Revista **U.D.C.A** Actualidad & Divulgación Científica
January-June 2024-Volume 27 No. 1:e2409
ISSN: 2619-2551 en línea
ISSN: 0123-4226 impreso

Check for updates

Scientific Article
http://doi.org/10.31910/rudca.v27.n1.2024.2409

Aquatic insects associated with macrophytes in wetlands of the middle basin of Atrato River, Chocó - Colombia

Insectos acuáticos asociados a macrófitas en ciénagas de la cuenca media del Río Atrato, Chocó - Colombia

Zuleyma Mosquera-Murillo[1]*; Karen Everni Córdoba-Aragón[1]; Mairin Minerva Mosquera-Mosquera[2]; Sandra Patricia Sanchez[3]; Leider Palacios-Palacios[1]

[1]Universidad Tecnológica del Chocó, Programa de Biología. Quibdó, Chocó-Colombia. e-mail: d-zuleyma.mosquera@utch.edu.co; d-karene@utch.edu.co; leider.palaciosp@utch.edu.co
[2]Universidad Tecnológica del Chocó, Grupo de Limnología. Quibdó, Chocó-Colombia. e-mail: mairynmosquera@hotmail.com
[3]Universidad Tecnológica del Chocó, Programa de Ingeniera Ambiental. Quibdó, Chocó, Colombia. e-mail: sandrapatricia0202@gmail.com
*Corresponding author: d-zuleyma.mosquera@utch.edu.co

How to cite: Mosquera-Murillo, Z.; Córdoba-Aragón, K.E.; Mosquera-Mosquera, M.M.; Sanchez, S.P.; Palacios-Palacios, L. 2024. Aquatic insects associated with macrophytes in wetlands of the middle basin of Atrato River, Chocó – Colombia. Rev. U.D.C.A Act. & Div. Cient. 27(1):e2409. http://doi.org/10.31910/rudca.v27.n1.2024.2409

Open access article published by Revista U.D.C.A Actualidad & Divulgación Científica, under a Creative Commons CC BY-NC 4.0 License.

Official publication of the Universidad de Ciencias Aplicadas y Ambientales U.D.C.A, a Higher Education Institution Accredited of High-Quality by the Ministry of National Education of Colombia.

Received: April 25, 2023 **Accepted:** May 10, 2024 **Edited by:** Helber Adrián Arévalo Maldonado

ABSTRACT

Aquatic macrophytes play an important role in lentic systems, since they constitute the particular habitat of several groups of aquatic insects and play a fundamental role in structuring their communities. The objective of this study was to contribute to the knowledge of the aquatic entomofauna associated with macrophytes in wetlands of the middle basin of the Atrato River, Chocó-Colombia. For four months, collections of aquatic insects associated with the roots of different aquatic plants were made, using a quadrat of one m^2, equipped with a 0.5 mm mesh, with three replicates per swamp. Simultaneously, some physical and chemical variables of the water were measured. The community of aquatic insects was composed of 6 orders, 23 families, and 36 genera. The most representative orders were Hemiptera (Heteroptera) and Odonata and the most abundant families were Noteridae (Coleoptera) and Libellulidae (Odonata). The diversity index presented a range between 2.39 and 2.07 bits/ind, with Plaza Seca as the most representative wetlands, while the dominance was between 0.16 and 0.11. The most abundant functional group was that of predators. The variables pH, water temperature and transparency presented significant differences between swamps and there were important associations between the aquatic entomofauna, and the abiotic variables analyzed.

Keywords: Aquatic ecosystems; Aquatic entomofauna; Aquatic plants; Functional diversity; Insect assemblages.

RESUMEN

Las macrófitas acuáticas juegan un rol importante en los sistemas lénticos, ya que constituyen el hábitat particular de varios grupos de insectos acuáticos y desempeñan un papel fundamental en la estructuración de sus comunidades. El objetivo de este estudio fue contribuir al conocimiento de la entomofauna acuática asociada las macrófitas en ciénagas de la cuenca media del Río Atrato, Chocó-Colombia. Durante cuatro meses se hicieron colectas de insectos acuáticos asociados a las raíces de diferentes plantas acuáticas, utilizando un cuadrante de un m^2, dotado de una malla de 0,5 mm, con tres replicas por ciénaga. Simultáneamente se midieron algunas variables físicas y químicas del agua. La comunidad de insectos acuáticos estuvo compuesta por 6 órdenes, 23 familias y 36 géneros. Los órdenes más representativos fueron Hemiptera (Heteroptera) y Odonata y las familias más abundantes fueron Noteridae (Coleoptera) y Libellulidae (Odonata). El índice de diversidad presentó un rango de entre 2,39 y 2,07 bits/ind, sobresaliendo la ciénaga Plaza Seca, mientras que la dominancia estuvo entre 0,16 y 0,11. El grupo funcional de mayor abundancia fue el de los predadores. Las variables pH, temperatura del agua y transparencia presentaron diferencias significativas entre ciénagas y existieron importantes asociaciones entre la entomofauna acuática y las variables abióticas analizadas.

Palabras clave: Diversidad funcional; Ecosistemas acuáticos; Entomofauna acuática; Ensamblajes de insectos; Plantas acuáticas.

INTRODUCTION

Macrophytes exhibit macroscopic forms of aquatic vegetation and serve as a link between water and sediment. Angiosperms, ferns, macroalgae and mosses found in both lotic and lentic aquatic ecosystems belong to this group (Regmi *et al*. 2021). They also act as indicators of the ecological conditions of surface waters, since they are primary producers of aquatic habitats, which serve as an important component in the functioning of the ecosystem, from the maintenance of biotic and abiotic factors (Upadhyay *et al.* 2022).

Macrophytes play an important role in structuring aquatic environments, especially those of lentic type, since their presence in these ecosystems increases the complexity of the habitat, significantly influencing aspects such as diversity, distribution, richness, and abundance of the aquatic macroinvertebrates (Heisi *et al.* 2023). These plants increase the structural heterogeneity of macroinvertebrates by providing refuges against predators (Misteli *et al.* 2022), offering food for herbivores and detritivores, (Fontanarrosa *et al.* 2013) and providing spaces that facilitate emergence and oviposition (Walker *et al.* 2013).

