Subsistence fisheries in the Sierra Manantlán Biosphere Reserve (Jalisco/Colima, Mexico)

Pesquerias de susbsitencia en la reserva de la Biosfera, Sierra de Manantlán (Jalisco/Colima, Mexico)

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Resumen. Las reservas de la biósfera enfrentan el doble objetivo de proteger ecosistemas ejemplares y proveer a las comunidades locales con oportunidades de desarrollo. Las pesquerías de subsistencia están presentes en muchas áreas protegidas en México, pero son poco conocidas. Los pescadores de subsistencia tienen pocas oportunidades para expresar sus opiniones acerca de la calidad de los ecosistemas de los cuales dependen para sobrevivir. Utilizamos encuestas para describir las pesquerías de subsistencia del Río Ayuquila, (Jalisco, Colima, México) y documentar las perspectivas que los pescadores tienen de la calidad ambiental del río y el manejo que se le da al mismo. La pesquería de subsistencia en el Ayuquila tiene gran importancia para las comunidades rurales de la Reserva de la Biósfera Sierra de Manantlán, pero está poco organizada, y es secundaria en importancia a actividades agropecuarias en la región. La pesquería ha sido afectada por la contaminación y la sobreexplotación, pero esfuerzos realizados por la dirección de la reserva y los gobiernos locales han resultado en mejoras a lo largo del tiempo. Estas mejoras se ven reflejadas en las opiniones que los pescadores tienen acerca de la situación ambiental actual del río, y de las instituciones que se encargan de darle manejo. Describimos cómo procesos regionales han afectado al manejo que se da al río e identificamos áreas donde es posible mejorar su situación. El empoderamiento de los pescadores de subsistencia es posible a través de su participación en encuestas como las que aquí presentamos y que pueden ser utilizadas por instituciones regionales para mejorar las condiciones de vida de los pobladores y las estrategias de conservación de recursos naturales.

Palabras clave: pesquerías de subsistencia, áreas naturales protegidas, pesquerías de río, Jalisco, Colima, Río Ayuquila

Abstract: Biosphere reserves are charged with the challenging dual objectives of protecting exemplary ecosystems and providing local communities with opportunities for development. Small-scale, subsistence fisheries occur in many protected areas in Mexico, but little is known about their characteristics. Additionally, subsistence fishermen rarely have the possibility to express their opinions on the quality of the ecosystems they depend on for survival. We used surveys to describe the Ayuquila River (Jalisco, Colima, western Mexico) fishery and document the fishermen's perspective towards environmental quality and river management. The subsistence fishery of the Ayuquila has major importance for rural communities in the Sierra de Manantlán Biosphere Reserve, but it is little organized and is secondary to agricultural activities in the region. The fishery has been affected by environmental problems including pollution and overexploitation, but regional efforts by the biosphere reserve and local governments have resulted in fishery improvement over the years. These events are reflected in the opinions that fishermen have of the current environmental situation of the river and of the institutions involved in conservation efforts. We describe how regional processes have affected river management and identify areas for further improvement. We suggest that empowering subsistence fishermen via their participation in surveys undertaken by regional institutions is a viable strategy to improve wellbeing of rural communities and natural resource conservation.

Key Words: subsistence fisheries, natural protected areas, river fisheries, Jalisco, Colima, Ayuquila River

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Introduction

Biosphere reserves serve the multiple purposes of conserving, studying, and protecting natural resources; conserving vital and exemplary ecosystems; and allowing the sustainable development of rural communities living within them; among others [1]. Rural communities are thus an integral part of natural resource conservation within reserve boundaries. Understanding the relationship of these communities to the natural resources required for their sustenance is key in achieving biological conservation strategies. The connectedness of native people to the resources they depend on for survival requires the attention of those responsible for regional decision-making processes [2]. People who depend directly on natural resources have a better understanding of them than those who have alternative sources for economic and social satisfaction [3].

Freshwater fisheries constitute an important source of protein and income for residents of rural communities [4,5], but in recent years many small-scale fisheries have collapsed due to ineffective governance [6]. Approximately 70% of the world's freshwater fishery production is obtained in developing countries, and most of it is used for domestic consumption [7]. Small-scale, dispersed, river fisheries in many parts of the world are used by local communities for sustenance [8-10]. In Mexico, a few published studies have shown that subsistence fishing is carried out with simple methods and inexpensive gear, and that it complements activities such as agriculture, cattle ranching, and timber extraction among other activities [10-12]. The importance of such fisheries as monetary and nutritional sources has recently increased, replacing traditional activities that are no longer economically important [13].

Subsistence fisheries are present throughout Mexican west coast (Pacific drainage) rivers but are poorly known [14]. Increasing our knowledge of these fisheries is of paramount importance for natural resource management and for assuring the long-term wellbeing of human communities that depend on them [12, 15].

Inclusive participation of members of rural communities in policy and management strategy implementation is key to the success of biosphere reserves [1]. Community opinions and interests should be reflected in biosphere conservation and management policies and activities. This is especially important when the natural resources these communities depend on are both subject to protection and affected by human activities occurring beyond the borders of the reserves. Communities along rivers where fishing is a primary subsistence activity can be affected by multiple human activities occurring upstream and downstream in the basin. Along with biosphere managers, fishing communities share an interest in protecting riparian resources. Thus, reserve managers, rural communities, and other stakeholders with interests in the protection and use of resources that can affect the reserve should co-participate in reserve management decision-making processes.

