EVALUATION OF *MANSONIA* SPP. INFESTATION ON AQUATIC PLANTS IN LENTIC AND LOTIC ENVIRONMENTS OF THE MADEIRA RIVER BASIN IN PORTO VELHO, RONDÔNIA, BRAZIL

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ABSTRACT. The females of *Mansonia* are voraciously hematophagous. The spiracular apparatus of the immature, larval, and pupal forms is adapted to perforate submerged aquatic vegetation, from whose aeriferous aerenchyma they obtain the oxygen necessary for breathing. The proliferation of aquatic plants, in some cases linked to anthropic modifications that reduce water flow and/or increase organic matter content, may therefore contribute to the spread of these mosquitoes. This study aims to assess the presence of immature individuals of *Mansonia* in different aquatic plants of the Madeira River basin in 10 lentic and lotic environments and correlate their population density with abiotic factors such as water pH, dissolved O_2, conductivity, and temperature. The sampling lasted from February 2016 to June 2018, a 29-month period during which 31,287 specimens belonging to the genus *Mansonia* were captured. Of the 12 species of macrophytes inspected, *Eichhornia crassipes* made up 70.1% of the samples. Lentic environments accounted for 58.9% of the samples and lotic environments for 41.1%. Immature individuals were most commonly found on *Eichhornia crassipes*, with this plant accounting for an average of 96.2% of all individuals, with a percentage ranging between 58.2% and 77.1% in different breeding areas. Only at the Foz do Igarapé Jirau site was a different distribution observed, with the number of aquatic plants more nearly equal: 83.3% of the larvae were found in *Eichhornia crassipes*, 9.2% in *Ceratopteris pteridoides*, 3.6% in *E. azurea*, 2.0% in *Salvinia* sp., and 1.9% in *Pistia* sp. The greatest richness was found in Iguapé do Raul. Concerning the larval/plant relationship, although less frequent, *E. azurea* had a higher larval density of *Mansonia* spp. It is important to emphasize that this finding may indicate a possible selection for this plant. Egg deposition by *Mansonia* spp. was more abundant in sample areas with *Eichhornia crassipes* and *Pistia* sp. The number of specimens collected was positively correlated with temperature, pH, and conductivity. These correlations showed a marked increase in the rainy season. Therefore, we were able to establish preliminary parameters of how environmental changes influence the ecology of this important genus of mosquitoes, the species of which are critical disease vectors.

KEY WORDS Abiotic factors, macrophytes, Madeira River, *Mansonia*, mosquitoes

INTRODUCTION

Mansonia Blanchard comprises 2 subgenera: *Mansonioides* Theobald, which has 10 species distributed in Asia and 2 in Africa (Ronderos and Bachmann 1963), and the nominotypical subgenus (*Mansonia*), which includes 15 species with primarily Neotropical distribution (Guimarães 1997, For-attini 2002, Barbosa 2007, Harbach 2020), with 12 species recorded in Brazil.

Females of *Mansonia* spp. are voraciously hema-tophagous. The spiracular apparatus of the active immature forms is adapted to perforate submerged vegetation to obtain oxygen from plant tissue (Harbach 2020). Immature individuals attach them-selves to aquatic plants, from whose aeriferous aerenchyma they get the oxygen necessary for breathing. Van den Assem (1958) and Wharton (1959) hypothesized that this behavior among immature stages of *Mansonia* spp. of piercing submerged plant tissues, especially the root tissue of floating plants (*Eichhornia*, *Pistia*, *Salvinia*, *Typha*, and grasses), emerged as an evolutionary survival strategy against attacks by fish, aquatic insects, and other aquatic animals.

The proliferation of aquatic plants is sometimes linked to a reduction in water flow and/or increase in organic matter content (eutrophication), often due to human activities, which may contribute to the spread of these mosquitoes (Forattini 2002). Although they are essentially forest species, they can become established on the outskirts of towns and inhabited centers, as long as favorable conditions exist in the form of suitable breeding sites (Forattini 2002).

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Breeding habitats are typically rich in nutrients and consist of medium or large accumulations of either still or slow-moving water. These include river and lake backwaters in which the water surface is partially or totally covered with plants (Forattini 2002). These processes provide insight into population dynamics, community structure, and ecosystem function, allowing us to explore the effects of environmental factors and interspecific interactions, making it possible to determine, for example, whether the population will persist in a certain habitat (Tibério 2021).

This study aims to evaluate the infestations of aquatic plants by *Mansonia* spp. lentic environments of the Madeira River basin near the Jirau Hydroelectric Power Plant (Jirau HPP), in Rondônia, Brazil. It also seeks to establish parameters for the analysis of environmental changes that influence the ecology of this important group of insects, which includes numerous taxa that use lentic environments (here the dam reservoir) as developmental habitats and that transmit pathogens.

Mansonia species are not known to be vectors of endemic pathogens in Brazil. However, some species have been found to be naturally infected with different viruses, and they are real plagues, making human life and livestock difficult in certain regions. For example, *Ma. pseudotitillans* (Theobald) was found to be infected with the Saint Louis encephalitis virus (Segura and Castro 2007), and *Ma. titillans* (Walker) with Venezuelan encephalitis virus and febrile disease arbovirus (Hervé et al. 1986, Consoli and Oliveira 1994).

