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Evaluation of the effect of urbanization on water quality using bioindicators

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Abstract - The study evaluated the cumulative influence of urbanization on water quality along the main river of a river basin, through the identification of aquatic insects, used as bioindicators in association with physical and chemical variables analysis. Six sites were sampled in four campaigns between 2011 and 2012. Two sampling sites were established at each municipality, one located upstream and the other downstream, considering cities as potential sources of impact. The study demonstrated the negative effect of the presence of urban areas along the river course, by comparing the diversity of aquatic insects before and after urbanization and the absence of a decreasing gradient of quality throughout the basin, suggesting the capacity for depuration and the influence of local factors. Despite the effect of the urbanization on the main river, forest environments can maintain a better balance of biotic and abiotic variables, which draws attention to the importance of maintaining riparian vegetation, especially in urbanized environments.

Key words: Streams. Anthropization. Aquatic insects. Biotic indexes. Atlantic Rain Forest.

Avaliação do efeito da urbanização na qualidade da água utilizando bioindicadores

Resumo - O estudo avaliou a influência cumulativa da ocorrência de cidades na qualidade da água ao longo do rio principal de uma bacia hidrográfica, através da identificação de insetos aquáticos, utilizando-os como bioindicadores em associação com a análise de variáveis físicas e químicas. Seis pontos foram amostrados em quatro campanhas entre 2011 e 2012. Dois locais de amostragem foram estabelecidos em cada município, um localizado a montante e outro a jusante, considerando as cidades como fontes de impacto. O estudo demonstrou o efeito negativo da presença de áreas urbanas ao longo do curso do rio, comparando a diversidade de insetos aquáticos antes e depois das cidades e a ausência de um gradiente decrescente de qualidade em toda a bacia, sugerindo a capacidade de depuração e a influência de fatores locais. Apesar do efeito das cidades no rio principal, os ambientes florestais podem manter um melhor equilíbrio das variáveis bióticas e abióticas, o que chama a atenção para a importância da manutenção das matas ciliares, especialmente em ambientes urbanizados.

Palavras-chave: Riachos. Antropização. Insetos aquáticos. Índices bióticos. Mata Atlântica.

Evaluación del efecto de la urbanización en la calidad del agua utilizando bioindicadores

Resumen - El estudio evaluó la influencia acumulativa de la aparición de ciudades en la calidad del agua a lo largo del río principal en la cuenca hidrográfica, a través de la identificación de insectos acuáticos, usándolos como bioindicadores en asociación con el análisis de las variables físicas y químicas. Se muestrearon seis puntos en cuatro campañas entre 2011 y 2012. Se establecieron dos sitios de muestreo en cada municipio, uno ubicado río arriba y otro río abajo, considerando las ciudades como posibles fuentes de impacto. El estudio demostró el efecto negativo de la presencia de áreas urbanas a lo largo del curso del río, comparando la diversidad de insectos acuáticos antes y después de las ciudades y la ausencia de un gradiente de calidad decreciente en la cuenca, lo que sugiere la capacidad de depuración y la influencia de factores locales. A pesar de los efectos de las ciudades en el río principal, los entornos forestales pueden mantener un mejor equilibrio de las variables bióticas y abióticas, lo que llama la atención sobre la importancia de mantener los bosques ribereños, principalmente en entornos urbanizados.

Palabra clave: Arroyos. Antropización. Insectos acuáticos. Índices bióticos. "Mata Atlántica".

Introduction

Urbanization causes numerous changes in ecosystems and the Atlantic Forest biome and its adjacent ecosystems are considered globally threatened environments as a result to different types of anthropic impacts, constant aggressions and the threat of destruction of its various types of habitat. Consequently, the quality of the lotic environments of the Atlantic Rain Forest has been increasingly reduced (Magnago et al. 2014; De Rezende et al. 2015; SOS Mata Atlântica and INPE, 2017, Mello et al. 2020; MapBioma 2021).

However, they still do not receive the same acceptance as terrestrial environments in conservation programs (Strayer and Dudgeon 2010). Studies related to changes in aquatic environments consider anthropogenic interferences, such as land use changes and urbanization, to be most responsible for the impacts on these environments and, consequently, loss of quality of its waters and biodiversity (Tulbure et al. 2014; Amaral et al. 2015; Chen et al. 2016; Nava-Lopez et al. 2016; Feijó-Lima et al. 2019). It is important to say, that by their intrinsic characteristics, lotic environments are affected both by local actions and actions affecting the water course along the basin (Coelho, Buffon, Guerra 2011; Ding et al. 2016; Nava-Lopez et al. 2016).