In this paper we make use of field data obtained via interviews and observations to address three main goals: 1) to increase knowledge about the subsistence fisheries in rivers of west central Mexico, 2) document the opinions and attitudes that rural fishermen have of the influence a biosphere reserve has on the resources they depend on, and 3) describe the role of regional institutions in fishery protection. To achieve these goals, we first describe the fishery of the Ayuquila River, which borders the Sierra de Manantlán Biosphere Reserve (Jalisco, Mexico). Then we present and analyze the opinions and attitudes that fishermen in the Ayuquila have of the environmental problems of the river. Finally, we discuss how various institutions have interacted to create management strategies for the watershed.

Materials and methods

Study system: The Sierra de Manantlán Biosphere Reserve (SMBR) is located in the north-western portion of the Sierra Madre del Sur ~50 Km inland from the Pacific Ocean in West Central Mexico (Fig. 1). The Ayuquila River is the northeastern boundary of the SMBR and is one of two main sub-basins in the Armería River basin. The Ayuquila originates about 100 Km north of the SMBR (where it is called the Ayutla River) and flows along the northern boundary of the reserve for about 40 Km before joining with the Tuxcacuesco River to form the Armería, which empties into the Pacific Ocean (total length ~ 240 km). This study focuses on a ~80 km segment of the Ayuquila that runs from the town of El Corcovado, ~1 km upstream from the valley of the cities of Autlán and El Grullo, through the valley, into and along the biosphere reserve, and downstream to the town of El Paso Real where the river exits the SMBR.

The Ayuquila River is an important source of water for irrigation in the region, and irrigation activities have important effects on water quantity and quality that influence the fishery of the river in the SMBR. Upstream from the study area, the Ayuquila has two large (>15 m high) dams that have created storage reservoirs for irrigation and hydroelectric power and that regulate river flows throughout the year. There are also several other smaller irrigation structures along the river course that influence river flows. The river provides water to two irrigation districts totaling ~ 36,000 ha in southern Jalisco and Colima (Comisión de Cuenca del Rio Ayuquila-Armería, URL http://www.ayuquila-armeria.col.gob.mx) and to numerous cities and communities for municipal and industrial uses. Of particular relevance to the SMBR, the Ayuquila provides the Autlán –El Grullo valley with water to sustain a valuable agricultural system dominated by sugar cane and tomato production [16].

Lack of fishery regulations, overexploitation, and the use of damaging fishing techniques such as explosives and poisons have also affected the fishery of the Ayuquila [17]. Although use of damaging fishing techniques was common in the past, for the last 10-15 years fishermen have decreased their use in the river [18].

According to a fishery survey made in the late 1990s (Martínez-Rivera, unpublished data) and other published reports, fishes are an important source of animal protein for several communities near the Ayuquila River [17-19]. These fisheries have particular importance in the small and remote communities located along the river. In these communities other sources of animal protein are scarce, protected, or too expensive. The relevance of fisheries increases where conditions are not favourable for year-round agricultural activities [18]. The Ayuquila faces several environmental problems common to rivers throughout west central Mexico including the introduction of nonnative species, habitat modification, water pollution, species overexploitation, lack of fishery regulation and, occasional destructive fishing practices [17, 18, 20-21].

Historically, the Ayuquila had a good reputation for the abundance and quality of its fishery [18]. However, fisheries in the river have declined [17, 21]. Environmental pollution is a major reason for the reduction in the quality of fishery in the Ayuquila. Industrial and agricultural wastes, urban sewage, and trash have altered water quality of the Ayuquila. Massive die-offs of fishes have occurred due to pollution coming from a sugar production plant (IMO, for Ingenio Melchor Ocampo) located upstream from the SMBR, and other important sources. For example, on March 20, 1998, the IMO accidentally spilled more than one hundred tons of molasses over a 10 - hour period into the Ayuquila causing massive fish and crustacean mortality over approximately a 100 Km stretch of the river [22]. Although this was an extreme event and subsequently efforts have been made to reduce human impacts on the Ayuquila, the IMO and two cities, El

Grullo and Autlán, continue to affect the river on a yearly basis, as many of their wastes are discharged to the river without specialized treatment [23-24].

In response to the environmental degradation of the river, the 'Commission for the Ayuquila-Armería River' was created in 1997. In this commission, local education and research institutions, the directorship of the SMBR, local municipalities, and other stakeholders have joined efforts to work towards improving environmental conditions in the river while accomodating the interests of agriculture and industry in the area [25]. In addition, local municipalities established the Junta Intermunicipal de Medio Ambiente para la gestion Integral de la Cuenca Baja del Río Ayuquila (JIRA) (~ intermunicipal environmental management council for the lower Ayuquila River basin) in 2001, providing for economic and technical means to implement strategies and projects to improve conditions in the river (URL: http://jira.org.mx). While environmental problems in the river are far from over, the commission and the JIRA serve as entities where the interests of all stakeholders, including fishermen, can be included in watershed planning.

Surveys: During July 2000 and June 2001, we interviewed fishermen in seven riverside towns located along the Ayuquila (upstream to downstream): 1) Palo Blanco, 2) El Aguacate, 3) Ventanas, 4) Zenzontla, 5) El Camichin, 6) El Paso Real and 7) San Pedro Toxín (Fig. 1). With the exception of Palo Blanco, all sites are located inside the SMBR. Two questionnaires were used to obtain information (Appendix 1). One focused on fishery description (hereafter 'fisheries survey') and the other on fishermen opinions and attitudes about the environmental situation of the Ayuquila (hereafter 'opinions survey'). Fishermen were initially identified and located through communication with researchers at the Centro Universitario de la Costa Sur, Universidad de Guadalajara (Autlán, Jalisco) and via interviews with other fishermen. An attempt was made to interview as many fishermen as possible inside the study area. All fishermen were interviewed at home; so most (see below) responses are based on fishermen's accounts and not on actual observations of the way they fish. The interviewer filled-in the survey forms. Fifty-eight fishermen completed the fisheries survey and 75 completed the opinions survey. Since interviewees sometimes declined to answer some of the questions in the survey, the analysis was based only on those who opted to respond. The number of surveys was different in each town: town 1 (4 fisheries, 9 opinions), town 2 (7, 11), town 3 (14, 14), town 4 (13, 13), town 5 (16,15), town 6 (0, 6), town 7 (4, 7).

