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Abstract

Ghana was reputed to be a fishing nation in the past. The collapse of its industrial distant water fleet, mainly induced by the fact that many of the countries where Ghanaian fleets were venturing declared an EEZ in the 1980s, led the industrial fleet to over-exploit fish stocks home. While official data reported to the FAO shows this decline, the contribution of other sectors that are not reported nor monitored to Ghanaians livelihoods is unknown, and thus their impact of fish stocks further overlooked. Herein, we try to grasp an image of the importance of these fisheries by reconstructing unreported segments of Ghanaian fisheries. Total catches were estimated at 20.2 million t between 1950 and 2010 compared to 11.3 million t reported to the FAO. Subsistence catches, notably from the Ghanaian lagoons represented the bulk of unreported catches and seemed to have increased overall, while artisanal and large scale sectors decreased.

Introduction

Ghana lies in West Africa, on the Gulf of Guinea, and has land area of 238,540 km², extending from 4 to 11 degrees north latitude and from 1 degree east longitude to 3 degrees west longitude. Ghana is bounded by Burkina Faso on the north, Côte d'Ivoire on the west, Togo on the east, and the Gulf of Guinea on the south. The country became independent from Britain in 1957 and its current present population is about 25 million (GSS 2011). Accra is Ghana's capital city. Other important cities are Takoradi, Kumasi and Tamale (Figure 1).

While one third of Ghana's territory is covered with tropical rain forests, grass-covered plateau savannahs are found in the northern parts and steppes are found in some part of the southern coastal region, with major rivers in the western part, i.e., the Pra, Ankobra and Tano. In the eastern part, a plain extends all the way to the border with Togo. Within this plain, the Black Volta River flows from the north-western part and the White Volta River flows through the northern-central part. They empty their water into Volta Lake, which covers 8,500 km², and came about because of the Akosombo hydroelectric dam, built in 1964, and which created one of the world's largest artificial lakes.

The coastline of Ghana is rather monotonous, except for relatively large lagoons that are located at its eastern and western extremities, while the continental shelf (i.e., waters down to 200 m) is relatively narrow, and ranges from 24 to 80 km offshore, with an area of 24,300 square kilometres. Ghana's EEZ covers 218,000 km² (Figure 1).

The Guinea Current flows from west to east, but further in the offshore area, the South Equatorial Current flows from east to west. Thus, on the continental shelf of Ghana, there are two seasonal upwellings, i.e., a major upwelling occurring from late June or early July to September or early October, during which the sea surface temperature (SST) drops from 25 °C to 17°C or lower, and a minor upwelling lasting up to a month, and occurring mainly in January or February (FRU/ORSTOM 1976; Longhurst and Pauly 1987; Mensah and Koranteng 1988).

Figure 1. Map of Ghana showing some major towns, Lake Volta and the Exclusive Economic Zone claimed by Ghana.

Ghana's fisheries

The Ghanaian fisheries account for about 4.2% of the agricultural GDP (GSS 2011). Fish is the major source of animal protein for Ghanaians, and *per capita* consumption of fish is about 26 kg which represents 60% of all animal protein (Sarpong *et al.* 2005). Fish and fishery products are now the country's most important non-traditional exports accounting for over 50% of earnings from non-traditional exports (Bennett 2002; Sarpong *et al.* 2005).

Fisheries in Ghana are currently governed by Fisheries Act 625 and the Fisheries Regulations 2010, LI. 1968. Under this law and act, some regulations such as ban of fishing in certain areas and season, control on mesh sizes of net, protection of juvenile fish or berried crustaceans and fishery licensing have been introduced. The new apex body in fisheries governance in Ghana is the Ministry of Fisheries and Aquaculture under which the Fisheries Commission operates. The Directorate of Fisheries is the executing arm of the Ministry and thus of the Commission as well. The Directorate of Fisheries has five sections under the supervision of the head of the Directorate. A deputy director is appointed to each section along with some staffers, and they are responsible for performing day-to-day business operations, notably devising of fishery policies, the issuance of fishing permits, the collection of fisheries statistics and the supervision of fisheries.

Ghana already had a fishing industry long before the introduction of mechanized fishing in 1946 (Irvine 1947). From 1960 onwards, serious attempts were made to modernize Ghana's fisheries. In those early days, there was a very powerful canoe-fleet using methods as '*ali*'-nets, beach-seines, hooks, cast-nets, and set-nets. In short, even in that pre-mechanization era, the fishing industry was having a favourable impact on the economy by providing food for the population and employment for coastal people. In fact, it may be stated that the Fisheries Department, formed in 1946 by the Colonial Administration were not intending to start an industry, but only to mechanize and modernize the pre-existing one.

About 85% of total fish caught in Ghana comes from the marine sector. Ofori-Adu (1988) listed 347 exploited fish species in Ghanaian coastal waters, i.e., 72% of the 485 species reported by FishBase (www.fishbase.org) from Ghanaian waters (as of August 2013). In addition to 347 fish species belonging to 82 families, Ofori-Adu (1988) listed 17 cephalopod species in 5 families, and 25 crustacean species in 15 families. In Ghanaian fisheries, pelagic and demersal species contribute about equally to the national catch.

The fisheries for small-pelagics

The most important pelagic fish species exploited in the Ghanaian coastal fisheries are the sardinellas, namely round sardinella (*Sardinella aurita)* and flat sardinella (*Sardinella maderensis)*, which are important in the entire Gulf of Guinea (Ansa-Emmim 1973).

Initially, the major upwelling was thought to be more important than the minor upwelling because more sardinellas are caught during the major upwelling period. However, work done by Koranteng (1989), Pezennec and Bard (1992), among others, have shown that the minor upwelling is equally as important as the major upwelling to the recruitment of sardinella in the Ivorian-Ghanaian ecosystem.

In addition to the upwelling, the distribution and abundance of sardinella in the western Gulf of Guinea have also been associated with rainfall (Ofori-Adu 1975; Binet 1982) and year-class strength (FRU/ORSTOM 1976).

The sardinella season begins with the decrease in the sea surface temperatures when the sardinellas initiate their migration. Usually, the bulk of the fish is first seen in the Western region of Ghana and moves eastwards, into Togo and Benin (Ansa-Emmim 1973). *Sardinella aurita* is the main species involved in this migration, which was known by early fishers and which dictated their movement. The abundance of *S. aurita* is limited to a number of environmental factors among which are the strength of the local upwelling (Mendelssohn and Cury 1987) and rainfall (Binet 1982). Flat sardinella, *S. maderensis* has lower abundances catches in the Ghanaian coastal fishery than round sardinella, but *S. maderensis* is believed to be around for most months of the year (Muta 1964).

Other pelagic fishes exploited by Ghanaian fleets belong to the taxonomic families Scombridae, Carangidae, other Clupeidae and Thunnus. The most important of these to the coastal fishery are the chub mackerel or Spanish mackerel (*Scomber japonicus*), often found in association with sardinellas (Stromme 1983), and the more sedentary anchovy (*Engraulis encrasicolus*).

Specialized fisheries for other pelagic fishes (except tunas) do not exist; most of the fishes mentioned above are by-catch of the sardinella fishery. However, there are instances where the sardinella failed to appear but *Scomber japonicus* was caught in excessive amounts (FRU/ORSTOM 1976). Generally, small pelagic fish catches constitute about 65 % of total landings.

Demersal fishery resources

Demersal fishes are caught by trawlers and artisanal gears such as beach seines, set nets and long-lines. A number of fish species contribute to the demersal fishery in the waters off Ghana. The most important of these are Sparidae or sea breams (mainly red pandora *Pagellus bellotti, Dentex canariensis* and *Sparus caeruleostictus*), Haemulidae or grunts, (e.g. *Pomadasys jubelini* and *Brachydeuterus auritus,* a semi-pelagic species); Sciaenidae or croakers (e.g. *Pseudotolithus* spp. or cassava fish) and Lutjanidae or snappers (e.g. *Lutjanus fulgens*). Others are Mullidae or mullets, (e.g., *Pseudupeneus prayensis*); Serranidae or groupers (e.g. *Epinephelus aeneus*) and Polynemidae or threadfins (e.g. *Galeoides decadactylus*).

The Fisheries Act establishes an Inshore Exclusion Zone (IEZ) which comprises the coastal waters between the coastline and the 30 meter depth contour or six nautical mile offshore limit, whichever is furthest. Large semi-industrial vessels and industrial vessels are not permitted within the IEZ and canoe support vessels are also prohibited, as are all towing gear. The IEZ is reserved exclusively for canoes and semi-industrial vessels (the latter are not to use towing gears in the zone).

Lawson and Kwei (1974) trace the development of demersal fisheries in Ghana, starting from the use of two vessels in 1948 to a number around 360 in 1973, and mentions that on its formation, the Fisheries Department imported two-thirty foot motorized boats from the United Kingdom. These two vessels were used by the Department for experiment intended to determine the effectiveness of the boats' engines and their overall performance in Ghanaian waters.

