# Reconstructing Panama's Total Fisheries Catches from 1950 to 2010: Highlighting Data Deficiencies and Management Needs

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## Introduction

Panama is located in Central America, and is the geographical divide between the South and North American continents, with (since the early 20th century) a canal connecting important shipping routes between the Atlantic and Pacific Oceans. Costa Rica is the nearest neighbor to the west, while Colombia is to the southeast. Early explorers of the country must have seen the potential for fisheries as the name Panama means "abundance of fish" (Holston, 1963). With its extensive coast relative to inland areas, Panama has a large and productive Exclusive Economic Zone (EEZ), measuring 331,465 km$^2$ (VLIZ, 2012).

The Panamanian EEZ includes both Atlantic (Caribbean) and Pacific waters, with the Pacific being much more productive biologically than the Caribbean (Fiedler et al., 1943). Domestic fisheries were somewhat slow to develop in Panama, with much of the locally consumed fish being imported in the 1940's (Fiedler et al., 1943). With the development of an important industrial Penaeidae shrimp fishery in the early 1950's and a fishmeal production industry in the 1960's, fisheries started to play a much more prominent role in the Panamanian economy.

Panama's shrimp fishery is concentrated on the Pacific coast in the Gulf of Panama and Gulf of Chiriqui (Fig. 1) with shrimping taking place mainly from May to July and October to December (Pruett et al., 1975). Several species of shrimp are targeted, including three species of blancos or white shrimp, *Litopenaeus occidentalis, L. stylirostris*, and *L. vannamei*; camaron rojo or pink shrimp, *Farfantepenaeus brevirostris*, and two species of seabob, *Xiphopenaeus kroyeri* and *Protrachypene precipua* (Pruett et al., 1975).

In the 1970's, management measures were put in place in an attempt to prevent over-exploitation of the valuable shrimp resources (e.g., restricting the number and power of vessels and limiting the harvest season: Pruett et al., 1975). For example, in 1973 there were 232 shrimp vessels limited to 250 horsepower engines and a fishing season from mid-February to mid-April. However, these management measures were poorly enforced, and some measures were subsequently abandoned (Pruett et al., 1975), except for seasonal bans, which continue to be enforced. A recent report indicated that all shrimp trawl vessels (since 2005) must be equipped with Turtle Exclusion Devices (TED's), and to better enforce regulations, all shrimp trawlers are required to depart and land at accredited ports or face heavy fines, particularly for repeat offences (Martinez et al., 2005).

A small lobster fishery exists on both Pacific and Atlantic coasts, al-

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*ABSTRACT—With extensive coastlines bordering the Pacific and Atlantic (Caribbean) Oceans, Panama has a valuable fisheries resource base. While the exploitation of these resources began long ago, it was not until the 1960's that Panama's most financially lucrative fishery developed—a reduction fishery, mainly for Pacific anchoveta,* Cetengraulis mysticetus, *and Pacific thread herring,* Opisthonema *spp. Today, this fishery continues to convert large quantities of small pelagic species into fishmeal and oil for export. Also economically important is the fishery for shrimp, Penaeidae, which began in the 1950's, mainly for export. The remaining fisheries of the country were slower to develop, and consequently, domestic consumption remained low in the early years. As new fisheries eventually developed and expanded, monitoring and the collection of catch data lagged. Aside from the major fisheries for export, fisheries catch data in Panama have not been adequately collected and/or made publicly available, with the official landings statistics representing but a portion of what is truly being extracted from Panamanian waters. Here, we present a first attempt at estimating total marine fisheries catches, including all fisheries subsectors and components. Our estimate of 8.59 million t for 1950–2010 suggests substantial under-reporting, with the total reconstructed catch being almost 40% higher than the official landings as supplied by Panama to the FAO for the 1950–2010 time period (6.15 million t). For Panama to continue deriving benefits from its fisheries resources, management measures are urgently needed, which include collecting detailed catch data for all its fisheries, territorial waters planning, and an overall reorganization of the fishing sector, including government agencies.*

though the Atlantic fishery is more important. On the Atlantic coast, the Caribbean spiny lobster, *Panulirus argus*, and the Caribbean sand lobster, *Scyllarides aequinoctialis*, are targeted, mainly in Bocas del Toro and Guna Yala (San Blas) (Fig. 1) by diving at low tide (Castillo and Lessios, 2001; Guzman and Tewfik, 2004). On the Pacific coast, fishermen initially used trammel nets to target the Pacific spiny lobster, *Panulirus gracilis,* and the Pacific sand lobster, *Evibacus princeps*, off San Carlos, Veracruz, and Los Santos (Pruett et al., 1975), but currently, fishing includes three protected areas, Islas Paridas, Isla Coiba, and Las Perlas, and the inclusion of free divers from Guna Yala using custom-made lobster hooks.

The U.S. Agency for International Development launched a study in 1961 to investigate the feasibility of developing a lobster fishery, with exploratory fishing starting the following year (Butler and Pease, 1965). By the end of the 2-year exploratory survey, three domestic commercial lobster fishing enterprises were under development (Butler and Pease, 1965). By the early 1970's there were an estimated 60 lobster fishermen along the Pacific coast and approximately 80 boats, mainly canoes and wooden sailboats. However, lobster landings do not appear in the FAO data until the mid-1970's for the Atlantic and the 1980's for the Pacific, with catch statistics for this fishery likely being derived from export records. Currently, the estimates for lobster populations are low and clearly suggest overexploitation on both sides of the isthmus for nearly all species (Guzman and Tewfik, 2004; Guzman et al., 2008).


Figure 1.—Panama, including the Exclusive Economic Zone, and some important fishing areas.

Panama's fishery for small pelagics began in the 1940's in the Gulf of Panama, initially supplying live bait to the U.S. tuna fleets and then developing into a lucrative fishmeal industry in the early 1960's. The main targets are Pacific anchoveta, *Cetengraulis mysticetus*, and four species of herring, *Opisthonema libertate, O. bulleri, O. medirastre,* and *O. berlangai*. Catches of anchoveta and herring were approximately 18,000 t in 1964, increasing to 77,000 t by 1973. At that time, two fishmeal plants were in operation, Pesquera Taboguilla and Promarine[1], each having its own seine fleet (15 and 10 vessels, respectively). Sardines, *Sardinella aurita*, were also commercially targeted alongside the anchoveta fishery, with catches being processed at Conserva del Mar, Panama's only sardine cannery, established in 1971.

Although evidence of tuna fishing exists as early as the 1940's (Fiedler et al., 1943), according to FAO data, the fishery for large pelagic species, including mainly yellowfin tuna, *Thunnus albacores*, and billfishes such as marlin, *Istiompax indica*, *Makaira mazara*, *Kajikia audax*; swordfish, *Xiphias gladius*; and Indo-Pacific sailfish, *Istiophorus platypterus*, in Panama began in the 1970's. While the FAO present data for tuna and billfish landings for Panama in the three FAO areas (Pacific eastern central, Pacific southeast, and Atlantic western central), which include the Panamanian EEZ, an important portion of these catches may have been taken outside the EEZ and some by foreign vessels flying the Panamanian flag and licensed by authorities (Panama is recognized as one of the more prolific Flag of Convenience (FOC) countries, making

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

data reports problematic).[2] Given the lack of transparency regarding reflagging of vessels, the number (relative to the truly domestic fleet) and origin of reflagged vessels is unknown, therefore we accepted the FAO data as presented in FAO Fisheries Statistics. In particular, FAO Yearbook notes state that: (a) during 1970–1982 catch data exclude quantities of tunas caught by vessels flying the Panamanian flag (FAO, 1984), (b) during 1983 to 1998 data for Tunnidae not reported by the national office have been estimated on the basis of ICCAT and IATTC, and U.S. import statistics (FAO, 1985; 2001), and (c) during 1999–2010 data concerning the nominal catch of tuna are reviewed in collaboration with ICCAT and IATTC, the regional agencies concerned with tuna with some slight variation in wording over the years (FAO, 2001; 2012).

Panama's scallop fishery began in 1963 in the Gulf of Panama, targeting bay scallops, *Argopecten ventricosus*, using shrimp trawls. It was an exploratory fishery for lobster in the early 1960's that uncovered the potential for scallop fishing in the Bay of Panama (Butler and Pease, 1965). Learning of this potentially lucrative new fishery, shrimp vessels were quickly retrofitted to target scallops, and thus a scallop fishery was born, exporting catches predominantly to the United States. The fishery prospered in the 1980's with catches of over 4,000 t in 1987, but it then collapsed in 1991 without recovery, affecting both artisanal and industrial fishermen (Medina et al., 2007).

