2011 2nd International Conference on Chemical Engineering and Applications
IPCBEE vol. 23 (2011) © (2011) IACSIT Press, Singapore

How to restore riverbanks in natural ecosystems with many people using ecological services at the same time?

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Abstract. Most of Mexico is not a territory characterized by great rivers, but rather, for temporary creeks and rivers with permanent riverbeds but with big seasonal fluctuations. The hydro period in these zones are very important, being outlined a rapid phase of rise, a period of stabilization of currents with big flows, a phase of water decrease that is very slow and finally, a period in which the river has very few water and slow current. These fluctuations are difficult to predict and rarely they are similar in ecological spirals at a short time, for what the use of the river bank, riparian and flow resources is chaotic and disordered. Local populations composed in many cases by indigenous communities are the owners of the land and by law, of the natural resources of the land. So they are using their resources as much as they can. In addition, the rivers in better condition of conservation, including their hydrological basin, are located in places with many social problems. And where indigenous people and other communities are in extreme poverty conditions. So, the way in which they use their natural resources is closer to the philosophy "bread for today, hunger for tomorrow" than that of the sustainability. And though the efforts for preserving the ecological processes of these ecosystems, connected in network with other basins are under the paradigm of the "integral ecology", the question that is still latent is: How is it possible to restore a riverbank if there is not known thoroughly the ecological functioning of the ecosystem and its functional interaction by the ecological bordering systems, if in addition all these systems are being chaotic overexploited by people in order to satisfy their primary needs of subsistence? The aim of this study was to outline the next step in the ecological description of a natural ecosystem that deserves to be preserved while still operated.

Keywords: freshwater habitats, running waters, intermittently flowing.

1. Introduction

The Mexico is an extremely diverse country in types of ecosystems, which has originated that also be mega diverse in biological species, to such a degree that is considered to be one of the five countries with more biodiversity of the world. High ecodiversity of México is primarily due to its geographical position, the two biogeography zones that compose it, to its high and extensive mountains chains (sierras) that cross in a transverse way (north-south direction). And that along the last 35 million years the erosive processes of the water and of the wind have formed deep canyons difficult to cross for many species and that you have propitiated development of endemism and rare species. The hydrographical Mexican basins reflect all this ecodiversity since they darn big desert regions, wooded zones and jungle and tropical rain forest areas until the get the two seas that border Mexican geography (Pacific and Atlantic oceans) (1).

Nevertheless, Mexico is not a country of many great and permanent rivers. Most of Mexican geography is characterized by temporary creeks, and by some permanent rivers but with huge seasonal fluctuations. The hydro period in these zones are very important, being outlined a rapid phase of rise, a period of stabilization of currents with big flows, a phase of water decrease that is very slow and finally, a period in which the river has very few water and slow current. These fluctuations are difficult to predict and rarely they are similar in ecological spirals at a short time, for what the use of the river bank, riparian and flow resources is chaotic

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and disordered (2). Rain season is very important because the river flow rise more than 100 times in just one or two days of extremely high rains. The great flow of the river persist approximately two weeks, and then water decrease slowly during about two months. After that, rivers looks like a small creek. The concern is that we do not know when does the river will growth, how long will last the mighty flow or when (if does) does the river will start to decrease. All these changes lead to changes in the biological composition of the river and its river shed and hydrological basin.

In addition, local human populations composed in many cases by indigenous communities are the owners of the land and by law, of the natural resources of the land. So they are using their resources as much as they can. But also, the rivers in better condition of conservation, including his hydrological basin, are located in places with many social problems, and where indigenous people and other communities are in extreme poverty conditions. So, the way in which they use their natural resources is closer to the philosophy "bread for today, hunger for tomorrow" than that of the sustainability (3). And though the efforts for preserving the ecological processes of these ecosystems, connected in network with other basins are under the paradigm of the "integral ecology", the question that is still latent is: How is it possible to restore a riverbank if there is not known thoroughly the ecological functioning of the ecosystem and its functional interaction by the ecological bordering systems, if in addition all these systems are being chaotic overexploited by people in order to satisfy their primary needs of subsistence?

2. Objective

Thepurpose of this paperis to delineatesome strategies forintegrated river basin management, particularly in the systemsinmore populatedby menwithdesirable characteristics ofbiological conservation.

3. Materials and methods

3.1. Study area

Due to the vast geography of Mexico, we eill exemplify the work in a region that holds much of the ecodiversity of the country, as it has all the rivers flow, temporary, permanent, altitudes, vegetation types and is located in central Mexico, in the transition zone between the Nearctic and Neotropical region, covering part of the new volcanic axis and part of the Eastern Sierra Madre Oriental. In sum, it is a regon that can be used as an experimental model and easily natural and politically boundary: The State of Querétaro.

