Journal of Fish Biology (1991) 38, 573-586

Myxosporea parasites in roach, *Rutilus rutilus* (Linnaeus), from four lakes in central Finland

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(Received 8 May 1990, Accepted 16 November 1990)

Ten myxosporean species belonging to three families were found in roach, *Rutilus rutilus* (Linnaeus), obtained in 1985 and 1986 from four lakes in central Finland which are connected to each other, but differ in water quality. One of the lakes is polluted by paper and pulp mill effluent, two are eutrophic and one is oligotrophic and still in its natural state. Eight species were found in all the lakes. The most common species were *Myxidium rhodei* Léger, 1905, *Myxobolus muelleri* Bütschli, 1882 and *Myxobolus pseudodispar* Gorbunova, 1936 with prevalences varying between 66-80, 16-31 and 32-59%, respectively, in the four lakes. The largest difference in myxosporean prevalence between lakes was found in the case of *M. pseudodispar* infection, which was highly significantly lower in the polluted lake. The locations of the myxosporean species in the tissues of the fish were found to be species-specific. *M. rhodei* and *M. muelleri* being prevalent in the kidney and *M. pseudodispar* in the muscles.

No clear seasonal variation was found but a tendency for a decrease in infection with increasing age was recorded in the case of *M. rhodei* and *M. pseudodispar.*

Key words: *Rutilus rutilus;* Myxosporea; parasites; age bound infection; seasonality; Central Finland.

I. INTRODUCTION

Myxosporean parasites are very common in teleost fishes, and the myxosporean fauna of Cypriniformes are more numerous than that in other fish groups (Shulman, 1966). Faunistic investigations into Myxosporea in cyprinids have been carried out effectively in the U.S.S.R. from 1930 (e.g. Dogiel, 1932; Shulman, 1966), in Czechoslovakia from 1950 (e.g. Lom, 1969; Lom & Noble, 1984) and in Great Britain (Kennedy, 1974).

In spite of the common occurrence of myxosporeans in wild cyprinids, only a few investigations have been made into seasonal and age-linked occurrences and factors influencing the composition of the myxosporean fauna (Bond, 1939; Gorbunova, 1936; Polyansky & Shulman, 1956). The capacity of myxosporeans to become located in given tissues and cavities of the fish's body may influence the damage they cause to their hosts. Increasing human activity in recent times has altered the characteristics of many water bodies and the immunological responses of fish to parasites, especially species migrating in their tissues, may well have changed too.

The present purpose was to study the myxosporean fauna of the roach, *Rutilus rutilus* (Linnaeus), in four lakes in central Finland which differ in water quality,

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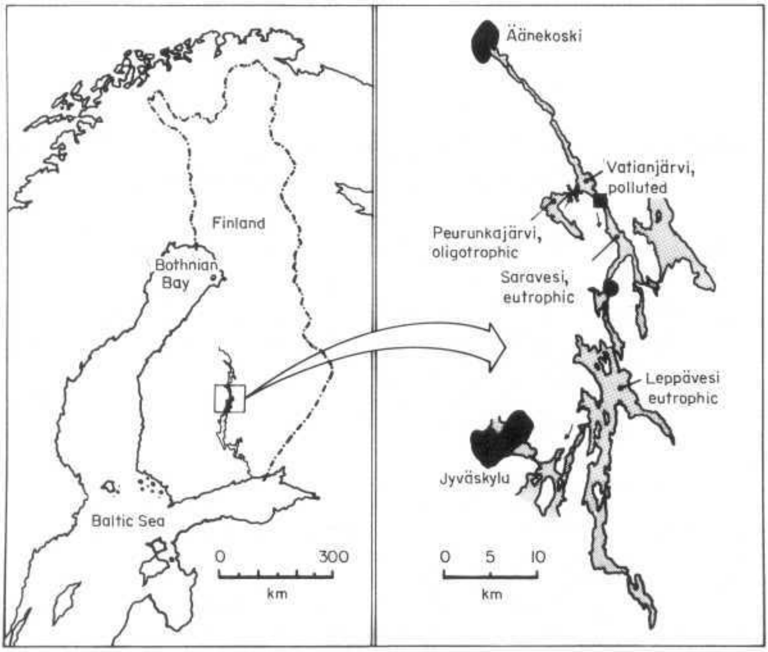


FIG. 1. Location of the four lakes studied in the Kymijoki river system (drainage basin). Obstacles for fish migration between the lakes are marked: ★, dam; ■, rapids; ●, hydro-electric power station.

