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SEASONAL VARIATION OF PARASITE INFECTION OF THREE-SPINED STICKLEBACK (*GASTEROSTEUS ACULEATUS* L.) IN THE SOUTHERN BALTIC

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ABSTRACT. Seasonal changes of infection were observed in the case of some species of ectoparasites: *Trichodina domerguei domerguei*, *T. tenuidens*, *Gyrodactylus arcuatus*, and *Thersitina gasterostei*, as well as for endoparasites: *Glugea anomala*, *Schistocephalus solidus*, *Diphyllobothrium ditremum*, and *Proteocephalus filicollis*. Same seasonal changes in frequency of developmental stages were observed in the case of females *T. gasterostei*. The highest level of infection with ectoparasites was observed in spring and summer and was probably an effect of increase of the reproductive activity with increase of temperature. Infection with tapeworms was generally low and was a result of feeding activity and fish diet.

Key words: parasites, seasonal changes of infection, three-spined stickleback.

INTRODUCTION

To the 1990s, the stocks of three-spined stickleback, *Gasterosteus aculeatus*, constituted a predominant fish population in the Baltic coastal waters (Skóra 1992, 1993), because of their exceptional resistance to the degradation of environment and their biology. In recent years, *Neogobius melanostomus* has challenged the position of the stickleback in the coastal waters of the Gulf of Gdańsk (Sapota and Skóra 2000).

Research on the sticklebacks from our coastal waters and its parasites seams to be important. Because of its abundance, wide dispersal and its omnivorous nature (Wootton 1976) the stickleback has been one of the most extensively infected fish and sometimes a vector of parasites in the food web (Morozińska-Gogol 1996).

The infection of fish hosts with parasites depends on various environmental factors. The most significant abiotic factors are salinity (Prost 1959, Möller 1978) and temperature (Möller 1978, Dzika 1987, Dzika and Dubas 1988, Poulin and FitzGerald 1988 and others). Also the effects of pollution on the parasitofauna have been observed (Rohde 1993, Yeomans et al. 1997 and Galli et al. 1998). All mentioned above factors change with season. Seasonality in fish

parasite occurrence was described several times in Poland (Pojmańska 1984 a, b, c, 1985 a, b; Grabda-Kazubska et al. 1987; Dzika 1987; Pojmańska and Dzika 1987; Pojmańska 1995 a, b, c) as well as in other countries (Hopkins 1959; Chappell 1969; Pennycuick 1971; Chubb 1976, 1980, 1982).

The aim of the present work was to study the seasonal changes in prevalence and mean intensity of infection with some parasites of the stickleback from the Baltic Sea. Also seasonal changes in the frequency of developmental stages of female *Thersitina gasterostei* on the three-spined stickleback have been described.

MATERIAL AND METHODS

A total of 2880 sticklebacks were caught with a hand-net in the coastal zone of the Gulf of Gdańsk (Gdynia, Puck, Hel) and the mouth of the Dead Vistula River (Górki Wschodnie). The samples from all sites were taken in the middle of every month for two years (24 months). All samples consisted of 30 sticklebacks.

The fish were transported in a live-box to the laboratory, at the Department of Invertebrate Zoology, University of Gdańsk, and immediately examined. The fish were killed by pithing. All sticklebacks were weighed (0.1–7.4 g, mean 2.1 g), measured (TL 1.5–9.7 cm, mean 5.92 cm), and their sex and age were determined (average 2+).

The fish were subsequently examined for ecto- and endoparasites under a dissecting microscope. The examination included the skin, fins, eyes (lens and vitreous humour), gills, body cavity, and visceral organs (stomach, intestine, liver, and gonads).

Parasites recovered were fixed and preserved using methods commonly accepted for particular groups (Bylund et al. 1980). Identification of parasites was aided by taxonomic keys (Kabata 1979, 1992; Bauer 1984, 1985, 1987; Pojmańska 1991) and some original papers.

Mean intensity and prevalence of infection were calculated for all samples and related to year seasons (winter: December-February; spring: March-May; summer: June-August; autumn: September-November). Statistical analysis were carried out using SPSS/PC+ software, version 7.0 for Windows (prevalence test of Pearson's chi-square conformity, mean intensity multiple regression analysis).