The effectiveness of these vessels encouraged people to approach the Fisheries Department for permission to buy similar vessels. However, as the project was still at an experimental stage, people were unable to purchase such vessels. In fact, the government issued a ruling that, until further notice, no one was allowed to operate a vessel of over 30 feet in length in Ghanaian waters. However, the success of the 30-footers was such that, in 1952, a boatyard was set up in Sekondi to build similar vessels.

In the same year, the Fisheries Department began to sell vessels to the public on hire/purchase terms. Before the Department would release a vessel to prospective buyer, the owner had to make a deposit on its purchase price. Then the buyer and the crew had to present themselves for training and thus show full proof to the Fisheries Department that fishers were capable of operating and maintaining the vessel. Even when the owner eventually started to operate the boat, the Fisheries Department checked the maintenance of the boat and recorded the size and the values of the catches.

In 1958, Mankoadze Fisheries Limited introduced the first 58-footer vessel in Ghana. This vessel, *The Provider A*, had several advantages: a stronger engine, larger catching and carrying capacities, and a longer range than the smaller vessels in use at that time. At this stage, instead of phasing out the 30-footers and introducing in their places the superior 58-footers, the planners allowed the 30-footers to grow in number.

Tuna resources

The principal tuna species that occur throughout the eastern Atlantic Ocean are: yellowfin tuna (*Thunnus albacores*), skipjack (*Katswonus pelamis*) and big-eye (*Thunnus obesus*). Assessment of tunas in the whole Atlantic is coordinated by the International Commission for the Conservation of Atlantic Tunas (ICCAT). Recent assessments by ICCAT show that yellowfin and big-eye tuna resources in the Atlantic are being optimally exploited, while the skipjack may still be under-exploited (DOF 2004).

Fish Preservation

Soon after it was established in 1946, the Fisheries Department set up a pilot cannery and fishmeal plant. The aim of the pilot cannery was to conduct trials into canning of *Sardinella* and mackerel of which there was, every year, a seasonal surplus. Trials were performed and it was found that the canned product was fully accepted by the public. At the stage, a policy should have been formulated to establish canneries at such key landing points as Tema/Accra and Elmina. However, this pilot cannery, which subsequently was handed over to Nsawam Canneries, remained a pilot plant. Had the planners succeeded in realizing the potentials of the cannery, they would have eliminated the need to import pilchards and sardines, thereby saving foreign exchange for the country.

Aims of this study

The present study uses an established catch reconstruction approach (Zeller *et al.* 2007) to estimate total marine fisheries catches for Ghana for the period 1950–2010, to derive a historic baseline and evaluate the overall magnitude of underreporting.

Materials and methods

National landing datasets were compared with the data supplied to the FAO. The first dataset is presented in three categories, i.e., artisanal, industrial and tuna landings, whereas FAO landing data shows species or higher taxonomic grouping. The comparison revealed that overall national data were higher than the data supplied to FAO (Figure 2). While the reason behind this is unknown,

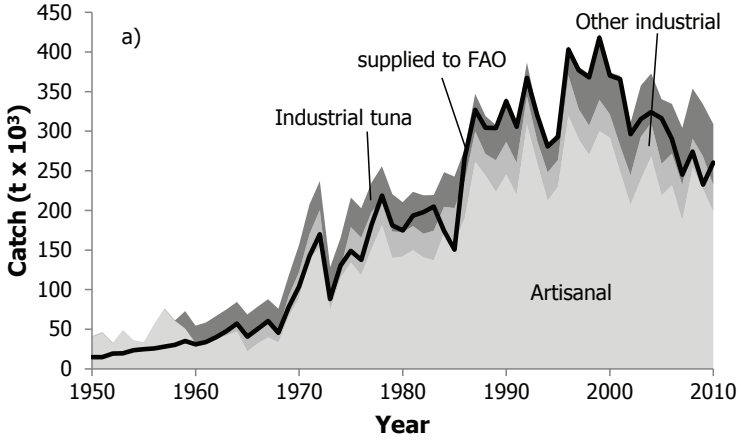

Figure 2. Comparison between national landing data and FAO data, 1950-2010.

we use the FAO data as a baseline and considered the difference as unreported catch given that catch data for commercial sectors (artisanal, industrial and tuna) are comprehensively assessed. We assumed the ratio of artisanal to industrial obtained from national data were similar to the FAO data which allowed the separation of the FAO data into three categories, namely: the tuna category including "Atlantic bonito", "Skipjack tuna", "Bigeye tuna", "Yellowfin tuna", "Frigate and bullet tunas" and "Little tunny (Atlantic black skipjack)", artisanal and industrial (others). We then compared each of these segments to the segments extracted from national data reports.

Small-scale fisheries

Small-scale fisheries include artisanal fisheries operated in the marine waters of Ghana, and subsistence fisheries, which are represented by the portion of the fish caught by the artisanal fleet that is taken home by fishers, and the subsistence lagoon component.

In the artisanal fishery, currently over 12,000 artisanal canoes and about 200,000 fishers (with about 2 million dependants) operate from 334 landing centres in 195 fishing villages located along the coast (Amador *et al.* 2006). Several gears are used, the main ones being beach seine, set net, hook and line, drift gill net, '*ali*', '*poli*' and '*watsa*' nets. For statistical purposes, the last three gear types are considered together resulting essentially in the use of five main gears. Dug-out canoes, most of them powered by outboard engines of up to 40 hp, are used in the fishery. The canoe fishers also use a wide variety of gears, including gill and entangling nets, seine nets (purse and seine nets), castnets and handlines, to exploit both pelagic and demersal fish species. Official data suggest that this fleet is responsible for over 70% of the total annual landings of both pelagic (sardinellas, mackerels and anchovies) and demersal fish species (croakers, breams, snappers etc). Frame surveys covering artisanal fisheries in Ghana are comprehensively established (Table 1), and only a part of the artisanal catch that is taken home for consumption (subsistence marine catches) are not reported.

Table 1. Results of canoe frame survey conducted between 1969 and 2004 and the calculated number of fishers (in italic).

Year	Fishing villages	Landing beaches	Fishermen	Canoes
1950	-	-	50,000	4,800
1955	-	-	60,000	5,000
1960	-	-	70,000	5,500
1969	198	269	79,000	8,728
1973	191	257	89,000	8,238
1977	200	238	81,000	8,472
1981	174	22	84,100	6,938
1986	188	276	104,700	8,214
1989	192	264	91,400	8,052
1992	189	206	96,400	8,688
1995	189	310	101,700	8,641
1997	191	308	103,340	8,610
2001	185	304	123,156	9,981
2004	195	334	124,219	11,213
2010	-	-	145,000	13,000

Estimation of subsistence marine sectors

Fish is taken out of the catch by fishers for personal consumption for their households before fish catch records are taken by Department of Fisheries for catch estimation. Fish for household consumption is therefore not reported nor included in official data. During low fishing seasons, the few fish caught is all taken home for consumption (Kofi Amador, pers. obs.). In the present work, we attempt to estimate these catches. The percentage of catch aimed at personal consumption was calculated by taking the national average of 25 kg of fish per caput (Awity 2005). It was observed that a fisher and his household took at least one and half times the national average, i.e., about 37.5 kg per year per capita (Awity 2005). The number of fishers for 1950, 1955, 1960, 1969 and 2010 was obtained by multiplying the number of canoes for each year respectively by the average number of fishers per canoe, i.e., 12 was deduced from the 2004 Ghana Canoe Frame Survey Report (Table 1). The average household size was reconstructed using government census data for 1960 (3.95), 1970 (4.36), 1984 (4.16), and 2000 (4.46) for coastal Ghana (Government of Ghana, unpublished data), assumed to be 4 in 2010, and then interpolated linearly to fill in the gaps.[1] To estimate catches that are aimed at consumption, we first multiplied the number of fishers by the average size of households, and then by the average consumption per capita. This formula resembles the method used by Serra (2013) to estimate total cocoa production from a survey area, where the average declared cocoa production is multiplied by the total number of cocoa owning families.

Koranteng (1989) estimated that each fisherman had between one and five wives and three to 26 other dependants. This means that at that time depending on the 94,000 fishermen are about 1.5 million wives, children and other relatives.

Estimation of lagoon subsistence fisheries catches

As mentioned previously, lagoons considered here are the large lagoons on the western and eastern end of the coast of Ghana. In between, however, there are numerous smaller lagoons whose number and surface area were estimated by Mr. Walter Pople, a marine scientist at the University of Ghana in the late 1960s and early 1970s (see also Figure 9 in Pauly 1976)

Overall, the large lagoons of Ghana, plus the small ones cover an area of 1,100 km^2. As elsewhere in the world, these lagoons are of outstanding economic importance for the over three million people who live close to them (Kapetstky 1984; Pauly and Yañez-Arancibia 2013). The larger ones are designated as Ramsar sites. The lagoons also contribute significantly to the diversity and status of fish stocks in coastal waters as many marine species spend part of their life cycle in these lagoons (Pauly 1975a).

[1] The later estimate is fairly conservative given that it takes the coastal average rather than fishers' households exclusively, where the Fisheries Commission's 2013 survey revealed that each fisher had 7 to 8 dependants.

