The influence of the trawl net mouth size and collection cod-end type on catch of ichthyoplankton

A influência do tamanho da rede e do tipo de copo coletor na captura do ictioplâncton

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ABSTRACT
Currently, there are several types and models of plankton nets available on the market. However, it is not known for sure how the differences in size and shape of these nets influence the capture of eggs and larvae. Therefore, the objective of this study was to investigate the influence of mouth size and collection cod-end type on the capture of ichthyoplankton organisms. Collections were carried out in October and November 2019 on the Ibicuí River (Rio Grande do Sul, Brazil) using four different plankton trawl nets: T1: Wide mouth pelagic net with closed collection cod-end; T2: Wide mouth pelagic net with opened collection cod-end; T3: Narrow mouth pelagic net with closed collection cod-end and T4: Narrow mouth pelagic net with opened collection cod-end. At the laboratory, the samples were screened and the larvae were classified in the Yolk-Sac, Pre-Flexion, Flexion and Post-Flexion stages. To evaluate the variation of eggs, total larvae and developmental stages in each of the trawl nets, a two-way Analysis of Variance (ANOVA) was used. When the ANOVA results were significant, Tukey's *a posteriori* test was performed to detect differences. There was no statistically significant difference ($P>0.05$) in the capture of eggs and total larvae in the different nets in October. However, November has registered the highest number of total larvae in the widest mouth nets. In both months of sampling, there was greater capture of the Flexion and Post-Flexion stages on the wide mouth and opened collection cod-ends nets. The efficiency of ichthyoplankton capture seems to be related to larval developmental stages, which demonstrates the importance of choosing a net that adapts to the objectives of each study.

Keywords: larval development, samplings methodology, ichthyoplankton trawl nets.

RESUMO
Atualmente, existem diversos tipos e modelos de redes de plâncton disponíveis no mercado. No entanto, não se sabe ao certo como as diferenças de tamanho e forma dessas redes influenciam na captura de ovos e larvas. Portanto, o objetivo deste estudo foi investigar a influência do tamanho da boca e do tipo de copo coletor na captura do ictioplâncton. As coletas foram realizadas em outubro e novembro de 2019 no Rio Ibicuí (Rio Grande do Sul, Brasil) utilizando quatro redes de arrasto diferentes: T1: Rede pelágica de boca larga com copo coletor fechado; T2: Rede pelágica de boca larga com copo coletor aberto; T3: Rede pelágica de boca estreita com copo coletor fechado e T4: Rede pelágica de boca estreita com copo coletor aberto. No laboratório, as amostras foram triadas e as larvas foram classificadas nas fases de Larval Vitelo, Pré-Flexão, Flexão e Pós-Flexão. Para avaliar a variação de ovos, larvas totais e estágios de desenvolvimento

em cada uma das redes de arrasto, foi utilizada a Análise de Variância bifatorial (ANOVA). Quando os resultados da ANOVA foram significativos, foi realizado o teste *a posteriori* de Tukey para detectar diferenças. Não houve diferença estatisticamente significativa (P>0,05) na captura de ovos e larvas totais nas diferentes redes no mês de outubro. No entanto, novembro registrou o maior número de larvas totais nas redes de boca mais larga. Em ambos os meses de amostragem, houve maior captura dos estágios de Flexão e Pós-Flexão nas redes de bocas largas e copos coletores abertos. A eficiência de captura do ictioplâncton parece estar relacionada aos estágios de desenvolvimento larval, o que demonstra a importância da escolha de uma rede que se adapte aos objetivos de cada estudo.

Palavras-chave: desenvolvimento larval, metodologias de coleta, redes de ictioplâncton

1 INTRODUCTION

Ichthyoplankton are the eggs and larvae of fish that form part of the plankton assemblages during their development. The work with the initial stages of fish provides relevant information about the biology and ecology of the species, constituting essential knowledge for fisheries biology and their cultivation (BLAXTER, 1984; HOUDE, 1987; NAKATANI et al., 2001; REYNALTE-TATAJE et al., 2008).

There are perhaps four principal reasons why ichthyoplankton surveys are made: (i) Studies are often aimed to obtain an estimate of the biomass of spawning fish; (ii) The studies aim to understand the success of recruitment of particular species (or group of species) and to understand the factors underlying population fluctuations and survival; (iii) Surveys are also used to assess the ichthyoplankton community in general and understand the interrelationship between different species in this community; (iv) These studies are also widely used to be able to identify the spawning sites of the species, as well as the period of greatest reproduction in the year of a species or a group of species.

Field investigations of ichthyoplankton originated in the late 1800s, initially being carried out in marine environments; although, decades later they were also carried out in inland water environments. In the neotropical hydrographic basins, studies gained strength from the last decade of the 20th century. The motivation for investigations in neotropical inland waters has been mainly the assessment of biomass and adult spawning distribution, in order to understand how environmental variations interfere in the distribution of ichthyoplankton and the determination of spawning sites (REYNALTE-TATAJE et al., 2008).

