Benin's fisheries: a catch reconstruction, 1950-2010[1]

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Abstract

Total marine fisheries catches from the Exclusive Economic Zone of Benin and its coastal lagoons were estimated between 1950 and 2010. The reconstruction considered artisanal and industrial sectors and their discards, subsistence fisheries from the marine and lagoon waters including those generated by women for the first time. Small-scale catch estimates were obtained using catch per unit of effort and per capita catch estimates alongside with the number of fishers and the number of pirogues, while industrial catches were estimated by country using the number of industrial vessels and their catch per unit of effort. Total catches were estimated at 4.0 million t between 1950 and 2010 of which 3.9 million t were domestic (and mainly from lagoon areas) compared to 1.7 million t of catch data supplied to the FAO. Catches showed a decreasing pattern in contrast to the increase observed in official data, which puts in jeopardy the livelihoods of the many fishers relying solely on fisheries.

Introduction

Benin (capital city; Cotonou, 6°28′N 2°36'E) is a small country of Central West Africa with a coast on the Gulf of Guinea, one of the smallest coastlines of Africa (the Gulf of Benin). The country is bordered by Nigeria on the East, Niger and Burkina Faso on the North and Togo on the West.

Historically, Benin held a major role in the slave trade, and hence its previous name of 'Slaves Coast', following the European colonial habit of naming areas of Africa after their major resources, such as the "Pepper Coast" for Côte d'Ivoire (itself another resource name, ivory), or the "Gold Coast" for Ghana (Bouche 1885). The country, known as Dahomey during the French colonization and shortly after independence in 1960, went through a period of political unrest and a major coup d'état in 1972, which triggered the establishment of a Marxist regime. The newly formed government renamed the country the People's Republic of Benin and started a multitude of politically driven initiatives such as nationalization of industries, and taking nuclear waste from the former Soviet Union and France. Ill-founded policies, conflicts and a badly managed economy governed under the "poverty is not fatality" motto contributed to Benin acquiring the reputation of being the "sick child of Africa" (Atti-Mama 1998).

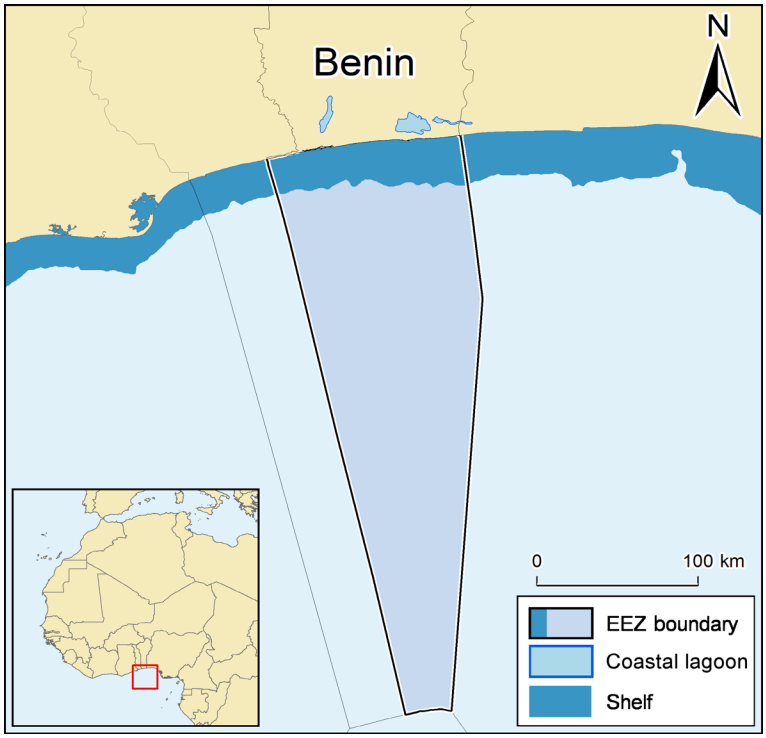

Figure 1. Map of Benin with Exclusive Economic Zone (EEZ).

The availability of fisheries resources within Benin's many lagoons and coastal areas contributed to the importance of this industry as it is the second major source of employment for coastal populations following agriculture (Bouche 1885). Benin has a well-established tradition of fishing as fish was then caught for personal consumption (Bouche 1885).

The absence of major upwelling phenomenon in Benin inshore waters (Djiman 1996; FAO 2007), the short coastline and the large size of the estuarine systems drove the growth of Benin's mostly lagoon-based fisheries, which are small-scale, largely subsistence operations conducted from small canoes. Artisanal and industrial marine fisheries operate in Benin's waters only since the early 1950s. They include small pelagic fisheries, operated by Fanti type pirogues and pelagic trawlers, cephalopod fisheries by industrial vessels flagged to Benin which land their catches in Benin, a demersal fish sector operated either by industrial trawlers reflagged to Benin or artisanal boats which land their catches in Benin (Senouvo 1990b; Chaboud and Charles-Dominique 1991; Ecoutin *et al.* 1993), and a shark fishery (Anon. 2010).

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Although new fisheries regulations were introduced in the 1990s, they faced serious challenges in effectively regulating these fisheries sectors, particularly in the face of the well-established implemented traditional system such as the one found in lagoons (Stoop *et al.* 2013).

Traditional systems of fisheries management built around animist beliefs ('*Voodoo*') were efficient in the past as fishers adhered to fishing rules, as they were those of their own villages and/or communities. For example, violation of fisheries regulations set up by villages was considered a sacrilege and therefore an animal sacrifice was required at the cost of the offender (Iroko 2005). Voodoo sanctions ranged from fines and confiscation of fishing gear to public flagellation and even death sentences (Briones Alonso *et al.* 2013). Measures to prevent overfishing or to allow fish to multiply went from prohibiting breastfeeding women and women having their periods to approach the water (Iroko 2005) to 'quotas'. Interestingly in Benin, even today, these quotas, i.e., definite quantities of fish to be taken, as set by villages, are traditionally defined by the customs of the two ethnic groups Houedah and the Xwlâ, exist. Although they have no scientific basis, and are based exclusively on tradition, they are believed to be efficient. Some other measures included fishing bans, release of bycatch and a feast day for the deities of the sea, when fishing was forbidden (Vogt *et al.* 2010). These rules are now slowly disappearing from among young fishers (Vogt *et al.* 2010) and destructive fishing techniques are increasingly used as the traditional system loses power to 'modern', but ineffective systems. Ironically, as noted by Vogt *et al.* (2010), while artisanal fishers observe strict rules, the 'deities' of the sea, a.k.a., illegal fishing vessels, are feasting upon the fish which small-scale fishers allow to rest, which creates more conflicts between the small-scale sector and the industrial sector.

Benin lacks the capacity to monitor its fisheries effort and catches, which often results in a lack of data and a lack of scientific knowledge leading to inadequate management (FAO 2007). However, data wise, the sampling techniques that were used were described as "efficient"–at least in the past for part of the fishing industry, at the dawn of FAO development projects in the 1970s (FAO 2007). On the other hand, some authors argue that large fractions of the catch were never registered, and that those that were recorded are unreliable. Furthermore "it has to be noted that even the national fishing authority does not have data on fishing quantities at its disposal." (Vogt *et al.* 2010). For example, industrial catches are unreliable as the FAO data for the industrial sector was in the past significantly higher than the national data presented by the Direction de Programmation et de Prospective (DPP), the latter likely being under-estimated given the high number of trawlers (Vogt *et al.* 2010).

