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Contribution of the Baikal Amphipod to the Feeding Pattern of Perch in the Littoral Zone of Lake Onega

Nikolay V. Ilmast*, **and Yaroslav A. Kuchko**

Institute of Biology, Karelian Research Centre, Russian Academy of Sciences

ORCID
Nikolay V. Ilmas: 0000-0001-8431-5226

Corresponding Author: Nikolay V. Ilmas; email: ilmast@mail.ru

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Abstract. The seasonal feeding pattern of juvenile perch in Petrozavodsk Bay of Lake Onega was studied. It was shown that in the fourth to sixth years of their life, a benthic type of feeding predominates. The fish that inhabit the littoral zone feed actively on the Baikal amphipod, a new food item. During the summer-autumn season, the colonizer accounts for over 50% of the biomass in the stomach of juvenile perch. The invasion of Lake Onega by the Baikal amphipod has thus led to changes in the structure of littoral communities and the availability of a new food item for the fish. Considering the resistance of the Baikal amphipod to unfavorable environmental factors, it is important to study its spatial expansion and the possible penetration of this amphipod via tributaries to other water bodies in the Lake Onega Lake catchment area.

Keywords: freshwater ecosystem, perch, trophic interactions, Baikal amphipod

1. Introduction

The penetration of new species into water systems is one of the pressing environmental problems that have arisen in the past few decades in many water bodies of Russia [1-5]. The Baikal amphipod *Gmelinoides fasciatus* has been introduced into the water bodies of the USSR since the 1960s to improve fish nutrition. The success of the introductions in water bodies of different types was due to the species' essential biological characteristics such as early maturation, high fecundity, rapid growth, omnivory, resistance to contaminants, and high dispersal capacity [6]. For example, the Baikal amphipod was introduced in lakes of the Ladoga Lake catchment in the 1980s. Having adapted to living in the lakes, it then dispersed to Lake Ladoga. It is now abundant in the lake, especially in its littoral zone, where it has become dominant [7]. The amphipod has reached Lake Onega via the River Svir and the Volga-Baltic Canal. In 2001, the invader was officially reported from the rocky and sandy littoral zone in southwestern Lake Onega [8].

The biological characteristics of this small crustacean have facilitated its adaptation and rapid population growth in the new environment. The results of the monitoring

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conducted in the past few years have shown that the Baikal amphipod has occupied the littoral zone of Lake Onega almost entirely, except Unitsa Bay and Lizhma Bay. On becoming part of the benthic communities, the Baikal amphipod has substantially altered their structural characteristics, and is now a dominant species in all types of the littoral zone of the lake [9].

Of the four native amphipods of Lake Onega, the Baikal amphipod is the most similar in distribution to *Gammarus lacustris*. The invasion of the Baikal amphipod has resulted in a considerable decline in the abundance of the gammarid, followed by its complete disappearance from littoral communities [9]. A similar situation has been reported from Lake Ladoga. According to Berezina [10], the predation of *G. fasciatus* on *G. lacustris* could be the main reason for the vanishing of the latter from many habitats. The predation pressure of one species on another varies depending on their abundance. A roughly triple increase in abundance is sufficient for one species to successfully displace another. It should also be noted that *G. fasciatus* is more resistant to some unfavourable environmental factors, including human impact, than *G. lacustris* [6].

The Baikal amphipod is omnivorous. Its food spectrum depends on the habitat's community structure and the availability of individual organisms. It has been shown experimentally that the Ladoga population of *G. fasciatus* is capable of active predation [10]. However, detritus and plant fragments contribute substantially to its diet [7]. The presence of macrophytes and the abundance of plant residues seem to be essential for the development of this species. It is in habitats with thick algal vegetation that the abundance and biomass of the Baikal amphipod in Lake Onega were the highest [11, 12].

A study of the dynamics of the population indices of the Baikal amphipod has shown that the species is becoming more abundant in Lake Onega. However, its role as a food item for fish in the lake has not been assessed yet. Therefore, this study undertook to estimate the contribution of the Baikal amphipod to the food ration of Lake Onega perch.

