Reconstruction of total marine fisheries catches for Haiti and Navassa Island (1950–2010)[1]

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Abstract

A reconstruction of total marine fisheries catches for Haiti and Navassa from 1950 to 2010 was undertaken. The catch reconstruction combines estimates of artisanal catches with subsistence catches estimated from seafood consumption data combined with trade and aquaculture data. The reconstructed total catch for Haiti and Navassa was estimated at 846,900 t for the study period (1950-2010), which is approximately three times the reported catch of 280,272 t. A large part of this discrepancy was due to the inclusion of unreported subsistence catch estimates and the improved accounting of conch, lobster, crab and shrimp artisanal fisheries catches in the early time period.

Introduction

Famous for its practice of the voodoo religion, a tumultuous history of successive dictatorship and, recently, a catastrophic earthquake in 2010, the rugged tropical Republic of Haiti shares the island of Hispaniola with the Dominican Republic. Hispaniola, "discovered" by Christopher Columbus in 1492, lies in the north central Caribbean, between 18° and 20° north latitudes, and 71° 30' and 74° 30' west longitudes (Figure 1). The island was the first Spanish settlement in the New World (Smucker 2001) and the world's first black republic. Haiti is a mountainous country characterized by steep slopes and a narrow shelf (Appledoorn and Meyers 1993). It is associated with 5 small islands: Tortuga Island, Gonaive Island, Vache, Les Arcadins, and Navassa Island, located between Haiti and Jamaica. Note that while Haiti claimed Navassa in 1804, it has been under the jurisdiction of the USA as part of the Caribbean Islands National Wildlife Refuge since 1856 (Wiener 2006). However, we at the *Sea Around Us* Project have allocated Navassa Island's EEZ to Haiti as it is Haitians who fish in Navassa's waters and not the US.

Haiti has a land area of approximately 27,750 km², occupying the western third of the island of Hispaniola. It is bounded to the north by the Atlantic Ocean and to the south by the Caribbean Sea. Haiti and its associated islands experience a tropical climate with temperatures between 25.5°C and 28°C depending on altitude and exposure to the prevailing north-east trade winds. Rainfall is irregular, giving Haiti a semi-arid climate, with little to no rainfall from December through February. A considerable portion of the Haitian coast is fringed with coral and rocky reefs, with large areas of sand and gravel beach and low-lying mangrove swamps (Fiedler *et al.* 1943), while Navassa Island is comprised of a raised plateau surrounded by limestone cliffs. In terms of ecosystem productivity, the waters off Haiti are largely regarded as rather poor producers of fish, since there are no large fluxes of nutrients available to support plankton production. However, to the north, a branch of the North Equatorial Current passes approximately 20 miles offshore. This current is one of the major migration routes of tuna, marlin, swordfish and other large migratory species (Fiedler *et al.* 1943). Also, due to its isolation and uninhabited status, Navassa had been described as having a relatively pristine reef community (Miller *et al.* 2002).

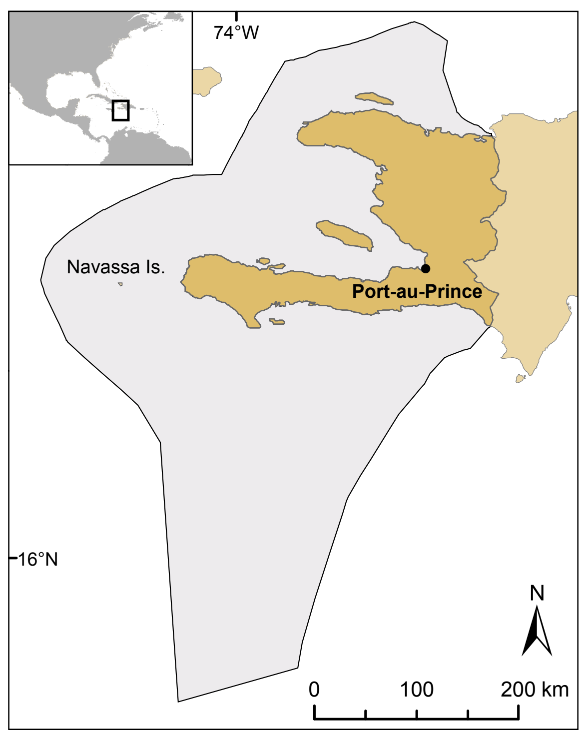

Figure 1. Map of Haiti and associated islands including Navassa. The black line corresponds to the demarcation of the Exclusive Economic Zone.

Haiti is one of the poorest and most densely populated countries in the Western Hemisphere. Current *per capita* GDP stands at $500 (UNEP 2010). Haiti is a country with enormous environmental problems, a direct consequence of the poverty which plagues a large fraction of the population. The diet of the average Haitian includes meals in which beans and occasionally meat (goat, beef, or pork) or fish serve as the main source of protein (Sebrell *et al.* 1959). However, such proteins are not consumed every day. Haiti has a continental shelf area of approximately

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435 km² and an Exclusive Economic Zone (EEZ) of approximately 112,000 km² (www.seaaroundus.org), which was declared in 1977. This is the smallest EEZ of all the Greater Antillean Islands, which also include Cuba, Jamaica, Puerto Rico, and the Dominican Republic. The main marine resources exploited within the EEZ are demersal (reef) fish and a limited quantity of pelagic fish, both over the continental shelf and offshore (Romain 2005). The continental shelf around Haiti is relatively narrow and easily accessible to fishers, and as a result, the coastal and demersal fish stocks are heavily over-exploited (FAO 1981). In contrast, offshore pelagic fisheries and deep-water demersal fisheries are said to be under-exploited due to technological limitations (Mateo and Haughton 2003). Marine species are also exploited in the mangrove forests, where people mainly catch crabs as well as shrimp, fish and shellfish (Aube and Caron 2001).

