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AQUATIC MACROINVERTEBRATES OF THE LERMA RIVER, MEXICAN HIGHLANDS: HIGH WATER REGULATION AND POLLUTION

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Abstract: In this study, the benthic macroinvertebrate community as a bioindicator and the physicochemical conditions of the Lerma River basin are used to evaluate its environmental quality and organic contamination. The applied BMWP Index with the macroinvertebrate community includes parallel water temperature, pH, dissolved oxygen, nitrogen, and total phosphorus records. During May (dry), the river water showed critical water quality with severe contamination; in August (rains), the upper basin presented a range of light to severe contamination, while the middle and lower basin maintained critical quality and highly contaminated water. Dissolved oxygen, pH, total Nitrogen, and Phosphorus with high variability in each site; hypoxia and anoxia conditions related to lentic conditions, as well as values up to 7 mg/L in lotic conditions, alkaline to slightly acidic waters and average nutrients of 4 to 12 mg/L and extremely high in the lower basin. Water quality is in a condition of degradation from the upper basin; macroinvertebrates are pollution indicators that reflect the environmental quality and pollution along the river and in dry and rainy conditions. It also shows the contribution of fertilizers from agricultural activity and nutrient enrichment conditions.
Keywords: regulated river, dams, fertilizers, hipoxia, lentic

INTRODUCTION

There is growing development in evaluation techniques for monitoring the water quality of rivers and estuaries using pollution bioindicators. These techniques emphasize that they are simple, fast, and less expensive than analytical techniques, with repeatability and acceptable scientific validity. Their use accepts their identification at the family level (Hilsenhoff, 1988; Barbour et al., 1999).

Among the most used communities are aquatic macroinvertebrates, including freshwater or estuarine insects, mollusks, crustaceans, and annelids. Each population has a tolerance level to contaminants; Its composition and abundance in time and space reflect sources of contamination, types or permanence of it, even time after the event occurred (Hawkes, 1979; Hellawell, 1986; López-Hernández et al., 2007). At the Family level, the BMWP index uses the total sum of the degree of sensitivity or tolerance to contamination of each Family. The indices thus obtained correspond significantly to the degree of anthropogenic impact (Thorne & Williams, 1997; Mengzhen et al., 2014).

In Mexico, the Lerma-Chapala basin is one of the most important agricultural areas in the central region. Since 1950, problems related to water availability and contamination have increased due to urbanization, industrialization, deforestation, and the increase in agricultural area and decrease in runoff (Mestre, 1997; INEGI, 1993).

The main objective was to evaluate the spatiotemporal variation of aquatic macroinvertebrates and use them as bioindicators of organic pollution in the upper, middle, and lower basins in five different years under conditions of drought and rain in the Lerma River, which is highly controlled at least by seven large reservoirs.

STUDY AREA

The Lerma River belongs to the Lerma-Chapala basin, located between 19º 05' and 21º 32' north latitude and 99º 22' and 103º 31' west longitude, in western central Mexico; it covers an approximate area of 53,391 km^2). The average rainfall is 705-744 mm annually, below the national average of 779 mm. Typically, drought conditions occur in May, and the most high rains occur in August and September. (Mestre, 1997; López et al., 2007)

There are approximately 552 dams and dams in the basin (Cotler & Gutiérrez, 2006), with 25% of the dams classified as large dams, according to the ICOLD classification. There are seven large reservoirs intended mainly for irrigation and various flood channeling and control works (López et al., 2007). More than 1,500 industries, various livestock activities, and important cities with a global population of more than 10 million inhabitants are reported (www.lermachapala.com.mx). The modification of the flow, associated with the release of waste directly into the system, has resulted in it being considered one of the most contaminated regions in the country and with a severe water deficit (Mestre-Rodríguez, 1997; 2002).

