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Seasonal variation in parasite occurrence and microhabitat distribution of monogenean parasites of gudgeon *Gobio gobio* (L.)

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Summary

Seasonal changes in occurrence, infracommunity composition and microhabitat distribution of the monogenean parasites of gudgeon *Gobio gobio* (L.) were studied during two years in the River Haná (Czech Republic). Altogether 212 specimens of gudgeon were examined and a total of 6456 specimens of eight monogenean species were recorded: *Dactylogyrus cryptomeres, Gyrodactylus gobiensis, Gyrodactylus gobii, Gyrodactylus gasterostei, Gyrodactylus vimbi, Gyrodactylus markakulensis, Gyrodactylus sedelnikowi* and *Paradiplozoon homoion*. The occurrence of monogeneans correlated with seasonal changes of water temperature. In 2001, gyrodactylids peaked in March and *D. cryptomeres* in May, whereas in 2002, gyrodactylids peaked in May and *D. cryptomeres* in July. The majority of specimens of all *Gyrodactylus* species were found on the fins; the remaining specimens of *Gyrodactylus* were located on the body surface and gills, and all *Dactylogyrus* and *Paradiplozoon* specimens were located on the gills. The microhabitat distribution of the monogeneans changed in relation to changing water temperature and intensity of infection.

Key words: *Gobio gobio* (L.), monogeneans, population dynamics

Introduction

Monogeneans are common members of fish parasite communities in freshwater and marine habitats. Most monogenean species are host-specific; others can infect several hosts from different families (Poulin, 1992). *Dactylogyrus* and *Paradiplozoon* species are oviparous and parasitize fish gills. Gyrodactylids are viviparous and parasitize mainly the fins, gills and the body surface. New-born worms are fully grown and attach themselves directly to the host alongside their parent and transmission becomes through host-to-host contact, including contact with dead fishes, and by reattachment of previously detached parasites (Bakke *et al*., 1992). This process together with the unique mode of reproduction allows a rapid increase of the population size in a relatively short period, which can have a significant negative effect on a condition and survival of fish (Bakke *et al*., 1992).

Variation in monogenean population size is mainly explained by seasonal changes in water temperature (Kamiso & Olson, 1986; Cone & Cusack, 1988; Valtonen *et al*., 1990; Barse, 1998). Temperature directly affects *Gyrodactylus* reproduction and survival time (Jansen & Bakke, 1991), parasite behaviour, host behaviour, host density and host responses to infection (Bakke *et al*., 1992; Aaltonen *et al*., 1994; Andersen & Buchmann, 1998; Bakke *et al*., 2007).

Microhabitat preference of monogenean parasites on host individuals has been investigated by many authors (e.g. Žitňan & Hanzelová, 1982; Jensen & Johnsen, 1991; Appleby, 1996; Mo, 1997). Gyrodactylids were found to be localized on different parts of the fish body depending on the phase of infection and developing host immune response (Harris, 1988; Buchmann & Bresciani, 1998; Lindenstrøm & Buchmann, 2000). Microhabitat preference might be also associated with changes in the intensity of infection (Jensen & Johnsen, 1991).

Gudgeon *Gobio gobio* (L.) is a benthopelagic cyprinid fish common throughout Europe. Component communities of parasites of gudgeon have been studied by Dorovskikh (2005) in Russia and there have been several studies on gudgeon monogeneans in the Czech Republic (Ergens, 1991; Gelnar, 1991; Pečínková *et al*., 2005); however there is no study focusing on seasonality of gudgeon monogeneans and their microhabitat distribution. Consequently we examined seasonal changes in intensity of infection and prevalence of monogenean species parasitizing gudgeon.

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In particular, infracommunity structure and microhabitat preference of parasites were investigated with respect to changing water temperature and intensity of infection.

Materials and Methods

Gudgeon were caught in the River Haná in southeastern Moravia, Czech Republic (49˚16´N, 16˚59´E). Mean width of the River Haná in the study area was 5 m, mean depth was 25 cm and the rate of flow varied from 0.2 to 0.5 m.s^{-1}. Each month during 2001 and 2002, a sample of 10 gudgeon was collected by electrofishing and water temperature was measured to the nearest 0.1 ˚C. Fish were transferred to the laboratory, kept individually in buckets and examined within 3 days for presence of metazoan parasites. Fish were killed by cutting the spine, measured to the nearest 0.1 cm and sex was determined. Altogether 106 specimens in 2001 (L_S, mean ± SD, 92.5 ± 15.7 mm) and 106 specimens in 2002 (116.0 ± 12.9 mm) were dissected. Microhabitat distribution of all parasites was recorded and all monogenean parasites were fixed in glycerine ammonium picrate (Malmberg, 1970) and later identified according to Gussev (1985).

