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Short Communication

Fish attractors when resources abound: prevalence of juveniles and lack of assemblage structure in a field experiment in the Amazon floodplain

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Abstract: Floating structures, both natural and artificial, attract fish by providing shelter, feeding areas, and nesting sites. Occupancy can be either more permanent, leading to a gradual gathering of the assembly, or transient, occurring randomly. The ability of an attractor to hold a fish assemblage may depend on the availability of habitat resources in the environment. New artificial attractors are more valuable when natural ones are scarce. Additionally, fish characteristics play a role; young and small fishes may need new habitat for shelter more than adult fish. As aquatic herbaceous areas are abundant during high water, coinciding with the period of fish reproduction, they are particularly relevant for juveniles. We constructed fish attractors composed of natural materials to investigate the structure of fish assemblages during the flood of an Amazonian floodplain lake. Our aim was to test the hypothesis that assembly processes during the flood period would be random, with a predominance of juveniles in the attractors. We collected fish at intervals of 5, 15, and 30 days, resulting in 39 observations, and classified them as either adult or juvenile. Species composition was compared among treatments using Principal Coordinates Analysis (PCoA). The assembly process was tested through species co-occurrence patterns employing null models and the C-score index. The proportion of juveniles and adults was compared using a Chi-square test. Species composition remained consistent throughout the experiment. The assembly was random, with a prevalence of juveniles, possibly serving only as temporary shelter and feeding areas. Our study contributes to understanding the role of habitat availability for floodplain fishes during high waters. The results suggest that floating attractors and new habitats may be more valuable for the juveniles than adult fish and can be used as a management strategy for population recovery, especially when floating herbaceous habitats are scarce.

Keywords: *Artificial attractors; assembly of fish assemblage; field experiment; habitat use; seasonality.*

Atratores de peixes quando os recursos são abundantes: prevalência de juvenis e falta de estrutura da assembleia em um experimento de campo na planície de inundação amazônica

Resumo: As estruturas flutuantes, naturais ou artificiais, atraem os peixes, fornecendo abrigo, áreas de alimentação e locais de nidificação. A ocupação pode ser mais permanente, resultando em um recolhimento gradativo da assembleia, ou transitória, ocorrendo aleatoriamente. A capacidade de um atrator de manter uma assembleia de peixes pode depender da disponibilidade de recursos de habitat no ambiente. Novos atratores artificiais são mais valiosos quando os naturais são escassos. Além disso, as características dos peixes desempenham um papel, já que peixes jovens e pequenos podem necessitar de novos habitats como abrigo mais do que peixes adultos. Como as áreas com herbáceas aquáticas são abundantes durante as cheias, coincidindo com o período de reprodução dos peixes, elas são especialmente relevantes para peixes juvenis. Construímos atratores de peixes compostos de material natural para investigar a estrutura das assembleias de peixes durante a cheia de um lago de várzea amazônico, a fim de testar a hipótese de que durante o período de cheia, os processos de montagem seriam aleatórios e com predominância de juvenis nos atratores. Os peixes foram coletados em intervalos de 5, 15 e 30 dias, resultando em 39 observações, e classificados como adultos ou juvenis. A composição de espécies foi comparada entre os tratamentos usando uma Análise de Coordenadas Principais (PCoA). O processo de montagem foi testado por meio de padrões de coocorrência de espécies usando modelos nulos e o índice C-score. A proporção de jovens e adultos foi comparada usando um teste Qui-quadrado. A composição de espécies permaneceu a mesma ao longo do experimento. A montagem da assembleia foi aleatória com prevalência de juvenis nos atratores, que possivelmente serviam apenas como abrigo temporário e áreas de alimentação. Nosso estudo contribui para entender o papel da disponibilidade de novos habitats para peixes de várzea durante a cheia. Os resultados sugerem que atratores flutuantes e novos habitats podem ser mais valiosos para os peixes jovens do que para adultos e podem ser usados como estratégia de manejo para a recuperação populacional, especialmente quando habitats de herbáceas flutuantes são escassos.

