Topics of limnological research in Mexico

Coordinator
Alfredo Pérez Morales

UNIVERSIDAD DE COLIMA

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This book is dedicated to
Dr. Singaraju Sri Subrahmanya Sarma,
in gratitude for all his teachings in the world of limnology.

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Aquatic Macroinvertebrates Diversity in the Grijalva and Usumacinta Rivers, Mexico

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Abstract

Aquatic macroinvertebrates are important and abundant components of the aquatic ecosystem, they transfer energy to higher trophic levels and can be used as bioindicator of aquatic ecosystem condition. The diversity of macroinvertebrates was determined through multihabitat diurnal sampling in three sections and five sites per section in the Grijalva and Usumacinta rivers, covering dry, rainy, and northern wind seasons. 75,482 individuals were recorded corresponding to 79 families, 128 genera, and 140 species, six species of mollusks, 11 of insects, and four of crustaceans for the Grijalva, and 17 of mollusks, 44 of insects, and 9 of crustaceans for Usumacinta were exclusive. The invasive mollusks *Tarebia granifera, Corbicula fluminea,* and *Melanoides tuberculata* accounted for 89.8 and 60.1 % of the abundance for the Grijalva and Usumacinta rivers. The maximum diversity values were in Lacantún section (Usumacinta) (H'=4.49, J'=1.14, D=1 and Margalef 22.76), and seasonally in northern winds (H'=3.42, J'=0.85 and Margalef 15.19), meanwhile, dominance was in dry (D=0.93). The dominant trophic groups were scrapers (74 %) and filter feeders (11 %), with maximum values in the Ostitán section (Grijalva) in rainy season. The collectors (10 %) were present in four sections, with the maximum value in the Tres Brazos section (Usumacinta) in the dry season. However, environmental variation reflects changes in the diversity of macroinvertebrates due to the function of these tropical rivers and their dependence on natural variation, hydraulic connectivity, and flow regulation. It is the first study that addresses the diversity of macroinvertebrates (three taxonomic groups) in two of the largest rivers in the country with contrasting ecohydrological conditions.

Keywords

Macroinvertebrates, diversity, wetlands, Grijalva-Usumacinta basin

Introduction

Aquatic macroinvertebrates (mollusks, crustaceans, and insects) are an important component in aquatic ecosystems for their abundance, in addition to being the intermediate link between primary producers and consumers, where their role as transformers and integrators of organic matter is relevant in the energy flows of the river systems (Barba-Macías et al., 2000). Mollusks, a group of marine origin, have a wide distribution and are associated with different types of habitats such as soft bottoms, logs and aquatic vegetation (Naranjo-García and Olivera-Carrasco, 2014). Furthermore, it is well known that, some bivalves are consumed in the lower basin of the Usumacinta River (Pantanos de Centla Biosphere Reserve), such as *Potamilus alatus* (Say, 1817), *Cyrtonaias tampicoensis* (Lea, I., 1839), *Pyganodon grandis* (Say, 1829), *Rangia cuneata* (Sowerby ł, 1832), and *Pomacea flagellata* (Say, 1829). Other species such as *P. flagellata, Vitta usnea* (Röding, 1798), *Neritina virginea* (Linnaeus, 1758), *Biomphalaria obstructa (havanensis)* (Morelet, 1849), and *Rangia cuneata* are used as indicators of moderately or uncontaminated environments (Naranjo-García & Meza-Meneses, 2000). While, the invasive species *Melanoides tuberculata* (Müller, 1774), *Tarebia granifera* (Lamarck, 1816) and *Corbicula fluminea* (Müller, 1774) have been recorded with high abundances and probably generate an imbalance in the biodiversity of the aquatic environments that they colonize (Naranjo-García & Meza-Meneses, 2000; Cruz-Ascencio et al., 2003; Albarrán-Melzer et al., 2009; Sánchez et al., 2012; Barba-Macías & Trinidad-Ocaña, 2017).

On the other hand, 89 % of the recorded crustacean species are of marine origin, 10 % are freshwater, and 1 % are terrestrial (Álvarez et al., 1996). Crustaceans inhabit a variety of substrates such as muddy bottoms, logs, submerged, floating, and emerging aquatic vegetation. These organisms play an important role in energy transfer to higher trophic levels (Barba-Macías et al., 2000). Species such as: *Macrobrachium* spp. (Camacho-Sánchez, 2007), *Hyalella azteca* (Keithly et al., 2004), *Mysidopsis bahia* (Raz-Guzmán, 2000) are used as indicators of water quality (Álvarez et al., 1996; Cumberlidge et al., 2009; Schertzinger et al., 2018). Furthermore, within this group, penaeid shrimp, carideans, and crabs are important in commercial and coastal fishing, and contribute 1.4 % of national production (CONAPESCA, 2013).

Aquatic insects are distributed in a wide variety of ecosystems, such as streams, rivers, lakes, etc., and their distribution depends on the concentration of dissolved oxygen and water temperature (Bass, 1995; Castella et al., 2001; Li et al., 2001; Sullivan et al., 2004), and water chemistry, including pH, salinity, and concentrations of ions or elements, as well as the presence of riparian vegetation (Subramanian et al., 2005). This group has been widely used as a bioindicator, where various authors with studies in temperate and tropical regions have found that the diversity and richness of species decreases in areas impacted by human activities (Stone & Wallace, 1998; Ometo et al., 2000; Benstead et al., 2003), in addition to presenting channels with a lack of boulders and the presence of terrigenous sediment, which drastically reduces the availability of niches and, as a consequence, a decrease in diversity (Allan et al., 1997). There are also other factors that, to a lesser extent, explain the structure and composition of the aquatic entomofauna, such as seasonal patterns (Miserendino & Pizzolon, 2003; Waite et al., 2004; Sporka et al., 2006; Joshi et al., 2007).

The Grijalva-Usumacinta basin (GUB) is characterized by its high-water wealth and biodiversity, in addition to contributing 30 % of the country's total surface runoff (García-García and Kauffer-Michel, 2011; Cruz-Paz et al., 2018). Previous studies have focused on the Usumacinta basin: mollusks and crustaceans (Trinidad-Ocaña et al., 2018) and insects for mountain areas of Tabasco (Benítez-Abud et al., 2016). However, the increase in anthropogenic activities causes greater pressure on the system due to the modification of land use (Kolb & Galicia, 2012), with the consequent decrease in riparian vegetation and an increase in the discharge of untreated wastewater, these affect water quality (Laino-Guanes et al., 2016). Therefore, records of invasive non-native species are increasingly frequent in the Grijalva-Usumacinta basin (Cruz-Ascencio et al., 2003; Rangel-Ruiz et al., 2011; Barba Macías et al., 2014).

This contribution analyzes the diversity of aquatic macroinvertebrates in two basins with contrasting hydrological conditions, a dammed river (Grijalva), and one with free flow (Usumacinta) and if there are significant differences between sites and between basins, depending on the state of the ecological quality of the banks and the natural flow of the river expressed in better hydrological conditions, high values of riparian quality, high species richness, abundance, and biomass in relation with altered and unaltered river functionality.

Materials and Methods

Study Area

The study area includes hydrological region number 30 (RH30) formed by the Grijalva and Usumacinta rivers, both rivers make up the largest hydrological basin in México (Conagua, 2014). Its runoff area is 112,500 km^2 and represents 4.2 % of the continental national territory (Andrade-Velázquez & Medrano-Pérez, 2020), with a discharge of 4,500 m^3/s, occupying second place in discharge to the Gulf of México after the Mississippi with an annual discharge of 18,000 m^3/s (Yàñez-Arancibia et al., 2009; Sánchez et al., 2015). Both rivers are transboundary, they originate in Guatemala and cross the states of Chiapas and Tabasco in Mexico and converge on the coastal plain of Tabasco providing conditions for extensive wetland areas that mainly make up the Pantanos de Centla Biosphere Reserve (Barba-Macías et al., 2006; Conagua, 2014). The climate of the region is generally composed of three climatic groups: the warm-humid ones with approximately 93.5 % of the territory are temperate-humid with 6.3 % and a small portion of dry climate (Conagua,2014).

The Usumacinta River annually transports around 59,397 hm^3 (including the contribution of the San Pedro River), its flow represents the largest contribution of water to the Laguna de Términos and the Pantanos de Centla Biosphere Reserve (PCBR) (Soria-Reinoso et al., 2022), this river does not have dams. While the Grijalva River is one of the largest rivers in the country, it annually transports a volume of 27,013 hm^3 and, in the rainy season, its flow increases. For this reason and to take advantage of the waters flow of this river, it was dammed with a system of four hydroelectric dams at the end of the 60's (Netzahualcóyotl, La Angostura, Chicoasén and Peñitas) (Conagua, 2014).

Three study areas were selected for each river, considering its main environmental, hydrological and ecological characteristics according to regulatory appendix F of the Ecological Flow Standard (MNX-AA-159-SCFI-2012), where Flow Study Units were determined. Ecological, which consists of the scale of analysis in the territory of the basin. These evaluation units refer to surface water bodies (rivers, lakes, lagoons, or other wetlands) or part of them in the same hydrological basin and that have the same hydrological regime to which an environmental objective is assigned. These were validated by a panel of experts before the selection of reference areas. The areas chosen in the Usumacinta River were Lacantún, Jonuta, and Tres Brazos, while for the Grijalva River they were Amacohite, Ostitán, and Chilapa, in each study area five sampling sites were selected.

