



## Temporal variation of monogenoideans component community in the gills of *Oreochromis niloticus* (Cichlidae) in fish farming in northern Parana state, Brazil

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**Abstract.** The present study assessed the temporal variations of the monogenoideans component community structure in the gills of adults of *Oreochromis niloticus* and the population indices of each species, as well as, the associations among species and the occurrence of reproduction in each analyzed tank. Eighty-five specimens of *O. niloticus* collected in April, August and November 2010 and February 2011 from earthen-ponds in a Fish Culture Station located in northern Parana state, Brazil, had their gills analyzed. A total of 1261 monogenoidean parasites of six Ancyrocephalidae species, all with African origin, were found, with *Cichlidogyrus sclerosus* as dominant species. This is the first report of *Cichlidogyrus rognoni* in Brazil. All parasite species presented the highest mean values of prevalence and abundance in April and November and the lowest values in August and February. Temporal variation of mean intensity differed between species; community structure also varied, presenting the lowest values in August. Positive correlation was observed between species abundance and richness. The species assessed were positively associated and presented individuals with eggs during all or part of the study period.

**Keywords:** Fish; tilapia farming; parasitism; seasonality; Ancyrocephalidae

**Resumo. Variação Temporal da comunidade componente de monogenóideos das brânquias de *Oreochromis niloticus* (Cichlidae) em piscicultura no norte do Paraná, Brasil.** Neste estudo avaliou-se as variações temporais da estrutura da comunidade componente de Monogenoidea das brânquias de adultos de *Oreochromis niloticus* e dos índices populacionais de cada espécie que a compõe, o tipo de associações entre as espécies e a ocorrência de reprodução no tanque estudado. Foram examinadas as brânquias de 85 exemplares de *O. niloticus*, coletados nos meses de abril, agosto e novembro de 2010 e fevereiro de 2011 em tanque escavado de uma Estação de Piscicultura no norte do Estado do Paraná, Brasil. Foram encontrados 1261 monogenóideos de seis espécies de Ancyrocephalidae, todas de origem africana, sendo *Cichlidogyrus sclerosus* a dominante. Destaca-se, neste trabalho, o primeiro registro de *Cichlidogyrus rognoni* no Brasil. Todas as espécies apresentaram os mais altos valores de prevalência e abundância média em abril e novembro e os menores em agosto e fevereiro. A variação temporal da intensidade média diferiu entre as espécies. A estrutura da comunidade componente também variou, sendo os menores valores obtidos em agosto. Correlação positiva foi constatada entre abundância e riqueza. As espécies eram positivamente associadas e tinham indivíduos com ovo durante todo ou parte do período do estudo.

**Palavras-chave:** Peixe; tilapicultura; parasitismo; sazonalidade; Ancyrocephalidae

## Introduction

Originally from Africa, the Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) was introduced in Brazil by the Department of Agriculture of São Paulo State in 1952 to restrain the proliferation of aquatic algae and macrophytes in dams (Boscardin 2008). In 1971, the National Department of Works Against Drought (DNOCS) conducted a new introduction of *O. niloticus* aiming to produce fingerlings for stocking public water reservoirs in the northeast region of the country and to promote fish farming (Borghetti & Teixeira da Silva 2008). As of 2002, this species has become the most cultivated in fish farms in several states and is currently farmed throughout the country (Boscardin 2008, Borghetti & Teixeira da Silva 2008).

Among Cichlidae, the species of *Oreochromis* Günther, 1889, *Coptodon* Gervais, 1848 (= *Tilapia* Smith, 1840), and *Sarotherodon* Rüppell, 1852 comprise the groups of hosts that exhibit the most diverse and complex parasite communities (Pouyaud *et al.* 2006). In Africa, Ancyrocephalidae Bychowsky, 1937 (Monogenoidea Bychowsky, 1937) is the most representative family of gill parasites of these cichlids, and the species that infest the gills of *O. niloticus* are distributed in two genera: *Cichlidogyrus* Paperna, 1960 and *Scutogyrus* Pariselle and Euzet, 1995 (Pariselle 1995, Pariselle & Euzet 2009).

Only the African species of Monogenoidea such as *Cichlidogyrus sclerosus* Paperna and Thurston, 1969, *Cichlidogyrus thurstonae* Ergens, 1981, *Cichlidogyrus halli* (Price & Kirk, 1967), *Cichlidogyrus. tilapiae* Paperna, 1960, and *Scutogyrus longicornis* (Paperna & Thurston, 1969) have been recorded infesting the gills of *O. niloticus* farmed in different Brazilian states (Lizama *et al.* 2007, Jeronimo *et al.* 2011, Pantoja *et al.* 2012, Martins *et al.* 2014, and Zago *et al.* 2014). Such records confirm that *O. niloticus* has brought along part or all of its native parasites, as preconized by Galli *et al.* (2005) and Lacerda *et al.* (2012) regarding the introduction of this species in Brazil. Nevertheless, quantitative data and evaluation of the population dynamics of these parasites in Nile tilapia farmed in Brazilian continental waters are still scarce.

In this context, the present study assessed the temporal variation of population indices of each species of monogenoidean in the gills of adults of *Oreochromis niloticus* farmed in earthen-ponds, as well as, of their component community structure. Associations between pairs of species and the

occurrence of reproduction in each analyzed tank were also studied.