Beginning in the 1980's, sharks (mainly Carcharhinidae and Sphyrnidae) were taken as incidental catch from other commercial fisheries. Later, the shark fishery developed into a targeted fishery of its own (ProAmbiente, 1999; Teplitzky, 2005), with both an artisanal and industrial component. Although the expansion of this fishery was, in part, driven by the growing international demand for fins and shark liver oil, shark meat was increasingly consumed domestically and thus, the entire shark utilized (Ramírez and Medina, 1999).

In the late 1990's, roughly half of shark fin exports went to Hong Kong, while another third went to the United States (ProAmbiente, 1999). Initially, the majority of sharks caught were taken from inshore waters, including nursery areas, whereas the targeting of pelagic shark species began fairly recently. While reported catches for this fishery are small in comparison with some of the other commercially targeted species, there is likely substantial under-reporting of catches by domestic vessels and possibly a large number of sharks being caught by foreign vessels operating illegally in the waters of Panama. In this study we address only catches by domestic vessels.

Since 1950, the FAO has presented fisheries landings statistics on behalf of its member countries, originally only in its annual yearbooks and later also available in their publicly accessible online database. While publicly accessible, these statistics are known to be incomplete (Pauly, 1998; Zeller et al., 2007; Harper and Zeller, 2011; Garibaldi, 2012). Most of the landings data presented by the FAO are supplied by its member countries, the quality of the data reflects the statistical collection capabilities within each country. It has been found that varying issues, including under-reporting, over-reporting, and a lack of transparency (i.e., how were these data collected and what part of the catch do they represent) are rampant in data submitted by member countries and lead to low reliability of officially reported data sources (i.e., see Pauly et al., 2013).

In Panama, the collection of fisheries catch data has focused predominantly on landings of commercially targeted and valuable species, much of which is deemed for export. For these sectors/species, the data may be fairly representative but with some concern over the species nomenclature, sometimes reported generically. In contrast, the small-scale sectors are likely substantially under-reported as statistical collection systems were not designed, at least in the early period, to account fully for these catch components.

In the early 1970's, a substantial amount of fish caught and sold on the local market was not reported to government officials (Pruett et al., 1975) and more recent reports suggest that small-scale catches are severely underestimated (Gillett, 2011). There has been no indication that reporting systems have improved sufficiently to account for all sectors and normally the reports are estimates provided by the fishermen with several species aggregated into a single taxonomic category such as "miscellaneous" fish.

Aside from under-estimating marine fisheries removals, there is a lack of trained fisheries officers to carry out comprehensive accounting, particularly of catches destined for the domestic market, which masks the importance of fish to national food security, resulting in incorrect low national seafood consumption estimates. Furthermore, management plans developed from incomplete catch accounting will ultimately be compromised in their effectiveness (Costello et al., 2012).

Here, we reconstruct total marine fisheries catches over the years 1950–2010, by accounting for all catch components and sectors. In particular, an effort is made to estimate under-reported artisanal catch, unreported subsistence catch, and discarded bycatch associated with the shrimp trawl fishery. Here we present only catch data as this is part of a larger, global effort to reconstruct fisheries catches for all countries of the world. A parallel study on creating a global fishing effort database is underway, which will generate estimates of effort independent of catch data, by sector, gear-, and vessel-type for all fishing countries of the world from 1950 to 2010. It is anticipated that these data will be available by mid-2015 and will provide an excellent complement to the catch data presented here.

## Methods

Fisheries landings data by year and taxa were obtained from FAO Fisher-

[2]www.itfglobal.org; accessed July 2012.

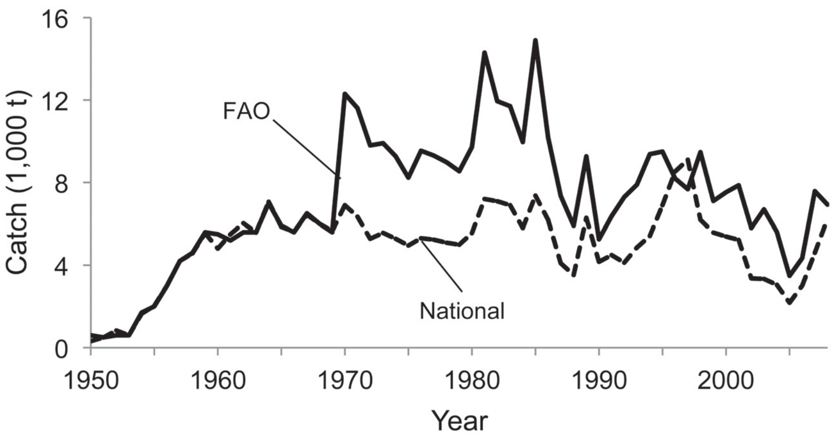


Figure 2.—Panama's national shrimp landings (in tail weight) as compared to those presented by the FAO (eastern Pacific Ocean catches, area 77) on behalf of Panama for the 1950–2008 time period (FAO after 1970 was assumed to have been converted to whole weight).

ies and Aquaculture Statistics[3] for the 1950–2010 time period. A time series of reported landings was also obtained from the Autoridad de los Recursos Acuaticos de Panama (ARAP), the Contraloria General de la Republica de Panama, and independent sources for the years 1950–2008 for the major taxonomic groups. These data also distinguished the taxa by sector from which they were caught (i.e., industrial and artisanal sectors). The national data also represent catches from EEZ waters only. Landings by taxa were compared between these two datasets and then independent sources were sought to estimate unreported or missing components.

The main fisheries identified within the industrial sector were the shrimp trawl fishery and the fishery for both large and small pelagics. For the industrial sector, corrections were made for years of misreporting and discards were estimated where possible.

The artisanal sector included fisheries for reef and inshore species, including shark (although in recent years shark were caught by both industrial and artisanal sectors). Adjustments were made to account for known under-reporting by the artisanal sector (see "Artisanal Fishery" section below).

Subsistence catches (i.e., the noncommercial component of the small-scale sector), assumed to be completely missing from the officially reported data, were estimated only for the indigenous people, known as the Guna of the Guna Yala region of the Caribbean coast (Fig. 1). Recreational catches, also missing from the reported data, were estimated separately (see "Recreational Catches" section below).

Together, these sectors and components—reported and unreported—were used to reconstruct total catches, providing the first comprehensive estimate of fisheries removals by Panama for the years 1950–2010. Each component is addressed separately below.

### Shrimp Fishery

Shrimp landings were obtained from national and independent sources for the 1950–2008 period and compared to FAO landings for the same period (Fig. 2). The national sources appear to be presented in tail weight, except for Cabezón, *Heterocarpus vicarius*, which according to Martinez et al. (2005), were reported in whole weight. Additionally, independent estimates for shrimp landings, based on exports, were given by Pruett et al. (1975), and match both national and FAO sources in the early period. This further suggests that landings were reported as tail weight. FAO Yearbook notes state that conversion factors of 2.0, 2.1, and 1.6 were applied to 1986 shrimp data (FAO, 1989). We assumed that a retroactive adjustment was made to the FAO shrimp landings back to 1970, but it did not correct data prior to 1970. Therefore, we assumed that the 1950–69 landings for all shrimp taxa except Cabezón, needed to be converted to whole weight. To do this, a conversion factor of 1.6 was applied to Atlantic seabob[4], *Xiphopenaeus kroyeri*, landings (FAO, 2000) and a conversion factor of 2.0 was applied to the remaining taxa (except Cabezón).

From 1970 onward, we assumed the FAO landings were a good representation of shrimp landings based on their close proximity to national and independent estimates, for the years where data were available for comparison (up to 2008). For the years 2009–10, we accepted shrimp landings data presented by FAO, as these were the only available estimates. To improve the FAO data taxonomically, national and independently sourced data were used, as these data provided catches by taxa, including the following groups: Camaron blanco (white shrimp: *Litopenaeus occidentalis*, *L. stylirostris*, *L. vannamei*); Rojo, *Litopenaeus brevirostris*; Fidel, *Solenocera florea* and *S. agassizii*; Caribali, *Rimapenaeus byrdi*; Titi, *Xiphopenaeus kroyeri*; and Cabezón, *Heterocarpus vicarius*.

