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Profitability and Sustainable Use of Traps for Amazon Shrimp (*Macrobrachium amazonicum*) From the Amazon River

Odair de Almeida Melo

Masters of Science, Tropical Aquaculture and Aquatic Resources Program – PPGAQRAT – Universidade Federal Rural da Amazônia – UFRA - Avenida Presidente Tancredo Neves, Nº 2501, Terra Firme, 66077-830, Belém, PA, Brazil.
E-mail: odair.dealmeidamelo@gmail.com

Luís Mauricio Abdon da Silva

Scientific and Technological Research Institute of the State of Amapá – Núcleo de Pesquisas Aquáticas – IEPA/NUPAq, Campus da Fazendinha. Rodovia Juscelino Kubitschek, km 10, Fazendinha, 68903-419 Macapá, AP, Brazil. E-mail:luis.abdon13@gmail.com

Pedro Henrique Campos Sousa (Corresponding author)

Masters of Science, Tropical Aquaculture and Aquatic Resources Program – PPGAQRAT – Universidade Federal Rural da Amazônia – UFRA - Avenida Presidente Tancredo Neves, Nº 2501 Bairro: Terra Firme, 66.077-830, Belém, PA, Brazil.
E-mail:pedropesca13@gmail.com

Sirley Luzia Figueiredo Silva

Scientific and Technological Research Institute of the State of Amapá – Núcleo de Pesquisas Aquáticas – IEPA/NUPAq, Campus da Fazendinha. Rodovia Juscelino Kubitschek, km 10, Fazendinha, CEP: 68903-419 Macapá, Amapá, Brazil. E-mail:sirleyfig@gmail.com

Jô de Farias Lima

Brazilian Agricultural Research Corporation - Embrapa Amapá. Rodovia Juscelino Kubitschek, km 5, n°2600, 68906-970, Caixa Postal 10, Macapá, AP, Brazil.

Luiz Claudio Feitoza dos Santos Júnior

State University of Amapá, Curso de Engenharia de Pesca. Av. Presidente Vargas, nº 650, 68900-000. Macapá, Amapá, Brazil. E-mail: luizjunioramapa@gmail.com

Libna Gomes Fernandes

State University of Amapá, Curso de Engenharia Ambiental. Av. Presidente Vargas, nº 650, 68900-000. Macapá, Amapá, Brazil. E-mail:bidafernandes06@gmail.com

Kátia Cristina de Araújo Silva

Socioambiental and Hydrological Resources Institute – ISARH, Laboratório de Crustáceos – LABCRUS, Universidade Federal Rural da Amazônia – UFRA - Avenida Presidente Tancredo Neves, Nº 2501 Bairro: Terra Firme, 66.077-830, Belém, PA, Brasil. E-mail: katia.silva@ufra.edu.br

Israel Hidenburgo Aniceto Cintra

Socioambiental and Hydrological Resources Institute – ISARH, Laboratório de Crustáceos – LABCRUS, Universidade Federal Rural da Amazônia – UFRA - Avenida Presidente Tancredo Neves, Nº 2501 Bairro: Terra Firme,66.077-830, Belém, PA, Brazil. E-mail: israel.cintra@ufra.edu.br

Abstract

The objective of this study was to evaluate the profitability, productivity and selectivity of traps used for the capture of freshwater prawn using different spacings between the laths. This study was developed in the estuary of the Amazon River near Santana island, Amapá, Brazil. Collections were conducted using traps called "matapi", which are cylindrical shrimp traps made with wooden slats or laths, with funnel-shaped entrances at both sides, and the spacings between the laths ranged between 1 to 10 mm in 1 mm increments. Each trap was covered with a net called a "sobrematapi", or trap cover. The length of carapace in centimeters and the weight in grams were measured for all specimens. The shrimp were categorized into small, medium, and large size classes. Selectivity curves were used to determine selectivity for the different lath spacings. Traps with lath spacing below 7mm should be considered as being predatory because they allow for the capture of small individuals, with more than 50% of these being captured using spacings from 1 to 5mm. Despite the fact that spacings between 8 and 10mm captured lower quantities of shrimp, this

enabled the capture of larger specimens with a similar total biomass yield, and this spacing is considered to be the most ecologically and economically viable. In order to minimize the capture of young shrimp without drastically affecting economic yield, it is suggested that shrimp trap lath spacings be above 6mm.

Keywords: regional shrimp, harvesting, traps, small-scale fishery

1. Introduction

For many years Amazonian rivers have been one of the principal sources of food for human populations. Currently, the demand for food sources is rapidly increasing, and animal production is not able to satisfy the demand for protein by the growing human population (Sainsbury, 1986; Delgado *et al.,* 2003), and the high yields of fisheries, especially those from developing countries, has contributed to the increase in production of global fisheries (Swartz *et al.,* 2010). According to the United Nations Food and Agriculture Organization (FAO), about 19% of world fishery stocks were overexploited in 2007 (FAO, 2012). Biello (2006) predicted that in 2048 all fish and shellfish stocks in the world would be practically exhausted, with no possibility of recuperation.