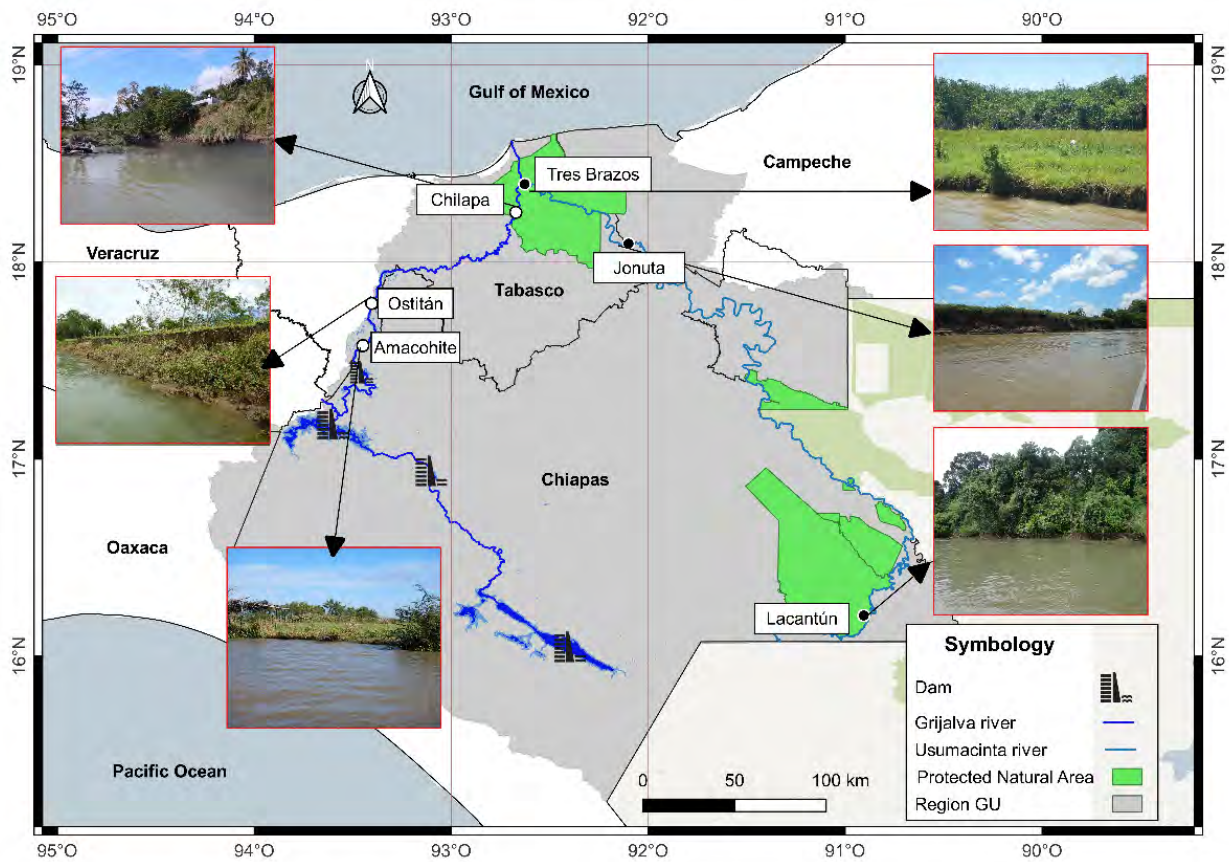


Figure 1. Sampling Sections of Grijalva and Usumacinta Rivers (Modified from Miranda-Vidal et al., 2023).

Ecological quality of the riverbanks at each selected site was evaluated using the Riverbank Quality Index (RQI) according to Miranda-Vidal et al. (in press), where seven attributes described in the protocol were evaluated; 1) riparian space (width) occupied by vegetation associated with the river, 2) longitudinal continuity of vegetation, 3) composition and structure of woody vegetation, 4) natural regeneration, 5) condition of banks, 6) transversal connectivity, and 7) vertical connectivity (González del Tánago et al., 2006; González del Tánago & García del Jalón, 2011) (Annex. 1).

Sampling

Samples were collected in the rainy season (wettest period of the year; 950 mm of precipitation), "northern winds" (locally known as "nortes", a condition where polar masses cross the Gulf of Mexico; 660 mm) and dry season (driest and hottest period of the year; 270 mm) (Ayala-Pérez et al., 2021; Cardoso-Mohedano et al., 2022) of an annual cycle of 2017-2018. At each site, the physicochemical parameters of the surface water were recorded using a Hanna HI9829 multiparameter for: temperature (°C), pH, dissolved oxygen (DO) (mg/L), conductivity (mS/cm^{-1}), total dissolved solids (TDS) (mg/L) and salinity (ups).

Aquatic macroinvertebrates were collected following the Macroinvertebrate Sampling Protocol in continental waters for the application of the Ecological Flow Standard (NMX-AA-159-SCFI-2012). The biological collection material was carried out through a multihabitat approach with various collector equipment's. For infauna, a nucleator with an area of 0.0044 m^2 was used (in rivers and shallow wetlands) and a Petite Ponar dredge with an area of 0.025 m^2 in rivers more than 2.5 m deep. Epifauna was collected with different types of nets: dip net with a mesh size of 500 microns and an area of 0.082 m^2, Renfro beam trawl net with a mesh size of 1 mm and an area of 2 m at the mouth with trawls of 25 m in length covering an area of 50 m^2, seine net 15 m in length, with a mesh size of 1 cm on the sides covering four meters on each side and a 2 mm mesh size in the center in a length of 7 m and a drop of 2.20 m covering 62 m^2. The use of each sampling equipment must be in accordance with the depth of the body of water and the conditions present in each location; at least three replicas must be taken per equipment used. All organisms were preserved in a plastic bag with 96 % alcohol.

Analysis

The organisms were identified, counted and weighed; identification was carried out to the lowest possible taxonomic level with various taxonomic keys for mollusks using Burch and Cruz-Reyes (1987), Thorp and Covich, (1991) and Hershler and Thompson (1992). For crustaceans were used: Bousfield (1972), Chace (1972), Felder (1973), Williams (1984), Pennak (1978), Throp and Covich (1991), Raz Guzmán et al. (1992), and Raz-Guzmán and Sánchez (1996). The insects were identified using the keys from: Wiggins (2000), Merritt et al. (2008), and Bueno-Soria (2010).

These organisms were assigned to food groups according to their trophic specialization. Eight trophic groups were determined following categories proposed by Cummins and Klug (1979), Merritt and Cummins (1996), Liévano and Ospina (2007) and Tomanova et al. (2006). From these, Herbivores (H) that feed on aquatic vascular plants or filamentous algae, Omnivores (Om) that feed on diverse types of food, Collector-Shredders (C-Sh) that feed on coarse particulate organic matter, Scrapers (Ra) that are herbivores and feed on algae or microbes attached to rocks or other substrates, Gatherers (Ga) that consume fine particulate organic matter, Filter feeders (Ff) which is a special group of collectors that filter in the water column, Predators (P) that feed on other living organisms and Shredders (Tr) are organisms that cut or chew pieces of living or dead plant material, including all plant parts like leaves and wood.

Abundance and weight data were standardized to density (org/m^2) and biomass (g/m^2). Diversity indices H' Shannon (Shannon and Wiener, 1963), species richness (D) of Simpson (1949) and evenness (J') of Pielou (1966) were applied; the indices were calculated with the statistical package PAST version 2.17c (Hammer et al., 2001).

Results

Environmental Description

Riparian quality of the Usumacinta River showed a gradient of riverbank quality ranged from very good (scores of 139) at the Lacantún site to Tres Brazos (classified as poor score 41), while at Grijalva, the evaluation of riverbank quality ranged from moderate with scores of 70 and 73 (Chilapa and Amacohite sites, respectively), to poor in Ostitán site (score of 58) (Annexe 1). In Grijalva, sampling sites revealed that the attributes of the riverbank are degraded and altered in their functioning. Temperature was uniformly in both basins with values between 23 and 30°C, the minimum value being recorded in the Amacohite section. Sections corresponding to Grijalva basin (GB) recorded lower values of conductivity and total dissolved solids than those of Usumacinta basin (UB), but the minimum record was from the Amacohite section for conductivity (166.69 $mScm^{-1}$) and 132.62 ppm to total dissolved solids (TDS) for the Chilapa section. Because they are freshwater environments, salinity is very low with records less than 1 ups. Dissolved oxygen registered values greater than 4 mg/L in the sections of both basins, the minimum value being recorded in the Jonuta section which registered 4.29 mg/L in the dry season (Table 1). However, data recorded corresponds to acceptable values for aquatic life.

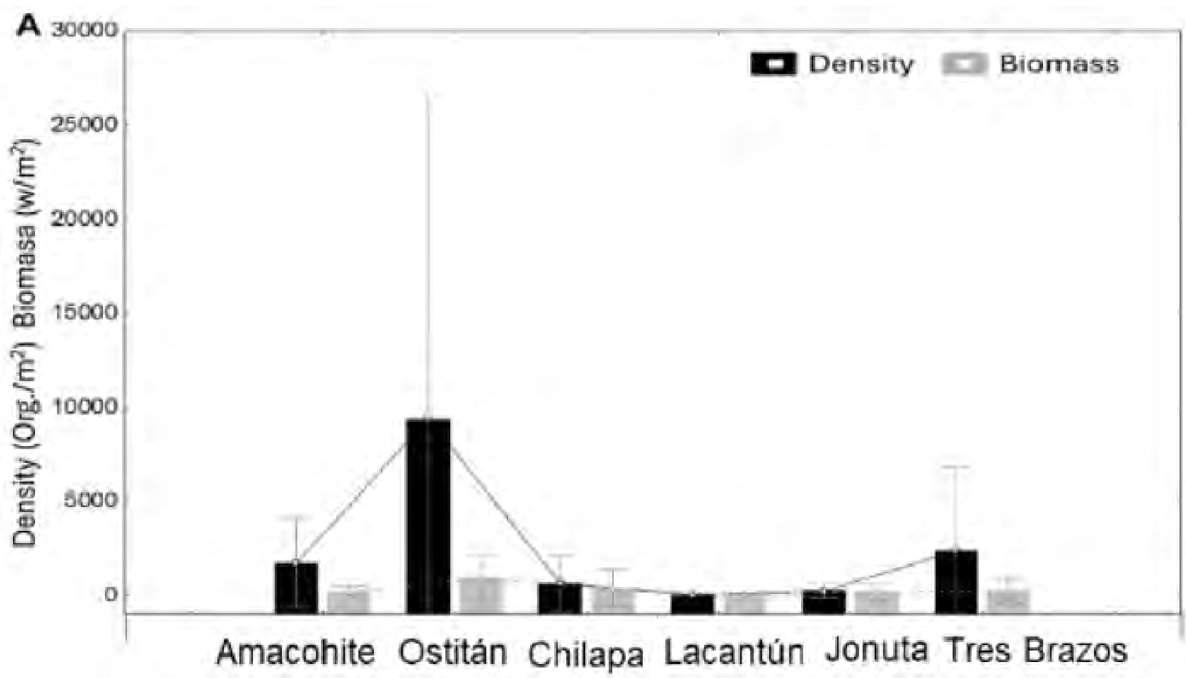
Table 1. Average Value of Physicochemical Parameters per Section and Season Sampling Areas of the Usumacinta and Grijalva Basin. R: Rainy, N: Northern Winds, D: Dry, Tr: Transparency, T: Temperature, OD: Dissolved Oxygen, TDS; Total Dissolved Solids.

Basin	Section	Season	Depth (m)	Tr (m)	T (°C)	pH	OD (mg/L)	Salinity (ppm)	Conductivity (mScm-1)	TDS (ppm)
Grijalva	Amacohite	N	1.73	0.62	23.35	4.49	5.15	0.1	166.69	138.89
		R	1.73	0.62	30.02	7.24	4.81	0.17	368.20	184.80
		D	1.72	0.62	27.97	10.14	8.33	0.17	361.70	180.90
	Ostitán	N	1.3	0.68	26.37	9.55	6.5	0.12	319.40	159.70
		R	1.23	0.68	29.87	7.39	4.93	0.2	360.20	219.20
		D	1.27	0.68	27.96	11.61	8.11	0.18	372.93	186.43
	Chilapa	N	2.53	0.33	25.4	7.55	4.64	0.15	265.25	132.63
		R	2.53	0.33	31.49	7.58	5.34	0.17	471.10	235.60
		D	2.53	0.33	27.58	9.73	8.05	0.11	429.60	214.60
Usumacinta	Lacantún	R	1.08	0.36	24.99	8.24	7.02	0.2	417.37	208.75
		D	0.57	0.58	26.26	9.76	10.01	0.32	653.26	326.66
	Jonuta	N	0.77	0.26	29.76	8.26	6.3	0.15	385.50	193.00
		R	1.8	0.54	28.68	7.99	5.66	0.16	384.50	192.25
		D	1.1	0.55	27.93	8.48	4.29	0.19	660.50	330.00
	Tres Brazos	N	1.9	0.3	30.31	7.99	6.73	0.24	377.13	188.75
		R	1.86	0.43	28.81	7.74	4.64	0.18	575.75	326.87
		D	1.83	0.58	28.65	8.64	4.3	0.94	1488.14	744.00

Aquatic Macroinvertebrates

A total of 75,482 individuals corresponding to 79 families, 128 genera, and 140 species were collected. GB recorded 44 families, 60 genera, and 66 species, nine species of crustaceans were recorded (4,918 indiv.), 33 insect genera were recorded (317 indiv.), and for mollusks with 24 species (50,110 indiv.). While in UB 69 families, 111 genera and 117species were recorded, 14 species of crustaceans were recorded (4,525 indiv.), 67 genera of insects (1243 indiv.) and 36 species of mollusks were recorded (14,369 indiv.). Species recorded exclusively in each basin were in GB 6 species of mollusks, 11 of insects, and 4 of crustaceans, while in UB there were 17 species of mollusks, 44 of insects, and 9 of crustaceans.

