Marine Policy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Poor fisheries data, many fishers, and increasing tourism development: Interdisciplinary views on past and current small-scale fisheries exploitation on Holbox Island

Nadia T. Rubio-Cisneros[a,b,*,1], Marcia Moreno-Báez[c], Jeffrey Glover[d], Dominique Rissolo[e], Andrea Sáenz-Arroyo[f], Christöpher Götz[g], Silvia Salas[a], Anthony Andrews[h], Gustavo Marín[i], Sara Morales-Ojeda[a], Francisca Antele[j], Jorge Herrera-Silveira[a]

[a] Centro de Investigación y de Estudios Avanzados (CINVESTAV), IPN, Unidad Mérida, Mexico
[b] Center for Marine Biodiversity and Conservation, Scripps Institution of Oceanography, University of California San Diego, United States
[c] Department of Environmental Studies, University of New England, Biddeford, ME, United States
[d] Department of Anthropology, Georgia State University, United States
[e] Cultural Heritage Engineering Initiative (CHEI) Qualcomm Institute, University of California, SanDiego, United States
[f] El Colegio de la Frontera Sur (ECOSUR), San Cristóbal de las Casas, Chiapas, Mexico
[g] Facultad de Ciencias Antropológicas, Universidad Autónoma de Yucatán, Mexico
[h] Division of Social Sciences, New College of Florida, Sarasota, FL, United States
[i] Centro de Investigaciones y Estudios Superiores en Antropología Social (CIESAS), Unidad Peninsular, Mexico
[j] Instituto Tecnológico de Conkal, Mexico

ARTICLE INFO

Keywords:
Traditional fishers' knowledge
Small-scale fisheries
Coastal exploitation
Island conservation
Ecosystem services
Tourism

ABSTRACT

Holbox Island is a contemporary hotspot for global tourism. Here, long-term coastal exploitation and increasing anthropogenic activities threaten coastal habitats and resources. The impact of these activities is exacerbated by the lack of a management plan for the past 24 years, until October 2018. An interdisciplinary approach that integrates fishers' traditional knowledge was used to determine how small-scale fisheries (SSF) exploitation contributed to the decline of resources over time. Open interviews with community members and surveys of fishers' perspectives on fisheries overexploitation and practices as well as knowledge of fishing sites were collected. Over one hundred fishing sites were documented that were once very productive. Furthermore, over 40 species were highly fished (*e.g.*, Carcharhinidae, Shpyrnidae, Pristidae, Cheloniidae) over the past 50 years. Survey results allowed for the construction of maps with baseline information of coastal exploitation. Additional data from archaeozoological remains (n = 545) of aquatic fauna identified 33 families of exploited taxa, of which finfish (*e.g.*, Haemulidaea, Ariidae, Serranidae), sharks (*e.g.*, Carcharhinidae), and sea turtles were the most abundant. Fishers and literature sources (n = 50) document Holbox's contemporary issues, including overfishing, illegal fishing, and accelerated tourism development. These types of data (fishers' perspectives, interdisciplinary literature, and archaeozoological data) were combined using historical ecology techniques and geospatial tools to obtain novel baseline information on SSF exploitation. This information is essential for conservation managers and scientists to meet the management needs of Holbox's natural and social capital, which can assure the future provision of coastal ecosystem services to humans.

1. Introduction

Habitat deterioration of barrier islands and their near shore environments (mangroves, sea grasses, and coral reefs), have become critical drivers for the creation of conservation initiatives that link ecological processes and socio-economic benefits (*e.g.* The National Oceanic and Atmospheric Administration Habitat Conservation Program for the conservation of barrier islands in the Gulf of México region, Landscape Conservation Cooperative Network, Island Conservation, among others) [1–3]. Globally, barrier islands (*e.g.* Cancun Island, Florida's St. Vincent Island, Frisian Islands at the Wadden Sea) have faced accelerated habitat deterioration by

* Correspondence to: Center for Marine Biodiversity and Conservation, Scripps Institution of Oceanography, University of California San Diego, 9500 Gilman DriveLa Jolla, California 92093, United States.
[1] Affiliation where the research took place: CINVESTAV Mérida, Km. 6 Antigua carretera a Progreso, Apdo. Postal 73, Cordemex, 97310, Mérida, Yucatán, México.

https://doi.org/10.1016/j.marpol.2018.10.003
Received 11 June 2017; Received in revised form 14 September 2018; Accepted 6 October 2018

anthropogenic actions associated with global economies such as: increasing fishing effort, human coastal migration, and large-scale tourism development.

A common globalization effect for many fishing communities on islands is overfishing [4–6]. But recently the popularity of tourism is also transforming traditional fishing communities into touristic sites [7]. This implies increasing anthropogenic transformations of the natural environment which usually occur unregulated by authorities [8,9].

Consequences of anthropogenic transformation involve the degradation and loss of ecological functions and biodiversity necessary to accomplish the coastal ecosystem services on which human welfare relies. These services include fisheries, which are the focus of this article, coastal protection, carbon sequestration, and water filtration, among others [10–14]. Over the past 40 years, the state of Quintana Roo in the Yucatán Peninsula (YP) has evinced growing coastal anthropization that has disrupted socio-ecological systems associated with the island environments (whose human occupation dates back to Pre-Columbian times) [15,16]. An extreme example is Cancun Barrier Island, where land refill and extensive constructions of hotels, marinas, and golf courses have completely modified and destroyed nearshore environments along with their historical fishing habitats [17,18].

This research takes place on Holbox Barrier Island (hereafter Holbox), which was previously a small fishing community (Fig. 1). In the past few decades, however, Holbox has faced socio-environmental transformations related to increasing coastal migration and fishing pressure as well as accelerated tourism and urban development largely associated with whale shark tourism [19,20]. For instance, Holbox's population is ~1143 people, but throughout the high season (May to September), a floating population of over 10,000 people demands services **[21]**. The increasing number of tourists together with no urban management plan and reduced government enforcement to protect the natural environment is leading to uncontrolled urban development in an island with precarious infrastructure for sewage disposal, freshwater supply, and electricity. The existing, regional problem of scarce baseline documentation of nearshore environments demonstrates the need to incorporate interdisciplinary environmental data along with traditional fishers' knowledge into the development of regional conservation policies. Overall historical and socio-cultural data on exploitation patterns of Caribbean small-scale fisheries (SSF) is scant, but necessary for successful management [22–24].

An interdisciplinary approach to understanding long-term fishing and human disturbances on coastal ecosystems has helped scientists to detect "shifted baselines" related to the spatiotemporal availability and abundance of fishery resources [25,26]. Furthermore, interdisciplinary data has proven to narrow the knowledge gap regarding potential limits to sustainable fisheries exploitation as a function of demography, culture, technology, and exploited area [6,27–30]. The following integrated history of coastal exploitation on Holbox will help detect the shifting baseline syndrome in fisheries and can allow scientists and managers to understand how spatial fishing patterns and the diversity of species targeted has changed over time.

This ongoing study aims to generate interdisciplinary results that can help build a comprehensive baseline to infer the trajectory of the diversity, availability, and extent of the exploitation of fishery and coastal ecosystem services on Holbox. The results presented in this paper include qualitative and spatial data of coastal exploitation on Holbox using fishers' traditional knowledge collected by interviews and participatory mapping as well as archeological data and interdisciplinary literature sources (Fig. 2). This information can help managers in the creation of policies for the preservation of coastal ecosystem services which are currently under fragile management. Though Holbox belongs to the Yum Balam Natural Protected Area (NPA), designated in 1994 by The National Commission of Natural Protected Areas in México (CONANP) to protect flora and fauna in the

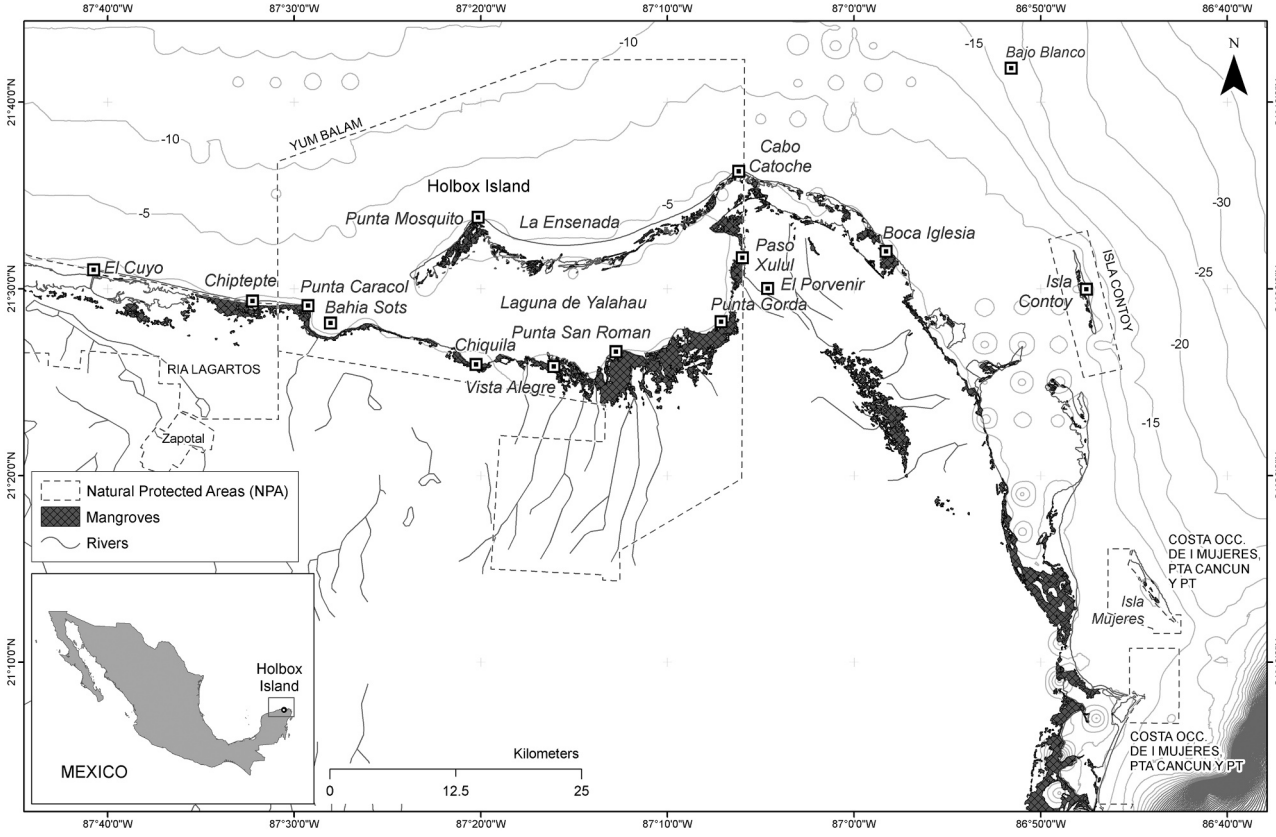

Fig. 1. Study area. The gray dotted lines show the polygon of Yum Balam Natural Protected Area.

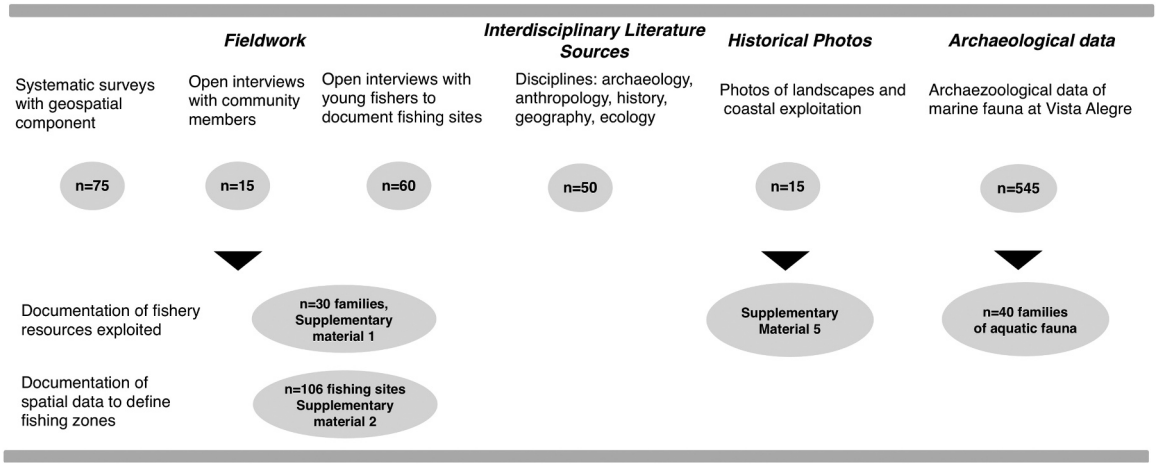

Fig. 2. Interdisciplinary data collected for this study.

region, the area's management plan was in preparation for the past 24 years until October 5th 2018[2] (Fig. 1). The previous has limited conservation efforts and has also threatened the future welfare of local fishers and Islanders [31].