Small-scale fishing has a long history along Haiti's coast (Fiedler *et al.* 1943), and it absorbed many underemployed and unemployed Haitians (Zacks 1998). Marine resource exploitation in Haiti has always been open-access. Thus the fisheries resources of Navassa are extremely important to Haitian fishers, and appear to have been exploited since at least the 1970s (Wiener 2006). The fishing sector is primarily artisanal, multi-gear, multi-species and marketed mainly for local sale and personal consumption (FAO 1981). Small-scale fishers operate from small wooden boats (Zacks 1998), canoes and pirogues, which are propelled by oars or sails (Brethes and Rioux 1986 in Appledoorn and Meyers 1993). Presently, the sector comprises about 52,000 fishers from 400 villages, operating a total of 26,400 vessels (Damais *et al.* 2007). Despite technological advances elsewhere in the Caribbean, the Haitian fisheries sector remains predominantly unmechanized. Only 1,400 motorized vessels were enumerated by the Ministry of Agriculture, Natural Resources and Rural Development (MARNDR) in a 2007 fisheries sector study.

Traditionally, fishing is done by men, while women, often called *Madam Sara*, do the marketing of the catch (Zacks 1998). Overall, fishing is multi-species and multi-gear. Fish pots, nets, lines and spearguns are the primary gears used. Occasionally, those who can afford them may use lights attached to a battery for night fishing called *pêch batri* (Wiener 2006). Pieces of fish, lobster, marine turtle, sea star, bird, sea cucumber, crab, orange, and corn-based animal feed made into a ball are used as bait. Anything which may have value either for consumption or sale, or use as bait is taken (M. Karnauskaus, pers. comm., National Marine Fisheries Service, NOAA).

Marine organisms exploited in Haiti are consumed by the fishers and their families or marketed locally or, in the case of conch and spiny lobster, internationally (Zacks 1998). After basic processing, fish catches are classified into three groups: red or pink *pwason rose*, white *pwason blanch* and black *pwason noir*. The least desired black fish include butterfly fish and puffer fishes, white fish is mid-range and includes dolphin fish (*Coryphaena hippurus*) and barracuda (*Sphyraena barracuda*) while "red" or "pink" fish such as snapper (Lutjanidae) and grouper (Serranidae) are the most desired (Wiener 2006). About 30% of the fish caught in Haiti is salted and dried before being marketed, the rest is consumed fresh (Damais *et al.* 2007). Post-harvest losses are reported to be common in Haiti's fishing villages, since ice and refrigeration are scarce or completely lacking. Poor sanitation standards have also affected Haiti's ability to trade internationally. Haitian seafood is banned from European and North American markets (Anon. 2003). However, some species are exported such as lobsters (*Panulirus argus*), conch (*Strombus* spp.), shrimp (*Penaeus* spp.), octopus (Octopodidae) and crabs (*Menippe mercenaria*) with a significant proportion of these catches informally entering the Dominican Republic (Anon. 2003). Overall, Haiti's demand for seafood is higher than local catches can satisfy, and thus Haiti is a net importer of fish (MARNDR 2009).

As in many Caribbean Islands, the fisheries sector has been neglected by the governments of Haiti. According to Mateo and Haughton (2003), the Haitian Fisheries Service initiated in 1952 has limited institutional capability and insufficient finances to operate satisfactorily. Fisheries legislations are outdated. The Fisheries Law of 1977 is still the main legal instrument by which fisheries activities are regulated (Mateo and Haughton 2003). Management regulations are generally neither respected by fishers nor enforced by the fisheries management authorities. Though data collection is one of the key functions of the Fisheries Service, limited human resources mean that statistical data for the sector are very poor.

It is widely recognised that catch statistics are crucial to fisheries management (Pauly 1998). Fisheries data of any kind, including catch data, are virtually impossible to find for Haiti. For instance, when reviewing tables documenting fisheries data for the various islands of the Caribbean region (in FAO, Caribbean Regional Fisheries Mechanism [CRFM], Gulf and Caribbean Fisheries Institute [GCFI] documents), Haiti's input is almost always left blank. This study aims to gather available information on fisheries catches and fishing practices to reconstruct Haiti and Navassa Island's total fisheries catches for the period 1950-2010. The catch reconstruction method used here is based on the approach developed by Zeller *et al.* (2007). We aim to improve the catch data both quantitatively and taxonomically.

Methods

Baseline catch, trade and aquaculture data were extracted from the FAO FishStat database. A review of accessible Haitian historical, dietary and fisheries literature was undertaken to identify anchor points required for inferences on seafood demand, total artisanal catches, number of fishers and species caught. Commercial fisheries landings consist of fish marketed locally or exported abroad. Due to the small-scale nature of all commerce in Haiti, all commercial landings in Haiti are attributed to artisanal catches. Here we define subsistence catches as those used primarily for home consumption or those which are bartered locally. Though we realise that the boundary between artisanal and subsistence is less than clear cut.