Regarding the density of macroinvertebrates, 70 % of the density was from the Grijalva basin and 30 % from the Usumacinta basin. Spatially, maximum values of density and biomass in Grijalva were in the Ostitán section (99.4 indiv./m^2 and 9.7 g/m^2); while in Usumacinta, they were in the Jonuta section 24.8 indiv./m^2, and 6.9 g/m^2 respectively (Fig. 2A). Temporally, maximum values of density and biomass in Grijalva were 112.5 indiv./m^2 in the rainy season, and 10.9 g/m^2 in northern winds, respectively; for Usumacinta, maximum temporal values were in the dry season, 31.9 indiv./m^2 and 5.3 g/m^2 respectively (Fig. 2B).



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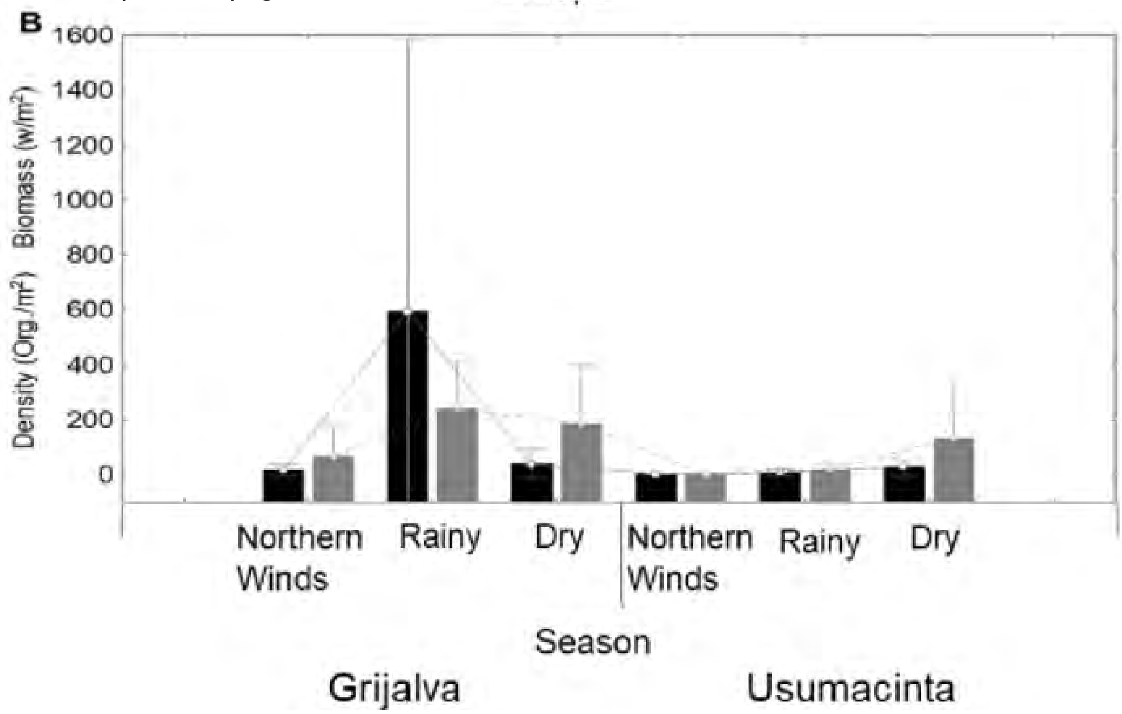

Figure 2. Mean and Standard Deviation of Density and Biomass of Aquatic Macroinvertebrates, Spatial (A) and Temporal (B) Distribution in Grijalva and Usumacinta Basins.

Table 2. Density and Biomass of AA<Aquatic Macroinvertebrates on Grijalva and Usumacinta Basins (*Exotic Species, CG=Grijalva Basin, CU=Usumacinta Basin, D=Density, B=Biomass). Many Species Recorded Densities Less than One Individual per Square Meter

Group/Species	GB		UB		Group/Species	GB		UB	
	D	B	D	B		D	B	D	B
Mollusks					*Berosus* sp.			0	0
Anodonta sp.			46	4	*Brachycerus* sp.	1	0	1	0
Aroapyrgus clenchi			141	1	*Camelobaetidius* sp.	1	0		
Aroapyrgus sp.			281	1	*Campsurus* sp.			1	0
Biomphalaria helophila	1	0	57	1	*Cheumatopsyche* sp.	0	0	0	0
Biomphalaria obstructa	1	0	69	1	*Chimarra* sp.			0	0
Biomphalaria subprona			1	0	*Chironomus* sp.	28	0		
Cochliopina francesae			47	0	*Chrysops* sp.			0	0

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Cochliopina infundibulum			5	0	*Coryphaeschna* sp.			1	0
Corbicula fluminea *	2,520	3,400	75	141	*Crambus* sp.			0	0
Cyrtonaias tampicoensis	0	38	5	113	*Cybister* sp.			0	0
Drepanotrema lucidum			2	0	*Desmopachria* sp.	0	0		
Eupera cubensis	101	1	169	3	*Dythemis* sp.			0	0
Hebentancylus excentricus			426	2	*Ellipes* sp.			0	0
Helisoma duryi					*Enallagma* sp.	18	0	6	0
Hydrobia sp.			675	2	*Enochrus* sp.	0	0		
Lamellaxis micra	0	0			*Ephoron* sp.	28	0	233	1
Littoraria nebulosa			0	0	*Eretes* sp.			1	0
Lucidella lirata	2	0	6	0	*Erpetogomphus* sp.			1	0
Margaritifera auricularia	2	103			*Gelastocoris* sp.			0	0
Mayabina polita	0	0			*Glossosoma* sp.	0	0		
Mayabina sp.			111	2	*Graptocorixa* sp.			36	0
Megalonaias sp.			0	0	*Gyretes* sp.			0	0
Megapitaria sp.			252	6	*Helichus* sp.			0	0
Melanoides tuberculata *	39	1	355	49	*Helobata* sp.			0	0
Mytilopsis leucophaeta	14	2	835	20	*Helochares* sp.			0	0
Neritina usnea	478	102	2,359	440	*Heptagenia* sp.			1	0
Neritina virginea	0	0	14	0	*Hetaerina* sp.	1	0	3	0
Physa sp.	35	0	209	1	*Heterelmis* sp.			1	0
Planorbella duryi	0	0	141	1	*Hexatoma* sp.			1	0
Polymesoda caroliniana	28	248			*Hydrometra* sp.	0	0		
Pomacea flagellata	6	14	332	812	*Hydrophilus* sp.			1	0
Potamilus alatus			4	14	*Lacophilus* sp.			1	0
Psoronaias crocodilarum	15	630	30	429	*Lachlania* sp.			0	0
Pyganodon grandis			14	9	*Leptohyphes* sp.	7	0	1	0
Pyrgophorus parvulus	3	0			*Leptonema* sp.	7	0	0	0

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Pyrgophorus coronatus	20	0	2,799	15	*Leptysma* sp.			0	0
Rangia cuneata			1	0	*Libellula* sp.	1	0	4	0
Stenophysa impluviata	0	0	6	0	*Limnogonus* sp.	0	0		
Subulina octona	1	0	10	0	*Maccaffertium* sp.			0	0
Succinea undulata	0	0	15	0	*Macrelmis* sp.			12	0
Tarebia granifera *	54,199	2,782	9,293	2,090	*Metrobates* sp.	0	0		
Texadina sphinctostoma			1464	5	*Microcylloepus* sp.			1	0
Crustaceans					*Neptopsyche* sp.			1	0
Armases cinereum			4	1	*Notonecta* sp.	0	0	3	0
Callinectes sapidus	0	0			*Omophron* sp.			0	0
Callinectes sp.			0	0	*Orchelimum* sp.			1	1
Cymadusa compta			40	0	*Palaemnema* sp.			0	0
Discapseudes mexicanus			2,774	7	*Paracleodes* sp.			0	0
Ericthonius brasiliensis			5	0	*Paraponyx* sp.	0	0	0	0
Hyalella azteca	0	0	4	0	*Pelocoris* sp.			12	1
Macrobrachium acanthurus	410	32	240	19	*Petrophila* sp.	0	0		
Macrobrachium carcinus	25	4	22	3	*Phyllocycla* sp.	0	0	20	4
Macrobrachium hubbsi	27	2			*Polyplectropus* sp.			0	0
Macrobrachium olfersii	113	11	642	286	*Probezzia* sp.			0	0
Minuca sp.			4	2	*Progomphus* sp.	14	0	2	0
Uhlorchestia uhleri			1	0	*Ranatra* sp.	0	0	1	0
Pachygrapsus transversus			1	1	*Rhagovelia* sp.	2	0	37	0
Potimirim mexicana	109	3	60	2	*Rhantus* sp.			0	0
Pseudothelphusa hartmanni	0	7			*Simulium* sp.	1	0	0	0

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Rhithropanopeus harrisii			1	0	*Stenus* sp.	3	0		
Uca pugilator	0	0			*Tabanus* sp.			0	0
Insects					*Tanysphyrus* sp.	2	0		
Aeshna sp.			0	0	*Thraulodes* sp.			4	0
Ambrysus sp.			3	0	*Tortopus* sp.			1	0
Anacroneuria sp.			2	0	*Traverella* sp.			1	0
Anaxipha sp.			2	0	*Trepobates* sp.	0	0	3	0
Aphylla sp.	0	0	2	0	*Triacanthagyna* sp.			0	0
Argia sp.	0	0	1	0	*Tricorythodes* sp.	11	0	2	0
Baetis sp.	9	0	58	0	*Tropisternus* sp.	0	0	2	0
Belostoma sp.	2	0	5	0					

Regarding the groups, mollusks represented 93 %, crustaceans 6 %, and insects 1 % of the total average density. Considering the density by basin, mollusks represented 98 % and crustaceans and insects 1 % respectively in the Grijalva basin (GB), while in the Usumacinta basin (UB) mollusks represented 83 %, crustaceans 15 %, and insects 2 %. Regarding biomass, in CG it registered 62 %, while CU 38 %. In both basins, mollusks represented more than 90 % of the total biomass.