Although some ecological patterns of fish that inhabit continental environments are already known, the recruitment process as well as the spatio-temporal distribution of eggs and larvae is still not fully understood. Part of this problem seems to be related to the sampling methodology, more specifically, to the use of equipment that can present small variations in its dimensions and structures that can influence the capture of ichthyoplankton organisms (MACLENNAN, 1992; JŮZA; KUBEČKA, 2007; JŮZA et al., 2010).

Of all the equipment available for carrying out the collection of eggs and larvae, currently the most used method for the ichthyoplankton studies in neotropical environments consists of the use of planktonic nets, which are towed behind the boat (CADA; LOAR, 1982; ANDERSON; FISHER; WILLIS, 1998; ČECH et al., 2005; KRATOCHVÍL et al., 2008) or attached to the sides or front end of the boat FRANKIEWICZ; DĄBROWSKI; ZALEWSKI, 1996; FRANKIEWICZ et al., 1997; QUIST et al., 2004). Despite their common use, these nets present some variations in the market such as: the size of the mesh opening, which normally varies from 300 to 500 microns; the mouth opening of the net, which are generally offered in sizes of 138 and 155 cm in diameter and the presence (or not) of an opening in the collection cod-end.

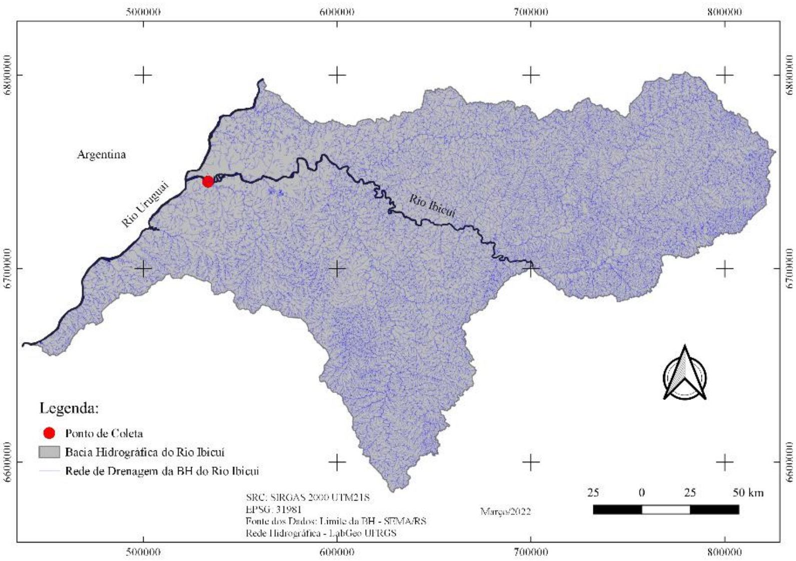
It is quite common that when purchasing a net, the researcher is only concerned with the size of the mesh opening, not giving much importance to the mouth size and the presence of an opening in the collection cod-end. This, according to some studies carried out in marine and continental environments, may be an error, since these nets are quite selective and their measurement ratio can influence both the density and the size of the captured organisms (TREASURER, 1978; WANZENBÖCK; MATENA; KUBEČKA, 1997; TISCHLER; GASSNER; WANZENBÖCK, 2000). Studies carried out outside the neotropics evaluating the mouth size and mesh opening of pelagic nets indicate that these factors can significantly affect their filtration efficiency and consequent capture of organisms (ITAYA et al., 2007; JŮZA; KUBEČKA, 2007; TREASURER, 1978); and the size of the mouth opening can also significantly influence the size of captured larvae (MOUS; VAN DENSEN; MACHIELS, 2002). Regarding the opening in the collection cod-end, no study was found that evaluated the influence of this factor on the capture of ichthyoplankton organisms. Thus, the objective of the present study was to investigate the influence of the mouth opening size of the pelagic net as well as the opening in the collection cod-end on the efficiency of capturing eggs and larvae in their different stages.

2 MATERIALS AND METHODS

2.1 STUDY AREA

The present work was performed in the Ibicuí River, which is considered the largest tributary of the Uruguay River in Brazil, located in the western region of Rio Grande do Sul and situated in a floodplain region within the Pampa biome. The sampling site is located in the lower stretch of the Ibicuí River (29°25'29"S; 56°39'20"W) in a region with a width of 245 meters and an average depth of 1.45 meters. In the studied section, the river is interspersed with puddles and rapids and, the banks have patches of riparian vegetation that are interspersed with the presence of sandbanks (Figure 1).

Figure 1: Location of sampling sites in the Ibicuí River, Middle Uruguay River.