To disaggregate the white shrimp category, we applied the species composition presented in Martinez et al. (2005), which suggested the following breakdown: *L. occidentalis* (65–97%), *L. stylirostris* (1–29%), and *L. vannamei* (<1%–7%). We assumed the mid-point of each of these ranges: 81%, 15%, and 4%, respectively. Fidel

[3]www.fao.org/fishery/statistics/software/fishstatj/en; accessed June 2012.

[4]Atlantic and Pacific seabob are no longer considered distinct species. *Xiphopenaeus kroyeri,* Atlantic seabob, is now the only valid name. However, within the FAO data the common name of Pacific Seabob is still present.

were split evenly into *S. florea* and *S. agassizii*.

Shrimp catches were only reported in the Pacific (FAO statistical area 77). As national sources matched the FAO data, with adjustments only being made for conversion to whole weight, it was assumed that all shrimp catches are taken from the Pacific and that there were no unreported shrimp catches for the Caribbean side (area 31).

*Discards*

Tropical shrimp trawl fisheries are known to incur substantial bycatch, much of which is discarded at sea (Kelleher, 2005). Shrimp fisheries in Panama are no exception. In Panama, *Litopenaeus* shrimps, Atlantic seabobs[4], and deepwater shrimps (*Heterocarpus* spp. and *Solenocera* spp.) are all targeted. National data sources (Autoridad de los Recursos Acuaticos Panamá) provide some estimates for incidental catch, which coincide with estimates given in López (1999) for landed bycatch for the shrimp fishery. We assumed that the landed portion of the bycatch, estimated by López (1999) to be 3% of overall bycatch, was reflected by these data. The remaining 97% of the bycatch was discarded and assumed to be unreported. López (1999) gives a shrimp to bycatch ratio for Panama of 1:7 (97% of which is discarded), which we considered was based on shrimp tail weight. This discard rate was therefore rescaled to represent the whole shrimp to bycatch ratio (1:3.5) and applied to the FAO landings by whole weight for the *Penaeus*[5] shrimp and Atlantic seabob[4] categories. The taxonomic composition for bycatch (landed and discarded) was based on the breakdown given by López (1999) for shallow-water shrimp fisheries in the Pacific Ocean, which included 70% fish, 15% Penaeidae, and 15% miscellaneous crustaceans. The fish were further disaggregated using a 5-year average (1998–2002) catch composition from the artisanal finfish fishery: 35% Lutjanidae, 3% *Scomberomorus sierra*, 1% *Seriola* spp., 8% Sciaenidae, and 53% miscellaneous marine fish.

[5]*Penaeus* shrimps (family Penaidae) are now largely *Litopenaeus* spp.

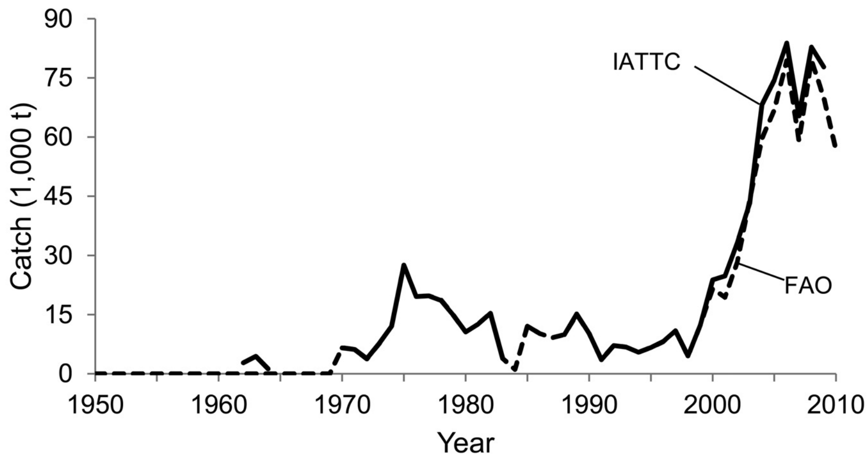


Figure 3.—Landings of large pelagic species from the eastern Pacific Ocean as presented by the Inter-American Tropical Tuna Commission as compared to FAO landings for the same species in FAO statistical areas 77 and 87, 1950–2010.

Deepwater shrimp have a much lower bycatch rate estimated at 5.66:1 (targeted catch to bycatch). However, while the bycatch rate is much lower than that of Litopenaeid shrimp and seabob (the shallow-water species), all of the bycatch is discarded (López, 1999). This rate was applied to FAO landings of Natantian decapods, which is the FAO category representative of the deepwater species (Fidel and Cabezón). The species composition for discards associated with the deepwater shrimp fishery was also based on a breakdown given in López (1999), which included 90% miscellaneous crustaceans, 4% miscellaneous molluscs, 4% fish (mainly *Peprilus* spp.), and 1% hake.

**Large Pelagics**

FAO presents tuna and billfish catches by Panama in statistical areas 87, 77, and 31 (Pacific southeast, Pacific eastern central, and Atlantic western central, respectively), although the majority of landings are from the Pacific. The Panamanian EEZ reaches into statistical areas 31 and 77; however, we assumed landings reported from these areas were taken both inside and outside the EEZ. We first compared Panama's tuna landings for the eastern Pacific Ocean as presented by the Inter-American Tropical Tuna Commission[6] with FAO landings for areas 87 (Pacific southeast) and 77 (Pacific eastern central), and found that the two sources match almost exactly (Fig. 3). We therefore accepted the FAO tuna landings as representative; however, due to landings being taken beyond Panamanian waters, we improved the data spatially by allocating catches within and outside the EEZ (for areas 31 and 77 only, as none of Panama's EEZ falls within area 87), based on limited available knowledge. To do this, we compared FAO's tuna landings (areas 31 and 77) to national tuna landings data, which are from EEZ waters only (ARAP).

The discrepancy between FAO and national sources in the 2000's was used to spatially disaggregate catches. We disregarded the first two years of national data and took the average ratio between national and FAO landings for the years 2004–08 as being representative of catches taken inside vs. outside the EEZ. We then assumed that this was representative of large pelagic fisheries catches for the entire 1970–

[6]IATTC; www.iattc.org/CatchReportsDataENG.htm; accessed July 2012.

2010 time period and therefore estimated that 57% of FAO area 31 and 77 landings for large pelagics were taken inside Panama's EEZ. While the regional fisheries management organization likely has the detailed information required to spatially resolve catches, these data are not made publicly available, and thus we must rely on assumptions to determine what portion of the catch is taken where. The large increase in tuna landings in the early 2000's may reflect the inclusion of Panamanian flagged vessels or new licenses for the international fleet, while prior to this, the FAO states that these landings were excluded from the reported data. However, until reporting distinguishes reflagged vessels from truly domestic fleets, this cannot be resolved.

The dominant gear types used in capturing tuna in this region are purse-seine net and tuna longline. Both of these have associated bycatch and discards. Sharks are often caught incidentally in the tuna fishery but the numbers are not adequately represented in the reported data (see Shark Fishery section). Some of this catch is kept and sold as there is a market for these species; however, discarding also occurs. López (1999) suggests a tuna to bycatch ratio of 1:1.5 for industrial longline, with 27% of the bycatch being discarded. López (1999) further suggests that where tuna landings are not associated with a specific gear, 10% can be assumed to be taken by longline.

Bycatch of nontarget species by purse seine, the dominant gear-type for tuna in this region, has been estimated by Restrepo (2011) to be 1.08% and information on discard rates for this gear-type was not found. As the majority of Panama's tuna fleet are purse-seine and bycatch and discard rates are likely low or very low, we did not estimate discards for the tuna fishery.

A recent development in the Pacific pelagic fishery is the targeting of dolphinfish, *Coryphaena hippurus*. While this taxon does not appear in the officially reported data (neither the national datasets nor the landings data as presented by the FAO on behalf of Panama), we were able to obtain catch data records from processing plants for the 2006–09 time period (Guzman et al.[7]). We assumed that the fishery started in the early 2000's and set catches to zero in the year 2000 and interpolated linearly to the first available anchor point in 2006. The 2009 anchor point was then carried forward unaltered to 2010 to complete the time series. We assumed that none of these catches were reported as this fishery is not managed and there were no visible taxonomic categories in the official data, which could have included these catches.

### Small Pelagics

The fishery for small pelagics targets mainly Pacific anchoveta and Pacific thread herring, *Opisthonema libertate*. The FAO presents landings for anchoveta, Engraulidae, and herring, Clupeidae, which correspond to national and independent landings data for these species. The catch from this fishery is almost entirely converted to fishmeal and fish oil at one of several fish processing plants in Panama. We accepted the small-pelagic data as presented by the FAO.