Palavras-chave: *Atratores artificiais; experimento de campo; montagem da assembleia de peixes; sazonalidade; uso do habitat.*

Introduction

In an aquatic environment, floating habitats such as aquatic macrophytes and underwater structures like wood branches increase environmental complexity and heterogeneity, attracting fish fauna (Freitas et al. 2002, Freitas et al. 2005, Thomaz and Cunha 2010; Rossoni et al. 2014, Yamamoto et al. 2014). These floating and underwater structures attract fish by providing shelter, feeding, and nesting sites for reproduction (Junk and Piedade 1997, Esteves 1998, Agostinho et al. 2003). The observation that fish aggregate near natural structures, such as rocks, fallen trees, aquatic herbaceous, and floating detritus, prompted the use of artificial structures that mimic the natural ones to attract fish (Bolding et al. 2004, Rossoni et al. 2014). This technique was first implemented in Japan in the late 1700s, aiming to increase the efficiency of fishery activities and was later adopted worldwide (Meier 1989). Nowadays, this technique serves various purposes, including habitat restoration, recreational diving and snorkeling activities, and scientific research (Bohnsack et al. 1997).

These structures form an important substrate for the growth of periphyton (consisting of algae, bacteria and associated micro-invertebrates) and macroinvertebrates, representing a crucial food source for many fish species (Araújo-Lima et al. 1986, Forsberg et al. 1993, Benedito-Cecilio et al. 2000) and allowing an assemblage to assembly. The colonization by periphytivorous fish can attract piscivores, triggering a process of assembling the local fish community (Chase 2003, Meerhoff et al. 2003, Mazzeo et al. 2010, Thomaz and Cunha 2010). Predation and interspecific competition are local-scale factors that can determine the composition of fish fauna, influencing the distribution of species (Hoeinghaus et al. 2007), and the local fauna within the attractors (Arrington and Winemiller 2006). The occurrence of a local assembly structure depends on how fish use these structures and the environmental availability of habitat (Arrington and Winemiller 2006). Individuals may stay for long periods or might only temporarily visit such places, either seasonally or occasionally during a period of less than a day (Talbot et al. 1978). In seasonal environments, the temporal pattern in the use of attractors is highly dependent on the availability of food resources and habitat surrounding the attractors (Arrington and Winemiller 2006).

Colonization in attractors can occur quickly or slowly (Bohnsack et al. 1991). The moment of setting them can influence the initial colonization and the use of attractors, making them more or less attractive in comparison to the surrounding environment (Bohnsack et al. 1991, Arrington and Winemiller 2006). During the flood season, these structures may not be as attractive due to the immense availability of habitats (Arrington and Winemiller 2006). However, despite being abundant during high-water periods, the availability of floating habitat, mainly aquatic herbaceous banks, have been described as the most important factor for fish recruitment in river floodplains (Sánchez-Botero and Araújo-Lima 2001). The observed higher juvenile survival in years of large floods (Bayley et al. 2018, Castello et al. 2019) has suggested that the availability of habitats for growth and feeding may regulate density-dependent processes (Bayley et al. 2018) and determine the occupation and fish assemblage structure in these habitats. We do not yet fully understand the colonization ecology of natural habitats, such as aquatic herbaceous banks, so experimental studies using artificial habitats are important to understand successional processes, such as community building (Bohnsack et al. 1991). Such processes depend on the moment in which they occur, making them more easily observed in artificial habitats than in natural ones.

This study examines fish assembly over 30 days in the high-water period through a manipulative experiment using floating attractors. We tested the hypothesis that during the flood period, assembly processes would not occur due to the high variety of habitats and the abundance of available food resources, and fish occupation in floating attractors would be random. However, we would expect a predominance of juveniles throughout the experiment as new habitat would be more valuable for this set of individuals.

Material and Methods

Most natural habitats of floating aquatic macrophytes occur in floodplain lakes and the border of flooding forests (Junk and Piedade 1997), serving as areas for fish growth and reproduction (Neves dos Santos et al. 2008, Röpke et al. 2022). The study was carried out in Lago do Padre, a floodplain lake at Ponta do Catalão, a lowland area located near the confluence of the Solimões and Negro rivers, about 10 km from the city of Manaus, Amazonas, Brazil (Figure 1). This area has a high diversity of floating habitats (Bleich et al. 2014), most available during high water. When the water level increases, typically between December and May, the pelagic area expands, providing habitat for the growth of aquatic herbaceous plants, which form extensive banks next to the edges of the surrounding flooded forest, as well as floating banks that detach from the margins (Junk and Piedade 1997). In this region, the most frequent and abundant aquatic plants are the emerging *Paspalum repens* (Poaceae), and the floating *Salvinia auriculata* (Salviniaceae), *Pistia stratiotes* (Araceae), and *Lemna valdiviana* (Araceae) (Junk and Piedade 1993; Bleich et al. 2014). Additionally, this area has a scientific station belonging to the National Institute for Amazonian Research (INPA), providing logistic support for the study. Fish samplings in macrophyte stands have been conducted in this area (Catalão project - CPD data not published), allowing easy fish identification and addition to the monitoring dataset with future value.