TABLE I. Mean depths, surface areas, water volumes and retentions in the four lakes studied in central Finland

Lake	Mean depth (m)	Size (km^2)	Water volume (million m^3)	Water retention
Peurunkajärvi, oligotrophic	8.6	6.5	61.5	3-4 years
Vatianjärvi, polluted	4.0	5.5	22.6	3 days
Saravesi, eutrophic	11.0	7.8	37.8	4 days
Leppävesi, eutrophic	11.0	36.0	38.0	32 days

myxosporean species composition, location of the spores in the tissues of the fish and patterns of seasonal and size-linked infection.

II. THE AREA STUDIED

The chain of three lakes and another connected lake located in central Finland, form part of the Kymijoki river system, the waters of which flow into the Gulf of Finland (Fig. 1). Mean depths, surface areas, water volumes and their retentions are given in Table I.

The lakes are covered by ice from 20-25 November to 10 May on average, while the highest water temperatures, 18-20° C, are measured at the end of July and the beginning of August.

Lake Peurunkajärvi is oligotrophic and in a natural state, its waters drain into Lake Vatia, which is polluted by pulp and paper mill effluent from the town of Äänekoski situated upstream. The influence of the effluent is seen in the phytoplankton and benthic animal composition of the area (Granberg, 1983; Anttila, 1983).

The two other lakes, Saravesi and Leppävesi, are eutrophic (Granberg, 1983). Essential features of the area are the obstacles to fish migration between the lakes: a dam built between the natural and polluted lakes in the 1960s in connection with the building of the Laukaa Fish Culture Research Station, a powerfully flowing stretch of rapids separating the polluted lake from one of the eutrophic ones (Saravesi) and a hydroelectric power station between the two eutrophic lakes.

Fourteen freshwater fish species occur in all of the lakes. The most common species in the oligotrophic lake, Lake Peurunkajärvi, are the roach, perch, *Perca fluviatilis* Linnaeus, vendace, *Coregonus albula* Linnaeus, whitefish, *Coregonus* sp., ruffe, *Gymnocephalus cernuus* (Linnaeus), and pike, *Esox lucius* Linnaeus, while the pike, burbot, *Lota lota* (Linnaeus), bream, *Abramis brama* (Linnaeus), and zander, *Stizostedion lucioperca* (Linnaeus), occur more frequently in the eutrophic lakes Saravesi and Leppävesi (Kurttila & Hyvarinen, 1983).

III. MATERIALS AND METHODS

A total of 541 roach from the four lakes were studied for myxosporeans. Eleven and 10 monthly samples of about 15 fish, respectively, were collected from the natural and polluted lakes between September 1985 and November 1986, and eight samples from each of the eutrophic lakes between February and November 1986. The fish were caught mainly by angling or fishing through the ice. The fish were measured, weighed, sexed and aged. Myxosporeans were studied by the method described by Bykhovskaya & Pavlovskaya (1969). Cysts on the skin, fins and gills were counted and studied and the gills were also pressed between two pieces of glass and studied with illumination from below. Cysts of the inner organs were also studied by compressing the organs piece by piece between two slides with illumination from below and 10-25 x magnification. Cysts on the muscles were studied systematically in fish from all the lakes in 1986. This was done by pressing a 1.5 x 1.5 cm piece of muscle between two slides and using illumination from below. The muscle was taken from above the lateral line behind the dorsal fin. A scale of 1-4, 5-20, 21-50 and > 50 was used to estimate the number of cysts per fish in each organ other than in muscles where the number refers only to those found in the piece under examination.

Spores from broken cysts were studied fresh and permanent slides were made using glycerine jelly. The specimens were identified at 1800 x magnification with phase contrast, using the key published by Shulman (1984).

IV. RESULTS

Ten myxosporean species belonging to three families were found in the lakes, eight of which occurred in all four lakes (Tables II and III). The occurrence of *Henneguya* sp. and *Myxobolus macrocapsularis* Reuss, 1906 in one of the eutrophic lakes is incidental. The most common species in all the lakes were *Myxidium rhodei* Léger, 1905, *Myxobolus muelleri* Bütschli, 1882, and *Myxobolus pseudodispar* Gorbunova, 1936 the prevalence of which varied in the ranges 66-80, 16-31 and 32-59%

TABLE II. Prevalences of Myxosporea infection in the four lakes studied in central Finland between August 1985 and November 1986