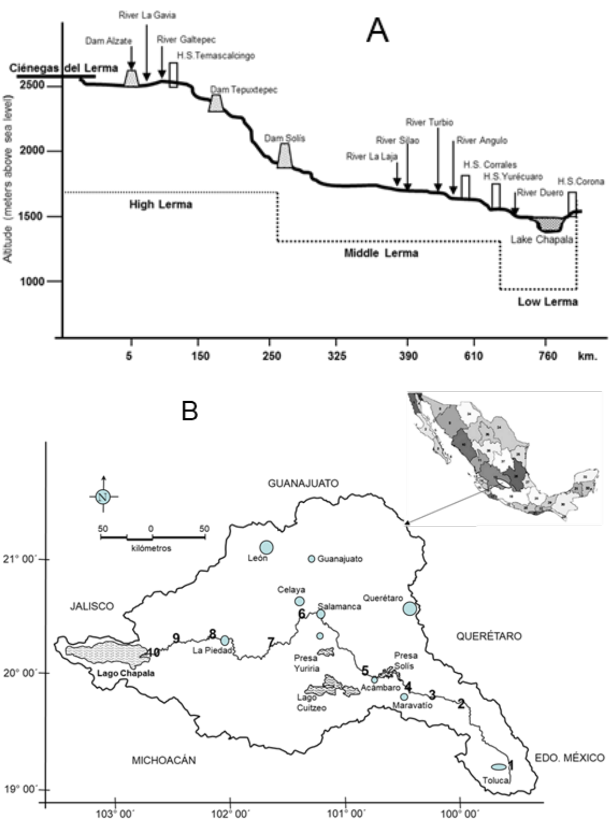

Figure 1. Altitudinal and longitudinal profile of the Lerma River, main dams, tributary rivers and hydrometric stations (HS), adapted from SRH (1977) and López et al. (2007). 1 B. Distribution of work sites, main cities and bodies of water.

METHODOLOGY

In five years, macroinvertebrates and water physicochemistry were sampled in ten sites in the basin in May (dry) and August (rain) (Figure 1B). The collections of aquatic insects included a kick net with a 2 m metal extension in a D shape with a 500 μ mesh opening, considering all available habitats. (Barbour et al., 1999, Merrit et al., 2008). The aquatic organisms were identified at the Family level with several dichotomous taxonomic keys (Mafla, 2005; Mc Cafferty, 1981; Merritt et al., 2008). (Armitage et al., 1983; Mafla, 2005).

With Hydrolab Surveyor II multisensor equipment, at a depth of 20 cm, the physicochemical parameters, Dissolved Oxygen (DO, mg/L), and pH were evaluated in situ. A water sample in a 500 ml glass bottle kept at four °C in a cooler for transfer to the laboratory to analyze Total Nitrogen (TN, mg/L) and Total Phosphorus (TP, mg/L). The methodology recommended by the American Public Health Association (APHA 1999) for the chemical analysis was TN, TP with a HACH DR 2010 spectrophotometer.

RESULTS

The macrobenthos community showed the Classes Turbellaria, Gastropoda, Oliogochaeta, Hirudinea, Crustacea, and Insecta, with 15 Orders and 34 Families, more than 90% in the Facultative or Pollution Tolerant range. The community indicates deterioration of the aquatic environment due to different contaminants. There were two records of indicators of good quality or intolerance to contamination. The BMWP rating with values mostly lower than 6; There were no Families with values of 9 or 10. Table 1

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Phyllum	Clase	Orden	Familia	Rango	BMWP
Platyhelminthes	Turbellaria	Tricladida	Planariidae	F	5
Mollusca,	Gastropoda	Basommatophora	Physidae	F	5
		Heterodonata	Sphaeriidae	F	3
Annelida	Oligochaeta	Haplotaxida	Tubificidae	T	3
	Hirudinea	Pharyngobdellida	Herpobdellidae	T	3
		Rhynchobdellida	Glossiphonidae	T	1
Arthropoda	Crustacea	Isopoda	Asellidae	F	3
		Amphipoda	Gammaridae	F	7
		Decapoda	Cambaridae	T	3
	Insecta	Ephemeroptera	Baetidae	F	3
			Tricorythidae	F	5
			Siphlonuridae	I	8
		Odonata	Coenagrionidae	F	8
			Lestidae	F	4
			Libellulidae	F	6
			Corduliidae	I	8
		Hemíptera	Belostomatidae	T	4
			Corixidae	F	4
			Notonectidae	F	4
			Veliidae	F	4
			Naucoridae	F	4
			Mesoveliidae	F	4
		Tricoptera	Hydropsychidae	F	5
			Polycentropodidae	F	6
		Coleoptera	Elmidae	F	5
			Dytiscidae	T	4
			Gyrinidae	F	4
			Hydrophilidae	T	4
		Diptera	Culicidae	T	2
			Chironomidae	F	2
			Simuliidae	F	4
			Tipulidae	F	4
			Stratiomydae	F	4
			Syrphidae	T	1
Phyla 4	Class 6	Order 15	Family 34	F 23, T 9, I 2	

Table 1. Families found in the sampling sites have ranges of tolerance to contaminated media (Wilhm, 1975). The BMWP is rated according to the degree of quality and contamination of the water (Mafla, 2005). I= intolerant; F=facultative; T = tolerant.