Within macroinvertebrates, aquatic insects are distinguished by presenting a high number of organisms that make up the most significant component of animal biomass in lotic and lentic ecosystems. Their contribution to the food web is relevant, because they allow energy circulation to other consumers, serving as food for fish and amphibians and becoming an important link between producers and the higher trophic levels of aquatic ecosystems (Walteros & Castaño, 2020).

In Colombia, a series of investigations have been conducted on aquatic macroinvertebrates associated with macrophytes and the most recent to be highlighted are those conducted by Rúa-García (2015), Hernández *et al.* (2016), Murillo-Montoya *et al.* (2018), and Núñez & Fragoso-Castilla, (2019). In the department of Chocó, on the topic of aquatic macroinvertebrates associated with macrophytes in wetland ecosystems, the research conducted by Mosquera-Murillo & Córdoba-Argón (2015); Mosquera-Murillo (2018), and Aguilar-Baldosea *et al.* (2022) is notable. However, further research is needed to continue contributing to the understanding of the dynamics of these communities.

Therefore, the objective of this research is to determine the composition, diversity, and abundance of aquatic entomofauna associated with macrophytes in wetlands of the middle basin of Atrato River (Chocó-Colombia), as well as to identify the functional groups of insects associated with macrophytes, in addition to establishing the possible relationship between them and the abiotic variables of the wetlands studied.

MATERIALS AND METHODS

Scope of study. The research was carried out in three wetlands in the middle basin of Atrato River, belonging to the municipality of Quibdó, Chocó-Colombia: Plaza Seca wetland 5°44’32.3”N 76°42’37.7”W, La Negra wetland 5°45›30.9»N, 76°41’14.7”W, and La Grande wetland 5°44›39.8»N, 76°42’42.1”W (Figure 1). This zone experiences a relative humidity close to 86% and temperatures that range between 28-32°C. The majority of the territory lies within the equatorial doldrums; therefore, rainfall regime extends throughout the year, with an annual precipitation reaching up to 12,000 mm (Rangel-Ch. & Arellano-P., 2004).

According to the Holdridge system (1996), the Atrato River basin in its course is classified into the humid tropical forest and too humid tropical forest life zones (bh-T, bmh-T). The middle and lower zones comprise the floodplain of Atrato River, characterized by vast floodplains and several swamps known for their high transparency, acidic pH, low conductivity, and concentration of solids, as well as low oxygen and few nutrients (Correa, 2014). The dominant macrophyte species in the studied wetlands are *Eichhornia azurea, Nymphoides indica, Ludwigia sedoides, Cabomba sp., Elodea sp.* (Mosquera & Córdoba, 2015).

Sampling. Monthly sampling was conducted in each of the studied wetlands, between June and September 2022, covering the climatic periods of the zone, the high water season (June-July) and the low water season (August-September).

In each studied wetland, a sampling station was established (coastal zone). Within the macrophyte-covered area, the physical and chemical water conditions were measured, such as water temperature, pH, electrical conductivity and dissolved oxygen concentration, total dissolved solids, and transparency using a multiparameter digital equipment and a Secchi disk. Additionally, water samples were collected for alkalinity, phosphorus, and nitrogen form analyses, following the recommendations of Standard Methods (APHA *et al.* 2012). Likewise, the forms of phosphorus (orthophosphates) and nitrogen (nitrites, nitrates, and ammonium) were analyzed using a NOVA SQ 60 spectrophotometer.

To collect insects, transepts perpendicular to the shoreline were established in the macrophyte belts. A one m^2 floating PVC frame, equipped with a 0.5 mm mesh was used, which was installed under the surface to be collected. Plants were extracted and the roots were carefully washed to remove the organisms. Using a sieve and tweezers, the organisms were extracted and stored in jars with 90% alcohol.

In the limnology laboratory of the Universidad Tecnológica del Chocó (UTCH), organisms were identified to the lowest possible level using a ZEIZZ brand stereomicroscope and the keys from Domínguez *et al.* (2006) and Domínguez & Fernández (2009). Additionally, each taxon was assigned to a functional group according to the classification proposed by various authors such as Chará-Serna *et al.* (2010), Rodríguez-Barrios *et al*. (2011), and Rivera-Usme *et al.* (2013). The considered groups were predators, collectors, collector-gatherers, collector-filterers, and shredders (Merrit & Cummins, 1996).

Data analysis. The aquatic insect assemblage was characterized based on the following variables: total number of individuals, relative abundance, Shannon-Wiener diversity, Simpson dominance, and classification of food functional groups. Differences in abundance, diversity, and dominance among wetlands were assessed using an ANOVA test. Mean and standard deviation were estimated for each measured abiotic variables, and differences among wetlands were evaluated using ANOVA. Assumptions inherent to the ANOVA test were verified for all cases and found acceptable ($p>0.05$). Significant differences were recorded using a Tukey test and the Minitab program was used. Finally, the potential relationship between aquatic insects and the abiotic variables of the wetlands was evaluated using a canonical correspondence analysis.

