zooplankton are considered. General zooplankton biomass and copepod biomass data are reported as well. All data are considered for spring and fall during the period 1986-1992.

The abundance of Sakhalin-Hokkaido herring year-classes was estimated from aircraft observations and Pope's cohort analysis. In further analyses, the abundance of year-classes at age 1 was displaced one year forward.

Zooplankton data were collected during the seasonal (spring and fall) hydrobiological surveys carried out at the standard stations. A total of 700 stations was occupied. A Juday net (diameter of input hole – 0.37 m) was used to collect zooplankton samples and an egg and larvae net (diameter of input hole – 0.37 m). The samples were collected by hauling the 0-100 m layer.

The method of zooplankton determination was standard. For Juday samples, a division on fractions was applied and a catching efficiency was used for different systematic and dimensional zooplankton groups. All data given in the report on the condition of zooplankton community are averages for the study area. Temperature was considered on the line of Slepikovsky Cape – the sea at 0-50 and 50-100 m layers averaged for April-May (spring) and September-November (fall).

Results

The main region of Sakhalin-Hokkaido herring inhabitation at present time is the southwestern coast of the Tartar Strait (Sea of Japan). Spawning, embryogenesis, and feeding of fry and fingerlings take place here. Within the Tartar Strait mature herring form the prespawning

stocks in March-May, and then feeding stocks in June-October, mainly in the region between 47-49°N near Sakhalin shelf and slope. The most intensive herring eat during the prespawning and after spawning periods in June-July. In August-September the intensity of feeding somewhat falls down. As a rule, the greatest stocks are being formed in places with significant water temperature gradients and high zooplankton biomass.

The base of feeding for herring juveniles near the southwestern Sakhalin is formed by Harpacticoida, Coryphiidae, Calanoida, and Euphausiidae. Adult fish eat mainly *Calanus*, Euphausiidae, *Sagitta*, and Mysidae i.e. the largest and most abundant forms of plankton.

In the area of the southern Tatar Strait, hydrobiological surveys found 4 species of Euphausiidae in the samples. These included the cold water species *Thysanoessa raschii*, *T. inermis*, *T. longipes* and a moderately-cold water species *Euphausia pacifica*. At the end of April to the beginning of May, the eggs, nauplii, calyptopis and furcilia stages were present together with adult specimens. In spring *T. inermis* was dominant in both frequency and biomass. Its average biomass in the region was 23.76 mg·m⁻³. In autumn, *T. longipes* occurred most often, their density was not high – 7.77 mg·m⁻³. As to biomass of euphausiids on the whole, its value is small and varies from 4 to 58 mg·m⁻³ in spring and from 6 to 40 mg·m⁻³ in autumn, making from 1 to 9.6% of total zooplankton biomass. Table 1 shows that the biomass of euphausiids does not play a leading part and their share does not exceed the average 8.0% in the community.

During the study period extensive stocks of euphausiids with high biomass, like those described in the literature for the 1950–70s, were not found. Euphausiids were not dominant in herring stomach samples as well.

Judging from the results of analysis of stomach contents, the copepods *Neocalanus plumchrus* and

Pseudocalanus minutus are the base of herring diet in recent years. These are the dominant plankton in the zooplankton community structure in the southern Tatar Strait. On a study area copepod prevailed in zooplankton community as in spring, so in autumn (Table 1).

Table 1 Biomass of zooplankton main groups, 1986 – 1992 (%)

Taxa	Spring	Fall
Copepoda	61.6	50.5
Euphausiidae	5.9	8.0
Amphipoda	3.8	10.9
Chaetognatha	16.3	13.5

Comparison of herring abundance with total zooplankton biomass and biomass of copepods has shown that in spring their indices are out of phase. For autumn period a similar tendency was not evident because this season is characterized not only by the active consumption of plankton by herring, walleye pollock, cod juveniles, and capelin, but also the development of a complex community of neritic zooplankton species (Fig. 1).

