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Feeding Peculiarities of the Juveniles of the Atlantic Salmon (*Salmo salar* L.) Infected with the Invasive Parasite *Gyrodactylus salaris* in the Keret River

I. A. Tyrkin[a], Ya. A. Shustov[b], E. N. Rasputina[b], and A. G. Legun[b]

[a]*Northern Fisheries Research Institute, Petrozavodsk State University, nab. Varkausa 3, Petrozavodsk, 185031 Russia*
e-mail: igor7895@yandex.ru
[b]*Petrozavodsk State University, pr. Lenina 33, Petrozavodsk, 185910 Russia*
e-mail: shustov@petrsu.ru, belyakovalena@yandex.ru, osdel@rambler.ru

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Abstract—Extremely low feeding intensity was registered for the juveniles of Atlantic salmon inhabiting the Keret River (the White Sea basin) and infected with the invasive monogenean *Gyrodactylus salaris*. This was due to the asthenia observed during the summer period. The infected fingerlings and parrs were characterized by single specimens of the bottom invertebrates in their guts (larvae of caddis flies, nymphs of stoneflies and mayflies, and mollusks). The stomach filling index in these specimens was five to seven times lower comparing to the healthy individuals inhabiting the Ponoi and Kachkovka rivers (Kola Peninsula). About one-third of the infected fingerlings had empty guts, which was never observed for the juveniles of the wild populations of Atlantic salmon during the summer growth period in the rivers of Karelia and the Kola Peninsula.

Keywords: Atlantic salmon, invasion, feeding, alien species

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INTRODUCTION

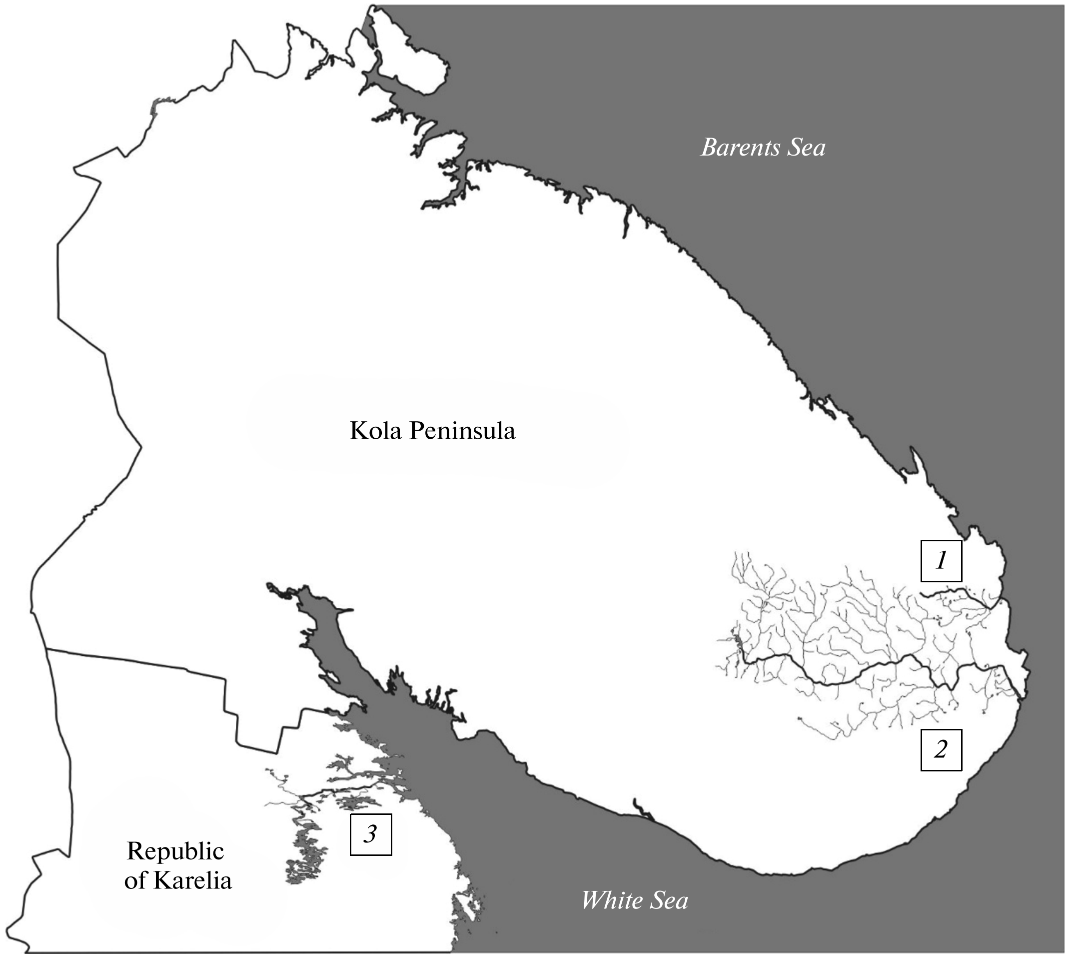
It is known that the Atlantic salmon (*Salmo salar* L.) inhabiting White Sea is characterized by a wide spectra of species-specific parasites infecting it historically; some of these parasites are pathogenic (Mitenev and Karasev, 1995). In 1992, the monogenea *Gyrodactylus salaris* was found for the first time in the Keret River (watershed area of the White Sea) (Ieshko and Shul'man, 1994). This penetration was due to the fry stock originating from a Petrozavodsk fish hatchery (Lake Onega watershed area) (Ieshko et al., 2008; Artamonova et al., 2011). Fingerlings of the Atlantic salmon are extremely vulnerable to infection, which causes their higher mortality rate compared to the older age groups.