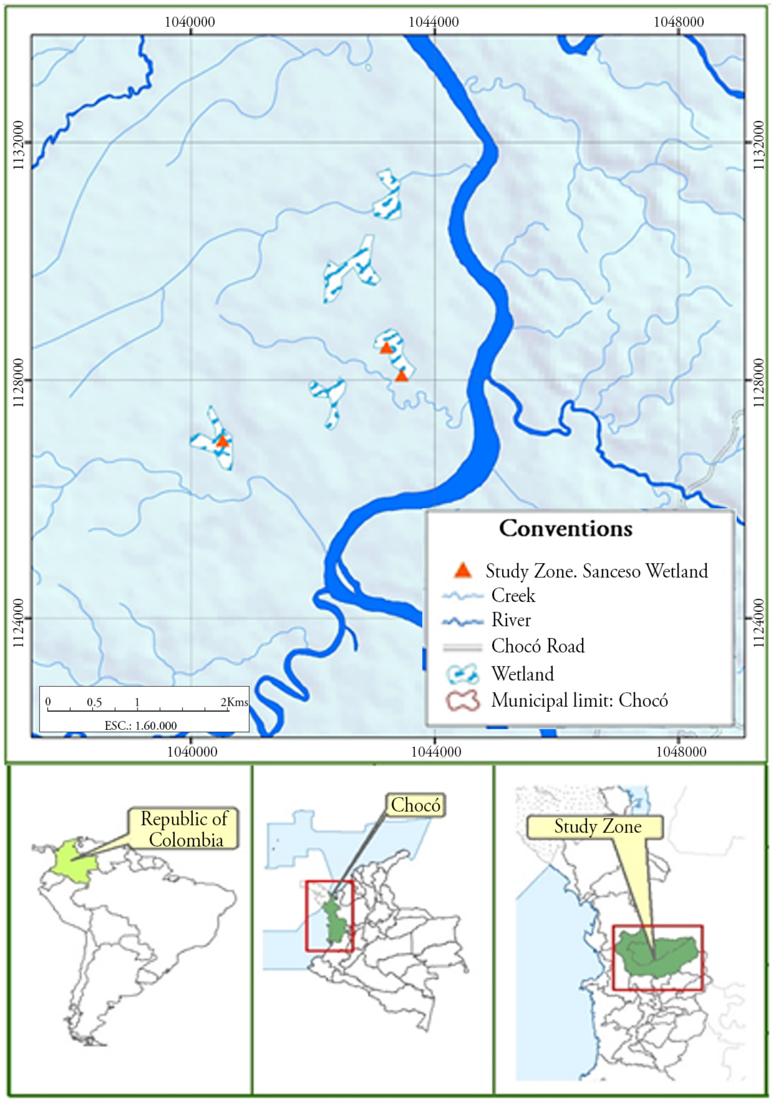

Figure 1. Study zone. Wetlands studied in the middle basin of Atrato River (Chocó-Colombia).

RESULTS AND DISCUSSION

Aquatic insects associated with macrophytes. A total of 654 individuals were registered, distributed in 6 orders, 23 families and 36 genera (Table 1). Plaza Seca wetland had the highest number of individuals (315), followed by La Grande wetland (183), and La Negra wetland (156). The variance test showed significant differences between the wetlands with respect to the abundance of aquatic insects.

The presence of aquatic insects associated with floating aquatic macrophytes is associated with the presence of a dense mass of plant roots that constitute colonization sites for different organisms. Root macrophytes provide microhabitats that serve as refuge against predators and for egg-laying, as well as resources as food for fauna (Padial *et al.* 2009).

Regarding orders, Hemiptera is the most representative in Plaza Seca and La Negra wetlands, while Odonata was the most representative in La Grande wetland (Figure 2). Among the families, Noteridae (16.32 ± 5.81) and Libellulidae (11.24 ± 4.75) were notable. According to Lasso *et al.* (2014), it is common to find a high representativeness of Odonata-Coleoptera-Hemiptera in lentic ecosystems of the country, as observed in this research. Aquatic and semi-aquatic hemipterans are notable for their variety, reflecting the variety of niches they occupy, thanks to the great adaptation capacity to the environment their species have (Vanegas, 2017). This can be found in a wide variety of natural environments, both lotic and lentic, coastal and oceanic, phytotelmata and even humid terrestrial environments (Mazzucconi *et al.* 2009).

As for odonates, their abundance has been positively related to the presence of aquatic plants typical of wetlands since emerging vegetation is a fundamental substrate for the emergence of larvae into their adult phase. Likewise, a high macrophyte coverage is important for the richness of Odonata taxa (Perron *et al.* 2021). In addition to the existence of aquatic plants, physicochemical characteristics are important factors that limit the richness and distribution of immature odonates (Córdoba-Aguilar, 2008).

The abundance of Noteridae and Libellulidae in this study corresponds to other research carried out in wetlands of the region, such as the one conducted by Mosquera-Murillo & Córdoba-Argón (2015). According to White & Roughley (2008), members of the family Noteridae are common into the roots of aquatic plants and their ability to take atmospheric oxygen makes them dependent on atmospheric oxygen. This is a primary factor that restricts these beetles to shallow waters (Eyre *et al.* 1992), which agrees with the characteristics of the studied wetlands.

For the Libellulidae, its abundance is associated with the great diversity of emerging rooted macrophytes present in the studied wetlands, which, according to López-Díaz *et al.* (2021), is a factor that can increase the complexity of the habitat. Nymphs of Libellulidae inhabit all freshwater aquatic environments, including lentic and lotic systems, as well as permanent and temporary environments (Neiss *et al.* 2018).

Plaza Seca wetland has the highest averages of diversity and specific richness, while dominance showed higher averages in La Negra wetland (Table 1). The analysis of variance shows that there were no significant differences in diversity ($F=1.84$, $p=0.2135$) and dominance ($F=2.23$; $p=0.1635$) among wetlands, but there were differences in specific richness ($F=7.24$; $p=0.0133$). These results may be associated with how aquatic vegetation is distributed in the wetlands under study and, in that sense, research such as that of Warfe *et al.* (2008) and Dibble & Thomaz, (2009) has shown that the complexity of this type of vegetation explains attributes of the invertebrate assemblages associated with it, such as abundance and diversity. Similarly, according to authors such as Quirós Rodríguez *et al.* (2010) and Kovalenko *et al.* (2012), the presence of floating vegetation, as well as the complexity of its architecture, provides a greater variety of environments and microhabitats that constitute a substrate and refuge, leading to greater diversity, richness, and abundance of associated organisms.

