Seasonality affects the parasitism levels in two fish species in the eastern Amazon region

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Summary

Fish parasite communities have strong interactions with the environment, the host fish, and the aquatic invertebrate communities. Thus, factors directly involving their different life cycles, such as different host populations and environments, as well as seasonal fluctuations in water levels can cause different responses. The main factors structuring parasite communities may be the hydrodynamic variations, together with seasonal variations in the availability of infectious stages of parasites in the environment. The purpose of this study was therefore to investigate the influence of the rainy and dry seasons on parasite infracommunities in fish species in the Amazon River System of Brazil. Between October 2009 and April 2011, specimens of *Colossoma macropomum* and *Colossoma macropomum* × *Piaractus brachypomus* hybrids (tambatinga) were examined for the presence of parasites. The parasite communities were similar in these two species that both showed aggregate dispersion, although the hybrid specimens were less parasitized. For both hosts, the Brillouin diversity, species richness, evenness and Berger-Parker dominance indices were similar in the rainy season and dry season, except that the Berger-Parker dominance index for the *C. macropomum* × *P. brachypomus* hybrid was higher during the dry season. *Ichthyophthirius multifiliis* was the dominant parasite, followed by *Piscinoodinium pillulare*, in both hosts. However, *C. macropomum* had a higher prevalence and abundance in the dry season, while in the *C. macropomum* × *P. brachypomus* hybrid, only the *I. multifiliis* prevalence increased. The abundance of monogenean species (*Anacanthorus spathulatus*, *Linguadactyloides brinkmanni*, *Mymarothecium* and *Notozothecium janauachensis*) was higher during the dry season in the gills of *C. macropomum*. Despite overdispersion of the lernaeid *Perulernaea gamitanae*, a seasonal pattern was seen only in the *C. macropomum* × *P. brachypomus* hybrid, with higher prevalence in the rainy season. The low prevalence and abundance of the ectoparasites *Tetrahymena* sp., *Trichodina* sp. and *Braga patagonica*, as well as of the endoparasites *Procamallus* (*Spirocamallanus*) *inopinatus* and *Neoechinorhynchus buttnerae*, were not affected by seasonality. This information is applicable in farming practice for these economically important fish, as it indicates the best time for prophylactic management and treatment against parasites, in order to prevent economic losses in fish farms.

Introduction

Adverse environmental factors affect fish physiology and the biological conditions under which they live, thereby increasing their susceptibility to different species of parasites, both in the natural environment (Kadlec et al., 2003; Violante-González et al., 2008; Rakauskas and Blazeevicius, 2009; Violante-González et al., 2009; Tavares-Dias et al., 2014a) and in aquaculture (Valtonen and Koskivaara, 1994; Banu and Khan, 2004; Godoi et al., 2012). In addition, such factors may increase the presence of invertebrates that are intermediate hosts of parasites with an indirect lifecycle (Kadlec et al., 2003; Violante-González et al., 2008; Rakauskas and Blazeevicius, 2009; Tavares-Dias et al., 2014a,b). The effects of environmental changes on parasite communities have thus received attention, especially with regard to seasonal variation (Valtonen and Koskivaara, 1994; Kadlec et al., 2003; Violante-González et al., 2008, 2009; Neves et al., 2013; Tavares-Dias et al., 2014b). However, few of these studies have addressed Neotropical fish species.

In temperate climate regions, temperature strongly influences parasite life cycles, such that parasitic infection levels follow annual patterns (Valtonen and Koskivaara, 1994; Kadlec et al., 2003; Rakauskas and Blazeevicius, 2009). On the other hand, seasonal variation in rainfall levels is a major environmental factor affecting the dynamics of parasite communities in the Amazon region. This promotes drastic changes in environmental quality and fish behavior (Malta and Varella, 1983; Neves et al., 2013; Tavares-Dias et al., 2014b).

In the Amazon rainforest region of South America, the most important climatological variable is convective activity (Fu and Li, 2004; Souza and Cunha, 2010). In the eastern Amazon region, the precipitation regime shows well-marked annual maximums from December through May, while the annual minimums occur from June through November (Souza and Cunha, 2010). Studies conducted on fishes in lakes in the Amazon region have shown that seasonal fluctuations influence the infection patterns in species of argulids (Malta, 1982; Malta and Varella, 1983), monogeneans, nematodes and protozoans (Neves et al., 2013). However, the effects of the rainy and dry seasons are one of the least-studied features of the parasite communities in fish species in the Amazon region, particularly in aquaculture.