Fishery resources that are not overexploited are those that have some type of regulation and have strong governance and control over the territory in which they are located, including quota systems and management and protection areas (Worm *et al.,* 2009). Although *Macrobrachium amazonicum* (Heller, 1862) is an economically important fishing resource that is the most exploited and consumed by populations in the Amazon and semiarid areas in the Northeast region of the country (Moraes-Valenti and Valenti, 2010; Aya-Baquero and Velasco-Santamaría, 2013), there is no regulation of the fishery resource.

A large part of the riverine communities in the region capture this shrimp using artisanal fishing methods using equipment such as the matapí (which are cylindrical traps made with wooden slats or laths, with funnel-shaped entrances at both sides, with laths made of material from the juruti or buriti palms), or a shrimp net made of nylon that is thrown out over the water. In the estuary of the Amazon capture of the Amazonian shrimp has intensified during the last few years, causing a reduction in natural stocks. The process of capture of this shrimp frequently involves the use of traps that are locally known as matapis. Compared to drag nets and puçás (dip nets), the matapi has demonstrated better economic and environmental results, because besides considerably minimizing capture of other species of fauna together with the shrimp they require a lower expenditure of time and energy for the capture of fauna (Vieira and Araújo-Neto, 2006). Through informal conversations with residents that fish for shrimp as a complement to their income, or that make a living exclusively as a fisherman, there is evidence that the high intensity of fishing in the region could have contributed to a decrease in the population of this Amazonian shrimp (Personal Communication).

In general, fishing equipment, when used by fishermen or researchers, is selective, meaning that they capture only species that are within a certain size of length. For this reason, if someone has an interest in describing the size distribution of a population it is necessary to explain the effect of selectivity and there are few studies on selectivity for *Macrobrachium*

amazonicum (Costa *et al*., 2016; Lima *et al*., 2016; Bentes *et al*., 2014; Lima and Montagner, 2014). The objective of this work was to evaluate the profitability, productivity and selectivity of traps used for the capture of these shrimp using different spacings between the laths.

2. Materials and Methods

This study was conducted in the estuary of the Amazon River near Santana island, city of Santana, in the state of Amapá, Brazil (Figure 1). The island is located at the coordinates 51º 08' 00" and 51º 12' 10" longitude (West) and 00º 03' 35" and 00º 06' 00" latitude (South) (Silva *et al.,* 2007).
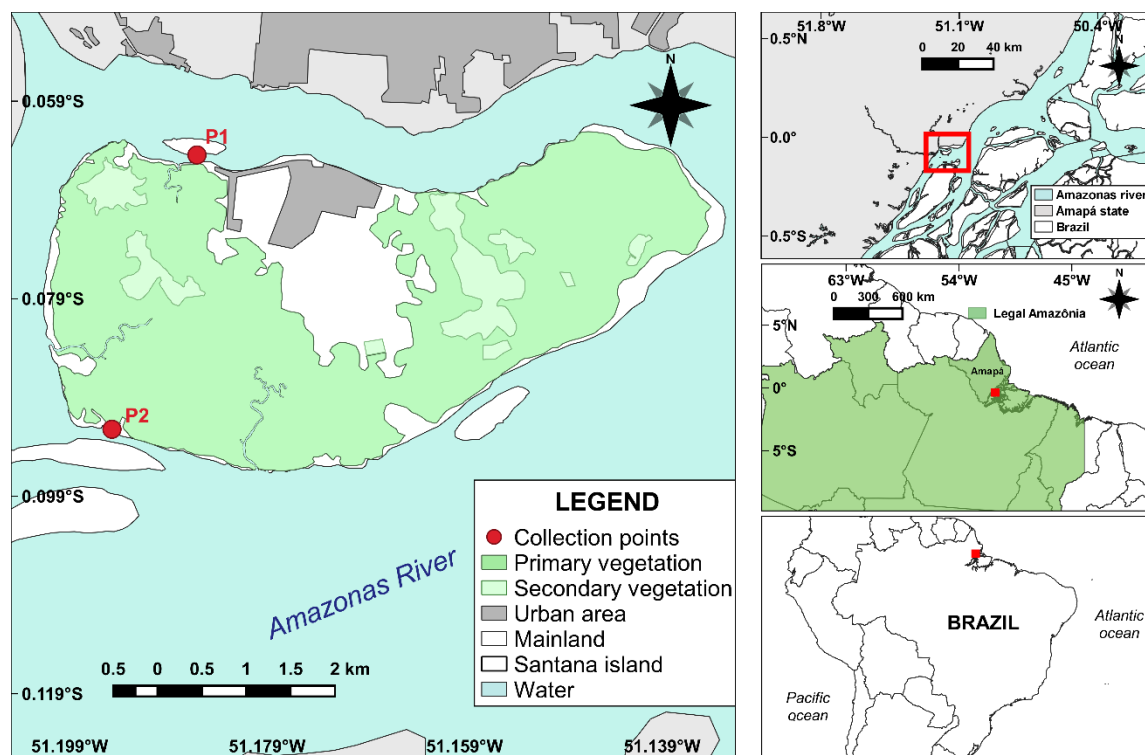

Figure 1. Location of Santana island

In order to incorporate seasonal climate variation in sample collection, a total of twelve monthly collections (May 2018 to April 2019) were conducted at two points on Santana island. According to the fishermen, placing traps always in the same place causes the shrimp to move to another environment, therefore two alternate collection points were chosen each month.

