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Atratores artificiais em pescarias de emalhe artesanal no rio Araguaia, Brasil

Artificial attractors in small scale fisheries gillnets on Araguaia river, Brazil

Atractores artificiales en la pesca artesanal en el río Araguaia, Brasil

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Resumo

Avaliou-se a eficácia de captura e seletividade de dois atratores artificiais - AA (fitilhos cinza brilhante e *lightsticks* verdes) em redes de emalhe visando incrementar a produtividade e a renda de pescadores artesanais. Cinco expedições foram conduzidas no rio Araguaia, onde os dois tratamentos de AA foram aplicados em dois terços da área de um petrecho entralhado, deixando o terço restante sem atratores (controle). Para uma melhor comparação, as capturas foram subdivididas em grupos ecológicos (carnívoros, detritívoros, herbívoros e onívoros).

Foram capturados 541 peixes, sendo 197 nos fitilhos, 177 nos *lightsticks* e 167 no controle. Os peixes carnívoros foram predominantes em todos os tratamentos (p=0.025 para Kruskal Wallis e p=0.03 para Mann-Whitney). O uso dos fitilhos e *lightsticks* proporcionaram um incremento nas capturas de peixes teleósteos carnívoros, proporcionando melhor margem bruta de lucro. Considerando os baixos rendimentos e frágil situação econômica das comunidades pesqueiras do Araguaia, a melhor escolha tecnológica neste estudo são os fitilhos cinza brilhantes, pois além de apresentar melhor produtividade, é de baixo custo e fácil manuseio.

Palavras-chave: Tecnologia pesqueira; Pesca continental; Ecologia comportamental; Bioma Amazônia.

Abstract

The catch and selectivity effectiveness of two artificial attractors-AA (bright gray curly ribbon and green lightsticks) in gillnets was evaluated in order to increase the productivity and income of small scale fishermen. Five expeditions were carried on the Araguaia River, where the two AA treatments were applied to two thirds of the area of gillnets, leaving the remaining third without the use of attractors (control). For a better comparison, the catches were subdivided into ecological groups (carnivores, detritivores, herbivores and omnivores). 541 fish were caught, 197 in the curly ribbon, 177 lightstick and 167 in the control. Carnivorous fishes were predominant in all treatments (p = 0.025 for Kruskal Wallis test and p = 0.03 for Mann-Whitney test). The use of the ribbon and lighstick provided an increase in the catch of carnivorous teleost fish, providing a better gross profit margin. Due the low incomes and fragile economic situation of the fishing communities of Araguaia, the best technological choice in this study is the curly ribbon, as in addition to presenting better productivity, it is accessible low cost and easy to handle.

Keywords: Fishing technology; Continental fisheries; Behavioral ecology; Amazon Biome.

Resumen

Se evaluó la eficiencia de captura y selectividad de dos atractores artificiales: AA (cinta gris brillante y *lightsticks* verdes) en redes de enmalle para aumentar la productividad y los ingresos de los pescadores artesanales. Se realizaron cinco expediciones en el río Araguaia, donde se aplicaron los dos tratamientos AA en dos tercios del área de un aceite tallado, dejando el tercio restante sin atractores (control). Para una mejor comparación, las capturas se subdividieron en grupos ecológicos (carnívoros, detritívoros, herbívoros y omnívoros). Se

capturaron 541 peces, 197 en la cinta, 177 *lightstick* y 167 en el control. Los peces carnívoros fueron predominantes en todos los tratamientos (p = 0.025 para Kruskal Wallis y p = 0.03 para Mann-Whitney). El uso de cinta gris brillante y lightstick proporcionó un aumento en la captura de peces teleósteos carnívoros, proporcionando un mejor margen de beneficio bruto. Teniendo en cuenta los bajos rendimientos y la frágil situación económica de las comunidades pesqueras de Araguaia, la mejor opción tecnológica en este estudio es la cinta brillante, porque además de presentar una mejor productividad, es de bajo costo y fácil de manejar.
Palabras clave: Tecnología pesquera; Pesca continental; Ecología del comportamento; Bioma Amazónico.

