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Fisheries Centre, University of British Columbia, Canada

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Edited by

Dyhia Belhabib, Dirk Zeller, Sarah Harper and Daniel Pauly

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Content

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Director's Foreword

Fisheries provide food for a large number of people all over the world. In West Africa, fish is a major source of animal protein and millions of people depend on it, being the cheapest and more accessible animal protein resource for local populations. The contribution of West African fisheries to food security is often undermined. Moreover, the low official fish consumption rate presented by the United Nations Food and Agriculture Organisation (14.7 kg per capita, 1999-2006) does not reflect a reality where significant catches are unreported and therefore under-estimated in official statistics. More comprehensive catch data reported herein reveal that annual fish consumption can be as high as 88 kg per capita in some coastal communities of West Africa, which demonstrates the importance of fish to their food security. Fisheries also provide jobs and incomes, further increasing food security and allowing people to purchase high calorie staples.

This report presents a historical perspective of fisheries and a more realistic estimate of fisheries removals from the exclusive economic zones of six Northwest African countries (Algeria, Morocco, Western Sahara, Mauritania, Cape Verde and Guinea). The rationale behind this work negates zero as a valid estimate for existing large-scale and small-scale fishing sector catches. The reconstructed catches include both domestic and foreign fisheries extractions, providing higher resolution catch data for six decades. Through a comprehensive review of the literature and local expert knowledge, the authors have reduced the level of uncertainty related to the catch reconstruction methods. As such, the results in this contribution provide a more realistic baseline, not only for determining future trends of fisheries but for estimating the sustainable surplus that can be accessed by distant-waters fleets in these waters. I therefore commend the authors for this important contribution.

U.R. Sumaila
Director, Fisheries Centre, UBC

Reconstruction of marine fisheries catches for Algeria, 1950-2010[1]

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Abstract

Total marine fisheries catches by Algeria were estimated from 1950 to 2010, including commercial landings, subsistence and recreational catches, as well as illegal and unreported catches. Commercial landings were obtained from FAO fisheries statistics database and from other sources. Non-commercial catch estimates were obtained from field survey data converted to *per capita* rates and catch per unit of effort estimates using Algerian population and effort data. Illegal catches and discards were estimated using recent at-sea observer data, expanded to cover the 1950-2010 time period. Total reconstructed catches were estimated to be 7.14 million tonnes over the study period, which is almost twice as high as the official landings of 3.9 million tonnes supplied to the FAO. In addition, we noted that the strong decline in catch per unit of effort is probably exacerbated by government subsidies to the fisheries sector.

Introduction

Located in the south of the Western Mediterranean basin, Algeria claimed an Exclusive Fishing Zone (EFZ) of 95,000 km² in 1994 (Cacaud 2002a) (Figure 1). The narrow continental shelf is a constraint to the development of the Algerian fisheries (Maurin 1962; Chaussade and Corlay 1989); thus, in Algeria, fisheries are mainly coastal (Coppola 2001) and target mainly small pelagic fish (Oliver 1983; Zeghdoudi 2006; www.mpeche.gov.dz [2001]), but also large pelagic fish and other species depending on the season (Coppola 2001; Sahi and Bouaicha 2003). The rocky bottoms hinder large-scale bottom trawling, which is mainly performed with small boats (Ordines *et al.* 2009). This fleet targets mainly high value species, e.g., red shrimp (*Aristeus antennatus*) (Belhabib 2007). The fisheries on the eastern and western coasts are the most productive, because of the strength of the Atlantic current (Furnestin 1961; Gulland 1971; Millot 1985, 1987) in the West and a relatively large continental shelf in the East (Oliver 1983).

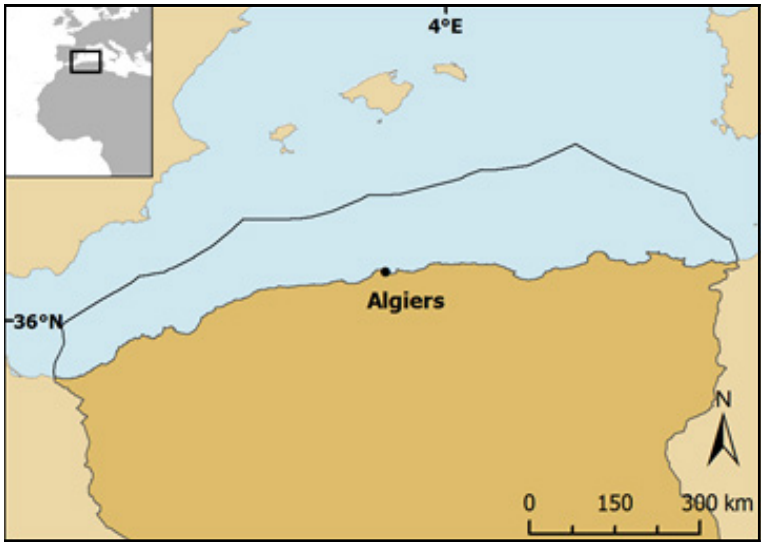

Figure 1. Map of the Exclusive Fishing Zone of Algeria.

From 1830 to 1962, Algeria was a French colony; the war for liberation started in 1954 and ended with independence in 1962, when many fishers left the country (Boude 1987). Afterwards, Algeria had a period of large investments in the agricultural and oil and gas sectors, and political stability during the 1970s and early 1980s (CIHEAM 2005). However, the fishing industry, privatized in the mid-1970s (Ministerial Decree of September 29, 1979) has been relatively neglected (FAO 2011).

These events have certainly impacted the fishing industry. From the late 1970s to the 2000s, unequal development and insecurity in rural areas accelerated the migration towards coastal cities, which led to an increasing demand for fish products. Yet, Algeria is still the country where the consumption of seafood is stated to be the lowest in the south-western Mediterranean (faostat.fao.org [2011]). Despite an overall increasing trend (71% increase in GDP since independence; www.worldbank.org [2011]), the fishing industry represents only around 1.3% of the GDP (Breuil 1997). Consequently, investment and financing programs targeting fisheries have been implemented in 1988, 1994, 2000-2003 and 2004-2007 (MPRH 2008), which led to increasing pressure on fish stocks (MATE 2006). Catch data reported to FAO often excludes important components such as by-catch, discards and recreational catches (Garibaldi 2012). Besides, fisheries lack a reliable landings data collection system to provide a better understanding

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of the fisheries dynamics in the country, which is a requirement for effective fisheries policy (MATE 2006; F. Hemida, pers. comm., Université de la Technologie et des Sciences Houari Boumedienne (UTSHB), 2011). With a fishing fleet of nearly 5,000 boats, including newly introduced industrial purse-seiners, and more than thirty seaports and 34 other landing sites in 14 coastal *wilayas* (districts), fishing in Algeria is important. Therefore, the trends in Algerian fisheries catches must be studied and analyzed to provide a solid basis for fisheries management and development policies.

Methods

Electronic time series of landings data from 1950 to 2010 were available through the Food and Agriculture Organization (FAO) FishstatJ database and used in this paper. In addition, we used data available from scientific and socio-economic reports (Furnestin 1961; Simonnet 1961; Vidal Junemann 1976; Oliver 1983) and statistical bulletins covering the period 1990 to 2007 of the Ministry of Fisheries and Fish Resources of Algeria (www.mpeche.gouv.dz [2011]). Reported landings are distinguished by species or higher taxonomic grouping and `miscellaneous groups´. Since the main goal of this study is to estimate total catches per species or higher taxonomic group, we compared the data supplied by Algeria to FAO to the above-cited national reports and used them as a reported baseline, to which we added: (1) illegal, unreported, and unregulated catches; (2) discards; (3) recreational and subsistence fisheries; (4) commercial catch adjustment including underreported catches of commercialized species; and (5) foreign flag catches.

Table 1. Taxonomic composition of the artisanal fisheries in Algeria, based on MPRH (2011) and Griffiths *et al.* (2007).

Common name	Taxon[a]	Catch (%)
Surmullets	*Mullus* spp.	2.59
European hake	*Merluccius merluccius*	3.97
Common pandora	*Pagellus erythrinus*	6.12
Gilthead seabream	*Sparus aurata*	10.70
Sole	Soleidae	0.06
Groupers	Epinephelidae; Polyprionidae	7.39
Pargo breams	*Pagrus* spp.	6.44
Axillary seabream	*Pagellus acarne*	0.12
Blackspot seabream	*Pagellus bogaraveo*	0.66
Sparidae	Sparidae	0.12
Moronidae	Moronidae	0.10
Red gurnard	*Aspitrigla cuculus*	0.01
Salema	*Sarpa salpa*	1.66
Rockfishes	Sebastinae and Scorpaeninae	7.31
Electric rays	Torpedinidae	0.19
Rays	Rajidae	0.27
Miscellaneous demersal fish	-	0.39
Sardinellas	*Sardinella* spp.	0.08
European anchovy	*Engraulis encrasicholus*	0.01
European pilchard	*Sardina pilchardus*	27.60
Horse mackerel	*Trachurus* trachurus	3.71
Atlantic mackerel	*Scomber japonicus; S. scombrus*	0.43
Bogue	*Boops boops*	0.34
Greater amberjack	*Seriola dumerili*	0.02
Barracudas nei	*Sphyraena sphyraena; S. virdensis*	0.18
Grey mullets	Mugilidae *(Liza* spp.*)*	0.97
Miscellaneous small pelagic	-	0.41
Yellowfin tuna	*Thunnus* spp.	1.36
Little tunny	*Euthynus alleteratus*	10.39
Swordfish	*Xiphias gladius*	1.56
Skipjack tuna	*Katsuwonus pelamis* and *Sarda sarda*	2.75
Blue and red shrimp	*Aristeus antennatus*	0.01
Deep-water rose shrimp	*Parapenaeus longirostris*	0.01
Palinurid spiny lobsters	Palinurus	1.81
Palinuridae	Palinuridae	0.08
Scyllaridae	*Scyllarus* spp.	0.03
Smooth-hound	*Mustelus mustelus*	0.08
Gulper shark	*Centrophorus granulosus*	0.01
Nursehound	*Scyliorhinus* spp.	0.01
Common cuttlefish	*Sepia officinalis*	0.09
Common octopus	*Octopus vulgaris*	0.02
European squid	*Loligo vulgaris*	0.01

[a] Djabali *et al.* (1993)

Illegal, unreported and unregulated commercial catches

This category includes the unreported portion of the artisanal catches since these are not properly covered by the official statistics. Illegal unreported catches also reported to as marine living resource crime by the United Nations and INTERPOL (INTERPOL 2010; UNODC 2011) include mainly undersized fishes.

Artisanal commercial landings

This paper highlights the under-reported portion of catches, with a particular emphasis on grouper catches, due to their overexploited status in the Mediterranean (Kara and Derbal 1999). Artisanal fisheries catches in Algeria are underestimated (MPRH 2011)[2], with about 80% of the catches being unreported (MATE 2005b; 2006; F. Hemida, pers. comm., UTSHB). From the 1950s to the late 1960s, only a few authors mentioned the artisanal fishing effort (Furnestin 1961; Simonnet 1961; Oliver 1983). From 1970 to 1980, development programs targeted some of the artisanal fleets (Boukhalfa and Rambeau 1993). Since then, fisheries subsidies to increase fishing effort have been provided through successive government programs (www.mpeche.gov.dz [2011]). Consequently, the interest in recording the artisanal fishing effort increased, but without focusing on concomitant catch. Since no national artisanal catch datasets are

[2] This information was provided by sources in local branches of the Ministry of Fisheries and Fisheries Resources who indicated that the real catch data were not reported to the Ministry. The individual sources preferred to remain anonymous.

available, we used local catch and artisanal effort data from two local branches of the Ministry of Fisheries and Fisheries Resources (MPRH 2011). The total small-scale landings reported are 176 t·year^{-1} for the first district and 341 t·boat^{-1}·year^{-1} for the second (MPRH 2011), and a catch per unit of effort (CPUE) of 84 t·year^{-1} for a third district (Bouazouni 2004). We adjusted the landings by +70% instead of +80% to allow for a conservative estimate. We then divided the estimated catch by the fishing effort, where all active boats are reported to both local branches. We averaged these estimates and obtained a CPUE of 38.15 t·boat^{-1}·year^{-1} for the active fleet in 2010 and generalized it over the other districts. Then, we assumed the CPUE was 50% higher in 1980 and 70% higher in 1950 because of the over-exploitation pattern of the coastal resources (Simonnet 1961; Oliver 1983). Thereafter, we interpolated linearly to estimate the annual CPUE. Based on the survey of Sahi and Bouaicha (2003), 89% of the artisanal fleet is active. We applied this to the available total effort data (1957, 1958, 1969, 1970, 1971, 1987-2009). We then estimated total catches using the derived CPUE and active effort time series, under the assumption that the fleet efficiency as well as the fishing grounds remained largely unchanged (PNUE 1996). Then, we interpolated linearly to complete the estimates for the missing years. During the period 2003-2004, a decrease in active artisanal fishing boats and landings was observed (MATE 2006). We applied an arbitrary correction rate of -15% to the effort, as a conservative approach to better represent the trend of the data.

Table 2. Anchor points for annual total catches of serranids in Algeria and the corresponding effort.

Year[a]	Catches (t·year^{-1})	Effort (Boats)	Data source
1950	26.00	-	Assumed
1957	182.64	296	Simonnet (1961); Oliver (1983)
1958	168.39	269	Simonnet (1961); Oliver (1983)
1969	159.77	221	www.fao.org [2011][b]
1971	125.10	169	Oliver (1983)
1987	326.15	456	Griffiths (1991)

[a]) the catch estimate is divided by 2 in 1962 (Meuriot and Dremiere 1986; Boude 1987).
[b])www.fao.org/docrep/005/D8317F/D8317F03.htm (accessed on June 1, 2011).

Species disaggregation: Coppola (2001) described the species composition of artisanal catches in the western Mediterranean Sea including Algeria. Griffiths *et al.* (2007) described the the gear type, i.e., gillnets, trammel nets and longlines (80% of the artisanal gears). Based on these sources, we estimated the percentage of catches for each species (taxonomic group) and applied this breakdown to the total reconstructed artisanal catches (Table 1).

Artisanal grouper catches: When artisanal catches were reported, they generally excluded groupers which accounted for 7.4% of the landings (DPRH 2011). Therefore, we assumed that a simple breakdown of the reconstructed artisanal catches would not reflect the development of this fishery, and thus we estimated these separately. Three species of serranids are caught in Algeria: the dusky grouper (*Epinephelus marginatus*), the white grouper (*Epinephelus aeneus*) and the dogtooth grouper (*Epinephelus caninus*) (Ouyahia 2004), while the red grouper (*Epinephelus morio*) was caught along the Algerian coast up to the late 1970s (Brualé 1985). Data provided to FAO by Algeria covered the `grouper nei´ and `groupers and seabasses´ for the years 1999-2003 and 2006-2009, respectively, but from 1950 until 1998, no commercial catches for this group were reported to the FAO. Here, we derived the percentage of boats targeting serranids (62.7%) by dividing the number of boats targeting groupers (among other fish) by the total artisanal active effort from Sahi and Bouaicha (2003) to estimate total catch per year. We used a CPUE of 0.53 t·year^{-1}·boat^{-1} in 2010[3], then applied the same adjustments assumed for small-scale CPUE described above. Then, we interpolated linearly assuming the CPUE in 1950 was the same as in 2010. Effort data were available for the years 1957 to 1958, 1969 to 1971 and 1990 to 2009. We interpolated linearly to complete the effort time series. In 1988 and 1989, only a few dozens of the artisanal boats were really active (Griffiths 1991). Consequently, we reduced the active effort by 80% for the years 1988 and 1989 (Table 2). We multiplied the effort by the CPUE to estimate total grouper catches for the 1950 to 2010 time period. For 2003 and 2004, we applied the same adjustment as for the artisanal catch estimation, i.e., -15%. Here, to remain conservative, we averaged grouper catches estimated above with grouper catches obtained using a species breakdown of total artisanal catches assuming a percentage of 7.4% (MPRH 2011). This better represents catch variations and captures the impact of increasing technological efficiency in targeting.

Illegal catches of small fish

Fish size regulations have been officially legislated since 1994 (Cacaud 2002b; Belala 2004). Since then, high value demersal species of sub-legal size, mainly surmulets (*Mullus barbatus* and *M. surmuletus)* and hake, (*Merluccius merluccius*) targeted by trawlers are often sold illegally in the market during October and November[4]. Local active effort data (381 trawlers), the quantity of illegal fish landed (0.2 t·day^{-1}·trawler^{-1}) for 60 days, and the species caught were available for 2010 (MPRH 2011). We first estimated the total illegal landings for the active segment of the Algerian trawling fleet for 2010 at 4,570 t·year^{-1}, and then assumed that in 1994 landings of small fish were reported, thus being 0% of the 2010 illegal catch, 80% in 2000 while in 2010 the catch estimated represented 30%.

[3] The source of this information preferred to remain anonymous.
[4] This information was passed on to us on condition of anonymity.

Commercial catch adjustment

Miscellaneous fish disaggregation

FAO data contains the category 'marine fishes nei'. To disaggregate the data taxonomically, we used detailed local catches by species or higher taxonomic level.

Small pelagic fish

Caddy *et al.* (1995) suggested that small pelagic fish catches were underreported in national data. To account for the unreported portion, we first combined the officially reported small pelagic catch with the amount of small pelagics estimated from the 'marine fishes nei' disaggregation. Thereafter, we adjusted the reported catch by a conservative rate of +10% per year from 1950 to 1962 during the French settlement, +20% from 1963 to 1994 after independence and during the black decade, when fishers failed to report their catches for security reasons, and +10% per year from 1994 to 2010, when new regulations were increasingly enforced.

Cephalopods

Six species of cephalopods are caught in Algerian waters: the horned octopus (*Eledone cirrhosa*), the musky octopus (*Eledone moschata*), the common octopus (*Octopus vulgaris*) (listed by FAO under `Octopuses´), the broadtail shortfin squid (*Illex coindetii*), the European squid (*Loligo vulgaris*) (listed under `Common squids´) and the common cuttlefish (*Sepia officinalis*) (Chavance 1987; MATE 2005b; Zeghdoudi 2006). FAO also reported miscellaneous cephalopod species under the category `Cephalopods nei´. Cephalopod catches have only been reported since 1989. In the 2000s, cephalopod catches represented 1% of the total landings (Zeghdoudi 2006). To adjust cephalopod catches, we first estimated the total cephalopod catch by applying the previous rate (1%) to the total reported landings to complete the time series from 1950 to 1988; then we used estimates from various sources (Table 3) as a proportion of the total cephalopod landings reported by FAO in order to disaggregate cephalopod catches.

Table 3. Composition of the cephalopod catches of Algeria (in %).

Reference	*Sepia* spp.	*Octopus* & *Eledone*	*Loligo vulgaris*
DPRH (2011)	55	43	5
DPRHA (2011)	18	18	63
MATE (2005b)	34	63	0
Chavance (1987)[a]	83	17	0
Mean	48	35	17

[a]) Estimated using the percentage of the cephalopod catches (3.88% of the demersal fishery catches) by the trawling fleet (20%) of the total catches.

Sharks and rays

Elasmobranch catches for Algeria are reported by the FAO under four categories: `Sharks, rays, skates, etc.´, `Rays, stingrays, mantas nei´, `Dogfish sharks nei´and`Catsharks, nursehounds nei´. The last two categories are reported only for the period 2007 to 2009. Shark and ray catches were reported as zero in 1963 and from 1986 to 1989. Shark catches were not reported from 1950 to 1953 due in part to species being confused as other pelagic fish (S. Hemida, pers. comm., UTSHB). We estimated rays to be 2.11% of the group 'sharks, rays and skates' (Hemida 2005) and thus disaggregated FAO data into two major categories: sharks and rays. To estimate shark catches for the period from

Table 4. Composition of the sharks and rays catches of Algeria for the period 1950-2010 (in %).

Ray species	Catches (%)	Source number	Shark species	Catches (%)	Source number
Dipturus batis	0.47	1	*Cetorhinus maximus*	84.89	1
Dipturus oxyrinchus	31.68	1	*Hexanchus griseus*	8.50	1
Leucoraja melitensis	0.15	1	*Heptranchias perlo*	0.20	1 ; 2
Raja africana	0.24	1	*Isurus oxyrhincus*	1.70	1
Raja asterias	13.32	1	*Alopias vulpinus*	1.70	1 ; 3 ; 4
Raja brachyura	12.49	1	*Carcharhinus brachyurus*	0.19	5 ; 6
Raja clavata	19.79	1	*Carcharhinus plumbeus*	0.16	5 ; 6
Raja miraletus	2.48	1	*Carcharhinus altimus*	0.39	5 ; 6
Raja montagui	6.58	1	*Carcharhinus obscurus*	0.10	5
Raja polystigma	0.59	1	*Carcharhinus brevipinna*	0.02	5
Raja radula	7.74	1	*Galeus melastomus*	0.01	1
Raja undulata	1.46	1	*Scyliorhinus canicula*	0.01	1
Rostroraja alba	0.02	1	*Scyliorhinus stellaris*	0.03	1
Leucoraja naevus	1.77	1	Triakidae[a]	0.30	1
Leucoraja circularis	1.11	1	Squalidae[b]	0.14	1
			Oxynotus centrina	0.01	1
			Echinorhinus brucus	1.70	1

1) Hemida (2005); 2) Canapé *et al.* (2003) ; 3) Fowler *et al.* (2005) ; 4) Pillans *et al.* (2008) ; 5) Hemida *et al.* (2002b) ; 6) Dieuzeide *et al.* (1953).
[a]) *Mustelus mediterraneus, M. mustelus ; Centrophorus granulosu ; C. uyato.*
[b]) *Dalatias licha, Etmopterus spinax, Squalus acanthias, S. blainvillei, Somniosus rostratus.*

1950 to 1953, we carried the catch trend from 1954 to 1957 using FAO landing data. For the periods from 1986 to 1989 and from 2003 to 2006, we performed simple linear interpolations based on FAO landings data and commercial catches (Hemida 1998). A literature review allowed for the estimation of shark and ray catches by species (Table 4). For the devil fish (*Mobula mobular*), Hemida *et al.* (2002a) reported a total catch of 3.3 tonnes for 1996, 1999 and 2001. We estimated an average catch of 1.1 $t \cdot year^{-1}$ for the years 1996 to 2009. This species was rare in 1953 (Dieuzeide *et al.* 1953; Notarbartolo-Di-Sciara 1987), but incurs high mortality from accidental catch in pelagic (Cavanagh and Guibson 2007) and drift-net fisheries (Cornax *et al.* 2006), which appeared in Algeria in 1989 (Abdelguerfi 2003). In this study, we assumed that catches started in 1976 (see Hemida *et al.* 2002a) and increased steadily until 1996, afterwhich catches remained stable.

FAO data for sharks and rays are considered to be underestimates (Kroese and Sauer 1998). We assumed that 37% of sharks were caught by the small-scale fishery (Canapé *et al.* 2003), with 40% of the catch being unreported (i.e., 37% x 40% =15%). Therefore, we applied this percentage (15%) to each of the shark and ray species caught by artisanal gears. For the remaining 63% of the reported shark and ray catch taken by trawlers, purse-seiners and drift-nets used largely in Algeria, we assumed 20% of the catch was unreported (i.e., 63% x 20%=12.6%) (Cornax *et al.* 2006; Cavanagh and Guibson 2007; EJF 2007). We applied the resulting rate (12.6%) to non-artisanal shark and ray catches from 1950 to 2010, excluding devil fish which has already been estimated separately (see above).

Crustaceans

The main crustacean species caught along the Algerian coast are the blue and red shrimp (*Aristeus antennatus*) and the deep water rose shrimp (*Parapenaeus longirostris*) (Maurin 1962; MATE 2005b; Zeghdoudi 2006). The `marine crustaceans nei´ group reported by FAO includes other crustacean species, mainly caught by the artisanal fleet: spider crab (*Maia squinado*), common spiny lobster (*Palinurus elephas*), pink spiny lobster (*Palinurus mauritanicus*), caramote prawn (*Penaeus kerathurus*), Mediterranean slipper lobster (*Scyllarides latus*) and small European locust lobster (*Scyllarus arctus*) (MATE 2005b). In Algeria, shrimp catches are also underreported due to trans-shipments to foreign vessels; thus, a portion of the real catch is not reported to the FAO (Boukhalfa and Rambeau 1993; Mediouni 1997). CPUEs based on at-sea observations are higher (Sardà 2000; Bouaicha 2011). Algeria supplied a catch of zero tonnes to FAO for the blue and red shrimp from 1950 to 1953; however, Anon. (1955) and Maurin (1962) reported large amounts of catch by the trawl fishery during the same period. Here, we first estimated the number of active trawlers (Table 5) based on the number of operating trawlers per year and the total number of registered trawlers, i.e., 75.8% in 2010, which we assumed constant (MPRH 2011). Then, we estimated the total effort as the total number of hours per year

Table 5. Active trawl fleet and number of hours.

Year	Number of trawlers	Active trawlers	Number of hours
1950	146	110	110,869
1951	136	102	103,275
1952	135	101	102,516
1953	138	104	104,794
1954	137	103	104,034
1955	146	110	110,869
1956	152	114	115,425
1957	147	110	111,628
1958	153	115	116,184
1959	152	114	115,425
1960	156	117	118,463
1961	158	119	119,981
1962	75	56	56,953
1963	75	56	56,953
1964	76	57	57,713
1965	76	57	57,713
1966	103	77	78,216
1967	100	75	75,938
1968	100	75	75,938
1969	99	74	75,178
1970	101	76	76,697
1971	110	83	83,531
1972	115	86	87,328
1973	130	98	98,719
1974	140	105	106,313
1975	149	112	113,242
1976	158	119	120,171
1977	167	126	127,100
1978	177	132	134,030
1979	186	139	140,959
1980	195	146	147,888
1981	204	153	154,818
1982	213	160	161,747
1983	222	167	168,676
1984	231	173	175,605
1985	240	180	182,535
1986	250	187	189,464
1987	259	194	196,393
1988	268	201	203,323
1989	277	208	210,252
1990	286	215	217,181
1991	285	214	216,422
1992	284	213	215,663
1993	285	214	216,422
1994	289	217	219,459
1995	293	220	222,497
1996	295	221	224,016
1997	294	221	223,256
1998	299	224	227,053
1999	305	229	231,609
2000	318	239	241,481
2001	338	254	256,669
2002	352	264	267,300
2003	354	266	268,819
2004	358	269	271,856
2005	403	302	306,028
2006	435	326	330,328
2007	476	357	361,463
2008	487	365	369,816
2009	494	371	375,131
2010	494	371	375,131

Table 6. Demersal and shrimp trawl catch per unit of effort.

Taxon name	English name	CPUE (kg·h^{-1})	Taxon name	English name	CPUE (kg·h^{-1})
Abralia veranyi	Eye-flash squid	4.959	*Parapenaeus longirostris*	Deep-water rose shrimp	11.252
Aristaeomorpha foliacea	Giant red shrimp	2.588	*Pasiphaea multidentata*	Pink glass shrimp	0.020
Aristeus antennatus	Blue and red shrimp	12.333	*Phycis blennoides*	Greater forkbeard	3.976
Arnoglossus laterna	Mediterranean scaldfish	0.072	*Phycis phycis*	Forkbeard	1.583
Arnoglossus rueppelli	Rüppell's scaldback	0.035	*Plesionika acanthonotus*	lesser striped shrimp	0.213
Chelidonichthys cuculus	Red gurnard	0.053	*Plesionika antigai*	Catalonian striped shrimp	0.057
Bathysolea profundicola	Deepwater sole	0.002	*Plesionika edwardsii*	Soldier striped shrimp	0.069
Boops boops	Bogue	1.374	*Plesionika giglioli*	Shrimp	1.004
Centrolophus niger	Rudderfish	0.462	*Plesionika heterocarpus*	Shrimp	1.095
Chlorotocus crassicornis	Green shrimp	0.313	*Plesionika martia*	Golden shrimp	0.128
Citharus linguatula	Spotted flounder	0.024	*Plesionika martia*	Golden shrimp	0.391
Conger conger	European conger	1.035	*Processa canaliculata*	Shrimp	1.621
Diplodus annularis	Annular seabream	0.308	*Pteroctopus tetracirrhus*	Fourhorn octopus	0.003
Echelus myrus	Painted eel	0.016	*Raja clavata*	Thornback ray	0.068
Eledone cirrhosa	Horned octopus	2.512	*Raja polystigma*	Speckled ray	0.058
Eledone moschata	Musky octopus	0.134	*Rondeletiola minor*	Lentil bobtail squid	0.096
Engraulis encrasicholus	European anchovy	0.892	*Sardina pilchardus*	European pilchard	0.246
Gadella maraldi	Gadella	0.242	*Scaergus unicirrhus*	Cephalopod	0.201
Galeorhinus galeus	Tope shark	0.648	*Scomber scombrus*	Atlantic mackerel	0.019
Galeus melastomus	Blackmouth catshark	3.864	*Scomberesox saurus*	Atlantic saury	0.227
Gnathophis mystax	Thinlip conger	0.078	*Scorpaena elongata*	Slender rockfish	0.245
Helicolenus dactylopterus	Blackbelly rosefish	1.505	*Scorpaena scrofa*	Red scorpionfish	0.010
Illex coindetii	Shortfin squid	0.905	*Scyliorhinus canicula*	Small-spotted catshark	0.454
Lepidorhombus boscii	Four-spot megrim	1.330	*Sepia elegans*	Elegant cuttlefish	1.156
Lepidotrigla cavillone	Large-scaled gurnard	0.452	*Sepia officinalis*	Common cuttlefish	0.078
Lepidotrigla dieuzeidei	Spiny gurnard	0.064	*Sepia orbignyana*	Pink cuttlefish	0.971
Loligo vulgaris	European squid	1.023	*Sepietta oweniana*	Common bobtail squid	1.574
Lophius budegassa	Blackbellied angler	0.680	*Sepiola* spp.	Bobtails	0.077
Lophius piscatorius	Angler	0.123	*Serranus cabrilla*	Comber	0.366
Merluccius merluccius	European hake	6.040	*Serranus hepatus*	Brown comber	0.522
Micromesistius poutassou	Blue whiting	2.913	*Solea solea*	Common sole	0.026
Molva dypterygia	Blue ling	0.236	*Spicara flexuosa*	Blotched picarel	0.600
Mullus barbatus	Red mullet	3.516	*Spicara smaris*	Picarel	1.506
Mullus surmuletus	Surmullet	0.862	*Symphurus nigrescens*	Tonguesole	0.345
Neorossia caroli	Carol bobtail	0.023	*Synodus saurus*	Atlantic lizardfish	0.041
Nephrops norvegicus	Norway lobster	2.380	*Todarodes sagittatus*	European flying squid	0.520
Octopus salutii	Long-armed octopus	0.344	*Todaropsis eblanae*	Lesser flying squid	1.137
Octopus vulgaris	Common octopus	0.385	*Torpedo marmorata*	Marbled electric ray	0.345
Oxynotus centrina	Angular roughshark	0.097	*Torpedo nobiliana*	Electric ray	0.050
Pagellus acarne	Axillary seabream	2.293	*Trachurus mediterraneus*	Mediterranean horse mackerel	0.073
Pagellus bogaraveo	Blackspot seabream	4.044	*Trachurus picturatus*	Blue jack mackerel	1.217
Pagellus erythrinus	Common pandora	1.906	*Trigla lucerna*	Tub gurnard	0.064
Pagurus excavatus	Hermit crab	0.284	*Trigla lyra*	Piper gurnard	0.160
Paralepis coregonoides	Sharpchin barracudina	0.037	*Zeus faber*	John dory	0.760

(1,017 hours per trawler), expressed in the total number of hour for the active trawl fleet based on the average operating time per day, i.e., 9 hours (Nouar 2007) and the number of days at sea, which were averaged between 32 and 193 days, i.e., 113 days at sea (FAO 1973; Nouar 2007), and then by the number of trawlers (Table 5) from 1950 to 2010 collected from Belouahem (2009), MPRH (2001), MPRH (2010) and Oliver (1983). Catches are then obtained by multiplying this effort by per species CPUEs based on at-sea observations for 2010 (Table 6) (Bouaicha 2011). We thus completed the estimate for the years when data were not reported to FAO, or reported as zero for the taxa mentioned above and we replaced the catch data provided to FAO whenever our approach provided higher estimates. We then completed the estimate with catch data for the species that were never reported (landed by-catch) to obtain a more complete estimate with a higher resolution.

Bluefin tuna catches of Algeria

FAO bluefin tuna (Thunnus thynnus) landings have been increasing since the 1950s. However, a dramatic increase in catches was reported after Algeria became a member of ICCAT in 2000 (ICCAT 2003). From the early 1990s,

when Algeria signed its first agreement for foreign longliners, to 2002, a large portion of Algerian bluefin tuna catch was attributed to foreign-flagged vessels (Abdelguerfi 2002; WWF 2006, 2008b). From 1991 to 1994, we believe Algeria over-reported its bluefin tuna catch, where the over-reported portion is allocated to foreign vessels operating under or without agreement. Thus, we assumed Algerian domestic bluefin tuna catch is the difference between the estimated foreign catch (see foreign flag catch section) and bluefin tuna catches reported by Algeria to FAO. From 1995 to 1997, we accepted bluefin tuna catches as reported by Algeria since there was no evidence to suggest over-reporting. It is only in 2004 that Algeria acquired its first purse-seiner, and evidence suggests that Algeria over-reported its bluefin tuna catch to maintain a high quota with ICCAT as a high portion of the reported catch was being allocated to foreign vessels for the period from 1998 to 2006. Consequently, from 1998 to 2003, we adjusted bluefin tuna landings by applying a CPUE estimate obtained from local catch data of aggregated tuna species (i.e., 0.5 t·year^{-1}·boat^{-1}) to the small-scale fleet (MPRH 2010, 2011). Thereafter, we added the estimated catch for the purse seine fleet of 600 t·year^{-1} from 2004 to 2006 and 1740 t·year^{-1} from 2006 to 2010 (WWF 2008a). Although considerable uncertainty exists in our catch estimate due the use of aggregated tuna CPUE, Abdelguerfi (2002) suggested that Bluefin tuna catches were underestimates, therefore our estimates are likely conservative.

Subsistence and recreational fisheries

Subsistence fisheries

Local estimates for subsistence catches per species, gear type and the number of fishers in Bouzadjar, Western Algeria were available for 1960[5], one of the 5 main maritime areas identified by the French administration (Oliver 1983) leading to a local catch of 68 t·year^{-1} for 1960. We assumed an equivalent catch over the 4 other maritime areas and estimated a total catch of 340 t·year^{-1} in 1960 (based on 68 t·year^{-1} x 5=340 t·year^{-1}). Given a local population of 1,020,000 in 1960 (www.populstat.com [2011]), this translates to an annual per capita catch of 0.33 kg·person^{-1}·year^{-1}. We applied this catch rate to the population data available for the years 1954, 1958, 1960, 1963, 1966, 1970, assuming that the consumption rate was constant (which is likely to underestimate catches). After 1970, development plans targeting fisheries (CIHEAM 2005) were issued and the first fisheries regulations were promulgated and gradually enforced (Belala 2004), thus reducing subsistence fishing. Consequently, we assumed that by 2000, subsistence catches were 1% of subsistence catch of 1970 and remained stable thereafter, and completed the time series by applying a series of linear interpolations for the missing years. We used the local estimate in 1960 to disaggregate the catches to the species/taxon level.

Table 7. Catch per recreational fisher (kg·fisher^{-1}) the corresponding catch composition of recreational fishing.

		1998					2002			
Taxon name	**English name**	**Weight (kg)**	**Frequency**	**Catch/ trip**	**Catch/ year**	**%**	**Frequency**	**Catch/trip**	**catch/ year**	**%**
Epinephelus marginatus	Dusky grouper	7.0	1.00	7.0	266.0	17.9	0.20	1.4	53.2	4.4
Epinephelus caninus	Dogtooth grouper	2.5	0.50	1.3	47.5	3.2	0.20	0.5	19.0	1.6
Epinephelus fasciatus	Blacktip grouper	2.5	0.50	1.3	47.5	3.2	0.20	0.5	19.0	1.6
Sphyraena sphyraena	European barracuda	4.0	0.33	1.3	50.7	3.4	0.33	1.3	50.7	4.2
Lichia Amia	Leerfish	18.8	1.00	18.8	714.8	48.0	1.00	18.8	714.8	58.8
Seriola Dumerili	Greater amberjack	3.0	0.10	0.3	11.4	0.8	0.10	0.3	11.4	0.9
Conger conger	European conger	5.0	0.10	0.5	19.0	1.3	0.10	0.5	19.0	1.6
Muraena helena	Mediterranean moray	5.0	0.10	0.5	19.0	1.3	0.10	0.5	19.0	1.6
Sphyraena spp.	Barracudas	1.0	0.67	0.7	25.3	1.7	0.67	0.7	25.3	2.1
Octopus vulgaris	Common octopus	1.0	0.07	0.1	2.5	0.2	0.07	0.1	2.5	0.2
Sepia spp.	Cuttlefish	0.5	0.07	0.0	1.3	0.1	0.07	0.0	1.3	0.1
Sciaena umbra	Brown meagre	0.5	0.33	0.2	6.3	0.4	0.10	0.1	1.9	0.2
Spondyliosoma cantharus	Black seabream	1.5	0.67	1.0	38.0	2.6	0.67	1.0	38.0	3.1
Diplodus puntazzo	Sharpsnout seabream	1.0	0.33	0.3	12.7	0.9	0.33	0.3	12.7	1.0
Dentex dentex	Common dentex	5.0	0.33	1.7	63.3	4.3	0.33	1.7	63.3	5.2
Sarpa salpa	Salema	1.0	0.33	0.3	12.7	0.9	0.33	0.3	12.7	1.0
Sparus aurata	Gilthead seabream	2.5	0.33	0.8	31.7	2.1	0.33	0.8	31.7	2.6
Diplodus sargus sargus	White seabream	1.5	0.25	0.4	14.3	0.9	0.25	0.4	14.3	1.2
Pagellus erythrinus	Common pandora	1.0	0.25	0.3	9.5	0.6	0.25	0.3	9.5	0.8
Pagrus auriga	Redbanded seabream	1.0	1.00	1.0	38.0	2.6	1.00	1.0	38.0	3.1
Balistes capriscus	Grey triggerfish	2.0	0.25	0.5	19.0	1.3	0.25	0.5	19.0	1.6
Umbrina cirrosa	Shi drum	2.3	0.33	0.8	29.1	1.9	0.33	0.8	29.1	2.4
Palinurus elephas	Common spiny lobster	2.5	0.10	0.3	9.5	0.6	0.10	0.3	9.5	0.8
Total CPUE		-	-	-	1.49	-	-	-	1.2	-

[5] G. Padilla, a subsistence fisher now living in France (pers. comm.).

Recreational fisheries

Recreational fishing in Algeria includes mainly boat-based line fishing (longline fishing, 80%), handline fishing, and spearfishing using boats of 5 to 7 meters (Boukhalfa and Rambeau 1993).

Spearfishing: Spearfishing was rarely practiced until the 1980s[6] and started increasing thereafter. We relied on a field survey targeting spearfishers, electronic qualitative data[7] and literature review (see MATE 2005b; Grau *et al.* 2009) to estimate catches by this gear type. We assumed an average number of 381 spearfishers (from 2002 to 2010) based on 28 scuba diving clubs (www.corbusmilchasse.com [2011]), the estimated number of divers practicing spearfishing per club (14) and a nominal effort of 38 days per year (M. Kharfellah, pers. comm., *Institut des Sciences de la Mer et de l'Aménagement du Littoral*, 2011). We assembled a catch frequency per species per day expressed as a probability of catch ranked from 0 to 1 from the field survey and www.corbusmilchasse.com [2011] (Table 7), we multiplied each frequency by the average weight of each species and the number of fishing days per spearfisher (38), then estimated the total catch per year for 1998 (567.32 t·year^{-1}) when the total recreational catch per fisher is the product of the number of fishing days by the sum of each species catch per day (1.49 t·year^{-1}·fisher^{-1}). We obtained the percentage of each species by dividing the weight of each species by the annual recreational catch per fisher for 1998 (Table 7). We reduced the catch frequency (given for 1998) by 80% for groupers (*Epinephelus marginatus, E. caninus* and *E. fasciatus)* and 25% for brown meagre (*Sciaena umbra*) for the last decade, beginning from 2002, to represent their decreasing trend (Kara and Derbal 1999; Grau *et al.* 2009), which led to a total catch of 462.84

Table 8. Species composition of recreational boat-based catch.

Scientific name	Common name	Mean weight (kg)	Source	Catches (%)
Boats using hooks				
Xiphias gladius	Swordfish	26.7	Chalabi *et al.* (1995)	56.5
Thunnus spp.	Tunas	142.0	ICCAT (2007) ; Bachet *et al.* (2007); estimated[a]	0.8
Prionace glauca	Blue shark	41.3	Hemida (2005)	14.6
Isurus oxyrinchus	Shortfin mako	63.0	OCEANA (2010); Megalofonou *et al.* (2005)	4.1
Galeorhinus galeus	Tope shark	19.1	OCEANA (2010)	0.1
Coryphaena hippurus	Common dolphinfish	3.31	Djabali *et al.* (1993); Bas Peired (2006); estimated[a]	0.6
Dasyatis pastinaca	Common stingray	44.0	Serena *et al.* (2003)[b]; www.fishbase.org [2011]	21.4
Alopias vulpinus	Thresher shark	104.9	Hemida (2005)	1.9
Other boat-based[c]				
Mullus spp.	Goatfish			29.0
Helicolenus dactylopterus; Scorpena porcus; S. scrofa; S. notate; S. elongata	Scorpionfishes			8.8
Sepia sp.	Common cuttlefish			2.9
Pagrus pagrus	Red porgy			5.9
Pagellus bogaraveo; P. erythrinus	Seabreams			14.7
Phycis spp.	Forkbeard			2.9
Sparidae	Porgies			5.9
Solea solea	Common sole			2.9
Merluccius merluccius	European hake			2.8
Raja spp.	Rays			2.9
Mustelus mustelus	Smooth-hound			2.9
Pagellus acarne	Axillary seabream			8.8
Epinephelus spp.	Groupers			2.9

[a]) Derived from length-weight relationship.
[b]) www.iucnredlist.org/apps/redlist/details/161453/0 (accessed on June 1, 2011).
[c]) Sahi and Bouaicha (2003) and Anon. (2005).

t·year^{-1} for 2002. From 2003 onwards, we assumed a decreasing rate of recreational catches of 10% per year, then applied it year by year until 2010 to represent the decreasing trend of catches (i.e., recreational catch (2003) = recreational catch 2002 x (100%-10%)). Here, we assumed recreational spearfishing begun in 1970 (10 years after the independence), thus interpolated linearly from zero in 1970 to 567.32 t·year^{-1} in 1998, to 462.84 t·year^{-1} in 2002, and then completed the time series with a 10% decrease of recreational catches per year.

Boat-based fishing: In Algeria, recreational fishing boats are about 5 to 7 meters of length, using hook and line (80%) or other gears. Here, we assumed boat-based recreational fishing started in 1970 , corresponding to the implementation of the first fisheries development program (CIHEAM 2005). Until 2002, recreational fishers had no legal restrictions (Abdelguerfi 2002).

Based on local effort and catch data (MPRH 2011; www.Algeria.com [2011]) we estimated a catch of 0.5 t·boat^{-1}·year^{-1} for a total of 1,680 recreational fishing boats per year over the period 2002-2010, resulting in a total

[6] www.bainsromains.com (accessed on June 13th, 2011).
[7] www.corbusmilchasse.com/corbusmil1/poisson%20miniature.htm (accessed on June 13th, 2011).

catch of 840 t·year^{-1} for 2010. To estimate recreational boat-based line catches and allow for species disaggregation, we combined data on the number of fishes per hook per fishing trip (Báez *et al.* 2009) with weight data per species (obtained from literature or derived from length-weight relationships (Table 8). We adjusted the estimated catch per species per hook by -50%, to account for the difference in boat efficiency since Báez *et al.* (2009) described these

Table 9. Demersal and shrimp trawl discard per effort.

Taxon name	CPUE (kg·trawl^{-1}·h^{-1})	Taxon name	CPUE (kg·trawl^{-1}·h^{-1})	Taxon name	CPUE (kg·trawl^{-1}·h^{-1})
Abralia veranyi	31.2	*Hoplostethus mediterraneus*	55.3	*Plesionika antigai*	14.0
Acanthocardia echinata	45.4	*Illex coindetii*	70.0	*Plesionika edwardsii*	4.1
Alpheus glaber	27.3	*Lampanyctus crocodilus*	39.7	*Plesionika giglioli*	64.7
Antonogadus megalokynodon	40.7	*Lepidopus caudatus*	70.4	*Plesionika heterocarpus*	71.0
Argentina sphyraena	62.8	*Lepidorhombus boscii*	81.8	*Plesionika martia*	23.4
Argyropelecus hemigymnus	12.2	*Lepidotrigla cavillone*	27.2	*Plesionika* spp.	14.7
Aristaeomorpha foliacea	118.1	*Lepidotrigla dieuzeidei*	8.3	*Policheles typhlops*	24.5
Aristeus antennatus	290.7	*Lesueurigobius friesii*	34.4	*Pontophilus spinosus*	28.8
Arnoglossus laterna	5.6	*Lesueurigobius spp.*	5.1	*Processa canaliculata*	31.0
Arnoglossus rueppelli	1.9	*Liocarcinus depurator*	18.7	*Pteroctopus tetracirrhus*	0.9
Chelidonichthys cuculus	8.7	*Loligo vulgaris*	56.4	*Raja clavata*	3.4
Bathysolea profundicola	0.6	*Lophius budegassa*	32.6	*Raja polystigma*	3.4
Benthocometes robustus	4.4	*Lophius piscatorius*	9.7	*Rondeletiola minor*	7.9
Benthosema glaciale	3.3	*Macropipus tuberculatus*	30.4	*Rossia macrosoma*	6.8
Blennius ocellaris	2.4	*Macropodia longipes*	0.2	*Sardina pilchardus*	28.9
Boops boops	88.5	*Macropodia* spp.	0.0	*Sardinella aurita*	0.4
Callionymus maculatus	8.1	*Macroramphosus scolopax*	76.3	*Scaergus unicirrhus*	12.7
Capros aper	24.1	*Maurolicus muelleri*	4.5	*Scaphander lignarius*	5.8
Centrolophus niger	12.9	*Merluccius merluccius*	263.5	*Scomber scombrus*	1.6
Centrophorus granulosus	27.7	*Micromesistius poutassou*	159.7	*Scomberesox saurus*	15.0
Cepola rubescens	13.9	*Molva dypterygia*	23.5	*Scorpaena elongata*	15.4
Ceratoscopelus maderensis	4.9	*Monodaeus couchi*	5.2	*Scorpaena notata*	4.8
Chimaera monstrosa	10.8	*Mullus barbatus*	154.6	*Scorpaena porcus*	0.5
Chlorophthalmus agassizi	56.1	*Mullus surmuletus*	22.8	*Scorpaena scrofa*	0.9
Chlorotocus crassicornis	23.7	*Munida iris*	0.1	*Scyliorhinus canicula*	26.4
Citharus linguatula	2.6	*Munida perarmata*	25.0	*Sepia elegans*	45.9
Coelorinchus caelorhincus	60.0	*Munida rugosa*	14.9	*Sepia officinalis*	3.5
Conger conger	36.0	*Myctophum punctatum*	10.6	*Sepia orbignyana*	37.9
Dalatias licha	39.3	*Nemichthys scolopaceus*	0.2	*Sepietta oweniana*	98.3
Dalophis imberbis	1.3	*Neorossia caroli*	3.4	*Sepiola* spp.	4.4
Dardanus arrosor	3.7	*Nephrops norvegicus*	131.7	*Sergestes arcticus*	4.0
Diplodus annularis	14.0	*Nettastoma melanurum*	3.6	*Sergia robusta*	12.7
Echelus myrus	0.2	*Nezumia aequalis*	50.4	*Serranus cabrilla*	11.6
Eledone cirrhosa	91.7	*Nezumia sclerorhynchus*	33.7	*Serranus hepatus*	18.6
Eledone moschata	3.4	*Notacanthus bonapartei*	8.3	*Solea solea*	3.7
Engraulis encrasicholus	48.6	*Octopus salutii*	26.8	*Solenocera membranacea*	61.0
Epigonus constanciae	0.8	*Octopus vulgaris*	11.9	*Spicara flexuosa*	19.0
Epigonus denticulatus	25.2	*Oxynotus centrina*	18.0	*Spicara smaris*	34.6
Epigonus telescopus	2.7	*Pagellus acarne*	85.4	*Sequilla mantis*	2.3
Etmopterus spinax	164.2	*Pagellus bogaraveo*	168.8	*Stomias boa*	15.7
Gadella maraldi	6.1	*Pagellus erythrinus*	83.0	*Symphurus nigrescens*	46.7
Gadiculus argenteus	57.2	*Pagurus excavatus*	11.4	*Synchiropus phaeton*	15.0
Galeorhinus galeus	51.0	*Paralepis coregonoides*	12.0	*Synodus saurus*	7.2
Galeus melastomus	164.5	*Parapenaeus longirostris*	528.0	*Todarodes sagittatus*	26.0
Geryon longipes	10.9	*Paromola cuvieri*	17.9	*Todaropsis eblanae*	63.2
Glossanodon leioglossus	35.9	*Parthenope macrochelos*	6.0	*Torpedo marmorata*	14.4
Gnathophis mystax	3.5	*Pasiphaea multidentata*	25.2	*Torpedo nobiliana*	3.2
Goneplax rhomboides	54.2	*Pasiphaea sivado*	11.6	*Trachurus mediterraneus*	2.2
Helicolenus dactylopterus	69.3	*Peristedion cataphractum*	20.5	*Trachurus picturatus*	59.4
Heteroteuthis dispar	7.0	*Phycis blennoides*	249.0	*Trigla lucerna*	2.5
Histioteuthis bonnellii	8.1	*Phycis phycis*	70.6	*Trigla lyra*	9.1
Histioteuthis reversa	24.3	*Plesionika acanthonotus*	17.9	*Zeus faber*	41.9
Homola barbata	4.2	-	-	-	-

catches for recreational boats ranging from 5 meters to 12.5 meters of length. By multiplying the sum of recreational catches per species (8.49 t·hook^{-1}·year^{-1}) by the total number of hooks, we obtained a total catch of 481.31 t·year^{-1} for 2010 which we assumed to be constant from 2002 to 2010 (M. Kharfellah, pers. comm., *Institut des Sciences de la Mer et de l'Aménagement du Littoral*, 2011) then we interpolated backwards to zero in 1970. The difference in total recreational catches (i.e., 840 t·year^{-1}–481.31 t·year^{-1} =358.68 t·year^{-1}) represents recreational catches by other boat based gear types in 2010 which we interpolated backwards to zero in 1970.

Discards

Discards include non-commercial species, damaged fish and illegal-size fish (GFCM 2011). Discards in the Western Mediterranean are not negligible (Carbonell *et al.* 1998; Kelleher 2005), and among all fishing gears, trawls have been recognized as the most problematic gear (Lleonart *et al.* 1999), besides the use of dynamite, which while not considered here, generates high rates of underwater gear mortality (Tudela and Sacchi 2003). We consider two types of discards: from the pelagic trawl fishery and the shrimp trawl fishery.

Pelagic trawl discards

Multi-purpose boats (trawler - seiner) introduced in the 1970s (Oliver 1983) started to generate increasing discards. Pelagic trawl fishery discards thus were about 20% of the pelagic trawl landings in 2010 (MPRH 2011). We first estimated the portion of pelagic fish landed by pelagic trawlers using catch per gear data (23% of the small pelagic fish landings), then applied the 20% discard rate to the reported landings from 1971 to 2010.

Shrimp fishery discards

Shrimp fishery discards in Algeria were as high as 49% of the total retained catches (FAO 1973; Carbonell *et al.* 1998; Bouaicha 2011). Here, we used a survey based on at-sea observations of discards, by-catch and targeted species catches for a commercial trawler of 368 kW and a length of 20 m (Bouaicha 2011). We multiplied the discard per hour per species (expressed in kg·h^{-1}) Bouaicha (2011) (Table 9) by the number of operating hours per trawler per year (1,017 hours) to estimate the discard per boat per hour, i.e., 48 kg·h^{-1}. Then, we applied this discard estimate to the total number of operating shrimp trawl hours (Table 5). Prior to 1994, when Algeria began regulating size limits (Belala 2004), we assumed that fishers were discarding commercially valuable catch only based on storage capacity constraints. Thus, we adjusted discards as a function of the storage capacity. Storage capacity expressed in GRT in the 1950s was 43% of what it is today (Simonnet 1961; Oliver 1983; Zeghdoudi 2006; Belhabib 2007). From the 1970s to late 1980s, it was 61% of the 2010 level (Belhabib 2007). Consequently, we adjusted the total discard, where from 1950 to 1960, 43% of the high value species discard where size restriction apply were retained, and from 1970 to 1994, 61% of the same discards were retained. As for the period from 1994 to 2010, no adjustment is applied, since discarding of valuable species was due to size limits.

Foreign flag catches

Many authors have described foreign fleets operating in Algerian waters since 1950 (Furnestin 1961; Simonnet 1961; Oliver 1983; Tudela and Sacchi 2003; Varela and Ojeda 2010). Here, we focused on bluefin tuna catches and other pelagic fish species.

Table 10. Anchor points for the foreign bluefin tuna catches in Algeria.

Year	Catches (t·year^{-1})	Reference
1950	0	assumed
2004	960	WWF (2006)
2005	666	WWF (2006); Anon. (2004)
2006	1,682	Bregazzi (2007); www.illegal-fishing.com [2011]
2008	2,260	WWF (2008a); www.illegal-fishing.info [2011]

Foreign bluefin tuna catches

Since the 1950s, Italian and Spanish fishing vessels, 20 times more efficient than Algerian vessels (Simonnet 1961), were known to target large pelagic species along the Algerian coast (Tudela and Sacchi 2003). However, no data were recorded. In 1992, the first foreign access fishing agreement for longliners was signed by Algeria (Abdelguerfi 2002). From 2000 to 2009, several cases of illegal bluefin tuna fishing have been recorded (Anon. 2004; WWF 2006; Bregazzi 2007; WWF 2008a), which allowed us to identify bluefin tuna catch anchor points (Table 10). Assuming that catches were zero in 1950, we interpolated linearly to the first anchor point in 2004. Also, we assumed catches remained unchanged in 2009 and 2010, which provides a conservative estimate, since illegal catches were likely increasing (WWF 2008b).

