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OCCURRENCE OF PROTEOCEPHALUS PERCAE AND P. CERNUAE IN THE PERCH AND RUFF IN NORTHERN FINLAND

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Abstract. The occurrence of two palearctic *Proteocephalus* species, *P. percae* and *P. cernuae*, in the perch and ruff, respectively, was studied in two areas of northern Finland in 1977—1983. In the Bothnian Bay, 243 perch (*Perca fluviatilis*) and 406 ruff (*Gymnocephalus cernuus*) were studied, of which 60 % and 40 %, respectively, were infected, while in Lake Yli-Kitka the prevalences were 10 % in 213 perch and 24 % in 307 ruff. Higher mean intensities of infection were found in the Bothnian Bay fish than in those from the lake, but no infected fish had as many as 10 worms. *Proteocephalus* infection in the perch and ruff did not vary significantly according to the length of the fish in either area, except that no *P. percae* were found in perch smaller than 70 mm in the lake. There was a prominent seasonal variation in the occurrence of *P. cernuae* in the ruff in both areas, but especially in the lake, where no proteocephalids were found in the ruff in July-October. Overlapping of generations was evident in *P. percae* in the sea perch, although only by virtue of the lack of mature worms at the end of the summer. Some mature proteocephalids were also found in winter in both fish species in the sea and in the ruff of the lake. The higher mean intensity values in winter, especially in *P. cernuae* infection in the sea ruff, may be explained partly by the active feeding of the ruff at this time in spite of very low water temperatures. Feeding activity in the perch is lower in the winter, and hence a lower mean intensity of *P. percae* infection was seen especially in the lake material at that time.

The seasonal occurrence of *Proteocephalus percae* (Müller, 1780) has been studied earlier in the perch (*Perca fluviatilis*) by Wierzbicki (1970), Wootten (1974) and Andersen (1978) and in pike by Moravec (1979), and that of *P. cernuae* in the ruff (*Gymnocephalus cernuus*) by Molnár (1966) and Willemse (1969). Schulman (1961) and Rybak (1985) have reported the occurrence of *P. percae* in the perch and Schulman (1961: and Rumjantsev and Maslov (1985) that of *P. cernuae* in the ruff in the Soviet Karelian lakes.

Temperature is known to have a strong influence on the development of fish parasites, e.g. there may be a pronounced delay in development in a colder environment (Dogiel 1958). It is not known, however, whether seasonal variation and development in proteocephalids are influenced by prolonged low temperatures in a water body, what is the case in present study.

This paper provides information on seasonal and size-bound infection of perch and ruff by *P. percae* and *P. cernuae*, respectively, in two water bodies in northern Finland. The waters of the oligotrophic Lake Yli-Kitka flow eastwards to the White Sea (USSR), while the Bothnian Bay is the oligohaline northeastern part of the Gulf of Bothnia, part of the Baltic Sea. The lake is covered by ice for about 7—8 months in the year and the Bothnian Bay for 6 months. The pronounced coldness of the two areas gives an additional aspect to the study of seasonality in proteocephalid populations. Another interesting aspect is the fact that the water bodies have been isolated from each other for the last 8400 years following the deglaciation of Scandinavia, when the connection of Lake Yli-Kitka with the Baltic Sea was severed and its waters began to flow only to the White Sea in the east (Heikkinen and Kurimo 1977).

STUDY AREAS, MATERIALS AND METHODS

The two study areas are described in more detail in the authors' earlier paper (Rintamäki and Valtonen 1988). Shortly it may be repeated that coldness is characteristic for both study areas. Despite the prolonged ice cover of half a year in the sea and 7—8 months in the lake, e.g. water temperature of the lake was above 10 °C in 1981 only two and half months from the end of June onwards (Kankaala et al. 1984).

243 perch and 406 ruff from the Bothnian Bay, northeastern Gulf of Bothnia, Baltic Sea, and 213 perch and 307 ruff from Lake Yli-Kitka in northeastern Finland were studied for proteocephalids in March 1977 — January 1979 in the sea and in March 1980 — June 1983 in the lake. Monthly or bimonthly samples of 20—30 freshly killed fish were caught using seine nets. In the open water period the perch and ruff from the Bothnian Bay were taken from trawl-net or fyke-net catches. A few samples were frozen before examination. After relaxing the living proteocephalids in tap water, they were conserved in 70 % ethanol for later examination. The worms in the fish from the Bothnian Bay were divided into immature and mature ones, while in the Lake Yli-Kitka material gravid worms were recognized as a separate group (mature worms being those in which the genitals are developing or developed and gravid worms those which have eggs). A rough analysis was also made of the food of the Bothnian Bay fish, and parallel samples for stomach analysis were taken from 9 monthly catches of ruff in the lake. The dispersion of *P. percae* and *P. cernuae* was studied in terms of the variance-to-mean ratio.