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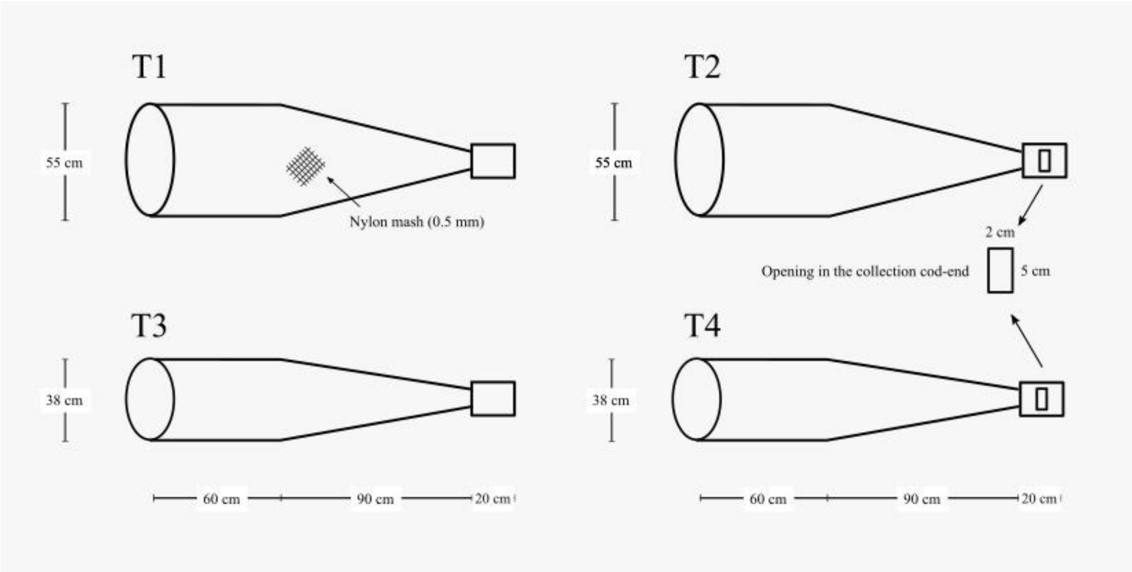
2.2 SAMPLING

Sampling ichthyoplankton in the Ibicuí River was carried out in October and November 2019. Collections were carried out to the surface, using conical-cylindrical plankton nets (500 µm mesh). During these samplings, four treatments were tested: T1: Wide mouth pelagic net with closed collection cod-end; T2: Wide mouth pelagic net with opened collection cod-end; T3: Narrow mouth pelagic net with closed collection cod-end and T4: Narrow mouth pelagic net with opened collection cod-end. The dimensions and characteristics of each of the nets can be seen in Figure 2.

Figure 2: Ichthyoplankton trawl nets used in samplings on the Ibicuí River, Middle Uruguay River.



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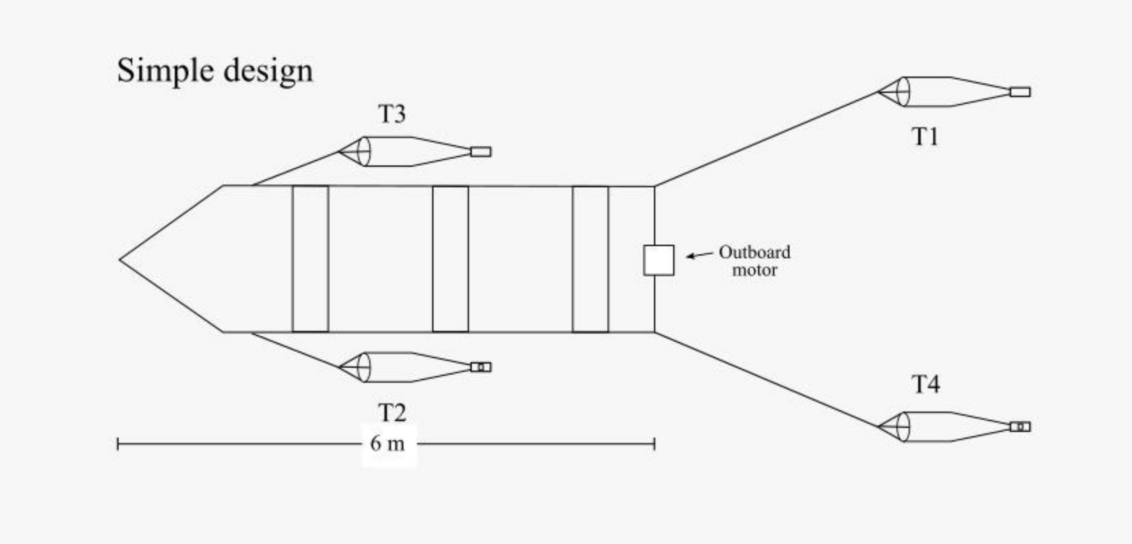
Collections were made in only one day of each month, in the early evening (between 8 pm and 9 pm), when the highest densities of eggs and larvae are captured (BIALETZKI et al., 2005; HERMES-SILVA; REYNALTE-TATAJE; ZANIBONI-FILHO, 2009). During this period, four simultaneous samplings were carried out with the four trawl nets, each lasting 10 minutes. A total of 16 samples were collected for each month (four for each treatment), and for the two months, a total of 32 samples were obtained. Each sampling consisted in installing the four nets on the side of the boat, two in front of it and two on the back of the boat. The last two nets were moved more laterally to prevent them from collecting the water already filtered by the nets located in front of the boat. The hauling of the nets was done by the boat at low speed (less than 5 m/s). The position of each net for each treatment on the boat was chosen at random (Figure 3).