Although López (1999) provides a targeted sardine landings to bycatch ratio of 19:1, the bycatch is all landed. However, we could not identify where in the FAO data this amount would have been reported. We assumed that it was not included in the official landings data. The landed bycatch was calculated based on the reported small-scale pelagic catch and added to the overall reconstructed catch as an unreported industrial catch component.

### Artisanal Fishery

Panama's artisanal fishery is a mixed species fishery, which includes pargo (snapper: *Lutjanus* spp.), sierra, *Scomberomorus sierra*; cojinua (amberjacks), and corvina (croakers and drums). Artisanal fisheries also exist for invertebrates (scallops, *Argopecten ventricosus*; conch, *Strombus* spp.; and lobster, *Panulirus* spp.); however, these are each addressed separately in the following sections. The artisanal finfish fishery occurs in Pacific waters only. Landings for these individually reported fish categories in both FAO and national/independent data sources correspond almost exactly.

The FAO category "miscellaneous marine fishes nei (nowhere else included)" and the "others" category from national/independent sources, are a relatively good match in recent years; therefore we assumed that the FAO "miscellaneous marine fishes" (MMF) category represents the remaining artisanal sector catches, not reported as separate taxonomic entities. A comparison was done between the estimated landed bycatch from the small-pelagic and shrimp fisheries to determine whether the FAO miscellaneous fish category may have included these landings, but the bycatch amounts were much greater in some years than the FAO MMF category. Therefore, we assumed that they were not included in the official data. Numerous reports and studies suggest artisanal catches are under-estimated and that the number of artisanal fishermen/vessels are not properly accounted for (Pruett et al., 1975).

Martinez et al. (2005) provide an estimate of 7,426 artisanal boats, which is the same number as the 2004 national estimate. However, the same sentence states that this is an underestimate of the artisanal fishery and does not reflect reality. Additionally, an FAO country profile for Panama from 2002[8] includes the statement that, "catch statistics do not reflect reality and underestimate the real impact of the artisanal fishery." In an FAO report on bycatch in small-scale tuna fisheries (Gillett, 2011), Panama is listed to have 5,925 lanchas (small boats less than 12 m) that are licensed

[7]Guzman, H. M., E. Diaz-Ferguson, A. J. Vega, and Y. A. Robles. Preliminary assessment of the dolphinfish, *Coryphaena hippurus,* fishery in Pacific Panama. Rev. Biol. Trop. (in review).

[8]www.fao.org/fi/oldsite/FCP/en/PAN/profile.htm; accessed July, 2012.

to fish tuna, among other species, but without landing statistics for these boats. Therefore, we conservatively estimated an unreported artisanal add-on component of 15% (of reported landings) in 2010 and 30% in 1950, applied to all artisanal fish catches including individually reported taxa. Artisanal catches in the early years may still be under-estimated; however, the literature suggests that fisheries in this time period focused mainly on industrial targets such as shrimp and small pelagics and that domestic fish consumption was heavily supplemented by imports in the early years (Fiedler et al., 1943; Pruett et al., 1975). The cojinua, *Caranx caballus*, is considered by Panamanians as the "fish of the poor"; however, it is under high fishing pressure and catch per unit effort suggests overfishing (Mair et al., 2012).

### Scallop Fishery

Independent estimates for the scallop fishery correspond almost exactly with FAO landings for the combined categories: "Clams, etc. nei" and "Marine molluscs nei." We accepted the FAO data as presented in the Fisheries and Aquaculture Statistics database but assigned all of this catch to the species *Argopecten ventricosus*. Medina et al. (2007) reported the historical fishing trend and collapse of the fishery. This is also a Pacific fishery.

### Conch

Several species of conch are caught in Panama, including *Strombus galeatus* on the Pacific coast and *S. gigas* and *S. costatus* on the Caribbean coast (Tewfik and Guzman, 2003; Martinez, 2006; Cipriani et al., 2008). The official data, as presented by the FAO, include landings for the category "Stromboid conchs nei" for the Pacific region. However, Cipriani et al. (2008) suggest that the data collected by Panama's Marine Authority are pooled between the Pacific and Caribbean region. These same catch amounts appear in the FAO landings statistics as being only from the Pacific region. In 2004, the Panamanian government established a 5-year fishing ban for all *Strombus* species due to the over-exploited status of Caribbean conch stocks (Cipriani et al., 2008), which was recently extended for five more years. To account for conch catches from the Caribbean prior to 2004, we reassigned 20% of the FAO catch as being from the Caribbean and the remaining 80% as Pacific catches based on expert opinion (Guzman[9]). From 2004 onward, 100% of the FAO landings of conch remained as reported from the Pacific.

### Lobster Fishery

The lobster fishery in Panama is mainly concentrated on the Caribbean coast, targeting *Panulirus argus*, with *P. guttatus* taken as incidental catch (Guzman and Tewfik, 2004). Guna Yala and Bocas del Toro are at the center of these efforts. The lobster fishery provides both food and income to the Guna of the Guna Yala region, with lobster being exported daily by plane to Panama City (Castillo and Lessios, 2001). Lobsters are caught exclusively through free-diving, as scuba diving is prohibited in the region.

In the late 1990's, lobster exports from Guna Yala were estimated at around 92.5 t per year (Castillo and Lessios, 2001). Ehrhardt (1994) suggests that Panama does not systematically record its lobster catches. Therefore, we considered estimates presented in Castillo and Lessios (2001) to be unreported catches. Assuming lobster exports from Guna Yala started in the 1970's, we set the catch in 1970 to zero and interpolated linearly to the first anchor point of 92.5 t in 1998. Evidence suggests that catch per unit of effort may be declining (Castillo and Lessios, 2001; Guzman and Tewfik, 2004). With lobsters being harder to catch, we assumed a slight decrease in catches from 1998 to 2010 (i.e., a decrease of 5%). These catches were added to the reported baseline presented by the FAO.

[9]Guzman, H. M. Smithsonian Tropical Research Institute, Apartado 2072, Balboa, Republic of Panama. Personal observ., 15 July 2012.

On the Pacific side, *Panulirus gracilis* is the main target. Exploratory fishing in the early 1960's revealed potential for a fishery and by the mid-1960's three commercial lobster fishing vessels were in operation (Butler and Pease, 1965). While catches were likely low, lobster catches from the Pacific seem to be poorly represented (if at all) in the official data. No adjustments were made in the reconstruction to account for these catches as useable data were nonexistent. We suspect that the Pacific and Caribbean data were pooled and presented as being only from the Caribbean (see Guzman et al., 2008). As catches from the Pacific are likely small, we reassigned 10% of the reported lobster catch as being from the Pacific until the early 2000's when we assumed lobster catches on the Pacific declined further to almost zero in 2008 as a recent population assessment indicated catches being under-sized and the fishery to be near potential collapse (Guzman et al., 2008). A linear interpolation was done between the estimated catch in 2000 and zero metric tons in 2008 for Pacific caught lobster.

### Shark Fishery

Shark catches are reported by the FAO in area 77 (Pacific) from 1999 onward as "sharks, rays, skates, etc. nei" and as "sharks" in the national data from 2002 onward. In corresponding years, these two data sources match exactly; however, independently sourced data suggest that actual catches are much higher than the reported data suggest and began earlier (Fiedler et al., 1943; Ramírez and Medina, 1999; Teplitzky, 2005). As described previously, a targeted shark fishery began in the late 1980's in the Pacific and expanded substantially in the 1990's to include both an export and a domestic market for shark products. To account for catches in this early period prior to being reported, we set catches in 1985 at zero and interpolated linearly to the FAO landing estimate for sharks in 2000.

While 1999 is the first year the FAO provides an estimate, we interpolated to the second year of reporting as this estimate seemed more realistic. Later, Teplitzky (2005) presented shark landings data gathered by the Authoridad Maritima de Panama for 2004 of almost 43 million lb of shark and 1 million lb of fins. As we were unable to determine whether the fins were from the same individuals as the separately presented shark amounts, we used only the fins as a means of comparison to the officially reported data.

Conservatively assuming the fins were already in wet weight, we converted the fin amounts to whole body weight using the conversion factor presented in Biery and Pauly (2012), which suggests that wet fins represent 3% of the total body weight. When converted to metric tons, the independent estimate for 2004 based on fin amounts recorded from the semi-industrial fleet at 6 major ports (Vacamonte, Mutis, Panama, Mensabe, Coquira, and Pedregal) was 16,000 t. The difference between these two estimates was used to raise shark landings to a more realistic level. This fleet operates within Panama's EEZ, and we consider these to be both industrial and artisanal catches. This estimate likely still underestimates shark landings as this was based on landings recorded at only some of the landing sites. Furthermore, the estimates presented in Teplitzky (2005) are made by the boat captains which may potentially also skew the data, as there are heavy fines for landing more than the licensed amounts.