Human population and fisher population

People reside on Haiti and adjacent islands, except Navassa Island, which is uninhabited, but visited by Haitians fishers. Human population statistics for Haiti were taken from Populstat (www.populstat.info) for 1950 and from World Bank from 1960–2010. A linear interpolation was used to derive population values for years with missing data. The overall population of Haiti has increased steadily from 3 million in 1950 to nearly 10 million in 2010 (Figure 2a). Population data were used in the calculation of total seafood demand from 1950 to 2010 (which was utilised in reconstructing subsistence catches) and also in the estimation of the proportion of fishers in the total population.

Table 1. Data sources of fishers, artisanal catches and calculated CPUEs.

Year	No. of fishers	Artisanal Catches (t)	Source	Artisanal CPUE (kg/fisher/year)
1942	3,017	938	Fiedler *et al.* 1943	311
1957	8,000	4,035	Beghin *et al.* 1970	504
1976	-	7,650	France (1977)	762[1]
1985	11,000	-	Laserre *et al.* (1985) in Mateo and Haughton (2003)	-
1989	12,000	-	UNDP/FAO (1989) in Mateo and Haughton (2003)	-
2000	30,000	-	Breuil (2000) in Mateo and Haughton 2003)	-
2006	52,000	15,850	MARDNR (2007)	305

[1]This CPUE was calculated using our estimate of number of fishers for 1976 (10,036) as derived through linear interpolation.

Data on the number of fishers in Haiti were available for six years from 1942 to 2006, from various sources (Table 1). We used a direct linear interpolation between anchor points to derive data for all years during the period 1942-2006. From the final anchor point (2006) we determined the proportion of fishers in the population and use this fixed figure to estimate number of fishers for 2007-2010. Using this approach suggests that nearly 55,000 fishers existed in Haiti in 2010 (Figure 2b).

Artisanal landings of Haiti

Annually, national organizations such as the MARNDR in Haiti submit catch data and other fishery statistics to FAO. Ideally, catch statistics should be collected for all fisheries sectors: industrial, artisanal, subsistence and recreational. Unfortunately, only a limited number of countries collect this information (Garibaldi 2012). Thus commercial landings are typically what the FAO reports in their landings statistics on behalf of a country. Estimates of Haiti's artisanal fisheries catches, used here as anchor points, are represented in Table 1. Dividing reported catches by the number of fishers reported for the corresponding year gave the catch per unit effort (CPUE) for artisanal fishers. We estimated four values of CPUE for 1942, 1957, 1976 and 2006. Linear interpolations were applied between these 4 anchor points to derive the CPUEs for 1950-2010. Multiplying CPUE by the number of fishers estimated for each year (Figure 2b.) we reconstructed an estimate of Haiti's artisanal fisheries catches from 1950 to 2010.

Subsistence catches

It is reported that Haitian fisheries are primarily subsistence based (Moal 1977; FAO 1981). However, data regarding subsistence fisheries in Haiti were not readily available. To independently estimate the subsistence catches in Haiti, we relied on a national nutrition study by

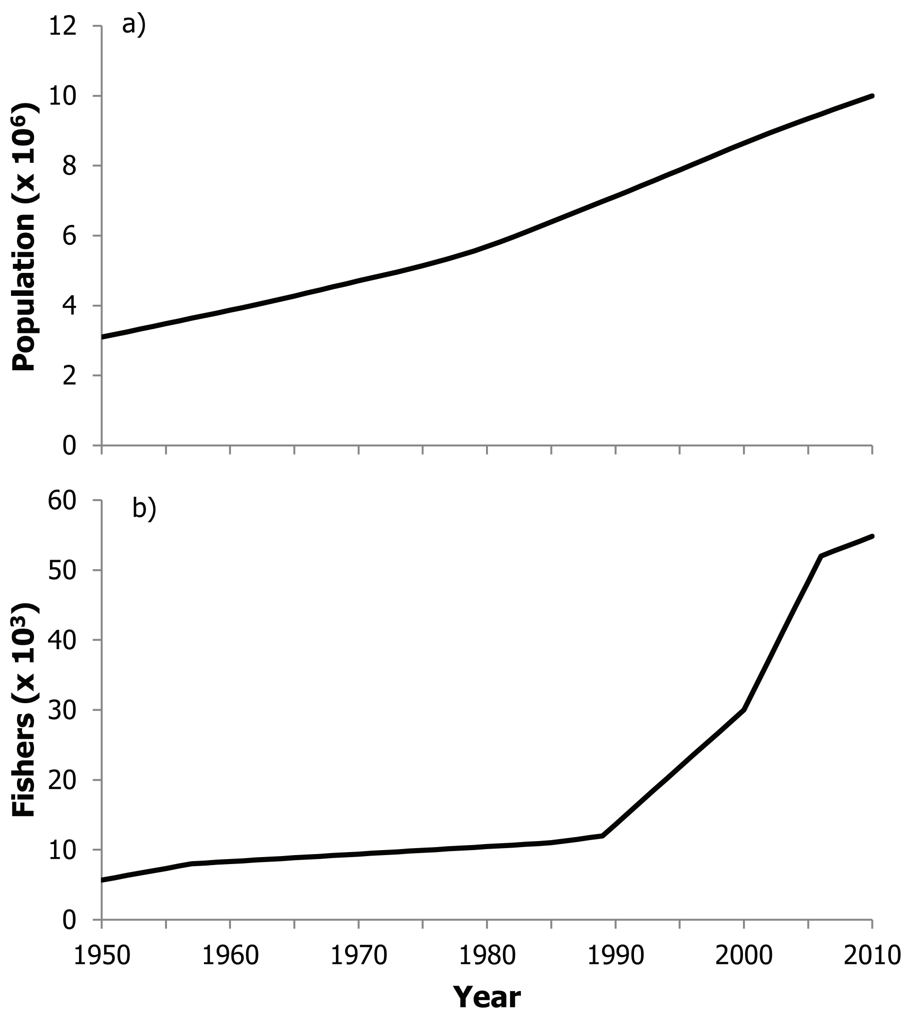

Figure 2. Basic statistics on Haiti: a) Total Haitian population and b) trend in the number of fishers.