Figure 3: Trawl nets distribution model in ichthyoplankton sampling on the Ibicuí River, Middle Uruguay River.



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The collected samples were fixed in 4% formalin and transferred to the laboratory, where the ichthyoplankton was separated from the rest of the material and quantified. All larvae collected were identified to the lowest possible taxonomic level and according to their larval development stage: Yolk-Sac (YS), Pre-Flexion (PF), Flexion (F) and Post-Flexion (FP) (AHLSTROM et al., 1976 modified by NAKATANI et al., 2001). Ichthyoplankton abundance was standardized to $10m^{-3}$ of filtered water (NAKATANI et al., 2001).

The volume of water filtered by each net was obtained using a mechanical flowmeter and calculated by the formula that considered the difference in the opening diameter of the nets mouth (Small mouth = 38 cm and Big mouth = 55 cm): V=a.n.c. Where: V= Volume of filtered water (m^3); a= net mouth area (m^2); n= number of flowmeter revolutions; c= flowmeter calibration factor.

2.3 STATISTICAL ANALYSIS

To evaluate the variation in the total abundance of eggs, larvae and of each of the larval stages (dependent variables) among the four treatments that had the following factors: size of the opening of the net mouth and opening of the collection cod-end (independent variables), two-factor analysis of variance (two-way ANOVA) were applied to the data. When the ANOVA results were significant, Tukey's *a posteriori* test was applied in order to detect these differences.

3 RESULTS

3.1 TAXONOMIC COMPOSITION OF ICHTHYOPLANKTON

During the study period, 32 samples were collected, in which 6,519 eggs (75,66% of the total ichthyoplankton) and 2,098 larvae were found. Larvae belonging to 5 orders, 19 families, 5 genera and 28 species were captured (Table 1), with Characiformes contributing with 18,87% of capture and Siluriformes with 80,64%. Individuals of another orders and unidentified larvae represented 0,47% of the total captured.

Table 1: Taxonomic composition of fish larvae captured on different trawl nets in the Ibicuí River, Middle Uruguay River.

Taxa	Treatments			
	T1	T2	T3	T4
CHARACIFORMES	0	5	0	0
ANOSTOMIDAE	7	17	4	13
Megaleoporinus obtusidens	1	0	1	1
Schizodon nasutus	0	2	2	0
BRYCONIDAE				
Brycon orbignyanus	0	0	0	2
Salminus brasiliensis	3	4	3	2
CHARACIDAE	26	18	24	26
Astyanax lacustris	20	26	12	10
Astyanax spp.	2	17	0	0
Bryconamericus iheringi	0	0	2	0
Charax spp.	7	9	10	11
Moenkhausia bonita	0	0	0	1
Piabarchus stramineus	6	12	5	2
CURIMATIDAE	9	7	1	6
ERYTHRINIDAE				
Hoplias spp.	1	1	7	0
CYNODONTIDAE				
Rhaphiodon vulpinus	1	2	0	0
PARODONTIDAE				
Apareiodon affinis	12	13	7	3
PROCHILODONTIDAE				
Prochilodus lineatus	0	1	3	9
GYMNOTIFORMES				
GYMNOTIDAE				
Eigenmannia virescens	0	0	0	1
PERCIFORMES				
SCIAENIDAE				
Pachyurus bonariensis	0	4	1	1
PLEURONECTIFORMES				
ACHIRIDAE				
Catathyridium jenynsii	1	0	1	0
SILURIFORMES	0	1	0	0
ASPREDINIDAE				
Bunocephalus doriae	0	0	2	2
AUCHENIPTERIDAE				
Trachelyopterus galeatus	20	10	6	5
CALLICHTHYIDAE				
Corydora paleatus	2	3	0	4
DORADIDAE				
Rhinodoras dorbignyi	4	13	0	0
HEPTAPTERIDAE				

Heptapterus mustelinus	0	1	1	0
Pimelodella gracilis	1	1	0	0
LORICARIIDAE				
Hisonotus spp.	1	1	1	2
Hypostomus spp.	0	0	1	1
PIMELODIDAE	409	567	289	231
Iheringichthys labrosus	8	15	2	7
Megalonema platanum	0	0	1	2
Parapimelodus valenciennis	1	0	0	0
Pimelodus maculatus	0	0	2	1
Pseudoplatystoma corruscans	4	7	5	2
Rhamdia quelen	2	1	2	4
Sorubim lima	7	25	8	5
PSEUDOPIMELODIDAE				
Pseudopimelodus mangurus	0	0	2	0
Total eggs	1.266	1.866	1.340	2.047
Total larvae	555	783	405	354
Non identified	0	0	1	0