RESULTS

Both the prevalence and the mean intensity of *P. percae* infection in the perch of the Bothnian Bay was higher than in Lake Yli-Kitka (60 and 10 %, 9 and 2 worms /inf. fish, respectively), and a similar difference, although not so prominent, was found in the prevalence of *P. cernuae* infection in the ruff in the two areas (Table 1).

Table 1. Occurrence of *Proteocephalus percae* in the perch and *P. cernuae* in the ruff in the Bothnian Bay and Lake Yli-Kitka

	Date	No. of fish	Prevalence (%)	$\bar{x}$/inf. fish	$\bar{x}$/fish	$\frac{s^2}{\bar{x}}$
P. percae in *Perca fluviatilis*						
Bothnian Bay	III 77—XI 78	243	60	8.9	5.3	28.9
Lake Yli Kitka	III 80—VI 83	213	10	1.8	0.1	2.3
P. cernuae in *Gymnocephalus cernuus*						
Bothnian Bay	III 77—I 79	406	40	3.7	1.5	7.1
Lake Yli-Kitka	III 80—III 82	307	24	2.7	0.7	4.6

Seasonal occurrence

The prevalences of *P. percae* in the Bothnian Bay perch came close to or exceeded 50 % in most monthly samples, the lowest records being found in November 1977 and January 1978. The lack of seasonal variation was found especially in the mean intensity of infection in the perch, with only 3—6 worms per infected fish in most cases. Only one higher record was found, in May 1977, with mean of 29 worms per infected fish (Fig. 1). The prevalence of infection in the lake was low (10 %), and hence the data are not sufficient to analyse seasonal variation in *P. percae* in the perch of that area. Accidental high prevalences are possible at these northern latitudes,

however, as is shown in the values for the samples collected separately in July 1982 and June 1983 (Table 2). Mature worms were found in the Bothnian Bay throughout the year except in September 1977 and August 1978. In Lake Yli-Kitka, mature worms were found only in June-August and gravid ones in June-July (Fig. 1, Table 2). At other times only a few worms were found in the lake.

Clear seasonal variations were found in the prevalences of *P. cernuae* infection in the ruff of both study areas, with the lowest values in the latter half of the year in the lake, where there was a clear gap between the *P. cernuae* generations, occurring in July-October 1980. In the Bothnian Bay material there is a slight difference between the two years studied as far as the lowest prevalences are concerned. The

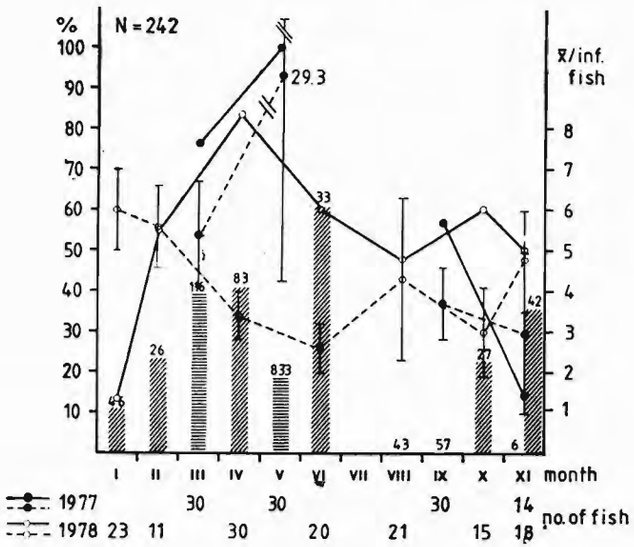

Fig. 1. Seasonal variations in the prevalence (%, solid line) and mean intensity of *Proteocephalus percae* infection (worms per infected fish and 95 % confidence limit) in the perch of the Bothnian Bay. The columns indicate the proportions of mature worms (%) among all the worms collected (≡ in 1977 and /// in 1978). The total number of worms found in each monthly sample is depicted at the end of each column.