The epidemiological terms such as prevalence, intensity of infection and dominance follow Bush *et al.* (1997). To determine the diversity of the infracommunity of each host fish Brillouin's index was calculated (Pielou, 1975). Fin area was determined using 20 specimens of gudgeon (L_S ± SD, 104.0 ± 2.1 mm). The density of gyrodactylids was obtained by dividing the number of parasites on each fin by the mean area of respective fin. Maximum density of gyrodactylids was evaluated from the fish on which the highest intensity of infection was observed and was calculated as one specimen of *Gyrodactylus* spp. per 5 mm² on

the pectoral fin of gudgeon in May 2001. Fish were separated into four groups according to temperature (0 – 4.9, 5 – 9.9, 10 – 14.9 and 15 – 20.5 ˚C) and into three groups according to intensity of infection (1 – 20, 21 – 50 and 51 – 100 parasites) to study the relationship between temperature, intensity of infection and microhabitat distribution of the monogeneans.

Statistical analyses were carried out with Statistica for Windows 7.1 (StatSoft, 2006). Quantitative data on intensity of infection were (log + 1) transformed prior to analysis. A Student t test was used to test for differences in monogenean intensities of infection between studied years and between male and female fish. The Spearman rank order correlation was used to measure the relationship between the intensity and prevalence of parasites and fish standard length, and the relationship between the intensities of monogenean species and water temperature. A χ^2 test was used to examine differences in prevalence of monogeneans and a Mann-Whitney U test tested the difference in infracommunity species richness between years studied. The differences in Brillouin's diversity index among sampling months were determined by One-way ANOVA. Differences in microhabitat distribution in relation to temperature and intensity of infection were evaluated by Friedman ANOVA.

Results

As many as 212 specimens of gudgeon were investigated for the presence of metazoan parasites. Altogether 3914 and 2542 monogenean parasites of eight species were found in 2001 and 2002, respectively. The highest intensities of infection were observed in *Dactylogyrus cryptomeres* (Bychowsky, 1934), *Gyrodactylus gobiensis*

Table 1. Monogenean species and their prevalence, mean intensity of infection, maximum intensity of infection with indication of month and dominance in gudgeon (*Gobio gobio*) in 2001 and 2002.

Species	Prevalence (%)		Mean intensity ± SD		Max intensity/month		Dominance (%)	
	2001	2002	2001	2002	2001	2002	2001	2002
D. cryptomeres	47.2	68.9	11.25 ± 22.07	11.45 ± 28.29	84/VI	172/VII	31.1	48.7
G. gobiensis	82.1	73.6	12.36 ± 17.15	6.58 ± 11.42	100/V	82/V	33.1	27.1
G. gobii	71.7	50.0	9.80 ± 13.09	4.30 ± 9.83	53/IV	70/V	26.6	18.0
G. markakulensis	23.6	18.9	0.52 ± 1.35	0.25 ± 0.73	8/VIII	3/VIII	1.4	1.1
G. gasterostei	46.2	37.7	1.69 ± 3.04	0.89 ± 1.59	16/V	9/V	4.7	3.7
G. vimbi	34.0	16.0	1.11 ± 2.45	0.27 ± 0.66	14/IV	5/V	3.0	1.1
G. sedelnikowi	0	2.0	0	0.02 ± 0.13	0	1/IV	0	0.1
P. homoion	2.0	4.7	0.02 ± 0.14	0.06 ± 0.27	1/XII	2/VII	0.1	0.2