Querétaro is located in the Central part of the Mexican Republic. It is in the junction of the Neartic and Neotropical Biogeographical regions, including three physiographical provinces: Neovolcanic axis, the Central Plateau (Bajío) and the Sierra Madre Oriental. Two hydrological basins cross the state: The basin of the Lerma-Santiago river system (south-western part of the state) and the basin of the Moctezuma-Pánuco river system (from centre to north-eastern part of the state) (Figure 1). Because of the high variation in altitude (0 to +2500 m above sea level) and the three climates identified (warm, dry, temperate), the following types of vegetation are found in this area: desert scrub, thorn woodlands, pine forest, oak forest, temperate hardwood forest, low tropical deciduous forest and agricultural lands.

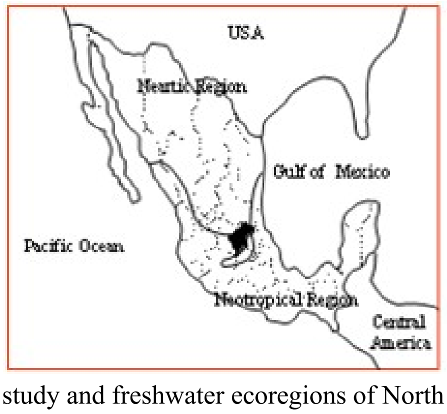

Figure 1. Location of the area of study and freshwater ecoregions of North America that comprises Querétaro

3.2. Sampling

Habitat factors, biotic and abiotic, were sampled fortnightly. Aquatic fauna were sampled with hand nets (shallow water ponds, less than 2 m depth), by skin diving (ponds between 2 and 5 m depth; and rivers), and electro fishing (slow streams and springs) from 1994-2006. Although the State of Querétaro has a lot of hypogean lotic and lentic waters, only epigean waters were sampled. In order to evaluate possible differences related to adaptation processes due to seasonality of their habitats (we sampled many vernal pools). Habitat parameters such as water quality (physicochemicals), geomorphology of the ecosystem (geological origin of the ecosystem, maximum width, mean width, depth, and substrate), and plant and terrestrial fauna composition (community of macrophytes, vertebrates and other macroinvertebrates) were documented at all river and stream sections and at different areas of each pond. Two kinds of data were analysed: cross sectional and longitudinal comparison using morphological and physiological data of crayfish individuals. All sampling sites were located in a map using a Garmin GPS 12 XL. Two databases were elaborated using the computer program developed by the National Council for the use and knowledge of biodiversity (CONABIO, in Spanish), called BIOTICA 3.2 (4), Using this program, environmental data can be associated to a georeferenciated distribution polygon of each species, producing a digital matrix of sizeable localities versus paired values of environmental conditions.

The uses of the natural resources by the local population it was estimated by means of specific interviews for every studied region (ecotopos). We have also included in the database if the users are indigenous, if they speak Spanish or only his native language, if they are half-caste but native of the region or if they are immigrant. Likewise, we take information of the economic and social status of the local human communities and what other economic options they might have if his natural resources were limited in his uses by law; or what will happen to them if we try to declare their region like natural protected area.

4. Result discussed

A total of 31 ecosystems and 86 ecotopes were sampled. One new crustacean species (*Procambarusyagoii*) for the science was reported. Most of the human communities in the Sierra and in the top of the high mountains of the volcanic axe belong to indigenous groups like Otomies, Nahuas, Pahmes and Chichimecans. Local human communities are characterized by using their natural resources intensively, within its capabilities, without control (legal or not) and are classified by National Institute of Geography as high social and economic backwardness.

Table 1. List of the analyzed sites, name of the type locality georefered, and habitat type