Table 2. Seasonal variations in prevalence (%), maturation and mean intensity of *Proteocephalus percae* infection in the perch of Lake Yli-Kitka

Date	No. of fish	%	No. of worms	No. of mature worms	No. of gravid worms	$\bar{x}$/inf. fish
1980 III—IV	20	5.0	1	—	—	1.0
VI—VIII	48	8.3	5	3	—	1.5
IX—XII	67	1.5	1	—	—	1.0
1981 I—IV	36	5.6	2	—	—	1.0
1982 III	10	—	—	—	—	—
VII	15	53.3	19	19	19	2.4
1983 VI	17	35.3	11	11	11	1.8

decrease in prevalences was not so clear at the end of 1978 as it was at the end of 1977. The intensity of infection followed the course of the prevalence curves in both areas. Mature worms were aslo seen in winter in both areas, and gravid worms in June 1980 in the lake (Fig. 2).

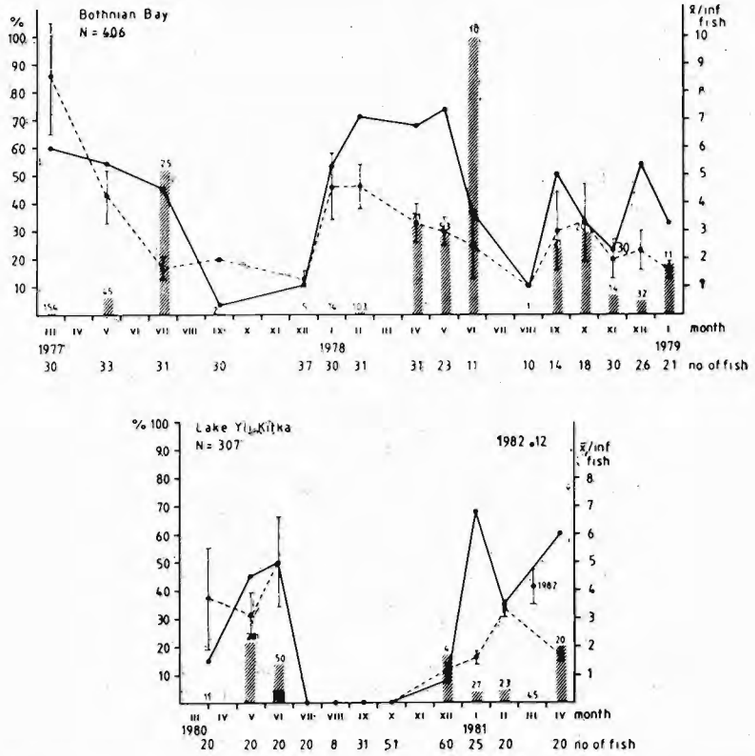

Fig. 2. Seasonal variations in the prevalence (%, solid line), and mean intensity of *Proteocephalus cernuae* infection (worms per infected fish and 95 % confidence limit) in the ruff of the Bothnian Bay and Lake Yli-Kitka. The columns indicate the proportions of mature (///) and gravid (■) worms (%) among all the worms collected. The total number of worms found in each monthly sample is depicted at the end of each column.

Occurrence of proteocephalids in relation to length of fish

P. percae prevalences in the perch in the Bothnian Bay varied between 40 and 70 % in most cases, except for a peak in fish of size classes 180—200 mm of fish and a minimum record of 20 % in the size class 210—220 mm. The smallest perch caught in the lake (< 70 mm) did not harbour any proteocephalids at all. The prevalence and mean intensity of infection remained low in size classes 70—130 mm, after which a peak of 70 % prevalence was found (Fig. 3).

Mean intensity of infection revealed a clearer variation with the length of the perch in both areas, the middle-sized fish having the highest numbers of worms per infected fish in both areas. The variation-to-mean ratios had a similar tendency. Overdispersion

of *P. percae* infection was clear in the sea perch, but a random distribution prevailed in the lake.

The prevalences of *P. cernuae* infection in the ruff of the two areas were quite stable in relation to length of fish, although a slight decrease was found in the largest size classes. The same was found in the mean intensity of *P. cernuae* infection. The variance-to-mean ratio indicated overdispersion in most cases (Fig. 4).