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3.2 VARIATION IN THE ABUNDANCE OF EGGS, LARVAE AND LARVAL STAGES BETWEEN THE DIFFERENT TREATMENTS

3.2.1 Collections in october

By means of two-way ANOVA, no statistical differences were observed in the capture of eggs and larvae between treatments (P>0.05). However, when the different larvae stages were evaluated, some statistical differences were observed. For Pre-Flexion larvae, greater capture was observed in nets with wider mouths and in those with opening in the collection cod-end (Tukey, P<0.05). For larvae in Flexion and Post-Flexion, greater capture was also observed in nets with an opened collector cod-end (Tukey, P<0.05). The results of the two-way ANOVA can be seen in Table 2 and in Figures 4 and 5

Table 2: Two-way ANOVA result comparing eggs, larvae and larval stages captured in October 2019 in the Ibicuí River, Middle Uruguay River, by planktonic nets with different sizes of mouth opening and presence or absence of opening in the collector cod-end. Bold values indicate significant statistical difference.

Factor	SS	DF	MS	F	P
Eggs					
Mouth size	4.10	1	4.10	0.632	0.433
Cod-end	19.38	1	19.38	2.99	0.095
Mouth size*Cod-end	0.89	1	0.89	0.138	0.713
Larvae					
Mouth size	0.004	1	0.04	0.467	0.500
Cod-end	0.007	1	0.007	0.750	0.394
Mouth size*Cod-end	0.01	1	0.01	1.099	0.303
Yolk-Sac larvae					
Mouth size	0.004	1	0.004	0.816	0.374
Cod-end	0.006	1	0.006	1.048	0.315
Mouth size*Cod-end	0.001	1	0.001	0.178	0.677
Pre-Flexion larvae					
Mouth size	0.009	1	0.009	4.270	**0.048**

Cod-end	0.009	1	0.009	4.270	**0.048**
Mouth size*Cod-end	0	1	0	0.242	0.627
Flexion larvae					
Mouth size	0	1	0	1.615	0.214
Cod-end	0	1	0	4.487	**0.043**
Mouth size*Cod-end	0	1	0	1.615	0.214
Post-Flexion larvae					
Mouth size	0.001	1	0.001	1.482	0.234
Cod-end	0	1	0	4.118	**0.042**
Mouth size*Cod-end	0.001	1	0.001	2.638	0.116

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Figure 4: Result of two-way ANOVA applied to the density of total eggs and larvae captured by different pelagic nets in October 2019 in the Ibicuí River, Middle Uruguay River. W= Wide mouth net; N= Narrow mouth net; O= Collector cod-end with opening; C= Collector cod-end without opening.