Sebrell *et al.* (1959), which cited an average fish intake of 2.92 kg·person^{-1}·year^{-1}. To derive subsistence catch rates, we assumed the consumption reported in Sebrell *et al.* (1959) remained constant over time. Hence we estimated total seafood demand by multiplying annual population numbers by 2.92 kg·person^{-1}·year^{-1}. This generated total demand for seafood, from which available import and aquaculture data were subtracted to arrive at estimated domestic marine catch demand. As import data were highly variable and unreliable, we used this derived marine catch demand as a guide only. From this, we derived an assumed average *per capita* seafood subsistence rate of approximately 1.0 kg·person^{-1}·year^{-1}. However, we also assumed subsistence catch rates were 25% higher in the earlier time period and 25% lower in the later time period. Thus we applied a seafood subsistence rate of 1.25 kg·person^{-1}·year^{-1} in 1950 and 0.75 kg·person^{-1}·year^{-1} in 2010. Interpolating linearly between these two *per capita* domestic marine subsistence rates, and subsequently multiplying by annual population figures, we estimated subsistence catches for Haiti from 1950-2010.

Composition of Haiti's catch

Catches as reported by the FAO on behalf of Haiti are highly aggregated, with just five groups being presented: "Natantian decapods nei", "Stromboid conchs nei", "Caribbean spiny lobster", "Marine crabs nei" and "Marine fishes nei". As detailed quantitative catch data for Haiti and Navassa were not readily available, we used the FAO breakdown in years with the most taxonomic categories as a starting point. Thus we calculated the proportion of total catch by group from 1995 to 2010 (1995 is the first year when all groups have a non-zero value recorded) and applied these proportions throughout the period 1950 to 1995 to the total reconstructed catch. The proportions were as follows: "Natantian decapods nei" (6.5%), "Stromboid conch nei" (5.2%), "Caribbean spiny lobster" (9.3%), "Marine crabs nei" (2.5%) and "Marine fishes nei" (76.5%). For 1995 onwards, we used annual proportions from the FAO dataset and applied these to total reconstructed catches.

For the artisanal sector we assumed 80% reef-demersal taxa, 10% pelagic taxa and 10% miscellaneous marine fishes in 1950. In 2010 we assumed 60% reef-demersal taxa, 30% pelagic taxa and 10% miscellaneous marine fishes, using direct linear interpolation in between. The reef-demersal component was further subdivided using Zacks (1998) while the pelagic taxa component was further subdivided using qualitative information from Prado *et al.* (1991, in Reynal *et al.* 2000) and Zacks (1998). For the subsistence sector, we assumed 20% miscellaneous marine fishes and 80% reef-demersal taxa for the period 1950-2010. Given the preference of Haitian people for delicate fish over "thick or greasy meat" (Zacks 1998) pelagic species are assumed not to form part of these catches. The reef-demersal component was further subdivided using Zacks (1998).

Table 2. Taxonomic breakdown for artisanal sector in Haiti.

Taxa	% in 1950	% in 2010
Ablennes hians	0.32	0.24
Acanthocybium solandri	1.25	3.75
Acanthurus bahianus	0.20	0.15
Caranx ruber	9.49	7.12
Chaetodon capistratus	0.52	0.39
Chaetodon sedentarius	0.20	0.15
Clepticus parrae	27.17	20.38
Conger triporiceps	0.28	0.21
Coryphaena hippurus	1.67	5.00
Decapterus macarellus	1.07	0.80
Epinephelus cruentatus	0.64	0.48
Gymnothorax moringa	0.32	0.24
Haemulon aurolineatum	1.67	1.25
Haemulon flavolineatum	0.52	0.39
Haemulon plumieri	1.47	1.10
Hemiramphus brasiliensis	0.48	0.36
Holocentrus adscensionis	1.55	1.16
Holocentrus rufus	1.51	1.13
Inermia vittata	0.44	0.33
Lactophrys spp.	0.20	0.15
Lutjanus apodus	0.20	0.15
Lutjanus campechanus	2.03	1.52
Lutjanus griseus	0.36	0.27
Makiara nigricans	1.67	5.00
Mulloidichthys martinicus	2.98	2.23
Myripristis jacobus	0.64	0.48
Ocyurus chrysurus	0.52	0.39
Priacanthus cruentatus	1.11	0.83
Pseudopeneus maculatus	1.83	1.37
Rhomboplites aurorubens	0.99	0.74
Scombridae	1.25	3.75
Selar crumenophthalmus	5.56	4.17
Sparisoma aurofrenatum	6.95	5.21
Sparisoma chrysopterum	0.52	0.39
Sparisoma rubripinne	0.24	0.18
Sparisoma viride	2.11	1.58
Sphyraena barracuda	1.25	3.75
Sphyraena picudilla	5.2	3.90
Thunnus spp.	1.25	3.75
Tylosurus crocodilus	0.75	0.57
Xiphias gladius	1.67	5.00
Misc. marine fishes	10.00	10.00