Feeding activity in the perch of the Bothnian Bay and the ruff of both areas was high in all cases, 73 % of the perch and more than 90 % of the ruff in both areas

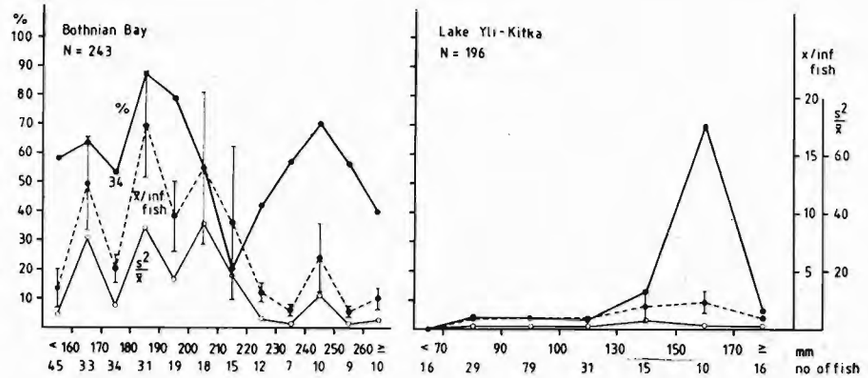

Fig. 3. Prevalence (%). mean intensity and over-dispersion index $\left(\frac{s^2}{\bar{x}}\right)$ of *Proteocephalus percae* infection in perch of different size classes in the Bothnian Bay and Lake Yli-Kitka. No. of fish studied is given below the figure.

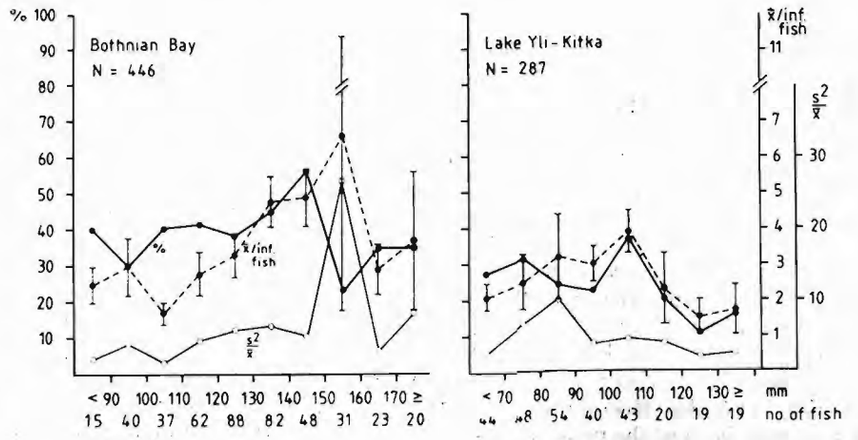

Fig. 4. Prevalence (%). mean intensity and over-dispersion index $\left(\frac{s^2}{\bar{x}}\right)$ of *Proteocephalus cernuae* infection in ruff of different size classes in the Bothnian Bay and Lake Yli-Kitka. No. of fish studied is given below the figure.

having at least some food in their stomachs. Seasonal variation was clear in the sea perch, the lowest values being found in midwinter (Fig. 5). In the ruff, lower values, 70 % and 44 %, were recorded only in the sea during the spawning time in May, in 1977 and 1978, respectively. In Lake Yli-Kitka at least 75 % of the ruff had food in their stomachs throughout the year.

8 % of the ruff stomachs studied in the sea and 13 % in the lake contained copepods, the potential intermediate hosts of proteocephalids. There were great differences between the sea and lake specimens regarding other food objects, the most common of which were Chironomidae larvae (93 %), Cladocera (36 %), Trichoptera (22 %), Ephemeroptera (15 %) and Sphaeridae (14 %) in the lake ruff and amphipods (43 %), ostracods (33 %), Chironomidae larvae (29 %), Mysidae (14 %) and fish (5 %) in the sea. The proportion of copepods was also low in the sea perch (1 %), but that of fish most prominent (56 %) (Fig. 5), Mysidae (22 %), Chironomidae larvae (4 %) and gammarids (4 %) being in the minority in the stomach contents.

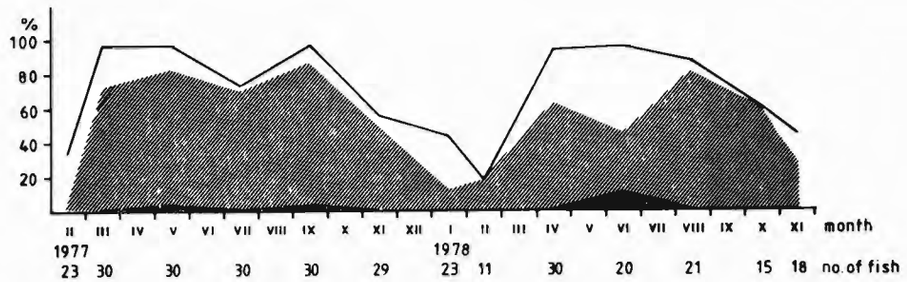

Fig. 5. Feeding activity (%) of perch in the Bothnian Bay. The shaded areas depict the proportions of stomachs containing fish and the black areas the proportions containing copepods.