Foreign flag large pelagic fishery by-catch

Two important species are reported as by-catch in the purse-seine and longline fisheries: bluntnose sixgill shark (*Hexanchus criseus)* and blue shark (*Prionace glauca)* from 1996 to 2002 (Canapé *et al.* 2003; Hemida 2005). To estimate the bluntnose sixgill shark by-catch, we used the weight-frequency data in Canapé *et al.* (2003). A total of 15.86 tonnes was calculated over the period 2000-2002 for a total unreported catch of bluefin tuna of 2,728 tonnes. Based on this estimate, a percentage of 0.58% was calculated and applied to the unreported bluefin tuna catch from 1950 to 2010. We used the same method for the blue shark using data from Hemida (2005). We only considered the non-reported catch of bluefin tuna assuming that the by-catch of the declared bluefin tuna was reported to the FAO. To estimate by-catch of other species, we used at-sea observer data provided by Burgess *et al.* (2010) for longliners from Malta and applied it to the blufin tuna reconstructed catch.

Foreign flag catches (excluding bluefin tuna)

In the 1950s, 50% of the fishers operating in Algerian territorial waters (i.e., inshore) were Italian and Spanish targeting pelagic fish (Furnestin 1961; Simonnet 1961). This number does not include fishers in the Algerian waters equivalent to the subsequent FEZ. In 1976, all foreign fishing in Algerian territorial waters was prohibited (Ordinance N° 76-84, 1976, act. 6). As a conservative approach, we estimated the foreign-flag catches as being 20% of the Algerian reported landings of small pelagic species in the FEZ equivalent waters in 1950. Then, we interpolated to zero in 1994 when Algeria declared its FEZ, assuming the catches were zero afterwards. To disaggregate catches, we identified two gear-types or vessel types: pelagic driftneters and pelagic seiners. We used data from Di Natale *et al.* (1995) to disaggregate the catches to species or higher taxonomic level.

Results

Algerian catches by sector

The investigation of local names and scientific names revealed some confusions in species catch classifications (e.g., dogfishes are sometimes not considered to be sharks). Herein, in many cases different local names refer to the same species (Table 11).

Artisanal catches

Small-scale commercial catches, mainly of European pilchard (*Sardina pilchardus*), gilthead seabream (*Sparus aurata*) and little tunny (*Euthynus alleteratus*), increased from 26,819 t·year^{-1} in 1950 to 96,973 t·year^{-1} in 2010. However, a slower rate of increase was observed since 2005. The artisanal portion of the catch data supplied to FAO represented only 30% of the artisanal commercial reconstructed catch (Figure 2a). Reconstructed artisanal grouper catches, as estimated separately, increased steadily from about 807 t·year^{-1} in 1950 to 3,316 t·year^{-1} in 2007 and have declined since. Swordfish (*Xiphias gladius*) represented 1% of artisanal catches and followed a similar trend as total artisanal catches, with peak of 1,158 t·year^{-1} in 2007 compared to a total catch of 602 t·year^{-1} supplied to FAO (including all the other vessels, i.e., trawlers and seiners) (Figure 2b).

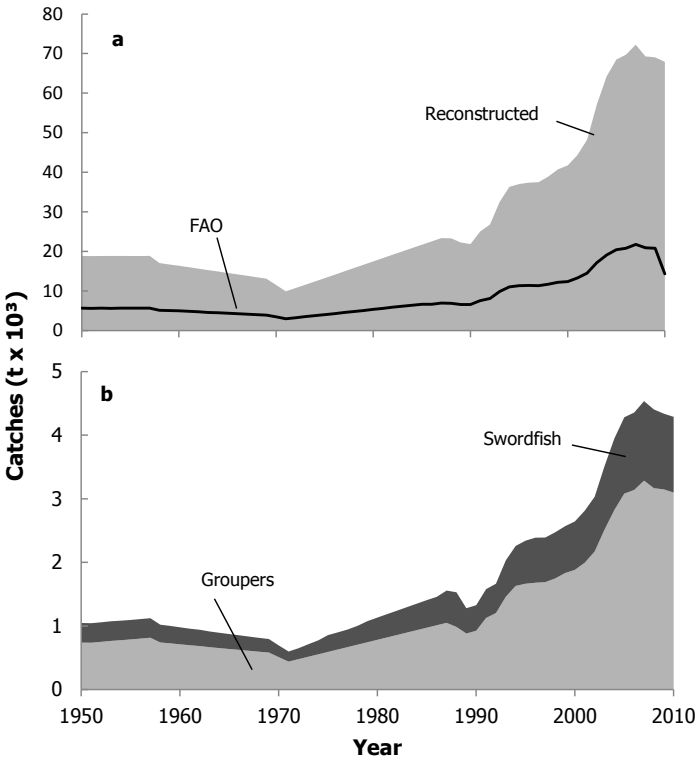

Figure 2. a) Estimated total artisanal marine fisheries catches by Algeria as compared to the artisanal portion of the data supplied to the FAO; and b) Estimated grouper catches (*Epinephelus* spp.) and swordfish catches (*Xiphias gladius*), 1950-2010.

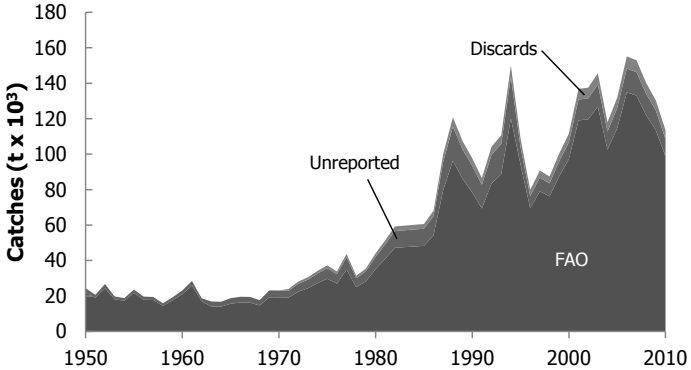

Figure 3. Total estimated small pelagic fishery removals by Algeria, 1950-2010.

Table 11. Arabic names of some species caught in Algeria. Assembled from Djabali *et al.* (1993) and Hemida (2005).

English name	Taxon name	Arabic name
African ray	*Raja africana*	Raya
Atlantic mackerel	*Scomber japonicus; S. scombrus*	Bacoreta; cavaya; kaballa; kaval
Axillary seabream	*Pagellus acarne*	Bazougue; boumchita; bizigo; chpigarel; mafroune
Barracudas nei	*Sphyraena sphyraena and S. virdensis*	Sirèn; la-alaz
Basking shark	*Cetorhinus maximus*	Chkara
Bignose shark	*Carcharhinus altimus*	Boudmaghe
Blackspot seabream	*Pagellus bogaraveo*	Mafroum; patchano
Blackspotted smooth-hound	*Mustelus mediterraneus*	Paloum; msola
Blonde ray	*Raja brachyura*	Raya
Blue shark	*Prionace glauca*	Zrika
Bluntnose sixgill shark	*Hexanchus griseus*	Chkara
Bluntnose sixgill shark	*Alopias vulpinus*	Zerdi; taous
Bogue	*Boops boops*	Bouga; vope; vopa
Brown ray	*Raja miraletus*	Raya
Common pandora	*Pagellus erythrinus*	El bejjij
Copper shark	*Carcharhinus brachyurus*	Boudmaghe
Dusky shark	*Carcharhinus obscurus*	Boudmaghe
European anchovy	*Engraulis encrasicholus*	Antchouva; bocorone; mentchouba
European hake	*Merluccius merluccius / Micromesistius poutassou*	Mernouze; pacalow
European pilchard	*Sardina pilchardus*	Sardine
Gilthead seabream	*Sparus aurata*	Quadjoudj
Greater amberjack	*Seriola dumerili*	Lichola; linchola, pech-limon
Groupers	Epinephelidae / Polyprionidae	Badecha; bayajo; merot; al- mara
Gulper shark	*Centrophorus granulosus*	Gagould; zaarour; gagaoul
Horse mackerel	*Trachurus* spp.	Saorel-lezreg; Saourine; Tcherel; Tonino
Little gulper shark	*Centrophorus uyato*	Zaarour; gagaoul
Longnose spurdog	*Squalus blainvillei*	Bouchouka
Longnosed skate	*Dipturus oxyrinchus*	Raya kahla
Mediterranean starry ray	*Raja asterias*	Raya
Moronidae	*Moronidae*	Gonfar; gonfran; kaross; liobarro
Grey mullets	Mugilidae *(Liza* and *Mugil* spp.*)*	Bouri; bousefra; bouri- mdehheb
Nursehound	*Scyliorhinus* spp.	Gat
Pargo breams	Sparidae *(Pagrus pagrus; P. auriga)*	El bedhar; pagri; pray
Red gurnard	*Aspitrigla cuculus*	Borraco
Rough ray	*Raja radula*	Raya
Salema	*Sarpa salpa*	Chelba; techelbine; tchelba
Sandbar shark	*Carcharhinus plumbeus*	Boudmaghe
Sardinellas	*Sardinella* spp.	Bouir; latcha; latchoum; salaga; sarakin
Rockfishes	Sebastinae and Scorpaeninae	Scorpa
Skipjack tuna	*Katsuwonus pelamis / Sarda sarda*	Bonite
Smooth-hound	*Mustelus mustelus*	Paloum; msola
Sole	Soleidae / Bothidae / Symphurinae	Pivola; sola; palaya
Sparidae	Sparidae	Sar
Speckled ray	*Raja polystigma*	Raya
Spinner shark	*Carcharhinus brevipinna*	Boudmaghe
Spotted ray	*Raja montagui*	Raya
Sharks	Squalidae	Bouchouka
Surmullets	*Mullus surmuletus / M. barbatus*	Rougi
Swordfish	*Xiphias gladius*	Boussif et-ouil; boussif; space; spadon
Thornback ray	*Raja clavata*	Raya
Tope shark	*Galeorhinus galeus*	Faux-paloum
Triakidae	Triakidae	Paloum; msola
Undulate ray	*Raja undulata*	Raya
Velvet belly	*Etmopterus spinax*	Far

Illegal small fish catch

Illegal small fish catch totaled about 118,043 tonnes over the period from 1950 to 2010. The illegal small fish catch trend followed governmental regulations and law enforcement incentives, increasing from zero in 1994 to a maximum of 12,200 t·year^{-1} in 2000. Illegal catches decreased thereafter to a plateau of around 4,600 t·year^{-1} from 2007 to 2010.

Small pelagic fisheries

Small pelagic species catches were about 3.6 million tonnes for the period 1950 to 2010 compared to 3.16 million tonnes reported to FAO. Catches were on average 11,600 – 17,000 t·year^{-1} from 1950 to 1968. After injection of subsidies, small pelagic catches increased dramatically to around 139,000 t·year^{-1} in 1994, then decreased by 71% in the late 1990s. Afterwards, catches increased to a maximum of 147,000 t·year^{-1} in 2006, and decreased thereafter (Figure 3).

Cephalopod catches

Reconstructed cephalopod (targeted) catches were approximately twice (40,500 tonnes) the catches reported the FAO (23,000 tonnes) over the period 1950 to 2010. Overall, the catches remained low from 1950 to the mid-1970s at approximately 250 t·year^{-1}, and increased thereafter, reaching a maximum of 2,300 t·year^{-1} in 2007. Since then, total reconstructed catches of cephalopods have been decreasing (Figure 4).

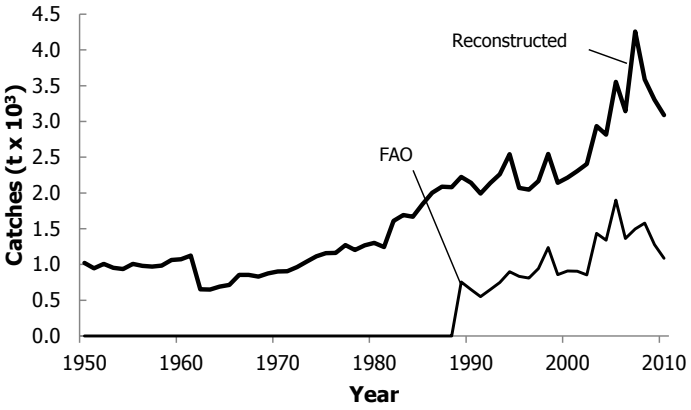

Figure 4. Total domestic cephalopod catch in Algeria, 1950-2010.

Shark and ray fisheries

Shark and ray catches were estimated to be about 46,900 tonnes for the period 1950 to 2010, of which slightly over 29,600 tonnes were sharks (63%), compared to a total of 28,719 tonnes reported to the FAO. Overall, the catches were decreasing from around 920 t·year^{-1} in 1950 to a minimum of 260 t·year^{-1} in 1976. Thereafter, catches increased to 1,700 t·year^{-1} in 1994, and then gradually decreased to around 640 t·year^{-1} in 2010 (Figure 5).

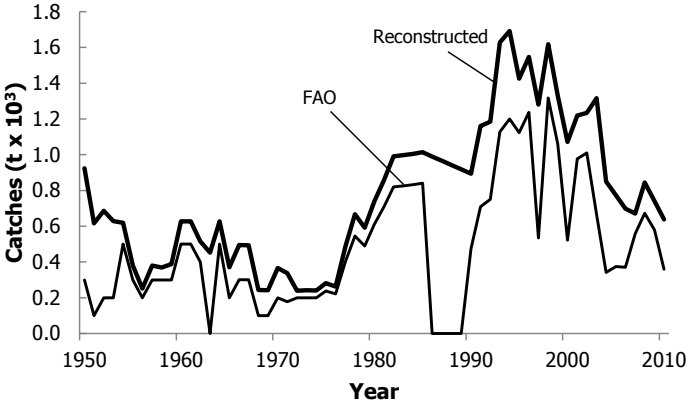

Figure 5. Total reconstructed sharks and rays catches compared to the total shark and ray catch data supplied to the FAO by Algeria, 1950-2010.

Crustacean/shrimp fisheries

Reconstructed crustacean catches in Algeria totalled over 382,900 tonnes for the period 1950 to 2010, compared to 129,077 tonnes reported to the FAO. Shrimp catches (mainly blue and red shrimp, and deep water rose shrimp) were estimated to be 271,000 tonnes for the same period. The unreported component includes 1,700 tonnes of trans-shipped catches over the 1994-2010 time period. Reconstructed shrimp catches increased three fold (11,000 t·year^{-1} in 2010) since the 1950s (3,600 t·year^{-1} compared to 1,700 t·year^{-1} reported to the FAO). Shrimp catches were smallest (1,800 t·year^{-1}) in 1962 due to the departure of many fishers to France when Algeria gained its independence. Thereafter, catches increased to a maximum of 10,900 t·year^{-1} in 2009 compared to 1,200 t·year^{-1} reported to FAO (Figure 6).

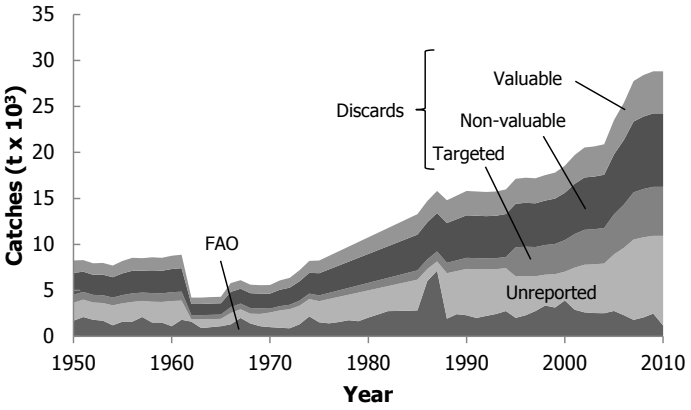

Figure 6. Reconstructed shrimp catches and discarded by-catch, 1950-2010.

Algerian bluefin tuna catches

Algerian bluefin tuna catches increased from 100 t·year^{-1} in 1950 to over 2,372 t·year^{-1} in 2010. Reconstructed commercial bluefin tuna catches were similar to those reported to the FAO for the 1950-1992 time period, when the first foreign longline fishing agreement was signed by Algeria. From 1992 to 1994, Algeria over-reported its bluefin tuna catches by over 2,300 tonnes. Thereafter, catches were similar to those reported to FAO until 1998 just before Algeria joined ICCAT. From 1998 to 2004, 73% (9,000 tonnes of a total of around 12,400 tonnes) of bluefin catches reported to FAO were considered to be from foreign vessels. Thereafter, Algerian catches increased to reach a total of 8,200 tonnes over the period 2005-2009, when Algeria started investing in industrial purse-seiners, compared to 4,000 tonnes reported to the FAO. Here, we assumed the 2009 catch to be the same for 2010 (Figure 7).

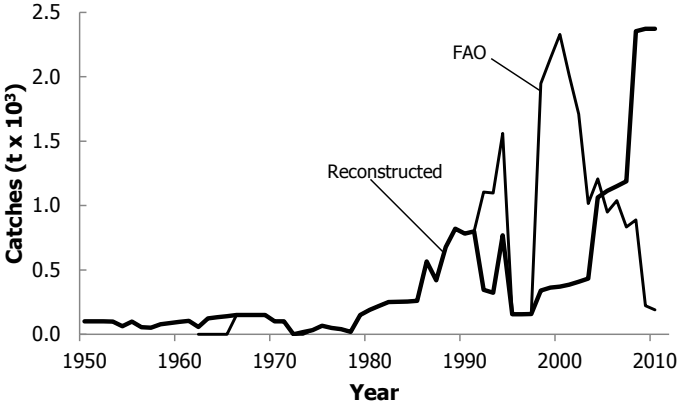

Figure 7. Reconstructed commercial Algerian bluefin tuna catches compared to the bluefin tuna catch data supplied to FAO, 1950-2010.

Subsistence fisheries

Catch data submitted to FAO by Algeria do not account for subsistence sector catches. Total reconstructed subsistence catches, consisting of swordfish (dominant in weight and caught using small-scale boats), seabreams (sparids), sharks, octopuses, groupers and tuna species, were estimated to be 65,340 tonnes from 1950 to 2010. Catches increased from around 1,300 t·year^{-1} in 1950 to reach their maximum of over 1,900 t·year^{-1} in 1970. During this period, subsistence fisheries catches were the equivalent of 20% of small-scale commercial fisheries catches. Since then, catches have been decreasing, estimated at about 200 t·year^{-1} in 2010 (Figure 8).

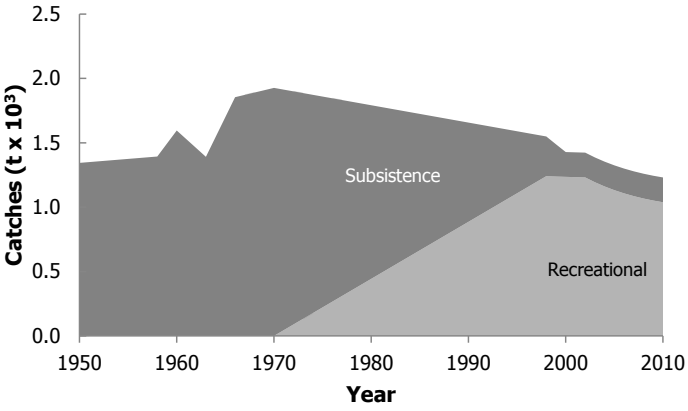

Figure 8. Estimated subsistence and recreational catches (spear, land-based handline, boat-based) for Algeria, 1950-2010.

Recreational fisheries

Recreational catches totalled approximately 31,750 tonnes for the period from 1970 (when recreational fishing began) to 2010. Recreational catches peaked at 1,200 t·year^{-1} in 2002, declining thereafter to about 1,000 t·year^{-1} in 2010 (Figure 8). Reconstructed recreational catches included leerfish (*Lichia amia*) which represented 25% of the catch, and which increased from zero in 1970 to 320 t·year^{-1} in the late 1990s, and decreased dramatically afterwards. Swordfish catches (18% of the reconstructed recreational catches) totalled 4,800 tonnes over the period 1970 to 2010, steadily increasing at first until a plateau was reached at about 300 t·year^{-1} during the 2000s. Stingrays and blue sharks (7% and 5% of the catches, respectively) amounted to 3,000 tonnes and were caught as by-catch by the swordfish fishery during the period 1970 to 2010, following the same trend as the swordfish fishery.

Grouper catches represented 10% of the reconstructed recreational catch, with a total of 2,500 tonnes for the period 1970 to 2010, and included three species: dusky grouper (7%),

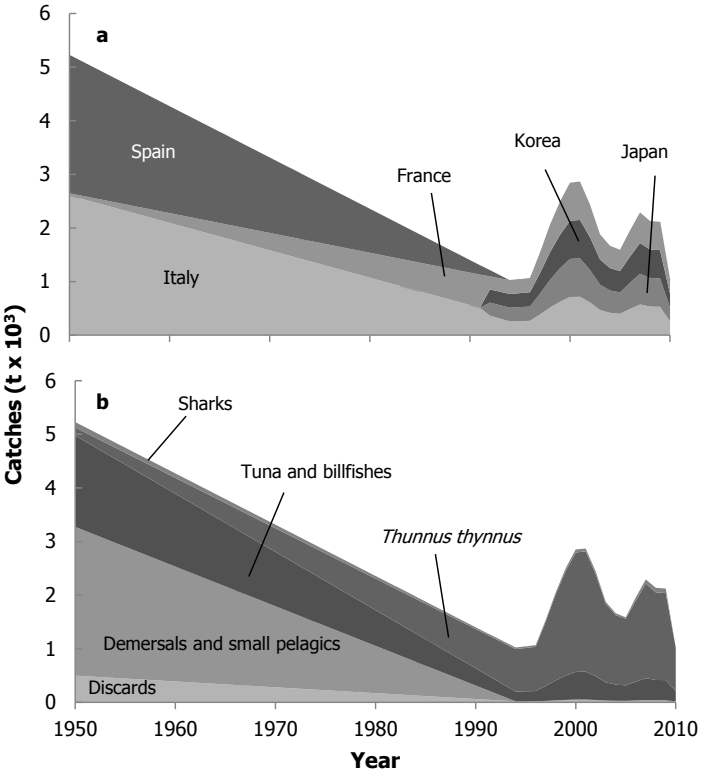

Figure 9. Estimated foreign flag catches for the 1950-2010 time period, a) by country; and b) by taxon. Discards include rays and other species.

dogtooth grouper and goldblotch grouper with together 3% of the total recreational catch. Grouper catches were increasing overall from zero in 1970 to a maximum of 150 t·year^{-1} in the mid-1990s, and then decreased to 26 t·year^{-1} by 2010.

Pelagic trawl discards

Pelagic trawl discards started in 1971 with the introduction of the multi-purpose trawls and have been increasing since, following the same trend as the small pelagic catches. Total pelagic trawl discards are estimated to be around 149,200 tonnes for the period 1950 to 2010 (Figure 3).

Shrimp fishery discards

Shrimp fishery discards (Figure 6) were estimated to be 24% higher than the total shrimp catch from 1950 to the early 1970, with an average discard of 4,555 t·year^{-1}, then decreased to 3,379 t·year^{-1} on average due to the increasing storage capacity of vessels after Algeria launched the first investment plans in the fisheries sector in the early 1970s. With the introduction in 1994 of new regulations on fish size limits, shrimp discards increased dramatically to 18,000 t·year^{-1} in 2010 (Figure 6), which included 5,300 t·year^{-1} of high value, targeted species (30%), 8,000 t·year^{-1} of other commercial species (45%) and 4,700 t·year^{-1} of non-marketable species (25%). Observer's presence on board could have resulted in overestimating targeted species discards as they are often kept and sold at the market illegally (F. Hemida, pers. comm., 2011).

Foreign flag catches

Foreign flag catches decreased from around 5,000 t·year^{-1} in 1950 to 1,300 t·year^{-1} in 2010, dominated by Italian catches (Figure 9a). Tuna and billfishes catches (60% of foreign fleet catches) followed the same trend, decreasing from around 1,850 t·year^{-1} in 1950 to a minimum of 1,030 t·year^{-1} in 1991 (Figure 9b). With the introduction of fishing agreements, catches started increasing and reached 3,160 t·year^{-1} in 2001 (Figure 9b). Thereafter, foreign flag catches of tuna and billfishes have been steadily decreasing (Figure 9b). By-catch of sharks and rays remained low from 1950 to 2010 (Figure 9b). Catches totalled 6,600 tonnes, of which 4,000 tonnes were discarded. However, in the 1950s, by-catch was much greater (200 t·year^{-1}) than in the recent period (70 t·year^{-1} in 2000s).

Total catches

Total reconstructed domestic catches for Algeria were more than 7.1 million tonnes for the period 1950 to 2010, almost twice as high as the data submitted by the government of Algeria to FAO (3.9 million tonnes, Figure 10). Although the unreported component appears to decrease over time from 131% in the 1950s to 89% in the 2000s, the minimum average recorded was at around 70% in the 1980s, which actually shows increasing

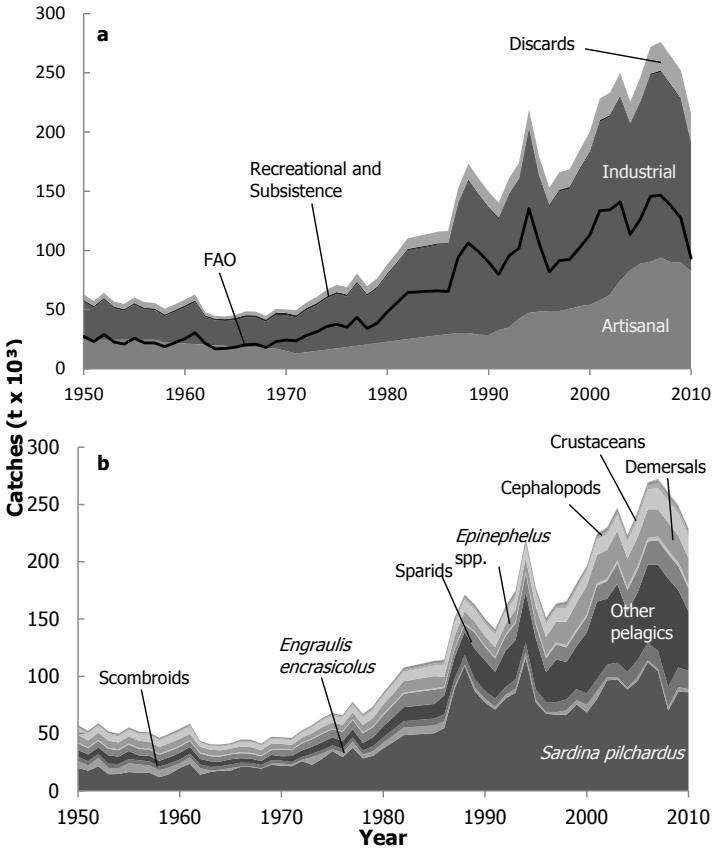

Figure 10. Reconstructed total marine fisheries catches by Algeria by a) fishing sector plus discards with data supplied to the FAO overlaid as line graph; and b) Major taxa caught by the domestic fisheries of Algeria, 1950-2010.

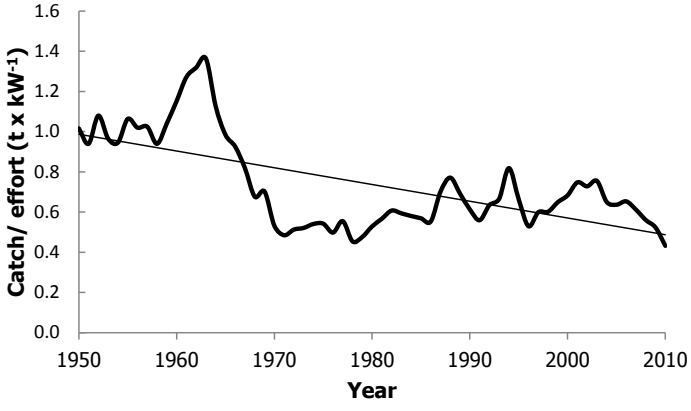

Figure 11. Estimated catch per unit of effort expressed in t·kW^{-1}.

unreported catches. Overall, total domestic catches increased steadily from around 57,500 $t \cdot year^{-1}$ in 1950 to 215,480 $t \cdot year^{-1}$ in 2010 (Figure 10). However, the most dramatic increase was observed from the late 1980s to the mid-1990s, after which the rate of increase was lower. Additionally, the CPUE has decreased overall from 1.02 $t \cdot KW^{-1}$ in 1950 to 0.44 $t \cdot KW^{-1}$ in 2010 (Figure 11).

Overall, the bulk of catches in Algeria were taken by the artisanal and industrial sectors. catches included mostly small-pelagics, particularly sardines, and demersal species at a lesser extent (Figure 10b).

Discussion

Here, we reconstructed Algeria's marine fisheries catches by accounting for all fisheries sectors and components, including unreported artisanal fisheries, inshore recreational and subsistence fisheries (Figure 10a). We also considered by-catch, which has been neither represented in FAO data nor documented in detail in the literature. Algerian catches increased dramatically over the 1950-2010 study period, though at a lower rate during the recent decades. More recently, catches seem to have experienced a decline. In contrast, CPUE has been decreasing continuously since the early 2000s.

Total marine fisheries catches by Algeria (excluding foreign flag catches) were almost twice the amount supplied to the FAO. Although some Algerian landings were presented in FAO fisheries statistics between 1950 and 2010[8], these data under-estimated actual catches. Demersal fisheries resources are not readily accessible because the narrowness of the continental shelf (Maurin 1962), which is likely why the pelagic fishery sector is the most developed, representing 35% of the total reconstructed catches and defining the general trend of Algerian catches. The small-scale fishery sector is also important and represented 14% of the total catches, a high portion of which is not accounted for in the official reports. This highlights the importance of domestic small-scale catches to food security. The decreasing catch trends and increasing prices are negatively affecting local fish consumption rates (Rahmouni 2010); as a result, per capita fish consumption in Algeria is one of the lowest in North Africa (Bouyacoub 2011). In contrast, increasing subsidized effort will lead to higher pressure on an already over-exploited coastal resource (Simonnet 1961; Maurin 1962; Kara and Derbal 1999; Ainouche and Nouar 2010). The narrow continental shelf along the Algerian coast (Leclaire 1972) and the nature of the effort subsidies programs offered, has increased fisher's debts and encouraged the use of illegal fishing methods (Cacaud 2002b; Chalabi *et al.* 2002).

Consequently, fish habitat loss (Chalabi *et al.* 2002) and high rates of by-catch and discards (Bouaicha 2011) have reduced the availability of fish in Algerian coastal waters (PNUE 1996)[9]. Moreover, demersal stock abundance has been declining since the early 1950s (Simonnet 1961; Oliver 1983; Laouar Stahi and Samar 1990; Belkessam and Issolah 1991; Nait Saidi and Taghanemt 1991; Kennouche 2003; Belhabib 2007). Small pelagic species and grouper abundance has also decreased due to a high exploitation rate (Kara and Derbal 1999; Bennoui *et al.* 2010; Bouaziz *et al.* 2010). Following this pattern, catches are likely to decrease substantially within the next 20-25 years. Nevertheless, the Algerian government, experiencing political and social turmoil related to unemployment and social crisis (Rarrbo 2009) has responded to concerns over decreasing catches (i.e., after 2006) by increasing fishing effort through financing programs (MPRH 2001; Zerrouki and Taftichte 2010; MPRH 2001), thus creating more pressure and conflicts among artisanal and other subsidized fishers (Boukhalfa and Rambeau 1993). Both of these factors are increasing the pressure on the ecosystem with a direct impact on fish stocks. This has serious implications for the national economy and domestic food security.

Furthermore, large pelagic fisheries, being heavily targeted both by illegal foreign fleets (WWF 2008a) and foreign fleets operating under fishing access agreements, account for more than 80% of estimated Algerian large pelagic catches. Without enhancing enforcement and monitoring, it is likely that illegal fishing by foreign countries will increase over time, as international markets (particularly fuelled by demand in Asia) become even more lucrative (WWF 2006). Algerian large pelagic catches also increased along with the unreported by-catch of sharks and rays, which include internationally protected species. This is mainly due to the increase in fishing capacity, the introduction of non-selective gears and increasing large pelagic fish prices (Chalabi *et al.* 1995).

A question which may be asked is whether there are persons in Algeria who benefit from the overall increase in illegal foreign fisheries. This situation raises serious issues regarding the Algerian policy of financial support for declining fisheries on one hand, and a poor to non-existent monitoring, a lack of fisheries data which leads to unreliable statistics (Chakour *et al.* 2010) and inefficient enforcement of fishing agreements (Bregazzi 2007) on the other hand. Indeed, monitoring and enforcement systems in Algeria rely on officially designated land-based observers, mostly non-qualified (in 50% of the areas) for coastal fisheries and a few at-sea observers on a few licensed foreign vessels operating under fishing agreements. Here, the importance of at sea-observations versus a system that hardly produces reliable data (MATE 2005a; Chakour *et al.* 2010) is highlighted by the difference between estimated catches based on direct observations and data supplied to the FAO. Fisheries data collection in Algeria seriously lacks necessary human resources with landing sites coverage of less than 2% (Anon. pers. comm.)[10].

In Algeria, fisheries catches have increased dramatically over the last six decades. However, past and present political

[8] We assumed catches in 2010 were 85% the amount in 2009 following a decreasing pattern since 2006.

[9] Programme des nations unis pour l'environnement.

[10] The person who submitted this information preferred to remain anonymous.

and social events have resulted in an increase in investments in this sector and poor monitoring of national fisheries. The continuous increase in capacity does not take into account the sustainable use of these resources. This study has shown that important components of Algerian fisheries are not accounted for in the official data and that catches of economically important taxa show signs of decline, including the small pelagic fishery which is of great importance for food security. This study also suggests that the lack of transparency, especially concerning the management of foreign fisheries may be jeopardizing domestic fisheries. This suggests that proper monitoring and statistical reporting must be prioritized and regulations more aggressively enforced.

Acknowledgements

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Appendix Table A1. Reported and reconstructed annual catches by Algeria.

Year	FAO	Artisanal	Industrial	Recreational	Subsistence	Discards	Total reconstructed
1950	27,201	24,523	32,243	0	1,344	4,612	62,722
1951	23,001	24,443	27,308	0	1,350	4,296	57,397
1952	29,101	24,498	33,982	0	1,356	4,264	64,101
1953	22,699	24,492	26,610	0	1,363	4,359	56,823
1954	20,962	24,542	24,555	0	1,369	4,327	54,794
1955	25,898	24,520	29,674	0	1,375	4,612	60,180
1956	21,956	24,505	25,642	0	1,381	4,801	56,329
1957	21,953	24,550	25,059	0	1,387	4,643	55,639
1958	18,578	22,180	22,385	0	1,394	4,833	50,792
1959	22,100	21,752	26,341	0	1,495	4,801	54,389
1960	25,500	21,363	30,589	0	1,596	4,928	58,475
1961	30,400	20,916	35,385	0	1,528	4,991	62,819
1962	21,500	20,390	23,378	0	1,459	2,369	47,597
1963	16,901	19,856	21,010	0	1,391	2,369	44,626
1964	17,300	19,469	20,962	0	1,546	2,401	44,378
1965	18,302	18,945	22,356	0	1,700	2,401	45,401
1966	20,351	18,485	24,972	0	1,854	3,253	48,565
1967	20,951	18,025	25,279	0	1,873	3,159	48,336
1968	18,051	17,490	22,192	0	1,891	3,159	44,731
1969	23,151	17,039	28,507	0	1,909	3,127	50,582
1970	24,235	15,017	30,250	0	1,927	2,994	50,188
1971	23,716	12,917	30,405	44	1,869	4,317	49,552
1972	28,314	14,011	35,438	89	1,811	4,647	55,995
1973	31,244	15,097	38,458	133	1,753	5,199	60,641
1974	35,708	16,181	43,083	177	1,696	5,653	66,790
1975	37,693	17,278	45,675	222	1,638	6,061	70,874
1976	35,122	18,355	42,560	266	1,580	6,178	68,939
1977	43,475	19,521	52,332	310	1,522	6,887	80,572
1978	34,143	20,649	40,649	355	1,464	6,612	69,730
1979	38,678	21,701	45,935	399	1,407	7,065	76,507
1980	48,000	22,845	56,123	443	1,349	7,711	88,470
1981	56,000	23,978	64,770	487	1,291	8,305	98,832
1982	64,500	25,117	74,392	532	1,233	8,919	110,193
1983	65,000	26,202	74,922	576	1,175	9,210	112,085
1984	65,500	27,286	75,345	620	1,118	9,501	113,870
1985	66,000	28,371	75,948	665	1,060	9,790	115,834
1986	65,261	29,192	75,266	709	1,002	10,391	116,560
1987	94,092	30,301	108,594	753	944	12,071	152,663
1988	106,434	30,246	128,070	798	886	13,250	173,250
1989	99,184	28,853	117,466	842	829	12,932	160,922
1990	90,192	28,475	106,727	886	771	12,776	149,634
1991	79,690	32,657	93,688	931	713	12,253	140,242
1992	95,266	34,907	110,979	975	655	13,003	160,519
1993	101,894	42,424	116,541	1,019	597	13,313	173,894
1994	135,402	47,382	154,855	1,064	540	15,165	219,005
1995	105,872	48,369	113,684	1,108	482	15,402	179,045
1996	81,989	48,808	88,473	1,152	424	14,199	153,056
1997	91,580	48,844	101,010	1,197	366	14,643	166,060
1998	92,332	50,600	101,622	1,241	308	14,676	168,448
1999	102,396	52,928	114,834	1,238	251	15,464	184,714
2000	113,158	54,110	128,062	1,236	193	16,426	200,027
2001	133,623	57,667	151,074	1,233	193	18,262	228,429
2002	134,320	62,747	150,377	1,231	193	18,799	233,346
2003	140,957	74,270	155,002	1,194	193	19,231	249,889
2004	113,462	83,291	122,777	1,161	193	18,156	225,577
2005	126,259	88,902	135,711	1,132	193	20,397	246,334
2006	145,762	90,550	157,594	1,107	193	22,581	272,025
2007	146,627	94,007	156,801	1,086	193	23,971	276,057
2008	137,895	90,198	148,982	1,067	193	23,807	264,247
2009	127,439	89,830	137,368	1,051	193	23,630	252,072
2010	93,607	82,208	108,595	1,038	193	23,986	216,020

Appendix Table A2. Reconstructed annual marine fisheries catches by Algeria by taxon.

Year	Sardine	Anchovy	Groupers	Scombroids	Sparids	Sharks and Rays	Cephalopods	Crustacea	Miscellaneous pelagics	Miscellaneous
1950	20,004	6,078	807	2,526	5,256	2,408	942	4,635	3,348	11,497
1951	17,534	4,675	795	2,361	5,126	1,926	873	5,008	3,882	10,092
1952	21,395	7,144	816	2,905	5,193	2,013	933	4,685	2,975	11,012
1953	14,486	5,503	830	2,262	5,211	1,969	877	4,653	5,177	10,921
1954	14,674	5,005	835	2,108	5,129	1,951	862	4,393	4,783	10,216
1955	16,436	7,648	848	2,256	5,145	1,729	926	4,687	5,091	10,670
1956	15,647	7,421	860	2,089	5,145	1,623	898	4,883	2,298	10,818
1957	15,843	6,325	874	1,988	5,144	1,634	888	5,058	3,059	10,274
1958	11,864	6,035	804	1,978	4,758	1,721	900	4,914	3,049	10,312
1959	14,656	5,859	800	2,080	4,730	1,735	978	4,981	3,481	10,728
1960	19,967	3,985	788	2,190	4,643	2,111	986	5,112	3,733	10,694
1961	23,672	5,523	771	2,153	4,552	2,098	1,037	5,177	3,687	9,979
1962	14,095	5,718	755	1,946	4,308	1,649	611	2,428	3,265	8,748
1963	16,484	1,294	719	4,002	4,038	1,337	608	2,463	1,547	8,155
1964	17,632	802	709	1,942	3,939	1,646	648	2,596	2,829	7,752
1965	17,817	2,005	700	2,672	3,857	1,306	672	2,526	2,730	7,328
1966	20,978	237	694	2,128	3,852	1,547	799	3,378	2,667	8,592
1967	20,733	467	680	1,990	3,746	1,528	798	3,766	2,541	8,488
1968	19,289	338	665	1,854	3,646	1,271	776	3,279	2,178	7,934
1969	22,726	995	659	2,070	3,628	1,266	819	3,246	3,086	8,681
1970	21,887	1,996	574	1,693	3,080	1,350	848	3,311	2,744	9,397
1971	21,487	1,483	508	1,702	2,709	1,331	845	3,594	2,920	9,756
1972	25,929	1,127	548	1,821	2,918	1,274	901	3,764	3,396	11,197
1973	22,697	6,817	592	1,922	3,178	1,365	969	4,243	3,611	12,223
1974	27,939	4,714	632	2,513	3,395	1,401	1,038	5,156	3,529	13,544
1975	34,723	1,595	673	2,970	3,621	1,509	1,079	4,873	3,452	13,546
1976	29,406	4,062	714	2,566	3,844	1,606	1,075	5,115	3,337	14,475
1977	37,681	5,317	756	2,525	4,072	1,840	1,180	5,455	3,787	15,318
1978	28,287	3,344	797	2,576	4,300	2,055	1,108	5,789	3,480	15,449
1979	30,595	4,010	838	3,518	4,522	2,065	1,169	6,118	4,403	16,819
1980	37,055	4,962	880	4,066	4,750	2,285	1,199	6,422	5,286	19,211
1981	42,649	5,781	921	4,520	4,977	2,473	1,136	6,731	6,061	21,323
1982	48,571	6,650	963	5,005	5,205	2,684	1,497	7,031	6,887	23,537
1983	49,144	6,703	1,004	5,082	5,432	2,744	1,573	7,331	6,977	24,026
1984	49,717	6,756	1,045	5,158	5,659	2,804	1,545	7,631	7,068	24,515
1985	50,253	6,814	1,087	5,240	5,885	2,873	1,716	7,938	7,155	24,996
1986	54,808	5,853	1,127	4,160	6,102	2,974	1,870	8,939	11,711	17,236
1987	88,841	2,163	1,168	6,261	6,328	2,993	1,949	9,841	10,807	20,625
1988	109,039	1,219	1,108	6,314	6,357	3,039	1,937	8,576	12,755	21,316
1989	86,958	3,439	1,023	6,105	13,557	2,903	2,078	9,329	14,525	19,509
1990	77,095	3,167	1,063	5,683	11,334	2,888	1,989	9,530	16,693	18,792
1991	70,884	2,574	1,268	4,795	11,413	3,210	1,842	9,402	14,330	19,220
1992	80,518	3,144	1,346	4,400	12,305	3,285	1,988	9,360	21,508	20,948
1993	85,754	3,386	1,605	5,082	14,218	3,873	2,113	9,393	23,820	23,027
1994	116,026	4,373	1,783	5,909	15,701	4,060	2,390	9,614	30,936	26,687
1995	77,117	2,303	1,824	6,155	10,341	3,804	1,916	9,614	35,221	29,214
1996	67,253	1,665	1,843	5,263	10,111	3,932	1,891	9,692	18,889	30,971
1997	66,406	2,238	1,855	5,567	10,140	3,024	2,012	9,705	29,530	33,575
1998	66,314	4,021	1,911	6,449	10,975	4,108	2,388	10,057	24,839	34,872
1999	75,475	3,645	1,901	6,339	11,140	3,811	1,981	10,073	28,931	38,484
2000	68,401	6,651	1,969	6,946	11,548	3,226	2,047	10,688	43,210	42,065
2001	80,107	6,966	2,069	7,563	12,204	3,881	2,129	11,303	55,916	43,007
2002	96,476	2,697	2,245	7,426	13,351	4,091	2,220	11,841	46,034	44,120
2003	97,165	2,223	2,592	11,607	15,519	4,489	2,748	11,623	52,829	46,816
2004	88,497	1,625	2,869	9,697	17,058	4,091	2,629	11,808	40,806	44,449
2005	95,991	3,558	3,123	9,178	18,188	4,275	3,341	13,214	47,428	46,073
2006	112,214	1,833	3,177	9,321	18,570	4,314	2,913	14,280	56,058	47,035
2007	104,493	1,849	3,515	9,959	20,063	4,526	4,007	15,657	61,468	47,890
2008	70,082	2,990	3,478	14,767	19,690	4,729	3,330	16,061	78,504	48,162
2009	86,413	4,033	3,394	11,382	19,456	4,657	3,042	16,256	54,446	46,567
2010	62,138	2,756	3,325	11,353	18,825	4,515	2,864	16,289	46,308	46,303

Reconstruction of marine fisheries catches for Morocoo (north, central and south), 1950-2010[1]

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Abstract

Fisheries catches in the Moroccan Exclusive Economic Zone (EEZ), including the Atlantic and Mediterranean areas, were reconstructed to include commercial small-scale, commercial large-scale, illegal and unregulated fisheries, non-commercial recreational and subsistence fisheries, and foreign catches in both EEZ areas. Estimated domestic catches suggest that Moroccan data supplied to FAO are less reliable than they should be, with over 41.5% of catches being unreported. This study also shows that 25.4 million tonnes of catches were taken from the southern EEZ area, which contributed to 52% of the Moroccan catch estimated at 48.4 million tonnes. This illustrates not only that Morocco needs to improve its fisheries monitoring system to include small-scale fishing and unregulated fishing, but also questions the impacts of the fishing access agreements signed by Morocco on the local economy and fisheries sustainability, particularly in the southern area where most foreign catches are taken.

Introduction

Morocco is located in North Africa, west of Algeria and shares the Alboran Sea with Spain in the North. On the West African coast, Morocco, including the former Spanish Sahara, ranges from Tangier (36° N) to Lagouira (20° N) on Cape Blanc, which is one of the richest fishing areas in the world due to the sustained east central Atlantic upwelling (Porter 1997; Anon. 2005a). Morocco proclaimed its EEZ in 1981 (Anon. 2007). Morocco maintains the southern area under its administration since 1976, after the Spanish Sahara territory became independent from Spain (Rojo-Diaz and Pitcher 2005). In this study, we do not take position on the legality of Moroccan fisheries in Saharan waters, which is a matter of the International Court of Justice 1975 ordinance on the right for self-determination (Barreira *et al.* 1998). Rather, we will attempt to first estimate total catches as defined above, and allocate these catches to the three areas defined above (northen Mediterranean, Atlantic central Moroccan and Atlantic southern areas) per fishing sector. Thus, this paper presents a reconstruction of the total removals from both the northern and central coasts of Morocco (Figure 1), along with the southern areas (Figure 2), from 1950 to 2010. It provides an update to the report by Baddyr and Guénette (2001), including small-scale fisheries catches and unreported catches of industrial fisheries. It also accounts for subsistence, recreational and unreported artisanal catches, as well as discards, including catches from the waters off the Mediterranean coast of Morocco.

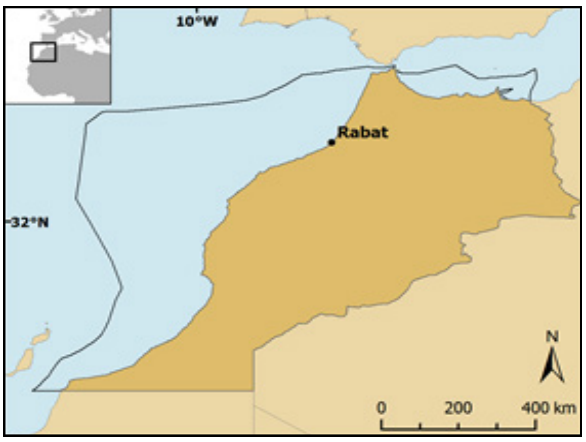

Figure 1. Map of Morocco showing the Mediterranean northern and the Atlantic central coasts.

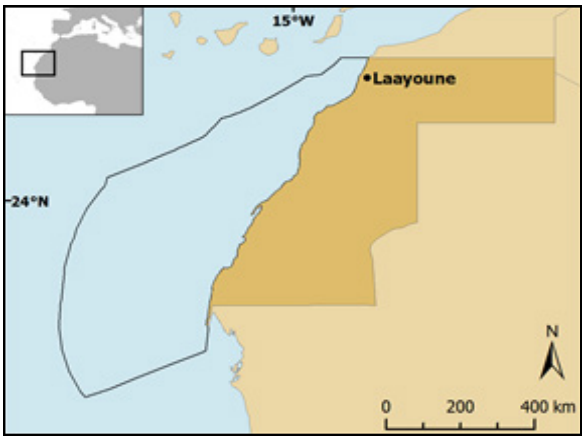

Figure 2. Map of the southern areas of Morocco.

The artisanal fishery is an informal sector in Morocco, and there is no data collection system (Malouli Idrissi *et al.* 2001; ArtFiMed 2009); it consists mostly of small wooden dories under six meters of length called *pateras,* targeting mainly small fish and other species. This category also includes hand collection of algae and mussels and shore-based fishing using lines (Baddyr and Guénette 2001). The large-scale fisheries include two types of activities: inshore or coastal fisheries initiated by Spanish and Portuguese fishers with 16 to 24 m wooden boats manufactured locally without catch preservation systems, and targeting pelagic species using purse seines, demersal species using long liners, bottom trawls and driftnets, and the off-shore industrial fishery

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which started in 1972 and has grown rapidly since then. It consists almost exclusively of large freezer trawlers fishing for several weeks at a time (Baddyr and Guénette 2001; Franquesa *et al.* 2001; Rojo-Diaz and Pitcher 2005; Tudela *et al.* 2005; Anon. 2007; FAO 2011). Fishing in Morocco has been a major activity since the 1930s, and the industry experienced tremendous growth during the 1980s (Rojo-Diaz and Pitcher 2005). However, heavy exploitation by both national and foreign vessels (Ariz 1985; Baddyr and Guénette 2001), a lack of monitoring and enforcement because of existing economic difficulties (Kaczynski 1989), and an emphasis on short-term profits from resource exploitation rather than long-term sustainable benefits (Kaczynski 1989) resulted in over-exploitation of important demersal stocks, shifting stocks (Balguerías *et al.* 2000; Baddyr and Guénette 2001; Pitcher *et al.* 2002; Anon. 2005a) and increasing illegal, unreported and unregulated fisheries (Anon. 2005c). Importantly, fisheries contribute to the livelihood of around 400 000 people in poor, rural areas, and represent 15% of the total Moroccan exports. Moreover, 20% of the Moroccan and former Spanish Saharan populations suffer from a lack of protein, and live under the poverty line (Anon. 2005a). For these reasons, it is important to analyze more complex trends of total fisheries catches and question the management strategy of Morocco.

Methods

Electronic time series of landings data were available from the Food and Agriculture Organization (FAO) from 1950 to 2010, and Moroccan National Fisheries Office reports (*Office national des pêches*, ONP) from 1999 to 2010. We also used data available from a previous reconstruction by Baddyr and Guénette (2001), which included the artisanal and the industrial fisheries effort and catches for Moroccan Atlantic and Western Sahara from 1950 to 1998. Reported landings are distinguished by species or higher taxonomic grouping and `miscellaneous groups´. Since the main goal of this study is to estimate the total catch per species or higher taxonomic group, we compared the FAO data to the above-cited national reports, and concluded that differences between the datasets from 1999 to 2010 were not significant. Thereafter, we aggregated catch data presented by area during the period from 2000 to 2010 (www.onp.co.ma [2011]), separated landings from northen, central and southern areas, and concluded that catches from southern areas represented around 56% of the total Moroccan landing data supplied to the FAO. We applied this rate to the data reported to the FAO from 1950 to 2010 to estimate reported catches by Morocco for the southern areas. We used the separated data for Morocco (Mediterranean northern and Atlantic central areas) and southern areas as a reported baseline, to which we added: (1) under-reported small-scale artisanal catches; (2) under-reported large-scale catches; (3) illegal catches; (4) discards; (5) subsistence catches and (6) recreational catches.

Table 1. Anchor points for small-scale fishing effort (number of boats) and the corresponding CPUE (t·boat-1·year^{-1}) for Morocco.

Year	Effort	Source	CPUE	Source	Catch (t)	Source
Atlantic central and southern areas						
1950	-	-	-	-	39,245	25% higher than 1981 catches
1981	2,700	Baddyr and Guénette (2001)	11.63	1.25 times $CPUE_{1991}$	31,396	Based on CPUE and effort
1985	4,028	Do Chi and Idelhadj (1991)	-	-	-	-
1988	4,035	Baddyr and Guénette (2001)	-	-	-	-
1991	-	-	9.10	Boudi *et al.* (1990), Do Chi and Idelhadj (1991)	-	-
1994	6,000	Baddyr and Guénette (2001)	-	-	-	-
2002	8,831	Faraj (2009), adjusted by 50%	-	-	-	-
2004	15,881	Anon. (2005a), adjusted by 20%	-	-	-	-
2006	6,175	Faraj (2009)	-	-	-	-
2007	15,496	Boudinar (2007)	-	-	-	-
2010	15,112	Assumption	6.78	1.25 times $CPUE_{1991}$	-	-
Mediterranean northern areas						
1950	-	-	-		19,117	30% higher than 1981 catches
1981	1,343	25% of Atlantic effort adjusted by 67%	11.75	1.25 times $CPUE_{1991}$	14,705	Based on CPUE and effort
1985	2,000	25% of Atlantic effort adjusted by 67%	-		-	-
1988	2,007	25% of Atlantic effort adjusted by 67%	-		-	-
1994	2,985	25% of Atlantic effort adjusted by 67%	-		-	-
1999	2,547	www.inrh.org.ma [2011] adjusted by 60%[a]	-		-	-
2002	-	-	9.12	Malouli Idrissi *et al.* (2001), ONP (2005)	-	-
2004	4,411	25% of Atlantic effort adjusted by 41%[a]	-		-	-
2007	5,757	25% of the Atlantic effort adjusted by 36%[a]	-		-	-
2010	2,600	www.inrh.org.ma 2011, adjusted by 30%[a]	3.0	Al Asri 2010	-	-

a) The rate of adjustment is based on an interpolation from an under-reporting rate of 67% in 1988 to 30% in 2010.