1. Introduction

Small scale fisheries is a relevant source of income and food security for nearly 120 million people around the world being majority effected in artisanal scale (FAO, 2015). This economic activity is historically developed aboard of canoes and small vessels with low motor power (<20HP), unexpressive conservation methods and catches destined by local/regional consumption (FAO, 2015).

In tropical and subtropical latitudes, inland small scale fisheries (lakes, rivers, and floodplains), has a significant socioeconomic and cultural relevance for riverside communities (Junk et al., 2007). Notably, the fishing activity in river basins located in the northern region of Brazil represents one of the few options to access animal protein, once those riverside communities are usually located in isolated areas (Prysthon & Farias, 2017).

The fishing gears adopted by inland fishemen in northern Brazilian region are derived from indigenous practices and/or adaptations brought by European immigrants, such as: longlines and gillnets (Zacarkim et al., 2015).

Gillnets are passive fishing gears made of fishing panel and two specific ropes (Gabriel et al., 2005). Fishing panels are composed by diamond meshes organized in monofilament polyamide panels. The upper and lower fishing ropes are provided by floats (styrofoam) and leads, respectively, to ensure the vertical opening of the fishing panel.

Several improvements in traditional fishing gears has been presenting to ensure food security for riverside communities: different trap geometries, natural baits, and the adoption of recycled materials (Camargo et al., 2009; Arunkjenish et al., 2017). However, there is a lack of efforts to increase catches in inland fisheries.

In this sense, artificial attractors (AA) can be a alternative in passive fishing gears.

According to Nguyen & Winger (2019), AA are devices allocated in fishing gears to increase the catches of some target species. LED lights in shrimp nets and lightsticks in longlines are AA examples adopted by coastal and oceanic fisheries (Nguyen & Winger, 2019; Farias et al., 2019). In the other hand, AA can increase the fishing selectivity, ensuring bycatch reduction (Virgili et al., 2018). At the same time, there are no records on the economic effectiveness of these devices in Brazilian inland fisheries.

Considering the AA efficacy for passive fishing and its strategic relevance to improve the incomes small scale fisheries for riverside communities in Brazil, the present study valuated two AA performances in gillnets during a year of fishing campaigns in Araguaia River (Tocantins state, Northern Brazil). This study represents a pioneer effort of AA application in Brazilian artisanal inland fisheries.

2. Material and Methods

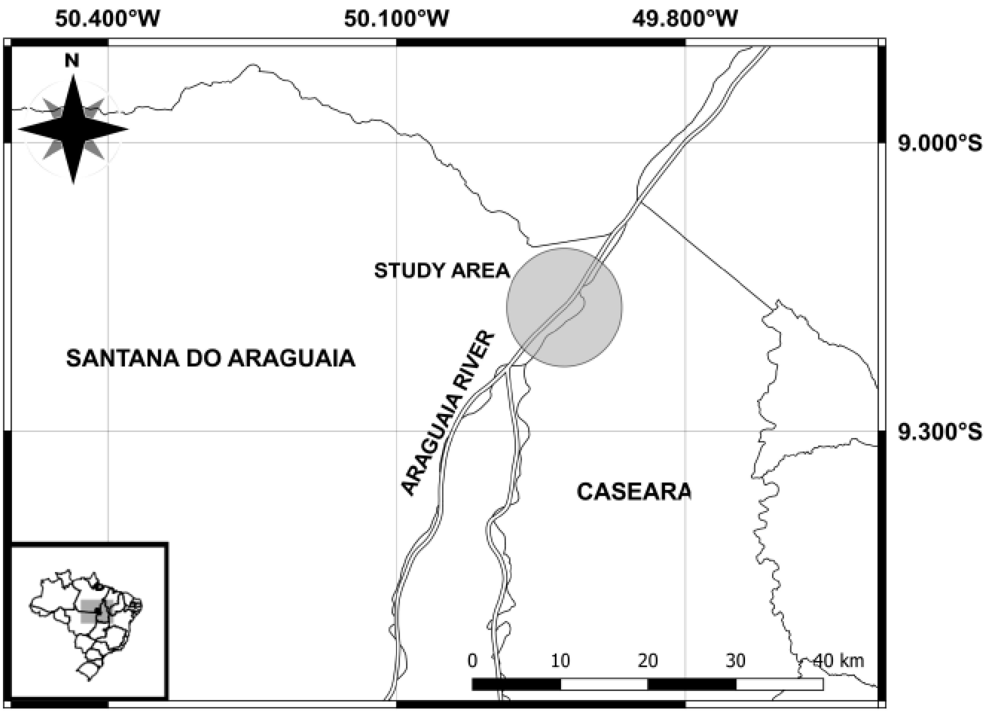
The study was carried on Araguaia River (central coordinates: 9.15°S and 49.9°W, Figure 1), located in northern Brazilian central region, one of the most relevant continental environments for fisheries activity in South America, being the second largest Brazilian basin.