The artisanal fleet also catches shark—an estimated 63% of artisanal boats catch shark with 30–50% of the catch being shark—but there are no official records of these catches (Teplitzky, 2005). Likewise, the industrial tuna fleet also catches shark as bycatch, but the extent of these catches is also unknown (Ramírez and Medina, 1999). Shark catches estimated here were assumed to be from both the industrial and artisanal sector. To disaggregate reconstructed shark catches by sector, we used a study conducted by Guzman et al.[10] From the species sampled in this study, roughly 57% were from the industrial sector and 43% from the artisanal sector. We applied this breakdown to the reported and unreported components of total reconstructed shark catches and then applied a species breakdown specific to each sector.

**Table 1.—Species composition (%) of artisanal shark catches in Panama from Rodriguez-Arriatti (2011a) and industrial shark catches from Guzman et al. (text footnote 10).**

| Artisanal shark catch | | Industrial shark catch | |
|---|---|---|---|
| Scientific name | % of catch | Scientific name | % of catch |
| *Sphyrna lewini* | 67.8 | *Carcharhinus falciformis* | 50.5 |
| *Rhizoprionodon longurio* | 15.4 | *Sphyrna lewini* | 12.9 |
| *Mustelus* sp. | 3.7 | *Alopias pelagicus* | 12.1 |
| *Dasyatis longus* | 2.6 | *Mustelus lunulatus* | 9.3 |
| *Sphyrna corona* | 2.6 | *Rhizoprionodon longurio* | 6.0 |
| *Mustelus henlei* | 2.0 | *Ginglymostoma cirratum* | 2.0 |
| *Carcharhinus limbatus* | 1.9 | *Carcharhinus porosus* | 1.9 |
| *Nasolamia velox* | 0.9 | *Galeocerdo cuvier* | 1.6 |
| *Carcharhinus porosus* | 0.5 | *Nasolamia velox* | 1.6 |
| *Carcharhinus leucas* | 0.5 | *Carcharhinus limbatus* | 1.1 |
| *Sphyrna tiburo* | 0.4 | *Heterodontus mexicanus* | 0.7 |
| *Ginglymostoma cirratum* | 0.4 | *Prionace glauca* | 0.2 |
| *Dasyatis* spp. | 0.3 | | |
| *Prionace glauca* | 0.3 | | |
| *Carcharhinus galapagensis* | 0.3 | | |
| *Carcharhinus falciformis* | 0.2 | | |
| *Carcharhinus obscurus* | 0.1 | | |
| *Sphyrna zygaena* | 0.1 | | |
| Other sharks[1] | 0.2 | | |

[1]Other sharks consists of *A. superciliosus, Galeocerdo cuvier, Galeorhinus galeus, Sphyrna media*, and *Triakis semifasciata*.

Artisanal shark catches are dominated by hammerheads, *Sphyrna* spp., but also include bull sharks, *Carcharhinus albimarginatus*; tiger sharks, *Galeocerdo* spp.; black tip, *Carcharhinus limbatus*; white tip, *Carcharhinus albimarginatus*; thresher, *Alopias superciliosus*; and blue sharks, *Prionace glauca* (Teplitzky, 2005). We used the catch composition presented in Rodriguez-Arriatti (2011a) for artisanal shark catches (Table 1). The industrial sector was dominated by silky shark, *Carcharhinus falciformis*; scalloped hammerhead, *Sphyrna lewini*; pelagic thresher, *Alopias pelagicus*; and sickle-fin smooth-hound, *Mustelus lunulatus* (Guzman et al.[10]) (Table 1).

## Subsistence Catches

Panama's Caribbean coast includes the sovereign indigenous territory of Guna Yala (Hoehn and Thapa, 2009). The Guna Yala region covers a large stretch of coastline and includes over 360 islands, many of which are inhabited. There are 38 communities on the islands and another 11 along the coastal zone and forests of the adjacent mainland. The Guna rely heavily on the marine environment for livelihood and sustenance. The primary economic activities include artisanal lobster, conch, and octopus fisheries (Hoehn and Thapa, 2009).

As much of the artisanal catch is sent to Panama City, these catches are likely accounted for in the national statistics or the adjustments to artisanal catches presented above. However, subsistence fishing is also prevalent, with fishermen going out 3–4 times per week to fish for this purpose. The Guna rely on the ocean for their main protein source (Torres de Araúz, 1969; Ventocilla et al., 1995). We assumed subsistence catches have not been accounted for by the national data collection system, and therefore estimated this as an unreported component of our reconstructed catch.

Lobster used to be a prominent part of the Guna diet, eaten 3–4 times per week; however, now all the lobster is sold for shipment to Panama City and potential export. This change started to occur as the frequency of flights from Guna villages to Panama City increased in the early 1980's. Aside from these accounts of the importance of seafood to the Guna diet and the prev-

[10]Guzman, H. M., R. Cipriani, and A. J. Vega. Biology and fisheries of sharks in Pacific Panama. Rev. Biol. Trop. (in review).

alence of subsistence fishing, quantitative estimates of the catch were not found in any of the literature searched.

Likewise, diet and/or consumption information was also lacking. The World Health Organization for 1997 provides a global average seafood consumption rate of ~16 kg of fish per capita.[11] Seafood consumption estimates for other parts of the Caribbean have been estimated at 20 kg per person (Adams, 1992); however, this is for countries much more reliant on imports and protein alternatives than the Guna. The Islands of the South Pacific, with some of the highest reliance on marine resources, have per capita seafood consumption rates ranging from 17–181 kg/person/year (Gillett et al., 2001). To be conservative, we assumed a seafood consumption rate for the Guna region of 40 kg/person/year in the recent period and 60 kg/person/year in 1950. Using this rate and population data for the region, we conservatively derived an estimated subsistence catch amount for the 1950–2010 time period.

To derive a population time series for the Guna Yala region, we first obtained population data for Panama as a whole from the World Bank[12] for the years 1960–2010 and from Populstat[13] for 1950. A linear interpolation was performed to complete the time series between 1950 and 1960. Population anchor points for the Guna Yala region were then obtained from various sources and used to calculate the percentage of the total population represented by the Guna. In the early period, the Guna represented roughly 18% of the Panamanian population while representing approximately 9% today. We interpolated between anchor points and applied the percentages to the overall population to estimate the population of Guna Yala from 1950 to 2010.

We assumed that a large proportion of the diet in the early period consisted of invertebrates (lobster, octopus, conch, and crab), while these represented a much smaller proportion of the diet in recent years, when these species were mainly exported. We assumed that in 1950 invertebrates made up 60% of the subsistence catch, whereas in 2010 it comprised 10%, and fish in 1950 represented 40% of the catch and now represent 90%. The invertebrate portion was further disaggregated into lobster (30%), conch (30%), octopus (20%), and crab (20%). While this catch was considered subsistence (i.e., noncommercial), we realize that in recent times this category overlaps considerably with the artisanal sector, as some of these catches do end up being sold. However, we consider this component to be a part of the informal sector and therefore are referred to here as subsistence.

## Recreational Catches

Descriptions of game fishing in the Gulf of Panama date back to the 1930's (Fiedler et al., 1943). At that time, the Pacific Sailfish Club had 184 members and there were roughly 23 vessels engaged in this club's activities. While Fiedler et al. (1943) provides an extensive list of species caught by recreational fishermen (68 species), catch amounts or rates are not thoroughly reported. This source does give an estimated number of Indo-Pacific sailfish, *Istiophorus platypterus,* and black marlin, *Istiompax indica*, caught in 1942, which converted to an approximate weight of 4 t using FishBase's life history tool.[14] This was the only quantitative information given for the early time period and was, therefore, used as our first anchor point for estimating recreational fisheries catches.

Recreational catch estimates were not readily available for much of the time period; however, the NMFS conducted a Pacific Billfish Angler Survey from 1969–84, which provided estimates of billfish effort and catch (Squire, 1987). Catch data were presented for blue marlin *Makaira nigricans*; black marlin; striped marlin, *Kajikia audax*; and swordfish, *Xiphias gladius*. The total for all these species combined ranged from a low of 0.8 t in 1969 to a maximum of 25 t in 1982. Given the substantial year to year variation, we took the average over this time period as the second anchor point, interpolating linearly between our 1942 data point of 4 t and the average catch of 11.2 t set for 1976 (the 1969–84 period).