The major lagoons are Keta, Sakumono, and Songhor (Vanden Bossche and Bernacsek 1990). Various types of gears are used including cast, set nets, etc. In the Keta lagoon, fishing is done almost all year round. In the Sakumo lagoon, the fishing seasons are more distinct, and coincide with the major and minor rainy season in the coastal areas of Ghana. Many lagoons are overexploited and suffer from pollution and environmental degradation (Koranteng *et al.* 2000), for example, Korle and Kpeshie lagoons near Accra, and Chemu lagoon near Tema. These lagoons are examples of seasonal fisheries resources destroyed by pollution (human and industrial). Another well studied small lagoon (of 1 km² in the early 1970s, which has been shrinking since) is Sakumo Lagoon, also near Tema[2] (Pauly 1975a, 1975b, 1976, 2002), which yielded an annual catch estimated at 15 t·km^{-2}·year^{-1}, and consisting over 90% of blackchin tilapia.

The largest and the most productive of these lagoons in terms of total annual fish landings is the Keta lagoon which occupies a surface area of 350 km² and estimated to have a potential annual yield of 4,000 tonnes (Balarin 1988), corresponding to 11.4 t·km^{-2}·year^{-1}. The major species caught in Keta lagoon are *Eucinostomus melanopterus*, *Oreochromis niloticus, Sarotherodon melanopteron, Tilapia zillii, Mugil hoefleri, Caranx* spp. and *Belone belone* whilst the major species obtained from the Sakumo[3] and other larger lagoons are blackchin tilapia *Sarotherodon melanotheron, Mugil hoefleri, Eucinostomus melanopterus, Clarias* spp., and *Sarotherodon galilaeus*.

The mean of the two estimates of fisheries catches in Ghanaian lagoons mentioned above (15 and 11.4 t·km^{-2}·year^{-1}) is 13.2 t·km^{-2}·year^{-1}, which is reassuringly close to the mean yield of 107 coastal lagoons presented by (Kapetstky 1984), i.e., 11.3 t·km^{-2}·year^{-1}. Multiplying the former figure by the cumulative surface area of coastal lagoons in Ghana, i.e., 1,100 km² gives an annual catch of lagoon fishes of 14,520 t·year^{-1}, which is assumed constant during the period considered here. The catch composition is assumed to consist of two-thirds blackchin tilapia (*Sarotherodon melanotheron*), which the rest distributed evenly among the other species mentioned above as component of coastal lagoon catches.

Table 2. Estimation of the number of recreational fishers in Ghana, 1950-2010.

Year	Total tourists	Recreation (%)	Recreational tourists	Fishers (%)	Number of fishers
1950-1973	-	-	-	1	–
1974	13,000	20	2,600	1	26
1975	26,000	20	5,200	1	52
1976	39,000	20	7,800	1	78
1977	52,000	20	10,400	1	104
1978	65,000	20	13,000	1	130
1979	78,000	20	15,600	1	156
1980	91,000	20	18,200	1	182
1981	104,000	20	20,800	1	208
1982	117,000	20	23,400	1	234
1983	130,000	20	26,000	1	260
1984	143,000	20	28,600	1	286
1985	156,000	20	31,200	1	312
1986	169,000	20	33,800	1	338
1987	182,000	20	36,400	1	364
1988	195,000	20	39,000	1	390
1989	208,000	20	41,600	1	416
1990	221,000	20	44,200	1	442
1991	234,000	20	46,800	1	468
1992	247,000	20	49,400	1	494
1993	260,000	20	52,000	1	520
1994	273,000	20	54,600	1	546
1995	286,000	20	57,200	1	572
1996	305,000	20	61,000	1	610
1997	325,000	20	65,000	1	650
1998	348,000	20	69,600	1	696
1999	373,000	20	74,600	1	746
2000	399,000	20	79,800	1	798
2001	439,000	20	87,800	1	878
2002	483,000	20	96,600	1	966
2003	531,000	20	106,200	1	1,062
2004	584,000	20	116,800	1	1,335
2005	428,533	20	83,030	1	1,068
2006	497,129	20	98,555	1	1,408
2007	587,000	20	117,400	2	1,845
2008	698,000	20	139,600	2	2,393
2009	803,000	20	160,600	2	2,983
2010	931,000	20	186,200	2	3,724

[a] data from http://www.indexmundi.com/facts/ghana/international-tourism [Accessed on 27/08/2013]; and http://www.tradingeconomics.com/ghana/international-tourism-number-of-arrivals-wb-data.html [Accessed on 27/08/2013].

Recreational fisheries

Recreational fishing in Ghana is a highly popular tourist activity, notably targeting tunas and billfishes[4] (Obeng 2003). Although, herein we assume this activity began with the creation of the first tourism board in 1974, this activity gained popularity after the release of the DVD "Ghana" in 2003 by Captain Clay Hensley showing record catches of tuna and marlin to the wide audience in 2003, onboard an icon in the sport fishing world "The Hooker",[5] which made Ghana a dream place for recreational fishers.

Herein, we first reconstructed the number of tourists between 1973 and 2010. Data on the number of tourists were available between 1995 and 2010 from diverse sources (Table 2), we interpolated from 0 in 1973 to the first anchor point in 1995. According to official data on tourism, 20% of the total number of tourists visited Ghana for recreational activities (Anon 2007). We assumed a constant rate over time and applied this rate to the total number of tourists. Since recreational fishing gained popularity since 2003, we assumed between 1973 and 2003, 1% of the recreational tourists visiting Ghana were fishers, and interpolated linearly to 2% in 2010, which allowed estimating the annual number of recreational fishers. Using the videos posted on YouTube documenting 25 recreational fishers and the species they caught daily, we could estimate the average weight caught by each tourist daily at 32.58 kg·tourist^{-1}·day^{-1}. When the number of tourists was unclear in the videos, we used the number of lines observed as a proxy. We assumed the CPUE was 20% higher in the past, given the general over-exploitation pattern in Ghana. Each

[2] There are two 'Sakumo' lagoons in Ghana, and D. Pauly, who did his field work in 1971, studied the smaller of the two, near Tema.
[3] See previous footnote.
[4] http://www.gipcghana.com/life-leisure/recreation.html [Accessed on 27/08/2013].
[5] http://worldwideanglermag.com/771-fishing-ghana-on-the-hooker [Accessed on 27/08/2013].

tourist spends on average 7 days fishing annually.[6] We therefore, estimated total recreational catches as the product of the number of tourists per year by the number of days and the average daily CPUE. The total weight per species was weighted by the occurrence of each species in the videos, i.e., the number of times each species was observed; the fraction of the weighted catch of each species over the total represents the percentage for each species (Table 3).

Table 3. Catch composition of recreational fisheries of Ghana.

English name	Scientific name	Cumulated weight	Occurrence[a]	%
Bigeye tuna	*Thunnus obesus*	8.0	2	0.7
Yellowfin	*Thunnus albacares*	15.0	2	1.3
Barracuda	*Sphyraena sphyraena*	175.7	9	68.8
Dolphinfish	*Coryphaena hippurus*	111.5	3	14.6
Blue marlin	*Makaira nigricans*	290.0	1	12.6
Marine fishes not identified	-	30.0	1	1.3
West African Spanish mackerel	*Scomberomorus tritor*	10.0	1	0.4
Yellowtail amberjack	*Seriola lalandi*	7.0	1	0.3

[a] Occurrence refers to the number of times observed in the videos

Large-scale fisheries

Large scale fisheries in Ghana are divided into three distinct categories, the semi-industrial sector, the industrial, also called distant water fleet of Ghana and the tuna fleets.

The semi-industrial fleet is made up of a number of locally built trawler/purse seiners with wooden hulls. They are used both for trawling and for purse seining. Both methods are carried out throughout the year although the latter method is intensified during the sardinella season (July-September). The vessels vary in size (length) 8.2-37 m (27-120 feet). For statistical purposes, these vessels are grouped into two categories, namely 8.2–12 m (27'-39') and 12.3-37 m (40'-120'). The vessels are powered by inboard engines of between 90 and 400 hp, and operate from seven coastal landing centres, i.e., Tema, Apam, Mumford, Elmina, Sekondi, Takoradi and Axim.

Distant-water vessels, which are all trawlers, are normally over 35 m in overall length and have main engines of more than 600 hp. Originally, the industrial vessels were fishing in more productive areas outside Ghanaian waters (e.g. Mauritania and Angola), but with the advent of the 200 nautical mile EEZ concept in the 1970s, along with financial difficulties and political instability (Atta-Mills *et al.* 2004) these large vessels have been forced to fish in Ghanaian waters, where the continental shelf is rather narrow, resulting in a sharp decline in the CPUE since 1980.

All fleets, including the artisanal canoes, operate in about the same area (the 15–75 m depth domain), resulting in a number of conflicts, notably the destruction of artisanal fishing gear. The artisanal and inshore fleets exploit both pelagic and demersal fishes, whereas the large trawlers of the former distant-water fleet catch mainly demersal and semi-pelagic fishes. A few Ghanaian industrial vessels were based outside Ghana, e.g. in The Gambia where they exploited only sardinellas under a joint venture partnership, Angola, and Namibia (Weber and Durand 1986), and some of these vessels were used to venture as far as the North Sea.