MATERIALS AND METHODS

Study area

The study was conducted on a 105.7 km stretch of the Madeira River (79 km as the crow flies) in the state of Rondônia that is affected by the reservoir of the Jirau HPP, with 8 sampling points upstream of the dam and 2 downstream. The predominant vegetation in the sample area is classified as lowland and submontane open rainforest and is also categorized as *terra firme* forest (IBGE 2012). The region's climate is classified as tropical humid hyperthermal (Cochrane and Cochrane 2010), with minimum annual average temperatures ranging between 20°C and 22°C and maximum temperatures between 31°C and 33°C, RH between 85% and 90%, and average rainfall between 2,000 mm and 2,200 mm (Sombroek 2001). The relief of the region is flat, with altitudes ranging from 100 m to 300 m above sea level.

Amazonian rivers are commonly divided into clear, white, and dark waters, depending on the type of sediment and/or organic matter they carry. Whitewater rivers drain geologically young regions (e.g., the Andes) and are rich in sediment. Clearwater rivers originate in older geological regions (central Brazil and the Guyanas).

Sampling points

Sampling was conducted monthly from February 2016 to June 2018, based on a survey of potential breeding sites for *Mansonia* spp. in the Jirau HPP reservoir. Sample points for aquatic macrophytes and *Mansonia* mosquitoes located in reservoir of the Jirau HPP, in 10 sampling sites were selected, as follows: Foz do Rio Jaci, site 1 (9°12′49.9″S, 64°24′06.0″W); Igarapé Flórida, site 2 (9°07′55.9″S, 64°31′46.5″W); Igarapé do Raul, site 3 (9°15′14.4″S, 64°42′16.1″W); Casa da Colina, site 4 (9°15′55.3″S, 64°40′16.6″W); Base da Barragem, site 5 (9°16′58.1″S, 64°38′09.4″W); Foz do Igarapé Jirau, site 6 (9°22′47.2″S, 64°45′30.0″W); Caiçara/Primavera, site 7 (9°24′11.8″S, 64°49′14.6″W); Igarapé Caiçara, site 8 (9°32′52.4″S, 64°50′25.8″W); Bolsão Mutum, site 9 (9°35′51.5″S, 64°55′55.1″W); and Igarapé São Lourenço, site 10 (9°33′52.50″S, 65°1′23.10″W) (Fig. 1).

Each site had a high concentration of aquatic vegetation belonging to the following plant species: *Eichhornia crassipes* (Mart.) Solms-Laubach, *E. azurea* (Sw.) Kunth, *Ceratopteris pteridoides* (Hook.) Hieron, *Pistia* sp., *Salvinia* sp., and *Paspalum* sp.

Sampling was performed between 9:00 a.m. and 5:00 p.m. with a total of 29 collections per site. There were 7 washing points for macrophytes, with 15 min spent on sampling per point, for a total of 105 min (1.45 h) per site. The same methodology was followed at all 10 sampling sites during a 14.5-h effort for each collection, totaling 420.5 h. Larval collections were carried out according to the methodology used by Ferreira (1999), where the locations were selected at random, following which they were removed manually and quantified, separated according to the species of the plant, and placed in a 25-liter white polypropylene tray (54 cm × 33.5 cm × 19 cm) to be washed with water. Subsequently, the water was filtered using a BioQuip® cone-shaped net to collect larvae detached from the roots. The specimens were then taken to the laboratory for further identification. Mosquito collections were authorized by the Chico Mendes Institute for Biodiversity Conservation (ICMBio), no. 26805-2.

The identification of the specimens to the genus level was performed from the direct observation of the morphological characters observed under the stereomicroscope (Zeiss®) and consultation of the respective descriptions/diagnoses of the genus using dichotomous keys prepared by Lane (1953), Consoli and Lourenço-de-Oliveira (1994), Forattini (2002), and Barbosa (2007). Later the specimens were incorporated into the Entomological Collection of the Federal University of Rondônia (UNIR).