To study fish colonization, we used artificial attractors aiming to simulate floating aquatic herbaceous banks. Each attractor consisted of a 1.0 m^2 square frame (Figure 2), constructed with 40 mm diameter PVC pipes, similar to the frame used by Santos et al. (2011). The pipes were connected by PVC connectors to prevent water from entering and allowing the structure to float. A black plastic screen was placed on this frame as a substrate to the root-like tufts made of sisal rope. Each tuft was composed of three pieces of sisal rope, each 60 cm long and 6 mm thick, in which the threads were untwined, forming bulky tufts to simulate the roots of floating plants (for instance, Eichhornia). Each attractor contained twenty-five tufts (Figure 2). Sisal rope was chosen because it is a natural product made from fibers of the species *Agave sisalana* (Agavaceae) that, when untwined, resembles the roots of aquatic herbs.

The attractors were placed in the water, close to the INPA research base, to initiate the initial colonization by periphyton for a substrate as close as possible to natural growth. Once the tufts were covered

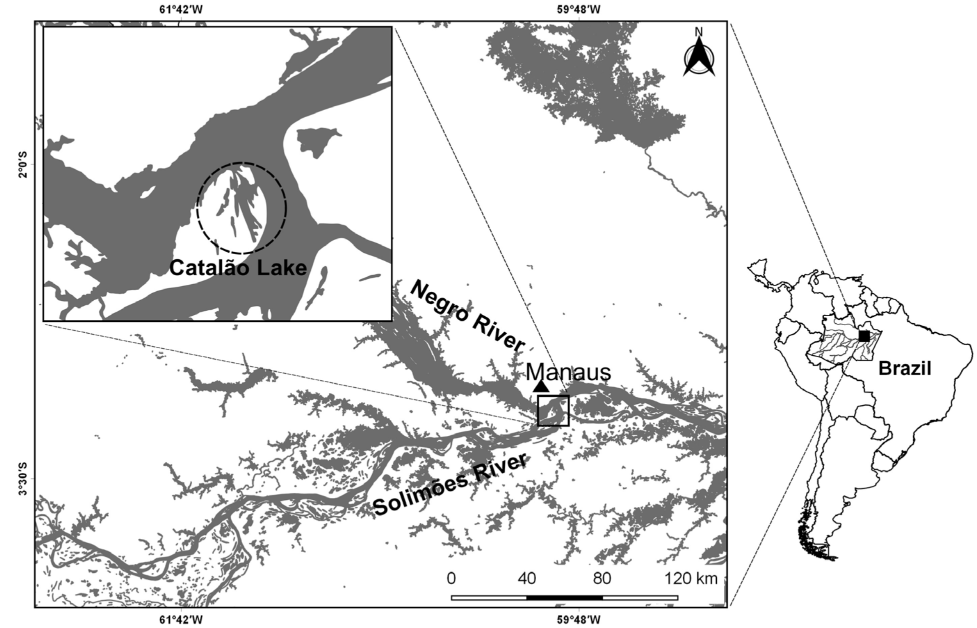

Figure 1. Map showing the Catalão area, Amazonas, Brasil.