The trawlers and shrimpers exploit demersal and semi-pelagic species and they operate from Tema and Takoradi. In 1986, commercial shrimping was resumed in Ghanaian waters nearly 12 years after the collapse of an earlier fishery. The numbers of vessels increased rapidly reaching a peak of 17 vessels in 1995 and declining thereafter. The earlier fishery collapsed around 1975 for various reasons including over-exploitation and the impact of the Volta dam at Akosombo on the hydrology of the Anyanui estuary and Keta lagoon. It is believed that the operation of the shrimp vessels, especially in shallow waters, was not conducive to the sustainability of the resources and conflicts with activities of artisanal fishers. Currently, there are no shrimpers operating in the Ghanaian coastal waters.

The commercial tuna fishery based at Tema in Ghana began in 1960 following a survey conducted in 1959-60 by the Star Kist Foods of USA under an agreement between the company and the Government of Ghana (Hammond 1977). One of the major aims of the survey was to study the distribution and abundance of tuna and tuna bait fishes in Gulf of Guinea. The results of the survey established, among others, that tuna species abound in the Gulf of Guinea of which Ghana is a part. Initially, the Ghanaian commercial tuna fleet consisted primarily of Japanese-and then Japanese and Korean-registered vessels. The peak of foreign fleet domination of the industry was in 1973 when there were as many as 40 foreign tuna vessels based at Tema (Kwei 1988).

The tuna species exploited in the Atlantic waters are yellowfin tuna (*Thunnus albacores),* bigeye tuna (*Thunnus obesus)* and skipjack tuna (*Katsuwonus pelamis)*. Other tuna and tuna-like species usually exploited are Atlantic black skipjack (*Euthynnus alleteratus*) Atlantic bonito (*Sarda sarda*), frigate mackerel (*Auxis thazard*), Atlantic sailfish (*Istiophorus albicans*) and Broadbill swordfish (*Xiphias gladius)*.

Estimation of bait fishing for anchovy by tuna bait boats

Since the beginning of commercial tuna fishing, sardinellas and anchovies were used as live bait and the industry depended entirely on the availability of these small pelagic fish species. Since the early 1970s when sardinella resources were drastically reduced in Ghanaian waters, anchovy has become the only fish species used as bait for tuna fishing. According to Mensah (1983), the anchovy *Engraulis encrasicolus* is more preferable than sardinella as bait. Mensah (1983) suggested that bait grounds were usually very close inshore – within the range of canoe fishermen – between 17 and 24 m depth**.**

[6] http://www.sportfishingmag.com/news/spots-availiable-ghana-trip [Accessed on 27/08/2013].

Anchovy was more reliable as bait partly because it is available almost throughout the year and also because it has been found to survive longer under artificial conditions (such as in bait-wells or tanks on tuna vessels) than sardinellas. Overall, anchovy is one of the most important marine fish species in Ghanaian waters, accounting for about a quarter of marine fish landings in Ghana (Koranteng 1993). Their exploitation as bait in the tuna industry competed with the artisanal canoe fishermen who depend on it. Mensah (1977) estimated that about 12.3 $t \cdot boat^{-1} \cdot trip^{-1}$ of anchovy Engraulis encrasicolus was harvested and used for each fishing trip. Since 1959 when the tuna industry was established in Ghana by Star Kist, an average of 30 bait boat operated in the country per year. A bait boat made at least 10 trips per year. Assuming a constant CPUE, where the decline of sardinella as bait was gradually replaced by anchovy, we multiplied this CPUE by the number of baitboats presented in table 4. Prior to 1974, we assume that 50% of baitfish catches are sardinella, and 50% is anchovy given the abrupt decline in sardinella catches in 1973 (Troadec and Garcia 1980; Binet *et al.* 1991). From then, we linearly decreased the proportion of sardinella to 0% in 1977, and 100% for anchovy.

Table 4. Commercial tuna fleet based in Ghana from 1959 – 2010

Year	Tuna bait boat	Tuna purse seiner	Tuna longliner	Origin
1959	1	1	-	Japan
1960	1	-	-	Japan
1961	1	-	-	Japan
1962	2	-	-	Japan
1963	4	-	-	Japan
1964	6	3	-	Japan
1965	6	-	-	Japan
1966	10	-	-	Japan
1967	10	-	-	Japan
1968	10	-	-	Japan
1969	-	-	-	Japan
1970	20	-	-	Japan
1971	20	-	-	Japan
1972	30	-	-	Japan
1973	38	2	-	Japan
1974	30	2	-	Japan
1975	34	2	1	Japan
1976	31	3	-	Japan
1977	35	3	-	Japan
1978	35	3	-	Japan
1979	-	-	-	Japan
1980	40	3	-	Japan
1981	42	6	-	Japan
1982	40	7	-	Japan, Korea
1983	38	5	-	Japan, Korea
1984	27	4	-	Japan, Korea
1985	26	6	-	Japan, Korea
1986	25	5	-	Japan, Korea
1987	26	6	-	Japan, Korea
1988	30	6	-	Japan, Korea, Ghana
1989	30	5	-	Japan, Korea, Ghana
1990	38	5	-	Japan, Korea, Ghana
1991	37	7	-	Japan, Korea, Ghana
1992	36	6	-	Japan, Korea, Ghana
1993	35	6	-	Japan, Korea, Ghana
1994	34	5	-	Japan, Korea, Ghana
1995	39	6	-	Japan, Korea, Ghana
1996	36	7	-	Japan, Korea, Ghana
1997	36	5	-	Japan, Korea, Ghana
1998	36	6	-	Japan, Korea, Ghana
1999	39	8	-	Japan, Korea, Ghana
2000	34	10	-	Japan, Korea, Ghana
2001	33	10	-	Japan, Korea, Ghana
2002	33	10	-	Japan, Korea, Ghana
2003	33	10	-	Japan, Korea, Ghana
2004	23	11	2	Japan, Korea, Ghana
2005	21	11	2	Japan, Korea, Ghana
2006	21	11	2	Japan, Korea, Ghana
2007	20	11	2	Japan, Korea, Ghana
2008	20	12	2	Japan, Korea, Ghana
2009	21	15	2	Japan, Korea, Ghana
2010	20	18	2	Japan, Korea, Ghana

Foreign legal fisheries

There is a relatively low access to Ghanaian waters by foreign fleets due to the already high pressure over Ghanaian fisheries (Atta-Mills *et al.* 2004). Dioury (1983) in his thorough report on fisheries of twelve countries in Africa, did only but mention the distant water fishing fleet, and categorized industrial fleets as those built in Ghana (purse-seiners and trawlers) and those built elsewhere then imported to Ghana and most likely fish also elsewhere. Weber and Durand (1986) mentioned agreements with the former Soviet Union, rather believed to be for building and exporting fishing vessels to Ghana, and fisheries agreements with Japan. Thus, foreign fisheries in the Ghanaian EEZ are officially restricted to tuna fisheries.[7] While in the past tuna vessels were mostly foreign (NOAA 1981) notably from (Japan); since 1981, all tuna vessels are operated on joint-venture basis with Korean and Japanese companies (NOAA 1981) with Ghanaians owing at least 25% of the shares in the past (Falaye 2008) and 50% today under the Ghana Fisheries Act 625 of 2002 (Anon. 2004). Similarly, tuna vessels who previously landed their catches elsewhere, and reported only a fraction of it, were constrained in 1981 to land at least 10% of their catches in Ghana, and today, all tuna is landed in Ghana and therefore catches are considered local (Falaye 2008). We estimated the unreported portion of these catches,[8] assuming that the unreported component was 10% of the declared national landings at the beginning of the fishery in 1959, and decreased linearly to 1% in 1986. We then re-allocated catches per flag of origin such as Japanese fleet caught 100% of industrial tuna catches between 1959 and 1981, half of catches were then taken by Korea in 1988, and then each of Japan, Korea and Ghana were responsible for around a third of these catches in 2010. We interpolated these rates, i.e., from 100% in 1981 to 50% in 1988 and then to 33% in 2010 for Japan, from 0% in 1981 to 50% in 1988 and then to 33% in 2010 for Korea, the remaining is allocated to Ghana.

[7] http://www.fao.org/docrep/v9982e/v9982e10.htm [Accessed on 26/08/2013]

[8] Considering the FAO data as the baseline, the total unreported tuna catch is the sum of the difference between the national tuna catch data and the FAO data to which is added this component.

All trawl vessels operating in Ghana are reported as Ghanaian regardless of their origin, however, the very Chinese names of a few companies found en passant in literature reviews (Pramod and Pitcher 2006) and their respective vessels suggest these are not entirely Ghanaian. Indeed, China has recently begun operating pair-trawlers in the waters of Ghana. Literature reports 16 vessels in 2003, 10 in 2007 and 2 in 2010 (Pauly *et al.* 2013), despite the ban of pair-trawling in 2007 (Bromfield 2010). These, according to Pauly *et al.* (2013) catch on average 1,252 t·vessel^{-1}·year^{-1}. Given that the Chinese-Ghanaian cooperation in the fisheries sector is relatively recent (GhanaNewsAgency 2005) and that first records of pair trawler catches were made in 2002 (Anon. 2004), we assumed that pair-trawling by China corresponded to the official start date of the agreement, i.e., 2002. We interpolated the effort to fill in the gaps for the intervening years. We assumed the CPUE in 2002 was 10% higher than 2010, given the over-exploitation pattern observed in Ghana. We multiplied the CPUE by the interpolated effort and obtained Chinese catches from Ghana EEZ. Given the low level of catches reported in 2002, i.e., 1,259.7 t (Anon. 2004), compared to a reconstructed total of 11,018 t, i.e., 11.4% reported, we assumed a constant figure between 2002 and 2010 of under-reporting. As for the species composition, Anon. (2004) reported 36% of seabreams, 33% of cuttlefish, 1% of burrito, 2.3% of cassava fish, and 27.7% of other miscellaneous species.