Collections were done using a trap referred to as a "matapi" (Figure 2) in the northern coastal region of Brazil. At each of the two collection points three "matapis" with different sizes of the spaces between the laths (1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 mm) were distributed, totaling 30 matapis. Each matapi was covered with a type of mosquito net, denominated a matapi cover, with the function of retaining shrimp that had escaped from the matapi (Costa *et al.,* 2016).
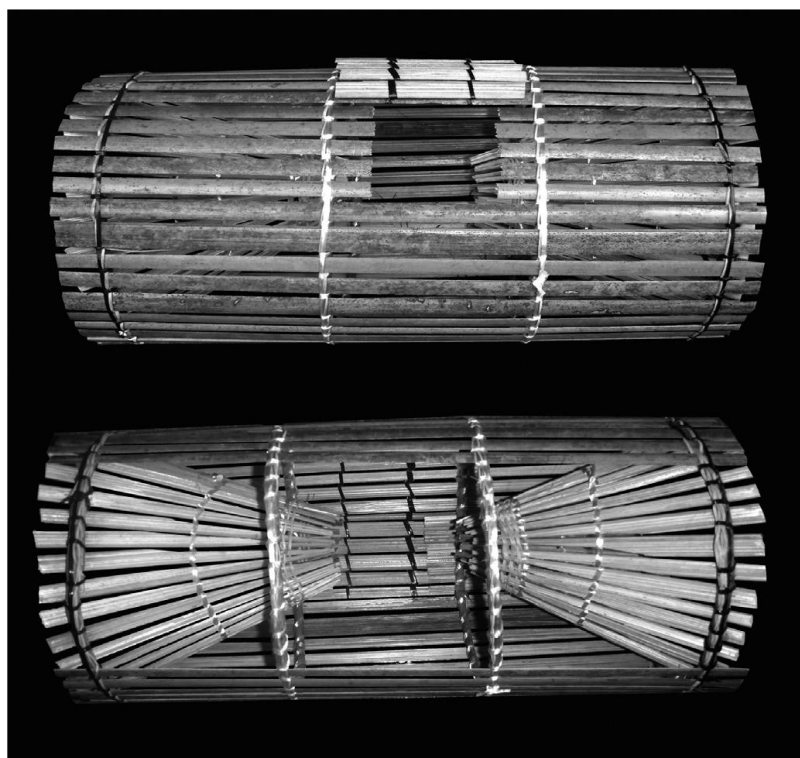
Figure 2. Traditional trap used in shrimp fishing. Photo: Jô de Farias Lima

The matapis were randomly distributed in the water at 18:00 and removed at 6:00 on the next day for a total of 12 hours of sampling. The captured shrimp, alive or dead, were placed in 1 kg plastic bags that were labeled with information about how they were captured (matapi or matapi cover), date, and lath spacing. For the shrimp collection, all captured specimens were separated by species, counted, weighed and preserved in 70% alcohol and deposited in the Laboratory of Biology and Dynamics of Fishery Resources of IEPA - AP.

In the laboratory, shrimps have been identified down to the species level (Mello, 2003) and the length of carapace in centimeters and the weight in grams were measured for all specimens of *M. amazonicum*. After the biometry measurements the shrimp were classified into groups that comprised immature young, represented by individuals that had a length of carapace that was inferior to the length of carapace of the smallest egg-carrying female, and adults represented by individuals that had length of carapace equal or greater than that of the smallest egg-carrying female (Lima *et al.* 2014). The shrimp were classified into three size classes according to labeling practices used in the commercialization of this product: small: length of carapace LC < 1.00 cm; medium: length of carapace $1.00 \leq LC \leq 1.5$ cm; big: length of carapace LC > 1.5 cm (Lima, 2014 b).

The data were analyzed using the Shapiro-Wilk normality test, and the Levene-Bartlett test was used to evaluate homogeneity and homoscedasticity (Zar, 1996).

Analysis of variance (one-way) was used to test shrimp length of carapace, biomass and quantity as a function of the spacing of the openings of the matapis. The analyses were run in PAST 3.17 (Hammer *et al.*, 2001). The selectivity curves for the different spacings between

laths of the matapis were obtained using the method described by Pope *et al.,* (1983); Jones (1976).

$$SL = \frac{1}{1 + EXP(S1 - S2 * L)}$$

Where *SL* = number of shrimp with length *L* in the matapi/ number of shrimp with length *L* in the matapi plus those retained in the matapi cover; *L,* is the average of the interval of the carapace length, and S1 and S2 are constants. Rewriting the equation for the logistic curve yields:

$$LN(1/SL - 1) = S1 - S2 * L$$

Which equals a straight line, where *S1* and *S2* represent, respectively, the parameters *a* and *b*.