Fisheries surveys were used to obtain information on fishing purpose, effort, and frequency; fishing expenses; target species; catch and release criteria; fishing locations, fishermen dependence on the fishery; and marketing (Appendix 1). One of the survey questions required a calculation of the weight of fish consumed per household. In their response, fishermen often responded with the number of fishes consumed rather than the weight, and to convert this to weight we assigned a value of 150 g per fish based on our observations of the average size/weight of fish caught by all fishermen. We then summed the consumption for all households in each town to obtain a total mass of fish consumed per week.

In addition to the surveys, we documented the catch and fishing effort of a group of three fishermen on two different occasions to estimate catch-per-unit-effort and relate this to economic value based on the selling prices obtained for the different fish species from the river. The number and type of fishing gears used, the duration of the fishing period, the number and identity of fishes and crustaceans caught as well as the total length of each fish were recorded. On both occasions data were obtained from the area of the river between towns 3 and 4 (See Fig. 1). Additionally, food markets in Autlán and El Grullo, two of the most important cities in the region, were visited to identify if fishery products from the Ayuquila were sold there and to obtain their selling prices.

Our opinions and attitudes survey included questions about the perception of environmental problems in the Ayuquila and how these related to the situation of the fisheries. Other questions helped identify entities

responsible for the environmental situation of the river, and asked for recommendations on strategies to improve environmental quality and fisheries in the Ayuquila (See Appendix 1).

Once surveys had been completed in the field, answers to survey questions were categorized. This allowed for quantification of the proportion of responses in each category. Most questions gave fishermen the option to answer in a category (i.e., yes, no), but a few questions offered the opportunity for open-ended responses. In the latter case, we analyzed the responses and constructed categories encompassing all answers we received. For each question, we then compared the proportion of responses in each category. For two of our questions addressing the perception of the current quality of the fishery and the environmental situation of the river, we analyzed responses for the whole study area and for each town. The number of answers in each category was then compared among towns.

Results

Fisheries Surveys

Our surveys appeared to encompass most of the fishermen within the study area and allowed us to characterize their demographics. Based on our discussions with fishermen and researchers familiar with the region, we estimate that we interviewed 80-90% of the resident fishermen in the stretch of the river between towns 1-5 and 60-70% of those in towns 6-7. Seventy-three percent of respondents were > 30 years of age (max. 75) and 14% were < 20 years of age (min. 12). Forty seven percent of interviewees had been fishing for at least 20 years, and only 21% had fished for less than 10 years. Ninety eight percent of interviewees considered fishing a subsistence activity, but only 28% regarded subsistence as their sole purpose of fishing. Forty-two and 28 % of fishermen also considered recreation and commerce, respectively, as their fishing objective. Twenty one percent considered subsistence, commerce and recreation as purposes of fishing. Most (68%) fishermen dedicated 5 or fewer hours per week to fishing. In most cases, fishermen did not travel far from their hometowns, and usually alternated between two or three nearby stretches of river. For 54% of fishermen interviewed, fishing involved a group of 3-4 individuals, but the remainder stated that they fished by themselves. Fishery in the Ayuquila was a year-round activity, but fishing intensity varied depending on weather and river conditions, job availability, and fish and crustacean life histories.

A relatively diverse fishery existed in the Ayuquila study area. Eleven species (prawns and fish) were used in the fishery (Table 1), but most (83%) fishermen did not target a particular species and would utilize any species they captured. Prawns (*Macrobrachium* sp.), locally known as 'chacales' had the highest commercial value but fishermen also targeted catfish (*Ictalurus dugesi* Bean 1880), nonnative tilapias (*Oreochromis aureus* Steindachner 1864 and *Tilapia rendalli* Boulenger 1897), other crustaceans, and mountain mullets (*Agonostomus monticola* Bancroft, 1834).

A variety of fishing techniques were used by fishermen. Castnets, lines with hooks, prawn traps ('chacaleras'), and gillnets were used by 87%, 67%, 31%, and 19% of fishermen, respectively. Only a few fishermen used harpoons (8%) and seines (1%). Eight percent of fishermen reported fishing only with their hands. Most (83%) fishermen combined two or more gears when fishing. Castnets and lines with hooks were used in combination by 40% of fishermen. Twenty-five percent of fishermen combined three or more gears, often including prawn traps, gillnets, lines with hooks and castnets. Fishermen with 8-10 or more traps usually had exclusive access to a certain reach of the river. Only 48% of all interviewed fishermen mentioned that small or egg-carrying individuals were returned to the water. Most fishermen kept all they caught.

No fishing cooperative existed in the Ayuquila, but some stretches of river had traditional 'ownership', and were traditionally used only by a certain group of fishermen. Only in towns 2-5 were there some fishing restrictions (i.e., prohibition of destructive fishing techniques, limits to access by non-local fishermen) enforced by town officials, but there were no bag limits. Restrictions on the use of explosives and venoms for fishing and seasonality of prawn-capture regulations were mentioned in towns 3-5. Local communities along with government officials or university representatives established these rules. Only 7% of fishermen mentioned the need to restrict access by individuals who used destructive fishing methods (e.g., explosives, venoms).