Fish parasite communities have strong interactions with the environment, host fish, aquatic invertebrate communities and seasonality; these factors can thus cause different responses to seasonal water level fluctuations. Factors structuring the parasite infracommunities of fish include hydrodynamic variation, host feeding behavior and seasonal variation in the availability of infective stages of parasites in the environment. Hence, these factors can influence the parasite infracommunities in the fish population, primarily through the seasonal fluctuations in rainfall levels that occur in the Amazon region (Tavares-Dias et al., 2014a,b).

Quantitative studies have been performed on the parasite fauna of *Colossoma macropomum* Cuvier, 1818 (Godoi et al., 2012; Santos et al., 2013) and the hybrid of *C. macropomum × Piaractus brachypomus* Cuvier, 1818 (Dias et al., 2015), farmed in the Amazon region. However, there is a lack of information on the influence of seasonality in the levels of infection. Determining whether the infection levels remain constant for different parasite infracommunities in

these fish is critical for predicting the parasites' reproductive periods and having the ability to implement adequate prophylaxis methods. Therefore, with a gradual increase in the intensive fish farming of *C. macropomum* and *C. macropomum × P. brachypomus*, there is a need for the constant monitoring of fish farms for diagnoses and control of parasitic infections. Thus, the aim of this study was to investigate the effects of the rainy and dry seasons on the parasite community structures in these two fish species at fish farms in the Amazon River System, in northern Brazil.

Materials and methods

Fish and study area

Between October 2009 and April 2011, fish were collected every second month from 10 fish farms in the municipality of Macapá, state of Amapá, in northern Brazil (Fig. 1). Among these fish farms, 70% are supplied with water from a tributary of the Amazon River (eastern Amazon region). A
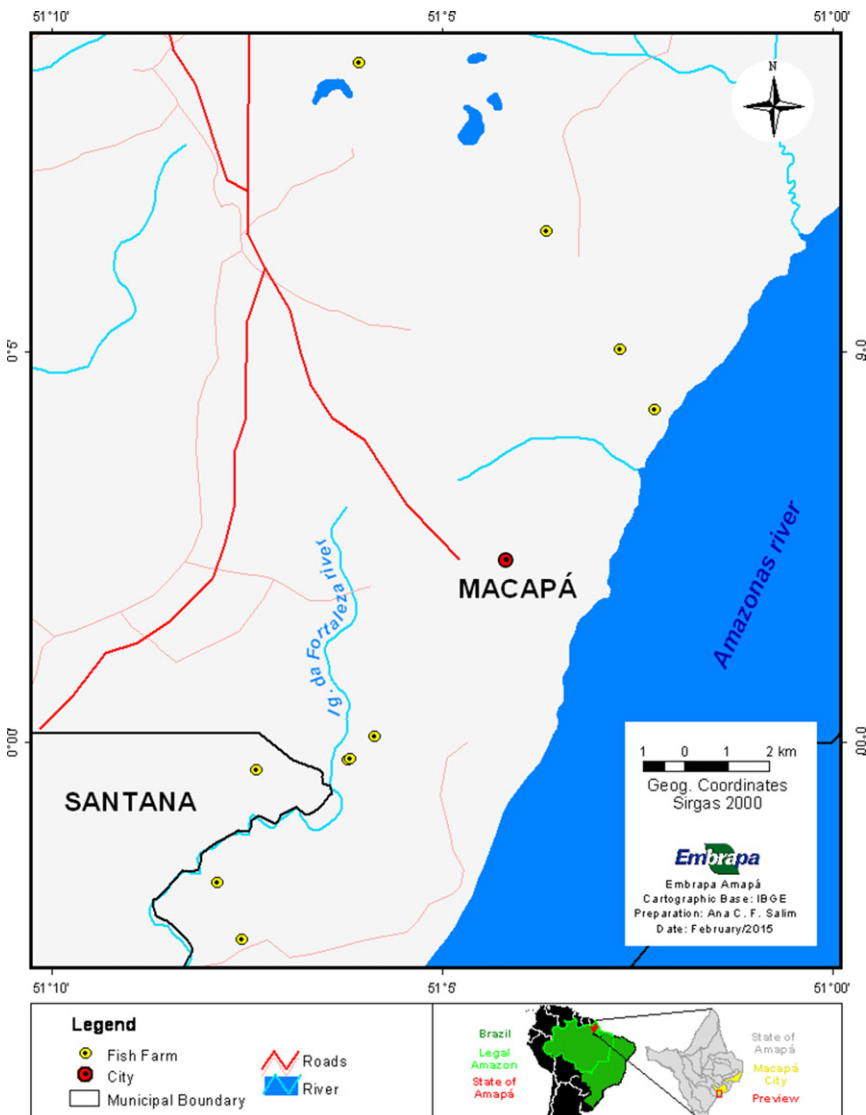