(Glaser, 1974) and *Gyrodactylus gobii* (Schulman, 1953). Other species observed were *Gyrodactylus markakulensis* (Gvosdev, 1950), *Gyrodactylus vimbi* (Schulman, 1954), *Gyrodactylus gasterostei* (Glaser, 1974), *Paradiplozoon homoion* (Bychowsky & Nagibina, 1959) and *Gyrodactylus sedelnikowi* (Gvozdev, 1950) (Table 1). Occasionally, metacercariae of the following three trematode species were observed: *Tylodelphis clavata* (Nordmann, 1832) (prevalence 5 %) in the eyes and *Rhipidocotyle illense* (Ziegler, 1883) (2 %) and *Rossicotrema donicum* (Skrjabin & Lindtrop, 1919) (0.4 %) in the fin tissue. Fish were significantly larger in 2002 as compared to 2001 (Student t test, t = -11.89, df = 210, $P < 0.01$). In 2001 no relationship between fish standard length and parasite intensity was observed (Spearman correlation, r_s = -0.121, $P > 0.05$), whereas in 2002 host length negatively correlated with parasite intensity (Spearman correlation, r_s = -0.199, $P < 0.05$). *D. cryptomeres* and *G. gobii* infected female gudgeon more frequently in 2001 (Student t test, both t > 2.65, df = 91, $P < 0.01$) whereas males were more frequently infected in 2002 (Student t test, both t < - 2.65, df = 100, $P < 0.01$).

Dactylogyrus cryptomeres specimens represented almost half of all monogenean specimens collected in 2002 (Table 1). The maximum number of *D. cryptomeres* on a single fish was 172 specimens (July 2002). For *Gyrodactylus* spp., the highest intensity of infection was observed for *G. gobiensis* with 100 specimens (May 2001) (Table 1). Significantly higher mean intensity of infection in 2001 as compared to 2002 was observed for *G. gobiensis*, *G. gobii*, *G. gasterostei* and *G. vimbi* (Student t test, all t > 2.16, df = 210, P < 0.05). However, prevalences of *G. gobii* and *G. vimbi* only were higher in 2001 (χ^2 test, both $P < 0.01$) (see Table 1). In contrast, *D. cryptomeres* was observed in similar intensities in both studied years (Student t test, t = -0.65, df = 210, $P = 0.516$) but the prevalence was higher in 2002 (χ^2 test, P < 0.01). Prevalence and mean intensity of *G. markakulensis* and *P. homoion* remained low in both years (Table 1).

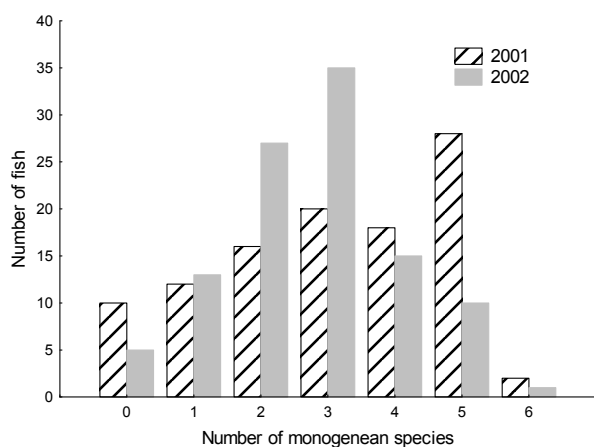There was a significant difference in monogenean infra-community species richness between years. The most

Fig. 1. Characteristics of monogenean infracommunities of gudgeon (*Gobio gobio*) in 2001 and 2002.

common infracommunity consisted of five species in 2001 and three species in 2002 (Mann Whitney U test, z = 1.982, $P = 0.047$) (Fig. 1). The highest values of Brillouin's diversity index of the monogenean infracommunity were recorded in both years during the spring months. Months were grouped in accordance with significant simi-
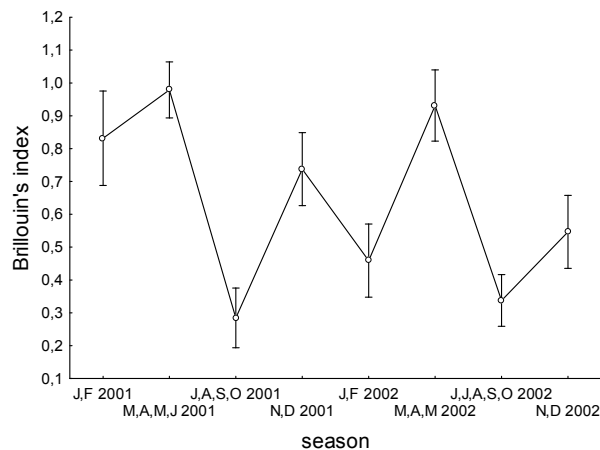

Fig. 2. Seasonal changes in Brillouin's index of monogenean infracommunities of gudgeon in 2001 and 2002. Months are grouped by seasons and similarity of Brillouin's index.

larities in Brillouin's index (Post-hoc tests of One-way ANOVA, $P < 0.05$) (Fig. 2).