The lengths, in which 25%, 50% and 75% of the shrimp are classified, were calculated using the equations:

$$L25\% = (S1 - LN3)/S2$$

$$L50\% = S1/S2$$

$$L75\% = (S1 + LN3)/S2$$

In order to determine the optimum spacing between the laths of the matapis, size at sexual maturation was taken to be 4.5 cm and 6.0 of total length (approximately 0.9 cm to 1.3 cm of length of carapace) (Bentes *et al.,* 2016; Freire *et al.,* 2012; Lima *et al.,* 2014; Sampaio *et al.,* 2007; Silva *et al.,* 2005).

Productivity was determined by the number and biomass of captured shrimp in each trap type according to the size categories, and profitability was based on the prices of shrimp sold in markets. The shrimps caught by the fishermen are preserved on ice or marketed fresh (not live) to the brokers who separate the prawns by size (large, medium and small) to be sold to consumers, thus having more profitability.

3. Results and Discussion

A total of 19,967 were captured in all the traps employed in this study. The quantity of shrimp captured in the matapis was greater for those with closer spacing (1mm to 5mm) and represented 62% of all captured freshwater prawn (Figure 3).
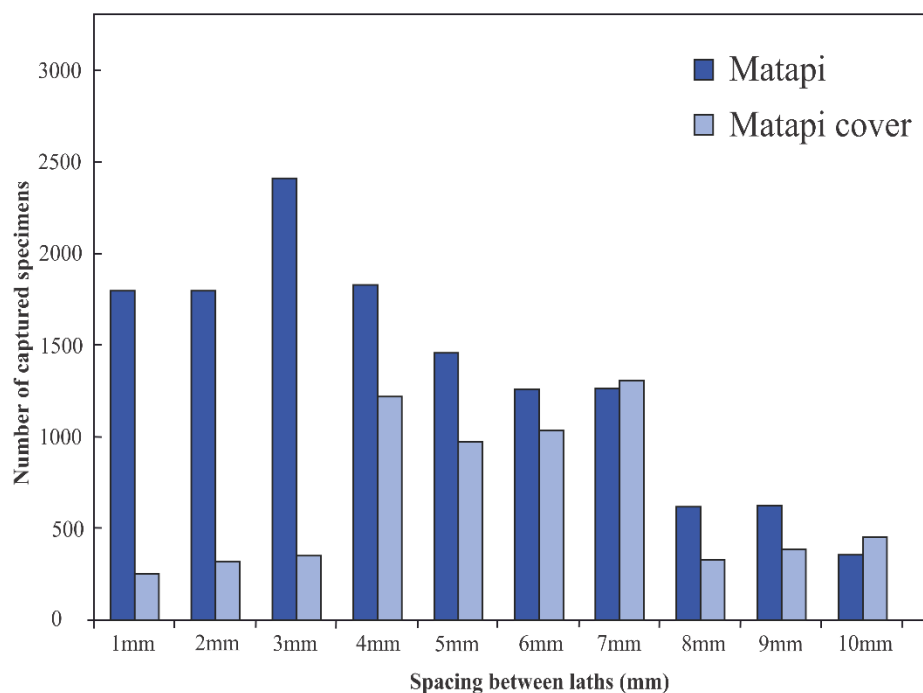
Figure 3. Quantity of freshwater prawn captured using different spacings between laths of the matapis. Data collected monthly between May 2018 and April 2019

In the lower Tocantins region, a maximum total length of 13.2 cm was reported, and samples from Tucuruí lake had a maximum total length of 8.0 cm (Odinetz-Collart, 1987). At Combú island, Silva (2006) registered a shrimp with a maximum total length of de 14.1 cm, very similar to that from Vigia (14.4 cm) by Silva *et al.* (2002). Silva *et al.* (2005) found a maximum total length of 10.5 cm below the Tucuruí hydroelectric dam. Rocha *et al.* (2015), studying morphometric relationships in Amazonian shrimp in a reservoir in Bahia found shrimp with a maximum total length of 9.74 cm. Freire *et al.* (2017) studied the morphometric characteristic of *M. amazonicum* in three localities in the Tocantins-Araguaia basin and at Cametá reported a maximum total length of 87.99 mm, at Tucuruí 69.38 mm and at Soure 98.25 mm, values that are well below those reported in the current study (12.7 cm). The maximum total length of adults tends to be greater in coastal environments than in interior waters (Silva *et al*., 2002; Flexa *et al*., 2005; Freire *et al*., 2012; Pantaleão *et al*., 2012).