To derive an anchor point for the recent time period, an estimate of 1,000 anglers (Lopez-Alfaro[15]) was used for the year 2010. The number of anglers was then combined with a catch rate of 6.7 billfish per angler per year (Ditton and Grimes, 1995), which was converted to weight using the catch composition given in the same report and weights calculated using FishBase[14] length-weight relationships.

The resulting catch rate was 0.33 t/angler/yr, with much of this being released. We assumed a conservative release rate of 70% for Panama (retention of 30%; because release is not mandatory, retention could in fact be higher) and used the number of anglers for 2010 to derive a third anchor point, to which a linear interpolation was used between the 1976 estimate of 11.2 t and this 2010 estimate of 99 t. To assign these catches taxonomically, we calculated the average species composition of billfish catches over the 1969–84 time period presented in Squire (1987). Indo-Pacific sailfish, striped marlin, black marlin, and blue marlin, represented 86%, 6%, 6%, and 2%, respectively of the total recreational catch.

# Results

Panama's marine fisheries catches were estimated over the 1950–2010 time period by fishery and/or sector. Total shrimp catches over the study period were estimated at 539,300 t (whole weight; Fig. 4). Of this total, 71,000 t were unreported catches, es-

[11]www.who.in.en; accessed July 2012; accessed July 2012.

[12]http://data.worldbank.org/indicator/; accessed June 2012.

[13]http://populstat.info/; accessed June 2012.

[14]www.fishbase.org; accessed July 2012.

[15]Lopez-Alfaro, L. R. Asociacion de Clubes de Pesca de Panama, Calle Walker, Ancon, Apartado 0819-0214, El Dorado, Panama City, Republic of Panama. Personal commun., 4 Apr. 2013.

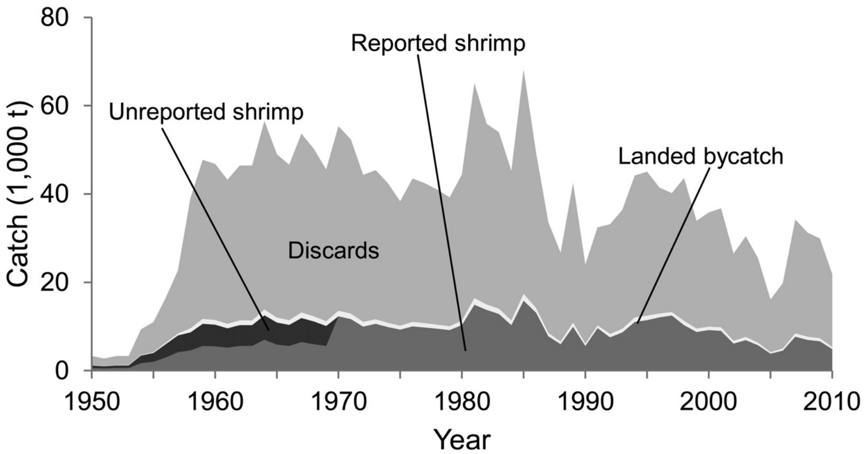


Figure 4.—Total reconstructed shrimp catches including reported and unreported catches, and landed and discarded bycatch, by Panama in the Pacific Ocean portion of the EEZ, 1950–2010.

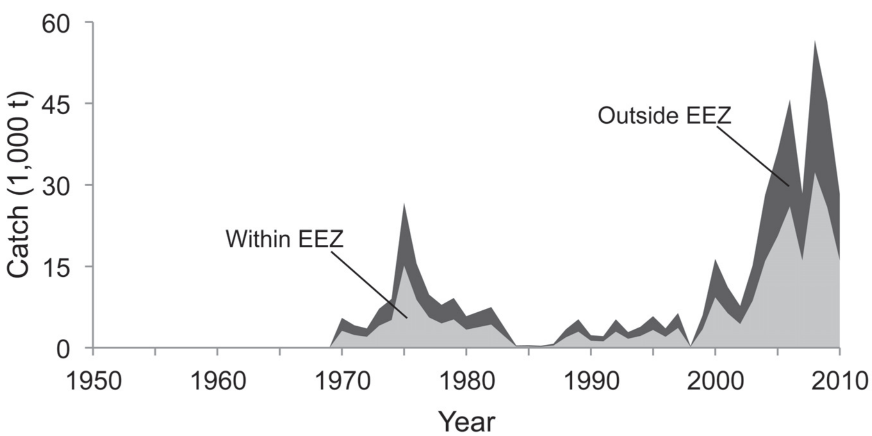


Figure 5.—Large pelagic catches by Panamanian vessels in FAO area 77 and 31, delineating catches taken within the EEZ (likely by domestic fleets) from those taken outside the EEZ (likely by re-flagged vessels), 1950–2010.

timated by converting landings in tail weight to whole weight for certain species from 1958 to 1969. Landed and discarded bycatch associated with this fishery, both considered unreported components, totalled 52,600 t and 1.7 million t, respectively, over the 1950–2010 time period.

Landings of large pelagic species, mainly skipjack and yellowfin tuna, were estimated at 490,400 t over the study period (Fig. 5). Overall, approximately half of these were considered to be taken within Panama's EEZ. A substantial portion of this catch was likely taken by foreign vessels flying the Panamanian flag as a Flag of Convenience. A relatively new fishery for dolphinfish caught an estimated 7,000 t since 2000, none of which was considered reported. Of the catches taken within the EEZ, 95% were taken from Pacific waters with the other 5% being caught in Caribbean waters.

The fishery for small pelagic species amounted to approximately 4.7 million t from 1950 to 2010, all of this being reported landings as presented by the FAO (Fig. 6). We estimated an additional 250,000 t of landed bycatch associated with this fishery, considered as unreported catch.

The shark fishery, which began in the mid-1980's, was estimated for our study period to be approximately 192,000 t (Fig. 7). Of this total, 25% was reported landings as presented by the FAO, while the remaining 75% was unreported catches, estimated from independent studies. Shark catches were further disaggregated by sector with a total of 109,500 t coming from the industrial sector and 82,600 t from the artisanal sector. Industrial shark catches were dominated by the silky shark accounting for just over 50% of the catch while the artisanal fishery was dominated by the hammerhead which represented roughly 68% of the artisanal shark catch.

Invertebrate fisheries for lobster, scallop, and other species were also estimated. Reported lobster catches were approximately 12,665 t (Fig. 8), as presented by the FAO for statistical area 31, with 930 t being reallocated to FAO area 77. We estimated an additional 2,400 t of unreported lobster catches from the Guna Yala lobster fishery (Fig. 8). Overall, 94% of the lobster fishery is estimated to be caught on the Caribbean side with only 6% being caught on the Pacific side. The scallop fishery had an estimated 37,000 t of reported landings from 1950 to 2010, with the majority of these taken between the mid-1970's and mid-1990's (Fig. 8). Other invertebrate catches, including conch, crab, and octopus were approximately 2,653 t, all of this being reported by FAO (Fig. 8). Of these other invertebrate catches, only a small amount of the conch catch is taken from Caribbean waters (19% of total conch catches).

Small-scale commercial catches were considered under-reported, while the noncommercial subsectors (subsistence and recreational fisheries) were completely unaccounted for in the official data. Total small-scale commercial (i.e., artisanal) catches were estimated to be 900,500 t over the 1950–2010

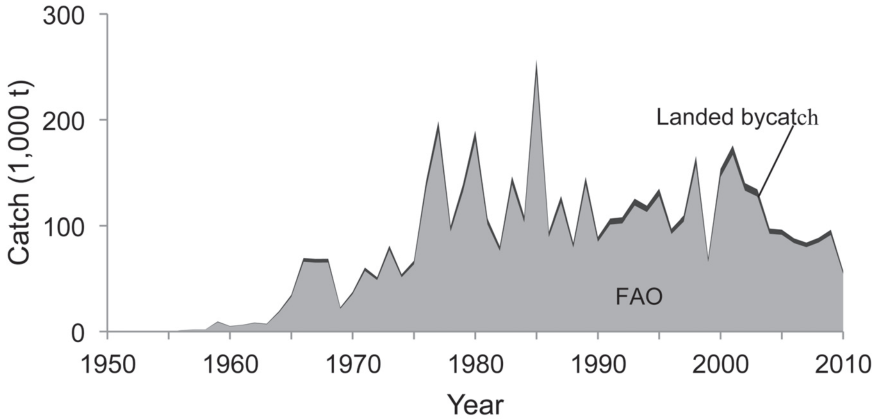


Figure 6.—Catches of small pelagic species as supplied to the FAO for area 77 (eastern Pacific) and estimated unreported landed bycatch associated with this fishery, 1950–2010.