Under-reported artisanal catches

Artisanal fishing effort in the Atlantic central and southern waters off Morocco and the corresponding catches are under-estimated (Lahnin *et al.* 1991; Anon. 2005a; Shelley 2008). Do Chi and Idelhadj (1991) estimated a catch per unit of effort (CPUE) of 57 kg·boat^{-1}·day^{-1} for 1991, where 36.4% is unreported crustaceans and cephalopods, for 170 days of fishing (Boudi *et al.* 1990), i.e., 9.7 t·boat^{-1}·year^{-1} (Table 1) compared to 1 t·boat^{-1}·year^{-1} provided by Baddyr and Guénette (2001). We assumed that the catch per boat in 1981 was 25% higher than in 1991, i.e., 11.63 t·boat^{-1}·year^{-1}. Due to continuing excessive effort (Peña *et al.* 2003), CPUE kept on decreasing after 1991 to reach 80% of the 1991 CPUE in 2010, i.e., 6.78 t·boat^{-1}·year^{-1}. Thus, we reconstructed small-scale catches for the period 1981 to 2010 based on these CPUE rates interpolated from 11.63 t·boat^{-1}·year^{-1} in 1981 to 9.7 t·boat^{-1}·year^{-1} in 1991 and to 6.78 t·boat^{-1}·year^{-1} in 2010. For the effort, we used data on the number of boats from 1981 to 1985, 1988, 1994, 1998, 1999, 2002 (which we adjusted by 50%, Faraj 2009), and 2004 (which we corrected by 20%, Anon. 2005a; Faraj 2009) and 2007. These data included the effort in the Mediterranean waters of Morocco; thus, we reduced the effort by 25% to exclude the Mediterranean effort (Do Chi and Idelhadj 1991). Thereafter, we interpolated linearly from each anchor point to bridge the gaps from 1981 to 2007, and carried the trend onward to estimate the effort for 2010 (Table 1). Thereafter, we multiplied the CPUEs by the number of boats from 1981 to 2010. For the period from 1950 to 1980, because of the presence of small-scale Spanish boats in the former Spanish Sahara waters, we assumed that the artisanal catch was 25% higher in 1950 than in 1980 and then performed a linear interpolation from 1950 to 1981. Here, we assumed that before 1975, 40% of catches were made off the southern areas mostly, because of the presence of the artisanal Spanish fleet (Ariz 1985); thereafter we assumed it decreased to be 30% of the total small-scale catches of the Atlantic area.

In the Mediterranean, the Moroccan CPUE was estimated to be 6.4 t·boat^{-1}·year^{-1} for 2000 (Malouli Idrissi *et al.* 2001), 11.85 t·boat^{-1}·year^{-1} for 2004 (ONP 2005), 2.1 t·boat^{-1}·year^{-1} for 2009 (ArtFiMed 2009) and 3 t·boat^{-1}·year^{-1} for 2010 (El Asri 2010). Since the official data provided by ONP (2005) represents an area of relatively high production, we averaged the first two estimates and obtained a CPUE of 9.12 t·boat^{-1}·year^{-1} for 2002 and used the catch per effort of 3 t·boat^{-1}·year^{-1} for

Table 2. Species composition of Mediterranean and Atlantic catches of Morocco for the period 1950-2010. Percentage composition derived from qualitative data in Barreira *et al.* (1998); Do Chi and Idelhadj (1991); Charbonnier and Caddy (1986); UNEP (2008); INRH (1999); Malouli Idrissi *et al.* (2001) and ArtFiMed (2009).

		Mediterranean	Atlantic
Common name	**Taxon name**	**Catch (%)**	**Catch (%)**
Gilthead seabream	*Sparus aurata*	5.0	-
Axillary seabream	*Pagellus acarne*	10.0	-
forkbeard	*Phycis* spp.	0.4	-
Shrimps	-	0.4	-
Other sparids	Sparidae	3.0	-
Norway lobster	*Nephrops norvegicus*	2.0	-
European eel	*Anguilla anguilla*	8.0	-
Octopus	*Octopus* spp.	22.0	-
Bullet tuna	*Auxis* spp.	5.0	-
Bonito	*Sarda sarda*	5.0	-
Swordfish	*Xiphias glaius*	1.0	-
European pilchard	*Sardina pilchardus*	8.0	-
Sharks	Various[a]	0.2	-
Blacktip grouper	*Epinephelus fasciatus*	0.3	-
Common dentex	*Dentex dentex*	2.0	-
Venus clam	*Chamelea gallina*	9.0	-
Bogue	*Boops boops*	11.0	-
European anchovy	*Engraulis encrasicolus*	2.0	-
Caramote prawn	*Penaeus kerathurus*	1.0	-
Miscellaneous	-	1.0	-
Blufin tuna	*Thunnus thynnus*	3.0	-
Bluespotted seabream	*Pagrus caeruleostictus*	1.0	-
Red porgy	*Pagrus pagrus*	2.0	-
Scorpaenids and Sparids	Scorpaenidae and Sparidae	1.0	-
Common two-banded seabream	*Diplodus* spp.	4.0	1
Surmulets	*Mullus* spp.	3.0	14
Sea breams, Pandora etc.	*Pagellus* spp.	4.0	1
Cuttlefish	*Sepia* spp.	10.0	5
Groupers	*Epinephelus* spp.	2.0	8
European conger	*Conger conger*	1.0	1
European squid	*Loligo vulgaris*	2.0	1
European seabass	*Dicentrarchus labrax*	6.0	1
Croaker	*Argyrosomus regius*	-	1
Sole	*Solea* spp.	-	1
Crayfish and lobsters	*Palinurus* spp.	-	15
Lobsters	*Homarus* spp.	-	15
Large pelagic fish	-	-	15
Other sharks	-	-	4
Bivalvia	-	-	4
Small pelagic fish	-	-	4
Barnacles	-	-	0 to 10%[b]
Finfish	-	-	0 to 10%[b]

a) Smooth-hound (*Mustelus mustelus*), sharpnose sevengill sharks (*Heptranchias griseus*), bluntnose sixgill shark (*Hexanchus griseus*) and sand tiger shark (*Carcharias taurus*).
b) A percentage of the illegal catches increasing from 0% in 1975 to 10% in 2010.

2010 (Table 1). Because of stock over-exploitation in the Mediterranean since the early 1980s (Oliver, 1983), we believe the catch per unit of effort was likely higher in the 1980s. Therefore, we conservatively assumed a CPUE of 11.75 t·boat^{-1}·year^{-1} in 1981 (20% higher) declining linearly to 9.12 t·boat^{-1}·year^{-1} in 2002, then 3 t·boat^{-1}·year^{-1} in 2010. Thereafter, we applied the same approach to the effort data available or derived from the Atlantic effort data, where the Mediterranean effort represented 25% of the Atlantic (Do Chi and Idelhadj 1991). We then adjusted the effort by an unreported factor of 67% in 1981 to 1985 (Charbonnier and Caddy 1986) to 30% in 2010 (Table 1), when artisanal fisheries were better documented. To complete the estimate for the period 1950 to 1980, we assumed conservatively that the catches in 1950 were 30% higher than in 1981 because of the presence of the French and Spanish boats (Oliver 1983); thereafter, we interpolated linearly.

Table 3. Unreported coastal demersal and pelagic landings per decade for Morocco.

Decade	Unreported landing (%)	Source
1950	60	Rojo-Diaz and Pitcher (2005)
1960	60	Rojo-Diaz and Pitcher (2005)
1970	23	Baddyr and Guénette (2001)
1980	23	El Hannach (1986)
1990	47	El Mamoun (1999)
2010	10	Modified from Anon. (2005c)

A part of this artisanal fisheries catch, estimated to be around 8.5% (Malouli Idrissi *et al.* 2001), is kept for personal consumption (i.e., here considered subsistence). However, this component is assumed to have been larger in the 1950s (around 30%). To estimate this subsistence catch, we interpolated personal consumption rates from 30% in 1950 to 8.5% in 2010, and then applied the estimates to the artisanal catch in the Mediterranean and the Atlantic.

Species disaggregation: Only a few authors described the taxonomic composition of small-scale fisheries catches for Moroccan central and southern areas. While Barreira *et al.* (1998) and Do Chi and Idelhadj (1991) described the species composition of catches as including: sparids, sole (*Solea* spp.), surmullets (*Mullus* spp.), European seabass (*Dicentrarchus labrax*), meager (*Argyrosomus regius*), conger (*Conger* spp.), groupers (*Epinephelus* spp.), cephalopods, bivalves and lobsters (*Homarus* and *Palinurus* spp.); Charbonnier and Caddy (1986) allocated a degree of importance to each species, i.e., 'important', 'average' or 'low', and UNEP (2008) described cephalopod catches. Here we used this information as a baseline and attributed a number to each degree of importance (Table 2). For the Mediterranean, a gear-based species disaggregation was provided by INRH (1999), from which we derived an average, in combination with the estimates provided by Malouli Idrissi *et al.* (2001) and ArtFiMed (2009) (Table 2).

Under-reported large-scale catches

Industrial fisheries: This component represents what is referred to as off-shore by Morocco, in contrast to coastal (semi-industrial fisheries which include coastal demersal and drfitnet fisheries). Industrial demersal catches are known to be under reported (Baddyr and Guénette 2001). The authors estimated the unreported industrial catch from 1972 (when the fishery started) to 1998 with a minimum under-reporting of 47%. Therefore, to complete the time series from 1999 to 2010, we applied an under reporting rate of 55% to the industrial catches from 1999 to 2010, which represents the average between the estimate by Durand (1995) (60% in the 1990s) and Pitcher *et al.* (2002) estimate of 50% to 60% in the 2000s.

Table 4. Number of active driftneters per year in the Mediterranean waters of Morocco.

Year	Number of boats	Source
1989	0	Tudela *et al.* (2005)
1993	120	Silvani *et al.* (1999)
1994	120	Silvani *et al.* (1999)
1995	200	Tudela *et al.* (2005)
1998	225	Abid (1998), Cornax *et al.* (2006)[a]
2002	267	Tudela *et al.* (2005), Rojo-Diaz and Pitcher (2005)[a]
2003	274	Cornax *et al.* (2006)
2004	300	Cornax *et al.* (2006), Srour and Abid (2004)[a]
2006	300	Abid and Idrissi (2007)
2007	300	Abid and Idrissi (2007)
2010	300	Assumed constant

[a] Average estimate.

Coastal demersal and pelagic fisheries: As for coastal pelagic and demersal fisheries, Baddyr and Guénette (2001) assumed an unreported catch of 23% in the 1970s, El Hannach (1986) reported the same rate for the 1980s which we applied here to the coastal catch. El Mamoun (1999) identified 47% of the catches as being unreported and Anon. (2005c) in the 2000s estimated only 8% to be unreported which is low given the prevalence of illegal marketing in Morocco (Rojo-Diaz and Pitcher 2005). To adopt a conservative approach, we assumed 10% of catches were not reported in 2010, and given the monitoring system development as reported by Morocco, interpolated from 47% in 1999 to 10% in 2010 (Rojo-Diaz and Pitcher 2005). For the 1950s and 1960s, we used Rojo-Diaz and Pitcher (2005) estimate of 60% which is justified by the total absence of a statistical monitoring system during this period (CGPM 1982; Oliver 1983) (Table 3).

Moroccan large-scale driftnet fishery: The driftnet fishery targets mainly swordfish and is considered under the coastal fisheries segment. The driftnet fishing effort developed quickly in the 1990s (Table 4) (Tudela *et al.* 2005; Anon. 2008). Although the net length is legally limited and reported to be 2 to 3 km (Abid and Idrissi 2009), it is largely under-estimated (Cornax *et al.* 2006). Driftnet fishers often fail to respect this regulation. Indeed, Anon. (2008) reported a length range of 3 to 14 km and Tudela *et al.* (2005) reported an average length of 6.8 km and a catch of 0.8 swordfishes per km of net per day for an average weight of 32 kg per fish (Srour and Abid 2002). This, when multiplied by the number of fishing days, i.e., 120 (Tudela *et al.* 2005), allowed estimating a swordfish CPUE of 20.9 t·boat^{-1}·year^{-1} for 2002 and 2003. Thereafter, we applied this estimate to the number of driftneters per year. We interpolated linearly between the years of known data to fill in the missing time periods (Table 4). Landed by-catch was then estimated, including sharks, 6% of bonito (*Sarda sarda*), 5% of pelagic stingrays (*Pteroplatytrygon*

spp.) and 0.5% of dolphinfish (*Coryphaena hippurus*) (Cornax *et al.* 2006), which we applied to the swordfish catch. Effort was relatively low from 1990 to 1994, we assumed that the unreported portion for this period was not significant. The progressive prohibition of driftnetting in Spain in 1991 (Silvani *et al.* 1999), and in Europe for driftnets of more than 2.5 km of length (Cornax *et al.* 2006), before being prohibited totally in 2002 (Tudela *et al.* 2005), contributed to the increase of such activity in Morocco, with nets exceeding 2.5 km since 1991. Furthermore, a possible decrease in the CPUE due to over-exploitation (Tudela 2000) would be compensated by an increase in gear capacity (i.e., total net length) per boat.

Illegal fisheries

Illegal fishing is defined as all fishing methods prohibited by the government of Morocco in waters under its sovereignty or jurisdiction. Dynamite fishing and illegal cephalopod fishing are the two main illegal domestic fishing activities. Although dynamite fishing is widespread along the Mediterranean coast of Morocco (Pitcher *et al.* 2002; Rojo-Diaz and Pitcher 2005; Tudela *et al.* 2005; Boudinar 2007), non-discarded catches are often reported; thus they are considered under small-scale fisheries catches. Illegal cephalopod fishing is mainly practiced along the Saharan (southern area) coastline (Barreira *et al.* 1998).

Illegal cephalopod fishery : Barreira *et al.* (1998) reported about 12,000 *pateras*, the majority of which are operating illegally (over the quota announced by the government), along the Saharan coast in 1998, targeting cephalopods and reportedly catching the same quantity as Spanish cephalopod boats, i.e., 20,000 $t \cdot year^{-1}$. Baddyr and Guénette (2001) documented that the legal artisanal fishery targeting cephalopods started in 1988; however, we assume that the illegal activities started along with the industrial fishery, i.e., in 1975 (Barreira *et al.* 1998). Therefore, we interpolated linearly from zero in 1975 to 20,000 $t \cdot year^{-1}$ in 1990 and kept this number unchanged to 2010, assuming that the number of *pateras* remained stable.

Discards

Small-scale fishery : Discards of the small-scale fishery were considered non-existent (Baddyr 1989) and therefore, not accounted for in Baddyr and Guénette (2001). However, due to the lack of preservation technology, the lack of carrying capacity of the boats and the opportunity of selling the products (Pitcher *et al.* 2002); Kelleher (2005) estimated a discard rate of 19%, and Weber and Durand (1986) reported a discard of 10% to 15%. Here, we estimated an average rate of 12.5% of the total small-scale catches for the period 1950 to 1989, then we interpolated linearly to 19% in 2010 (Table 5).

Table 5. Discard rates per fishing sector in the northen, central and southern areas of Morocco.

Year	Discard (%)	Source
Small-scale		
Northen, central and southern areas		
1950	12.5	Asumption
1989	12.5	Durand (1995)
2010	19.0	Kelleher (2005)
Industrial cephalopod		
Central and southern areas		
1970	66.0	Balguerías (1997)
1980	46.0	Balguerías (1997)
1990	30.0	Haddad (1994)
2002	45.0	Veguila (2011), Kelleher (2005)
2010	45.0	Veguila (2011), Kelleher (2005)
Coastal demersal trawl fishery		
Northern areas		
1950	75.0	Rojo-Diaz and Pitcher (2005)
1989	75.0	Rojo-Diaz and Pitcher (2005)
2000	43.0	El Mamoun (1999), Kelleher (2005)
2010	43.0	El Mamoun (1999), Kelleher (2005)
Central and southern areas		
1950	80.0	Weber and Durand (1986)
1989	80.0	Weber and Durand (1986)
2000	45.0	Kelleher (2005)
2010	45.0	Kelleher (2005)
Coastal pelagic fishery		
Northern, central and southern areas		
1950	4.0	El Mamoun (1999)
1980	4.0	El Mamoun (1999)
2000	2.5	Kelleher (2005)
2010	2.5	Kelleher (2005)

Large-scale fisheries: Large-scale fisheries include the cephalopod industrial fishery, coastal trawl demersal fishery, coastal small pelagic fishery and coastal driftnet fishery (in the northen areas).

The industrial cephalopod fishery is associated with higher rates of discarding. In the 1970s, 66% of the industrial cephalopod fleet catches were thrown overboard and in the 1980s, discards represented 46% of the retained catch (Balguerías 1997). Haddad (1994) estimated that 30% of the catch was discarded in the 1990s and Rojo-Diaz and Pitcher (2005) and Kelleher (2005) estimated that 45% was discarded in the 2000s. We interpolated linearly to derive annual estimates for the periods 1970 to 1980, 1981 to 1990, 1991 to 2002. From 2002 onward, the discard rate was held constant at 45% due to the adoption of a global quota for the industrial cephalopod fishery in 2002 (Veguila 2011), which likely maintained a high discard rate. However, to remain conservative, we kept the rate constant (Table 5). Then, we applied these rates to the reconstructed cephalopod industrial catches.

By-catch from the demersal shrimp trawl fishery in North West Africa accounted for 85% of the shrimp catch (Kaczynski 1989). According to Rojo-Diaz and Pitcher (2005), 75% of this was discarded in the Atlantic areas, while Kelleher (2005) estimated that 20% to 70% was discarded. In Mediterranean Morocco, a discard rate of 12% is suggested by El Mamoun (1999). Here, we used a discard rate of 75% from 1950 to 1989, decreasing thereafter due to an increase in mesh size and boat capacity to an average rate of 43% in the 2000s. Weber and Durand (1986) reported higher discards of around 70% to 90% for the Atlantic coast. We applied the average discard rate of 80% to the reconstructed demersal catches from 1950 to 1989, and decreased the rate linearly thereafter to 45% in the 2000s (Kelleher 2005; Table 5).

Small pelagic fishery

Sardine fishery discards were estimated to be relatively low. For the 2000s, Kelleher (2005) provided a discard rate of 2.5%, for the 1990s, Haddad (1994) provided a discard of 5%, while El Mamoun (1999) estimated 4%. Here we applied a discard rate of 4% for the period 1950 to 1980, decreasing linearly to 2.5% in the 2000s (Table 5).

Driftnet fishery

The driftnet fishery mainly targets swordfish (Abid 1998) and generates high levels of by-catch and discards. Indeed, shark by-catch ranges from 50% (Cornax *et al.* 2006) to between 78% and 92% (Tudela *et al.* 2005) of total estimated swordfish catches. Here, we applied an average of 67.5% to the swordfish catch for the period from 1990, when driftneting began in Morocco, to 2010. The species composition of non-targeted catch was 33% blue sharks (*Prionace glauca*), 36% shortfin mako (*Isurus oxyrhinchus*) and 31% thresher sharks (*Alopias vulpinus*) (Tudela *et al.* 2005). A portion of this by-catch is discarded and therefore not reported nor accounted for in Baddyr and Guénette (2001). In this paper, since no data were available, we considered 50% as discarded and 50% as sold illegally. Driftneting also generates high levels of by-catch of non-commercial species, which are mainly discarded. Based on Tudela *et al.* (2005) estimate of discarded ocean sunfish (*Mola mola*) (508 sunfish for 2,990 swordfish) and an average weight of 46 kg for the ocean sunfish (www.fishbase.org [2011]), and 32 kg for the swordfish (Srour and Abid 2002), we derived a discard rate of 25% of swordfish catches. This is likely an under-estimate (see Stewart 2001) because of the average weight reported for ocean sunfish (about 1,000 kg)[2] is over 20 times higher than the one we used here. Then, we applied the previous discard rates to the annual swordfish catch from 1990 to 2010.

Subsistence fisheries

Bivalves were mainly caught to sustain subsistence fishers. Shafee (1999) documented a CPUE of 22 t·boat^{-1}·year^{-1} in the 1990s of which 70% was for subsistence. Catches have been steeply declining since the early 1980s (Anon. 2005b), therefore, we conservatively assumed the CPUE was 40% higher in 1980 than in 1990, i.e., 30.8 t·boat^{-1}·year^{-1} and we kept the trend declining and estimated a CPUE of 14.12 t·boat^{-1}·year^{-1} in 2010. The effort targeting bivalves decreased from 350 boats in 1980 to 233 boats in the 1990s and continued decreasing to an estimated 30% of the 1990s effort in 2010 due to a decreasing biomass (Shafee 1999). Here, we used CPUE and effort data to estimate catches from 1980 to 2010, then we assumed that the catches in 1950 were 20% higher than in 1980. Thereafter, we allocated 30% of these catches to the small-scale commercial fishery. This approach likely underestimates the real catch, since shore-based fishers (Shafee 1999) were not accounted for. We also conservatively assumed that the by-catch reported by Shafee (1999), often used as bait, was 5% of total bivalve catches. Here, bivalve catches were mainly documented for Mediterranean Morocco (Shafee 1999; Anon. 2005b), thus we assumed that the catches in the Mediterranean represented 70% of total removals, while 20% were caught along the central areas and 10% in the southern areas where the Zenaga were fishing for their subsistence along with the Imraguen of Mauritania (Gaudio 1984; de Brisson and Gaudio 1993); then assigned catch to species for the Mediterranean, where information was available (Shafee 1999) (Table 6). The portion of the catch taken home by artisanal fishers for personal consumption is also considered subsistence in the present study. Malouli Idrissi (2001) estimated the portion taken home to be 8.5% of the artisanal catch. Here, we assumed this rate was higher (30%) from 1950 to 1975, before the first fisheries plans were legislated, interpolated linearly to 8.5% in 1999 (Malouli Idrissi 2001), and kept the personal consumption rate constant between 1999 to 2010. We then applied this rate to the estimated artisanal catch for the northern, central and southern areas of Morocco.

Table 6. Catches composition for the Mediterranean bivalve subsistence fishery (in %).

Common name	Taxon name	Catch (%)
Spiny cockle	*Acanthocardia aculeata*	15.0
European prickly cockle	*Acanthocardia echinata*	14.0
Moroccan cockles	*Acanthocardia tuberculata*	14.0
Smooth callista	*Callista chione*	21.0
Donax	*Donax denticulatus*	2.0
Venus clam	*Chamelea gallina*	34.0
Total		100.0
		Bait use (%)
Olive green cockle	*Cerastoderma glaucum*	1.0
Pilose bittersweet	*Glycyremis pilosa*	0.5
Brown mussel	*Perna perna*	1.0
Queen scallop	*Aequipecten opercularis*	1.0
Sword razor	*Ensis ensis*	1.0
Cockle	*Glycyremis violacescens*	0.5
Total		5.0

Recreational fisheries

Recreational fisheries include rod and reel fishing and underwater spear-fishing. In the Mediterranean, these activities are becoming increasingly important (Zahri and Abdelaoui 2010). The number of fishing licenses and the species targeted in the Mediterranean

Table 7. Recreational fishing effort expressed in number of licenses in the northern area[a].

Year	Underwater spearfishing licences	Rod-fishing licenses
1950[b]	0	0
2004[c]	100	1,000
2005[c]	180	2,200
2006[c]	200	2,800
2007[c]	230	5,300
2008[c]	260	6,200
2009[c]	180	5,000
2010[c]	180	5,000

a) Effort in Atlantic derived from the effort in the Mediterranean; b) Assumption; c) from Abdelaoui (2010).

[2] http://www.websters-online-dictionary.org/definitions/ocean+sunfish [Accessed on 16/12/2011].

from 2004 to 2009, have been well documented (Gaudin *et al.* 2007; Abdelaoui 2010; Zahri and Abdelaoui 2010), however, no effort estimate was available for the Atlantic.

The number of spearfishing and rod-fishing licenses for the Mediterranean were available from 2004 to 2009[3] (Abdelaoui 2010). The number of fishing licenses indicates the number of spearfishers and rod-fishing boats, respectively. To estimate the number of spearfishers and rod-fishing boats for the period from 1950 to 2003, we assumed recreational fisheries started in 1950, i.e., zero spearfishers and zero rod-fishing boats, then interpolated linearly to 100 spearfishers and 1,000 rod-fishing boats in 2004. Since no effort data were available for the central and southern areas, we assumed the effort in the Mediterranean represented 70% of the total effort, 20% in the central areas, and in the southern areas where there was no spearfishing represented 10% of the total number of rod-fishing boats. The number of fishing days was also derived from Abdelaoui (2010) to be conservatively 70 days per year (i.e., during the summer) for the time period from 1950 to 2010, which allowed to estimate the total recreational effort (Table 7). We estimated a CPUE of 58.8 kg·fisher^{-1}·day^{-1} based on observations from recreational fishers (www.hassan-peche.com [2011]; www.pecheurmarocain.com [2011]) for Atlantic central and southern areas rod-fishing, and assumed a same CPUE for the Mediterranean recreational rod-fishing fleet. We also derived a spearfishing CPUE of 17.14 kg·fisher^{-1}·day^{-1} (www.hassan-peche.com [2011]) for Atlantic areas, while for the Mediterrean, the majority of the spearfishing catch per unit of effort (70%) was estimated to be 20.6 kg·day^{-1} of seabreams (Zahri and Abdelaoui 2010), i.e., a total CPUE of 28 kg·day^{-1}. Thereafter, to reconstruct recreational rod-fishing and spearfishing catches from 1950 to 2010, we applied these CPUE estimates to the effort of each segment in the Mediterranean, Atlantic Morocco and Western Sahara. This approach uses the same CPUE for the 1950 to 2010 time period; therefore, it accounts for the increasing popularity of recreational fishing by Moroccans and tourists (increasing number of fishing days).

Foreign fishing

Foreign fisheries catches were not estimated here. However, a global overview was available through the report by Guénette *et al.* (2001) by the Spanish fishing fleet, whose activities were prominent in Moroccan central and southern areas among the European fleets. Belhabib *et al.* (this volume) reconstructed foreign fishing through fishing access agreements, with a particular focus on Spain being prominent in the area. Although we believe illegal fishing activities have significant removals, we focused on the legal removals.

Results

Total catches

Total reconstructed domestic catches for Morocco were estimated to be over 48.4 million tonnes for the period 1950 to 2010 compared to 28.3 million tonnes reported to the FAO (Figure 3a). In the 1950s, catches represented almost 3 times the data supplied to FAO on average compared to the 2000s when they were 50% higher than the data supplied to FAO. The Mediterranean fisheries of Morocco were two to three times the data submitted by the government of Morocco to the FAO over the period from 1950 to 2010, i.e., 3.8 million tonnes compared to 1.48 million tonnes supplied to the FAO. The unreported component accounted for about twice the reported catch in the 1950s, and decreased since the mid-1970s after Morocco declared its EEZ. Overall, total reconstructed catches for Morocco increased from about 311,000 t·year^{-1} in 1950 to around 1.6 million t·year^{-1} in 2010, reaching a peak of 1.8 million t·year^{-1}

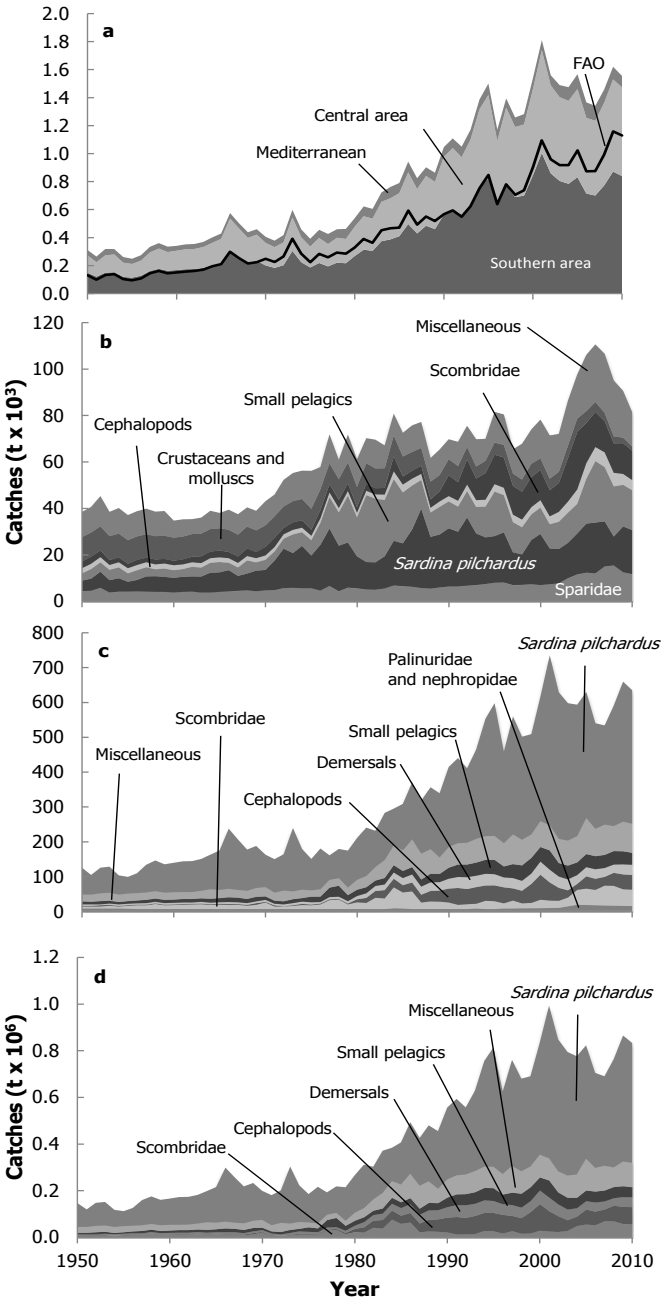

Figure 3. a) Estimated total marine fisheries catches by Morocco for the 1950-2010 time period as compared to the total catch reported to the FAO; b) seven most important taxa caught in the mediterranean; c) seven most important taxa caught in the central areas and; d) six most important taxa caught in the southern areas EEZ by the Moroccan fleet, 1950-2010.

[3] We assumed the same number of licenses for 2010.

in 2001, around 1 million tonnes of which were caught off the southern areas (Figure 3a).

Catches in the northern areas are dominated by sardines, other small pelagic species and scombrids, observing declining catches since the mid-2000s (Figure 3b). Catches in the central areas were dominated by sardines, cephalopods and other demersal species (Figure 3c), while catches in the southern areas were overwhelmingly dominated by sardines (Figure 3d).

Moroccan catches by sector in the northen and central areas

Artisanal catches

Small-scale reconstructed catches in Moroccan northern and central areas, mainly of crayfish, lobster, large pelagic fish and octopus, increased from 43,000 t·year^{-1} in 1950 to a maximum of 105,000 t·year^{-1} in 2004 and decreased afterwards (Figure 4). Catches increased substantially after the 1970s, when Morocco granted its first effort subsidies for fisheries. Reconstructed catches totaled around 2.8 million tonnes for the period 1950 to 2010, of which 44% were from the Mediterranean EEZ, i.e., 1.2 million tonnes (Figure 4). From a total of 2.8 million tonnes, more than 580,500 tonnes were used for personal consumption, thus not considered commercial. Personal consumption decreased from 12,800 t·year^{-1} in 1950 (1.5 kg·person^{-1}·year^{-1}) to 6,300 t·year^{-1} (0.6 kg·person^{-1}·year^{-1}) in 2010.

Unreported large-scale catch

Moroccan large-scale catches totaled 15.7 million tonnes over the period from 1950 to 2010 (Figure 5). This sector alone was over 47% higher than the data supplied to FAO for Atlantic Moroccan area (10.7 tonnes) (Figure 5). Coastal pelagic fisheries represented the bulk of Atlantic Moroccan (central areas) large scale catches with 83% of the total (13.1 million tonnes) over the study time period (Figure 5). Coastal demersal catches of over 793,700 tonnes represented 6% of total large scale catches. Coastal demersal catches increased from 7,620 t·year^{-1} in 1950 to a peak of 40,042 t·year^{-1} in 2000, and then decreased to around 25,100 t·year^{-1} in 2010 (Figure 5). Industrial catches which were estimated at over 1.6 million tonnes for the 1950-2010 time period, increased since the 1970s, when they started, to their maximum of about 86,100 t·year^{-1} in the early 1990s, and decreased thereafter (Figure 5).

Catches in the Mediterranean were reconstructed to be over 1.6 million tonnes compared to 1.2 million tonnes reported to the FAO over the period 1950 to 2010. The unreported component for the Mediterranean area decreased from 1,900 t·year^{-1} (42%) in 1950 to a maximum of approximately 18,000 t·year^{-1} in 2006, when 50% of the catches were not reported (Figure 5).

Driftnet unregulated fisheries

The bulk of unreported catches off the Mediterranean coast of Morocco started after the introduction of the driftnet fishery in the early 1990s, when swordfish, billfishes and sharks represented 46% of total unreported catches for the Mediterranean (Figure 6).

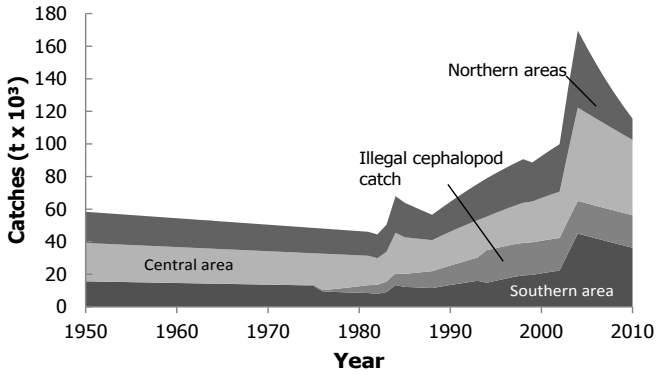

Figure 4. Morocco reconstructed small scale (artisanal) catches for the period 1950 to 2010.

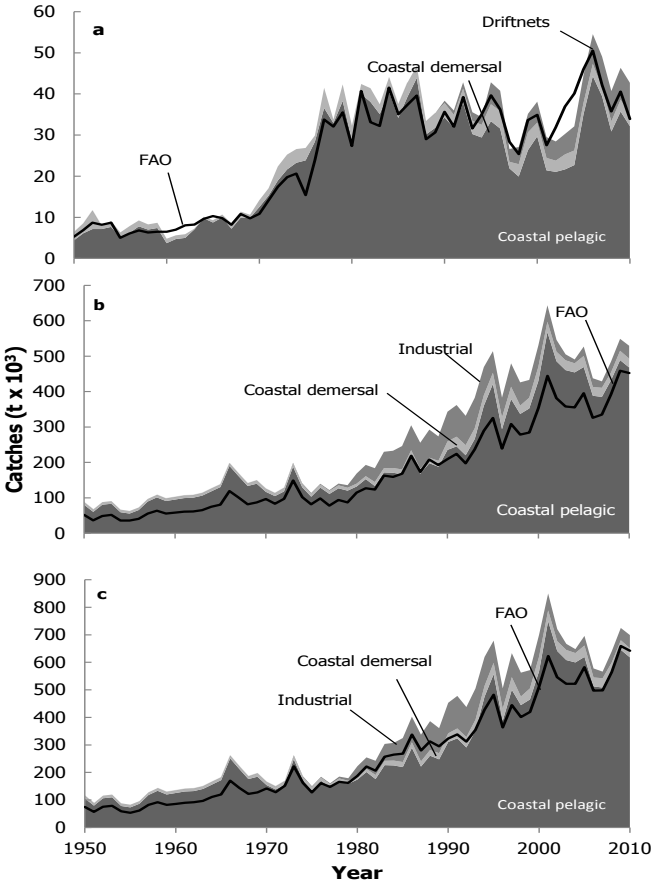

Figure 5. Domestic large-scale catches by a) Morocco in the North, compared to FAO data from Moroccan northern areas, and b) by Morocco from Atlantic central area compared to FAO data from the Moroccan Atlantic central EEZ and c) Morocco from the southern areas, compared to FAO data from the southern areas, 1950-2010.

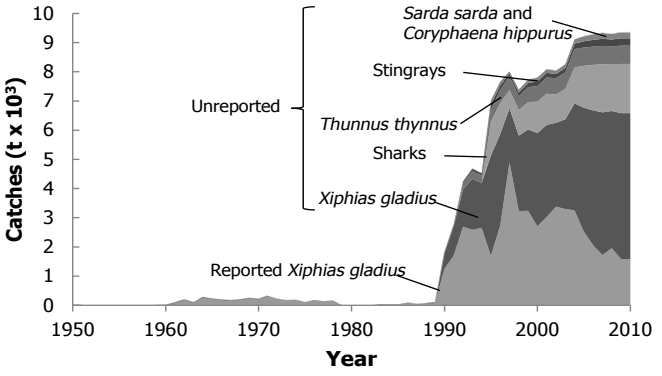

Figure 6. Reconstructed domestic driftnet catches by Morocco from the Mediterranean coast of Morocco, 1950-2010.

Unreported driftnet catches totaled approximately 100,000 tonnes for the period from 1990 (when the fishery started) including 65% of swordfish (64,000 tonnes) and 23% of sharks and stingrays (23,000 tonnes) over the period between 1990 and 2010 (Figure 6). Morocco failed to report increasing bluefin tuna (*Thunnus thynnus*) catches from 188 t·year^{-1} in 1990 to 630 t·year^{-1} in 2004 (Figure 6). Unreported bluefin tuna catches remained stable thereafter (Figure 6).

Discards

Discarded by-catch in Atlantic Morocco represented 9% of total catches from 1950 to the late 1970s, with average discards of 12,300 t·year^{-1} (Figure 7). Discarding from the 1980s onward increased to an average of 48,000 t·year^{-1} in the 2000s, due to the development of industrial fisheries as well as coastal demersal fisheries after Morocco launched its 'encouragement code' for fisheries investments in the mid-1970s and consecutive four-year plans in the 1980s and 1990s (Figure 7). The total discards estimated here were over 1.7 million tonnes from 1950 to 2010. Industrial fisheries were responsible for the bulk of discards, with over 550,000 tonnes from 1973 to 2010, whereas coastal pelagic fisheries represented 27% from 1950 to 2010, and demersal fisheries 29% (505,000 tonnes). Small-scale discards which totaled 225,000 tonnes from 1950 to 2010, increased by a factor of 4 during the same time period (Figure 7).

Discards in the Mediterranean are relatively low, with 286,000 tonnes discarded over the period 1950 to 2010 (Figure 7). However, the driftnet fishery alone contributed to 28% of Mediterranean discards since its introduction to Morocco in 1990, reaching over 44,000 tonnes from 1990 to 2010 (Figure 7), consisting of ocean sunfish (49%) and sharks (51%).

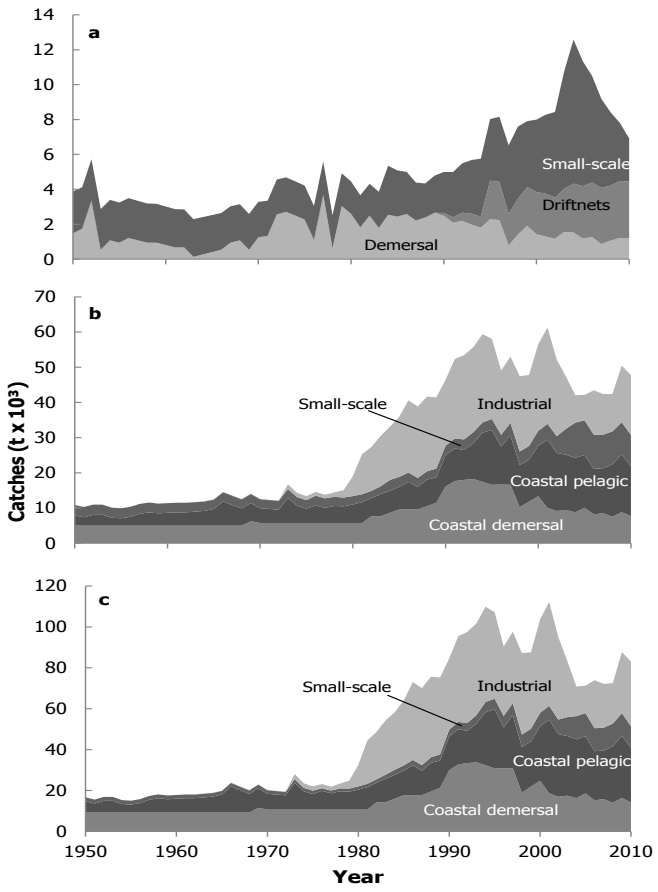

Figure 7. Estimated discards by sector for a) Mediterranean Morocco, b) Atlantic central areas and ; c) southern areas , 1950 to 2010.

Subsistence fisheries

Morocco does not supply subsistence catch data to the FAO. The total reconstructed subsistence catches from Atlantic Morocco were estimated to be 409,310 tonnes from 1950 to 2010 (Figure 8), of which 32% were bivalves (134,000 tonnes). Subsistence catches for the Mediterranean, consisting of 63% of bivalves (dominant in weight and caught manually or using small boats) decreased from 14,700 t·year^{-1} in 1950 to around 1,800 t·year^{-1} in 2010 (Figure 8).

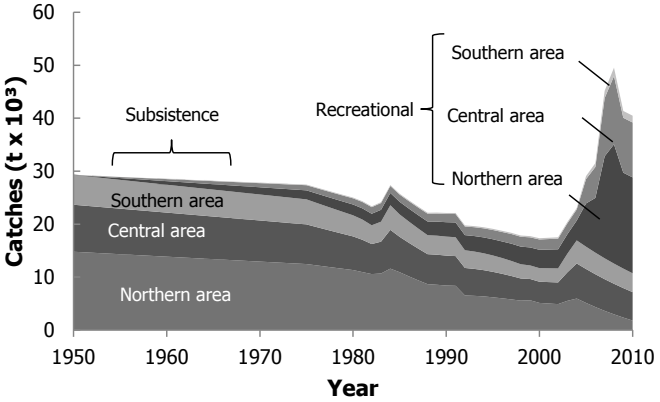

Figure 8. Estimated subsistence and recreational catches for Morocco, 1950-2010.

Recreational fisheries

Recreational catches in the central areas of Morocco were estimated at 113,000 tonnes for the period 1950 to 2010, increasing from 40 t·year^{-1}, right before independence of Morocco, to 10,400 t·year^{-1} in 2010 (Figure 8). Similarly, in the Mediterranean, recreational catches increased from 70 t·year^{-1} to 18,000 t·year^{-1} in 2010 (Figure 8), with a total of 198,000 tonnes for the 1950 to 2010 time period (Figure 8).

Moroccan (and former Spanish Saharan) catches by sector from the southern areas

Artisanal catches

Small-scale reconstructed catches in the southern areas increased from 15,700 t·year^{-1} in 1950 to a maximum of 45,000 t·year^{-1} in 2004 and decreased afterwards (Figure 4). Catches from the southern areas of Morocco were reconstructed to be around 1.5 million tonnes, of which 31% were illegally caught cephalopods from 1950 to 2010 (Figure 4). More than 224,000 tonnes have been used for personal consumption, thus not considered commercial. Personal consumption remained relatively stable over the 60 year time period at an average of 3,700 t·year^{-1}.

Unreported large scale catch

Coastal pelagic fisheries catches off the southern areas of Morocco were estimated at 17.3 million tonnes over the period from 1950 to 2010. These catches increased from an average of 101,000 t·year^{-1} in the 1950s to a peak of about 750,000 t·year^{-1} in 2001, and decreased thereafter to less than 618,000 t·year^{-1} in 2010 (Figure 5). Coastal demersal catches were reconstructed to be over 1.3 million tonnes for the 60 year time period (Figure 5). Catches increased by a factor of five from the 1950s (10,000 t·year^{-1}) to 2000 (53,000 t·year^{-1}), then decreased by almost half in 2010, when catches were estimated at 33,000 t·year^{-1} (Figure 5). Industrial fisheries removed 3,300 t·year^{-1} in 1973, the year they began, and increased to a maximum of 118,000 t·year^{-1} in the early 1990s (Figure 5). Overall, large scale catches (including coastal and industrial sectors) were estimated to be over 20.7 million tonnes for the 1950-2010 time period, compared to 16.1 million tonnes supplied by Morocco to FAO for these areas (Figure 5).

Illegal and unregulated fisheries

Illegal cephalopod catches in the southern areas totaled 480,000 tonnes for the period from 1950 to 2010, increasing from 800 t·year^{-1} in 1972, when the fishery started to a plateau of 20,000 t·year^{-1} from 1994 to 2010 (Figure 4).

Discards

Fisheries off the southern areas accounted for 60% of the discards for the period 1950 to 2010, with over 3 million tonnes discarded, increasing after 1976, when Morocco took control of the area (Figure 7). Discards represented 12% of the total reconstructed catch in the southern areas, where in 2010, they were 5 times (83,000 t·year^{-1}) as high as discards in 1950 (16,600 t·year^{-1}) with a peak of 112,000 t·year^{-1} in the early 2000s (Figure 7). Small-scale discards represented 8% of total discards with 232,000 t·year^{-1} for the study period; coastal fisheries represented 59% of discards with coastal pelagic fisheries responsible for over 870,000 tonnes and demersal coastal fisheries for 938,000 tonnes (Figure 7). Industrial fisheries which started in 1973, were responsible for over a third of total discards in the southern areas, i.e., 1 million tonnes over the 1950-2010 time period.

Subsistence fisheries

Subsistence and recreational catches in the southern areas were estimated to be 261,000 tonnes from 1950 to 2010. Subsistence catches in these areas decreased overall from 5,600 t·year^{-1} in 1950 to less than 3,600 t·year^{-1} in 2010 (Figure 8), the lowest in the areas under Morocco's jurisdiction.

Recreational fisheries

Recreational catches were estimated at 14,000 tonnes for the period 1950 to 2010. Recreational catches in the southern areas increased from 5 t·year^{-1} in 1950, when the area was under the Spanish rule, to 1,300 t·year^{-1} in 2010 (Figure 8).

Discussion

Our reconstruction of Moroccan domestic fisheries accounts for various fisheries sectors (commercial and non-commercial) not previously included in statistical time series supplied to the FAO. Thus, it represents the most comprehensive estimate available of total domestic marine fisheries catches for Morocco. Moreover, it provides catch estimates by species or taxon and it allocates data to three separate areas, i.e., Mediterranean versus central and southern Atlantic areas.

Total marine fisheries catches by Morocco in the Mediterranean and the Moroccan Atlantic EEZ were approximately 48.4 million tonnes for the period from 1950 to 2010, which is nearly two times higher than the data supplied to the FAO. The southern areas, with the largest contribution to the sardine landings (Machu *et al.* 2009), accounted for a large part of Moroccan catches, with an estimated 25.4 million tonnes for the 1950-2010 time period.

Although the artisanal sector is important, accounting for 16% of the total removals, it remains relatively neglected (Charbonnier and Caddy 1986) in terms of management and monitoring, with a high portion of catches not being presented in the official statistics. Coastal fisheries accounted for 71% of the domestic catch, which drives the general trend of the Moroccan fisheries during the period from 1950 to 2010.

Domestic catches had an overall increasing trend; however, catches increased at a higher rate after Morocco introduced its first 'encouragement code' for fisheries in the 1970s followed by a succession of subsidies. The resulting increase in subsidized effort added further pressure on already depleted and over-exploited stocks: pelagic fisheries since the mid-1990s (Zahri 2006; Menioui 2007), and demersal resources since the mid-1980s (Balguerías *et al.* 2000; Slimani and Hamdi 2004; Menioui 2007). Demersal fisheries, especially in southern areas, where the continental shelf area remained freely accessible to fishing vessels after the Spanish occupation ended, have been heavily exploited (Garcia and Newton 1994). A plateau, with a slight decreasing tendency, is observed since 2001 where the catch was 1.8 million t·year^{-1} and reached 1·6 million t·year^{-1} in 2010.

The Moroccan population, particularly in the southern areas, suffers from malnutrition and anemia as a result of a lack of animal protein (Skretteberg 2008), while 80% of the Morocco's large-scale fleet output is exported to overseas markets (Suárez *et al.* 1996). Furthermore, these waters are subject to a constant fishing pressure by foreign fishing vessels under agreements or joint ventures with Morocco (Kaczynski 1989; Riché 2004, Belhabib *et al.* This volume).

In the Mediterranean area, the gradual prohibition of driftnets by European countries and an increasing demand for swordfish has contributed to the increasing use of driftnets in Moroccan waters (Cornax *et al.* 2006). Moreover, poverty in some fishing areas has encouraged the use of dynamite for fishing (Boudinar 2007), which although not considered here, usually leads to high discard rates and unrecovered mortality, as well as substantial habitat destruction.

Illegal fishing practices (Boudinar 2007), foreign fishing pressure (Porter 1997), lack of control and surveillance (Kaczynski 1989), fish habitat loss (Menioui 2007) and high rates of discards have led to the over-exploitation of demersal resources. Heavy trawling activity led to shifting stocks (Balguerías *et al.* 2000) and declining stock abundance (Faraj and Bez 2007). In addition, inequity of domestic fishing license attribution has favored an increasing migration of Moroccans and thus Moroccan fishing vessels towards southern waters (Veguila 2011). This, combined with the 2002 management decision to adopt a quota for cephalopods (Faraj and Bez 2007), led to the development of informal markets and thus illegal fishing, in addition to increasing the competition between the industrial and the artisanal sectors over the resource, thus increasing conflicts among fishers.

This raises the question of the resource rent not captured by the Moroccan southern populations, but mainly transferred to northern areas of Morocco via migrant flows (Veguila 2011). Furthermore, the unreliability of Moroccan statistics, both in the Mediterranean and in the Atlantic areas, is highlighted by the substantial difference between our reconstructed estimate and total landings data as supplied to the FAO by Morocco.

Given the extent of foreign fishing in Morocco, the question of how fishing access agreements contribute to the local economy needs to be raised. Access fees are often diverted to activities other than direct improvements to the management of fisheries resources. Decision-makers often negotiate access-agreements that are harmful to sustainable fisheries for their own personal gain. Therefore, allowing foreign fleets access to Moroccan waters does little to benefit the majority of the Moroccan population (Porter 1997).

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Appendix Table A1a: Annual catches by the Moroccan fleet.

Year	Mediterranean	FAO	Central areas	Southern areas	FAO Atlantic
1950	38,515	5,300	123,866	148,933	126,600
1951	40,624	6,900	102,897	121,070	93,000
1952	45,302	8,700	123,956	149,321	123,900
1953	38,545	8,200	126,658	152,962	130,500
1954	40,182	8,700	101,626	119,538	94,700
1955	37,125	5,000	97,537	114,137	89,200
1956	38,782	6,100	107,642	127,776	102,000
1957	39,885	6,800	132,562	161,200	138,200
1958	38,648	6,300	144,520	177,286	155,300
1959	38,895	6,500	133,682	162,901	137,800
1960	34,746	6,500	137,832	168,528	144,100
1961	35,297	6,981	142,025	174,212	150,500
1962	35,421	8,049	143,133	175,748	153,400
1963	36,104	8,235	149,062	183,762	162,000
1964	38,975	9,635	161,649	200,566	186,047
1965	38,111	10,298	173,909	217,124	200,188
1966	39,505	9,782	235,780	300,007	289,198
1967	37,578	8,185	205,625	259,745	245,171
1968	40,462	10,793	176,651	221,040	203,882
1969	39,027	9,756	186,262	234,621	214,641
1970	43,129	10,869	161,238	200,871	238,308
1971	45,967	14,130	148,334	183,793	211,754
1972	52,361	17,437	162,756	202,790	248,599
1973	55,245	19,756	238,158	304,939	371,425
1974	56,239	20,631	177,834	224,065	264,282
1975	56,142	15,419	148,830	186,660	209,397
1976	57,860	23,932	178,994	218,668	259,314
1977	71,891	33,791	159,683	194,391	225,664
1978	60,969	32,071	177,943	220,788	260,040
1979	71,800	35,539	173,277	216,860	249,034
1980	61,187	27,328	209,352	268,764	302,049
1981	70,223	40,730	239,033	313,465	348,835
1982	69,601	33,121	229,983	305,531	329,205
1983	67,104	32,193	281,379	374,368	420,129
1984	80,839	41,557	293,613	387,113	424,323
1985	72,554	35,052	307,234	410,134	436,732
1986	75,786	37,378	369,454	497,221	556,366
1987	77,195	39,597	317,219	429,704	452,777
1988	61,660	28,975	355,905	484,612	521,383
1989	65,350	30,655	337,422	460,665	487,756
1990	69,778	35,660	412,995	563,769	531,777
1991	68,712	32,018	438,647	601,232	562,565
1992	75,599	39,239	409,576	564,506	509,896
1993	69,809	31,623	463,535	637,827	591,262
1994	69,951	34,999	551,535	764,653	717,576
1995	81,530	39,669	596,259	822,624	807,775
1996	80,422	36,268	456,957	633,676	602,216
1997	65,487	28,374	558,695	770,007	752,819
1998	67,830	25,369	500,642	689,573	679,908
1999	73,974	33,647	508,415	699,534	704,475
2000	78,237	34,902	615,412	844,691	866,242
2001	71,466	27,517	734,885	1,004,123	1,066,906
2002	72,088	31,856	629,114	858,820	927,647
2003	86,280	36,959	598,196	804,752	880,026
2004	97,641	40,090	592,614	784,268	877,203
2005	106,043	45,973	629,621	831,465	977,487
2006	110,562	50,523	540,742	714,613	822,929
2007	106,496	42,137	534,213	700,530	833,106
2008	95,051	35,752	589,938	773,152	956,934
2009	90,600	40,578	658,018	871,604	1,118,463
2010	81,449	33,913	633,938	839,759	1,095,090

Appendix Table A1b: Annual catches by the Moroccan fleet.