A greater quantity of shrimp was captured using spacings between 3 and 4 mm, while the lowest quantity captured was with a spacing 10 mm (ANOVA F 9;110 = 3.688; p = 0.00045) (Figure 4).
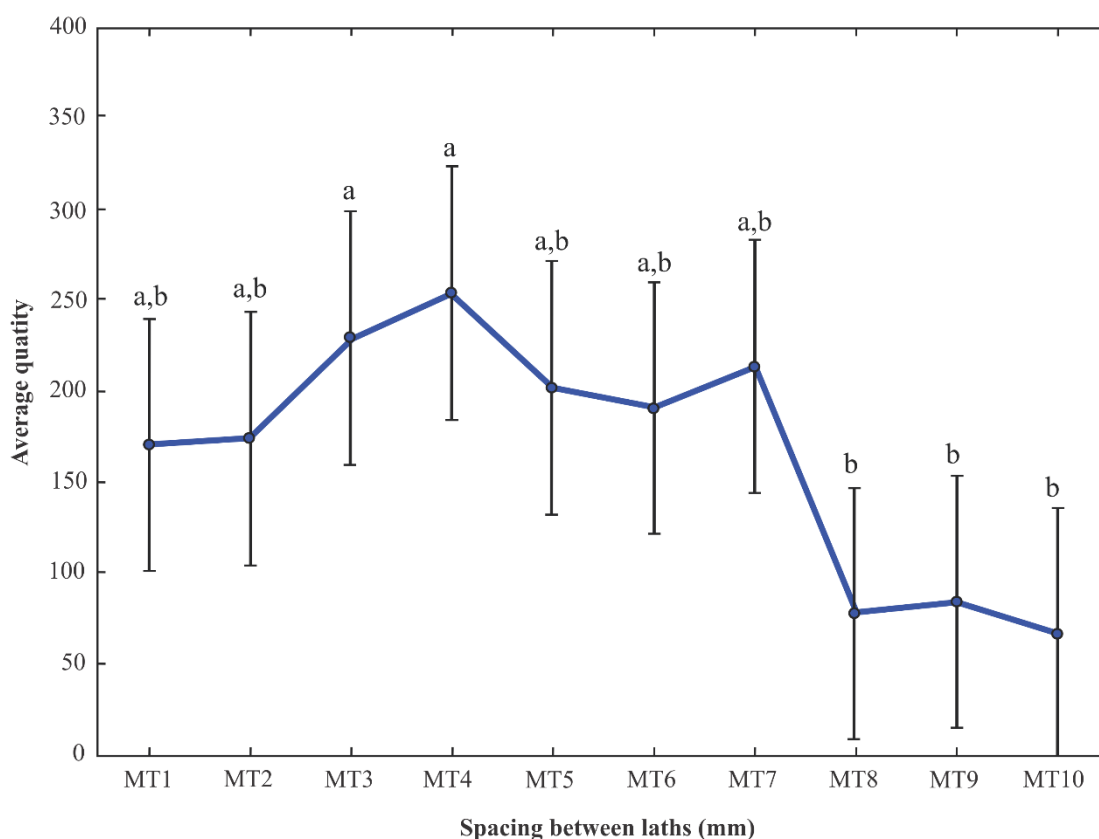
Figure 4. Average quantity of shrimp captured for each lath spacing. The bars indicate the confidence interval for the averages. Data collected monthly between May 2018 and April 2019. Values with the same lowercase letters are not significant

The number of small shrimps captured was 10,970 (54.94%), for medium shrimp it was 5,227 (26.18%), and for big the quantity was 3,770 (18.88%). The percentages for small shrimp captured for all spacings was greater, except for spacings of 8 to 10 mm where big shrimp had greater percentages (Table 1).

With respect to economic yield, it was observed that big shrimp had greater yield for all lath spacings in spite of the lower number of shrimps captured for spacings between 1 and 7 mm (Table 1). The greater capture of big shrimp using spacings between 8 and 10 mm allowed for larger economic yield per capture (Table 1).

Table 1. Abundance, biomass, percent of shrimp and profitability with respect to spacing between the laths of the matapi (matapi + matapi cover). Data collected monthly between May 2018 and April 2019. Size: B (Big), M (Medium), S (Small)

	Size	Abundance	Biomass (kg)	Percentage (abundance)	Value of sale (R$)	Total profit (R$)
	B	370	1.75	1.85	15	26.23
MT1	M	534	0.77	2.67	10	7.67
	S	1144	0.58	5.73	6	3.49
	B	347	1.64	1.74	15	24.65
MT2	M	557	0.78	2.79	10	7.84
	S	1187	0.64	5.94	6	3.83
	B	399	1.55	2.00	15	23.31
MT3	M	796	1.16	3.99	10	11.64
	S	1558	0.82	7.80	6	4.89
	B	311	1.23	1.56	15	18.52
MT4	M	653	0.96	3.27	10	9.57
	S	2087	0.95	10.45	6	5.70
	B	250	1.05	1.25	15	15.70
MT5	M	639	0.96	3.20	10	9.57
	S	1534	0.78	7.68	6	4.68
	B	327	1.38	1.64	15	20.70
MT6	M	650	0.96	3.26	10	9.63
	S	1315	0.78	6.59	6	4.70
	B	446	1.81	2.23	15	27.10
MT7	M	725	1.06	3.63	10	10.62
	S	1396	0.72	6.99	6	4.31
	B	419	2.00	2.10	15	30.01
MT8	M	161	0.26	0.81	10	2.60
	S	353	0.22	1.77	6	1.29
	B	486	2.13	2.43	15	32.02
MT9	M	232	0.43	1.16	10	4.32
	S	291	0.15	1.46	6	0.88
	B	416	1.90	2.08	15	28.46
MT10	M	279	0.45	1.40	10	4.49
	S	105	0.06	0.53	6	0.38