Fig. 1. Collection sites of *Colossoma macropomum* and *Colossoma macropomum × Piaractus brachypomus* in fish farms from eastern Amazon, Brazil.

Table 1
Body parameters and stocking density of farmed fish, eastern Amazon region, Brazil

Fish farms	*Colossoma macropomum* × *Piaractus brachypomus* (n = 503)				*Colosssoma macropomum* (n = 473)			
	n	Weight (g)	Total length (cm)	Density (fish/m²)	n	Weight (g)	Total length (cm)	Density (fish/m²)
1	57	687.4 ± 459.23	31.6 ± 7.9	2.5	54	527.3 ± 279.4	29.7 ± 6.3	2.5
2	60	461.4 ± 340.4	27.8 ± 8.4	2.0	59	514.1 ± 385.1	26.6 ± 9.5	2.0
3	66	986.7 ± 597.75	34.3 ± 11.4	2.8	68	884.7 ± 676.7	33.1 ± 13.8	2.8
4	32	542.8 ± 372.24	28.5 ± 8.4	0.6	68	332.9 ± 265.9	22.6 ± 9.7	2.0
5	67	244 ± 188.91	17.5 ± 7.6	2.0	70	303.8 ± 145.5	26.4 ± 4.5	2.8
6	68	470.9 ± 235.27	29.3 ± 6.1	2.8	71	747.4 ± 485.1	32.8 ± 8.5	2.3
7	58	898 ± 630.79	32.6 ± 11.9	1.2	52	397.3 ± 168.9	27.9 ± 4.8	0.8
8	30	62.8 ± 66.13	11.31 ± 6.2	0.8	31	384.3 ± 219.3	37.2 ± 43.9	1.5
9	35	334.3 ± 237.2	20.2 ± 6.2	1.5	–	–	–	–
10	30	491.95 ± 493	25.2 ± 13.3	1.2	–	–	–	–

total of 976 fish were examined, comprising 473 specimens of *Colossoma macropomum* and 503 *C. macropomum* × *P. brachypomus* hybrids, known as tambatinga hybrids. Fish length, body weight, and the sampling rate and stocking density at each fish farm, are shown in Table 1.

This region has a tropical forest climate, with a rainy season from December through May and a dry season from June through November (Souza and Cunha, 2010). This seasonality leads to rainy and dry seasons in the water levels; these dynamics in the Amazon region can promulgate changes in the environmental quality (Tavares-Dias et al., 2014a).

On each occasion of fish collecting, the pH, temperature and dissolved oxygen were measured using digital devices suitable for each purpose. Rainfall data were obtained from the Hydrometeorology and Renewable Energy Center (NHMET) of the Scientific and Technological Research Institute of the State of Amapá (IEPA).

Parasites and sampling procedures

At each fish farm, the fish specimens were necropsied and the mouth, operculum and gills examined for ectoparasites. The viscera and the gastrointestinal tract were then examined for endoparasites. For necropsy and for collecting, fixing, conserving, counting and staining the parasites, the techniques described previously were used (Boeger and Vianna, 2006; Eiras et al., 2006). Voucher specimens were deposited in the office of the curator for the Scientific Collection of the Fauna of Amapá (CCFA), at the Scientific and Technological Research Institute, State of Amapá (IEPA), under the accession number IEPA 019-032-P.