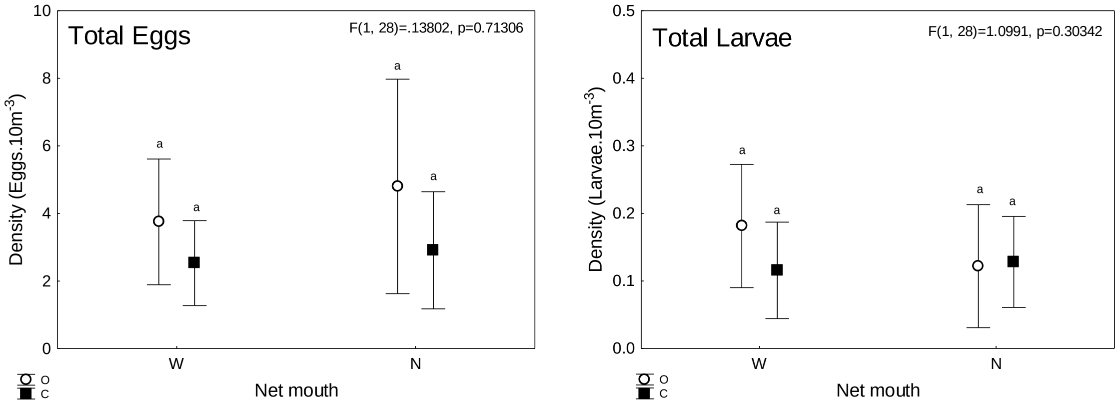

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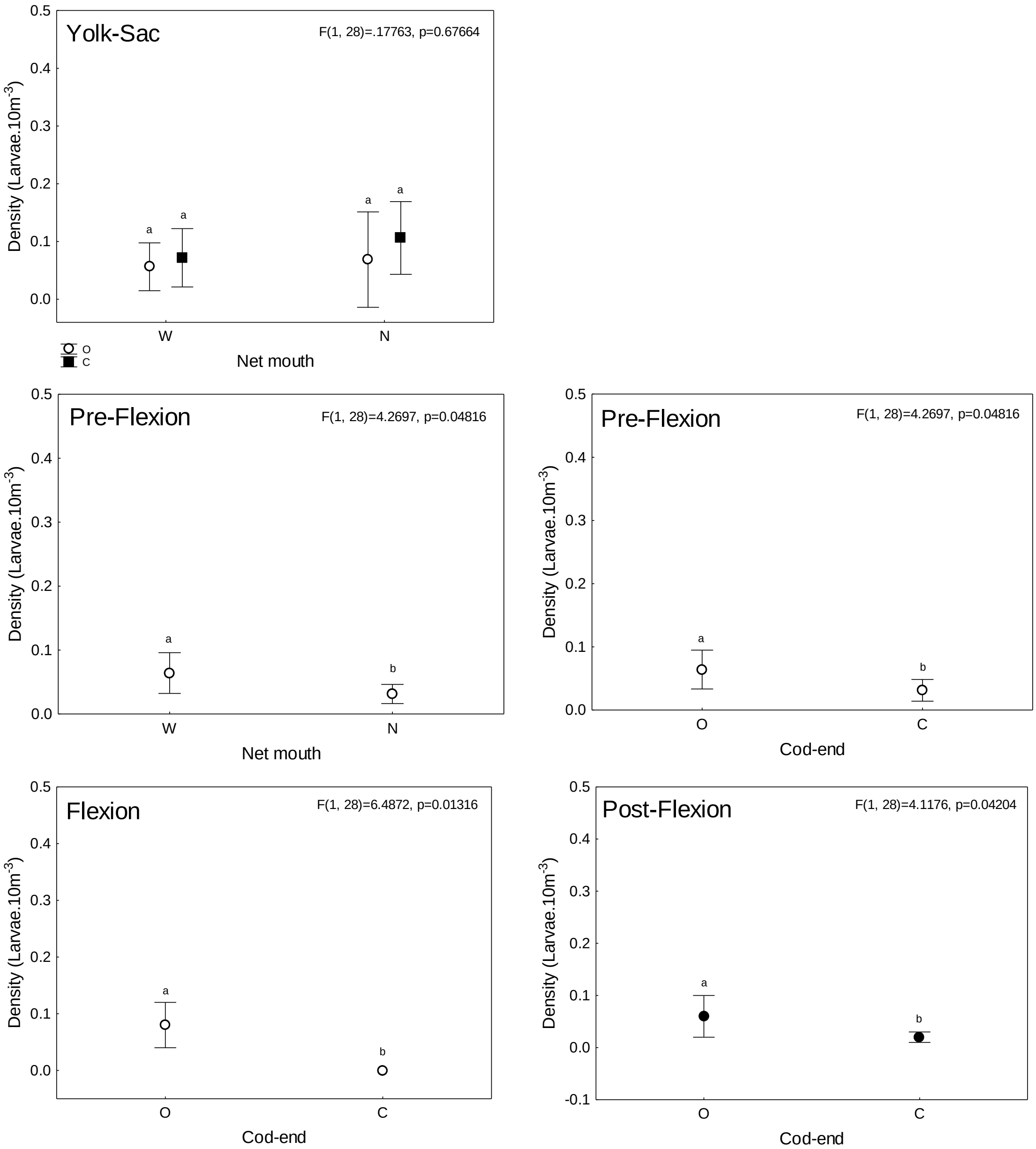
Figure 5: Result of the two-way ANOVA applied to the density of the different larval stages captured by the different pelagic nets in October 2019 in the Ibicuí River, Middle Uruguay River. W= Wide mouth

net; N= Narrow mouth net; O= Collector cod-end with opening; C= Collector cod-end without opening. Different letters indicate significant statistical difference.



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3.2.2 Collections in November

Two-way ANOVA showed no statistical differences in the capture of eggs and larvae in the Yolk-Sac and Pre-Flexion larval stages between treatments (P>0.05). However, when the Flexion and Post-Flexion stages were evaluated, statistical differences were observed. In both Flexion and Post-Flexion larvae, greater capture was observed in nets with wider mouths and in those with opening in the collection cod-end (Tukey, P<0.05). There was greater capture of total larvae in the wider mouth nets (Tukey, P<0.05). The results of the two-way ANOVA can be seen in Table 3 and in Figures 6 and 7.

Table 3: Two-way ANOVA result comparing eggs, larvae and larval stages captured in November 2019 on the Ibicuí River, Middle Uruguay River by planktonic nets with different sizes of mouth opening and presence (or not) of opening in the collector cod-end. Bold values indicate significant statistical difference.