County of Querétaro	Sampling Site	HR (Basin)[1]	Habitat	Altitude[2]	UTM[3] (x)	UTM (y)
Amealco	Llano Largo	HR-12 (Lerma)	Lentic	2280	366900	2242100
	San Ildefonso	HR-12 (Lerma)	Lentic	2280	399300	2233500
	Tlaxcaltepec	HR-12 (Lerma)	Lentic	2460	382600	2224200
Cadereyta de Montes	El Boyecito	HR-26 (Pánuco)	Lotic	2090	424100	2286900
	El Pathé	HR-26 (Pánuco)	Lotic	1790	426900	2277900
Colón	La Esperanza	HR-26 (Pánuco)	Lentic	2000	384400	2283300
Corregidora	Presa El Batán	HR-12 (Lerma)	Lentic	1890	351900	2267800
El Marques	Pocitos	HR-12 (Lerma)	Lentic	2080	363400	2300300
Ezequiel Montes	Presa San Antonio	HR-26 (Pánuco)	Lentic	1950	401300	2281600
Humilpan	El Vegil	HR-12 (Lerma)	Lentic	2070	359500	2259600
	Nuevo Vegil	HR-12 (Lerma)	Lentic	2080	359500	2259600
	San Pedro	HR-12 (Lerma)	Lentic	2280	366900	2253400
Jalpan de Serra	La Saldiveña	HR-26 (Pánuco)	Lotic	800	448800	2350700
Landa de Matamoros	Agua zarca	HR-26 (Pánuco)	Lotic	1300	490200	2346200
	Río verdito	HR-26 (Pánuco)	Lotic	1300	487900	2350400
	Neblinas	HR-26 (Pánuco)	Lotic	584	490500	2335500
	Tangojó	HR-26 (Pánuco)	Lotic	484	485000	2333900
Pedro Escobedo	Los Cues	HR-12 (Lerma)	Lentic	2000	368000	2267200
	San Fandila	HR-12 (Lerma)	Lentic	1980	373400	2267600
Pinal de Amoles	Bucareli (Los Plátanos)	HR-26 (Pánuco)	Lotic	1100	436200	2326300
Querétaro	Corea	HR-12 (Lerma)	Lotic	1950	346700	2294700
	Jurica	HR-12 (Lerma)	Lentic	1900	348400	2294700
	Pie de Gallo	HR-12 (Lerma)	Lentic	2100	344500	2299000
San Juan del Río	El Organal	HR-26 (Pánuco)	Lentic	1980	390100	2269300
	La Llave	HR-26 (Pánuco)	Lentic	1900	396200	2263200
	Presa Constitución 1917	HR-26 (Pánuco)	Lentic	1980	385000	2256000
	Río San Juan	HR-26 (Pánuco)	Lotic	1920	396000	2254700
Tequisquiapan	El Divino Redentor	HR-26 (Pánuco)	Lentic	1975	394200	2262800
	Paso de Tablas	HR-26 (Pánuco)	Lentic	1900	412500	2271800
	Presa Centenario	HR-26 (Pánuco)	Lentic	1880	406600	2268300
	Río San Juan	HR-26 (Pánuco)	Lotic	1880	406900	2269300

List of localities are by alphabetical order of the County and then by sampling site. [1]HR: Mexican hydrological region (Basin of the river system Lerma-Santiago or Basin of the river system Moctezuma-Pánuco). [2]Altitudes are in meters above the sea level; [3]UTM's are in meters.

One of the thrusts of modern ecology is to identify areas of biological importance based on their great biodiversity, species richness, endemism, and biological distinctiveness (5). It is also very important for conservation biology to identify species assemblages that inhabit these special areas or the highly specialised, unique or restricted habitats, since they are considered to be especially vulnerable to extinction (6). The watersheds of Querétaro have most, if not all of this traits, since they are located in the junction of Biogeographic regions (Neotropic and Neartic), three freshwater of North America ecoregions 1) Río Verde Headwaters; 2) Tamaulipas-Veracruz; and 3) Lerma, and in the transition area of three physiographic provinces: 1) Neovolcanic sierras and plains, 2) Mexican high plateau and 3) Eastern Sierra Madre. These ecoregions are characterised by endorheic, xeric and subcoastal rivers, lakes and springs. Under this perspective, the geographic position of Querétaro raises interesting biogeographical questions about the origins of its fauna, much of which is endemic (7) (See Table 1).

Two areas from Querétaro are considered Priority Class I for North America freshwater ecosystems conservation because they remain relatively un-degraded and have high biological distinctiveness levels (8). These two hot spots are the section of the Lerma river located in the state of Querétaro, and the Moctezuma basin. In the ecoregion Lerma, although there are few small-protected areas the most important threats for aquatic biota are alteration of the habitats, pollution, and heavy surrounding land uses (especially industry). Exotic fauna, mainly fishes (for instance: carps *Cyprinus carpio*, black bass *Micropterus salmoides* and *Carassiusauratus*), are of considerable impact to the local biota (9). The Moctezuma basin hot spot is distinguished by a high degree of endemism in fish and crayfish (10). Although this area is located in the Sierra Gorda Biosphere Reserve, and there is one small-protected area such as National Park in San Joaquín municipality, species are threatened by overexploitation of water, especially underground water, salinisation from agriculture and industry, human population pressure, and introduction and translocation of exotic species. These exotic species are fishes such as tilapias *Oreochromis mossambicus*, *Oreochromis aureus* and *Oreochromis niloticus*, *M. salmoides*, sun fish *Lepomismacrochirus*, and one native cichlid *Cichlasoma cyanoguttatum*. It is important to note that locals report that they have found exotic big crayfish in their waters (Concá river), though we never caught any. These exotics may be the consequence of efforts to culture *Cherax destructor* and/or *Cherax quadricarinatus* since 1995 in this area.