Data analysis

In order to analyze the parasite communities, their prevalence and abundance were considered, as recommended by Bush et al. (1997). The parasite communities were calculated by: (i) species richness; (ii) Brillouin diversity index (*HB*); (iii) evenness associated with the Brillouin diversity index (*E*); (iv) Berger-Parker dominance index (*d*); and frequency of dominance, i.e. percentage of infracommunities in which any parasite species was numerically dominant (Rohde et al., 1995; Magurran, 2004), using diversity software (Pisces Con-

servation Ltd, UK). The dispersion index (ID) and Poulin discrepancy index (D) were calculated using the Quantitative Parasitology 3.0 software, in order to detect the distribution pattern of each parasite infracommunity (Rózsa et al., 2000) in species with >10% prevalence. The significance of the ID for each parasite infracommunity was tested by means of *d*-statistics (Ludwig and Reynolds, 1988).

The Shapiro-Wilk's test was used to determine whether the parasite abundance data followed a normal distribution pattern. The difference in the prevalence of each parasite species between the rainy season and the dry season was evaluated using the chi-square (χ^2) test and the difference in parasite abundance, using the Mann–Whitney (*U*) test. For each host, the differences in species richness, diversity (*HB*), evenness (*E*) and dominance (*d*), between the rainy season and dry season and between host species, were determined using the Mann–Whitney *U* test (Zar, 2010). Seasonal comparisons of parasitic prevalence and abundance were made only for parasites with prevalence >10%. Statistical tests were performed using the Sigma Stat software.

Data on body weight (g) and total length (cm) were used to calculate the relative condition factor (Kn) of the hosts (Le Cren, 1951). The differences in the hosts' Kn values between the rainy season and dry season were compared using the Mann–Whitney *U*-test.

The dry-season physical characteristics of the ponds that contained *C. macropomum* were determined, as follows: temperature (30.2 ± 0.7°C), pH (6.5 ± 0.8) and oxygen levels (2.5 ± 1.8 mg L^{-1}). The corresponding rainy-season characteristics were: 29.9 ± 1.1°C; 6.6 ± 0.5; and 3.4 ± 2.7 mg L^{-1}. In the ponds containing *C. macropomum* × *P. brachypomus*, the dry-season characteristics were: temperature (30.5 ± 1.1°C), pH (6.5 ± 0.7) and oxygen levels (2.3 ± 1.3 mg L^{-1}), while during the rainy season they were: 29.7 ± 0.9°C, 6.6 ± 0.6 and 3.1 ± 2.1 mg L^{-1}, respectively. In the dry season, the rainfall was 77.0 ± 84.2 mm and in the rainy season, 282.0 ± 90.6 mm.

Results

Colossoma macropomum was parasitized by *I. multifiliis* Fouquet, 1876; *Piscinoodinium pillulare* Schäperclaus, 1954; Lom, 1981; *Trichodina* sp.; *Tetrahymena* sp. (Protozoa);

Perulernaea gamitanae Thatcher & Paredes, 1985; *Braga patagonica* Schiödte & Meinert, 1884 (Crustacea); *Anacanthorus spathulatus* Kritsky, Thatcher & Kayton, 1979; *Linguadactyloides brinkmanni* Thatcher & Kritsky, 1983; *Mymarothecium boegeri* Cohen & Kohn, 2005; *Notozothecium janauachensis* Belmont-Jegu, Domingues & Martins, 2004 (Monogenea); and *Procamallanus* (*Spirocamallanus*) *inopinatus*) Travassos, Artigas & Pereira, 1928 (Nematoda). In the host's gills, *I. multifiliis* and *P. pillulare* predominated in both the rainy and the dry season, but both of these protozoa had higher prevalence and abundance in the dry season. The abundance of monogeneans (*A. spathulatus*, *M. boegeri*, *N. janauachensis* and *L. brinkmanni*) was higher in the dry season. *Trichodina* sp. only occurred in the dry season, while *Tetrahymena* sp., *P.* (*S.*) *inopinatus*, *P. gamitanae* and *B. patagonica* showed low infection rates in both the rainy and the dry season (Table 2). *Ichthyophthirius multifiliis* and *P. pillulare* presented aggregate dispersion pattern, a pattern also observed for monogeneans and *P. gamitanae* (Table 3).