With respect to captured biomass, the ANOVA results were (F 9;110 = 0.848; p = 0.573) with
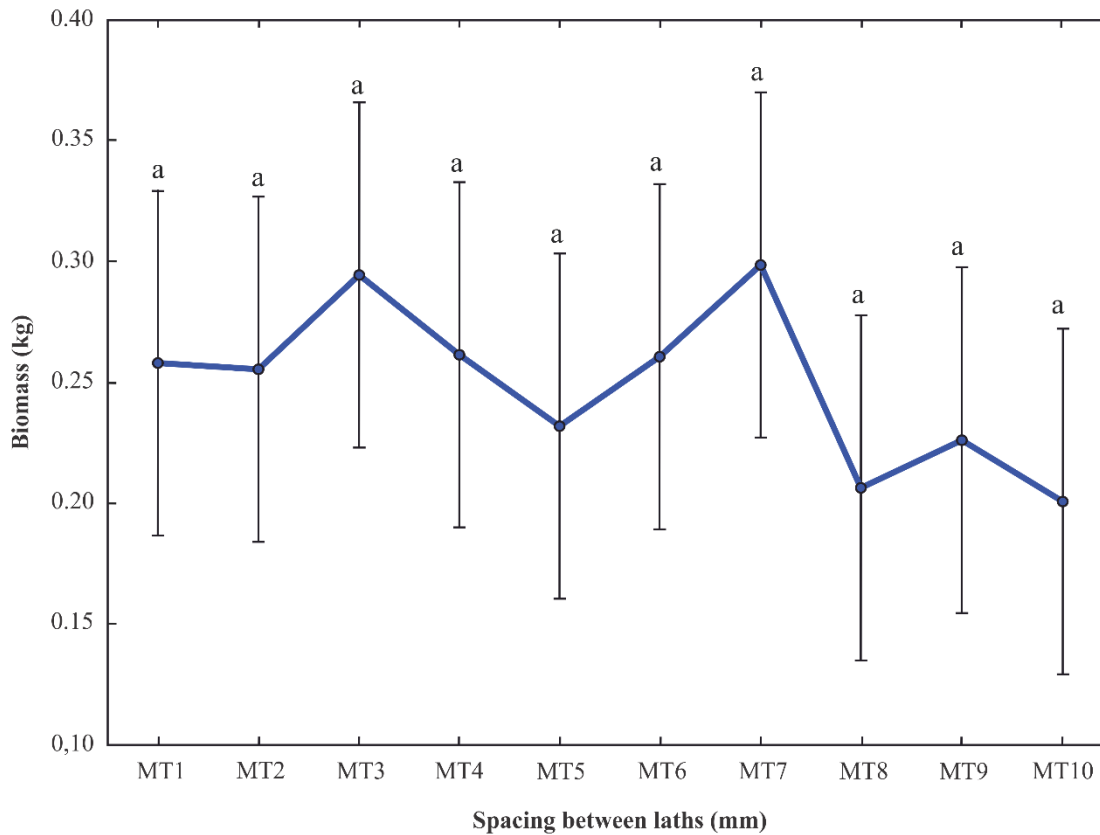
no significance for lath spacing (Figure 5).

Figure 5. Biomass (kg) captured for different matapi (matapi + matapi cover) lath spacing size. The bars indicate the confidence interval. Data collected monthly between May 2018 and April 2019. Values with the same lowercase letters are not significant

Based on lengths and biomass of captured specimens it was observed that the spacing between laths of 8 to 10 cm capture larger shrimp and in greater abundance than the other spacings. According to Silva *et al.* (2016), the recruitment period of Amazonian shrimp has a peak in the month of July, and 70.7% of juvenile Amazonian shrimp make up the stock that comprises the range of 19.09 mm to 41.09 mm of standard length (corresponding to 0.6 to 1.6 of carapace length). Therefore, it could be deduced that the use of lath spacings below 7 mm, common among fishing communities in the region (5 mm is generally the spacing used), could be negatively affecting renovation of the natural stock of shrimp in the region. Similarly, Silva *et al.* (2007) demonstrated that fishing pressure on the population of *M. amazonicum* at Combú island, state of Pará, is having a negative effect. For the region of Amapá, Lima (2014a, 2014b) suggested an adjustment of the laths of traditional traps to a minimum distance of 1.0 cm, and the establishment of a minimum capture size of 7.0 cm of total length, which corresponds to 1.6 cm of carapace length.