Prevalence of all monogenean species correlated with mean intensity of infection (Spearman correlation, all $r_s > 0.830$, $P < 0.05$). The intensity of gyrodactylids increased in spring with an increase of temperature above 6 ˚C (March 2001 and May 2002). During the summer months, intensity of gyrodactylids declined and started to increase again with falling temperature during the autumn and winter months. Amongst the gyrodactylids, only *G. markakulensis* was found more commonly during summer than in other months (Fig. 3A). Moreover, the occurrence of *G. markakulensis* was negatively correlated with the occurrence of *G. gobiensis* and *G. gobii* (Spearman correlation, both $r_s < -0.150$, $P < 0.05$). The intensities of *D. cryptomeres* and *G. markakulensis* positively correlated with the water temperature (Spearman correlation, both $r_s > 0.187$, $P < 0.05$), whereas the relationships of the water temperature and the intensities of *G. gobiensis*, *G. gobii* and *G. gasterostei* were negative (Spearman correlation, both $r_s < -0.285$, $P < 0.05$), (Fig. 3A-C). The intensity of *D. cryptomeres* peaked when the water temperature increased above 14 ˚C during both years of study (May and June 2001 and July 2002) (Fig. 3C).

Dactylogyrus cryptomeres and *P. homoion* were strictly found on the gills (Fig. 4). Gyrodactylids were found primarily on the fins (88.7 %), but also on the skin (8.9 %), gills (2.4 %) and rarely on the barbels (0.1 %). In comparison with other gyrodactylids, *G. gasterostei* and *G. vimbi* were found more often on the skin (more than 20%). More than 26 % of *G. markakulensis* were observed on the gills, whereas less than 3 % of the other gyrodactylids were
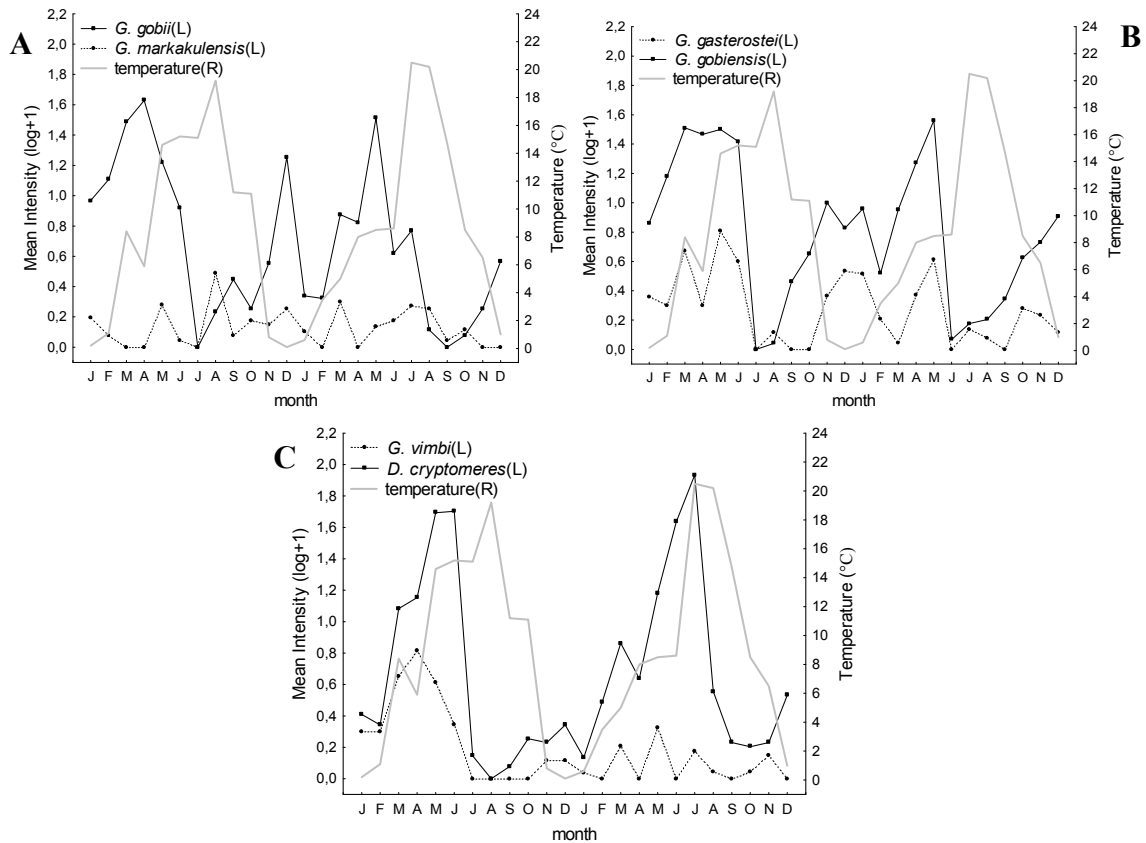
Fig. 3. Seasonal changes in the mean intensity of infection of monogenean species in gudgeon during 2001 and 2002. A) *Gyrodactylus gobii* and *G. markakulensis*; B) *G. gasterostei* and *G. gobiensis*; C) *G. vimbi* and *Dactylogyrus cryptomeres*.

