

# Fisheries Centre

---



The University of British Columbia

## Working Paper Series

Working Paper #2013 - 11

### **A Reconstruction of Fisheries Catches for the Galápagos Islands, 1950-2010**

Laurenne Schiller, Juan José Alava, Jack Grove,  
Günther Reck and Daniel Pauly

Year: 2013

Email: [l.schiller@fisheries.ubc.ca](mailto:l.schiller@fisheries.ubc.ca)

A RECONSTRUCTION OF FISHERIES CATCHES FOR THE  
GALÁPAGOS ISLANDS, 1950-2010

Laurenne Schiller<sup>a</sup> (l.schiller@fisheries.ubc.ca), Juan José Alava<sup>a,b,c</sup>, Jack Grove<sup>d</sup>, Günther Reck<sup>e</sup>, & Daniel Pauly<sup>a</sup>

<sup>a</sup>*Sea Around Us Project, Fisheries Centre, University of British Columbia, 2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada*

<sup>b</sup>*Fundación Ecuatoriana para el Estudio de Mamíferos Marinos (FEMM), Guayaquil, Ecuador*

<sup>c</sup>*School of Resource and Environmental Management, Simon Fraser University, 8888 University Drive, Burnaby, BC, V5A 1S6, Canada*

<sup>d</sup>*Section of Ichthyology, Natural History Museum of Los Angeles County, 900 Exposition Blvd., Los Angeles, CA, 90007, USA*

<sup>e</sup>*Instituto de Ecología Aplicada, Universidad San Francisco de Quito, Quito, Ecuador*

## ABSTRACT

The Galápagos Islands are one of Earth's last biodiversity edens. As such, the conservation of their terrestrial and marine wildlife, including the sustainable management of local fisheries, is of paramount importance. Although the commercial exploitation of marine resources in the Galápagos did not begin until the 1930s, issues of overexploitation and mismanagement are already of serious concern. However, to date, research on Galápagos fisheries has been largely species or island specific, and no long-term cumulative catch statistics exist. In this study, total landings associated with the industrial and artisanal fisheries of the Galápagos Islands, were compiled and analyzed in an effort to accurately depict the amount of seafood that has been extracted from this region over the last six decades. The total catch for all sectors from 1950-2010 was 797,000 t, of which industrially caught tuna made up 80%. Our results also show a high degree of fishing down within the in-shore ecosystem catch, whereby planktivorous mullets have replaced high trophic level groupers within the past three decades. This shift has coincided with the spatial expansion of the Galápagos fishing fleet to farther off-shore, where predatory species are not yet depleted. In addition to legally caught and exported seafood, the Galápagos is also a hotspot for illegal fishing. Of primary concern is the amount of shark finning that has occurred and continues to occur in the Galápagos Marine Reserve, despite attempts at mitigating this ecologically destructive and wasteful practice.

## INTRODUCTION

### *Island geography and demographics*

Located 1,000 km west of mainland Ecuador in the eastern Pacific Ocean, the Galápagos Islands (1°40'N–1°36'S, 89°16'–92°01'W) have been a subject of curiosity, mystery, and scientific discovery for nearly five hundred years. Charles Darwin's voyage aboard the *H.M.S. Beagle* in 1835 (Pauly 2004) offered him the unique opportunity to take a variety of biological specimens from this region. And, although best known for his descriptions of finches, Pauly (Pauly 2004) demonstrates that Darwin's subsequent research on speciation was actually largely influenced by the phenotypic variations that he observed in fish species, rather than in birds.

At present, the Galápagos archipelago encompasses thirteen islands (> 10 km<sup>2</sup>; Table 1) and over 100 islets (Snell *et al.* 1996). Although frequented by sailors and explorers since their initial discovery, permanent human residency on the Galápagos only began in the 1830s (Camhi 1995). The population remained quite low until the 1970s, when political and social issues in Ecuador, combined with increased tourism to the Islands, contributed to substantial emigration from the mainland (Epler 2007). Realizing the need to preserve the unique environment of the archipelago, the Government of Ecuador proactively designated the Galápagos as a national park in 1959; in 1979, it was further declared a UNESCO World Heritage Site (Camhi 1995; Bensted-Smith *et al.* 2002). In 1998, the foundation of the Galápagos Marine Reserve (GMR) endowed a protective boundary around the archipelago, which extends 60 km beyond the islands and encompasses 138,000 km<sup>2</sup> (Camhi 1995; Heylings and Bensted-Smith 2002), making it one of the largest marine protected areas in the world.

With five inhabited islands, the 2010 population of the Galápagos was estimated at over 25,000—a dramatic increase from the ~2,000 individuals who lived there in 1959 (Bremner and Perez 2002; INEC 2011). Unfortunately, as a result of this colonization, the Galápagos suffers from many of the same problems that have affected geographically isolated regions throughout history: species invasions (1,321 spp. as of 2007), increasing human population growth, and the use of natural habitat for agriculture (Causton *et al.* 2006; Watkins and Cruz 2007; Mauchamp and Atkinson 2010).

Additionally, the ecotourism industry of this archipelago has exploded over the latter

half of the 20<sup>th</sup> century. Until the mid-1970s, tourism in the Galápagos Islands was virtually non-existent. Approximately two-thousand people visited the archipelago in 1969 (Epler 2007); a tiny fraction of the 180,831 people who visited them in 2012 (PNG 2013), and whose activities result in a direct, local, annual profit of over \$60 million (Watkins and Cruz 2007). This exponential gain in foreign attention and the negative impact it is having on the Islands' environment remains one of the primary threats facing the Galápagos today.

### *Overview of Galápagos fisheries*

The biodiversity of the Galápagos Islands is extensive: they are home to a cornucopia of species, and nearly 20% of the sea life is endemic (Bustamante *et al.* 2002). One of the most unique characteristics of these islands is the unconventional co-existence of tropical species, temperate species, and typically Southern Ocean species within such a small region (Jackson 2001). Such assemblages are made possible by deep near-shore waters, strong currents, and nutrient-rich upwellings, which provide an excellent habitat for over 2,900 fish, aquatic invertebrates, and marine mammals (Grove and Lavenberg 1997; Bustamante *et al.* 2002; Okey *et al.* 2004; Castrejón 2011). Human exploitation of marine life at a large scale in the Galápagos began in the late 18<sup>th</sup> century, with the onset of hunting of Galápagos fur seals (*Arctocephalus galapagoensis*) for their pelts, and with commercial whaling, the latter subsequently leading to the rapid local depletion of sperm whales (*Physeter macrocephalus*) (Townsend 1934; Whitehead *et al.* 1997; Toral-Granda *et al.* 2000). Although these industries lasted less than a few decades each, fishers have exploited the rich marine ecosystem surrounding the Galápagos ever since and, presently, the economic importance of the fishing sector is second only to tourism (Bremner and Perez 2002).

Fishing activity within the GMR is currently organized by zones, whereby subsistence and artisanal fishing is allowed in specified locations and all large-scale industrial fishing has been prohibited since 1998 (Jennings *et al.* 1994; Jacquet *et al.* 2008). The main fishing ports in the Galápagos are located on San Cristóbal (Puerto Baquerizo Moreno), Isabela (Puerto Villamil) and Santa Cruz (Puerto Ayora) (Castrejón 2011); these towns service the three primary artisanal fisheries in the archipelago: finfish<sup>1</sup> (year round),

---

<sup>1</sup> More commonly known as “whitefish” in the Galápagos, despite the fact that both white-fleshed (e.g. serranids) and red-fleshed (e.g. scombrids) fish are landed by this fishery.

sea cucumber (seasons from March/April to May/June), and lobster (July/September to December/February) (Bustamante 1999; Jácome and Ospina 1999; Toral-Granda *et al.* 2000). The artisanal fleet of the Galápagos is largely made up of small fishing boats with limited technology. Based on size, the vessels are divided into three main types: *botes* (wooden boats, 7-16 m with diesel engines), *pangas* (plywood boats, 3-6 m with 60Hp outboard motor) and *fibras* (fiberglass boats, 5-9m with >60Hp large outboard motor) (Bustamante 1998). Between 1971 and 2000, the number of fishers increased by 326% from 160 to 682 individuals (Bustamante 1998; Toral-Granda *et al.* 2000). This substantial intensification in fishing effort and vessels (mainly *pangas*) was largely influenced by the economical incentives generated by the lucrative sea cucumber fishery in the 1990s. Conversely, from 2000-2007, there was a 65% decrease in the total number of active fishers in the Galápagos, likely due to the diminishing profitability of the major export fisheries (spiny lobster and sea cucumber), and subsequent shifts in livelihood (Castrejón 2011).

### *Artisanal fisheries*

Since 1998, the artisanal fisheries were regulated through a co-management approach and internal consensus process led by the Galápagos Marine Reserve's Participatory Management System Board (PMS), which encompassed several stakeholder groups (Artisanal Fishers Association, Charles Darwin Research Station, Tourism Galápagos Chamber and Galápagos National Park Service) and was approved by the Inter-institutional Management Authority (IMA)<sup>2</sup>. The PMS was legally founded on three fundamental principles: participation, precaution, and adaptive management, with the overall aim of creating a consensus building process that allowed local stakeholders (i.e., fishers, natural guides, tourism operators, and conservationist-environmentalist groups) to participate in decision making for the sustainable use of marine resources (Castrejón *et al.* 2005; Castrejón 2011). Therefore, artisanal fishing was conducted in agreement with negotiations and regulations enacted by the GNPS. The legal framework for fishing was thus focused on permits, including seasonal fishing openings, quotas, and limits on the number of active fishers.

---

<sup>2</sup> The IMA is the government entity conformed by the Ministries of Fishery, Tourism, Environment and Defense and is based on continental Ecuador.

However, declines in sea cucumber and spiny lobster abundances, and diminishing economic rent resulted in the realization that the initial co-management model coupled with legal tools for sustainable fisheries management in the GMR had not accomplished its original goals (Castrejón 2011). As such, the Participatory Fisheries Stock Assessment (*ParFish*) model was developed to assess and improve the co-management system by taking into account the local idiosyncrasies of the Galápagos and the legal framework of fisheries management. The *ParFish* process ran from February 2006 to January 2009, and the activities and results obtained are described in Castrejón (2011). The outcomes of this exercise were used as inputs by the PMS to formulate a new proposal for the GMR fishery management (“Capítulo Pesca”), which was approved by the IMA in 2009<sup>3</sup>.

#### i) Bacalao and finfish

The Galápagos finfish fishery has a long history in the Islands and dates back to the time of colonization, when about a dozen species of fish were taken for subsistence (Toral-Granda *et al.* 2000; Castrejón 2011). Today, fish have four potential destinations: i) local markets where they are sold fresh to Galápagos residents; ii) the tourism sector (e.g., hotels, dive boats) for consumption by tourists; iii) dried and exported to mainland Ecuador for local consumption; or iv) freshly exported to the mainland for further export to the United States (Nicolaidis *et al.* 2002). As detailed in Reck (1983), commercial finfish fishing became permanently established in 1945, after failed attempts in the 1920s and 1930s. For decades, the primary target of this hand-line fishery was the Galápagos grouper, *Mycteroperca olfax*, a species locally referred to as *bacalao*<sup>4</sup> (Reck 1983; Nicolaidis *et al.* 2002). In the past, this species was fished from October to March, dried, and exported to mainland Ecuador for use in traditional Easter soup (Nicolaidis *et al.* 2002).