In the case of females of *Thersitina gasterostei* (Copepoda) five developmental groups were distinguished on the basis of egg-sacs development:

- Young female without egg-sacs
- Adult female without egg-sacs "resting stage"
- Adult female with short egg-sacs
- Adult female with normal length of egg-sacs, immature eggs (white colour)
- Adult female with turquoise coloured egg-sacs, mature eggs.

RESULTS

In this study 25 species (taxa) of parasites were recorded. But only 8 of them were found throughout the whole year, enabling analysis of their seasonality. The whole-year species included ectoparasites *Trichodina domerguei domerguei* (Wallengren, 1897), *T. tenuidens* (Fauré-Fremiet, 1943) (Ciliata), *Gyrodactylus arcuatus* (Bychowsky, 1933) (Monogenea), and *Thersitina gasterostei* (Pagenstecher, 1861) (Copepoda) (Tables 1–4), as well as endoparasites *Glugea anomala*

Table 1. The annual occurrence of *Trichodina domerguei domerguei*

Month	1995			1996		
	Prevalence (%)	Intensity range	(indiv.) mean	Prevalence (%)	Intensity range	(indiv.) mean
January	1.7	2–12	7.0	14.2	7–180	38.8
February	4.2	5–15	11.6	10.0	6–31	17.0
March	42.5	5–125	55.5	49.2	10–120	60.6
April	36.7	3–150	47.5	45.0	6–401	66.7
May	31.7	4–315	133.2	38.3	5–460	60.1
June	45.0	2–206	61.6	40.8	4–350	63.5
July	28.3	2–130	30.6	31.7	5–200	66.5
August	14.2	5–35	13.4	20.8	5–140	17.7
September	6.7	12–70	43.5	27.5	1–213	34.7
October	10.8	5–71	20.0	30.0	2–320	29.9
November	2.5	8–14	10.3	23.3	3–120	25.6
December				6.7	4–30	13.8

Table 2. The annual occurrence of *Trichodina tenuidens*

Month	1995			1996		
	Prevalence (%)	Intensity range	(indiv.) mean	Prevalence (%)	Intensity range	(indiv.) mean
January						
February						
March				5.8	10–45	31.8
April	1.7	2–90	52.0	4.2	10–60	26.2
May	2.5	35–90	65.0	6.7	7–55	28.9
June	4.2	9–211	67.8	3.3	10–150	25.8
July	3.3	5–26	13.7	5.0	3–200	43.5
August	1.7	16–32	24.0	3.3	4–12	18.2
September	2.5	25–62	38.0	10.0	2–24	10.8
October				2.5	3–8	5.0
November				4.2	5–52	22.8
December				2.5	4–13	9.7

Table 3. The annual occurrence of *Glugea anomala*

Month	1995			1996		
	Prevalence (%)	Intensity (indiv.) range	mean	Prevalence (%)	Intensity (indiv.) range	mean
January	8.3	1–4	1.4	5.0	1–6	2.0
February	5.8	1–4	1.4	7.5	1–10	1.8
March	6.7	1–12	3.0	10.8	1–24	2.3
April	9.2	1–2	1.3	10.0	1–9	1.7
May	7.5	1–5	1.4	9.2	1–2	1.4
June	10.0	1–31	2.9	10.0	1–5	1.8
July	5.8	1–25	3.3	6.7	1–2	2.0
August	4.2	1	1.0	3.3	1–4	1.0
September	12.5	1–5	1.6	10.8	1–4	1.5
October	108	1–4	0.8	10.8	1–32	3.5
November	10.8	1–17	2.5	14.2	1–50	4.1
December	8.3	1–7	1.9	10.8	1–4	1.5

Table 4. The annual occurrence of *Gyrodactylus arcuatus*

Month	1995			1996		
	Prevalence (%)	Intensity (indiv.) range	mean	Prevalence (%)	Intensity (indiv.) range	mean
January				1.7	1	1.0
February	2.5	1–2	1.0	1.7	1–2	1.5
March	1.7	1–42	34.5	13.3	1–9	3.4
April	11.7	1–27	6.4	25.8	1–35	3.4
May	9.2	1–24	5.8	20.0	1–55	5.7
June	38.3	1–164	12.2	22.5	1–72	4.0
July	10.8	2–7	6.0	41.7	1–38	7.2
August	12.5	1–7	2.8	11.7	1–11	3.0
September	4.2	1–5	11.6	14.2	1–9	3.0
October	5.0	1–23	7.7	10.0	1–9	3.7
November	1.7	2	2.0	0.8	2	2.0
December	1.7	2–6	6.0			