Statistical analyses

The Kruskal-Wallis test, with a 5% significance level, was used to test for significant differences between the mosquito larvae captured and the
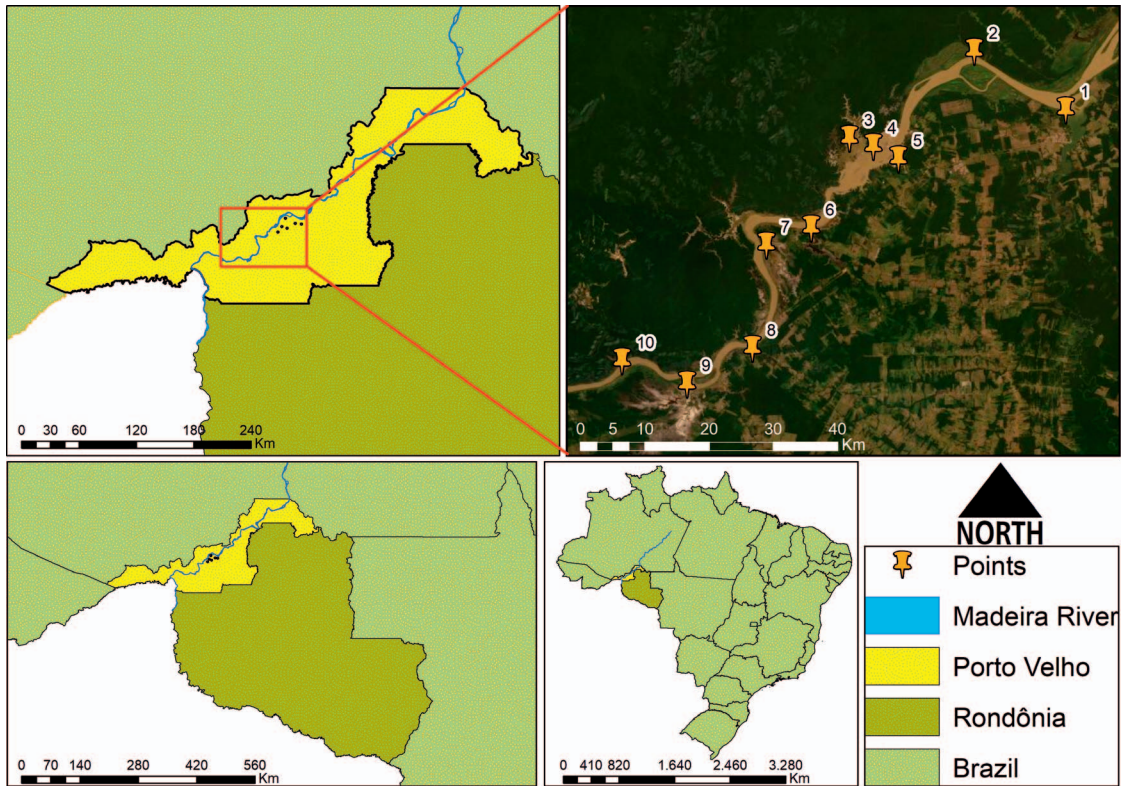
Fig. 1. Sample points located in areas of influence of the Jirau Hydroelectric Power Plant, near the margins of the Madeira River under the influence of the Amazon Biome, Rondônia state, Brazil. Foz do Rio Jaci, site 1; Igarapé Flórida, site 2; Igarapé do Raul, site 3; Casa da Colina, site 4; Base da Barragem, site 5; Foz do Igarapé Jirau, site 6; Caiçara/Primavera, site 7; Igarapé Caiçara, site 8; Bolsão Mutum, site 9; Igarapé São Lourenço, site 10.

different macrophyte species at the 10 capture sites. Dunn's post hoc Multiple Comparisons Test was then used. Both analyses were performed using SPSS® statistics software (IBM 2015) Version 23 and Past (Hammer et al. 2001) Version 4.5.

The X^2 (chi-square) test was used to verify if there was an association between *Mansonia* larvae and plant species. In addition, the standard error of the association relationship was calculated.

The graphs of the mosquito population curves were established using Williams (geometric means) means (Williams 1937, Haddow 1960) and their 95% confidence intervals. We were able to observe the monthly frequency of immature individuals in each of the analyzed locations and compare periods of lower population abundances. To check for possible differences in water quality metrics, the *t*-test was used. The influence of climatic factors (water pH, dissolved O_2, conductivity, and temperature) on the population density of mosquitoes was analyzed with the Spearman's rank correlation coefficient, with a 95% and 99% confidence level, using SPSS (IBM 2015) Version 23.

RESULTS

During the sampling period, 31,013 larvae of *Mansonia* spp. were collected at 10 sample sites, 4 of which were in lotic and 6 in lentic environments. Though fewer in number, the lotic environments accounted for 58.9% of collected individuals, with the highest abundance of larvae found at the Igarapé Florida site (28.33%) and the lowest at Casa da Colina (1.32%). The X^2 test showed no equality of proportions based on given probabilities, as follows: $X^2 = 144,450$, df $= 5$, $P < 2.2^{e-16}$.

Mansonia larvae showed the highest abundance during March, April, and May 2016 and January, February, and December 2017, indicating a greater abundance during the rainy season. In contrast, the number of individuals recorded dropped sharply during the dry season, with an especially sharp drop in June 2016 and the lowest levels in September 2016; we also observed lower density in the dry months of the years 2017 and 2018 (Fig. 2).