Holbox is a barrier island off the northern coast of the YP. It is 42 km long and 2 km wide. The island complex forms the Yalahau Lagoon (hereafter Yalahau), which is one of the largest coastal lagoons in the YP (275 km^2) [32] (Fig. 1). Yalahau's mouth opens westward into the Gulf of México [33]. Mangroves surround the lagoon and seagrasses and macroalgae cover its benthos. The near and offshore waters of Holbox are influenced by currents from the Gulf of México and the Caribbean Sea and by rich upwelling events from the northeastern shelf of the YP [34]. Upwelling events sustain diverse near-shore and offshore fauna including large aggregations of whale sharks (*Rhincodon typus*), which are currently an important tourist attraction.

2. Methods

2.1. Collection of Archaeozoological data and literature review

Archaeozoological data of marine fauna remains give us a view of ancient coastal exploitation by the past Maya inhabitants. These data are from off-structure test excavations at the ancient Maya port site of Vista Alegre (Fig. 1). Archaeozoological remains were collected as part of an international, ongoing research effort called "The Costa Escondida Project," directed by co-authors Glover and Rissolo [16,35,36]. Since 2006, this project has investigated the social and environmental factors that conditioned the resilience and vulnerability of Maya and their coastal landscape over the past 3,000 years. The Costa Escondida Project investigation is based on the collection of interdisciplinary data related to archaeological surveys and excavations, sediment cores, along with water salinity and coastal ecological surveys. For details on identifications of archaeozoological remains used in this paper see [36,37]. In general, the excavated remains reveal a population that heavily utilized the rich marine resources of Laguna Yalahau, which included a diversity of bony fish (*e.g.* catfish, jack, grunt, grouper, snapper), cartilaginous fish (*e.g.* blacknose and sandbar sharks, and spotted eagle rays), adult sea turtles, and a large number of mollusk species [38].

Trends of coastal exploitation on Holbox were also documented using literature sources (Fig. 2). Grey literature, historical references, and photographic sources were obtained at: Casa de la Cultura de Isla Holbox; Casa de la Cultura de Cancún; Biblioteca Pública "Dr. Enrique Barocio Barrios" in Cancún; Biblioteca de la Universidad Autonoma de Yucatán, Mérida; Instituto Nacional de Antropología e Historia (INAH) Mérida; and from Mr. Gaspar Maglah, the historian of the municipal capital Kantunilkin. Interdisciplinary literature sources from the region were collected online from Web of Science and at the libraries of: CINVESTAV, Mérida; Centro de Investigación Científica de Yucatán; and Centro de Investigaciones y Estudios Superiores en Antropología Social (CIESAS). Data on trends in coastal exploitation were grouped into four historical periods based on key socio-cultural events of the region [6,39] (Table 1). For each period, information on the types of fishing gear employed and habitats and animals exploited was collected and compiled into a single database for analysis.

2.2. Fishers' surveys and interviews

Field surveys from elder (57–90 years old), middle age (37–56 years old), and young fishers (21–36 years old) were collected, along with open interviews from key community members (*e.g.* native Holbox residents, community leaders, community members involved in conservation, and some elder fishers) (Fig. 2; Appendix 1). In order to identify fishers, the snowball approach was used [40]. This approach helps to identify community members through referrals made among people. Positive social bonds have been established with fishers and key community members since September 2015.

Surveys were used to gather information on traditional fishers' knowledge related to historical and current small-fisheries, fishing grounds, species caught, changes in fishing technology, and fishers' perceptions of the future of fisheries (Appendix 1). Surveys were developed using published guidelines and acknowledging local customs [6,29,41]. Surveys were tested in the field in 2015, then further collected throughout seven field sessions in 2016. Focus groups with fishers were used as a tool to account for any biases in our survey results or to prevent untruthful responses either of fishing sites locations or of species identifications.

2.3. Documentation of species fished

Data on species fished on Holbox obtained through fishers' interviews, surveys and participatory mapping, were resolved to the extent possible (*e.g.* generic, and family identifications) based on published taxonomies [42,43] (Appendix 2). A fishers' species identification workshop was held in December 2015. At the workshop fishers associated the common species names with their scientific name by using published fish guides provided by this project. In the field an extra

[2] The disclose of Yum Balam's NPA management plan on The Official Journal of the Federation (Diario Oficial de la Federación DOF) occurred while this paper was in the final stages of publication.
https://www.dof.gob.mx/nota_detalle.php?codigo=5540179&fecha=05/10/2018

Table 1
Fishery ecosystem services exploited for each time period at Holbox.

Time Period	Year	Characteristic
Pre-Columbian (Post-Classic)	1100–1521	Exploitation of diverse marine fauna (Fig. 3) in coasts and estuaries. Strong hurricanes and pestilence before the conquest period.
Spanish Occupation	1546–1821	Spanish conquest brought depopulation of natives and land abandonment for almost 3 centuries. The Island and its surrounding were an important site for pirates, trafficking mainly of arms and of palo de tinte existed. Regional fisheries were minor at that time (Appendix 4).
Mexico's Independent Period	1820–1910	*1839* Settlements of mestizo hunters exploited sea turtles and sponges, commercialization of dried fish existed. *1850* Exploitation of sea turtles, manatees, Caribbean monk seals, dolphins and sharks. *1900s* Intense fishing and export of sea turtles to a burgeoning market in Belize.
Contemporary Mexico	1910-Present	*1920* Historical documentation of declines in sea turtles, fisheries are open-access. *1930* Proliferation of ranches that exploited coconut trees. Declines in sea turtle and sponges are documented. *1940s* Shark fishery blooms. *1964* Fishing cooperatives initiate at the Island. *1960s to 1970s* The lobster fishery turns into an important export item. Introduction of outboard motors and nylon nets begins. Fishing in nearshore and lagoonal sites is widespread but self-regulated. *1980s* Migration of people to the coast driven by Government policies and subsidies. *Late 1980s* Fisheries of diverse finfish families gain importance. Lobster catches begin to decrease. *1990s* The fishers' population increases. Fishing cooperatives face overcapacity of members, which leads to overfishing, and use of unsustainable fishing practices. The Yum Balam NPA is decreed.*2000s* The fishers' population continues increasing. The Yum Balam NPA lacks a management plan. Illegal fishing, the use of prohibited gears in lagoonal and nearshore sites together with fishing activities during bans are widespread.

reference (when possible) for the identification of fished species was used to document in real time the unloaded fished species of the fishers' catches while they were interviewed at shore.

2.4. Spatial data collection on fishing grounds, assembly and analysis

Spatial data on fishing grounds was collected using standard participatory mapping techniques that included printed maps with basic information such as the coastline (INEGI 1:50,000 topographic maps), bathymetry, and general landmarks with local names. Maps were printed at different scales ranging from 1:250,000 to 1:50,000. Printed maps were tested *a priori* with fishers in the species identification workshop to document any particular problems or needs. During the workshop fishers were asked to identify the location and draw fishing grounds for several species known to be exploited on Holbox [44,45] (Appendix 3). Once tested, printed maps were added to the fishers' surveys and used as a template to allow fisher interviewees to draw fishing grounds on Holbox. A second approach to gathering data on fishing grounds was used for young fisher interviewees, since often young fishers lacked disposition towards completely answering the fishers' survey. For this age group we included a semi-open interview that was structured according to the research goals of our fishers' survey instrument, and the printed map was included. This information was also coupled with available field survey data of young fishers and their fishing sites collected in 2014 [46]. The latter approach allowed us to spatially represent the fishing zones being used by young, middle age, and elder fishers.

All printed maps' data on fishing grounds was georeferenced and exported to digital format using onscreen digitizing techniques. A geographic information system (GIS) database build in ArcGIS 10.4 was used to integrate all digitized fishing grounds [47]. Spatial data of fishing grounds for each fisher survey was linked to other data attributes collected from the survey, which included information related to: ecological site location-based data of fishing grounds, species information and distribution by fishing ground mapped, time period of species exploitation, fishers' age, and more. Fishing grounds were analyzed by species and a simple overlay analysis was performed to understand the frequency of times fishers mentioned a certain fishing ground. In addition, a spatial relationship analysis was performed on the data in order to understand the location and distance of fishing grounds in relation to Holbox.

3. Results

Fishing has existed in lagoonal and near-shore areas of Holbox and Yalahau since pre-Columbian times [16,48] (Fig. 2). Natives exploited finfish, sharks, sea turtles, rays, and shellfish, using simple types of equipment (*e.g.* hooks, harpoons, fishing nets most likely made of cotton weighted down by net weights, a large number of which have been recorded at Vista Alegre (*pers. comm.,* J. Glover) Fig. 3). The salting of seafood and meat was a common practice among the Maya at the time of the conquest [49,50]. This region harbored important

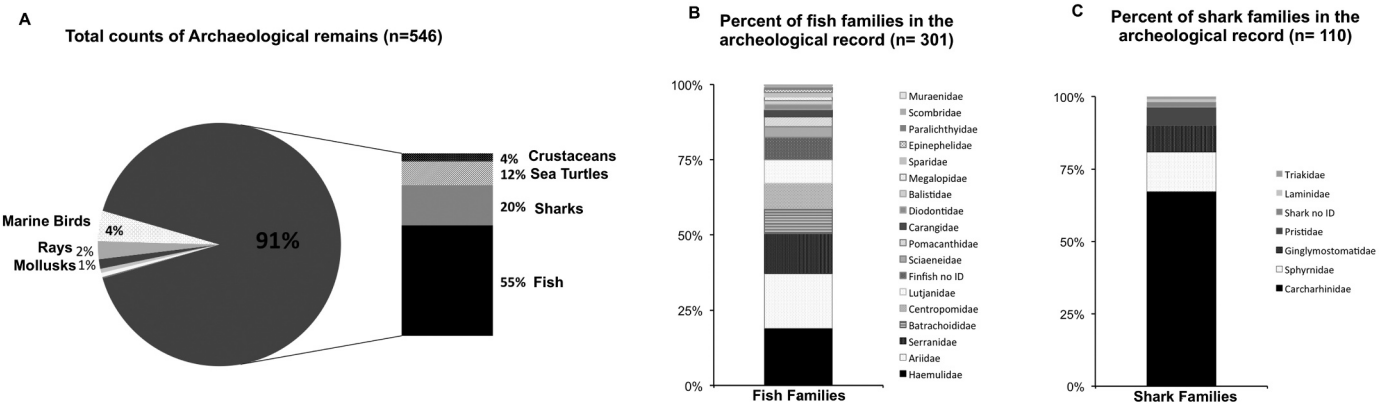

Fig. 3. Archaeozoological data; A) percent of the main species groups of marine faunas in the archaeozoological remains; B) and C) Percent of fish and shark families in the archaeozoological record.

circum-peninsular trade networks for the ancient Maya [36] (Appendix 4). However, these trade networks largely disappeared with the Spanish conquest in the 16th century, which led to the depopulation of indigenous peoples in the area [51,52]. Coastal areas were barely populated and were under mild Spanish enforcement for almost three centuries, which lead to piracy in the region (~1590–1680) [53,54]. A main item exploited and exported to Europe by pirates was the "palo de tinte" tree (*Haematoxylum campechianum*), which abounded in wetlands inland from the Yalahau Lagoon [54]. The richness of fishery resources in the Holbox region for this period is narrated in historical documents [55,56]. During this time, food webs had abundant sharks (*e.g.* Pristidae, Carcharhinidae, Shpyrnidae), manatees (*Trichechus manatus*), Caribbean monk seals (*Neomonachus tropicalis*, extinct), sea turtles (*e.g.* Cheloniidae), numerous shellfish (*e.g.* queen conch, *Strombus gigas*), and large predatory fish (*e.g.* goliath groupers; *Epinephelus itajara*) [53,55,57–60].

The northern coast of the YP was repopulated during the first half of 19th century when small "Ranchos de pesquería (fishing ranches)" were established all along the coast. Fishing ranches are not well documented and there were not a formal exploitation system regarding them decreed by the government nor did they have exclusive access rights. In addition to the catch of many species of fish, they also harvested sea turtles, sponges, manatees, and Caribbean monk seals on a relatively small scale. During the 19th century, many of these ranches also planted extensive coconut groves and exploited salt beds behind the coastal barrier beaches. Several of the small ports of that time also exported substantial quantities of precious hardwoods and "palo de tinte" to international markets [50,52,61–67] (Appendix 4).