Biological monitoring stands out in the assessment of aquatic environments and is an important tool providing temporal information on water quality and the interaction of organisms with physical and chemical parameters, as well as changes in the original environmental conditions. Moreover, its determination is economical in its application when compared to traditional methods (Goulart and Callisto 2003; Bem et al. 2015).

Indicator organisms, or bioindicators, are defined as those that have specific environmental needs. Studies of aquatic bioindication require the definition of an indicator whose presence, abundance or behavior reflects the effect of a stressor on biota (Buss et al. 2003; Bonada et al. 2006). The use of insects as indicators of the quality of water and ecosystems is becoming widespread around the world for presenting groups sensitive to pollutants and other types of environmental stress, besides their important function in the dynamics of water body nutrients and their inclusion as a standard in legislation of some states and countries (Gullan and Cranston 2012; Amaral et al. 2015; Rosa et al. 2018).

Recognizing the importance of these environments and the use of bioindication tools, the present study aimed to evaluate, the cumulative influence of the occurrence of cities on water quality along the main river of the Almada River Basin (BHRA) in the Atlantic Forest region, through the identification of aquatic insects, using them as bioindicators in association with the analysis of physical and chemical variables. As hypothesis, it is expected that urban areas negatively and cumulatively affect the water quality, demonstrated by the less diversity of aquatic insects in stretches downstream of the cities along the main course of the river.