There has been a decline in the abundance of *M. olfax* (Ruttenberg 2001; Banks 2008), and 64% of fishers from Puerto Baquerizo Moreno (traditionally the main fishing port for the catch and export of bacalao) have observed declines in their catch rates (Castrejón 2011). However, Galápagos-wide catch rates appear to have remained stable since the 1970s (Castrejón 2011). These two seemingly contradictory observations suggest that the fishery is

---

<sup>3</sup> [http://www.galapagospark.org/documentos/capitulo\\_pesca\\_reserva\\_marina\\_galapagos.pdf](http://www.galapagospark.org/documentos/capitulo_pesca_reserva_marina_galapagos.pdf)

<sup>4</sup> The English translation of *bacalao* is ‘cod’ (Family Gadidae); however *M. olfax* is a grouper (i.e. a member of the family Serranidae).

expanding throughout the Islands. Castrejón (2011) additionally suggests that within the finfish fishery there exist cases of ‘shifting baselines syndrome’, whereby newer generations of fishers do not perceive declines in abundance to be as dramatic as they are in reality, since the state of the environment for their initial frame of reference (i.e., when they started fishing) is already vastly different from the pristine, pre-fished state (Pauly 1995).

## ii) Sea cucumber

Initially established in 1991 after Ecuadorian coastal stocks collapsed, the artisanal sea cucumber fishery has a relatively short, but problematic, history in the Galápagos (Shepherd *et al.* 2004; Castrejón *et al.* 2005; Hearn *et al.* 2005; Toral-Granda 2008). The primary fishing grounds are located on the west side of Isabela Island, near the Bolivar Channel (Castrejón 2011). While nearly forty species of sea cucumber occur within the archipelago (Maluf (1991) in Toral-Granda 2008), it is only legal to harvest the brown sea cucumber (*Isostichopus fuscus*); illegal fishing operations exist for at least three other species (Toral-Granda 2008).

Although there were initial efforts to ensure the sustainable extraction of this resource, overfishing and illegal catches strongly contributed to the closure of the fishery in 1992 (Bremner and Perez 2002). However, this moratorium lasted only two years before the fishery was again opened for a brief three-month trial period. The total allowable catch (TAC) set for the trial period was 500,000 sea cucumbers, but a lack of enforcement and management resulted in an actual take of between 6-10 million individuals before the fishery was again closed (Camhi 1995). The sea cucumber fishers (*pepineros*) did not take the closure lightly, and violently protested to the Ecuadorian Government by seizing Galápagos National Park Service offices and the Charles Darwin Foundation (CDF), and by threatening Galápagos tortoises (*Geochelone* spp.), an action that has occurred on more than one occasion (Camhi 1995; Stone 1995; Ferber 2000). However, despite these demonstrations, the fishery remained closed until 1999.

Recent management efforts, including the implementation of an individual transferable quota (ITQ) system and minimum size restrictions suggest that there are ongoing attempts to manage the sea cucumber fishery more effectively. However, population sizes are still variable and recovery appears to be slow (Toral-Granda 2008; Castrejón 2011).



Additional conservation precaution was made in 2003, when *I. fuscus* became the first sea cucumber species listed under Appendix III of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Toral-Granda 2008). However, the following year, 383,000 sea cucumbers (~100 t) were caught without a CITES permit (Toral-Granda 2008). Additionally, although the CDF estimated a maximum sustainable quota of 450,000 sea cucumbers for 2004, the IMA allowed an opening season for two months with a maximum capture of three million individuals, and a total moratorium for 2005 and 2006. However, the last resolution was revoked, leading to a judicial trial and claims for an extension of the fishing season, as well as to permit fishing of sea cucumbers in no-take areas, where fisheries or extractive activities are excluded (i.e., Fernandina Island and Bolivar Channel). Ultimately, the fishery was open for 2005, but closed in 2006 in an effort to allow the population to recover. Due to increased concerns over population health, it was again closed between 2009-2010.

iii) Spiny and slipper lobsters

The red spiny lobsters (*Panulirus penicillatus*) and the green (or blue) spiny lobster (*Panulirus gracilis*) have been fished for commercial export since the 1960s (Bustamante *et al.* 2000), and previous estimates suggest that the Galápagos has always contributed upward of 90-95% to Ecuador's total spiny lobster export (Reck 1983; Bustamante *et al.* 2000). Between 1979 and 1980, the average CPUE for spiny lobsters was 10.7 kg of tails diver<sup>-1</sup>·day<sup>-1</sup> (peaking at 12.4 kg of tails diver<sup>-1</sup>·day<sup>-1</sup> in 1978), however from 1994-2006, the average CPUE was only 6.6 kg of tails diver<sup>-1</sup>·day<sup>-1</sup>, and an all-time low of 4.0 kg of tails diver<sup>-1</sup>·day<sup>-1</sup> was observed in 2005 (Hearn *et al.* 2006, from Castrejón 2011). Given these changes in catch rate, the spiny lobster fishery incurred a brief 18-month closure in 1994. Although declines in abundance have caused the commercial value of these species to increase (US \$28.60/kg in 2006 compared to US\$7.92 in 1997), there has been a substantial decrease in the gross income of the fishery (Hearn *et al.* 2006). In addition to the spiny lobsters, a similar species, the slipper lobster (*Scyllarides astori*), is also harvested at a smaller scale (Hearn 2006). Although endemic to the Eastern Pacific, the slipper lobster is not as valuable as the spiny lobsters; thus is sold primarily for local consumption (Bustamante *et al.* 2000; Andrade and Murillo 2002).

### *Industrial fishery (tuna)*

Records allude to industrial fleets in Galápagos waters catching approximately 400 t of tuna back in 1933, and 2,300 t in 1940 (CDF 2010). Fishing pressure from both foreign fleets and mainland-based Ecuadorian vessels has increased ever since (Shimada 1958; Castro 2005; Bedoya 2009), and the primarily targeted species in the Eastern Pacific Ocean (EPO) are skipjack (*Katsuwonus pelamis*), bigeye (*Thunnus obesus*), and yellowfin (*Thunnus albacares*). At present, Ecuador's EPO tuna fleet consists of 86 vessels (IATTC 2011), although only a small fraction of these operate within the Galápagos EEZ. Since the GMR prohibits large-scale industrial fishing within its borders, this type of tuna fishing is limited to regions farther offshore. However, it has been observed that foreign vessels operating as Ecuadorian partners do not respect the rules or the integrity of the GMR (Bustamante 1999), and incidents of illegal fishing within the marine reserve are an ongoing concern (Altamirano and Aguiñaga 2002; Reyes and Murillo 2007). Independent of the industrial endeavors of Ecuador's fleet, artisanal tuna fishing by local Galápagos fishers is allowed within the GMR and these catches are part of the finfish fishery.

### *Shark fishery*

In addition to the plethora of teleost fishes in the Galápagos Islands, a significant diversity of sharks has also been recorded in this region (Grove and Lavenberg 1997; Zarate 2002; Carr *et al.* 2013). Among these species, it is possible to find schools of hammerhead (scalloped, *Sphyrna lewini* and smooth, *S. zygaena*), tiger (*Galeocerdo cuvierii*), mako (*Ixurus oxyrinchus*), white-tipped reef (*Triaenodon obesus*), blue (*Prionace glauca*), Galápagos (*Carcharhinus galapagoensis*), oceanic whitetip (*Carcharhinus longimanus*), silky (*Carcharhinus falciformis*), three species of thresher (*Alopias vulpinus*; *A. superciliosus*; and *A. pelagicus*), and even whale sharks (*Rhincodon typus*). About 90% of the elasmobranchs found around the Galápagos have been included on the IUCN Red List as Threatened or Near-Threatened (IUCN 2007). The scalloped hammerhead, one of the most abundant and gregarious sharks in Galápagos marine waters (Grove and Lavenberg 1997; Compagno *et al.* 2005), was recently moved up from Near Threatened to Endangered status (IUCN 2007), and both the whale and great white sharks are categorized as Vulnerable.

Shark fishing and finning has been conducted in the Galápagos since the 1950s (Watts and Wu 2005; Jacquet *et al.* 2008). Sharks caught in Galápagos waters are typically landed on the Ecuadorian mainland; the destination and connection ports where illegal operations take place are Guayaquil and Manta, the two major industrial and harbor fishery cities. Fishing for sharks in the Galápagos became increasingly prevalent in the 1980s and the magnitude of this endeavor has increased ever since (Camhi 1995; Coello 1996; Watts and Wu 2005). Between 1988 and 1991, illegal shark fisheries were discovered to be using sea lions as bait, and the onset of finning practices with the discard of shark bodies led to the slaughter of tens of thousands of sharks for the Asian market (Camhi 1995; Merlen 1995). These operations were conducted largely by Ecuadorian, Colombian, Costa Rican, Japanese, Taiwan and Korea semi-industrial and industrial longline fishing fleets, some of which were licensed only for tuna fishing, but were illegally fishing for sharks (Camhi 1995; Merlen 1995).

### *Sportfishing*

The traditional ‘trophy hunting’ approach to sport fishing began in the Galápagos in the 1990s, however these activities were highly unregulated and operated without the consent of local fishers (Schuhbauer and Koch 2013). As such, this type of tourism is not currently supported by the GMR and prohibited within its boundaries (PNG 2009); since 2005, recreational sport fishing by tourists in the Galápagos has been based on the Pesca Artesanal Vivencial (PVA) approach instead (Schuhbauer and Koch 2013). This new, experimental initiative aims at giving local fishers an alternative to commercial fishing, and tourists the chance to spend a day with a local licensed fisher. Fish are meant to be caught using traditional gear and methods and, with the exception of spiny lobsters caught during the harvest season, all catch is legally required to be released (PNG 2009). Although very little assessment of PVA has been conducted, initial research suggests that this program has not been successful (largely due to a lack of organization and clearly defined regulations), and despite efforts to avoid traditional sport fishing, these activities remain prevalent within the archipelago (Schuhbauer and Koch 2013).

### *Purpose of study*

Since 1950, the United Nation's Food and Agriculture Organization (FAO) has collected annual fisheries landings from its member countries and these are compiled in their FishStat database (see [www.fao.org](http://www.fao.org)). These statistics rely on the accuracy of reporting countries and, in many cases, refer primarily to commercial and large-scale operations (Zeller *et al.* 2007; Wielgus *et al.* 2010). Consequently, smaller sector fishing (e.g. subsistence, recreational, artisanal) and illegal and unreported catches are often overlooked and unreported. This discrepancy is largely due to a lack of infrastructure for acquiring these data in developing countries (Jacquet *et al.* 2010; Castrejón 2011) or, as in the Galápagos, fishers may not even be required to record or report their catches (Born *et al.* 2003). As such, very little cumulative catch data for this region are available, and most of what can be obtained is a result of independent scientific research.

The primary objective of this study is to give an accurate representation of the total marine fisheries landings from all sectors by both Galápagos fishers and fleets from mainland Ecuador within the Exclusive Economic Zone of the Galápagos Islands between 1950 and 2010. A secondary goal is, in view of the ongoing debate about the validity of the 'fishing down' phenomenon (Pauly *et al.* 1998; Caddy *et al.* 1998; Pauly and Palomares 2005; Essington *et al.* 2006; Pauly, 2010, 2011; Branch *et al.* 2011), to observe whether this trend is also occurring in the Galápagos Island fisheries and, if it is, at what intensity.

## METHODS

Given the lack of catch reporting by Galápagos fishers, it is unknown how much (if any) data from the fisheries of the Galápagos are pooled with FAO data for Ecuador as a whole. The finfish species associated with the Galápagos (e.g. bacalao, mullet) were not featured independently in Ecuador's data set and we therefore assumed they were not included. Conversely, the start of Ecuador's recorded catch data of other species, including spiny lobsters and sea cucumbers, did appear to be correlated with the commencement of these fisheries in the Galápagos. Therefore, in an effort to avoid overestimating or double counting, we assumed that for these fisheries, Galápagos catches were included within FAO Ecuador data.