In relation to the composition of functional groups of aquatic insects associated with macrophytes, in the three studied wetlands, predators were the largest group with a range among wetlands between 87.94 and 73.77%, with 15 families corresponding to Odonata, Hemiptera and Coleoptera, and certain families of Diptera (Chaoboridae and Ceratopogonidae). They are followed by collector-gatherers with a range between 11.48 and 4.76%, represented by 3 families of Ephemeroptera. Collectors showed a range between 10.38 and 1.28% with two families of Lepidoptera and Diptera (Chironomidae). Collectors-filters had a range between 8.97 and 4.37%, with a family of Diptera (Culicidae) (Table 1).

The greater representativeness of predators may be related to the high structural complexity of the habitat generated by macrophytes (Heino, 2000), which is an indicator of an abundant food supply. Particularly, aquatic vegetation constitutes a refuge zone for invertebrates to avoid predation by fish, therefore representing an important supply for predatory invertebrates whose number can increase when there is more prey (De Neiff & Neiff, 2006).

Environmental conditions of macrophyte habitat and aquatic insect community. Regarding the abiotic variables analyzed in the three studied wetlands, pH, water temperature, and transparency showed significant differences among wetlands (ANOVA, $p<0,05$), with pH and transparency presenting their highest averages in Plaza Seca wetland, and water temperature in La Grande wetland. The remaining variables did not have significant differences (ANOVA, $p>0.05$) (Table 2); however, dissolved oxygen, alkalinity, electrical conductivity, and total solids were higher in La Grande wetland. As for nutrients, these tend to be higher in La Grande (Nitrites), Plaza Seca (Nitrates) and La Negra (Orthophosphates) wetlands. Ammonium was not detectable. Depth was greater in La Negra wetland.

Dissolved oxygen and pH variables had values similar to those reported for other wetlands in the Atrato basin, such as the studies conducted by Mosquera-Murillo & Córdoba-Argón (2015) and Mosquera-Murillo (2020). According to Martínez-Rodríguez & Pinilla-A. (2014), one of the wetland characteristics is oxygen deficiency, as a result of slow exchange with air since water turbulence is less than that of a river. As for pH, the recorded values are largely attributable to the nature of the soils in the zone, which are acidic like those of the majority in the department of Chocó, being within the limits for the survival of aquatic organisms that is between 4.5 to 8.5 (Roldán & Ramírez, 2008). Water temperature averages, in turn, are typical of aquatic environments located in tropical regions, with values between 25 and 30°C (Roldán & Ramírez, 2008).

Electrical conductivity, alkalinity and total dissolved solids variables were within the ranges established for Colombian neotropical ecosystems, with values less than 1,500 $\mu S.cm^{-1}$, 100 $mg.L^{-1}$ and 200 $mg.L^{-1}$, respectively (Roldán & Ramírez, 2008). Transparency is within the values established for wetlands in Colombia (<1.13 m), while depth is associated with variations in the flow of Atrato River, as a result of the climatic regime of the zone.

Table 1. Taxonomic list and ecological indexes of aquatic insects associated with macrophytes in three wetlands in the middle basin of Río Atrato, Chocó (Chará-Serna *et al.* 2010; Rodríguez-Barrios *et al.* 2011; Rivera-Usme *et al.* 2013).

Order/Family	Genus	Wetlands			Total abundance	Relative abundance	Functional group
		La Grande	Plaza Seca	La Negra			
Odonata							
Coenagrionide	*Acanthagrion*	5	5	3	13	1.99	Pre
	Telebasis	9	8	5	22	3.36	Pre
	Ischnura		5	0	5	0.76	Pre
	Argia	3	0	0	3	0.46	Pre
Libellulidae	*Macrothemis*	11	8	2	21	3.21	Pre
	Tramea	14	37	7	58	8.87	Pre
Aeschnidae	*Aeschna*	2	0	0	2	0.31	Pre
	Coryphaeschna	1	0	0	1	0.15	Pre
	Boyeria	5	1	0	6	0.92	Pre
Proteneuridae	*Protoneura*	8	20	1	29	4.43	Pre
Coleoptera							
Noteridae	*Hydrocanthus*	36	62	15	113	17.28	Pre
Dytiscidae	*Laccophylus*	16	10	11	37	5.06	Pre
Ephemeroptera							
Baetidae	*Callibaetis*	4	8	4	16	2.45	CG
	Americabaetis		1	0	1	0.15	CG
	Cloeodes	1	2	0	3	0.46	CG
Caenidae	*Caenis*	12	4	9	25	3.82	CG
Leptohyphidae	*Leptohyphodes*	4	0	0	4	0.61	CG
Hemiptera							
Notonectidae	*Notonecta*	4	0	0	4	0.61	Pre
Corixidae	*Tenagobia*	7	14	11	32	4.89	Pre
Gerridae	*Telmatometra*		3	12	15	2.29	Pre
	Rheumatobates		48	11	59	9.02	Pre
Hydrometridae	*Hydrometra*		1	0	1	0.15	Pre
Naucoridae	*Ambrysus*		0	9	9	1.38	Pre
	Pelocoris		4	0	4	0.61	Pre
Hebridae	*Hebrus*		8	0	8	1.22	Pre
Mesoveliidae	*Mesovelia*		5	5	10	1.53	Pre
Belosomatidae	*Belostoma*	1	5	3	9	1.38	Pre
Pleidae	*Neoplea*	10	9	3	22	3.36	Pre
Diptera							
Chiromomidae	*Ablabezmyia*	11	8	2	21	3.21	CL
	Chironomus	4	1	0	5	0.76	CL
	Pentaneura	3	0	0	3	0.46	CL
Chaoboridae	*Chaoborus*		0	11	11	1.69	Pre
Ceratopogo-nidae	*Bezzia*	3	24	18	45	6.88	Pre
Culicidae	*Culex*	2	0	0	2	0.31	CF
	Culiseta	6	14	14	34	5.20	CF
Lepidoptera							
Crambridae	*Petrophila*	1			1	0.15	CL
Diversity		2.26 ± 0.145	2.39 ± 0.097	2.07 ± 0.373			
Specific Richness		13 ± 3.697	15 ± 2.63	11 ± 4.031			
Dominance		0.13 ± 0.012	0.11 ± 0.017	0.16 ± 0.056			