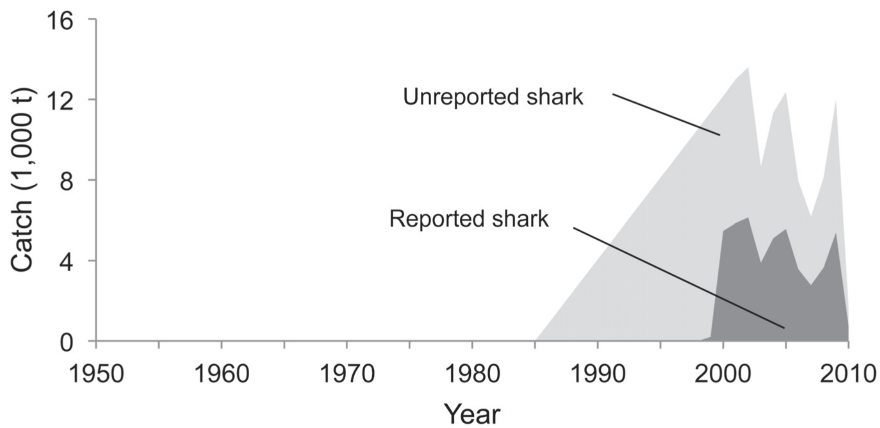


Figure 7.—Panama's shark (and ray) catches, 1950–2010. Reported data represent those presented by the FAO on behalf of Panama for FAO area 77 (eastern Pacific).

time period with 717,900 t being reported (Fig. 9). In addition to the artisanal shark and invertebrate catches, which have already been discussed, there is an artisanal finfish fishery. Reported artisanal finfish catches equalled 644,405 t over the 1950–2010 time period, with an additional 118,000 t estimated due to known under-reporting by this sector (Fig. 9).

Artisanal finfish catches increased steadily throughout the study period from 520 t/yr in 1950 to a substantial peak of over 71,000 t in 2001 (Fig. 9). Subsistence catches, only estimated for the Guna Yala region on the Caribbean coast, totalled approximately 84,500 t over the study period (or roughly 1,400 t/yr; Fig. 10a). Recreational billfish catches, considered a minimum estimate, totalled 2,139 t over the 1950–2010 time period.

Total marine fisheries catches as reconstructed here for Panama's domestic fisheries inside their EEZ equivalent waters (1950–2010) were estimated to be almost 8.59 million t (Fig. 10 and 11). This total is almost 40% higher than the officially reported landings of 6.15 million t as presented by FAO.[16] By sector, industrial fisheries (shrimp and associated discards, small pelagics, and tuna) represented 88% of the total reconstructed catch, while artisanal, subsistence, and recreational sectors made up the remaining catch (10%, 1%, and >0.05%, respectively).

[16]FAO tuna landings included in this total are those deemed to have been taken within Panama's EEZ.

Panamanian catches are taken from two oceans and of the total catches taken within the EEZ waters, 98.7% are taken from Pacific waters with only 1.3% coming from Caribbean waters (Fig. 10). In Caribbean waters there are only pelagic, conch, and lobster fisheries, and subsistence fishing (Fig. 10a). Pacific fisheries include: (a) the industrial and artisanal shark fisheries, (b) the shallow-water and deepwater shrimp fisheries (industrial), (c) a pelagic fishery which includes a fairly recently developed Dolphinfish fishery (industrial), (d) a small pelagic fishery (industrial), (e) the artisanal finfish, conch, and lobster fisheries (artisanal), and (f) the recreational fishery (Fig. 10b; recreational fishery is not visible on the graph).

The overall reconstructed catches derived from both the Pacific and Caribbean coasts, were dominated by the Pacific Anchoveta with 41% of the catch. Pacific thread herring (14%), Lutjanidae (7.5%), Penaeidae (3.2%), crustaceans (3.1%), and Atlantic seabob (2.0%), also contribute significantly to the catch (Fig. 11).

## Discussion

Panama's total marine extractions within its EEZ waters were estimated to be 8.55 million t over the 1950–2010 time period. This total was almost 40% higher than what FAO reports for the same time period. While the majority of overall catches are attributed to shrimp and small pelagics, unreported catches consisted of discards associated with the shrimp fishery, artisanal, recreational, and subsistence fisheries.

Panama's official fisheries statistics seem to adequately represent the industrial fisheries (except discards, which were not accounted for), whereas small-scale fisheries were substantially under-represented. This situation is not unique to Panama. Similar reconstruction approaches have shown that small-scale fisheries are consistently under-reported in countries all over the world, including developed (Zeller et al., 2011a; Zeller et al., 2011b) and developing countries (Zeller et al., 2007; Zeller and Harper, 2009; Harper and Zeller, 2011), further contributing to the marginalization of small-scale fishermen (Pauly, 2006).

Fisheries in Panama play an important role in the national economy, with major exports of shrimp, lobster, and fishmeal and oil (Castillo and Lessios, 2001). Domestically, while the Panamanian diet relies heavily on non–seafood protein sources (i.e., chicken, beef, etc.), seafood does play a role in food security, particularly for rural and small-island communities such as in the Guna Yala and Las Perlas Archipelago (Torres de Araúz, 1969; Ventocilla et al., 1995; Hoehn and Thapa, 2009). Overexploitation of fisheries resources has been observed for species such as lobster, scallop, conch, shark, and others (Castillo and Lessios, 2001; Teplitzky, 2005; Medina et al., 2007), with the scallop fishery having recently collapsed. Management measures have been employed to prevent further exploitation in some areas such as Las Perlas Archipelago (Harper et al., 2010); however, more is needed to protect threatened stocks.

Many accounts of poor fisheries data collection were cited throughout the literature reviewed for this study (Ehrhardt, 1994; Gillett, 2011; Costello et al., 2012). As highlighted in this study, there is a clear need for better fisheries monitoring and data collection as well as regulation and enforcement which are considered critical in the country by several stakeholders.

As important as monitoring and data collection is to the proper management of fisheries, surveying small-scale fisheries (which are usually highly dispersed) can be quite costly, and it is understood that many developing countries, including Panama, have limited financial resources. However, resource-limited countries can still effectively monitor their fisheries by implementing regular, nonannual surveys (every 2–5 years), which would provide information on fisheries catches through estimation and interpolation (Zeller et al., 2007).

Shark resources have been heavily exploited since the late 1980's in response to an attractive market for fins (Rodriguez-Arriatti, 2011a). Today, there is evidence of population declines, likely the result of intense fishing pressure on certain species. The dominant species in the artisanal fishery for sharks is the hammerhead with 96% of catches of this species being juveniles (Rodriguez-Arriatti, 2011b; Guzman et al.[10]). The capture of juveniles is common due to operations concentrating on near-shore areas using gillnet as their primary gear-type.

Shark fisheries in Panama are largely unregulated but this is expected to change due to recent restrictions imposed by the Convention on Interna-

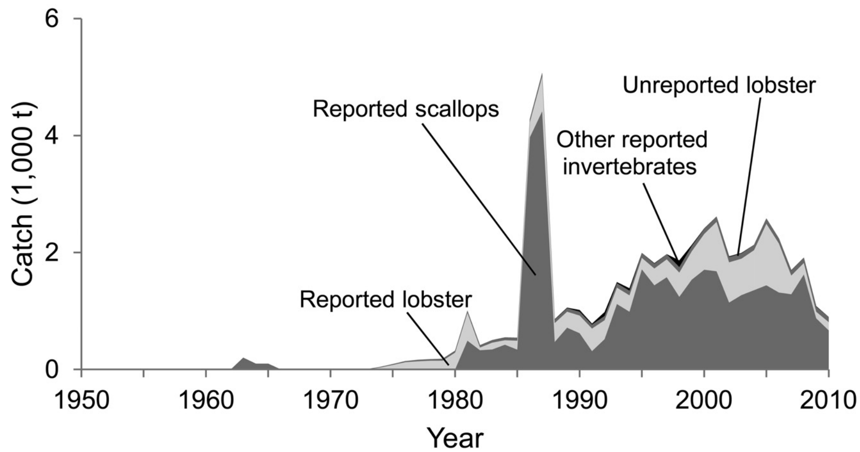


Figure 8.—Panama's artisanal invertebrate fisheries, 1950–2010. The other invertebrates' category includes Stromboid conchs, marine crabs, various squids, and miscellaneous gastropods. The majority of the reported and all of the unreported lobster are from the Atlantic (Caribbean, area 31), as well as a small amount of the Stromboid conchs. All other artisanal invertebrate catches are from the eastern Pacific (area 77).