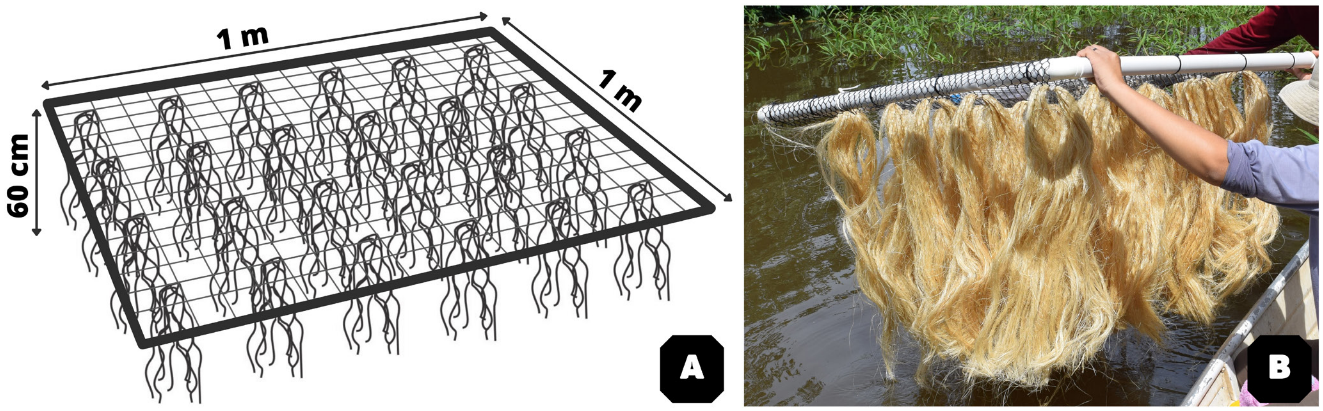

Figure 2. Illustration of the attractor with its respective dimensions (A) and the actual attractor being immersed in the water at the experiment site (B).

with periphyton, which could be observed with the naked eye (about 5–6 days), the attractors were removed from the water, checked for the presence of macroscopic organisms adhered to the tufts (which were then removed), and finally immersed in the water to begin the experiment. The attractors were placed close to the natural banks of aquatic herbaceous plants, anchored by rocks to prevent them from moving due to wind or water current.

The experiment was conducted over a period of 30 days, from June 9 to July 10, 2017, during a period of high water when the natural banks of aquatic herbaceous plants were already formed. The attractors were installed in the pelagic zone at standardized distances of at least 5 m from each other and 2.0 m from the border of the banks of herbaceous plants. To maintain the same distance from the marginal habitat, daily visits were made to the experiment site, adjusting the positions of the attractors when necessary.

The total number of attractors built and initially used in the experiment was 28. Several attractors were reused during the experiment and the removal of fish from the attractors after the intervals of 5, 15, and 30 days was carried out. Each time the attractors were removed for fish collection, the tufts of rope were meticulously inspected to ensure no fish were left adhered to the strings, so as not to interfere with the results of the next moment of colonization. The treatments were as follows:

1) Treatment 1 (5 days): five attractors were used. After 5 days of colonization, the attractors were removed from the water, the fish were collected, and the same attractors were returned to the water to restart the 5-day treatment. This procedure was repeated three times to obtain a total of 15 observations for the first treatment of 5 days;
2) Treatment 2 (15 days): eight attractors were used, which, at the end of 15 days, were reused for an equal period, totaling 16 observations for the second treatment of the 15 days;
3) Treatment 3 (30 days): 15 attractors were used, but two attractors were lost during the experiment, thus obtaining 13 observations for this third and last treatment.

To maintain the balance of the number of observations in the treatments, 2 and 3 observations from the first and second treatments, respectively, were excluded by drawing lots. Thus, in the end, each treatment had 13 observations (Table 1). The attractors were always inspected in the morning, and fish were collected using a 5 mm mesh net between opposite nodes and 1.5 meters high, tied to a 1.5 × 1.5 m square metal frame. The bottom of the seine net was closed to avoid fish escape. For collection, each attractor was carefully enveloped (from the bottom to the surface) with the adapted net and carefully removed from the water (Figure S1). Then, the fish were collected and immediately euthanized according to the CONCEA Euthanasia Practice Guidelines. Fish were immersed in a solution of clove oil (Eugenol) in the proportion of 1ml for each liter of water until the opercular movement ceased. After euthanized, the fish were fixed in a 10% formalin solution and deposited in containers containing information about the sample and the date of collection. Samples were then taken to the Fish Population Dynamics Laboratory at the National Institute for Amazonian Research (INPA) in Manaus, where each fish was identified at the species level by taxonomic specialists. Biometric data such as standard length (cm) and total weight (g) were registered for each specimen (data available at Rocha et al. 2023). The total number of fish and species in each sample was recorded (data available at Rocha et al. 2023). This study was authorized by IBAMA nº101932 e nº 74454-1and the Ethics Committee on the Use of Animals at INPA (CEUA Authorization 037/2017).