## Materials and methods

Eighty-five adult individuals of *O. niloticus*, sexually reverted, donated by a fish farm located in the municipality of Londrina, Parana state, Brazil (51°12'30,1" W, 23°19'17,2" S) were analyzed. These fish were caught using cast nets or trawls in a 1000 m<sup>2</sup> water surface pond, weighed (body mass - Wt - in grams) on analytical balance, and measured (total length - Lt - in centimeters) using an ichthyometer. The following numbers of fish with their respective mean total length (Lt) in centimeters (cm) and mean body mass (Wt) in grams (g) were analyzed: April 2010 - 20 specimens (Lt = 26.94 ±2.73 and Wt = 408.19 ±99.88); August 2010 - 20 specimens (Lt = 31.91 ±2.90 and Wt = 746.07 ±218.91); November 2010 - 20 specimens (Lt = 28.90 ±3.88 and Wt = 464.70 ±181.13); February 2011 - 25 specimens (Lt = 25.42 ±2.88 and Wt = 339.45 ±125.25).

The gills of each fish were removed and examined in detail under magnification using a stereomicroscope. The monogenoidean parasites were fixed in A.F.A solution (acetic acid, formaldehyde, and 70% ethyl alcohol), preserved in 70% alcohol, clarified in Gray & Wess or stained with Gomori trichrome, and placed singly on a histological slide (Eiras *et al.* 2000). Each individual was identified according to the descriptions by Paperna (1964), Paperna & Thurston (1969), Ergens (1981), Douëllou (1993), Pariselle & Euzet (1995), Pariselle *et al.* (2003) and the determination key proposed by Pariselle & Euzet (2009).

Individuals of each species were counted and then the values of Prevalence (P%), Mean Intensity (MI), and Mean Abundance (MA) were calculated (Bush *et al.* 1997). Relative abundance, corresponding to the proportion of parasites of each species in the total collected in each month of the study, was also calculated.

Parasites with eggs were counted to determine the relative frequency, given in percentage, in each month of the study in order to evaluate the probable reproductive period of each species. To evaluate the component community structure of Monogenoidea in the gills of *O. niloticus* specimens, richness, total abundance, and Brillouin diversity and Berger-Parker dominance indices (Von Zuben & Nering 2010), were considered for each month and total of the study. The values of these indices were calculated and compared using the Past 3.0 software.

Associations between pairs of species were assessed through the application of the Chi-square test with data displayed in 2x2 contingency table (Ludwig & Reynolds 1988, Valentin 2000) using:

**a:** number of hosts in which both species occurred;

**b:** number of hosts in which only species A occurred;

**c:** number of hosts in which only species B occurred;

**d:** number of hosts in which neither species occurred;

Positive or negative associations were assessed by calculating the value expected for **a**, [E(**a**)], applying the formula:  $E(a) = \frac{(a+b)(a+c)}{N}$ , where **N** corresponds to the total number of analyzed hosts. If the value of **a** is greater than expected [E(**a**)], the association is positive, that is, the two species occur simultaneously more often than they occur separately. If the value of **a** is lower than [E(**a**)], the association is negative, that is, although the species occur simultaneously in some cases, they occur more frequently separately than simultaneously.

The possible correlation between richness and abundance of parasites was tested using the Spearman's rank correlation coefficient "rs" (Zar 1996).

The following measures with the respective standard deviations were also calculated: number of hosts that contained infracommunities with different numbers of species, percentage of these infracommunities in the total number of hosts (relative proportion), and total and mean numbers of parasites in the different infracommunities. Infracommunity was considered as all species of monogenoideans found in the gills of each individual host and the component community comprised all infracommunities of the total of hosts at a given location and time (Bush & Holmes 1986, Esch *et al.* 1990, Bush *et al.* 1997).

All statistical analyses and calculations were performed using GraphPad InStat 3.05 and a 5% level of significance was adopted. Individuals representative of each species were deposited in the Helminthological Collection of Oswaldo Cruz Institute (CHIOC), Rio de Janeiro, Brazil (CHIOC 38422, 38426, 38429, 38433, 38439, 38440).

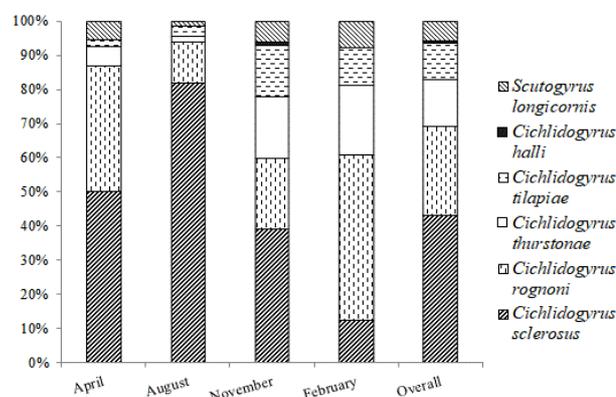
## Results

The component community of monogenoideans infesting the gills of the *O. niloticus* analyzed was composed of the following

species of Ancyrocephalidae: *C. sclerosus*, *Cichlidogyrus rognoni* Pariselle, Bilong Bilong and Euzet, 2003, *C. thurstonae*, *C. tilapiae*, and *Scutogyrus longicornis* during all months of the study. In November 2010, *C. halli* was also present. Thus, richness was as follows: five in April and August 2010 and in February 2011, and six in November 2010 (Fig. 1; Tables I and II).

Of the 1261 Ancyrocephalidae specimens collected, 544 (43.1%) were *C. sclerosus*; 329 (26.0%), *C. rognoni*; 173 (13.7%), *C. thurstonae*; 135 (10.7%), *C. tilapiae*; 74 (6.0%), *S. longicornis*; and six (0.5%) were *C. halli* (Fig. 1).