To further disaggregate the "Marine fishes nei" category, we relied on quantitative and qualitative catch data from Zacks (1998) and Prado *et al.* (1991, in Reynal *et al.* 2000). Zacks' (1998) study included an examination of three separate catches from each of ten fishers using multiple traditional gears (bamboo traps, gill nets, hook and line, and spearguns) from June to August 1995 in Luly, Haiti. Prado *et al.* (1991, in Reynal *et al.* 2000) provided details of a pelagic fish aggregating device (FAD) fishery being established in Haiti in the early 1990s, allowing fishers with the means (i.e., motors) to exploit larger coastal pelagic species such as dolphinfish (*Coryphaena hippurus*), blue marlin (*Makaira nigricans*) and sailfish (*Xiphias gladius*). Zacks (1998) also described that fishers targeting sailfish incidentally capture wahoo (*Acanthocybium solandri*), dolphinfish, mackerel (*Scomberemous* spp.), barracuda (*Sphyraena barracuda*) and tunas (*Thunnus* spp.). Hence, the following species breakdown was applied to the pelagic category: blue marlin (16.7%), sailfish (16.7%), dolphinfish (16.7%), wahoo (12.5%), mackerels (12.6), barracuda (12.5%) and tunas (12.5%). The complete species breakdowns for the artisanal and subsistence sectors are shown in Tables 2 and 3, respectively.

Navassa catch levels and composition

Three scenarios of annual landings for fish, lobster and queen conch at Navassa were estimated by Miller *et al.* (2008). Methods included extrapolations of landings observed in on-site visits and stated by fishers working in Navassa in semi-directed group and individual interviews in 2004 and 2005. Their extrapolations were based on number of boat trips to Navassa per year, mean daily boats observed in November 2004 and mean daily boats observed in 2002. Since fish caught in Navassa and landed in Haiti is already processed (head and guts removed), Miller *et al.* (2008) applied FAO conversion factors (2.0 and 2.5) to arrive at a max-min range of fresh whole catches landed annually under the following fishing scenarios: 150 trips, 99 trips and 45 trips. We took the minimum total catch landed and assumed a discard rate of zero (M. Karnauskaus, pers. comm., National Marine Fisheries Service, NOAA), which provided a conservative mean estimate of 31 t·year^{-1}, which we applied each year, beginning in 1970 to reconstruct the minimum fish catches from Navassa Island.

To disaggregate Navassan catches, we utilized Miller *et al.* (2002) enumeration of species caught in fishing boats observed at Navassa Island from October to November 2002 (Table 4). These were converted to weights using the species common weights in Fishbase (www.fishbase.org; accessed January, 2012) and a trap fishing survey of Pedro Bank (Hartsuijker 1982).

Table 3. Taxonomic breakdown for the subsistence sector in Haiti.

Taxa	%
Ablennes hians	0.32
Acanthurus bahianus	0.20
Caranx ruber	9.49
Chaetodon capistratus	0.52
Chaetodon sedentarius	0.20
Clepticus parrae	27.17
Conger triporiceps	0.28
Decapterus macarellus	1.07
Epinephelus cruentatus	0.64
Gymnothorax moringa	0.32
Haemulon aurolineatum	1.67
Haemulon flavolineatum	0.52
Haemulon plumieri	1.47
Hemiramphus brasiliensis	0.48
Holocentrus adscensionis	1.55
Holocentrus rufus	1.51
Inermia vittata	0.44
Lactophrys spp.	0.20
Lutjanus apodus	0.20
Lutjanus campechanus	2.03
Lutjanus griseus	0.36
Mulloidichthys martinicus	2.98
Myripristis jacobus	0.64
Ocyurus chrysurus	0.52
Priacanthus cruentatus	1.11
Pseudopeneus maculatus	1.83
Rhomboplites aurorubens	0.99
Selar crumenophthalmus	5.56
Sparisoma aurofrenatum	6.95
Sparisoma chrysopterum	0.52
Sparisoma rubripinne	0.24
Sparisoma viride	2.11
Sphyraena picudilla	5.20
Tylosurus crocodilus	0.75
Misc. marine fishes	20.00

Results

Haiti artisanal catches

Reconstructed artisanal catches for Haiti totalled 492,273 t, which accounts for 58.1% of the total reconstructed catches for Haiti and Navassa Island (Figure 3a). In 1950, artisanal catches amounted to 2,350 t·year^{-1}, increasing to 7,650 t·year^{-1} in 1976 before stabilizing until 1989. From 1990 onwards, catches increase substantially to a peak of 16,710 t·year^{-1} in 2010. Catches of large pelagic species prior to FAD fishery development (1950-1989) averaged approximately 370 t·year^{-1}, and increased to an average of 1,758 t·year^{-1} from 1990 to 2010 due to FADs.

Haiti subsistence catches

Reconstructed subsistence catches for Haiti increased steadily from 3,871 t·year^{-1} in 1950 to 7,495 t·year^{-1} in 2010 (Figure 3a). Total reconstructed catches from this sector amounted to 353,355 t, which accounts for 41.7% of the total reconstructed catches for Haiti and Navassa Island.