Principal coordinate analysis (PCoA) was used to explore the similarity in the composition of fish species among treatments, using a Bray-Curtis distance matrix, which considers the abundance of species in the samples. Species with only one occurrence in the dataset were excluded from this analysis (6 species). The statistical significance of the similarity among treatments was tested using the similarity analysis (ANOSIM), with 999 permutations (Legendre and Legendre 1998).

To identify possible effects of biotic interactions on how fish assembled on the attractors, species co-occurrence patterns were tested using null models, through the C-score index (Stone and Roberts 1990). For this, we created matrices of presence and absence of species for each treatment/time interval, in which the lines represented the species, and the columns represented the artificial attractors. Subsequently, the original matrices were randomized, and the C-scores were calculated, using the SIM9 algorithm, which maintains fixed sums of rows and columns (fixed-fixed model) (Connor and Simberloff 1979) and has good properties to avoid type I errors (Gotelli 2000). Therefore, the occurrence of each species among the attractors was simulated through randomizations, assuming the same probability of occurrence of the species. Then, the C-scores obtained from the original matrices were compared statistically with the values calculated from matrices generated through a null distribution based on 5000 Monte Carlo permutations, using the EcoSim program.

The average size of each species was compared to the maximum and/or L50 sizes available in the literature to identify the life stage of each fish occupying the attractors (Wolf 2014, Hernandes 2015, Röpke et al. 2017). The proportion of juveniles and adults were tested among treatments by a Chi-squared test based on pooled data. The expected proportion of juveniles was set at 29% and adults 71%, these proportions were estimated from 12 samplings in aquatic macrophytes between

Table 1. Number of samplings and total number of observations for each treatment.

Treatment	1ª sampling (5º day)	2ª sampling (10º day)	3ª sampling (15º day)	4ª sampling (30º day)	Initial number of observations	Number of observations after exclusion
1	5	5	5		15	–2* = **13**
2			8	8	16	–3* = **13**
3				15	15	–2** = **13**

*attractors withdrawn from analyses by drawing lots.

**attractors lost during the experiment.

May and August in 2009, 2011, and 2012 (Catalão project, unpublished data), to which collected fishes have the life stage determined. A krukall-wallis test was applied to test differences in the average fish size among treatments.

Results

A total of 208 specimens of 21 fish species, belonging to 9 families and 2 orders, were captured. Characiformes contributed with 16 species distributed among 7 families, being the predominant group in this study. Serrasalmidae (Characiformes) and Cichlidae (Cichliformes) were the families with the highest richness values, hosting 6 and 4 species, respectively. The most abundant species were *Mesonauta festivus* (Heckel 1840) and *Serrasalmus maculatus* Kner 1858, with 40 and 36 specimens, respectively, representing together 36.53% of the total abundance (Table 2).

Out of the 21 species captured, 11 occurred throughout the experiment (across all three treatments). These species are *Cichla monoculus* Agassiz, 1831, *Ctenobrycon spilurus* (Valenciennes, 1850), *Hemigrammus diagonicus* Mendonça & Wosiacki, 2011, *Heros notatus* (Jardine, 1843), *Hoplias malabaricus* (Bloch, 1794), *Mesonauta festivus* (Heckel, 1840), *Moenkhausia intermedia* Eigenmann, 1908,

Table 2. List of the species collected during the experiment at Catalão Lake with their respective abundances for each treatment (T).