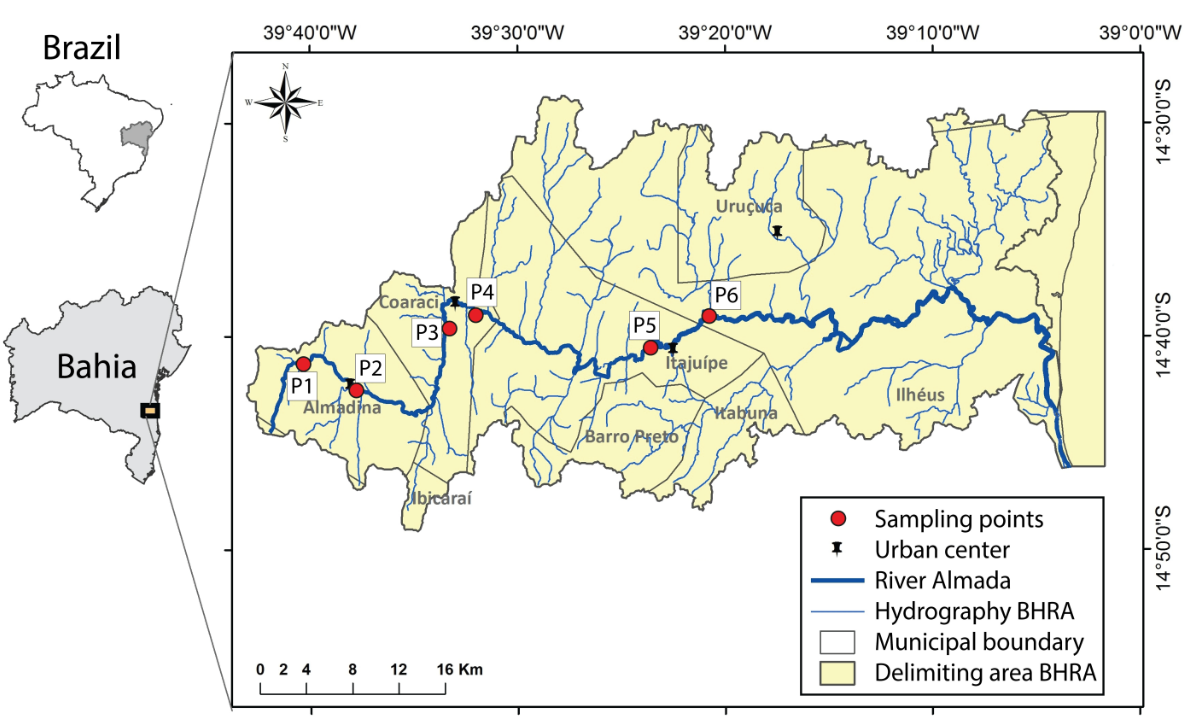
Materials and methods

Study sites

The Almada River Basin (BHRA), with a drainage area of 1,575 km2, is located in South Bahia, Brazil. It is totally inserted in Atlantic Forest, which is a biome recognized as a Biosphere Reserve. The region still has sites with remnants of original forest tree species, as well as pasture environments and agriculture (SOS Mata Atlântica and INPE, 2017). The BHRA covers the municipalities of Almadina, Coaraci, Itajuípe, Uruçuca, Ilhéus, Itabuna, Ibicaraí and Barro Preto, which are all supplied by its waters. In addition, water use includes agribusiness, livestock watering, dilution of domestic effluents and food industries, demonstrating the importance of the resource (Franco et al. 2015).

Six sampling sites were established for the present study, starting near the source and going towards the river mouth, and always along the course of the main river. The river presents environments with substrate of the sandy type as well as background of leaf and deposited organic matter and the sites presented a mean width of 15m and a mean depth of 1m. (Figure 1). The sampling sites encompassed the municipalities of Almadina (14°42'20"S and 39°38'05"W), Coaraci (14°38'29"S and 39°33'01"W) and Itajuípe (14°41'06"S and 39°21'51"W), with two sampling sites at each municipality, one located upstream and the other downstream, considering the cities as potential sources of impact since the main river crosses the urban areas of the three cities (Figure 1). In the selected area there are two of the municipalities with the largest areas in the basin: Itajuípe and Almadina, with 90% and 83%, respectively (NBH 2001a).

Figure 1. Location of the sampling points in the Almada River Basin, Bahia, Brazil.



Sample design

The understanding of environmental changes must consider the integration of methods and results of biotic and abiotic variables as tools for assessing stressors on the aquatic ecosystem (Junqueira et al. 2000; Buss, Baptista, Nessimian 2003). Therefore, four sample campaigns were carried out (one every three months) between December 2011 and September 2012 to include the rainy and dry periods. The aquatic organisms were collected using an entomological network (Network D) (0.5 mm) which followed the standard effort of 40 minutes for each sampling sites. The collected material was fixed in 80% alcohol, duly labeled and sent to the laboratory for screening and identification by specific references (Salles et al. 2004; Costa et al. 2006; Domínguez et al. 2006; Domínguez and Fernández 2009, Stark et al. 2009). The specimens are in the entomological collection of the Laboratory of Aquatic Organisms of the Universidade Estadual de Santa Cruz (LOA/UESC), under authorization number SISBIO (Sistema de Autorização e Informação em biodiversidade) 24195-1. For the analysis of the faunistic data, we calculated the measures of taxonomic richness (S), abundance and diversity by the Shannon-Wiener index (H ‘). Verification of the spatial independence of the samples was performed through the Mantel Test and a cluster analysis was performed using the Jaccard Similarity Index to order the spatio-temporal distribution of the collected insects (Mantel 1967; Magurran 1988).

During the collection period, limnological variables of temperature, electrical conductivity, hydrogen potential - pH, dissolved oxygen - DO, total dissolved solids - TDS and turbidity were measured *in situ* using a multi-parameter probe. Precipitation values were obtained from Instituto Nacional de Pesquisas Espaciais/ Programa de Monitoramento Climático em Tempo Real da Região Nordeste - PROCLIMA (CEPTEC/ INPE 2012) and flow data was provided by Agência Nacional de Águas (ANA 2012). Precipitation data were analyzed monthly for the collection period, while flow was analyzed for a historical series of thirty years (1982-2012), in addition to the variation for the collection year. Water quality classification was performed through the application of the Biological Monitoring Work Party Score System (BMWP) (Alba-Tercedor and Sánches-Ortega 1988; Junqueira et al. 2000), as well as the EPT Percentage (EPT%) (Gonçalves and Menezes 2011).