Fish from the river comprised an important part of the diet of fishermen. Of 53 fishermen who offered information on household fish consumption, 75% consumed more than 1 kg·week^{-1} (maximum reported by an individual = 5 kg·week^{-1}) (Fig. 2). Approximately 93 kg·week^{-1} of fish were consumed from the Ayuquila, but some catches were used for animal rather than human consumption. Fish were the main source of animal protein for fishermen and their families. Other sources of animal protein, including wild animals (e.g., lizards, birds) were consumed only occasionally. Most (64%) fishermen consumed only fish they caught, but 37% also purchased fish for consumption. Approximately 86% of interviewed fishermen considered that their families did not depend on fisheries for their survival, but 14% stated that they strongly depended on the fisheries. Eighty one percent of fishermen said that agriculture was their main occupation.

The value of species from the fishery varied. Catfish *I. dugesi*, was the fish species with the highest commercial value (Year 2000 US ~ $5.00/Kg) followed by *Scartomyzon austrinus* Bean 1880, *Nandopsis istlanum* Jordan & Snyder 1900, and *A. monticola* ($4.00 – $4.50/Kg); tilapias and carp *Cyprinus carpio* L. 1758 ($1.60 – $3.25/Kg). Crustaceans had a comparatively high value depending on their size; prawns above 25 cm total length were sold for about $16.25/Kg, whereas smaller individuals were usually sold for $8.11/Kg. Most of these sales were made directly to restaurants in nearby cities.

Our observations and analyses of the catch and fishing effort of a group of fishermen allowed us to calculate fishing efficiency. Five gillnets (located in slow-moving sections of the river) and three prawn-traps (located in rapids) placed overnight for two nights (from 1800 hrs to 0730 hrs the next day) in a 200 m section of the river produced 3 *S. austrinus*, 16 *I. dugesi*, 34 *T. rendalli* / *O. aureus*, 7 *A. monticola*, and one *Micropterus salmoides* Lacépéde 1802, plus 4 smaller crustaceans for a total of ~ 9.8 Kg. This catch had an approximate monetary value of $42.00 (based on prices reported above). Each gillnet had a length of about 20 m, a depth of about 2.5 m and a 50 mm stretch mesh.

We did not observe native fishes captured in the study area in markets of nearby cities. Fish being sold in these markets were either marine, from nearby reservoirs, or produced in local fish farms (non-native tilapias and largemouth bass *Micropterus salmoides*).

Opinions surveys

Opinions about the condition of the Ayuquila varied along the length of the study area. Overall, 62% of fishermen regarded river quality as good, 15% considered it neither good nor bad, and 23% thought it was bad. Positive (i.e., good quality) opinions were more common in downstream portions of the study area (Fig. 3), and negative opinions (i.e., poor quality) were absent downstream from town 4. However, nearly all (90%) fishermen considered that pollution was a problem for the river. Still, 61% of respondents had noticed a reduction in the amount of solid trash in the previous 5 years. Eighty percent of fishermen attributed most of the responsibility for the pollution of the river to the IMO. Cities (e.g., Autlán, El Grullo) and local communities were also recognized as important sources of pollution by 55% and 30% of interviewees.

Most fishermen thought that the fishery was improving in the river, but many mentioned declines in the catch of catfishes (*I. dugesi*). Quality of the catches (number of fishes caught and/or fish size) in the five years prior to the interview had improved according to 81% of interviewees, but 15% and 4% stated that catches were worse or had not changed. Negative (worse or no change) opinions on the quality of fisheries were found throughout the study area, but were more common in towns 1-5 (on average 30%), closer to the cities of Autlan and El Grullo and the IMO, than in towns 6-7 (on average 7%).

Fishermen attributed at least some of the fishery improvements to institutional activities. Sixty nine percent of fishermen stated that they had noticed positive changes (improved river quality and fisheries) as a result of activities carried out by different regional institutions. Similarly, 92% of interviewees were aware of the activities carried out by managers of the SMBR. Eighty per cent had a positive perspective on the existence of the SMBR, specifically as an entity that provided protection to the river and other natural resources, and control of other activities in the region. They also acknowledged technical support received from the managers of the SMBR. Interviewees with negative attitudes (20%) about the presence of the SMBR were mostly concerned with it being an obstacle to wood extraction, livestock feeding, and hunting.

Despite the perception of an improving fishery, nearly all fishermen had suggestions to improve the fishery. Ninety-nine percent of fishermen supported fish stocking in the Ayuquila; especially for catfish, (52% of all fishermen), mountain mullets (34%) and prawns (*Macrobrachium* sp.) (20%). Tilapia, largemouth bass and common carp were also mentioned as species to stock. About 25% of fishermen did not mention a specific species of fish but favored stocking generally. Other management needs suggested by 70% of interviewees were related to improving environmental quality of the river, implementation of sewage treatment by cities in the watershed, and control of IMO wastewater discharge. Local city, federal and state governments, the IMO, and the entire community were deemed responsible for the implementation of these strategies by 45%, 18% and 18% of respondents respectively. The directorship of the SMBR and the Centro Universitario de la Costa Sur [Universidad de Guadalajara] (the primary regional research institution) were mentioned by only 5% of respondents as having responsibility for improving the environmental situation of the river.