(Moniez, 1887) (Microsporidia), *Schistocephalus solidus* (Müller, 1776) (Cestoda; plerocercoids), *Diphyllobothrium ditremum* (Creplin, 1825) (Cestoda; plerocercoids) and *Proteocephalus filicollis* (Rudolphi, 1802) (Cestoda; adults) (Tables 5–8). The remaining parasites (Digenea: *Diplostomum* sp., *Apatemon* sp., *Phyllodistomum folium*; Cestoda: *Bothriocephalus scorpii*; Nematoda: *Eustrongylides mergorum, Anisakis simplex, Hysterothylacium aduncum, Raphidascaris acus, Ascarophis longispicula*; Acanthocephala: *Neoechinorhynchus rutili, Echinorhynchus borealis, E. salmonis, Acanthocephalus clavula, A. lucii, Pomphorhynchus laevis*; Hirudinea: *Piscicola geometra*; Mollusca: Glochidium indet.; and Crustacea: *Argulus foliaceus*) occurred with insignificant differences or sporadically.

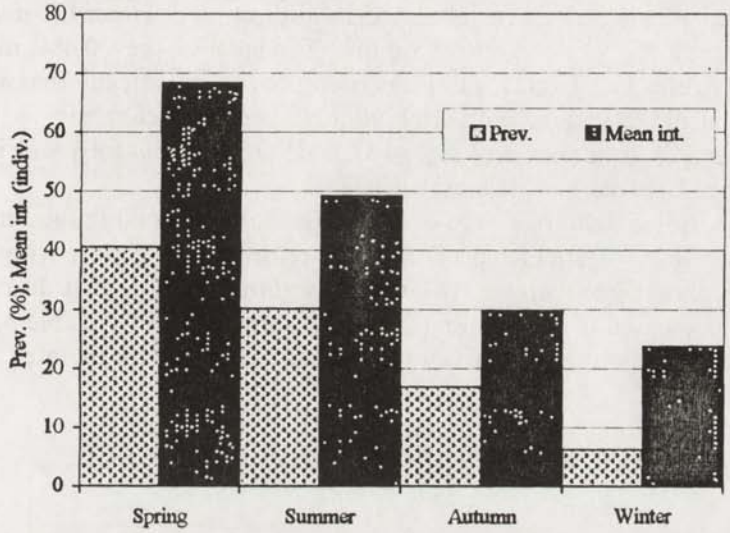

Fig. 1. Seasonal occurrence of *Trichodina domerguei domerguei* on *Gasterosteus aculeatus*.

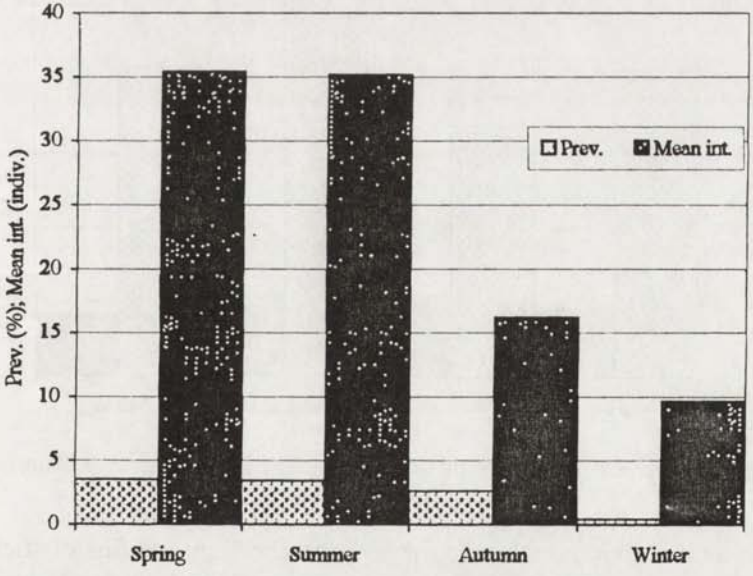

Fig. 2. Seasonal occurrence of *Trichodina tenuidens* on *Gasterosteus aculeatus*.