In April, 86.9% of the Ancyrocephalidae specimens infesting the gills of *O. niloticus* corresponded to *C. sclerosus* and *C. rognoni*, with *C. sclerosus* as dominant species (Fig. 1). The same was verified in August, when these two species comprised 93.4% of the collected parasites (Fig. 1). In November, although *C. sclerosus* had remained as dominant species, it comprised only 39.2% of the parasites, whereas *C. rognoni* corresponded to 20.6%, *C. thurstonae* to 17.8%, and *C. tilapiae* to 15.3% (Fig. 1). However, it is worth noting that *C. rognoni* was the dominant species in February, with *C. thurstonae* corresponding the second abundant species with 20.3% of the observed parasites, and only 12.5% belonged to the *C. sclerosus* (Fig. 1).



**Figure 1.** Temporal variation of relative abundance for each species of the component community of Ancyrocephalidae species in the gills of *Oreochromis niloticus* specimens collected from a fish tank in northeastern Parana state, Brazil, from April 2010 to February 2011.

Analysis of the population indices showed differences between the relative abundance values observed for each species in the component community of Ancyrocephalidae found in the gills of *O. niloticus* (Fig. 1; Table I). The highest prevalence values were

observed in specimens parasitized by *C. sclerosus* and *C. rognoni*, whereas the lowest value was verified in hosts of *C. halli* (Table I). With respect to prevalence, temporal variation was similar for the Ancyrocephalidae species, except for *C. halli*, which was observed only in November. The highest values of prevalence of all monogenoidean species were registered in April and November and the lowest in August and February. The same was verified for the mean abundance values of all parasites (Table I).

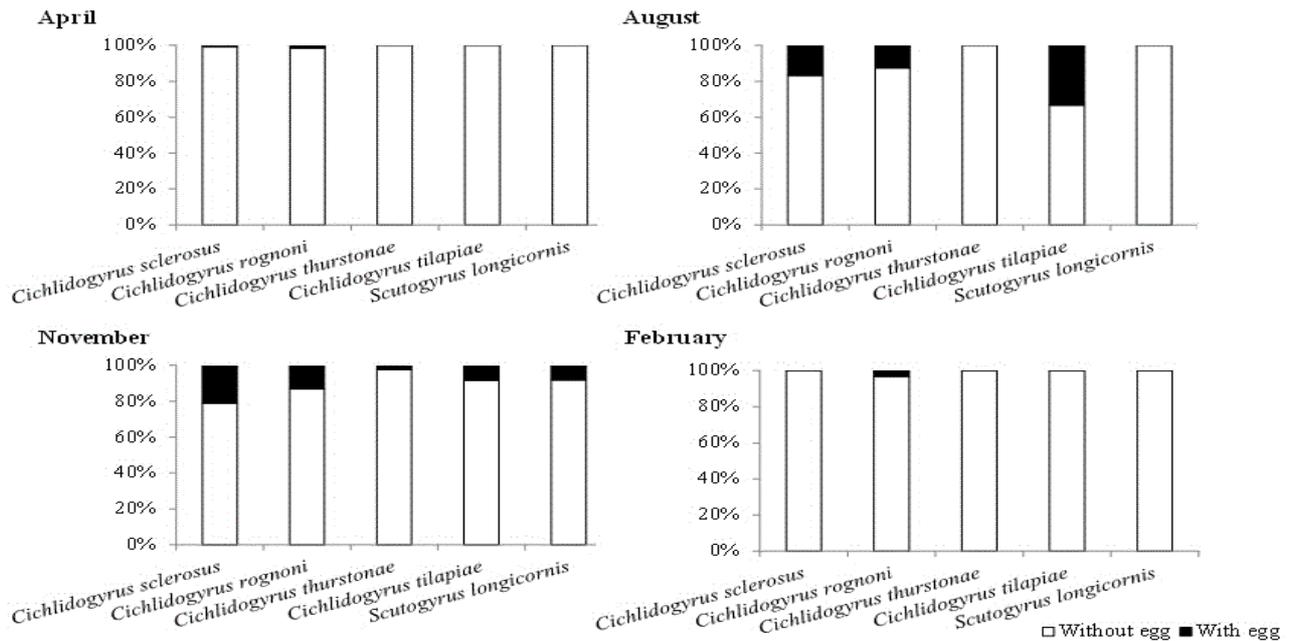
Nevertheless, temporal variation of mean intensity differed between species (Table I): *Cichlidogyrus sclerosus* showed unchanged mean intensity from April to November 2010 ( $p>0.05$ ) but presented the lowest value

( $p<0.05$ ) in February 2011 (Table I), whereas *C. rognoni* showed a decrease in August ( $p<0.05$ ), an increase in November ( $p<0.05$ ), and remained unchanged in February ( $p>0.05$ ). As for *Cichlidogyrus thurstonae* and *C. tilapiae*, the highest mean intensity values were observed in November ( $p<0.05$ ), with a reduction in February ( $p<0.05$ ) (Table I). Only *S. longicornis* did not have its mean intensity values altered throughout the study months ( $p<0.05$ ) (Table I).

*Cichlidogyrus rognoni* was the only parasite species with individuals with egg in all months of the study, with higher percentages observed in August and November 2010 (Fig. 2).

**Table I.** Temporal variation of Prevalence (P), Mean Intensity (MI), and Mean Abundance (MA) of Ancyrocephalidae species found in the gills of *Oreochromis niloticus* specimens in fish farming in northeastern Parana state, Brazil, from April 2010 to February 2011.