DISCUSSION

According to Barysheva and Bauer (1957) and Shulman (1958), *P. percae* and *P. cernuae* are palearctic species found in northern Europe and Asia. *P. cernuae* is chiefly found in the intestine of the ruff and perch and occasionally in the pike-perch, pike and stickleback (Yamaguti 1959; Bykhovskaya—Pavlovskaya et al. 1962). According to experimental work by Willemse (1969), *Cyclops scutifer* may act as an intermediate host in the life cycle of *P. cernuae*. This species does not occur in the present study areas.

According to Yamaguti (1959), 9 fish species may act as the definitive host for *P. percae*, of which the perch is most important. Many copepod species have been reported as intermediate hosts, e.g. *Cyclops strenuus*, *Eucyclops serrulatus*, *Thermocyclops oithonoides* (Ginetsinskaya 1958), *C. vicinus* and *E. agilis* (Freze 1965), *M. leuckarti* and *Acanthocyclops viridis* (Wootten 1974). *M. leuckarti* and *T. oithonoides* occur in both of the present areas and *A. viridis* in the Bothnian Bay (Vasama 1986, Kankaala 1987), but their possible role as intermediate hosts for *P. percae* has not been studied.

The prevalence of *P. percae* in the sea perch (60 %) was higher than in earlier

reported cases in perch (about 40 % according to Wierzbicki 1970, Andersen 1978 and Rybak 1985). On the other hand, Shulman (1961) has found a perch population with only 6.6 % infection in a Soviet lake although a 33 % prevalence was found in another lake. Concerning *P. cernuae* infection in the present lake ruff the mean prevalence was clearly higher than that found in ruff from Soviet Karelian lakes (24 % compared with 7 %) (Shulman 1961, Rumjantsev and Maslov 1985). Proteocephalid infection in the ruff of the Bothnian Bay was closest to the figures found by Molnár (1966) and Willemse (1969) (40 % compared with 52 and 30 %, respectively).

As far as the high prevalence of *P. percae* infection in the fish of the Bothnian Bay is concerned, one may wonder at the low proportions of copepods in the diet of the larger fish. It has been suggested that larger perch obtain their proteocephalids by eating smaller ones. The proportion of fish in the diet of the perch was high (56 %) and supports this suggestion, especially as Willemse (1968) has confirmed experimentally the transplantation of proteocephalids from one fish to another ones through. In addition one should remember that the proportions of the smallest and youngest perch in the present material do not conform to the role of the same sizeclasses in the sea and lake, because fishing gear is selective for larger size classes.

The high amount of food objects in the stomachs of the ruff in winter in both study areas may partly be due to reduced assimilation in the very cold water temperatures, which keeps near 1—3 °C for months in both areas. This cannot be the main reason, however, because there were clear lowered values for the food in the stomachs of the perch in midwinter, and in this case the feeding activity of fish had quite obviously declined in addition to reduced assimilation. The variability in ruff food objects reflects the opportunistic food habits of this species, utilizing the food available in its environment.

The more abundant feeding of the larger perch has obviously caused the peak in the prevalence of *P. percae* infection in the lake material to move up to fish of size 170 mm or more. The decrease from this size-class onwards is difficult to explain, especially since no similar phenomena were found in the sea perch or in the ruff in either area. The low prevalences in middle-sized fish in the Bothnian Bay material may be due to be an accident.

The quite stable situation concerning the occurrence of *P. cernuae* in the ruff in both areas may be explained by the younger fish feeding on copepods and by the larger fish obtaining them through predation by post-cyclic transmission. Bauer and Nikol'skaya (1957) report the role of changes in diet as a function of age to influence in the parasite fauna of fish.