Araguaia river basin has 382,000km^2 and 2,115 km of extension being an important transition zone between Cerrado to Amazon biome (Ferreira et al., 2011). It is a plain river with distributed vegetation and low drainage density and soil fertility (Ribeiro et al., 1995; Latrubesse & Stevaux, 2006).

Gillnet fishery is the most relevant local fishing gears and its catchability was evaluated with and without artificial attractors (AA) close to flooded forests in fishing grounds with 2 to 8 meters of depth during the fishery season of 2018.

Was carried five campaigns in 2018, between April to October. Eight different fishing grounds were visited on Araguaia river and a total of 53 sampling throws were carried. Was valuated two low cost AA on gillnet: (I) Curly silver ribbon with 10-15 cm of length, 0.5 cm thickness, and made by polyethylene (65%) + polypropylene (35%) and (II) lightsticks with chemical light emission (green color), 0.4 cm of thickness, and ~3,5 cm of length and (III) Control panel.

Figure 1: Map of the study area in Araguaia River.

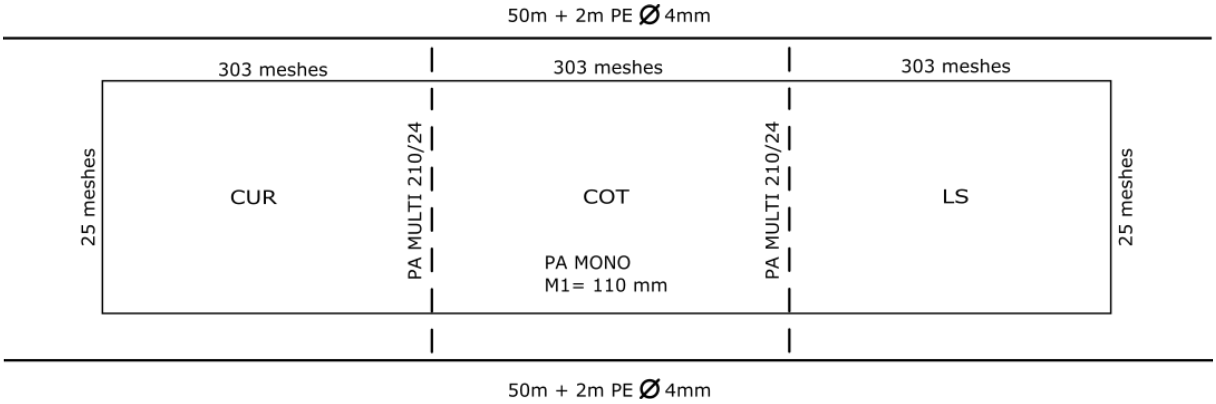


Source: Authors.

The gillnet used in fishing campaigns presented 9 cm (± 2cm) of meshes sizes and two ropes with 0.4 cm of thickness (twisted polyethylene) each one. The fishing gear had 909 meshes of length and 25 meshes of height (hanging coefficient= 0.55).