Discussion

Small-scale fisheries are an important source of food, income and employment among the rural poor in developing countries [26-28] but they remain understudied in many areas of the world. The small-scale fishery in rural communities located on the banks of the Ayuquila River is essential to human subsistence and recreation. This fishery remains an important resource despite years of changing productivity dynamics in the region and after significant periods of environmental stress. Moreover, although the fishery is just one of several economic activities available for rural communities in the area, it provides food and income diversity for rural poor who are subject to food insecurity [29] and a buffer against fluctuations in agricultural activities.

In the Ayuquila, most fishermen can be found in three family units of production: 1) those family units with no land tenure, 2) subsistence family units with land, and 3) those units dedicated to small-scale agriculture and livestock production (evaluated from data in [16]). These groups are generally impoverished and require the nutritional value provided by fishes form the river. Indeed, consumption of fish results in relatively "more balanced" diets for people in communities located near the river compared to other areas of the SMBR (Hugo Melgar-Quiñones, Department of Human Nutrition, The Ohio State University, September 2001, personal communication). In most communities, animal protein consumption other than fish is restricted to 2 to 4 times per month [18].

Recreation and income generation are also important benefits for fishermen in the Ayuquila. For many, fishing in the river is one of few recreational activities for their families, and in many cases fishing knowledge is transferred among generations. Although prawns and perhaps other fishes may be sold to local restaurants, income generation from Ayuquila fisheries may not be presently as important as it had been in the past. Fish caught in reservoirs and produced in fish farms dominate markets in larger cities in the area (Martínez-Rivera, unpublished data). It is possible that declines in the water quality of the river, followed by population declines in several fish species may have also reduced the income generation importance of the fishery of the Ayuquila.

Fisheries in the Ayuquila depend on relatively inexpensive fishing methods. Castnets, because of their ease of construction and transportation, are the most common fishing gear in the Ayuquila. These along with lines with hooks are used by recreational and subsistence fishermen who seek a few fish for a single meal. These gears are usually effective for capturing cichlids (native *Nandopsis istlanum* and exotic tilapia) and mountain mullets. A comparatively low number of fishermen use prawn traps and gillnets. These, however, may yield larger catches than other (non destructive) fishing techniques, with a greater proportion of native species, and are usually used by fishermen who allocate a significant amount of time and effort to fishing (versus agricultural activities, for example). Prawn traps are cone-shaped devices are usually built by the fishermen with stems of "otatillo" (*Otatea acuminata* spp. a*ztecorum* [POACEAE]) and "bejuco" (*Combretum farinosum* [COMBRETACEAE]), two common bamboo-like species [18]. Traps are placed across the river in rocky riffles, one next to each other with their open end facing upstream towards the current. When rain events occur upstream and the river rises, prawns are carried downstream into the traps. Many traps are lost when floods occur, and new ones have to be built every year. The ones that remain in place are usually discarded after a season has ended. Traps are usually checked daily during the rainy season. Gillnets are used to fish slow deep reaches of the river. They are left to fish overnight (approximately 12 hours) and are especially efficient in capturing catfish, *S. austrinus,* and mountain mullets. The catch in these nets is most vulnerable to predation by the native, threatened river otter, *Lontra longicaudis* Olfers 1818, which is considered harmfull by some fishermen [30]. Fishermen say it is common to find only fish heads hanging from the nets or fish with severe bites. In many cases these fish are still used by fishermen to feed farm or house animals. Fortunately, environmentally destructive fishing techniques (i.e. poisons and explosives) are now rarely used. According to the fishermen interviewed and other sources [18], local people are no longer using environmentally damaging fishing techniques, but people coming from other areas were reported to occasionally use these methods. Lime, explosives, and plant venoms (i.e. from *Hura polyandra* [EUPHORBIACEAE] [17-18]) were commonly used in the past. The use of poisons still occurs in other basins in the SMBR (Coahuayana and Purificación Rivers) in the prawn fishery (Mercado-Silva, personal observation). Prevention of this practice should be pursued to prevent overexploitation of this important resource.

Most fishermen in the Ayuquila do not select for a species and nonnative fishes comprise a significant amount of the catch in the river. Most often they will capture common carp and tilapias, nonnative fishes tolerant to environmental degradation that are common throughout the basin [20-21]. However, most fishermen expressed a preference for native species (i.e., catfish and mountain mullets) and would like to see them increase in abundance. Catfish have probably experienced heavy exploitation through time [17]. Although no population census information exists for this or other species in the Ayuquila, several fishermen agreed that a reduction in size and abundance of the species has occurred throughout the river. Prawns may have also declined in the Ayuquila as a consequence of overexploitation [31].

Although the presence of nonnatives has been reported harmful for native species populations elsewhere in Mexico [32-35], their effect in the Ayuquila has not been evaluated. Nonnative species in the Ayuquila present an interesting dichotomy. While potentially threatening for native species, they are beneficial for

the fisheries, and it is unlikely that they can be removed from the river. Not only must fishermen see their nutritional needs satisfied, but water releases from dams upstream and breakage (during the rainy season) of smaller impoundments where nonnatives comprise the entire fish community mean that nonnatives are regularly being transported into the study area. Species such as the nonnative predator largemouth bass, stocked in up stream impoundments, could pose a threat to fisheries in the study area, but more studies are required. The restitution of natives as the most important components of the fishery in the Ayuquila depends on an increase in the environmental quality of the river that leads to abundance of natives coupled with an increased value and revalorization of the natives versus nonnatives.