	FAO	Artisanal	Industrial	Recreational	Subsistence	Discards	Total reconstructed
1950	131,900	41,101	210,456	112	29,170	30,942	311,780
1951	99,900	40,823	165,672	112	28,986	29,417	265,010
1952	132,600	40,545	216,239	223	28,803	31,385	317,195
1953	138,700	40,266	220,659	335	28,619	31,528	321,408
1954	103,400	39,988	165,173	447	28,436	29,096	263,139
1955	94,200	39,709	152,586	558	28,253	27,955	249,061
1956	108,100	39,431	176,916	670	28,069	29,123	274,209
1957	145,000	39,152	234,096	781	27,886	31,630	333,546
1958	161,600	38,874	260,436	893	27,702	32,799	360,704
1959	144,300	38,596	236,559	1,005	27,519	31,967	335,645
1960	150,600	38,317	245,260	1,116	27,336	32,442	344,471
1961	157,481	38,039	255,627	1,228	27,152	32,810	354,856
1962	161,449	37,760	259,657	1,340	26,969	32,815	358,541
1963	170,235	37,482	273,604	1,451	26,785	33,383	372,706
1964	195,682	37,203	304,754	1,563	26,602	34,125	404,247
1965	210,486	36,925	332,732	1,674	26,419	35,693	433,443
1966	298,980	36,647	471,588	1,786	26,235	41,458	577,714
1967	253,356	36,368	402,241	1,898	26,052	38,627	505,185
1968	214,675	36,090	340,932	2,009	25,868	35,795	440,694
1969	224,397	35,811	358,657	2,121	25,685	38,874	461,148
1970	249,177	35,533	306,462	2,233	25,501	35,140	404,869
1971	225,884	35,254	281,306	2,344	25,318	34,520	378,743
1972	266,036	34,976	320,478	2,456	25,135	33,873	416,917
1973	391,181	34,698	487,847	2,568	24,951	47,482	597,545
1974	284,913	34,419	354,996	2,679	24,768	40,483	457,346
1975	224,816	34,133	285,953	2,791	24,584	38,166	385,627
1976	283,246	34,290	354,973	2,902	23,969	40,424	456,557
1977	259,455	34,432	326,924	3,014	23,360	38,377	426,107
1978	292,111	34,565	365,223	3,126	22,758	40,589	466,261
1979	284,573	34,691	360,977	3,237	22,164	42,597	463,667
1980	329,377	34,809	426,892	3,349	21,576	54,158	540,785
1981	389,565	34,919	498,768	3,461	20,783	72,457	630,387
1982	362,326	34,071	469,539	3,572	19,704	76,306	603,192
1983	452,322	39,076	575,022	3,684	20,380	85,122	723,284
1984	465,880	53,301	592,848	3,795	23,490	90,628	764,063
1985	471,784	50,701	615,645	3,907	21,754	98,260	790,267
1986	593,744	49,273	755,469	4,019	20,400	111,933	941,093
1987	492,374	47,822	644,013	4,130	19,096	107,383	822,444
1988	550,358	46,350	716,131	4,242	17,842	114,798	899,362
1989	518,411	50,209	673,856	4,354	17,759	113,125	859,302
1990	567,437	54,034	841,867	4,465	17,582	122,730	1,040,678
1991	594,583	57,825	881,689	4,577	17,469	137,963	1,099,522
1992	549,135	61,574	820,030	4,689	15,029	140,828	1,042,150
1993	622,885	65,281	929,615	4,800	14,788	147,213	1,161,696
1994	752,575	68,900	1,133,323	4,912	14,466	160,054	1,381,655
1995	847,444	72,378	1,247,066	5,023	14,049	156,864	1,495,381
1996	638,484	75,798	938,164	5,135	13,561	131,128	1,163,787
1997	781,193	79,158	1,150,130	5,311	13,007	142,319	1,389,924
1998	705,277	82,457	1,023,658	5,424	12,389	132,722	1,256,650
1999	738,122	81,323	1,050,086	5,537	12,163	132,043	1,281,152
2000	901,144	84,923	1,277,743	5,650	11,658	155,319	1,535,293
2001	1,094,423	88,378	1,531,976	5,763	11,635	171,892	1,809,643
2002	959,503	91,685	1,308,931	5,876	11,610	146,505	1,564,606
2003	916,985	125,282	1,220,038	5,989	14,394	129,519	1,495,221
2004	917,293	155,770	1,190,656	6,102	16,901	112,460	1,481,888
2005	1,023,460	146,215	1,284,382	13,330	15,719	112,238	1,571,885
2006	873,452	137,162	1,083,940	16,897	14,596	118,002	1,370,597
2007	875,243	128,609	1,054,373	31,632	13,530	114,859	1,343,003
2008	992,686	120,708	1,175,018	36,982	12,537	116,141	1,461,386
2009	1,159,041	113,256	1,330,788	29,755	11,597	138,035	1,623,431
2010	1,129,003	106,258	1,284,503	29,755	10,709	131,899	1,563,124

Appendix Table A2a: Most important taxa caught by domestic fisheries in the Mediterranean EEZ of Morocco, 1950-2010.

Year	Sparidae	*Sardina pilchardus*	Other small pelagics	Cephalopods	Scombroids	Crustaceans	Molluscs and bivalves	Miscellaneous
1950	5,534	4,801	3,749	2,866	3,359	479	10,497	7,229
1951	5,614	5,540	4,692	2,956	3,499	478	10,437	7,408
1952	6,845	7,273	4,631	2,856	3,407	478	10,378	9,434
1953	4,895	5,605	5,019	2,707	2,614	470	10,314	6,922
1954	5,205	6,095	5,232	2,794	2,642	468	10,253	7,493
1955	5,183	4,578	4,216	2,762	2,454	462	10,191	7,280
1956	5,293	5,263	4,727	2,849	2,681	460	10,131	7,380
1957	5,198	6,880	4,493	2,733	2,493	458	10,070	7,560
1958	5,088	7,054	3,500	2,708	2,648	453	10,009	7,187
1959	5,088	6,785	4,111	2,690	2,540	450	9,948	7,284
1960	4,959	6,455	3,820	2,753	2,425	442	9,885	4,008
1961	5,061	6,814	3,849	2,536	2,704	440	9,824	4,070
1962	5,160	6,833	4,651	2,516	2,961	437	9,763	3,101
1963	4,962	6,997	4,382	2,499	3,446	434	9,702	3,682
1964	4,979	8,605	4,774	2,590	3,302	434	9,642	4,648
1965	5,072	8,624	5,011	2,567	3,431	430	9,581	3,395
1966	5,180	9,478	3,701	2,553	3,135	428	9,521	5,509
1967	5,466	6,692	4,170	2,526	3,180	422	9,459	5,662
1968	5,684	7,502	6,162	2,418	3,744	421	9,399	5,131
1969	5,272	9,145	4,050	2,392	3,055	417	9,337	5,359
1970	5,666	9,045	4,873	2,412	4,121	424	9,278	7,309
1971	5,692	13,021	4,420	2,434	4,386	440	9,235	6,339
1972	6,658	17,156	4,808	2,387	3,257	430	9,161	8,503
1973	6,676	15,260	8,511	2,479	3,696	447	9,101	9,074
1974	6,557	18,440	6,427	2,427	3,706	434	9,082	9,166
1975	6,508	14,365	7,058	2,405	3,046	414	8,979	13,367
1976	5,495	19,906	9,989	2,378	4,028	441	8,911	6,712
1977	7,463	24,922	14,011	2,384	4,081	428	8,848	9,755
1978	5,099	19,837	14,779	2,304	3,931	444	8,774	5,802
1979	6,628	19,682	20,609	2,364	3,571	420	8,963	9,563
1980	6,302	14,037	17,129	2,365	2,808	391	8,660	9,495
1981	5,705	12,086	29,197	2,245	3,353	395	8,701	8,543
1982	5,604	12,027	27,713	2,286	2,963	393	8,417	10,198
1983	6,240	14,077	24,628	2,739	3,238	435	8,292	7,455
1984	7,781	19,482	27,031	3,883	6,877	859	8,572	6,354
1985	7,364	18,669	22,371	3,877	3,950	539	8,384	7,401
1986	7,034	24,910	19,255	3,377	3,795	503	7,804	9,108
1987	6,372	34,305	12,733	2,969	3,922	465	7,337	9,092
1988	5,940	22,526	10,761	2,358	3,930	410	7,419	8,318
1989	6,569	22,931	12,209	2,599	4,653	447	6,839	9,102
1990	6,885	25,285	11,877	2,662	8,593	492	6,686	7,298
1991	6,912	23,819	11,074	2,908	7,225	504	6,688	9,582
1992	7,262	29,620	11,667	3,141	9,568	547	4,934	8,860
1993	7,534	22,429	11,732	3,237	7,478	554	4,924	11,922
1994	8,033	20,257	13,514	3,341	9,912	576	4,924	9,394
1995	8,571	20,242	19,443	3,522	8,754	578	4,911	15,510
1996	8,600	21,761	16,329	3,448	9,479	606	4,932	15,267
1997	7,480	14,266	13,284	3,504	10,169	588	4,850	11,346
1998	7,526	13,275	11,979	3,510	8,892	603	4,941	17,104
1999	7,758	19,153	11,256	3,254	9,660	545	5,337	17,011
2000	7,430	22,122	11,548	3,496	9,060	612	4,618	19,350
2001	7,809	15,504	10,677	3,627	7,550	628	4,464	21,206
2002	8,205	14,941	11,934	4,597	8,872	690	4,320	18,530
2003	10,526	15,443	13,340	5,100	15,035	952	4,738	21,146
2004	12,341	17,853	13,153	6,671	20,373	1,126	5,015	21,109
2005	12,950	21,328	19,646	7,048	12,462	959	4,334	27,317
2006	12,618	21,979	26,787	6,334	9,671	811	3,694	28,668
2007	15,392	19,579	23,624	6,643	7,609	645	3,089	29,914
2008	15,837	12,519	21,786	6,047	7,099	561	2,535	28,666
2009	12,796	19,800	18,034	4,938	7,228	490	2,026	25,288
2010	11,833	19,155	17,289	4,394	6,678	395	1,551	20,154

Appendix Table A2b: Most important taxa caught by the domestic fisheries in the central areas of Morocco, 1950-2010.

Year	Palinuridae and Nephropidae	Scombridae	Cephalopods	Demersal fishes	Small pelagics	Miscellaneous	*Sardina pilchardus*
1950	6,993	6,713	1,958	3,650	7,734	20,442	76,304
1951	6,948	6,541	2,164	3,820	6,984	21,099	55,288
1952	6,903	6,823	2,155	3,866	7,908	22,607	73,667
1953	6,858	8,178	2,146	3,869	7,883	23,039	74,614
1954	6,813	5,715	2,008	3,915	6,900	21,361	54,868
1955	6,768	8,034	2,085	3,874	7,124	21,835	47,773
1956	6,723	9,253	1,946	4,093	7,987	20,760	56,871
1957	6,678	9,388	1,980	4,354	9,006	21,105	79,976
1958	6,633	13,148	2,014	4,400	9,180	21,020	88,084
1959	6,587	9,326	2,005	4,618	8,922	20,849	81,301
1960	6,542	10,019	1,996	4,750	9,164	21,108	84,176
1961	6,497	11,529	1,944	4,107	9,880	19,903	88,084
1962	6,452	11,937	1,935	3,852	9,683	20,292	88,859
1963	6,407	12,557	1,969	5,018	9,973	21,498	91,556
1964	6,362	10,785	2,046	4,676	10,693	27,442	99,421
1965	6,317	11,833	2,166	4,808	11,479	23,438	113,633
1966	6,272	11,392	2,243	5,328	13,785	24,128	172,429
1967	6,226	11,130	2,104	5,417	12,922	22,019	145,072
1968	6,181	8,559	2,483	5,204	11,844	23,656	117,843
1969	6,136	11,456	4,397	5,473	12,655	25,415	120,535
1970	6,101	17,801	2,237	5,390	9,739	27,088	92,625
1971	6,062	7,774	1,971	4,694	8,748	22,988	95,897
1972	6,022	6,207	1,722	4,504	8,571	31,457	104,016
1973	5,956	8,385	2,030	5,778	11,399	22,035	182,296
1974	5,920	10,846	3,282	6,717	9,892	24,324	116,631
1975	5,745	10,433	2,028	6,320	16,097	18,075	89,918
1976	6,661	12,091	2,226	4,548	15,220	20,981	117,022
1977	6,430	24,489	2,166	6,695	26,462	22,338	70,936
1978	6,176	26,308	2,220	5,949	31,339	21,750	84,002
1979	5,962	12,760	2,247	6,720	17,134	21,701	106,429
1980	6,073	18,373	8,799	9,308	17,660	28,828	120,063
1981	5,427	17,201	14,576	13,184	17,279	32,259	138,834
1982	4,919	32,823	19,299	14,495	15,256	38,844	104,098
1983	5,482	30,336	23,578	16,502	18,261	51,867	135,057
1984	7,470	60,195	24,619	17,603	21,000	56,754	105,712
1985	6,781	46,030	21,067	20,025	20,051	59,526	133,503
1986	6,392	49,714	25,426	22,582	21,030	80,093	163,702
1987	6,039	17,749	22,612	22,954	20,602	73,958	152,508
1988	5,717	21,271	30,334	24,167	25,027	70,309	177,918
1989	5,994	20,262	32,136	23,993	23,281	47,665	183,899
1990	6,223	17,929	39,813	28,195	31,501	59,678	229,325
1991	6,450	10,905	48,077	31,930	35,170	61,684	244,019
1992	6,642	12,298	43,643	33,702	36,120	63,308	213,674
1993	6,817	13,522	47,946	32,192	37,911	67,898	256,799
1994	6,130	22,805	43,778	33,441	39,659	68,596	337,021
1995	6,457	21,327	45,417	32,112	40,891	68,890	380,673
1996	6,764	14,753	45,818	28,760	30,752	67,419	262,413
1997	7,040	22,646	34,805	29,532	39,801	85,290	338,822
1998	7,363	14,313	36,086	28,546	43,994	73,926	295,341
1999	7,495	15,288	54,618	29,732	44,323	68,119	287,631
2000	7,850	24,063	71,789	37,244	41,842	74,602	357,219
2001	8,199	21,226	51,975	36,756	55,033	72,571	487,311
2002	8,598	20,133	37,249	32,567	38,480	69,105	421,216
2003	12,971	25,126	21,069	31,068	39,011	72,518	394,372
2004	17,235	42,851	17,271	25,076	36,536	75,444	377,332
2005	16,654	47,070	35,320	26,230	37,113	104,291	361,487
2006	16,099	43,871	31,881	27,389	37,244	78,598	303,380
2007	15,607	56,958	25,182	25,277	37,104	87,259	284,953
2008	15,039	56,965	37,170	23,624	38,355	71,821	346,031
2009	14,446	47,465	42,656	28,825	37,171	85,567	401,373
2010	13,909	46,855	42,390	28,777	34,345	83,689	383,401

Appendix Table A2c: Most important taxa caught by Morocco from the southern areas, 1950-2010.

Year	Scombroids	Cephalopods	Demersal fishes	Small pelagics	Miscellaneous	*Sardina pilchardus*
1950	6,561	1,663	5,102	7,774	23,985	102,377
1951	6,349	1,941	5,328	6,781	24,931	74,306
1952	6,736	1,935	5,383	8,041	26,907	98,961
1953	8,543	1,929	5,381	8,025	27,517	100,213
1954	5,301	1,752	5,436	6,714	25,279	73,680
1955	8,382	1,860	5,377	7,023	25,832	64,228
1956	10,009	1,683	5,660	8,194	24,335	76,470
1957	10,203	1,734	6,000	9,585	24,773	107,445
1958	15,190	1,785	6,055	9,845	24,301	118,377
1959	10,151	1,779	6,338	9,511	24,056	109,267
1960	11,082	1,773	6,507	9,852	24,381	113,139
1961	13,094	1,710	5,651	10,820	22,770	118,377
1962	13,648	1,704	5,307	10,575	23,095	119,402
1963	14,483	1,754	6,843	10,982	24,900	123,075
1964	12,155	1,862	6,385	11,958	32,684	133,580
1965	13,556	2,027	6,554	13,031	27,486	152,655
1966	12,988	2,135	7,236	16,164	28,892	231,459
1967	12,656	1,958	7,348	15,008	25,914	194,790
1968	9,271	2,464	7,061	13,567	28,175	158,292
1969	13,117	5,001	7,559	14,665	30,757	161,993
1970	21,522	2,151	7,386	10,794	32,852	124,593
1971	8,278	1,805	6,460	9,493	26,065	128,810
1972	6,221	1,482	6,203	9,269	38,713	139,439
1973	9,116	1,896	8,372	13,132	26,498	244,629
1974	12,385	3,557	9,544	11,082	29,511	156,661
1975	11,901	2,721	8,998	19,432	21,168	120,959
1976	12,998	2,544	6,479	17,094	20,693	157,232
1977	29,491	3,302	9,303	32,148	22,419	95,965
1978	32,009	4,215	8,411	38,856	21,289	113,513
1979	14,205	5,093	9,730	20,309	22,232	143,117
1980	21,751	14,604	14,424	21,291	33,783	161,415
1981	20,324	23,090	21,611	21,071	38,735	186,561
1982	41,214	30,225	23,969	18,751	48,578	140,249
1983	37,669	36,578	27,235	22,627	65,580	181,730
1984	76,255	38,392	28,972	25,523	72,087	142,925
1985	57,856	34,626	33,021	24,739	76,713	179,782
1986	62,883	41,250	37,629	26,384	105,406	220,419
1987	20,768	38,388	38,061	26,071	97,511	204,914
1988	25,575	49,456	40,119	32,249	93,122	239,056
1989	24,122	52,588	39,634	29,969	62,409	246,802
1990	20,928	63,493	45,173	40,944	78,336	307,739
1991	11,526	75,173	51,647	45,833	81,673	327,332
1992	13,277	70,071	54,505	47,140	84,911	286,818
1993	14,815	76,526	52,586	49,660	91,000	344,684
1994	27,399	76,787	54,502	53,240	91,159	452,705
1995	25,302	78,897	51,800	54,878	91,309	511,203
1996	16,478	79,375	45,748	41,296	88,951	352,432
1997	26,796	64,764	46,933	53,361	114,080	455,086
1998	15,629	66,399	45,772	58,735	97,051	396,585
1999	16,861	90,882	47,059	59,135	89,828	386,317
2000	28,304	113,524	58,735	55,809	97,943	479,573
2001	24,403	87,263	58,639	73,294	95,345	654,128
2002	22,815	67,733	50,986	51,197	90,774	565,282
2003	27,442	45,547	46,276	50,007	95,758	529,388
2004	48,984	39,766	35,528	44,887	100,785	506,749
2005	54,817	63,735	36,537	45,850	136,244	485,576
2006	50,840	59,288	39,557	46,172	101,904	407,674
2007	68,394	50,530	35,410	46,204	106,162	383,231
2008	68,650	66,480	32,445	48,151	83,964	465,048
2009	56,330	73,832	41,933	46,864	106,730	539,004
2010	55,764	73,576	42,111	43,312	104,104	514,172

An overview of fish removals from Morocco by Distant-Water Fleets[1]

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Abstract

Morocco has productive fishing grounds. As such, especially the Atlantic areas of Morocco are targeted by distant-water fleets from more than 19 countries, which together caught approximately 90.8 million tonnes between 1950 and 2010. These foreign countries reported 64 million tonnes to FAO during the same time period for the entire Eastern Central Atlantic area (FAO area 34), which suggests massive underreporting. Asian fleets were found to have the highest level of underreporting, followed by Western Europe, with 300% and 80% higher catches than reported landings, respectively. Foreign catches increased dramatically after Morocco extended its jurisdiction over the southern areas in the mid-1970s, after which foreign catches decreased despite increasing fishing effort, suggesting over-exploitation.

Introduction

Morocco is located on the boundary between the Mediterranean Sea and the Atlantic Ocean in North West Africa (Figure 1), and experiences high productivity due to the flow of nutrient-rich Atlantic waters into the Mediterranean. The Moroccan central and southern EEZs are 254,020 km² and 300,653 km², respectively. Together, these areas encompass the Canary Current Large Marine Ecosystem within which high marine productivity supports some of the most valuable fishing operations in the world (Cruzado 1979; Pauly *et al.* 2008). The narrow shelf of the central areas of Morocco offers good opportunities for pelagic fishing fleets, while a larger continental shelf in the southern areas, along with coastal upwelling, result in significant demersal and cephalopod resources for foreign fleets to exploit (Cruzado 1979; Pauly *et al.* 2008).

In 1956, Morocco was the first French colony in West Africa to gain independence. The former Spanish Sahara (here referred to as southern areas) was under Spanish colonial rule from 1884 to 1975. Spain handed over the former Spanish Sahara to Morocco and Mauritania under the Madrid treaty in exchange for fishing and phosphate mining rights in this area, ending the Spanish occupation. Mauritania forfeited its claim and Morocco extended its jurisdiction (Buteau 2005). Morocco is the only North African country with undiscovered oil resources, making its rich fishing grounds a significant source of foreign currency. These fishing grounds are attractive to foreign fleets, mostly from Europe and Asia, with foreign exchange earnings of US $ 1.4 billion (Anon. 2011b). While Norway and France started fishing in these waters at the beginning of the twentieth century (Baddyr and Guénette 2001), Spain, through the former Spanish Sahara, granted fishing rights to Italy, Portugal, South Africa, the former Soviet Union, Japan and South Korea from 1950 until 1975 (Martínez Milán 2006). Thereafter, these grounds remained freely accessible to foreign fleets (Alder and Sumaila 2004). After Morocco extended its jurisdiction over the southern areas, access agreements were offered by Morocco and expanded to include countries from Eastern Europe (Barreira *et al.* 1998; Martínez Milán 2006).

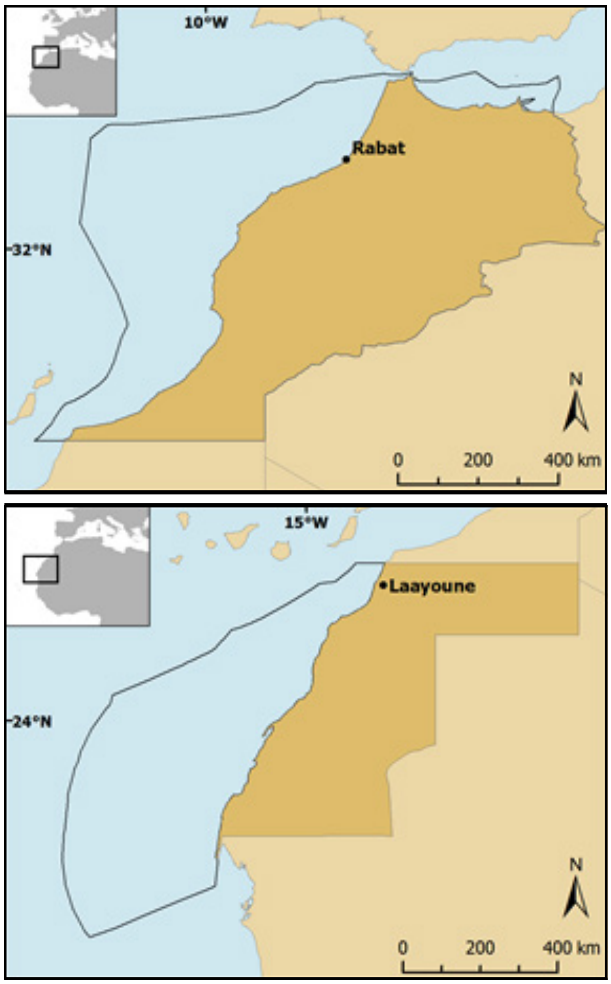

Figure 1. Map of Moroccan central (Top) and southern (Bottom) areas.

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These agreements were justified by their potential financial contribution to food security and fisheries export developments (Atmani 2003). Although operating under fishing access agreements, foreign fishing countries do not supply catch data by Exclusive Economic Zone (EEZ) to the FAO. Rather, catch data are provided for the entire Eastern Central Atlantic area, which corresponds to FAO area 34, covering the area from Morocco in the north to the Democratic Republic of the Congo in the South, including high seas waters half way to the Americas. This makes it difficult to trace the spatial origin of catches and assess the real impacts of fishing access agreements with Morocco, where only a fraction of the catch is landed and where the true beneficiaries of these agreements are under question (Anon. 2011a). Countries considered here are those for which presence has been historically documented, including Portugal, Spain, Italy, Norway, France, the Netherlands and Germany for Western Europe; Bulgaria, Romania and Poland for Eastern Europe; the former Soviet Union and its members; Japan, China and Korea for Asia; and South Africa. Given the significance of these fisheries, we herein analyse foreign catches in the waters of Morocco to provide more realistic estimates of these catches than what has been officially reported.

Methods

In this study, we independently estimated catches by each foreign country operating in the central areas of Morocco corresponding to the northern Atlantic area and the southern areas of Morocco (i.e., the former Spanish Sahara), which allows higher spatial resolution to refflect the species distribution. An extensive literature review resulted in a number of fragmentary catch time series and anchor points for 19 countries. We used these data to complete foreign catch estimates by country, including unreported catches. Illegal catches were only estimated for the Russian Federation, which prominently fished for small pelagics in the southern areas. We then compare reconstructed catches to the data supplied to FAO for the entire FAO area 34, since no other EEZ specific baseline was available. However, this provides a general idea of underreporting tendencies by foreign countries fishing in the waters of Morocco (and the rest of West Africa).

Moroccan central areas

Most of the foreign catches reported in waters under Morocco's jurisdiction were from the southern areas, and represented 70% of the total reported landings by foreign fleets (Belveze and Bravo de Laguna 1980; Kaczynski 1989). Similarly and more recently, Riché (2004) inferred that a large amount of catches off Morocco by the international fleets are actually from these same southern areas. Therefore, we assumed catches in central Morocco represented 30% of the total catch by foreign vessels during the 1950-2010 time period. This translates into catches from central Morocco being the equivalent of 42% of catches from the southern areas, i.e., foir every tonne taken from the southern areas, 0.42 tonnes is taken from the central areas. Here, we first estimated foreign catches in the southern areas, then applied the previously suggested rate to estimate foreign catches from the central areas.

Moroccan southern areas (former Spanish Sahara)

Spain

Data for Spanish catches from the southern areas were available from 1950 to 1998 (Guénette *et al.* 2001). To update these catches, we estimated a catch per unit of effort (CPUE) of 1,617 t· boat^{-1}·year^{-1} in 1997 based on a catch of 194,632 t·year^{-1} (Guénette *et al.* 2001) and the number of Spanish vessels operating in these waters. We assumed that the number of vessels operating in the southern areas was proportional to the catch, i.e., off the 172 Spanish vessels fishing under agreements with Morocco, 70% were operating in the southern areas in 1997 (Belveze and Bravo de Laguna 1980; Milano 2006). Then we applied this CPUE to 70% of the reported 110 Spanish vessels in 2010 under the EU-Morocco Agreement (eur-lex.europa.eu [2012]), to estimate a catch of 83,835 t·year^{-1} for 2010. We interpolated catches from 121,065 t·year^{-1} in 1998 (Guénette *et al.* 2001) to 83,835 t·year^{-1} in 2010. Using the catch composition from Guénette *et al.* (2001) for 1998, we disaggregated updated total catches from 1999 to 2010 into the 5 groups, i.e., 41% small pelagics, 45% demersal and deep water fish, 6% miscellaneous fish, 8% cephalopods and 2% other invertebrates. We disaggregated the cephalopod group reported by Guénette *et al.* (2001) into three taxa according to Ariz (1985): Octopus (67%), squid (22%) and cuttlefish (11%). Then, we completed the gaps, when no catches of cephalopods were reported using estimates presented in Balguerías *et al.* (2000), and when catches from Guénette *et al.* (2001) were considered comparatively low. Thereafter, we assigned 3.6% of the miscellaneous fish group to tunas and large pelagics and 96.4% to miscellaneous fish (Balguerias 1985).

Italy

Italy started fishing in the southern areas through an agreement with the Spanish government in 1963 (Martínez Milán 2006), and continuously fished until 2011 under the EU-Morocco fishing partnership agreements. Barbier (2003) reported a catch of 450,000 t·year^{-1} in 1969, which corresponds to a period when foreign fishing boat traffic was high (Martínez Milán 2006; Besenyő 2009). According to the FAO statistics, catches by Italian vessels in FAO area 34 decreased by 95% from 1969 to 2010. Therefore, we estimated that catches in 2010 would be 22,477 t·year^{-1},

95% lower than catches in 1969. We then interpolated linearly from zero in 1963 to 450,000 t·year^{-1} in 1969 then to 22,477 t·year^{-1} in 2010. We disaggregated Italian catches based on the targeted species composition from Martínez Milán (2006): octopus (20%), demersal fish (20%), crustaceans (20%), cephalopods (20%), sharks (5%), rays (5%) and others (10%).

Portugal

Portuguese vessels started fishing in the southern areas in 1963 (Martínez Milán 2006) and caught 22,000 t·year^{-1} in 1969 (Barbier 2003). Data from the FAO fisheries statistics database suggest that Portuguese reported landings decreased continuously from 1969 to 2010 by 68%. Using this rate, we estimated a total catch of 7,087 t·year^{-1} in the southern areas of Morocco for 2010. We performed a series of linear interpolations from zero in 1963 to 22,000 t·year^{-1} in 1969, then to 7,087 t·year^{-1} in 2010. We disaggregated catches using the species composition in Guénette *et al.* (2001).

Germany (former East Germany)

The former German Democratic Republic (GDR) mackerel catch data were available from 1967 to 1972 and from 1978 to 1983, and sardine catches were available from 1974 to 1980, which we carried onward assuming a constant figure (FAO 1985a). We performed a series of linear interpolations to complete sardine and mackerel catch estimates from zero in 1963 to 1,561 t·year^{-1} in 1974 for sardine and from zero in 1963 to 569 t·year^{-1} in 1978 for mackerel, assuming East Germany started fishing in this area along with other important European fleets (Martínez Milán 2006). We estimated total catches by applying the ratio (mackerel + sardine): (other species) of 1.8. Between 2006 and 2010, 6 boats per year were operating in Western Sahara, which when multiplying by a CPUE of 1,607 t·year^{-1}·boat^{-1} allows for a total catch of 9,642 t·year^{-1} from 2006 to 2010. We interpolated linearly to complete the estimate from 1983 to 2006. Since the Democratic Republic of Germany ceased to exist and was incorporated into the Federal Republic of Germany in 1990, we simply considered catches as 'German' for the entire time period.

Norway

Norway was fishing in the southern areas as far back as 1918 (Baddyr and Guénette 2001). Sardine catches from Morocco were reported for a group of countries all together including Norway, the former Soviet Union, Poland, Romania, Bulgaria and Bermuda[2] at 425,900 t·year^{-1} in 1974, while catches by the former Soviet Union, Poland, Romania, Bulgaria and Bermuda (i.e., excluding Norway) were estimated at 318,606 t·year^{-1} for the same year (Belveze and Bravo de Laguna 1980; FAO 1985a; Anon. 2011a). Therefore, the subtraction allowed to estimate the Norwegian catch from Morocco. We assumed 70% of these catches were from the southern areas and 30% from the central areas (Belveze and Bravo de Laguna 1980; Kaczynski 1989; Riché 2004), and estimated Norwegian sardine catches of 75,106 t·year^{-1} in southern areas in 1974. Norway's sardine catch was the equivalent of 83% of Spanish small pelagic catches in 1974. Thus, assuming a constant figure over time, which is likely since Norway and Spain started fishing similarly targeting the same species under Spanish permits, we applied this rate (83%) to the Spanish small pelagic catch from 1950 to 1973 and 1975. After Spain left the former Spanish Sahara in 1975, agreements were no longer offered by Spain, therefore, we used a different approach to estimate Norwegian catches off these areas. Catch data reported by Norway to FAO from FAO area 34 in 1998 were 15% of the reported catch of 1975. Thus, we prorated Norway's 1998 sardine catch to 15% of the estimated Norwegian sardine catch of 1975 (94,712 t·year^{-1}), i.e., 14,207 t·year^{-1} in 1998. We assumed catches were zero in 2010 when Norway stopped fishing in the southern areas under agreements with Morocco (Anon. 2010). We performed a series of linear interpolations to complete the estimated sardine catch by Norway. Mackerels (*Scomber* spp.) catches represented the equivalent of 11% of the estimated sardine catches between 1971 and 1975 (FAO 1985a). By applying this to the reconstructed sardine catch, we estimated mackerel catches from 1950 to 2010. Then, we applied a ratio (mackerel + sardine): (other species) of 1.8 (FAO 1985a; Goffinet 1992) to estimate catches of other species and then disaggregated catches using the same method as for Spain.

France

France has also been fishing in Morocco since 1918 (Baddyr and Guénette 2001). France's sardine catches were documented from 1965 to 1975 only from Moroccan central areas (FAO 1985a). Therefore, we carried the 1965 catch estimate backwards, assuming a constant figure from 1950 to 1965. Then, we applied a CPUE estimate of 1,617 t·boat^{-1}·year^{-1} to the number of French vessels authorized to fish in the waters under Moroccan jurisdiction, i.e., 9 boats in 2010. A large portion of the small pelagic stocks including sardine lies in the southern areas. Therefore, we conservatively assumed France's sardine catches were the equivalent of 30% of the catch reported from Moroccan central areas. To complete the estimate for other small pelagic species, we assumed these represented 20% of the total catch based on the average ratio between sardine catches and small pelagic catches by Norway and Spain. Then, we smoothed the estimated catch data time series.

[2] According to the reflagging history of vessels from Bermuda, these are suspected to be Spanish vessels (www.grosstonnage.com [Accessed on 02/08/2012]).

The Netherlands

We assumed the Netherlands started fishing off Morocco in 1963 (Martínez Milán 2006). From 1972 to 1974, 20 Dutch vessels were operating in the southern areas (Barreira *et al.* 1998), and from 2006 to 2010, 6 vessels, i.e, a third of the total of 18 vessels allowed for Lithuania, Germany and the Netherlands (eur-lex.europa.eu [2012]). We performed a series of linear interpolations from zero vessels in 1963 to 20 in 1972, and from 20 in 1974 to 6 vessels in 2010 to complete the effort time series. Then, we applied a CPUE of 1,607 t·boat^{-1}·year^{-1} to the interpolated effort to estimate the total catch by the Netherlands.

Japan

Barbier (2003) documented catches by Japan from 1964 to 1985. These catches were concordant with the decrease observed by Kaczynski (1989) of 25% from 1976 to 1985. Barbier (2003) reported no catches from 1950 to 1963; however, Barreira *et al.* (1998) reported that Japan, along with Spain, was already fishing in the southern area waters since 1950, targeting cephalopods. Therefore, given a similar fishing effort, we assumed that Japan caught the same quantity as Spain in 1950, and then interpolated linearly to 20,196 t·year^{-1} in 1964 (Barbier 2003). Morocco signed several agreements with Japan to develop Moroccan fisheries, with the last agreement signed in 2009. To estimate Japanese catches, we calculated the rate of change from 1985 to 2010 from Japanese catch data in area 34, i.e., a decrease of 14%, which we applied to the catch in 1985, i.e., 225,000 t·year^{-1} (Barbier 2003). Thereafter, we interpolated linearly to complete the time series.

The Republic of Korea (South Korea)

South Korea started fishing in the southern areas in 1963 (Martínez Milán 2006), and caught around 50,000 t·year^{-1} in 1969 (Barbier 2003). According to the FAO statistics database, reported catches by the Republic of Korea in FAO Area 34 increased 2.89 times from 1969 to 1981 and then decreased by 75% from 1981 to 2010. We applied these rates to the catch in 1969 and estimated the Korean catch in the southern areas to be 94,674 t·year^{-1} in 1981 and 23,101 t·year^{-1} in 2010. We performed a series of linear interpolations to complete the Korean catch time series from southern areas. To disaggregate catches, we assumed the Korean fleet targeted the same species as other fleets (Barbier 2003) and used the species breakdown in Guénette *et al.* (2001).

China

China signed the first fishing agreement with Morocco in 1985, and has been fishing there ever since. China operated 63 to 70 Chinese vessels under joint ventures off Morocco in 2003 and 2010[3]. Therefore, we assumed the number of boats was zero in 1985, and we interpolated linearly to an average of 63 boats in 2003 and then to 70 boats in 2010. We multiplied the number of boats by an average CPUE of 2,283 t·year^{-1}·boat^{-1} (based on data in Pauly *et al.* 2012) to estimate total catches from 1985 to 2010.

Former Union of Soviet Socialist Republics (USSR) members

According to the FAO statistics database, the former USSR and its members started reporting catches in 1988. However, Belveze and Bravo de Laguna (1980) documented catches by the USSR off Morocco as early as 1964. Barbier (2003) and FAO (1985a) estimated sardine and mackerel catches by USSR as well as Romania which started fishing in these waters in 1967. We first interpolated catches from zero in 1964 to the reported catch of sardine in 1970 (80,100 t·year^{-1}) and the reported catch of mackerel in 1973 (111,765 t·year^{-1}). Goffinet (1992) reported total catches of 200,000 t·year^{-1} for 1970, therefore, using the ratio (mackerel + sardine): (other species) of 1.8, we estimated other taxa caught by the USSR fleets from 1964 to 1970. We then interpolated all catches from 200,000 t·year^{-1} in 1970 to zero in 1991 (Garibaldi and Grainer 2002) when the Soviet Union ceased to exist.

Illegal catches by the USSR were estimated by Goffinet (1992) to be around 250,000 t·year^{-1} in the 1970s and the 1980s. We assumed these catches started in 1965 along with legal fishing activities, increased linearly to 250,000 t·year^{-1} in 1971, remained constant until 1987, then decreased linearly to be zero in 1991.

Russian Federation: the Russian Federation (Russia) renewed fishing agreements with Morocco up until 2011 (Eyckmans 2011). Under these agreements, the Russian Federation was mainly operating in the southern areas, catching around 100,000 t·year^{-1} (Eyckmans 2011). We reconstructed Russian catches from 1950 to 1991 as part of the former USSR catch, and independently as the Russian Federation after the collapse of the Soviet Union. Assuming the same Soviet Union catch allocation as for Mauritania (IMROP, unpub. data), Russian catches represented 22% of the total Soviet Union catch from 1950 to the late 1980s. Russian catches were then around 100,000 t·year^{-1} from 2000 to 2010, when Russia was mostly fishing off the southern areas (Eyckmans 2011). Thereafter, we performed a linear interpolation to complete the estimate and disaggregated catches taxonomically using the same method applied to Spain.

[3] http://wuxizazhi.cnki.net/Search/ZYJJ200402001.html , http://www.leconomiste.com/article/la-peche-hauturiere-en-crise-grave and http://www.aujourdhui.ma/economie-details35916.html [Accessed August 13th, 2011].

Lithuania: Lithuanian vessels took 22% of total catches by the Soviet Union (IMORP, unpub. data) from 1950 to 1990. We applied this rate to catches by the USSR from 1950 to 1990. The agreement between Morocco and the EU in 2006 allowed Lithuania, Germany and the Netherlands to operate 18 industrial fishing vessels in Morocco for a quota of 50,000 t·year^{-1}. We assumed the effort was distributed evenly between Lithuania, Germany and the Netherlands and allocated 1/3, i.e., 6 vessels per year to each of the above mentioned countries from 2006 to 2010. We used a CPUE of 1,607 t· boat^{-1}·year^{-1}, i.e., the same as for Spain, to estimate total catches by Lithuania from 2006 to 2010. We then performed a linear interpolation from 1990 to 2010.

Latvia and Ukraine: Latvia and the Ukraine represented 33% and 22% respectively of former Soviet Union catches (IMROP, unpub. data). Therefore, we applied these rates to the Soviet Union reconstructed catch to allocate the catches to country assuming a constant figure over time. No catches were recorded after 1991, since the Ukraine resumed agreements with Morocco only in 2012 (Danine 2012), while Latvia resumed fishing with one vessel in the southern areas in 2011 (Catzeflis 2011).

Other former Soviet republics, such as Georgia and Estonia were not reported historically as having significant catches from the waters of Morocco, thus they were not considered in the present study.

Romania

Romania started fishing in the southern areas of Morocco in 1967 (FAO 1985a). Landings by the Romanian fleet from these areas were documented by FAO (1985a) from 1971 to 1983 for mackerel, and from 1974 to 1981 for sardine. We assumed Romania stopped fishing in the southern areas (at least legally) in 1993 when catches for FAO area 34 were no longer reported to FAO. We then interpolated linearly to complete the time series. Thereafter, we applied the same approach as for the USSR to determine the portion of other species caught along with sardines and mackerels. We disaggregated catches using the species composition presented in Guénette *et al.* (2001).

Bulgaria

Catches of mackerel and sardine by Bulgaria were estimated by FAO (1985a), since 1968 and 1973, respectively. We assumed Bulgaria started fishing in the southern areas when Bulgaria started reporting catches from area 34 to the FAO, i.e., 1964 and ended its fishing activities in the area in 2000. We interpolated linearly each estimate from zero in 1964 to the first anchor point for both species, then from 1983 and 1982 respectively for mackerel and sardine to 0 zero in 2000. We then applied the ratio (mackerel + sardine): (other species) of 1.8 to estimate catches of other species.

Poland

Poland reported catches in FAO area 34 between 1957 and 2010, and caught 19,000 t·year^{-1} from the southern areas in 1969 (Barbier 2003). FAO (1985a) reported sardine catches from 1970 to 1977, then in 1979, and mackerel catches from 1967 to 1977 and for 1980 and 1981. Here we considered that Poland started fishing in the southern areas in 1963 (FAO 1985b). To estimate the catch in 2010, we used the rate of change of the Polish landings in area 34 as reported to FAO from 1981 to 2010, when reported landings increased by a factor of 24. We estimated a catch of mackerel of 2,137 t·year^{-1} and a catch of sardine of 38,759 t·year^{-1} in 2010 from the southern areas. We performed a series of interpolations to complete the time series for sardine and mackerel. Thereafter, we estimated catches of other taxa using the ratio (sardine and mackerel): (other species) as 0.41 (Barbier 2003), then disaggregated catches using the catch composition in Guénette *et al.* (2001).

South Africa

South Africa did not report any catches from the Eastern Central Atlantic (FAO area 34). However, South Africa is fairly active in the area, and started fishing off Morocco as early as 1963 (Martínez Milán 2006), catching an estimated 100,000 t·year^{-1} in 1969 (Barbier 2003), and was still operating there in 2008 (Anon. 2008). Although South Africa has diplomatic relationships with the unofficial government of 'Western Sahara' (here Morocco southern areas), which would infer prohibiting fishing activities in these waters under Moroccan licensing, South African companies were operating under private Moroccan licenses in 2008 (Anon. 2008). Therefore, we assumed catches in 2010 by South Africa in the southern areas were 1% of the 1969 catch as a conservative approach, since catches decreased substantially with improved diplomatic relations between the unofficial government and South Africa. We then interpolated linearly to complete the time series, and applied the species breakdown provided in Guénette *et al.* (2001).

To allow for comparison and assess underreporting, FAO landings by each country were extracted from FAO FishstatJ covering the entire FAO statistical area 34 from Morocco in the North to the Democratic Republic of the Congo in the South. These were then compared to reconstructed catches, as estimated here, to assess the levels of reporting by each country.

RESULTS

Total reconstructed catches

Total foreign catches in the waters of Morocco were estimated to be 90.8 million tonnes between 1950 and 2010, compared to 56.9 million tonnes reported to FAO from the complete FAO area 34, which suggests strong underreporting at least by 30%. This assumes all catches in area 34 outside Morocco were properly reported. Catches increased from on average 175,000 t·year^{-1} in the 1950s to a peak of 4.3 million t·year^{-1} in 1978, after Morocco took over the former Spanish Sahara, and then decreased to one million t·year^{-1} in 2010 (Figure 2a).

Total foreign catches in the southern areas were estimated at 65.8 million tonnes from 1950 to 2010, 13% higher than catches supplied by these countries to FAO for the entire FAO area 34, i.e. 56.9 million tonnes (Figure 2a). Catches followed the same pattern as the data supplied to FAO, increasing from 110,000 t·year^{-1} in 1950 to a peak of 3 million t·year^{-1} in 1978, after Morocco extended their jurisdiction over the former Spanish Sahara (Figure 2a). Catches decreased thereafter to around 753,000 t·year^{-1} in 2010 compared to 623,000 t·year^{-1} supplied to the FAO for the entire FAO area 34 (Figure 2a). Overall, catches from the southern areas were 14% higher than landings supplied to FAO from FAO area 34 in the 1950s, 30% to 100% higher in the 1980s, and up to 55% higher in the 2000s.

Total foreign catches in central waters were estimated at 25 million tonnes between 1950 and 2010, the equivalent of 40% of the foreign catch from the waters off Western Sahara. Foreign catches from Morocco's central areas (50 million tonnes) represented half of landings data supplied to FAO for the FAO area 34 between 1950 and 2010 (Figure 2a).

Overall, catches include 40% of clupeids (sardines and sardinellas), 23% of demersal fish species (Sparidae and Mercuccidae), 21% of cephalopods including squids, octopus and cuttlefish, 6% of large pelagic species, and 10% of other miscellaneous marine species (Figure 2b).

Southern areas

Spain

Spanish catches from the waters of the southern areas, were reconstructed to be 12 million tonnes for the time period considered in this study, which was almost as high as total catches declared by Spain from the entire FAO area 34 (13.6 million tonnes). Between 1950 and 2010, Spanish reconstructed catches were 20% higher than the reported catch by Spain covering the entire FAO area 34 (Figure 3). Spanish catches from the southern areas increased from 52,000 t·year^{-1} in the 1950s to 378,000 t·year^{-1} on average in the late 1970s corresponding to the highest catch, when these areas were a free fishing access zone. Catches decreased thereafter to less than 125,000 t·year^{-1} in 2010.

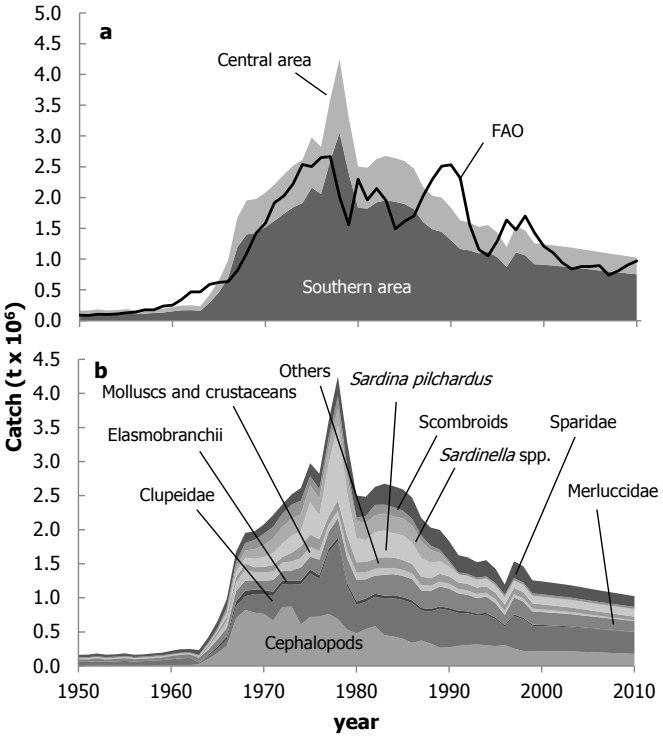

Figure 2. Total reconstructed foreign catches by a) the two areas of Moroccan waters conscribed; and b) by taxon, compared to total reported catches by the same foreign countries from FAO area 34, 1950-2010.

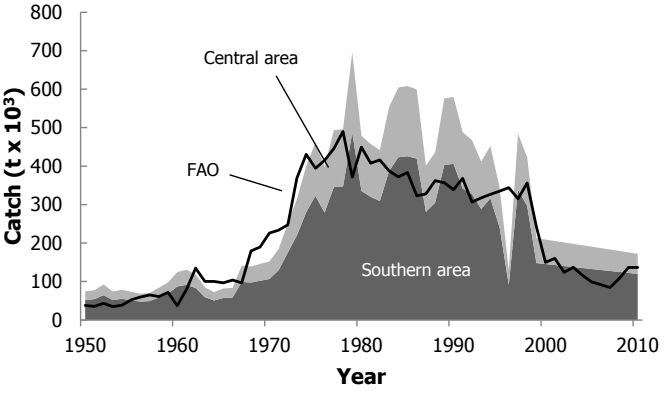

Figure 3. Reconstructed Spanish catch from Morocco central and southern areas, compared to the reported catch by Spain from FAO area 34, 1950-2010.

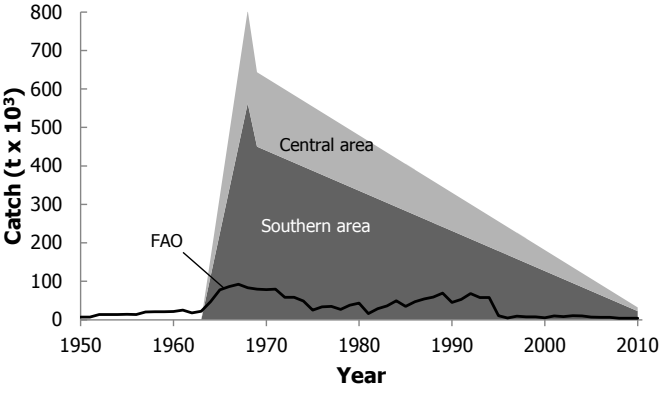

Figure 4. Reconstructed catches by Italy from Morocco central and southern areas, compared to the reported catch by Italy from FAO area 34, 1950-2010.

Italy

Italian catches were estimated at 11.6 million tonnes between 1950 and 2010, i.e., 8 times higher than what Italy submitted to FAO for the entire FAO area 34 (1.5 million tonnes), which suggests substantial underreporting. Italian catches from the southern areas increased from zero in 1963, when Italy started fishing in the area, to 562,500 t·year^{-1} in 1968, compared to 62,000 t·year^{-1} supplied to the FAO for FAO area 34 (Figure 4).

Portugal

Portuguese catches were estimated at 665,000 tonnes for the period 1950 to 2010, which represented 50% of the catch data supplied by Portugal to FAO for FAO area 34, i.e., 1.4 million tonnes (Figure 5). During the 1960s and the early 1970s, Portuguese reconstructed catches in the southern areas were as high as the Portuguese data supplied to FAO for the entire area 34 (Figure 5). Reconstructed catches were around 10% higher than the reported catch in FAO area 34 in 1980, i.e., 17,800 t·year^{-1} compared to 16,030 t·year^{-1} (Figure 5).

Germany

German catches were estimated at 567,000 tonnes between 1950 and 2010. Catches varied substantially over the study period, however, there was an increasing trend from 3,200 t·year^{-1} in 1964 to a peak of 31,500 t·year^{-1} in 1970 and then a decreasing pattern to a plateau of 9,600 t·year^{-1} in the 2000s (Figure 6).

France

French catches from the southern areas totalled 124,000 tonnes between 1950 and 2010. French catches increased from 2,100 t·year^{-1} in 1950 to a peak of 4,300 t·year^{-1} in 1969 (Figure 7). Catches decreased thereafter, and were estimated at 1,600 t·year^{-1} in 2010 (Figure 7).

Norway

Norwegian catches were estimated at over 2.9 million tonnes for the 1950-2010 time period. Catches increased from 4,000 t·year^{-1} in 1950 to a peak of 163,000 t·year^{-1} in 1975 (Figure 8). Norwegian catches decreased rapidly

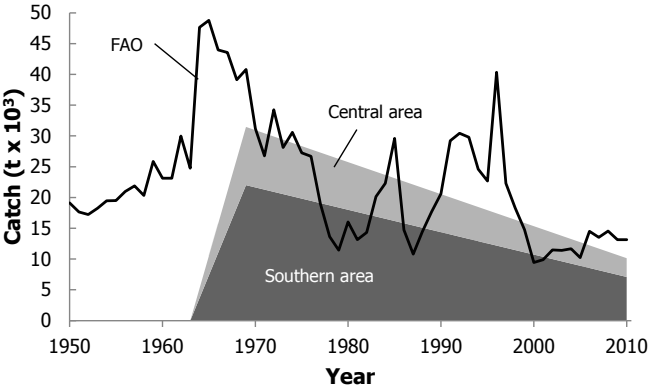

Figure 5. Reconstructed catches by Portugal from Morocco Atlantic areas, compared to reported catch by Portugal from FAO area 34, 1950-2010.

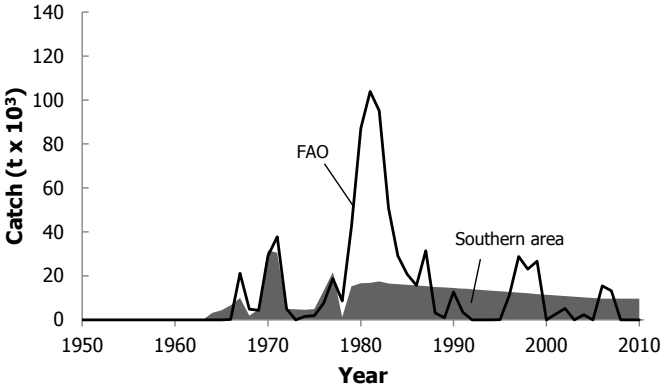

Figure 6. Reconstructed catches by Germany from the southern areas, compared to reported catches by Germany from FAO area 34, 1950-2010.

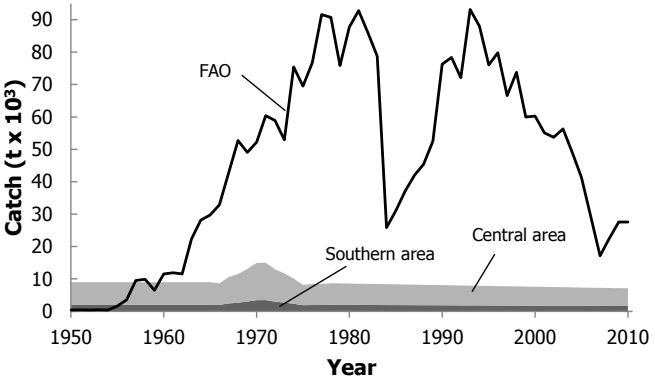

Figure 7. Reconstructed catches by France from Morocco central and southern areas, compared to reported catches by France from FAO area 34, 1950-2010.

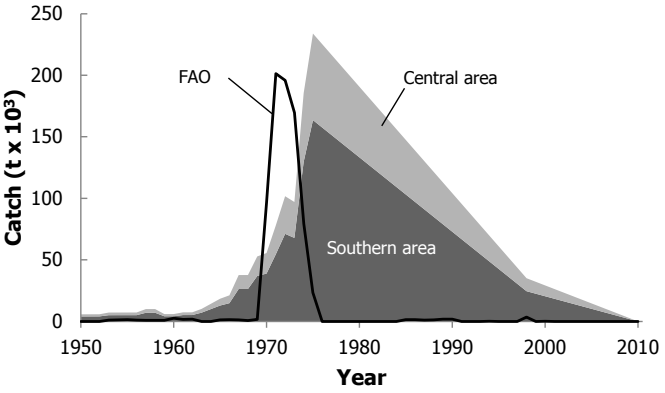

Figure 8. Reconstructed catches by Norway from Morocco Atlantic areas, compared to reported catch by Norway from FAO area 34, 1950-2010.

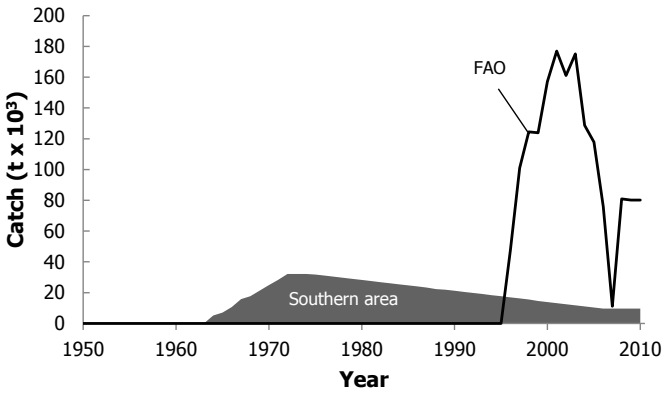

Figure 9. Reconstructed catches by the Netherlands from the southern areas of Morocco, compared to reported catches by the Netherlands from FAO area 34, 1950-2010.

to zero in 2010 when Norway gave up fishing operations in the southern areas (Figure 8).

The Netherlands

Catches by the Netherlands increased from 5,000 t·year^{-1} in 1964 to a peak of 33,700 t·year^{-1} in the mid-1970s, then decreased gradually to 9,900 t·year^{-1} on average in the late 2000s (Figure 9). The Netherlands reported catches from the FAO area 34 only since the mid-1990s, therefore, all reconstructed catches prior to the mid-1990s were not reported (Figure 9). After 1995, Netherlands' reconstructed catches represented 17% of the catch reported to FAO in FAO area 34 on average.