Illegal fisheries

Unlike many other West African countries, the problem of IUU fishing in Ghana lies mostly in the licensed trawlers operating in the artisanal fishing zone, or using illegal fishing gear, illegal transhipments etc. (Falaye 2008). However incursions, notably by unlicensed trawlers from the EU, and China do happen (Antwi 2006; Pauly *et al.* 2013). MRAG (2005) estimated illegal unreported and unregulated catches to be 4% of the total legal catch. Arrests documented in the literature within Ghanaian waters were exclusively due to fishing without licenses/ authorization (Kwadjosse 2009). Therefore, we assumed the previous rate to apply to illegal vessels only. Another reason is that mostly all the industrial fishing vessels that are flagged to Ghana are equipped with transponders for vessel monitoring (Kwadjosse 2009). This percentage is believed to be higher in the past given that the government commissioned new regulations notably on VMS tracking systems only recently. We therefore assumed that illegal catches were the equivalent of 8% at the introduction of the tuna commercial fishery to Ghana after the joint US-Ghana tuna survey of 1959, decreasing linearly to 4% between 2005 and 2010. We then multiplied tuna landings by this rate and estimated the total illegal catch from Ghana. We assumed 100% of these catches were of Spanish origin (incursions from Togo) before 1983, and that 50% were Chinese and 50% Spanish since then.

Discards

In the Ghanaian artisanal fisheries, discards are negligible as almost all catch is sold and consumed. In the industrial sector, however, and especially the shrimping sector, up to 80% of the catch is by-catch, and much of it is discarded. Similarly, tuna bait boats use only live bait, thus discard the rest. A barter system called 'seiko' fishing has developed between some canoe fishers and industrial shrimpers, trawlers and tuna bait boats, wherein vegetables and fruits are exchanged against such fish or fish from the industrial vessels; alternatively, the fish is sometimes sold to these canoe fishers (often very cheaply). The 'seiko' system can be operated officially, i.e. with the consent of the fishing companies, or unofficially.

Estimation of discards by tuna purse seiners and tuna bait boats

Mensah (1977) estimated that about 2,015 t·boat^{-1}·year^{-1} of juvenile tuna were discarded at sea. Table 4 shows the numbers of tuna bait boat and tuna purse seiners which operated from Ghana from 1959 to 2010. If a bait boat discarded 2,015 t·year^{-1}, a purse seiner would have discarded at least twice that quantity in a trip since purse seiners were less selective of size; they had higher fishing capacity than bait boats per trip (Kofi Amador, pers. obs.,). We first interpolated the number of bait boats and purse-seiners and then multiplied the number of bait boats per year by a discard rate of 2,015 t·boat^{-1}·year^{-1} and the number of purse-seiners by a discard rate of 4,030 t·boat^{-1}·year^{-1} to estimate the quantity of discards of the tuna fleet operating from the Tema port in Ghana annually between 1959 and 2010.

Estimation of discards by industrial trawlers and shrimpers

In the industrial trawl and the shrimping fleet sectors of the Ghanaian fisheries, valuable demersal fish species like the breams, groupers, croakers, snappers, cephalopods, shrimps and lobsters are the target species. Small fishes, juvenile and species that are of lower value are discarded at sea and not landed. Discard rates were most often very high in these fleets. Discards rates were estimated to be equivalent to landings in the past, i.e., 50% of total catches (Koranteng 2003) and range between 30% and 80 % (Kofi Amador, pers. obs.). Averaging these three estimates landed a discard rate of about 50% of total catches. More recently, since evidence suggests that artisanal fishers would buy part of these catches, we conservatively assumed that only 40% was really discarded at sea. Since this practice is recent and

Table 1. Taxonomic breakdown of purse-seine discards

Common name	Scientific name	%
Atlantic bonito	*Sarda sarda*	20
Triggerfish	Balistes	20
Blue runner	*Caranx crysos*	19
Sailfin	*Istiophorus platypterus*	15
Doctorfish	*Acanthurus chirurgus*	9
Wahoo	*Acanthocybium solandri*	8
Marine fishes not identified	-	4
Atlantic tripletail	*Lobotes surinamensis*	2
Red cover	*Emmelichthys ruber*	2
Sergeant-major	*Abudefduf saxatilis*	1

unwanted by-catch in Ghana are increasingly being used as highlighted by (Nunoo *et al.* 2009), discard rates were likely higher in the past. Therefore, we assumed a linear decrease from 50% (average estimate) of total catches, i.e., 100% of landings in 1958, when trawling began in Ghana, to 40% of landings in 2010.

The main bycatch and discards during the course of a typical purse seine fishing trip were Sarda, *Sarda sarda* (Scombridae), the trigger fish *Balistes capriscus* (Balistidae), blue runner *Caranx crysos* (Carangidae), Pompano *Coryphaena equiselis* (Coryphaenidae); others were Atlantic sailfin *Isthiophorus albicans*, black marlin *Makaira albicans* (Istiophoridae), sawara *Acanthocybium solandri* (Scombridae), doctor fish *Elegatis bipinnulata* (Carangidae). The rest were the red rover ('Kwamisei') *Emmelichthys rubber* (Emmelichthydae), Atlantic tripletail *Lobotes surinamensis* (Lobotidae) and sergeant major *Abududefduf sexatilis* (Pomadasidae). Table 5 shows the major bycatch and their approximate percentages encountered during a trip.

As part of the spatial allocation process, large-scale catches that were taken from outside of the Area 34 were filtered out. Catches from outside the EEZ declined by 50% between 1975 (a reported catch of 50,000 t) and 1981 (25,000), of which 22% were taken from The Gambia in 1974, 67% from Angola and Namibia (outside area 34) and the remaining from Ghana, Mauritania, i.e., 5.5% each (Diouy 1983). By multiplying catch rates for The Gambia (22%) by the total industrial reported catch (other than tunas) which were likely taken from in and outside the Ghanaian EEZ, we estimated Ghanaian catches from The Gambia at 11,000 t·year^{-1} for 1974 (50% of the reported catch to the FAO) and 5,500 t·year^{-1} for 1981 (17% of the reported catch to the FAO) and assumed these to be zero in 1985, since then the Ghanaian fleet rejoined the Ghanaian EEZ. Similarly, we applied the same method for catches from the Mauritanian and Ghanaian EEZs. Since 1985, all catches reported catches (landed in Ghana) were assumed to have been taken from the Ghanaian EEZ.

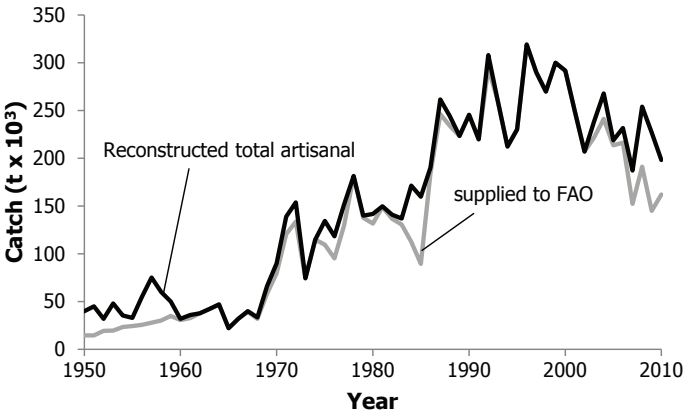

Figure 3. Reconstructed artisanal catch data compared to the data supplied to the FAO for Ghana, 1950-2010.

Results

Artisanal catches

Artisanal catches were assessed through national surveys at around 9.2 million t between 1950 and 2010 compared to 8.4 million t of catch data supplied to the FAO. Catches increased overall, with however an oscillating trend, from 40,000 t·year^{-1} in 1950 compared to 14,600 t·year^{-1} supplied to the FAO, to a peak of 320,000 t·year^{-1} in 1996 similar to the catch data supplied to the FAO, and decreased since then to 198,000 t·year^{-1} compared to 162,000 t·year^{-1} supplied to the FAO (Figure 3).