Dominant species by density in the GB, were mollusks: *Tarebia granifera* with 77% while in biomass, they were *C. fluminea* (46 %) and *T. granifera* (38 %). For crustaceans, the dominant species in density were *Macrobrachium acanthurus* (28%), *M. olfersii* and *Potimirim mexicana* with 19 % respectively. *M. acanthurus* represented the largest biomass of crustaceans in the basin with 53%. In insects, the dominant species in density were *Chironomus* sp. and *Ephoron* sp. with (20 %) respectively, and *Enallagma* sp. (13 %), while the highest biomass was for *Progomphus* sp. and *Ephoron* sp. (18 %) respectively, followed by *Chironomus* sp. (16 %). In UB, the dominant species in density for mollusks were *T. granifera* (45 %), *Pyrgophorus coronatus* (13 %), and Neritina usnea (11 %). Regarding biomass, the dominant species were *T. granifera* (50 %) and *Pomacea flagellata* with 19 %. In crustaceans, the dominance in density was for *Discapseudes mexicanus* with 73 % of the density, while in biomass it was *M. olfersii* with 88 %. Regarding insects, the dominant species in density were *Ephoron* sp. (49 %), and *Baetis* sp. (12 %), while the species *Phyllocycla* sp. (45 %), and *Ephoron* sp. (13 %), were for biomass (Table 2).

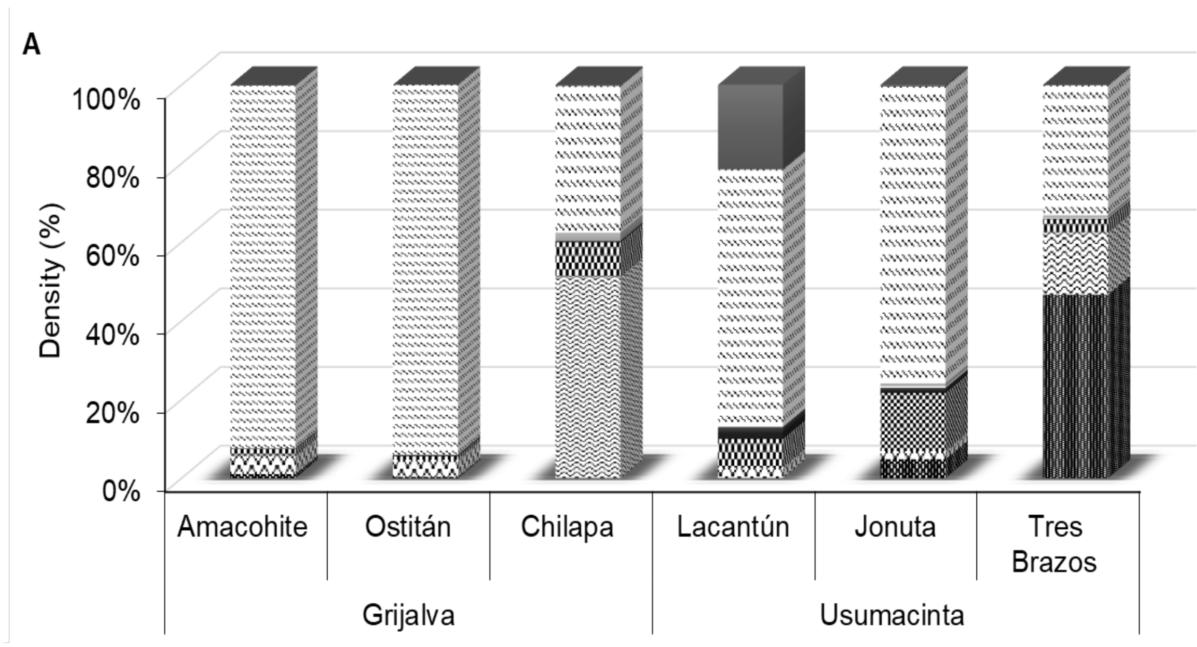
Diversity indices by basin, UB presented maximum values, spatially maximum diversity values were in the Lacantún section in upper basin (H’=4.49, J’=1.14, D=1 and Margalef=22.76). Temporally, maximum values were in the Northern winds (H’=3.42, J’

=0.85 and Margalef=15.19) and in the dry season (D=0.93) (Table 3). Maximum values of diversity in GB were in lower basin section Chilapa (H'=1.78, J'=0.48 y D=0.71), seasonally maximum values were in dry season (H'=2.28, J'=0.79, D=0.58 y M=8.73) (Table 3)

Table 3. Spatial and Temporal Diversity of Aquatic Macroinvertebrates in Grijalva and Usumacinta Rivers.

Basin / Section	**Grijalva**			**Usumacinta**		
	Amacohite	**Ostitán**	**Chilapa**	**Tres Brazos**	**Jonuta**	**Lacantún**
Shannon_H	0.98	0.79	1.78	2.93	2.52	4.49
Equitability_J	0.28	0.22	0.48	0.73	0.58	1.14
Simpson_1-D	0.28	0.25	0.71	0.93	0.77	1.00
Margalef	7.09	6.25	6.77	8.00	13.21	22.76
Season	**Northern Winds**	**Rainy**	**Dry**	**Northern Winds**	**Rainy**	**Dry**
Shannon_H	1.70	1.06	2.28	3.42	2.73	3.07
Simpson_1-D	0.70	0.36	0.79	0.89	0.88	0.93
Equitability_J	0.56	0.27	0.58	0.85	0.63	0.70
Margalef	5.18	7.10	8.73	15.19	11.74	10.97

The dominant Trophic groups were the scrapers (74 %) and the filter feeders (11 %) present in all the sampled sections, presenting the maximum values in GB in the Ostitán section and the rainy season. Collectors (10 %) were present in four sections, having the maximum value in UB in the Tres Brazos section in the dry season (Fig. 3).



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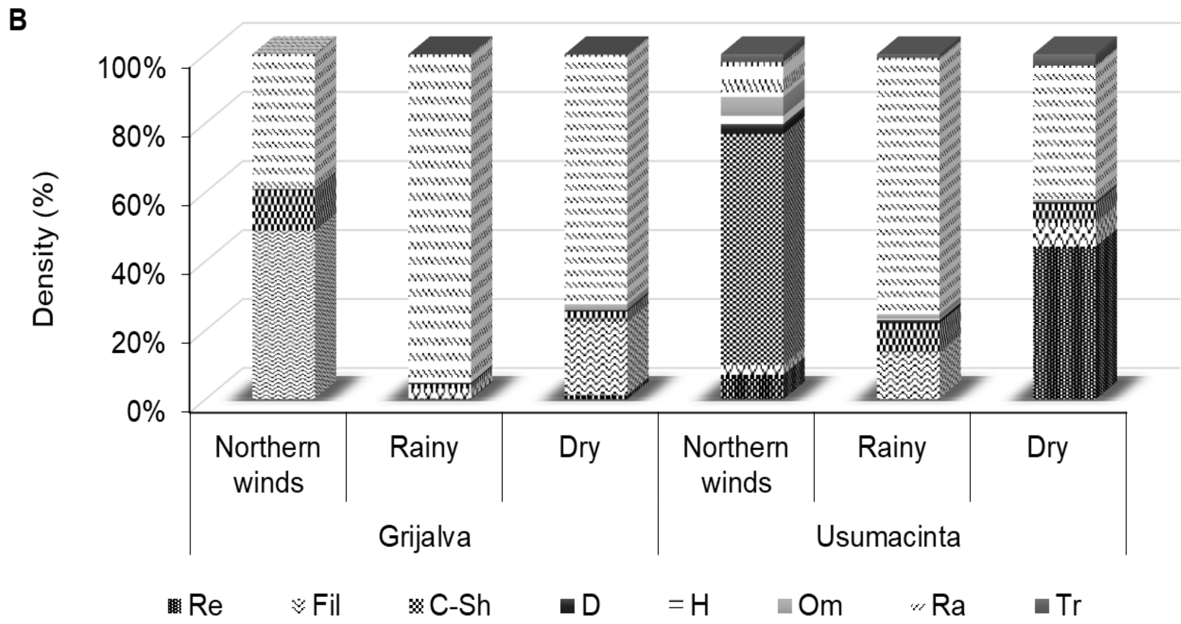

Figure 3. Spatial (A) and Temporal (B) Distribution of Trophic Groups in Grijalva and Usumacinta Rivers. Collector (Re), Filtering (Fil), Collector-shredders (C-Sh), Predator (D), Herbivores (H), Omnivores (Om), Scrapers (Ra) and Shredders (Tr)

Trophic groups per basin, presented significant differences with respect to density, mollusks ($p \leq 0.001$), these differences occurred between Filter feeders BG over scrapers BU and filter feeder's BU over scrapers BU. Regarding crustaceans ($p \leq 0.05$), these presented differences between gathering in BU over omnivores in BU and shredders in BU over omnivores in BU, and insects ($p \leq 0.001$) the differences were presented between shredders in BG over predators BG, shredders BU over predators BG, and with a $p \leq 0.05$ gathered BG over predators BG, shredders BU predators BU, predators_BG: predators_BU and shredders BU: shredders _BG.

Discussion

In the Grijalva River, it has been identified that main causes of modification of the river ecosystem are the construction of hydraulic infrastructure, urban growth, and pressure on aquatic resources related to primary activities (Sánchez et al., 2015; Sandoval-Rivera et al., 2022). This pattern of riparian quality form regular to poor, is a common condition that has also been observed in other basins (Escalona-Domenech et al., 2022). On the other hand, variation of parameters of temperature, salinity, and TDS in Grijalva, because of urbanization, changes in the use of land, modification of drainage networks, discharges of untreated water from the cities of Villahermosa and Tuxtla Gutiérrez, agricultural activities, oil industry and sugar mills (Ramos-Herrera et al., 2012; Marin, 2014; Musálem-Castillejos et al., 2018).

While in the Usumacinta River, the ecological condition of the river bank from very good to poor, could be explained by its location, since areas in Montes Azules Biosphere Reserve (MABR) in the state of Chiapas (Salinas-Rodríguez et al., 2021; Soria-Reinoso et al., 2022), so the riparian vegetation still presents natural conditions (Ochoa-Gaona et al., 2018), to Jonuta classified as good, this could be because there are unsustainable practices in the area (such as subsistence agriculture, use of agrochemicals, extensive plantations such as oil palm and in the lower areas of Tabasco, extensive livestock farming) (Salcedo-Garduño et al., 2019; Camacho-Valdez et al., 2022), and the Tres Brazos site, located in the Pantanos de Centla Biosphere Reserve in Tabasco, presented a poor riparian state. Due to economic activities such as agriculture, fishing, and livestock are developed in the area, coupled with presence of the oil and gas industry (Barba-Macías et al., 2006; Barba et al., 2018). These activities put the PCBR and its environmental services at risk and keep them under constant pressure (Barba Macías et al., 2014, 2015, 2018; Puc-Carrasco et al., 2016; Ochoa-Gaona et al., 2018).

