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## Epilogue: Fisheries Management of Estuarine Systems of Mexico and Central America, what we know and what we need

The aim of this book is to contribute scientific information at an interdisciplinary level that will help to attain adequate fisheries management of the estuarine systems of Mexico and Central America. As pointed out in the introduction and chapters of this book, fishing activities within ecosystems in this region of the world are generally undertaken by small-scale fishers within an inherently complex framework. Complexity arises from the various types of fishing gears employed; the number and characteristics of a myriad of exploited species; the socioeconomic, educational and cultural context of the fishers exploiting these systems; as well as the environmental and anthropogenic factors. However, proper management and regulation of these small-scale fisheries is inhibited by a lack of physical and biological information in the area being fished, inadequate legislation for the protection and conservation of these ecosystems, and a paucity of strong governmental institutions with an ecosystem perspective to ensure effective governance.

It is generally recognized that successful conservation and management of fisheries requires adequate data about the exploited species and the ecosystem as a whole, as well as information about the socioeconomic context of the fishers and others that directly affect the exploited resources, as was indicated in the introduction. Unfortunately, this biological and socioeconomic knowledge is scarce or nonexistent for the majority of the estuarine systems in Mexico and Central America, and for those ecosystems where some information is available; the results are generally treated as independent or unrelated to other processes occurring in these systems. In this sense, this book collected relevant available information useful for adequate management of these ecosystems including the ecology of the exploited species and fisheries-related issues, results and information on physicochemical aspects and their relation to the flora and fauna inhabiting the estuarine systems, and socioeconomic aspects.

The first part of the book dealt with naturally occurring and anthropogenically caused physicochemical issues of estuaries throughout the region, and how these characteristics

are relevant for the conservation and management of these ecosystems. In Chap. 1 and 3, De La Lanza et al. and Calvario et al., respectively, highlight the importance and negative effects of untreated waste effluents discharged into estuarine and lagoon systems that impact estuarine habitat, fisheries, and water quality by increasing organic matter and nutrients such as ammonium, total nitrogen and phosphorus. In both studies, it was concluded that the studied systems (one in the Gulf of Mexico and the other on the Pacific Coast) were heterotrophic, and that although the level of pollutants discharged into these systems was high, the water quality was of sufficient quality to maintain productive fisheries. In both cases, the hydrological period and short water residence time helped to sufficiently eliminate the discharged pollutants. However, both studies also highlighted the importance of controlling urban discharges because as human population abundance increases, so will the amount of anthropogenic discharges. In turn, additional discharge could affect water quality and cause eutrophication, which could provoke decreased biodiversity and lower fisheries yields.

In Chap. 2, Ruelas et al. discussed how the pollution of estuaries could increase the presence of Mercury (Hg) in edible parts of fish and invertebrates, which could have an effect on human health through bioaccumulation. After analyzing the available information on Hg levels in fish (elasmobranchs and teleosts) and some of the most important edible invertebrates (shrimps, clams, mussels and oysters) landed in estuarine systems from Mexico, they concluded that only scalloped hammerhead sharks (*Sphyrna lewini*) present a clear risk to humans due to the level of Hg and methyl Hg in edible muscle tissue. However, the authors also indicated that the available information regarding Hg concentration of many exploited fish species, and the rates of fish consumption in Mexico, is scarce. Further, it is important to incorporate this information into fisheries management programs to limit or preclude consumption of effected species by size, sex, or during specific seasons when the risk of health effects is greatest.

In Chap. 4, Jara-Marini et al. studied the food web of an estuarine system in the Gulf of California that received a considerable amount of sewage from a nearby urban area (this system was also studied in Chap. 2). They documented a food web with 5 trophic levels in this estuary, which is consistent with previous studies in coastal environments, and indicates that although this system has been affected by anthropogenic activities, the food web still functions adequately. However, the results also showed enrichment of  $\delta^{15}\text{N}$  in the food web, which suggests nutrient enrichment by anthropogenic discharges into the ecosystem. The consequence of nutrient enrichment is that it can cause structural changes to coastal lagoon ecosystems, such as a reduction in species diversity and changes to the top-down and bottom-up regulating forces in food webs. Another consequence of nutrient enrichment is the stimulation of bacterial activity that can result in benthic oxygen depletion, which may cause long-term changes in the structure of benthic assemblages. Further changes could, in turn, affect fish abundance, which is strongly dependent on benthic organisms as this study demonstrated. An artisanal fishery that primarily targets finfish is also present in this estuary and thus, removal of fishes from the system without proper management guidelines could affect the long-term nutrient budget of the estuary by disrupting the linkage between coastal and marine processes.

The four chapters describing physicochemical characteristics of Mexico estuaries represent a baseline for evaluating the current state of estuarine water quality in Mexico and Central America and indicate a need for proper future management. It is apparent that these estuaries are not yet at their breaking point and that conditions could be much worse; however, the consequences of anthropogenic pollution are becoming more evident. Estuaries are reaching their nutrient carrying capacities and nearing eutrophic status, and bioaccumulation of Mercury in human-consumable tissues of the top piscine predators has been documented. Overall, these studies highlight an urgent need for proper waste water management before the effects to fisheries and other exploited species are irreversible.