### *Local consumption*

In order to calculate the amount of fish consumed at a local level, we used GraphClick to extract permanent residency data from Taylor *et al.* (2008), and Galápagos National Park entry records were used to estimate the amount of tourism from 1979 to present<sup>5</sup>. Additional information was also obtained from González *et al.* (2008) and Ecuador's Instituto Nacional de Estadística y Censos (INEC)<sup>6</sup>, and linear interpolations were performed to “fill in” data gaps. Although an archipelago-wide value of seafood consumption could not be found, as determined in a study on consumption on Santa Cruz Island, 6.75 kg person<sup>-1</sup> year<sup>-1</sup> was used as the 2010 *per capita* consumption rate for locals, and 1.1 kg person<sup>-1</sup> vacation<sup>-1</sup> was used for tourists (Manuba 2007). Given decreased accessibility to food from the mainland, we assumed that locally caught seafood was more prominent in people's diets on the Islands for the earlier time period. Thus, a starting *per capita* consumption 1.5 times higher than present (i.e., 10.1 kg person<sup>-1</sup> year<sup>-1</sup> for locals and 1.4 kg person<sup>-1</sup> trip<sup>-1</sup> for tourists) was used for 1950. Linear interpolation between past and present *per capita* consumption rates applied to the population over time was therefore used to determine a subsistence catch component.

### *Lobster*

FAO data show landings for only one species of lobster (*P. gracilis*); however we assumed that these data were meant to include *P. penicillatus* as well. We also assumed that all FAO lobster data referred exclusively to Galápagos catches (i.e., no lobsters from mainland Ecuador) since the fishery in the archipelago has contributed roughly 90-95% to Ecuadorian catches since its establishment. We largely accepted these FAO data as correct. However, additional catches (‘ad-ons’) for 1973-1976 were obtained from Reck (1983), Hearn and Murillo (2008) for 1995-2003, and export data provided by the Charles Darwin Foundation (CDF) for 2004-2010<sup>7</sup>. In most cases, lobster weight was given in terms of tail weight, thus a conversion factor of 2.86 (as determined by Reck 1983) was used to calculate whole animal weight. Most sources provided a species breakdown; when this was unavailable, an approximate species catch composition of 45% *P. penicillatus*, 45% *P. gracilis*, and 10% *S. astori* was used for catches prior to 2000. An approximate catch

---

<sup>5</sup> [http://www.galapagospark.org/onecol.php?page=turismo\\_estadisticas](http://www.galapagospark.org/onecol.php?page=turismo_estadisticas)

<sup>6</sup> <http://www.inec.gob.ec/cpv/>

<sup>7</sup> <http://www.galapagospark.org/boletin.php?noticia=354>.

composition for the last decade was adjusted based on information in Hearn and Murillo (2008), which suggests that “*P. penicillatus* makes up over 75% of the yearly spiny lobster catch”. We used available information to estimate export percentages, such that prior to 1982, 95% of spiny lobster was exported (Reck 1983), 92% was exported in the 1990s (Bustamante *et al.* 2000), and between and 2000-2010, 88% was exported (Castrejón 2011).

### *Sea cucumber*

Sea cucumber catches were obtained from a variety of sources, namely: Bremner and Perez (2002), Shepherd *et al.* (2004), Reyes and Murillo (2007), Toral-Granda (2008) and Wolff *et al.* (2012). When a range was given, the authors’ preferred value was used. An average weight of 271 g (Sonnenholzner 1997) was used to calculate tonnage in cases where the original data referred to the number of individuals caught rather than total weight. Some data were available for illegal catches of *I. fuscus* (Shepherd *et al.* 2004) and linear interpolation was used between these anchor points. Hearn and Pinillos (2006) suggest that illegal fishing for the warty sea cucumber (*S. horrens*) began in 2004, and an illegal catch estimate was determined from this time onward using the annual average of known seizures. Unfortunately, very little qualitative information and no quantitative data were found for the other two species (*Holothuria atra* and *H. kefersteini*) fished illegally in the archipelago.

### *Bacalao and finfish*

Early anecdotal estimates by Reck (1983) suggest annual finfish landings of approximately 500 t in the 1950s. However, this observation is difficult to contextualize, as no other catch statistics for this time exist. Nonetheless, we used this tonnage as the starting point for 1950 and held it constant until 1955. No data were available until 1977 (Reck 1983), so linear interpolation was used between these years. GraphClick was used to extract data from a time series of catches in Castrejón (2011) and additional time series (Andrade and Murillo 2002; Anonymous 2009) served as anchors for further interpolations. Export data provided by CDF were again used to calculate the catch between 2004-2010. Up until the 1970s, mullets were not considered part of the finfish catch (Reck 1983); since later data sets did include them with as part of the finfish fishery, we chose to add the calculated catches of *Mugil galapagensis* and *Xenomogil thornburi* to the earlier finfish catch data.

Approximate species breakdowns were available from the aforementioned sources; when these were unavailable, we calculated the species composition for known years and applied it to the total catch. Specifically, we used the composition from Reck (1983) for 1977-1981 and applied it to the finfish catch for all years prior. Subsequently, we used the species composition available from the most recent years (i.e., 2004-2010 CDF export data) and applied these ratios to the catch since 1981 for years where the composition was unknown.

For each year, we used the total annual calculated consumption to determine an approximate exported catch. Between 1950-1970, we determined that finfish catches were 95% exported, compared to 49% exported for the last two decades. However, given the way in which total consumption was calculated, this value is a coarse approximation.

#### *Tuna (industrial)*

Although the Inter-American Tropical Tuna Commission (IATTC) has published various reports on tuna caught in the eastern Pacific since the 1950s, a lack of information pertaining to the country fishing made it impossible to deduce how much of this tuna was caught in the Galápagos by Ecuador's industrial fleet. As such, only one two data sets (Jácome and Ospina 1999; Pacheco-Bedoya 2010) for three species (skipjack, yellowfin, and bigeye) of Ecuador-caught tuna in the Galápagos could be found. Similar to the spiny lobster and sea cucumber fisheries, we assumed that industrially caught tuna in the Galápagos was included with Ecuador's FAO data. We accepted Ecuador's tuna catches to be accurate and used the two time series available to estimate what proportion of Ecuador's tuna was from the Galápagos. Since it closely matched Bustamante's (1999) suggestion that 24.3% of Ecuador's tuna comes from the Galápagos, we used the percentage breakdown from Pacheco-Bedoya (2010) to determine the total Galápagos catch and species composition for all years in which data were unavailable.

#### *Sharks*

Based on anecdotal evidence, we used 1950 as the starting year for this fishery. Values for sharks caught in the Galápagos were obtained primarily by calculating the difference between the reconstructed shark catch of mainland Ecuador and Ecuador's shark

exports from 1979-2004, as determined by Jacquet *et al.* (2008). We were aware that the degree of shark fishing that occurred in the past was not as substantial as it is presently. However, since no estimates were available, we chose to average the first available data set (from 1979-1984) and apply 15% of this catch to 1970. We then interpolated between 1950 and this anchor point. There are no numerical or anecdotal indications that shark finning ever declined or stopped in the Galápagos. Thus, when export data from Jacquet *et al.* (2008) were less than Ecuador's reconstructed catch, we still assumed shark fishing was occurring in the archipelago, but that exports during this time were under-reported and we interpolated between these years instead. A species breakdown was determined from the Fundación Natura-World Wildlife Fund's *Galápagos Report* (1998) which states that, "the main shark species captured in Galápagos in 1994 were the blue shark (*P. glauca*), accounting for 67.2% of the catch; the thresher (*A. vulpinus* and *A. superciliosus*), at 13.2% of the catch; the Mico<sup>8</sup> at 15.6%; and the hammerhead (*Sphyrna* spp.), at 2.3%." Although these percentages refer to only one year, this breakdown appears consistent with anecdotes in Jacquet *et al.* (2008), which suggest that blue sharks and thresher sharks currently constitute nearly 90% of all shark landings in the 'shark mafia' epicenter of Manta, Ecuador.

### *Trophic level analysis*

Given reported quantitative and qualitative changes in catch composition, we additionally chose to analyze the mean trophic level (TL) of the artisanal catch to see if 'fishing down'<sup>9</sup> was occurring (i.e., if there were any noticeable ecological shifts in the species landed over time). Although still caught by Ecuadorian vessels in the Galápagos EEZ (i.e. Ecuadorian waters), we chose to omit industrially and illegally caught tuna and sharks from this analysis since these species are not directly related to the fisheries and fishers of the Galápagos.

We used the average of the trophic level values provided by Okey *et al.* (Okey *et al.* 2004) and FishBase ([www.fishbase.org](http://www.fishbase.org)) for fishes, and SeaLifeBase ([www.sealifebase.org](http://www.sealifebase.org)) for invertebrates. However, since the fishing down effect can be easily masked by

---

<sup>8</sup> Silky shark (*Carcharhinus falciformes*)

<sup>9</sup> Here, we define 'fishing down' as a decline in the mean trophic level of fisheries catches, reflecting a decline of higher-trophic level (predatory) species, relative to species low in food webs, such as planktivores (e.g., mullets) and detritivores (e.g, sea cucumbers).



aggregating data from different ecosystems, we defined an ‘in-shore’ ecosystem that comprised all species typically occurring along the coast, or within the inshore fishing area (IFA; area up to 50 km off-shore or 200 m deep). Given the instability and innate boom-and-bust nature of the sea cucumber fishery, we also chose to perform the in-shore analysis with and without sea cucumbers. The separate ‘off-shore’ species category refers to larger pelagic fishes that would typically be found outside of the IFA (Table 2). We used the average TL value (3.54) of all species in this analysis for finfish landings that could not be disaggregated by species (i.e., the ‘others’), and kept these fish in both spatial categories. Regression analyses were performed to assess the changes in mean trophic level over time.

## RESULTS AND DISCUSSION

Although primarily established within the last sixty years, this catch reconstruction demonstrates a relatively high level of overexploitation within the commercial fisheries of the Galápagos, particularly with regard to sea cucumber and spiny lobster. Of additional concern is the decline in abundance of large apex-level fish, such as the groupers, and the subsequent changes in catch composition that followed.

Given that no cumulative baseline data set from either the FAO or Government of Ecuador was available for the Galápagos, we are unable to give a total comparison between landings reported to the FAO and those presented in this reconstruction. Nonetheless, when taking into account all legal and illegal fisheries in the Galápagos, we determined that from 1950-2010, a total of 797,000 t of seafood was extracted from the EEZ surrounding this archipelago (Figure 1). It should be recognized that 80% of these landings are tuna caught by Ecuador’s industrial fleet, and shark fishing—which is currently illegal—is the second highest contributing fishery, accounting for 13% of these landings. These and additional sector breakdowns are discussed below.

### *Subsistence fishery*

Since spiny sea cucumbers are entirely exported, locally consumed seafood is composed of finfish species (including tuna), slipper lobster and a small amount of spiny lobster. Given the increased residency and tourism on the Galápagos, it is understandable that there has also been an increase in the amount of seafood consumed on the Islands. From

1950 to 2010, we estimate that a total of 6,700 t of finfish, 700 t of slipper lobster, and 600 t of spiny lobster have been taken for subsistence. The aforementioned *per capita* seafood consumption rates are very low in comparison to other oceanic islands and countries (see Harper and Zeller 2011). However, this disparity is likely due to the prominence of agricultural and farmland on the islands; many Galápagos residents maintain a diet similar to that of people on the mainland, consuming primarily grains and meat.

### *Sea cucumber*

Taiwan and Hong Kong are the primary importers of sea cucumber, and between 2005-2006, they accounted for 83% of exported dried sea cucumber from the Galápagos (Toral-Granda 2008). Given that a kilogram of dried sea cucumber can fetch as much as US\$170 in Asia (Castrejón 2011), lucrative financial incentives promoted by global demand have generated both a substantial legal and illegal take of this resource. Our reconstruction determined that 16,100 t of sea cucumber was caught in the Galápagos between 1950 and 2010. Of this, 13,000 t was legally caught *I. fuscus* and the rest illegal catch of both *I. fuscus* (3,060 t) and *S. horrens* (40 t). This reconstructed catch is 36 times as much as Ecuador's reported landings of sea cucumber to FAO for the same period (Figure 2). The largest annual catch of *I. fuscus* (2,800 t) occurred in 1994, just prior to the four-year closure of this fishery (when it was still largely unregulated).