found attached to the gills (Fig. 4).

Dactylogyrus cryptomeres preferred the first gill arch in warm months and the second and third gill arches in cooler months (ANOVA χ^2 (N = 4, df = 3) = 9.300, $P = 0.026$) and was more often attached to the third gill arch when the intensity of infection was high (ANOVA χ^2 (N = 4, df = 2) = 6.500, $P = 0.039$) (Fig. 5A). Most *Gyrodactylus* individuals were observed on the pectoral and pelvic fins and
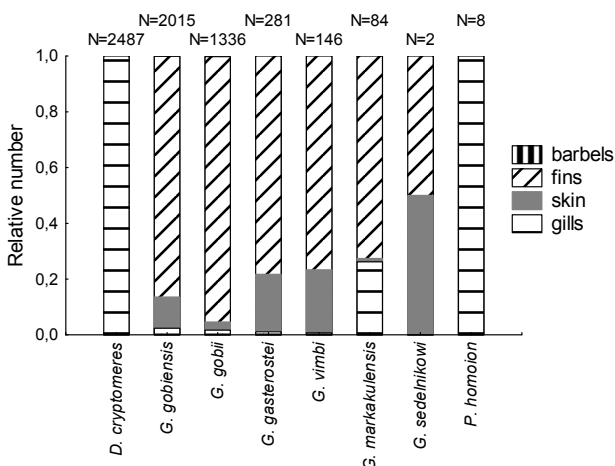

Fig. 4. The microhabitat of monogenean species. on gills, fins, skin and barbels of gudgeon. The number of individuals of species (N) is indicated above the bars.

G. gobiensis also on the dorsal fin. *Gyrodactylus markakulensis* was found mainly on the gills (86 %) in cold months whereas in warm months 94 % of the specimens were attached to the fins. *Gyrodactylus gobiensis* and *G. gobii* frequently parasitized pectoral and pelvic fins but their numbers increased on the skin in warm months (ANOVA χ^2 (N = 8, df = 3) > 8.846, $P < 0.04$ for both species). At higher intensity, the latter *Gyrodactylus* species were attached more frequently to pectoral fins and *G. gobii* also to pelvic fins (ANOVA χ^2 (N = 8, df = 2) > 11.290, $P < 0.005$ for both species) (Fig. 5B, C).

Discussion

In the present study, eight monogenean species were observed on gudgeon. Four species (*D. cryptomeres*, *G. gobiensis*, *G. gobii* and *G. markakulensis*) were reported only from gudgeon and are considered as strict specialists (Harris *et al.*, 2004). Three species (*G. gasterostei*, *G. vimbi* and *P. homoion*) are generalists. *Gyrodactylus sedelnikowi* is reported as a specific parasite for stone loach *Barbatula barbatula* (L.) (see Harris *et al.*, 2004) and its finding in gudgeon is accidental. Stone loach was abundant at the sampling locality and during a growth and dispersal of gyrodactylids, they may also have transferred to the non-specific gudgeon host (Poulin, 1992).