Whereas some aquatic endemic macroinvertebrates species has not been severely affected by human activities and it is currently invading degraded environments of the Moctezuma river basin, *Procambarus* spp. (the biggest crustacean in the area and one of the key stone species detected to keep the principal energetic routes of the ecosystem) is very sensitive to human perturbations. Major threats to *Procambarus* spp. are habitat loss and fragmentation of habitat, since all of the species that belong to this genus have restricted distributional ranges. Moreover, these species exist as relict populations, especially in "the Bucareli arroyo". Gilpin and Soulé (11) and Taylor (6) stated that species with narrow distributional ranges should not be denied conservation attention, because they are extremely vulnerable to extirpation. Thus, the *Procambarus* species in Querétaro, must be listed in the red book of threatened and endangered species from México, and they must be considered a priority for their preservation (1).

Because modern practices in Conservation Biology are trying to protect habitats and/or ecosystems rather than to preserve species alone, it is very important to improve the efforts of conserving the ecological processes of the ecosystems from the Sierra Gorda Biosphere Reserve, where as with crayfish, these areas also have many endemic fish such as *Notropis sellaei*, *Ictalurus australis*, *Ictalurus mexicanus*, *Gobiomorus dormitor*, and *Pilodictis olivaris* (Gutiérrez-Yurrita and Morales-Ortiz 2000); rare species of dragonflies from the genus *Myathiria*, *Dythemis* and *Progomphus* (7); among other groups of hydrophytes or plants associated to water (*Thypha latifolia*, *T. Mucronatum,Platanus mexicana, Ludwigia peploides*, *Hydrocotytle ranunculoides*, *Mimulus glabratus*, *Zannichellia palustris,Callitriche deflexa* for instance) (12). More important, in a few streams that flow into the Moctezuma river, near Tangojó (Landa de Matamoros municipality) *Procambarus* sp. is sharing habitats with two other endangered species of macrocrustacean: *M. carcinus* or *M. olfersi*. Because the major threats for this unique biota are habitat loss, habitat deterioration, pollution and introduction of exotics, the management action plans could focus on the necessary actions for a reasonable (sustainable) management of the biota habitat (the ecological functioning of their ecosystems)

(13). At present, any wise use of the ecosystems has considerable potential for improving the survival of the native, endemic and endangered species populations.

5. Conclusions

The use of natural resources in the best preserved natural areas is more intensive than in other areas and their rate of environmental deterioration and ecological degradation is higher. The difference in degradation areas is that in the best preserved areas are indigenous groups who make use of those resources with its technological capabilities and knowledge of the environment. However, their social status behind, with no short-term productive options, makes selling their land to large trade-groups with great capital to exploit them with modern machinery. Thus, these people communities in addition to losing what little they have, will be displaced to the cities or immigrate to the United States. The field will be abandoned and the ecological integrity of resilient ecosystems will be lost before the next decade.

In the future, computer simulations of metapopulation survival over multiple generations, and molecular analysis of the biota populations, to elucidate their systematic status and to prevent their extinction are necessary. Furthermore, hypogean waters must be sampled and ecologically characterised because all of these areas have many subterranean rivers and lakes that may be connected to subterranean and/or epigean rivers from the neighbouring States (San Luis Potosí, Veracruz and Hidalgo). Extraordinary attention is needed to hypogean fauna from these states, because they have a lot of species listed in the Mexican red book (NOM-059-SEMARNAT-2010) and inhabit one of the most important protected natural areas of México, the Sierra Gorda Biosphere Reserve. Further studies concerning the ecology and physiology of cave biota should also be a research priority to determine levels of environmental flexibility of these forms. In addition, studies to understand how to preserve, not only the species, but also the ecological processes of these singular ecosystems are needed. The problem remains the same, you can not preserve the ecological integrity with a people hungry. And there is no real options to remove them out of poverty, at least in the short term.

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