For *C. macropomum*, the parasite species richness, diversity (*HB*), evenness (*E*) and dominance (*d*) showed no difference between the rainy and drainage seasons (Table 4), because the parasites occurred in both seasons, except for *Trichodina* sp. Among the specimens of this fish, parasitism by five to six parasite species predominated, while for the *C. macropomum* × *P. brachypomus*

Table 4
Seasonal differences in parasite infracommunities in farmed *Colossoma macropomum*, eastern Amazon region, Brazil

Diversity index	Rainy season (n = 279)	Dry season (n = 194)	U	P
Species richness	2.5 ± 0.9 (0–5)	2.7 ± 1.1 (0–5)	24 762.0	0.116
Brillouin (*HB*)	0.3 ± 0.3 (0–0.9)	0.4 ± 0.3 (0–1.0)	26 640.5	0.777
Evenness (*E*)	0.1 ± 0.3 (0–0.4)	0.2 ± 0.1 (0–0.5)	24 240.0	0.499
Berger-Parker (*d*)	0.8 ± 0.3 (0–1.0)	0.7 ± 0.2 (0–1.0)	26 231.5	0.570

U, Mann–Whitney test; mean ± SD, range and significance level (P).

hybrids, parasitism by zero and by five to six parasite species predominated.

Despite the higher infection levels that were observed in the drainage season, the Kn of parasitized *C. macropomum* did not showed no difference (*U* = 24 603.0; P = 0.345) between the flood season (0.999 ± 0.079) and the dry season (1.000 ± 0.038).

The *C. macropomum* × *P. brachypomus* hybrids were parasitized by the same parasite species as *C. macropomum*, except for *Neoechinorhynchus buttnerae* Golvan, 1956 (Acanthocephala), which was found only in this hybrid, and *B. patagonica*, which was found only in the *C. macropomum*

Table 2
Seasonal variation of parasites in farmed *Colossoma macropomum*, eastern Amazon region, Brazil

Parasites	Rainy season (n = 279)			Dry season (n = 194)			χ²	U
	P (%)	MA ± SD (range)	FD (%)	P (%)	MA ± SD (range)	FD (%)		
Ichthyophthirius multifiliis	87.1	171 600 ± 168 657 (0–1 709 480)	90.1	93.3	311 041 ± 310 598 (0–2 266 280)	87.3	4.74*	20 193.0**
Piscinoodinium pillulare	47.3	18 506 ± 41 741 (0–305 235)	9.7	58.2	44 349 ± 81 094 (0–514 800)	12.4	5.48*	21 128.5**
Tetrahymena sp.	1.1	49 ± 504 (0–7072)	0.02	5.2	348 ± 2185 (0–21 294)	0.97	–	–
Trichodina sp.	0	0	0	4.6	47 ± 273 (0–2673)	0.01	–	–
Monogeneans	91.0	228 ± 274 (0–1574)	0.12	87.6	531 ± 937 (0–6733)	0.15	1.43	23 364.0*
Procamallalus (S.) inopinatus	3.9	0.1 ± 0.8 (0–10)	–	4.1	0.1 ± 0.5 (0–5)	–	–	–
Perulernaea gamitanae	17.7	0.5 ± 1.7 (0–10)	–	19.6	0.8 ± 2.6 (0–13)	–	0.45	26 987.5
Braga patagonica	0.4	0.004 ± 0.06 (0–1)	–	5.7	0.005 ± 0.23 (0–1)	–	–	–

P, prevalence; MA, mean abundance; FD, frequency of dominance; χ², chi-square; *U*, Mann–Whitney test. *P < 0.05 and **P < 0.001.

Table 3
Index of dispersion (ID), *d*-statistics and discrepancy index (D) for parasite infracommunities in two farmed fish species, eastern Amazon region, Brazil