During the height of the Caste War, ca 1847 to 1860, the northeast coast of the YP saw a decline in population, though the ports of San Felipe, Rio Lagartos, El Cuyo, Yalahau, and Chiquilá remained populated [52,68]. The Caste War was an indigenous Maya rebellion against the social organization imposed by the Spanish that continued after Mexican independence from Spain in the early 19th century [69]. Still, the fisheries and the exploitation of sponges, sea turtles, manatees, and seals continued on a limited scale into the late 19th and early 20th centuries. In the 1940s, the shark fishing industry took off in Holbox, but then went into decline in the 1980s.

In the decades after the 1940s, fisheries were open access. Elder fishers mention that nets were made of natural fibers and buoys were made of cork (*Annona* sp.). Hooks, harpoons, lines, and chains were used with wooden sail boats propelled by paddles [70] (Table 1; Appendix 5). The main types of bait for sharks as documented by elder fishers' traditional knowledge were the very abundant dolphins (*Tursiops* sp., *Delphinus* sp.), leatherback sea turtles (*Dermochelys coriacea,*), and giant mantas (*Manta birostris,* Appendix 5), of which the former two are considered vulnerable by the IUCN criteria.

Traditional knowledge of elder and middle age fishers demonstrates that a diversity of resources existed on Holbox throughout the 1950s (*e.g.* abundant sharks, sawfishes, finfish, sea turtles, edible snails, and manatees) and were fished at what they describe as "the very productive lagoonal and near-shore environments of Holbox[3]" (Figs. 4 and 5). From the 1950s to 1970s, offshore fishing occurred within 20 miles off the coast. A total of 41 families of aquatic fauna were recorded from fishers' interviews (Fig. 4; Appendix 2). Elder fishers report a higher number of productive fishing sites (n = 60) when compared to sites documented by middle-age fishers (n = 47) (Fig. 4I). Elder fishers mentioned lagoonal sites were very productive and had cultural relevance (Fig. 5A, D-N), especially for the bountiful fisheries of immature and small sharks that existed in the Yalahau Lagoon (*e.g.* Carcharhinidae, Lamnidae, Sphyrnidae; Fig. 5E; Appendix 5). However, fishers mention that this tradition ended during the late 1980s due to the reduction in numbers of small sharks. Elder fishers also mention that precarious inland roads made water transportation essential so that goods could arrive to the island. This also allowed for the early commercialization of salted shark and fish meat. The meat had to be salted because the lack of electricity on the island did not allow the marketing of fresh seafood [56]. Surveys and open interviews also indicate that beef and pork were scarce and manatee meat was an important source of protein highly valued by Islanders (Appendix 5).

During the few decades after the 1960s, the population on Holbox and in the port of Chiquilá increased and the government organized people into fishing cooperatives [70]. At this time, the lobster (*Panulirus argus*) fishery gained high importance, fueled (until recently) by its international demand [71] (Table 2). Towards the early 1970s diversification of fishing technologies enhanced fishing effort of lobster and large finfish (*e.g.* Serranidae, Centropomidae, Lutjanidae, among others) with the introduction of fiberglass skiffs, outboard motors, nylon nets, and diving air compressors. Furthermore, electricity on the island (towards the end of 1970s) allowed for refrigerated warehouses, which facilitated the preservation of catches for commercialization. Lastly the introduction of GPS devices in early 1990s allowed the recording of important fishing spots [70].

Consequences of introducing new fishing technologies are exemplified by lobster exploitation, which was initiated with free diving in nearshore and lagoonal sites around Holbox. Elder fishers describe immense lobster aggregations in the form of spheres that were sometimes fished with nets. They also describe the infinite lobsters that were seen advancing through the sea floor during their migration (Fig. 5I). The introduction of air compressors allowed fishers to dive for longer and explore deeper offshore habitats. By the early 1990s, GPS devices allowed easier and faster accessibility to lobster habitats; and fishing lobster became accessible to "new fishers" without a traditional fishing culture. The latter were agricultural workers who moved to Chiquilá during the "*March towards the sea*" initiative, which occurred during México's agricultural crisis in the 1980s and promoted human coastal migration for fisheries exploitation as a way to generate income [72,73].

Despite a lobster fishing ban that has existed since 1981 (May to June; NOM 1993) to preserve lobsters, fishers' surveys and literature report that the increase in the population of fishers and illegal fishing practices has largely reduced lobster catches, size, and abundance in near shore environments [70] (Appendix 6). Another example of an exploited species is the now critically endangered "chernas" (Goliath groupers; *Epinephelus itajara;* ~ 2.5 m total length, > 400 kg) [74,75]. Fishers documented that *chernas* and other diverse grouper species populated lagoonal and near-shore caves. Improvements in fishing technologies (*e.g.* spear guns, GPS) facilitated the catching of chernas, mainly by the middle-age fishers (Fig. 5J). Overall, fishers interviewed state that chernas are extremely rare nowadays. Some middle-age and young fishers mentioned they have never seen this species, although some young fishers recently reported traveling far offshore to try and catch groupers (Fig. 5C).

Contemporary fisheries in the Holbox region are multispecific and focus on grunts (*Haemulon* sp.), corvinas (*Cynoscion* sp.), snooks (*Centropomus undecimalis*), snappers (*Lutjanus analis, L. Synagris, L.buccanella*), mojarras (*Gerres* spp.), mullets (*Mugil* spp.), groupers (*Epinephelus morio, E. striatus*); lobster (*Panulirus argus*), and octopus (*Octopus maya*, *O. vulgaris*) [76,77]. Shark fisheries on Holbox are largely gone, as documented by fishers, given their low market value and the high traveling cost of fishing sharks. Existing shark fisheries are seasonal and are more of an "alternative fishery" when fishing bans for species with high economic value are in place (*e.g.* lobster) [78] (Appendix 6). Chiquilá has a small-scale fleet that targets sharks,

[3] Video 2 shows underwater documentation of Cabo Catoche Historical Fishing site. This video and photographic material are being used to generate conservation awareness with islanders and the general public. Several outreach videos have been created and were shared with key community members and school teachers. See Instagram account for more details, https://www.instagram.com/marsustentable 1/

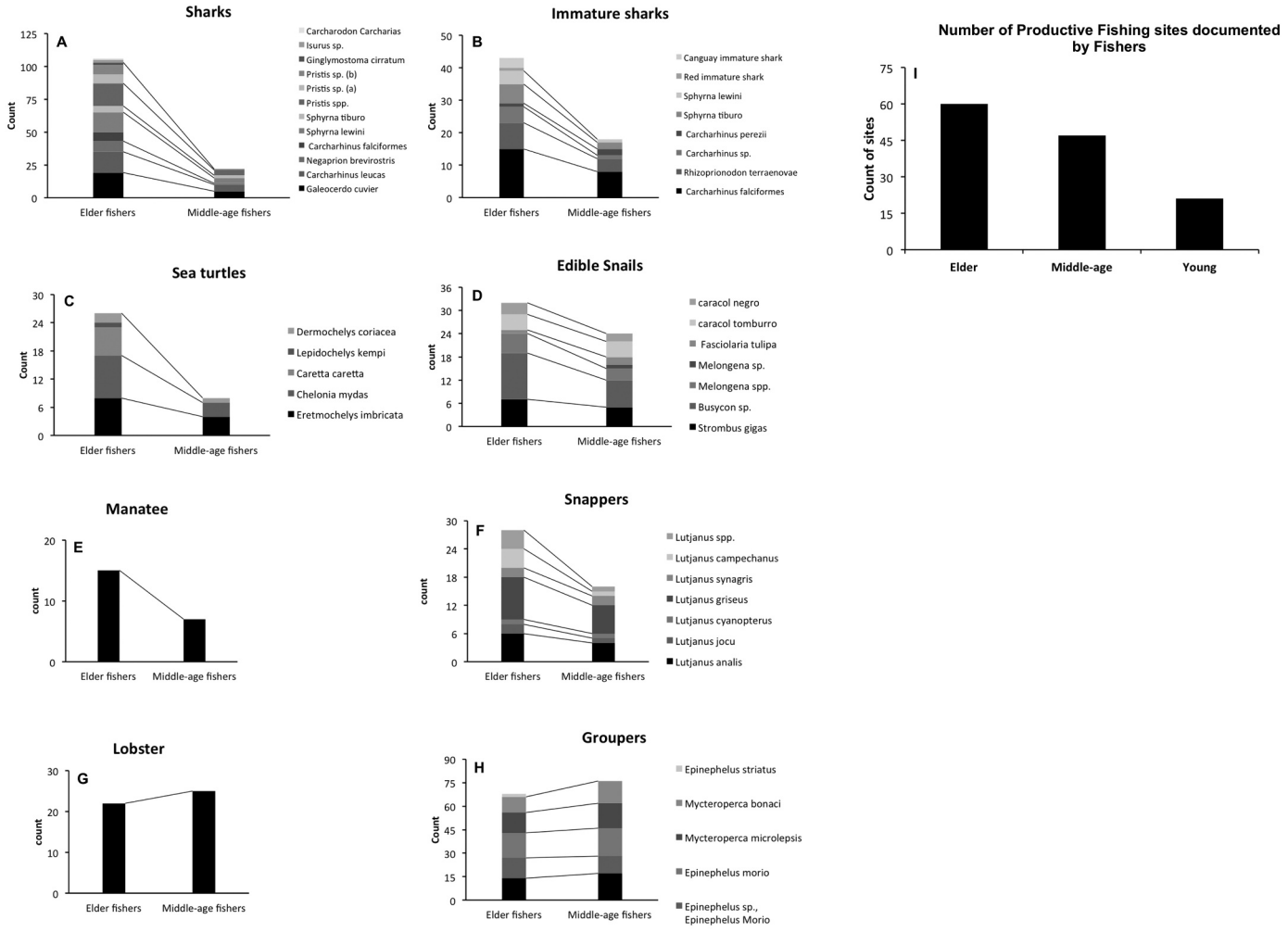

Figure 4.

Fig. 4. A-H) counts of fishers' responses (elder fishers n = 36; middle age fishers n = 30) from the systematic surveys section related to "fishers' perspectives" on the availability and diversity of species that inhabited Holbox waters. I) number of productive fishing sites documented by fishers of different age classes.

including small and immature sharks such as cazon (*Rhizoprionodon terraenovae*) and jaqueton (*Carcharhinus brevipinna*) [78]. Overall, regional shark fisheries are hardly documented, but Yalahau is considered a nursery site for black tip sharks (*Carcharhinus limbatus*) [79,80].

Throughout the late 20th and early 21st centuries, fishing effort intensified in Quintana Roo and coastal populations increased, fueled, in part, by continuing government policies and subsidies that supported fishing and promoted tourism development [24]. Holbox and Chiquilá have the highest fishing effort in the state with ~187 registered fishers, representing close to 30% of the fishers in the state [77]. However, this number is conservative since fishing trips include up to three fishers and many "free fishers" exist for which no official records are available [81]. Our surveys document that increasing fishing effort has initiated clashes over fishery resources between Holbox and Chiquilá fishers, mainly because people fish with nets inside the lagoon [82]. This is supposed to be a "no fishing area" within the Yum Balam NPA. Furthermore, fishers document that the growing number of fishing boats transiting in and out of the lagoon and navigating fast and carelessly is more frequently destroying floating fishing gears placed in nearshore areas of Holbox outside the lagoon, which implies continuous economic losses and social conflict.

Ideally, a different conservation scenario can be envisioned for Holbox as part of the Yum Balam NPA (Fig. 5). This conservation instrument should help citizens understand the importance of enforcing existing fishery and environmental regulations (*e.g.* related to species bans; no fishing areas, gear restrictions, among others) for the preservation of fishery ecosystem services. However, the impact of conservation tools is unclear in the region due to the continuing actions of non-compliance for fisheries regulations (*e.g.* fishing during bans and catching immature finfish and lobsters) that demonstrate a lack of fisheries stewardship from the community, limited governance, and weak government enforcement [82,84,85]. In the field, the matter of non-compliance towards fisheries regulations was of high concern for interviewed fishers. A novel way of illegal fishing documented by young fishers is night diving, fast motorboats arrive with divers that fish "everything" they find available. Some of these species are: sea turtles, a diversity of edible snails, lobsters, sea cucumbers, and fish. Open interviews document night divers are people from nearby communities or from out-of-state.