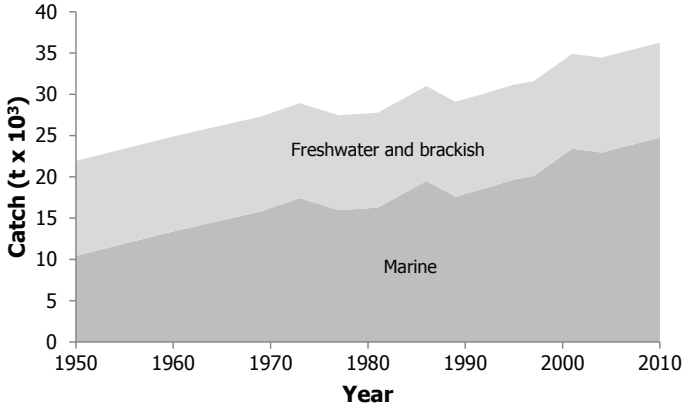

Figure 4. Reconstructed subsistence catches from the marine and lagoon waters of Ghana, 1950-2010.

Subsistence marine and lagoon catches

Total subsistence catches were estimated at around 1.8 million t between 1950 and 2010, of which 40% are caught in the lagoons of Ghana. Subsistence marine catches were estimated at 1,062,000 t between 1950 and 2010. Due to the increased in the number of fishers, marine catches similarly increased from around 10,400 t in 1950 to 24,800 t in 2010 due to the increase in the number of fishers (Figure 4).

Recreational catches

Recreational catches were estimated at 6,600 t. Recreational fisheries increased slowly from very low levels in the mid-1970s to around 300 t in 2004, and then increased rapidly to their maximum of 850 t in 2010 with the rapid increase of tourism in Ghana (Figure 5).

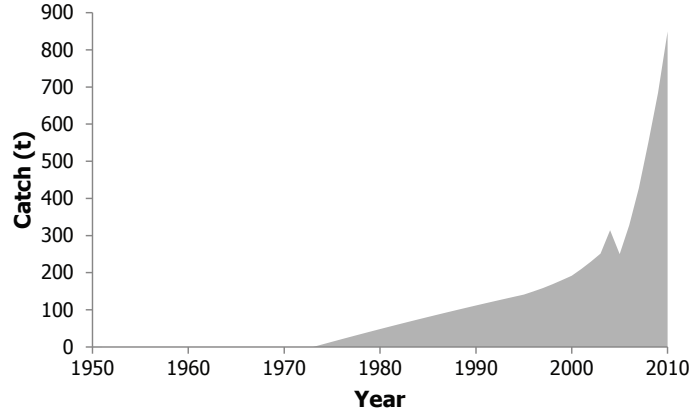

Figure 5. Reconstructed recreational catches from the waters of Ghana, 1950-2010.

Tuna catches

Tuna catches from the waters of Ghana were estimated at 2.4 million t between 1950 and 2010 compared to 1.7 million t supplied to the FAO on behalf of Ghana. The under-reporting component was higher in the past, when the Japanese fleet (reflagged to Ghana) was responsible for the bulk of tuna catches (100% between 1959 and 1981), the under-reporting component decreased thereafter with the increase of restrictions upon joint ventures for tuna fisheries in Ghana in 2010 when unreported catches were estimated at around 3% of reported catches (Figure 6). Overall, tuna catches increased from low levels in 1959 when the tuna fishery began by Japan, to a peak of around 88,000 t in 2001, of which 40% were caught by Korean vessels, 40% by Ghanaian vessels and 20% by Japanese vessels (Figure 6).

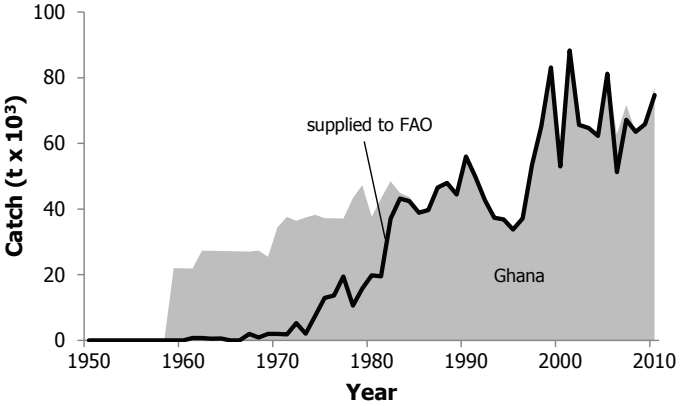

Figure 6. Reconstructed tuna catches from the waters of Ghana compared to the catch data supplied to the FAO, 1950-2010. Vessels from Japan and Korea are originally reflagged to Ghana.

Other industrial catches

Industrial catches, other than tuna, were estimated at 1.96 million t between 1950 and 2010 of which 1.7 million t were reported to the FAO. Industrial catches increased from 1,200 t in 1950 compared to 437 t reported to the FAO, to a peak of over 95,000 t in 1972 after which catches declined drastically to 32,000 t likely due to a period of unrest induced by the 1972 military coup. Catches oscillated thereafter around 35,000 t between then and 2002, and declined after the introduction of Chinese pair trawlers (in the early 2000s) to 31,000 t in 2010 (Figure 7).

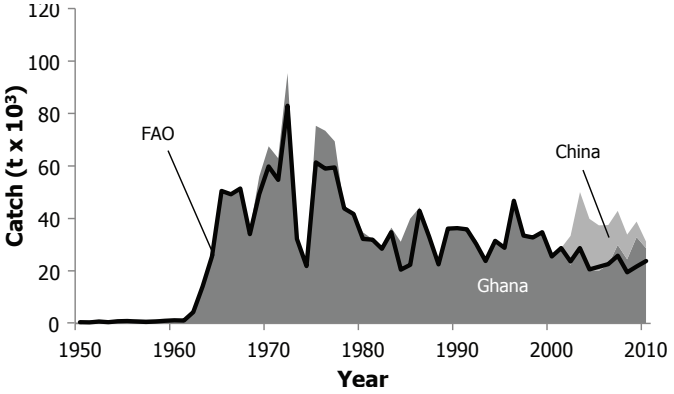

Figure 7. Reconstructed industrial catches (excluding tuna) from the waters of Ghana, 1950-2010.

Baitfish catches

Baitfish catches were estimated at 164,000 t between 1950 and 2010, of which 67% were caught by Japan, a quarter by Korea and nearly 8% by Ghana (Figure 8). Baitfish catches increased between 1959 and reached a peak of around 5,000 t in 1980 (Figure 8). Baitfish catches declined to 4,000 t after the second coup of 1981, and increased thereafter to a peak of 4,700 t in 1990 after the first phase of Economic Recovery program was introduced after 1983 (Figure 8). Catches remained relatively constant between the early 1990s and the early 2000s and then started decreasing following the same pattern than tuna catches after fuel subsidies were removed in 2001 to less than 2,500 t in 2010.

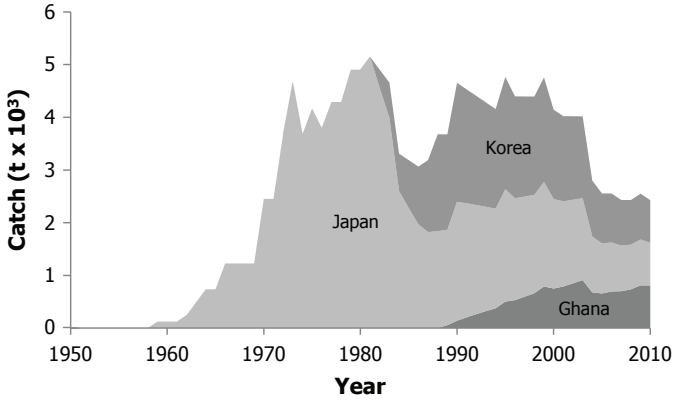

Figure 8. Reconstructed unreported baitfish catches from the waters of Ghana, 1950-2010.

Illegal and unregulated catches

Illegal and unregulated foreign catches were estimated at around 124,000 t between 1950 and 2010. Catches were considered unregulated prior to 2009 given that Ghana had ratified UNCLOS thereby declaring officially an EEZ in 2009. Illegal catches increased from 1,600 t in 1959, taken by Spain (which vessels were reflagged to Togo in the more recent periods), to a peak of nearly 4,000 t in 2001. Catches declined slightly thereafter and remained relatively constant after the declaration of the Ghanaian EEZ in 2009 (Figure 9). While in the past Spain was responsible for all illegal and unregulated catches from Ghana, more recently, Chinese contribution to illegal and unregulated catches increased to be around 1,600 t in 2010 (Figure 9).

Discards

Discards were estimated at 5.2 million t between 1950 and 2010 (Figure 10), of which 52% were generated by baitboats, given their behavior towards keeping only live bait for tuna fisheries. Domestic discards by trawlers represented the bulk of discards with an average of 50% between 1958 and 1972 (30,000 t·year^{-1}), compared to a quarter each for the tuna baitboats and purse-seiners (mainly reflagged to Japan and Korea). Discards by trawlers declined over time,

likely induced by over-exploitation, upon the return of Ghana's distant water fleet to Ghana combined with fewer fuel subsidies. However, significant increases in discards were obtained by purse-seiners and baitboats which were estimated at 123,000 t in 2010.