Pre= Predator; CG=Collector-Gatherer; CF= Collector-Filterer; CL= Collector

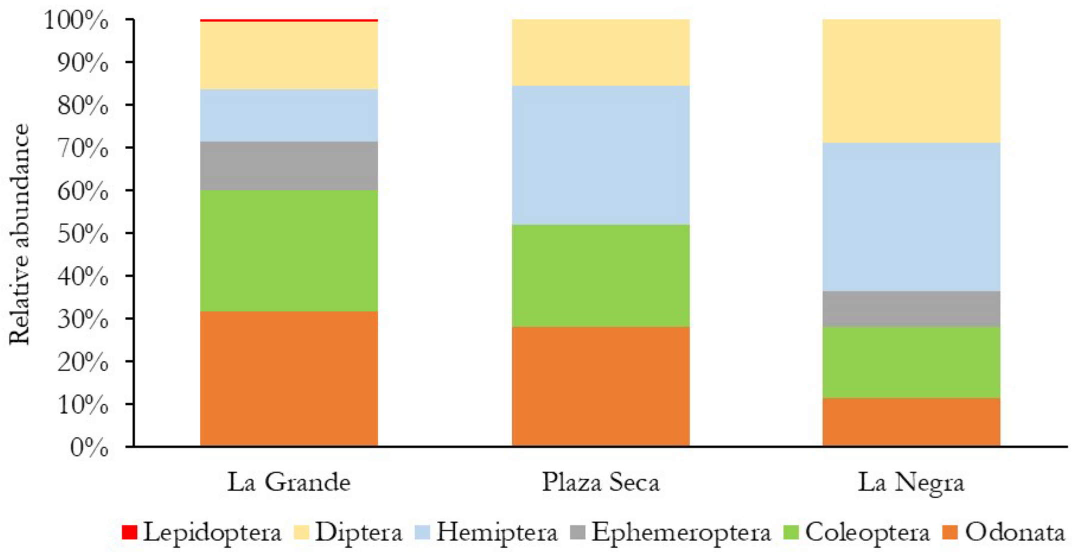

Figure 2. Abundance of specimens of insect orders found in the studied wetlands in the middle part of Atrato River.

Table 2. Abiotic variables of the studied wetlands in the middle part of Atrato River.

Abiotic Variables	**Wetlands**			**p-Value**
	La Grande	**Plaza Seca**	**La Negra**	
Dissolved Oxygen (mg/L)	6.18 ± 0.85	5.93 ± 0.23	5.59 ± 0.84	0.5063
pH (units)	5.53 ± 0.38	6.26 ± 0.32	5.61 ± 0.39	0.0371
Water Temperature (°C)	28.88 ± 0.71	27.26 ± 0.79	28.21 ± 0.93	0.0498
Alkalinity (mg/L)	34.24 ± 27.63	22.22 ± 22.24	24.88 ± 24.90	0.7812
Electrical Conductivity (µS/cm)	196.67 ± 26.35	167.93 ± 37.78	147.66 ± 49,25	0.254
Total dissolved solids (mg/L)	147.28 ± 83.24	85.11 ± 15.78	115.87 ± 17.18	0.2636
Nitrites (mg/L)	0.089 ± 0.05	0.0705 ± 0.04	0.0839 ± 0.05	0.8466
Nitrates (mg/L)	0.648 ± 0.41	0.752 ± 0.44	0.688 ± 0.63	0.9444
Ammonium (mg/L)	<0,010	<0,010	<0,010	
Orthophosphate (mg/L)	0.102 ± 0.15	0.070 ± 0.06	0.117 ± 0.45	0.3598
Transparency (m)	0.45 ± 0.19	0.85 ± 0.09	0.84 ± 0.17	0.0073
Depth (m)	1.392 ± 0.35	1.933 ± 0.43	2.389 ± 0.82	0.0992

Average values ± standard deviation

Nitrites were found in low concentrations in the studied wetlands in comparison to nitrates. According to Wetzel (2001), nitrogen as nitrites tends to be low in aquatic systems, since it quickly changes to nitrates depending on the oxygen concentration in water, or to reduced forms such as ammonium if the conditions are anoxia, a situation that may be occurring in the studied wetlands. As for ammonium, the values were extremely low and were below the detection range. Orthophosphates, in turn, had averages above 0.05 $mg.L^{-1}$, which is the limit required for aquatic life.

According to the canonical correspondence analysis, the first two canonical axes explain 68.32% of the variance. The analysis demonstrates that organisms of the Protoneuridae, Pleidae, Chironomidae and Culicidae showed a positive relationship with electrical conductivity, nitrites, and nitrates and a negative relationship with transparency. Corixidae, Gerridae, and Ceratopogonidae were negatively related to electrical conductivity, nitrites, and nitrates and positively to transparency. Caenidae and Culicidae were positively associated with phosphates and depth, while Dytiscidae showed an opposite relationship (Figure 3).

The association shown between the aquatic insect community and the physicochemical conditions of the aquatic ecosystem has been highlighted in research such as that of Rocha-Ramírez *et al.* (2007) and Rúa-García (2015); which ratifies the close correlation between organisms and environmental factors. In this sense, physicochemical factors are considered by various authors, such as Domínguez (2009), as the aspects that have the most influence on the distribution, abundance, and richness of aquatic insects. For Salles & Ferreira-Júnior (2014), physicochemical variations along with other characteristics, such as the substrate, are determining factors that influence the adaptation of organisms. Thus, some aquatic insect groups show morphological adaptations in the shape and structure of their gills, in response to changes in water temperature and oxygen availability (Barbour *et al.* 1999), changes in pH can influence physiology and development of some insects, with morphological variations in response to the water acidity (Allan, 2004), and turbidity can affect eye morphology and sensory structures (Merritt *et al.* 2008).