Stocking native fishes is a popular enhancement strategy suggested by fishermen in the Ayuquila. However, a stocking program faces several constraints. Local or state hatcheries and fish farms do not usually handle native species and many aspects of their biology that could allow them to be raised remain unknown. Although aquaculture has previously been reported to produce more animal protein per hectare than any other method of animal production in Mexico [36], most of the species used are nonnative [32, 37]. Even if programs of native species aquaculture could be implemented in the Ayuquila, caution should be taken that different genetic stocks are not mixed, nor that diseases be introduced. Additionally, excessive stocking of predators such as the catfish might lead to undesirable ecosystem-wide consequences [37].

Prawn populations in the Ayuquila are poorly known and there is need to acquire basic biological information before a management strategy can be recommended. Although some fishermen seem interested in establishing artificial ponds with running water for prawn production, their feasibility may depend on the ability of prawn to survive such conditions, the intensity of rain events, and the availability of relatively clean water in the river. In addition, a closure of the prawn fishery during June and July might be beneficial as it is during these two months that fishermen report prawns are most active with reproduction. Some fishermen would support such a conservation strategy. However, a possible difficulty in establishing a closed season would be the requirement to eliminate all “barrier” fishing methods, not only the traps, from the water, to allow the movement of individuals along the river. Removing gillnets would likely reduce the capture of fish species by fishermen during these two months.

Inland fishery studies have often focused on population ecology and harvesting of fish, with less attention to the socioeconomic dimensions of small-scale fisheries [38]. The studies also do not often integrate fishermen’s perceptions of environmental problems faced by the ecosystems they depend on. As a result, fisheries and ecosystem conservation management initiatives often are implemented without input from individuals whose livelihood is perhaps most affected by those efforts, and who often have valuable local ecological knowledge [39]. Because management initiatives regularly fail to take into account the reality of fishers’ lives or their interests, they have the potential to quickly lose fishers’ cooperation and may not meet objectives [40]. Our inclusion of fishermen’s opinions on issues related to the environmental situation of the Ayuquila can help managers of the SMBR in designing conservation and natural resource management strategies. Increasing social inclusion of fishers via their participation in cross-scale institutional arrangements could help not only create a more sustainable ecosystem in the river, but allow them better opportunities for improving their social status [41].

Fishermen’s generally positive opinion about the environmental quality of the Ayuquila and its fisheries reflects the impact of management actions in the watershed. Following the 1998 spill of molasses and recurrent events of fish die-offs, the IMO, local governments and research institutions implemented numerous strategies to reduce pollution impacts on the river. These efforts were successful in controlling some of the most visible impacts to the river and were widely publicized. However, our finding that negative opinions on river environmental quality still exist, especially in towns closer to the most important sources of pollution, points to the need to further improve many processes affecting the river. A relatively

large number of fishermen identified the biosphere reserve and local research institutions as allies in efforts to implement positive actions to improve the situation of the Ayuquila. Protection of the river from pollution events, biomonitoring activities, and efforts to extend basic services (e.g., electricity, water) into their communities certainly help in advancing a positive perception of the biosphere reserve. Interviewees readily identified point sources of pollution (e.g., cities and the IMO) as problems for the Ayuquila, but several other environmental problems are known in the river. Survey participants did not identify riparian forest clearing, increases in the number of nonnative fishes and declines of some native species, and overabundance of water hyacinth as problems [23, 42-43]. There is a need to expand our knowledge of these problems not only to fishermen in the area but also to the many stakeholders involved in managing the river.

While efforts continue to build and achieve adequate operation of water treatment plants, relocate landfills from river banks to other locations, and monitor water quality, there are other management strategies that could lead to improved fisheries and the overall environmental condition of the Ayuquila. Implementation of minimum instream flows or flow regime management, restoration of various areas now lacking riparian vegetation, the adoption of bag or size limits or harvest seasons for various species, and long term monitoring of catches and creel surveys, are some of the strategies that we encourage for the river. Some of these strategies will require that fishermen along with local research and management institutions create regulatory frameworks that allow for a sustainable fishery in the Ayuquila. Small-scale fishing communities with a regulatory framework have a better chance of achieving a sustainable fishery than those practicing open-access, unregulated fishery [44].

The Ayuquila represents a special opportunity to understand the ecological and social dynamics that occur in river basins throughout west central Mexico. The interactions between the SMBR, education and research institutions, and involved governmental and non-governmental stakeholders have helped create an opportunity for this river to be used in a relatively sustainable way allowing for the conservation of natural resources and the social/economical development of individuals living in the watershed. It is to this audience that our study can provide further information that should result in better management strategies for natural resources in this and other basins. Further, since there are no other studies of riparian fisheries in the region, we hope that our study in the Ayuquila can 1) serve as an illustration of the fisheries in this part of Mexico, and 2) encourage future and improved studies in other basins. What subsistence fishermen know can provide unparalleled guidance to the conservation of natural resources and natural ecosystems.

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Table 1. Fishes and crustaceans targeted by the fishery of the Ayuquila River, Jalisco and Colima, Mexico.