Despite the fact that the base of the Tatar Strait zooplankton community and the base of herring diet are copepods, we have considered a relationship between a number of herring year-classes and the biomass of euphausiids, so far as this zooplankton group is important in the diet of herring, especially juveniles. For the period between 1986–1992, the most numerous year-class of herring was observed in 1988. The number of 1 year old individuals reached 312.4 million. This was a harvestable generation during a period of generally weak recruitment during the 1980s and early 1990s. Though its abundance was lower than the 1983 generation, it was a harvestable year-class from 1984 – 1995.

During the period 1986–1992, a relatively high biomass of euphausiids was recorded in the spring of 1990 and in spring and autumn 1992. Our observations indicated that in 1987, the year

before the formation of the harvestable year-class, and in 1988, the biomass of euphausiids was below the interannual level. A small fraction of euphausiids, which in summer-autumn period is one the main dietary components for herring fingerlings was not high as well. Zooplankton predators' biomass in spring was also low (Fig. 2).

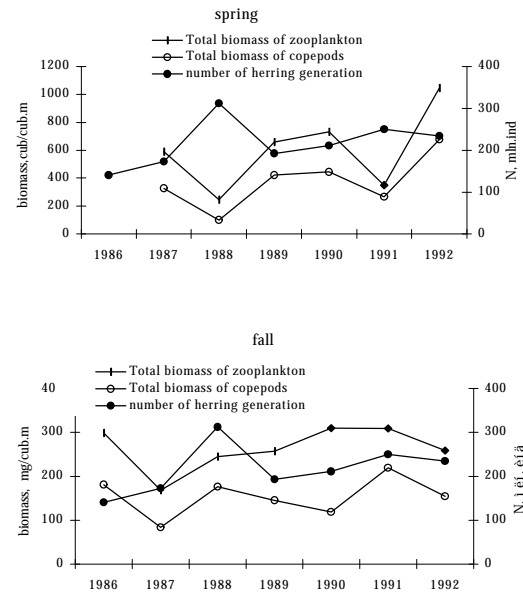


Fig. 1 Total biomass of zooplankton and herring generation

In 1988, a significant negative temperature anomaly in the 0–50 and 50–100 m layers in southern Tatar Strait was registered, and most clearly observed in the spring period (see Figures 4 and 5). In 1989–1990, high values for total euphausiid biomass were distinctive in spring and autumn and high values of zooplankton predators were found as well. Small zooplankton fractions were distinguished by the low biomass, especially in autumn period (Fig. 3). Unlike 1988, these years had positive temperature anomalies (Fig. 3 and 4).

A significant negative correlation was observed only between the number of herring and the biomass of small euphausiids in spring (-0.72) and biomass of predators in spring (-0.87). But

such situation occurs only in the summer period, since the new generation of herring begins to eat small zooplankton in summer, at the same time the predators begin to act.