		<i>Cichlidogyrus sclerosus</i>	<i>Cichlidogyrus rognoni</i>	<i>Cichlidogyrus thurstonae</i>	<i>Cichlidogyrus tilapiae</i>	<i>Cichlidogyrus halli</i>	<i>Scutogyrus longicornis</i>
April	P (%)	90	95	40	30	-	65
	MI±s (Range)	9.8 ±10.2 (1-35)	6.8 ±4.7 (1-20)	2.5 ±1.8 (1-6)	1.2 ±0.4 (1-2)	-	1.5 ±0.7 (1-3)
	MA±s (Range)	8.8 ±10.1 (0-35)	6.5 ±4.8 (0-20)	1.0 ±1.7 (0-6)	0.4 ±0.6 (0-2)	0	1.0 ±0.9 (0-3)
August	P (%)	25	25	5	10	-	5
	MI±s (Range)	10.8 ±11.2 (1-27)	1.6 ±1.3 (1-4)	1.0	1.0	-	1.0
	MA±s (Range)	2.7 ±7.0 (0-27)	0.4 ±0.9 (0-4)	0.1 ±0.2 (0-1)	0.1 ±0.3 (0-1)	0	0.1 ±0.2 (0-1)
November	P (%)	100	90	70	60	20	65
	MI±s (Range)	15.3 ±12.3 (3-49)	8.9 ±7.7 (1-24)	9.9 ±10.8 (1-34)	10.0 ±13.8 (1-41)	1.5 ±1.0 (1-3)	3.8 ±3.3 (1-11)
	MA±s (Range)	15.3 ±12.34 (3-49)	8.0 ±7.73 (0-24)	6.9 ±10.1 (0-34)	6.0 ±11.7 (0-41)	0.3 ±0.7 (0-3)	2.5 ±3.2 (0-4)
February	P (%)	8	20	12	8	-	8
	MI±s (Range)	2.6 ±1.3 (1-4)	4.7 ±4.5 (1-13)	3.3 ±2.2 (1-6)	3.5 ±2.1 (2-5)	-	1.7 ±1.2 (1-3)
	MA±s (Range)	0.4 ±1.1 (0-4)	1.2 ±2.9 (0-13)	0.5 ±1.5 (0-6)	0.3 ±1.1 (0-5)	0	0.2 ±0.7 (0-3)
Overall	P (%)	52	55	31	26	5	34
	MI±s (Range)	12.1 ±11.3 (1-49)	6.9 ±6.1 (1-24)	6.3 ±8.4 (1-34)	6.0 ±10.7 (1-41)	1.5 ±1.0 (1-3)	2.6 ± 2.4 (1-11)
	MA±s (Range)	6.4 ±10.2 (0-49)	3.8 ±5.7 (0-24)	2.1 ±5.6 (0-34)	1.6 ±6.1 (0-41)	1.1 ±0.4 (0-3)	0.9 ±1.9 (0-11)



**Figure 2.** Temporal variation of Relative Frequency of individuals with egg for each species of the Ancyrocephalidae component community in the gills of *Oreochromis niloticus* specimens collected in fish tanks in northeastern Parana state, Brazil, from April 2010 to February 2011.

Among the *C. sclerosus* parasites observed in the gills of *O. niloticus* specimens captured in April 2010, only one individual (0.6%) contained egg. August and November also presented the highest rates (16.7% and 21.2%, respectively) of *C. sclerosus* individuals with egg (Fig. 2). Occurrence of *C. tilapiae* individuals with egg was equally verified in August and November, whereas *C. thurstonae* and *S. longicornis* presented individuals with egg only in November (Fig. 2).

Although in August the component community composition was the same as in April and February, the structure was quite altered, showing low total abundance, the lowest Brillouin diversity value, and the highest Berger-Parker dominance value (Table II), with *C. sclerosus* as dominant species (Fig. 1). In November, when the highest total abundance was obtained, both the composition and structure of the component community were again altered, mainly by the presence of *C. halli* and by the higher and lower values of diversity and dominance, respectively (Table II). In contrast, in February, although total abundance was similar to that obtained in August, the diversity and dominance indices were similar to those observed in April and November (Table II), with *C. rognoni* as dominant species (Fig. 1).

Most (77%) of the parasitized *O. niloticus* presented co-occurrence of *C.*

*sclerosus* and *C. rognoni*. Co-occurrence of *C. tilapiae* and *S. longicornis* was observed in a smaller proportion of hosts (Table III). However, all pairs of species were positively associated, ( $a > E_a$ ), that is, species occurred simultaneously in a larger number of hosts than they occurred separately.

It was possible to observe that the higher the infracommunity richness, the greater the parasite abundance ( $r=0.745$ ,  $p<0.0001$ ). The same was verified with respect to the mean number of parasites per infracommunity (Table IV). However, only three infracommunities (5.8%) were composed with six species found, with abundance equal to 146 but mean of parasites equal to those of infracommunities comprising five species ( $p=0.773$ ). Five hosts presented infracommunity containing one to five individuals of a single species (Table IV). Most of the infracommunities (69.3%) were composed of two to four species, with total abundance of 680 parasites, corresponding to 53.9% of the Ancyrocephalidae species collected.