Temporal variability of the physicochemical parameters of the water occurred due to the dynamics of tropical rivers, which depend on precipitation and flow rates (Soria-Reinoso et al., 2022), combined to this, human settlement and land use change in this river generate alterations in the physicochemical conditions of the water, mainly in dry season, when the volume of water decreases and, therefore, the concentration of discharges increases, increasing the concentration of contaminants and decreasing water quality (Salcedo-Garduño et al., 2022). It should be noted that in the Grijalva River, the depth did not show variation throughout the climatic seasons, which could be explained by the management that the dams carry out on the flow, since it is a characteristic of the reservoirs to compensate for low flows during the dry season and regulate high flows in the rainy season (Wang et al., 2016).

Tropical seasonality differs from the temperate zone whereas temperature differences in tropical streams are usually very subtle (≈10°C), where taxonomic composition, richness, and trophic guilds are driven by the seasonality through the contrasting (rainy and dry seasons) (Cortés-Guzmán et al., 2021).

Aquatic macroinvertebrate species richness was considerably lower in Grijalva (66 spp.) compared to those in the Usumacinta River (117 spp.). It is the first study that groups three phyla (mollusks, crustaceans, and insects) and therefore, the importance of the information generated. For group of mollusks, 24 species are recorded in the Grijalva River, compared to Mellano-Hernández et al. (2015) who reported 17 species of Gastropods and six species of Bivalvia, with *P. coronatus, M. impluviata, L. tenuipes, M. polita, and Pomacea flagellata* being dominant in abundance. For the Usumacinta River, in this study, 36 species of mollusks were recorded having a similarity with those reported by Trinidad-Ocaña et al. (2018) recording 35 species.

For the group of crustaceans in Grijalva, nine species were recorded, according to Álvarez et al. (2005), 72 species of crustaceans are registered for the State of Tabasco, of which

44 were counted for decapods and peracarids; It is considered that there is an underestimation of the records for invertebrates and especially crustaceans and insects since most of the studies have been carried out with species of commercial importance (Sánchez & Barba, 2005). For the Usumacinta River, 14 species were recorded, compared to what was reported by Trinidad-Ocaña et al. (2018) with 13 species. Insects in the Grijalva basin were recorded with 33 genera and for the Usumacinta River, 67 genera were recorded, which compared to Castillo et al. (2018) the value is lower than what they report (127 genera). This may be due in part to the fact that for some individuals of some orders, identification at the genus level was not possible.

73 % of total density was in the Grijalva River, due to a high number of exotic mollusk species, *Tarebia granifera,* with 65 % of total density (both rivers). This is the first study which groups three phyla (mollusk, crustaceans and insects), past reports are about a single zone *p.e.* Lacantún (Cortés-Guzmán et al., 2021), or just Insects (Castillo et al., 2018), or mollusk and crustaceans in Usumacinta (Barba-Macías et al., 2018). In Lacantún section 63, the genera of benthic macroinvertebrates were recorded from 39 families and ten orders of those 24 genera (40 %) have been previously reported from the Usumacinta River Basin (Castillo et al., 2018). In the Grijalva river, 17 species of Gastropod and six species of Bivalvia were recorded, being dominant in abundance *P. coronatus, M. impluviata, L. tenuipes, M. polita* and *Pomacea flagellata* (Mellano-Hernández et al., 2015),

Macroinvertebrate diversity was higher in the Usumacinta River, in the Lacantún section, and in northern winds, in Grijalva, the diversity was higher in the Chilapa section in the dry season. Spatial distribution of density by the taxonomic group in Grijalva, crustaceans and insects were higher in Chilapa, and mollusk in Ostitán, in Usumacinta mollusks and insects were higher in Jonuta, and crustaceans in Tres Brazos. Temporal distribution was in Grijalva, mollusks and insects higher in rainy, crustaceans in northern seasons, meanwhile, in Usumacinta highest density values were in dry season.

Scrapers group were dominant in all sections, with highest density values in Ostitan GB, in the rainy season, collectors were present in four sections with highest values in Tres Brazos in the dry season, differences between sections and rivers can be explained by differences in hydrological regime. The Usumacinta River is free-flowing with a maximum 220 discharge (averaged 3,632 m^3/s) in the rainy season and a minimum (723 m^3/s) in the dry season. This reflects the relationship between the rainfall regime in the rainy season with flow volume. The Grijalva River flow drastically modified, showed a decrease in volume to less than a half; being notorious in dry season with an increase in 156 (m^3/s) of natural volume (Miranda-Vidal et al., 2023). Free-flow of the Usumacinta River has flow regimes well marked by seasonality (rainy and dry), with natural conditions of hydrological connectivity and flow regimes (Salinas-Rodríguez et al., 2021). These conditions facilitate the lateral and longitudinal migration of fish and their permanence in the aquatic systems of the floodplain (Castillo, 2011). In addition, hydrological connectivity is very important for the dynamics of aquatic and riparian vegetation (Mendoza, 2014), because it promotes the dispersal of seeds, fruits, or parts of the plant in the rainy season which enables individuals to develop for repopulation and, in addition, facilitates the flow and transfer of nutrients (Ochoa-Gaona et al., 2018).

Loss of seasonal flow variation in the Grijalva river compromised the seasonal variation of geomorphology creation and maintenance, reflected in the homogeneity of riparian and aquatic habitats (Wang et al., 2016). Furthermore, hydrological connectivity was altered for various aquatic species that require extreme flows to complete their life cycles (Metcalfe et al., 2013). With such alteration to the flow, temporal pulses, and homogenization of levels (depth), the entry and permanence of invasive species are facilitated (Ormerod et al., 2011). Reduced flow favors soil and water salinization and decreases the inflow of freshwater to the sea, as in the mouth of the Grijalva River where the salt wedge has reached up to 46 km upstream (Alcérreca-Huerta et al., 2019). This threatens fluvial ecological processes and the permanence of freshwater species, especially in the RBPC (Mata-Zayas et al., 2017).

On the other hand, maximum values of richness and abundance recorded in the Usumacinta River could be so since it still has good natural conditions of flow and hydrological connectivity, so the heterogeneity of the landscape as a riparian condition represents an important role for aquatic macroinvertebrates. A similar situation occurs with fish diversity, Soria-Barreto et al. (2018) reported 172 species, through a search of bibliographic information and sampling carried out from the Lacantún River in Chiapas to the Centla Swamps in Tabasco and the Palizada River in Campeche. Contrary to the Grijalva River, only 92 species of fish have been listed (Gómez-González et al., 2015).

Conclusions

Present work enriches information on the diversity and trophic groups of aquatic macroinvertebrates in the Grijalva River and Usumacinta River, one of the most important rivers in México, and due to their high water and natural wealth, they not only gather a large part of the biodiversity, but they also contribute 30 % of the country’s total surface runoff.

Analysis of study and temporal zones for each basin allows us to demonstrate difference in macroinvertebrate diversity that exists between them. The Grijalva River had the highest density values represented by the exotic mollusk *Tarebia granifera* with 77 %. Other exotic species were *Melanoides tuberculata* and *Corbicula fluminea*. The Usumacinta River had the greatest richness and diversity of macroinvertebrates. Presence of trophic groups such as fragmenters and collectors are strongly related in the Usumacinta areas with better water quality. This relationship could be because the habitat where they are found has greater vegetation cover. However, trophic groups such as predators and scrapers are strongly associated with the Grijalva areas with lower water quality values and with evident human intervention.

Results confirm that rivers with natural flow regimes and high riparian quality values have greater diversity and trophic levels. The Usumacinta River has a natural seasonal flow corresponding to maximum and minimum flood seasons, providing various resources (habitat, food, shelter, connectivity) to aquatic populations. In addition, it provides various services such as supply and cultural services by obtaining water and food from the river and providing areas for sport fishing and recreation.

However, given the extension, complexity of the landscape, and the hydrological characteristics of the basin, it is necessary to carry out studies at a finer scale such as sub-basins and geomorphological units in such a way that the biogeographic and diversity patterns are explained, not only of macroinvertebrates, but of all the aquatic species that inhabit them.

Riparian habitats of the Usumacinta and Grijalva rivers are compromised by various anthropogenic activities and need urgent attention. Studies are needed to exhaustively evaluate the management of tropical forests to prolong and maintain the ecosystem services that the basins still have and focused on trophic groups, since this constitutes an approach to the ecology of the macroinvertebrate community where greater studies are necessary to understand the effects of changes in aquatic habitats on functional aspects of the community and its relationship with the quality of habitats and their environmental services.

Authors' Contributions

EBM, JJF, sampling design, obtaining financing. EBM, JJF, CTO, FJMV sample collection, species identification, analysis. EBM, JJF, CTO, drafting of the document

References

Albarrán-Melzer, N. C., Rangel-Ruiz, L. J., & Gamboa-Aguilar, J. (2009). Distribución y abundancia de *Melanoides tuberculata* (Gastropoda: Thiaridae) en la Reserva de la Biosfera Pantanos de Centla, Tabasco, México. *Acta Zoológica Mexicana*, *25*, 93-104. https://doi.org/10.21829/azm.2009.251599

Alcérreca-Huerta, J. C., Callejas-Jiménez, M. E., Carrillo, L., & Castillo, M. M. (2019). Dam implications on salt-water intrusion and land use within a tropical estuarine environment of the Gulf of Mexico. *Science of the Total Environment*, 652, 1102-1112. https://doi.org/10.1016/j.scitotenv.2018.10.288

Allan, D. J., Erickson, D. L., & Fay, J. (1997). The influence of catchment land use on stream integrity across multiple spatial scales. *Freshwater Biology, 37*, 149-161. https://doi.org/10.1046/j.1365-2427.1997.d01-546.x

Álvarez, F., Villalobos, J. L., & Lira, E. (1996). Decapoda. II. Grupos de Arachnida y Crustacea. In Llorente-Bousquets, J. García-Aldrete, A. N., González E. S. (Eds.) *Biodiversidad, taxonomía y biogeografía de artrópodos de México: hacia una síntesis de su conocimiento* (pp. 103–132). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad/ Bayer/ Facultad de Ciencias, Universidad Nacional Autónoma de México.