Japan

The Japanese fleet, which operated from 1950 to 2010 in the southern areas, caught over 11.1 million tonnes during this time period. Japanese catches were almost 3 times higher than data supplied by Japan to FAO for the entire FAO area 34 (3.1 million tonnes), which suggests substantial underreporting by Japan (Figure 10). Although underreporting by Japan was already high in the late 1960s, the underreported component further increased after Morocco extended their jurisdiction over the former Spanish Sahara in the mid-1970s (Figure 10). The underreported component was at its maximum in 2002, when Japan caught 203,600 t·year^{-1} in the southern areas compared to 8,440 t·year^{-1} for the whole FAO area 34 supplied to the FAO, i.e., 23 times higher. The peak of Japanese catches off the southern areas corresponds to the maximum Japanese catch of the entire FAO area 34 in the late 1960s. Thereafter catches decreased but at a slower rate than reported Japanese catches in the entire FAO area 34 (Figure 10).

South Korea

South Korean catches were estimated to be 276,000 tonnes for the period between 1950 and 1964, during which Korea supplied no catch data for FAO area 34 to FAO (Figure 11). Thereafter, catches were about 50% higher than the data supplied by Korea to FAO, i.e., 2.8 million tonnes compared to 1.8 million tonnes reported to FAO. Korean catches increased gradually to a peak of 95,120 t·year^{-1} in 1981 and decreased thereafter to 23,200 t·year^{-1} in 2010, almost as high as the catch

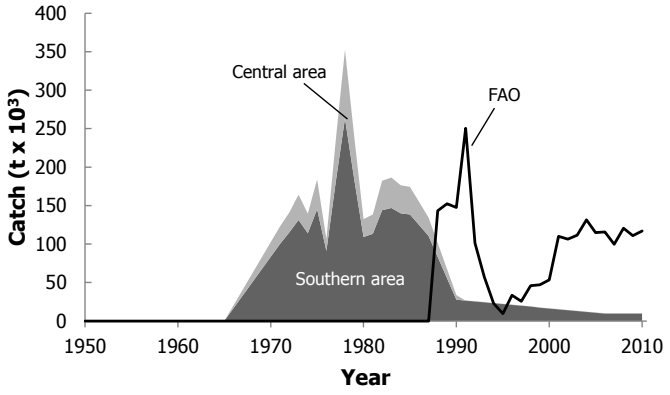

Figure 14. Reconstructed catches by Lithuania from Morocco central and southern areas, compared to reported catches by Lithuania from FAO area 34, 1950-2010.

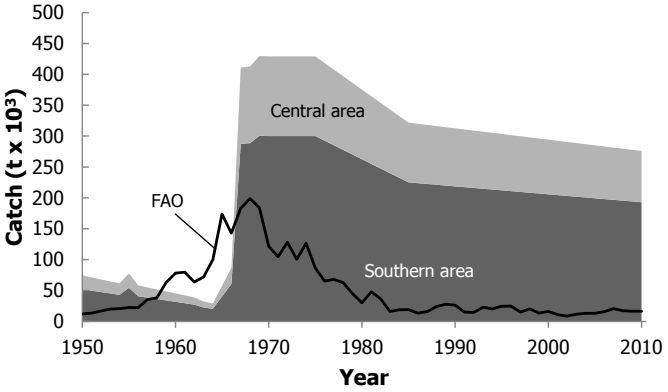

Figure 10. Reconstructed Japanese catches from Morocco central and southern areas, compared to the reported catch by Japan from FAO area 34, 1950-2010.

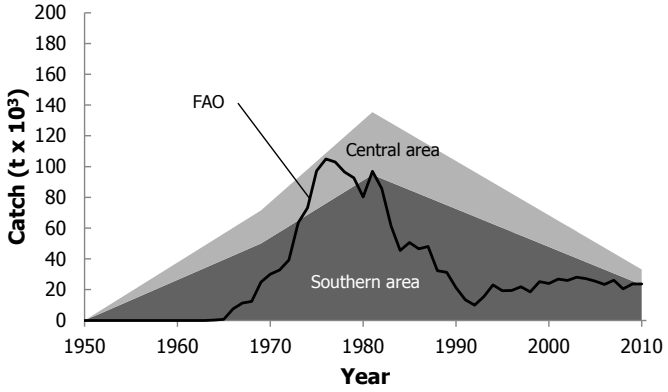

Figure 11. Reconstructed catches by South Korea from Morocco central and southern areas, compared to reported catch by South Korea from FAO area 34, 1950-2010.

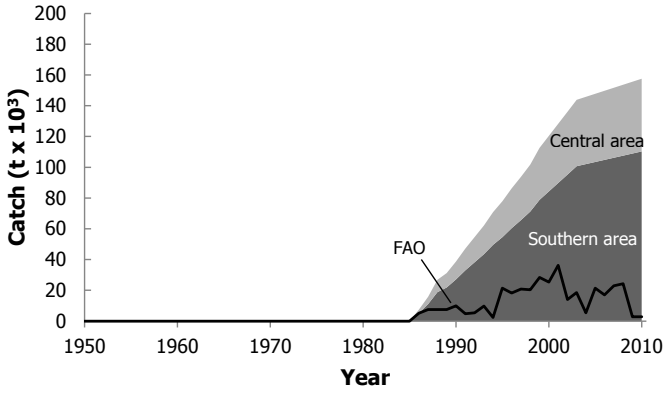

Figure 12. Reconstructed catches by China from Morocco central and southern areas, compared to reported catches by China from FAO area 34, 1950-2010.

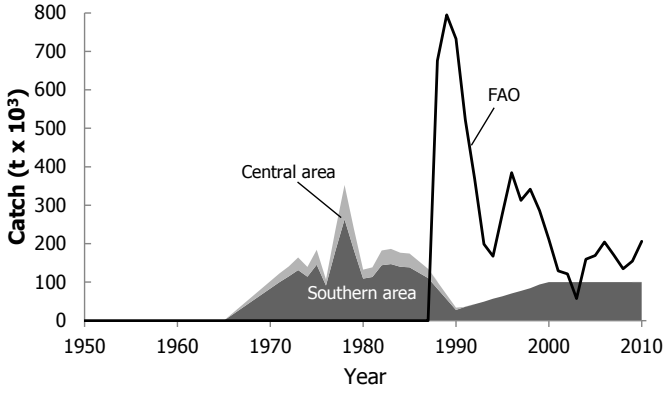

Figure 13. Catches by Russia from Morocco central and southern areas, compared to reported catches by the Russian Federation from FAO area 34, 1950-2010.

supplied by Korea to FAO for the entire FAO area 34, i.e., 23,700 t·year^{-1} (Figure 11).

China

Chinese catches were estimated at 1.7 million tonnes between 1950 and 2010, compared to a reported catch of 360,012 tonnes in FAO area 34, which suggests substantial underreporting (Figure 12). Chinese catches increased from 5,200 t·year^{-1} in 1986 to 110,269 t·year^{-1} in 2010, showing an increasing presence of Chinese fishing fleets in the southern areas (Figure 12).

Former Soviet Union

Russian Federation: Russian catches from the southern areas were estimated at 4.4 million tonnes between 1950 and 2010, which is 30% of the catch by the former Soviet republics. Catches started at 16,700 t·year^{-1} in 1966, increasing to a peak of 263,130 t·year^{-1} in 1978. Catches decreased thereafter to 27,600 t·year^{-1} in 1991 with the collapse of the Soviet Union and then increased to around of 100,000 t·year^{-1} from 2001 onwards (Figure 13).

Lithuania: Similarly, Lithuanian catches increased from 16,700 t·year^{-1} in 1966 to a peak of 263,000 t·year^{-1} in 1978. Catches decreased rapidly to 27,600 t·year^{-1} in 1991 and then to 9,700 t·year^{-1} by 2010. Overall, catches by Lithuania were estimated at 3.1 million tonnes between 1950 and 2010, accounting for 21% of catches by all former Soviet republics considered here (Figure 14).

Latvia: Catches by Latvia from the southern areas totalled 4.1 million tonnes, most of which were caught within the 1970-1990 time period, with a peak of 263,000 t·year^{-1} in 1978. Latvian catches represented over 29% of the total catch by former Soviet republics (Figure 15).

Ukraine: Ukrainian catches followed the same trend as other former Soviet Union members. Catches were estimated at 2.8 million tonnes between 1950 and 2010, which is 19% of the total catch by republics of the former Soviet Union. Catches increased from 16,700 t·year^{-1} in 1966 to a peak of 263,000 t·year^{-1} in 1978, then decreased rapidly to zero from 1991 onwards (Figure 16).

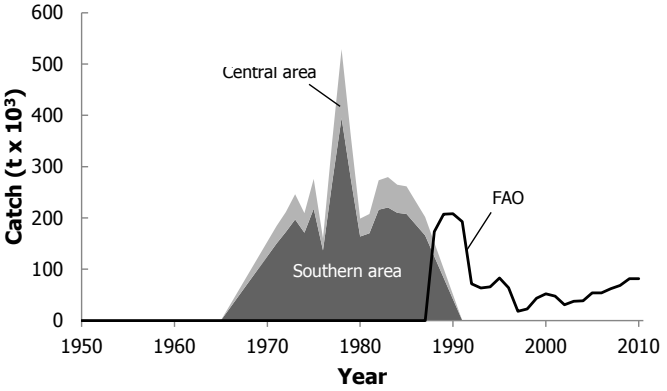

Figure 15. Reconstructed catches by Latvia from Morocco central and southern areas, compared to reported catches by Latvia from FAO area 34, 1950-2010.

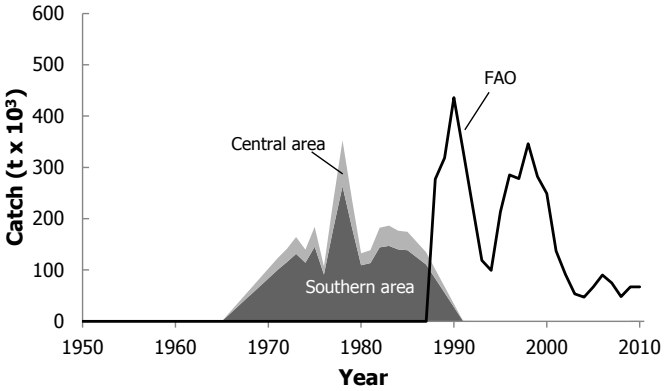

Figure 16. Reconstructed catches by Ukraine from Morocco central and southern areas, compared to catches supplied by Ukraine from FAO area 34, 1950-2010.

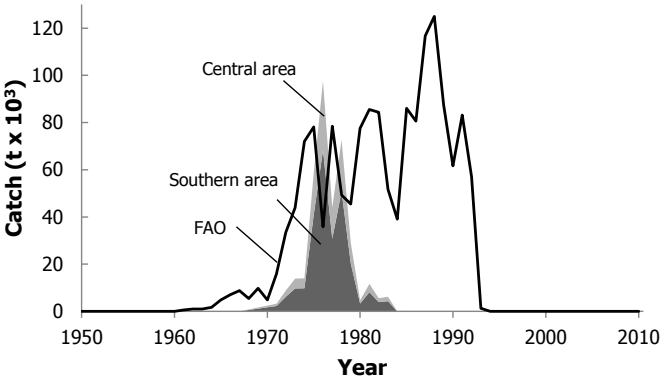

Figure 17. Reconstructed catches by Romania from Morocco Altantic areas, compared to the reported catch by Romania from FAO area 34, 1950-2010.

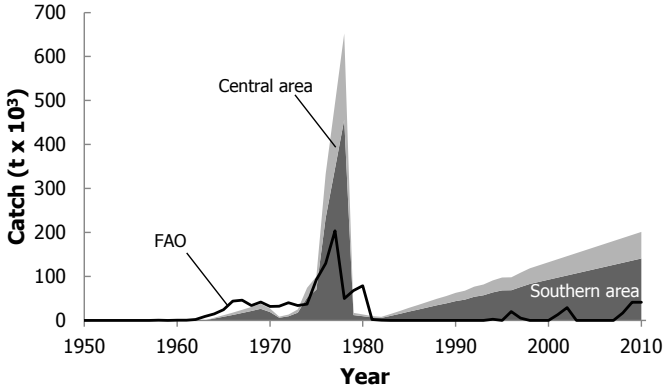

Figure 19. Reconstructed catches by Poland from Morocco central and southern areas, compared to the reported catch by Poland fromFAO area 34, 1950-2010.

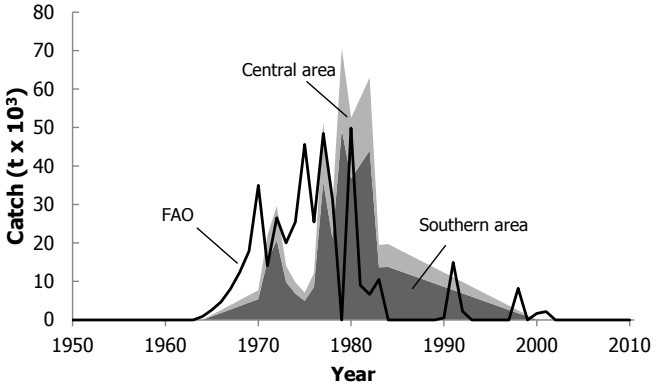

Figure 18. Reconstructed catches by Bulgaria from Morocco central and southern areas, compared to the reported catch by Bulgaria from FAO area 34, 1950-2010.

Romania

The reconstructed Romanian catch was estimated to be over 261,700 tonnes for the 1950-2010 time period. Catches reached a maximum of 68,200 t·year^{-1} in 1976, and then decreased to zero since 1984 (Figure 17). In the mid-1970s, reconstructed catches surpassed reported catches by Romania from the entire FAO area 34 (Figure 17).

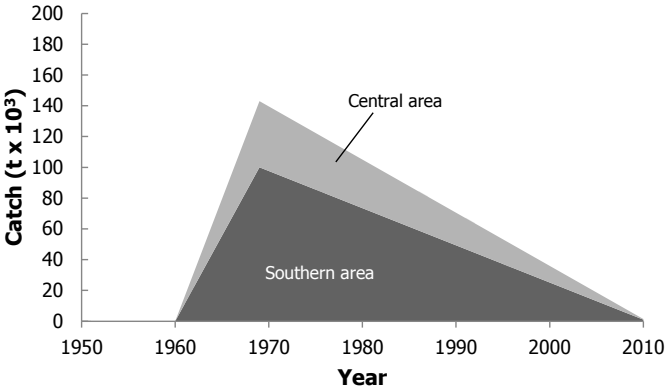

Figure 20. Reconstructed catches by South Africa from Morocco central and southern areas, no catches were reported to FAO from FAO area 34, 1950-2010.

Bulgaria

Bulgarian catches in the southern areas increased from zero in 1963 to a peak of 49,500 t·year^{-1} in 1979, when Bulgarian data as supplied to FAO were zero for FAO area 34 (Figure 18). Overall, reconstructed Bulgarian catches were slightly higher than reported catches, which indicates underreporting by Bulgaria (Figure 18).

Poland

Polish catches were estimated at 3.5 million tonnes over the period from 1950 to 2010, twice higher than the catch supplied by Poland to FAO for the entire FAO area 34, i.e., 1.2 million tonnes (Figure 19). Catches increased drastically in the mid-1970s to 470,000 t·year^{-1}, and then decreased to less than 6,000 t·year^{-1} in the early 1980s. Thereafter, catches increased by a factor of 24 from 1985 to 2010, when Polish catches were estimated at 141,000 t·year^{-1} (Figure 19).

South Africa

Although South Africa did not supply catch data from FAO area 34 to FAO, a total catch of 2.5 million tonnes was estimated, increasing from 11,000 t·year^{-1} in 1961 to a peak of 100,000 t·year^{-1} in 1969, and then decreasing to 1,000 t·year^{-1} by 2010 (Figure 20).

Central areas

Spain

Spanish catches in Moroccan central areas were estimated at 5.1 million tonnes for the 1950-2010 time period, i.e., 38% of the data supplied by Spain to FAO (13.6 million tonnes). Catches were relatively constant at 23,700 t·year^{-1} in the 1950s, increasing gradually to a peak of 209,000 t·year^{-1} in 1979, and were variable thereafter, with a decreasing trend (Figure 3).

Italy

Italy caught around 5 million tonnes from the mid-1960s, when the Italian fleet started fishing in Morocco's central areas to 2010. These catches are 2.3 times higher than landing data supplied by Italy to FAO for FAO area 34 (1.5 million tonnes) (Figure 4). This underreporting tendency increased over time, with average catches being twice as high as Italian reported landings for FAO area 34, i.e., 58,300 t·year^{-1} on average reported to FAO compared to a reconstructed catch of 153,200 t·year^{-1} in the 1960s (Figure 4). Between 1970 and 1999, reconstructed catches were three times higher than landings supplied to FAO, i.e., 31,100 t·year^{-1} supplied to FAO compared to 124,000 t·year^{-1} on average, and 6 times higher in the 2000s with 5,200 t·year^{-1} supplied to FAO compared to 32,000 t·year^{-1} on average (Figure 4).

Portugal

Catches by Portugal totalled 286,000 tonnes from 1950 to 2010, which represented 21% of landings supplied by Portugal to FAO, i.e., 1.3 million tonnes (Figure 5). Catches by Portugal increased from 1,600 t·year^{-1} in 1964 to a peak of 9,460 t·year^{-1} in 1969, and decreased since then to around 3,000 t·year^{-1} in 2010 (Figure 5).

France

France catches in the Moroccan central areas were estimated at over 413,000 tonnes during the 1950-2010 time-period. Catches by France increased from 6,900 t·year^{-1} on average in the 1950s to over 14,000 t·year^{-1} in the late 1960s, and then decreased to around 5,500 t·year^{-1} in 2010 (Figure 7).

Norway

As in the southern areas, Norwegian catches increased considerably until 1975, when the issue around the Moroccan borders started, and reached 70,300 t·year^{-1} in 1975. Catches decreased thereafter to zero in 2010 (Figure 8). Norwegian catches in the Moroccan central areas were estimated at 1.3 million tonnes between 1950 and 2010, which is 60% higher than landings supplied by Norway to FAO for FAO area 34 (780,000 tonnes).

Japan

Japanese catches from Moroccan central areas were 57% higher (4.8 million tonnes) than the catch data supplied by Japan to FAO (3.05 million tonnes) covering the entire FAO area 34 (Figure 10). Japanese catches off the Moroccan central areas were as high as the catches supplied to FAO for the FAO area 34 for the 1950s, 30% of the catch supplied to FAO for the 1960s, twice higher in the 1970s, and 5 to 6 times higher since the 1980s (Figure 10).

South Korea

South Korean reconstructed catches in Moroccan central areas were estimated at 103,000 tonnes over the period from 1950 to 1963, where no catches from FAO area 34 were supplied by South Korea to FAO. Between 1964 and 1968, reconstructed catches (18,100 t·year^{-1} on average) were three times as high as landings supplied by South Korea to FAO with 6,400 t·year^{-1} on average (Figure 11). Reconstructed catches represented the equivalent of 56% of the catch supplied by South Korea to FAO from 1969 to 1987 with 33,000 t·year^{-1} compared to 67,000 t·year^{-1} on average supplied to FAO (Figure 11). Between 1988 and 1998, reconstructed catches were 51% higher than landings supplied by South Korea to FAO with a reconstructed catch of 27,900 t·year^{-1} on average compared to 19,300 t·year^{-1} supplied to FAO (Figure 11). The underreporting tendency was then reversed in the 1990s and 2000s, when reconstructed catches represented 63% of landings supplied by South Korea to FAO for the FAO area 34 (Figure 11). This denotes inconsistencies in catch reporting by South Korea to FAO.

China

Chinese catches off the Moroccan central areas were estimated in the present study at 725,000 tonnes from 1950 to 2010. Catches by China increased continuously from 2,200 t·year^{-1} in 1986 to over 47,300 t·year^{-1} in 2010, over 20 times in less than 25 years (Figure 12).

Former Soviet Union

Catches by former Soviet republics represented 20% of landings supplied to the FAO for FAO area 34, with a total of 3.2 million tonnes for the period between 1950 and 2010 compared to 17.9 million tonnes of catch data supplied to the FAO. Catches increased from 17,200 t·year^{-1} in 1966, when the Soviet Union started fishing in Morocco, to a maximum of 407,000 t·year^{-1} in 1978, then decreased gradually to zero in the early 1990s.

Russia : Russian catches off Moroccan central areas increased from around 3,700 t·year^{-1} in the mid-1960s to a peak of over 88,100 t·year^{-1} in the mid-1970s (Figure 13). Reconstructed catches decreased thereafter to 26,000 t·year^{-1} on average in the 1980s and zero in the 1990s and 2000s when Russian fleets moved south towards the former Spanish Sahara waters (Figure 13).

Lithuania: Lithuanian catches from the Moroccan central areas were estimated at around 703,600 tonnes between 1950 and 2010. The bulk of this was caught in the mid-1970s with 51,000 t·year^{-1} on average (Figure 14). Catches declined in the 1980s and were zero in the 1990s, at the collapse of the Soviet Union. Lithuania followed the same pattern as Russia in the 2000s, moving southwards.

Latvia: Latvia was the most prominent Soviet republic in terms of catches totalling over one million tonnes between the mid-1960s and the early 1990s, when the Soviet Union collapsed. Latvian catches increased from 5,700 t·year^{-1} in 1966 to a peak of 134,000 t·year^{-1} in 1978 and decreased thereafter to zero in 2010 (Figure 15).

Ukraine: Ukrainian catches in the Moroccan central areas increased from 3,700 t·year^{-1} in 1966 to a peak of 89,400 t·year^{-1} in 1978, and then decreased gradually to zero in the early 1990s, when the Soviet Union collapsed (Figure 16).

Romania

Romanian catches were estimated at 112,500 tonnes, i.e., 7% of landings data supplied by Romania to FAO from the FAO area 34, i.e., 1.5 million tonnes between 1950 and 2010 (Figure 17). Catches by Romania in Morocco's central areas increased from 240 t·year^{-1} in the late 1960s to a peak of 29,300 t·year^{-1} in 1976, when Morocco took over Western Sahara. Catches decreased thereafter to 1,850 t·year^{-1} in 1983, after which Romania was reportedly no longer fishing in Morocco (Figure 14).

Bulgaria

Catches by Bulgaria in Morocco's central areas were estimated at 191,000 tonnes for the period from 1950 to 2010, which represented 45% of the catches supplied by Bulgaria to FAO for FAO area 34 (424,000 tonnes). Although Bulgaria did not report any catches from FAO area 34 for the years 1979, from 1984 to 1989, 1993 to 1997, and 1999, catches were reconstructed here for Morocco and estimated at 21,200 t·year^{-1} in 1979, 5,000 t·year^{-1} on average between 1984 and 1989, and 1,700 t·year^{-1} in the 1990s (Figure 18).

Poland

Polish catches in the Moroccan central areas were 30% higher than data supplied by Poland to FAO for FAO area 34, with a total of 1.5 million tonnes over the study time period compared to 1.2 million tonnes supplied to FAO. Catches increased from 1,800 t·year^{-1} in 1964 to a peak of 202,000 t·year^{-1} in the late 1970s, then decreased to about 60,500 t·year^{-1} in 2010 (Figure 19).

South Africa

South African catches in the Moroccan central areas were estimated at around 1.1 million tonnes for the 1950-2010 time period, whereas this country did not supply any data to FAO from the entire FAO area 34. Catches increased from 4,800 t·year^{-1} in 1961 to a peak of 43,000 t·year^{-1} in 1969, and have been decreasing since then to a minimum of 430 t·year^{-1} in 2010 (Figure 20).

Discussion

Overall total catches by foreign fleets in the waters of Morocco were conservatively estimated at 90.8 million tonnes between 1950 and 2010. Here, we treat the waters of Morocco as the EEZ equivalent waters for time periods prior to actual declaration of the EEZ. Catches reached their maximum in the mid-1970s when Morocco extended their jurisdiction over the southern areas, and when these EEZ equivalent waters were freely accessible to foreign fleets. Although reconstructed catches within EEZs cannot be directly compared to catches supplied to FAO for the entire FAO area 34, by analyzing the trends we can begin to assess the underreporting trends. Since the late 1980s, reconstructed catches within Morocco's EEZ and waters under Moroccan jurisdiction alone were 37% higher on average than catch data supplied to FAO from the entire FAO area 34, showing no significant improvements in reporting. Underreporting may in fact be higher since here we compare catch data from Morocco to landings supplied to FAO for the entire FAO area 34.

Furthermore, our estimate of total catches from Morocco is likely conservative since it does not include illegal catches, nor the catch of flag of convenience countries such as Belize (used by the United Kingdom, Sweden, Germany), Bermuda (used by Spain), Panama (used by Russia), Comoros (used by Sweden) and vessels reflagged to Morocco (Spanish origin) which land catches elsewhere (Catzeflis 2011) [information collected from different vessel databases www.vesselfinder.com, www.shipspotting.com, and www.marinetraffic.com)].

Western Europe was responsible for over half of the total foreign catch from Morocco as estimated here, and thus caught almost twice as much as Western Europe reports for the entire FAO area 34. Eastern Europe, including former Soviet republics, caught 32% of the total foreign catch, mainly from Morocco southern area, compared to 29% of the total foreign catch by Asian countries. Eastern European and Asian catches were 7% higher than the total catch reported to FAO for FAO area 34. When analyzed individually, some countries performed even more poorly in terms of reporting. China, for example, caught almost 7 times what was reported by FAO as Chinese catch in FAO area 34, indicating high underreporting and poor spatial accounting, as described in Pauly *et al.* (2012).

When Morocco extended its jurisdiction over the southern areas, the Moroccan government assumed exploitation rights and signed bilateral agreements offering access to the country's resources. This allowed foreign fleets to extract from the waters of the southern areas two to three times as much as they were catching in the central areas.

Historical events in Morocco directly impacted fisheries by foreign fleets. For example, the unreported component by Western Europe was lower in the 1950s when Spain was the colonial power ruling the former Spanish Sahara.

The underreporting component increased drastically in the 1980s after Morocco extended their jurisdiction over the southern areas, especially during the armed conflict, before the cease-fire agreement was reached (UN 2011). The underreporting component decreased again in later years. However it still remains high.

After the 1995 EU-Morocco fishing access agreement dispute, Morocco and the EU agreed to reduce the fishing quota by 40%, to protect Moroccan resources and fishing industry, which at the time represented 11% of the GDP. However, as shown here, for the same period, actual catches by EU members increased by 5%, which further questions the validity of these agreements in terms of sustainability and the ability of Morocco to monitor foreign fleets in its waters and the waters under its control. This also points to a failure of EU flag-state control over its fishing fleets. At the time of this study, the international community questioned the real contribution of the EU-Morocco fishing access agreements to food security in Morocco's southern areas. This further illustrates how these agreements were of limited benefits to poor populations for years.

In this study, we illustrated that foreign countries which accessed the waters of Morocco, increased their catches, but reported less over time. European Union members, for which access agreement information is freely available in the EU law database (eur-lex.europa.eu), underreported their catches substantially. These countries act under the 1982 UN Convention of the Law of the Sea (UNCLOS), where in cases where a country cannot utilise the full perceived surplus, this country shall give other nations access to the surplus (Anon. 1982). However, the host country must also prioritize local population interests and livelihoods and enforce fisheries rules and legislations. Non-transparency and non-effectiveness of West African management issues have been well documented for decades (Virdin 2005; Standing 2008, 2011), yet countries such as those in the European Union fail to adhere to the latter when applying their fishing rights under UNCLOS. Furthermore, results of this study, where Western European catches in Morocco were higher than the catch data supplied to FAO covering the area from Morocco to the Democratic Republic of the Congo, suggest these countries are an integral part of a failing fisheries management system in West Africa. Furthermore, the pattern of underreporting shows an increase after the independence of these countries from Europe (Spain and France), highlighting how their development path followed the colonial pattern of exporting primary natural resources.

This high level of underreporting suggests that Moroccan fishing access agreement partners do not comply with the obligation of comprehensive reports, or landing a large part of the catch at Moroccan landing sites, contrary to what is stated by official sources and reported to FAO (Atmani 2003). Thus, these agreements did not help reshape food security, especially in southern areas which still suffer from a lack of animal protein (FAO 2003). Furthermore, out of 11 exploited stocks included in fishing access agreements with the EU, 9 are overfished and 2 are unassessed. This challenges the Moroccan logic of offering access agreements to foreign fleets, while at the same time in 1999, this country cancelled the fishing access agreement with the EU to preserve fisheries resources for local populations. Additionally, these agreements have little to no economic value for the local populations.

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Appendix Table A1. Reconstructed catches by W. European countries from Morocco's southern areas.

Year	France	Germany	Italy	Netherlands	Norway	Portugal	Spain
1950	2,074	0	0	0	4,010	0	52,003
1951	2,074	0	0	0	4,017	0	54,193
1952	2,074	0	0	0	4,043	0	64,524
1953	2,074	0	0	0	5,008	0	51,814
1954	2,074	0	0	0	5,038	0	54,912
1955	2,074	0	0	0	5,039	0	51,297
1956	2,074	0	0	0	5,051	0	47,682
1957	2,074	0	0	0	6,981	0	49,104
1958	2,074	0	0	0	6,989	0	58,491
1959	2,074	0	0	0	4,140	0	68,315
1960	2,074	0	0	0	4,155	0	87,129
1961	2,074	0	0	0	5,125	0	91,373
1962	2,074	0	0	0	5,141	0	82,934
1963	2,074	0	0	0	7,096	0	59,335
1964	2,074	3,159	112,500	4,914	9,967	3,508	50,635
1965	2,074	4,350	225,000	6,606	12,852	6,887	57,285
1966	2,074	6,628	337,500	10,068	14,793	10,399	58,337
1967	2,074	9,946	450,000	15,431	26,314	14,327	98,919
1968	1,650	1,915	562,500	17,682	26,336	18,334	97,306
1969	4,346	4,698	450,000	21,297	36,898	22,000	102,001
1970	3,116	31,505	439,573	24,666	38,793	21,422	106,411
1971	3,882	30,594	429,145	27,215	54,611	20,437	129,174
1972	4,238	4,932	418,718	32,089	71,123	20,876	175,225
1973	1,716	4,791	408,290	33,780	67,839	21,594	220,441
1974	1,991	4,572	397,863	31,880	129,800	20,018	279,976
1975	1,682	4,919	387,436	33,725	163,412	21,039	322,653
1976	2,022	13,112	377,008	30,919	157,274	19,345	279,028
1977	2,011	21,671	366,581	29,837	151,184	18,751	345,382
1978	2,000	1,188	356,153	28,371	145,180	17,912	346,972
1979	1,988	15,254	345,726	29,413	139,522	18,659	486,915
1980	1,977	16,637	335,299	27,943	133,160	17,791	335,142
1981	1,966	16,831	324,871	25,827	127,488	16,529	320,218
1982	1,954	17,539	314,444	26,719	121,546	17,219	309,094
1983	1,943	16,541	304,017	25,845	115,364	16,727	387,156
1984	1,932	16,241	293,589	25,184	109,281	16,398	422,866
1985	1,920	15,917	283,162	25,075	102,961	16,404	425,571
1986	1,909	15,637	272,734	24,028	96,937	15,797	419,613
1987	1,898	15,355	262,307	23,553	91,093	15,619	281,038
1988	1,886	14,906	251,880	22,381	84,858	15,141	304,892
1989	1,875	14,760	241,452	21,637	78,917	14,541	403,211
1990	1,864	14,496	231,025	21,274	72,966	14,388	405,760
1991	1,852	14,162	220,597	19,599	66,825	13,396	341,403
1992	1,841	13,875	210,170	20,069	60,760	13,816	327,333
1993	1,830	13,603	199,743	18,750	54,761	13,007	288,489
1994	1,818	13,279	189,315	18,730	48,743	13,186	316,285
1995	1,807	12,994	178,888	18,220	42,632	12,913	241,181
1996	1,796	12,681	168,460	16,543	36,597	11,891	90,945
1997	1,784	12,407	158,033	15,989	30,575	11,613	338,752
1998	1,773	12,117	147,606	15,946	24,549	11,742	296,064
1999	1,761	11,707	137,178	14,907	22,501	11,344	153,615
2000	1,750	11,413	126,751	14,187	20,456	10,971	150,949
2001	1,739	11,120	116,324	13,468	18,410	10,599	148,283
2002	1,727	10,826	105,896	12,749	16,364	10,227	145,617
2003	1,716	10,533	95,469	12,030	14,319	9,855	142,950
2004	1,705	10,239	85,041	11,311	12,273	9,483	140,284
2005	1,693	9,946	74,614	10,591	10,228	9,111	137,618
2006	1,682	9,649	64,187	9,864	8,182	8,739	134,952
2007	1,671	9,649	53,759	9,864	6,136	8,367	132,286
2008	1,659	9,649	43,332	9,864	4,091	7,995	129,620
2009	1,648	9,649	32,904	9,864	2,045	7,623	126,953
2010	1,637	9,649	22,477	9,864	0	7,250	124,286

Appendix Table A2. Reconstructed catches by former Soviet republics and East European countries from Morocco's southern areas.

Year	Bulgaria	Latvia	Lithuania	Romania	Russia	Poland	Ukraine
1950	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0
1952	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0
1955	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0
1964	0	0	0	0	0	4,239	0
1965	895	0	0	0	0	8,468	0
1966	1,792	25,004	16,669	0	16,669	12,720	16,669
1967	2,689	49,861	33,345	0	33,345	16,967	33,241
1968	3,586	75,036	50,024	567	50,024	21,217	50,024
1969	4,482	100,049	66,699	1,133	66,699	26,184	66,699
1970	5,361	124,996	83,331	1,698	83,331	18,966	83,331
1971	15,418	150,171	100,114	2,269	100,114	6,019	100,114
1972	20,732	172,678	115,105	6,178	115,105	9,188	115,119
1973	9,819	197,341	131,295	9,695	131,295	17,371	131,560
1974	6,812	171,971	114,126	9,789	114,126	54,862	114,648
1975	4,951	218,005	145,148	40,819	145,148	70,310	145,337
1976	8,486	136,291	91,041	68,179	91,041	242,355	90,861
1977	35,829	269,489	179,927	30,723	179,927	347,490	179,660
1978	21,151	389,708	262,807	50,777	262,807	469,949	259,805
1979	49,469	276,230	184,079	20,199	184,079	12,015	184,153
1980	36,682	163,329	109,072	3,285	109,072	9,562	108,886
1981	40,441	168,967	113,426	8,138	113,426	7,205	112,645
1982	44,136	216,083	144,189	3,919	144,189	5,615	144,055
1983	13,655	220,254	147,006	4,306	147,006	10,433	146,836
1984	13,781	210,004	140,027	0	140,027	15,254	140,003
1985	12,886	207,823	138,314	0	138,314	19,978	138,549
1986	12,028	186,608	124,426	0	124,426	24,785	124,405
1987	11,192	166,256	110,656	0	110,656	29,713	110,837
1988	10,309	124,442	82,898	0	82,898	34,387	82,961
1989	9,461	82,875	55,295	0	55,295	39,283	55,250
1990	8,612	41,502	27,659	0	27,659	44,208	27,668
1991	7,740	0	26,474	0	35,790	48,903	0
1992	6,877	0	25,428	0	42,426	53,677	0
1993	6,022	0	24,382	0	49,062	58,574	0
1994	5,165	0	23,151	0	56,869	63,460	0
1995	4,297	0	22,166	0	63,114	68,083	0
1996	3,438	0	20,996	0	70,531	72,911	0
1997	2,580	0	19,950	0	77,166	77,809	0
1998	1,721	0	18,842	0	84,193	82,747	0
1999	860	0	17,322	0	93,830	87,557	0
2000	0	0	16,233	0	100,000	92,379	0
2001	0	0	15,145	0	100,000	97,200	0
2002	0	0	14,056	0	100,000	102,021	0
2003	0	0	12,967	0	100,000	106,843	0
2004	0	0	11,878	0	100,000	111,664	0
2005	0	0	10,789	0	100,000	116,485	0
2006	0	0	9,699	0	100,000	121,307	0
2007	0	0	9,699	0	100,000	126,128	0
2008	0	0	9,699	0	100,000	130,949	0
2009	0	0	9,699	0	100,000	135,771	0
2010	0	0	9,699	0	100,000	140,591	0

Appendix Table A3. Reconstructed catches by East Asian countries and South Africa from Morocco's southern areas.

Year	China	Japan	South Korea	South Africa
1950	0	52,128	0	0
1951	0	49,529	2,620	0
1952	0	47,603	5,276	0
1953	0	45,092	7,871	0
1954	0	43,159	10,573	0
1955	0	54,273	13,161	0
1956	0	40,806	15,827	0
1957	0	38,448	18,419	0
1958	0	36,063	20,977	0
1959	0	33,927	23,679	0
1960	0	31,650	26,294	0
1961	0	29,327	28,859	11,077
1962	0	27,068	31,473	22,147
1963	0	22,774	34,410	33,528
1964	0	20,164	36,784	44,374
1965	0	40,262	39,346	55,376
1966	0	60,518	42,057	66,590
1967	0	287,143	44,713	77,737
1968	0	288,574	47,368	88,889
1969	0	300,418	50,000	100,000
1970	0	299,163	53,573	97,313
1971	0	301,018	57,640	95,494
1972	0	300,047	61,178	92,771
1973	0	300,000	64,891	90,342
1974	0	300,756	68,786	88,148
1975	0	299,362	72,182	85,330
1976	0	291,367	75,764	82,776
1977	0	283,610	79,392	80,290
1978	0	276,302	83,144	77,931
1979	0	270,874	87,509	76,099
1980	0	261,637	90,650	73,198
1981	0	256,204	95,119	71,360
1982	0	249,309	92,880	69,111
1983	0	241,037	90,127	66,481
1984	0	233,328	87,584	64,008
1985	0	224,161	84,491	61,137
1986	5,188	222,954	82,060	58,750
1987	11,048	222,990	80,074	56,678
1988	18,790	220,352	77,129	53,927
1989	21,842	219,810	74,924	51,695
1990	27,085	219,298	72,714	49,455
1991	32,945	217,191	69,976	46,856
1992	38,188	215,683	67,440	44,396
1993	43,431	214,856	65,116	42,074
1994	49,599	213,896	62,744	39,719
1995	54,534	211,737	60,025	37,146
1996	60,394	210,536	57,586	34,749
1997	65,637	209,591	55,212	32,391
1998	71,188	208,744	52,857	30,039
1999	78,803	207,417	50,376	27,614
2000	84,258	206,131	47,904	25,195
2001	89,714	204,844	45,433	22,776
2002	95,169	203,557	42,962	20,356
2003	100,680	202,270	40,491	17,937
2004	102,054	200,983	38,020	15,518
2005	103,424	199,696	35,549	13,099
2006	104,794	198,409	33,078	10,679
2007	106,164	197,123	30,607	8,260
2008	107,533	195,836	28,136	5,841
2009	108,903	194,549	25,665	3,421
2010	110,269	193,260	23,195	1,002

Appendix Table A4. Reconstructed catches by West European countries from Morocco's central areas.

Year	France	Italy	Norway	Portugal	Spain
1950	6,914	0	1,724	0	22,288
1951	6,914	0	1,727	0	23,227
1952	6,914	0	1,738	0	27,655
1953	6,914	0	2,154	0	22,208
1954	6,914	0	2,166	0	23,535
1955	6,914	0	2,167	0	21,986
1956	6,914	0	2,172	0	20,436
1957	6,914	0	3,002	0	21,046
1958	6,914	0	3,005	0	25,069
1959	6,914	0	1,780	0	29,280
1960	6,914	0	1,786	0	37,344
1961	6,914	0	2,204	0	39,162
1962	6,914	0	2,211	0	35,545
1963	6,914	0	3,051	0	25,431
1964	6,914	48,375	4,286	1,508	21,702
1965	6,914	96,750	5,526	2,962	24,552
1966	6,914	145,125	6,361	4,471	25,003
1967	6,914	193,500	11,315	6,161	42,397
1968	5,500	241,875	11,324	7,884	41,705
1969	14,486	193,500	15,866	9,460	43,718
1970	10,388	189,016	16,681	9,212	45,608
1971	12,940	184,532	23,483	8,788	55,364
1972	14,125	180,049	30,583	8,977	75,101
1973	5,719	175,565	29,171	9,285	94,481
1974	6,638	171,081	55,814	8,608	119,998
1975	5,608	166,597	70,267	9,047	138,289
1976	6,741	162,114	67,628	8,319	119,592
1977	6,703	157,630	65,009	8,063	148,031
1978	6,666	153,146	62,427	7,702	148,712
1979	6,628	148,662	59,994	8,023	208,692
1980	6,590	144,178	57,259	7,650	143,642
1981	6,552	139,695	54,820	7,108	137,245
1982	6,514	135,211	52,265	7,404	132,478
1983	6,477	130,727	49,606	7,193	165,935
1984	6,439	126,243	46,991	7,051	181,240
1985	6,401	121,760	44,273	7,054	182,400
1986	6,363	117,276	41,683	6,793	179,846
1987	6,325	112,792	39,170	6,716	120,453
1988	6,288	108,308	36,489	6,511	130,677
1989	6,250	103,824	33,934	6,253	172,816
1990	6,212	99,341	31,375	6,187	173,909
1991	6,174	94,857	28,735	5,760	146,325
1992	6,136	90,373	26,127	5,941	140,295
1993	6,098	85,889	23,547	5,593	123,646
1994	6,061	81,406	20,959	5,670	135,560
1995	6,023	76,922	18,332	5,552	103,370
1996	5,985	72,438	15,737	5,113	38,979
1997	5,947	67,954	13,147	4,994	145,189
1998	5,909	63,470	10,556	5,049	126,943
1999	5,872	58,987	9,675	4,878	64,679
2000	5,834	54,503	8,796	4,718	63,556
2001	5,796	50,019	7,916	4,558	62,434
2002	5,758	45,535	7,037	4,398	61,311
2003	5,720	41,052	6,157	4,238	60,189
2004	5,683	36,568	5,277	4,078	59,066
2005	5,645	32,084	4,398	3,918	57,944
2006	5,607	27,600	3,518	3,758	56,821
2007	5,569	23,116	2,639	3,598	55,698
2008	5,531	18,633	1,759	3,438	54,576
2009	5,494	14,149	879	3,278	53,453
2010	5,456	9,665	0	3,118	52,330

Appendix Table A5. Reconstructed catches by former Soviet republics and East European countries from Morocco's central areas.

Year	Bulgaria	Latvia	Lithuania	Romania	Russia	Poland	Ukraine
1950	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0
1952	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0
1955	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0
1964	0	0	0	0	0	1,823	0
1965	385	0	0	0	0	3,641	0
1966	771	5,684	3,717	0	3,717	5,470	3,790
1967	1,156	11,372	7,520	0	7,520	7,296	7,582
1968	1,542	17,062	11,375	244	11,375	9,123	11,375
1969	1,927	22,750	15,167	487	15,167	11,259	15,167
1970	2,305	28,410	18,892	728	18,892	8,155	18,940
1971	6,630	34,167	22,431	961	22,431	2,588	22,778
1972	8,915	38,768	25,829	2,655	25,829	3,951	25,845
1973	4,222	49,210	33,405	4,245	33,405	7,470	32,807
1974	2,929	38,136	25,328	4,193	25,328	23,591	25,424
1975	2,129	58,146	39,647	17,952	39,647	30,233	38,764
1976	3,649	23,246	15,488	29,299	15,488	104,212	15,498
1977	15,406	80,578	53,471	13,150	53,471	149,421	53,719
1978	9,095	134,036	88,104	21,528	88,104	202,078	89,357
1979	21,272	83,256	55,759	8,725	55,759	5,166	55,504
1980	15,773	34,877	23,182	1,408	23,182	4,112	23,251
1981	17,390	37,685	24,519	3,415	24,519	3,098	25,123
1982	18,978	57,527	38,210	1,679	38,210	2,414	38,351
1983	5,872	59,344	39,351	1,842	39,351	4,486	39,563
1984	5,926	54,842	36,400	0	36,400	6,559	36,562
1985	5,541	53,738	36,050	0	36,050	8,590	35,825
1986	5,172	44,780	29,876	0	29,876	10,658	29,853
1987	4,813	35,898	24,002	0	24,002	12,777	23,932
1988	4,433	26,863	17,954	0	17,954	14,786	17,909
1989	4,068	17,928	11,899	0	11,899	16,892	11,952
1990	3,703	8,971	5,978	0	5,978	19,009	5,981
1991	3,328	0	0	0	0	21,028	0
1992	2,957	0	0	0	0	23,081	0
1993	2,590	0	0	0	0	25,187	0
1994	2,221	0	0	0	0	27,288	0
1995	1,848	0	0	0	0	29,276	0
1996	1,478	0	0	0	0	31,352	0
1997	1,109	0	0	0	0	33,458	0
1998	740	0	0	0	0	35,581	0
1999	370	0	0	0	0	37,650	0
2000	0	0	0	0	0	39,723	0
2001	0	0	0	0	0	41,796	0
2002	0	0	0	0	0	43,869	0
2003	0	0	0	0	0	45,942	0
2004	0	0	0	0	0	48,016	0
2005	0	0	0	0	0	50,089	0
2006	0	0	0	0	0	52,162	0
2007	0	0	0	0	0	54,235	0
2008	0	0	0	0	0	56,308	0
2009	0	0	0	0	0	58,381	0
2010	0	0	0	0	0	60,454	0

Appendix Table A6. Reconstructed catches by Asia and South Africa from Morocco's central areas.

Year	China	Japan	South Korea	South Africa
1950	0	22,415	0	0
1951	0	21,297	1,127	0
1952	0	20,469	2,269	0
1953	0	19,390	3,385	0
1954	0	18,558	4,546	0
1955	0	23,338	5,659	0
1956	0	17,547	6,805	0
1957	0	16,533	7,920	0
1958	0	15,507	9,020	0
1959	0	14,589	10,182	0
1960	0	13,609	11,306	0
1961	0	12,611	12,409	4,763
1962	0	11,639	13,533	9,277
1963	0	9,793	14,796	13,989
1964	0	8,671	15,817	19,081
1965	0	17,313	16,919	23,178
1966	0	26,023	18,084	27,097
1967	0	123,471	19,227	33,223
1968	0	124,087	20,368	38,222
1969	0	129,180	21,500	43,000
1970	0	128,640	23,036	41,546
1971	0	129,438	24,785	39,315
1972	0	129,020	26,333	39,752
1973	0	129,000	28,221	39,935
1974	0	129,325	30,316	35,603
1975	0	128,726	31,899	37,795
1976	0	125,288	32,277	36,353
1977	0	121,952	34,139	34,284
1978	0	118,810	35,779	33,524
1979	0	116,476	37,836	32,900
1980	0	112,504	39,230	31,631
1981	0	110,168	41,239	29,517
1982	0	107,203	40,192	29,348
1983	0	103,646	38,690	28,355
1984	0	100,331	37,442	27,365
1985	0	96,389	36,568	26,372
1986	2,224	95,870	35,460	25,213
1987	4,735	95,886	34,652	24,193
1988	8,053	94,751	33,273	23,177
1989	9,361	94,518	32,376	21,946
1990	11,608	94,298	31,456	21,065
1991	14,119	93,392	29,417	20,170
1992	16,366	92,744	29,202	19,358
1993	18,613	92,388	27,424	18,045
1994	21,257	91,975	27,172	17,132
1995	23,372	91,047	26,097	16,059
1996	25,883	90,530	23,437	15,215
1997	28,130	90,124	23,617	13,955
1998	30,509	89,760	22,939	12,947
1999	33,773	89,190	21,880	11,941
2000	36,111	88,636	20,807	10,895
2001	38,449	88,083	19,734	9,849
2002	40,787	87,529	18,661	8,803
2003	43,149	86,976	17,587	7,757
2004	43,737	86,423	16,514	6,710
2005	44,325	85,869	15,441	5,664
2006	44,912	85,316	14,367	4,618
2007	45,499	84,763	13,294	3,572
2008	46,086	84,209	12,221	2,526
2009	46,673	83,656	11,148	1,480
2010	47,258	83,102	10,074	433

Preliminary estimation of realistic fisheries removals from Mauritania, 1950-2010[1]

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Abstract

Mauritania enjoys large fisheries resources, exploited by an important domestic small-scale sector and industrial fleets operated mainly by foreign countries. Total marine fisheries catches by Mauritania were estimated from 1950 to 2010, including commercial landings, subsistence, illegal and unreported domestic catches, as well as catches by non-Mauritanian legal and illegal fleets. Commercial landings were obtained from FAO fisheries statistics database and from the Mauritanian Institute of Oceanography and Fisheries Research (IMROP) for both domestic and foreign fleets. Non-commercial data were obtained from field surveys and grey literature, which were converted to per capita rates and catch per unit of effort estimates using population data. Illegal catches and discards were estimated using recent at-sea observer data, collected by IMROP expanded to cover the 1950-2010 time period. Total reconstructed catches were estimated to be 72.1 million tonnes over the study period, increasing from 59,400 t·year^{-1} in 1950 to a peak of 2.3 million t·year^{-1} in 1976, and then decreasing to 1.9 million t·year^{-1} in 2010, and were overwhelmingly by foreign fleets. Domestic catches were reconstructed to be three times as high as official landings data reported by Mauritania, with 11.8 million t compared to 3.9 million t reported to the FAO. In addition, we noted that catches , including illegal catches, from the Banc d'Arguin National Park, an important marine protected area, were twice as high as official landings. This poses questions about protection of the park area. The data presented here are preliminary, and will be improved using local expertise.

Introduction

Mauritania is located in Northwest Africa, and is member of the Committee for the Eastern Central Atlantic Fishery (CECAF) and the Sub-Regional Fisheries Commission (SRFC) of the West Africa sub-region created in 1985 (FAO 2002). The waters off Mauritania are influenced by upwelling systems and the Canary island current which stimulates high levels of marine resource productivity (M'Barek and Mahfoudh 1995; Campredon and Cuq 2001). This makes these waters some the richest fishing grounds in the world (Goffinet 1992).

Fisheries in Mauritania have been historically the subject of exploitation by foreign fleets, particularly from Europe (Gascuel *et al.* 2007). After the independence from France in 1960, it took almost 20 years for Mauritania to implement its first fisheries policy 'nouvelle politique de pêches' adopted in 1979 (Ould Cheikhna *et al.* 2005), shortly after the government declared the Mauritanian EEZ, and promoting nationalization of catches, artisanal fisheries development and monitoring with the first fisheries landings surveys in the 1980s (Bakhayokho *et al.* 1988). In 1994, a monitoring body was created to enforce fisheries legislations (Anon. 2002a).

There are two distinct fishing sectors active in Mauritanian waters. The industrial (large-scale) sector is operated almost exclusively by foreign fleets under fishing access agreement or joint ventures (Josse and Garcia 1986), and more recently flags of convenience. This sector directs the vast majority of catches to the international market (UNDP 2001). The artisanal sector mainly operates canoes under 12 m long, pirogues and Tarifian purse-seine boats of 14 to 15 m (Josse and Garcia 1986). Small-scale fishing was largely aimed for subsistence until the 1980s (Nancy 2010). It was a seasonal activity, where fishers were often migrating to follow moving fish stocks (Campredon and Cuq 2001).

[1] Cite as: Belhabib, D., Gascuel, D., Kane, E.A., Harper, S., Zeller, D. and Pauly, D. (2012) Preliminary estimation of realistic fisheries removals from Mauritania, 1950-2010. pp 61-78. In: Belhabib, D., Zeller, D., Harper, S. and Pauly, D. (eds.), Marine fisheries catches in West Africa, 1950-2010, part I. Fisheries Centre Research Reports 20 (3). Fisheries Centre, University of British Columbia, Canada [ISSN 1198-6727].

This activity, historically operated by the Imraguen and N'Diago populations (Sall and Thioye 2006), had the main purpose of sustaining fishers and their families, and mainly targeted grey mullets for the Imraguen (Bakhayokho *et al.* 1988; Sall and Thioye 2006) and mainly groupers, mullets, sardinellas, blackspot seabreams for the N'Diago (Sall and Thioye 2006).

In 1958, the urbanization of coastal cities attracted agricultural populations to part-time fishing practices (Marfaing 2005). Furthermore, in the south of Mauritania, N'Diago fishers were fishing for subsistence following the same pattern than the Imraguen in the North until the mid-1980s (Trouillet *et al.* 2011). Subsistence fishing decreased thereafter and gradually shifted to commercial cephalopod fishing for the N'Diago fishers (CMAP 2010) and shark fishing for the Imraguen (Anon. 2002b) along with the industrialization of the artisanal fleet and fisheries harbours in Nouadhibou and Nouakchott. This marketing pattern, along with climate change, and droughts in the 1970s and the 1980s in the Sahel area, contributed to increased migrations towards the coast of Mauritania (Tacko Kandji *et al.* 2006), thus increasing fishing pressure on coastal areas and the dependence of the Mauritanian population on seafood. At the same, time the number of pirogues increased from less than 500 in the 1970s to more than 2,000 in the 1990s and about 4,000 in recent years.

Artisanal fishing is particularly important because of its contribution to food security in Mauritania (Lenselink 2004). Imraguen traditional fishing communities depend directly on fish for their livelihood. These communities have the exclusive fishing rights in the Parc National du Banc d'Arguin (Picon 2002), the largest marine protected area in Africa stretching along the Mauritanian coast from Cape Blanc to Cap Timiris (Campredon and Cuq 2001). This park was created in 1976 and stretches along about a third of the Mauritanian coast. Designated as a Rmsar Convention Wetland site in 1982, and considered as a 'gift to earth' in 2001 by the United Nations (UNEP 2011), the PNBA is particularly important because it represents the main spawning ground for many commercially important and endangered species (Boëly *et al.* 1979; Troadec and Garcia 1980; Jager 1993).

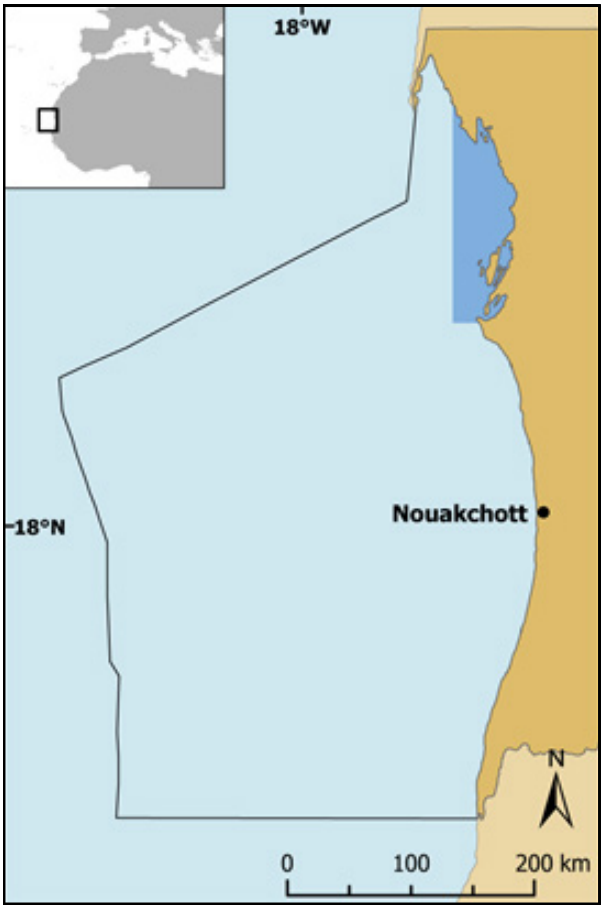

Figure 1. Map of the Mauritanian Exclusive Economic Zone highlighting the Banc D'Arguin National Pak.