2. Methods and Equipment

Lake Onega is the largest fishery lake in the Republic of Karelia. It covers an area of 9 890 km^2, of which 350 km^2 are occupied by islands. The lake is deep: its maximum depth is 120 m and its average depth is 30 m. The water surface area of Petrozavodsk Bay, where samples were collected, is 73 km^2 and its average depth is 16 m. The lake is highly heterogeneous hydrologically, and the human impact is variable. The central

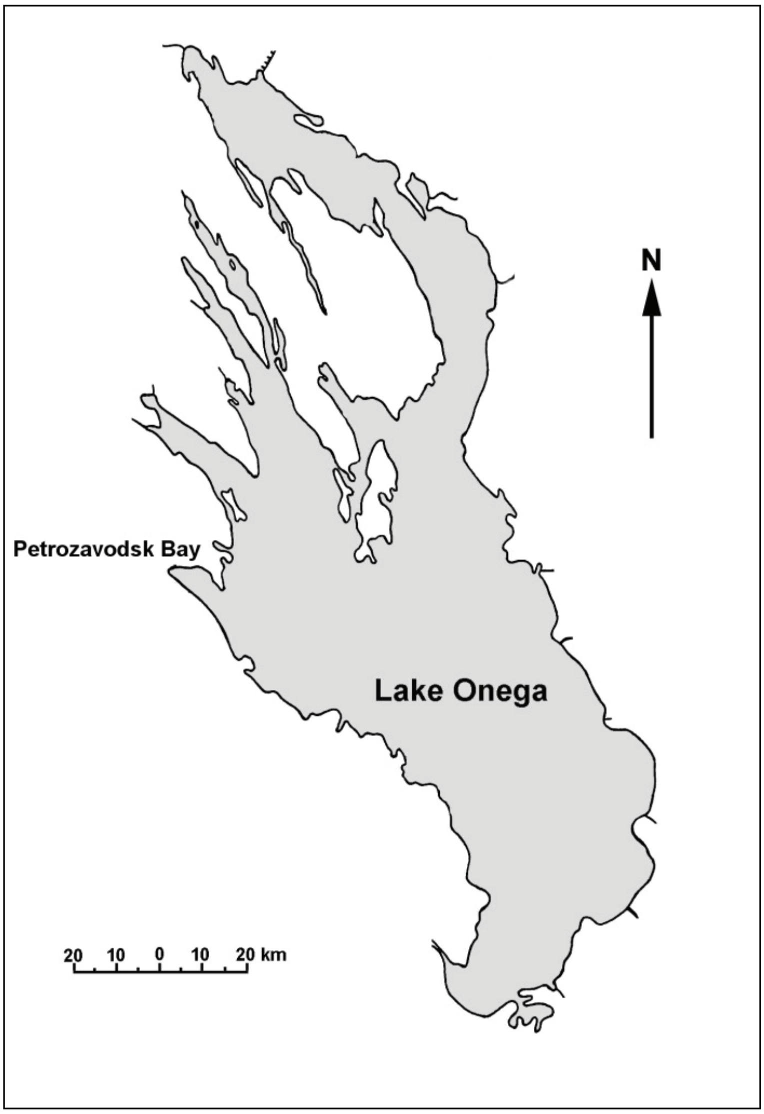

Figure 1: Study area.

deep-water zone, formed of the Great Onega region and Povenets Bay, has retained an oligotrophic status. Large bays, such as Kondopoga Bay and Petrozavodsk Bay, have become mesotrophic. Some bays and areas are near-eutrophic [13, 14].

According to Kalinkina et al. [11], the total abundance of *G. fasciatus* in June-July 2005 was 132-462 ind./m^2 in Petrozavodsk Bay and 2280-2680 ind./m^2 in other parts of Lake Onega. The authors attribute the low abundance in Petrozavodsk Bay to the lack of thick higher aquatic vegetation stands, where the species is most abundant.

Ichthyological samples were collected with monofilament nets (mesh size 10-20 mm) in July 2019-2020 and in September 2021 in the littoral zone of Petrozavodsk Bay of Lake Onega at a depth of 0.5-1.5 m (Fig. 1). The sample size was 177 *Perca fluviatilis* specimens. The samples were treated by commonly accepted methods [15-18].