Of the 12 species of macrophytes collected, 70.1% of all plants belonged to *Eichhornia crassipes*, which contained, on average, 96.2% of all *Mansonia* spp. larvae collected at each site, increasing to 100% at
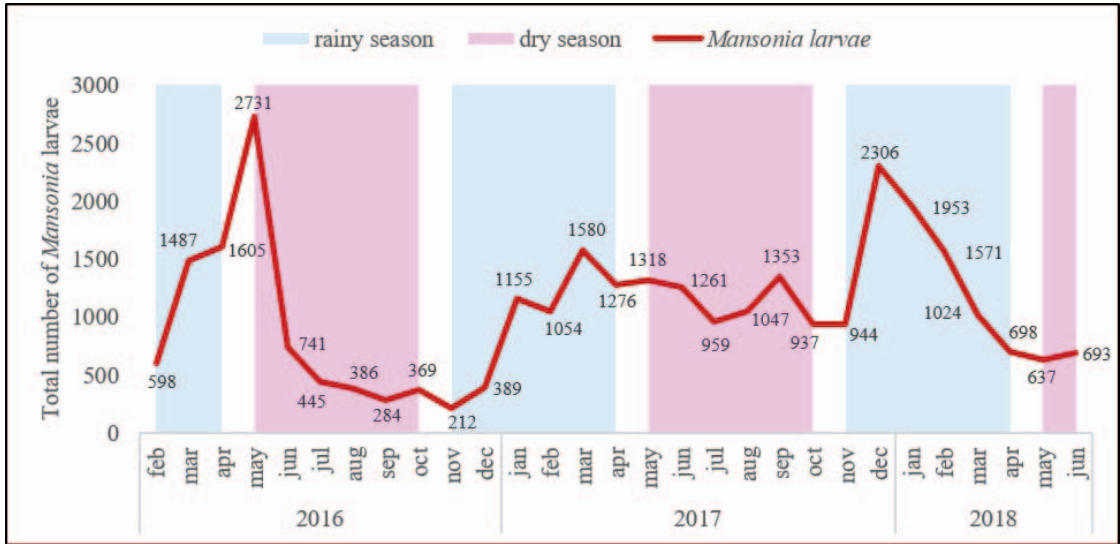
Fig. 2. Total number of *Mansonia* spp. immatures collected in a stretch of the Madeira River affected by the Jirau Hydroelectric Power Plant, Rondônia state, Brazil, between February 2016 and June 2018.

certain sites and never lower than 83.3% of all larvae. *Ceratopteris pteridoides* had the second-highest number of larvae, with 2.3% of the total larvae. The other 11 species of macrophytes accounted for the remaining 29.9% of the plants collected and just 3.8% of the larvae (Table 1). The highest density of *Mansonia* larvae was found on *E. azurea*, though the latter species was one of the least common (Fig. 3). This pattern could indicate a possible element of selection for this plant species. No *Mansonia* spp.
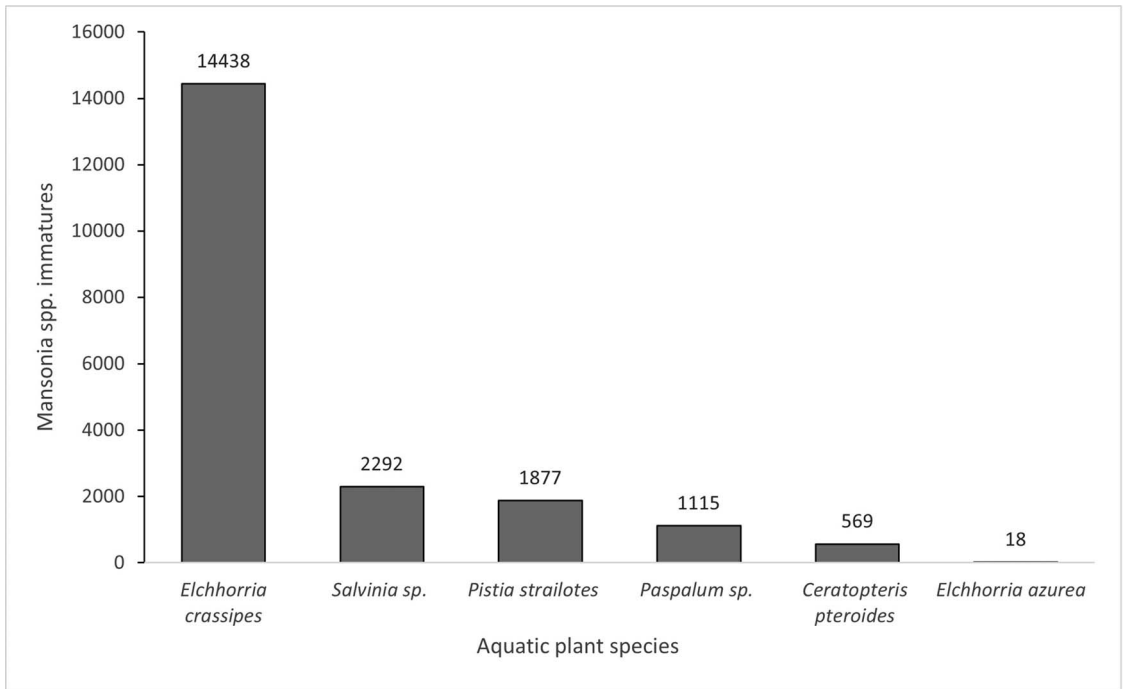

Fig. 3. Matrix plot of the ratio of *Mansonia* spp. immatures per species of aquatic plant for the locations analyzed: Igarapé Flórida, Caiçara/Primavera, Igarapé Caiçara, Foz do Igarapé Jirau, Foz do rio Jaci, Base da Barragem, Casa da Colina, Igarapé do Raul, São Lourenço, Bolsão do Mutum, Rondônia state, Brazil, between February 2016 and June 2018.

