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Trade-offs in fishery yield between wetland conservation and land conversion on the Gulf of Mexico

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1. Introduction

Wetlands are recognized as highly productive ecosystems because of the goods and ecosystem services that they provide (Mitsch and Gosselink, 2007). Mangroves are among the most productive coastal wetlands (Ewel et al., 1998), and one of their most important ecosystem functions is as a habitat for the juveniles of both crustacean and fish species consumed by humans and traded in local and international markets (Costanza et al., 1989; Millennium-Ecosystem-Assessment, 2005). Freshwater wetlands are among the most productive ecosystems in the world and, similarly, are of great importance due to their additional ecosystem functions (Drew et al., 2005; Zedler and Kercher, 2005), including their natural litter fall productivity (Infante-Mata et al., 2012; Moreno-Casasola et al., 2012), their role as a habitat for species caught by fishermen (Ewel, 2010; Hamerlynck et al., 2011; Knowler et al., 2003) and their nutrient contribution to water bodies (Fisher and Acreman, 2004; Posthumus et al., 2010).

Based on the market value of fishing in Louisiana, the economic value of coastal wetlands was estimated at $317 to $846 USD/acre/1983 (Costanza et al., 1989). On the Gulf of Thailand, the economic importance of mangroves based on their providing habitats that increase fishing productivity was estimated at $83.69 to $110.23 USD/ha/1993 (United States dollar, USD) (Barbier, 2000). In Pakistan, the economic value of mangrove shoreline was calculated at $1,287 USD/ha/2005, highlighting the economic relationship between *in situ* mangroves and *ex situ* local communities (Pervaiz and Lftikhar, 2005). In Latin America and the Caribbean more than 15 million biomass tons were caught in 2010, and over 80% of this was associated with estuarine environments such as mangroves and brackish lagoons (Salas et al., 2011). This is supported by a study carried out by Aburto-Oropeza et al. (2008), in which they estimated the value of mangroves at $37,500 USD/ha/year based on their value to commercial fishing in the Gulf of California. Another estimate for mangroves was $895 USD/ha/year because they offer habitat and refuge from predators (Sanjurjo et al., 2005) based on information from the fishermen's organization, their mode of fishing, and the percentage of mangrove cover.

Few studies have focused on valuing the economic importance of freshwater wetlands from the perspective of the ecosystem services provided by these habitats. Knowler et al. (2003) obtained values of C$1,322 to C$7,010 (Canadian Dollars) per kilometer by correlating freshwater wetland cover and salmon fishing productivity, and concluded that managers must take into account the trade-offs between ecosystem services and land use alternatives in order to optimize the benefits that can be obtained from wetland conservation. This is an example of the economic valuation of ecosystem services as a practical measure to help decision-makers, rather than just an exercise that can create a blindspot, a problem characteristic of various economic valuation studies (Laurans et al., 2013). The economic contribution of the freshwater wetlands of the floodplains and lakes of Tanzania to local fisheries was between $0.2 and $0.8 USD/fishery/hour, depending on management regime and water flow (Hamerlynck et al., 2011). Also, Ewel (2010) mentioned that the value of fishery products obtained from forested wetlands on the island of Kosrae, Federated States of

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Micronesia, was $666,000 USD per year, illustrating not only the importance of mangroves, but also of freshwater forested wetlands.

Despite the importance of wetlands, these ecosystems are still being transformed for anthropogenic activities (Siikamäki et al., 2012). It is estimated that worldwide 3.6 million hectares of mangrove, equivalent to 20% of the total, were lost between 1980 and 2005 (FAO, 2007). Mexico has lost or degraded 62.1% of its wetlands (Landgrave and Moreno-Casasola, 2012) and even though the law protects mangroves and logging is prohibited, López-Portillo and Ezcurra (2002) estimated the annual rate of mangrove loss at 5%. For example, the state of Veracruz, located on the coastal plain of the Gulf of Mexico, has lost 58% of its brackish and freshwater wetlands (Landgrave and Moreno-Casasola, 2012). One of the natural systems in this region most threatened by agricultural activities is the Alvarado Lagoon System (ALS), located in the lower basin of the Papaloapan River. In the ALS 14.5% of its freshwater wetland and mangrove area has been transformed into sugarcane crops (mainly by draining freshwater wetlands) and 65.5% into livestock pastures (Vázquez-González et al., 2014). This conversion has reduced the habitat of harvested species (clams) and of those used in fisheries (crustaceans and fish) (Juárez-Eusebio, 2005; Moreno-Casasola et al., 2012). The reduction in the surface area of freshwater forested wetlands and broad-leaved and cattail marshes has also resulted in a decrease in the quantity of nutrients and organic matter relative to that of neighboring rivers and lagoons (Drew et al., 2005; Ewel, 2010). Thus, fishing activity in the ALS is in danger due to the loss of wetland habitat and corresponding decline in the productivity of water bodies because of pollution and overfishing.