When the brown sea cucumber fishery was closed following the initial and unsustainable boom in 1991, extensive illegal fishing was undertaken to continue exporting this species to the Asian seafood and aphrodisiac market (Deborah Chiriboga, pers. comm.; Jacquet *et al.* 2008). Although both *H. atra* and *H. kefersteini* are also fished illegally in the Galápagos (Toral-Granda 2008), no annual catch estimations could be found and therefore these species are excluded from this reconstruction. Therefore, and given that the illegal catch estimates are based only on known seizures, the total tonnage for illegal sea cucumber landings is likely highly conservative.

Given substantial declines in *I. fuscus* (Toral-Granda 2008), there have been suggestions for legalizing the fishery for *S. horrens*, as well as for the white sea urchin (*Tripneustes depressus*) (Castrejón 2011). Although these initiatives have the potential to provide short-term economic benefits, this shift in targeted species is not unlike the mainland

to Galápagos sea cucumber boom-and-bust scenario of the 1990s. As such, if management and enforcement were the same as with *I. fuscus*, similar stock depletion of these other two invertebrates should be anticipated.

### *Spiny lobsters*

This reconstruction determined that since 1950, 9,200 t of spiny lobster has been extracted from the EEZ of the Galápagos. While FAO spiny lobster data for the past appear to be accurate, the reconstructed catch of *P. penicillatus* and *P. gracilis* was 400% higher than the FAO data from 1995-2010; this underreporting may be attributable to changes in reporting structure in the region. The notable decrease in the total catch of spiny lobsters since 2000 (Figure 3) is likely a result of the aforementioned changes in their abundance.

Declines in spiny lobster have additionally been linked to an increased presence of sea urchins in the sub-tidal zone. As a result of this competitive release, sea urchin cover has dramatically increased (Banks 2007), contributing to reduced growth and coverage of macroalgae and corals—habitats that were once prevalent in the waters surrounding the Galápagos. At present, only 5% of the original macroalgae beds remain and, in combination with the impact of the urchins, these threatened environments are under additional high stress due to the effects of climate change (Banks 2007). These habitats play a key role in the archipelago and, as Castrejón (2011) explains, “their disappearance is worrying because of their direct effect on the distribution and abundance of many other species that depend on them as sources of food, shelter, and reproduction”<sup>10</sup>.

Given the current state of the spiny lobster fishery, there has been increased pressure to allow the export of slipper lobster (*S. astori*) as well (Hearn 2006). However, Hearn (2006) recommends a cautious approach, as the life history characteristics of *S. astori*, combined with the past overexploitation of many Galápagos fisheries suggest that this species could be at a heightened risk of overexploitation.

### *Bacalao and finfish*

Between 1950 and 2010, artisanal fishers in the Galápagos landed 26,500 t of finfish, of which approximately 75% has been exported. Most significant to this finding is not the

---

<sup>10</sup> Translated from Spanish by authors.

tonnage, but rather the changes in species composition that have occurred over the years (Figure 4).

Between 1977-1981, *M. olfax* constituted 36% of the annual finfish catch and, in general, serranids made up 89% (Reck 1983). Despite the finfish fishery's simple origins, catches today are from two distinct spatial groups (in-shore and off-shore), and include 68 different species from 27 families (Castrejón 2011). Between 1997 and 2001, the finfish fishery was primarily composed (41%) of two mullets: *X. thoburni* and *M. galapagensis* (Andrade and Murillo 2002), species which, during the 1970s, were only fished occasionally. During this time, mullets were not exported and were consumed locally as subsistence, or used as bait for larger fish (Reck 1983). Between 2000 and 2010, *M. olfax* constituted only 17% of the total catch, and another endemic serranid, *Paralabrax albomaculatus*, which made up 32% of the catch between 1977-1981 (Reck 1983), made up only 3% between 2000-2010. It is also particularly troublesome to note that, although only scientifically described in 1993 (Lavenberg and Grove 1993), *Epinephelus cifuentesi* was fished so heavily that the average annual catch fell by 80% between 1998 and 2003 (Nicolaidis *et al.* 2002). As such, the Galápagos population of this grouper is currently listed as Vulnerable under the IUCN (Rocha *et al.* 2008).

In addition to the mullets, coastal pelagics such as wahoo (*Acanthocybium solandri*) and pomfret (*Seriola rivoliana*) have taken on increased economic importance (Castrejón 2011), which is reflected by an increasing prominence in current catches. With a total landing of 840 t over sixty years, artisanal-caught tuna in the Galápagos contributes a very small fraction (0.1%) to the total tuna caught in this EEZ. However, given the observed decline in the abundance of *M. olfax* within the GMR, the importance of tuna in the finfish fishery will likely continue to increase.

#### *Tuna (industrial)*

This reconstruction estimated that within the Galápagos EEZ, Ecuador's industrial fishery caught 639,000 t of tuna between 1950 and 2010, with skipjack constituting 68% of this catch, followed by yellowfin (23%) and bigeye (9%). Tuna fisheries in the Pacific Ocean contribute over two-thirds of the world's annual tuna catch (Sibert *et al.* 2006) and Ecuador is the primary tuna fishing country in the EPO (IATTC 2011). Given this heavy

fishing pressure, it is not surprising that in 2006, the IATTC listed the yellowfin stock as fully exploited and bigeye as overexploited (Castrejón 2011). In response to these concerns, the IATTC imposed a range of fishing restrictions on its member countries, including a TAC of 500 t for Ecuador's industrial longline fleet and closure of their seine fishery in August and September 2007 (Castrejón 2011). While these efforts should not be overlooked, continued management will be required for the long-term health of these stocks and their associated fisheries.

Although no catch estimates were available for illegal industrial tuna fishing, these illicit activities are an ongoing problem within the waters of the GMR. Between 1989 and 1996, 48 vessels (both Ecuadorian and foreign) were caught illegally fishing for tuna (Altamirano and Aguiñaga 2002). Subsequently, from 1996-1998, 119 tuna boats were either caught or observed, although this decreased to a total of 61 boats in the following six years (Reyes and Murillo 2007). These vessels are primarily purse-seiners. However, some also use longlines, a largely non-selective technique that catches both targeted marine life, and untargeted species (e.g. sea turtles, dolphins, seabirds) as well. Gales (1998) suggests that “the best available evidence indicates that longline fishing is the most serious threat facing albatrosses today”— a statement that is even more applicable in the Galápagos since the Critically Endangered<sup>11</sup> waved albatross (*Phoebastria irrorata*) breeds almost exclusively on Española Island (Merlen 1998).

### *Sharks*

As suggested by Jacquet *et al.* (2008), the underreporting of shark catches in Ecuador is substantial. We determined that, since 1950, approximately 105,500 t of shark has been caught in the Galápagos Islands by the Ecuadorian fleet; the highest catch (7,050 t) was, ironically, from 2000. If it is assumed that most sharks are caught at half their maximum size, the tonnage converts to roughly 112,000 individual sharks caught by Ecuador alone in this year. Therefore, despite attempts to mitigate the amount of shark fishing occurring in these waters, government and policy failures, and the imperfections of open access markets encouraged by millions of dollars, have allowed this unacceptable traffic to continue, thus violating and ignoring both the Special Law of Galápagos and the conservation goals of the

---

<sup>11</sup> <http://www.iucnredlist.org/details/106003955/0>

GMR. In addition to fishing by Ecuador, foreign boats from Costa Rica, Columbia, and Japan are also known to fish for sharks in Galápagos waters (Watts and Wu 2005; Reyes and Murillo 2007). As such, this reconstruction likely shows only a fraction of the total illegal shark fishing (and finning) occurring in the archipelago.

Carr *et al.* (Carr *et al.* 2013) recently documented that of 379 sharks taken by an illegal Ecuadorian longlining vessel in 2011, 80% were bigeye thresher (*A. superciliosus*), 11% were silky (*C. falciformes*), and only 6% were blue (*P. glauca*). Although these numbers refer to one isolated seizure, there is a notable difference in the catch composition when compared to the species breakdown used in this study. At an ecosystem level, these findings may therefore reflect a change in abundance of certain species, specifically a decline in *P. glauca*.

The main incentive for shark fishing and finning in the last decade has been the demand from mainly East Asian markets, and Hong Kong in particular (Clarke *et al.* 2007). Although tasteless, cartilaginous shark fins can cost upward of \$400/ kg (Jacquet *et al.* 2008), and are the principal ingredient in fashionable sharkfin soup. With an estimated minimum worth of \$400-550 million annually (Clarke *et al.* 2007), the trade of shark products is a very lucrative global industry and one that needs immediate and focused attention in Ecuador, and the Galápagos in particular.

As a result of growing concerns over the sustainability and health of shark populations, large-scale shark fishing and shark fin export were banned in Ecuador in 1989 (Official Register, No. 194; 19 May 1989) and 2004 (Executive Decree 2130; Official Register, No. 437) respectively (Jacquet *et al.* 2008). While these efforts initially made Ecuador a world-leader in protective shark legislation, in July 2007, the Ecuadorian Government officially enacted Executive Decree 486 (Official Record 137), an amendment to the previous laws. This amendment still prohibits shark finning and the dumping of sharks at sea. However, fishers are now allowed to trade fins extracted from sharks incidentally caught during fishery activities under a special permit (Jacquet *et al.* 2008). Unfortunately, in Ecuador, “incidental catch” can be as high as 70% (Aguilar *et al.* 2007), with 100% mortality of by-caught sharks (Coello *et al.* 2010), and this loophole has allowed fishers to continue to trade shark fins without legal consequences (Carr *et al.* 2013). All activities associated with shark fishing were completely forbidden in Galápagos by the GNPS in 2000 (Jacquet *et al.*

2008). However, given that between 2001-2007, there were 29 reported seizures of boats illegally shark fishing in the GMR (Carr *et al.* 2013), and based on the total shark catch determined by this reconstruction, the effect these efforts have had on actually protecting sharks in the archipelago appears to be negligible.

Along with other pelagic fish, sharks play a vital role as apex predators in top-down regulated marine ecosystems (Stevens *et al.* 2000; Myers *et al.* 2007). Using an ecosystem model, Okey *et al.* (2004) predicted that the complete removal of sharks in the Galápagos would result in increases in toothed cetaceans, sea lions, and non-commercial reef predators, and subsequently lead to a decrease in bacalao and other commercially valuable fish species.

### *Trophic Level Analysis*

Figure 5A illustrates the changing composition of artisanal fisheries catches around the Galápagos through trends of the mean trophic levels of the organisms landed (fish and invertebrates); regression analysis showed a significant change ( $r^2 = 0.59$ ;  $F(1, 60) = 85.9$ ;  $p < 0.001$ ) in the mean TL between 1950-2010. While this may demonstrate a very strong example of fishing down at a cumulative level ( $0.23 \text{ TL decade}^{-1}$ ), it is important to note that if the ecosystem is ill-defined, and combines species that do not interact with each other (such as lobster and tuna), observed levels of fishing down could potentially be masked or enhanced. Thus, the overall strength of this trend will be a function of the extent of the spatial/ecological over-aggregation error that is committed, and the relative catches involved. Specifically worrisome is that if only an aggregate mean TL is observed, one can get the impression that mean trophic levels in the catch from the exploited 'ecosystem' can actually increase, as suggested by Branch *et al.* (2011). As is observed in the Galápagos, the mean TL of the catch steadily declined until the early 2000s, at which point it began to increase (see Figure 5A). Although this positive trend could initially be interpreted as the fishery in the process of rebuilding, in reality it is due to the collapse of the sea cucumber fishery, combined with a change in the directed efforts of the artisanal fleet to off-shore fish species, rather than a result of in-shore stock recovery.