	Peurunka, oligotrophic 166 fish studied		Vatia, polluted 136 fish studied		Saravesi, eutropic 128 fish studied		Leppävesi, eutrophic 120 fish studied
Myxidium rhodei Léger, 1905	65.7		73.5		79.7		72.5
Zschokkella nova Klokačewa, 1914	15.2		2.4		4.2		12.9
Myxobolus muelleri Bütschli, 1882	15.7	**	30.9		22.7		24.2
M. pseudodispar Gorbunova, 1936	49.1	***	32.4	***	58.6		55.8
						***	
M. macrocapsularis Reuss, 1906	—		—		—		0.9
Myxobolus spp. (see Table III)	6.6		7.4		9.4	*	18.3
						**	
						**	
Henneguya sp.	—		—		—		1.7
Chloromyxum sp.	0.7		1.6		5.9		3.4

Significant differences between the lakes are indicated: *P<0.05; **P<0.01; ***P<0.001, Student's *t*-test.

TABLE III. Occurrences of Myxosporean species in the tissues of roach, *Rutilus rutilus*, from the four lakes studied in central Finland, prevalences of Myxosporea infection in Lake Peurunka (P%), Lake Vatia (V%), Lake Saravesi (S%) and Lake Leppävesi (L%)

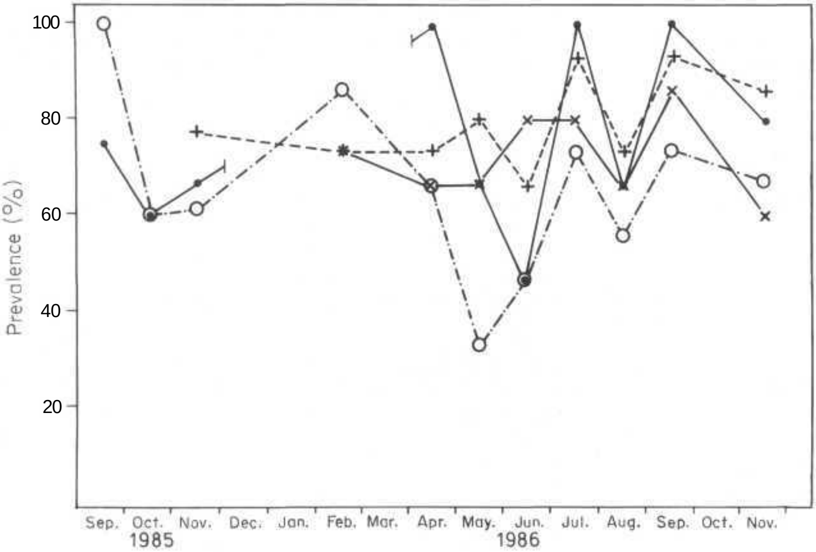
Species	Site	P%	V%	S%	L%
Myxidium rhodei	Kidney	62.0	72.8	79.7	72.5
	Musculature	3.0	2.2	—	—
	Liver	1.8	0.7	—	—
	Spleen	0.6	—	—	—
	Gonads	0.6	0.7	—	—
	Heart	0.6	—	—	—
	Swimbladder	0.6	—	—	—
Zschokkella nova	Gall bladder	15.2	2.4	4.2	12.9
Chloromyxum sp.	Gall bladder	0.7	1.6	5.9	2.6
	Gills	—	—	—	0.9
Henneguya sp.	Skin	—	—	—	1.7
Myxobolus spp.*	Gills	6.6	5.9	8.6	16.6
	Fins	—	0.7	—	1.7
	Skin	—	0.7	0.8	4.2
M. macrocapsularis	Gall bladder	—	—	—	0.9
M. muelleri	Kidney	11.4	26.5	18.0	19.2
	Liver	4.8	9.6	5.5	5.0
	Spleen	0.6	—	0.8	—
	Gall bladder	—	—	0.8	0.8
	Swimbladder	0.6	—	—	—
M. pseudodispar	Musculature	45.4	30.1	58.6	55.8
	Kidney	2.5	0.7	—	—
	Liver	—	0.7	—	—
	Spleen	1.2	—	—	—
	Gall bladder	0.6	—	—	—
	Eye	—	0.7	—	—

* *Myxobolus* cysts from the gills, fins and skin were not identified to species in every case. The proportions of the three species, *M. bramae* Reuss, 1906, *M. rutili* Donec et Tozyjakova, sp.n. and *M. elegans* Kaschkovsky, were 3 : 1.25 : 1 respectively.

respectively. In the case of *M. rhodei* and *M. muelleri* there was only one significant difference in the prevalence of infection when comparing the lakes in pairs (Table II), but *M. pseudodispar* infection differed significantly between the polluted Lake Vatia and the other three lakes, while *Myxobolus* spp. on the gills were significantly more numerous in the eutrophic Lake Leppävesi than in the other three lakes.