Population dynamics of monogeneans is influenced by water temperature, which directly affects reproduction and
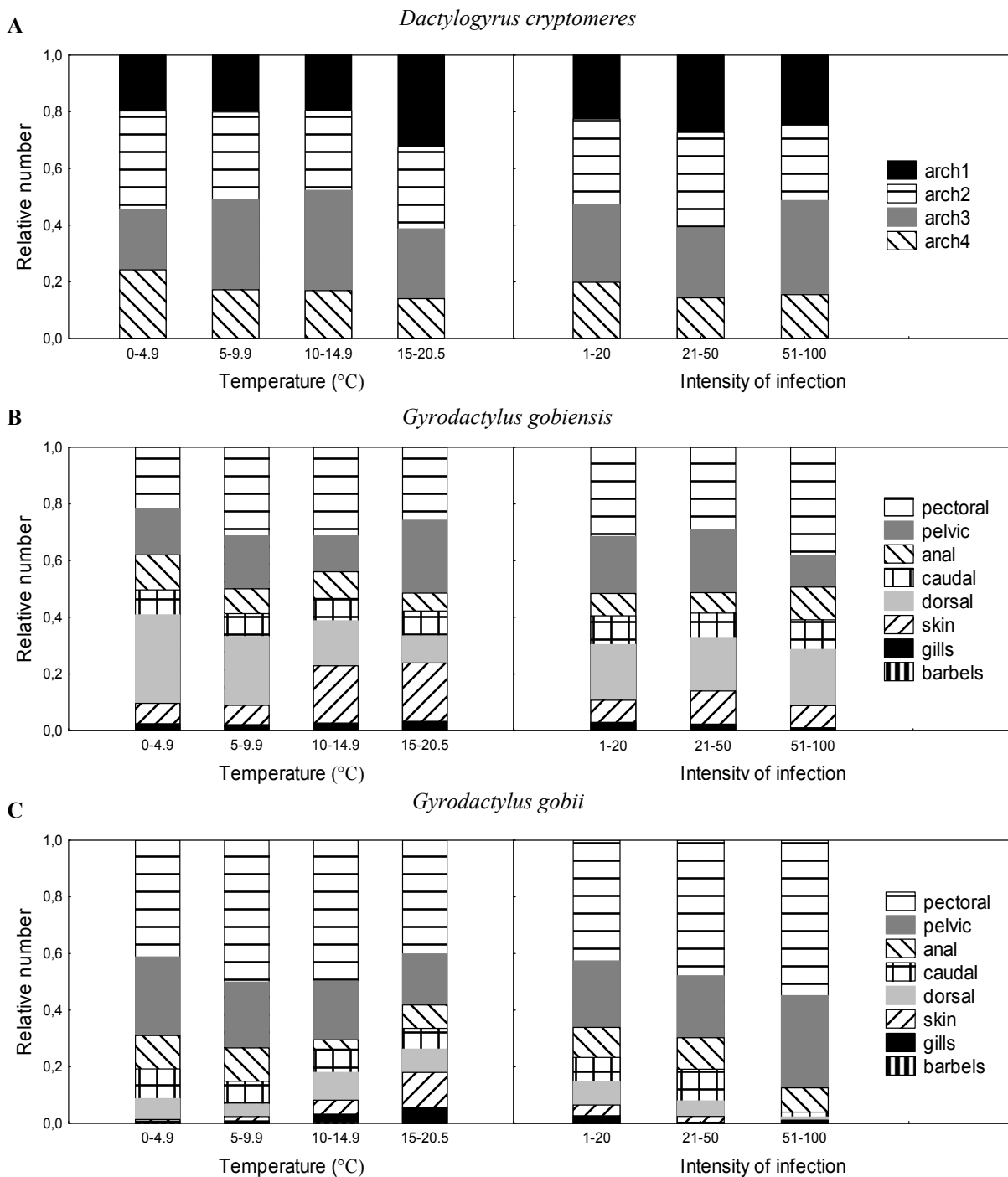
A

Dactylogyrus cryptomeres

B

Gyrodactylus gobiensis

C

Gyrodactylus gobii

Fig. 5. Distribution of monogenean A) *Dactylogyrus cryptomeres*, B) *Gyrodactylus gobiensis* and C) *G. gobii* on different microhabitats on gudgeon in relation to the water temperature and intensity of infection.