Fishers' surveys documented tourism as a leading economic activity for contemporary Holbox that is a main driver of a change in (1) the demand of fishery resources; (2) socioenvironmental and landscape changes; (3) diversification of jobs for income; and (4) changes in sociocultural values. First, since tourism began, demand has risen for fish species that previously lacked commercial value, such as chopas (tripletail, *Lobotes surinamensis,* least concern IUCN), macabi (bonefish, *Albula vulpes,* near threatened IUCN), tambor (black drum, *Pogonias cromis,* least concern IUCN), pez loro (parrotfish, *Sparisoma* spp.), and

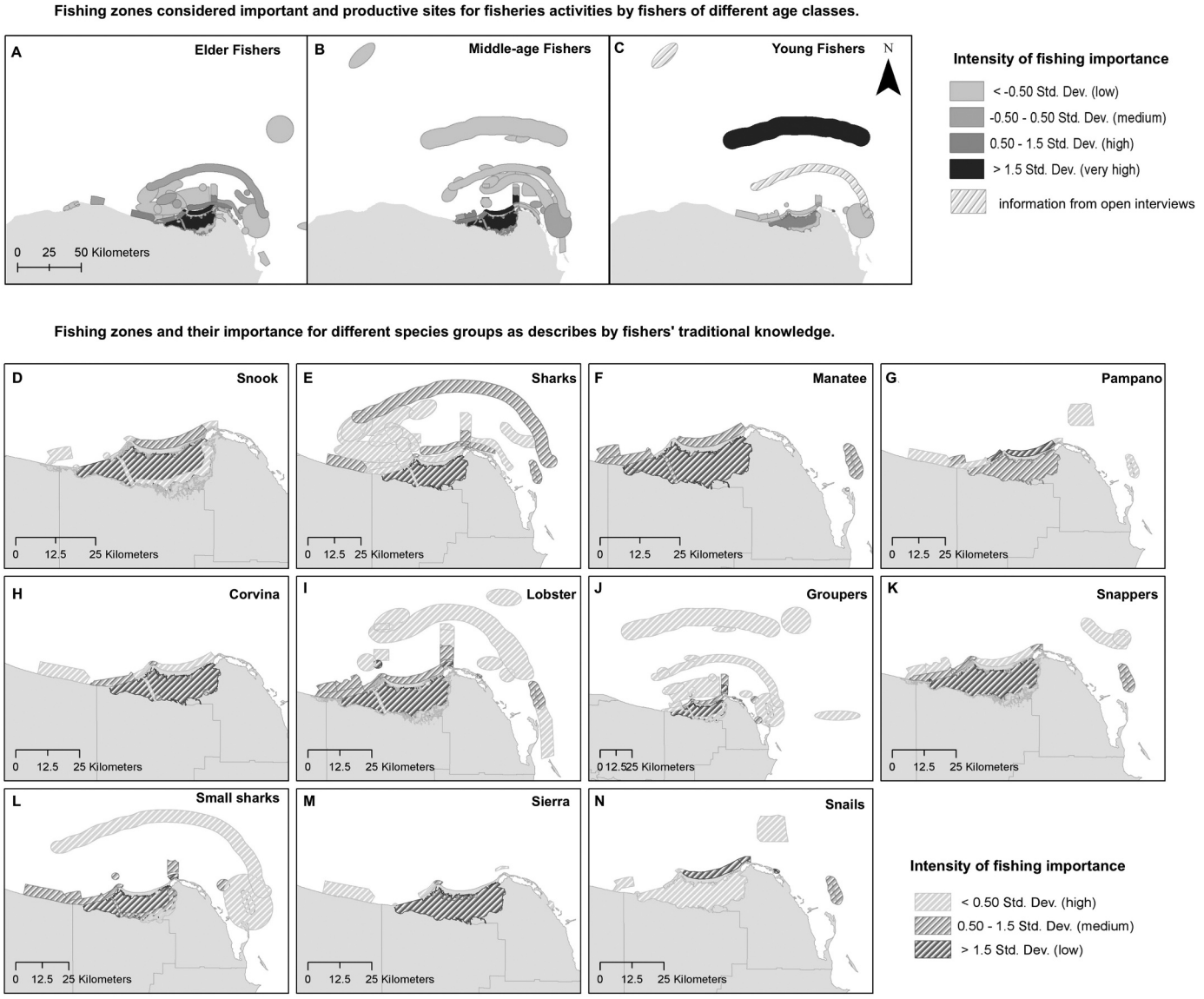

Figure 5.

Fig. 5. A-C) Fishing areas and their intensity of fishing importance as documented by fishers of different age classes. D-N) fishing zones and their intensity of fishing importance for different species groups as recorded by traditional fishers' knowledge.

tilapia (*Oreochromis* sp.). These species are gaining commercial importance in the high season for tourism. Fishers commented that they use these species to prepare "ceviche" (a regional fish plate) mainly for thousands of tourists that go on whale shark tours. This information has management implications in terms of these species' roles in supporting regional biodiversity, since limited regional information exists about the population dynamics of these species [83].

Second, Holbox's rapid tourism development is generating socio-environmental threats which include the loss of mangrove area as a result of urban development, water pollution, excessive plastic trash, solid and liquid toxic wastes, and more [7,20,86–90] (Appendix 6). Fishers' surveys document these events have contributed to physically modifying productive historical fishing grounds, especially in Yalahau (Fig. 5A and B). In the lagoon, fishers recall a change in the color of water from clear to murky and an increase in sedimentation at lobster habitats that are formed by large sponges existing in the mouth of Yalahau (Fig. 5F). Fishers also document that the long-term species composition of Holbox's fishery resources has decreased (Fig. 4; Appendix 2).

Third, tourism jobs are emerging on Holbox for fishers, but they are mainly temporary during the whale shark season (May to September), when fishers can be employed as boat captains, crew members, or as whale shark swimming guides. A whale shark tour costs ~ $120 USD per person. The boat captain and crew make ~ $67 USD each per day plus tips (*pers. comm.,* Holbox fishers 2017). Fishers also provide the "classic tours" which occur year-round and take tourists to Yalahau's iconic sites and to Cabo Catoche and Boca de Santa Paula for snorkeling. The classic tour costs ~ $23 USD per person. Commonly, fishers that run classic tours alternate this with fishing. Some fishers are part-time taxi drivers of the golf carts that provide transportation on the island.

Fourth and finally, sociocultural values are also evolving on the island as consequence of tourism development. A main driver was the large selloff of communal land (locally known as *ejido*) by fishers to private investors since 2005 [86,91,92] (Fig. 1). Ejido land was given by the government to peasant communities during México's agrarian revolution in the 1930s. Elder fishers mention that a strong trade economy existed on Holbox until mid 20th century. However, with the

Table 2
Fishers' quotes related to coastal exploitation.

Age	Quote
89	Before, the only good thing about whale sharks was that schools of esmedregal (*Rachycentron canadum*) could be found swimming with them and we could fish these. Many large mantas also existed and were fished and used as bait for shark fishing.
84	Before whale sharks were irrelevant, today "whale sharks entertain everyone."
80	There were many types of sharks and plenty of sea turtles at the lagoon. Back in 1958 you could catch up to 50 sea turtles on a good day.
72	The lagoon was a "nest" for hammerhead sharks and large sawfish, and the small shark fisheries were prosperous with catches of up to 500–700 kg per night. However then, Holbox fleet was only ~ 12 boats.
69	The human plague ended our productive lagoonal fisheries. Migrants arrived at Chiquilá, and occasional dynamite fishing was noticed, they also used large fishing nets (~1500 m) in the lagoon.
69	For over 40 years I have not seen sawfishes (*Pristis* spp.). Large ones (over 500 kg) could be seen swimming through sandy bottoms in groups of 10 or more. In the 1960s, foreign factory ships intensively fished sharks ~ 12 miles off Holbox.
60	In 1960s we fished manatees using wooden sailboats and harpoons, to eat their meat. When motorboats arrived, fishing manatee became faster. Currently, I see more sea turtles, sometimes up to 15 in one day, I have not seen this since ~16 years ago.
60	There used to be a lot of grey snapper (*Lutjanus griseus*) at the lagoon, but not now. People from Chiquilá started throwing nets in the lagoon, killing much unnecessary fish.
46	The water of the lagoon was clear, not brackish as it is today.
45	Sharks would arrive near the coast to eat sea turtles. Large sponges existed near the mouth of the lagoon and lobsters were fished there. The sponges were their habitat, but nowadays those sponges are buried in sediment.
48	Fishing bans for fish and lobster are not respected, that is why fishery resources have diminished. Mainly because fishers are not allowing young fish and lobsters to grow.
33	When I was a teenager, I used to fish in shallow waters of the lagoon where abundant fish existed. We started using gillnets in the lagoon and resources started going down.
24	Night divers arrive in fast boats to the lagoon and near shore areas and fish "everything."

arrival of tourism in late 1990s, young islanders are much more interested in "money," mainly gained from selling the family's communal land. Consequently, elder fishers document that the islanders' valuation of money has rapidly changed, and for the case of land selloffs, conflicts between and among families, community members, and government authorities have become widespread.

4. Discussion

How can the results presented here can help management actions on Holbox Island?

4.1. Historical Data

Increasing fishing pressure on coastal and marine resources is a global phenomenon [27], and the results of this research on Holbox document how changing fishing activities on the island have changed the diversity and availability of fishing resources. Exploitation of sea turtles, and Caribbean monk seals occurred during the pre-Columbian and seemingly intensified during the period of Spanish occupation. Further during the Contemporary period (decades ago) fishers' document goliath groupers; *Epinephelus itajara*; sharks, and sawfishes populated Holbox's nearshore environments and were primarily decimated (Fig. 5). This exploitation occurred before modern SSF technologies. Similar exploitation patterns are common in other tropical latitudes (*e.g.* Jamaica, Florida Keys) [39,93-95].

Results for the pre-Columbian period demonstrate natives were exploiting large quantities of finfish, sharks, sea turtles and shellfish using simple gear. However, no information exists to confirm overexploitation. For the Spanish occupation period, results show fishery resources were lightly valued by Spaniards similarly to other Mexican and Caribbean sites under the Spanish Empire [6,39]. Although information to confirm overcapacity of fishing fleets during the Spanish occupation is missing, intensive coastal exploitation of marine fauna occurred at a basin scale in Caribbean waters by pirates and foreign navies. For example, sea turtles and Caribbean monk seals were a popular commodity exploited for centuries in the Caribbean after European contact, which caused a historical reduction of their distribution range and population numbers, eventually leading to the extinction of the Caribbean monk seal [60,93,94].

In other regions, the information above helped to understand recovery times for fish populations, when combined with modern studies of recovery inside Marine Protected Areas (MPAs) [95,96]. Recovery times for MPAs exist in México for the Loreto Bay National Park, where fishing is allowed, and the no-take area is less than 1% of the park, and for Cabo Pulmo National Park, a complete commercial no-take area [97]. Quantitative and temporal data of phase shifts on fish assemblages and reef degradation also exist for coral reefs near Holbox [98]. Integrating these data with the qualitative and spatial results on Holbox's coastal exploitation can help to initiate studies focused on the recovery times for fish of the island's nearshore environments. However, an issue to consider when trying to estimate recovery times are the effects of climate change (*e.g.* intense storms) in the region, especially since the growing human population on Holbox together with urban development creates increased vulnerability to the adverse effects of hurricanes. For Holbox prevailing storm conditions exist which favor continuous morphological changes in sand spits due to the natural recycling of sediment along the spits leading to the spatiotemporal development of eroding and prograding sectors [99,100]. Holbox's prevailing storm conditions together with the effects of climate change can be a trigger that limits the ecological functions of nearshore habitats such as mangroves and coral reefs and their role as nurseries for aquatic species. These factors can also impact the recovery of fish populations, but further studies are needed for the region.

4.2. Overcapacity on Holbox's fishing fleet and tourism activities on the island

Results for Holbox's Contemporary period show signs of fisheries overcapacity. First, fishers' surveys document changes in the diversity and abundance of fishery resources (*e.g.* sharks, lobster, and grouper; Fig. 4) that were highly exploited (1980s-1990s) with new fishing technologies (*e.g.* motorboats and GPS technology). These technologies were promoted by fisheries policies that aimed to increase human coastal migration and subsistence fishing [73]. Second, spatial results show young fishers' travel farther to fish when compared to elder fishers (Fig. 5C). Third, entrenched conflicts over fisheries on Holbox related to illegal fishing (*e.g.* fishing during bans) are a consequence of the "race to fish behavior" [6,101]. Fourth, Holbox's contemporary human migration related to the burgeoning tourism economy is, according to fishers' interviews, leading to resource depletion since increasingly new immigrants start fishing. Fisheries overcapacity as exemplified by Holbox is a common problem of México's SSF but the continuing economic incentives for fishing, the lack of full-time, alternative jobs, and weak enforcement limits restraint [6,102,103].