The length of carapace of captured shrimp for different lath spacings was significant ($F_{(9:13377)} = 271.18$; $p = 0.0000$), with matapis using spacings of 7 to 10 mm individuals with greater average values (Figure 6).
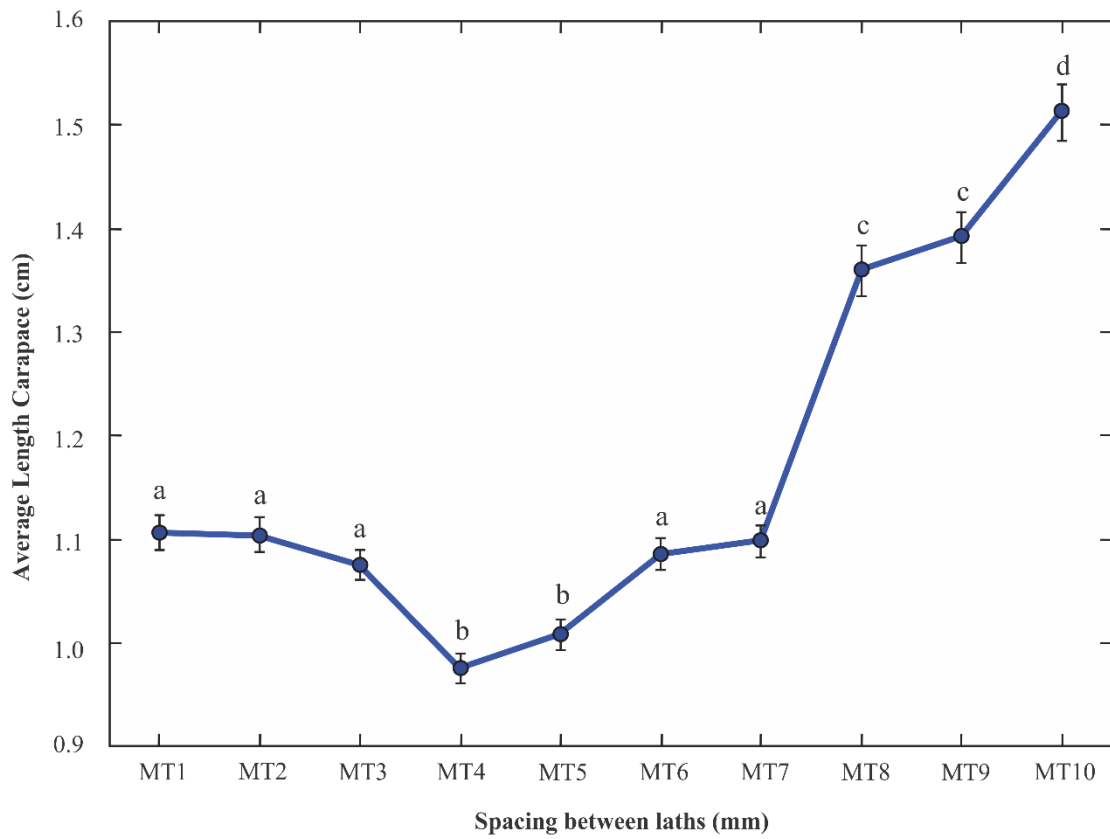
Figure 6. Average length of carapace for lath spacings of matapis. The bars indicate the confidence interval for the averages. Data collected monthly between May 2018 and April 2019. Values with the same lowercase letters are not significant

Table 2. Frequency and composition of capture of the Amazonian shrimp (*Macrobrachium amazonicum*) for different spacings between laths, Santana island, city of Santana. Data collected monthly between May 2018 and April 2019

Lath spacing (mm)	Place of capture	N	%	Min	AVG ± SD	Max
1	Matapi	1796	10.26	0.5	1.14 ± 0.43	3
	Matapi cover	252		0.5	0.87 ± 0.37	2.7
2	Matapi	1778	10.47	0.5	1.16 ± 0.0.4	3
	Matapi cover	313		0.4	0.76 ± 0.16	1.5
3	Matapi	2407	13.78	0.2	1.12 ± 0.36	2.9
	Matapi cover	345		0.2	0.75 ± 0.13	1.4
4	Matapi	1832	15.28	0.1	1.11 ± 0.34	3
	Matapi cover	1219		0.3	0.77 ± 0.25	2.2
5	Matapi	1457	12.14	0.1	1.14 ± 0.38	2.7
	Matapi cover	966		0.4	0.81 ± 0.20	1.9
6	Matapi	1261	11.48	0.2	1.20 ± 0.41	3
	Matapi cover	1031		0.4	0.94 ± 0.21	1.8
7	Matapi	1262	12.86	0.5	1.33 ± 0.40	3
	Matapi cover	1305		0.4	0.88 ± 0.21	2.1
8	Matapi	614	4.67	0.6	1.60 ± 0.47	3.3
	Matapi cover	319		0.5	0.89 ± 0.20	2.1
9	Matapi	625	5.05	0.5	1.60 ± 0.46	2.9
	Matapi cover	384		0.5	1.06 ± 0.34	2.3
10	Matapi	354	4.01	0.6	1.79 ± 0.38	2.9
	Matapi cover	446		0.6	1.29 ± 0.32	2.3

AVG ± SD = Mean ± Standard Deviation

The frequency and composition of capture for different spacings between laths is shown in Table 2, and the selectivity analysis is shown in Table3. The lengths for which 25%, 50% and 75% of the captured shrimp are grouped are shown in Table 3.