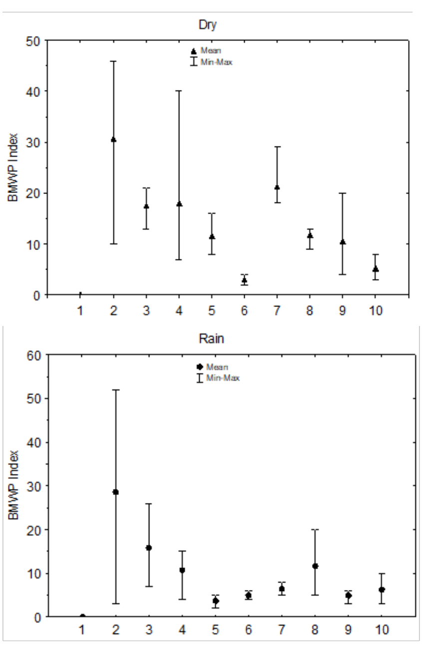

Figure 2. Variations in the 5-year average (n=5), maximum, and minimum values of the BMWP index, a high difference in the limits of the values, and few changes in the averages.

Dissolved oxygen presented values of hypoxia (1-2 mg/L) and anoxia (< 1 mg/L) in sites 1 and 2 in drought and rain; in drought, from sites 3 to 10, the concentrations were between 2 and 7.5 mg/L, with substantial variations in each site, from conditions close to hypoxia (< 2-4 mg/L) to 7 mg/L and with averages between 3 and 5.2 mg/L. In rainy conditions, sites 1 and 2 had values similar to those in the dry season, and from sites 3 to 10 there were anoxia values in site 6 and hypoxia in the remaining sites, averages between 2.8 and 4.3 mg/L. Figure 3a

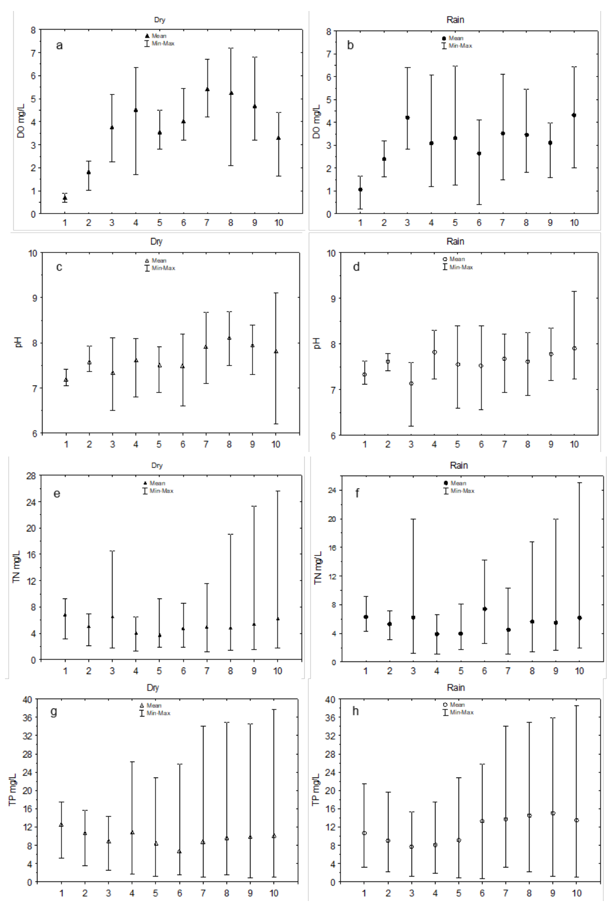

Figure 3. Variations in the 5-year average (n=5), maximum, and minimum values of Dissolved Oxygen (DO), pH, Total Nityrogen (TN) and Total Phosphorous (TP), high variability in space but not in time. Anoxia-hypoxia, semi acid values at upper basin, overfertilized waters in low basin

