Baikal amphipod (G*melinoides fasciatus*) and is contribution to the feeding of Ladoga Lake perch

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Abstract. The feeding of perch (*Perca fluviatilis*) from the littoral zone of Ladoga Lake was studied. Attention was focused on the colonizer species, a Baikal amphipod (*Gmelinoides fasciatus*), and its contribution to feeding. The invasion of Ladoga Lake by the Baikal amphipod has provided a new food item accessible to the fish. The results of the study have shown that the habitat of perch is largely the same as that of the Baikal amphipod. The food of perch was found to consist of various bottom fauna representatives. The colonizer Baikal amphipod made up over 40% of the food bolus by weight, indicating its great contribution to perch's feeding.

1 Introduction

The invasion of aquatic ecosystems by new species, mainly fish and various invertebrates, has been an acute ecological problem in many Russia's water bodies over the past few decades. This process may be either purpose-oriented or accidental. The ecosystem is often subjected to stress comparable with the negative impact of some industries [1-7].

In modern water bodies, some amphipod-group species spread actively outside their natural areas. As a result, recipient ecosystems are substantially changed.

It is known that the amphipod *Gmelinoides fasciatus*, inhabiting the littoral zone of Lake Baikal, has been purposely introduced since the1960-1970 to other Russia's water bodies to increase food supply for commercial fish species [8-10]. After its invasion of Ladoga Lake in the early 1980s, the Baikal amphipod became the dominant component of benthos in all types of the lake's littoral biotopes [11]. This has led to considerable structural changes in the benthic communities of the littoral zone. The Baikal amphipod now contributes markedly to the formation and functioning of bottom biocenoses in the lake's littoral zone.

It should be noted, however, that the literature on the contribution of the Baikal amphipod to fish's feeding is scanty. The purpose of the present project was to assess the contribution of the colonizer *G. fasciatus* to the feeding of the fish inhabiting Ladoga Lake's littoral zone (a case study of the river perch *Perca fluviatilis*).

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2 Materials and methods

The Ladoga is Europe's largest lake. It is located in northwestern European Russia and is part of the Baltic Sea basin. Its covers an area of 17700 km^2 and has a water volume of 908 km^3 (Table 1). It has an average depth of 51 m and the greatest depth of 230 m [12-13]. Its total water mineralization is 60 mg/l. The lake's water is of a hydrocarbonate class, Ca-group, as indicated by its ion composition. Ladoga Lake receives run-off from a drainage basin, which covers an area of 258 300 km^2, and includes four secondary basins: a private Ladoga Lake basin (28.4 thousand km^2); the Onega-Svir basin (83.2 thousand km^2); the Ilmen-Volkhov basin (80.2 thousand km^2) and the Saima-Vuoksa basin (66.5 thousand km^2). The lake's drainage basin is located in three countries: Russia (80%), Finland (19.9%) and Byelorussia (0.1%). Ladoga Lake's drainage basin is a highly developed economic region, where various industries are concentrated. In Russia, it covers the Leningrad Oblast (39%), Karelia (29%), the Novgorod Oblast (17%), the Pskov Oblast (6%), the Tver Oblast (4%), the Vologda Oblast (3%), and the Arkhangelsk Oblast (2%). Any changes in this territory inevitably affect the lake. Its complete water exchange takes12 years.

Table 1. Main morphometric characteristics of Lake Ladoga.

Index	Value
Lake area, km^2	17700
Coastline length, km	1570
Water volume, km^3	910
Lake length, km	219
Average width, km	81
Largest width, km	112
Average depth, m	51
Greatest depth, m	230
Catchment area, km^2	258300

It is known from the literature that the lake's ecosystem was highly restructured in 1976-1983, when human-induced lake eutrophication (increase in the biogenic load on the lake) increased. Because Ladoga Lake has cold poorly mineralization water, it remained resistant to the invasion of alien invertebrate species, including those with a high invasive potential.

Fish feeding material was collected in the summers of 2016-2022 on the north shore of Ladoga Lake. Nets for catching fish were mounted in the lake's littoral zone. A total of 231 fish were caught and analysed in the laboratory using standard methods [14].

A food bolus was taken from the fish's stomachs, organisms were subdivided into basic systematic groups, identified to species when possible, counted and weighed on a torsion scale. Items seldom occurring in fish feeding were referred to as "Others". The total index of fullness (in per mil. ($^0/_{000}$) was calculated. The index of fullness was also calculated separately for water and air fractions.

3 Results

Ladoga Lake is inhabited by 42 fish and fish-like species, not counting those resulting from acclimatization [15]. The lake has a total of 58 fish species and varieties. Many of its cyclostomes and fish (23 species making up 54% of total composition), e.g. whitefish,

vendace, smelt, pike-perch, bream, roach and perch, are of commercial value. Perch is one of mass fish species in Ladoga Lake. It displays high ecological plasticity. In water bodies, it forms separate ecological forms differing in the lifetime of individuals, growth rate, reproduction ecology, distribution and a feeding pattern. The littoral zone is inhabited by small-sized and early-spawning (May-June) perch and the open zone by a large-sized pelagic perch, whish spawns 1-2 months later. Juveniles, up to 6 cm in length, feed mainly on small crustacean plankton followed by benthos. Reaching a length of 13-15 cm, perch begins to behave as a predator but continues to eat benthos. Thus, perch and the Baikal amphipod have largely the same habitats in the lake. The perch's abundance and economic value are of great scientific interest [16].