Trichodina domerguei domerguei occurred on the skin and fins of *G. aculeatus* while *T. tenuidens* on the gills and more rarely on the skin, generally near gill cavity. *T. domerguei domerguei* were found with highest prevalence and mean intensity in spring and summer, with maximum in spring (prev. 40.6%, mean int. 68.2 indiv.). The highest infection parameters of *T. tenuidens* were also observed at the same time (prev. 3.5%, mean int. 35.4 indiv.). The

least infected sticklebacks were observed in autumn and winter (*T. domerguei domerguei*: prev. 6.2%, mean int. 23.8 indiv., *T. tenuidens*: prev. 0.4%, mean int. 9.7 indiv.) (Tables 1, 2; Figs. 1, 2). It has been proved statistically that seasonal differences in prevalence of both trichodinids were significant (sig. = 0.00000 for *T. domerguei domerguei* and sig. = 0.00015 for *T. tenuidens*) and in mean intensity for *T. domerguei domerguei* (sig. T = 0.0000).

Microsporidian xenomas were observed in the subdermal tissues, intestine, gonads, and liver of sticklebacks. Mean intensity of infection with *Glugea anomala* increased from winter (1.7 indiv.) to autumn (2.3 indiv.). In contrast, prevalence decreased from autumn (11.6%) to summer (6.8%) (Table 3, Fig. 3). The differences among seasons were significant only for mean intensity (sig. T = 0.0131).

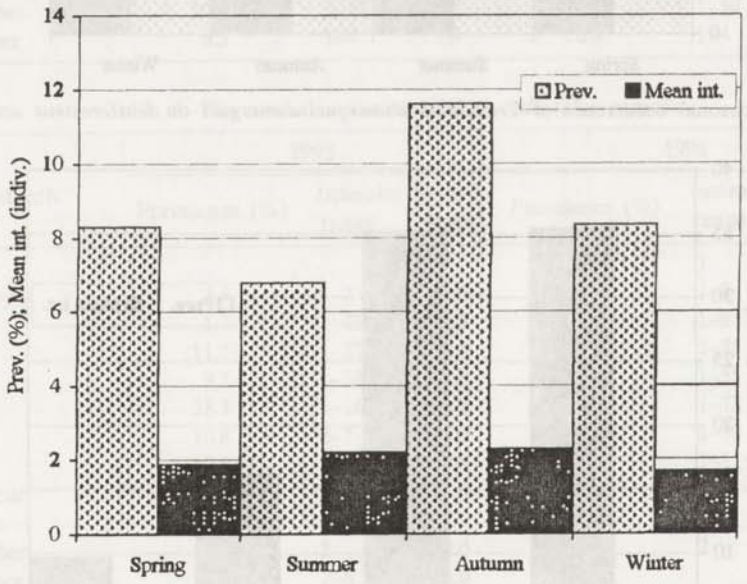

Fig. 3. Seasonal occurrence of *Glugea anomala* on *Gasterosteus aculeatus*.

Gyrodactylus arcuatus occurred mostly on the skin and fins of stickleback, and more rarely on the gills. *G. arcuatus* was noted predominantly in summer, when it attained maximum values of both prevalence and mean intensity of infection (prev. 23.0%, mean int. 7.2 indiv.). The lowest level of infection (prev. 1.3%, mean int. 2.2 indiv.) was noted in winter (Table 4, Fig. 4). Seasonal differences in prevalence were significant (sig. = 0.00000).