Hosts Parasites	*Colossoma macropomum*			*Colossoma macropomum* × *Piaractus brachypomus*		
	ID	*d*	D	ID	*d*	D
Ichthyophthirius multifiliis	16.1	95.2	0.400	16.8	98.3	0.595
Piscinoodinium pillulare	22.1	113.7	0.665	11.6	76.2	0.804
Monogeneans	5.72	81.3	0.924	8.97	63.2	0.641
Perulernaea gamitanae	13.3	42.7	0.446	6.73	50.5	0.950

tegument. Although *I. multifiliis* and *P. pillulare* were again the predominant parasite species during both the rainy and the dry season, the prevalence and abundance of *P. pillulare* did not show any significant seasonal influence. On the other hand, *I. multifiliis* had higher prevalence in the dry season, while it had higher abundance in the rainy season. *Trichodina* sp. and *N. buttnerae* only occurred in the dry season, while *Tetrahymena* sp. and *P. (S.) inopinatus* showed low prevalence and abundance in both seasons. The prevalence of monogeneans (*A. spathulatus*, *M. boegeri*, *N. janauachensis* and *L. brinkmanni*) and of *P. gamitanae* was higher during the dry season (Table 5). In addition, aggregate dispersion of these parasites was found (Tables 2 and 3).

For the *C. macropomum* × *P. brachypomus* hybrids, the parasite species richness, Brillouin diversity index and evenness were similar during the dry and rainy seasons, while the Berger-Parker dominance index was higher during the dry season (Table 6).

The relative condition factor (Kn) of parasitized *C. macropomum* × *P. brachypomus* hybrids did not show any difference ($U = 14\ 314.0$; $P = 0.422$) between the flood season (Kn = 1.000 ± 0.151) and the drainage season (Kn = 1.013 ± 0.211), although higher infection levels occurred during the drainage season.

For *C. macropomum*, the Brillouin diversity index ($U = 64\ 059.00$, $P < 0.001$), parasite species richness ($U = 70\ 164.0$, $P < 0.001$) and evenness ($U = 72\ 603.0$, $P < 0.001$) were higher than those of the *C. macropomum* × *P. brachypomus* hybrids, but the Berger-Parker dominance index ($U = 112\ 465.5$, $P = 0.053$) was similar for the two hosts (Fig. 2).

Discussion

Seasonal variations in rain levels promote changes in the water quality of fish farm ponds and to fish behavior, thereby modifying the host-parasite relationship and leading to greater aggregation of fish in the dry season. These changes facilitate horizontal transmission of protozoa in *C. macropomum* and in the *C. macropomum* × *P. brachypomus* hybrid. In contrast, for *Astronotus ocellatus* Agassiz, 1831 in Pracuúba Lake, in the eastern Amazon region, the infection levels of *I. multifiliis*, *P. pillulare* and *Trichodina* sp. were higher during the rainy season (Neves et al., 2013). Therefore, environmental factors caused by the dry and rainy seasons seem to have contributed to the presence of these ectoparasites. The dry season causes a reduction in water quality, thereby favoring reproduction among protozoan species (Valtonen and Koskivaara, 1994; Banu and Khan, 2004) and increasing the susceptibility of farmed fish to infections from these ectoparasites.

On the other hand, in temperate climatic regions, the seasonal variation in temperature is the predominant factor influencing the levels of parasitism by these ectoparasites in farmed fish populations (Valtonen and Koskivaara, 1994; Banu and Khan, 2004) and in wild fish populations (Valtonen and Koskivaara, 1994; Rakauskas and Blazeevicius, 2009). Moreover, prolonged rainy periods may cause an

Table 5
Seasonal variation of parasites in farmed *Colossoma macropomum* × *Piaractus brachypomus,* eastern Amazon region, Brazil

Parasites	Rainy season (n = 281)			Dry season (n = 222)			χ^2	U
	P (%)	MA ± SD (range)	FD (%)	P (%)	MA ± SD (range)	FD (%)		
Ichthyophthirius multifiliis	42.7	90 431.1 ± 148 029.2 (0–803 068)	90.6	60.3	78 012 ± 156 639.7 (0–906 192)	83.3	15.645**	29 012.0
Piscinoodinium pillulare	26.7	9 339.9 ± 21 029.4 (0–132 440)	9.3	29.1	15 491.3 ± 60 270.2 (0–451 470)	16.5	0.36	30 895.0
Tetrahymena sp.	0.7	7.5 ± 95.9 (0–1260)	–	1.8	5.4 ± 47.5 (0–567)	–	–	–
Trichodina sp.	0	0	–	1.8	21.5 ± 285.7 (0–4233)	0.2	–	–
Monogeneans	42.3	69.6 ± 108.8 (0–647)	0.01	70.4	56.3 ± 81.1 (0–512)	0.06	40.149**	29 869.5
Procamallalus. (S.) inopinatus	1.8	0.03 ± 0.2 (0–3)	–	0.9	0.03 ± 0.3 (0–4)	–	–	–
Perulernaea gamitanae	19.2	2.1 ± 8.5 (0–70)	0.002	4.9	0.6 ± 3.7 (0–45)	–	23.442**	29 281.0
Neoechinorhynchus buttnerae	0	0	0	5.7	2.3 ± 12.9 (0–133)	–	–	–