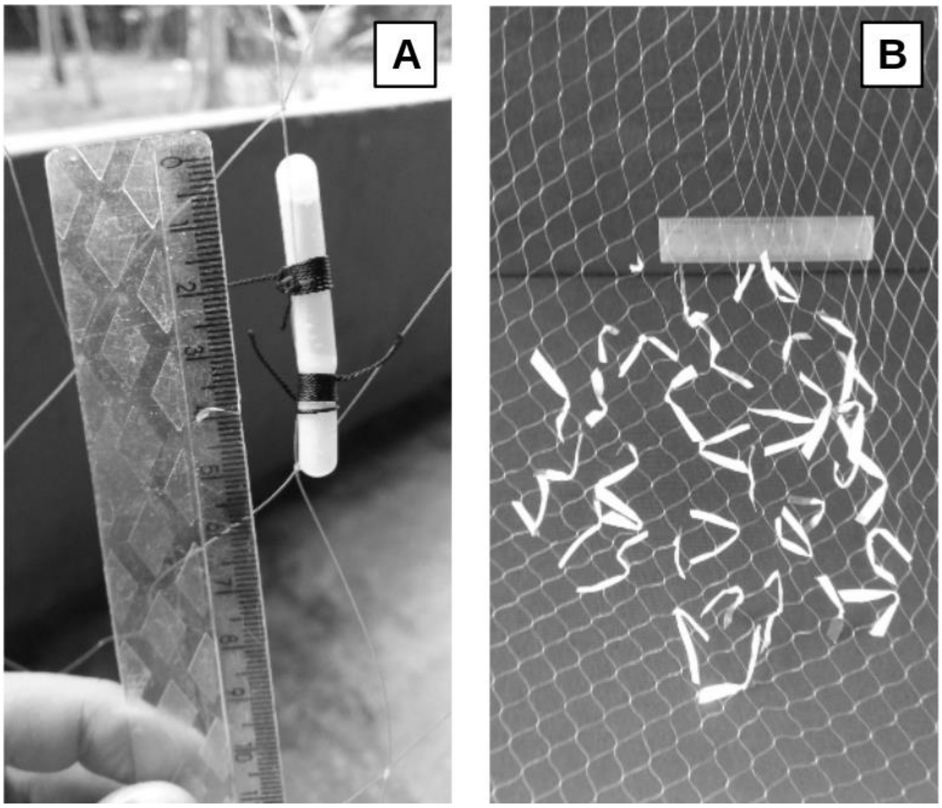
The fishing panel was organized in three portions containing 303 meshes of length and 25 meshes of height each one. The AA were fixed in 66% of total panel area (33% by each AA approach) and 33% was denominated control panel, i.e without any AA. Black polyfilament yarn (210/24 DEN) was inserted in order to highlighted the fishing panel edges. AA were alternately allocated close to top and bottom of the fishing panel with a meter of spacing between them (Figure 2 and 3).

Figure 2: Gillnet technical plan. CUR = curly silver ribbon area, COT=control panel area (without AA) and LS= lightsticks area.



Source: Authors.

Figure 3: Details of AA attached on the gillnet. (A) LS. (B) CUR.



Source: Authors.

Biometry were performed in all fishes caught (weight, height, and total length). Additionally, bony fishes were identified and conditioned into plastic bags labeled according to fishing panel area which they were caught, as follow: CUR= curly silver ribbon area, COT=control panel area (without AA) and LS= lightsticks area.

Considering the connection between feeding ecology and species behavior (Gibran,

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2007, Condini et al., 2011), the fish caught were grouped in four categories: carnivores, detritivores, herbivores and omnivores.

To verify possible statistical differences between the catches by treatment (CUR, COT, and LS), Kruskal-Wallis (p=0.05) test was performed (Siegel & Castellan-Júnior, 1988) over the biomasses caught considering the feeding ecology of the species. After, the Mann-Whitney post-test (p=0.05) were adopt to verify possible paired differences between the catches.

AA economic analysis was carried in order to evaluated the gross profitability based on the price paid for the fisherman. The information about prices were collected in 2018 at the same region and presents the prices received by the fishermen from their buyers.