When separating the artisanal catch by specific in-shore and off-shore regions (see Figure 5B), we found that (even when excluding sea cucumbers) the in-shore mean TL has declined significantly from 4.1 in 1950 to 3.6 in 2010 ( $r^2 = 0.53$ ;  $F(1, 60) = 65.7$ ;  $p < 0.001$ ).

Conversely, the mean TL of the off-shore catch has increased slightly over the last sixty years. However, this change was not statistically significant ( $r^2= 0.05$ ;  $F(1, 60)= 3.4$ ;  $p= 0.67$ ). As depicted in Figure 4, the fish species that nowadays contribute most to the finfish catch were all being exploited in the 1950s; it is their relative proportions that have changed. This transition thus represents a strong case of fishing down marine food webs, and not of ‘fishing through marine food webs’, which pertain to cases where low trophic level taxa are added to the exploited max, without the high-trophic level species being depleted (Essington *et al.* 2006). Given the rate of the decline in mean TL ( $0.12 \text{ decade}^{-1}$ ), the degree of fishing down observed in the in-shore Galápagos finfish fishery is consistent with global trends (Pauly *et al.* 1998).

## CONCLUSION

Given not only their intrinsic value as one of the most unique and highly biodiverse regions on Earth, but also their economic value in terms of tourism and fisheries, the conservation of the Galápagos Islands and their marine life is essential. As of 2006, 57 marine species (including 17 sharks) from the Galápagos were on the IUCN Red List, and the principal threat to 32% of marine species ranked Vulnerable or higher was fisheries related (Banks 2007). Since many of the serranids described in this study are endemic to the Galápagos, they are innately at a high risk of extinction, and therefore require immediate conservation attention. The removal of large fish can be detrimental to the ecosystem as a whole, and Ruttenberg (2001) suggests that fishing for *M. olfax* not only directly impacts the size and health of targeted populations, but also triggers indirect cascading effects, resulting in decreased natural diversity in community fish structure at sites incurring high levels of fishing. A potential remedy against this ‘fishing down’ could be the strengthening of restricted zones within the Galápagos Marine Reserve, which could enable the fished-down populations to rebuild their biomass, and allow for high-trophic level predators to regain their ascendancy. The effectiveness of these zones, however, remains inconclusive (Edgar *et al.* 2004; Banks 2008; Lester *et al.* 2009; Babcock *et al.* 2010).

Serial depletion and subsequent spatial expansions is a common characteristic to many of the world’s invertebrate fisheries (Anderson *et al.* 2011a, 2011b; Johnson *et al.* 2012). Therefore, given the past history of sea cucumber fishing in the Galápagos and the



current state of the in-shore finfish fishery in this region, if additional invertebrate fisheries for other sea cucumbers and urchins were initiated here, it is likely that these species would face a similar threat of overexploitation. As discussed above, trophic interactions between the fish and invertebrate species in the Galápagos appear to be fragile and highly susceptible to the impacts of fishing. Castrejón (2011) discusses the importance of using traditional ecological knowledge to help develop a comprehensive fisheries management plan. Since single-resource management does not appear adequate, shifting to an ecosystem-based approach within the Galápagos should also be strongly considered.

We echo the sentiments of Carr *et al.* (2013) who recommend urgent and immediate attention to the shark fishing problem in the GMR. Of paramount importance should be the development of proactive, targeted conservation measures aimed at eliminating illegal shark fishing and finning operations within the archipelago. The sheer quantity of sharks and the rate at which they continue to be extracted from the EEZ of the Galápagos archipelago are likely among the highest in the world. In 2002, the whale shark was listed under Appendix II of the Convention on International Trade in Endangered Species (CITES 2002), and the recent inclusion of three hammerhead species and the oceanic whitetip on this list (CITES 2013) will hopefully result in increased export monitoring. Nonetheless, the scope of illegal fishing that exists in this region is so vast that unless solid legislation is passed at both a global and national level, and on-water enforcement dramatically improves, it is not unrealistic to imagine several shark species being locally extirpated from the Galápagos within the next few decades.

## ACKNOWLEDGEMENTS

We thank the *Sea Around Us* Project, a scientific collaboration between the University of British Columbia and The Pew Charitable Trusts. Many additional thanks to the Charles Darwin Foundation, Rodrigo Bustamante, Jack Nelson, and Anna Schuhbauer for sharing their ideas, information, and experiences.

## REFERENCES

- Aguilar F, Revelo W, Coello D, Cajas J, Ruiz W, Díaz M and Moreno J (2007) Desembarques artesanales de tiburones y rayas en los principales puertos pequeños del Ecuador durante 2006. Instituto Nacional de Pesca, Guayaquil, Ecuador. 23 p.
- Altamirano M and Aguiñaga M (2002) Control y respeto al marco jurídico. pp. 459-473 *In* Danulat E and Edgar GJ (eds.), Reserva Marina de Galápagos: Línea Base de la Biodiversidad Fundación Charles Darwin and Servicio Parque Nacional Galápagos, Santa Cruz, Ecuador.
- Anderson SC, Flemming JM, Watson R and Lotze H, K. (2011a) Rapid global expansion of invertebrate fisheries: trends, drivers, and ecosystem effects. *PLoS ONE* 6(3).
- Anderson SC, Flemming JM, Watson R and Lotze H, K. (2011b) Serial exploitation of global sea cucumber fisheries. *Fish and Fisheries* 12: 317-339.
- Andrade R and Murillo JC (2002) Lisas. pp. 166-175 *In* Danulat E and Edgar GJ (eds.), Reserva Marina de Galápagos: Línea Base de la Biodiversidad. Fundación Charles Darwin and Servicio Parque Nacional Galápagos, Santa Cruz, Ecuador.
- Anonymous (2009) Galápagos Marine Area (MMA) socioeconomic and government assessment. Universidad San Francisco de Quito and Conservation International (Ecuador). 127 p.
- Babcock RC, Shears NT, Alcalá AC, Barrett NS, Edgar GJ, Lafferty KD, McClanahan TR and Russ GR (2010) Decadal trends in marine reserves reveal differential rates of change in direct and indirect effects. *Proceedings of the National Academy of Sciences* 107(43): 18256-18261.
- Banks S (2007) Estado de especies y hábitats marinos en Galápagos. pp. 122-127 *In* Stimson J, Cárdenas S and Marín A (eds.), Informe Galápagos 2006-2007. Charles Darwin Foundation, Galápagos National Park and Galápagos National Institute, Puerto Ayora, Galápagos.
- Banks S (2008) Subtidal ecological monitoring of the coastal management subzones: 2004 to 2006. Galapagos Report 2006-2007, CDF, GNP and INGALA, Puerto Ayora, Galapagos. 154 p.
- Bedoya LP (2009) Volúmenes de captura de atún industrial 2000-2008. Instituto Nacional de Pesca. 3 p.
- Bensted-Smith R, Powell G and Dinerstein E (2002) Planning for the ecoregion. pp. 1-5 *In* Bensted-Smith R (ed.), A biodiversity vision for the Galapagos Islands. Charles Darwin Foundation and World Wildlife Fund, Puerto Ayora, Galapagos.
- Born AF, Espinoza E, Murillo JC, Nicolaides F and Edgar GJ (2003) Effects of the *Jessica* oil spill on artisanal fisheries in the Galápagos. *Marine Pollution Bulletin* 47: 319-324.
- Bremner J and Perez J (2002) A case study of human migration and the sea cucumber crisis in the Galapagos Islands. *Ambio* 31(4): 306-310.
- Bustamante RH (1998) The artisan fishing sector of the Galápagos and the 1997 fishing season. Galapagos Report 1997-1998, Fundación Natura and World Wildlife Fund (WWF), Quito Ecuador. 25-29 p.
- Bustamante RH (1999) La pesca industrial del atún y Galápagos Fundación Charles Darwin. 11 p.

- Bustamante RH, Branch GM, Bensted-Smith R and Edgar GJ (2002) The status of and threats to marine biodiversity. pp. 80-95 *In* Bensted-Smith R (ed.), *A biodiversity vision for the Galapagos Islands*. Charles Darwin Foundation and World Wildlife Fund, Puerto Ayora, Galapagos. .
- Bustamante RH, Reck GK, Ruttenberg BI and Polovina J (2000) The Galápagos Spiny Lobster Fishery. pp. 210-220 *In* Phillips BF and Kittaka J (eds.), *Spiny Lobsters: Fisheries and Culture*. Fishing News Books, Oxford, UK.
- Camhi M (1995) Industrial fisheries threaten ecological integrity of the Galapagos Islands. *Conservation Biology* 9(4): 715-719.
- Carr LA, Stier AC, Fietz K, Montero I, Gallagher AJ and Bruno JF (2013) Illegal shark fishing in the Galapagos Marine Reserve. *Marine Policy* 39: 317-321.
- Castrejón M (2011) Co-manejo pesquero en la Reserva Marina de Galapagos: tendencias, retos y perspectivas de cambio. Fundación Charles Darwin, Fundación Tinker and Kananki, Puerto Ayora, Ecuador. 418 p.
- Castrejón M, Hearn A, Elao R and Gravez V (2005) Evaluación poblacional del pepino demar *Isostichopus fuscus* en la Reserva Marina de Galapagos, pre-pesquería 2005. Fundación Charles Darwin, Santa Cruz, Galapagos, Ecuador. 45 p.
- Castro X (2005) Analysis of the current socio-economic situation of the Galapagos artisanal fishing community. JICA. 162 p.
- Causton CE, Peck SB, Sinclair BJ, Roque-Albelo L, Hodgson CJ and Landry B (2006) Alien insects: threats and implications for conservation of Galápagos Islands. *Annals of the Entomological Society of America* 99(1): 121-143.
- CDF (2010) Charles Darwin Foundation Annual Report 2010. Charles Darwin Foundation, Puerto Ayora, Santa Cruz. 48 p.
- Clarke S, Milner-Gulland EJ and Cemare TB (2007) Perspectives: social, economic, and regulatory drivers of the shark fin trade. *Marine Resource Economics* 22: 305-327.
- Coello D, Herrera M, Calle M, Castro R, Medina C and Chalén X (2010) Incidencia de Tiburones, Rayas, Aves, Tortugas y Mamíferos Marinos en la Pesquería Artesanal con Enmalle de Superficie en la caleta pesquera de Santa Rosa (Provincia de Santa Elena) Boletín Especial 2, Instituto Nacional de Pesca, Guayaquil, Ecuador. 55 p.
- Compagno L, Dando M and Fowler S (2005) *Sharks of the World*. Princeton Field Guides. Princeton University Press, Princeton, NJ. 480 p.
- Edgar GJ, Bustamante RH, Fariña JM, Calvopiña M, Martinez C and Toral-Granda MV (2004) Bias in evaluating the effects of marine protected areas: the importance of baseline data for the Galapagos Marine Reserve. *Environmental Conservation* 31(3): 212-218.
- Epler B (2007) *Tourism, the economy, population growth, and conservation in Galapagos*. Charles Darwin Foundation, Puerto Ayora, Ecuador. 75 p.
- Ferber D (2000) Galápagos Station Survives Latest Attack by Fishers. *Science* 290: 2059-2061.
- Gales R (1998) Albatross populations: status and threats. pp. 20-45 *In* Robertson G and Gales R (eds.), *Albatross Biology and Conservation*. Surrey Beatty and Sons, Chipping Norton, UK.
- González JA, Montes C, Rodríguez J and Tapia W (2008) Rethinking the Galapagos Islands as a complex social-ecological system: implications for conservation and management. *Ecology and Society* 13(2): 13 [online].