3. Results

Lake Onega is inhabited by 36 cyclostome and fish species of 15 families. The whitefish *Coregonus lavaretus*, the bream *Abramis brama,* and the ruffe *Gymnocephalus cernuus* are typical benthos-eaters. However, benthic organisms are part of the diet of most juvenile fish species inhabiting the lake [9, 19].

Perch is an abundant fish species in Onega. Its distribution is confined to the littoral zone and the shallowest open lake areas [20, 21]. Thus, the habitats of perch and of the Baikal amphipod in the lake largely coincide.

According to Gulyaeva [20], Onega Lake perch is represented by two ecological forms that differ in habitats, food composition, and growth rates. The small shallow-water perch grows slowly and feeds on invertebrates, while the deep-water perch grows rapidly and mainly behaves as a predator, consuming juvenile fish of various species. It should be noted that 2-3 forms (races) of perch often occur in large lakes and storage reservoirs with diverse food supply and an abundance of suitable habitats [22].

Onega perch fingerlings are predominantly plankton-eaters, but juveniles in the second year of life feed on both benthos and plankton. Three-year-old perch switches completely to feeding on benthos, and it is not until juvenile perch is at least 10 cm in length that it begins to predate [23]. It should be noted, however, that perch eats benthos until it is seven to eight years old (AD length up to 29 cm) [20]. According to Alexandrov [24], only 23% of perch in the lake eat nothing but benthos. Perch diet consists of various bottom-dwelling organisms (chironomids, caddis flies, dobson flies, and mayflies), including crustaceans (mysids, pallacea, etc.).

To assess the contribution of the Baikal amphipod to the food ration of fish, the feeding of perch as the most abundant species in the littoral zone of Lake Onega was studied. Perch samples consisted of four age groups (2+-5+), and four-year-old fish accounted for about 70%. The average size of the fish (AD) was 14 cm (12.0-16.5 cm) and the body mass was 40 g (30-65 g). No substantial differences were observed in the feeding of the different age groups. The composition of the perch diet was quite diverse (Fig. 2). Benthic organisms dominated in prevalence and biomass (over 90%). Mayfly larvae (63% in summer, 59% in autumn) and the Baikal amphipod (18% in summer, 14% in autumn) were the most common, while chironomid and oligochaete larvae were scarcer. Planktonic organisms were mostly represented by littoral forms of copepods and cladocerans (about 5%). Mayflies (42% in summer, 56% in autumn) and amphipods (51% in summer, 32% in autumn) stand out in terms of biomass, while other organisms contribute a small share. The index of stomach fullness of the fish was within 2300/000

(15.1-230), the average index being 1230/000. Perch did not behave as predators, which could be due both to the ongoing fishing season and the hydrological characteristics of the shoreline (surf zone and the absence of macrophytes).

Analysis of the results shows that perch in the fourth to sixth years of life are predominantly benthos-eaters. The fish that inhabited the littoral zone eagerly consumed the Baikal amphipod, a new food item. During the summer-autumn season, the colonizer accounted for over 50% of the biomass in the stomach of juvenile perch. The invasion of Lake Onega by the Baikal amphipod has thus led to changes in the structure of littoral communities and the availability of a new food item to the fish.

4. Discussion

As the Baikal amphipod in Lake Onega has become more abundant, it is not clear which population growth phase the invasive species is in (the species colonized the lake about 10 years ago). Considering the resistance of the Baikal amphipod to unfavourable environmental factors and its biological characteristics, it is also important to study the ways of its spatial expansion and the possible penetration of the amphipod via tributaries to other water bodies in Lake Onega Lake catchment.

Genetically different invertebrates, including amphipods, have been lately reported to more rapidly invade European water bodies, leading to changes in the species diversity of the ecosystems [2]. The physical removal of natural barriers between different drainage basins by humans is an essential factor for the penetration of amphipods into new water bodies [6]. Some authors assume that the invasion of water bodies by aquatic animals, including the invasion of northern waters by thermophilic organisms, could have been facilitated by climatic changes, e.g. a warming event [25]. The vagility of amphipods contributes greatly to their invasion. It is typical of many amphipods in both freshwater and marine ecosystems [26]. The ability to migrate horizontally and acyclically raises the population's survival chances under unfavourable impacts.