The second section of this book dealt with general- and fisheries-ecology topics from estuarine systems in Mexico. In Chap. 5, Flores et al. discussed the effects of hydrological regimes on estuarine systems. Using a case study from the most extensive mangrove region in the American Pacific, "Marismas Nacionales" (National Floodplains), these authors described how the opening of a water-connection channel from one coastal lagoon to the open sea triggered a major ecological disaster. A channel that was originally planned to be 40-m wide by 2-m deep grew uncontrollably until it reached a width of 700 m and a depth of 20 m due to strong ebbing currents that provoked bank erosion. The consequence of this was the mortality of more than 15,000 ha

of mangroves and the affectation of 33% of the total mangroves in the system. Counterintuitively, local artisanal fisheries improved as landings of finfish and shrimp increased dramatically once this channel was formed. It has been typically believed that mangroves are a key habitat for sustainable fisheries, but in this chapter the authors indicate that environmental conditions in some areas of mangrove forests can be extremely difficult for the survival of aquatic resources due to oxygen depletion. They concluded that water inputs to mangrove forests are required for adequate fish habitat, and to sustain a productive fishery. In this sense, only certain types of mangrove forests are beneficial to fisheries, whilst other types of mangrove forests play other different ecological functions than supporting fisheries. This chapter is controversial in that it challenges the widely held belief that extensive areas of mangrove forests are needed for high fishery yields; however, the authors provide evidence that this paradigm may not always be true, particularly for Marismas Nacionales.

In Chap. 6, Vera and Salas reviewed the link between fish productivity and the variation in physical and chemical processes, which directly affect the abundance and distribution of zooplankton in areas of freshwater influence. Their goal was to describe how changes in environmental factors affected zooplankton, and they documented functional relationships that could be used to predict changes in zooplankton biomass and abundance, which in turn has an effect on the biomass of exploited species. In fact, the authors concluded that there is a direct link between zooplankton biomass and abundance of fish, and that the distribution pattern of fishes is similar to that of the zooplankton. Therefore, it is important to understand these processes in order to establish management tools that take into account the phenomena affecting the early life history stages of fish.

In Chap. 7, Ramirez et al. dealt explicitly with fisheries management issues of small-scale fisheries and proposed a management plan for the artisanal fisheries in the State of Sinaloa, Mexico, which has some of the highest fisheries landings among all of this country. In this paper, the authors agreed that the information needed for proper management of such a complex activity is lacking and they highlighted the urgent need for a management plan. They proposed a management strategy based on the use of zones as management units so that fishing processes could be understood by region, and to identify possible spatiotemporal changes of the marine communities between zones. Thanks to this zonation, the targeted species were identified and categorized per region, and it was discussed how using this method could allow the identification of catch trends for adaptive management.

Turk-Boyer et al., in Chap. 8, showed that an ecosystem-based approach to fisheries management is possible when

the necessary information is available. They exemplified this using a case study in wetlands from the upper Gulf of California. Using data from trophic studies, oceanographic-biological models on larval dispersion, genetic data from commercial species, and information on the patterns of human use along the coast including fisheries, tourism and coastal development, the authors defined essential habitats for target species and identified their trophic interactions. It was then determined that these areas can be protected to ensure sustainability of the fisheries resources.

The last section of the book dealt with socioeconomic topics, which are an essential part of the management of small-scale fisheries, but are usually overlooked by stakeholders, the government, and decision-makers. Chapter 9, by Fargier et al., analysed participatory management processes of small-scale fisheries in Costa Rica, a country in which the fisheries data and the biological information of the exploited species is scarce, and with management plans that are not adequate for the existing conditions. Using the "Marine Area of Responsible Fishing" model, they described how the inclusion of small-scale fishers organizations into the development of management plans can help to achieve long-term success in fisheries conservation through a set of measures outlined by the authors.

In the 10th and final chapter of the book, Turk-Boyer et al. outlined a management strategy for a coastal area in the upper Gulf of California that has been developed significantly due to tourism. This strategy included the designation of Natural Protected Areas, Federal Zone Concessions and Ramsar Sites by the federal government, as well as the active participation of fishers, local communities and civil society organizations in order to guarantee long-term protection of essential coastal habitats. Government and civic organiza-

tions have conjointly developed a series of programs of different themes (educational, tourism development, handicrafting) that include the fishers and their families, and are aimed to help them solve environmental and financial problems. Thanks to these programs, fishers are participating in management initiatives for individual species, and a vision for ecosystem-based management is growing. A wetland conservation ethic is also emerging and could be as important in the long term as other tools that have been utilized.

Overall, this book presents a much-needed diagnosis of the anthropogenic factors affecting estuarine systems, and the potential medium- and long-term impacts that a lack of management could have on exploited resources. These impacts vary from threats to human health by the consumption of organisms with bioaccumulated toxins, to the loss of fishery yields as a consequence of coastal habitat destruction. Furthermore, information on the current condition of coastal areas of Mexico and Central America is presented, such as the effects of abiotic factors on zooplankton and the need to understand these processes due to their direct influence on the distribution and abundance of exploited fish species. Information was additionally presented about the relationship between mangrove-forest types and fisheries yield, and several case scenarios were presented to exemplify practical management tools. Conclusively, this cumulative knowledge of estuaries will assist decision makers in managing and restoring coastal ecosystems. Although more information is needed on the biology and ecology of Mexico and Central American estuaries, this book offers a glimpse of hope, and a first step, in achieving proper management of estuaries and estuarine fisheries.

Felipe Amezcua and Brian Bellgraph

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