ORDER/Family/*species*	**T1**	**T2**	**T3**	**Total**
	5 days	**15 days**	**30 days**	
CHARACIFORMES				
Anostomidae				
Leporinus fasciatus (Bloch, 1794)	1	0	3	4
Rhytiodus microlepis Kner, 1858	0	1	0	1
Characidae				
Ctenobrycon spilurus (Valenciennes, 1850)	1	1	1	3
Hemigrammus diagonicus Mendonça & Wosiacki, 2011	10	8	3	21
Moenkhausia intermedia Eigenmann, 1908	3	2	4	9
Curimatidae				
Cyphocharax plumbeus (Eigenmann & Eigenmann, 1889)	1	0	0	1
Erythrinidae				
Hoplias malabaricus (Bloch, 1794)	8	9	5	22
Lebiasinidae				
Copella nigrofasciata (Meinken, 1952)	0	1	0	1
Prochilodontidae				
Prochilodus nigricans Spix & Agassiz, 1829	1	0	0	1
Semaprochilodus taeniurus (Valenciennes, 1821)	0	0	1	1
Serrasalmidae				
Mylossoma albiscopum (Cuvier, 1818)	2	0	0	2
Pygocentrus nattereri Kner, 1858	2	1	0	3
Serrasalmus elongatus Kner, 1858	4	10	8	22
Serrasalmus maculatus Kner, 1858	7	20	9	36
Serrasalmus rhombeus (Linnaeus, 1766)	2	3	2	7
Serrasalmus sp "rob"	0	1	0	1
CICHLIFORMES				
Cichlidae				
Cichla monoculus Agassiz, 1831	3	1	3	7
Heros notatus (Jardine, 1843)	1	2	2	5
Mesonauta festivus (Heckel, 1840)	12	17	11	40
Pterophyllum scalare (Schultze, 1823)	4	11	5	20
Eleotridae				
Microphilypnus ternetzi Myers, 1927	0	1	0	1
TOTAL	**62**	**89**	**57**	**208**

Pterophyllum scalare (Schultze, 1823), *Serrasalmus elongatus* Kner, 1858, *Serrasalmus maculatus* Kner, 1858, and *Serrasalmus rhombeus* (Linnaeus, 1766). Two species appeared in two treatments: *Pterophyllum scalare* (Schultze, 1823) (T1 and T2) and *Leporinus fasciatus* (Bloch, 1794) (T1 and T3). Some species occurred only in one treatment, such as *Cyphocharax plumbeus* (Eigenmann & Eigenmann, 1889), *Prochilodus nigricans* Spix & Agassiz, 1829, and *Mylossoma albiscopum* (Cuvier, 1818), which appeared only in T1; *Semaprochilodus taeniurus* (Valenciennes, 1821), captured only in T3; *Rhytiodus microlepis* Kner, 1858, *Copella nigrofasciata* (Meinken, 1952), *Serrasalmus* sp. "rob", and *Microphilypnus ternetzi* Myers, 1927 that were present exclusively in T2 (Table 2).

PCoA analysis did not reveal different groups of species PCoA (Figure 3), and the similarity analysis (ANOSIM) showed that the composition of fish species remained similar in the three treatments (ANOSIM, $R = -0.03579$, $p = 0.792$).

Species co-occurrence analysis (C-score) indicated that the construction of fish assemblages during high-water occurred randomly over time. The observed C-score values were not significantly different from the expected values generated by null models for the time intervals (Table 3).

The attractors were mostly colonized by juveniles (Chi-squared = 198.41, $df = 1$, $p < 0.001$) for all treatments. No difference in fish body size was detected among treatments (Kruskal-Wallis = 3.7825, $df = 2$; 205, $p = 0.1509$), suggesting that fish were not resident and did not grow in the attractors.

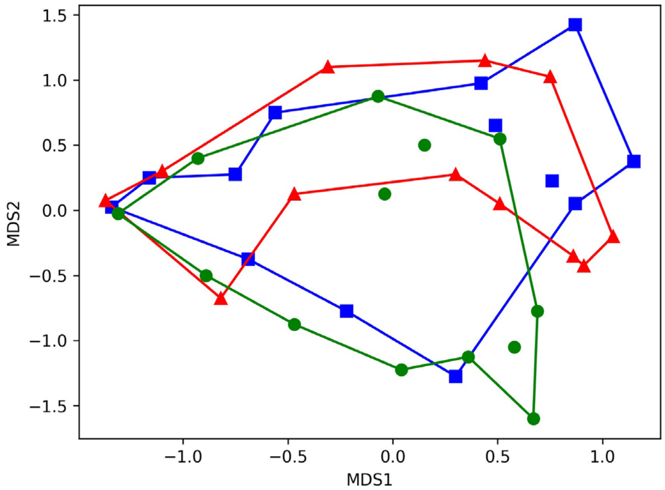

Figure 3. PCoA analysis for the treatments (time of colonization) using species taxonomic composition and respective abundances. Green dots indicate five-day treatment, red triangles a fifteen-day treatment and blue squares a thirty-day treatment (n = 13 for each treatment).