Table 1. Absolute values of aquatic plants (AP) and the respective *Mansonia* spp. larvae collected at each of the 10 locations analyzed—Foz do Rio Jaci (FRJ), Igarapé Flórida (IF), Igarapé do Raul (IR), Casa da Colina (CC), Base da Barragem (BB), Foz do Igarapé Jirau (FIJ), Caiçara/Primavera (C/P), Igarapé Caiçara (IC), Bolsão do Mutum (BM), and São Lourenço (SL)—in a stretch of the Madeira River affected by the Jirau Hydroelectric Power Plant, Rondônia state, Brazil, between February 2016 and June 2018.

Species	FRJ		IF		IR		CC		BB		FIJ		CP		IC		BM		SL		Total		
	AP	Larvae	AP	Larvae	AP	Larvae	AP	Larvae	AP	Larvae	AP	Larvae	AP	Larvae	AP	Larvae	AP	Larvae	AP	Larvae	AP	Larvae	% Larvae
Eichhornia crassipes	2,038	4,964	1,926	8,784	1,257	1,435	1,260	401	1,507	663	827	2,320	1,284	2,993	1,523	2,955	1,171	1,130	1,130	4,202	13,923	29,847	96.2%
Eichhornia azurea	0	0	0	0	0	0	0	0	9	1	9	101	0	0	0	0	0	0	0	0	18	102	0.3%
Ludwigia helminthorriza	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0.0%
Ceratopteris pteridoides	1	0	0	0	5	0	89	0	0	0	165	257	1	0	168	41	14	4	126	396	569	698	2.3%
Hymenachne amplexicaulis	45	0	12	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	59	0	0.0%
Pistia sp.	254	9	249	0	229	30	195	8	140	3	159	52	315	199	136	0	82	0	118	2	1,877	303	1.0%
Salvinia sp.	237	1	500	1	238	0	258	0	242	0	133	56	231	0	193	2	146	0	114	0	2,292	60	0.2%
Phyllanthus fluitans	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0.0%
Oxicarium cubensis	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0.0%
Paspalum sp.	98	1	117	0	145	0	126	0	122	0	129	0	75	0	113	0	106	2	84	0	1,115	3	0.0%
Total	2,680	4,975	2,806	8,785	1,878	1,465	1,928	409	2,020	667	1,422	2,786	1,906	3,192	2,133	2,998	1,519	1,136	1,572	4,600	19,864	31,013	100.0%
% larvae		16.04		28.33		4.72		1.32		2.15		8.98		10.29		9.67		3.66		14.83		100.00	

Table 2. Percentage values of *Mansonia* spp. larvae and the main aquatic plants (AP) collected at each of the 10 locations analyzed—Foz do Rio Jaci (FRJ), Igarapé Flórida (IF), Igarapé do Raul (IR), Casa da Colina (CC), Base da Barragem (BB), Foz do Igarapé Jirau (FIJ), Caiçara/Primavera (C/P), Igarapé Caiçara (IC), Bolsão do Mutum (BM), and São Lourenço (SL)—in a stretch of the Madeira River affected by the Jirau Hydroelectric Power Plant, Rondônia state, Brazil, between February 2016 and June 2018.

Species	FRJ AP	FRJ Larvae	IF AP	IF Larvae	IR AP	IR Larvae	CC AP	CC Larvae	BB AP	BB Larvae	FIJ AP	FIJ Larvae	CP AP	CP Larvae	IC AP	IC Larvae	BM AP	BM Larvae	SL AP	SL Larvae
Eichhornia crassipes	76.0	99.8	68.6	100.0	66.9	98.0	65.4	98.0	74.6	99.4	58.2	83.3	67.4	93.8	71.4	98.6	77.1	99.	71.9	91.3
Eichhornia azurea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.6	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ceratopteris pteridoides	0.0	0.0	0.0	0.0	0.3	0.0	4.6	0.0	0.0	0.0	11.6	9.2	0.1	0.0	7.9	1.4	0.9	0.4	8.0	8.6
Hymenachne amplexicaulis	1.7	0.0	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pistia sp.	9.5	0.2	8.9	0.0	12.2	2.0	10.1	2.0	6.9	0.4	11.2	1.9	16.5	6.2	6.4	0.0	5.4	0.0	7.5	0.0
Salvinia sp.	8.8	0.0	17.8	0.0	12.7	0.0	13.4	0.0	12.0	0.0	9.4	2.0	12.1	0.0	9.0	0.1	9.6	0.0	7.3	0.0
Phyllanthus fluitans	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paspalum sp.	3.7	0.0	4.2	0.0	7.7	0.0	6.5	0.0	6.0	0.0	9.1	0.0	3.9	0.0	5.3	0.0	7.0	0.2	5.3	0.0
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

larvae were found in any of the other aquatic plant species present, including *Hymenachne* sp., *Oxicarium cubensis* (Poepp. and Kunth) Lye, *Ludwigia helminthorriza* (Mart.) H. Hara, *Phyllantus fluitans* Benth. Ex Mull. Arg., *Eleocharis* sp., and grasses (Table 1).