The pH of dry and rainy conditions was similar, from acidic conditions with pH 6.3 to alkaline conditions with pH 9.1, on average, from site 1 with pH 7.2-7.4. there were increases until reaching pH 7.9 in site 10; from site 3 to 6, corresponding to the area with solid pig farming activity, the minimum values of acid condition 6.5

TN with highly variable concentrations consistently above 2 mg/L, maximum values up to 25 mg/L in dry conditions and 24.2 mg/L in rainy conditions: On average, there was a range of 3.8-7.2 mg/L in dry conditions in sites 5 and 1, respectively. Figure 3e: In rainfall, the range was 5.9-12.2 mg/L in sites 6 and 1. Site 1 has the highest concentrations, and sites 5 and 6 have the lowest. Figure 3f TP in dry conditions with very high concentrations, minimums of 0.9 mg/L sites 5 to 10 and maximums of 25.9-37.3 mg/L between sites 4 -10, averages of 6.8-12.1 mg/L in sites 3 and 10; Figure 3g: Rainfall with minimums in the range 0.2-3.8 mg/L, maximums 23.9 to 37.3 mg/L from sites 5 to 10; in the averages, the range was 7.9 to 13.2 mg/L. Figure 3h

DISCUSSION

The macroinvertebrate community of the Tula River has practically no indicator organisms of good water quality, such as insects of the Order Plecoptera; There were few families from the Orders Ephemeroptera and Trichoptera and more from the Hemiptera and Diptera, resenting the negative effect of the wastewater in which they live (Ceneviva-Bastos et al., 2017).

More than 90% of the Families are facultative or tolerant to pollution (Wilhm, 1975; Mustow, 2002), adapted to conditions of hypoxia and anoxia, to high concentrations of nutrients and, therefore, organic matter; despite being contaminated, in sites 4 and 8, due to the effect of nearby uncontaminated tributaries, there is occasional presence of populations intolerant to contamination.

The low presence of families intolerant to pollution is related to agricultural activities, human densities, and the increase in the values of polluting chemicals (Parr & Mason, 2003). The conditions of environmental quality and contamination based on the BMWP index reflected the conditions of doubtful water quality and contamination, as well as critical quality and doubtful highly contaminated waters. Using macroinvertebrates, Bueno et al. (1980) found that diversity decreased along the course of the Lerma River and was even null in some sites, which agrees with the results of this five-year study.

The conditions of the type of flow, current speed, the slope of the terrain, as well as anthropogenic activities and their waste in the channel, influence the physicochemical dynamics. In the case of dissolved oxygen (DO) at site 4, turbulent flow conditions always favor high concentrations of this dissolved gas. On the contrary, in localities where the water supply control significantly reduces the flow through dams or different diversion works, in addition to the permanent dumping of urban, industrial, and livestock waste, dissolved oxygen is strongly reduced, as found between sites 5 and 7. In sites 8 to 10 an almost lentic or stagnant system, high concentrations of DO are found, probably due to photosynthetic activity and high concentrations of nutrients incorporated into the river by runoff from the irrigation districts of that area, where the use of fertilizers is frequent.

During the dry season, the flow decreases alarmingly due to excessive dam retention. Site 6 frequently lacks water; previous sites 4 and 5 retained water by placing barriers with sandbags or shallow excavations. Water retention and drought promote concentrations that exceed permissible limits of organic pollutants such as toluene, gasoline, phenols, and sometimes agrochemicals (Hansen & Van Afferden, 2001).

This study shows that there is a degradation of water quality from the upper basin; Solís Dam shows a positive influence on the physicochemistry during the residence time and microbiological and limnological processes; after its release, there are better oxygen conditions and a decrease in nutrients; The positive effect of rain is the increase in flow and favoring oxygenation in the water, but transporting more nutrients (Miyake & Akiyama, 2012). High variations in precipitation and high evaporation rates in the different dams and the excessive use of water in irrigation, industry, and urbanization promoted a decrease in water levels in the main channel, thus increasing pollutants, salts, and inorganic nutrients. (Aparicio, 2001)

The water of the Lerma River is considered suitable for industrial and agricultural use, but with prior treatment, some restrictions for these two activities are even determined, making it unacceptable for fishing and aquatic life (SEMARNAT, 2001).

CONCLUSIONS

The use of macroinvertebrates as pollution indicators was appropriate. It efficiently reflected the hydrological and physicochemical conditions of the system along the river and in dry and rainy conditions. It also showed the contribution of fertilizers from agricultural activity and the conditions of nutrient enrichment.

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