Tourism is a fast-growing industry on Holbox that is generating job alternatives that for some cases these can help relief fishing pressure. For instance, during the whale shark season (summer), fishers can be

employed as a boat captain, a crew member, or as a whale shark swimming guide and can make ~ $67 USD per day plus tips[4] (*pers comm.,* Holbox fishers 2017). Administrative and cleaning duties are also emerging on Holbox, but fishers mentioned that they lack qualifications for the first and overall are not interested in cleaning duties. It is well documented that the tourism industry rarely provides realistic job alternatives for locals and commonly this industry does not consider the community's needs or qualifications when tourism jobs are created (*e.g.* Riviera Maya, Bocas del Toro Archipelago, Panama). For the YP the social and biophysical environment of many fishing towns has been negatively impacted, as they evolved into touristic sites [104–106].

Tourism development in Holbox is also linked to large sell-offs of communal land by fishers to private investors. In some cases this has allowed some small business development for islanders. Some Holbox fishers invested the money from selling their communal land and have profitable businesses (*e.g.* golf cart rentals, convenience stores, and small hotels), this has allowed them to stop fishing for income. Though this can be beneficial for reducing fishing effort, most businesses on Holbox have unfriendly environmental traits. For instance, golf cart rentals are growing. The increasing traffic is compacting the island's sandy paths and decreasing the soil's filtration properties. Holbox is evincing massive floods during rains; stagnant water can last for weeks and gets polluted by the increasing trash throughout the island. Pollution via overland flow occurs during rains and can reach mangroves that surround the island and are essential fish nurseries, but little documentation exists [107].

Given that non-ocean related industries exist on Holbox, and tourism is becoming the major component of the local economy, ecotourism, when coupled with mild conservation stewardship, can help reduce fishing pressure and buffer the habitat degradation that is taking place on Holbox as a result of rapid tourism development. However, to seriously embrace Holbox's ecotourism potential, stronger communication between the community, fishers, Yum Balam MPA authorities and CONANP (the government) is needed. This can help to jointly define and promote other ecotourism activities lightly exploited by fishers' touristic businesses that can generate sustainable economic revenues in addition to whale shark activities. For example, bird watching and tours to the Vista Alegre archaeological site, although this involves discussions with another Federal government agency, the National Institute of Anthropology and History (INAH), that is outside of the scope of this paper. The bird watching industry is gaining momentum in many countries [108]. In central México, thousands of national and international birdwatchers visit the area. Using an estimate of 78,000 bird watchers for the year 2006, Revollo-Fernández estimated that birdwatchers were willing to pay between $79 USD and $296 USD for bird watching activities per year respectively [109]. This information was then used to evaluate that the bird migration environmental service in Central México can range between $2836 USD and $3999 USD per hectare [109]. The Holbox region is an Important Biodiversity Area (IBA), globally acknowledged to be essential for bird conservation [110]. In recent years some islanders have increased their interest in birdwatching (including fishers), they organized bird watching clubs, and some are certified bird watching guides. The same is happening on the mainland port of Chiquilá. This social capital could benefit the development of stable birdwatching businesses that could promote local jobs and help to prevent coastal habitat degradation and ameliorate fishing effort.

[4] The minimum wage in México is ~ $4.65 USD per day (https://www.gob.mx/conasami). A fisher on Holbox can make from ~ $21 USD to ~ $32 USD per day depending on the fishing season and weather conditions. There can be days when fishers have no daily income for example if adverse weather and strong north winds prevail on the island, especially in winter months.

4.3. Socio-cultural values on Holbox

Socio-cultural values can aid conservation planning by enhancing "social memory," which in turn can influence resilience in socio-ecological systems [111–113]. Resilience is obtained through the diversity of individuals and institutions that draw on reservoirs of practices, knowledge, and values [111]. At Marismas Nacionales on México's Pacific coast, the government ignored socio-cultural values of fishing cooperatives by allowing the influx of many new migrant fishers, and the privatization of historically communal fishing grounds for the creation of aquaculture farms. Consequently, reduced trust among local fishers became widespread which was compounded by increasing social conflicts with the incoming new fishers throughout Marismas neighboring towns. The larger population of fishers led to overfishing in nearshore waters which opened the door to illegal fishing activities and an expanded black-market to sell seafood. The situations mentioned above have with time fostered a loss of social memory in the region [6].

On Holbox fishers' perceptions document how increasing coastal migration has also increased the population of fishers, which, in turn, has led to a widespread "race to fish" that has resulted in resource depletion. Consequently, illegal fishing evolved in an environment that according to fishers has mild prosecution against illegal fishing. Though the Yum Balam MPA authorities can report illegal fishing, it is the Federal Attorney Generalship of Environmental Protection (Procuraduría Federal de Protección al Ambiente, PROFEPA) who is the legal authority to prosecute illegal fishing. However, fishers' and community members' interviews denote concern for the social chaos that exists by uncontrolled illegal fishing that is implicitly allowed by the ineffectiveness of authorities. Some temporary government programs exist for patrolling prohibited fishing areas where local fishers can participate, but fishers mention their participation is risky, since illegal fishers can be aggressive. On the other hand, local fishers of Chiquilá port burned motorboats belonging to illegal fishers as a way protest in May 2017 [114]. The above sentences denote behavioral drivers that are fostering the loss of social memory about how to use the natural resources in a sustainable manner. The growing tensions between fishers denote behavioral drivers that are fostering the loss of social memory which, in a way, is reflected in the loss of the human relationships and social values that are critical in a social system in order to foster positive and appreciative behaviors towards natural resources and their exploitation.

Elder fishers' document that socio-cultural values related to self-fishing regulations existed in the Yalahau Lagoon since the site is historically considered by locals as a nursery for aquatic species. Spatial results on Holbox's historical fishing sites also demonstrates the cultural importance of fishing. Elder fishers mentioned traditional knowledge of historical fishing sites (*e.g.* the species that inhabited those sites and how the sites looked in the past) is fading in younger generations of islanders. The transfer of traditional knowledge to younger islanders can allow the continuity of Holbox's socio-cultural values for the environment, which can positively influence conservation of landscapes and potentially facilitate reestablishing self-fishing regulations by locals, which can help to promote and preserve social memory. The conservation of these areas matters because some of Holbox's historical fishing sites are now key for tourism activities (*e.g.* Cabo Catoche, Isla Pasion; Appendix 5). Still, these sites are threatened by overfishing and by outcomes of Holbox's tourism development (excessive trash, water pollution, and habitat fragmentation) [7,20,86,88–90,107].

Fishers' surveys and the literature review also evince other changes in Holbox's socio-cultural values, for example, the ones associated with the privatization of communal land throughout Holbox town and La Ensenada, the stretch of uninhabited coast to the east of town that was purchased by outside developers, which ignited a strong value for "money" by locals (Appendix 5; Fig. 1) [92]. Consequently, conflict for land is widespread on Holbox. However, positive socio-cultural changes have evolved on the island as a response to tourism's environmental

threats. This has led islanders to organize conservation groups for sea turtles (Alma Verde), manatees (Grupo Manaholchi), and socio-environmental issues (Comite Ciudadano por la Paz y Seguridad de Holbox). By recognizing the changes in socio-cultural values, both positive and negative, occurring on Holbox, conservation managers can develop actions that enhance the positive shifts in socio-cultural values and possibly use the conservation groups to foster social memory. For example, promoting the reestablishment of self-regulating extractive and use behaviors tied to particular species and habitats is crucial to help contemporary islanders understand the real potential of their natural capital and to cope with ongoing environmental changes and social conflicts associated with fisheries and tourism on the island.

4.4. Holbox's Natural Capital

Results from the Contemporary period highlight some intertwined activities of fishers, local community members, and the government that have led to resource exploitation and habitat use that threaten Holbox's natural capital. For fishers, it can be argued that they can be a source of natural capital degradation. However, their current "race to fish" is an outcome of fishing behaviors that evolved as a consequence to governmental policies that promoted fishing and human coastal migration. This pattern occurred throughout México's coastal towns [6,102]. Fishers' surveys and quotes (Table 2) document negative qualitative changes in the diversity and availability of fishery resources (Fig. 4; Appendix 1). The local community pushed by tourism development has also triggered the loss of Holbox's natural capital, since a considerable amount of communal land was sold to private investors giving way to the proliferation of non-environmentally friendly businesses and development.

Our results expose Holbox's urgent needs related to fisheries overexploitation and the need to establish missing urban, and tourism management plans, that can supplement the newly established management plan of Yum Balam NPA. The above can help to preserve the island's natural capital. Holbox's fishers have lobbied to reduce fishing pressure and illegal fishing, but interviewed fishers mention their petitions are largely ignored by the governments' mild or null fisheries enforcement. The community also considers the need for tourism regulations. On July 2017, some areas of the island had no electricity nor water services for several days, locals mentioned there were too many people on Holbox, but until now the human capacity for the island is unknown. The lack of this basic knowledge questions if the government has undermined conservation efforts on Holbox.

México is a signing party of agreements that promote the preservation of natural capital [115]. In 2016 the country housed the Conference of the Parties to the Convention on Biological Diversity (COOP) in Cancun, and México compromised for conservation progresses. However, a management plan for the Yum Balam NPA was fully developed after 24 years on October 5th 2018, while this paper was in its last stages of publication. A swift draft of it was published in December 2016, this was timed to coincide with the COOP 2016, but this publication initiated social turmoil among fishers, NGOs, and broader communities of the Yalahau Lagoon. For example, a broad concern was the consideration for constructing ~800 overwater bungalows (~6845 hec) for tourism in nearshore areas off La Ensenada, a site that has historically provided fishery ecosystem services (Figs. 1 and 5). The construction of overwater bungalows can increase anthropogenic waste, risking the health and delivery of ecosystem services of nearshore environments. Holbox lacks waste and water treatment plants and is already facing severe issues to dispose of the excessive wastes generated by tourism [88,90]. The issue of excess waste and the lack of treatment facilities is very important for conservation managers since overall the Yum Balam NPA polygon is populated with historical fishing sites (Appendix 7) reported for this study which are key sources of Holbox's natural capital and is increasingly threatened by human activities. Despite the above even though Yum Balam's new plan does protect landscapes and biodiversity of the region, however, it continues allowing the construction of the overwater bungalows.

Other countries have prevented the loss of natural capital by adopting views of contemporary fisheries research, ecosystem service science, and environmental economics. These increasingly embrace the socio-ecological and economic importance of nearshore environments for the provision of ecosystem services to humans [116–119]. However, adopting these views is challenging in top-down government systems like México's where fishers' perceptions and socio-cultural knowledge is largely excluded from policy design. Contemporary fisheries research increasingly shows that neglecting fishers' perceptions and socio-cultural knowledge (as the ones presented here) can lead to establishing inappropriate policies for the realities of coastal communities [120–123].

The development of economic incentives (*e.g.* fishing quotas, payments for ecosystem services for biodiversity) for conservation on the island is an available tool worthy of consideration because habitat and biodiversity preservation on Holbox has implications beyond the local scale given the connectivity of coastal ecosystems [124–126]. Economic incentives for conservation can be a way to help secure Holbox's natural capital shortly. According to the news in The Economist published on August 19th of the present year, a study funded by private resources suggests that Holbox could support up to 9000 new hotel rooms in the coming two decades [127]. Besides, they also estimate that Chiquilá could in the same period harbor the construction of 12,000 rooms [127]. Given that a well-developed and robust tourism economy might evolve in the region, tourists could become critical players in funding initiatives for economic incentives focused on preserving the natural capital of Holbox and Chiquilá. However other target populations outside Holbox may exist, possibly birdwatchers. For example, Rubio-Cisneros et al. suggest waterfowl hunters in the United States can potentially help for wetland and mangrove conservation in southern latitudes of the Gulf of California where diverse waterfowl species that can be hunted in the United States winter [124].

Though the new management plan for Yum Balam NPA may fade away the idea that a robust tourism economy may evolve on Holbox, however, it might be early to predict what will happen. For the past years, Holbox has been in the news for many ecological and political issues which questions where Yum Balam's NPA management plan will lead regarding ameliorating existing political, social, and environmental problems on Holbox. The publication of the management plan has generated turmoil between stakeholders of the Advisory Committee of Yum Balam NPA (Consejo Asesor del Área de Protección de Flora y Fauna de Yum Balam). The Committee's intentions to take legal action against Yum Balam's NPA management plan is national news[5]. The committee mentions the management plan ignores previous government agreements with stakeholders where the idea of tourism development on the region was an option.