Table 3. Selectivity curve (SL) equations and values for L_{25}, L_{50} and L_{75} of the different matapi lath spacings (between 1 and 10 mm) used in the capture of the Amazonian shrimp (*Macrobrachium amazonicum*) for different spacings between laths, Santana island, city of Santana. Data collected monthly between May 2018 and April 2019

Lath spacing (mm)	L_{25}	L_{50}	L_{75}	Equations
1	0.001	0.34	0.69	$S1 = 1/[1+\exp(1.103-3.197*LC)]$
2	0.41	0.6	0.79	$S2 = 1/[1+\exp(2.529-5.868*LC)]$
3	0.31	0.52	0.72	$S3 = 1/[1+\exp(2.779-5.416*LC)]$
4	0.35	0.72	1.09	$S4 = 1/[1+\exp(2.099-2.910*LC)]$
5	0.5	0.8	1.1	$S5 = 1/[1+\exp(2.936-3.663*LC)]$
6	0.47	0.96	1.45	$S6 = 1/[1+\exp(2.150-2.238*LC)]$
7	0.78	1.02	1.26	$S7 = 1/[1+\exp(4.756-4.658*LC)]$
8	0.71	0.94	1.16	$S8 = 1/[1+\exp(4.606-4.913*LC)]$
9	0.6	1.2	1.8	$S9 = 1/[1+\exp(2.201-1.832*LC)]$
10	1.32	1.85	2.37	$S10 = 1/[1+\exp(3.907-2.113*LC)]$

Recruitment data reported by Silva *et al.* (2016) reinforce the necessity of adoption of such recommendations for the Amazonian shrimp. The increase of space between laths for size 8 mm to 10 mm makes the trap more selective, drastically reducing the volume of juvenile individuals that are captured, and increases the capture of medium and large-sized shrimp (Lima, 2014a), a fact that is shown by the L_{50} of the selectivity curves.

The size at the initial maturation of *M. amazonicum* has been reported as being between 4.5 cm and 6.0 cm in total length (approximately 0.9 cm to 1.3 cm of carapace length) (Sampaio *et al.,* 2007; Freire *et al.,* 2012; Lima *et al.,* 2014; Bentes *et al.,* 2016), and this clearly shows that larger spacings capture much larger shrimp than those at the size at initial maturation, independent of sex and collection period. However, due to variations in population structure, size, fecundity and fertility among the continental and estuarine populations of *M. amazonicum,* there is a necessity to establish differentiated planning measures to organize the framework that regulates the fishing of these shrimp, including improvements of the fishing equipment and establishing the minimum size for capture of *M. amazonicum* in the Amazon, tailored to peculiarities of each region.

The selectivity curves demonstrate that, when considering that size at initial sexual maturation varies between 0.9 cm and 1.3 cm in carapace length, more than 50% of young shrimp would be protected by the use of traps with a spacing ≥ 7 mm. Nevertheless, current regulations for the use of traps used to capture the Amazonian shrimp do not exist, and this severely limits the adequate management of this species. Some studies indicate that selective fishing based only on management models that establish a minimum capture size could compromise the shrimp population and the ecosystem, causing age suppression (Garcia *et al.,* 2012), recruitment problems (Berkeley *et al.,* 2004), early maturation of individuals

(Jørgensen *et al.,* 2007), thus favoring slower genotypes (Conover and Munch, 2002) and alteration of phenotypic variation (Zhou *et al.,* 2010).

4. Conclusion

The matapis that have spacing between laths that is less than 7 mm, currently used by riverine communities and artisanal fishermen (generally 5 mm), can be considered predatory, since they permit the capture of small individuals, because in the current study more than 50% of shrimp were captured between spacings of 1 to 5 mm. In spite of the fact that spacings of 8 to 10 mm between the laths captured a smaller quantity of shrimp, these spacings enable the capture of larger shrimp and a similar biomass yield, and for this reason these should be considered more viable in ecological and economic terms.

Therefore, in order to minimize the capture of young shrimp, without drastically affecting economic yield from this activity, it is suggested that the distance between the laths of the matapis be adjusted between 6 and 8 mm. It is also recommended that this suggestion becomes incorporated into official laws that regulate the capture of the Amazonian shrimp at the mouth of the Amazon River.

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