Factor	SS	DF	MS	F	P
Eggs					
Mouth size	176.3	1	176.3	0.772	0.387
Cod-end	413.8	1	413.8	1.811	0.189
Mouth size*Cod-end	49.0	1	49.0	0.214	0.646
Larvae					
Mouth size	1395	1	1395	14.85	**0.000**
Cod-end	114	1	114	1.21	0.281
Mouth size*Cod-end	265	1	265	2.82	0.104
Yolk-Sac larvae					
Mouth size	0.723	1	0.723	0.251	0.620
Cod-end	0.518	1	0.518	0.180	0.675
Mouth size*Cod-end	0.039	1	0.039	0.013	0.909
Pre-Flexion larvae					
Mouth size	197.8	1	197.8	2.583	0.119
Cod-end	89.9	1	89.9	1.175	0.288
Mouth size*Cod-end	0	1	0	0	0.994
Flexion larvae					
Mouth size	349.9	1	349.9	15.458	**0.002**
Cod-end	354.8	1	354.8	15.535	**0.002**
Mouth size*Cod-end	226.3	1	226.3	3.530	0.071
Post-Flexion larvae					
Mouth size	13.90	1	13.90	12.77	**0.001**
Cod-end	4.11	1	4.11	8.78	**0.006**
Mouth size*Cod-end	0.96	1	0.96	0.88	0.355

Own authorship, 2022.

Figure 6: Result of two-way ANOVA applied to the density of total eggs and larvae captured by different pelagic nets in November 2019 in the Ibicuí River, Middle Uruguay River. W= Wide mouth net; N= Narrow mouth net; O= Collector cod-end with opening; C= Collector cod-end without opening.