Over almost half a century, fishing pressure on the coastal areas, the extent of foreign fishing and a lack of reliable catch data created serious concerns over the Mauritanian resources sustainability, which is not an exception in Western Africa (Goffinet 1992). This, along with a high corruption profile and a low governance rate (MRAG 2005) frames a perfect opportunity for overfishing and under-reporting by the industrial fleet, and overcapitalization by the domestic artisanal fleet (Goffinet 1992; Agnew *et al.* 2010). Furthermore, of a total population of 3.3 milion in Mauritania, 1.5 milion is dependent on fishing (Ould Mohamed Vall 2004; Anon. 2011), especially in the northern maritime areas where communities livelihood is based almost entirely on this activity, with no other opportunities apart from fishing (Njock 2007). Hence, reconstructing fisheries catches would enhance chances for better management, as required for poverty reduction and food security. This study will update the reconstruction of Mauritanian catches by Gascuel *et al.* (2007), including the under-reported catches, as well as unreported artisanal catches. It will also provide the first comprehensive estimate of the Imraguen fisheries catch being an important subsistence and traditional activity for the Imraguen population, and the total removals from the Banc d'Arguin National Park (PNBA), which is itself of significant importance for West African fish stocks (Lefeuvre 2007).

Methods

Electronic time series of reported landings data from 1950 to 2010 were available and used in this study. In addition, we used data available from Gascuel *et al.* (2007), and unpublished data from the Mauritanian Institue of Oceanographic and Fisheries Research (IMROP) covering the period 1990 to 2005, and statistical time series covering the period from 2004 to 2010 (Kane Élimane 2011). Reported landings are distinguished by species or higher taxonomic grouping and `miscellaneous groups´. Since the main goal of this study is to estimate the total catches per species or higher taxonomic group, we used previously reconstructed data (Gascuel *et al.* 2007) as a more comprehensive baseline for foreign fishing, and FAO data as a reported baseline for artisanal fishing, to which we added: (1) illegal, unreported, and unregulated commercial catches; (2) non-commercial catches; (3) discards; and (4) illegal foreign flag catches.

This reconstruction is tentative and an improved version, including official data from IMROP and additional input from IMROP experts will be produced later. In the meantime, we hope that this contribution may serve as a place-holder, as it broadly identifies the catch in the Mauritanian EEZ.

Artisanal catches

Fishing effort surveys conducted by IMROP started along the coast of Mauritania in 1982 and have been expanding to cover most of the coast since 1985 (Ferraris and Chaboud 1995). While the number of pirogues was believed to be estimated fairly well since that period (based on two surveys performed each year in all the Mauritanian fishing camp sites), artisanal catches were monitored by IMROP only in Nouakchott and Nouadhibou from 1981 to 1992 (Josse and Garcia 1986; Josse 1989; Failler *et al.* 2004), and expanded to cover the north area and Nouakchott from 1993 to 1997, and the PNBA and the central areas from 1997 onward (Labrosse *et al.* 2010). These surveys were based on samples taken by IMROP observers twice a week, directly when pirogues arrived on the beach (Chaboud and Ferraris 1995).

To conservatively estimate artisanal catches, we first assembled anchor points for the number of pirogues and the observed CPUEs, reported at two landings sites, for the 1980s and 2000s. We interpolated the number of pirogues to complete the time series from 1950 to 2005 (Table 1). We estimated the geometric mean for the CPUEs observed at both landing sites (Table 2), then performed an extrapolation back and forward to complete the time series. We multiplied the number of pirogues by the annual CPUE, which is the overall average – regardless of the number of fishing days - and estimated the artisanal catch between 1950 and 2005, then added to the offcially IMROP recorded data 8% of artisanal unreported catches, which represents the general rate of under-reporting estimated by MRAG (2005) from 2005 and 2010. Our method is conservative, since catches are based on effort data that are known to be fragmentary and started covering the entire coast after the 1980s (Bakhayokho *et al.* 1988). The fishing efficiency of pirogues is known to have strongly increased over time, especially due to the motorization of pirogues in the 1970s, but also to the introduction of ice, more efficient gear and more recently electronic devices (such as GPS). At the same time, the decrease in resources abundance is also well documented (Christensen 2005; Gascuel *et al.* 2007). This compensated for the increase in CPUE caused by the increasing fishing technology, which here translated into a slow decline as observed.

Table 1. Anchor points representing the number of pirogues operating in Mauritania between 1950 and 2010.

Year	Pirogues	Source
1950	125	Chavance 2004
1982	519	IMROP unpublished data
1985	622	IMROP unpublished data
1986	580	IMROP unpublished data
1987	735	IMROP unpublished data
1988	703	IMROP unpublished data
1989	748	IMROP unpublished data
1990	763	Inejih et al. 2004
1991	785	Inejih et al. 2004
1992	729	Inejih et al. 2004
1993	1,263	Inejih et al. 2004
1994	1,565	Inejih et al. 2004
1995	2,295	IMROP unpublished data
1996	2,842	IMROP unpublished data
1997	2,728	IMROP unpublished data
1998	3,142	IMROP unpublished data
1999	2,640	IMROP unpublished data
2000	2,750	IMROP unpublished data
2001	2,850	IMROP unpublished data
2002	3,700	IMROP unpublished data
2003	3,800	IMROP unpublished data
2004	3,950	IMROP unpublished data
2005	3,950	IMROP unpublished data

Table 2. CPUE anchor point used for the extrapolation of the average CPUE per pirogue ($t \cdot pirogue^{-1} \cdot year^{-1}$) in two areas of Mauritania.

Year	Nouadhibou	Nouakchott	Total
1982	17.7	18.3	-
1985	33.6	14.7	-
1986	39.9	18.0	-
1987	45.7	26.5	-
1998	-	-	22.5
1999	-	-	26.1
2000	-	-	25.9
2001	-	-	27.9
2002	-	-	23.4

Artisanal catches in the PNBA

In the Banc d'Arguin waters, fishing for flathead grey mullet (*Mugil cephalus*) by the nomadic Imraguen population has been described since the 15th century mainly for subsistence (Picon 2002).These fishers developed a rudimentary, but unique land-based fishing technique using a net on a wooden stick fishers carried on their shoulders (Anon. 2002b; Bernardon and Ould Mohamed Vall 2004). This selective technique, combined with traditional territorial fishing rights per village and seasonal closure of the fishery (Picon 2002; Bernardon and Ould Mohamed Vall 2004), was a recipe for durability.

Imraguen fishers started using small wooden sailing boats introduced by Canarian fishers, in the early 1950s. This, along with growing commercial interest, intensified fishing for mullets and meager (*Argyrosomus regius*) which developed quickly in the 1950s (Anon. 2002b; Picon 2002) and for shark fins from 1980 to 2003, when this fishery was banned in the park area (Diop and Dossa 2011). This activity was practiced in the Parc National du Banc d'Arguin, created in 1976, where Imraguen maintain exclusive fishing rights, as well as north up to Villa Cisneros and south to Cape-Timiris (Lotte 1937).

From 1950 to 1980, the establishment of fishing villages South of Cape Timiris (Chaboud *et al.* 1988) contributed to increasing fishing effort and capacity. Imraguen catches, as part of the total artisanal catch, were grossly under-reported before 1985 (Bakhayokho *et al.* 1988; Trouillet *et al.* 2011) and are still under-estimated (Failler *et al.* 2002). Therefore, we estimated Imraguen catches as a portion of the artisanal catch to have an estimate of the total removals from the PNBA area, and to be able to determine unreported catches taken by Imraguen from the park

area. Surveyed catch data time series were available only recently, i.e, since 1997 (Bernardon and Ould Mohamed Vall 2004; Kane 2012 unpub. data).

Therefore, to reconstruct Imraguen catches, from 1950 to 1993, we combined CPUE estimates for land-based fishers with the number of land-based fishers, and CPUE estimates for boats with the number of boats. We conservatively assumed the catch per land-based fisher in the 1950s and 1960s was 80% of the 1980s catch per land-based fisher of 8.5 t·year^{-1}·fisher^{-1} (Bakhayokho *et al.* 1988), i.e., 6.8 t·year^{-1}·fisher^{-1}. The catch per boat in 1959 was estimated at 55.3 t·year^{-1}·boat^{-1}, by dividing the catch of 700 t·year^{-1} of dried fish (Ould Mohamed 2010), converted to wet weight using a conversion factor of 2.37 (FAO Fishstat) by the effort of 30 boats in 1959 (Ould Mohamed 2010). The catch

Table 3. Anchor points representing the population of Imraguen in the PNBA equivalent waters.

Year	Land-based CPUE	Source	Fishers	Source	Boat-based CPUE	Source	Boats	Source
1950	6.8	Assumption[a]	461	Estimated	N/A	N/A	0	Assumption
1960	6.8	Assumption[a]	400	Anthonioz (1967)	55.3	Assumption[a]	31	Anthonioz (1967)
1970	8.5	Bakhayokho *et al.* (1988)	164	Assumption	49.2	Interpolated	73	Picon (2002)
1980	8.5	Bakhayokho *et al.* (1988)	125	Assumption	43.1	Interpolated	95	Estimated
1997-2010	Between 1997 and 2010, surveyed catch data were available and directly used.							

a) assumed to be 20% lower than the estimate provided by Bakhayokho et al. (1988).
b) assumed to be 10% higher than estimate provided by Chaboud et al. (1988).

per boat in 1988 was estimated based on Chaboud *et al.* (1988) at 38.2 t·year^{-1}·boat^{-1} (Table 3). In 1950, when fish were exclusively caught by land-based fishers, the number of land-based fishers[2] was derived to be 461. In 1960, 31 boats and 400 land-based fishers were operating (Anthonioz 1967). In 1970, 73 boats were operating (Maigret 1970 in Picon 2002) employing 4.5 fishers on average (Anthonioz 1967) for a number of 164 land-based fishers, assuming the number of land-based fishers was proportionally half the number of boat-based fishers, as the use of boats was increasingly attractive for the Imraguen (Table 3). We applied the same method for 1980, when 95 boats were operating for 125 land-based fishers, i.e., a third of the number of boat-based fishers. We interpolated CPUE estimates and the corresponding effort linearly from 1950 to 1980, which we multiplied to estimate the total Imraguen catch per year. Thereafter, we performed a linear interpolation from the estimated catch in 1980 to the surveyed catch of 1,000 t·year^{-1} in 1997 (Bernardon and Ould Mohamed Vall 2004).

Subsistence catches

Subsistence fisheries in Mauritania comprise: (1) Imraguen subsistence catches in the PNBA including catches given or shared as almsgiving, Neerane, fish offered to people who help landing catches; and Ndawal, catches offered to retired fishers who can't operate anymore (Chaboud *et al.* 1988), and (2) N'Diago subsistence catches.

Imraguen subsistence catches

Inside the PNBA, Imraguen fishing from June to September was mainly for subsistence, while mullets fishing (from October to January) and meager (from January to June) was partly commercial (Josse and Garcia 1986). Outside the PNBA, Imraguen historically fished for subsistence during the wet season from August to January (Murray-Lee 1987). To estimate subsistence catches in the PNBA, we first aggregated available data on Imraguen population from 1,500 in 1950 to 1,800 in 1960 (Picon 2002), and then to 2,750 on average from 2001 to 2010 (Anon. 2002b), which we interpolated to complete the time series. For 1978, Doucet *et al.* (1981) estimated a total Imraguen catch of 7,000 t·year^{-1}, which were refered to as being for subsistence (Doucet *et al.* 1981). However given the nature of Imraguen catches, this number is more likely to include both subsistence and artisanal catches. Subsistence catch here is not defined as the consumption per capita, since part of the subsistence catch is sold to markets outside the PNBA, this rather shows both the consumption of the Imraguen population and catches that are taken by the Imraguen and sold informally. Therefore, the difference between the latter and the estimated artisanal catch represents the subsistence catch of the Imraguen population for 1978, i.e., a subsistence catch of 1,981 t·year^{-1}. The subsistence catch divided by a total interpolated Imraguen population of 2,217 landed a per capita catch of 0.89 t·capita^{-1}·year^{-1} for 1978. We assumed this consumption rate (including Neerane and Ndawal) was 10% higher in 1950, i.e., 0.98 t·capita^{-1}·year^{-1}, since evidence suggests catches aimed at personal consumption decreased since the 1950s (Failler *et al.* 2002), with expanding market (COPACE 1993) and the growing interest in trading the catch (Diop and Ould Cheibani 2000). We performed a linear interpolation to estimate the catch per capita per year from 1950 to 1978. Total subsistence catches in the Imraguen area were obtained as the product of the total Imraguen population per year and the per person estimated catch from 1950 to 1978. In 1988, 15% of the Imraguen catch was consumed, 10% was offered as Neerane and 10% was allocated to the Ndawal (Chaboud *et al.* 1988), to which 2% of catch consumed by the crew is added (Chaboud and Ferraris 1995), leading to the equivalent of 37% of Imraguen artisanal catches being for subsistence in 1988, thus not reported. In 2009, the subsistence portion was equivalent to 11% of the total artisanal catch, whereas 9% was donated for almsgiving (Ly and Zein 2009). This, added to the crew consumption of 2%, represented the equivalent of 22% of the Imraguen artisanal catch not reported nor accounted for previously.

[2] http://www.la-croix.com/Archives/2004-03-24/La-petite-communaute-des-Imraguen-veut-preserver-ses-ressources-halieutiques-_NP_-2004-03-24-204732 [Accessed on November 24th 2011].

We interpolated these rates linearly, which we applied to the total Imraguen artisanal catch to estimate subsistence catches by this population in the PNBA, and kept the subsistence catch constant for 2009 and 2010.

N'Diago subsistence catches

The N'Diago people, living in south Mauritania, accounted for around a tenth of the total artisanal catch in the 1950s (E.K., Pers. Obser., IMROP) and 8% of the artisanal fisheries removals in the 1980s (Bakhayokho *et al.* 1988). We interpolated these rates assuming these were constant from 1980 to 2010. Thereafter, we applied these rates to the total Mauritanian artisanal catch to estimate commercial catches by the N'Diago people for the 1950-2010 time period. We calculated the percentage of subsistence catches over artisanal catches for 1950 and 1978 for the Imraguen subsistence catch, i.e., 82% and 48% for 1950 and 1978, and 37% and 22% for 1988, 2009-2010, respectively. We then applied the same rates then for N'Diago subsistence catches, given that the fish market was homogenous between both areas and that both populations share the same fishing tradition in Mauritania (Trouillet *et al.* 2011).

Industrial fishing

The Mauritanian industrial fleet is made up of vessels of foreign origin that have either been reflagged to Mauritania or operate under chartering arrangements (Bru and Hatti 2000; Gascuel *et al.* 2007), being mostly Chinese and European vessels for the most recent period (Obaidullah and Osinga 2010; Mallory 2012). This reflagging of boats was common in Mauritania, and driven by reduced fishing fees. For example, 109 Chinese and 44 EU industrial fishing vessels were reflagged in 1999 (Agnew *et al.* 2010), while in the past it was mostly Soviet Union vessels that were offered joint ventures in Mauritania.

Mauritania started chartering vessels and encouraging joint ventures in the 1970s (Gibbs 1984) to nationalize the catch after the bankruptcy of the Societé Mauritanienne de l'Armement des Pêches with its 13 industrial vessels, which cost over $10 million (using a French loan). Joint ventures were 43% Mauritanian state owned, 49% foreign owned and 7.6% private owned (Gibbs 1984). Flags of convenience appeared in Mauritania in 1995 and have been increasing since then (Obaidullah and Osinga 2010). We updated Gascuel *et al.* (2007) reconstructed industrial catches from 2005 to 2010 data using data from CMAP (2010). While Gascuel *et al.* (2007) used an under-estimation percentage of 30%, we believe catches were still grossly under-estimated. Ould Taleb Ould Sidi (2000) estimated the total catch to be twice as high, i.e., under-estimated by 100%. However here, to remain conservative, we used Gascuel *et al.* (2007) under-reporting rate. Gascuel *et al.* (2007) already estimated foreign catches with the under-reporting of 30% of catches, We here updated this estimate by applying the same under-reporting rate to the data by IMROP from 2005 to 2010. To allocate catches to actual beneficiary or owner country, we assumed the year of first reported catch data in Fishstat by each country in FAO area 34 as the same year of fishing in Mauritania, and used IMROP catch data per country thereafter (Gascuel *et al.* 2007). To disaggregate USSR catches to member country, we used the most recent data by IMROP per member country (Gascuel *et al.* 2007), which we aggregated and estimated the percentage of catch per country assuming a constant figure since the start of USSR fishing operations in the Mauritanian EEZ in 1958.

Domestic industrial catch data from Gascuel *et al.* (2007) was updated using the domestic industrial catch data from 2005 to 2010 from CMAP (2010) on one hand, and the conservative under-estimation rate estimated by Gascuel *et al.* (2007) on the other hand, given that Mauritanian flagged vessels are more likely to land catches in Mauritania.

Canarian fishing

The period between the early 1950s and the beginning of the 1980s was characterized by the presence of a relatively important Canarian purse-seine fleet, estimated between 100 and 200 wooden vessels of 8 to 25 m, landing their catches in Las Palmas, and supplying the 'Societe industrielle de la grande pêche' (SIGP, 'industrial fishing company') since 1924 (Ould Mohamed 2010) and IMAPEC later, a fish processing factory based in Nouadhibou (Mohamed Mahmoud Ould Sadegh, *Fédération nationale des pêches*, pers. comm.). In some cases, several hundred Canarian vessels were believed to have operated in Mauritanian waters until 1980, when Canarian fishers left Mauritanian fishing grounds (Mohamed Mahmoud Ould Sadegh, *Fédération nationale des pêches*, pers. comm.). Herein, we averaged the number of vessels at 150 in 1950, interpolated to 200 in 1959 (Ould Mohamed 2010) and then to zero in 1980. While in 1980, 7,000 $t \cdot year^{-1}$ were caught by Canarian fishers in the waters of the PNBA (Ould Mohamed 2010); in 1959 Ould Mohamed (2010) estimated that 16,000 $t \cdot year^{-1}$ of meager were caught by the Canarian fleet and in 1968, around 15,000 $t \cdot year^{-1}$ were supplied to the IMAPEC[3] , and 4,000 $t \cdot year^{-1}$ in 1978 and 1979 as reported by Doucet *et al.* (1981) and Bakhayokho *et al.* (1988). We estimated the CPUE in 1959 by dividing the catch of 15,000 $t \cdot year^{-1}$ by the effort of 200 vessels, i.e., 80 $t \cdot year^{-1} \cdot vessel^{-1}$, multiplied this CPUE by the averaged effort of 150 Canarian vessels in 1950, and then interpolated catches to complete the time series from 1950 to 1980.

Illegal fishing

Massive illegal fishing is taking place in the Mauritanian EEZ (Scharm and Schack 2006). Four types of illegal fishing are known to occur in Mauritania: unlicensed fishing practiced by foreign fishers; illegal gear use by the industrial

[3] http://mauritania.lezajsk.pl/development-program/125 [Accessed on April 9th 2013].

fleet, illegal demersal and small pelagic artisanal fisheries; and fishing in the protected PNBA. These illegal activities were inferred to be the equivalent of 9% of the total current legal catch reported by Mauritania to the FAO in the late 2000s (Agnew *et al.* 2010). Illegal or pirate fishing decreased since 1996-1998 because of the increase in the level of monitoring, control and surveillance (Agnew *et al.* 2010), but still remained at high levels (Ould Taleb Ould Sidi 2005). Here, we estimated three categories: illegal unlicensed artisanal Senegalese fishing, illegal fishing in closed areas using illegal artisanal gear (in the PNBA), and illegal industrial fishing which was either unlicensed or operated in closed areas in conflict with exclusive artisanal fishing areas.

Senegalese illegal artisanal catches

Senegalese fishers operated in Mauritanian waters due to the depletion of local fish stocks in Senegal (Obaidullah and Osinga 2010). Illegal Senegalese fisheries catches have been estimated to be 13,000 t·year^{-1} in 2005, the equivalent of 15% of the reconstructed Mauritanian artisanal catches, with an estimated 704 unlicensed Senegalese artisanal vessels in Mauritanian waters (Agnew *et al.* 2010). There is evidence of proportionality between Senegalese illegal fishing activities and Mauritanian artisanal fisheries in the 2000s. Indeed, many Senegalese fishers operate two thirds of the time for Mauritanian fishers and one third of the time on their own accounts (Marfaing 2005). Therefore, we assumed illegal Senegalese catches were the equivalent of 15% of the Mauritanian artisanal reconstructed catch per year from 2005 (13,000 t·year^{-1}) to 2010 (13,200 t·year^{-1}). In 1989, political relations between Mauritania and Senegal resulted in border closure, and expatriation of Senegalese workers from Mauritania (Gousseau 2007). Therefore, illegal Senegalese fisheries practices increased and fishers were operating frequently in Mauritanian waters without authorization (Marfaing 2005). We assumed catches in 1989 were 50% of the 2001 illegal catch, since closure of boarders increased the segment of unreported and illegal Senegalese fisheries catches off Mauritania from 1989 to 2001. Since then, 705 illegal Senegalese boats per year were operating in Mauritania (Marfaing 2005). During the same period, Mauritania handed over fishing licenses to Senegalese fishers for pelagic fish (mainly *Sardinella*) excluding mullets and high value species, with 250 licenses in 2001, and 270 in 2004 and 2005. The ratio illegal:legal boats decreased by 8% from 2001 to 2005. Thus, we assumed catches in 2001 were conservatively 8% higher than catches in 2005. From 1950 to 1989, we referred to catches as being unregulated, and assumed the same trend as for Mauritanian artisanal fisheries, since the most recent periods show similar patterns. To disaggregate these catches, we used the Senegalese migrants catch description by Sall and Thioye (2006). In order to derive a species disaggregation index, we assumed the number of months spent targeting these species relatively to the total time allocated to fishing all these species, is a good indicator of the quantity caught, then we derived the proportion of each species catch relatively to the total catch (Table 4).

Table 4. Taxonomic composition of illegal Senegalese catches and N'Diago subsistence catches.

Taxon name	Common name	Frequency	Contribution to catches (%)	Source
Sardinella spp.	Sardinellas	All year	12.5	Sall and Thioye (2006)
Pagrus spp.	Seabreams	All year	12.5	Sall and Thioye (2006)
Epinephelus aeneus	White grouper	All year	12.5	Sall and Thioye (2006)
Octopus spp.	Octopus	9 months	10.5	Sall and Thioye (2006)
Sepia spp.	Sepia	9 months	10.0	Sall and Thioye (2006)
Mugil spp.	Mullets	6 months	5.0	Sall and Thioye (2006)
Solea spp.	Soles	5 months	1.0	Sall and Thioye (2006)
Pomatomus saltatrix	Bluefish	2 months	1.0	Sall and Thioye (2006)
Selachians	Selachians	-	30.0	Vernet (2007)
Miscellanuous	-	6 months	5.0	Sall and Thioye (2006)
Total	-	-	100	-

Illegal catches in the PNBA

Illegal fishing in the PNBA refers to all unreported catches by non Imraguen fishers inside PNBA waters, and Imraguen or non-Imraguen catches using motorized boats inside the PNBA. The park is referred to as a 'tank' for illegal fishers by Failler *et al.* (2002) to highlight the extent of illegal fishing in the park area. The number of infractions and the corresponding number of illegal boats observed in the PNBA were available from 1999 to 2003 (Table 5) from Marfaing (2005), including pirogues and occasional sightings of trawlers. Here, we assumed that the real number of illegal boats would realistically be 20% higher, since not all illegal boats have been observed. In 2002, 2,500 t·year^{-1} of illegal fish were caught in the waters of the PNBA (Failler *et al.* 2002). Using this catch, with the corresponding number of boats, we estimated a CPUE of 5.8 t·year^{-1}·boat^{-1}, which we applied to the available effort data, i.e., from 1999 to 2003, assuming a constant CPUE. From 1976 to 1999, we assumed illegal catches were proportional to the legal component from the PNBA, which is justified by the popularity of the park and the 'tank' effect described by Failler *et al.* (2002). These activities were already widespread in 1976, and illegal fishing has decreased since then, thus, we assumed illegal catches in 1976 were 50% higher than the catch in 1999. With the advancement of monitoring techniques (Agnew *et al.* 2010) and the implementation of a locally implemented surveillance system in 1998 (FAO 2006), illegal catches in the PNBA decreased considerably (Marfaing 2005; Scharm and Schack 2006; Agnew *et al.* 2010), therefore we assumed in 2010, they were 50% of the 2003 illegal catch (Table 5). Thereafter, we interpolated between the three estimates linearly to complete the time series from 1976 to 2010.

Catches by illegal industrial fleets

Although Mauritania made significant improvements in reducing foreign illegal fishing during the 2000s (Pramod *et al.* 2008), illegal fishing was, and still is, of major concern (Gibbs 1984; Anon. 2002a; Addico 2008; Pramod *et al.*

2008). Illegal catches in West Africa were at least 1.3 times the reported catch in the late 1970s (Gibbs 1984). In Mauritania, from 1973 to 1977, most of the industrial catch was taken by unlicensed vessels from the Mauritania (Gibbs 1984), and probably in territorial waters. Right after independence and before the declaration of the Mauritanian EEZ, these waters were legally accessible for large foreign fleets with no government regulations, as they were legal High Seas waters. Therefore, before the declaration of the Mauritanian EEZ in the late 1970s, these catches are considered unregulated rather than illegal. Catches in 1978 were therefore considered to be twice as high as the legal industrial catch. In the 1990s and the 2000s, 30 to 40 boats from Asia were operating illegally in the Mauritanian waters[4], thus, despite significant improvements in monitoring techniques, illegal catches in 2010 were assumed to be 50% lower than the illegal/unregulated catch in 1978. Therefore, we assumed illegal catches from 1950 to 1969 were 1.3 times the industrial catch from Gascuel *et al.* (2007), twice as high as the industrial reconstructed catch from 1975 to 1985, and decreased thereafter by 50% in 2010. We interpolated the estimated illegal catch to complete the time series. Before the declaration of the Mauritanian EEZ, we consider catches as being unregulated rather than illegal.

Table 5. Illegal *pirogues* and corresponding catches in the waters of the PNBA.

Year	Number of boats[a]	CPUE ($t \cdot boat^{-1} \cdot year^{-1}$)	Catch ($t \cdot year^{-1}$)	Method
1950-1975	0	-	0	Assumed
1976	-	-	3,071	Assumed to be 50% higher than 1999 catches
1999	355	5.8	2,047	Effort multiplied by CPUE
2000	493	5.8	2,842	Effort multiplied by CPUE
2001	386	5.8	2,227	Effort Multiplied by CPUE
2002	299	5.8	2,500	Effort multiplied by CPUE
2003	185	5.8	1,065	Effort Multiplied by CPUE
2010	-	-	533	Assumed to be 50% of the 2003 catches

a) From Mainfraing (2005) adjusted by +20%

Discards

Discards of the artisanal sector

The discard rate is around 5% of the total artisanal catch, based on direct observations in 2009 (Ly and Zein 2009). Thus, we assumed a constant rate of 5% from 1950 to 2010, and applied this to the reconstructed artisanal and subsistence catch from 1950 to 2010.

Discards of the industrial sector

Discards of the domestic industrial sector were estimated using data from Gascuel *et al.* (2007) from 1950 to 2005, then updated based on the percentage of discards derived from Gascuel *et al.* (2007) for 2005. This discard rate was then applied to industrial catches from 2006 to 2010, to allowing the update of the 1950-2005 discards time series provided by Gascuel *et al.* (2007).

Recreational catches

The 'Baie de l'étoile', located in the Nouadhibou, is the only recreational fishing centre in Mauritania, allowing 24 tourists to fish for 5 days during a trip of 8 days (Tomatis 2001). This facility opened in 1960 (Ould Mohamed 2010), and in 1972, the first records of tourist fishing were found in the 'livres d'or' reporting number of fishes, species and the weight caught for a period of 25 years from 1972 to 1997. Using these records, we estimated the average CPUE per tourist by dividing total catches reported by the number or tourists, and assumed the CPUE was constant from 1995 to 2010. We then assumed the number of tourists fishing was zero in 1970s when this activity began, 10% of the total number of tourists visiting Mauritania as reported by Diarra (2009) between 1997 and 2006, corresponded to the number or 'reporters' in the 'livre d'or' from 1972 to 1995, and decreased by 50% between 2006 and 2010 because of political and security reasons in the Sahel area. Recreational tourist catches from the waters of the PNBA are estimated as the product of the CPUE by the number of tourists and the number of fishing days per tourist (i.e., 5 $days \cdot boat^{-1} \cdot year^{-1}$).

Species disaggregation

Artisanal, subsistence and illegal artisanal catches in the PNBA were disaggregated to taxon level using survey data from the Mauritanian Institute of Fisheries (IMROP) in the Banc d'Arguin National Park (Kane Élimane 2011). To disaggregate catches by the N'Diago for subsistence, and illegal Senegalese catches, we estimated a percentage per taxon based on the number of months that fishers spend targeting the latter taxon (Table 3), assuming the same species composition for both sectors, since market value and food preferences are homogenous between

[4] http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+WQ+E-2001-1464+0+DOC+XML+V0//EN [Accessed on November 23rd 2011].

the southern areas of Mauritania and Senegal (Sall and Thioye 2006). Similarly, we converted IMROP artisanal catch data per taxon (IMROP, unpub. data) to percentages and applied this to the difference between total artisanal catches and Imraguen artisanal catches. We applied the same method to estimate foreign legal catches per taxon, where reported catch data in the Mauritania EEZ per country were available from IMROP for the late 1990s to the mid-2000s for Spain, Korea, China, Lithuania, France, Cyprus, Netherlands, Latvia, Italy, Romania, Ireland, Slovenia, Japan, Ukraine and Iceland, whereas for Russia we applied the same species breakdown as for Lithuania, a former USSR member, and the Irish species breakdown to the UK where data were not reported. To disaggregate illegal catches by non-African countries, we aggregated reported catches by all foreign countries (IMROP, unpub. data) and estimated percentages per taxon which we applied to the illegal catch per country, i.e., Russia, Ukraine, Romania, Lithuania, Netherlands, Spain, Italy, Japan, Korea, China and other non-identified flags.

Domestic discards for trawlers were assumed to have the same taxonomic composition as trawlers operating in Senegal, i.e., *Brachydeuterus auritus*, *Galeoides decadactylus*, *Chloroscombrus chrysurus*, *Sepia* spp., *Trichiurus lepturus*, *Arius* spp., *Pseudotholithus* spp., and *Cynoglossus monody*, while small-pelagic trawlers (joint ventures with Russia) were assumed to discard the same species described by ter-Hofstede and Dickey-Collas (2006), i.e., 24.9% of *Sardina pilchardus*, 16.2% of *Scomber japonicus*, 15% of *Trachurus trecae*, 5.1% of *Sardinella maderensis*, 2.9% of *Sardinella aurita* and 35.9% of 'marine fishes nei'.

Results

Total reconstructed catches

Reconstructed Mauritanian domestic catches totaled 11.8 million tonnes for the 1950-2010 time period (Figure 2a), compared to total removals by foreign countries of 60.3 million tonnes within the Mauritanian EEZ (Figure 2a). The Mauritanian small-scale catch was estimated to be only 4% of the total reconstructed catch including foreign removals. Total reconstructed domestic Mauritanian catches (11.8 million tonnes) were 200% higher than the officially reported data (Figure 2a). The under-reporting tendency decreased by half during the last six decades, which shows improvement in monitoring (Figure 2a). However, foreign catches still constitute the bulk of catches (Figure 2a). Over the total 72.1 million tonnes reconstructed catches, over 60 million tonnes were caught by foreign vessels during the 1950-2010 time period, of these catches, 27.9 million tonnes (47%) were caught by illegal vessels/pirogues.

Domestic catches include carangids, sardinellas and cephalopods (Figure 2b).

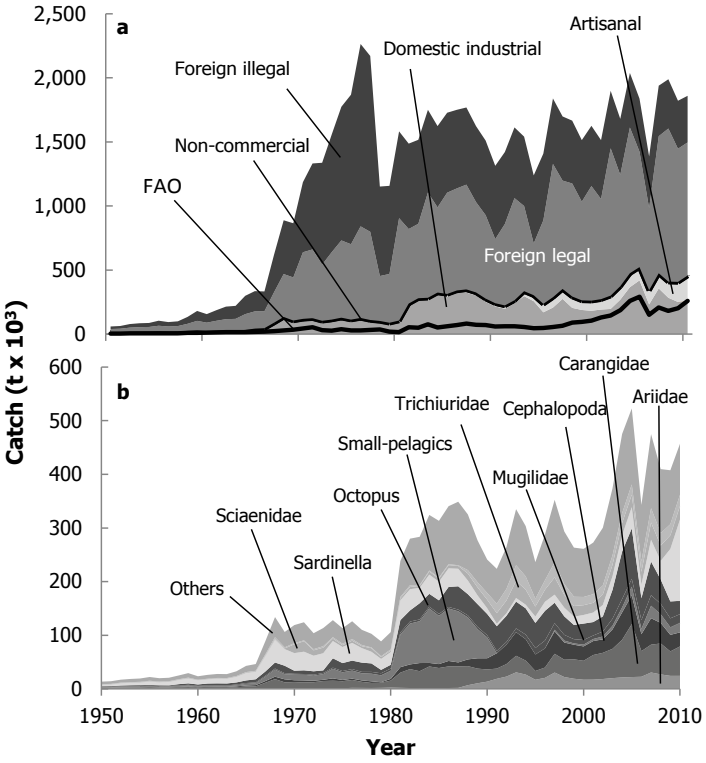

Figure 2. Reconstructed total removals from Mauritanian waters compared to the data supplied to FAO a) by the foreign and domestic fleets and b) by taxon, 1950-2010.

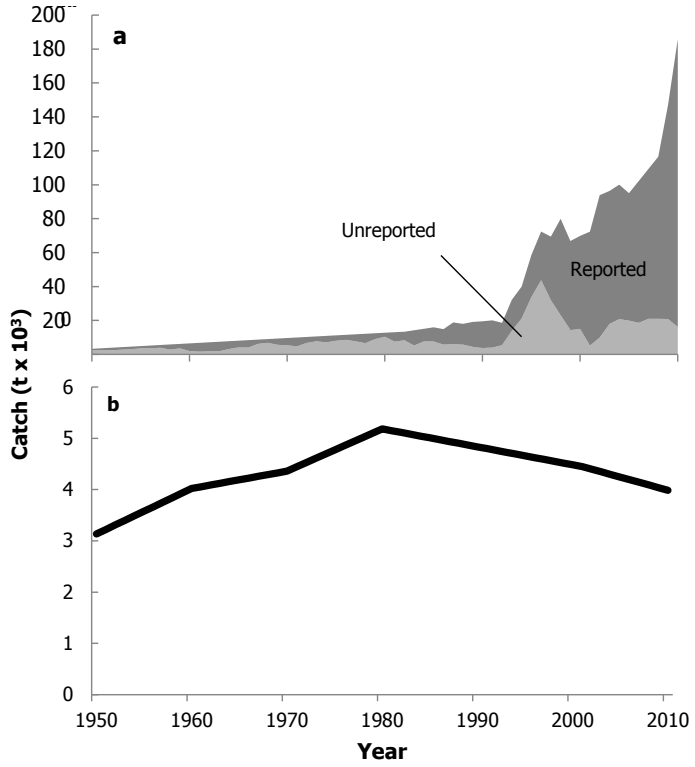

Figure 3. Estimated artisanal catches from a) Mauritania and b) the PNBA, 1950-2010.

Reconstructed catches by sector

Artisanal catches

Artisanal reconstructed catches totaled 2.2 million tonnes over the 1950 2010 time period (Figure 3a). Reconstructed artisanal catches increased from around 3,500 t·year^{-1} in 1950 to around 110,000 t·year^{-1} on average in the 2000s (Figure 3a). A sharp increase was observed in the mid-1990s driven by the high interest in the shark fin fishery. Imraguen catches were part of the artisanal catch, and were estimated to be 268,000 tonnes from 1950 to 2010, i.e., 16% of the total artisanal catch. These catches increased from around 3,100 t·year^{-1} in 1950, to a peak of 5,200 t·year^{-1} in 1980, when shark fishing begun (Figure 3b).

Subsistence catches

Total reconstructed subsistence catches, including catches by the Imraguen and N'Diago, were estimated to be over 139,000 tonnes for the 1950-2010 time period, i.e., more than 1% of the total reconstructed domestic catch (Figure 2a). Subsistence catches increased slightly from around 1,600 t·year^{-1} in 1950 to 2,900 t·year^{-1} in 2010, driven by the increase of N'Diago subsistence fishing activities in southern waters (Figure 4). The contribution of Imraguen catches to subsistence fisheries decreased from 90% in 1950 (1,500 t·year^{-1}) to less than 25% in 2010 (680 t·year^{-1}, Figure 4).

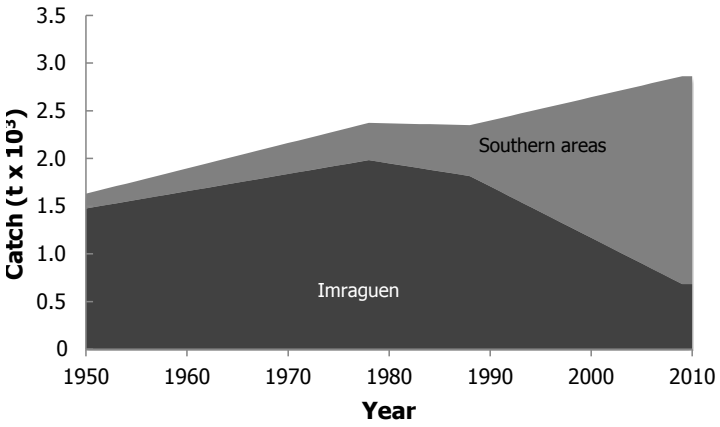

Figure 4. Reconstructed subsistence catches from Mauritania, 1950-2010.

Industrial catches by legal fleets

Domestic industrial catches in Mauritania were estimated at 9.4 million tonnes between 1950 and 2010, of which 5.2 million tonnes were discards. Industrial Mauritanian catches increased from 8,300 t·year^{-1} in 1950 to a peak of 420,000 t·year^{-1} in 2005, then decreased to 260,000 t·year^{-1} in 2010 (Figure 5a).

Legal industrial catches by the foreign fleet from Mauritanian waters, estimated at 32.1 million tonnes between 1950 and 2010, were the equivalent of around three times the domestic catch (Figure 5a). Foreign industrial catches increased from 14,230 t·year^{-1} in 1950 to be almost hundred times higher in 2008 (1.2 million t·year^{-1}), decreasing slightly thereafter to 1.04 million t·year^{-1} in 2010. Very large quantities were caught by eastern European and former Soviet Union countries (Latvia, Lithuania, Romania, Russian Federation, Slovenia and Ukraine) with 37% of the legal foreign catch, i.e., around 12 million tonnes for the period from 1950 to 2010. Flag of convenience (FOC) countries (mainly Chinese flying the flags of Cyprus and Belize) caught between 1987 and 2010 as much fish as Western Europe countries (France, Germany, Iceland, Italy, Netherlands, Spain, United Kingdom) in 60 years, with over 8.1 million tonnes (25%), whereas East Asian countries (China, Japan and Korea) were responsible of 8% of the total legal foreign removals (Figure 5b).

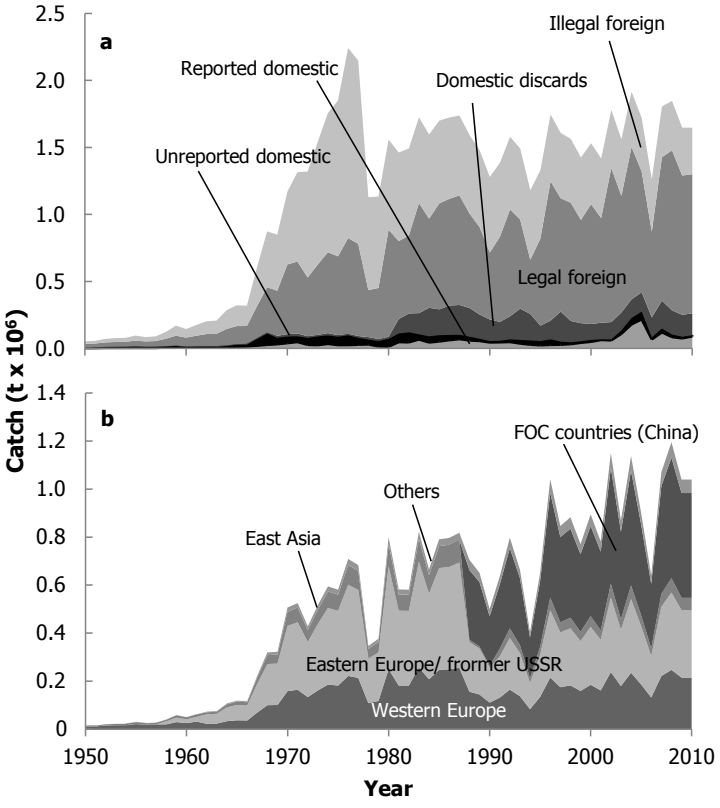

Figure 5. a) Estimated industrial domestic and foreign catches from the Mauritanian EEZ, and b) catches by the foreign legal fleets from Mauritania per country/region of origin, 1950-2010.

Canarian catches

Canarian catches were estimated at 372,500 tonnes between 1950 and 1980, when Canarian fishers left Mauritania. Catches increased slightly from 12,000 t·year^{-1} in 1950 to 16,000 t·year^{-1} in 1959, and then

decreased to zero in 1980. Canarian catches were overwhelmingly from the PNBA waters (Figure 6).

Illegal catches

Unregulated and illegal catches by foreign fleets in Mauritania were estimated to be over 27.9 million tonnes for the period from 1950 to 2010, which represented about 40% of the total removals by legal domestic and foreign vessels in Mauritania (Figure 2). Catches increased from 19,900 t·year^{-1} in 1950 to their maximum of 1.4 million t·year^{-1} in 1976, before the declaration of the Mauritanian EEZ, when they were considered unregulated rather than illegal. Illegal catches decreased thereafter to 359,000 t·year^{-1} in 2010 (Figure 7).

Illegal catches in the PNBA: Illegal catches in the Park National du Banc D'Arguin area totaled around 75,400 tonnes between 1950 and 2010 (Figure 8). Illegal fishing in the PNBA started in 1976 at around 3,070 t·year^{-1}, i.e., the equivalent of 26% of the total Imraguen catch (Figure 8). Catches decreased thereafter to 533 t·year^{-1} in 2010 representing 10% of the Imraguen artisanal and subsistence catch in the park area (Figure 8).

Illegal Senegalese catches: Illegal Senegalese catches in Mauritania totaled 435,200 tonnes betwen 1950 and 2010 (3% of the total illegal catch). Illegal Senegalese catches increased from 1,400 t·year^{-1} from 1950 to a peak of 15,600 t·year^{-1} in 2001, right when Mauritania handed over fishing authorizations to some 300 Senegalese pirogues, before increasing again to 17,000 t·year^{-1} in 2010 (Figure 8).

Illegal foreign (non-African) catches: Illegal catches by non-African countries (.e., excluding Senegal)were estimated at 27.4 million tonnes from 1950 to 2010 (Figure 9). Illegal catches by non-African countries increased from 18,500 t·year^{-1} in 1950 to reach a peak of 1.4 million t·year^{-1} in 1976, and then decreased to an average of 370,000 t·year^{-1} in the late 2000s (Figure 9). The former Soviet Union members and Eastern Europe countries (Lithuania, Romania, Russian Federation and Ukraine) totaled around 11.9 million tonnes between 1950 and 2010, i.e., 43% of the total non-African illegal catch (Figure 9). The Netherlands, Spain and Italy together caught more than 5.4 million tonnes over the same period, with Spain being responsible for most of the illegal catch by Western Europe (2.8 million tonnes) (Figure 9). Catches by Asian countries led by China (1.1 million tonnes) represented 14% of the total illegal non-African catch (Figure 9). Other countries (suspected to be of Chinese and Korean origins) contributed to 24% of these catches with over 6.5 million tonnes (Figure 9). These are most likely vessels flying flags of convenience.

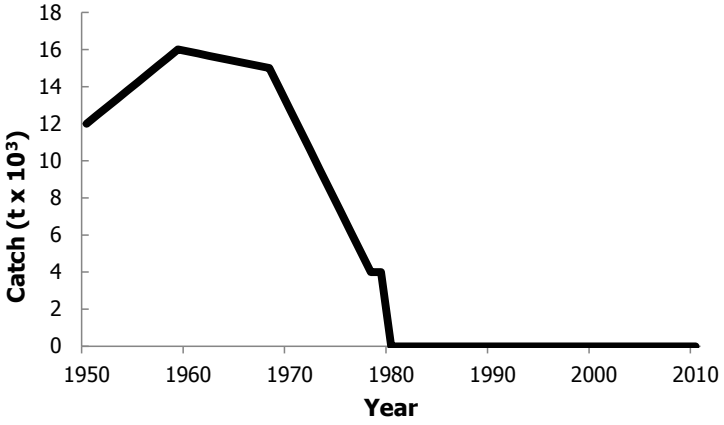

Figure 6. Reconstructed catches by fishers from the Canarian islands from Mauritania, 1950-2010.

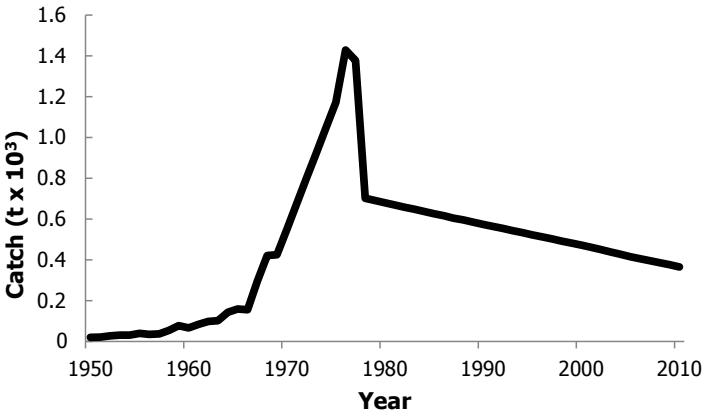

Figure 7. Estimated catches by illegal fleets from the waters of Mauritania, 1950-2010.

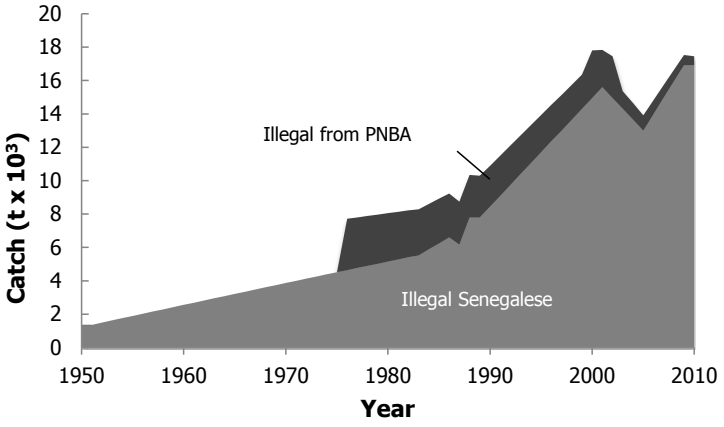

Figure 8. Illegal catches from the waters of the PNBA and by Senegalese illegal fishers in Mauritania, 1950-2010.

Domestic discards

Discards, estimated to be around 5.3 million tonnes for the period from 1950 to 2010, increased from 1,700 t·year^{-1} in 1950 to 16,000 t·year^{-1} in 1980 (Figure 10) and then increased rapidly with the increase of industrial domestic catches to 213,000 t·year^{-1} in 1984, and remained relatively at a high level since then (Figure 10).

Recreational catches

Reconstructed recreational catches in Mauritania, particularly in the PNBA, were relatively low, estimated at 1 t·year^{-1} in 1971, increased to a peak of 138 t·year^{-1} in 1984, decreased drastically to less than 8 t·year^{-1} in 1989, with the conflict between Mauritania and Senegal and then increased again to 108 t·year^{-1} in 2003, before decreasing to a minimum of 3 t·year^{-1} in 2010 (Figure 11).

Discussion

Total reconstructed catches taken from Mauritanian waters were estimated to be 72.1 million tonnes over the 1950-2010 time period. These catches went overwhelmingly to fleets of foreign origin, i.e., 60 million tonnes, of which over 27.9 million tonnes were illegally caught. The foreign legal catch provided few and low domestic benefits, and most of the value was going overseas (Barbut 2008). Mauritanian domestic catches, including the artisanal and subsistence catch, and the industrial sector operated by vessels of foreign origin, were estimated at 11.6 million tonnes, three times the catch data of 3.8 million tonnes supplied to the FAO. However, this work excluded the relatively high Senegalese catch under agreement with Mauritania, which in 2012 was estimated at around 100,000 t·year^{-1}.

The political context played an important role on how Mauritanian fisheries evolved over time. Indeed, the ten years that followed Mauritanian independence from France (in 1960) exposed Mauritanian waters to the bulk of illegal foreign fishing. Furthermore, prior to the 1989 events between Mauritania and Senegal, Senegalese illegal catches were a matter of lack of regulation and monitoring. It is only after the political events that the Mauritanian government began to enforce prohibition of unregulated 'foreign' fishing in its territorial waters. Senegalese fishers seeking economic refuge were forced to operate in waters off Mauritania because of the scarcity of the resources in their traditional fishing grounds (Failler and Binet 2012). These fishers accuse EU and Asian illegal vessels of depleting fisheries resources (UNEP 2006). Although ignored by the management body, this activity contributed to the extraction of over 422,000 tonnes during the last 60 years, which is almost as high as the Imraguen catch in the PNBA. Furthermore, another 100,000 t·year^{-1} caught by legal Senegalese fisheries could be added to the equation in the late 2000s according to anonymous official sources.

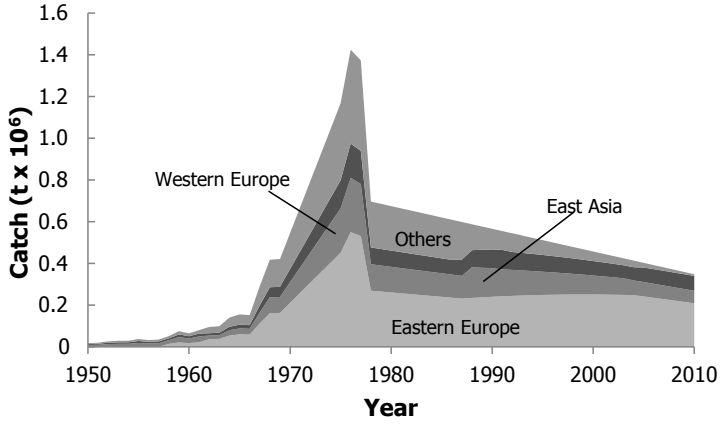

Figure 9. Catches by the illegal foreign (non-African fleets) from Mauritania, 1950-2010.

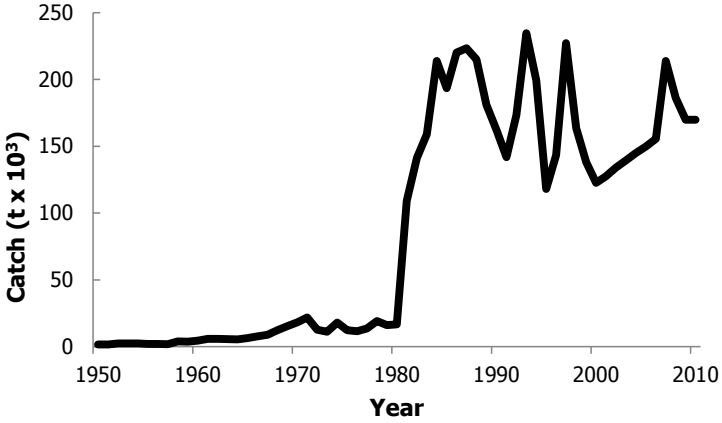

Figure 10. Discards by the domestic fisheries of Mauritania, 1950-2010.

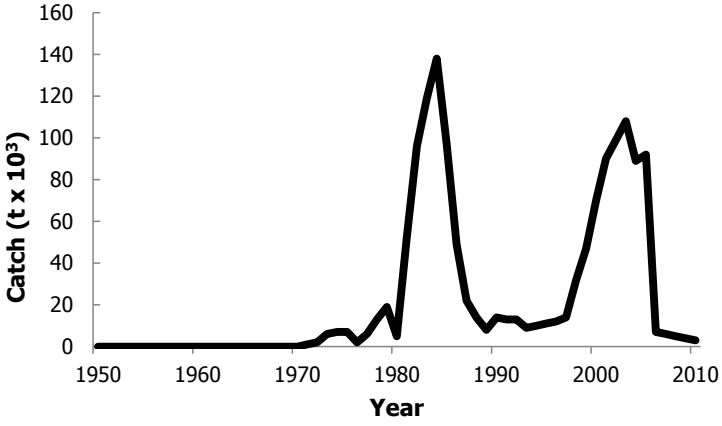

Figure 11. Recreational catches from Mauritania, 1950-2010.

This raises serious concerns regarding the quality of data submitted to FAO by Mauritania, and highlights the significant correlation existing between IUU fishing and poor governance (Mallory 2012). Furthermore, the Mauritanian government reporting the chartered and joint-venture vessel catches as 'domestic', despite the majority of the benefit of these catches going overseas (e.g. most of them are Chinese), is only but aggravating the transparency issues around the low benefits received by the Mauritanian population (Agnew *et al.* 2010). Indeed, despite this large contribution to fisheries removals, the true economic, social and food security contribution of joint ventures and charter activities beyond access fees in questionable (Goffinet 1992; Ould Cheikhna *et al.* 2005; Folsom and Weidner 1976 in Pramod *et al.* 2008; Dobo 2009; Cherif 2011).

Thus, in Mauritania, the extent of foreign fishing access agreements is strongly related to the level of debt of the country, and the fees paid suggest economic desperation (Gorez and Oriordan 2003). For example, in the case of foreign industrial tuna vessels operating off Mauritania, the cost of fishing licenses paid to Mauritania represented as little as 0.18% of the estimated catch value (Solie 2004). Another example is the octopus stock which has been driven to its lowest historical abundance (UNEP 2006), yet new fishing agreements have been signed with China to target these species (Cherif 2011). Moreover, subsidized access by the EU fleet to Mauritanian waters unfairly outcompeted the local artisanal industry (Gorez and Oriordan 2003; CTA 2011).