Table 3. Co-occurrence analysis (C-score) using randomized matrices of presence and absence of species, for each treatment. Obs. = observed value with co-occurrence index; Exp. = expected value from the randomized matrices; p (obs > exp) = probability of a value greater than the observed one, from the randomization process. Level of significance: $p \leq 0.05$.

Index	Values	5 days	15 days	30 days
C-score	Obs.	2,85	3,19167	4,47436
	Exp.	2,94763	3,15484	4,52778
	p (obs > exp)	0,9098	0,3354	0,7096

Discussion

In this experimental study conducted in a lowland area of the Brazilian Amazon during the high-water season, the prevalence of young fish in the attractors was observed, and there was no evidence of structure in fish assemblages. Amazonian floodplains are dynamic environments and rich in fish species (Lowe-McConnell 1999). Given this scenario, we expected fish to assemble on the attractors through biotic interactions, resulting in interspecific competition (MacArthur 1972, Pianka 1974). Several studies suggest that biotic interactions are more influential in assemblages of tropical fish with high species richness (Willis et al. 2005, Arrington and Winemiller 2006, Montaña et al. 2014, Fitzgerald et al. 2017). However, such observations more frequently occurred during low-water periods when habitat availability decreases, and predation pressure overall increases (Hoeinghaus et al. 2003).

Notably, during the high-water period, our results demonstrated that the fish assemblages at the attractors did not exhibit a predictable organizational structure throughout the colonization time. This indicates that the occurrence of the species may have happened randomly, with no evidence of competitive forces acting in the assembly of these assemblages. Few studies carried out in the Amazonian floodplains have found that fish assemblages are stochastically built, such processes seem to be more likely in the high-water period (Goulding et al. 1988, Jepsen 1997, Saint-Paul et al. 2000, Santorelli et al. 2014). A general model of community building predicts that this process must be neutral, where both the effect of competition and habitat selection is weak (Weiher and Keddy 1995). In the high-water period, the flooded area expands, distributing the species over a larger area and reducing their competitive and/or predatory interactions. Under these conditions, in the floodplains, biological processes may have a weak influence, generating random patterns of colonization.

The period of the experiment (high waters) may have influenced this random pattern of colonization of the attractors, since the high connectivity between environments, provided by the flood, allows fish to disperse and colonize the newly available areas so that the occurrence of species is common in several habitats (Arrington et al. 2005, Freitas et al. 2010). Additionally, the habitat of aquatic herbaceous abounds, representing no limiting resource and reducing the environmental filtering effect. Thus, the high-water condition seems to have enabled similar opportunities for the colonizing species so that different combinations of species were possible, regardless of the time interval considered. The increased mobility of fish during this period may also increase the chances of fish only shortly visiting the experiment. Despite that juveniles were present for the entire month of the experiment. Although our results of the assembly process only represent the taxonomic pattern of species assembly and regarding the massive presence of juveniles as colonizers, the occupation may not be totally random if other functional aspects are considered. This result raises important insight that availability of floating habitat may be always limited for juveniles in the early life stage and corroborates the hypothesis that this is the limiting factor regulating fish recruitment for many Amazonian fish (Bayley et al. 2018, Castello et al. 2019).

In general, the fish assemblages in the attractors were characterized by the occurrence of young individuals by both, small-sized (*Mesonouta festivus*, *Pyterophylum scalare*) and larger or medium-sized species (*Hoplias malabaricus*, *Cichla monoculus*, *Serasalmus* spp.); many were sedentary species. Other experimental studies, using artificial aquatic herbaceous, have also registered specimens of small fish, such as the study by Teixeira-de-Melo et al. (2015), in which the specimens measured 4.6 cm ± 0.2 SE, and Santos et al. (2011), with fish measuring 10 cm on average. In natural aquatic macrophytes banks, Sánchez-Botero and Araújo-Lima (2001) and Röpke et al. (2014) found that the fish assemblages collected in aquatic herb banks were represented mainly by juveniles and small-sized species (90%). These results confirm the role that aquatic herbaceous play as shelter for young fish and small species, which use these environments mainly to prevent predation (Araújo-Lima et al. 1986).