Results

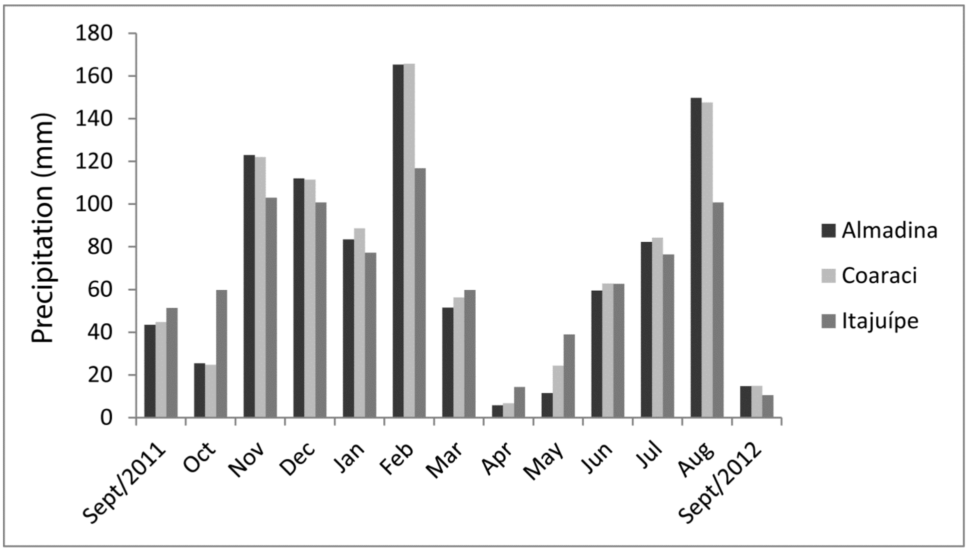
Limnological and climatological variables

Rainfalls was concentrated in February and August 2012, with maximum value of 165.7mm in February in the municipality of Coaraci (P4 and P5) (Table 1, Figure. 2). In the period of April and May 2012, mean rainfall was low, with a minimum of 5.81 mm in April 2012 for the municipality of Almadina (P1 and P2) (Table 1, Figure. 2).

Table 1. Limnological and climatological variables in the Almada River Basin, Bahia, Brazil. * collection 1 = December 2011; collection 2 = March 2012; collection 3 = June 2012; collection 4 = September 2012.

Variables								
Collection*	Sampling sites	Water temperature (ºC)	pH	DO (mg/L^{-1})	Electrical conductivity (µScm-1)	tds (mg/L^{-1})	Turbidity (NTU)	Precipitation
01	P1	24,01	8,08	2,80	695	354	3,4	111,94
01	P2	25,99	7,86	2,53	788	387	7,13	111,94
01	P3	24,97	7,47	4,00	120	60	2,24	111,43
01	P4	26,87	7,85	4,34	153	74	8,26	111,43
01	P5	28,4	8,27	4,07	109	52	3,93	100,77
01	P6	26,76	7,50	3,01	100	49	1,06	100,77
02	P1	26,37	8,39	-	1280	626	5,52	51,45
02	P2	25	7,56	-	1102	546	6,87	51,45
02	P3	23,7	7,45	-	100	49	1,89	56,31
02	P4	23,6	7,33	-	143	69	4,94	56,31
02	P5	25,4	7,56	-	100	47	1,89	59,84
02	P6	25,6	7,6	-	106	50	1,16	59,84
03	P1	22,1	7,93	5,17	1660	876	5,74	59,49
03	P2	21,2	7,50	2,20	1112	588	9,7	59,49
03	P3	22,6	7,0	5,65	73	38	2,87	62,74
03	P4	25	7,5	5,70	140	70	0,21	62,74
03	P5	25,8	6,98	8,70	101	50	0,23	62,6
03	P6	25	6,53	2,62	112	56	1,42	62,6
04	P1	24	6,95	4,45	1990	1027	10,03	14,82
04	P2	22,7	7,55	1,26	1045	537	52,86	14,82
04	P3	24,2	7,31	4,34	81	44	3,39	14,85
04	P4	28,2	7,13	5,60	125	60	5,02	14,85
04	P5	26,9	7,37	7,30	87	42	1,90	10,6
04	P6	27,5	6,90	2,09	109	52	1,55	10,6