Fisheries in Benin shifted from a time of abundance, waste and carelessness when "dried fish was even used to replace the cattle cake normally used in making fire" (Iroko 2005), to fisheries depletion, social disparities created by the use of 'acadja' systems (see below), as early as the 1960s (Iroko 2005) and raising conflicts with the industrial marine fleet, which ultimately led to piracy.

Herein, we reconstruct Benin marine and lagoon fisheries catches to have a realistic idea of total fisheries removals from Benin in contrast to officially ill-documented data.

Methods

Data on fisheries landings are collected and compiled by the Centre de Recherche Halieutique et Océanographique du Benin (Fisheries and Oceanographic Research Centre of Benin, CRHOB); these are then submitted to the Fisheries Directorate. Monitoring of marine artisanal fisheries is based on ARTFISH stratified sampling technique, which was introduced by FAO in 1976 at the launch of the Technical Cooperation Programme (TCP). Between 1987 and 2002, the Fisheries Directorate counted daily the number of dugout canoes in the port of Cotonou. Monitoring decreased after 2003 for economic reasons. One of the particularities of Benin however, is that marine fishers were actively involved in data collection as they received a financial compensation from the Fisheries Directorate for their work. The program stopped in 2007 and fisheries monitoring shrunk again to cover only the Port of Cotonou (FAO 2007). The industrial fleet is dominated by foreign vessels, notably bottom trawlers, onboard of which no observers were taken. Similarly, there is hardly any control on the mesh size or the fishing grounds of these fleets (FAO 2007).

Herein we reconstruct total catches from Benin EEZ for the artisanal marine and lagoon sectors notably catches taken by acadja systems, subsistence fisheries catches, domestic and industrial foreign catches and their discards (including legal and illegal sectors).

Coastal population

Coastal population, i.e., rural and urban population living within the 10 km strip of the coast was given for 1990, 2000 and 2010 (CIESIN 2012). We extracted total population estimates from the WorldBank database (www.worldbank.org) from 1960 to 2010, and completed these using data from www.populstat.com from 1950 to 1960. We divided the coastal population estimate for 1990 by the total population estimate for the same year and obtained a percentage of coastal population for 1990. We assumed this percentage was constant between 1950 and 1990 and multiplied it by the total population for the same time period to obtain coastal population of Benin between 1950 and 1989. We interpolated between coastal population estimates between 1990 and 2010 to fill in the gaps (Figure 2).

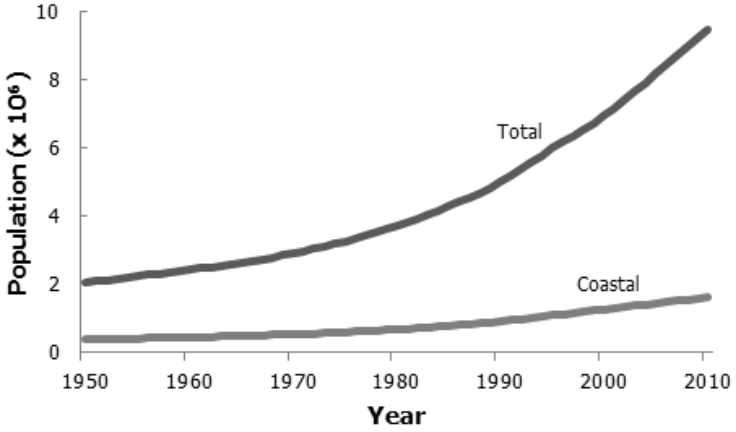

Figure 2. Total and coastal population of Benin, 1950-2010.

Artisanal catches

Although artisanal catches in Benin are relatively unknown, they seem to be important particularly in the lagoons (Boëly and Fréon 1979). Data are often referred to as "patchy" which is explained by the fact that to the 80 landing sites are difficult to monitor properly (Turay and Verstralen 1997).

Marine catches

To reconstruct artisanal marine catches, we multipled the catch per unit of effort by the effort (number of pirogues). Literature documented the number of marine pirogues for a certain number of years for the years 1983, 1985, 1986, 1987, 1988, 1992, 1993, 1994, 1997 and 1999 (Senouvo 1990a, 1990b; Ssentongo 1990; Gbaguidi and Meyizoun 1994; Horemans and Jallow 1997; Turay and Verstralen 1997; FAO 2007) and the number of marine fishers for the early 1980, 1983, 1992, 1993, 1994, 1997, 1999 and 2010 (Chaboud and Charles-Dominique 1991; Ecoutin *et al.* 1993; Horemans 1994; Horemans and Jallow 1997; Turay and Verstralen 1997; FAO 2007; Njock and Westlund 2010; Dessouassi 2011) (Table 1). We estimated the number of pirogues for 1980 by multiplying the number of fishers (2,500) by the number of fishers per pirogue obtained from the first available anchor point documenting both the number of pirogues and the number of fishers, i.e., around 5 fishers per pirogue in 1983. The total number of coastal fishers (lagoon and marine) was estimated at 15,300 for 1960 (Anon. 1964), thus to estimate the number of marine artisanal fishers among these, we first obtained the number of lagoon fishers using the ratio lagoon fishers estimated at 11,000 (Lemasson 1961): Coastal population for 1955 (Figure 2), i.e., 3%, multiplied by the coastal population for 1960 and obtained a number of lagoon fishers of 11,939 for 1960. The difference between the total number of coastal fishers and lagoon fishers is the number of artisanal marine fishers for 1960, i.e., 3,361 for 639 pirogues (assuming 5 fishers per pirogue). Similarly, we obtained the total number of coastal fishers as 4% of the coastal population within the primary sector (80% of the coastal population) as documented by Anon. (1964) for 1950, i.e., 11,925 fishers. We then estimated the number of lagoon fishers for 1950 at 10,061 using the proportion of lagoon fishers for 1955, i.e., 11,000 (Lemasson 1961) over the coastal population for 1955, then multiplied by the coastal population for 1950. We then estimated marine artisanal fishers by subtracting the number of lagoon fishers from the total estimated for 1950 (Table 1), which was then divided by 5 to estimate the number of pirogues. We interpolated to fill in the gaps.

Table 1. Artisanal fishing effort in the marine waters of Benin and its lagoons. Italics indicate interpolations.

	Marine effort			Lagoons fishers		
Year	Pirogues	Fishers	Source	Total	Sources	Using acadjas
1950	354	1,864	Estimated	10,061	Estimated	2,515
1955	*496*	*2,613*		11,000	Lemasson (1961)	2,750
1956	*525*	*2,762*		11,000	Lemasson (1961)	2,750
1957	*553*	*2,912*		11,000	Lemasson (1961)	2,750
1958	*582*	*3,062*		10,000	Buffe (1958)	2,500
1960	639	3,361	Estimated	14,455		3,614
1969	*565*	*2,974*		34,500	Welcomme 2003	8,625
1977	*500*	*2,629*		38,300	Dioury 1983	7,295
1980	475	2,500	Estimated based on the number of fishers (Chaboud and Charles-Dominique 1991)	38,545		7,686
1987	*477*	*4,000*		39,117	Turay and Verstralen (1997)	8,615
1988	*654*	*3,840*		42,619	Turay and Verstralen (1997)	9,513
1989	*657*	3,680		45,292	Turay and Verstralen (1997)	10,245
1990	*660*	*3,520*		50,284	Turay and Verstralen (1997)	11,523
1991	*662*	*3,360*		50,470	Turay and Verstralen (1997)	11,716
1992	665	3,200	Horemans (1994)	47,672	Turay and Verstralen (1997)	11,209
1993	731	3,237	Horemans and Jallow (1997)	50,014	Turay and Verstralen (1997)	11,908
1994	731	3,237	Horemans and Jallow (1997)	48,874	Turay and Verstralen (1997)	11,782
1995	*786*	*3,357*		48,895	Turay and Verstralen (1997)	11,933
1996	840	3,476	Turay and Verstralen (1997)	48,947		12,091
1997	840	3,596	Turay and Verstralen (1997)	49,000	Turay and Verstralen (1997)	12,250
1999	816	4,345	FAO (2007)	52,600		13,150
2002	*804*	*4,524*		58,000	FAO (2007)	14,500
2003	800	4,583	Njock and Westlund (2010)	57,949		14,487
2006	*860*	*4,762*		57,796	Ahouandjogbe *et al.* (2013)	14,449
2009	*919*	*4,940*		58,000	Anon. (2010)	14,500
2010	939	5,000	Estimated based on the number of fishers (Dessouassi 2011)	59,217		14,804
2012				61,650	Ahouandjogbe *et al.* (2013)	