To assess the role of the Baikal amphipod *G. fasciatus* as fish's food item, the feeding of perch, the most abundant species in the littoral zone of Ladoga Lake, was studied. The age composition of catches was represented by fish of two age groups (3+ - 4+); three-year-old fish dominated (about 60%). The fish had an average size (AD) of 14 cm (11.2-15.9 cm) and body mass of 37 g (21-72 g). No substantial differences in the feeding of perch of variable age were detected.

Perch's food was qualitatively diverse (Figure 1). Chironomid pupae (82%), caddis flies (58%), the Baikal amphipod (55%) and chironomid larvae (41%) were most abundant; insects, mayflies and others were less common. The Baikal amphipod (45%), fishes (25%), caddis flies (14%) and chironomid pupae (12%) display the highest weight indices. Other organisms make up less than 2%. The index of fullness of the fish was $86^{0}/_{000}$ on the average (0.2 – 350). No empty stomachs were detected.

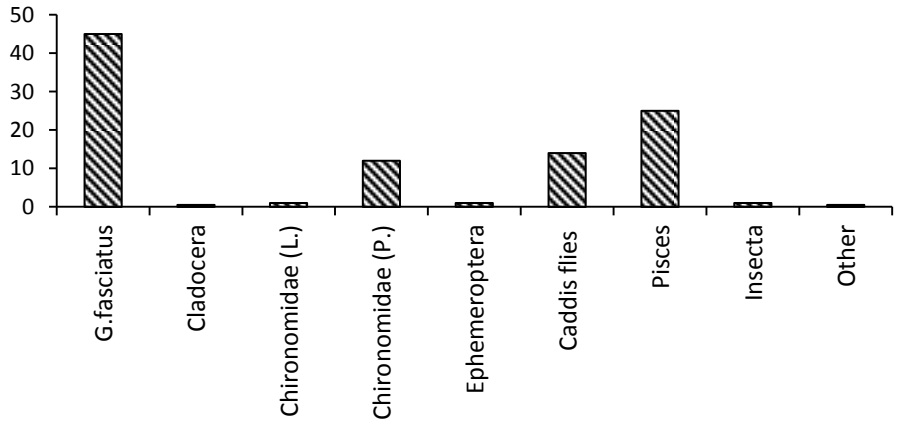

Fig. 1. The feeding of perch from the littoral zone of Ladoga Lake (biomass, %).

4 Discussion

In the past few decades Europe has seen the rapid invasion of variably originated invertebrate species (including amphipods) leading to changes in the species composition of various water bodies [17]. The main factors contributing to the invasion of amphipods are commonly of anthropogenic origin or are related to it. The amphipod *Gmelinoides fasciatus*, whose natural environment is Lake Baikal, is now actively invading water bodies and streams in European Russia, provoking considerable changes in the structure of bottom communities [18-19]. This species is now widespread in the littoral zones of Ladoga and Onega lakes, where it is a major contributor to the transformation of littoral communities [20]. After purpose-oriented introduction, conducted for improving the food supply of fish,

the Baikal amphipod has adapted to a new habitat and began to invade neighbouring water bodies by itself. The successful acclimatization of this species was provided by some biological factors, such as high fecundity, high growth rate, early maturation, resistance to environmental pollution, self-invasion and an omnivorous nature. It should be noted that a predatory type of feeding also contributes to the active invasion of *Gmelinoides fasciatus*. For example, it has ousted the aboriginal species *Gammarus lacustris* from the littotal biocenoses of Ladoga Lake [21].

The composition of fish's food spectrum is directly controlled by the structure of biocenoses and the accessibility of organisms. As a new food item appeared in the lake's littoral zone, benthos-eating perch, feeding on aboriginal food supplies, began to use the invader as another food item.

5 Conclusion

Analysis of the contents of the stomachs has shown that in the 4^{th}-5^{th} year of perch's life a benthic type of feeding prevails. In the summer season the invader *G. fasciatus* makes up a high percentage in the food of perch from the lake's littoral zone (over 40% by biomass). Thus, as a result of the invasion of Ladoga Lake by the Baikal amphipod, a new accessible mass food item appeared. The invasion of the amphipod has also provoked changes in the structure of the lake's littoral biocenoses. The Baikal amphipod is now abundant in Ladoga Lake's littoral zone. Because the species easily invades due to some of its biological features, it is essential to study the possible ways of its further invasion along tributaries to other water bodies of the Ladoga Lake basin. It should be noted that seasonal fish feeding dynamics should be studied to better assess the contribution of the invader as a food item.

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