**Discussion**

Ancyrocephalidae species present high host specificity, with *Cichlidogyrus* comprising the genus with the largest number of species

**Table II.** Temporal variation of the component community structure of Ancyrocephalidae species found in the gills of *Oreochromis niloticus* specimens in fish farming in northeastern Parana state, Brazil, from April 2010 to February 2011

Parameters	April	August	November	February	Total
Richness	5	5	6	5	6
Total abundance	351	66	780	64	1261
Brillouin diversity index	1.09	0.57	1.48	1.26	1.40
Berger-Parker dominance index	0.50	0.82	0.39	0.48	0.43

**Table III.** Relative frequency (%) of *Oreochromis niloticus* specimens where simultaneous occurrence of pairs of Ancyrocephalidae species was observed in the gills of specimens collected from fish tanks in northeastern Parana state, Brazil, from April 2010 to February 2011

	<i>Cichlidogyrus rognoni</i>	<i>Cichlidogyrus thurstonae</i>	<i>Cichlidogyrus tilapiae</i>	<i>Scutogyrus longicornis</i>
<i>Cichlidogyrus sclerosus</i>	77	54	40	57
<i>Cichlidogyrus rognoni</i>	-	49	44	58
<i>Cichlidogyrus thurstonae</i>	-	-	45	53
<i>Cichlidogyrus tilapiae</i>	-	-	-	34

infesting African tilapia cichlids (Paperna 1996, Pariselle & Euzet 2009, Pariselle *et al.* 2011 and Vanhove *et al.* 2016). Monoxenic parasites, such as monogenoideans, are easily introduced along with their hosts, and the worldwide distribution of *O. niloticus* has contributed to the dispersion of their parasites (Vanhove *et al.* 2016). In South America, the African species *C. sclerosus* and *C. tilapiae* were recorded for the first time in the early 1970s in Colombia, parasitizing *O. mossambicus* (Peters, 1852) (Kritsky & Thatcher 1974).

In this study, all six species of the component community of monogenoideans found in the gills of *O. niloticus* are of African origin (Douëllou, 1993, Pariselle, 1995, Bounou *et al.* 2008, Pariselle & Euzet, 2009, Akol *et al.* 2011, El-Seify *et al.* 2011, Tombi *et al.* 2014, and Blahoua *et al.* 2016). Similar results were observed for *O. niloticus* from other fish farms in Brazil. In the countryside of Sao Paulo state, *O. niloticus* specimens were infested with *C. sclerosus* and with four unidentified *Cichlidogyrus* species (Lizama *et al.* 2007). In the state of Santa Catarina, specimens also cultured in fish farms had their gills infested with *C. sclerosus* and *Cichlidogyrus* sp. (Ghiraldelli *et al.* 2006), as well as, with *C. sclerosus*, *C. halli*, *C. thurstonae*, and *S. longicornis* (Jerônimo *et al.*

2011). Similar findings were reported by Martins *et al.* (2014), except for the absence of *C. halli* and the presence of *C. tilapiae*. In contrast, a study conducted in four fish farm in the municipality of Macapá, Amapá state, described *C. tilapiae* as the only parasite species infesting the gills of *O. niloticus* (Pantoja *et al.* 2012).

Ranzani-Paiva *et al.* (2005) reported parasitism by *Cichlidogyrus* sp. in *O. niloticus* from the Guarapiranga River dam, Sao Paulo state. In the same state, specimens farmed in net cages in the Agua Vermelha reservoir, Rio Grande basin, had their gills parasitized with *C. thurstonae*, *C. halli*, *Cichlidogyrus* sp., and *S. longicornis* (Zago *et al.* 2014). *Cichlidogyrus sclerosus*, *Cichlidogyrus* sp., and *C. longicornis* (= *S. longicornis*) were observed in an urban reservoir in Parana state (Graça & Machado 2007). Therefore, although *O. niloticus* was first introduced in Brazil in the 1950s and it is currently distributed throughout the country (Boscardin 2008), there are no records of parasites of the native ichthyofauna on this fish species (Bittencourt *et al.* 2014). The same can be verified regarding infestation/infection of native fish by parasites of introduced species. Nevertheless, the only study assessing native species of Brazilian cichlids found in the specific scientific literature does not report infestations by monogenoidean parasites in *O. niloticus* (Graça & Machado 2007). According to Gendron *et al.* (2012), establishment

**Table IV.** Richness, number of hosts (N), relative proportion (%), total number of parasites, and mean number of parasites per fish, with standard deviation and minimum and maximum values (min-max) of Ancyrocephalidae infracommunities found in the gills of *Oreochromis niloticus* specimens collected in a fish tank in northern Parana state, Brazil, from April 2010 to February 2011

Richness	1	2	3	4	5	6
N	5	11	12	13	8	3
Relative proportion	9.6	21.2	23.1	25.0	15.4	5.8
Total number of parasites	11	124	155	401	414	146
Mean number of parasites per fish	2.2±1.8	11.3±8.1	12.9±11.1	30.8±28.1	51.8±42.8	48.7±22.3
Range	1-5	2-28	5-45	8-116	15-140	23-63

time of native parasites in introduced species can be long. A study conducted in southeastern Mexico reported transfer of the African Ancyrocephalidae *C. sclerosus*, *C. longicornis longicornis* (= *S. longicornis*) and *Enterogyrus malmbergi* Bilong Bilong, 1988 to native cichlids, and of *Sciadicleithrum bravohollisae* Kritsky, Vidal-Martínez & Rodríguez-Canul, 1994 - a native host parasite - to the introduced species *O. aureus* (Steindachner, 1864) (Jiménez-García *et al.* 2001).

Although the parasitic communities of tilapia present remarkable richness (more than five per host species), parasite distribution among hosts is uneven (Pouyaud *et al.* 2006). The number of species recorded in the present study is noteworthy, especially that observed in November, when six species were recorded, corresponding to the highest richness of Ancyrocephalidae found in the gills of *O. niloticus* in environments of Brazilian continental waters. It is also worth mentioning that the present study reports the first record of *C. rognoni* in Brazil. This species ranked second in abundance in the Ancyrocephalidae component community observed in the gills of the *O. niloticus* specimens analyzed, and it was the only one to present individuals with eggs in all months studied.