Family and Species	*Common Name (E)*	*Common Name (S)*
Fishes		
Catostomidae		
Scartomyzon austrinus (Bean 1880)	Sucker	Chuime / *Boquinete*
Centrarchidae		
*Micropterus salmoides** (Lacépède 1802)	Largemouth Bass	Lobina negra
Characidae		
Astyanax aeneus (Filippi 1853)	Banded tetra	pepesca / *charal*
Cichlidae		
Nandopsis istlanum (Jordan & Snyder 1900)	Redside cichlid	Mojarra del Balsas/ *chopa nativa*
*Oreochromis aureus** (Steindachner 1864)	Blue Tilapia	Tilapia azul / *chopa*
*Tlapia rendalli** (Boulenger 1897)	Redbreast tilapia	Tilapia roja / *chopa*
Cyprinidae		
*Cyprinus carpio** (L. 1758)	Common carp	Carpa común
Gobiidae		
Sicydium multipunctatum (Regan 1905)	Multispotted goby	dormilón punteado/ *Jalmiche*
Goodeidae		
Ilyodon furcidens (Jordan & Gilbert 1882)	Goldbreast Ilyodon	Mexcalpique del Armería / *bulón*
Ictaluridae		
Ictalurus dugesi (Bean 1880)	Lerma catfish	Bagre del Lerma
Mugilidae		
Agonostomus monticola (Bancroft 1897)	Mountain mullet	Trucha de tierra caliente
Crustaceans		
Atydae		
Atya ortmannioides (Villalobos 1956)	Shrimp	Chacal, Burro or Camarón
Atya margaritacea (Milne-Edwards 1874)	Shrimp	Chacal, Burro or Camarón
Atya sp.	Shrimp	Chacal, Burro or Camarón
Cambaridae		
Cambarellus sp.	Crayfish	Chacal, Burro, Acocil or Camarón
Palaemonidae		
Machrobrachium occidentale (Holthuis 1950)	Prawn	Chacal or Langostino
Machrobrachium americanum (Bate 1868)	Prawn	Chacal or Langostino
Pseudothelphusidae		
Pseudotheluphusa dilatata (Rathbun 1898)	Crab	Cangrejo or Jaiba
Pseudothelphusa sp	Crab	Cangrejo or Jaiba

Table organized alphabetically by family name. Common names in English (E) [45] and Spanish (S) [46] are included. Local common names in *italics*. Crustacean data from [17]. Nonnative species are indicated with an asterisk.

Figure 1. Study area in the Ayuquila River, Jalisco – Colima, Mexico. The states of Jalisco and Colima are shaded in dark grey on Mexico's location map; the Ayuquila Basin is indicated in white. The detailed map shows the boundary of the basin, the Ayuquila River, and the location of the Sierra de Manantlán Biosphere Reserve (in grey). Dotted shades indicate the towns of Autlán (to the West) and El Grullo (to the East); the square-shaded area indicates the location of a sugar production plant (Ingenio Melchor Ocampo). The Towns where surveys were conducted are included in the map: (1) Palo Blanco, (2) Aguacate, (3) Ventanas, (4) Zenzontla, (5) El Camichin, (6) El Paso Real and (7) San Pedro Toxín.

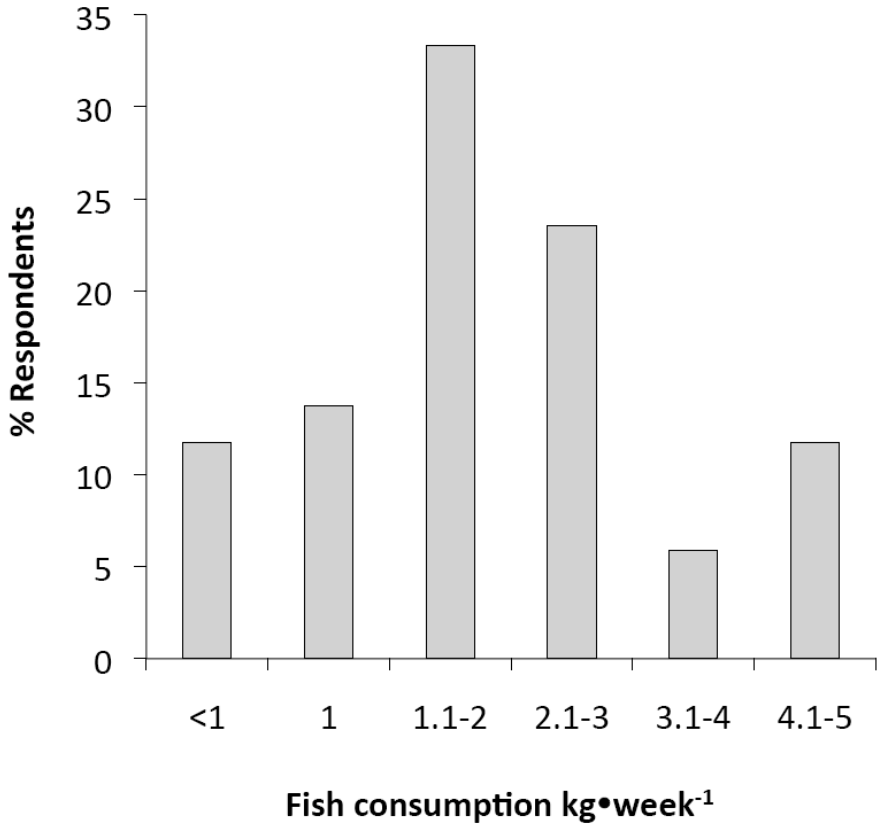

Figure 2. Fish consumption per week in households in riverside communities in the Ayuquila River. Total weight of fish consumed per week for all classes: 90.35Kg.