Surveyed catches by gear type and the number of artisanal boats were obtained from Turay and Verstralen (1997) for 1995 and 1996, which were used to calculate an average CPUE of 14.26 t·pirogue^{-1}·year^{-1} for 1995 and 1996. Given the over-exploitation pattern (Stoop *et al.* 2013), we assumed this CPUE was slightly higher (10%) in 1950, and lower in 2010 (10%). We interpolated and then multiplied the estimated number of pirogues by the CPUE.

Lagoon catches

Non-*acadja* catches

There are three main lagoons in Benin, Porto Novo, Lake Aheme and Lake Nokoué, which in contrast to what their names suggest, are two of the most important lagoon systems in Benin. Literature suggests Benin lagoons contribute the most to artisanal fisheries in the country (Iroko 2005; FAO 2007). Data on the number of artisanal fishers were available and completed by a series of linear interpolations (Table 1). Some of these fishers use acadjas, i.e., "artificial systems aimed at enhancing fish production by providing additional substrata for development of plants and animals upon which the fish will feed" (Niyonkuru and Lalèyè 2010), to aggregate, then catch fish. Since these systems are well documented, we reconstructed their catches separately. We first estimated the number of fishers not using acadjas by subtracting the number of those using acadjas from the total number of artisanal lagoon fishers. We obtained the proportion of fishers using acadjas over total lagoon fishers by dividing the number of fishers using this technique for Lake Aheme and Porto-Novo Lagoon (3,500) by the total number of fishers provided for both lagoons for 1997 (14,025), i.e., 25% (Turay and Verstralen 1997; SOFRECO 2002). Given that acadjas are mainly on inheritance basis and new entries are restricted (Vogt *et al.* 2010), we assumed the rate remained constant over time except for the time when the acadjas were prohibited in Lake Aheme between 1970 and 1976. Thus, we assumed the proportion of acadja fishers over total number of fishers for 1976 was 25% lower than that of 1997, i.e., 9%. We assumed this proportion was 25% between 1950 and 1970, when acadjas were prohibited in Lake Aheme, interpolated to 9% in 1976, and then interpolated to 25% in 1997, kept constant thereafter. We multiplied these rates by the total number of lagoon fishers (Table 1) and then subtracted the result from the total number of lagoon fishers to obtain the number of lagoon fishers not using acadjas (Table 1).

We estimated the CPUE using the total non-acadja observed catch divided by the number of fishers for 1960, i.e., 22,500 t by 11,000 fishers (Lemasson 1961), and we assumed that this CPUE was constant between 1950 and 1960. We divided the CPUE by 2 for 1983 (Dioury 1983). Similarly, we estimated the CPUE based on catch and effort data by Turay and Verstralen (1997) at 1.1 $t \cdot fisher^{-1} \cdot year^{-1}$. Ahouandjogbe *et al.* (2013) surveyed lagoon catches per trip, the number of trips and the number of pirogues by lagoon in Benin for 2012, which allowed to estimate a weighted average CPUE for all coastal lagoons, and excluded 25% of it as being taken by acadjas, i.e., 1.65 $t \cdot pirogue^{-1} \cdot year^{-1}$ or 1.2 $t \cdot fisher^{-1} \cdot year^{-1}$ (with 1.37 fishers per pirogue). Pérez-Ruzafa and Marcos (2012) estimated a lower CPUE of 0.99 $t \cdot fisher^{-1} \cdot year^{-1}$ for the same year, of which we removed 25% as taken from acadja systems and obtained 0.74 $t \cdot fisher^{-1} \cdot year^{-1}$. We averaged the previous CPUE estimates and obtained 0.98 $t \cdot fisher^{-1} \cdot year^{-1}$ for 2012. Anon. (2010) documented that the CPUE declined by a third during the last 20 years. Therefore, we assumed the CPUE in 1989 was 33% higher than the CPUE in 2012, i.e., 1.3 $t \cdot fisher^{-1} \cdot year^{-1}$. These declines of CPUE are illustrated throughout the literature and surveys, where catches per trip and fish sizes were declining (Atti-Mama 1998; Niyonkuru and Lalèyè 2010), and fish stocks decreasing (Stoop *et al.* 2013) in lagoons which were previously known to be abundant in fish (Bouche 1885). We interpolated between the CPUE estimates and multiplied the resulting annual values by the estimated number of fishers to obtain lagoon non-acadja catches.

Acadja catches

Acadjas were introduced in Benin through Lake Nokoué and Porto Novo lagoons in the beginning of the 20th century (Lalèyè 2000). They quickly became an effective way of aggregating and catching large amounts of wild fish within lagoons. However, this technique is controversial since it tends to aggregate wild fish otherwise caught by non-acadja users. Furthermore, the area occupied by acadjas is often high enough, i.e., 35% of Lake Nokoué for example, to produce spatial conflicts (Niyonkuru and Lalèyè 2010). These conflicts and inequalities have led to a moratorium in 1970 in Aheme lagoon (Weigel 1985; Dangbégnon 2000; Cofad and Gut 2002). The total surface area of acadjas was estimated at 433 ha in 1959 (Welcomme 1972), 156 ha after the prohibition in 1970 (Welcomme 1972) and at 6,691 ha for 1996 (Gbaguidi and Djanato 1997). We estimated the surface areas of acadjas for 1950 at 414 ha (by estimating the surface area per fisher for 1959 obtained by dividing the surface area by the estimated number of acadja fishers; Table 1). We applied the same method to estimate the surface area between 1960 and 1969, prior to the prohibition acadjas in Lake Aheme and assumed the surface area was constant between 1971 and 1976 because of the prohibition in place. We estimated the surface area of acadjas for 2010 by dividing the surface area for 1996 by the number of fishers for the same year, then multiplying the resulting rate by the number of acadja fishers for 2010 and obtained a surface area of 8,192 ha for 2010. We interpolated between the estimates to fill in the gaps.

Catches per hectare were obtained from Buffe (1958) for the period between 1955 and 1958, Welcomme (1972) for 1959 and 1970 and Lalèyè (2000) for 1980 and 1998. We also estimated the CPUE for 1994 based on the survey by Anon. (1994) estimating the catch for 12 ha of different acadjas, over 93 fishing days and 33 fishers, at 13.8 $kg \cdot ha^{-1} \cdot day\text{-}1$, i.e., 4.14 $kg \cdot ha^{-1} \cdot year^{-1}$ assuming 300 fishing days. We assumed the CPUE was constant between 1950 and 1955 and that it declined by 10% between 1998 and 2010 to account for overexploitation despite an increase in catches since 1976 (Ajao 1999). We interpolated between the CPUE estimates and multiplied them by the surface area of acadjas to obtain total artisanal acadja catch.