According to Eiras (1994), most species of Monogenoidea present well-defined annual patterns of infestation, with higher number of parasites occurring in the warmer months and decreasing in the cooler ones. Tinsley & Jackson (2002) and Buchmann & Bresciani (2006) stated that water temperature has great influence on egg production and hatching, and on the larval phase of

monogenoideans. Higher water temperatures alter fish metabolism and favor parasite reproduction (Martins *et al.* 2014). However, the results obtained in this study contradict such statements, considering that *C. sclerosus*, *C. rognoni*, and *C. tilapiae* had specimens with egg in August, indicating that they were breeding in the winter. In contrast, although all species presented individuals with egg in November, total abundance, prevalence per species, and the mean infestation intensity of each parasite, decreased in February of the following year. The lowest abundance values of Ancyrocephalidae component community in the gills of *O. niloticus* were obtained in August, corresponding to the coldest month (water temperature of 20.1 °C at the time of host collection), as well as in February, month with higher temperatures (28.6 °C at the time of collection). Such results differed from those reported in the studies by Jerônimo *et al.* (2011) and Martins *et al.* (2014), which showed the highest abundance values for monogenoideans in the gills of *O. niloticus* in spring and summer. Conversely, no seasonal variation in *O. niloticus* gill infestation with monogenoideans was observed by Tavares-Dias (2001). With regards to the relative abundance of each species, in the present study, all species presented a trend towards lower values in August and increased values in February, except for *C. sclerosus*, which corresponded to approximately 82% of the total number of parasites collected in August and only 12.5% of those collected in February. In contrast, temporal variations did not follow the same pattern when population indices were evaluated. All species showed different

fluctuations in mean intensity, except for *S. longicornis*, which presented no variation throughout the studied months. However, all species showed the same variation trend for prevalence and mean abundance, with the highest values found in April and November and the lowest in August and February. According to Aguirre-Fey *et al.* (2015), it is still not clear whether in regions with tropical climates water temperature influences the infestation dynamics of oviparous monogenean, which are transmitted via oncomiracidium. Abiotic factors, such as concentration of suspended solids and conductivity and transparency of water should be considered because they can also have an effect on the seasonal abundance of parasites (Bilong Bilong & Tombi 2005; Blahoua *et al.* 2016). In most studies, water collection for the assessment of physical and chemical parameters is performed at the time of fish capture, so that the environmental variations to which these hosts and their parasites are subjected over time are not considered. Under these conditions, it is difficult to establish with certainty the relationship between parasite indices and the abiotic factors of host habitats. In addition, breeding system, management of tanks, feeding rate, and fish population density, may also interfere with the life cycle of these parasites (Martins *et al.* 2014).

The positive association between the most abundant species: *C. sclerosus* and *C. rognoni*, and between them and the other species, as well as the positive correlation observed in the infracommunities between abundance and richness, are worth noting. According to Guegan & Hugueny (1994), the parasite community structure is determined by host biology, which influences the subset of parasites available, and richness and abundance in each host are related to facilitation processes between species. Thus, the presence of two or more parasite species in the same host facilitates successful and intensive infestation by other species, as it seems to have occurred among the species of the component community assessed in the present study. Therefore, the component community of Ancyrocephalidae species infesting the gills of *O. niloticus* specimens does not seem to comprise a stochastic subset of species, but rather it can be considered predictable. Even considering the temporal variations observed, the component community evaluated seems to be well structured, which together with the richness and occurrence of reproduction in all species, demonstrates the success of these African parasites in the fish culture studied.

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## References

- Aguirre-Fey, D., Benítez-Villa, G. E., León, G. P. P. & Rubio-Godoy, M. 2015. Population dynamics of *Cichlidogyrus* spp. and *Scutogyrus* sp. (Monogenea) infecting farmed tilapia in Veracruz, México. **Aquaculture**, 443: 11-15
- Akoll, P., Fioravanti, M. L., Konecny, R. & Schiemer, F. 2011. Infection dynamics of *Cichlidogyrus tilapiae* and *C. sclerosus* (Monogenea, Ancyrocephalinae) in Nile tilapia (*Oreochromis niloticus* L.) from Uganda. **Journal of Helminthology**, 1-9.
- Bilong Bilong, C. F. & Tombi, J. 2005. Temporal structure of a component community gill parasites of *Barbus martorelli* Roman, 1971 (Freshwater Cyprinidae) in the Centre Province, Cameroon. **Cameroon Journal of Biological and Biochemical Science**, 13: 9-18.
- Bittencourt, L. S., Pinheiro, D. A., Cárdenas, M. Q., Fernandes, B.M. & Tavares-Dias, M. 2014. Parasites of native Cichlidae populations and invasive *Oreochromis niloticus* (Linnaeus, 1758) in tributary of Amazonas River (Brazil). **Brazilian Journal of Veterinary Parasitology**, 23 (1): 44-54.
- Blahoua, G. K., Yao, S. S., Etilé, R. N. & N'Douba, V. 2016. Distribution of gill Monogenean parasites from *Oreochromis niloticus* (Linné, 1758) in man-made Lake Ayamé I, Côte d'Ivoire. **African Journal of Agricultural Research**, 11(2): 117-129.
- Borghetti, J. R. & Teixeira da Silva, U. A. 2008. Principais sistemas produtivos empregados comercialmente. Pp. 73-94. In: Ostrensky, A., Borghetti, J. R. & Soto, D. (Eds.). **Aquicultura no Brasil: O desafio é crescer**. FAO, Brasília, 276 p.
- Boscardin, N. D. 2008. A produção aquícola brasileira. Pp. 27-72. In: Ostrensky, A., Borghetti, J. R. & Soto, D. (Eds.). **Aquicultura no Brasil: O desafio é crescer**. FAO, Brasília, 276 p.
- Boungou, M., Kabre, G. B., Marques, A. & Sawadogo, L. 2008. Dynamics of population of five monogeneans of *Oreochromis niloticus* Linné, 1758, in the Dam of Loumbila and possible