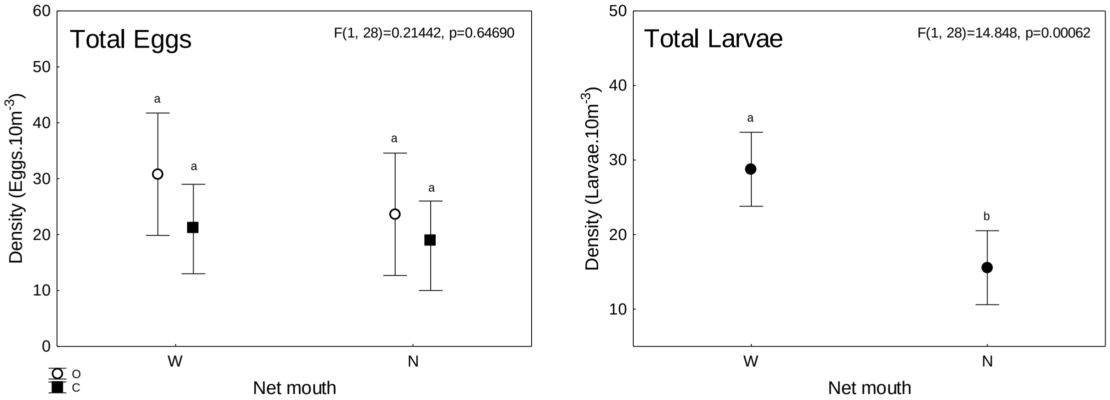

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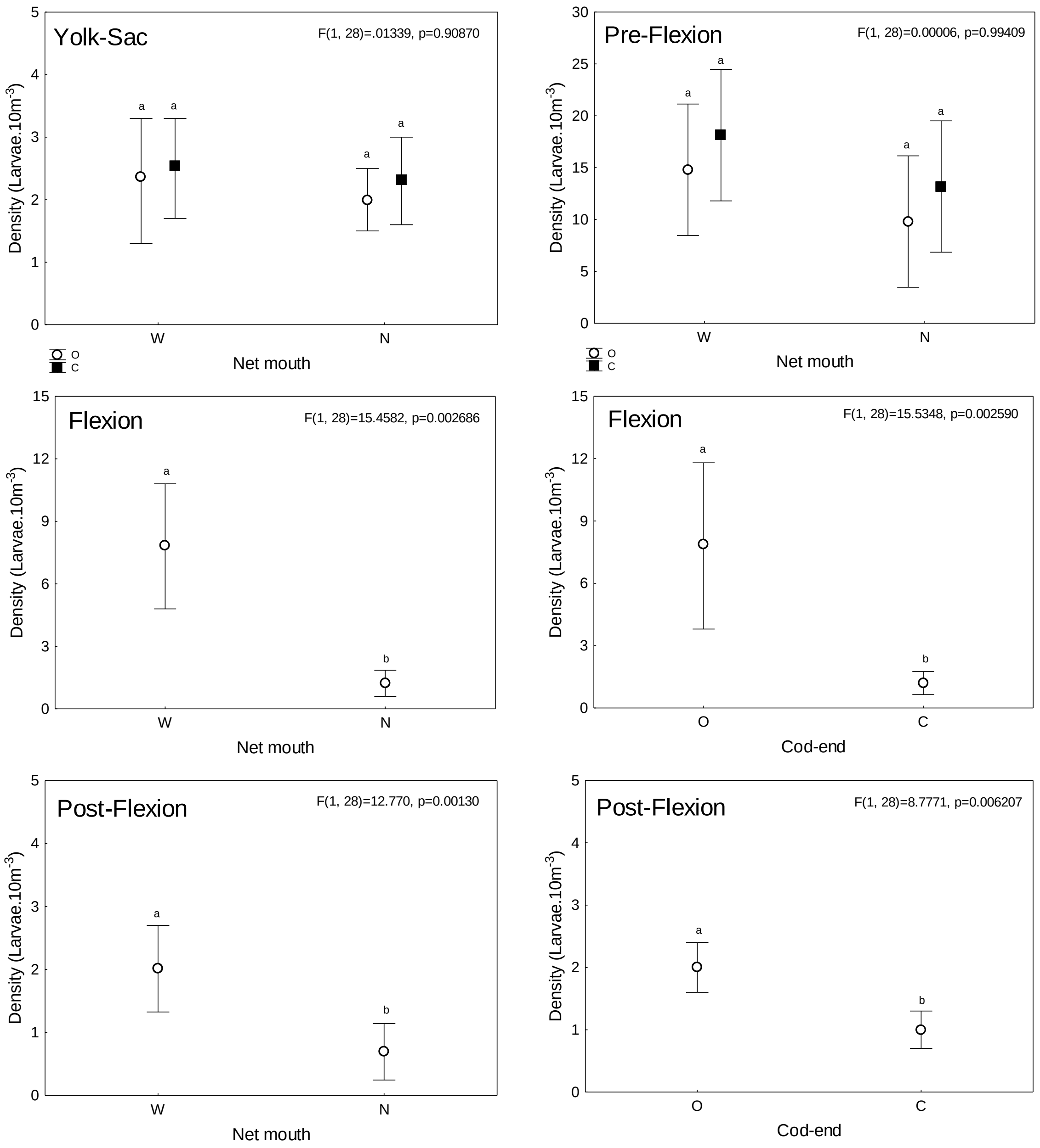
Figure 7: Result of two-way ANOVA applied to the density of the different larval stages captured by the different pelagic nets in November 2019 in the Ibicuí River, Middle Uruguay River. W= Wide mouth net; N= Narrow mouth net; O= Collector cod-end with opening; C= Collector cod-end without opening. Different letters indicate significant statistical difference.



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4 DISCUSSION

Our results clearly show that there are differences in the efficiency of the trawls tested. In general, the differences between the tested equipment are positively related to the increase in larval development. During the two studied months, a tendency was observed to greater capture of more developed larvae in the equipment that presented wider mouths and the presence of an opening (small window) in the collection cod-ends. This trend was more evident in November, the month that presented a greater capture of larvae mainly in the more advanced stages, which may have helped to maximize the difference between treatments.

In the essay, it is interesting to observe that there were no statistically significant differences for eggs and total larvae in October and for eggs in November. This result is related to the higher density of ichthyoplanktonic organisms in drift, eggs and the first larval stages (YS and PF), which have no swimming power and cannot avoid the sampling equipment, so these organisms ended up falling in a similar way in all networks.

The treatments with wider mouth proved to be very efficient in capturing the ichthyoplankton organisms, mainly the more developed organisms. Several studies carried out in other environments have shown that nets with a wider mouth opening are more efficient in capturing larger larvae (ITAYA et al., 2007; JŮZA et al., 2010). Jůza et al., (2010), working with cyprinids and perch from a reservoir, in the Czech Republic, found that trawls with a larger mouth opening are more efficient in capturing more developed individuals of these species. Furthermore, according to these authors, nets with mouths with openings smaller than $1m^2$ are not efficient for capturing these taxa. Itaya et al (2007) reported differences in avoidance behavior of different species and this effect was caused by the different ranges of each species' body lengths. According to Jůza et al (2010), evasion from nets is not only related to the size of the larvae but also to the species, some of which seem to have a greater power of escape from the equipment. In any case, although it is not the only variable, it is increasingly clear that the ability of a fish to escape the fishing gear is strongly dependent on its size (NELSON; SIEFERT; SWEDBERG, 1968; GODØ; PENNINGTON; VØLSTAD, 1990; MACLENNAN, 1992).

Our study showed that the presence of the opening in the collection cod-end also influences the greater capture of larvae, especially those with greater development. It is likely that this opening allows a better passage of filtered water, preventing the organisms that are entering the net from being "regurgitated", especially when the net starts to clog due to the entry of organic matter and other suspended particles.

Finally, the need to work with trawl nets with a wider mouth and opening in the collection cod-end seems clear, especially if the focus of the studies is related to the capture of larger larvae. Further studies should aim at the influence of different trawl nets commonly used in neotropical environments on the taxonomic composition of captured ichthyoplankton organisms, as well as the use of nets that are larger in length and mouth size than those used in the present study.

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