The plerocercoids of cestodes *Schistocephalus solidus* occurred in the body cavity and *Diphyllobothrium ditremum* on the liver while the adults of *Proteocephalus filicollis* in the intestine. For all cestode species both prevalence

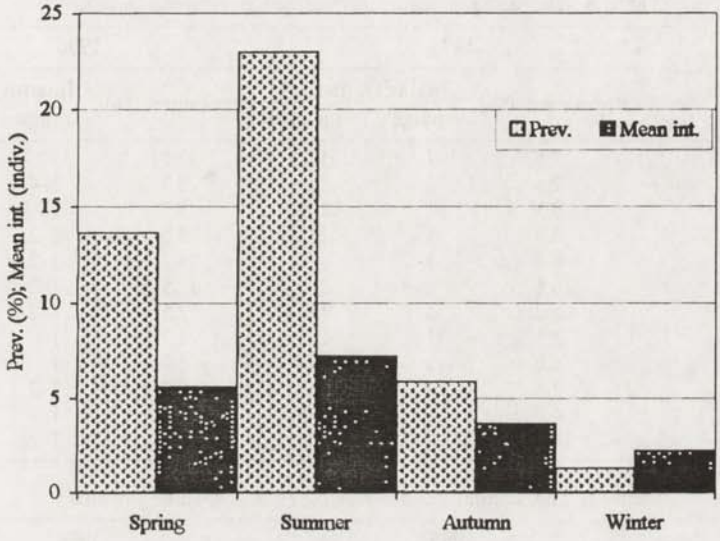

Fig. 4. Seasonal occurrence of *Gyrodactylus arcuatus* on *Gasterosteus aculeatus*.

Table 5. The annual occurrence of *Diphyllobothrium ditremum*

Month	1996		
	Prevalence (%)	Intensity (indiv.) range	mean
January	0.8	1	1.0
February			
March	3.3	1–2	1.3
April	2.5	1–6	2.0
May	1.7	1	1.0
June	4.2	1–30	7.8
July	0.8	1	1.0
August	0.8	1	3.0
September	0.8	1	1.0
October			
November	2.5	1–3	2.0
December	0.8	1	1.0

and mean intensity were low (Figs 5–7). Generally one parasite per fish was observed. Only in summer mean intensity of *D. ditremum* achieved 6.0 specimens (Fig. 5). The highest prevalence of infection by *S. solidus* was observed in winter (7.1%), in the remaining seasons it was about 4% (Fig. 6). Prevalence of *P. filicollis* tended to increase from autumn to summer (0.5–1.9%) (Fig. 7). Differences in prevalence and mean intensity were significant only for *S. solidus* (sig. = 0.00363, sig. T = 0.0011).

Table 6. The annual occurrence of *Schistocephalus solidus*

Month	1995			1996		
	Prevalence (%)	Intensity (indiv.) range	mean	Prevalence (%)	Intensity (indiv.) range	mean
January	7.5	1	1.0	12.5	1	1.0
February	2.5	1	1.0	3.3	1–4	2.0
March	3.3	1	1.0	1.7	1	1.0
April	5.0	1	1.0	5.0	1–2	1.3
May	6.7	1–2	1.3	4.2	1–2	1.2
June	10.8	1–3	1.2	12.5	1–2	1.2
July	5.0	1	1.0	7.5	1–2	1.3
August	3.3	1	1.0	1.7	1	1.0
September	5.0	1	1.0	1.7	1	1.0
October	7.5	1	1.0	6.7	1–2	1.2
November	4.2	2	2.0	4.2	1	1.0
December	10.0	1–2	1.4	6.7	1–2	1.3

Table 7. The annual occurrence of *Proteocephalus filicollis*

Month	1995			1996		
	Prevalence (%)	Intensity (indiv.) range	mean	Prevalence (%)	Intensity (indiv.) range	mean
January						
February	1.7	1–2	1.5	0.8	1	1.0
March						
April	0.8	1	1.0	0.8	1	1.0
May	3.3	1–2	1.2	1.7	1–2	1.5
June	2.5	1–3	2.7	6.7	1–2	1.4
July				2.5	1	1.0
August						
September				3.3	1	1.0
October						
November	0.8	1	1.0			
December				0.8	1	1.0

Table 8. The annual occurrence of *Thersitina gasteroste*

Month	1995			1996		
	Prevalence (%)	Intensity (indiv.) range	mean	Prevalence (%)	Intensity (indiv.) range	mean
January	65.0	1–113	17.5	37.5	1–115	15.0
February	66.7	1–103	18.0	45.8	1–91	13.2
March	75.8	1–177	20.8	48.3	1–168	14.0
April	79.2	1–142	31.2	58.3	1–93	25.1
May	75.8	1–109	17.5	78.3	1–111	30.1
June	81.7	1–120	25.6	84.2	1–101	24.1
July	100.0	7–203	41.0	96.7	2–115	22.6
August	96.7	1–142	33.0	83.3	1–141	35.7
September	85.8	1–66	14.3	75.8	1–77	7.8
October	78.3	1–98	20.8	77.5	1–158	22.6
November	70.0	1–116	27.8	76.7	1–93	20.6
December	65.8	1–147	24.3	78.3	1–142	24.0