- interest in intensive pisciculture. **Pakistan Journal of Biological Sciences**, 11(10): 1317-1323.
- Buchmann, K. & Bresciani, J. 2006. Monogenea (Phylum Platyhelminthes). Pp. 294–341. *In*: Woo, P. T. K. (Ed.). **Fish diseases and disorders. Protozoan and metazoan infections**. CAB International, Wallingford. 791 p.
- Bush, A. O. & Holmes, J. C. 1986. Intestinal parasites of lesser scaup ducks: an interactive community. **Canadian Journal of Zoology**, 64: 142–152.
- Bush, A. O., Lafferty, K. D., Lotz, J. M. & Shostak, A. W. 1997. Parasitology meets ecology on its own terms: Margolis *et al.* revisited. **Journal Parasitology**, 83(4): 575-583.
- Douëllou, L. 1993. Monogeneans of the genus *Cichlidogyrus* Paperna 1960 (Dactylogyridae: Ancyrocephalinae) from cichlid fishes of lake Kariba (Zimbabwe) with descriptions of five new species. **Systematic Parasitology**, 625: 159-186.
- Eiras, J.C. 1994. **Elementos de Ictioparasitologia**. Fundação Eng. Antônio de Almeida, Porto, 339 p.
- Eiras, J. C., Takemoto, R. M. & Pavanelli, G. C. 2000. **Métodos de estudo e técnicas laboratoriais em parasitologia de peixes**. EDUEM, Maringá, 171 p.
- El-Seify, M. A., Zak, M. S., Desouky, A. R. Y., Abbas, H. H., Hady, O. K. A. & Zaid, A. A. A. 2011. Seasonal variations and prevalence of some external parasites affecting freshwater fishes Reared at Upper Egypt. **Life Sciences Journal**, 8(3): 397-400.
- Ergens, R. 1981. Nine species of the genus *Cichlidogyrus* Paperna, 1960 (Monogenea: Ancyrocephalinae) from egyptian fishes. **Folia Parasitologica**, 28: 205-214.
- Esch, G. W., Shostak, A. W., Marcogliese, D. J. & Goater, T. M. 1990. Patterns and processes in helminth parasite communities: an overview. Pp. 1-19. *In*: Esch, G. W., Bush, A.O. & Aho, J. (Eds). **Parasite Communities: Patterns and Processes**. Chapman and Hall, New York, 335 p.
- Galli, P., Stefani, F., Benzoni, F. & Zullini, A. 2005. Introduction of alien host–parasite complexes in a natural environment and the symbiota concept. **Hydrobiologia**, 548: 293-299
- Gendron, A. D., Marcogliese, D. J. & Thomas, M. 2012. Invasive species are less parasitized than native competitors, but for how long? The case of the round goby in the Great Lakes-ST. Lawrence Basin. **Biological Invasions**, 14: 367-384.
- Ghiraldelli, L., Martins, M. L., Jerônimo, G. T., Yamashita, M.M. & Adamante, W. B. 2006. Ectoparasites communities from *Oreochromis niloticus* cultivated in State of Santa Catarina, Brazil. **Journal of Fisheries and Aquatic Science**, 1(2): 181-190.
- Graça, R. J. & Machado, M. H. 2007. Ocorrência e aspectos ecológicos de metazoários parasitos de peixes do Lago do Parque do Ingá, Maringá, Estado do Paraná. **Acta Scientiarum Biological Sciences**, 29(3): 321-326.
- Guegan J. F. & Hugueny, B. 1994. A nested parasite species subset pattern in tropical fish: host as major determinant of parasite infracommunity structure. **Oecologia**, 100: 184–189.
- Jerônimo, G. T., Speck, G. M., Cechinel, M. M., Gonçalves, E. L.T. & Martins, M. L. 2011. Seasonal variation on the ectoparasitic communities of Nile tilapia cultured in three regions in southern Brazil. **Brazilian Journal of Biology**, 71 (3): 365-373.
- Jiménez-García, M. I., Vidal-Martínez, V. M. & López-Jiménez, S. 2001. Monogeneans in introduced and native Cichlids in México: Evidence for transfer. **The Journal of Parasitology**, 87(4): 907-909.
- Kritsky, D. C. & Thatcher, V. E. 1974. Monogenetic trematodes (Monopisthocotylea: Dactylogyridae) from freshwater fishes of Colombia, South America. **Journal of Helminthology**, 48: 59-66.
- Lacerda, A. C. F., Yamada, F. H., Lopes, L. P. C., Lizama, M. A. P., Pavanelli, G. C. & Takemoto, R. M. 2012. Ameaça silenciosa: a introdução de peixes e seus parasitos. Pp. 59-80. *In*: Silva-Souza, A. T.; Lizama, M. A. P. & Takemoto R. M. (Orgs.). **Patologia e Sanidade de Organismos Aquáticos**. Massoni, Maringá, 404 p.
- Lizama, M. A. P., Takemoto, R. M., Ranzani-Paiva, M. J. T., Ayroza, L. M. S. & Pavanelli, G. C. 2007. Relação parasito-hospedeiro em peixes de pisciculturas da região de Assis, Estado de São Paulo, Brasil. 1. *Oreochromis niloticus* (Linnaeus,1757). **Acta Scientiarum Biological Sciences**, 29(2): 223-231.
- Ludwig, J. A., Reynolds, J. F. 1988. **Statistical Ecology: a primer on methods and computing**. John Wiley e Sons, Canada, 337 p.
- Martins, M. L., Sá, A. R. S., Jerônimo, G. T., Tancredo, K. R., Gonçalves, E. L. T., Bampi, D., Speck, G. M. & Sandin, A. M. 2014. Microhabitat preference and seasonality of gill monogeneans in Nile Tilapia reared in Southern Brazil. **Neotropical Helminthology**, 8(1): 47-58.