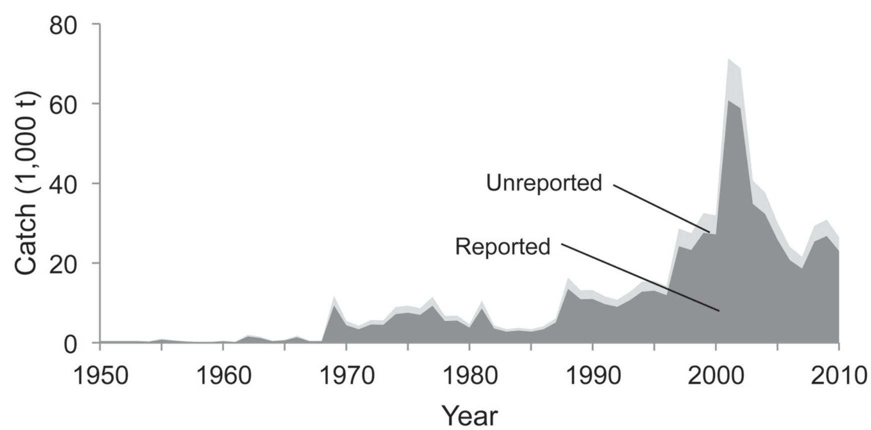


Figure 9.—Panama's reconstructed artisanal finfish catches, including reported and unreported components, 1950–2010, from the eastern Pacific portion of Panama's EEZ.

tional Trade in Endangered Species of Wild Fauna and Flora (CITES) in 2013. Sharks are increasingly also caught as bycatch in the offshore fisheries for tuna. Although an issue of concern for the IATTC, methods to reduce incidental shark catches are only beginning to be explored (Rodriguez-Arriatti, 2011c). Legislation to curb the overexploitation of vulnerable shark species in Panamanian waters is urgently needed. Protection for juvenile habitat and nursery grounds, gear restrictions, seasonal closures, and outreach programs to educate fishermen are all measures that should be adopted to prevent further declines in shark populations. However, an important and crucial first step in developing management plans for this fishery is to reliably estimate the magnitude of annual shark catches.

As a major player in the reflagging of vessels, Panama's FAO landing data are biased by FOC vessels (DeSombre, 2005). Although the FAO suggests in some years that these vessels are excluded from the tuna landings, foreign vessels flying the Panamanian flag are likely included in the more recent years when landings of large pelagics increased dramatically over a short period of time. Thus, the tuna data presented by the FAO for areas 77 and 87 match perfectly the IATTC tuna data for Panamanian flagged vessels.

Data collection and presentation of tuna landings should reflect the true origin of the vessels (i.e., whether they are domestic Panamanian vessels or foreign vessels that have been reflagged). Fishing under FOC undermines conservation efforts to sustainably manage fish stocks, particularly for highly migratory species such as tuna (DeSombre, 2005). To properly assess effort and capacity in a fishery, as well as beneficial ownership of the catch, fisheries data resolution should include vessel, as opposed to simply flag, ownership. Panama provided 258 international licenses in 2010 (INEC, 2013).

For Panama to retain meaning in its name ("abundance of fish"), fisheries management will need to make

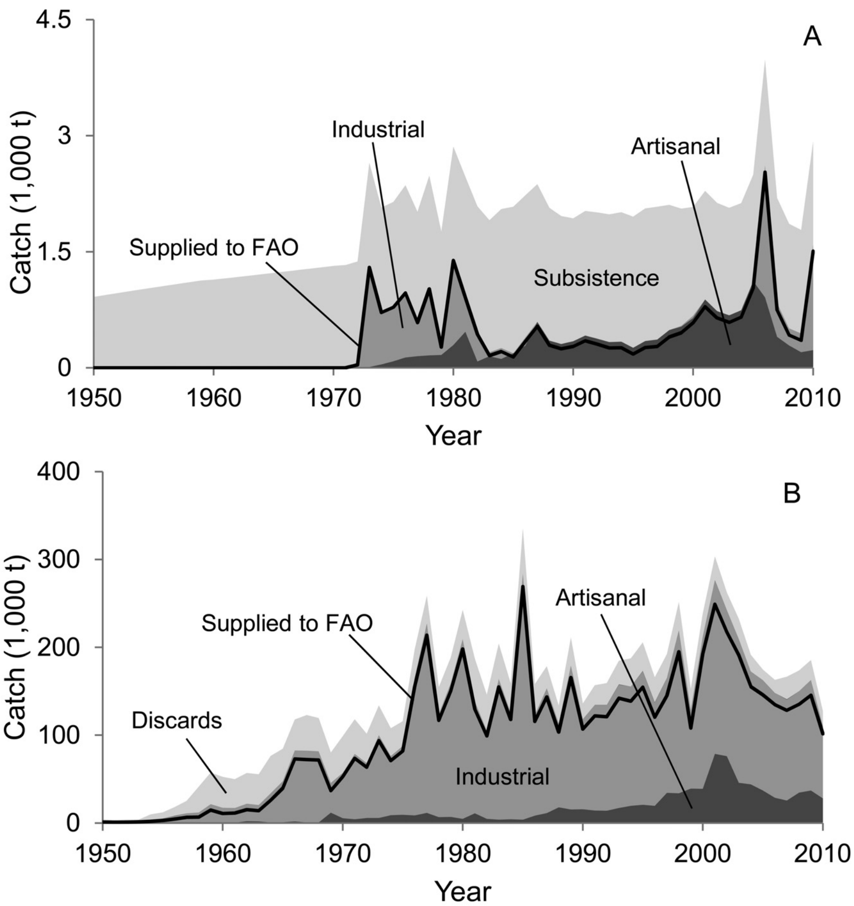


Figure 10.—Total reconstructed domestic catches in the EEZ equivalent waters of Panama, 1950–2010, by sector for a) the western central Atlantic, with comparison to the portion of the FAO data considered to be taken within Panamanian waters in FAO area 31, and b) the eastern central Pacific, with comparison to the portion of the FAO data considered to be taken within Panamanian waters in FAO area 77. Recreational catches in area 77 are not visible on the graph.

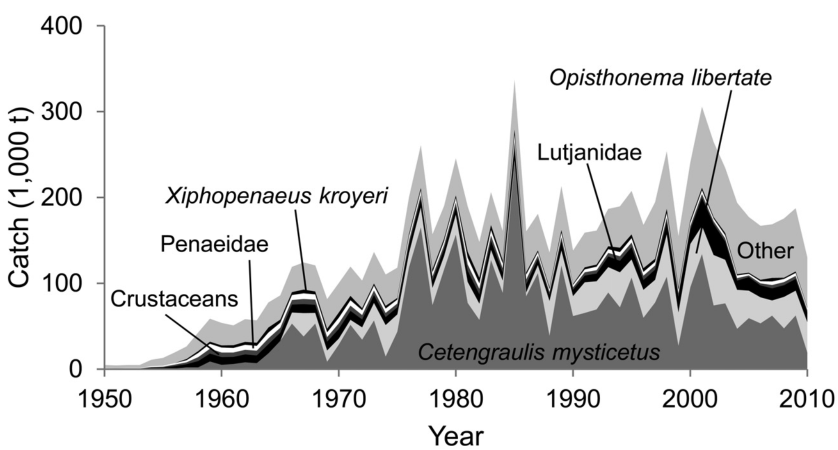


Figure 11.—Total reconstructed domestic catches in the EEZ equivalent waters of Panama, 1950–2010, for both the Pacific and Atlantic, by taxon, with the 'Other' category representing 63 additional taxonomic categories.

substantial improvements. Addressing overexploitation and overcapacity in Panama's fisheries requires understanding the status of the resource and the effort being exerted. Better monitoring and the collection of comprehensive catch data would be the logical first step in a move toward sustainable management of Panama's fisheries resources. To improve catch estimates for those sectors which are currently the most under-reported (i.e., artisanal, subsistence, and recreational sectors), we strongly recommend random stratified sampling survey and census work be done every few years, which should be raised to country level and interpolated for intervening years (Zeller et al., 2007).

## Acknowledgments

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