Analysis of the data shows that intentional introductions have led to changes in the areas inhabited by many amphipod species. Large-scale introductions of amphipods were conducted in Russia in the 1950-1970s [27]. Many species introduced rapidly from one environment to another without an acclimation treatment failed to naturalize. However, the Baikal amphipod, characterized by a short life cycle, high fecundity, rapid growth, early maturation, and resistance to contaminants, is now actively colonizing Russia's water bodies [28].

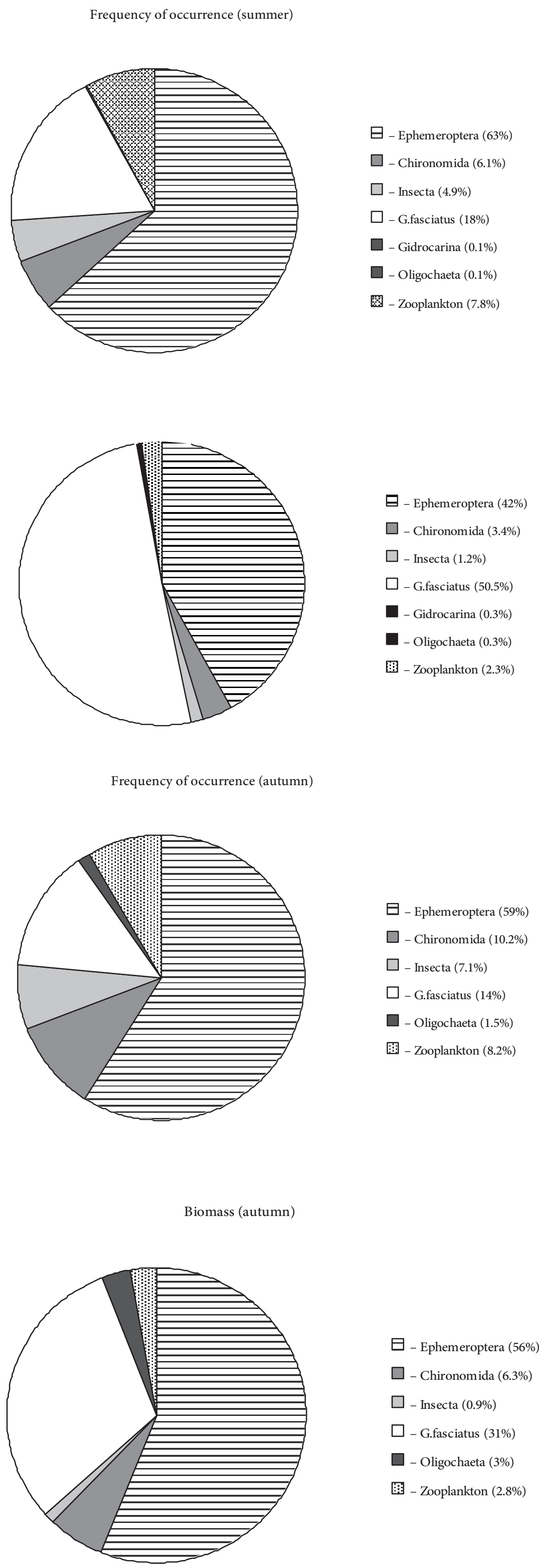

Figure 2: Food composition of juvenile perch (*Perca fluviatilis*) in Lake Onega.

On invading a new water body, amphipods sometimes augment the food supply for fish. It has been noted e.g., that the Baikal amphipod contributes considerably to the food supply of benthos-eating fish in Lake Otradnoe, Leningrad Region [29]. Amphipods made up about 10% of the food bolus of juvenile bream and roach, and prevailed in perch (65% on average).

However, alien amphipods may bring over fish parasites to the new ecosystems. For example, *G. fasciatus* carries several acanthocephalan species of the genus *Acanthocephala* [30]. Alternatively, in the absence of native amphipods, alien ones can serve as intermediate hosts for their parasites.

5. Conclusions

Thus, the main factors conducive to the invasion of amphipods are of anthropogenic origin [28]. The removal of natural barriers and alteration of natural habitats contribute to the invasion of new ecosystems by amphipods, their successful naturalization, and displacement of native species.

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