Mauritania does not have a long-standing fishing tradition (Scharm and Schack 2006; Gascuel *et al.* 2007), with official fish consumption figures between 6.8 kg·capita^{-1}·year^{-1} and 17 kg·capita^{-1}·year^{-1} in coastal areas, and 3 kg·capita^{-1}·year^{-1} in eastern areas (Ould Cheikhna *et al.* 2005). However, such average official numbers do not reflect the vital importance of fish for traditional fishing communities, where fish consumption can reach up to 80 kg·capita^{-1}·year^{-1} in the case of the Imraguen and N'Diago (Failler *et al.* 2002). Unfortunately, fish consumption in the area is in rapid decline (Failler *et al.* 2002), due to the over-exploitation of fish stocks (UNEP 2006; Agnew *et al.* 2010) and trade liberalization on shark fisheries which are not traditionally consumed by Mauritanian people for religious and cultural reasons (UNEP 2006). In the PNBA, the Imraguen who are strictly dependent on fishing activities, have seen their catch decline by almost three fold. The increase shown by official reports may be due to an increase in reporting rather than an increase in catches, which would be questionable given the over-exploitation pattern the area witnessed. This suggests a shifting baseline (Pauly 1995). When compared to available recent survey data (Kane Élimane 2011), these catches are two fold the reported numbers. These estimates have low uncertainty, since onsite surveys from direct observations by Failler *et al.* (2002) showed similar catches in the waters of the PNBA. Likewise, artisanal catches in the 2000s were estimated to be around 80,000 t ± 10,000 t by Ould Cheikhna *et al.* (2005), which corresponds to our estimate in the present study.

Subsistence fishing, which in 1950 represented 36% of the small-scale catch, decreased to around 2% in recent years. This could be related to the increase in catch-based economic activities by both Imraguen and N'Diago traditional fishing communities. The economic interest in species like sharks resulted in strong overfishing, which besides impacting livelihoods, increased conflict over fishing grounds and resources (Lenselink 2004). Furthermore, evidence suggests effort in Mauritania is focused on resource exploitation and profit maximization in the short term (Trouillet *et al.* 2011) rather than long term economic profitability and food security, with only 10% of the catch being landed in Mauritania (CTA 2011). Indeed, Mauritania was identified as suffering from abnormal food shortages in the 1980s (Pollnac 1985), yet most of the fish produced goes overseas. Furthermore, development strategies around fisheries are still based on exports and handing over fishing access agreements or joint ventures. This represents a danger, both for fisheries sustainability and for food security in Mauritania. Mauritania, like its neighbors is at risk of facing a major food security issue related to the lack of protein if the current questions around fisheries, such as the realistic benefits of fishing access agreements, illegal fishing, and short term profits are not addressed.

Our estimation of artisanal catches from the entire Mauritanian coast from 1950 to 2010 showed that the bulk of the artisanal Mauritania catches were caught by the Imraguen in the waters of the PNBA up until the early 1980s. This further supports the hypothesis that the data on Mauritania artisanal effort are heavily under-estimated and was fragmentary up until the 1980s when data collection started expanding to cover the rest of the Mauritanian regions. Futhermore, this illustrates the importance of fisheries to local communities dependant upon them.

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Appendix Table A1. Annual catches from Mauritania's EEZ, 1950-2010.

Year	Reported to FAO	Artisanal	Subsistence	Industrial	Discards	Total domestic	Total foreign
1950	3,000	3,286	1,629	6,835	1,680	13,166	34,089
1951	3,000	3,608	1,656	7,285	1,677	13,962	36,541
1952	5,000	3,930	1,682	9,079	2,395	16,806	48,460
1953	5,000	4,252	1,709	10,079	2,411	18,152	52,955
1954	5,000	4,573	1,735	10,565	2,433	18,991	53,899
1955	5,000	4,894	1,762	13,343	2,077	21,743	68,363
1956	5,000	5,214	1,788	10,755	2,090	19,498	59,317
1957	5,000	5,534	1,815	11,613	1,743	20,337	64,036
1958	10,000	5,853	1,841	13,389	3,829	24,528	93,550
1959	10,000	6,172	1,868	17,538	3,745	28,922	135,406
1960	12,000	6,491	1,894	10,614	4,447	23,028	116,749
1961	14,000	6,809	1,921	11,521	5,806	25,621	144,820
1962	15,000	7,127	1,947	12,935	5,738	27,293	171,805
1963	15,000	7,444	1,974	12,353	5,722	27,021	178,075
1964	15,000	7,761	2,000	17,461	5,526	32,260	251,557
1965	17,000	8,077	2,027	26,435	6,298	42,332	278,297
1966	19,000	8,393	2,053	28,024	7,803	45,751	272,590
1967	22,700	8,708	2,080	69,336	8,931	88,516	518,061
1968	29,000	9,023	2,107	110,405	12,297	133,276	742,815
1969	35,000	9,338	2,133	79,169	15,396	105,462	748,324
1970	43,570	9,652	2,160	88,921	18,174	118,316	1,058,611
1971	52,925	9,966	2,186	90,258	21,747	123,549	1,201,253
1972	30,291	10,279	2,213	78,480	12,764	103,112	1,228,166
1973	27,190	10,592	2,239	89,417	11,108	112,714	1,442,044
1974	37,697	10,905	2,266	96,818	18,091	127,421	1,644,901
1975	27,921	11,217	2,292	87,219	12,339	112,392	1,755,672
1976	27,834	11,528	2,319	97,462	11,630	125,317	2,141,277
1977	31,897	11,839	2,345	79,297	13,557	109,355	2,064,540
1978	35,467	12,150	2,372	65,917	19,190	101,883	1,049,584
1979	18,541	12,460	2,369	54,546	16,177	87,748	1,069,230
1980	15,598	12,770	2,367	71,002	16,742	105,016	1,483,061
1981	52,779	13,079	2,364	111,090	109,026	237,636	1,253,656
1982	50,288	13,349	2,362	120,136	141,297	279,162	1,241,946
1983	75,600	14,222	2,359	105,074	158,966	282,551	1,473,594
1984	51,676	15,094	2,357	90,011	213,978	323,283	1,305,077
1985	60,277	15,965	2,354	98,641	193,559	312,273	1,420,851
1986	70,614	14,877	2,352	100,440	220,257	339,690	1,416,175
1987	82,397	18,840	2,350	101,726	223,390	347,827	1,426,319
1988	71,666	18,007	2,347	87,304	214,993	324,169	1,300,084
1989	70,000	19,146	2,372	71,949	181,070	275,953	1,235,279
1990	60,000	19,517	2,396	54,625	162,129	240,018	1,074,170
1991	61,637	20,066	2,420	57,058	141,825	222,647	1,199,703
1992	61,054	18,621	2,445	67,461	173,519	263,351	1,350,873
1993	54,452	32,188	2,469	63,465	234,587	333,290	1,208,348
1994	46,746	39,920	2,494	59,391	199,384	301,337	937,455
1995	48,147	58,501	2,518	54,946	118,072	233,210	1,174,693
1996	55,324	72,394	2,542	67,376	143,450	284,196	1,553,252
1997	65,127	69,442	2,567	51,150	227,164	348,858	1,348,358
1998	89,043	79,924	2,591	45,298	163,527	289,306	1,374,626
1999	94,527	66,828	2,616	53,516	138,301	259,836	1,252,488
2000	104,456	69,856	2,640	63,032	122,560	257,305	1,366,374
2001	130,142	72,345	2,664	67,745	127,618	268,850	1,243,074
2002	144,131	93,856	2,689	67,253	133,984	295,455	1,600,210
2003	187,650	96,326	2,713	134,167	139,397	368,716	1,307,894
2004	258,733	100,058	2,738	226,558	144,874	470,077	1,564,616
2005	291,877	95,043	2,762	274,145	149,913	517,886	1,316,408
2006	150,312	102,204	2,786	81,530	155,562	337,669	1,045,176
2007	208,207	109,366	2,811	148,212	213,816	469,357	1,465,632
2008	180,328	116,528	2,835	103,388	186,296	403,764	1,580,825
2009	201,900	123,690	2,860	72,984	169,868	363,684	1,415,180
2010	261,238	123,690	2,860	64,403	169,868	355,027	1,404,298

Appendix Table A2. Six most important taxa caught by domestic fisheries in Mauritania's EEZ, 1950-2010.

Year	Ariidae	Carangidae	Cephalopoda	Small-pelagics	Mugilidae	Octopus	Sciaenidae	Trichiuridae	Othersa
1950	809	1,101	384	3,795	711	910	839	204	4,673
1951	840	1,188	382	4,067	779	923	875	224	4,943
1952	828	1,350	589	5,486	803	1,434	866	237	5,490
1953	863	1,527	595	5,996	874	1,466	906	278	5,941
1954	894	1,623	593	6,290	941	1,477	942	300	6,243
1955	916	2,038	523	7,950	999	1,324	969	410	6,943
1956	928	1,625	485	6,901	1,042	1,247	984	313	6,319
1957	939	1,723	397	7,717	1,084	1,049	999	349	6,445
1958	896	1,711	974	9,553	1,052	2,437	954	273	7,059
1959	959	2,366	1,037	11,343	1,161	2,608	1,025	430	8,391
1960	863	1,212	1,042	9,229	1,049	2,609	923	134	6,381
1961	899	1,337	1,399	9,518	1,128	3,484	965	116	7,208
1962	895	1,422	1,435	10,776	1,150	3,582	963	139	7,380
1963	906	1,370	1,392	10,677	1,193	3,491	978	127	7,354
1964	992	2,078	1,544	12,649	1,355	3,893	1,075	300	8,859
1965	1,051	3,336	1,915	16,988	1,480	4,815	1,144	569	11,535
1966	1,080	3,561	2,343	17,536	1,557	5,866	1,178	568	12,579
1967	1,191	10,166	3,189	36,690	1,777	7,943	1,305	2,083	24,705
1968	1,242	16,865	4,578	55,491	1,899	11,303	1,366	3,542	37,543
1969	1,217	10,906	5,642	40,591	1,886	13,869	1,341	2,028	28,551
1970	1,007	11,614	3,421	43,315	1,528	5,725	16,466	2,102	33,723
1971	955	10,884	3,893	45,269	1,440	6,839	19,380	1,805	33,690
1972	1,172	11,184	2,739	38,430	1,856	6,394	10,037	2,190	29,731
1973	1,241	13,347	2,330	42,636	1,998	4,848	10,424	2,759	33,776
1974	1,150	13,995	4,342	50,168	2,070	17,498	4,449	2,667	31,742
1975	1,205	13,049	2,292	44,323	2,367	14,790	3,365	2,647	29,031
1976	1,840	14,776	2,334	48,050	2,929	15,771	4,087	3,075	33,146
1977	1,734	11,275	2,749	40,379	2,565	17,260	3,571	2,184	28,346
1978	1,628	9,356	3,032	35,883	3,394	15,813	6,638	1,528	25,347
1979	1,840	9,498	1,036	33,311	3,864	6,318	3,282	1,672	27,682
1980	2,265	13,094	3,250	38,767	4,120	7,007	2,667	2,448	32,155
1981	1,891	28,324	10,219	97,848	3,760	23,115	3,525	2,707	67,067
1982	1,544	35,269	8,721	115,751	3,772	20,778	4,114	3,272	86,819
1983	1,510	31,381	15,226	106,668	3,315	30,183	3,688	1,631	89,893
1984	1,323	40,422	6,561	137,355	3,323	23,999	5,663	1,990	103,653
1985	1,277	37,557	7,307	124,512	3,687	25,324	5,868	2,044	105,704
1986	1,577	40,254	10,184	132,492	2,914	37,325	5,947	1,672	108,232
1987	1,815	40,006	7,474	127,929	3,269	43,416	5,228	1,409	118,358
1988	6,805	35,538	12,562	103,653	3,813	39,575	13,030	6,400	103,821
1989	10,406	27,335	19,234	70,624	4,173	42,519	15,019	9,590	78,132
1990	13,396	22,717	20,908	49,427	4,179	39,774	15,952	12,486	62,283
1991	18,712	19,083	28,552	4,546	4,504	45,958	19,737	17,678	65,010
1992	22,870	23,300	36,295	4,656	5,009	48,683	23,895	21,640	78,066
1993	30,767	30,860	44,084	6,721	7,011	49,945	31,995	29,208	104,438
1994	26,598	26,075	39,976	6,773	8,520	48,960	28,010	24,719	93,834
1995	16,935	16,357	30,948	11,814	11,920	46,796	18,687	14,479	68,332
1996	20,508	19,258	35,728	16,939	14,655	55,338	22,477	17,625	85,423
1997	30,423	34,915	41,957	18,049	12,140	38,172	32,197	28,147	116,469
1998	22,018	32,336	32,009	19,846	10,701	34,531	23,763	20,206	98,051
1999	18,851	36,159	27,252	17,979	7,844	26,503	19,912	17,204	91,647
2000	17,023	35,297	26,791	19,356	8,635	30,648	18,218	15,348	89,700
2001	17,150	45,912	26,045	21,522	6,529	25,083	18,120	16,074	96,252
2002	18,339	48,818	25,187	26,633	9,243	28,175	19,570	16,845	107,568
2003	19,956	54,668	36,163	32,272	13,021	53,826	21,294	17,607	124,966
2004	21,326	70,135	51,103	39,517	15,615	88,667	22,785	18,414	147,741
2005	21,976	98,652	53,752	55,766	14,642	94,066	23,248	19,178	141,585
2006	22,543	47,750	31,618	35,021	16,371	40,844	23,924	19,597	105,256
2007	30,528	51,854	49,301	63,968	19,680	62,729	32,155	26,705	138,050
2008	26,922	57,702	38,374	50,688	19,497	45,305	28,543	23,141	119,564
2009	24,211	45,611	30,856	112,101	16,528	31,516	25,557	20,623	100,582
2010	24,234	54,829	26,233	169,372	16,043	24,922	25,509	20,716	95,124

a) 'others' includes *Alectis alexandrinus, Brachydeuterus auritus, Cynoglossus goreensis, Decapterus rhonchus, Dentex* spp., D*icentrarchus punctatus, Dicolocoglossa cuneata, Diplodus* spp., Drepanidae, *Epinephelus* spp., *Galeoides decadactylus, Gynglimostoma ceratum, Leptocharias smithii, Mycteroperca rubra, Pagellus bellottii, Panulirus regius,* elasmobranchii and other fishes and crustaceans.

Reconstruction of marine fisheries catches for the Republic of Cape Verde, 1950-2010[1]

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Abstract

Total marine fisheries catches were estimated for the islands of Cape Verde from 1950 to 2010. Fisheries catch data were very limited before 1981, when the first fisheries landing surveys started. Catches reported by the Cape Verdean National Institute of Fisheries Development to FAO represent only domestic commercial catches by national fleets. Inconsistencies were found in the data supplied to FAO and were adjusted using various governmental and non-governmental sources. Total marine fisheries catches for 1950-2010 were estimated at over 758,500 t, including subsistence catches (131,600 t), recreational catches (7,700 t), baitfish catches (177,000 t). Total reconstructed catches of over 758,500 t were 1.7 times the landings of 442,318 t reported by Cape Verde to FAO.

Introduction

The Republic of Cape Verde, a former Portuguese colony which gained independence in 1975, is comprised of 10 major islands and numerous islets of volcanic origin. Situated off West Africa between latitude 15.8°N and longitude 23.8°W, it covers a land area of approximately 4,000 km² with an Exclusive Economic Zone (EEZ) of around 790,000 km² (Figure 1, www.seaaroundus.org). Nine of these islands are inhabited with a total human population of 491,875 (INE 2010). The uninhabited islands are often used by fishers for overnight encampments (Meintel 1984; Silva 2009).

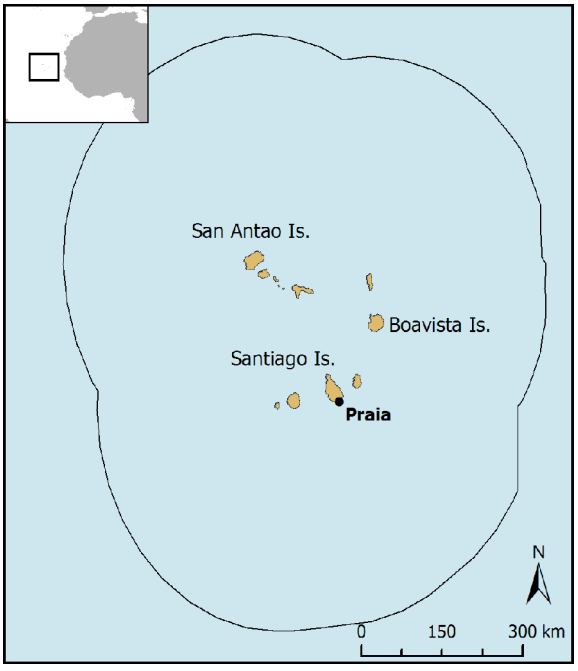

Figure 1. The Cape Verde islands and their Exclusive Economic Zone.

Darwin's visit to Cape Verde aboard the *M.H.S. Beagle* in 1832 highlighted these islands' marine life (Almeida 1997; Pauly 2004; Stobberup 2005). However, fisheries research and monitoring were neglected until recently (MAAP 2004). It was only in 1981 that a national fisheries agency started to collect catch and effort data (Monteiro 2002; Stobberup and Erzini 2006). Today, the National Institute of Fisheries Development (INDP) is responsible for the collection of fisheries statistics.

Domestic fisheries in Cape Verde are classified into three sectors: artisanal (small-scale), semi-industrial and industrial (INDP 2008, 2009; MegaPesca 2010). Small-scale fisheries represent an important source of employment (Baptista *et al.* 2006) and supply of animal protein for the local population (Tvedten and Hersoug

[1] Cite as: Trindade Santos, I., Monteiro, C.A., Harper, S., Zylich, K., Zeller, D. and Belhabib, D. (2012) Reconstruction of marine fisheries catches for the Republic of Cape Verde, 1950-2010. pp 79-90. In: Belhabib, D., Zeller, D., Harper, S. and Pauly, D. (eds.), Marine fisheries catches in West Africa, 1950-2010, part I. Fisheries Centre Research Reports 20 (3). Fisheries Centre, University of British Columbia, Canada [ISSN 1198-6727].

1992). The small-scale fleet comprises boats ranging from 3 to 8 meters, which use hand-lines for large pelagic and demersal species, and purse seine, beach seine (*arrasto de praia*), gill net and dynamite for small pelagic species. The latter are used as baitfish or for direct human consumption (MegaPesca 2004). Scuba diving is practiced to catch coastal lobsters, mollusks and demersal fish species (MAAP 2004). Florida fighting conch (*Strombus alatus*) is widely exploited for tourist and domestic consumption (SEPA 1999). Both activities, scuba diving and catching conch, are considered small-scale fisheries.

The domestic semi-industrial and industrial fleets, here called "large-scale", operate boats from 8 to 20 meters and 20 to 28 meters, respectively (Fonseca 2000; MegaPesca 2004, 2010). These fleets target mainly large pelagic and demersal fishes using hand-line and pole and line, small pelagic species with purse-seine, and lobsters using traps (MAAP 2004). Prior to 1991, tuna landings represent about 80% of the total large-scale catch. In 1992, when new purse seine vessels targeting small pelagic species were introduced to this fishery sector, tuna landings started to decrease, and eventually tuna in total large-scale landings decreased to about 40% by 1998 (Fonseca 2000).

Recreational fisheries, which started, along with tourism in 1939 (Fialho 2011; CVRS 2012), are encouraged by the government and have developed alongside the tourism industry (Cabral 2005; MegaPesca 2010; ESR 2011). However, recreational catch data in Cape Verde, as in many other countries (e.g., Zeller *et al.* 2008), is scarce as the fisheries lacks monitoring.

Despite substantial investments in Cape Verdean fisheries, many coastal fishing communities suffer high rates of poverty (Baptista *et al.* 2009). These populations are heavily dependent on foreign aid, which covers about 40% of food imports (MegaPesca 2010). Furthermore, rising temperatures, decreasing rainfall and cyclical droughts related to climate change in the Sahel have further exposed rural populations to food security issues due to declining agricultural production (Kandji *et al.* 2006; Badjeck *et al.* 2011). Subsequently, populations tend to respond to climate change effects on agriculture by increasing fishing effort, thus placing increased pressure on coastal fisheries resources (MAAP 2004).

Extractions of marine fisheries resources are often underestimated in official statistics (Zeller *et al.* 2007). Landings data presented by FAO on behalf of countries cover mainly commercial fisheries (Garibaldi 2012), and Cape Verde is no exception (MAAP 2004). Cape Verdean fisheries play an important role in national food security and the local economy (Baptista and Santos 2008; ESR 2011). Hence, the aim of this study is to provide a comprehensive estimate of total domestic marine fisheries catches from Cape Verde, including reported landings and unreported catches (i.e. subsistence catches, discards, and recreational catches) from 1950 to 2010.

Methods

Reported landings data were acquired from the FAO FishStatJ database, along with various publications, including bulletins from the National Institute of Fisheries Development of Cape Verde (INDP) for the period from 1950 to 2010 (Stobberup 2005). Using all available sources, we derived estimates of (1) adjusted landings, (2) baitfish catch, (3) discards, (4) recreational catches, and (5) subsistence catches, using a catch reconstruction approach (Zeller *et al.* 2007; Zeller and Pauly 2007).

Adjusted and unreported landings

Differences between the data reported by FAO and those supplied by INDP were identified for some time-periods, mainly 1950-1985 and 2004-2010. From 1986 to 2002, we kept the data supplied by INDP as the reported baseline, since they were consistent with FAO (Figure 2). We used landings data presented by Watanabe (1981, in Stobberup 2005) from 1956 to 1980 as a more reliable estimate, based on a compilation from various sources, and replaced the data reported to FAO for this period. To estimate landings from 1950 to 1956, we carried the 1956-1960 trend backwards and completed the time series. From 1981 to 1985, landings data from Stobberup (2005) were used, as the data supplied to FAO contained extrapolations errors, which were later identified by the INDP (Figure 2). From 2004 to 2010, FAO landings were greater than reported landings by INDP, due to the inclusion of catches by re-flagged foreign vessels targeting large pelagic species in the FAO data (Carlos Alberto Monteiro, pers. obs. INDP). These reflagged catches were identified as such, and

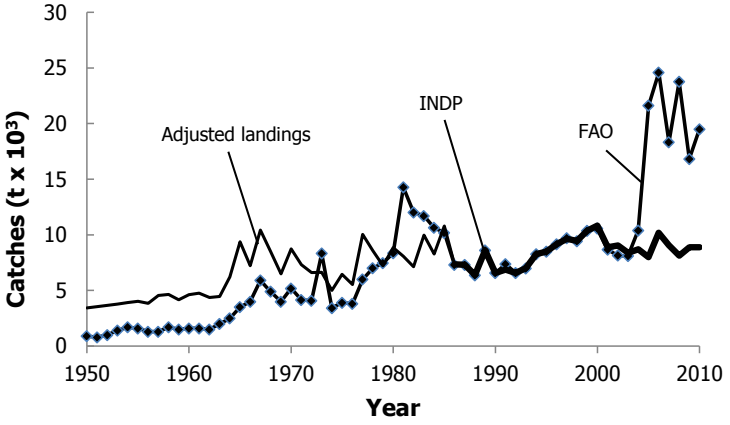

Figure 2. Adjusted landings from 1950 to 1985 (non-marked thin line without dots) and official INDP reported landings from 1986 to 2009 (thick line without dots). Lines without dots were used as domestic base line used in the resconstruction process, line with dots: data reported by FAO.

treated as non-EEZ reported landings. These adjusted for 1950-2010 were used as the baseline to estimate unreported domestic catch components (adjusting landings revealed that part of these were unreported between 1950 and 1980). Landings were separated into two sectors based on INDP (1998; 2008; 2009): the artisanal sector operated by boats between 3 and 8 meters, and the large-scale (also-called semi-industrial) sector operated by boats of over 8 meters long.

Table 1: Cape Verdean fleets and trips reported by INDP and its respective quantity of bait fish used per trip.

Fleet	Year	Boats	Effort (trips·boat^{-1}·year^{-1})	Catches (t)	Source	Bait·boat^{-1}·trip^{-1} (kg)	Source
Small-scale fleet	2009	136	135	4,552	INDP 2009	5	Silva (2009)
Large-scale fleet	2009	89	69	4,328	INDP 2009	380	MAAP (2003)

Baitfish catches

Baitfish is important for both small-scale and large-scale fisheries in Cape Verde (MegaPesca 2004). The small-scale fishery uses about 5 kg·boat^{-1}·trip^{-1} of live bait (Table 1) to catch large pelagic and demersal species (SEP 1985; Silva 2009). Similarly, the large-scale fleet, which also targets large pelagic and demersal species, and lobsters (MegaPesca 2010), uses around 380 kg·boat^{-1}·trip^{-1} of bait fish (Table 1), where 50% are eventually discarded (MAAP 2004).

The number of boats and the corresponding number of trips were obtained from INDP (2009) for 2009 (Table 1), then multiplied by 5 kg·boat^{-1}·trip^{-1} for small-scale boats and 380 kg·boat^{-1}·trip^{-1} for large-scale boats, resulting in a baitfish catch rate of 700 t·year^{-1} for small-scale boats and 2,333 t·year^{-1} for large-scale boats. Thereafter, we used landings by INDP (2009) to estimate the ratio 'bait fish/landings of targeted species', where 700 t·year^{-1} of bait fish were used to catch 4,552 t·year^{-1} of fish by the small-scale fleet, and 2,333 t·year^{-1} of bait fish were used to catch 4,328 t·year^{-1} by the large-scale fleet, i.e., 15% and 54%, respectively in 2009. We assumed constant rates from 1950 to 2010 and applied these rates over the adjusted landings to estimate total small pelagic baitfish catches from 1950 to 2010.

Dynamite use in bait fisheries

Fishers have been using dynamite to catch baitfish in Cape Verde since the 1950s, (MAAP 2004). This practice is illegal, but is still widely used. We treat these baitfish catches as unreported catch, since it is not regulated or monitored (Medina *et al.* 2002). Dynamite fishing is particularly damaging as it generates high rates of underwater mortality (Vakily 1993). In 1985, a development programme encouraged the use of purse seines in the artisanal small-scale fishery, as an alternative to the use of explosives (MAAP 2004; Silva 2009). Since then, purse seine fishing has increased and slowly replaced dynamite fishing (MAAP 2004). Therefore, we assumed that from 1950 to 1985, the amount of baitfish caught by dynamite fishing was the equivalent of 50% of the total baitfish estimated, and decreased this percentage to 10% by 2010, as the use of dynamite decreased (MAAP 2004).

Discards

Cape Verdean fishery discards are generated by the baitfish fishery. However for the purposes of this study, the underwater mortality generated by explosives was not considered. Keeping baitfish alive onboard fishing vessels is an important issue in Cape Verde fisheries (SEP 1985). The issue here is lack of sufficient space to keep the baitfish alive. Hence, a large proportion of the live baitfish, i.e. 50%, dies onboard fishing vessels (MAAP 2004). Therefore, to estimate onboard discards generated by the baitfish fishery, we used a discard rate of 50% applied to the total reconstructed baitfish catch.

Recreational catches

Cape Verde does not supply any recreational catch data to FAO. Recreational fishing in Cape Verde, a member of the International Game Fish Association (IGFA 2012), started after the first airport opened in 1939 (Fialho 2011), and is practiced exclusively by tourists (MAAP 2004). The total number of tourists

Table 2: Recreational fishery estimates for Cape Verde.

Year	Number of Tourists	Number of tourists fishing	CPUE (t·tourist^{-1}·year^{-1})	Catches (t)
1939	0[a]	0	-	-
1988	14,000[b]	175	0.248	44
1990	23,000[b]	288	0.248	71
1995	58,000[b]	727	0.215	157
2000	145,076[c]	1,818	0.183	332
2001	162,000[c]	2,030	0.176	358
2002	152,000[c]	1,905	0.170	323
2003	178,790[c]	2,241	0.163	366
2004	184,738[c]	2,315	0.157	363
2005	233,548[c]	2,927	0.150	439
2006	280,582[c]	3,517	0.144	505
2007	312,880[c]	3,921	0.137	537
2008	333,354[c]	4,178	0.131	545
2009[d]	330,319[c]	4,140	0.124	513
2010	381,831[b]	4,786	0.124	593

[a]Assumed-value; [b]www.ine.cv [2012]; [c]Anon (2010); [d] For 2009, the catches were extracted from the web site [www.capeverdemarlin.com], Anon (2012).

was available for 1988, 1990, 1995, and from 2000 to 2010 (CCIT 2010) (Table 2). We interpolated linearly from zero tourists in 1939 to 14,000 tourists in 1988 and completed the time series by a series of linear interpolations between 1988 and 2000.

Table 3: Taxonomic composition of recreational catches.

Common name	Taxon name	%[a]
Marlins	*Makaira* spp.	70
Wahoo	*Acanthocybium solandri*	7
Yellowfin tuna	*Thunnus albacares*	10
Sailfish	*Istiophorus platypterus*	3
Gilthead seabream	*Sparus* spp.	3
Groupers	*Epinephelus* spp.	3
Others		3

a) Percentages from Anon (2012).

The number of recreational fishers (92 tourist·month^{-1}), the number of trips (4 trips·tourist^{-1}·year^{-1}), and catch per tourist (124 kg·tourist^{-1}·day^{-1} or 0.496 t·tourist^{-1}·year^{-1}), were available for 2009 from a company offering "fishing safaris" in Cape Verde (Anon. 2012). As these catches were likely highliner catches from the most successful fishers, presented for advertising and promotional purposes, we assumed the actual catch rate to be 25% of the reported catch, i.e., 0.124 t·tourist^{-1}·year^{-1}. Due to the high development of tourism in the archipelago (Cabral 2005), we conservatively assumed the number of companies offering fishing safaris was 1 per island (9 companies in total), with the same average number of tourists per company, i.e., 828 tourists·month^{-1}. Since the number of fishing tourists represents a monthly average over seven months, we conservatively assumed that the number of recreational fishers was five times as high as the previous estimate over a one year period. We estimated the percentage of recreational fishers (4,140) out of the total number of tourists (330,319), i.e., 1.3%, and applied this rate to the total number of tourists from 1950 to 2010 (excluding 2009) to derive a time series of recreational fishers (Table 2).

We assumed the annual catch per tourist from 1950 to 1990 was twice (0.248 t·tourist^{-1}·year^{-1}) the 2009 and 2010 catch rate (0.124 t·tourist^{-1}·year^{-1}, Table 2) because of the overexploitation of large pelagic species targeted by tourists in the archipelago and commercial fisheries (Monteiro 2002; Stobberup 2005). A linear interpolation was used between 1991 and 2009 to complete the time series. We then estimated the total annual catch by multiplying the total number of recreational fishers by the catch per tourist for each year (Table 2). Recreational catches were disaggregated using catch data by Anon. (2012, Table 3).

Subsistence catches

Cape Verdeans catch fish to meet their nutritional needs via subsistence fishing (WorldBank 2008; Baptista *et al.* 2009). These catches consist mainly of mackerel scad (*Decapterus macarellus*) and other small pelagic species, which are not reported, and thus not included in official catch figures (MAAP 2004). Subsistence fishers commonly use beach seine, purse seine, gillnet, hand line and dynamite (SEP 1985; MAAP 2004). Therefore, subsistence catches for Cape Verde were estimated as a proportion of reported catches from each fishing gear.

Beach seine catches were available from INDP bulletins from 1997 to 2001, and for 2008 and 2009 (INDP 1998, 2008, 2009). These included catches used for bait and for personal consumption. We divided these catches by total reported landings and estimated the proportion caught by beach seines between 1997 and 2001, and for 2008 and 2009, i.e., 2.1%, 3.6%, 5.4%, 4.7% and 4% respectively for the years between 1997 and 2001, and 13.6% and 15.9% for 2008 and 2009 respectively. After the independence of Cape Verde in 1975, the contribution of beach seines to total catches was lower because of the increasing use of purse-seine (MAAP 2004). Thus, we conservatively assumed beach seine catches accounted for 10% of the total catch between 1950 and 1974. Thereafter, we interpolated linearly from 10% in 1974 to 2.1% in 1997 and from 4% in 2001 to 13.6% in 2008 to complete the time series assuming the same rate for 2009 and 2010, and applied these rates to the total reported landings. We assumed the equivalent of 50% of estimated beach seine catches were used for personal consumption, i.e., subsistence, because of their low value (MAAP 2004), thus not reported nor used as bait fish.

Since fish caught by other, mainly offshore gears (e.g., gillnet, purse seine, hand line and dynamite), are of better quality and are more likely to be sold and used as baitfish (MAAP 2004), we assumed the equivalent of 25% of the reported landings by these gears to be

Table 4: Main fishing gears used by foreign fleets operating in Cape Verde and the development of licences drawn. Source: DGP, Cape Verde.

Gears by vessel	Flag	Licences drawn			
		2007	2008	2009	2010
Surface long line	Japan	18	18	16	8
Pole and line	Senegal	7	2	4	0
Total (non - EU)		**25**	**20**	**20**	**8**
Surface long line	EU	28	27	26	28
Pole and line		11	10	8	8
Purse seine		8	10	12	21
Total (EU)		**47**	**47**	**43**	**57**

Table 5: Development of declared foreign fleet catches by main species (Japan and US), within Cape Verdean EEZ. Only about 9.4% of the foreign fleets reported their catches (DGP in Fonsceca 2000). Source: (MAAP 2004).

Main species	1997	1998	1999	2000	2001	2002
Yellowfin tuna	63.0	44.3	54.8	31.5	35.9	124.8
Skypjack tuna	263.0	-	-	-	-	40.2
Bigeye tuna	-	32.0	211.7	279.1	148.1	144.8
Bill fish	21.4	-	7.0	23.7	5.0	3.2
Swordfish	146.0	159.6	54.7	52.9	11.1	72.4
Sharks	522.9	590.3	125.4	331.3	109.5	486.2
Others	101.3	293.4	51.6	205.2	58.7	170.8

unreported subsistence catch kept for personal consumption. We then applied this rate to the total landings (excluding estimated catches of beach seine) from 1950 to 2010.

Industrial foreign fleet catches

Foreign fishing vessels operating in the Cape Verde EEZ are mainly longliners and some purse seiners. According to Hallier and Vieira (1996 in Fonseca 2000), their annual average catches are around 4,000 t. Between 43 and 57 foreign vessels from Japan, Senegal and the EU have been fishing in Cape Verde from 2007 to 2010 (Table 4), under a range of different access arrangements and there is no record of landings from these vessels in Cape Verdean ports (MegaPesca 2010). Most recently, new agreements were made with China (Carlos Alberto Monteiro, pers. obs.). The inconsistencies found between the statistics presented by INDP and FAO for the period 2004-2010 are likely due to re-flagging of foreign vessels, considered as domestic catch by FAO. Only a few truly domestic Cape Verdean vessels have the capacity to operate in offshore waters within the Cape Verde EEZ. While FAO reports these catches as being caught by Cape Verde, based on data from ICCAT, no knowledge of these catches exist among Cape Verdean fisheries experts (Carlos Alberto Monteiro, pers. obs.), and hence these catches are likely exclusively for foreign beneficial ownership. However, because we were unable to identify the beneficial country of origin, these catches were treated here as Cape Verdean catches. This highlights a need for greater transparency of actual beneficial vessel ownership in order to improve fisheries accounting not just in Cape Verde, but everywhere.

The number of licenses given to foreign fleets from the Europe Union and Japan are registered by General Direction of Fisheries (DGP) of Cape Verde (Table 4). The main species targeted by those fleets are highly migratory species, e.g., bigeye tuna (*Thunnus obesus*), swordfish (*Xiphias gladius*), yellowfin tuna (*Thunnus albacares*) and sharks (as by-catch) (Table 5). Furthermore, all foreign fleets have to fill in logbooks and report to the port authorities fishing location, catch, entry and exit from Cape Verde jurisdiction as well as allow observers on board (MegaPesca 2004). However, only about 10% of the foreign fleets really declare their catches (DGP, in Fonsceca 2000).

Taxonomic composition

We derived a species composition of major taxonomic groups from INDP (1998, 2008, 2009) reports. We converted quantities by species to percentages for both small-scale (Table 6) and large-scale (Table 7) fleets. We applied the species breakdown for small pelagic and demersal species from 1950 to 1998 based on INDP (1998), and from 1999 to 2010 from INDP

Table 6: Taxonomic composition in (%) for main groups of small-scale reported landings derived from INDP (1998, 2008, 2009).

Period	Large pelagics	Small pelagics	Demersal	Others	Sharks	Lobsters	*Buzio cabra*[d]	Octopus[c]
1950-1986[a]	63	27	8	0.11	0.31	0.10	1.16	0.05
1987[a]	63	25	10	0.18	0.31	0.06	1.17	0.05
1988[a]	66	21	11	0.14	0.31	0.09	1.16	0.05
1989[a]	47	41	11	0.38	0.32	0.08	1.19	0.05
1990[a]	47	40	10	0.51	0.32	0.09	1.20	0.05
1991[a]	43	42	13	0.30	0.32	0.09	1.18	0.05
1992[a]	45	44	9	0.22	0.31	0.09	1.17	0.05
1993[a]	45	45	8	0.42	0.32	0.09	1.19	0.05
1994[a]	44	45	9	0.17	0.31	0.08	1.17	0.05
1995[a]	45	41	12	0.42	0.32	0.09	1.19	0.05
1996[a]	44	41	13	0.35	0.32	0.09	1.18	0.05
1997[a]	44	37	17	0.72	0.32	0.09	1.21	0.05
1998[a]	35	52	12	0.57	0.15	0.13	0.00	0.00
1999[b]	38	40	20	0.60	0.15	0.11	1.23	0.06
2000[b]	34	41	22	0.69	0.14	0.09	1.24	0.06
2001[b]	44	32	22	0.45	0.17	0.11	1.21	0.05
2002[b]	47	31	20	0.47	0.19	0.11	1.21	0.05
2003[b]	46	31	20	0.52	0.21	0.10	1.21	0.05
2004[b]	33	40	24	0.42	0.21	0.10	1.21	0.05
2005[b]	30	44	23	0.64	0.24	0.10	1.22	0.06
2006[b]	41	32	25	1.23	0.28	0.10	1.25	0.06
2007[b]	34	34	29	1.75	0.29	0.11	1.27	0.06
2008[b]	33	34	29	1.77	0.34	0.10	1.27	0.06
2009-2010[c]	41	31	26	1.89	0.31	0.13	0.43	0.06

[a]INDP (1998); [b]INDP (2008); [c]INDP (2009); [d]*Strombus alatus*

Table 7: Taxonomic composition (in %) of main groups for large-scale reported landings derived from INDP bulletins (1998, 2008, 2009) and SEP (1985).

Period	Large pelagics	Small pelagics	Demersals	Others	Lobsters	Sharks
1950-1985[a]	83	10	4.97	0.02	1.41	0.03
1986[a]	84	10	4.68	0.00	1.36	0.01
1987[a]	86	13	0.14	0.01	1.42	0.02
1988[a]	91	7	0.95	0.00	1.56	0.01
1989[a]	80	11	7.85	0.01	1.12	0.02
1990[a]	84	10	4.76	0.01	1.38	0.02
1991[a]	82	15	1.04	0.01	1.86	0.02
1992[a]	84	12	0.21	0.01	2.83	0.02
1993[a]	43	52	0.23	0.01	4.66	0.02
1994[a]	40	56	0.95	0.06	3.49	0.02
1995[a]	33	63	1.82	0.01	2.36	0.01
1996[a]	44	51	2.81	0.01	1.54	0.01
1997[a]	40	54	4.98	0.06	0.70	0.01
1998[a]	27	70	2.58	0.03	0.55	0.01
1999[b]	29	67	3.30	0.08	0.66	0.01
2000[b]	49	46	4.07	0.10	0.82	0.04
2001[b]	47	50	2.70	0.06	0.78	0.04
2002[b]	41	55	2.81	0.15	0.83	0.04
2003[b]	30	67	1.72	0.01	0.66	0.04
2004[b]	32	66	1.46	0.10	0.56	0.04
2005[b]	38	59	2.57	0.01	0.78	0.04
2006[b]	22	74	3.76	0.03	0.41	0.04
2007[b]	26	70	4.12	0.47	0.20	0.04
2008[b]	19	78	2.93	0.22	0.20	0.04
2009-2010[c]	20	76	3.06	0.02	0.21	0.04

[a]INDP (1998); [b]INDP (2008); [c]INDP (2009).

(2008, 2009). The taxonomic breakdown for tuna from 1950 to 1983 was derived from SEP (1985). For 1984-1998, we used the percentages from INDP (1998), and for 1999-2010 we used the percentages found in INDP (2008, 2009). We disaggregated baitfish catches using the same species composition as that of the small pelagic fishery, and for subsistence catches we used the same species composition as that of small pelagic and demersal fisheries.

Results

Baitfish catches

Our total reconstructed baitfish catches (utilized in the fishery, i.e., not discarded) for Cape Verde from 1950 to 2010 were estimated to be around 88,450 t (Figure 3). Between 1950 and 1965, catches remained at around 900 t·year^{-1}. Between 1966 and 2010, baitfish catches varied with large catches in 1985 (2,600 t) and 2006 (2,200 t) and lower catches in 1976 (1,100 t) and 1990 (1,200 t). Baitfish caught using dynamite, and utilized in the fishery, were estimated at 15,500 t from 1950 to 1985 and 9,100 t between 1986 and 2010. Baitfish catches were dominated by mackerel scad with 48,800 t, blackspot picarel (*Spicara melanurus*) with 19,900 t and bigeye scad (*Selar crumenophthalmus*) with 11,200 t, over the 1950-2010 time period.

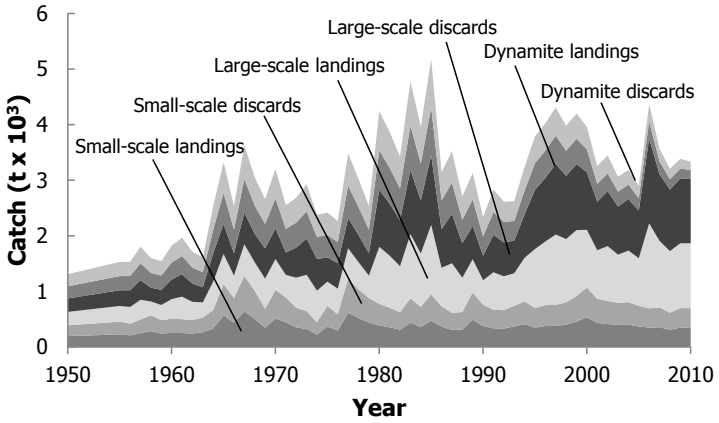

Figure 3. Small and large-scale baitfish catches (i.e., live baitfish used in the fishery) and the corresponding baitfish discards generated by sector.

Discards

Discards generated by baitfish catches totaled around 88,450 t between 1950 and 2010, and included mainly small pelagics (Figure 3). Baitfish discards increased from 655 t·year^{-1} in 1950 to 1,700 t·year^{-1} in 2010, with peaks of 1,800 t in 1967, 2,600 t in 1985, and around 2,200 t in 2006. Small pelagic species, such as mackerel scad represented over 50% (48,800 t) of the discards from 1950 to 2010.

Recreational catches

The total recreational catch was estimated at approximately 7,700 t over the period 1950-2010, which included 5,400 t of marlin (*Makaira* spp.), 540 t of wahoo (*Acanthocybium solandri*), 770 t of yellowfin tuna (*Thunnus albacares*), and just under 1,000 t of other pelagic species including sailfish (*Istiophorus platypterus*) and demersal species such as gilthead seabream (*Sparus aurata*) and groupers (*Epinephelus* spp.).

Subsistence catches

Subsistence catches totaled 132,000 t for the period between 1950 and 2010, of which 17,600 t (13%) were taken by beach seine, and 12,300 t (9%) by dynamite. Subsistence catches by other gears (purse seine, gillnet and hand line) were estimated at approximately 101,800 t (77%) (Figure 4). Mackerel scad represented 41% of the subsistence catches with over 54,600 t.

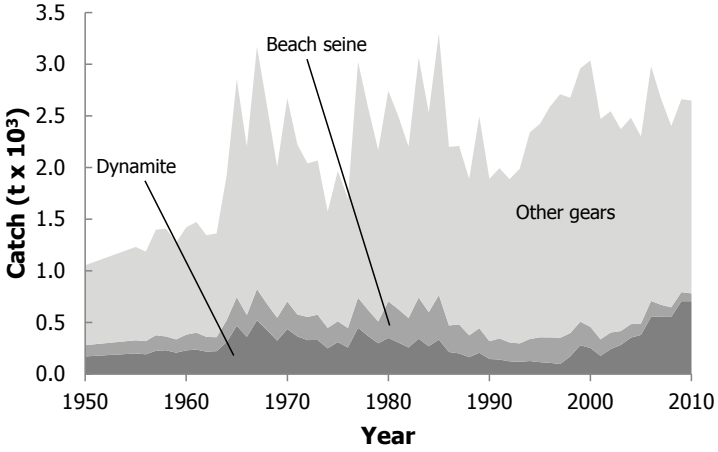

Figure 4. Subsistence catches by different gears; beach seine, dynamite and other gears (purse seine, gillnet and hand line) from Cape Verde waters, 1950-2010.

Industrial foreign fleet catches

For the period from 2004 to 2010, the data reported to FAO was higher than the data shown in INDP reports for the same period (Figure 2). These catches were higher due to the inclusion of re-flagged foreign fleet catches (Carlos Alberto Monteiro, pers. obs. INDP). From 2004 to 2010, INDP reported 17,800 tonnes of large pelagic "*Tunídeos"*, yellowfin tuna, common dolphinfish (*Coryphaena hippurus*), frigate tuna (*Auxis thazard*), little tunny

(*Euthynnus alletteratus*) and wahoo, for the same period, data supplied to FAO were 93,600 t, which represented an addition of 75,700 t in this category. While these catches are technically foreign, the unknown origin of these fleets required that they continue to be considered domestic landings.

Total reconstructed catches

Total reported catches for Cape Verde were estimated to be approximately 287,200 t between 1950 to 2010 for the small-scale fishery and 155,000 t for the large-scale fishery (Figure 5a). The overall reconstruction includes adjusted landings, bait fish catches (utilized and discarded), recreational catches and subsistence catches, for a total reconstructed catches of 758,500 t from 1950 to 2010 (Figure 5a). Yellowfin tuna is the most abundant large pelagic species, representing 16% of the total reconstructed catch (Figure 6b) and the most abundant small pelagic species was mackerel scad, representing 32% of the total reconstructed catch. From 1950 to 1963, total reconstructed catches remained relatively constant at around 7,000 t·year^{-1}, and then increased to 16,600 t·year^{-1} in 1977. Catches reached a peak of 19,300 t·year^{-1} in 1985, and then decreased to 10,900 t·year^{-1} in 1992, increasing again to 18,100 t·year^{-1} in 2006. The unreported component showed a decreasing trend, in 1950 reconstructed catches were over 6 times the landings data supplied to FAO and in 2010 the under-reporting tendency was reversed, when the data reported by FAO were 26% higher. However, in recent years FAO data included essentially non-domestic catches of large pelagic species by foreign fleets, if these were excluded in 2010, reconstructed catches would be about 1.7 times the data provided by Cape Verde to FAO.

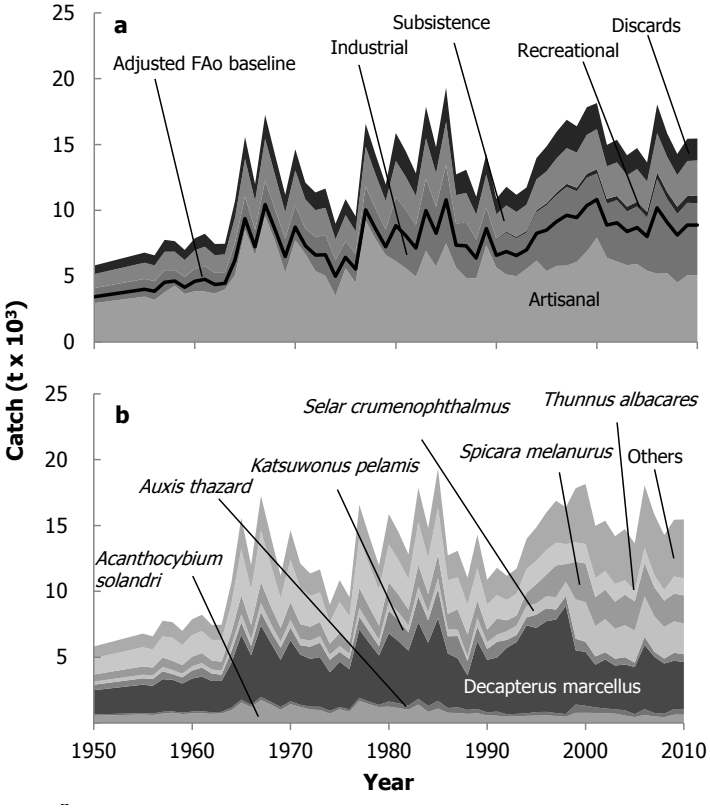

Figure 5. Overall catch reconstruction compared to data supplied to FAO (a) and and its taxonomic breackdown by major taxa (b) from 1950 to 2010. Others inlude large pelagics (7 taxa), small pelagics (10 taxa), demersal (26 taxa), lobsters (4 taxa), sharks, molluscs (*Strombus alatus* and *Octopus* spp.).

Discussion

Total reconstructed catches for Cape Verde for the period 1950-2010 were estimated at approximately 758,500 t, nearly 1.7 times the total landings supplied by Cape Verde to FAO (448,200 t). Overall, unreported components were: 132,000 t (subsistence catches), 176,900 t (bait fish catches, including discards as bait fish) and 7,700 t (recreational catches). Adjusted landings, now acounting for the under-reporting prior to 1980, and over-reporting in the 2000s, based on reported INDP bulletins and other literature sources were 442,318 t.

The current fisheries data monitoring system only covers about 15% of landings sites in Cape Verde (INDP 1998, 2008, 2009), which suggests substantial under-reporting, as illustrated in this study. Research efforts have mainly focused on the study of fishing possibilities in the archipelago (Fonseca 2000; Stobberup 2005; Baptista *et al.* 2006; Baptista and Santos 2008), without emphasizing the importance of collecting consistent catch time series (Stobberup *et al.* 2005; Merino 2006). This report is the first attempt of accounting for all Cape Verdean fisheries removals.

Besides poor monitoring coverage and a lack of reliable data, environmental concerns about Cape Verdean marine resources and the sustainability of fisheries are increasing (FOPESCA 1997; SEPA 1999; Baptista 2005). Ecosystems are threatened by the use of destructive gears such as dynamite (MAAP 2004; Merino 2006) and the loss generated by these gears (discards as underwater mortality) could be as high as 265,000 t from 1950 to 2010, which is the equivalent to about 38% of total reconstructed catches. Although these numbers illustrate the destruction and waste caused by the use of dynamite, they were not included in the analysis of fisheries trends described in the present study.

The increasing trend in subsistence catches suggests a rising dependence on fish as source of food. This dependence is accentuated by climate change which has caused cyclical droughts since 1968 affecting agricultural production (Anon. 1999; NAPA 2007). Subsistence fisheries show high vulnerability to climate change in most West African

countries (Allison *et al.* 2009). Tourism development in the Cape Verde archipelago has resulted in increasing sport fishing (ICCAT 2009). Catches by tourists from 1950 to 1980 were relatively low, about 23 t·year^{-1}, due to the low number of tourists participating in recreational fishing. These catches increased to 325 t·year^{-1} from 1990 to 2010, due to the expansion of tourism (Cabral 2005). This trend shows that recent developments of tourism in the archipelago along with the complete absence of monitoring of recreational fisheries (MAAP 2004) has generated considerable unreported catches. Tourist catches represented about 7% of the Cape Verdean artisanal reconstructed domestic catch from 2000 to 2010, which suggests a strong interest in recreational fishing by tourists over the past decade.

Overall, this study shows that fisheries data in Cape Verde, as in many countries in the world, are a substantial under-estimate of total domestic fisheries removals. In this context, we present a more realistic estimate of total domestic catches for Cape Verde.

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Appendix Table A1: FAO reported landings of the Cape Verde Islands vs. large and small-scale adjusted landings (baitfish included), subsistence catches, discards and recreational catches.