Andrade-Velázquez, M., & Medrano-Pérez, O. R. (2020). Precipitation patterns in Usumacinta and Grijalva basins (southern Mexico) under a changing climate. *Revista Bio Ciencias*, *7*, e905. https://doi.org/10.15741/revbio.07.e905

Ayala-Pérez, M. P., Armstrong-Altrin, J. S., & Machain-Castillo, M. L. (2021). Heavy metal contamination and provenance of sediments recovered at the Grijalva River delta, southern Gulf of Mexico. *Journal of Earth System Science*. *130*, 88. https://doi.org/10.1007/s12040-021-01570-w

Barba-Macías, E., Magaña-Vázquez, M., & Juárez-Flores, J. (2014). Nuevos registros de los gasterópodos *Melanoides tuberculata* (Müller, 1774) y *Tarebia granifera* (Lamarck, 1822) en las cuencas Grijalva, Usumacinta y Tonalá, Pajonal-Machona, Tabasco. In Low Pfeng, M. A., Quijon, P. A., Peters-Recagno, E. M. (Eds.) *Especies invasoras acuáticas: casos de estudio en ecosistemas de México* (pp. 359–379). Semarnat (Secretaría de Medio Ambiente y Recursos Naturales), INECC (Instituto Nacional de Ecología y Cambio Climático) y UPEI (University of Prince Edward Island). https://doi.org/10.1007/978-3-319-90584-6_20

Barba-Macías, E., Mesa-Jurado, M., Espinoza Tenorio, A., & Ortega-Argueta, A. (2018). Biodiversity Conservation in the Pantanos de Centla Biosphere Reserve: Ecological and Socioeconomic Threats: Recent Case Studies. In Ortega-Rubio, A. (Ed.) *Mexican natural resources management and biodiversity conservation: Recent Case Studies*. (pp. 455-477). https://link.springer.com/book/10.1007/978-3-319-90584-6

Barba-Macías, E., Rangel-Mendoza, J., & Ramos-Reyes, R. (2006). Clasificación de los humedales de Tabasco mediante sistemas de Información Geográfica. *Universidad y Ciencia 22*(2), 101-110. https://www.redalyc.org/pdf/154/15422201.pdf

Barba-Macías, E., Sánchez-Martínez, A. J., Raz-Guzmán, A., & Gallegos, M. E. (2000). Dieta natural y tasa de forrajeo del carideo *Hippolyte zostericola* (Smith) sobre epífitas de *Thalassia testudinum* Banks et Solander ex König. *Hidrobiológica*, *10*, 139–146. https://hidrobiologica.izt.uam.mx/index.php/revHidro/article/view/914

Barba-Macías, E., & Trinidad-Ocaña, C. (2017). Nuevos registros de la almeja asiática invasora *Corbicula fluminea* (Bivalvia: Veneroida: Cyrenidae) en humedales de las cuencas Papaloapan, Grijalva y Usumacinta. *Revista Mexicana de Biodiversidad*, *88*, 450–453. https://doi.org/10.1016/j.rmb.2016.10.021

Barba-Macías, E., Carmona-Osalde, C., Quiñones-Rodríguez, L., & Rodríguez-Serna, M. (2015). Registros nuevos de cambáridos (Crustacea: Cambaridae: *Procambarus*) en la cuenca del Grijalva-Usumacinta, Tabasco. *Revista Mexicana de Biodiversidad*, *86*(3), 620-628. https://doi.org/10.1016/j.rmb.2015.04.036

Bass, D. (1995). Species composition of aquatic macroinvertebrates and environmental conditions in Cucumber Creek. *Proceedings Oklahoma Academy of Science, 75*, 39-44.

Benítez-Abud, J. A., Barba-Macías, E., & Juárez-Flores, J. (2016). Composición y distribución de la entomofauna acuática en arroyos de Tabasco, México. *Hidrobiológica, 26*(3), 509-518. https://doi.org/10.24275/uam/izt/dcbs/hidro/2016v26n3/BarbaM

Benstead, J. P., Douglas, M. M., & Pringle, C. M. (2003). Relationships of stream invertebrate communities to deforestation in eastern Madagascar. *Ecological Applications, 13*(5), 1473-1490. https://doi.org/10.1890/02-5125

Bousfield, E. L. (1972). *Shallow water, Gammaridean Amphipoda of New England*. Cornell University Press.

Bond, J. G., Casas-Martinez, M., Quiroz-Martinez, H., Novelo-Gutiérrez, R., Marina, C. F., Ulloa, Orozco-Bonilla, A., Muñoz, M., & Williams, T. (2014). Diversity of mosquitoes and the aquatic insects associated with their oviposition sites along the Pacific coast of Mexico. *Parasit Vectors, 7*(41). https://doi.org/10.1186/1756-3305-7-41

Bueno-Soria, J. (2010). *Guía de Identificación Ilustrada de Los Géneros de Larvas de Insectos del Orden Trichoptera de México.* (1er ed.). México. Universidad Nacional Autónoma de México.

Bueno-Soria, J., & Barba-Álvarez, R. (2011). Trichoptera of Chiapas (in Spanish). In F. Álvarez (Ed.) *Chiapas: estudios sobre su diversidad biológica.* (pp. 345–362). Instituto de Biología, Universidad Nacional Autónoma de México.

Bueno-Soria, J., Santiago-Fragoso, S., & Barba-Álvarez, R. (2005). Insectos acuáticos. In Bueno-Soria, J., Álvarez, F., Santiago S. (Eds.), *Biodiversidad del estado de Tabasco*. (1er ed.) (pp. 195-224). Instituto de Biología, UNAM-CONABIO.

Burch, J. B., & Cruz-Reyes, A. (1987). *Clave genérica para la identificación de gastrópodos de agua dulce en México*. Instituto de Biología, Universidad Nacional Autónoma de México.

Camacho-Sánchez, M. I. (2007). Bioconcentración y toxicidad de metales en el langostino *Macrobrachium rosenbergii* (de Man). *Revista de Toxicología*, *24*(1), 14–17. https://www.redalyc.org/pdf/919/91924103.pdf

Camacho-Valdez, V., Rodiles-Hernández, R., Navarrete-Gutiérrez, D. A., Valencia-& Barrera, E. (2022). Tropical wetlands and land use changes: The case of oil palm in neotropical riverine floodplains. *PLoS ONE*, *17*(5), 1–23.https://doi.org/10.1371/journal.pone.0266677

Cruz, L. C. & Pompeu, P. S. (2020). Drivers of fish assemblage structures in a Neotropical urban watershed. Urban Ecosystems, *23*(4),819–829. https://doi.org/10.1007/s11252-020-00968-6

Carabias, J., Zorrilla, M., Escobedo, A. H., Gallardo, A., Rodríguez, Y., Fernández, A. I., Charruau, P., Martínez, M., & Rodríguez, A. (2015). *Diagnóstico integral de la cuenca baja del Río Usumacinta en Tabasco. Informe técnico. Proyecto TAB-2012-C28-194316. Retos para la sustentabilidad en la cuenca baja del río Usumacinta en Tabasco: ecosistemas, cambio climático y respuesta social. Resumen ejecutivo.* CCGSS-Conacyt.

Cardoso-Mohedano, J. G., Canales-Delgadillo, J. C., Machain-Castillo, M. L., Sánchez-Muñoz, W. N., Sánchez-Cabeza, J. A., Esqueda-Lara, K., & Merino-Ibarra, M. (2022). Contrasting nutrient distributions during dry and rainy seasons in coastal waters of the southern Gulf of Mexico driven by the Grijalva-Usumacinta River discharges. *Marine Pollution Bulletin*, *178*, 113584.

Castillo, D. A. (2011). Ictiofauna del río San Pedro, Balancán, Tabasco, México. [Tesis Doctoral]. El Colegio de la Frontera Sur. Tabasco, México.

Castillo, M. M., Barba-Álvarez, R., & Mayorga, A. (2018). Riqueza y diversidad de insectos acuáticos en la cuenca del rio Usumacinta en México. *Revista Mexicana de Biodiversidad, 89*, 45–64. https://doi.org/10.22201/ib.20078706e.2018.0.2177

Castella, E., Adalsteinsson, H., Brittain, J. E., Gislason, G. M., Lehmann, A., Lencioni, V., Lods-Crozet, B., & Snook, D. L. (2001). Macrobenthic invertebrate richness and composition along latitudinal gradient of European glacier-fed streams. *Freshwater Biology, 46*, 1811-1831. https://doi.org/10.1046/j.1365-2427.2001.00860.x

Chace, F. J. (1972). The shrimps of the Smithsonian-Bredin Caribbean Expeditions with a summary of the West Indian shallow-water species (Crustacea: Decapoda: natantia). *Smithsonian Contributions to Zoology*, (98). https://doi.org/10.5479/si.00810282.98

Comisión Nacional del Agua (Conagua). (2014). Programa de medidas preventivas y de mitigación de la sequía en el consejo de cuenca de los ríos Grijalva y Usumacinta. Consejo de Cuenca de los ríos Grijalva y Usumacinta. https://www.gob.mx/cms/uploads/attachment/file/99961/PMPMS_CC_R_os_Grijalva_y_Usumacinta.pdf

Comisión Nacional de Acuacultura y Pesca (CONAPESCA). (2013). *Anuario estadístico de acuacultura y pesca*. https://fec-chiapas.com.mx/sistema/biblioteca_digital/anuario-estadistico-de-acuacultura-y-pesca-2013.pdf

Cortés-Guzmán, D., Alcocer, J., & Cummins, K. W. (2021). Benthic macroinvertebrates of tropical streams: functional and trophic diversity of the Lacantún River, México. *Limnology, 22*, 313–328. https://doi.org/10.1007/s10201-021-00658-y

Cruz-Ascencio, M., Florido, R., Contreras-Arquieta, A., & Sánchez, A. J. (2003). Registro del caracol exótico *Thiara* (*Melanoides*) *tuberculata* (Müller, 1774) (Gastropoda: Thiaridae) en la Reserva de la Biosfera Pantanos de Centla. *Universidad y Ciencia*, *19*, 101–103.

Cruz-Paz, G., Castillo, M.M., Espinoza-Tenorio, A., Bravo-Peña, L., Valencia Barrera, E., & Mesa-Jurado, M. A. (2018). Áreas prioritarias de conservación en la Cuenca Usumacinta, la aplicación de un enfoque multicriterio. *Investigaciones Geográficas*, *97*. http://doi.org/10.14350/rig.59482

Cumberlidge N., Peter, K. L., Darren, C. J., Magalhães, C., Campos, M. R., Álvarez, F., & Mala, R. (2009). Freshwater crabs and the biodiversity crisis: importance, threats, status, and conservation challenges. *Biological Conservation*, *142*(8), 1665–1673. https://doi.org/10.1016/j.biocon.2009.02.038

Cummins, K. W., & Klug, M. J. (1979). Feeding ecology of stream invertebrates. *Annual Review of Ecology and Systematics*,*10*, 147-172. https://doi.org/10.1146/annurev.es.10.110179.001051

Diario Oficial de la Federación (DOF). (2012). *NMX-AA-159-SCFI-2012: Que establece el procedimiento para la determinación del caudal ecológico*. https://www.gob.mx/cms/uploads/attachment/file/166834/NMX-AA-159-SCFI-2012.pdf

Escalona-Domenech, R. Y., Infante-Mata, D., García-Alfaro, J. R., Ramírez-Marcial, N., Ortiz-Arrona, C. I., & Barba Macías, E. (2022). Assessment the water quality and the riparian quality in the Margaritas River basin, Chiapas, Mexico*. Revista Internacional de Contaminación Ambiental*, *38*, 37–56. https://doi.org/10.20937/RICA.54092

Felder, D. L. (1973). *An annotated key to crabs and lobsters (Decapoda, Reptantia) from coastal waters of the northwestern Gulf of Mexico*. Center for Wetland Resources, Louisiana State University.