Catch composition

Fisheries catches of Haiti were dominated by reef and demersal species (Figure 3b) such as wrasses (Labridae; 20%) and parrotfish (Scaridae; 7%). Also important were small coastal pelagics, such as jacks (Carangidae; 12%) and southern sennet (*S. picudilla;* 4%). Invertebrate species were also dominant, as is demonstrated by the importance of lobster (Panuliridae; 9%), miscellaneous decapods (6.5%), conch (Strombidae; 5%) and miscellaneous crabs (3%). Large pelagics account for approximately 7% of total catches but are increasing in significance. Pelagic species dominant in FAD catches were blue marlin, dolphinfish, swordfish, wahoo, barracuda and tunas. "Others" comprised 22 families of reef and demersal species including surgeonfish (Acanthuridae), butterflyfish (Chaetodontidae), squirrelfish (Holocentridae), trunkfish (Ostraciidae), eels (Congridae), stingrays (Dasyatidae and Urotrygonidae), sharks (Carcharhinidae), octopus, and sea cucumbers (Holothuroidea), as well as "Marine fishes nei". Reconstructed catches from Navassa Island totalled 1,271 t for the 1970–2010 time period and are included in Figure 3. These catches were dominated by *Sphyraena barracuda* (32%).

Table 4. Taxonomic breakdown for Navassa Island catches. The breakdown was based on Miller *et al.* (2002).

Taxa	%
Balistidae	6.73
Urotrygonidae	3.05
Monacanthidae	6.75
Lutjanidae	5.60
Malacanthidae	0.77
Sphyraenidae	35.15
Holocentridae	0.53
Ostraciidae	25.99
Acanthuridae	4.28
Carangidae	9.00
Scaridae	0.15
Dasyatidae	0.31
Carcharhinidae	1.43
Serranidae	0.26

Total reconstructed catch

Total annual reconstructed landings linearly increased from an average of 6,800 t·year^{-1} in the early 1950s to 12,000 t·year^{-1} in the early 1970s, and then stabilized at an average of 13,100 t·year^{-1} from the mid-1970s to 1990 (Figure 3a). From there catches increased again up to their peak in 2010 of 24,236 t·year^{-1}. This trend differs from the data presented by FAO on behalf of Haiti. Landings increased to a peak in the mid-1980s, where they then decreased in to the mid-1990s and increased again to a new high in 2004 and stayed constant until 2010 (Figure 3a). The reconstructed total catch for Haiti and Navassa for the period 1950-2010 was estimated at 846,900 t, which is approximately 3 times the catch supplied to the FAO by Haiti (Figure 3a).

Discussion

Haiti and Navassa Island's total catches from 1950-2010, as estimated in our reconstruction, were approximately 846,900 t. Over the same period, FAO reported landings of 280,272 t on behalf of Haiti. The reconstructed catch is 3 times the total landings as supplied to the FAO. Our reconstruction does three things: it assesses fisheries sectors that have been overlooked, including Navassa Island fisheries and a sizeable subsistence fishery, it improves on what has been reported for the artisanal sector by filling in catches of invertebrates for a time period when catches were wrongly recorded as zero, and it improves the taxonomic resolution of the catch.

Catches from the subsistence sector, contributing 41.7% to the overall fisheries reconstruction for Haiti, were the largest contributor to the difference in reported catches and reconstructed catches. Haitian fisheries are demonstrating some of the symptoms of Malthusian overfishing (Pauly 1994): the population of fishers increased by a factor of 2.5 in the decade 1990 to 2000, and CPUEs fell by 60% from 1976 to 2005. Uncontrolled population growth has placed considerable pressure on Haiti's resources, and this pressure is rapidly being transferred to the sea. With several recommendations pointing to further investment in exploiting offshore FAD fisheries (Mateo and Haughton 2003; MARNDR 2009; Damais *et al.* 2007), the likely response will be larger and more powerful boats fishing further offshore as described by Pauly and Froese (2001). Due to high demand, Haiti relies heavily on imported seafood. However, a significant portion of seafood demand is still being satisfied by domestic catches. Of these catches, only those from the artisanal sector are partially being recorded and hence reported to the FAO. This is demonstrated by the similarity of FAO landings data in 1950 to our reconstructed catches from the artisanal sector. Given the high likelihood that Haiti, at least in recent times, is one the countries that fails to report their catches to FAO (Garibaldi 2012), it is likely that FAO utilises an expert estimate only. This is also reflected in the very limited taxonomic accounts in official data.