3. Results and Discussions

Fishery campaigns caught 541 bony fishes being 72% represented by carnivorous species, 13% of detritivorous species, 8.5% of omnivorous, and 6.5% of herbivores fishes. Notably, CUR panel presented the best fishing performance, assimilating 197 individuals, followed by LS (177 individuals), and finally COT that caught 167 fishes. The total CUR biomass (76.5 kg) was over 56% higher than COT (49.1 kg), suggesting a positive significant difference using AA. The LS biomass was 28% (62.9 kg) higher COT and there was not diference between CUR and LS.

The biomass caught by feeding behavior classes were: carnivorous=151.5 kg, detritivorous= 14.5 kg, omnivorous=12.6 kg and herbivorous=10 kg, totaling 188.6 kg. Carnivorous species were predominant in all fishing panel areas: CUR = 85.5% (76.5 kg) , LS = 80.6% (63 kg) , and COT = 82.6% (49.1 kg) (Figure 4).

Pygocentrus nattereri, *Hydrolycus scomberoides*, and *Plagioscion squamosissimus*, represents almost 62% of total carnivorous catches in all fishing panel areas. Thirty detritivores individuals were caught in CUR and nineteen in LS and COT, respectively. Thirteen omnivores individuals were caught by CUR, twelve and twenty two in COT and LS panel areas. Considering the same order by herbivorous individuals, ten, twelve and ten fishes were caught in CUR, COT and LS fishing panel areas (Figure 5).

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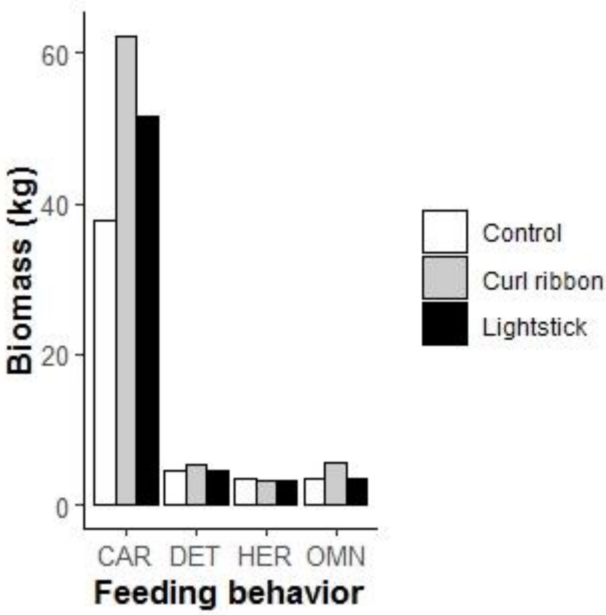
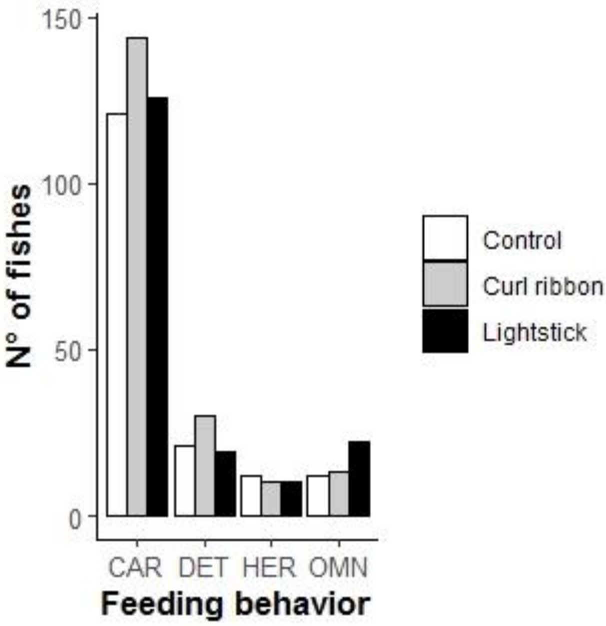
Figure 4: Total biomass caught by fishing panel area. CAR=Carnivores, DET= Detritivores, HER=Herbivores, and OMN=Omnivores.