Subsistence catches

Acadja catches

Acadja catches per trip were surveyed by Anon. (1994) and accounted for commercial catches, consumption, donations and stolen fish. These would not be landed and therefore not accounted for in artisanal catches or surveys targeting artisanal catches. Consumption (including personal consumption, donations and stolen fish) was estimated at 1.5 kg·fisher^{-1}·day^{-1}, i.e., 451 kg·fisher^{-1}·year^{-1} for 1994. We assumed this consumption was 20% higher between 1950 and 1969 prior to the prohibition of acadjas in Lake Aheme. Given evidence of a decrease of retained catches for personal consumption (Vogt *et al.* 2010), we assumed consumption in 2010 was 15% lower than that of 1994. Similarly, we assumed consumption during the acadja prohibition period (between 1970 and 1976) was 15% lower than in 1994. We interpolated and multiplied the estimated consumption by the number of fishers using acadjas.

Other marine and lagoon subsistence catches

Subsistence marine catches were estimated as the equivalent of 17% of artisanal catches for 2010, part of which is the taken home portion of the artisanal catch (Vogt *et al.* 2010), i.e., 1,939 t·year^{-1} for 2010. This converts into a consumption rate of around 48 kg·capita^{-1}·year^{-1} for fishers and their households of 8 members (Ijff and Tempelman 1990). For 1990, Ijff and Tempelman (1990) estimated a consumption from subsistence fishing of 54 kg·capita^{-1}·year^{-1} which, when multiplied by the number of fishers and their households, provides a subsistence catch of 1,521 t·year^{-1} for 1990. Given the evidence of declining subsistence consumption (Vogt *et al.* 2010), we extrapolated the previous consumption rates per capita backwards and estimated a consumption rate of 65.1 kg·capita^{-1}·year^{-1} for 1950, i.e., 970 t·year^{-1} when multiplied by the number of marine artisanal fishers and their household in 1950. We then interpolated linearly between the three anchor points and estimated marine subsistence catches.

We applied the same method for lagoon non-acadja subsistence catches, where for 2010 the equivalent of 17% of artisanal catches were for subsistence (Vogt *et al.* 2010), i.e., 7,476 t·year^{-1} or 21.04 kg·capita^{-1}·year^{-1}, and for 1990, a consumption rate of 38.33 kg·capita^{-1}·year^{-1} was estimated (Ijff and Tempelman 1990), i.e., a catch of 11,884 t·year^{-1}. We extrapolated the previous consumption rates backwards and estimated a consumption rate of around 73 kg·capita^{-1}·year^{-1} for 1950, i.e., 4,401 t·year^{-1}. We interpolated linearly lagoon non-acadja subsistence catches.

Table 2. Reconstructed number of industrial fishing vessel operating in Benin per country (Dioury 1983; Ssentongo 1990; Turay and Verstralen 1997; SOFRECO 2002; Anon. 2010). Interpolations are indicated in italics.

Year	Total	Benin	Nigeria	Cameroon	Sudan	Greece	China	Spain	France	Italy	Portugal
1950-1957	-	-	-	-	-	-	-	-	-	-	-
1958	1	-	-	-	-	-	-	-	-	1	-
1959	1	-	-	-	-	-	-	-	-	1	-
1960	2	-	-	-	-	-	-	-	-	1	1
1961	2	-	-	-	-	-	-	-	1	1	-
1962	2	-	-	-	-	-	-	-	1	1	-
1963	3	-	-	-	-	-	-	-	1	1	1
1964	6	-	-	-	-	1	-	-	1	2	2
1965	6	-	-	-	-	1	-	-	1	2	2
1966	5	-	-	-	-	1	-	-	1	2	1
1967	7	1	-	-	-	1	-	-	2	2	1
1968	7	1	-	-	-	1	-	-	2	2	1
1969	7	1	-	-	-	1	-	-	2	2	1
1970	9	2	-	-	-	1	-	-	3	2	1
1971	11	2	-	-	-	1	-	-	3	3	2
1972	12	3	-	-	-	1	-	-	3	3	2
1973	11	2	-	-	-	1	-	-	3	3	2
1974	19	3	-	-	-	1	-	-	10	3	2
1975	8	2	-	-	-	1	-	-	2	2	1
1976	6	2	-	-	-	1	-	-	2	1	-
1977	6	2	-	-	-	1	-	-	2	1	-
1978	4	1	-	-	-	1	-	-	1	1	-
1979	4	1	-	-	-	1	-	-	1	1	-
1980	16	3	1	1	1	1	-	1	4	2	2
1981	9	2	1	1	1	1	-	1	2	1	1
1982	1	1	-	-	-	-	-	-	-	-	-
1983	1	1	-	-	-	-	-	-	-	-	-
1984	5	1	-	1	1	-	-	-	-	-	-
1985	6	1	1	2	1	-	-	-	-	-	-
1986	6	2	1	1	1	-	-	-	-	-	-
1987	*7*	*2*	*1*	*1*	*1*	*1*	-	*1*	*1*	-	-
1988	*7*	*2*	*1*	*1*	*1*	*1*	-	*1*	*1*	-	-
1989	*8*	*2*	*1*	*1*	*1*	*1*	-	*1*	*1*	-	-
1990	*8*	*3*	*1*	*2*	*1*	*1*	-	*1*	*1*	-	-
1991	*9*	*3*	*1*	*2*	*1*	*1*	-	*1*	*1*	-	-
1992	*9*	*3*	*1*	*2*	*1*	*1*	-	*1*	*1*	-	-
1993	*10*	*3*	*1*	*2*	*1*	*1*	-	*1*	*1*	-	-
1994	9	3	1	2	1	1	-	1	1	-	-
1995	7	3	1	1	-	-	-	1	1	-	-
1996	7	3	1	1	-	-	-	1	1	-	-
1997	7	3	1	1	-	-	-	1	1	-	-
1998	9	3	1	1	-	-	1	1	1	-	-
1999	10	*3*	*1*	*2*	*1*	-	*3*	*1*	*1*	-	-
2000	12	*2*	*1*	*2*	*1*	*1*	*4*	*1*	*1*	-	-
2001	13	*2*	*1*	*3*	*1*	*1*	*5*	*1*	*1*	-	-
2002	15	*2*	*1*	*3*	*2*	*1*	*7*	*1*	*1*	-	-
2003	14	*3*	*1*	*2*	*1*	*1*	*6*	*1*	*1*	-	-
2004	13	*3*	*1*	*2*	*1*	*1*	*6*	*1*	*1*	-	-
2005	12	*4*	-	*1*	*1*	-	*5*	*1*	-	-	-
2006	11	*4*	-	*1*	-	-	*5*	*1*	-	-	-
2007	10	5	-	-	-	-	4	1	-	-	-
2008	14	4	1	1	1	1	6	1	1	-	-
2009	18	3	1	1	2	1	8	1	1	-	-
2010	20	3	8	-	-	-	8	-	-	-	-

Women catches

Literature documenting women fishing in Benin is scarce, most reviews refer to their role in fish processing. Yet, to improve their financial situation, women along the coast tend to have other activities such as financing fishing gear, or fishing for crabs and oysters along the lagoons (Gnakadja 2000). In Benin, these women fish for cash sale (Trottier 1987). Capo-Chichi (2006) estimated the number of these women at 9,724 for 2006, which is the equivalent of 16% of the total number of male lagoon fishers. Since these women are most likely relatives of male fishers themselves and directly or indirectly related to them, we assumed this percentage was constant over the 1950-2010 time period and multiplied it by the total number of lagoon male fishers to obtain the total number of female fishers. We assumed the same CPUE than for the acadja subsistence catch and multiplied the CPUE by the number of female fishers.