In the Amazon, very few works used attractors (artificial microhabitats) to study fish assemblage (Yamamoto et al. 2014, Arrington and Winemiller 2006), usually using submerged reefs. The use of midwater attractors made by a large tangle of branches has been described as used by fishermen to capture the discus fish (*Symphysodon aequifasciatus*, Pellegrin 1904) during the low-water in the Piagaçu-Purus Sustainable Development Reserve (RDS-PP), lower Purus River, Amazonas (Rossoni et al. 2014). Attractors have been used and tested in different environments to improve and restore fishery by increasing fish abundance by enhancing recruitment (Schroeder 1987, Bolding et al. 2004). Our results support the use of floating artificial habitat to increase fish recruitment and support the restoration of fish population when habitat availability was reduced by natural (short flood pulses due to natural hydrological variation) or anthropogenic (flow control) causes.

It may be worth mentioning here that we tried to replicate this experiment during the low-water season (October 2017) following the same protocol implemented during the high-water period. Each attractor was about 5 meters distant from each other and 2 m distant from the marginal area once banks of aquatic herbaceous were absent. Five days after the period of periphyton colonization, during the first sampling, it was observed that tufts of sisal rope were present only as remains and no longer were present after the 5 days (Figure S2). No fish were captured, and the colonization process was not observed. One hypothesis is that sisal was consumed by the detritivorous, periphytivous fishes when foraging the periphyton and macroinvertebrates which colonize the tufts of sisal rope in the attractors. Despite the experiment failure, this observation raises important evidence for food limitation during low-water (Lowe-McConnell 1987) and may help to design new studies using attractors to understand the role of food and habitat availability for fish assemblages in low-water season when floating habitats are almost nonexistent.

Due to the advantages of the method, a discussion about the material used is also current, mainly regarding the use of plastic structures due to the problem of plastic residues (Wilbur 1978, Baumann et al. 2016). Despite the lower durability, researchers have argued that attractors made of natural material should be preferred (Baumann et al. 2016). Bright gray curly ribbon and green light sticks were used by Gentil et al. (2020) as floating attractors in the Araguaia River and could be a non-natural option during low-water season. As natural options, the use of midwater reefs made of wood and branches should be considered.

In this experiment, we tried to control many confounding factors that would weaken the interpretation of the results. However, some points may limit the experiment and should be improved in future study replications. The small size of the attractors may have contributed to these results, as fish would gather around the attractor in higher numbers than it would support. Larger attractor should be used in the future or different sizes tested. The number of days of experiment was too short, and treatments should regard longer periods than 30 days with larger períodos between samplings. Freitas et al. (2002) and Yamamoto et al. (2014) conducted experiments with artificial reefs for about one year, with at least two months between samplings. Arrington and Winemiller (2006) repeated the experiments with the attractors in low, falling, and rising waters, and sampling occurred always after 21–24 days. These authors identified a temporal effect, Yamamoto et al. (2014) and Arrington and Winemiller (2006) found seasonal differences in the species occupying the attractors. Linked to the length of the experiment, the period of the peak of high water may also limit the assembly processes and changes in species composition, and future studies may start earlier. As already mentioned, our experiment failed, having data for seasonality, and future studies would elucidate the effect of seasonality on the attractors use. Finally, performing experiments with attractors regarding interannual variation would elucidate the effect of habitat limitation in juveniles' colonization of attractors, as well as the value of using these structures for fish management and conservation.

Supplementary Material

The following online material is available for this article:

Figure S1 - Adapted fishing seine net used for fish collection during the experiment.

Figure S2 - The remains of sisal tufts were observed on the attractors during the first fish collection conducted in the low-water season (October 2017).

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Authors Contributions

Silvia I.B. da Rocha: Contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual content.

Tiago H.S. Pires: Substantial contribution in the concept and design of the study; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual content.

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Cristhiana Röpke: Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual content.

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Conflicts of Interest

The author(s) declare(s) that they have no conflict of interest related to the publication of this manuscript.

Data Availability

The data collected and generated during this study are available in the Biota Neotropica Dataverse at https://doi.org/10.48331/scielodata.LEUSD8. The authors confirm that all data necessary for reproducing the study findings are available in the designated dataset.

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