- Grove JS and Lavenberg RJ (1997) *The Fishes of the Galápagos Islands*. Stanford University Press, Stanford, USA.
- Harper S and Zeller D, editors (2011) Fisheries catch reconstructions: Islands, part II. Fisheries Centre Research Reports (4). 143 p.
- Hearn A (2006) Life history of the slipper lobster *Scyllarides astori* Holthuis 1960, in the Galapagos islands, Ecuador. *Journal of Experimental Marine Biology and Ecology* 328: 87-97.
- Hearn A, Martínez P, Toral-Granda MV, Murillo JC and Polovina J (2005) Population dynamics of the exploited sea cucumber *Isostichopus fuscus* in the western Galápagos Islands, Ecuador. *Fisheries Oceanography* 14(5): 377-385.
- Hearn A, Murillo J, Nicolaidis F, Moreno J and Reyes H (2006) Evaluación de la pesquería de langosta espinosa (*Panulirus penicillatus* y *P. gracilis*) en la Reserva Marina de Galápagos. pp. 46-116 *In* Hearn A (ed.), Evaluación de las pesquerías en la Reserva Marina de Galapagos, Informe Compendio 2005. Fundación Charles Darwin, Puerto Ayora, Santa Cruz.
- Hearn A and Murillo JC (2008) Life history of the red spiny lobster, *Panulirus penicillatus* (Decapoda: Palinuridae), in the Galápagos Marine Reserve, Ecuador. *Pacific Science* 62(2): 191-204.
- Hearn A and Pinillos F (2006) Baseline information on the warty sea cucumber *Stichopus horrens* in Santa Cruz, Galápagos, prior to the commencement of an illegal fishery. *SPC Beche-de-mer Information Bulletin* (24): 3-10.
- Heylings P and Bensted-Smith R (2002) Zonificación e historia de la Reserva Marina de Galápagos. pp. 10-21 *In* Danulat E and Edgar GJ (eds.), Reserva Marina de Galápagos: Línea Base de la Biodiversidad. Fundación Charles Darwin and Servicio Parque Nacional Galápagos, Santa Cruz, Ecuador.
- IATTC (2011) Quarterly Report (Jan-Mar 2011). Inter-American Tropical Tuna Commission, La Jolla, California. 36 p.
- Jackson MH (2001) *Galápagos: A Natural History*. University of Calgary Press, Calgary, Alberta.
- Jácome R and Ospina P (1999) La Reserva Marina de Galápagos: Un primer año difícil. pp. 35-42 *In* Informe Galápagos 1998-1999. Fundación Natura y Fondo Mundial para la Naturaleza (WWF) and Global Environmental Facility (GEF), Quito, Ecuador.
- Jacquet J, Alava JJ, Pramod G, Henderson S and Zeller D (2008) In hot soup: sharks captured in Ecuador's waters. *Environmental Sciences* 5(4): 269-283.
- Jacquet J, Fox H, Motta H, Ngusaru A and Zeller D (2010) Few data but many fish: marine small-scale fisheries catches for Mozambique and Tanzania. *African Journal of Marine Science* 32(2): 197-206.
- Jennings S, Brierley AS and Walker JW (1994) The inshore fish assemblages of the Galápagos Archipelago *Biological Conservation* 70: 49-57.
- Johnson TR, Wilson JA, Cleaver C and Vadas RL (2012) Social-ecological scale mismatches and the collapse of the sea urchin fishery in Maine, USA. *Ecology and Society* 17(2).
- Lavenberg RJ and Grove JS (1993) *Epinephelus cifuentesi*. p. 129 *In* Heemstra PC and Randall JE (eds.), *Groupers of the World (Family Serranidae, Subfamily Epinephelinae): An Annotated and Illustrated Catalogue of the Grouper, Rockcod, Hind, Coral Grouper and Lyretail Species Known to Date*. FAO Fisheries Synopsis 16. FAO, Rome, Italy.

- Lester SE, Halpern BS, Grorud-Colvert K, Lubchenco J, Ruttenberg BI, Gaines SD, Aíramé S and Warner RR (2009) Biological effects within no-take marine reserves: a global synthesis. *Marine Ecological Progress Series* 384: 33-46.
- Manuba E (2007) Report of study of fisheries products distribution and consumption state in Santa Cruz Island. Japan International Cooperation Agency and Galapagos National Park. 41 p.
- Mauchamp A and Atkinson R (2010) Rapid, recent and irreversible habitat loss: Scalesia forest on the Galapagos Islands. *Galapagos Report 2009-2010* Puerto Ayora, Galápagos, Ecuador. 189 p.
- Merlen G (1995) Use and misuse of the seas around the Galapagos Archipelago. *Oryx* 29(2): 99-106.
- Merlen G (1998) Scavenging behavior of the waved albatross in Galápagos : a potential problem with increasing longlining? *Noticias de Galápagos* 59: 20-23.
- Myers RA, Baum JK, Shepherd TD, Powers SP and Peterson CH (2007) Cascading effects of the loss of apex predatory sharks from a coastal ocean. *Science*: 1846-1850.
- Nicolaides F, Murillo JC, Toral-Granda MV and Reck GK (2002) Bacalao. pp. 146-165 *In* Danulat E and Edgar GJ (eds.), *Reserva Marina de Galápagos: Línea Base de la Biodiversidad*. Fundación Charles Darwin and Servicio Parque Nacional Galápagos, Santa Cruz, Ecuador.
- Okey TA, Banks S, Born AF, Bustamante RH, Calvopiña M, Edgar GJ, Espinoza E, Fariña JM, Garske LE, Reck GK, Salazar S, Shepherd S, Toral-Granda V and Wallem P (2004) A balanced trophic model of a Galapagos subtidal rocky reef for evaluating marine conservation strategies. *Ecological Modelling* 172: 383-401.
- Pacheco-Bedoya L (2010) Volúmenes de captura de atún industrial 2000-2008. Instituto Nacional de Pesca, Guayaquil, Ecuador. 3 p.
- Pauly D (1995) Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology and Evolution* 10(10): 430.
- Pauly D (2004) *Darwin's Fishes: An Encyclopedia of Ichthyology, Ecology and Evolution*. Cambridge University Press, Cambridge, UK.
- Pauly D, Christensen V, Dalsgaard J, Froese R and Torres Jr. F (1998) Fishing down marine food webs. *Science* 279: 860-863.
- PNG (2013) Informe anual de visitantes que ingresaron a las áreas protegidas de Galápagos 2012. Parque Nacional Galápagos and Ministerio del Ambiente, Santa Cruz, Ecuador. 6 p.
- Reck GK (1983) The coastal fisheries in the Galapagos Islands, Ecuador: Description and consequences for management in the context of marine environmental protection and regional development. PhD thesis, Kiel University, Kiel, Germany. 235 p.
- Reyes H and Murillo JC (2007) Efforts to control illegal fishing activities in the Marine Reserve. *Galapagos Report 2006-2007*, CDF, GNP & INGALA, Puerto Ayora, Ecuador. 154 p.
- Ruttenberg BI (2001) Effects of fishing in the Galapagos. *Conservation Biology* 15(6): 1691-1699.
- Schuhbauer A and Koch V (2013) Assessment of Recreational Fishery in the Galapagos Marine Reserve: Failures and Opportunities. *Fisheries Research*: in press.

- Shepherd SA, Martinez P, Toral-Granda MV and Edgar GJ (2004) The Galápagos sea cucumber fishery: management improves as stocks decline. *Environmental Conservation* 31(2): 102-110.
- Shimada BM (1958) Geographical distribution of the annual catches of yellowfin and skipjack tuna from the Eastern Tropical Pacific Ocean from vessel logbook records, 1952-1955. IATTC, La Jolla, California. 77 p.
- Sibert J, Hampton J, Kleiber P and Maunder M (2006) Biomass, size, and trophic status of top predators in the Pacific Ocean. *Science* 314: 1773-1776.
- Snell HM, Stone PA and Snell HL (1996) Geographical characteristics of the Galapagos Islands. *Island of Biogeography* 23: 619-624.
- Sonnenholzner J (1997) A brief survey of the commercial sea cucumber *Isostichopus fuscus* (Ludwig, 1875) of the Galapagos Islands, Ecuador. *SPC Beche-de-mer Information Bulletin* (9): 12-15.
- Stevens JD, Bonfil R, Dulvy NK and Walker PA (2000) The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. *ICES Journal of Marine Science* 57: 476-494.
- Stone R (1995) Fishermen Threaten Galápagos. *Science* 267: 611-612.
- Taylor JE, Hardner J and Stewart M (2008) Ecotourism and economic growth in the Galapagos: an island economy-wide analysis. *Environmental and Developmental Economics* 14: 139-162.
- Toral-Granda MV (2008) Galapagos Islands: a hotspot of sea cucumber fisheries in Latin America and the Caribbean. pp. 231-253 *In* Toral-Granda MV, Lovatelli A and Vasconcellos M (eds.), *Sea cucumbers. A global review of fisheries and trade*(Fisheries and Aquaculture Technical Paper No. 516). FAO, Rome, Italy.
- Toral-Granda MV, Bustamante RH, Murillo JC, Espinoza E, Nicolaidis F, Martinez PC, Cedeño I, Ruttemberg B, Moreno J, Chasiluisa C, Torres S, Yépez M, Barreno JC, Andrade R, Figueroa L and Piu M (2000) La pesca artesanal en Galápagos 1999-2000. pp. 53-61 *In* Informe Galapagos 1999-2000. Fundación Natura y Fondo Mundial para la Naturaleza (WWF) and Global Environmental Facility (GEF), Quito, Ecuador.
- Townsend CH (1934) The fur seals of the Galapagos Islands. *Zoologica* 18(2): 43-56.
- Watkins G and Cruz F (2007) Galapagos at risk: a socioeconomic analysis of the situation in the archipelago. Charles Darwin Foundation, Ayora, Galápagos Islands, Ecuador. 21 p.
- Watts S and Wu V (2005) At rock bottom: the declining sharks of the Eastern tropical Pacific. WildAid, San Fransisco, USA. 30 p.
- Whitehead H, Christal J and Dufault S (1997) Past and distant whaling and the rapid decline of sperm whales off the Galápagos Islands. *Conservation Biology* 11(6): 1387-1396.
- Wielgus J, Zeller D, Caicedo-Herrera D and Sumaila R (2010) Estimation of fisheries removals and primary economic impact of the small-scale and industrial marine fisheries in Columbia. *Marine Policy* 34: 506-513.
- Wolff M, Schuhbauer A and Casterjón M (2012) A revised strategy for the monitoring and management of the Galapagos sea cucumber *Isostichopus fuscus* (Aspidochirotida: Stichopodidae). *Revista de Biología Tropical* 60(2): 539-551.
- WWF (1998) Galapagos Report 1997-1998. Fundación Natura and the World Wide Fund for Nature (WWF), Quito, Ecuador.

- Zarate P (2002) Tiburones. pp. 373-388 *In* Danulat E and Edgar GJ (eds.), Reserva Marina de Galápagos: Línea Base de la Biodiversidad. Fundación Charles Darwin and Servicio Parque Nacional Galápagos, Santa Cruz, Ecuador.
- Zeller D, Booth S and Pauly D (2007) Fisheries contributions to the Gross Domestic Product: understanding small-scale fisheries in the Pacific. *Marine Resource Economics* 21: 355-374.