5. Conclusions

The results presented here on the changing diversity, availability,

[5] For example, see online news:

Caballero, S. Anuncian "lluvia" de amparos contra plan de manejo de Yum Balam, Quintana Roo. Proceso.com.mx. Published October 15 2108.https://www.proceso.com.mx/555461/anuncian-lluvia-de-amparos-contra-plan-de-manejo-de-yum-balam-quintana-roo

Aguila, C. Plan de Manejo de Yum Balam "no tiene nada de sustentable". La Jornada Maya. Published October 15 2108.

https://www.lajornadamaya.mx/2018-10-15/Plan-de-Manejo-de-Yum-Balam——no-tiene-nada-de-sustentable—

El Heraldo. Consejo Asesor no aprueba plan de manejo de reserva Yum Balam. EL Heraldo de Mexico. Published October 6 2018.

https://heraldodemexico.com.mx/estados/consejo-asesor-no-aprueba-plan-de-manejo-de-reserva-yum-balam/

and exploitation of fishery resources on Holbox, provide an interdisciplinary baseline of coastal exploitation and can assist policymakers and conservation managers to better understand the long-term trajectory of coastal ecosystem services in the region. The lack of interdisciplinary results on coastal exploitation is a challenge for conservation managers and has led to knowledge gaps that have limited the successful conservation of fishery resources, biodiversity, and marine habitats in many coastal towns in developing countries [6,128–130]. By conducting studies on fishers' perceptions and their traditional knowledge, like the study done here, scholars can enrich our understanding of how cultural perceptions influence the ways (*e.g.* individual, and collective concepts and attitudes) in which social groups exploit coastal resources [6,39,120]. This, in turn, can help managers and government authorities recognize the need of including fishers' traditional knowledge in conservation planning. This recognition could evolve into true empowerment for fishers' where their knowledge and participation are recognized in decision-making processes of resource exploitation, which could then increase compliance for resource preservation [131,132].

In the case of Holbox, the social awareness of islands environmental degradation by fishers and community members has led some of the island's inhabitants to become active participants in the island's conservation. This turn toward environmental activism is another factor that can help managers to reshape the use and exploitation of the island's natural capital, possibly by establishing regional, bottom-up management policies that can supplement conservation measures of the new management plan [91,92,133]. For example, Rare is working with CONANP in the Sian Ka' an Biosphere Reserve on the east coast of the Yucatán Peninsula to promote and create compliance among fishers in the region to prevent the decay of local marine resources [134]. Lastly, the establishment of commercial, no-take areas, marine reserves, or fisheries refugia around Holbox is a subject that needs serious consideration in México's conservation agenda. Holbox's historical fishing sites presented here could be considered in the existing fishery refugia[6] [135]. The latter will allow local communities to continue obtaining economic gains from their island's natural capital well into the future.

Acknowledgements

N. Rubio-Cisneros greatly thanks The Rufford Foundation for supporting her research on Holbox Island and acknowledges The Consejo Nacional de Ciencia y Tecnología CONACYT for her postdoctoral grant during the period of this study. Authors kindly thank CONANP for their support and for allowing us to work on Holbox. Special thanks to each and one of the many Holbox fishers that collaborated with us, especially to: Miguel Zapata, Vicente Cáceres, Jose Guadalupe Peraza, Julio Zapata, Rodolfo Escamilla, Baron, and Edgardo Zapata who were a great help in the field. Special thanks to community members of Holbox who strongly supported this project: Eduardo Pacheco Cetina (nature photographer); Ingrid Baselis, (former Director of the Casa de la Cultura de Isla Holbox); Yara Ancona, Elber Zapata and Franklin Campos Ancona (teachers at Holbox's high school: "Escuela Secundaria Técnica Pesquera, Francisco Hernández de Cordoba"); Mercedes and Baron, Janitzin Gutierrez and Tania Huitrón (all environmental activists on Holbox). Thanks to Marine Biologist and underwater photographer Erick Higuera from Pelagic Life for his collaboration and supervision of underwater video production for this research project. Thanks to the interns who worked on this project, biologists Carolina Gallegos and Andres Canul from Universidad Autonoma de Yucatán. Thanks to Chapin Dorsett from Whitman College, for her help on English editing during the early stages of this manuscript. Special thanks to The National Institute of Anthropology and History (INAH), The National Oceanic and Atmospheric Administration, U.S. Department of Commerce (NOAA), and to The National Science Foundation (NSF) for funding the archaeological research of this study.

[6] Fishery refugia "*refugios pesqueros*" are under the management of the Commission of Aquaculture and Fisheries, CONAPESCA. For these areas, fishing is limited, usually as no-take zones. Fishery refugia aim to protect and to rebuild fish stocks.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2018.10.003.

References

[1] Cambers, G. (2003). Monitoring beach changes as an integral component of coastal management: final report of the project on Institutional strengthening of beach management capabilities in the Organization of Eastern Caribbean States and the Turks and Caicos Islands.
[2] C.D. Stallings, J.F. Bruno, Fishery-independent data reveal negative effect of human population density on Caribbean predatory fish communities, PLoS One *4* (5) (2009) e5333.
[3] N. Seddon, G.M. Mace, S. Naeem, J.A. Tobias, A.L. Pigot, R. Cavanagh, M. Walpole, Biodiversity in the anthropocene: prospects and policy, Proc. R. Soc. B: Biol. Sci. *283* (2016) 1844.
[4] S. Salas, R. Chuenpagdee, J.C. Seijo, A. Charles, Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean, Fish. Res. *87* (1) (2007) 5–16, https://doi.org/10.1016/j.fishres.2007.06.015.
[5] Food and Agriculture Organization of the United, N., & Fisheries and Aquaculture, D, The State of World Fisheries and Aquaculture: Opportunities and Challenges, Food and Agriculture Organization of the United Nations, Rome, 2014.
[6] N.T. Rubio-Cisneros, O. Aburto-Oropeza, J. Jackson, E. Ezcurra, Coastal Exploitation Throughout Marismas Nacionales Wetlands in Northwest México, 1940082917697261, Trop. Conserv. Sci. 10 (2017), https://doi.org/10.1177/1940082917697261.
[7] G. Marín-Guardado, Los tristes trópicos del turismo en México: industria, reflexividad y otras ficciones, in: G. Marín-Guardado, A.D. Fuentes, M. (Eds.), En Turismo, Globalización y Sociedades Locales en la Península de Yucatán, México, ACA y PASOS, RTPC, El Sauzal (Tenerife. España), 2012, p. 275 (pp. 17-44).
[8] J. Davenport, J.L. Davenport, The impact of tourism and personal leisure transport on coastal environments: a review, Estuar., Coast. Shelf Sci. 67 (1–2) (2006) 280–292.
[9] UNESCO. (2010). The Shades of Blue: Upgrading Coastal Resources for the Sustainable Development of the Caribbean SIDS. Retrieved from Kingston, Jamaica.
[10] B. Worm, E. Beaumont, S. Folke, J. Jackson, R. Micheli, E. Sala, J. Stachowicz, Impacts of biodiversity loss on ocean ecosystem services, Science *314* (5800) (2006) 787.
[11] N. Knowlton, J.B. Jackson, Shifting baselines, local impacts, and global change on coral reefs, PLoS Biol. *6* (2) (2008).
[12] F. Bulleri, M.G. Chapman, The introduction of coastal infrastructure as a driver of change in marine environments, JPE J. Appl. Ecol. *47* (1) (2010) 26–35.
[13] L.C. Cullen-Unsworth, L.M. Nordlund, J. Paddock, S. Baker, L.J. McKenzie, R. Unsworth, Seagrass meadows globally as a coupled social–ecological system: Implications for human wellbeing, Mar. Pollut. Bull. *83* (2) (2014) 387–397, https://doi.org/10.1016/j.marpolbul.2013.06.001.
[14] S. Agata, L. Vigliola, N. Graham, L. Wantiez, V. Parravicini, S. Villéger, D. Mouillot, Unexpected high vulnerability of functions in wilderness areas: evidence from coral reef fishes, Proc. R. Soc. B: Biol. Sci. *283* (2016) 1844.
[15] P. Klepeis, Ii, B.L. Turner, Integrated land history and global change science: the example of the Southern Yucatán Peninsular Region project, Land Use Policy *18* (1) (2001) 27–39, https://doi.org/10.1016/S0264-8377(00)00043-0.
[16] Glover, J. B., Rissolo, D., & Mathews, J. P. (2011). The Hidden World of the Maritime Maya: Lost Landscapes Along the North Coast of Quintana Roo, México.
[17] Wiese, P. (2000). Environmental impact of urban and industrial development a case history: Cancún, Quintana Roo, México. UNESCO Environment and development in coastal regions and in small islands.
[18] E. Vargas-Martínez, M. Castillo, C. Viesca, Ending a touristic destination in four decades: Cancun´s creation, peak and agony, Int. J. Hum. Soc. Sci. *3* (2013) 16–26 Retrieved from.
[19] J. Ziegler, P. Dearden, R. Rollins, But are tourists satisfied? Importance-performance analysis of the whale shark tourism industry on Isla Holbox, México, Tour. Manag. *33* (3) (2012) 692–701, https://doi.org/10.1016/j.tourman.2011.08.004.
[20] López Santillán, Á. A. (2010). Metamorfosis del paraíso la producción de Isla Holbox como destino turístico del Caribe Mexicano. Zamora, Michoacán, México. Available from ⟨http://worldcat.org/z-wcorg/database⟩.
[21] SEDETUR (2015). Indicadores Turísticos. Caribe Mexicano. Retrieved from ⟨http://sedetur.qroo.gob.mx/estadisticas/indicadores/indicadores-turisticos-2015.pdf⟩. Gobierno de México.
[22] A. Neil, Diagnosis and management of small-scale fisheries in developing countries, Fish Fish. *8* (3) (2007) 227–240.
[23] J.I. Fernández, P. Álvarez-Torres, F. Arreguín-Sánchez, L. López-Lemus, G. Ponce, A. Díaz-de-León, P. del Monte-Luna, Coastal fisheries of México, in: S. Salas, R. Chuenpagdee, A. Charles, J.C. Seijo (Eds.), Coastal Fisheries of Latin America and the Caribbean, FAO, Rome, 2011, pp. 231–260 2011. 430p.: FAO Fisheries and Aquaculture Technical Paper. No. 544.
[24] S. Salas, R. Chuenpagdee, A. Charles, J.C. Seijo, Coastal fisheries of Latin America