P, prevalence; MA, mean abundance; FD, frequency of dominance; χ^2, chi-square; *U*, Mann–Whitney test. *P < 0.05;**P < 0.001.

Table 6
Seasonal difference in parasite infra-communities in *Colossoma macropomum* × *Piaractus brachypomus,* eastern Amazon region, Brazil

Diversity index	Rainy season (n = 281)	Dry season (n = 222)	U	P
Species richness	1.5 ± 1.3 (0–5.0)	1.6 ± 1.1 (0–3.0)	26 011.0	0.6440
Brillouin (*HB*)	0.2 ± 0.3 (0–0.724)	0.15 ± 0.25 (0–0.8)	28 213.0	0.0650
Evenness (*E*)	0.08 ± 0.1 (0–0.4)	0.09 ± 0.13 (0–0.4)	30 701.0	0.3360
Berger-Parker (*d*)	0.5 ± 0.4 (0–1.0)	0.7 ± 0.4 (0–1.0)	26 250.5	0.0003

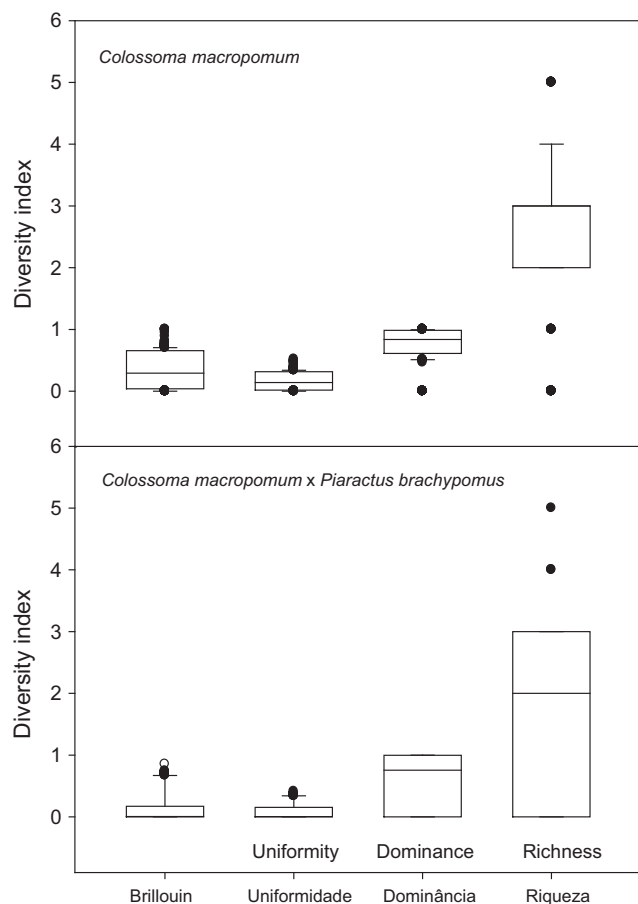*U*, Mann–Whitney test; mean ± SD, range and significance level (P).

Fig. 2. Parasite diversity index for two farmed fish species, eastern Amazon region, Brazil. Box plots represent median, interquartile range (25–75%), minimum–maximum and outliers

increase in environmental stress, thereby affecting the parasite communities (Kadlec et al., 2003).