Fernández, E. A., Romero, C. R., &Zavala, H. J. (2012). *Atlas Climático de México y Áreas Adyacentes. Volumen 1. Centro de Ciencias de la Atmosfera, Universidad Nacional Autónoma de México.* Servicio Meteorológico Nacional, Comisión Nacional del Agua. https://atlasclimatico.unam.mx/ACM/#1

García-García, A., & Kauffer-Michel E. F. (2011). Las cuencas compartidas entre México, Guatemala y Belice: Un acercamiento a su delimitación y problemática general. *Frontera Norte 23*, (45). https://doi.org/10.17428/rfn.v23i45.840

González del Tánago, M., García de Jalón, D., Lara, F., & Garilleti, R. (2006). Índice RQI para la valoración de las riberas fluviales en el contexto de la directiva marco del agua. *Ingenieria Civil*, *143*, 97-108. https://www2.montes.upm.es/Dptos/dsrn/Hidrobiologia/Publicaciones/INDICE_RQI.pdf

González del Tánago, M., & García de Jalón, D. (2011). Riparian quality index (RQI): a methodology for characterising and assessing the environmental conditions of riparian zones. *Limnetica*, *30*(9), 235-254. https://doi.org/10.23818/limn.30.18

Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, *4*, 1–9. https://palaeo-electronica.org/2001_1/past/past.pdf

Hershler, R., & Thompson, F. G. (1992). A review of the aquatic gastropod subfamily Cochliopinae (Prosobranchia: Hydrobiidae). *Malacological Review Supplement*, *5*, 1–140.

Joshi, P. C., Negi, R. K., & Negi, T. (2007). Seasonal variations in benthic macroinvertebrates and their correlation with the environmental variables in a freshwater stream in Garhwal Region (India). *Life Science Journal*, *4*(4), 85-89. https://www.ephemeroptera-galactica.com/pubs/pub_j/pubjoship2007p85.pdf

Keithly J., Brooker, J., DeForest, D. K., Wu, B. K., & Brix, K. V. (2004). Acute and chronic toxicity of nickel to a cladoceran (*Ceriodaphnia dubia*) and an amphipod (*Hyalella zteca*). *Environmental Toxicology and Chemistry*, *23*, 691–696. https://doi.org/10.1897/02-630

Kolb, M., & Galicia, L. (2012). Challenging the linear forestation narrative in the Neo-tropic: regional patterns and processes of deforestation and regeneration in southern Mexico. *The Geographical Journal*, *178*(2), 147–161. https://doi.org/10.1111/j.1475-4959.2011.00431.x

Laino-Guanes, R., González-Espinosa, M., Ramírez-Marcial, N., Bello-Mendoza, R., Jiménez, F., Casanove, F., & Musálem-Castillejos, K. (2016). Human pressure on water quality and water yield in the upper Grijalva river basin in the Mexico-Guatemala border. *Ecohydrology and Hydrobiology*, *16*, 149 –159. https://doi.org/10.1016/j.ecohyd.2015.12.002

Lamarck, J. B. (1816). Liste des objets représentés dans les planches de cette livraison. In *Tableau encyclopédique et méthodique des trois règnes de la Nature.* Mollusques et Polypes divers.

Lea, I. (1839). Description of new freshwater and land shells. *Transactions of the American Philosophical Society*, *6*, 1-154. https://doi.org/10.70249/9798893984934-005

Li, J., Herlihy, A. T., Gerth, W., Kaufmann, P., Gregory, S., Urquhart, S., & Larsen, D. P. (2001). Variability in stream macroinvertebrates at multiple spatial scales. *Freshwater Biology, 46*, 87-97. https://doi.org/10.1111/j.1365-2427.2001.00628.x

Liévano, A., & Ospina, R. (2007). *Guía ilustrada de los macroinvertebrados acuáticos del río Bahamon.* Universidad del Bosque – Instituto Alexander Von Humboldt.

Linnaeus, C. (1758). *Systema Naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis* (10th ed.). Sociedad Linneana de Londres, BL. https://doi.org/10.5962/bhl.title.542

Marin, C. I. J. (2014). *Diagnóstico de la Calidad del Agua del Río Grijalva en el Periodo 2000-2008*. [Tesis de Maestría]. Instituto Politécnico Nacional, México.

Mata-Zayas, E. E., Gama, L., Vázquez-Navarrete, C., Diaz López, H., Figueroa Maheng, J. M., & Rincón Ramírez, J. (2017). Vulnerabilidad de los servicios ecosistémicos en la zona de influencia costera de la Reserva de la Biosfera Pantanos de Centla, ante la elevación del nivel medio del mar asociada al cambio climático. In Botello, A. V., Villanueva, S., Gutiérrez, J., Rojas-Galaviz, J. L. (Eds.) *Vulnerabilidad de las zonas costeras de Latinoamérica al cambio climático*. https://www.redicomar.com/wp-content/uploads/2018/10/Vulnerabilidad-de-las-Zonas-Costeras-de-Latinoame%CC%81rica-al-Cambio-Clima%CC%81tico.pdf

Mellano-Hernández, S. V., Rangel-Ruiz, L. J., Gamboa-Aguilar, J., de la Cruz, J. A., Montiel-Moreno, J., García-Morales, M., Arias-García, S., Padrón-López, R. M., Pacheco-Figueroa, C. J., & Gama-Campillo, L. (2015). Freshwater mollusk species richness in the Río Grijalva-Villahermosa and Río Tonalá, Lagunas del Carmen-Machona Watersheds from Tabasco, México. *Hidrobiológica*, *25*(2), 239-247. https://hidrobiologica.izt.uam.mx/index.php/revHidro/article/view/481

Mendoza, C. M. (2014). *Vegetación Ribereña: Indicador de la Salud del Río de la Reserva de la Biosfera de la Barranca de Metztitlán.* [Tesis Doctoral]. Colegio de Postgraduados.

Merrit, R. W., & Cummins, K. W. (1996). *An Introduction to the aquatic insects of North America (*3rd ed). Kendall/Hunt.

Merritt, R. W., Cummins, K. W., & Berg, M. B. (2008). *An Introduction to the Aquatic Insects of North America* (4th ed.). Kendall/Hunt Publishing Company.

Metcalfe, R. A., Mackereth, R. W., Grantham, B., Jones, N., Pyrce, R. S., Tim Haxton, Luce, J. J., & Stainton, R. (2013). *Aquatic Ecosystem Assessments for Rivers*. https://dr6j45jk9xcmk.cloudfront.net/documents/2672/stdprod-109908.pdf

Miranda-Vidal, J. F., Barba-Macías, E., Ramos-Reyes, R., Castellanos-Morales, G., & Sánchez, A. J. (2023). *Fish assembly in two tropical rivers with different hydrological flows, southeastern Mexico* (submitted).

Miserendino, M. L., & Pizzolon, L. A. (2003). Distribution of macroinvertebrate assemblages in the Azul-Quemquemtreu river basin, Patagonia, Argentina. *New Zealand Journal of Marine and Freshwater Research, 37*, 525-539. https://doi.org/10.1080/00288330.2003.9517187

Morelet, A. (1849). *Testacea novissima insulae Cubanae et Americae Centralis.* Biodiversity Heritage Library. https://doi.org/10.5962/bhl.title.11067

Müller, O. F. (1774). *Vermium terrestrum et fluviatilium, seu animalium infusoriorum, helminthicorum, et testaceorum, non marinorum, succincta historia*. Biodiversity Heritage Library. https://doi.org/10.5962/bhl.title.12733

Musálem-Castillejos, K., Laino-Guanes, R., Bello-Mendoza, R., González-Espinoza, M., & Ramírez-Marcial, N. (2018). Water quality of the Grijalva river in the Chiapas and Tabasco border. *Ecosistemas y Recursos Agropecuarios, 5*(13), 55–64. https://doi.org/10.19136/era.a5n13.1334

Naranjo-García, E., & Meza-Meneses, G. (2000). Moluscos. In De la Lanza, G., Hernández, P. S., Carbajal P. J. (Eds.) *Organismos indicadores de la calidad del agua y de la contaminación (bioindicadores).* (1er ed.) (pp. 304–404). Comisión Nacional del Agua/ Instituto de Biología, Universidad Nacional Autónoma de México.

Naranjo-García, E., & Olivera-Carrasco, M. T. (2014). Moluscos dulceacuícolas introducidos e invasores. In Mendoza R., Koleff, P. (Eds.), *Especies acuáticas invasoras en México.* (1er ed.) (pp. 337–345). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad.

Ochoa-Gaona, S., Ramos-Ventura, L. J., Moreno-Sandoval, F., Jiménez-Pérez, N. del C., Haas-Ek, M. A., & Muñiz-Delgado, L. E. (2018). Diversidad de flora acuática y ribereña en la cuenca del río Usumacinta, México. *Revista Mexicana de Biodiversidad*, *89*, 3–44. https://doi.org/10.22201/ib.20078706e.2018.0.2395

Ometo, J. P. H. B., Martinelli, L. A., Ballester, M. V., Gessner, A., Krusche, A. V., Victoria, R. L., & Williams, M. (2000). Effects of land-use on water chemistry and macroinvertebrates in two streams of the Piracicaba river basin, southeast Brazil. *Freshwater Biology, 44*, 327-337. https://doi.org/10.1046/j.1365-2427.2000.00557.x

Ormerod, S. J., Durance, I., Hatton-Ellis T. W., Cable J., Chadwick E. A., Griffiths S., Jones T. H, Larsen S., Merrix F.L., Symondson W. O. C., Thomas R. J. & Vaughan I. P. (2011). Landscape Connectivity of Freshwater Ecosystems: Strategic Review and Recommendations. *CCW Contract Science Report* (932).

Pielou, E. C. (1966). The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology, 13*, 131-144. https://doi.org/10.1016/0022-5193(66)90013-0

Pennak, R. W. (1978). *Freshwater invertebrates of the United States*. Wiley.

Puc-Carrasco G, Olivera-Gómez L D, Arriaga-Hernández S, & Jiménez-Dominguez D. (2016). Relative abundance of antillean manatees in the Pantanos de Centla Biosphere Reserve in the coastal plain of Tabasco, México. *Ciencias Marinas, 42*, 261-270. https://doi.org/10.7773/cm.v42i4.2678

Ramos-Herrera, S., Broca-Martínez, L. F., Laines-Canepa, J. R., & Carrera-Velueta, J. M. (2012). Tendencia de la calidad del agua en ríos de Tabasco, México*. Revista Académica de La Facultad de Ingeniería*, *16*(3), 207–217. https://www.redalyc.org/pdf/467/46725267005.pdf

Rangel-Ruiz, L. J., Gamboa-Aguilar, J., García-Morales, M., & Ortiz-Lezama, O. M. (2011). *Tarebia granifera* (Lamarck, 1822) en la región hidrológica Grijalva-Usumacinta en Tabasco, México. *Acta Zoológica Mexicana*, *27*, 103–114. https://doi.org/10.21829/azm.2011.271737

Raz-Guzmán, A. (2000). Crustáceos y poliquetos. In De la Lanza, G., Hernández P. S., Carbajal. P. J. L. (Eds.) *Organismos indicadores de la calidad del agua y de la contaminación (bioindicadores).*(1er ed.) (pp. 265–307). Plaza y Valdés.

Raz-Guzmán, A., & Sánchez, A. J. (1996). *Catálogo ilustrado de cangrejos braquiuros (Crustacea) de la laguna de Tamiahua, Veracruz, México. Cuadernos del Instituto de Biología,* Universidad Nacional Autónoma de México, *Cuaderno 31*, 9-52.

Raz Guzmán, A., Sánchez, A. J., & Soto, L. A. (1992). Catálogo ilustrado de cangrejos braquiuros y anomuros (Crustacea) de la Laguna de Alvarado, Veracruz, México. *Cuadernos del Instituto de Biología, Universidad Nacional Autónoma de México. México, Cuaderno 14*, 3-51.