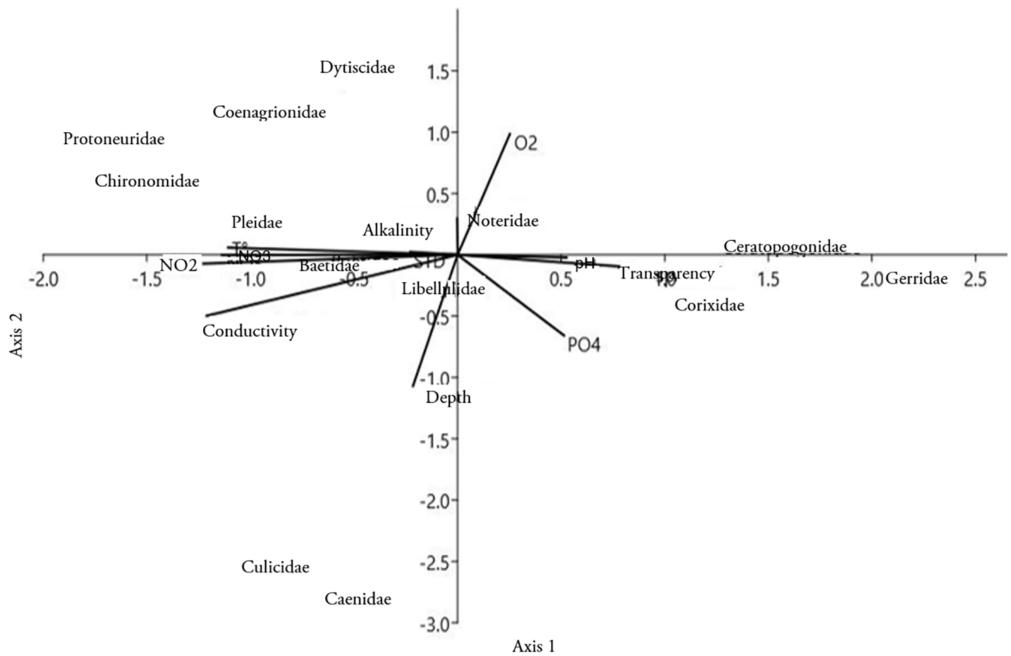

Figure 3. Canonical Correspondence Analysis (CCA) showing the relationship between the aquatic insect taxa of the studied wetlands and the abiotic variables analyzed.

Acknowledgments. The authors thank the Vice Rectorate of Research of the Universidad Tecnológica del Chocó for the financial support provided for conducting this research, as well as its Limnology Laboratory for providing the field and laboratory infrastructure for the study development. Additionally, the authors thank to Fondo Nacional de Financiamiento para la Ciencia, Tecnología y la Innovación Francisco José de Caldas for the financial support for the translation of this article through the project "Propuesta fortalecimiento gestión editorial de revistas científicas de la Universidad de Ciencias Aplicadas U.D.C.A 2023-2024". Conflicts of interest: The manuscript was prepared and revised with the participation of all authors, who declare that there is no conflict of interest that would jeopardize the validity of the results presented. Authors' contribution: Zuleyma Mosquera-Murillo, Karen E. Córdoba, Mairin M. Mosquera and Sandra P. Sánchez: conceptualization, research, formal analysis, and writing; Leider Palacios: conceptualization and formal analysis . Universidad Tecnológica del Chocó: Resources.

REFERENCES

AGUILAR-BALDOSEA, W.; LÓPEZ-RAMÍREZ, I.C.; CHÁVEZ-MOSQUERA, L. Y.; RENGIFO MURILLO, L.; HALABY-GUERRERO, J.C. 2022. Efecto de la minería en macroinvertebrados acuáticos de la ciénaga plaza seca, Atrato, Chocó. Revista Politécnica. 18(35):9-23. https://doi.org/10.33571/rpolitec.v18n35a1

ALLAN, J.D. 2004. Landscapes and riverscapes: The influence of land use on stream ecosystems. Annual Review of Ecology, Evolution, And Systematics 35:257-284. https://doi.org/10.1146/annurev.ecolsys.35.120202.110122

AMERICAN PUBLIC HEALTH ASSOCIATION-APHA; AMERICAN WATER WORKS ASSOCIATION-AWWA; WATER ENVIRONMENT FEDERATION-WEF. 2012. Standard methods for the examination of water and wastewater. 22nd Edition. American Public Health Association. Washington, USA. 1360p.

BARBOUR, M.T.; GERRITSEN, J.; SNYDER, B.D.; STRIBLING, J.B. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish. 2nd Edition. U.S. Environmental Protection Agency, Office of Water, EPA. Washington, D.C.

CHARÁ-SERNA, A.M.; CHARÁ, J.D.; ZÚÑIGA, M. DEL C.; PEDRAZA, G.X.; GIRALDO, L.P. 2010. Clasificación trófica de insectos acuáticos ecorregión cafetera colombiana. Universitas Scientiarum. 15(1):27-36.

CÓRDOBA-AGUILAR, A. 2008. Dragonflies y damselflies: Model organisms for ecological and evolutionary research. Oxford University Press. USA. 303p.

CORREA, J.D. 2014. Calidad del agua en humedales del plano de inundación del Río Atrato. Revista Ciencias Ambientales y Sostenibilidad CAS. 1(1):93-109.

DE NEIFF, A.P.; NEIFF, J.J. 2006. Riqueza de especies y similaridad de los invertebrados que viven en plantas flotantes de la planicie de inundación del Río Paraná (Argentina). Interciencia. 31(3):220-225.

DIBBLE, E.D.; THOMAZ, S.M. 2009. Use of fractal dimension to assess habitat complexity and its influence on dominant invertebrates inhabiting tropical and temperate macrophytes. Journal of Freshwater Ecology. 24(1):93-102. https://doi.org/10.1080/02705060.2009.9664269

DOMÍNGUEZ, E.; MOLINERI, C.; PESCADOR, M.I.; HUBBARD, M.D.; NIETO, C. 2006. Ephemeroptera of South América. En: Adis, J.; Arias J.R.; Rueda-Delgado, G.; Wantzen, K.M. (eds). Aquatic Biodiversity en Latin América (ABLA), Sofia-Moscow Pensoft, 2. Moscu. p.1-646.