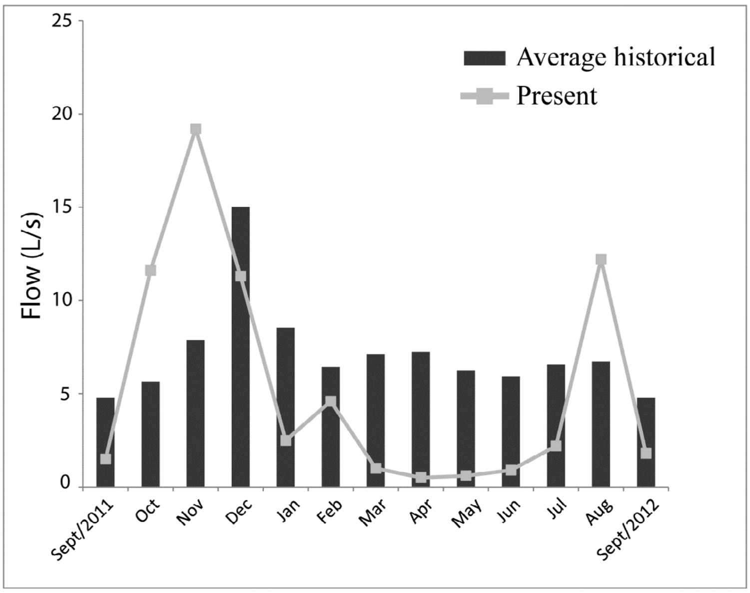
Figure 2. Monthly precipitation in the municipalities of Almadina, Coaraci and Itajuípe (Bahia, Brazil), from September 2011 to September 2012.



Source: CEPTEC/INPE 2012

In the months of November 2011 and August 2012 the river presented a higher volume of water and maximum flow occurred in November 2011, reaching 19.2 m3s-1. Between April and June 2012 flow values were reduced and collections were marked by dry weather characteristics, with some sites in non-flowing water with decomposing aquatic vegetation. The minimum flow rate was 0.5 m3.s-1 in April 2012. The relationship between historical flow and current flow revealed a decrease in values over the last 30 years, with drier periods and reduced flow in the months from March to July of 2012. This result, associated with the precipitation values, characterizes the last years as dry with highly reduced flow. The months of October and November 2011, as well as August 2012 are exceptions, since the values surpassed the historical average (Figure 3).

Figure 3. Mean of historical flow (1982-2012) and current flow (September 2011 to September 2012) of station 53050000, located in the municipality of Itajuípe (Bahia, Brazil).



Source: ANA / SNIRH 2012

The limnological variables presented variation regarding the sample sites (Table 1). Dissolved Oxygen presented the worst conditions with reduced values, characteristic of altered environments. The pH and turbidity remained within an acceptable range, both parameters being influenced by the macrophytic banks at sites 2, whereby macrophytes, besides being important acidic sources, make the penetration of rays of light difficult. The electrical conductivity, in turn, was intimately related to the values of total dissolved solids for all collection sites, as well as to the low rainfall indexes found near the source.

Aquatic insects

A total of 2,223 organisms were collected, these being distributed among eight orders and 32 families (Table 2). The Shannom index indicated P4 as having the lowest diversity (0.5). The lowest levels of taxonomic wealth were found in P4 (7 genera) and P6 (8 genera). Sites 1 and 5 presented the same wealth (16 genera) and the highest abundance among the other site sampled (Table 2).

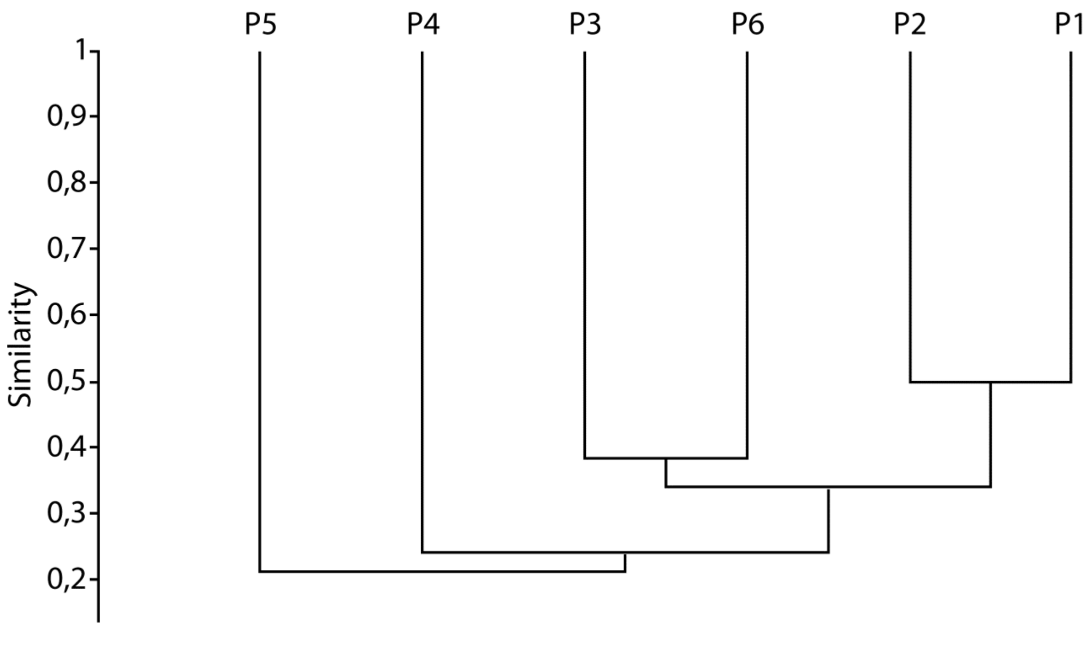
Table 2. List of taxa of aquatic insect in the Almada River Basin, collected between December 2011 and September 2012.