The locations of the present myxosporean species in the roach seem to be species-specific (Table III). *Chloromyxum* sp. was incidentally found on the gills and in the gall bladder, and *M. macrocapsularis* in the gall bladder. The most favoured site for *M. rhodei* and *M. muelleri* was the kidney, although cysts of their spores were also found in several other organs. *M. pseudodispar* was also found in a number of tissues, but most often in the muscles.

The seasonal variation in *M. rhodei* infection (Fig. 2) showed quite constant high prevalences throughout the year in all of the lakes except for lower values in May and June 1986 in the unpolluted lake (Peurunkajärvi) and in June in the polluted Lake Vatia. The monthly prevalences of *M. pseudodispar* infection (Fig. 3) varied



No. of fish studied

15	15	13	15	15	15	15	15	18	15	15	○
10	15	18		4	15	15	15	15	14	15	•
		9	15	15	15	15	15	15	15	14	+
			15	15	15	15	15	15	15	15	×

FIG. 2. Seasonal variation in the prevalence of *Myxidium rhodei* infection in roach, *Rutilus rutilus,* from four lakes in central Finland between August 1985 and November 1986. Numbers offish studied each month are given beneath the figure. ○, Lake Peurunka; ●, Lake Vatia; +, Lake Saravesi; X, Lake Leppävesi.

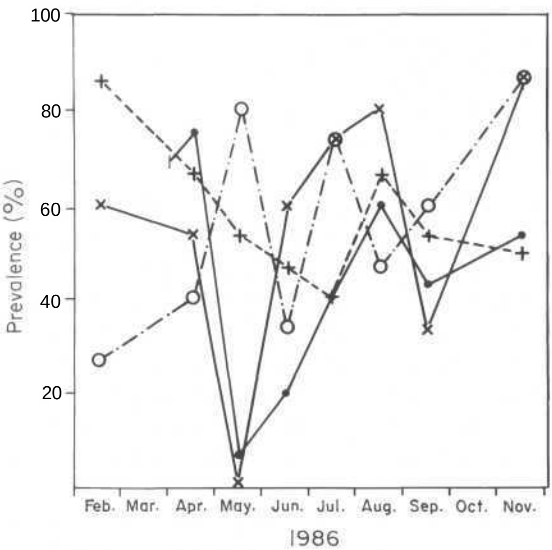


FIG. 3. Seasonal variation in the prevalence of *Myxobolus pseudodispar* in roach, *Rutilus rutilus,* from four lakes in central Finland between February and November 1986. For numbers of fish studied each month and key see Fig. 2.