The Foz do Igarapé Jirau site was the only one in which larvae were more evenly distributed between macrophyte species, with 83.3% of larvae found in *E. crassipes*, 9.2% in *C. pteridoides*, 3.6% in *E. azurea*, 2.0% in *Salvinia* sp., and 1.9% in *Pistia* sp. (Tables 1 and 2; Fig. 4).

The null hypothesis of the Kruskal-Wallis test was rejected ($H = 33.767$, df = 5, $P = 0.000$), and the analysis indicated significant differences between the number of larvae caught and the different macrophyte species across the 10 sites; aquatic plant species with zero larvae for all locations were not included. The test was performed for larvae found in *E. crassipes*, *E. azurea*, *C. pteridoides*, *Pistia* sp., *Salvinia* sp., and *Paspalum* sp.

Dunn's post hoc Multiple Comparisons Test indicated which species showed differences. The number of larvae caught in *E. crassipes* was significantly different from the number of *E. azurea*, *C. pteridoides*, *Salvinia* sp., and *Paspalum* sp. ($P < 0.001$). Meanwhile, larval populations did not differ in *E. azurea*, *C. pteridoides*, *Pistia* sp., *Salvinia* sp., and *Paspalum* sp. ($P > 0.001$).

There were some differences between sites in terms of the number of *Mansonia* spp. larvae collected each month. The total number of larvae of these mosquitoes tended to increase between August and December at the Igarapé Florida site. Meanwhile, at the Caiçara/Primavera site, January and the period between July and September had the main increases. In Igarapé Caiçara, the months of March and May were the most favorable. However, in the sample areas of Foz do Igarapé Jirau, Casa da Colina, Igarapé Raul, and São Lourenço, the highest total number of larvae was observed from January to May. The site at the Jaci River's mouth saw the highest numbers of larvae during December, January and April, while April and June saw the highest figures of larvae at the Dam Base site (Fig. 5).

The Spearman's correlation analysis indicated a significant positive correlation between the number of larvae collected in and pH at the Igarapé Florida and Casa da Colina sites. The number of larvae collected in *E. crassipes* was significantly and positively correlated with conductivity at Caiçara/Primavera, Dam Base, Igarapé Raul, and Bolsão Mutum. In addition, the number of larvae collected was negatively correlated with temperature at Caiçara/Primavera and Foz do Rio Jaci, meaning that there was a decrease in the population density of these larvae when temperature increased. However, at the Foz do Igarapé Jirau site, there was a positive correlation between the number of larvae found in *C. pteridoides* and temperature (Table 3).
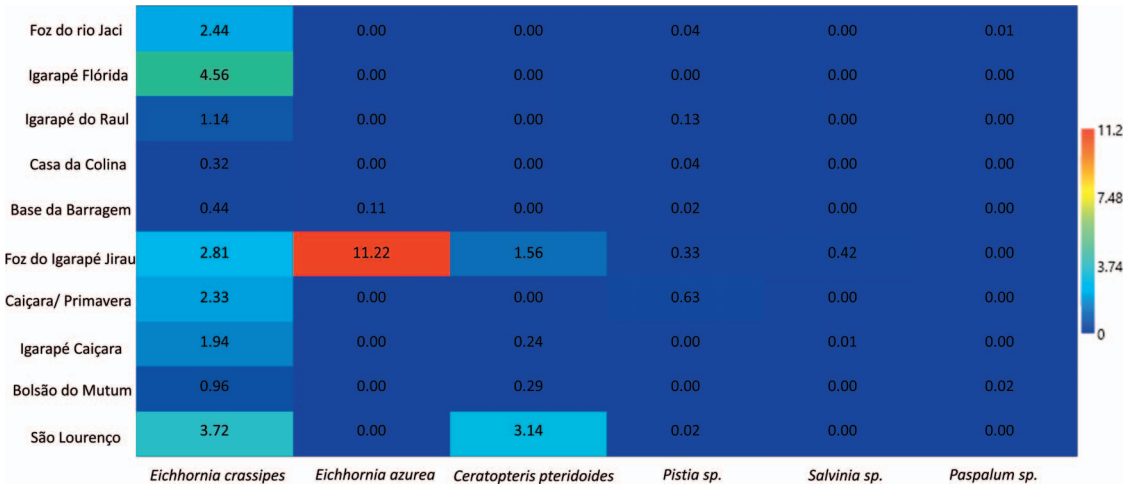
Fig. 4. Abundance of *Mansonia* spp. immatures per aquatic plant in a stretch of the Madeira River affected by the Jirau Hydroelectric Power Plant, Rondônia state, Brazil, between February 2016 and June 2018.