ORDER	FAMILY	P1	P2	P3	P4	P5	P6	TOTAL
Coleoptera	Dytiscidae	9	0	0	0	0	0	9
	Elmidae	1	1	0	0	4	0	6
	Hydrochidae	2	8	0	0	0	0	10
	Hydrophilidae	2	0	0	0	0	0	2
	Gyrinidae	1	0	0	0	0	0	1
	Noteridae	0	6	0	0	0	0	6
	Scirtidae	11	5	0	0	0	0	16
Diptera	Chironomidae	206	159	6	105	90	69	635
	Culicidae	6	36	1	0	0	2	45
	Simuliidae	233	0	1	0	216	2	452
Ephemeroptera	Baetidae	62	0	15	5	493	6	581
	Caenidae	99	0	0	0	0	1	100
	Leptohyphidae	0	0	7	0	10	0	17
	Leptophlebiidae	0	0	0	0	49	0	49
Hemiptera	Belostomatidae	5	21	1	0	0	0	27
	Gerridae	0	0	0	0	0	1	1
	Mesoveliidae	0	0	0	1	0	0	1
	Naucoridae	0	0	0	1	0	0	1
	Notonectidae	1	8	0	0	0	1	10
	Veliidae	0	0	1	0	1	0	2
Lepidoptera	Pyralidae	0	0	0	0	12	0	12
Megaloptera	Corydalidae	0	0	0	0	4	0	4

ORDER	FAMILY	P1	P2	P3	P4	P5	P6	TOTAL
Odonata	Calopterygidae	0	0	0	0	21	0	21
	Coenagrionidae	0	7	0	0	0	0	7
	Gomphidae	0	0	0	1	1	0	2
	Lestidae	3	5	5	1	0	0	14
	Libellulidae	4	4	1	4	6	12	31
Trichoptera	Hydropsychidae	14	0	0	0	162	0	176
	Hydroptilidae	0	0	0	0	1	0	1
	Leptoceridae	0	0	0	0	2	0	2
	Philopotamidae	0	0	0	0	1	0	1
	Polycentropodidae	0	0	1	0	0	0	1
ABUNDANCE		659	260	39	118	1073	94	2243
RICHNESS		16	11	10	7	16	8	
SHANNON		1,647	1,414	1,791	0,5143	1,594	0,9742	

The lowest abundance was found in the third collection campaign, in June 2012, a period considered dry, in which the water did not flow at some sampling sites. The highest values occurred in the first and fourth collection campaigns, which, in turn, presented higher values of precipitation and flow than the 3rd campaign. The Mantel test did not present significant results (r = -0.12 and p = 0.66), which indicates spatial independence between the sites. The cluster analysis using the similarity index (Jaccard) considered sites 1 and 2 to be more similar and site 5 the most dissimilar (Figure 4).

Figure 4. Dendogram of the cluster analysis of the sample sites through the similarity between the abundance of aquatic insects sampled between December 2011 and September 2012 in the Almada River Basin, Bahia, Brazil.



Biotic indexes

The results of the indexes indicated a classification tendency with variation between sites of doubtful quality to bad, which was determined by the presence and absence of organisms from different families influencing the classification based on the indices. The results demonstrate that sites 2, 4 and 6 already show signs of changes in water quality. It should be noted that site 5 presented the best classification for applied biotic indexes (Table 3).