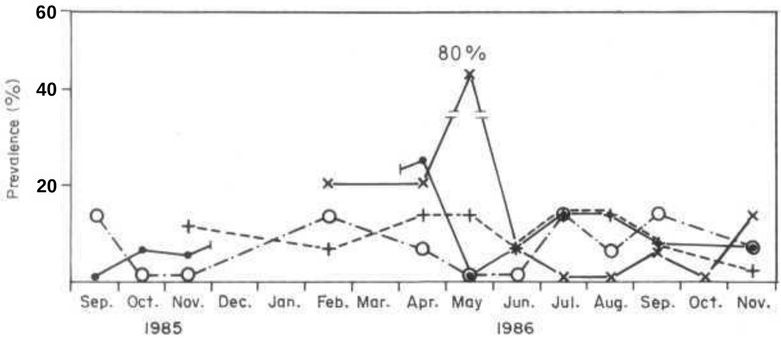


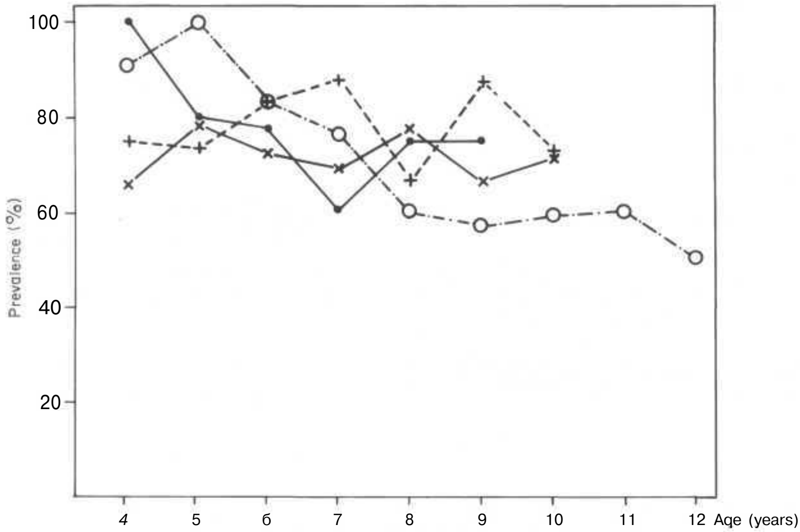
FIG. 4. Seasonal variation in the prevalence of *Myxobolus* spp. on the gills of roach, *Rutilus rutilus,* from four lakes in central Finland. For numbers of fish studied each month and key see Fig. 2.

TABLE IV. Seasonal prevalences of *Zschokkella nova* infection in roach, *Rutilus rutilus,* from four lakes in central Finland

Lake	1985		1986					
	Sep.-Nov.		Feb.-May		Jun.-Aug.		Sep.-Nov.	
	No.	%	No.	%	No.	%	No.	%
Peurunka	43	7.0	30	20.0	48	16.7	30	20.0
Vatia	40	2.5	13	—	44	2.3	29	3.4
Saravesi	9	—	45	4.4	35	2.9	29	6.9
Leppävesi	—		44	18.2	44	9.1	30	10.0

without any clear trend in all four lakes. Thus, both high and low values were found in samples collected from the four lakes at the same time in May 1986. The prevalences of the three *Myxobolus* species on the gills of the roach in the four lakes are given in Fig. 4. In most cases the infection was low and even throughout the year, with higher values encountered only in February, April and May in one of the eutrophic lakes (L. Leppävesi) and in April in the polluted Lake Vatia. *Zschokkella nova* Klokačewa, 1914 was found in all four lakes throughout the year without any clear seasonal variation (Table IV). Another species found in the gall bladder, *Chloromyxum* sp., was found only once in February in L. Leppävesi and in the period April-July in all the lakes, with prevalences of 2.2,4.8,14, and 3.4% in the oligotrophic, polluted and two eutrophic lakes, respectively.

As far as the relations of fish age and prevalence of *M. rhodei* were concerned (Fig. 5), a tendency for decreasing prevalences with increasing age of the fish was found apart from in the two eutrophic lakes. *M. pseudodispar* had an even clearer tendency for decreasing prevalences with increasing fish age in all lakes (Fig. 6), but no such tendency was found for the three *Myxobolus* species on the gills and *M. muelleri* in the inner organs. The only exception was *M. muelleri* in the polluted lake where the highest prevalence 64% was found in the oldest fish.



No.of fish studied

n	11	3	17	17	35	21	22	20	14	○
n	4	20	47	38	16	8				•
n	4	23	37	33	15	8	11			+
n	6	24	18	23	18	9	7			×

FIG. 5. Prevalence of *Myxidium rhodei* infection in roach, *Rutilus rutilus,* from four lakes in central Finland, by age of fish. Numbers of fish in each age group are given under the figure, key as Fig. 2.

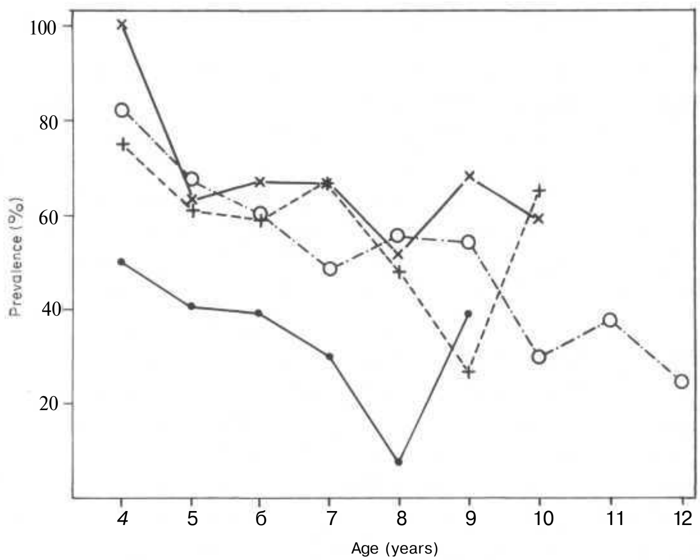


FIG. 6. Prevalence of *Myxobolus pseudodispar* in roach, *Rutilus rutilus,* from four lakes in central Finland, by age of fish. For numbers of fish studied in each age group see Fig. 5, key as Fig. 2.