survival of parasites (Scott & Nokes, 1984; Jansen & Bakke, 1991; Mo, 1997) and determines the immune response of the host (Aaltonen *et al.*, 1994). Several authors previously described seasonal patterns in occurrence of monogenean parasites (Žitňan & Hanzelová, 1982; Valtonen *et al.*, 1990; Appleby, 1996; Mo, 1997). In the present study, intensity of infection of all monogenean species correlated with their prevalence, as did abundance and prevalence in the studies of Poulin (1999) and Morand and

Guégan (2000). Gyrodactylids peaked in spring, when the water temperature increased above 6 °C. *Dactylogyrus cryptomeres* seems to be more thermophilous and in both years peaked later when water temperature increased above 14 °C. Among gyrodactylids, *G. markakulensis* peaked in August in both studied years and thus it appears to be more thermophilous than the other species of this group. Water temperature optimal for reproduction and survival varies among *Gyrodactylus* species. For example, Cone and

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Cusack (1988) observed the highest numbers of *Gyrodactylus salmonis* and *Gyrodactylus colemanensis* at water temperature below 8 °C, whereas Žitňan and Hanzelová (1982) recorded the optimal temperature for reproduction of *G. shulmani* to be 20 °C. In the present study, gyrodactylid populations started to grow with increasing temperature in spring. With further increase of temperature gyrodactylids decreased, probably due to a combination of shortening life span together with host-induced parasite mortality (Andersen & Buchmann, 1998). The host response is enhanced in a few weeks at 15 °C (Aaltonen *et al.*, 1994). In the autumn, the intensity of infection of gyrodactylids increased again, but slowly, due to lower population growth in cold water (Jansen & Bakke, 1991).

Microhabitat of monogenean parasites depends on parasite species, its developmental stage or phase of the parasite population, on host fish species and on the immune response of host. In addition, abiotic factors of the water environment play a significant role (Koskivaara *et al.*, 1991; Buchman & Uldal, 1997; Buchmann & Bresciani, 1998). In the present study, *D. cryptomeres* and *P. homoion* occurred strictly on the gills. When the highest intensity of *D. cryptomeres* was observed, parasites were attached mainly on the third gill arch, which is the largest one with the strongest respiratory current (Paling, 1968). The majority of gyrodactylid specimens were found on the fins. *Gyrodactylus gasterostei* and *G. vimbi* were both observed on the skin in more than 20 % of cases. These species are considered as generalists (Harris *et al.*, 2004) and might not be so specific to microhabitat as reported for specialists such as *G. gobiensis* and *G. gobii*. Even with increasing temperature, when conditions for survival of *G. gobiensis* and *G. gobii* became unsuitable, these species remained on pectoral and pelvic fins, but also occurred on the skin. A different pattern was observed in thermophilous species *G. markakulensis*: in warm months the fins harboured 94 % of specimens and in cold months when conditions for survival worsened, parasites preferred the gill apparatus (86 %). Similarly, Koskivaara *et al.* (1991) found gyrodactylids more frequently on the gills when the environmental conditions were not suitable for parasite survival.

Also with increased intensity of infection, *G. gobiensis* and *G. gobii* were attached more often to pectoral and pelvic fins, due to the better possibility of transmission to a new host fish (Cone & Cusack, 1989). In the study of Jensen and Johnson (1991) *G. salaris* was more likely to attach to the skin of *Salmo salar* as intensity increased, because microhabitats on the fins were already occupied. Gudgeon is a fish inhabiting the river bottom, so it was predicted that pectoral and pelvic fins are likely to be the most important sites for gyrodactylid transmission because detached parasites might transfer also via the sediment (Bakke *et al.*, 1992).

Maximal density of *Gyrodactylus* spp. observed was one specimen per 5 mm². It seems, therefore, that gyrodactylids of gudgeon under natural conditions usually do not occur in densities leading to death of the host, as observed e.g. by Bakke *et al.* (1992) in *Gyrodactylus salaris* parasitizing *S. salar*. In the present study, most monogeneans were aggregated in a few fish and so much higher standard deviations than means of the intensity of infection were observed (Table 1).

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