and the Caribbean, Food and Agriculture Organization of the United Nations, Rome, 2011.
[25] D. Pauly, Anecdotes and the shifting base-line syndrome of fisheries, 430-430, Trends Ecol. Evol. 10 (10) (1995), https://doi.org/10.1016/s0169-5347(00)89171-5.
[26] J.B.C. Jackson, Reefs since Columbus. Coral reefs, J. Int. Soc. Reef Studies. 16 (1997) 23–32.
[27] J.B.C. Jackson, M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R.R. Warner, Historical Overfishing and the Recent Collapse of Coastal Ecosystems, Science *293* (5530) (2001) 629–638.
[28] H.K. Lotze, H.S. Lenihan, B.J. Bourque, R.H. Bradbury, R.G. Cooke, M.C. Kay, J.B.C. Jackson, Depletion, degradation, and recovery potential of estuaries and coastal seas, Science (Washington D C) *312* (5781) (2006) 1806–1809, https://doi.org/10.1126/science.1128035.
[29] A. Sáenz-Arroyo, C.M. Roberts, J. Torre, M. Cariño-Olvera, Using fishers' anecdotes, naturalists' observations and grey literature to reassess marine species at risk: the case of the Gulf grouper in the Gulf of California, México, Fish Fish. *6* (2) (2005) 121–133, https://doi.org/10.1111/j.1467-2979.2005.00185.x.
[30] A. Sáenz-Arroyo, C.M. Roberts, J. Torre, M. Cariño-Olvera, R.R. Enríquez-Andrade, Rapidly shifting environmental baselines among fishers of the Gulf of California, Proc. R. Soc. B-Biol. Sci. *272* (1575) (2005) 1957–1962, https://doi.org/10.1098/rspb.2005.3175.
[31] Vázquez, J. (2015). Para este 2015, el plan ambiental de Yum Balam. Retrieved from 〈http://eleconomista.com.mx/estados/2015/07/23/2015-plan-ambiental-yum-balam〉.
[32] J. Herrera-Silveira, S. Morales-Ojeda, Subtropical Karstic Coastal Lagoon Assessment, Southeast México, in: M. Kennish, H. Paerl (Eds.), Coastal Lagoons Critical Habitats of Environmental Change, Taylor & Francis, Boca Raton, 2010, pp. 307–333.
[33] C.M. Appendini, P. Salles, E.T. Mendoza, J. López, A. Torres-Freyermuth, Longshore sediment transport on the Northern Coast of the Yucatán Peninsula, J. Coast. Res. (2012) 1404–1417, https://doi.org/10.2112/JCOASTRES-D-11-00162.1.
[34] O. Reyes-Mendoza, I. Mariño-Tapia, J. Herrera-Silveira, G. Ruiz-Martínez, C. Enríquez, J.L. Largier, The Effects of Wind on Upwelling off Cabo Catoche, J. Coast. Res. (2015) 638–650, https://doi.org/10.2112/JCOASTRES-D-15-00043.1.
[35] J.B. Glover, D. Rissolo, J.P. Mathews, C.A. Furman, El proyecto costa escondida: Arqueología y compromiso comunitario a lo largo de la Costa Norte de Quintana Roo, México, Chungara *44* (3) (2012) 511–522.
[36] Glover, J.B., Rissolo, & Mathews, J.P. (2013) El Proyecto Costa Escondida: Una Investigación Paleoambiental Y Arqueológica Del Puerto Maya Vista Alegre Y La Costa Norte De Quintana Roo, México. Temporada de Campo 2011 y Análisis 2012 Informe Técnico Anual al Consejo de Arqueología del Instituto Nacional de Antropología e Historia septiembre 2013. México. 360.
[37] C. Gotz, Coastal and inland patterns of faunal exploitation in the prehispanic northern Maya lowlands, Quat. Int. 191 (1) (2008) 154–169.
[38] D. Smith, La Ecología Costal y las Conchas de Moluscos Arqueológicos de Vista Alegre, in: J. Glover, D. Rissolo, J. Mathews (Eds.), El proyecto costa escondida: una investigación paleoambiental y arqueológica del puerto maya vista alegre y la costa norte de Quintana Roo, México, Consejo de Arqueología del Instituto Nacional de Antropología e Historia, México, 2013, p. 360.
[39] M.J. Hardt, Lessons from the past: the collapse of Jamaican coral reefs, Fish Fish. *10* (2) (2009) 143–158.
[40] Vogt, W. P., & Johnson, R. B. (2016). The Sage dictionary of statistics & methodology a nontechnical guide for the social sciences. Los Angeles; London; New Delhi: SAGE.
[41] L. Bunce, P. Townsley, R. Pomeroy, R. Pollnac, Socioeconomic manual for coral reef management. Australian Institute of Marine Science, Global Coral Reef Monitoring, Australian Institute of Marine, Science, The World Conservation Union, United States, National Oceanic and Atmospheric Administration, Townsville, Australia, 2000.
[42] A. Gallardo-Torres, M. Badillo-Alemán, F. Rivera, J. Rubio-Molina, C. Galindo De Santiago, J. Loera-Pérez, X. Chiappa-Carrara, Catálogo de Peces de la Costa Norte de Yucatán, Segunda Edición ed., Universidad Nacional Autónoma de México - CONCIYTEY, 2014.
[43] Humann, P., & DeLoach, N. (2014). Reef fish identification: Florida, Caribbean, Bahamas.
[44] C. Eghenter, Mapping Peoples' Forests: The Role of Mapping in Planning Community-based Management of Conservation Areas in Indonesia, Biodiversity Support Program, Washington, D.C., 2000.
[45] M. Moreno-Báez, B.J. Orr, R. Cudney-Bueno, W.W. Shaw, Using fishers' local knowledge to aid management at regional scales: spatial distribution of small-scale fisheries in the northern Gulf of California, México, Bull. Mar. Sci. *86* (2) (2010) 339–353.
[46] Antele, F. A. (2014). Caracterización y evaluación de la pesquería de escama del Área Natural de Protección de Flora y Fauna APFF Yum Balam en Quintana Roo. (Bachelors thesis), Instituto Tecnológico de Conkal, Quintana Roo.
[47] ESRI (2015). ArcGIS Workstation. Redlands, California.
[48] E.W. Andrews, Excavation of an early shell midden on Isla Cancun, Quintana Roo, México, National Geographic Society, Tulane University, Program of Research in Yucatán, New Orleans, 1974.
[49] Andrews, A. (1979). Salt and the Maya: Major Prehispanic trading spheres. Paper presented at the Interdisciplinary Approaches to Maya Studies: Margins and Centers of the Classic Maya., Vancouver, Canada.
[50] A.P. Andrews, Maya Salt Production and Trade, University of Arizona Press, 1983.
[51] K., M. Antochiw, C. Dachary, Historia de Cozumel, Consejo Nacional para la Cultura y las Artes, México, D.F, 1991.
[52] A.P. Andrews, El antiguo puerto maya de Conil, Estudios de Cultura Maya *22* (2002) 137–149, https://doi.org/10.19130/iifl.ecm.2002.22.413.
[53] C. Carrillo y Ancona, Compendio de la historia de Yucatán; precedido del de su geografía y dispuesto en forma de lecciones, J.D. Espinosa é hijos, Mérida, 1871.
[54] A.P. Andrews, G.D. Jones, Asentamientos coloniales en la costa de Quintana Roo, Temas Antropológicos (México) *23* (01) (2001) 20–35.
[55] D. d Landa, B. Brasseur de, Relation des choses de Yucatán de Diego de Landa; texte espagnol et traduction française en regard, comprenant les signes du calendrier et de l'alphabet hiéroglyphique de la langue maya, A. Durand, Paris, 1864.
[56] Martínez-Carbajal, A. (1994). *Holbox la bella isla, homenaje a 100 años de su fundación*: Ayuntamiento Constitucional. Quintana Roo, México.
[57] N. González, La Costa Norte de Yucatán, Breve esbozo de su desarrollo Cultural, Instituto Nacional de Antropología e Historia (INAH), Mérida, Yucatán, 1972.
[58] Miller, D. L. (1982). *México's Caribbean fishery: recent change and current issues*. Available from 〈http://worldcat.org/z-wcorg/database〉.
[59] Contreras-Sánchez, Presencia inglesa y contrabando en Walis, in: D. Quezada-Domínguez (Ed.), Memorias XIX Conferencia de la Asociación de Estudios del Caribe, Caribbean Studies Association, Universidad Autonoma de Yucatán, Mérida, Yucatán, México, 1995, pp. 225–235.
[60] L. McClenachan, A.B. Cooper, Extinction rate, historical population structure and ecological role of the Caribbean monk seal, Proc. Biol. Sci. / R. Soc. *275* (1641) (2008) 1351–1358.
[61] J.L. Stephens, Incidents of Travel in Yucatán. v. 2. Harper & Brothers, New York, 1848.
[62] A.D. Le Plongeon, M.H. Saville, L. Huntington Free, H.F. Museum of the American Indian, Here and There in Yucatán. Miscellanies, J. W. Bouton, New York, 1886.
[63] V. Suárez-Molina, La Evolución Económica de Yucatán a través del Siglo XIX, Ediciones de la Universidad de Yucatán, Mérida, Yucatán, México., 1977.
[64] Dachary, C. & Burne, S. (1985). El Caribe mexicano: hombres e historias. SEP Cultura, Centro de Investigaciones y Estudios Superiores en Antropología Social: Museo Nacional de Culturas Populares.
[65] L. Millet-Cámara, Yucatán: su entrada al mercado mundial de materias primas, in: O. Baños-Ramírez (Ed.), Sociedad, estructura agraria y Estado en Yucatán, Universidad Autónoma de Yucatán, Mérida, Yucatán, México., 1990, pp. 21–44.
[66] Victoria-Ojeda, J. (1996). Nueva Málaga [Yalahau]. *Unicornio* 5 Suplemento Cultural de *Por Esto,* pp. 3-7.
[67] L. Millet-Cámara, A. Andrews, Panorama Histórico de la Costa Norte de Yucatán durante el siglo XIX y principios del XX, in: R.T. Alexander, S.M. Kepecs (Eds.), El Pueblo Maya del Siglo XIX: perspectivas arqueológicas e históricas, Universidad Nacional Autonoma de México, México., 2014, pp. 71–91.
[68] T. Rugeley, Preface: the caste war, The Americas *53* (4) (1997) vi–xiii, https://doi.org/10.2307/1008144.
[69] J.L. Peña-Chapa, M. Castillo, J. González-Ávila, The Performance of the Economy of the Yucatán Peninsula from 1970–1993, in: W. Lutz, L. Prieto, W.C. Sanderson (Eds.), Population, Development, and Environment on the Yucatán Peninsula: From Ancient Maya to 2030, International Institute for Applied Systems Analysis, Laxenburg, Austria, 2000.
[70] Marín-Guardado, G. (2000). *Holbox, antropología de la pesca en una isla del Caribe mexicano*: El Colegio de Michoacán, Centro de Investigación Científica de Yucatán in Zamora, Michoacán, Mérida, Yucatán, México.
[71] Ríos-Lara, G., Espinoza-Méndez, C., Cetina-Moguel, C., Aguilar-Cardozo, C., & Ramírez-Estévez, A. (2013). *La pesquería de langosta Panulirus argus en la plataforma de Yucatán y Caribe Mexicano*. In Instituto Nacionalde la Pesca (Ed.), (pp. 120).
[72] L. Paré, J. Fraga, La costa de Yucatán: desarrollo y vulnerabilidad ambiental, Instituto de Investigaciones Sociales, México, D.F., 1994.
[73] J.L. Cifuentes-Lemus, F.G. Cupul-Magaña, Un vistazo a la historia de la pesca en México: administración, legislación y esfuerzos para su investigación, Ciencia Ergo Sum *9* (1) (2004) 112–118.
[74] A. Aguilar-Perera, C. González-Salas, A. Tuz-Sulub, H. Villegas-Hernández, Fishery of the Goliath grouper, Epinephelus itajara (Teleostei: Epinephelidae) based on local ecological knowledge and fishery records in Yucatán, México, Revista Biol. Trop. *57* (3) (2009) 557–566.
[75] M.T. Craig, Epinephelus itajara, The IUCN Red List of Threatened Species 2011 (2011).
[76] F.A. Antele, Caracterización y evaluación de la pesquería de escama del Área Natural de Protección de Flora y Fauna APFF Yum Balam en Quintana Roo. (Bachelor), Instituto Tecnológico de Conkal, Quintana Roo, 2014.
[77] Bobadilla, T. F. (2014). Diagnóstico socioeconómico de las comunidades pesqueras artesanales en Quintana Roo. Retrieved from Guaymas, México.
[78] COBI (2016). Caracterización de la Pesquerías de tiburones en Quintana Roo. Comunidad y Biodiversidad.
[79] R. Bonfil, Status of shark resources in the Southern Gulf of México and Caribbean: implications for management, Fish. Res. *29* (2) (1997) 101–118.
[80] Hueter, R. E., Castillo-Geniz, J. L., Márquez-Farías, J. F., & Tyminski, J. P. (2007). The Use of Laguna Yalahau, Quintana Roo, México as a Primary Nursery for the Blacktip Shark. in: Proceedings of American Fisheries Society Symposium (Conf 50), 345-364.
[81] CONAPESCA, Programa de ordenamiento pesquero de la langosta de la península de Yucatán, México, Dirección General de Ordenamiento Pesquero y Acuícola, Quintana Roo, México, 2014, p. 86.
[82] SAGARPA (Secretaría de Agricultura, G., Desarrollo Rural, Pesca y Alimentación). (2010). Estrecha vigilancia en costas de Quintana Roo para evitar pesca furtiva; se implementa operativo en Laguna Yalahau, Isla Holbox – Chiquilá, municipio de Lázaro Cárdenas. Retrieved from Quintana Roo, México:
[83] A. Gallardo-Torres, M. Badillo-Alemán, F. Rivera, J. Rubio-Molina, C. Galindo De Santiago, J. Loera-Pérez, X. Chiappa-Carrara, Segunda Edición (Ed.), Catálogo de Peces de la Costa Norte de Yucatán, Universidad Nacional Autónoma de México - CONCIYTEY, 2014.
[84] Yuum-Kaah, Pesca Ilegal golpea a trabajadores del mar, Municipality of Lazaro Cardenas, Yuum-Kaah regional online news, Quintana Roo, México, 2014.
[85] Coba, H. (2016). Pesca Ilegal acaba con langosta. In (pp. 1-8). Quintana Roo, México: Diario Respuesta.

[86] Restrepo, I. (2014). Los problemas de Holbox, noticia en la prensa mundial ⟨http://www.jornada.unam.mx/2014/09/29/eco-j.html⟩. La Jornada Ecológica, México.

[87] Á.A. López Santillán, Turismo y desarrollo sustentable en áreas protegidas o sobre los "nuevos" contrasentidos para la producción y el marasmo en el ámbito rural, Desacatos 47 (2015) 36–53.

[88] E. Alonzo, C. Hernández, Generación y manejo de residuos sólidos en áreas naturales protegidas y zonas costeras: el caso de Isla Holbox, Quintana Roo, Sociedad y Ambiente *1* (2014) 92–114.

[89] Herrera-Silveira, J. A., Pech Cárdenas, M. A., Cortes-Balán, O., Pech Poot, E., & Linares, M. (2014). *Caracterización De La Calidad Del Agua De Isla Holbox De Acuerdo A Su Estado Trófico: Lluvias 2013-Nortes*. Mérida, Yucatán.