In the gills of *C. macropomum* and *C. macropomum* × *P. brachypomus*, the infection level due to dactylogyrid monogeneans (*A. spathulatus*, *M. boegeri*, *N. janauachensis* and *L. brinkmanni*) was constant throughout both seasons. For *C. macropomum*, the abundance of these monogeneans was higher during the dry season, and for *C. macropomum* × *P. brachypomus*, the prevalence was higher during the dry season (Godoi et al., 2012). In these fish farms, the fish density in the ponds was high and the water quality was poor, which may explain the permanently high levels of infection by monogenean species, throughout the year. In farmed *C. macropomum* in the central Amazon region, higher numbers of young forms of *A. spathulatus*, *L. brinkmanni*, *Mymarothecium* spp. and *Notozothecium* sp. were also reported during the dry season (Godoi et al., 2012). This seasonal pattern of infection by dactylogyrids was favored by the reduced water levels, thereby concentrating parasites and hosts and increasing the likelihood of infection, since these parasites have a simple direct life cycle (Neves et al., 2013).

Thus, these results indicate that reproduction among the dactylogyrid communities in the hosts studied follow a well-defined pattern, i.e. with high prevalence and abundance

throughout the year but with the highest peak of abundance during the dry season. In contrast, a study on the abundance of *Dactylogyrus* spp. in a temperate climatic region showed that this was strongly influenced by rains, with a reduction in the rainy season, and that it increased with rising temperatures (Kadlec et al., 2003), because temperature directly affects the reproduction of dactylogyrids and host response to infection (Valtonen and Koskivaara, 1994). Therefore, in Amazon region with tropical humid climate, the life cycle of monogeneans can be completed in less than 1 day and these parasites proliferate rapidly (Flores-Crespo and Flores-Crespo, 2003).

In wild fish in the Brazilian Amazon region, *B. patagonica* has been reported to have low abundance and low parasitic specificity (Tavares-Dias et al., 2014b). However, parasitism by this isopod is uncommon in farmed fish. In the gills of *C. macropomum*, *B. patagonica* presented low prevalence and abundance in both the rainy and the dry seasons. *P. gamitanae*, a lernaeid that is specific for this Amazonian host, had low abundance and higher parasite aggregation. However, in the *C. macropomum* × *P. brachypomus* hybrids, which are hosts having greater susceptibility to *P. gamitanae* than to *C. macropomum* (Tavares-Dias et al., 2011), the prevalence of this lernaeid was lower in the dry season. During this period, parasites have greater difficulty in finding hosts, because of their lower mobility in this environment with less water flow. Despite the moderate infection levels of *P. gamitanae*, there was very high parasite aggregation in the mouth of both hosts. This can cause mortality among these fish, especially among fry and juveniles (Mathews et al., 2011). Therefore, prophylactic management should be adopted in the fish farms in order to avoid economic losses caused by this Amazonian lernaeid.

The main factors structuring the parasite infracommunities in *Aequidens tetramerus* Heckel, 1840, were found to be the hydrodynamic variation, host feeding behavior and seasonal variation in the availability of infective stages of these parasites in the environment. These factors influenced the structure of parasite infracommunities either through accumulation of endohelminths (nematodes, acanthocephalans and cestodes) or through ingestion of infective stages of these parasites during the rainy season, when the increased availability of food resources caused increased ingestion of infective stages of these endoparasites transmitted trophically (Tavares-Dias et al., 2014a). In *C. macropomum* and *C. macropomum* × *P. brachypomus*, low parasitism by *P. (S.) inopinatus* was observed during the rainy and dry seasons. Therefore, in the present study, the low infection level and diversity of endohelminths was due to reduced abundance of intermediate hosts in the farm ponds.

Among the various groups found parasitizing *C. macropomum* and *C. macropomum* × *P. brachypomus*, some species may cause excessive economic losses in fish farm. Therefore, due to the gradual increase in intensive production of these fish species form Brazilian Amazon, there is a need of constant monitoring of these fish for control of parasitic infections. Furthermore, the parasite communities were characterized by a few numerically dominant species that occurred during both the rainy and the dry season, and the

gills were the organ most infected. However, *C. macropomum* × *P. brachypomus* was less parasitized than its parental species, probably due to its higher resistance to parasitic infections and tolerance to intensive management, which seem be favored by the hybridization. A seasonal pattern was detected for some ectoparasite infracommunities in both hosts, but the body conditions were not affected. Lastly, this initial report on seasonal patterns of parasites for *C. macropomum* and *C. macropomum* × *P. brachypomus* can assist fish farmers in understanding the parasite dynamics in these farmed fish, helping in programs for fish disease prevention and control because they indicate the correct season for the application of adequate prophylactic measures to reduce the negative impact of parasites in fish farms.

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