Reconstructed total catches

Total catches from the waters of Ghana were estimated at 20.8 million t between 1950 and 2010, of which 44% were taken by the artisanal fleet, 22% by the industrial fleet (notably that reflagged to Ghana), which discarded around 25% of the reconstructed total catch (5.2 million t between 1950 and 2010), 8% were non-commercial subsistence and recreational catches, and around 1% were taken illegally by foreign vessels operating in the Ghanaian EEZ. Domestic and reflagged vessel catches were estimated to be almost twice as high as the data supplied to the FAO with 20.6 million t compared to 11.8 million t between 1950 and 2010. Total catches increased from around 63,000 t in 1950 compared to 15,000 t reported to the FAO (for FAO area 34), to a first peak of 469,000 t in 1972 compared to 222,000 t reported to the FAO (Figure 11a). Catches declined rapidly after the 1972 military coup to 291,000 t in 1973 compared to 108,000 t reported to the FAO (Figure 11a). Catches increased thereafter gradually to a peak of 588,000 t in 1999, with however a varying pattern, notably a slight decrease after the second military coup of 1979, and a rapid increase after the 1983 Economic Recovery Programme was initiated (Figure 11a). Catches declined gradually thereafter, notably after 2001 decision to remove fuel subsidies, to 472,000 t in 2010 (Figure 11a).

Taxonomically, small pelagic fishes such as anchovies, sardinellas and other clupeidae represented the bulk of the catch. Sardinella catches declined at first drastically in the early 1970s and then since the mid-1990s. Similarly anchovy catches have been steadily declining since the mid-1990s, while tuna and billfish catches show a gradual increasing pattern, due to an increasing fleet targeting large pelagic species (Figure 11b).

Results and discussion

The reconstructed total catch for Ghana for the 1950-2010 period totalled over 20.8 million t which was around twice the total catch reported by Ghana to the FAO. The discrepancy between the reported and reconstructed total is mainly due to a large amount of unreported subsistence catch, tuna baits of anchovy harvested along the inshore waters, discards by industrial vessels at sea. This study shows conservative results since it does not include the part of catches that is exported at-sea by artisanal fishers (Bromfield 2010).

Discards of juvenile tuna at sea represented the largest proportion of catch not recorded. This situation is exacerbated by the fact tuna purse seiners are becoming more important in the Ghanaian tuna fishing industry (Table 2). Tuna purse seiners do not only have higher fishing power and capacity but are less selective for size and species of fish harvested. With inclinations towards the deployment of the bigger and more powerful purse seiners, the waste as regards juvenile catches and non-target species would be phenomenal if appropriate measures are not put in place to check this wanton waste.

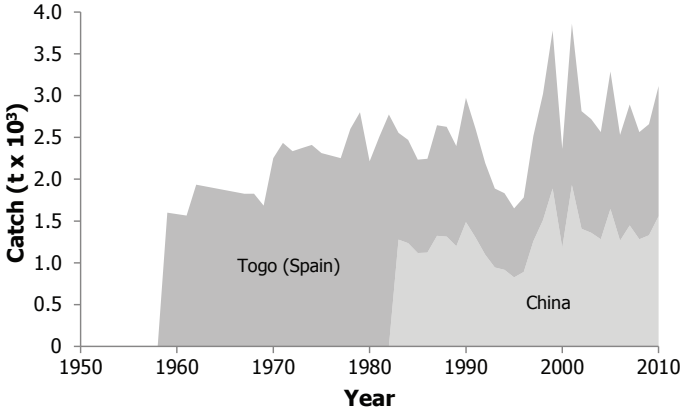

Figure 9. Foreign illegal and unregulated catches.

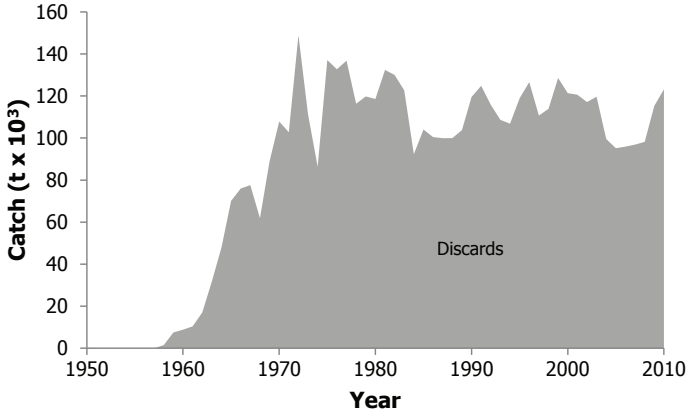

Figure 10. Reconstructed discards from the waters of Ghana, 1950-2010.

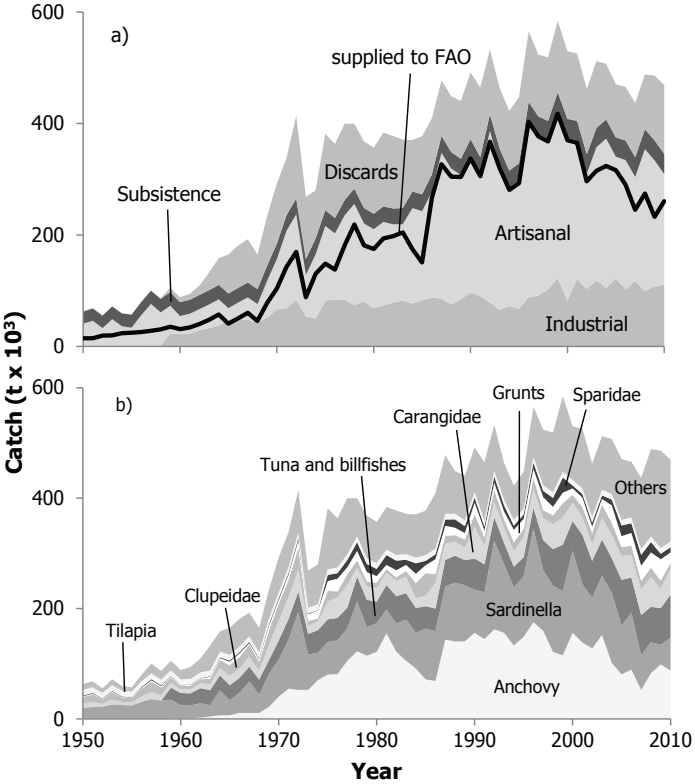

Figure 11. Reconstructed total catches from the waters of Ghana by a) sector and b) taxon, 1950-2010. "Others" contain 73 additional taxonomic categories.

Discards from the industrial trawlers was also significant. According to many reports of the Fisheries Department, there is downward trend in fish catch in both the artisanal and the industrial catches in the Ghanaian waters. Implication is that catch sizes are getting smaller which will in turn lead to more discards of juvenile discards at sea. Higher rate of discards at sea would inevitably be expected.

Our findings also reinforce what Pauly and Zeller (2003) emphasized: 'there is a need to complement the data supplied to FAO and incorporate estimates of previously ignored catches, even if these are based on estimations and assumptions'.

The present study illustrates that the marine fishing sector is a far more important asset to national food security for Ghana- and the magnitude of resource extraction much greater–than has been previously recognised. In Ghana, little data do not mean small catches. These reconstructions provide impetus for the reconsideration of the role of fish in domestic food security, and for caution in allowing international agreements (such as those with China) to stimulate additional fishing effort, especially through ill-conceived foreign access agreements.

With high incidence of poverty (32-70%; Asiedu and Nunoo 2013) in the fishing communities, more attention should be directed towards poverty reduction by provision of alternative livelihood options and wealth creation as these will enhance sustainable fisheries management. Indeed, with the pressure over Ghanaian fisheries too high, and overcapacity, alternative employment opportunities for artisanal fishers will have to be found (Atta-Mills *et al.* 2004).

The reliance on incomplete and substantially under-reported national data puts the fisheries authorities under serious risk of over-licensing fishing access, underestimating the contributions of Ghana's fisheries and mismanaging the marine ecosystems thereby affecting national food security.