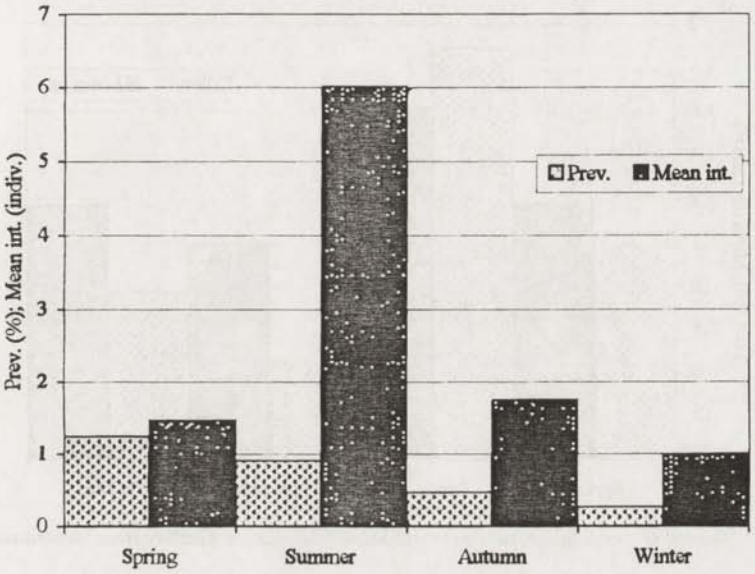

Fig. 5. Seasonal occurrence of *Diphyllobothrium ditremum* in *Gasterosteus aculeatus*.

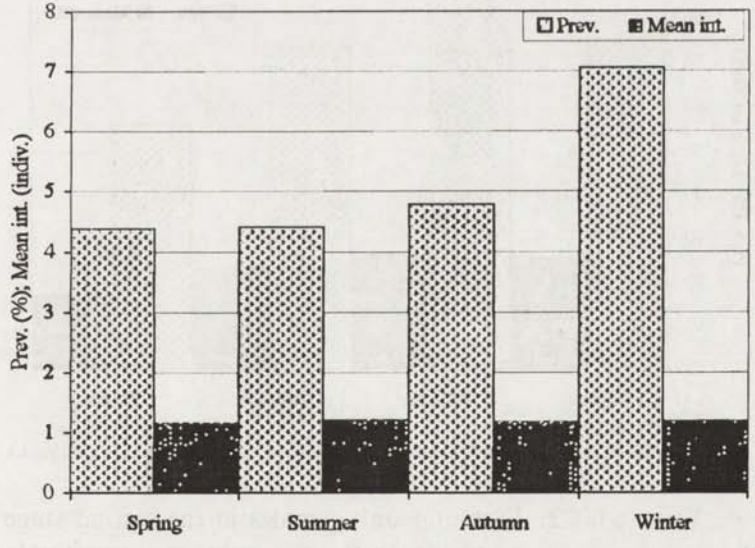

Fig. 6. Seasonal occurrence of *Schistocephalus solidus* in *Gasterosteus aculeatus*.

Thersitina gasterostei (the females) was the most abundant parasite of stickleback. It occurred with highest mean intensity and prevalence in summer (26.5 indiv., 89.7%) and lowest in winter (17.0 indiv., 56.5%), (Fig. 8). The significant differences were observed for prevalence (sig. = 0.00000) and mean