- Pantoja, W. M. F., Neves, L. R., Dias, M. K. R., Marinho, R. G. B., Montagner, D. & Tavares-Dias, M. 2012. Protozoan and metazoan parasites of Nile tilapia *Oreochromis niloticus* cultured in Brazil. **Revista MVZ Córdoba**, 17(1): 2812-2819.
- Pariselle, A. 1995. Etudes des parasites de Cichlidae en Afrique de l'Ouest. Pp. 44-52. In: Agnese, J. F. (Ed.). **Comptes Rendus de Atelier Biodiversité et Aquaculture**. Centre de Recherches Oceanographiques, Abidjan, Cote D'Ivoire, 115p.
- Pariselle, A., Bilong Bilong, C. F. & Euzet, L. 2003. Four new species of *Cichlidogyrus* Paperna, 1960 (Monogenea, Ancyrocephalidae) all gill parasites from African mouthbreeder tilapias of the genera *Sarotherodon* and *Oreochromis* (Pisces, Cichlidae), with a re-description of *C. thurstonae* Ergens, 1981. **Systematic Parasitology**, 56:201-210.
- Pariselle, A., Boerger, W. A., Snoeks, J., Bilong Bilong, C. F., Morand, S. & Vanhove, M. P. M. 2011. The Monogenean parasite fauna of Cichlids: a potential tool for host biogeography. **International Journal of Evolutionary Biology**, 2011: 1-15.
- Pariselle, A. & Euzet, L. 1995. *Scutogyrus* gen. n. (Monogenea: Ancyrocephalidae) for *Cichlidogyrus longicornis minus* Dossou, 1982, *C. l. longicornis*, and *C. l. gravivaginus* Paperna and Thurston, 1969, with description of three new species parasitic on african cichlids. **Journal of the Helminthological Society of Washington**, 62(2): 157-173.
- Pariselle, A. & Euzet, L. 2009. Systematic revision of dactylogyridean parasites (Monogenea) from cichlid fishes in Africa, the Levant and Madagascar. **Zoosystema**, 31(4): 849- 898.
- Paperna, I. 1964. Parasitic helminths of inland-water fishes in Israel. **Israel Journal of Zoology** 13:1-26.
- Paperna, I. 1996. **Parasites, infections and diseases of fishes in Africa - An update**. CIFA Technical Paper. Rome, FAO. 31. 220p.
- Paperna, I. & Thurston, J. P. 1969. Monogenetic Trematodes collected from cichlid fish in Uganda; including the description of five new species of *Cichlidogyrus*. **Revue de Zoologie et de Botanique africaines**, 79: 15-33
- Pouyaud, L., Desmarais, E., Deveney, M. & Pariselle, A. 2006. Phylogenetic relationships among monogenean gill parasites (Dactylogyridea, Ancyrocephalidae) infesting tilapiine hosts (Cichlidae): Systematic and evolutionary implications. **Molecular Phylogenetics and Evolution**, 38: 241-249.
- Ranzani-Paiva, M. J. T., Felizardo, N. N. & Luque, J. L. 2005. Parasitological and hematological analysis of Nile tilapia *Oreochromis niloticus* Linnaeus, 1757 from Guarapiranga reservoir, São Paulo State, Brazil. **Acta Scientiarum Biological Sciences**, 27(3): 231-237.
- Tavares-Dias, M., Moraes, F. R., Martins, M. L. & Kronka, S. 2001. Fauna parasitária de peixes oriundos de "pesque-pagues" do município de Franca, São Paulo, Brasil. II Metazoários. **Revista Brasileira de Zoologia**, 18: 81-85.
- Tombi, J., Akoumba, J. F. & Bilong Bilong, C. F. 2014. The monogenean community on the gills of *Oreochromis niloticus* from Melen fish station in Yaounde, Cameroon. **International Journal of Modern Biological Research**, 2: 16-23.
- Tinsley, R. C., Jackson, J. A. 2002. Host factors limiting monogenean infections: a case study. **International Journal for Parasitology**, 32: 353-365.
- Valentin, J. L. 2000. **Ecologia numérica: uma introdução à análise multivariada de dados ecológicos**. Interciência, Rio de Janeiro, 117 p.
- Vanhove, M. P. M., Hablützel, P. I., Pariselle, A., Šimková, A., Huyse, T. & Raeymaekers, J. A. M. 2016. Cichlids: A host of opportunities for evolutionary parasitology. **Trends in Parasitology**, 10: 1-13
- Von Zuben, C. J. & Nering, C. M. 2010. **Métodos Quantitativos em Parasitologia**. FUNEP, Jaboticabal, 72 p.
- Zago A. C., Franceschini, L., Garcia, F., Schalch, S. H. C., Gozi, K. S. & Silva, R. J. 2014. Ectoparasites of Nile tilapia (*Oreochromis niloticus*) in cage farming in a hydroelectric reservoir in Brazil. **Brazilian Journal of Veterinary Parasitology**, 23(2): 171-178.
- Zar, J. H. 1996. **Biostatistical analysis**. Prentice-Hall, New Jersey, 662 p.

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