Acknowledgements

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

Year	FAO landings	Reconstructed total catch	Industrial	Artisanal	Subsistence	Recreational	Discards
1950	14,700	62,900	925	40,000	21,900	-	-
1951	14,800	68,200	955	45,000	22,200	-	-
1952	19,500	55,300	745	32,000	22,500	-	-
1953	19,700	71,700	893	48,000	22,800	-	-
1954	23,700	59,300	702	35,500	23,100	-	-
1955	24,700	57,000	642	33,000	23,400	-	-
1956	25,900	79,800	1,061	55,000	23,700	-	-
1957	28,000	100,100	1,150	75,000	24,000	-	-
1958	30,400	86,800	1,026	60,000	24,300	-	1,500
1959	35,300	105,100	22,964	50,000	24,600	-	7,530
1960	31,100	88,300	22,557	32,000	24,900	-	8,830
1961	33,800	94,100	22,550	36,000	25,200	-	10,430
1962	40,000	109,300	29,177	37,700	25,400	-	16,990
1963	48,000	132,700	32,991	42,200	25,700	-	31,780
1964	57,100	158,400	37,451	47,000	26,000	-	47,960
1965	40,800	165,000	46,642	22,000	26,200	-	70,110
1966	50,300	181,100	46,608	32,000	26,500	-	75,990
1967	60,400	192,300	48,097	39,900	26,800	-	77,600
1968	45,500	164,800	42,647	33,300	27,000	-	61,830
1969	78,600	234,100	51,676	66,200	27,300	-	88,950
1970	103,900	292,300	66,763	90,000	27,700	-	107,860
1971	142,700	338,400	68,643	138,900	28,100	-	102,800
1972	169,800	414,500	83,319	153,700	28,500	-	148,930
1973	88,200	268,400	54,033	74,300	28,900	-	111,220
1974	130,400	280,000	50,223	114,900	28,600	7	86,340
1975	148,800	381,500	81,820	134,400	28,200	14	137,110
1976	137,700	363,300	84,304	118,500	27,800	21	132,730
1977	181,800	399,600	83,964	151,400	27,500	28	136,790
1978	218,700	399,600	74,311	181,400	27,500	35	116,330
1979	181,300	368,100	80,687	140,000	27,600	42	119,800
1980	174,900	356,700	68,571	141,800	27,700	48	118,570
1981	193,600	383,800	73,704	149,800	27,800	55	132,400
1982	197,600	377,600	78,209	140,900	28,400	61	130,030
1983	204,800	371,200	82,355	137,000	29,100	68	122,690
1984	174,500	370,400	77,015	171,200	29,700	74	92,320
1985	150,600	377,200	82,809	159,900	30,400	81	104,050
1986	266,800	409,200	87,414	190,200	31,000	87	100,470
1987	326,800	477,700	85,828	261,500	30,400	93	99,930
1988	304,400	448,900	75,088	244,000	29,700	100	99,970
1989	304,000	440,700	84,252	223,400	29,100	106	103,780
1990	337,800	491,600	97,016	245,500	29,400	112	119,560
1991	305,500	464,700	90,245	219,800	29,800	118	124,850
1992	367,300	532,800	78,801	307,900	30,100	124	115,810
1993	320,500	464,100	65,393	259,400	30,500	129	108,650
1994	280,600	422,600	72,533	212,300	30,800	135	106,840
1995	292,700	447,800	67,392	230,100	31,200	141	118,960
1996	403,000	565,600	88,232	319,200	31,400	150	126,620
1997	376,900	523,700	91,265	290,000	31,600	159	110,710
1998	367,800	518,700	102,401	269,800	32,400	169	113,910
1999	417,900	584,600	122,643	300,000	33,200	180	128,580
2000	370,200	529,900	82,607	291,700	34,100	192	121,360
2001	365,800	525,600	120,995	248,900	34,900	210	120,620
2002	296,300	462,200	103,030	207,100	34,700	230	117,130
2003	315,300	512,100	118,773	238,800	34,600	251	119,650
2004	323,900	507,200	104,943	267,900	34,400	314	99,560
2005	316,200	470,600	121,524	218,900	34,700	250	95,170
2006	290,300	465,800	102,777	231,700	35,000	328	95,920
2007	245,100	436,800	117,052	187,100	35,400	428	96,890
2008	274,200	488,300	99,782	254,100	35,700	552	98,190
2009	232,500	485,900	107,186	226,800	36,000	684	115,320
2010	260,500	469,200	110,712	198,200	36,300	849	123,180

Appendix Table A1. Reconstructed total catch (in tonnes) by major taxa for Ghana, 1950-2010. 'Others' contain 73 additional taxonomic categories.

Year	Anchovy	Sardinella	Tuna and billfishes	Carangidae	Clupeidae	Grunts	Sparidae	Tilapia	Others
1950	-	19,900	-	8,000	11,900	1,210	1,340	10,300	10,200
1951	-	21,300	-	9,000	13,500	1,370	1,530	10,300	11,100
1952	-	21,500	-	5,600	8,000	820	910	10,300	8,100
1953	-	25,900	-	8,700	13,100	1,330	1,480	10,300	10,900
1954	-	24,900	-	5,800	8,300	850	940	10,300	8,200
1955	-	24,500	-	5,300	7,500	770	850	10,300	7,800
1956	-	30,900	-	9,500	14,300	1,460	1,620	10,300	11,600
1957	-	35,800	-	12,700	18,800	2,410	2,130	10,300	17,900
1958	-	33,000	-	9,800	14,000	2,020	1,590	10,300	16,000
1959	1,100	33,500	22,000	8,500	9,700	1,780	1,100	10,300	17,100
1960	1,100	23,700	22,000	6,800	6,000	1,200	680	10,300	16,600
1961	1,100	23,100	21,900	7,600	6,500	1,250	730	10,300	21,700
1962	2,100	26,100	27,300	8,700	7,400	1,400	830	10,300	25,200
1963	4,300	20,400	27,300	10,800	10,000	3,380	1,130	10,300	45,200
1964	6,400	45,100	27,200	13,900	14,100	3,150	1,590	10,300	36,700
1965	6,400	27,300	27,200	16,700	19,400	6,470	2,190	10,300	49,100
1966	10,700	36,300	27,100	17,300	20,400	6,720	2,310	10,300	50,000
1967	10,700	56,900	27,100	18,100	21,600	2,460	2,450	10,300	42,700
1968	10,700	33,100	27,300	15,800	16,600	4,660	1,880	10,300	44,400
1969	21,500	59,600	25,500	27,300	26,100	8,500	2,950	10,300	52,500
1970	40,200	67,300	34,400	35,600	30,900	7,000	3,490	10,300	63,100
1971	54,600	88,600	37,600	39,200	31,400	9,600	3,550	10,300	63,600
1972	52,400	141,600	36,400	39,700	40,300	12,730	4,560	10,300	76,500
1973	52,400	64,000	37,400	14,700	8,800	12,220	1,360	10,300	67,200
1974	70,100	49,500	41,000	15,800	5,500	14,280	900	10,300	72,700
1975	80,100	59,100	41,000	32,300	19,300	17,770	11,190	10,300	110,500
1976	81,000	61,000	40,800	37,600	10,400	23,000	10,050	10,300	89,200
1977	104,900	58,800	37,800	40,400	19,900	12,730	13,300	10,300	101,500
1978	122,300	90,200	45,100	16,300	13,200	16,950	16,220	10,300	69,000
1979	114,300	51,600	49,800	24,100	8,900	17,070	14,750	10,300	77,300
1980	121,400	52,000	38,900	24,800	9,500	11,950	13,120	10,300	74,800
1981	154,700	43,300	44,300	22,300	6,400	7,950	17,740	10,300	76,800
1982	121,800	50,600	49,900	27,600	6,600	12,820	17,420	10,300	80,700
1983	105,100	74,800	47,600	29,800	10,600	10,930	9,350	10,300	72,800
1984	91,200	64,700	45,000	17,800	27,400	16,770	19,000	10,300	78,200
1985	71,400	91,900	40,700	18,800	41,300	14,250	7,900	10,300	80,600
1986	68,600	90,000	41,100	47,200	15,000	27,130	8,970	10,300	100,800
1987	143,600	96,200	48,000	28,900	14,900	18,130	11,380	10,300	106,200
1988	140,000	106,900	48,900	25,200	11,700	13,580	15,190	10,300	77,200
1989	140,400	101,500	45,400	22,700	14,600	11,930	12,500	10,300	81,200
1990	155,800	77,900	56,800	57,000	23,300	20,920	9,330	10,300	80,300
1991	144,500	84,900	50,500	34,400	14,500	12,300	7,210	10,300	106,200
1992	162,200	160,200	43,100	27,600	21,500	13,030	11,600	10,300	83,100
1993	156,000	124,600	38,300	27,600	15,000	14,140	11,440	10,300	66,600
1994	133,000	104,800	37,800	28,700	16,100	21,990	7,800	10,300	62,100
1995	148,600	109,500	34,600	35,200	15,800	18,400	7,990	10,300	67,300
1996	175,000	169,700	37,900	33,800	19,800	16,750	11,240	10,300	91,100
1997	159,400	110,100	54,100	39,800	14,400	23,660	11,440	10,300	100,500
1998	121,200	120,000	66,100	44,800	16,700	15,220	16,310	10,300	108,100
1999	115,100	116,400	84,100	49,200	26,100	18,900	27,220	10,300	137,300
2000	155,800	148,700	53,900	32,600	15,100	11,350	5,400	10,300	96,800
2001	138,300	105,400	89,700	32,400	17,800	17,080	6,620	10,300	108,000
2002	127,400	91,500	67,200	30,500	19,700	11,770	7,440	10,300	96,300
2003	152,200	107,100	65,700	39,000	24,600	9,600	6,640	10,300	96,900
2004	101,000	126,800	63,300	42,100	21,800	31,540	10,620	10,300	99,700
2005	80,600	88,400	82,900	43,000	16,000	19,970	19,380	10,300	110,000
2006	89,100	103,400	63,500	41,100	16,700	23,290	17,430	10,300	101,100
2007	52,400	62,600	72,900	46,000	16,000	27,600	19,650	10,300	129,400
2008	82,800	56,200	64,100	54,000	16,900	27,650	18,720	10,300	157,700
2009	98,600	35,300	66,400	35,200	14,900	38,580	10,020	10,300	176,500
2010	87,300	60,000	77,800	45,700	12,300	18,410	9,590	10,300	147,900