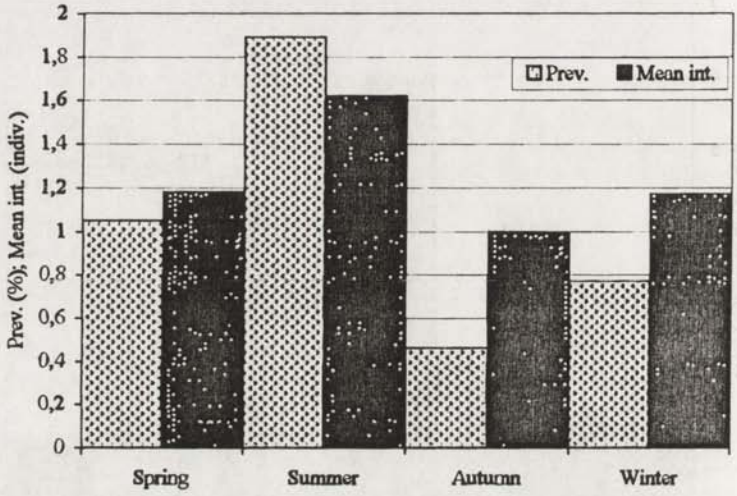

Fig. 7. Seasonal occurrence of *Proteocephalus filicollis* in *Gasterosteus aculeatus*.

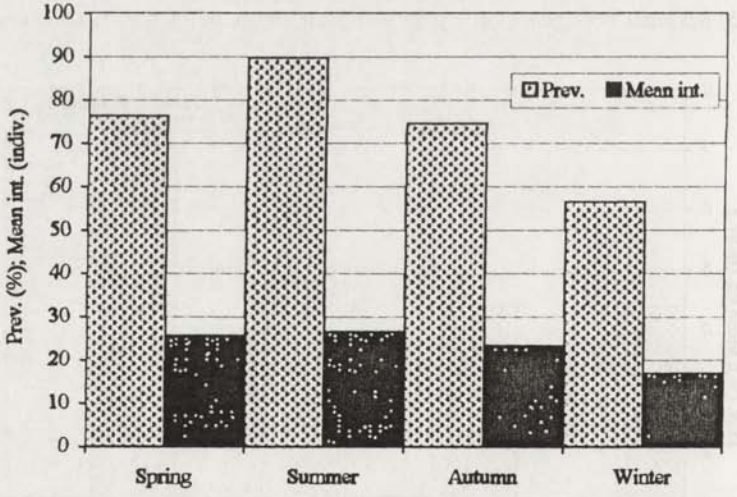

Fig. 8. Seasonal occurrence of *Thersitina gasterostei* in *Gasterosteus aculeatus*.

intensity (sig. T = 0. 0022). In winter only females in the second stage (adult female without egg-sacs) were present. In the remaining seasons females of all stages were found with various frequency (Fig. 9).