Industrial

Most of the industrial fleet that is operating and holds legal agreements to fish within Benin is either foreign owned, foreign flagged or under joint venture and thus based in Benin (Dioury 1983). This situation did not change over time as in the 2000s, and most vessels operating within Benin legally were foreign owned, targeting demersal stocks notably shrimps (Turay and Verstralen 1997; FAO 2007). It is also widely recognized that industrial foreign vessels do not land their catches in Benin (Allegre and Dupret 2010), nor do they have observers onboard and therefore their catches, reflected by low numbers in official data, are mostly unknown. This situation worsened after the 1972 coup d'état, when French, Italian and Greek fishing vessels based in Cotonou left Benin ports because of the fear of nationalization (NOAA 1981), which makes catch data collection even more difficult. We reconstructed the total number of industrial shrimp trawlers within Benin using different literature sources and then allocated these number to a nationality based on the available literature (Table 2). For example, the Chinese fleet, particularly the Kelly fleet (see below), operate in Benin since 2002 and has been increasingly reflagging to the country since then (Vogt *et al.* 2010). The number of these boats was given at –at least – 4 for 2007, and therefore we assumed the number of Chinese vessels in the following years was at least 4 plus part of the number of vessels flagged to Benin. CPUEs estimated were given by the literature from 1958 to 1988 (Dioury 1983; Ssentongo 1990). We performed a linear extrapolation to model the CPUE between 1950 and 2010, then multiplied the resulting CPUE estimates by the estimated number of boats per country.

Discards

The discard rate for the domestic fleet was estimated by Kelleher at 0.5% for 2005, a low rate that is due to increasing retention and landing of bycatch by the domestic demersal fleets. This rate was assumed constant between 2005 and 2010. In the early 1960s, trawl surveys within fishing areas revealed that over the total catch, 15% of species were non-commercial and thus discarded species (Crosnier and Berrit 1964). We assumed this percentage was constant between the 1950s and 1969 and then interpolated to 0.5% in 2005. We multiplied discard rates by the domestic catch to obtain discarded bycatch.

To estimate foreign discards, we used the percentage of discards provided by Kelleher (2005) for Spain (30%) and Greece (32%) between the 1950s and 2010 and then applied them to Spanish and Greek catches. We averaged the previous discard rates and applied them to the industrial catch by France, Portugal, Italy and China. For Nigeria, Cameroon, and Sudan, we applied the domestic discard rates given that these fleets are likely landing their bycatch for local markets.

Table 3. Artisanal marine catch composition (Ssentongo 1990; Djiman 1996) in %.

Percentage of total catch	20	80
Pseudotolithus spp.	13.7	9.7
Galeoides decadactylus	13.9	7.3
Pentanemus quinquarius	0.1	-
Arius spp.	-	-
Brachydeuterus auritus	0.4	-
Drepane africana	0.5	-
Belonidae	2.4	-
Chloroscombrus chrysurus	14.3	-
Trichiurus lepturus	3.4	-
Others	51.3	-
Dentex spp.	-	2.5
Sphyraena spp.	-	6.2
Lutjanus spp.	-	2.9
Illisha africana	-	50.0
Pomadasys spp.	-	0.8
Polydactylus quadrifilis	-	0.6
Pagellus spp.	-	0.3
*Sardinell*a spp.	-	8.6
Scombromorus tritor	-	11.2

Illegal

Illegal fishing in Benin is operated by Nigerian flagged Chinese vessels and particularly the 'Kelly Company's fleet', whose incursions to the artisanal fishing area often results in loss of gear and conflicts with artisanal fishers (Vogt *et al.* 2010). MRAG (2005) estimated illegal, unreported and unregulated catches to be the equivalent of 12% of the legal reported catch, but it is unclear to which category these catches belong. The available information suggests that illegal tuna fishing was most likely offshore (FAO 2007). Trawl illegal fishing referred to in the literature considers the unregulated activities of the Kelly fleet and vessels that are Nigerian flagged holding legal right to operate in Benin, but use illegal mesh size and often operate within areas reserved for artisanal fishers. Herein, we did not reconstruct illegal catches as these might be already included in the industrial component.

Species disaggregation

To disaggregate artisanal and subsistence marine catches we combined the taxonomic breakdown by Ssentongo (1990), who provided the species disaggregation for demersal catches, i.e., 20% of total catches, and Djiman (1996), who documented the species breakdown for the rest of the catch (Table 3).

Similarly, we used the species breakdown provided by (Ssentongo 1990) and Djiman (1996) between 1965 and 1993, completed with a series of linear interpolations and assuming that the same species breakdown since 1993.

It should be noted that the *Sea Around Us* is solely focused on marine and brackishwater fisheries catches. Therefore, once the species disaggregation of the lagoon catches was complete, the catch of purely freshwater species was removed and all analysis was performed on marine and brackish water species only. Herein, artisanal and subsistence lagoon catches refer exclusively to the marine/brackish water species estimates.

Results

Artisanal catches

Artisanal catches from the marine and estuarine waters of Benin were estimated at about 3.1 million t between 1950 and 2010, mainly taken from lagoons (81.6%). Artisanal marine catches increased from 5,600 t·year^{-1} in 1950 to a first peak of around 10,000 t·year^{-1} in 1960 and then decreased after independence due to a series of socio-political events to their historical minimum of 6,200 t·year^{-1} in 1985 then increased to a peak of 12,000 t·year^{-1} in 1996 to remain relatively constant despite an increase in the effort later on (Figure 3).

Artisanal lagoon catches increased from 15,400 t in 1950 to a first peak of 35,000 t in 1969, to decrease thereafter to 28,000 t·year^{-1} in the mid-1970s after the 1972 coup d'état that triggered insecurity (Figure 3). Catches increased thereafter to their historical maximum of 67,000 t in 1993, before declining to 58,000 t·year^{-1} in the late 2000s and then remaining relatively constant despite an increasing number of fishers (Figure 3). The data set does not separate artisanal catches into acadja/non-acadja catches.

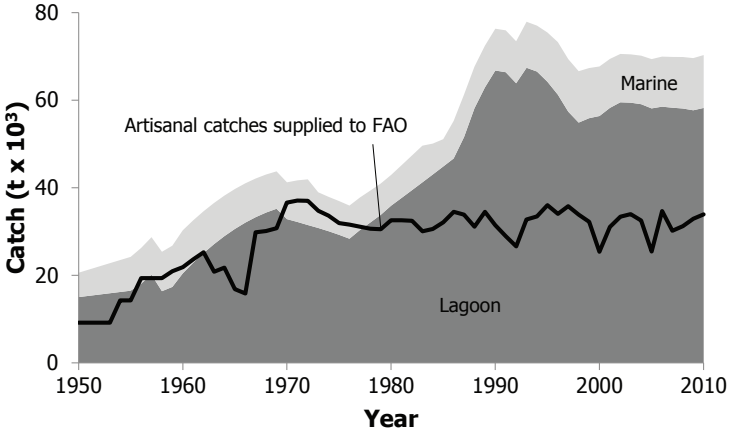

Figure 3. Artisanal reconstructed catches within marine and lagoon waters of Benin, 1950-2010. Black line indicating FAO reported values has been adjusted to remove freshwater catches from lagoons.