Table 3. Score obtained by the BMWP (Biological Monitoring Working Party Score System) index and EPT% (EPT percentage) for the families of aquatic insects found in the Almada River Basin, Bahia, Brazil.

SAMPLING SITES	BMWP		EPT%	
	Score	Quality	Percentage of EPT	Quality
P1	75	Acceptable	33,65	Regular
P2	59	Doubtful	0	Bad
P3	60	Doubtful	58,97	Good
P4	39	Doubtful	4,23	Bad
P5	113	Good	66,91	Good
P6	30	Critical	7,44	Bad

Comparing the classifications of the sample sites through the indices, it can be seen that they did not show divergence for the different sites (Table 4). Site 3 is the exception as it diverged in the classification of the two indices.

Table 4. Comparison of the classifications obtained by the collection sites between the biotic indexes applied in the Almada River Basin, Bahia, Brazil (A = Good-Clean, B = Acceptable-Moderate, C = Doubtful, C / D = Doubtful to Bad, D = Critical-Severe).

SAMPLING SITES	BMWP	EPT
P1	B	B
P2	C	C/D
P3	C	A
P4	C	C/D
P5	A	A
P6	D	D

Discussion

The results of the analyses of limnological and biotic variables demonstrated strong anthropic interference at distinct locations of the basin, influencing the individual characteristics of the sampling sites. Regarding limnological variables, the significant increase in the conductivity value near the source of the Almada River is associated with the lithological and pedological characteristics of the region, as in the BHRA weathering of the rocks may reflect in the water chemistry, especially in the region of headwaters together with the type of soil, chromic luvisols, which are shallow and with high base saturation (Franco et al. 2012).

In turn dissolved oxygen presented low values and alterations for most of the sampling sites. This result draws attention to the reduced flow values in recent years and thus the influence of precipitation on river flow and water quality. The reduction of flow interferes with the velocity of the current and consequently the availability of dissolved oxygen, since constant flows cause turbulence and increase water oxygenation (Gullan and Cranston 2012). The decrease in dissolved oxygen may also be related to organic contamination suffered in the basin, since the cities located near the main riverbed lack adequate final disposal of domestic sewage and solid waste. For BHRA the loss of sanitary water quality in stretches located downstream of urban areas has already been diagnosed, and the release of domestic sewage considered a serious problem (Franco et al. 2015).

Although the municipalities of Bahia have an average of 54.1% of the population with access to sewage services, the municipalities of Almadina, Coaraci and Itajuípe have respectively 0.08%, 0.63% and 0.67% of their sewage managed properly. The three cities have averages above 99% with regard to the absence of collection and/or proper treatment (SNIS 2019). The greater number of inhabitants and the lack of urban infrastructure, which in turn generate a greater volume of sewage, are related to the decrease in the quality of the aquatic environment in watersheds located in the state of Bahia (Pessoa et al. 2018), which, consequently, influences the maintenance of aquatic biodiversity, as evidenced by the results of this study in relation to aquatic entomofauna.

The results of the biotic variable showed low diversity at the sample sites when compared to the percentage of aquatic insects found in tropical water environments, possibly due to local changes in the basin. The fauna composition showed a significant decrease in the taxonomic richness and abundance of aquatic insects as the sites approached places with greater human activity such as housing, waste disposal and agriculture. The aquatic organisms present different tolerances to the anthropic disturbances and thus different faunistic compositions occur in places with different impact intensities (Alba-Tercedor and Sánches-Ortega 1988; Sonoda 2011; Legendre and De Cáceres 2013; Saito et al. 2015). Studies indicate a negative influence of urbanization on fauna, which can be explained mainly by habitat loss and/or degradation (McKinney 2008). In the present study, Chironomidae are in abundance even in places of critical or doubtful quality. Changes resulting from urbanization may have influenced the predominance of this group, which are considered more tolerante and are usually very abundant in places with organic pollution (Goulart and Callisto 2003; Domínguez and Fernandéz 2009) thus, the homogenization of fauna occurs, as observed for some groups of insects in relation to the impacts of urbanization (Monteiro-Junior et al. 2014; Villalobos-Jiménez et al. 2016; Sganzerla et al. 2021).