DOMÍNGUEZ, E.; FERNÁNDEZ, H.R. 2009. Macroinvertebrados bentónicos sudamericanos. Sistemática y biología. Fundación Miguel Lillo. Argentina. 656p.

EYRE, M.D.; CARR, R.; MCBLANE, R.P.; FOSTER, G.N. 1992. The effect of varying site-water duration on the distribution of water beetle assemblages, adults and Larvae (Coleoptera: Haliplidae, Dytiscidae, Hydrophilidae). Archiv für Hydrobiologie. 124:281-191. https://doi.org/10.1127/archiv-hydrobiol/124/1992/281

FONTANARROSA, M.S.; CHAPARRO, G.N.; O'FARRELL, I. 2013. Temporal and spatial patterns of macroinvertebrates associated with small and medium-sized free-floating plants. Wetlands. 33:47-63. https://doi.org/10.1007/s13157-012-0351-3

HEINO, J. 2000. Lentic macroinvertebrate assemblage structure along gradients in spatial heterogeneity, habitat size and water chemistry. Hydrobiologia. 418:229-242. https://doi.org/10.1023/A:1003969217686

HEISI, H.D.; AWOSUSI, A.A.; NKUNA, R.; MATAMBO, T.S. 2023. Phytoextraction of anthropogenic heavy metal contamination of the Blesbokspruit wetland: Potential of wetland macrophytes. Journal of Contaminant Hydrology. 253:104101. https://doi.org/10.1016/j.jconhyd.2022.104101

HERNÁNDEZ, J.L.; GUZMÁN-SOTO C.; TAMARIS-TURIZO, C.E. 2016. Macroinvertebrados acuáticos de la ciénaga de Sahaya y en tres de sus .afluentes (Cesar, Colombia). Revista Intropica. 11(1):11-20. https://doi.org/10.21676/23897864.1857

HOLDRIDGE, L. 1996. Ecología basada en Zonas de vida. Instituto Interamericano de Cooperación para la Agricultura. Costarica. 216p.

KOVALENKO, K.E.; THOMAZ, S.M.; WARFE, D.M. 2012. Habitat complexity: approaches and future directions. Hydrobiologia. 685:1-17. https://doi.org/10.1007/s10750-011-0974-z

LASSO, C.; GUTIÉRREZ, F.; MORALES, D. 2014. X. Humedales interiores de Colombia: Identificación, caracterización y establecimiento de límites según criterios biológicos y ecológicos. Serie editorial recursos hidrobiológicos y pesqueros continentales de Colombia. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. Colombia. 255p.

LÓPEZ-DÍAZ, J.A.; GÓMEZ, B.; GONZÁLEZ-SORIANO, E.; GÓMEZ-TOLOSA, M. 2021. Odonata (Insecta) como indicador de la calidad ambiental en humedales de montaña neotropicales. Acta Zoológica Mexicana. 37:1-17. https://doi.org/10.21829/azm.2021.3712379

MARTÍNEZ-RODRÍGUEZ, M.D.A.; PINILLA-A., G.A. 2014. Valoración de la calidad del agua de tres ciénagas del departamento de cesar mediante macroinvertebrados asociados a Eichhornia crassipes (Pontederiaceae). Caldasia. 36(2):305-321. https://doi.org/10.15446/caldasia.v36n2.47489

MAZZUCCONI, S.A.; LÓPEZ, R.U.; BACHMANN, A.O. 2009. Hemiptera-Heteroptera: Gerromorpha y Nepomorpha. En: Domínguez, E.; FERNÁNDEZ, H. (ed.) Macroinvertebrados bentónicos sudamericanos: sistemática y biología. Editorial Fundación Miguel Lillo. Tucumán, Argentina. p.167-231.

MERRITT, R.W.; CUMMINS, K.W. 1996. An introduction to the aquatic insects of North America. Kendall-Hunt Publishing Company. Iowa. 1498p.

MERRITT, R.W.; CUMMINS, K.W.; BERG, M.B. 2008. An introduction to the aquatic insects of North America. Kendall/Hunt Publishing Company. Dubuque. 1214 p.

MISTELI, B.; PANNARD, A.; LABAT, F.; FOSSO, L.K.; BASO, N.C.; HARPENSLAGER, S.F.; PISCART, C. 2022. How invasive macrophytes affect macroinvertebrate assemblages and sampling efficiency: Results from a multinational survey.Limnológica. 96:125998. https://doi.org/10.1016/j.limno.2022.125998

MOSQUERA-MURILLO, Z.; CÓRDOBA-ARGÓN, K.E. 2015. Caracterización de la comunidad de macroinvertebrados acuáticos en tres ciénagas de la cuenca media del Río Atrato, Chocó, Colombia. Revista Institucional Universidad Tecnológica del Chocó Investigación, Biodiversidad y Desarrollo. 34(1):22-35. https://doi.org/10.18636/riutch.v34i1.538

MOSQUERA-MURILLO, Z. 2018. Insectos acuáticos asociados a Eichhornia azurea (Schwartz) Kunth en ciénagas del Río Atrato, Chocó - Colombia. Revista

Colombiana de Ciencia Animal – RECIA. 10(1):15-24. https://doi.org/10.24188/recia.v10.n1.2018.533

MOSQUERA-MURILLO, Z. 2020. Fitoperifíton asociado con macrófitas en una ciénaga tropical de la cuenca del Río Atrato, Quibdó (Chocó), Colombia. Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales. 44(173):1060-1072. https://doi.org/10.18257/raccefyn.1207

MURILLO-MONTOYA, S.A.; RESTREPO-BASTIDAS, E.S.; MENDOZA-MORA, A.; FADUL-VÁZQUEZ, C.J.; CALDERÓN-GARCÍA, X.F.; Y RODRÍGUEZ, M.Á. 2018. Macroinvertebrados asociados a raíces de Eichhornia crassipes (Pontederiaceae) en la Ciénaga de Palagua (Colombia). Ambiente y Desarrollo. 22(43):22-34. https://doi.org/10.11144/Javeriana.ayd22-43.mare

NEISS, U.G.; FLECK, G.; PESSACQ, P.; TENNESSEN, K. J. 2018. Superfamily Gomphoidea. En: Hamada, N.; Thorp, J.H.; Rogers, C. (eds.). Freshwater Invertebrates. 4th ed. Academic. Boston, USA. p.399-447.