TABLES

**Table 1. Geography and fisheries demographics of the Galápagos Islands.**

Island	Location <sup>1</sup>	Land area <sup>1</sup> (km <sup>2</sup> )	Inhabited	Number of fishers <sup>2</sup>	Primary fishing port <sup>2</sup>	Inshore fishing area <sup>3</sup> (km <sup>2</sup> )
Isabela	0°25'30"S, 91°7'W	4588	Y	149	Puerto Villamil	2201
Fernandina	0°22'0"S, 91°31'20"W	642	N	-	-	137
Santa Cruz	0°37'0"S, 90°21'0"W	986	Y	220	Puerto Ayora	1897*
Floreana	1°17'0"S, 90°26'0"W	173	Y	N/A	N/A	708
Pinzón	0°36'30"S, 90°39'57"W	18	N	-	-	60
Santa Fé	0°49'0"S, 90°3'30"W	24	N	-	-	860
Baltra	0°25'30"S, 90°16'30"W	26	Y	N/A	N/A	1897*
San Cristóbal	0°48'30"S, 89°25'0"W	558	Y	290	Baquerizo Moreno	1033
Española	1°22'30"S, 89°40'30"W	60	N	-	-	434
Santiago	0°15'30"S, 90°43'30"W	585	N	-	-	461
Marchena	0°20'20"N, 90°28'25"W	130	N	-	-	95
Genovesa	0°19'40"N, 89°57'20"W	14	N	-	-	44
Pinta	0°35'18"N, 90°45'17"W	59	N	-	-	51

\*combined IFA of Santa Cruz and Baltra

<sup>1</sup>Snell *et al.* (1996)

<sup>2</sup>Castrejon (2011)

<sup>3</sup>provided by Melissa Nunes, *Sea Around Us* Project

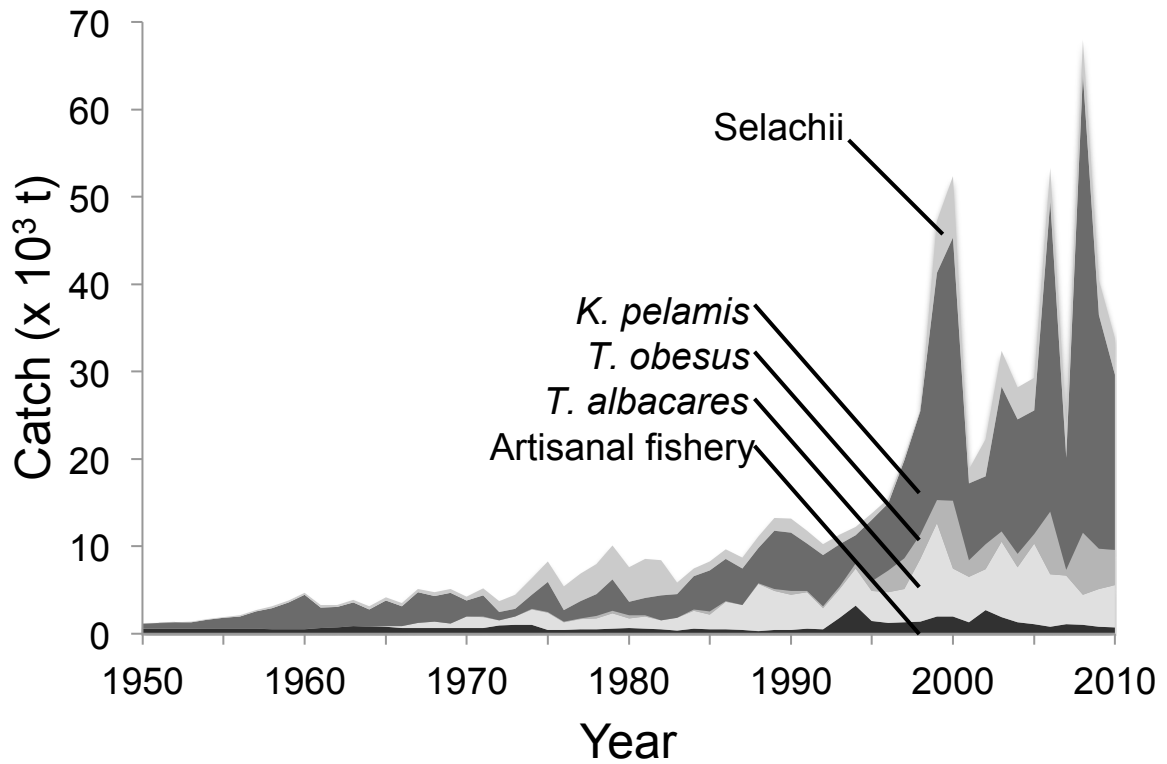


**Table 2.** Commonly caught finfish and invertebrate species of the Galápagos.

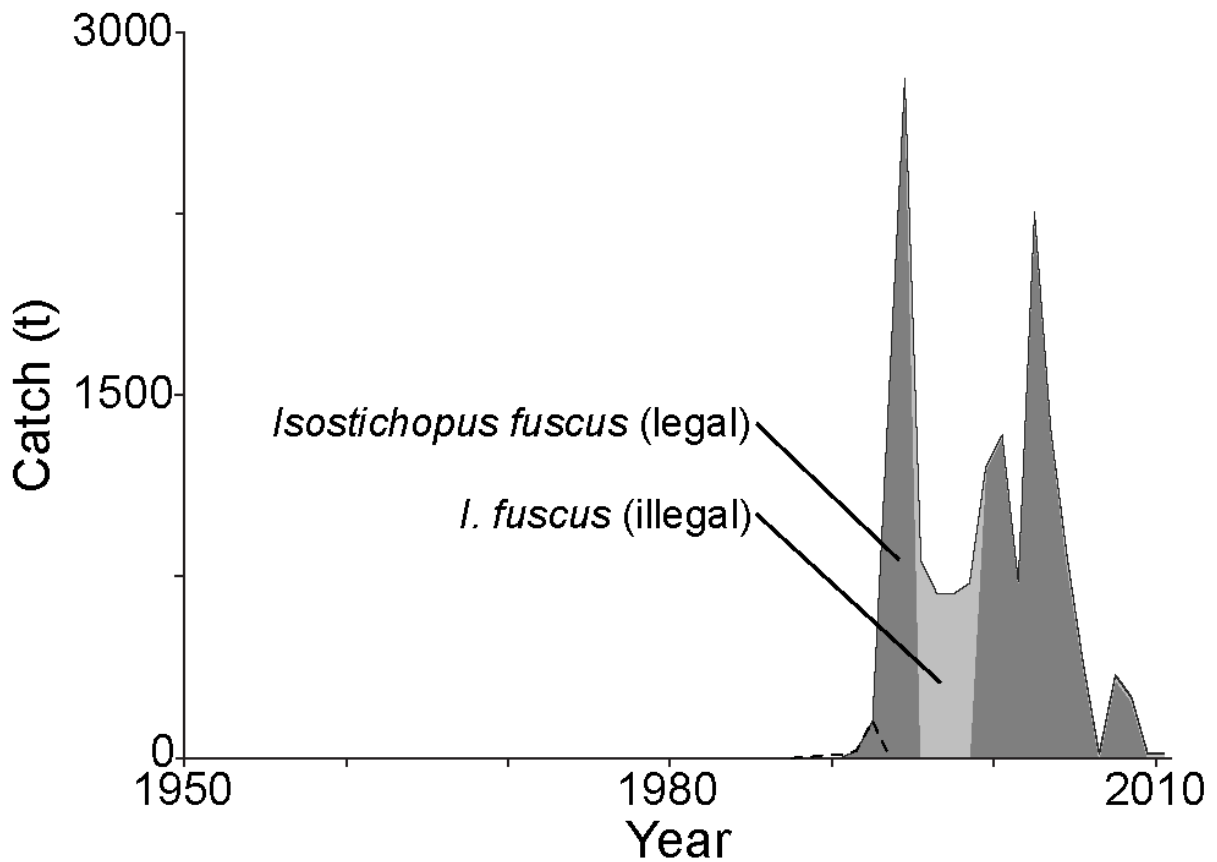
Habitat	Family	English name	Spanish name	Latin name	MTL*
In-shore	Serranidae	<b>Galápagos grouper</b>	Bacalao	<i>Mycteroperca olfax</i>	4.4
		<b>Misty grouper</b>	Mero	<i>Epinephelus mystacinus</i>	4.4
		-	Camotillo	<i>Paralabrax albomaculatus</i>	4.4
		<b>Starry grouper</b>	Cabrilla	<i>Epinephelus labriformis</i>	4.0
		<b>Leather bass</b>	Cagaleche	<i>Dermatolepis dermatolepis</i>	4.4
		<b>Olive grouper</b>	Norteño	<i>Epinephelus cifuentesi</i>	4.0
	Mugilidae	<b>Galápagos mullet</b>	Lisa rabo amarillo	<i>Mugil galapagensis</i>	3.0
		<b>Thoburn's mullet</b>	Lisa rabo negro	<i>Xenomugil thoburni</i>	2.9
	Labridae	<b>Galápagos sheephead wrasse</b>	Vieja mancha dorada	<i>Semicossyphus darwini</i>	3.6
	Hemilutjanidae	<b>Grape-eye seabass</b>	Ojón/Ojo de uva	<i>Hemilutjanus macrophthalmos</i>	3.8
	Scorpaenidae	-	Brujo	<i>Scorpaena</i> spp.	3.5
	Malacanthidae	<b>Ocean finfish</b>	Blanquillo	<i>Caulolatilus princeps</i>	3.9
	Lutjanidae	<b>Pacific cubera snapper</b>	Pargo mulato/ pargo rojo	<i>Lutjanus novemfasciatus</i>	3.7
	Palinuridae	<b>Red spiny lobster</b>	Langosta roja	<i>Panulirus penicillatus</i>	2.8
	Palinuridae	<b>Blue spiny lobster</b>	Langosta verde	<i>Panulirus gracilis</i>	2.8
	Scyllaridae	<b>Slipper lobster</b>	Langostino	<i>Scyllarides astori</i>	2.7
	Stichopodidae	<b>Brown sea cucumber</b>	Pepino de mar	<i>Isostichopus fuscus</i>	2.1
Off-shore	Scombridae	<b>Wahoo</b>	Guajo	<i>Acanthocybium solandri</i>	4.2
		<b>Bigeye tuna</b>	Atún patudo/ atún ojo grande	<i>Thunnus obesus</i>	4.2
		<b>Yellowfin tuna</b>	Atún aleta amarilla	<i>Thunnus albacares</i>	4.2
		<b>Pacific sierra</b>	Sierra	<i>Scomberomorus sierra</i>	4.2
		<b>Albacore tuna</b>	Albacora	<i>Thunnus alalunga</i>	4.2
	Carangidae	<b>Longfin yellowtail</b>	Palometa	<i>Seriola rivoliana</i>	4.2
		<b>Steel pompano</b>	Pampano acerado	<i>Trachinotus stilbe</i>	3.8
	Xiphiidae	<b>Swordfish</b>	Pez espada	<i>Xiphias gladius</i>	4.5

\* Trophic levels based on Okey *et al.* (2004), FishBase ([www.fishbase.org](http://www.fishbase.org)), and SeaLifeBase ([www.sealifebase.org](http://www.sealifebase.org)).