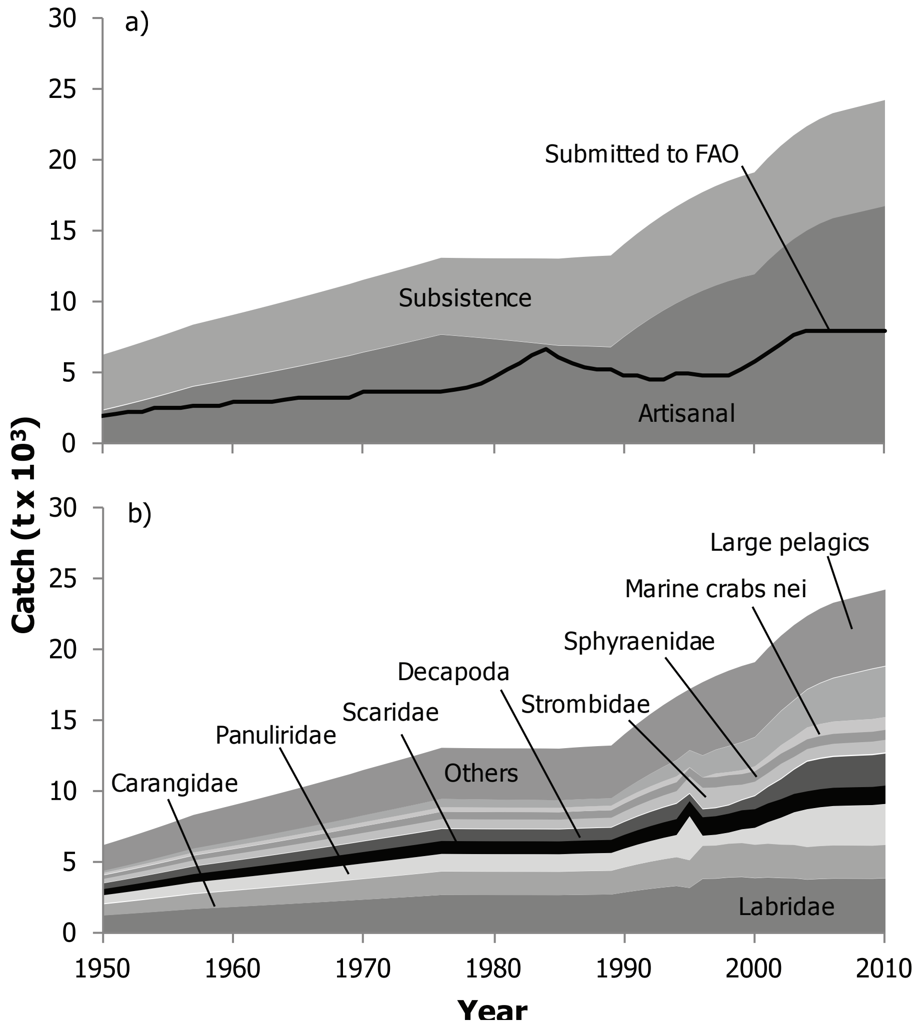

Figure 3. a) Total reconstructed catches for Haiti and Navassa Island by sector, compared to data reported to the FAO from 1950 to 2010. b) Total reconstructed catches for Haiti and Navassa Island by main taxa caught. 'Others' category comprised 20 taxa of reef and demersal fish.

While our approach requires assumption-based inferences and interpolations, we believe that our estimate reflects more correctly the likely scale of actual catches than does reported data (Zeller *et al.* 2007). The people of Haiti depend on fisheries, both as a vital source of protein and as a livelihood. As it stands, they are degrading the very system which supports them. Haiti reports about a third of what is being removed from its waters. Better accounting of fisheries extractions by the subsistence sector is urgently needed to better understand total resource use. Given the difficulties in fisheries monitoring, especially subsistence fisheries, this can be best achieved through regular, albeit non-annual, surveys (Zeller *et al.* 2007).

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Appendix Table A1. FAO landings vs. total reconstructed catch (in tonnes), by sector, for Haiti and Navassa Island, 1950-2010.

Year	FAO landings	Total reconstructed catch	Subsistence	Artisanal
1950	2,000	6,220	3,870	2,350
1951	2,100	6,510	3,940	2,560
1952	2,200	6,800	4,010	2,790
1953	2,200	7,100	4,080	3,020
1954	2,500	7,400	4,140	3,260
1955	2,500	7,720	4,210	3,510
1956	2,500	8,040	4,270	3,770
1957	2,700	8,370	4,330	4,040
1958	2,700	8,590	4,390	4,200
1959	2,700	8,820	4,450	4,370
1960	2,900	9,050	4,510	4,540
1961	2,900	9,280	4,570	4,710
1962	2,900	9,510	4,630	4,880
1963	3,000	9,750	4,690	5,060
1964	3,100	9,990	4,750	5,240
1965	3,200	10,240	4,810	5,430
1966	3,200	10,480	4,870	5,620
1967	3,300	10,740	4,930	5,810
1968	3,300	10,990	4,990	6,000
1969	3,300	11,240	5,050	6,200
1970	3,700	11,530	5,100	6,430
1971	3,700	11,780	5,150	6,630
1972	3,700	12,040	5,200	6,830
1973	3,700	12,290	5,250	7,040
1974	3,700	12,550	5,300	7,250
1975	3,700	12,820	5,360	7,460
1976	3,700	13,090	5,410	7,680
1977	3,850	13,080	5,470	7,610
1978	4,000	13,070	5,540	7,530
1979	4,200	13,060	5,610	7,450
1980	4,700	13,060	5,690	7,370
1981	5,200	13,050	5,770	7,280
1982	5,700	13,050	5,860	7,190
1983	6,200	13,050	5,950	7,100
1984	6,600	13,050	6,040	7,010
1985	6,100	13,040	6,130	6,910
1986	5,700	13,100	6,210	6,890
1987	5,450	13,160	6,300	6,870
1988	5,200	13,210	6,380	6,840
1989	5,200	13,250	6,450	6,800
1990	4,800	14,050	6,530	7,510
1991	4,800	14,790	6,610	8,180
1992	4,500	15,480	6,680	8,790
1993	4,550	16,110	6,750	9,360
1994	5,000	16,700	6,820	9,880
1995	5,017	17,230	6,890	10,340
1996	4,745	17,720	6,960	10,760
1997	4,801	18,150	7,030	11,120
1998	4,759	18,530	7,090	11,440
1999	5,300	18,850	7,150	11,700
2000	5,800	19,120	7,200	11,920
2001	6,400	20,110	7,250	12,860
2002	7,000	20,980	7,300	13,690
2003	7,600	21,740	7,340	14,400
2004	8,000	22,380	7,370	15,010
2005	8,000	22,900	7,400	15,500
2006	8,000	23,310	7,430	15,880
2007	8,000	23,540	7,450	16,100
2008	8,000	23,780	7,460	16,310
2009	8,000	24,010	7,480	16,520
2010	8,000	24,240	7,490	16,740

Appendix Table A2. Total reconstructed catch (in tonnes) for Haiti and Navassa Island by major taxa, 1950-2010.