[90] García, A. (2016). Holbox en problemas: aguas negras dañan salud de isleños. *sipse.com.,* pp. 1-5.

[91] Vázquez, P., & González, J. (2014). Empresa abandona proyecto de construcción en la Isla Holbox ⟨http://www.jornada.unam.mx/2014/06/08/estados/026n1est⟩. La Jornada, online.

[92] T.K. Huitrón-Tecotl, Áreas naturales protegidas y tenencia ejidal; binomio perfecto para la acumulación por desposesión desde el discurso del desarrollo turístico sustentable: Holbox, Quintana Roo (Masters), Universidad de Quintana Roo, Quintana Roo, México, 2017 Retrieved from ⟨http://www.cozumel.uqroo.mx/mgst/productos/TESIS_Tania-KHT-FINAL.pdf⟩.

[93] L. McClenachan, J.B.C. Jackson, M.J.H. Newman, Conservation Implications of Historic Sea Turtle Nesting Beach Loss, Front. Ecol. Environ. *4* (6) (2006) 290–296.

[94] K.L. Cramer, History of human occupation and environmental change in western and central Caribbean panama, Bull. Mar. Sci. *89* (4) (2013) 955–982, https://doi.org/10.5343/bms.2012.1028.

[95] G.R. Russ, A.C. Alcala, Marine reserves: rates and patterns of recovery and decline of large predatory fish, Ecol. Appl. *6* (3) (1996) 947–961, https://doi.org/10.2307/2269497.

[96] R.C. Babcock, N.T. Shears, A.C. Alcala, N.S. Barrett, G.J. Edgar, K.D. Lafferty, G.R. Russ, Decadal trends in marine reserves reveal differential rates of change in direct and indirect effects, Proc. Natl. Acad. Sci. *107* (43) (2010) 18256–18261, https://doi.org/10.1073/pnas.0908012107.

[97] O. Aburto-Oropeza, B. Erisman, G. Galland, I. Mascareñas-Osorio, E. Sala, E. Ezcurra, Large recovery of fish biomass in a no-take marine reserve, PLoS One *6* (8) (2011).

[98] G. Acosta-González, F.A. Rodríguez-Zaragoza, R.C. Hernández-Landa, J.E. Arias-González, Additive diversity partitioning of fish in a Caribbean coral reef undergoing shift transition, PLoS One *8* (6) (2013) e65665, https://doi.org/10.1371/journal.pone.0065665.

[99] C.M. Appendini, P. Salles, E.T. Mendoza, J. López, A. Torres-Freyermuth, Longshore sediment transport on the northern coast of the Yucatán Peninsula, J. Coast. Res. (2012) 1404–1417, https://doi.org/10.2112/JCOASTRES-D-11-00162.1.

[100] Silva, R.; Martínez, M.L.; Hesp, P.; Catalan, P.; Osorio, A. F.; Martell, R.; Fossati, M. ; Miot da Silva, G.; Mariño- Tapia, I.; Pereira, P.; Cienfuegos, R.; Klein, A., and Govaere, G., 2014. Present and future challenges of coastal erosion in Latin America. In: (eds.), Coastal Erosion and Management along Developing Coasts: Selected Cases. Journal of Coastal Research, Special Issue, No. 71, pp. 1–16. Coconut Creek (Florida), ISSN 0749-0208.

[101] D. Pauly, Small-Scale Fisheries in the Tropics: Marginality, Marginalization and Some Implication for Fisheries Management, in: E.K. Pikitch, D.D. Huppert, M.P. Sissenwine (Eds.), Global Trends: Fisheries Management, 20 American Fisheries Society Symposium, Bethesda, Maryland, USA, 1997, pp. 40–49.

[102] J.R. McGoodwin, México's conflictual inshore Pacific fisheries: problem analysis and policy recommendations, Hum. Organ. *46* (3) (1987) 221–232.

[103] M.L. Cruz-Torres, Local-level responses to environmental degradation in Northwestern México, J. Anthropol. Res. *57* (2) (2001) 111–136.

[104] L. Carte, M. McWatters, E. Daley, R. Torres, Experiencing agricultural failure: Internal migration, tourism and local perceptions of regional change in the Yucatán, Geoforum Geoforum *41* (5) (2010) 700–710.

[105] T.L. Leatherman, A.H. Goodman, T. Stillman, Changes in stature, weight, and nutritional status with tourism-based economic development in the Yucatán, Econ. Hum. Biol. *8* (2) (2010) 153–158.

[106] E. Vargas-Martínez, M. Castillo, C. Viesca, Ending a touristic destination in four decades: Cancun´s creation, peak and agony, Int. J. Humanit. Soc. Sci. *3* (2013) 16–26.

[107] N.T. Rubio-Cisneros, J. Herrera-Silveira, S. Morales-Ojeda, M. Moreno-Báez, J. Montero, M. Pech-Cárdenas, Water quality of inlets' water bodies in a growing touristic barrier reef Island "Isla Holbox" at the Yucatán Peninsula, Reg. Stud. Mar. Sci. *22* (2018) 112–124, https://doi.org/10.1016/j.rsma.2018.06.006.

[108] Rochelle Steven, Clare Morrison, J. Guy Castley, Birdwatching and avitourism: a global review of research into its participant markets, distribution and impacts, highlighting future research priorities to inform sustainable avitourism management, J. Sustain. Tour. 23 (8–9) (2015) 1257–1276, https://doi.org/10.1080/09669582.2014.924955.

[109] D.A. Revollo-Fernández, Does money fly? The economic value of migratory birdwatching in Xochimilco, México, Mod. Econ. 6 (2015) 643–663, https://doi.org/10.4236/me.2015.66061.

[110] E. Gómez, Reporte Del Programa De Monitoreo De Las Reporte Del Programa De Monitoreo De Las Aves Migratorias Y Residentes En ElÁrea De Protección De Flora Y Fauna Yum Balam, Isla Holbox, Quintana Roo, México, Temporada 2015 (2015) 45.

[111] W. Adger, T.P. Hughes, C. Folke, S.R. Carpenter, J. Rockström, Social-ecological resilience to coastal disasters, Science *309* (5737) (2005) 1036–1039.

[112] J.E. Cinner, A. S., Integrating customary management into marine conservation, Biol. Conserv. *140* (3-4) (2007) 201–216.

[113] K.L. Cochrane, Primary fisheries management: a minimum requirement for provision of sustainable human benefits in small-scale fisheries, Fish Fish. *12* (3) (2011) 275.

[114] F. Leon, Piratas en Chiquilá; jugar con fuego, La Jornada Maya (2017), ⟨https://www.lajornadamaya.mx/2017-05-13/Piratas-en-Chiquila–jugar-con-fuego⟩.

[115] A. Jesus, J. Fraga, Coastal and Marine Protected Areas in México, International Collective in Support of Fishworkers, Chennai, India, 2008, p. 80.

[116] J. Jacquet, D. Pauly, Funding priorities: big barriers to small-scale fisheries, Conserv. Biol. *22* (4) (2008) 832–835.

[117] O. Aburto-Oropeza, E. Ezcurra, G. Danemann, V. Valdez, J. Murray, E. Sala, Mangroves in the Gulf of California increase fishery yields, Proc. Natl. Acad. Sci. U.S.A. *105* (30) (2008) 10456–10459.

[118] R. Costanza, R. de Groot, P. Sutton, S. van der Ploeg, S.J. Anderson, I. Kubiszewski, R.K. Turner, Changes in the global value of ecosystem services, Glob. Environ. Change *26* (2014) 152–158, https://doi.org/10.1016/j.gloenvcha.2014.04.002.

[119] K.L. Cochrane, Primary fisheries management: A minimum requirement for provision of sustainable human benefits in small-scale fisheries, Fish Fish. *12* (3) (2011) 275.

[120] S. Salas, D. Gaertner, The behavioral dynamics of fishers: management implications, Fish Fish. *5* (2) (2004) 153–167, https://doi.org/10.1111/j.1467-2979.2004.00146.x.

[121] A. Cinti, W. Shaw, J. Torre, Insights from the users to improve fisheries performance: Fishers' knowledge and attitudes on fisheries policies in Bahia de Kino, Gulf of California, México, Mar. Policy *34* (6) (2010) 1322–1334, https://doi.org/10.1016/j.marpol.2010.06.005.

[122] A. Cinti, W. Shaw, R. Cudney-Bueno, M. Rojo, The unintended consequences of formal fisheries policies: Social disparities and resource overuse in a major fishing community in the Gulf of California, México, Mar. Policy *34* (2) (2010) 328–339.

[123] S. Salas, R. Chuenpagdee, J.C. Seijo, A. Charles, Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean, Fish. Res. *87* (1) (2007) 5–16, https://doi.org/10.1016/j.fishres.2007.06.015.

[124] N. Rubio-Cisneros, O. Aburto-Oropeza, J. Murray, C. González-Abraham, J. Jackson, E. Ezcurra, Transnational ecosystem services: the potential of habitat conservation for waterfowl through recreational hunting activities, Hum. Dimens. Wildlife 19 (1) (2014) 1–16, https://doi.org/10.1080/10871209.2013.81953.

[125] V.H. Rivera-Monroy, R.R. Twilley, D. Bone, D.L. Childers, C. Coronado-Molina, I.C. Feller, E. Weil, A conceptual framework to develop long-term ecological research and management objectives in the Wider Caribbean Region, BioScience *54* (9) (2004) 843–856, https://doi.org/10.1641/0006-3568(2004)054[0843:ACFTDL]2.0.CO;2.

[126] J. Herrera-Silveira, F.A. Comín, L. Capurro, Landscape, use, and management in the coastal zone of Yucatán Peninsula, in: J. Day, A. Yañez-Arancibia (Eds.), The Gulf of México, Its Origin, Waters, Biota and Human Impacts, Texas A& MUniversity Press, Texas, 2013, pp. 225–242.

[127] J. Vázquez, Holbox soportaría hasta 9000 cuartos de hotel, El Economista (2018) Online source ⟨https://www.eleconomista.com.mx/estados/Holbox-soportaria-hasta-9000-cuartos-de-hotel-20180819-0081.html⟩.

[128] X. Basurto, A. Cinti, L. Bourillon, M. Rojo, J. Torre, A. Hudson Weaver, The emergence of access controls in small-scale fishing commons: A comparative analysis of individual licenses and common property-rights in two Mexican communities, Hum. Ecol. *40* (4) (2012) 597–609, https://doi.org/10.1007/s10745-012-9508-1.

[129] A.M. Cisneros-Montemayor, M.A. Cisneros-Mata, S. Harper, D. Pauly, Extent and implications of IUU catch in México's marine fisheries, Mar. Policy *39* (2013) 283–288, https://doi.org/10.1016/j.marpol.2012.12.003.

[130] N.T. Rubio-Cisneros, O. Aburto-Oropeza, E. Ezcurra, Small-scale fisheries of lagoon estuarine complexes in Northwest México, Trop. Conserv. Sci. *9* (1) (2016) 78–134, https://doi.org/10.1177/194008291600900106.

[131] J. Kearney, F. Berkes, Communities of interdependence for adaptive co-management, in: F. Berkes, D.R. Armitage, N. Doubleday (Eds.), Adaptive Co-management Collaboration, Learning, and Multi-level Governance, UBC Press, Vancouver, 2009, pp. 191–207 Retrieved from ⟨http://site.ebrary.com/id/10203177⟩.

[132] D. Armitage, Building resilient livelihoods through Adaptive Co-Management: The role of adaptive capacity, in: F. Berkes, D.R. Armitage, N. Doubleday (Eds.), Adaptive Co-management Collaboration, Learning, and Multi-level Governance, UBC Press, Vancouver, 2009, pp. 62–82 Retrieved from ⟨http://site.ebrary.com/id/10203177⟩.

[133] NOTIMEX, Plan de Manejo para Yum Balam y Holbox en Quintana Roo, La Jornada Maya (2016) Retrieved from https://www.lajornadamaya.mx/2016-11-04/Plan-de-Manejo-para-Yum-Balam-y-Holbox-en-Quintana-Roo.

[134] RARE. (2018) Sustainable Fisheries Sian Ka'an, México. Online resource. ⟨https://www.rare.org/campaign/sian-kaan-México-sustainable-fisheries#.W5mFky2ZPIE⟩.

[135] Diario Oficial de la Federacion DOF. (2017). ACUERDO por el que se amplía la vigencia del similar que establece una red de zonas de refugio pesquero en aguas marinas de jurisdicción federal ubicadas en el área de Sian Ka' an, dentro de la Bahía Espíritu Santo en el Estado de Quintana Roo, publicado el 30 de noviembre de 2012. Noviembre 30 2017, México.