The results obtained for P5 are noteworthy for being considered the best quality water. This sample site obtained the same classification as biotic indexes classified as good and from clean water. This positive result is also manifests in the limnological variables, since the dissolved oxygen value was the best among all the sampling sites. It is interesting to note that the site has undergone little urbanization and direct anthropogenic pressure is only found on a right bank of the river, in the other margin riparian forest still being present, which may have contributed to greater protection of the water body. Studies analyzing water quality in urbanized environments indicate greater impairment to water quality of the basins in relation to sites with better preservation of forest remnants, due to changes in land use (Coelho et al. 2011; Tulbure et al. 2014; Leal et al. 2016; Cerqueira et al. 2020).

Another contributing factor on this sampling site is the influence of microbasins from more preserved sites. Material transported from these microbasins may have influenced the diversity of the fauna and the presence of sensitive organisms.

Therefore, the present study confirms the importance of riparian forests for the maintenance of aquatic communities, given that, despite the imposed impacts, a site situated after the cities presented the highest quality, reinforcing the importance of the maintenance of riparian forest to provide a variety of habitats and allow the dispersion of organisms (Tonkin et al. 2016; Nava-Lopez et al. 2016; Krynak et al. 2019). Similar results from applied indexes (BMWP and EPT%) emphasize the quality of the research results and the applicability of aquatic insects as bioindicator organisms and an important source of information on water quality. The divergence between the indexes, albeit subtle, is probably the result of the absence of more refined taxonomic levels used by biotic indexes, or may even be due to results camouflaged by species that are considered generalist but which, nonetheless, present median values in these indexes. It is believed that the EPT% index may have been influenced by Baetidae (Insecta: Ephemeroptera), which is considered cosmopolitan and abundant with a wide distribution across almost the entire planet and in distinct environments within the rivers (Domínguez and Fernandez 2009). This reality draws attention to the need for entomofaunistic surveys in different countries and the development or improvement of biotic indexes for specific regions and biomes, as well as the integration of taxonomy with ecological studies and conservation programs. It is important to include sensitive groups of local fauna to improve the indexes and to expand research that considers watercourses with different anthropic impacts.

Finally, the data presented demonstrated the importance of aquatic insects as indicator organisms and show the need for efficient strategies with regard to minimizing the impacts by urbanization and, especially recovery and preservation of riparian forests as well as adequate final treatment for sewage and solid materials in urban areas within the river basin. It is necessary to implement a permanent monitoring program in this important basin, located in one of the most threatened biomes in the world, considering that the result of this study reveals a significant de structuring of its natural environment and its consequences on water quality and faunistic composition. In addition, the maintenance of riparian vegetation and planned urbanization can contribute to the reduction of another problem that affects the sampling points of the BHRA, which is the infestation of aquatic macrophytes that is related to sewage discharges and increased nutrients in the water and it can also affect aquatic biodiversity (Dodds and Smith 2016; Santana et al. 2016).

Conclusion

The present study demonstrated the negative effect of the presence of cities along the course of the river, by comparing the diversity of aquatic insects before and after these cities. On the other hand, it also demonstrated the absence of a decreasing gradient of quality along the basin, suggesting the capacity for depuration and influence of local factors. The main river suffered changes in water quality at the sites after the cities, thus demonstrating the effect of urbanization on the aquatic environment and its diversity. It was observed that the highest quality site, despite being located downstream of the urban centers, was differentiated due to the presence of less disturbed native vegetation. It is concluded that despite the effect of cities on the main river, forested environments can maintain a better balance of biotic and abiotic variables, which draws attention to the importance of maintaining riparian forests, especially in urbanized environments.

Treatment of domestic sewage from the municipalities inserted along the main courses of the rivers, as well as those located on its banks is also considered important. Finally, it is understood that although the management of the river basins as a whole is ideal to guarantee the quality of water bodies, actions in the municipal spheres that consider the sewage system and changes in land cover of the surroundings of aquatic environments are also of relevant importance.

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Authors' contributions: all authors have been personally and actively involved on the design of the work, analysis, and inter pretation of the data and on the preparation of the manuscript.

Compliance with ethical standards: authorization number SISBIO (Sistema de Autorização e Informação em biodiversidade) 24195-1

Data availability: available in the collection of the Laboratório de Organismos Aquáticos / Universidade Estadual de Santa Cruz.

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