Subsistence catches

Subsistence catches were estimated at around 800,000 t between 1950 and 2010, most of which taken from the lagoons (538,000 t). Subsistence marine catches increased with the coastal population from around 1,000 t·year^{-1} in 1950 to around 2,100 t·year^{-1} in 2010 (Figure 4). The lagoon subsistence catches of male fishers increased from around 4,400 t·year^{-1} in 1950 to a peak of 12,000 t·year^{-1} in 1990, mainly taken as consumption from the acadja fishery (60%), before declining to 8,100 t·year^{-1} in 2010 (Figure 4). Women catches increased from 1,000 t·year^{-1} on average in the 1950s to a peak of around 3,000 t·year^{-1} in 1969 right after decreasing because of increasing insecurity in the early 1970s (Figure 4). Catches increased gradually thereafter to reach a peak of 4,100 t·year^{-1} in 2002, before decreasing to around 3,800 t·year^{-1} in 2010 (Figure 4).

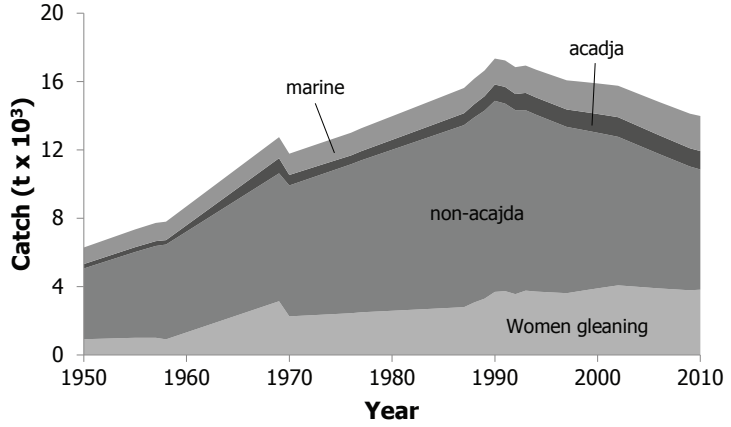

Figure 4. Subsistence reconstructed catches within coastal and lagoon waters of Benin, 1950-2010.

Industrial catches

Industrial domestic catches increased from 240 t in 1959 to a first peak of 1,100 t·year^{-1} in 1974 and declined rapidly to less than 400 t·year^{-1} in the late 1970s (Figure 5). Industrial catches peaked again in 1980 at 1,100 t·year^{-1} before declining to less than 400 t·year^{-1} in 1984. Industrial catches varied later on but reached a peak of 1,600 t·year^{-1} in 2007 before declining drastically due to the decline in the number of industrial domestic vessels (Figure 5).

Foreign catches, on the other hand, reached a historical peak of around 7,800 t·year^{-1} in 1974, after which the departure of vessels from Benin translated into a drastic decline in industrial foreign legal catches, dropped to around 1,100 t·year^{-1} in 1978, mostly by French, Italian, Greek and Sudanese vessels (Figure 5). Catches peaked again in 1980 with the increase in the number of industrial vessel at 5,900 t, before declining to very low levels in 1982 (0 from 1982-1983) (Figure 5). Catches increased again thereafter to reach a peak of 2,500 t·year^{-1} in the early 1990s, when industrial fleets were dominated by African flagged vessel (Cameroon, Nigeria, Sudan) and European vessels (Figure 5). Catches increased to around 5,800 t·year^{-1} in 2002, dominated by Chinese catches, decreased slightly before reaching 5,900 t·year^{-1} in 2010; they were dominated by China and Greece (Figure 5).

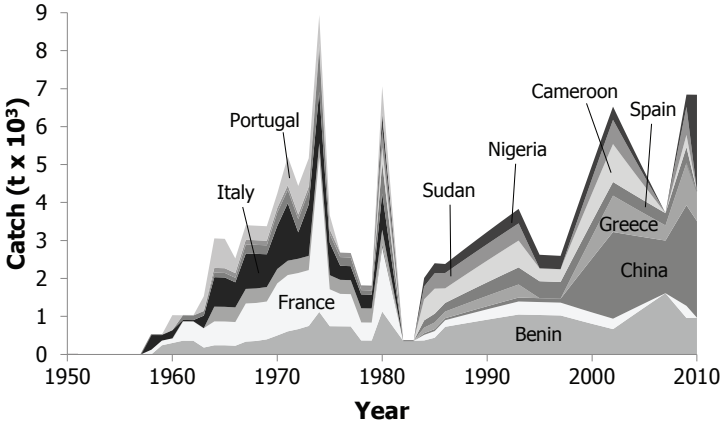

Figure 5. Industrial domestic and foreign reconstructed catches from Benin, 1950-2010.

Discards

Discards were estimated at around 29,100 t between 1950 and 2010. Discards increased gradually from low levels in the mid-1950s to a peak of 1,900 t·year^{-1} in 1974, due to high discarding rates. Discards lowered with the decline of the industrial fleet to low levels in 1983 before increasing gradually to around 800 t·year^{-1} in 2010 (Figure 6).

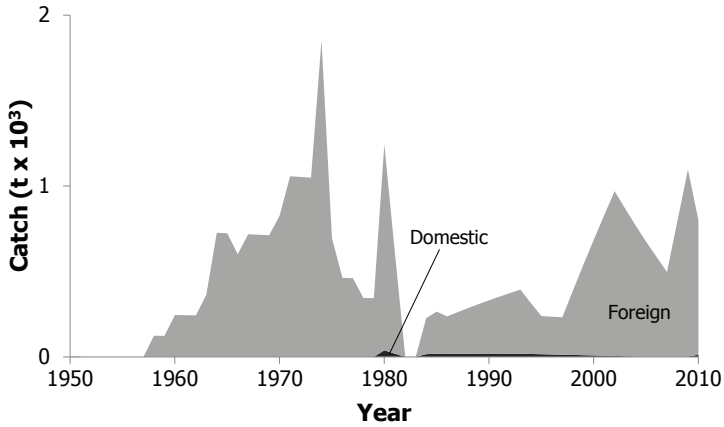

Figure 6. Industrial domestic and foreign reconstructed discards from Benin, 1950-2010.

Reconstructed total catches

Total removals from Benin waters were estimated at 4.0 million t between 1950 and 2010, of which 76 % were taken from the lagoons of Benin, and less than 4 % by the foreign fleets operating in Benin. Domestic catches were estimated at 3.8 million t, of which only 1.7 million t were reported to FAO[2] on behalf of Benin. Domestic catches increased to 26,900 t in 1950 compared to 9,200 t reported to FAO, to 56,900 t in 1969, contrasted to the 31,000 t reported to FAO. Catches declined during the 1970s before increasing to a peak of over 94,000 t·year^{-1} in the early 1990s, almost three times what was reported to the FAO (Figure 7a). Catches decreased thereafter to 85,000 t in 2010, while landing data reported to FAO increased to 35,000 t (Figure 7a).

Taxonomically, blackchin tilapia (*Sarothoredon melanotheron*) dominates catches with approximately a third of total reconstructed catches (38%) followed by Perciforms (11.5%). However the contribution of the two previous taxa to total catches has been declining and slowly replaced by bonga shad (3.8%) in the most recent periods (Figure 7b). 'Others' contain 91 additional categories and composed 25.7% of reconstructed total catches.