NUÑEZ, J.C.; FRAGOSO-CASTILLA, P.J. 2019. Uso de Macroinvertebrados Acuáticos como Bioindicadores de Contaminación del Agua de la Ciénaga Mata de Palma Colombia. Información tecnológica. 30(5):319-330. https://dx.doi.org/10.4067/S0718-07642019000500319

PADIAL, A.A.; THOMAZ, S.M.; AGOSTINHO, A.A. 2009. Effects of structural heterogeneity provided by the floating macrophyte Eichhornia azurea on the predation efficiency and habitat use of the small neotropical fish Moenkhausia sanctaefilomenae. Hydrobiologia. 624:161-170. https://dx.doi.org/10.1007/s10750-008-9690-8

PERRON, M.A.C.; RICHMOND, I.C.; PICK, F.R. 2021. Plants, water quality and land cover as drivers of Odonata assemblages in urban ponds. Science of The Total Environment. 773:145467. https://doi.org/10.1016/j.scitotenv.2021.145467

QUIRÓS RODRÍGUEZ, J.A.; DUEÑAS RAMÍREZ, P.R.; BALLESTEROS CORREA, J. 2010. Macroinvertebrados asociados a las raíces de Eichhornia crassipes (Mart). Solms, en dos sectores del complejo cenagoso del bajo Sinú, departamento de córdoba, Colombia. Revista de la Asociación. Colombiana de Ciencias Biológicas. 22:147-157.

RANGEL-CH., O.; ARELLANO-P., H. 2004. Clima del Chocó Biogeográfico/Costa Pacífica de Colombia. En: Rangel-Ch., J.O. ed. Diversidad Biótica IV. El Chocó Biogeográfico/Costa Pacífica. Universidad Nacional de Colombia, Instituto de Ciencias Naturales, Conservación Internacional. Bogotá, Colombia. p.39-82.

REGMI, T.; SHAH, D.N.; DOODY, T.M.; CUDDY, S.M.; SHAH, R.D.T. 2021. Hydrological alteration induced changes on macrophyte community composition in sub-tropical floodplain wetlands of Nepal. Aquatic Botany.178:103413. https://doi.org/10.1016/j.aquabot.2021.103413

RIVERA-USME, J.J.; PINILLA-AGUDELO, G.; CAMACHO-PINZÓN, D.L. 2013. Grupos tróficos de macroinvertebrados acuáticos en un humedal urbano andino de Colombia. Acta Biológica Colombiana. 18(2):279-292.

RODRÍGUEZ-BARRIOS, J.; OSPINA-TÓRRES, R.; TURIZO-CORREA, R. 2011. Grupos funcionales alimentarios de macroinvertebrados acuáticos en el río Gaira, Colombia. Revista de Biología Tropical. 59(4):1537-1552.

ROCHA-RAMÍREZ, A.; RAMÍREZ-ROJAS, A.; CHÁVEZ-LÓPEZ, R.; ALCOCER, J. 2007. Invertebrate assemblages associated with root masses of Eichhornia crassipes (Mart.) Solms-Laubach 1883 in the Alvarado Lagoon al System, Veracruz, México. Aquatic Ecology. 41(2):319-333. https://doi.org/10.1007/s10452-006-9054-2

ROLDÁN, G.; RAMÍREZ, J.J. 2008. Fundamentos de limnología neotropical. 2a ed. Medellín, Colombia: Universidad de Antioquia-ACCEFYN-Universidad Católica de Oriente. Colombia. 442p.

RÚA-GARCÍA, G. 2015. Macroinvertebrados acuáticos asociados a raíces de Eichhornia crassipes (Mart.) Solms, en la ciénaga de Zapayán, Magdalena, Colombia. Revista Intropica. 10:52-59. http://dx.doi.org/10.21676/23897864.1647

SALLES, F.F.; FERREIRA-JÚNIOR, N. Hábitat e hábitos. En: Hamada, N.; Nessimian, J.L.; Querino, R.B. 2014. Insetos aquáticos na Amazônia brasileira: taxonomia, biologia e ecologia. Editora do INPA. Manaus-Brasil. p.39-50.

UPADHYAY, K.D.; MAINALI, J.; GHIMIRE, N.P. 2022. Diversity of aquatic plants and macroinvertebrates and their spatial patterns in a Himalayan Watershed, Central Nepal. Aquatic Botany. 180:103529. https://doi.org/10.1016/j.aquabot.2022.103529

VANEGAS, M. 2017. Estado limnológico de los humedales Tibanica, Guaymaral, Jaboque y Meridor utilizando macroinvertebrados como bioindicadores. En: Quillot Monroy, G.H.; Pinilla Agudelo, G.A. (eds.). Estudios ecológicos en humedales de Bogotá: aplicaciones para su evaluación, seguimiento y manejo. Editorial Universidad Nacional de Colombia. Bogotá. p.218-231.

WALKER, P.D.; WIJNHOVEN, S.; VELDE, G.V.D. 2013. Macrophyte presence and growth form influence macroinvertebrate community structure. Aquatic Botany. 104:80-87. https://doi.org/10.1016/j.aquabot.2012.09.003

WALTEROS, J.M.; CASTAÑO, J.M. 2020. Composición y aspectos funcionales de los macroinvertebrados acuáticos presentes en una microcuenca de cabecera en los Andes de Risaralda, Colombia. Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales. 44(171):581-592. https://doi.org/10.18257/raccefyn.1085

WARFE, D.M.; BARMUTA, L.A.; WOTHERSPOON, S. 2008. Quantifying habitat structure: Surface convolution and living space for species in complex environments. Oikos. 117(12):1764-73.

WETZEL, R.G. 2001. Limnology: Lake and river ecosystems. 3rd ed. Academic Press. San Diego, USA. p.1006