Source: Authors.

Figure 5: Number of individuals caught by fishing panel area. CAR=Carnivores, DET= Detritivores, HER=Herbivores, and OMN=Omnivores.



Source: Authors.

The main carnivorous species caught were: *Plagioscion squamosissimus*, *Pellona castelnaeana* and *Hydrolycus scomberoides*. *Semaprochilodus brama* and *Curimata spp*, were the main detritivores species caught (87%). In this sense, *Mylossoma sp* and *Hypophthalmus* *marginatus* corresponding to 91% of herbivores caught, and *Hypostomus affinis* and *Oxydoras niger* represented 55% of total omnivores caught (Table 1).

Table 1: General table of catch species, total biomass and number of individuals caught by different AA: lightstick (LS), curly silver ribbon (CUR), and control (COT).

Species	**Number of individuals**			**Total Biomass**			**Feeding Regime**
	COT	**CUR**	**LS**	**COT**	**CUR**	**LS**	
Ageneiosus brevifilis	14	10	15	5345	3710	4445	carnivore
Boulengerella cuvieri	-	1	2	-	560	1620	carnivore
Cichla kelberi	7	6	12	4265	3790	8385	carnivore
Crenicichla spp.	-	-	1	-	-	220	carnivore
Hydrolycus scomberoides	29	26	14	8330	9180	5860	carnivore
Osteoglossum bicirhosum	-	1	4	-	1166	4535	carnivore
Pellona castelnaeana	6	13	15	4495	12415	7110	carnivore
Phractocephalus hemioliopterus	1	2	-	1525	6795	-	carnivore
Pinirampus pirinampu	2	1	4	1225	250	1500	carnivore
Plagioscion squamosissimus	14	14	16	6815	9830	7445	carnivore
Pygocentrus nattereri	42	47	33	4220	9880	5721	carnivore
Rhaphiodon vulpinus	1	8	3	385	2840	1310	carnivore
Serrasalmus eigenmanni	4	2	4	310	100	370	carnivore
Serrasalmus rhombeus	-	1	1	-	205	80	carnivore
Pseudoplatystoma punctifer	1	2	2	850	1590	2870	carnivore
Curimata spp	10	17	11	1015	1600	1135	detritivore
Prochilodus nigricans	-	-	2	-	-	1525	detritivore

Semaprochilodus brama	11	10	5	3500	3555	1855	detritivore
Triportheus spp	-	3	1	-	260	75	detritivore
Hypophthalmus marginatus	3	4	3	2000	2120	2100	herbivore
Mylossoma duriventre	-	-	1	-	-	155	herbivore
Mylossoma sp.	8	5	4	1340	860	695	herbivore
Myleus sp	1	1	2	140	155	370	herbivore
Satanoperca jurupari	1	-	11	120	-	1065	omnivore
Geophagus spp	1	3	7	85	420	500	omnivore
Hypostomus spp	6	2	3	2685	685	1115	omnivore
Leporinus trifasciatus	-	-	1	-	-	895	omnivore
Oxydoras niger	-	3	-	-	2495	-	omnivore
Schizodon vittatus	2	5	-	425	2045	-	omnivore

Source: Authors.

The Kruskal-Wallis test (Table 2) for carnivorous and omnivorous caught by different fishing panel areas revealed p-values equal 0.025 and 0.001, suggesting the AA influence over the catches. In the other hand, detritivorous and herbivorous species did not presented any catch differences between the fishing panel areas ($p = 0.66$ and $p = 0.41$). Thus, for these groups the AA presence was statistically irrelevant.

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Table 2. Kruskal-Wallis test on the biomass captured in the carnivore, detritivore, herbivore, omnivore groups.

Feeding behavior	**H**	**df**	**P-value (0.05)**
Carnivore	7.365	2	0.025
Detritivore	17.857	2	0.409
Herbivore	0.8181	2	0.664
Omnivore	12.605	2	0.001

Source: Authors.