Röding, P. F. (1798). Pars secunda continens conchylia sive testacea univalvia, bivalvia & multivalvia. In Bolten, J. F., (Ed.) *Museum Boltenianum sive catalogus cimeliorum e tribus regnis naturæ quæ olim collegerat Joa*. Fried Bolten Trapp.

Salcedo-Garduño, M. G., Galaviz-Villa, I., & Pérez-Vázquez, A. (2022). Determining water quality of the lower basin of the Usumacinta River in Tabasco, Mexico. *Agro Productividad*, 23–31. https://doi.org/10.32854/agrop.v15i8.2205

Salcedo-Garduño, M. G., Castañeda-Chávez, M. del R., & Lango-Reynoso, F. (2019). Presión antrópica sobre la calidad del agua en la cuenca baja del Río Usumacinta, Tabasco. In

Galaviz-Villa I., & Sosa-Villalobos C. (Eds.) *Fuentes Difusas y Puntuales de Contaminación. Calidad de Aguas superficiales y Subterráneas.* Instituto EPOMEX; Universidad Autónoma de Campeche; Tecnológico Nacional de México; Instituto Tecnológico de Boca del Río.

Salinas-Rodríguez, S. A., Sánchez-Navarro, R., & Barrios-Ordóñez, J. E. (2021). Frequency of occurrence of flow regime components: a hydrology-based approach for environmental flow assessments and water allocation for the environment. *Hydrological Sciences Journal*, *66*(2), 193–213. https://doi.org/10.1080/02626667.2020.1849705

Sánchez, A. J., Florido, R., Salcedo, M. A., Ruiz-Carrera, V., Montalvo-Urgel, H., Raz-& Guzmán, A. (2012). Macrofaunistic diversity in *Vallisneria americana* Michx. in a tropical wetland, Southern Gulf of Mexico. In Mahamane A. (Ed.) *Diversity of ecosystems.* (pp. 1-26). InTech.

Sánchez, A. J., Salcedo, M. A., Florido, R., Mendoza, J. D, Ruiz-Carrera, V., Álvarez-Pliego, N. (2015). Ciclos de inundación y conservación de servicios ambientales en la cuenca baja de los ríos Grijalva-Usumacinta. *Contactos*, *97*, 5–14.

Sandoval-Rivera, J. P., Sáenz-Arroyo, A., Alcérreca-Huerta, J. C., & Rodiles-Hernández, R. (2022). Impacto histórico de la deforestación y la modificación de los ríos en la morfología de la costa del sur del Golfo de México. *Revista de Historia (Concepción)*, *1*(29), 150–181. https://doi.org/10.29393/rh29-6ihjr40006

Say, T. (1817). Conchology. In Nicholson, W. (Ed.) *American edition of the British Encyclopedia, or, dictionary of arts and sciences comprising an accurate and popular view of the present improved state of human knowledge*. (1st ed.) (pp. 1-20). Mitchell y Ames.

Say, T. (1829). *Descriptions of some new terrestrial and fluviatile shells of North America.* Biodiversity Heritage Library. https://doi.org/10.5962/bhl.title.8024

Secretaría de Economía (2012, 20 de septiembre). *NMX-AA-159-SCFI-2012, Norma que establece el procedimiento para la determinación del caudal ecológico en cuencas hidrológicas*. Diario Oficial de la Federación.

Schertzinger, G., Ruchter, N., & Sures, B. (2018). Metal accumulation in sediments and amphipods downstream of combined sewer overflows. *Science of The Total Environment*, *616–617*, 1199–1207. https://doi.org/10.1016/j.scitotenv.2017.10.199

Shannon, E. C., & Weaver, W. (1963). *The Mathematical Theory of Communication*. University of Illinois. Urbana.

Simpson, E. H. (1949). Measurement of diversity. *Nature* 163:688 https://doi.org/10.1038/163688a0

Soria-Barreto, M., González-Díaz, A. A., Castillo-Domínguez, A., Álvarez-Pliego, N., & Rodiles-Hernández, R. (2018). Diversidad íctica en la cuenca del Usumacinta, México. *Revista Mexicana de Biodiversidad*, *89*, 100–117. https://doi.org/10.22201/ib.20078706e.2018.0.2462

Soria-Reinoso, I., Alcocer, J., Sánchez-Carrillo, S., García-Oliva, F., Cuevas-Lara, D., Cortés-Guzmán, D., & Oseguera, L. A. (2022). The Seasonal Dynamics of Organic and Inorganic Carbon along the Tropical Usumacinta River Basin (Mexico). *Water (Switzerland)*,*14*(17). https://doi.org/10.3390/w14172703

Sowerby G. B. (1832) Characters of New Species of Mollusca and Conchifera, collected by Mr. Cuming. *Proceedings of the Committee of Sciense and correspondence Zoological Society of London*, *2*, 113–120.

Sporka, F., Vlek, H. E., Bulankova, E., & Krno, I. (2006). Influence of seasonal variation on bioassessment of streams using macroinvertebrates. *Hydrobiologia, 566*, 543-555. https://doi.org/10.1007/s10750-006-0073-8

Stone, M. K., & Wallace, J. B. (1998). Long-term recovery of a mountain stream from clear-cut logging: the effects of forest succession on benthic invertebrate community structure. *Freshwater Biology, 39*, 151–169. https://doi.org/10.1046/j.1365-2427.1998.00272.x

Subramanian, K. A., Sivaramakrishnan, K. G., & Gadgil, M. (2005). Impact of riparian land use on stream insects of Kudremukh National Park, Karnataka state, India. *Journal of Insect Science, 5*, 49-59. https://doi.org/10.1093/jis/5.1.49

Sullivan, S. M. P., Watzin, M. C., & Hession, W. C. (2004). Understanding stream geomorphic state in relation to ecological integrity: evidence using habitat assessments and macroinvertebrates. *Environmental Management, 34*(5), 669-683. https://doi.org/10.1007/s00267-004-4032-8

Thorp, J. H., & Covich, A. P. (1991). *Ecology and classification of North American freshwater invertebrates*. Academic Press.

Tomanova, S., Goitia, E., & Helesic, J. (2006). Trophic levels and functional feeding groups of macroinvertebrates in neotropical streams. *Hydrobiologia, 556*, 251-264. https://doi.org/10.1007/s10750-005-1255-5

Trinidad-Ocaña, C., Juárez-Flores, J., Sánchez, A. J., & Barba-Macías, E. (2018). Diversidad de moluscos y crustáceos acuáticos en tres zonas en la cuenca del río Usumacinta, México. *Revista Mexicana de Biodiversidad*, *89*(Supl. dic), 65-78. https://doi.org/10.22201/ib.20078706e.2018.4.2387

Waite, I. R., Herlihy, A. T., Larsen, D. P., Urquhart, N. S., & Klemm, D. J. (2004). The effect of macroinvertebrate taxonomic resolution in large landscape bioassessments: an example from Mid-Atlantic Highlands, U.S.A. *Freshwater Biolology, 49*, 474-489. https://doi.org/10.1111/j.1365-2427.2004.01197.x

Wang, Y., Rhoads, B. L., & Wang, D. (2016). Assessment of the flow regime alterations in the middle reach of the Yangtze River associated with dam construction: potential ecological implications. *Hydrological Processes*, *30*(21), 3949–3966. https://doi.org/10.1002/hyp.10921

Wiggins, G. B. (2000). *Larvae of North American caddisfly genera (Trichoptera)* (2nd ed.). University of Toronto Press.

Williams, A. B. (1984). *Shrimps, lobsters, and crabs of the Atlantic coast of the Eastern United States, Maine to Florida*.Smithsonian Institution Press.

Yáñez-Arancibia, A., Day, J. W., & Currie-Alder, B. (2009). Functioning of the Grijalva-Usumacinta River delta, Mexico: challenges for coastal management. *Ocean Yearbook*, *3*, 479-507. https://doi.org/10.1163/22116001-90000205

Annexe 1. Environmental Characteristics of the Selected Sites in the Usumacinta River; Season (D): Dry, (R): Rainy; Habitat: EMV (Emerged Vegetation, Trees and Shrubs *Phragmites australis, Typha dominguensis*), FFV (free floating vegetation, *Salvinia minima, Eichhornia crassipes)*. SAV (Submerged Vegetation *Vallisneria americana, Cabomba palaeformis*) HA: Human Activities, MI: Marine Influence, RQI: Riparian Quality (Miranda-Vidal et al., 2023).

Section	Depth (m)	Habitat	HA	RQI	MI	Reference Image
Lacantun 90°54’20.083”W 16°12’30.938”N	0.57 (D) 1.08 (R)	EMV Substrate Boulders and Sand, Moderate Current.	Agriculture, Fishing Harvest, Forest Tourism	Very Good	No	
Jonuta 92°05’59.676” W 18°05’42.492” N	0.90 (D) 1.80 (R)	EMV, FFV, Substrate Sand, Gravel, or Mud, and Moderate Current.	Agriculture, Livestock Fishing	Moderate	No	
Tres Brazos 92°37’38.267”W 18°23’50.702” N	1.83 (D) 1.96 (R)	EMV, SAV, Substrate Sand, Silt, and Clay, Strong Current.	Agriculture Livestock Fishing Tourism	Poor	Yes	

Annexe 2. Environmental Characteristics of the Selected Sites in the Grijalva River; Season (D): Dry, (R): Rainy; Habitat: EMV (Emerged Vegetation, Trees and Shrubs *Phragmites australis, Typha dominguensis*), FFV (free floating vegetation, *Salvinia minima, Eichhornia crassipes*). SAV (Submerged Vegetation *Vallisneria americana, Cabomba palaeformis*) HA: Human Activities, MI: Marine Influence, RQI: Riparian Quality (Miranda-Vidal et al., 2023).

Section	Depth (m)	Type of Habitat	HA	RQI	MI	Reference Image
Amacohite 93°26’56.016” W 17°34’40.449” N	1.47 (D) 1.62 (R)	EMV, Substrate Boulders, Gravel, and Sand, Moderate Current.	Agriculture, Fishing Aquaculture Livestock, Forest	Moderate	No	
Ostitan 93°24’14.918” W 17°47’30.883” N	1.05 (D) 1.07 (R)	FFV, Substrate Sandy and with Moderate-slow Current.	Agriculture, Fishing Livestock, Forest River Transport	Poor	No	
Chilapa 92°40’19.311” W 18°15’14.303” N	2.16 (D) 2.53 (R)	EMV, FFV, Substrate Mud and Silt, with Strong Current.	Agriculture, Fishing Livestock	Moderate	Yes	

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This book takes a significant step in showcasing the relevance of limnology to our survival. Freshwater habitats, though they cover less than 1 % of the Earth's surface, are home to a substantial portion of the world's biodiversity—at least 10 % of all known species. Freshwater habitats and the biodiversity they support are under threat. Moreover, our survival depends on access to high-quality freshwater. This book not only highlights the beauty of limnology and the scientific methods used to study it, but it also draws attention to the major causes of biodiversity loss in freshwater ecosystems. It shows all readers what it means to deal with inland waters as a scientist interested in understanding ecosystems and protecting them.

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