Discussion

Domestic and foreign fishing fleets caught around 4.5 million t between 1950 and 2010. Only 41% of the catches taken domestically were reported to the FAO on behalf of Benin. The under-reporting component remained relatively constant over time and then increased during the recent time periods, which shows a lack of improvement in the monitoring system. Furthermore, while official data shows stagnation to a slight increase in the recent years, the

[2] 1.7 million t represents the adjusted FAO baseline, after the removal of freshwater species.

reconstructed data suggest catches are decreasing despite (or rather because of) an increase in effort, which explains over-exploitation perceived by small-scale fishers. This overexploitation causes increasing conflicts with industrial fishing fleets. Furthermore, marine catches including artisanal, industrial catches and the discards they generate are above Maximum Sustainable Yield (MSY), estimated to be between 8,000 and 10,000 t·year^{-1} (Anon. 2010).

The decline of fisheries and the increasing number of conflicts (Vogt *et al.* 2010) threatens small-scale fishers' livelihoods. Indeed, more than a tradition, fisheries are often in Benin the only available occupation for a large number of people as it remains a more profitable activity than agriculture (Atti-Mama 1998). Yet, the economic situation of fishers is increasingly deteriorating (Vogt *et al.* 2010), which suggests increasing presence of industrial vessels and increasing use of acadjas. Although some authors argue that acadjas contribute to increasing fish sizes and repopulating lagoons (Atti-Mama 1998), these large brush parks remain controversial since they "physically impede fishing in the waters they occupy and, as they attract fish from a wider area, they also reduce the stocks available to capture fisheries to some extent" (Cofad and Gut 2002).

Fisheries are also affected by socio-political conditions. For example, the 1972 coup d'état triggered insecurity in the country which resulted in a decline in small-scale catches on one hand, and the departure of formerly Benin-based foreign fleets fearing nationalization (NOAA 1981) by the newly implemented Marxist regime, on the other hand. As a result, when the livelihoods of fishers are threatened, the traditional rules aimed at the sustainable use of fisheries resources via bans, periods of rest, restricted gear and entry to the fishery, are overcome by short term high yields (Vogt *et al.* 2010), resulting in further over-exploitation of fisheries. This decline is also shown by the decrease in discarding rates leading to previously discarded species and juvenile fish increasingly appearing in local markets (Vogt *et al.* 2010). This, along with climate-change induced sea level rise and a low adapting capacity (Dossou and Glèhouenou-Dossou 2007) dangerously challenges of the management approaches aimed at development in Benin.

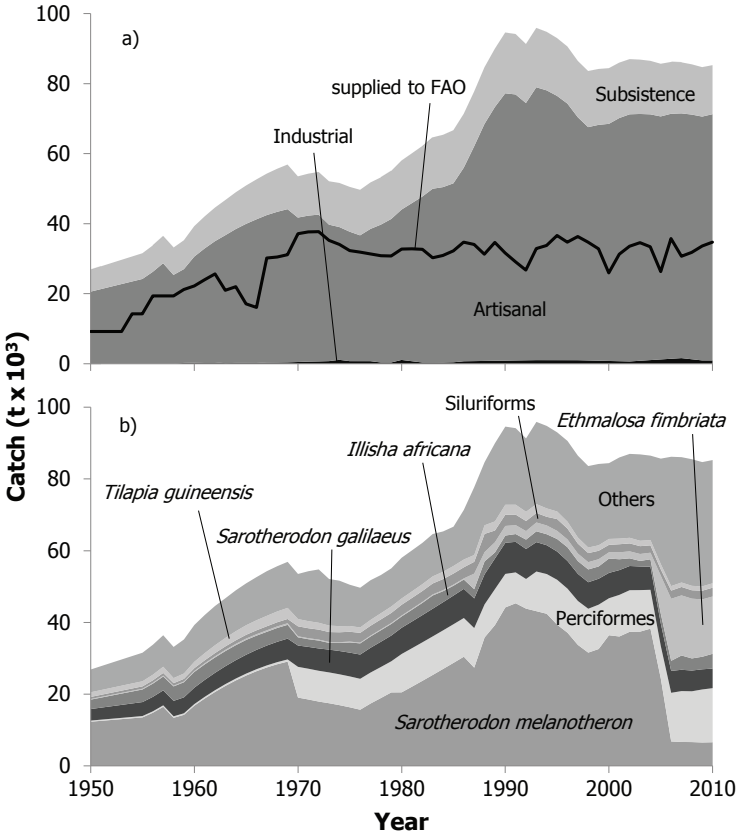

Figure 7. Reconstructed total catches from Benin EEZ by a) sector, with the solid line representing the adjusted FAO reported baseline after the removal of freshwater species; and b) by taxonomic composition, 1950-2010. 'Others' contain 91 other taxonomic categories.

Another dangerous aspect of the decline in Beninese fisheries is that 90% of fisheries and related activities involve "the exchange of sexual favors or transactional sex which is highly related to HIV and AIDS" (Allison and Seeley 2004). The decline in fisheries may have severe implications for exacerbating the HIV/AIDS pandemic.

As fish catch decline, the growing desperation of fishers could intensify catch effort and capacity, hence placing additional pressures on both marine and lagoon resources. The expansion of fishing territory, which further increases competition (Vogt *et al.* 2010) and the lack of management measures to control foreign industrial fleets, have led to the increasing spread of piracy and violence in the Gulf of Guinea. This was prevalent in 2007, when Chinese trawlers sailing under the Benin flag were attacked by local fishers (Gletton-Quenum 2010). By reconstructing the total marine catches of Benin, the severity of the current state of the fisheries and the stark implications for Benin fishers becomes apparent.

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Appendix Table A1. Adjusted FAO landings vs. reconstructed total catch (in tonnes), and catch by sector with discards shown separately, for Benin, 1950-2010.