Year	Labridae	Carangidae	Panuliridae	Scaridae	Decapods	Strombidae	Sphyraenidae	Brachyura	Large Pelagics	Others[1]
1950	1,290	767	580	467	405	322	248	156	180	1,800
1951	1,350	802	607	488	424	337	259	163	196	1,880
1952	1,410	839	634	510	443	352	271	170	213	1,950
1953	1,470	875	662	533	462	367	282	178	231	2,030
1954	1,540	913	691	556	482	383	295	185	249	2,110
1955	1,600	952	720	579	503	400	307	193	269	2,190
1956	1,670	992	750	603	523	416	320	201	288	2,280
1957	1,740	1,032	780	628	545	433	333	210	309	2,360
1958	1,790	1,060	801	645	560	445	342	215	321	2,420
1959	1,830	1,088	823	662	574	457	351	221	334	2,480
1960	1,880	1,116	844	679	589	468	360	227	347	2,540
1961	1,930	1,144	865	696	604	480	369	232	360	2,600
1962	1,980	1,173	887	714	619	492	379	238	374	2,660
1963	2,030	1,203	909	732	635	505	388	244	387	2,720
1964	2,080	1,232	932	750	651	517	398	250	401	2,780
1965	2,130	1,263	955	768	666	530	407	256	415	2,850
1966	2,180	1,293	978	787	683	543	417	263	430	2,910
1967	2,230	1,324	1,001	806	699	556	427	269	444	2,980
1968	2,280	1,355	1,025	825	716	569	437	275	459	3,040
1969	2,340	1,387	1,049	844	732	582	447	282	474	3,110
1970	2,390	1,421	1,074	863	749	596	458	288	499	3,190
1971	2,440	1,452	1,097	882	765	610	468	294	514	3,260
1972	2,490	1,483	1,121	901	782	623	478	301	530	3,320
1973	2,550	1,515	1,145	920	798	636	488	307	546	3,390
1974	2,600	1,547	1,169	940	815	649	498	314	562	3,460
1975	2,660	1,580	1,194	960	833	663	509	320	578	3,520
1976	2,710	1,614	1,220	980	851	678	520	327	595	3,600
1977	2,710	1,612	1,219	979	850	677	519	327	589	3,600
1978	2,710	1,611	1,218	979	849	676	519	327	584	3,600
1979	2,710	1,610	1,217	978	849	676	519	326	578	3,600
1980	2,710	1,609	1,216	978	848	676	518	326	571	3,610
1981	2,710	1,609	1,216	977	848	675	518	326	565	3,610
1982	2,710	1,609	1,216	977	848	675	518	326	558	3,620
1983	2,710	1,608	1,216	977	848	675	518	326	551	3,630
1984	2,700	1,608	1,215	977	847	675	518	326	543	3,630
1985	2,700	1,607	1,214	976	847	674	518	326	536	3,640
1986	2,720	1,615	1,221	981	851	678	520	327	535	3,660
1987	2,730	1,622	1,226	986	855	681	523	329	533	3,680
1988	2,740	1,629	1,231	989	858	684	525	330	531	3,700
1989	2,750	1,633	1,235	992	861	686	526	331	528	3,710
1990	2,890	1,720	1,308	1,045	913	727	554	351	640	3,900
1991	3,020	1,797	1,377	1,092	961	765	579	369	758	4,060
1992	3,140	1,867	1,442	1,134	1,006	801	602	387	881	4,220
1993	3,240	1,929	1,501	1,172	1,047	834	621	403	1,009	4,350
1994	3,340	1,983	1,556	1,205	1,085	864	639	417	1,139	4,480
1995	3,200	1,904	3,087	1,157	514	1,201	613	58	1,194	4,300
1996	3,840	2,279	710	1,385	559	1,492	735	19	1,547	5,160
1997	3,850	2,288	756	1,390	566	1,435	737	268	1,673	5,180
1998	3,930	2,336	779	1,420	583	1,362	753	229	1,832	5,300
1999	3,960	2,354	960	1,430	710	1,067	759	284	1,970	5,360
2000	3,880	2,308	1,187	1,403	922	989	744	362	2,055	5,270
2001	3,930	2,336	1,508	1,420	1,161	943	753	471	2,259	5,330
2002	3,890	2,312	1,887	1,405	1,407	1,049	745	599	2,411	5,280
2003	3,880	2,304	2,287	1,400	1,714	858	742	714	2,574	5,270
2004	3,780	2,248	2,655	1,366	2,095	839	724	838	2,678	5,150
2005	3,830	2,275	2,717	1,382	2,144	859	733	858	2,876	5,230
2006	3,850	2,290	2,765	1,392	2,182	874	738	873	3,059	5,280
2007	3,850	2,289	2,794	1,391	2,204	883	738	882	3,215	5,300
2008	3,850	2,287	2,821	1,390	2,226	892	737	890	3,374	5,310
2009	3,840	2,284	2,848	1,388	2,248	900	736	899	3,536	5,320
2010	3,880	2,304	2,876	1,400	2,269	909	743	908	3,582	5,370

[1] Others category includes 22 additional families.