The paired Mann-Whitney post-test (Table 3) between carnivores to omnivores showed significant values between COT vs CUR (p = 0.03) and COT vs LS (p = 0.01), suggesting the AA effect over the catches. However, CUR vs LS did not reveal statistical differences between AA (p = 0.69). The same paired test over the omnivores species suggested that CUR vs LS fishing panel areas presented a significant difference (p = 0.0002). However, this pattern can not be identified in COT vs LS as well in CUR vs COT fishing panel areas (p = 0.12 and p = 0.28, respectively).

Table 3. Mann-Whitney test between artificial attractors lightstick (LS), curl silver ribbon (CUR) and control (COT).

Feeding behavior	Artificial attractors	W	p-value (0.05)
Carnivore	LS vs CUR	8818	0.6921
	CUR vs COT	7388.5	0.0332
	LS vs COT	6180	0.0101
Omnivore	LS vs CUR	251.5	0.0002
	CUR vs COT	58	0.2886
	LS vs COT	175.5	0.1206

Source: Authors.

In terms of AA economic analysis, CUR presented the highest revenue (R$ 411.83) followed by LS (R$ 399.20) and COT (R$ 309.82) (Table 4). Concerning the cost per AA, the LS had the highest cost (R$648.00) which resulted in a negative gross margin (-R$ 248.80). The best gross margin was reached by CUR (R$ 408.43) and COT (R$ 309.82).

Carnivorous species were the most important category in terms of revenue among the three treatments (84% COT, 81% CUR and 87% LS) and the omnivore presented the lowest revenue (1% COT, 7% CUR and 1% LS).

The gillnets catch efficiency depends of several parameters like feeding ecology for example (carnivorous, omnivorous, etc.) (He, 2006). Fishing technology associated with biological knowledge can maximize the catch of different fisheries resources during their daily displacement, mainly species of active behavior (Hubert, 2012).

Table 4: Economic analysis (only economic species) by different AA: lightstick (LS), curly silver ribbon (SR) and control (COT).

Species	Feeding Regime	Revenue per species and per AA						
		Prices paid to the fishermen (2018, R$/kg)	COT	%	SR	%	LS	
Ageneiosus brevifilis	carnivore	8	42.76		29.68		35.56	
Cichla kelberi	carnivore	13	55.44		49.27		109.00	
Hydrolycus scomberoides	carnivore	5.5	45.81		50.49		32.23	
Pellona castelnaeana	carnivore	5	22.47		62.07		35.55	
Pinirampus pirinampu	carnivore	9	11.02		2.25		13.5	
Plagioscion squamosissimus	carnivore	7	47.70	84%	68.81	81%	52.11	87%
Pygocentrus nattereri	carnivore	5	21.1		49.4		28.60	
Serrasalmus marginatus	carnivore	5	1.55		0.5		1.85	
Serrasalmus rhombeus	carnivore	5	-		1.02		0.4	
Sorubimichthys planiceps	carnivore	13.5	11.47		21.46		38.74	
Curimata sp	detritivore	6	6,09		9.6		6.81	
Prochilodus nigricans	detritivore	5.5	-	8%	-	7%	8.38	6%
Semaprochilodus brama	detritivore	5.5	19.25		19.55		10.20	
Hypophthalmus marginatus	herbivore	5	10		10.6		10.5	
Mylossoma duriventre	herbivore	8.5	-	7%	-	5%	1.31	5%
Mylossoma sp.	herbivore	8.5	11.39		7.31		5.90	
Myleus sp	herbivore	8.5	1.19		1.31		3.14	

Leporinus trifasciatus	omnivore	6	-		-		5.37	
Oxydoras niger	omnivore	6.5	-		16.21		-	
Schizodon vittatus	omnivore	6	2.55		12.27		-	
Total revenue per AA			**309.82**	**100**	**411.83**	**100**	**399.2**	**100**
Total cost per AA			**0**		**3.4**		**648**	
Gross margin per AA*			**309.82**		**408.43**		**-248.8**	

*Note: Gross margin does not consider other costs as fuel, food and maintenance of boat.
Source: Authors.