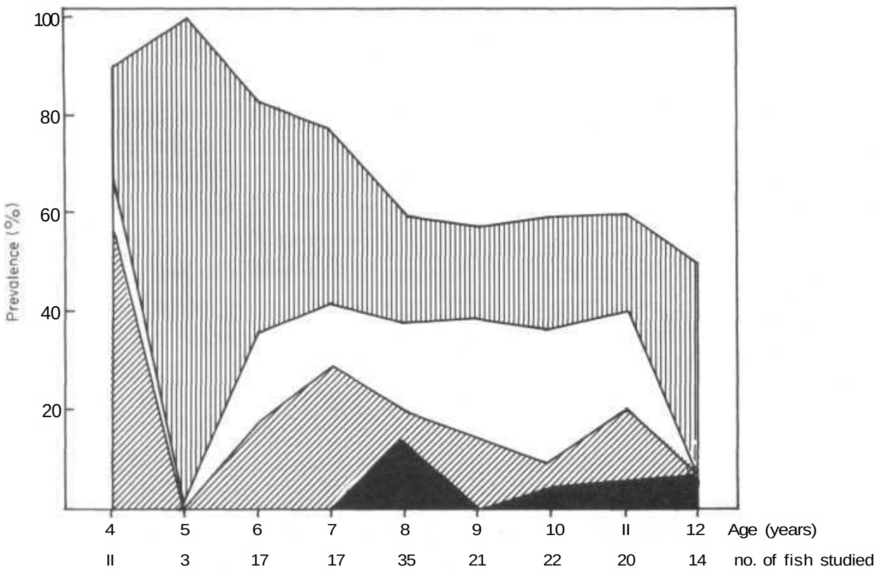


FIG. 7. Mean intensity of *Myxidium rhodei* infection in roach, *Rutilus rutilus*, from Lake Peurunka in central Finland by age offish. Estimated numbers of cysts per infected fish: ,1-4; ,5-20; ,21-50; , >50.

There were no great differences between the four lakes in the mean numbers of cysts per fish according to the age classes of the hosts. As an example, the intensity of *M. rhodei* infection in Lake Peurunka is given in Fig. 7. Fish with less than 20 cysts prevail in most age classes.

V. DISCUSSION

A total of 27 myxosporean species have been found in roach in Soviet Karelia and the Kola Peninsula, of which 19 were encountered in a geographical zone of Soviet Karelia corresponding to the present study area in Finland. The data from Soviet Karelia are based on research carried out for over 50 years, and the material has been collected from about 50 lakes and rivers differing in size, trophic level and water quality. The number of myxosporean species in each lake varies from 1 to 15 (Petrushevski & Bykhowskaya, 1935; Petrushevski, 1940; Polyansky & Shulman, 1956; Shulman *et al.*, 1959; Shulman & Rybak, 1961; Malakhova, 1961; Shulman *et al.*, 1974; Mitenev, 1977, 1979, 1986; Ieshko *et al.*, 1982). As an example, Rumyantsev & Maslov (1985) found eight myxosporean species in an oligotrophic lake, Lake Jänisjärvi, flowing into Lake Ladoga in Soviet Karelia of which five *(M. rhodei, Z. nova, M. pseudodispar, M. muelleri, M. bramae)* are the same as in the present material. It can be expected that the myxosporean fauna in the roach in Finland will prove to be richer than those found here when a greater number of different types of water body are studied. This is supported by the findings of E. T. Valtonen & P. Rintamäki (unpubl. data), who found six myxosporean species in roach from Lake Yli-Kitka in NE Finland, including two *Chloromyxum* species *(C. fluviatile* and *C. mitenevi)* which were not found in the present material.

Great variety in the composition of the parasite fauna of the roach has also been found between different localities in Siberia by Pugachev (1984), who attributes this to the great flexibility and variety in the diet of the roach, which can occupy niches in different types of water body throughout the Palaearctic region.