Wierzbicki (1970) and Halvorsen (1972) found the lowest levels of *P. percae* prevalence in perch to occur in summer, while Andersen (1978) did not find any proteocephalids at all in perch in June-July. Although the present *P. percae* prevalences do not reveal any clear decrease in summer, the total lack of mature worms in Agust-September points to a change in parasite generations. Overlapping of the generations is evident in the sea, because half of the perch from that time harboured immature proteocephalids. This means that mature worms become gravid early in summer and produce their eggs. In the sea perch proteocephalids mature in spring and early summer. A new generation develops in the copepods in the warm summer temperatures and recruitment to fish starts by the end of summer. Maturation may also occur at the end of the year, although it was not studied whether these worms were also gravid in the sea material. The occurrence of mature worms in winter, as in present case, has also been reported by Wootten (1974) in England.

The occurrence of plerocercoids throughout the year in the intestine of perch in the present material may be evidence that infected copepods are available throughout the year or that development at all stages of the parasite population is delayed or ceases entirely at very low water temperatures during the time when the water bodies are covered by ice. The existence of infected copepods throughout the winter and spring, as is suggested in the present case, means that the total life span of proteocephalids may be prolonged to at least even more than a year. Reduced feeding activity and mortality in the low water temperatures may have caused the low prevalence values found in November 1977 and January 1978 (see also Hopkins 1959 and Tedla and Fernando 1969).

A clear seasonal cycle as is found in *P. cernuae* in the ruff of the present material is also seen in *Proteocephalus* sp. in the brown trout in Norway (Lien and Borgström 1973) and in *P. percae* in the perch (Andersen 1978) and in the pike in Czechoslovakia (Moravec 1979). The present lake material, however, may have had shorter gap between the generations, because the fish collected in September and October were the ones which were deep-frozen before studying. This may have influenced the rate of discovery of the smallest immature worms in the intestine. Molnár (1966) similarly found that the prevalence of *Proteocephalus* spp. infection in the ruff in Lake Nalaton was lowest in July-October and highest in January-June. The gap between *P. cernuae* generations in the Bothnian Bay is not so clear as in the lake, and may change somewhat according to the conditions each year. This may be an adaptation to northern latitudes. The lack of mature worms in the sea ruff in August confirms the change in proteocephalid generations.

Molnár (1966) reports the mean intensity of proteocephalid infection in the ruff to reach its peak in January-February. The highest mean intensities in the Bothnian Bay ruff were also found at the beginning of the year. This may be caused by he ruff eating actively throughout the year, which means that recruitment of new worms does not cease even in winter. Some mature worms are also found in winter in both areas. The present results suggest a certain flexibility on the part of the parasites which enables them to survive even under conditions as cold as in the present study areas, partly by prolonging their lifespan (see also Gibson and Valtonen 1984).

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ВСТРЕЧАЕМОСТЬ *PROTEOCEPHALUS PERCAE* И *P. CERNUAE* В ОКУНЯХ И ЕРШАХ СЕВЕРНОЙ ФИНЛЯНДИИ

Э. Т. Валтонен и П. Ринтамеки

Резюме. Встречаемость двух палеарктических видов рода *Proteocephalus*, *P. percae* и *P. cernuae* в окунях и ершах соответственно, изучались в двух районах северной Финляндии в 1977—83 годах. В районе бухты Bothnian Bay было изучено 243 окуня (*Perca fluviatilis*) и 406 ершов (*Gymnocephalus cernuus*), среди которых было инфицировано 60 % и 40 % соответственно, в то время как в озере Yli-Kitka встречаемость составила 10 % в 213 окунях и 24 % в 307 ершах. В среднем более высокая интенсивность инфекции была найдена в рыбах из бухты Bothnian Bay чем в рыбах из озера, но ни в одной из инфицированных рыб не было больше 10 червей. Интенсивность инфекции паразитами рода *Proteocephalus* в окунях и ершах в этих районах не менялась значительно в зависимости от размеров рыб, за исключением того факта, что в озере мы не нашли ни одного *P. percae* в окунях, длина которых была меньше 70 мм. Обнаружена сезонная зависимость встречаемости *P. cernuae* в ершах в обоих районах, особенно в озере, где с июля по октябрь не найдено ни одного протеоцефалида. Перекрывание генераций было заметно в случае *P. percae* в морских окунях, хотя только из-за отсутствия зрелых червей к концу лета. Несколько зрелых протеоцефалидов мы нашли зимой в обоих видах рыб в море и в ершах из озера. Более высокую интенсивность инфекции зимой, особенно в случае инфекции *P. cernuae* в морских ершах, можно частично объяснить активным кормлением ершов в это время несмотря на очень низкую температуру воды. Активность кормления окуней зимой ниже, и поэтому можно наблюдать в это время в среднем более низкую интенсивность инфекции *P. percae*, особенно в материале из озера.

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