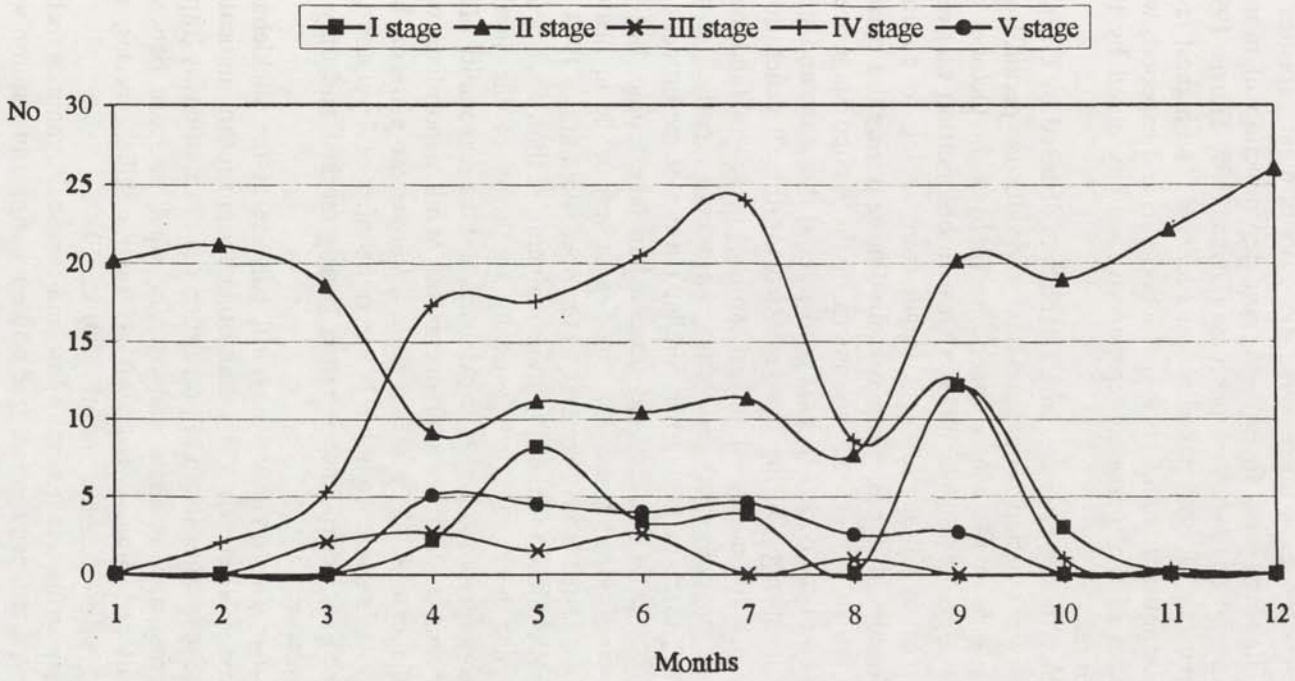

Fig. 9. Frequency of five developmental stages of females of *Thersitina gasterostei* on *Gasterosteus aculeatus*.

DISCUSSION

The highest level of infection by ectoparasites in spring and summer and lowest in colder months is typical for seasonal dynamics of most parasites in temperate climate. Time necessary for growing and reproduction of monogeneans is shorter in highest water temperature (Dzika 1987, Harris 1993, Rohde 1993) and expansion of more parasites was observed. The highest level of prevalence and mean intensity of infection by trichodinids and copepods was probably also an effect of the increased reproductive activity cused by the increase of temperature.

Seasonal occurrence of *T. gasterostei* in England was detected by Gurney (1913, 1933). He observed a period of rest in winter, reproductive period from March and disappearance of the winter generation in May. In October all females were without egg-sacs (Gurney 1933). Our own observation was very similar. The occurrence of all development stages from spring to autumn showed that young females of *T. gasterostei* colonized hosts during this period and gradually matured. In winter only specimens of the second stage were found what suggested that the copepods pass the winter at this stage and start reproductive season in spring. During the year two (or three?) generations could be observed – one colonizing fish in early spring and second (and, may be, third) in summer or early autumn. Main reproductive period of all generations lasts from March to September. Similar pattern of recruitment of another copepod – *Ergasilus sieboldi*, was observed in lake Gopło, but its reproductive period was shorter (from May to September), while in heated lakes of Konin region it lasted from February to October (Pojmańska 1984 a). Probably *T. gasterostei* is more tolerant for lower temperature than *E. sieboldi.*

Glugea anomala has been reported generally on hosts of the family Gasterosteidae and was very abundant in stickleback, but the seasonality of its occurrence has never been studied. Seasonal occurrence of microsporidians was examined only in the case of *G. stephani* from *Pleuronectes platessa*, but McVicar (1975) did not observe correlation between the infection level and the season. In my material the dependence is rather poorly marked and only in relation to the prevalence.

Infection by *Gyrodactylus arcuatus*, a typical parasite of the stickleback (Prost 1957, Kennedy 1974, Harris 1985), like other monogeneans indicated seasonal changes. The seasonal pattern of prevalence and mean intensity (rapid increase between spring and summer and equally rapid decrease between summer and autumn) can suggest, that this is "thermophilic" species, reproducing mainly in worm summer months (Dzika 1987).

Infection with tapeworms was generally low and seasonal dynamics feebly expressed, nevertheless a tendency to increase between spring and autumn was observed. It is in accordance with fish feeding activity and diet. The most important item of stickleback's diet are crustaceans especially from spring to

autumn. Crustaceans are the intermediate hosts for many species of cestodes, e.g. cyclops for *P. filicollis* (cf. Hopkins 1959) and *S. solidus* (cf. Meakins and Walkey 1975, Folstad et al. 1994) or other planctonic crustaceans for *D. ditremum* (cf. Curtis and Bylund 1991, Folstad et al. 1994), and these two seasons are the most favourable for transferring the parasites between subsequent hosts in their life cycle.

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