This dangerous parasite nearly eliminated the Norwegian population of the Atlantic salmon in the last century (Bakke et al., 2007; etc.). According to monograph *Atlantic Salmon of the White Sea: Problems of Reproduction and Management* (Kalyuzhin, 2004), Norwegian researchers described a severe problem (Johnsen and Jensen, 1991): "For the first time, *Gyrodactylus* was registered in Norway in 1975 as a parasite of the Atlantic salmon. By 1990, it penetrated into 32 rivers and infected 35 salmon fish farms from southern to northern Norway. The population of Atlantic salmon infected by this parasite is nearly eliminated within 1–5 years. Monogenea *G. salaris* feeds on the mucus and epithelial cells; as a result of this, ulcerations appear, the gill tissues die, and the blood composition changes, so the infected fish grows slowly, loses weight, and finally dies."

The monitoring of the population of the Atlantic salmon of the Keret River performed by the researchers at the Northern Fisheries Research Institute, Petrozavodsk State University, showed that a significant decrease in the fish population occurred after the appearance of this invasive parasite (Ieshko et al., 2008), and the gene pool and phenotypes of this population also changed greatly (Artamonova et al., 2011). The study aims to analyze the changes in feeding peculiarities of the juveniles of the Atlantic salmon in river in the summer period after the invasion of the dangerous parasite *G. salaris*. No data exist on the influence of the invasive species *G. salaris* on the feeding of juveniles of the Atlantic salmon in the natural environment.

MATERIALS AND METHODS

The infected specimens were caught in the Keret River (figure) in August 2010 by electric fishing gear in the lower rapids situated in 1 km upstream of the mouth. The specimens were immediately placed in



Sampling site map of the studied rivers of the watershed area of the White Sea: (*1*) the Kachkovka River; (*2*) the Ponoi River; (*3*) the Keret River.

96% ethanol. The material was analyzed in the laboratory using the method of reduced parasitological examination (Barskaya et al., 2008). The fins and gills were studied under a stereomicroscope to assess the intensity of invasion by *G. salaris*. The feeding was analyzed by the standard methods (*Metodicheskoe posobie…*, 1974). In particular, this included assessing the food spectra, counting the number of the food items, and calculating the stomach filling index (Table 2). The last parameter was calculated as the rate of the tenfold bolus weight (mg) to the fish body weight (g) and expressed as prodecimille (‱). In total, fifteen specimens of juveniles of different ages sampled in the Keret River were taken for the analysis (0+, 10 ind.; 1+, 2 ind.; 2+, 3 ind.). For comparison, we provide here the data on the feeding of fingerlings and parrs of the Atlantic salmon inhabiting two other rivers belonging to the watershed area of White Sea and located on the Kola Peninsula coast: Kachkovka and Ponoi rivers (figure). These data were obtained in August 2008. In the Ponoi River, 62 specimens were analyzed (0+, 25 ind.; 1+, 29 ind.; 2+, 8 ind.); in the Kachkovka River, 60 specimens (0+, 17 ind.; 1+, 31 ind.; 2+, 12 ind.).

RESULTS

In 2010, the abundance of the juveniles of the Atlantic salmon in the Keret River was very low; only fifteen specimens were sampled. All the sampled fish were infected with *G. salaris* (Table 1).