The present results are in accordance with earlier data for the most common myxosporean species in the roach. Of the eight myxosporean species identified by Rumyantsev & Maslov (1985) in Lake Janisjärvi in Soviet Karelia, every fish was infected with *M. rhodei*, 84% with *M. pseudodispar* and 27% with *M. muelleri*. In a more northerly lake, Lake Segozera, flowing into the White Sea, *M. rhodei* and *M. pseudodispar* were also the most common among the five myxosporean species found in the roach, with prevalences of 87 and 13%. Gorbunova (1936) found 15% of the roach in Lake Konchezero in Soviet Karelia to be infected by *M. pseudodispar*, but Malakhova (1961) found a low prevalence of *M. pseudodispar* infection (11%) in the same are in 1957-1958.

Myxosporeans are known to generally have a wide host specificity, but frequently some fish are preferred over others (Shulman, 1966). For example, *M. bramae* showed 78% infection in *A. brama* in Lake Sjamozero but only 65% in the roach of the same locality (Ieshko & Malakhova, 1982). Similarly, the accidental or less common Myxosporea species in the roach in central Finland may occur more commonly in other cyprinid species not studied here.

Chloromyxum species occur only in the gall bladder and the present findings of *Chloromyxum* sp. on the gills in Lake Leppävesi are incidental. *M. macrocapsularis* has been found on the gills, kidney, spleen, intestine wall, and swimbladder of the roach by Shulman (1984), although it occurred in the gall bladder in the present material. *M. rhodei, M. muelleri* and *M. pseudodispar* may occur in a number of tissues and the present findings are in accordance with the records provided by Shulman (1966). However, *M. muelleri* was not recorded in the kidney by Shulman (1984), although it was the favoured place for this species in the present data occuring in 1 in 3 fish in the polluted Lake Vatia compared to its presence in the liver of 1 in 10 fish. Davies (1968) found free *M. muelleri* spores to occur very commonly in the urinary ducts of roach from the R. Lugg in Great Britain. It should be noted here that spores of different myxosporean species can be dispersed into the kidney and other inner organs and cavities in the blood, causing accidental infections.

It is reasonable to admit that we do not yet understand the whole life cycle of myxosporeans (see Lom & Dykova, 1987; Wolf & Markiv, 1984; El-Matbouli & Hoffmann, 1989). It is known that their spores can enter fish directly from the water but that the degree of infection depends on the maturity of the spores. They can take a few months to mature on the lake bottom (Uspenskaya, 1955, 1984; Shulman, 1966; Yunchis, 1981) or only a few days (see Wyatt, 1978). Some myxosporean species can retain their infective capacity for some years (Auerbach, 1909; Lom, 1964; Shulman, 1966; Uspenskaya, 1984). It seems that these biological peculiarities of myxosporeans are intended to ensure the success of infection. Another possibility, according to Wolf & Markiv (1984) and El-Matbouli & Hoffmann (1989), is that they may enter the fish with invertebrates that they consume which are the real intermediate hosts for *Myxobolus (Myxosoma) cerebralis* and thus *Triactinomycon* represents a real developmental stage. Since Lom & Dykova (1987) did not succeed in successfully repeating the experiment performed by Wolf & Markiv (1984), and since Uspenskaya (1984) was able to infect salmon directly with spores of *M. cerebralis,* it seems that the role of invertebrates has not yet been resolved and a function as a reservoir host must also be considered as a possible alternative.

Another problem which has not been solved is the way in which the spores are released from the fish, e.g. from the muscles. Natural mortality is perhaps not enough to keep up the high prevalences in the roach population. The role of predators in releasing the spores from their definitive hosts has not been studied, but it may be essential. It would also be reasonable to try to explain the role of the intestine of predators in stimulating the maturation of spores. These features of the myxosporean life cycle which are under discussion to some extent restrict our scope for interpreting the present data. The benthos of the polluted Lake Vatia contains high numbers of oligochaetes including *Tubifex tubifex* (Muller) compared with the natural Lake Peurunka (Granberg & Hakkari, 1977; J. Särkkä, unpubl. data), but there are no myxosporean species with a significantly higher prevalence of spores in the polluted lake than in the natural one. When comparing these results with the prevalences of *Raphidascaris acus* nematode larvae, the first intermediate host of which is also an oligochaete and the second, the roach we found a 23% mean infection by the latter in the roach of the oligotrophic, unpolluted lake and 61 % infection in the polluted lake (Valtonen & Koskivaara, 1989).

It is nevertheless interesting to distinguish some ecological groups among the myxosporean species, e.g. according to the speed of sedimentation of the spores (Shulman, 1966), especially in this case because the present four lakes differ markedly in their water current. This may help us to compare the probability of spores being transmitted to the fish hosts.