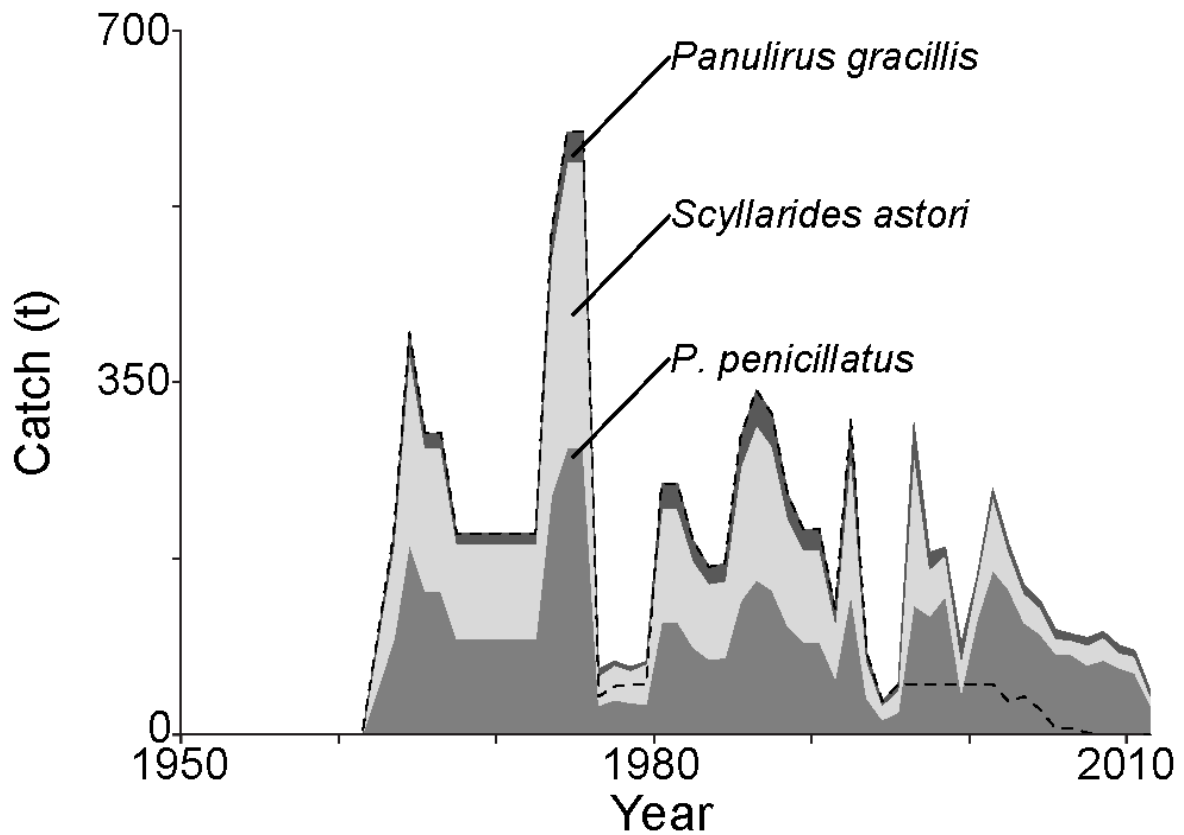
FIGURES



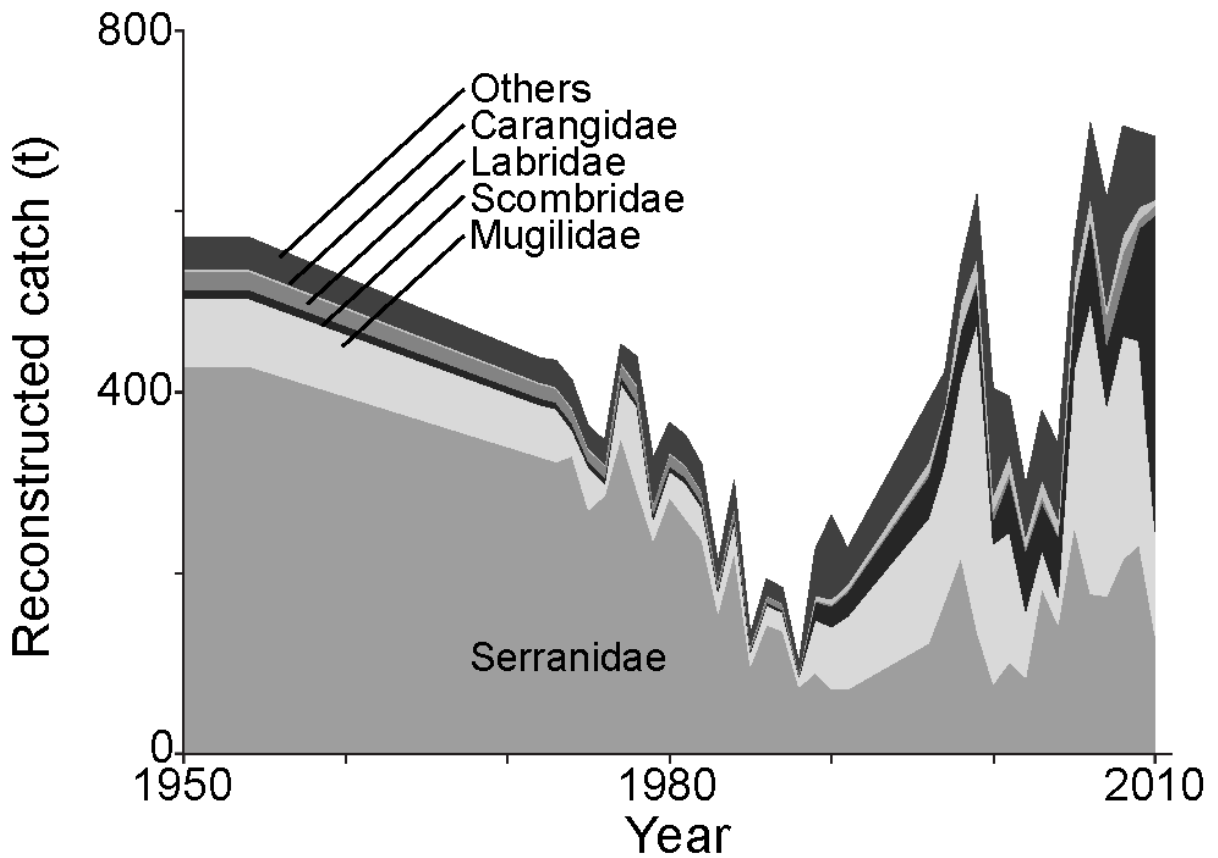
**Figure 1.** Total catch of all species in the Galapagos Islands EEZ between 1950-2010. The artisanal catch (i.e. finfish, lobsters and sea cucumbers) constituted only 52,500 t (7%) of the total catch, whereas catches of industrially caught tuna (i.e. *K. pelamis*, *T. obesus* and *T. albacares*) amounted to 639,000 (80%). Approximately 105,500 t (13%) of industrially caught shark species (i.e. Selachii) were taken during this time. With the exception of the industrial tuna, catches of all species were under-reported by varying degrees in FAO FishStat.



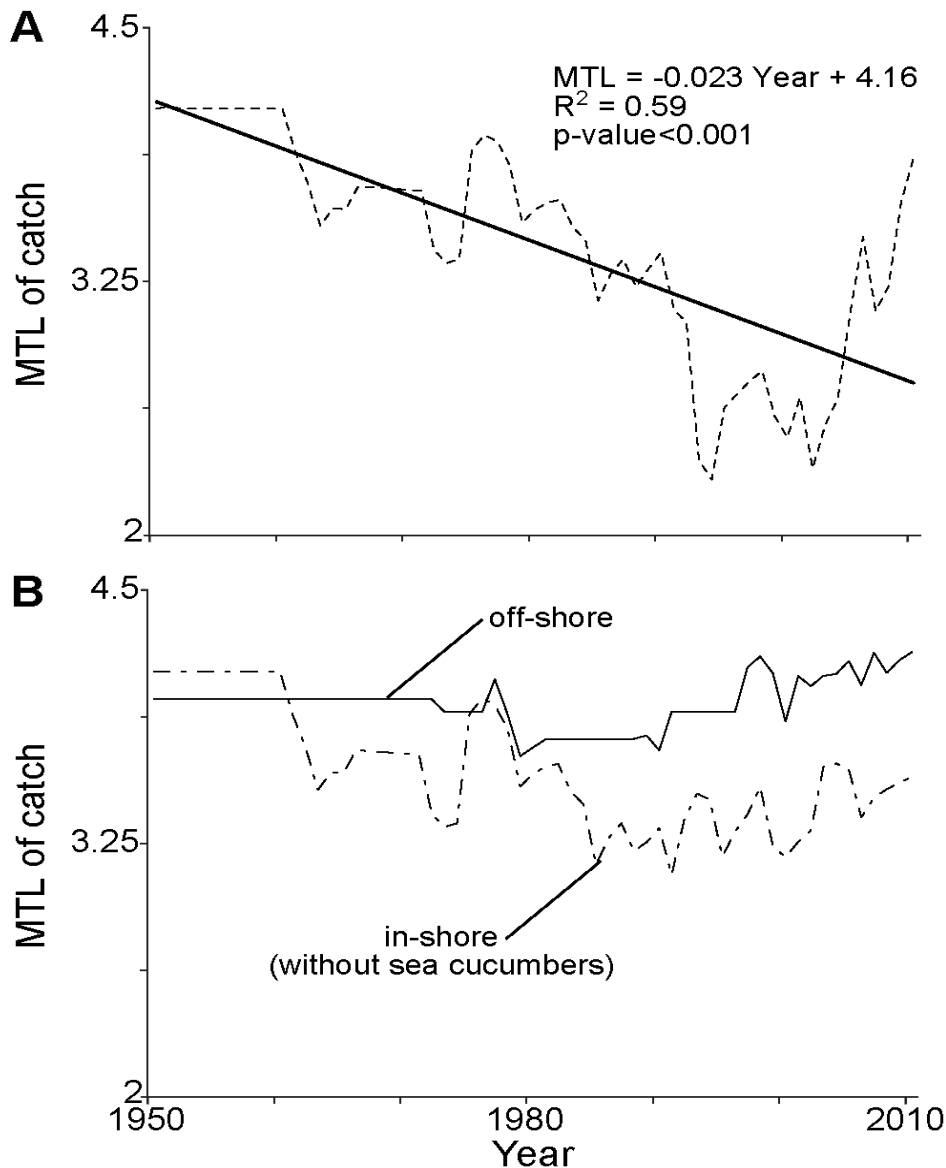
**Figure 2. Total reconstructed sea cucumber catch for the Galápagos archipelago, 1950-2010.** An estimated 13,000 t of the brown sea cucumber (*Isostichopus fuscus*) were legally gathered for export since the establishment of the fishery; 30 times as much as reported by the FAO (dashed line) for the same time period. An additional 3,000 t of this species has been illegally taken, primarily between 1994 and 1999. The reconstructed illegal catch of the warty sea cucumber (*Stichopus horrens*) is an estimated 40 t.



**Figure 3. Reconstructed catch of spiny and slipper lobsters for the Galápagos, 1950-2010.** Approximately 9,200 t of spiny lobster (*Panulirus penicillatus* and *P. gracilis*) and 700 t of slipper lobster (*Scyllarides astori*) were caught within the Exclusive Economic Zone (EEZ) of the Galápagos from 1950 to 2010. The reconstructed catch of *P. penicillatus* and *P. gracilis* was 400% higher than reported by the FAO (dashed line) between 1995 and 2010.



**Figure 4. Reconstructed Galápagos artisanal finfish catch (1950-2010), classified by family.** Prior to the 1980s, the bulk of landings were composed of large, predatory in-shore serranids (in particular *Mycteroperca olfax*). Over the last two decades, the species composition has changed such that off-shore species (e.g., tuna) and smaller in-shore forage fish (e.g., mullets) are now much more prevalent in the catch.



**Figure 5. Changes in mean trophic level (MTL) of the artisanal catch in the Galápagos Islands.** **(A)** At a cumulative level (i.e., all species and spatial scales), there has been a significant decline ( $r^2 = 0.59$ ;  $F(1, 60) = 85.9$ ;  $p < 0.001$ ) in the MTL of the catch from 1950 to 2010, much of which is attributable to a high level of sea cucumber fishing during the 1990s; the increase in the late 2000s is not due to stock recovery (see text). **(B)** When species are spatially disaggregated, we observed that the MTL of the off-shore catch increases, although not significantly over time ( $r^2 = 0.05$ ;  $F(1, 60) = 3.4$ ;  $p = 0.67$ ). However, over the same time period, the MTL of the in-shore catch (not including sea cucumbers) shows a significant decline of  $0.12 \text{ TL decade}^{-1}$  ( $r^2 = 0.53$ ;  $F(1, 60) = 65.7$ ;  $p < 0.001$ ).