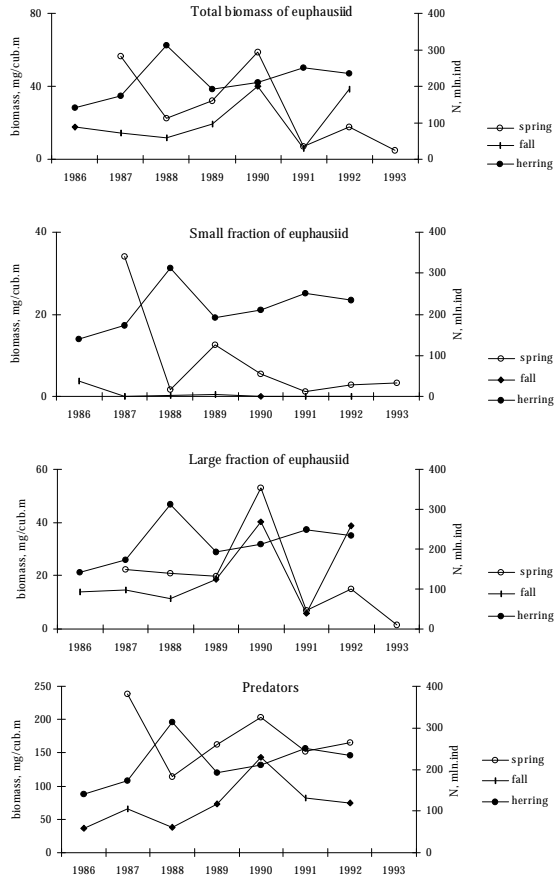


Fig. 2 Biomass of euphausiids, predators and number of herring generations

A relationship between the number of herring, autumn and spring biomass of euphausiids and water temperature was not evident. But for the year in which the 1988 herring year-class was formed, low water temperatures in the upper layer in spring and autumn, and low values of euphausiid biomass occurred as well. In general, a feedback between the number of herring and biomass of euphausiids and predators was observed. However, some clear dependency on interannual scale between the number of herring

generations and biomass of euphausiids was not determined for a study period. It is probably caused to the fact that euphausiids are not the main component of the herring feeding, and to the reduction of a total euphausiid biomass coincided with the period of depression of the Sakhalin-Hokkaido herring population.

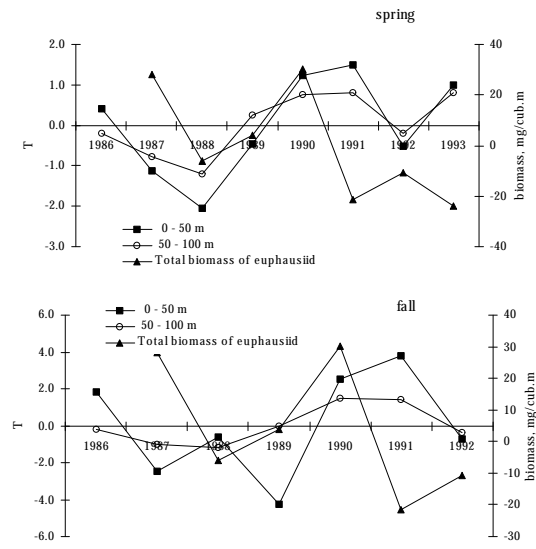


Fig. 3 Total biomass of euphausiid and layer temperature (0-50, 50-100 m), deg C.

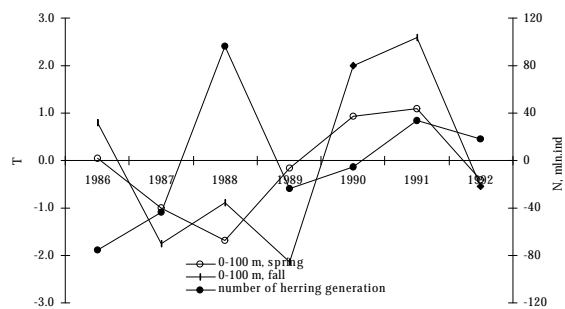


Fig. 4 Number of herring generation and layer temperature (0-100 m), deg C.

Table 2 Correlation between the annual number of herring at age 1 and the biomass of some zooplankton forms.

Total Euphausiid		Small euphausiids		Large euphausiids		Predator biomass	
Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
-0.63	-0.14	-0.72	-0.57	-0.25	-0.08	-0.87	-0.03

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Fish predation on krill and krill antipredator behaviour

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Krill constitute a key component in oceanic food webs. They have a diverse diet and are prominent prey for fish. The search strategies of fish foraging on krill differ among species, locations, and time of day and may involve visual search as well as ambush feeding based on hydrodynamic signals created by the swimming

prey. This talk addresses the feeding behaviour of herring (*Clupea harengus*), whiting (*Merlangius merlangus*) and Norway pout (*Trisopterus esmarki*) foraging on krill (*Meganyctiphanes norvegica*), mainly based on research carried out in the Oslofjord, Norway.