Carnivorous species were the most important category in terms of revenue among the three treatments (84% COT, 81% CUR and 87% LS) and the omnivore presented the lowest revenue (1% COT, 7% CUR and 1% LS).

The gillnets catch efficiency depends of several parameters like feeding ecology for example (carnivorous, omnivorous, etc.) (He, 2006). Fishing technology associated with biological knowledge can maximize the catch of different fisheries resources during their daily displacement, mainly species of active behavior (Hubert, 2012).

Some freshwater fishes are attracted by visual stimuli: color, brightness, and contrast can increase the fishing catches in aquatic environment (Hubert, 2012). Several artificial light intensities and wavelength emitted can impact the bony fish species behavior (Marchesan, 2014). In this sense, artificial lights are one of the most prominent AA adopted by fishermen around the world (Hazin et al., 2005; Nguyen & Winger, 2019; Farias et al., 2019), with highlighted to chemical sticks (lightsticks), that optimizes the fishing effort increasing the selectivity in commercial and sportfishing (Nguyen & Winger, 2019).

Lightsticks with different visible spectrum colors showed different catch levels and bycatch assimilation (Wang, 2017). In this study, we adopted a lightstick with green color emission due the facility to found this AA in many stores and markets in Brazil being usual its adoption in some sportfishing modalities and longlines. However, lightsticks composition are potentially toxic due the presense of some chemicals such as hydrogen peroxide and polycyclic aromatic hydrocarbons (Ribeiro et al., 1995). Additionally, lightsticks can be a source of plastic litter generating possible impacts over the aquatic environment (Nguyen & Winger, 2019).

Likely, curly silver ribbon presented a higher catch rates due its erratic movements derived from the currents interactions in the fishing gear. This pattern can generate a positive feedback in visual, quasi-sensorial perception and lateral line system of bony fishes once the curly silver ribbon simulating the prey displacement affecting the hunting behavior (Kasumyan, 2013). Previous study analyzing the spatial arrangement of lateral line neuromas of some species suggested that vibration can to incite the attack behavior (Kasumyan, 2013).

Probably, the combination of curly silver ribbon color + erratic movements generating mechanical vibration in water column is associated with catch success obtained in this study. Although more specific efforts related to curly silver ribbon in fisheries are not available in literature, Utne-Palm (2000) suggest that the prey activity and size combination determine the predator attack (Utne-Palm, 2000). Note that the fibers composition of curly silver ribbon is polyethylene terephthalate. This material can also contaminate the aquatic ecosystem provoking potential environment impacts.

The higher LS cost compared to CUR is related to its elevated price and also due to its short useful life (two or three fishing campaigns). In comparison, CUR can be used for thirty times. Moreover, LS is not a available in the region and therefore the fishermen must to travel into the larger cities to find it.

4. Conclusions

The total biomass caught by AA showed the potential of these technologies to increase catches considering the feeding ecology of some species, can be an important component to improve the fishermen income in small scale fisheries. Thus, we suggest more efforts to determine the visual stimuli patterns in bony fishes and its effects over the catch patterns in passive fishing gears.

Note that any technological intervention to increase the fishing effort need to considerate the exploitation capacity over the target species. Thus, AA operational adoption in artisanal fisheries need to consider ecological parameters, such as: growth, recruitment, and mortality.

Lightsticks has a short service life (12 hours) and longest half life in aquatic ecosystem. This same problem can be observed in curly silver ribbon, which showed better catches and economic results. At this point, the potential of biodegradable materials need to be evaluated in future AA researches. Moreover, other colors should be evaluated, to ratify or refute the best performance of curly silver ribbon in relation to lightsticks. The same approach need to be performed to different AA sizes and geometries with focus to get a more selective fishing gear.

Considering the low incomes and fragile economic situation of the fishing communities of Araguaia, the best AA choice in this study would be the CUR, since in addition to presenting better productivity, it is cheap and easy to handle.

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