Year	FAO landings[1]	Reconstructed total catch	Industrial	Artisanal	Subsistence	Discards
1950	9,190	26,900	-	20,600	6,290	-
1951	9,190	27,800	-	21,300	6,500	-
1952	9,190	28,800	-	22,000	6,710	-
1953	9,190	29,700	-	22,800	6,920	-
1954	14,280	30,600	-	23,500	7,130	-
1955	14,280	31,600	-	24,200	7,340	-
1956	19,370	33,800	-	26,200	7,530	-
1957	19,370	36,400	-	28,700	7,720	-
1958	19,370	33,200	-	25,400	7,800	-
1959	21,190	35,300	240	26,800	8,250	-
1960	22,190	39,300	300	30,300	8,700	-
1961	24,010	42,100	360	32,600	9,150	-
1962	25,650	44,600	360	34,600	9,600	-
1963	21,010	46,700	180	36,500	10,050	-
1964	22,010	48,900	240	38,200	10,500	-
1965	17,100	50,900	240	39,700	10,950	-
1966	16,080	52,600	228	41,000	11,400	-
1967	30,160	54,300	336	42,100	11,850	-
1968	30,460	55,700	354	43,000	12,300	-
1969	31,160	56,900	396	43,700	12,740	-
1970	37,100	53,500	499	41,200	11,780	-
1971	37,670	54,300	606	41,700	11,980	-
1972	37,680	54,800	666	41,900	12,190	-
1973	35,250	52,100	749	39,000	12,390	-
1974	34,070	51,600	1,119	37,900	12,600	-
1975	32,290	50,500	743	37,000	12,800	-
1976	31,890	49,700	740	35,900	13,000	-
1977	31,390	51,800	737	37,800	13,270	-
1978	30,880	53,200	367	39,400	13,500	-
1979	30,770	55,100	365	41,000	13,740	-
1980	32,780	58,000	1,091	42,900	13,970	38
1981	32,790	60,100	724	45,100	14,210	18
1982	32,650	62,200	361	47,400	14,440	-
1983	30,250	64,600	359	49,600	14,680	-
1984	30,910	65,400	352	50,100	14,910	16
1985	32,250	66,700	420	51,100	15,150	18
1986	34,690	71,400	709	55,300	15,390	17
1987	34,090	77,700	756	61,300	15,620	18
1988	31,290	84,700	803	67,700	16,170	18
1989	34,660	90,000	850	72,400	16,650	19
1990	31,630	94,600	896	76,300	17,340	19
1991	29,070	94,200	942	76,000	17,230	19
1992	26,750	91,300	987	73,500	16,840	19
1993	32,900	95,900	1,031	77,900	16,930	18
1994	33,750	94,800	1,027	77,000	16,700	17
1995	36,630	93,000	1,022	75,500	16,490	15
1996	34,710	90,600	1,018	73,300	16,280	14
1997	36,350	86,500	1,013	69,400	16,070	13
1998	34,690	83,600	941	66,600	16,010	11
1999	32,820	84,200	868	67,300	15,950	10
2000	25,980	84,400	797	67,700	15,890	8
2001	31,290	86,000	729	69,400	15,820	7
2002	33,560	87,000	660	70,600	15,750	6
2003	34,560	86,800	854	70,500	15,510	3
2004	33,380	86,500	1,046	70,200	15,280	2
2005	26,350	85,700	1,237	69,400	15,040	1
2006	35,720	86,200	1,425	70,000	14,800	-
2007	30,720	86,100	1,612	69,900	14,570	-
2008	31,830	85,500	1,283	69,900	14,340	1
2009	33,660	84,700	958	69,600	14,120	2
2010	34,690	85,300	953	70,300	13,980	13

[1] For the purposes of *Sea Around Us*, freshwater species catch have been removed from reported FAO landings, yielding an adjusted baseline.

Appendix Table A2. Reconstructed total catch (in tonnes) by major taxa for Benin, 1950-2010. 'Others' contain 91 additional taxonomic categories.

Year	*Sarotherodon melanotheron*	Perciformes	*Sarotherodon galilaeus*	*Ilisha africana*	*Ethmalosa fimbriata*	Siluriformes	*Tilapia guineensis*	Others
1950	12,300	317	3,210	2,620	189	569	1,300	6,340
1951	12,600	329	3,350	2,800	193	587	1,330	6,660
1952	12,800	341	3,490	2,980	196	605	1,350	6,990
1953	13,100	353	3,620	3,150	200	623	1,380	7,310
1954	13,300	365	3,760	3,330	204	641	1,400	7,630
1955	13,500	377	3,900	3,510	207	659	1,430	7,950
1956	14,800	394	4,030	3,680	227	699	1,560	8,350
1957	16,500	413	4,170	3,860	253	747	1,730	8,780
1958	13,400	410	4,310	4,030	206	693	1,410	8,690
1959	14,300	425	4,440	4,210	218	725	1,500	9,480
1960	16,800	448	4,580	4,380	257	795	1,770	10,250
1961	18,800	468	4,720	4,330	287	852	1,980	10,640
1962	20,600	487	4,850	4,280	315	906	2,180	10,950
1963	22,300	506	4,990	4,220	341	957	2,360	11,060
1964	23,800	524	5,120	4,170	364	1,005	2,520	11,400
1965	25,200	541	5,260	4,120	385	1,049	2,670	11,670
1966	26,400	558	5,400	3,960	403	1,089	2,800	12,020
1967	27,500	574	5,530	3,830	418	1,127	2,910	12,450
1968	28,300	589	5,670	3,850	432	1,160	3,010	12,610
1969	29,100	603	5,810	3,840	443	1,191	3,090	12,830
1970	19,100	8,568	5,940	2,290	290	2,778	2,030	12,570
1971	18,500	8,576	6,080	2,140	282	2,778	1,970	13,920
1972	17,900	8,585	6,220	2,200	273	2,778	1,910	14,870
1973	17,500	8,592	6,350	1,870	259	2,765	1,810	12,980
1974	16,900	8,600	6,490	2,220	244	2,752	1,710	12,670
1975	16,300	8,607	6,630	2,850	230	2,738	1,610	11,500
1976	15,700	8,616	6,760	3,110	214	2,725	1,500	11,070
1977	17,400	8,639	6,900	3,160	232	2,756	1,620	11,070
1978	18,900	8,658	7,040	3,210	246	2,780	1,710	10,660
1979	20,500	8,681	7,170	3,240	259	2,804	1,800	10,620
1980	20,500	10,694	7,310	3,160	253	3,002	1,750	11,350
1981	22,100	10,717	7,450	3,280	265	3,022	1,830	11,430
1982	23,700	10,735	7,580	3,410	277	3,041	1,910	11,500
1983	25,400	10,753	7,720	3,690	288	3,059	1,980	11,800
1984	27,000	10,756	7,860	3,060	299	3,074	2,050	11,240
1985	28,700	10,777	7,990	2,740	308	3,088	2,110	10,950
1986	30,400	10,791	8,130	2,590	318	3,100	2,170	13,830
1987	27,400	11,034	8,270	2,570	4,336	3,291	1,900	18,910
1988	35,800	9,214	8,400	3,590	2,569	5,096	2,390	17,580
1989	39,300	10,027	8,540	1,680	2,840	3,269	2,540	21,790
1990	44,200	9,342	8,680	2,010	2,681	3,136	2,770	21,780
1991	45,300	8,605	8,510	2,180	2,483	2,936	2,750	21,340
1992	43,900	8,263	8,350	2,620	2,371	2,808	2,580	20,470
1993	43,100	11,054	8,190	3,020	2,462	2,665	2,460	22,910
1994	42,400	11,070	8,030	3,070	2,440	2,419	2,340	22,990
1995	39,400	12,519	7,870	3,490	2,272	3,291	2,110	22,070
1996	37,100	12,281	7,710	3,820	2,182	3,019	1,930	22,510
1997	33,700	12,252	7,550	3,560	2,097	2,771	1,700	22,820
1998	31,600	12,228	7,390	3,570	2,023	2,532	1,550	22,710
1999	32,600	12,365	7,230	3,420	2,028	2,341	1,540	22,670
2000	36,400	10,318	7,070	3,990	1,744	2,082	1,650	21,130
2001	36,100	11,602	6,910	3,020	1,936	2,248	1,570	22,620
2002	37,400	11,592	6,740	2,130	1,945	2,217	1,570	23,390
2003	37,400	11,577	6,580	1,550	1,933	2,183	1,500	24,080
2004	38,300	10,827	6,420	2,080	1,838	2,049	1,470	23,540
2005	24,300	9,069	6,260	2,740	10,622	1,733	1,490	29,410
2006	6,800	13,564	6,100	2,820	17,300	2,268	1,270	36,040
2007	6,700	14,181	5,940	3,980	16,751	2,352	1,240	34,930
2008	6,600	14,163	5,780	3,370	16,665	2,337	1,230	35,290
2009	6,500	14,783	5,620	3,500	15,983	2,422	1,210	34,630
2010	6,600	15,079	5,460	4,120	15,979	2,458	1,230	34,340