According to the sedimentation speed classification of myxosporean spores given by Shulman (1966), *M. rhodei* and *M. pseudodispar* spores sediment slowly and the three *Myxobolus* species found on the gills in the present material sediment rapidly. To study this, the seasonal prevalences of *M. rhodei, M. pseudodispar* and *Myxobolus* spp. on the gills of fish from Lake Saravesi are presented side by side (Fig. 8). The very similar seasonal occurrence of the species with a slow sedimentation speed as compared with those with a rapid one is striking. This may be explained at least partly by the slow sedimentation speed, which enables invasion of the fish in the water, or it also may be due to more intense feeding on objects from the water carrying spores than on benthos.

According to Malakhova (1964), Kashkovski (1966) and Shulman (1966), *M. rhodei* has a life cycle with several generations a year, the developmental time required for the spores of one generation being about 3 months, and the development continuing during the winter.

Kashkovski (1966) found roach from the Iriklinskoe reservoir in the Middle Urals in the U.S.S.R. to be infected with *M. rhodei* throughout the year, as is also apparent in the present case. The differences in prevalence and intensity found in Kashkovski's material were explained by seasonal variation in feeding objects and activity, which in turn affected the number of spores consumed by fish.

Only a few earlier studies of the seasonal variations in *M. pseudodispar* have been carried out in the U.S.S.R. These are reviewed by Shulman (1966). No noticeable regular seasonal variation has been found in the roach, although great differences exist between the seasons and from one year to another (Shulman, 1966).

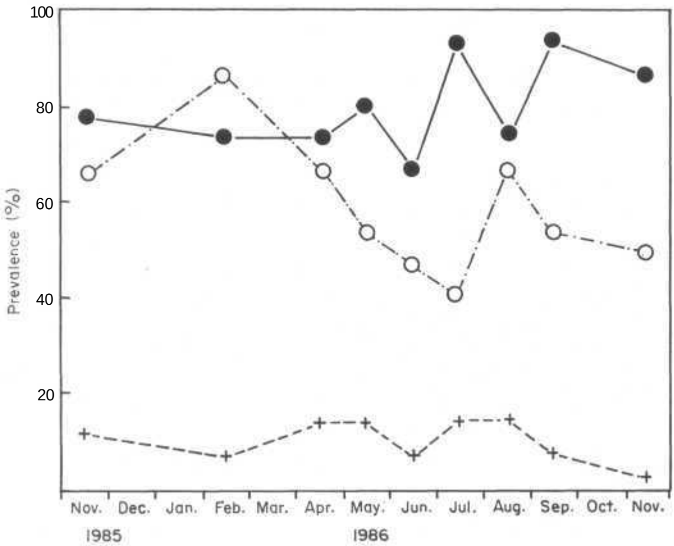


FIG. 8. Seasonal occurrence of *Myxidium rhodei*, ●, *M. pseudodispar*, ○ and *Myxobolus* spp., + in roach, *Rutilus rutilus*, from Lake Saravesi in central Finland.

However, it is not easy to understand the pronounced irregular seasonal variation in *M. pseudodispar* prevalences in the roach in the present study, especially when it is a species whose spores are located in the muscles. Bond (1939) obtained an even seasonal occurrence for *Myxosoma subtecalis* Bond, 1938, in the kidney and brain of *Fundulus heteroclitus* (Linnaeus) in spite of variation in the occurrence of this species on the fins. Bond explains this as being due to the inability of the spore to release itself from the organs of the fish. In the present material the variations in *M. pseudodispar* infection may arise from uneven infection of the roach population, however, we do not know the basic biology of the myxosporean species, e.g. their invasion time or longevity of the spores in fish.

The tendency for decreasing prevalences with increasing age of the fish was much clearer in cases where infection was high as with *M. rhodei* and *M. pseudodispar*. These results may be explained by an increasing immune response with age. Immune response may depend on the timing and intensity of the first infection of the young fish and on the numbers of repeated infections in subsequent years, but these aspects would merit experimental clarification.

This work was financed by the Research Council for the Environmental Sciences of the Academy of Finland. The joint agreement for exchange visits of scientists between Finland and the Soviet Union enabled the contributors to work together in both Leningrad and Jyväskylä. The authors greatly appreciate the help received from Aarre Valkonen, Olavi Järvinen, Pekka and Juha Manninen, who provided live specimens of roach throughout the year even when the weather and ice conditions were discouraging. We thank Malcolm Hicks for revision of the English.

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