Table 1. Extensiveness and intensity of infection of juvenile Atlantic salmon with the parasite *G. salaris* in the Keret River

Age of the fish	Number of studied specimens (*n*)	Extensiveness of infection, %	Intensity of infection, ind./fish specimen
0+	10	100	18.41
1+	2	100	34.58
2+	3	100	132.36

Table 2. Feeding of the juveniles of Atlantic salmon infected with *G. salaris* in the Keret River (August 2010)

Food composition	Age of the fish		
	0+	1+	2+
Chironomidae (L.)	10.0*/+	–	–
Ephemeroptera (N.)	50.0/2.1	50.0/1	66.6/1
Plecoptera (N.)	60.0/2.2	100.0/3.5	66.6/2
Trichoptera (L.)	70.0/2.3	50.0/1.5	66.6/2
Mollusca	–	–	33.3/+
Stomach filling index, ‱	35.2	33.4	19.6
Total number of food items, ind.	6.7	6.0	5.7
Fish body length (AB), cm	7.2	10.6	16.4
Fish body weight, g	3.6	11.5	41.9
Number of studied fish specimens, ind.	10	2	3

* The numbers above the line indicate the frequency of occurrence, %; below the line, average number of studied specimens, ind.; "+" indicates less than one specimen. L.—larvae; P.—pupae; N.—nymphs.

Table 3. Feeding of the juveniles of the Atlantic salmon in August 2008 in the Ponoi River and the Kachkovka River, the watershed area of the White Sea

Age group	Ponoi River			Kachkovka River		
	n	total number of food items, ind.	stomach filling index, ‱	*n*	total number of food items, ind.	stomach filling index, ‱
0+	25	13	323	17	13	129
1+	29	51	202	31	53	159
2+	8	91	195	12	69	76

Both fingerlings (0+) and parrs (1+ and older) of the Atlantic salmon infected with *G. salaris* and inhabiting the Keret River fed scarcely (Table 2). In August, the fish usually feed and grow actively; the studied specimen carried only several food items in the guts (5–6 on average). The food spectra were represented by three groups of invertebrates (nymphs of stoneflies and mayflies, larvae of caddis flies). Terrestrial and flying insects were absent in the guts of parrs (age groups 1+ and 2+). Feeding rates were extremely low: the stomach filling index was in the range of 20–35‱; one-third of all the fingerlings were characterized by empty guts.

The feeding activity of the healthy (noninfected) juveniles of Atlantic salmon inhabiting the Kachkovka and Ponoi rivers (Table 3) corresponds to the range of the feeding rates of the fingerlings and parrs of the same species inhabiting the rivers of Karelia and Kola Peninsula (Shustov, 1983, 1990; Belyakova, 2013). The food spectra were represented by the list of the zoobenthic species specific to the salmon rivers of White Sea: larvae and pupae of chironomids and sand flies, nymphs of stoneflies and mayflies, and larvae of caddis flies, as well as imagoes and subimagoes of the aquatic, terrestrial, and flying insects occurring on the water surface and in the stream. The number of the food items in the guts of these fish was dozens of individuals; the stomach filling index was in the range of 100–300‱.

DISCUSSION

Our studies show that infected juveniles of Atlantic salmon inhabiting the Keret River were characterized by significantly lower stomach filling index (5–7 times) compared to healthy specimens from the Ponoi and Kachkovka rivers (Kola Peninsula). The number of food items was half as much in the bolus of the fingerlings and about nine times lower in older age groups. Undoubtedly, such scarce feeding of both fingerlings and parrs of the Atlantic salmon in the Keret River during the summer period was caused by the invasive parasite *G. salaris* that infected the fish. The fish cannot perform active movements to catch food in the stream and on the surface within their territories because of the infection and, therefore, low phisical condition. As a result, the food spectra of these fish comprised only single specimens of large benthic invertebrates that can be found in vicinity of their permanent location. Earlier, the imagoes of Diptera comprised 99% by biomass of the bolus in the noninfected parrs of the Atlantic salmon inhabiting the Keret River (Kostylev and Kriulin, 1972).

CONCLUSIONS

Therefore, our study indicates that the juveniles of the Atlantic salmon infected with the dangerous invasive parasite *G. salaris* nearly stop feeding during the period of active growth. This has a negative effect on the linear growth rate and the weight gain, so their survivability in the winter period may also decrease.

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