DISCUSSION

The formation of large hydroelectric reservoirs completely alters the landscape, eliminating the floodplain and transforming the lotic system into a lentic system, which tends to favor the floating species of aquatic macrophytes (Resende et al. 2019). As a result, aquatic macrophytes form a microclimate that is much richer in oxygen (Raven 1977), and it becomes an excellent place for the development of several species of mosquitoes.

In the present study, it was observed that despite the lotic environments being represented by a lower number of sampling points, 4 and 6 in lentic environments, the collection points located in the lotic environment corresponded to 58.9% of the collected larvae; thus the rainy period in this region demonstrated the greatest abundance.

The aquatic macrophytes contribute with quality food to animals within the aquatic habitat (Gadelha et al. 1990) since they store various nutrients in their biomass (Moore et al. 1994). However, the high rates of infestation by aquatic plants in the reservoirs of hydroelectric power plants lead to the urgent need for control measures due to the plants' high capacity of propagation and biomass production (Martins et al. 2003).

In a study carried out by Ferreira (1999) on Marchantaria Island, in the municipality of Iranduba, Amazonas, the number of larvae and pupae found in
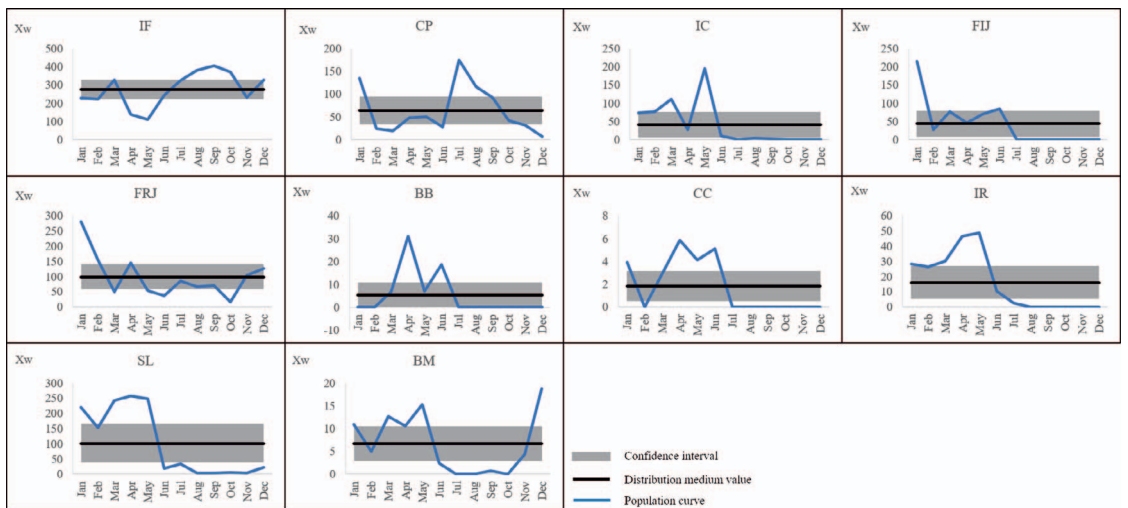

Fig. 5. Seasonal frequency of of *Mansonia* spp. immatures, according of Williams means (geometric means) collected in a stretch of the Madeira River affected by the Jirau Hydroelectric Power Plant, Rondônia state, Brazil, between February 2016 and June 2018.

Table 3. Spearman's correlation analysis (r) between the abiotic factors and *Mansonia* sp. populations collected at each of the 10 locations analyzed—Foz do Rio Jaci, Igarapé Flórida, Igarapé do Raul, Casa da Colina, Base da Barragem, Foz do Igarapé Jirau, Caiçara/Primavera, Igarapé Caiçara, Bolsão do Mutum, and São Lourenço—in a stretch of the Madeira River affected by the Jirau Hydroelectric Power Plant, Rondônia state, Brazil, between February 2016 and June 2018.