The objective of this study was to estimate the economic value of mangroves and freshwater wetlands based on the commercial value of fishing in the ALS and to determine whether there is any statistical correlation between economic output and the different types of wetland cover. We compared the monetary value of fishermen's cooperatives with the monetary value of raising livestock and growing sugarcane, the two main productive activities replacing wetlands. At the national and international levels, this analysis will enable decision makers to choose the most profitable option in direct and indirect economic terms based on the activities upon which local communities depend. It also provides a basis for regional planning and development to select the best economic alternative, as proposed by Aburto-Oropeza et al. (2008) and Knowler et al. (2003) for Mexico and Canada, respectively. This approach provides a model for the economic valuation of fisheries, linking them to the wetland gradient of coastal areas, including a variety of wetland vegetation, thus helping to manage and conserve wetlands.

2. Methods and materials

2.1. Description of the study area

In Mexico, there are more coastal wetlands than inland wetlands (Olmsted, 1993). Coastal wetlands are located on coastal plains and are formed by estuaries with mangroves bordering lagoons, seagrass, forested wetlands, broad-leaved and cattail marshes. These establish along salinity and flood gradients (Mitsch and Gosselink, 2007; Moreno-Casasola et al., 2009; Odum, 1961). However, in many regions of Mexico, such as the Alvarado Lagoon System (ALS), wetlands have been transformed into flooded grasslands for grazing cattle or drained for crops (Guevara and Moreno-Casasola, 2008; Vázquez-González et al., 2014).

The ALS is located on the central coastal plain of the state of Veracruz on the western Gulf of Mexico. With an area of 373,021 ha, the ALS covers 8.15% of the Papaloapan River Basin and 22.85% of the lower basin (Vázquez-González et al., 2014). The region is the largest lagoon-wetland complex in the state of Veracruz and sustains many fisheries (Moreno-Casasola and Infante-Mata, 2010) (Fig. 1). The ALS is an estuarine lagoon with the seagrass *Ruppia maritima*, surrounded by mangrove, and also has several oligohaline water bodies surrounded by freshwater wetlands (Contreras-Espinosa and Warner, 2004; Rivera-Guzmán et al., 2014). The latter authors describe salinity changes, especially in the main water body of Alvarado, from freshwater values during the rainy season to brackish during the dry season.

The study region has thirteen municipalities, rather than the nine cited by Vázquez-González et al. (2014) based on the administrative region known as the ALS. We decided to include four more municipalities (Cosamaloapan, Chacaltiaguis, Tierra Blanca, and Tlalixcoyan) that overlap the Papaloapan Basin. During field work (interviews with fishermen in 2007, field vegetation analysis and mapping in 2009, and analysis of database was in 2013), we realized these four municipalities engage in fishing activities in nearby lagoons, though not all of them have fishing cooperatives. Hereafter, references to the ALS encompass the 14 municipalities mentioned (Fig. 1).

In the ALS, crop cultivation and raising livestock are the main types of land use, with sugarcane crops representing 22.52% (50,318 ha) and livestock pastures 33.49% (73,747 ha) of the area (Fig. 2).

2.2. Brief socioeconomic description of the ALS

In each of the 14 municipalities, more than 25% of the population works in the primary sector (agricultural and fishing activities). Ixmatlahuacan has the highest proportion of people employed in the primary sector at 61.5%, and Carlos A. Carrillo, where the San Cristobal sugarcane mill is located, has the highest proportion of its inhabitants working in the secondary sector (36.1%) (CONAGUA-CONACYT-48247, 2009). In the municipality of Tierra Blanca, livestock and sugarcane activities employ 28% of the population working in the primary sector; activities that had a production value of $12.5 and $5.6 million USD, respectively, in 2012 (Table 1). Fishing is also a common way to make a living for local populations, and in the study area more than 10,000 fishermen belong to 84 fishing cooperatives for a total of 2,500 families that are directly dependent upon fishing activities; an additional 1,500 people are not organized into cooperatives (CONAGUA-CONACYT-48247, 2009). This highlights the importance of the primary sector in the regional economy. However, there are trade-offs when considering the allocation of land for agricultural purposes versus the conservation of the freshwater wetlands and mangroves that maintain fishing productivity levels (Vázquez-González et al., 2014).

2.3. Characterization and productivity of riverine fishing

From the regional study by CONAGUA-CONACYT-48247 (2009), we obtained the number of fishing cooperatives in the ALS (Fig. 4) and the area their work covers within the wetlands. We surveyed 39 of the 84 cooperatives listed in this study (46% of the total) (CONAPESCA, 2006). We gave our questionnaire to six members of each cooperative, for a total of 234 questionnaires. Members were asked about the number of people in the cooperative, the name of the lagoon or water body where they operated, the biomass of crustaceans and fish extracted, fishing methods used, and seasons of capture. In this paper, we will only present the information obtained for the six most representative species based on their yearly levels of marketing and consumption: snook (*Centropomus undecimalis*), chucumite (*Centropomus parallelus*), tilapia (*Orechromis mossambicus*), shrimp (*Macrobrachium acanthurus*), and crab (*Callinectes rathbunae* and *Callinectes sapidus*).