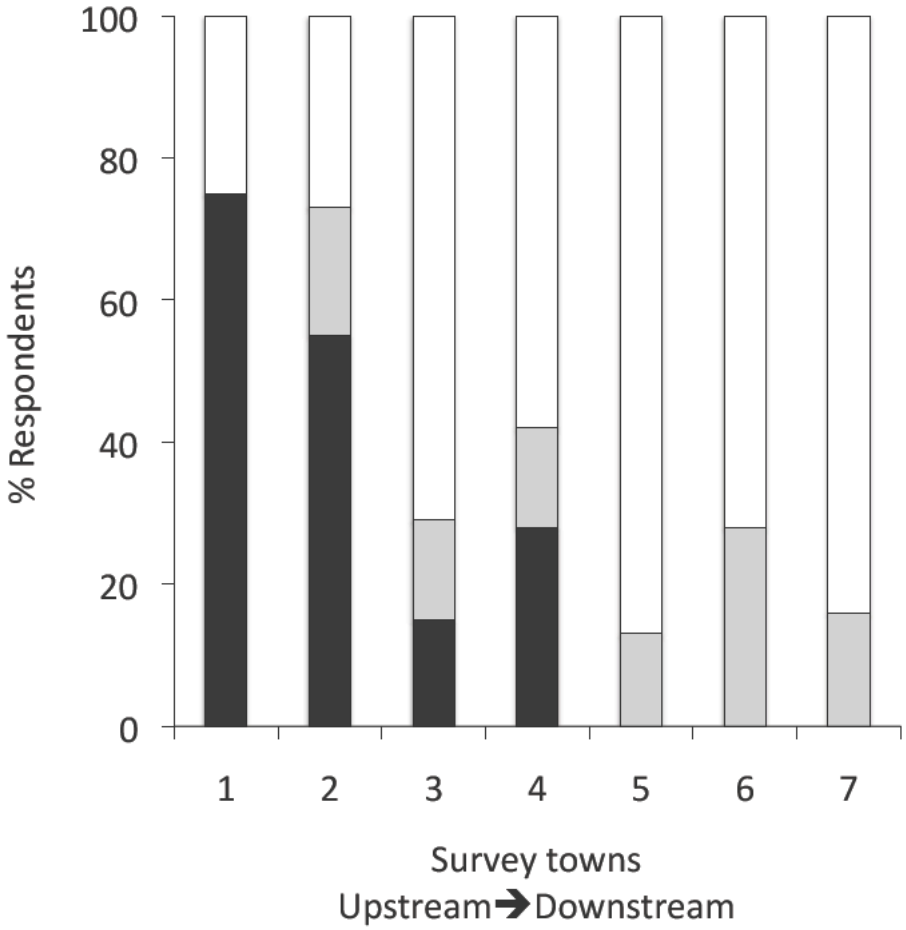

Figure 3. Perceptions of river quality from fishermen in the Ayuquila River. Refer to methods section for identification of survey towns. Black, grey and white columns represent bad, fair, and good environmental quality.

Appendix. Survey forms used to gather data on the fisheries and the opinions of fishermen participating in the subsistence fisheries of the Ayuquila River, Jalisco, Colima, Mexico.

Survey for Fisheries and Opinions for Fishermen in the Ayuquila River Basin

Sheet No._____ Date_____ Town_____ Surveyor_____

Name of Fisherman _____ Procedence _____ Age (aprox)___

1) Group Fishing? Yes No 2) Number of fishermen in group _____

3) Fishing for: Sale Self subsistence Recreation

4) Fishing frequency: Dry Season _____ Wet Season_____ All Year_____ Occasional_____

5) Fishing duration (hrs/day y days/week)_____ from_____ to _____.

6) How long since started fishing? _____

7) Fishing gear used _____ Quantity_____

8) What are your expenses when fishing? _____ _ ¿$?_____

9) Looking for a fish species in particular? Yes No Which?_____.

10) Uses all fished for? Yes No What is returned? _____

11) Are breeding females returned ? Yes No

12) What are your preferred fishing sites? Why?

_____
_____

13) Do you change fishing sites? Yes No
Where do you go? _____ Frequency of change? ____

14) Fishing in: pools_____ whitewater _____

15) Are there rules on how, how much and where to fish? Yes No

¿How is the community organized with regards to fishing?

_____
_____
_

16) Are fishing sites reserve for each fisherman? Yes No

17) ¿Can fishermen from other communities access the river freely? Yes No

18) ¿Should their access be restricted? Yes No

Fish catch data (fill up only when analyzing the catch)

Species	Quant.	Use (sale, consumption, other)	Size (cm)	$ Sale

Fish catch data (fill up only when analyzing the catch)

Species	Quant.	Use (sale, consumption, other)	Size (cm)	$ Sale

19) If so, who do you sell your fish to? _____
20) How do you transport your product?_____
21) Which are bestseller species?_____

22) How many fish are consumed (per month) at home? _____

23) Other type of meat consumed at home?(which?) _____

24) How is fish consumed at home?_____

25) Do you purchase fish from other people or do you obtain it all yourself?_____

26) Is your family completely dependent on fishery? Yes No

27) What other activities do you have? _____

28) Is the existence of the river otter beneficial? Yes No Don't know

Why?

_____
_____

Survey on opinions on river quality for fishermen in the Ayuquila

Name of fisherman_____Sheet No. _____

1) How satisfied are you with the environmental quality in the river?
Good Mid Bad

2) Has fish quality improved for the last 5 years or more?

Yes Same Worse

3) Are fish bigger today than 5 years ago? Are they more abundant?

Yes Same No

4) Has the university done something for the quality of the river (is it cleaner?)?

Yes Same No

5) Are trash and pollution a problem?

Yes No

6) Have trash and pollution in the river:

Decreased Increased Stayed the same

7) Who is (are) responsible for trash and pollution in the Ayuquila?

---

8) Are you affected by the presence of the SMBR? *Yes* *No*
9) What is your opinion about the SMBR?
_____
____
10) Would you like fish to be stocked into the river? Yes No Not important
Which species?_____
11) You would be better off if the river:
_____
12) Who should make these changes and be responsbile for protecting the river?
_____