Location and species	pH		Dissolved O_2		Conductivity		Temperature	
	r	p	r	p	r	p	r	p
Foz do Rio Jaci								
Eichhornia crassipes	−0.135	0.485	0.269	0.158	0.129	0.506	−0.583[**]	0.001
Pistia sp.	0.079	0.683	−0.079	0.683	−0.237	0.215	−0.260	0.173
Salvinia sp.	0.204	0.289	0.090	0.641	−0.090	0.641	0.023	0.907
Paspalum sp.	0.271	0.154	−0.113	0.56	−0.136	0.483	0.079	0.683
Igarapé Flórida								
E. crassipes	0.395[*]	0.034	0.307	0.105	0.143	0.46	0.358	0.056
Salvinia sp.	0.316	0.095	−0.090	0.641	0.136	0.483	−0.147	0.447
Igarapé do Raul								
E. crassipes	−0.246	0.199	−0.208	0.280	−0.684[**]	0.000	−0.166	0.390
Pistia sp.	−0.224	0.243	−0.257	0.178	−0.283	0.137	−0.415*	0.025
Casa da Colina								
E. crassipes	−0.435[*]	0.018	−0.069	0.723	−0.278	0.144	−0.079	0.682
Pistia sp.	−0.133	0.490	−0.152	0.430	−0.083	0.669	−0.077	0.690
Base da Barragem								
E. crassipes	−0.327	0.084	−0.164	0.396	−0.551[**]	0.002	−0.068	0.725
E. azurea	0.090	0.641	−0.045	0.816	0.045	0.816	−0.271	0.155
Pistia sp.	−0.237	0.215	0.000	1.000	−0.056	0.771	−0.192	0.318
Foz do Igarapé Jirau								
E. crassipes	−0.124	0.522	−0.126	0.514	−0.138	0.474	0.301	0.113
E. azurea	−0.090	0.641	−0.158	0.412	0.068	0.727	0.294	0.121
Ceratopteris pteridoides	−0.146	0.449	−0.296	0.119	0.098	0.614	0.536[**]	0.003
Pistia sp.	0.009	0.965	−0.339	0.072	−0.018	0.928	0.257	0.178
Salvinia sp.	−0.130	0.501	−0.136	0.482	−0.112	0.562	0.112	0.563
Caiçara/Primavera								
E. crassipes	0.319	0.092	0.014	0.942	0.530[**]	0.003	−0.422[*]	0.023
Pistia sp.	0.277	0.145	0.960	0.619	0.197	0.306	−0.217	0.258
Igarapé Caiçara								
E. crassipes	0.320	0.091	−0.114	0.556	−0.271	0.154	0.144	0.455
C. pteridoides	0.065	0.738	0.038	0.844	−0.323	0.087	0.292	0.124
Salvinia sp.	−0.011	0.954	−0.023	0.907	−0.271	0.155	0.249	0.194
Bolsão do Mutum								
E. crassipes	0.212	0.269	−0.302	0.111	0.445[*]	0.016	0.039	0.839
C. pteridoides	−0.192	0.318	0.011	0.954	−0.237	0.215	0.283	0.138
São Lourenço								
E. crassipes	0.252	0.187	−0.103	0.595	0.053	0.786	0.047	0.809
C. pteridoides	−0.022	0.912	−0.109	0.575	−0.224	0.244	0.161	0.405
Pistia sp.	−0.136	0.483	0.215	0.264	−0.011	0.954	0.260	0.173

[**] Correlation is significant at the 0.01 level (2-tailed).
[*] Correlation is significant at the 0.05 level (2-tailed).

E. crassipes was higher than in *P. stratiotes*. Ferreira et al. (2003) similarly demonstrated a strong association between *Mansonia* larvae and the macrophytes *E. crassipes* and *Ceratopteris* sp. in a study carried out in Lago Camaleão, Amazonas. These observations are consistent with the present findings, in which *E. crassipes* had a greater association with larvae than other macrophytes, followed by *Pistia* sp. Ferreira et al. (2003) developed hypotheses to explain these patterns, including the fact that the size of the aerenchyma in *E. crassipes* is larger than in *Ceratopteris* sp. Thus, *Eichhornia* can maintain higher levels of oxygen and consequently a larger number of larvae, while the root tissues of *Ceratopteris* sp. are more rigid, which makes it difficult for larvae to perforate the plant tissue; factors related

to toxic secondary substances also play a role (Tokarnia et al. 1979) since *Ceratopteris* sp. may contain secondary substances that are harmful or repellent to *Mansonia* larvae.

In this study, we observed that two sample areas showed a positive correlation between the populations of *Mansonia* spp. and temperature. Ferreira et al. (2003) reported high water temperatures in *Mansonia* spp. habitat in their study area (29°C to 32°C) and discussed the possibility that temperature is related to the absence of *Trichomyces* fungi in *Mansonia* spp. larvae.

Martins et al. (2003) evaluated the chemical composition of 4 important species of aquatic plants found in the reservoir of the Salto Grande hydroelectric power plant in Americana, São Paulo, Brazil.

They found that *E. crassipes* and *P. stratiotes* had the highest average potassium, calcium, and magnesium levels. According to the results found by Martins et al. (2003) on the chemical constitution of macrophytes, the population density of *Mansonia* spp. in the study area may be influenced by the potassium, calcium, and magnesium content of the macrophages.

In this study, the populations of *Mansonia* spp. did not show a defined seasonal pattern throughout the year. In contrast, Ferreira et al. (1999) observed that the largest number of immatures of *Mansonia* spp. were found in August–October), with a peak in August, which was not significantly correlated with abiotic factors.

In conclusion, the larvae of *Mansonia* spp. were more abundant in sample areas with *E. crassipes* and *Pistia* sp. The number of specimens collected was positively correlated with temperature, pH, and conductivity. These correlations showed a marked increase in the rainy season. In parallel with the findings of Martins et al. (2003), it is also possible to consider that the presence of *Trichomycetes* fungi may influence the larval density of *Mansonia* spp. in the experimental area.

The findings of the present study are of great relevance since they contribute to the orientation of entomological surveillance and to the conduction of the application of mosquito control measures in the region.

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