Year	FAO	Small-scale	Large-scale	Subsistence	Discards	Recreational	Total reconstructed
1950	900	2,955	1,139	1,055	655	10	5,354
1951	800	3,054	1,177	1,090	677	11	5,522
1952	1,000	3,153	1,215	1,125	699	12	5,719
1953	1,400	3,252	1,253	1,161	721	12	5,935
1954	1,700	3,352	1,292	1,196	743	13	6,142
1955	1,600	3,451	1,330	1,232	765	14	6,309
1956	1,300	3,199	1,417	1,186	766	15	6,073
1957	1,300	3,776	1,667	1,399	903	16	7,158
1958	1,700	4,273	1,165	1,409	800	17	7,131
1959	1,500	3,650	1,284	1,273	772	18	6,482
1960	1,600	3,861	1,667	1,421	912	19	7,271
1961	1,600	3,843	1,904	1,474	983	20	7,569
1962	1,500	3,679	1,549	1,345	856	20	6,877
1963	2,000	3,989	1,284	1,363	807	21	6,925
1964	2,500	5,083	2,406	1,922	1,265	22	9,855
1965	3,500	8,487	2,553	2,856	1,662	23	14,472
1966	4,000	6,597	1,904	2,201	1,267	24	11,148
1967	5,900	9,559	2,686	3,171	1,814	25	16,046
1968	4,900	7,624	2,406	2,593	1,528	26	13,156
1969	4,000	5,268	2,553	2,007	1,330	27	10,297
1970	5,181	7,730	2,613	2,671	1,602	28	13,575
1971	4,153	6,682	1,904	2,223	1,276	28	11,262
1972	4,078	5,394	2,553	2,040	1,343	29	10,464
1973	8,333	5,027	3,070	2,068	1,463	30	10,682
1974	3,428	3,504	2,686	1,574	1,188	31	8,190
1975	3,900	5,595	2,052	1,966	1,209	32	10,049
1976	3,800	4,507	2,170	1,704	1,133	33	8,793
1977	6,000	9,208	2,568	3,024	1,741	34	15,420
1978	7,000	7,782	2,302	2,580	1,512	35	13,209
1979	7,476	6,597	1,904	2,169	1,267	36	11,136
1980	8,351	6,142	4,835	2,743	2,121	36	14,474
1981	14,272	5,600	4,408	2,494	1,934	37	13,197
1982	12,019	4,957	3,901	2,201	1,712	38	11,681
1983	11,697	6,919	5,447	3,064	2,390	39	16,286
1984	10,634	5,734	4,513	2,532	1,981	40	13,498
1985	10,190	7,490	5,896	3,298	2,587	41	17,615
1986	7,309	5,643	3,273	2,200	1,574	42	11,724
1987	7,309	4,874	4,199	2,209	1,760	43	11,982
1988	6,374	4,828	2,914	1,890	1,355	44	10,206
1989	8,601	7,357	2,822	2,495	1,566	58	13,374
1990	6,570	5,659	2,087	1,891	1,168	71	10,208
1991	7,369	5,126	3,166	1,994	1,417	91	11,002
1992	6,564	5,004	2,876	1,888	1,307	109	10,476
1993	6,995	5,556	2,756	1,988	1,312	126	11,052
1994	8,256	6,183	3,693	2,340	1,620	142	13,160
1995	8,495	5,377	5,012	2,422	1,894	157	13,934
1996	9,155	5,782	5,387	2,590	2,014	197	15,022
1997	9,705	5,805	5,976	2,710	2,154	235	15,852
1998	9,424	6,094	5,355	2,676	1,989	271	15,472
1999	10,360	6,881	5,590	2,960	2,100	303	16,909
2000	10,586	7,922	4,880	3,036	1,981	332	17,317
2001	8,676	6,402	4,115	2,471	1,627	358	14,317
2002	8,145	6,116	4,658	2,545	1,722	323	14,738
2003	8,103	5,837	4,079	2,372	1,531	366	13,654
2004	10,396	5,924	4,369	2,482	1,593	363	14,197
2005	21,617	5,413	4,037	2,301	1,449	439	13,190
2006	24,590	5,186	7,196	2,981	2,184	505	17,430
2007	18,328	5,220	5,637	2,662	1,783	537	15,355
2008	23,768	4,514	5,218	2,403	1,604	545	13,883
2009	16,828	5,078	5,495	2,661	1,692	513	15,070
2010	19,500	5,053	5,495	2,649	1,668	593	15,063

Appendix Table A2: Taxonomic composition of the reconstructed catch of the Cape Verde Islands.

Year	*Thunnus albacares*	*Katsuwonus pelamis*	*Acanthocybium solandri*	*Auxis thazard thazard*	*Decapterus macarellus*	*Selar crumenophthalmus*	*Spicara melanurus*	Others
1950	1,242	414	551	95	1,845	238	536	891
1951	1,284	428	570	98	1,907	246	554	921
1952	1,326	442	589	101	1,969	254	572	951
1953	1,368	456	607	104	2,031	262	590	981
1954	1,410	470	626	108	2,093	270	609	1,011
1955	1,452	484	644	111	2,156	278	627	1,040
1956	1,367	513	605	117	2,099	271	608	1,004
1957	1,613	604	714	138	2,476	320	717	1,179
1958	1,743	433	780	100	2,406	310	704	1,189
1959	1,521	470	677	108	2,213	285	644	1,078
1960	1,645	605	728	138	2,511	324	728	1,200
1961	1,666	687	735	157	2,634	340	761	1,244
1962	1,563	562	693	128	2,370	306	688	1,139
1963	1,649	472	736	108	2,353	303	686	1,155
1964	2,192	871	967	198	3,424	442	990	1,614
1965	3,493	946	1,559	217	4,915	633	1,434	2,383
1966	2,705	707	1,209	162	3,775	486	1,103	1,846
1967	3,913	1,001	1,749	229	5,433	699	1,587	2,644
1968	3,150	889	1,405	204	4,477	577	1,305	2,169
1969	2,279	923	1,005	210	3,582	462	1,035	1,687
1970	3,215	962	1,432	220	4,635	597	1,349	2,235
1971	2,737	708	1,224	162	3,810	491	1,113	1,868
1972	2,327	924	1,027	211	3,634	469	1,051	1,717
1973	2,248	1,101	984	250	3,766	486	1,083	1,740
1974	1,629	957	707	217	2,924	378	836	1,335
1975	2,344	751	1,043	172	3,439	443	1,000	1,663
1976	1,947	784	860	179	3,051	394	882	1,450
1977	3,767	957	1,685	219	5,210	671	1,522	2,545
1978	3,198	854	1,429	196	4,471	576	1,305	2,182
1979	2,705	707	1,210	162	3,760	484	1,098	1,847
1980	2,873	1,723	1,244	391	5,178	669	1,479	2,321
1981	2,620	1,571	1,134	356	4,717	609	1,347	2,119
1982	2,318	1,390	1,004	315	4,171	539	1,191	1,881
1983	3,238	1,942	1,402	440	5,821	752	1,662	2,603
1984	2,718	1,700	839	449	4,812	622	1,374	2,286
1985	3,551	2,222	1,096	587	6,284	812	1,794	2,967
1986	2,561	1,298	781	360	4,148	536	1,161	1,888
1987	2,426	1,696	756	439	3,715	480	1,560	2,014
1988	2,269	1,087	690	305	2,619	339	1,673	2,047
1989	2,451	1,110	744	316	5,150	663	1,320	2,543
1990	1,895	813	576	235	3,993	515	961	1,889
1991	1,774	1,195	556	311	4,108	531	1,240	2,079
1992	1,541	592	489	177	5,054	662	826	1,843
1993	1,656	538	502	190	5,462	715	765	1,911
1994	1,797	600	545	187	6,684	879	1,006	2,282
1995	1,790	1,013	559	273	6,391	843	1,466	2,527
1996	1,854	980	578	269	6,882	909	1,652	2,846
1997	1,733	754	539	217	7,107	950	2,399	3,181
1998	1,514	722	477	203	8,232	1,088	1,350	2,799
1999	1,478	878	770	632	4,120	2,986	2,858	4,111
2000	1,481	765	773	539	4,094	3,007	2,938	4,555
2001	1,457	629	762	422	3,244	2,303	2,193	3,962
2002	1,418	558	740	363	3,720	2,512	2,238	3,815
2003	1,343	517	705	334	3,325	2,270	2,066	3,624
2004	1,082	557	573	392	3,474	2,434	2,324	3,893
2005	825	334	448	220	3,589	2,432	2,216	3,575
2006	1,153	612	619	434	4,879	3,085	2,513	4,757
2007	908	391	497	262	4,267	2,682	2,214	4,617
2008	799	374	443	257	3,821	2,404	1,994	4,191
2009	1,300	604	635	428	3,664	2,388	2,107	4,312
2010	1,290	588	636	414	3,581	2,346	2,134	4,469

Guinean fisheries, past, present and...future?[1]

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Abstract

Guinea is known for the wealth of its fisheries resources, targeted by both the domestic as well as foreign legal and illegal fleets. Domestic fisheries catches along the Guinean coast between 1950 and 2010 were estimated at 8.3 million t, compared to 2 million t of landings as reported to FAO. Small-scale fisheries subsectors accounted for over 5.6 million t. Foreign fisheries, with an estimated 22.6 million t between 1950 and 2010, constituted the bulk of fisheries removals in Guinean waters, and threaten the sustainability of Guinea's already over-exploited fisheries. These fleets caught over 3 times the maximum potential catch estimated by the Guinean government. This poses serious concerns regarding the domestic food security of Guinea, as well as livelihood of fishers and the local economy, as thousands of jobs are lost to illegal foreign fishing.

Introduction

Guinea is located in the 'corner' of North West Africa, with Guinea Bissau to the North and Sierra Leone, Liberia and Côte d'Ivoire to the south (Figure 1). With an Exclusive Economic Zone of 59,400 km² (www.seaaroundus.org) and the largest continental shelf of North West Africa (second in all of West Africa), Guinea enjoys a productive marine environment induced by the Guinea Current upwelling system.

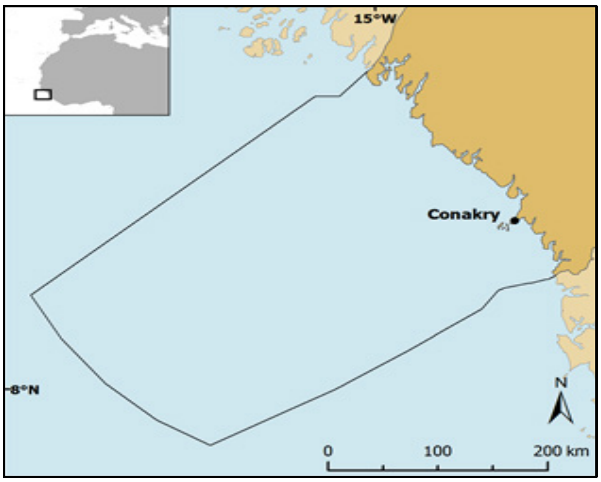

Figure 1. Map of Guinea showing the Guinean EEZ.

Historically, Guinea was one of the first countries of the West African French colonial empire to gain independence from France in 1958. After independence, Guinea suffered governance issues, a succession of political conflicts, poverty and food security crises, and the Guinean population has been under the risk of serious hunger for decades (Anon. 2004; von Grebmer *et al.* 2010; Anon. 2011b). With an annual per capita consumption spendings of US$ 175-452, half of the population lives under the poverty line and 13% in extreme poverty (Anon. 2004; www.worldbank.org [2012]).

More than 1.5 million people directly depend on fish for their livelihoods, with 60% of the protein intake of the Guinean population from fish (Goujet *et al.* 1992; Anon. 2003; N'Dia 2004; WFC 2005). The Guinean population suffers from malnutrition and animal protein deficits (Lopriore and Muehlhoff 2003; Touré 2006), which can be related to declining fish productivity (Figure 2) caused by over-exploitation (Gascuel *et al.* 2009). It is clear, however, that fisheries, if well managed, could provide more security in terms of food and income to local communities. Fisheries management initiatives should be supported by fisheries catch data for local and foreign sectors in the Guinean EEZ. This is far from being the case. Moreover, Guinea is known to be the country most strongly affected by illegal fishing in West Africa, which makes it one of the worst cases of illegal fishing in the world (Godoy 2010). It is important to better understand how much fish is taken from Guinean waters, before attempting to make any plan on how management incentives should be implemented. Not surprisingly, without proper knowledge of long-term

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fisheries removals in Guinean waters, many fisheries development initiatives since the 1950s have failed, since they prioritized the expansion of fishing as key to 'sustainable development' (Kaczynski and Fluharty 2002).

The available literature on fisheries in Guinea documents an artisanal sector comprised of traditional fishing with *pirogues* of less than 12 m since the 1950s, and advanced artisanal fishing (or semi-industrial fishing) with trawlers under 100 GRT, and to a lesser extent, an industrial demersal fishing sector (Chavance and Diallo 1996; Damiano 1999; Gascuel *et al.* 2009) alongside the foreign industrial sector which is prominent in Guinean waters (Lesnoff *et al.* 1999). Subsistence fishing is also important in Guinea and constitutes an important source of protein for the Guinean population (Chavance and Diallo 1996; Chauveau *et al.* 2000; Sidibe 2003). Guinea was handing out fishing licenses to foreign fleets in the early 1950s, even before the declaration of the Guinean EEZ in 1980, and the definition of artisanal fishing zones in 1985 (Lesnoff *et al.* 1999). Artisanal fishing zones are also subject to non-authorized exploitation by foreign vessels operating illegally (Gorez 2010). This paper analyses the fisheries in one of the poorest countries of the world and reconstructs historic fisheries catches (1950-2010) using the method described by Zeller *et al.* (2007) in an attempt to provide a more realistic estimate of Guinean fisheries removals including the prominent foreign catches.

Table 1. Artisanal effort anchor points and the corresponding CPUE. Interpolations are indicated by '-'.

Year	Number of boats	Source	CPUE ($t \cdot boat^{-1} \cdot year^{-1}$)
1950	1,000	Bouju (1993)	22.4[a]
1951-1982	-		-
1983	1,700	Pollnac (1985)	-
1984	1,700	Weber and Durand (1986)	-
1985-1988	-		-
1989	1,788	Gascuel *et al.* (2009)	29.8[b]
1990-1991	-		-
1992	2,306	Chavance and Diallo (1996)	-
1993-1994	-		-
1995	2,343	CNSHB 1995-2004 in Gascuel *et al.* (2009)	-
1996	2,358	CNSHB 1995-2004 in Gascuel *et al.* (2009)	-
1997	2,561	CNSHB 1995-2004 in Gascuel *et al.* (2009)	-
1998	2,361	CNSHB 1995-2004 in Gascuel *et al.* (2009)	-
1999	2,361	CNSHB 1995-2004 in Gascuel *et al.* (2009)	-
2000	2,564	CNSHB 1995-2004 in Gascuel *et al.* (2009)	-
2001	3,637	CNSHB 1995-2012, unpub. data	-
2002	3,636	CNSHB 1995-2004 in Gascuel *et al.* (2009)	-
2003	3,636	CNSHB 1995-2004 in Gascuel *et al.* (2009)	-
2004	3,636	CNSHB 1995-2004 in Gascuel *et al.* (2009)	-
2009	6,025	CNSHB 1995-2012, unpub. data	
2010	6,030	CNSHB 1995-2012, unpub. data[d]	26.8[a]

a) Assumption;
b) Chavance and Domalain (1999).

Methods

Reported fisheries landings time series were extracted from the Food and Agriculture Organisation database (FishstatJ) covering the 1950-2010 time-period, and used as a reporting baseline for this study. Effort time series including the number of artisanal and industrial vessels were available through the 'Centre national des sciences halieutiques de Boussoura' (CNSHB) and an extensive literature review that covered the period from 1950 to 2010. Effort estimates combined with catch per unit of effort estimates (CPUE) allowed estimating total catches for industrial (domestic and foreign) and artisanal sectors in the Guinean Exclusive Economic Zone (EEZ), from which subsistence fisheries and discards were inferred.

Artisanal fisheries

Artisanal fishing in Guinea is conducted by canoe-type boats of less than 12 m. This sector includes all motorized and unmotorized canoes as long as their activity is defined as artisanal for commercial purposes by the Guinean legislation. This sector operates in Guinea since 1950. This definition excludes the Senegalese *Yoli*-type *pirogues* that target sharks for their fins since the mid-1980s. Official artisanal fishing effort surveys in Guinea started in 1989 (Gascuel *et al.* 2009). These surveys included catches since the mid-1990s (Chavance 2002). The number of traditional artisanal *pirogues* was documented in the 1950s, 1980s, 1990s and 2000s (Table 1), from which we derived a complete series for the 1950-2010 time-period by linear interpolations. We estimated a catch per unit of effort (CPUE) of 29.8 $t \cdot boat^{-1} \cdot year^{-1}$ by dividing a catch of 53,300 $t \cdot year^{-1}$ in 1989 (Chavance and Domalain 1999) by the corresponding effort of 1,788 *pirogues* (Gascuel *et al.* 2009; Anon. 2011a). Given that most fishers (also farmers) were operating part-time (50%) in the agricultural sector in the early 1950s (Chavance and Domalain 1999), we divided the 1989 CPUE by two, which accounted for the time spent fishing, then again by two to account for the lower efficiency of the non-motorized *pirogues* used in the 1950s compared to the 1980s (Sidibe 2003), considering that increasing technology and modernization (motorization) lead to considerably higher catches (Mathew 2001). Therefore, the CPUE in 1950 was estimated at 75% of the CPUE in 1989, i.e., 22.4 $t \cdot boat^{-1} \cdot year^{-1}$. Discussions with local representatives or artisanal fisheries revealed that although Guinean waters are heavily over-exploited (Figure

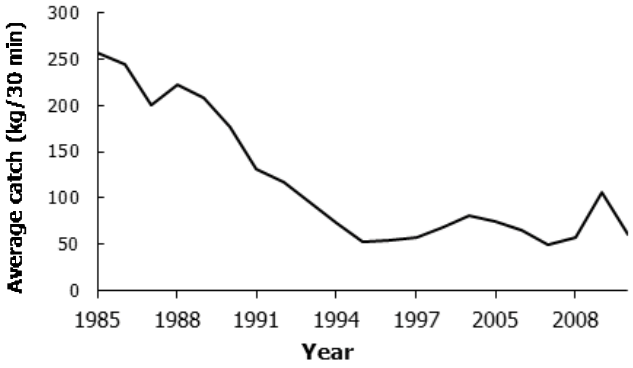

Figure 2. Relative abundance in the marine environment from 1985 to 1995, adapted from trawl surveys documented Domain *et al.* (1999), updated by the CNSHB.

2), artisanal fishers increased the time spent at sea per day, and the distance to fishing grounds, as well as the total number of days per year. Therefore, we assumed the catch per year was 10% lower in 2010 compared to 1989 (i.e., 26.8 t·boat^{-1}·year^{-1}) to account for this increase in the intensity of fishing, which illustrates via increasing costs the over-exploitation of Guinean coastal fisheries resources (Domain 1999; Gascuel *et al.* 2009). Furthermore, during discussions within the CNSHB with local experts, fishers representatives noted that annual artisanal catch per boat was much higher than the official estimate of 16 t·boat^{-1}·year^{-1}. We believe this further illustrates the importance of the unreported component in the 2000s as shown previously in the study of Chavance and Domalain (1999). Thereafter, we performed a linear interpolation between CPUE anchor points (Table 1), and then multiplied the resulting rates by the estimated number of *pirogue*s. To derive a taxonomic breakdown, we applied the average species disaggregation provided by Gascuel *et al.* (2009), accounting for a multi-gear artisanal fishery from 1985 to 2004 (Table 2).

Table 2. Breakdown of artisanal species by Gascuel *et al.* (2009).

Taxon name	Scientific name	Percentage (%)
Bonga shad	*Ethmalosa fimbriata*	53
Bobo croaker	*Pseudotolithus elongatus*	8
Sardinellas	*Sardinella* spp.	7
Guinean sea catfish	*Arius* spp.	7
Croakers	*Pseudotolithus* spp.	6
Seabreams	*Sparus* spp.	6
Mullets	*Mugilidae*	3
Royal threadfin	*Pentanemus quinquarius*	2
Demersal fishes	-	2
Jacks	*Caranx* spp.	1
Grunt	*Pomadasys* spp.	1
Soles	*Solea* spp.	1
Giant African threadfin	*Polydactylus quadrifilis*	0.9
Rays	Elasmobranchii	0.5
Sharks	Elasmobranchii	0.5
Large pelagics	Scombroids	0.5
Barracudas	*Sphyraena* spp.	0.5
Lesser African threadfin	*Galeoides decadactylus*	0.1

Semi-industrial fisheries

Semi-industrial fishing is also commonly called advanced-artisanal fishing in some countries of West Africa[2]. This sector in Guinea is operated by trawlers of which the capacity is under 100 GRT. Although this sector started in 1981, it only expanded from 1985 onward (Chavance and Diallo 1996), with the first vessels delivered from Spain (Damiano 1999). Anchor points for the number of vessels (exclusively trawlers) were available from Damiano (1999), Bah *et al.* (2002) and Richard *et al.* (2006). We assumed effort from 2006 to 2010 was constant since the overall artisanal effort was constant over the same time period (Table 3). We then interpolated linearly to complete the time series. CPUE rates were estimated at 122 t·boat^{-1}·year^{-1} for 1981 and 111 t·boat^{-1}·year^{-1} for 2002 based on catch and effort estimates by Damiano (1999), Chavance and Diallo (1996) and Bah *et al.* (2002). We assumed a 10% lower CPUE for 2010, i.e., 100 t·boat^{-1}·year^{-1}. This rather low decreased in CPUE, despite strong over-exploitation of Guinean fisheries resources, is justified by the increasing fishing capacity (e.g., the number of fishing days per year per boat). We interpolated linearly between the CPUE rates and applied these to the estimated effort (Table 3). Thereafter, we disaggregated catches using the taxonomic breakdown provided by Damiano (1999, Table 4).

Table 3. Semi-industrial effort anchor points and the corresponding CPUE. '-' indicate Interpolations.

Year	Number of boats	Source	CPUE (t·boat^{-1}·year^{-1})
1950	0	Assumption[a]	0
1980	0	Assumption[a]	0
1981	1	Damiano (1999)	122[b]
1982	1	Damiano (1999)	-
1983	1	Damiano (1999)	-
1984	1	Damiano (1999)	-
1985	2	Damiano (1999)	-
1986	5	Damiano (1999)	-
1987	7	Damiano (1999)	-
1989	17	Damiano (1999)	122[c]
1990	11	Damiano (1999)	-
1991	9	Damiano (1999)	-
1992	11	Damiano (1999)	-
1993	16	Damiano (1999)	-
1995	10	CNSHB, unpub. data	
1996	11	CNSHB, unpub. data	-
1997	10	CNSHB, unpub. data	
1998	4	CNSHB, unpub. data	
1999-2000	0	CNSHB, unpub. data	
2001	-		-
2002	18	Bah *et al.* (2002)	111[d]
2003-2005	-		-
2006	14	Richard *et al.* (2006)	-
2007-2009	-		-
2010	14	Assumed constant	100[c]

a) Advanced artisanal fishing started in 1981 (Damiano 1999);
b) Derived from the available average catch per day of 0.9653 t·boat^{-1}·day^{-1} for 1989 and the number of fishing days for 1981 (126 days) (Damiano 1999);
c) Assumption;
d) Derived from a catch of 2000 tonnes and an effort of 18 vessels for 2002 (Bah *et al.* 2002).

Subsistence fisheries

Small-scale fishing before the 1980s was mainly for subsistence (Chavance 1999). Guineans, along with other migrant fisher groups from Ghana and Sierra Leone, were catching fish for personal consumption. Subsistence fishing in Guinea can be land-based or operated by dugout-canoe type boats propelled by paddle, sail and/or motor of less than 25 hp, mostly of 8 and 15 hp. The most important part of small-scale fishing was thus for subsistence in the 1950s and 1960s (Chauveau *et al.* 2000). Therefore, it is reasonable to assume that at least the equivalent of the commercial catch (i.e., the equivalent of 100% of artisanal catch) was caught for personal consumption, i.e., subsistence from 1950 to 1980 when the Guinean EEZ was declared. In the last decade (2000s), a portion of small-scale catches intended for commercialization were kept for personal consumption (N'Dia 2004). Consequently, we assumed that subsistence catches from 2000 to 2010 were equivalent to 10% and 5% of the artisanal catch respectively, which we interpolated. We interpolated from 100% in 1980 to 30% in 2000 to complete

[2] For the purposes of the *Sea Around Us* Project, the semi-industrial sector was treated as 'industrial'.

the time series, and then applied the resulting rates to the reconstructed artisanal catch from 1950 to 2010. Bonga shad (*Ethmalosa fimbriata*), sardinellas (*Sardinella* spp.) and other small pelagics (Clupeidae) are the main taxa kept for subsistence in Guinea (Goujet *et al.* 1992), and were assigned to the estimated subsistence catch equally (33% per taxon).

Table 4. Semi-industrial catches taxonomic breakdown.

Taxon name	Scientific name	Percentage (%)
Cassava croaker, longneck croaker and law croaker	*Pseudotolithus senegalensis, P. typus* and *P. brachygnathus*	30
Bobo croaker	*Pseudotolithus elongatus*	11
Cameroon croaker, Guinea croaker	*Pseudotolithus epipercus, P. moori*	7
Royal threadfin	*Pentanemus quinquarius*	6
African sicklefish	*Drepane africana*	2
Sompat grunt	*Pomadasys jubelini*	1
Lesser African threadfin	*Galeoides decadactylus*	17
Guinean sea catfish	*Arius* spp.	13
Rays	Rajiformes	7
Other demersal species	-	6

Industrial

Domestic

Guinean industrial fishing is mostly composed of trawlers operating under joint venture arrangements (Sidibe 2003). Joint ventures are second-generation fishing agreements which allow the transfer of part of a vessel ownership to a third party in the host country and commonly translate into reflagging vessels. In Guinea, it mainly consists of reflagging foreign vessels, but with highly variable or no real Guinean ownership. This fishery started in 1950 (Moal 1961 in Lesnoff *et al.* 1999). N'Dia (2004) provided effort data with 23 vessels in 1985, 13 in 2002, and 12 in 2004, which then represented 7% of the total industrial fleet including foreign vessels. We assumed that this rate remained constant until 2010, and calculated the number of vessels to be 13 trawlers. To reconstruct catches by these joint venture vessels, we first interpolated effort data of the number of trawlers per year from zero vessels in 1950 to 23 trawlers in 1985, and performed a series of linear interpolations to complete the time series. We multiplied this effort by the CPUE of 2,400 $t \cdot boat^{-1} \cdot year^{-1}$ (Kaczynski 1989) from 1950 to 2010, assuming the resulting decline in CPUE caused by over-exploitation (Gascuel *et al.* 2009) would be compensated for with increasing vessel capacity and the number of fishing trips.

Table 5. Anchor points for annual industrial fishing effort by foreign fleets.

Year	General bottom trawlers	Demersal fish trawlers	Cephalopod trawlers	Shrimp trawlers	Small pelagic seiners	Large pelagics (longline and purseiners)	Mixed
1950	12[a]	1[f]	1[f]	1[f]	0[f]	0[f]	0[a]
1961	12[a,b]	-	-	-	-	-	-
1966	10[c]	-	-	-	-	-	-
1971	-	4[g]	-	1[f]	-	-	-
1972	-	5[f]	-	0[f]	-	-	-
1973	-	9[f]	-	2[f]	-	-	-
1974	-	10[f]	-	3[f]	-	-	-
1975	-	6[f]	-	1[f]	-	-	43[h]
1976	10[c]	10[f]	-	6[f]	-	0[f]	-
1977	-	25[f]	-	4[f]	-	0[f]	-
1978	-	48[f]	-	5[f]	-	2[f]	-
1979	-	47[f]	5[f]	8[f]	-	8[f]	-
1980	-	58[f]	5[f]	10[f]	-	9[f]	-
1981	-	45[f]	7[f]	12[f]	-	11[f]	-
1982	-	46[f]	3[f]	12[f]	-	7[f]	-
1983	-	49[f]	9[f]	13[f]	-	11[f]	-
1984	14[d]	43[f]	10[f]	12[f]	-	21[f]	-
1985	-	23[f]	14[f]	11[f]	-	45[f]	-
1986	-	33[f]	24[f]	10[f]	-	28[f]	0g
1987	-	41[f]	24[f]	7[f]	-	47[f]	21g
1988	-	31[f]	18[f]	9[f]	-	40[f]	13[g]
1989	-	11[f]	19[f]	8[f]	-	51[f]	15[g]
1990	-	49[f]	31[f]	13[f]	0[f]	41[f]	11[g]
1991	-	49[f]	24[f]	3[f]	11[f]	23[f]	7[g]
1992	-	40[f]	15[f]	6[f]	9[f]	19[f]	0[g]
1993	-	36[f]	64[f]	8[f]	8[f]	23[f]	0[g]
1994	-	34[f]	-	5[f]	4[f]	24[g]	-
1995	-	42[g]	34[g]	6[h]	2[g]	26[g]	-
1996	-	37[g]	25[g]	16[g]	4[g]	37[g]	-
1997	-	72[g]	55[g]	24[g]	6[g]	38[g]	-
1998	-	76[g]	55[g]	11[g]	4[g]	49[g]	-
1999	-	54[g]	38[g]	17[g]	3[g]	50[g]	-
2000	-	75[g]	58[g]	45i	5[g]	43[g]	-
2001	-	67[g]	46[g]	43i	5[g]	47[g]	-
2002	-	55[g]	38[g]	58i	4[g]	39[g]	-
2003	-	61[g]	42[g]	18[g]	5[g]	43[g]	-

a) Assumption ; b) Moal (1961) in Lesnoff *et al.* (1999); c) Caverivière (1979) in Lesnoff *et al.* (1999); d) Weber and Durand (1986); e) Richard *et al.* (2006); f) Lesnoff *et al.* (1999); g) Sidibe (2003); h) Chavance and Diallo (1996); i) CNSHB (2004).

Foreign

Herein, we first estimated total foreign catches by the legal fleets using an overall average CPUE, then we separately estimated catches by the Chinese fleet, as a subset, using a CPUE that is typical of the Chinese fleet. Catches by the EU fleet were also estimated as a subset of total foreign catches. The remaining foreign catch (after subtracting Chinese and EU catches) were disagregated per beneficial country of origin and per taxon.

Total foreign catches: Although Guinea declared its EEZ in 1980, the first formal industrial fishing licences were distributed in the early 1970s (Lesnoff *et al.* 1999; Sidibe 2003), and Moal (1961 in Lesnoff *et al.* 1999) already documented foreign industrial trawlers operating in Guinea's EEZ equivalent waters in the 1950s. Industrial fishing effort by gear type from 1950 to 2003 was reconstructed and interpolated for years when data were not available (Table 5), while the 2005 data point was fragmentary, the total effort was available for 2004 (177 vessels) and 2010 (169 vessels) including all gear types

(N'Dia 2004; Fontana 1998, in Richard *et al.* 2006; Diop and Dossa 2011). We calculated the annual sum representing the total effort from 1950 to 2003, then interpolated linearly the total effort by year to 2004 and 2010 to complete the time series. The effort between 1950 and 2003 was documented on the basis of licences; we conservatively assumed each licence accounted for one vessel. Thereafter, we applied an average CPUE of 2,400 t·boat^{-1}·year^{-1} (Kaczynski 1989) to the total number of vessels. These estimates are considered conservative especially for the earlier time period when fishing licences and vessels were not all reported (Lesnoff *et al.* 1999). Total foreign catch by all authorized fishing under foreign flags in Guinea's waters includes catches by the European fleet under EU Fisheries Partnership Agreements (FPAs), China, Japan, Korea, African countries and other fleets notably those from Flag of Convenience countries (FoC).

Industrial catches under EU agreements: Guinea and Europe signed their first fishing access agreements in the early 1980s (N'Dia 2004), for shrimp trawlers from Spain, Portugal and Greece; demersal fish and cephalopod trawlers from Spain, Italy and Greece; tuna seiners and pole and line vessels from France and Spain; and tuna longliners from Portugal and Spain (EU 2004). The number of vessels were available from formal agreements between 1980 and 2010 from the EU agreements database (eur-lex.europa.eu[2012]) which corresponded to the number of EU vessels operating in Guinea (N'Dia 2004) (Table 6). We converted the effort expressed in GRT to the number of vessels using an average of 141 GRT·vessel^{-1}. We then multiplied the number of vessels by the average CPUE of 2,400 t·boat^{-1}·year^{-1} (Kaczynski 1989) to estimate total catches by the European countries under EU-Guinea agreements. Although European countries benefiting from these agreements are often not specified, based on the European Community – Guinea 2003 agreement (EU 2004), 59% of the effort was from Spain, 20% was from France, 9% was from Greece, 6% from Portugal and 6% from Italy. We assumed these rates were constant from 1980 to 2010, except for Portugal who started fishing in Guinea in 1981 and was no longer under EU agreements after 2007. We allocated 0% of EU catches to Portugal in 1980 and from 2007 to 2010; the remaining 6% (originally Portuguese) was distributed evenly to the remaining countries, i.e., Spain, France, Greece and Italy. Effort estimates under agreements are conservative, since they only include agreements between Guinea and the EU on behalf of EU countries, whereas other occasional government fishing agreements and joint ventures (for example with Spain and Greece) were documented for the 1970s and 1980s, but not accounted for in this estimation (Weber and Durand 1986).

Table 6. Number of vessels per gear type from the European Union under formal agreements (EU 2004; N'Dia 2004; EU 2009).

Year	Tuna seiners	Small pelagic seiners	Longliners (tuna)	Trawlers
1950 to 1979	0	0	0	0
1980	25	25	0	12
1981	25	25	0	12
1982	25	25	0	12
1983	25	25	0	12
1984	25	25	0	12
1985	45	25	6	12
1986	45	25	6	12
1987	45	25	6	12
1988	45	25	6	12
1989	45	25	10	12
1990	45	25	10	12
1991	24	8	5	12
1992	24	10	5	17
1993	24	10	5	17
1994	28	7	7	20
1995	28	7	7	20
1996	33	13	28	20
1997	33	13	28	20
1998	36	14	22	18
1999	38	14	16	16
2000	38	14	16	16
2001	38	14	16	16
2002	38	14	16	16
2003	38	14	16	16
2004	34	12	16	70
2005	31	10	15	60
2006	28	8	15	50
2007	24	6	15	41
2008	21	4	15	31
2009	17	2	14	21
2010	14	0	14	12

Table 7. Anchor points for annual fishing effort in capacity converted to number of Chinese vessels operating in the Guinea EEZ.

Year	GRT trawlers	GRT Cephalopod Trawlers	Number of vessels	Source
1950	0	0	0	assumption
1996	1,500	2,048	26	N'Dia (2004)
1997	1,500	2,048	26	N'Dia (2004)
2000	1,000	2,200	22	N'Dia (2004)
2001	1,000	2,200	22	N'Dia (2004)
2003	800	1,500	16	N'Dia (2004)
2004	800	1,500	16	N'Dia (2004)
2010	NA	NA	30	Anon. (2012)

The Chinese distant water fleet: The Chinese distant water fishing fleet was operating in Guinea between the 1950s and 2010 (Lesnoff *et al.* 1999), until the 2000s with formal fishing access agreements mainly for cephalopod and demersal resources (Lesnoff *et al.* 1999; Sidibe 2003; Anon. 2012). To estimate the number of Chinese vessels operating under licence in Guinea, we divided the reported total GRT (N'Dia 2004) by an average GRT of 250 GRT·vessel^{-1} (Anon. 2003) (Table 7) of which 55% were targeting cephalopods and 45% demersal fish and crustaceans (N'Dia 2004). We performed a series of linear interpolations to complete the effort time series between 1950 and 2010 (Table 7). We then multiplied the derived effort time-series by a CPUE of 221 t·boat^{-1}·year^{-1} for cephalopod vessels

and 1,252 t·boat^{-1}·year^{-1} for trawlers (Pauly *et al.* 2012). Assuming a constant CPUE overtime for the Chinese fleet particularly highlights the compensation due to first increasing fishing capacity per boat, but also refflects upon the increasing unregulated practices of the Chinese fleet fishing in the artisanal and near-shore zones of Guinea, on contrast to fleets of other origin. These vessels were operating under licence with Guinea. Although we assumed all catches were exclusively from the Guinean EEZ, these estimates remain conservative since they do not account for the occasional and seasonal Chinese fleets operating in Guinea. Catches of the demersal and cephalopod fleets consist to 50% of scianids (*Pseudotolithus senegalensis, P. typus, P. elongatus, Cynoglossus canariensis, C. monody, C. senegalensis, Arius heudeloti, A. istiscutatus, A. parkii, Galeoides decadactylus, Pomadasys incisus, P. jubelini*), 44% of cephalopods (*Sepia* spp. and other cephalopods), 2.4% of sparids (*Pagellus bellottii* and *Sparus caeruleostictus*) and 3.6% of crustaceans (*Penaeus notialis, P. kerathurus and Perapenaeopsis atlantica*) (Lesnoff *et al.* 1999). We used these rates to disaggregate Chinese catches from Guinean waters.

Table 8. Countries operating in the Guinean EEZ under agreements.

Country	Period	Source
Russia	1950-2000s	Lesnoff *et al.* (1999); Sidibe (2003)
Ukraine	1950-2000s	Lesnoff *et al.* (1999); Sidibe (2003)
Korea	1958-2010	Weber and Durand (1986); Lesnoff *et al.* (1999); Sidibe (2003); Gorez (2010)
Poland	1958-2010	Lesnoff *et al.* (1999)
Japan	1966-mid 2000s	Weber and Durand (1986); OECD (2010)
Yugoslavia	1966-1984	Weber and Durand (1986)
Malta[a]	1971-2000	Sidibe (2003)
Germany	1958-1984	Lesnoff *et al.* (1999)
Liberia[a, b]	1966-1986	Weber and Durand (1986); Lesnoff *et al.* (1999); Sidibe (2003); Dobo (2009)
Ghana[a, b]	1966-1986	Weber and Durand (1986); Lesnoff *et al.* (1999); Sidibe (2003); Dobo (2009)
Côte d'ivoire	1966-2010	Weber and Durand (1986); Lesnoff *et al.* (1999); Sidibe (2003); Dobo (2009)
USA	1966-2010	Weber and Durand (1986); Lesnoff *et al.* (1999); Sidibe (2003); Dobo (2009)
Senegal	1971-2010	Weber and Durand (1986); Lesnoff *et al.* (1999); Sidibe (2003); Dobo (2009)
Sierra Leone	1971-2010	Weber and Durand (1986); Lesnoff *et al.* (1999); Sidibe (2003); Dobo (2009)

a) Korean vessels reflagged.
b) Operating under joint ventures with Guinea.

Other fleets: The difference between the total estimated catch and the sum of European (Greece, Italy, Portugal, Spain and France) and Chinese catches was allocated to other flags operating under licences in the Guinean EEZ (Table 8). We determined the presence or absence of a foreign fishing country per year based on a literature review, i.e., when a country is mentioned as fishing in Guinea's waters, then that country was present during that year. We assumed the absence of literature documenting a country fishing in Guinea meant the absence of that country during that period/year, and the first time this country was mentioned would correspond to the first year it started fishing in Guinea. According to the presence or absence of a country in the Guinean EEZ, we first assumed an even distribution by country depending on the number of countries operating and the start and end of fishing operations by country. For example, the former USSR (Russia and Ukraine) were the only fleet fishing in Guinea from 1950 to 1957, therefore, we allocated 100% of catches to these former Soviet republics from 1950 to 1957. In 1958, Korea, Poland and Germany started fishing in the Guinean EEZ, we allocated 0% of the catch to these countries in 1957, and then interpolated from these rates to 20% for each country (USSR, Korea, Poland, Germany) in 1965 assuming approximately the same catch per country. In 1966, USA, Japan, Liberia, Ghana Ivory Coast and Senegal started industrial fishing operations in Guinea; therefore they were allocated 0% in 1965 increasing linearly to 10% for each country in 1970, right before Malta (mostly Korean reflagged vessels), Sierra Leone and Senegal started fishing in Guinea etc. This rationale assumes an even distribution of catches where countries which started fishing earlier get a higher percentage of unallocated catches in the earliest time-periods, decreasing thereafter when other countries start fishing.

Illegal fishing

There are three main types of illegal fishing in Guinea: fishing without a licence (42% of the cases), industrial fishing in artisanal zones (21%, i.e., the equivalent of 50% of illegal unlicensed vessels), and fishing using illegal gear (31%) (EJF 2006; Gorez 2010). In this study, we only estimated catches by non-licenced or non-authorized foreign vessels as a conservative approach to avoid double counting, since legal vessels may have been using illegal mesh size or operating in artisanal zones. Foreign fleets operate increasingly in Guinea without authorizations (Godoy 2010). In 2006, illegal fishing by foreign fleets represented the equivalent of 63% of legal landings, when 22 boats of an observed total of 104 boats were illegal (EJF 2006). Chinese vessels (including under flags from Belize and Panama) represented 50% to 60% of illegal fishing vessels (Dobo 2009; EJF 2009; Mallory 2012). The remaining countries include South Korea (with flags from Korea, and FoC countries like Malta, Panama and Belize), vessels reflagged to Guinea and to Senegal and others (Anon. 2006; EJF 2009). We estimated that illegal vessels represented the equivalent of 13% of the legal fleet in 2006, i.e., 22 vessels (EJF 2006) divided by the total legal fleet in 2006 (176 vessels). We then applied this percentage to the total legal fleet from 1950 to 2010. Catches taken before the declaration of the EEZ are considered legal but unregulated in this study. Thereafter, we distributed catches by flag, where China represented 60% of catches, and the remaining catch was allocated evenly between Korea, Guinea, Senegal and others.

Although industrial catches in artisanal areas are already accounted for here, since the catch reconstruction disregards the zone of the catch, it is important to establish an estimated amount taken from reserved artisanal fishing zones in Guinea. The equivalent of 50% of illegal catches are caught within artisanal zones (Gorez 2010).

Therefore, we applied the latter rate to the estimated illegal catch from 1950 to 2010, to retrace illegal catches in artisanal areas.

Discards

Discards in the industrial fisheries of Guinea (domestic and foreign) are important and range between 40% and 67% of demersal fish catches (discarding mainly cephalopods), 78% to 150% of shrimp catches and 82% of cephalopod catches from 1986 to 1998 (Weber and Durand 1986; Sidibe 2003). Artisanal fisheries discards ranged between 10% and 15% of the artisanal catches (Weber and Durand 1986) and here were assumed to be constant. Therefore, to estimate discards by sector, we assumed discard rates were constant from 1950 to 1986 for industrial fisheries, and during the 1950-1986 and 1998- 2010 time periods for artisanal fisheries. Comparative results by Sidibe (2003) show a 6% decrease in the catch kept onboard industrial vessels since 1998, i.e., here increase in discards by 6% from 1998 to 2010. We interpolated linearly the above mentioned discard rates by sector from 1986 to 1998 for artisanal fisheries, and from 1986 to 1998, then from 1998 to 2010 for industrial fisheries. We applied these discard rates to the reconstructed demersal fish, shrimp and cephalopod catch for the domestic and foreign sectors along with artisanal domestic reconstructed catches. We performed a species breakdown for large-scale shrimp and cephalopod sector discards using the estimated discard rates per species by Sidibé *et al.* (2003), i.e., 71% of lesser African threadfin catches, 53% of bobo croaker catches, 35% of longneck croaker catches and 28% of the Cassava croaker catch by calculating corresponding species rates and assuming 20% is unknown fish species, we disaggregated the remaining 80% to include the four species listed above.

Results

Total reconstructed catches in Guinea

Total catches (domestic and foreign) taken in Guinea's waters between 1950 and 2010 accounted for 31.8 million t (Figure 3a). Guinean domestic catches were estimated at 8.4 million t between 1950 and 2010 compared to 2 million t of landings as reported by FAO, i.e., 4.2 times as high (Figure 3b). Domestic catches in the Guinean EEZ increased from 47,800 t·year^{-1} in 1950 to a first peak of around 178,000 t·year^{-1} in 1985, decreasing in the late 1990s, and then increased again and reach their maximum of 231,000 t·year^{-1} in 2009, i.e., over twice as high as the data supplied to FAO (81,000 t·year^{-1}) (Figure 3b). Over a total of 8.4 million t, 130,000 were caught by industrial vessels of foreign beneficial ownership reflagged to Guinea.

Guinean domestic catches were almost as high as foreign industrial catches including illegal removals between 1950 and the early-1970s, with a total domestic catch of 2.3 million t compared to a foreign catch of 2.3 million t between 1950 and 1973 (Figure 3a). This trend has changed since the early 1980s, after Guinea declared its EEZ, when foreign catches (19.2 million t) were over three times the reconstructed

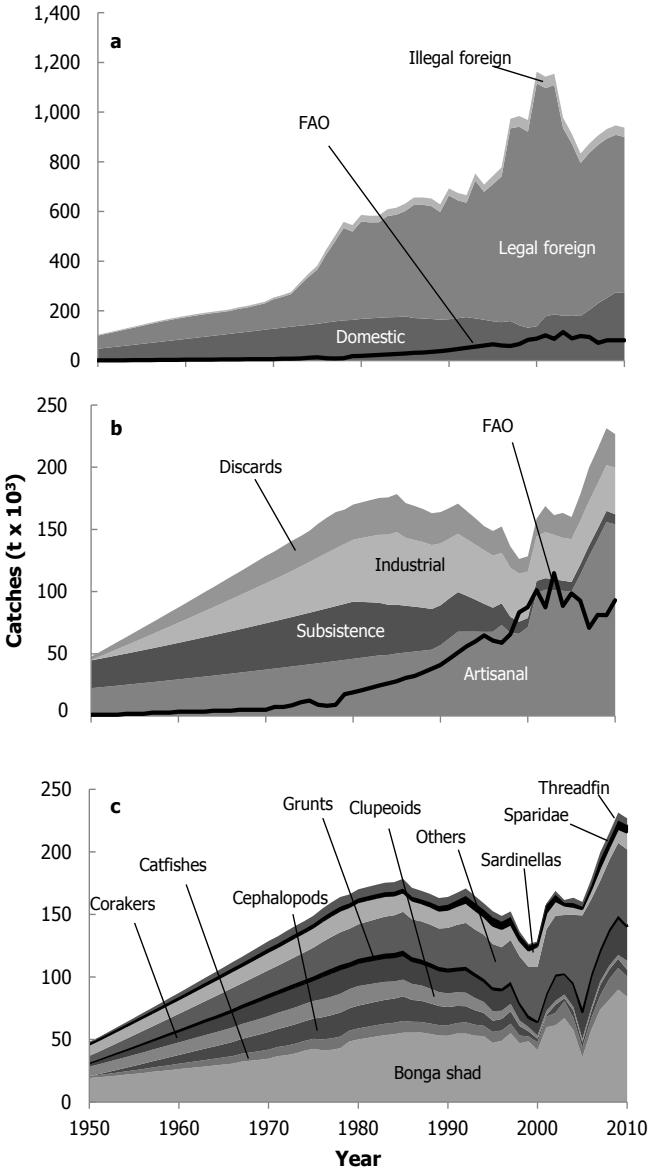

Figure 3. Estimated catch from the Guinea EEZ by a) the domestic and foreign sectores, b) the domestic sector compared to catches supplied to FAO, and c) taxon, 1950-2010.

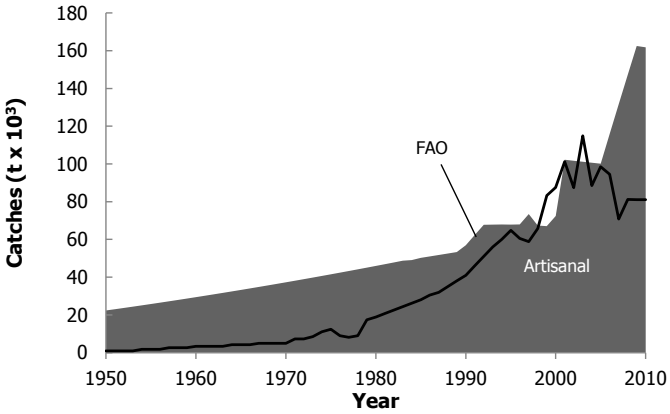

Figure 4. Total reconstructed artisanal catches by Guinea compared to data supplied to the FAO, 1950-2010.

domestic catch (5.1 million t) between 1980 and 2010 (Figure 3a).

Domestic catch breakdown is dominated by Bonga shad, other small pelagics including sardinella, and cephalopods (Figure 3c).

Reconstructed catches by sector

Artisanal

Artisanal landed catches (i.e., excluding discards) were estimated at 3.4 million t for the period between 1950 and 2010, increasing from around 22,000 t·year^{-1} in 1950, to a plateau of 101,000 t·year^{-1} in the eary 2000s (Figure 4). Thereafter, catches increased, driven by the increase in the fishing effort to a maximum of 156,000 t·year^{-1} in 2009 (Figure 4). Artisanal catches were constituted mainly of Bonga shad, sardinellas and croakers.

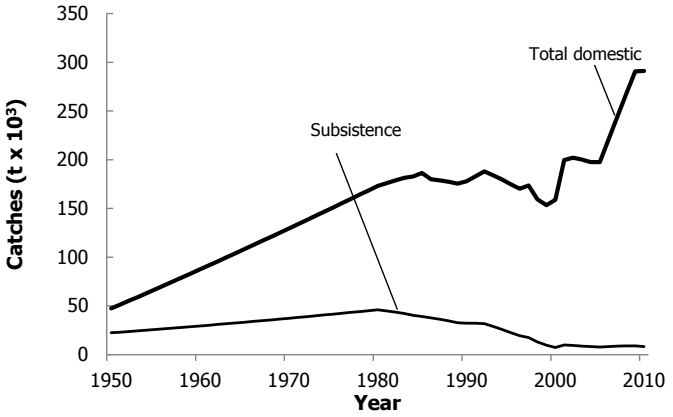

Figure 5. Reconstructed subsistence compared to total domestic catches in Guinea, 1950-2010.

Semi-industrial fisheries

Semi-industrial catches were estimated at around 40,000 t between 1950 and 2010, which is less than 1% of the total reconstructed catch (Figure 3b). Catches increased from 0 t·year^{-1} in 1950 to a peak of around 1,900 t·year^{-1} in 2001 then decreased steadily thereafter. Semi-industrial catches were dominated by croakers (Scianidae).

Subsistence

Subsistence catches increased from 22,400 t·year^{-1} in 1950 to about 46,000 t·year^{-1} in 1980 then decreased to 8,200 t·year^{-1} in 2010 (Figure 5). Subsistence catches totalled around 1.7 million t from 1950 to 2010 which represents 20% of the total reconstructed catch in Guinea since 1950 (Figure 5). This included small pelagic species, mostly sardinella and bonga shad, which accounted for 66% of total subsistence catches.

Industrial

Domestic: Domestic industrial landed catches (i.e., excluding discards) were estimated at 2.1 million t between 1950 and 2010, accounting for 25% of the total domestic catch (Figure 6), and equivalent to over half of the Guinean artisanal catch. Around 130,000 t of these domestic industrial catches were taken by foreign vessels reflagged to Guinea. Industrial catches in the Guinean EEZ increased from 325 in 1950, when the fishery started, to a peak of 58,500 t·year^{-1} in 1985, then decreased to around 36,000 t·year^{-1} in 2001 (Figure 6). Guinean industrial catches remained relatively constant during the last decade at about 36,000 t·year^{-1} (Figure 6).

Foreign: Foreign legal catches (excluding discards)in the Guinean EEZ were estimated at nearly 15 million t over the period from 1950 to 2010. Industrial foreign catches increased from 36,400 t·year^{-1} in 1950 to their first peak of 351,600 t·year^{-1} in 1988, i.e, twice as high as total domestic catches (166,400 t·year^{-1}), then decreased to 338,000 t·year^{-1} in 1993 after the first attempt to limit foreign industrial fishing by Guinea (Figure 7). Thereafter, foreign industrial catches increased drastically to reach a peak of 551,000 t·year^{-1} in 2000, over 3 times higher than the reconstructed domestic catch in Guinean EEZ (Figure 7), then decreased again to 424,000 t·year^{-1} in 2010. Overall,

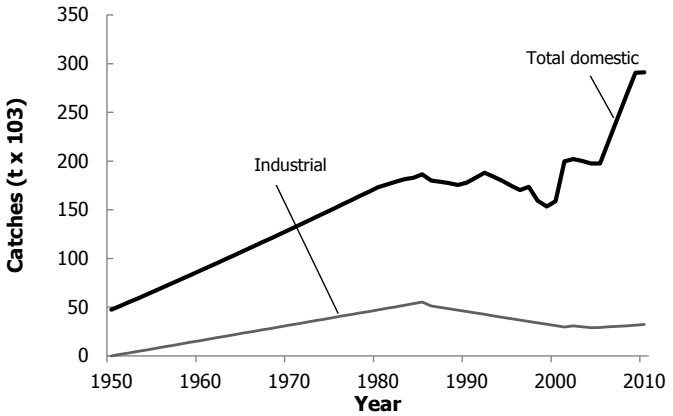

Figure 6. Domestic industrial catches in Guinean EEZ compared to total reconstructed catches, 1950-2010. Semi-industrial catches, also called advanced-artisanal, are not included in the industrial catch shown in this figure.

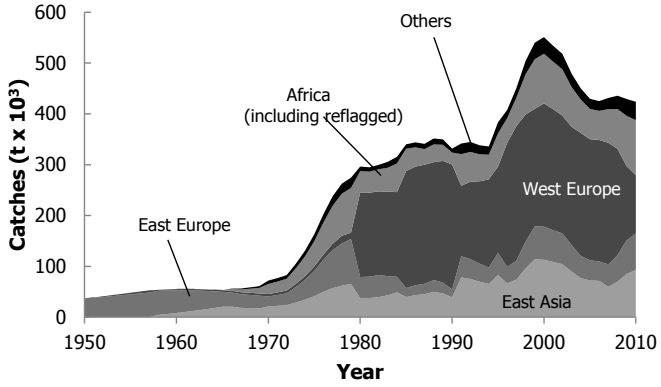

Figure 7. Foreign catches by legal fleets in Guinea, 1950-2010.

industrial foreign catches (15 million t) were almost twice as high as the domestic catch (8.4 million t) during the 1950-2010 time-period. Countries from Eastern Europe (Russia, Ukraine, Yugoslavia and Poland) and East Asia (Korea, Japan and China) accounted for the bulk of foreign industrial catches in the Guinean EEZ between 1950 and 1980, with 68% of the total foreign catch (Figure 7). After 1980, when Guinea declared its EEZ, foreign industrial catches were dominated by Western European countries accounting for 50% of the industrial reconstructed catch and East Asian countries with 20% of the total foreign industrial catch from 1981 to 2010 (Figure 7). More recently, western European industrial catches decreased to account for 43% of industrial catches in Guinean EEZ between 2005 to 2010, whereas African vessel (mostly non-African reflagged) catches increased from being 14% of the total foreign catch in Guinea waters from 2005 to about 20% in 2010 (Figure 7).

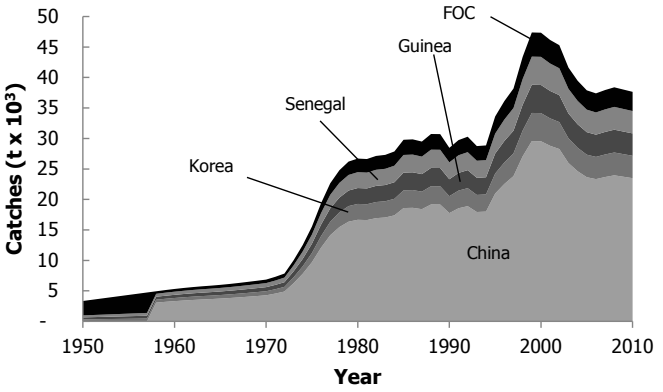

Figure 8. Illegal catches in the Guinean EEZ by country of origin, 1950-2010.

Illegal

Illegal foreign catches totalled around 1.3 million t from 1950 to 2010 (Figure 8). Illegal catches increased from around 3,300 t·year^{-1} in 1950 to around 26,700 t in 1980, when Guinea declared its EEZ. Catches prior to the EEZ declaration were considered unregulated rather than illegal. Illegal catches remained relatively constant from 1980 to 1993 at around 27,000 t·year^{-1}. Thereafter, illegal catches increased, after Guinea reduced the number of foreign fishing licences, to a peak of at least 47,400 t·year^{-1} in the late 1990s, then decreased to remain at a relatively constant catch of around 37,000 t·year^{-1} in the 2000s (Figure 8). Overall, China was responsible for the bulk of illegal catches in Guinea, with over 60% of the illegal catches between 1950 to 2010 (approximately 800,000 t), whereas vessels reflagged to Guinea and Senegal were responsible for 20% of the total illegal catch in the Guinean EEZ, followed by Korea with 10% (approximately 130,000 t, Figure 8).

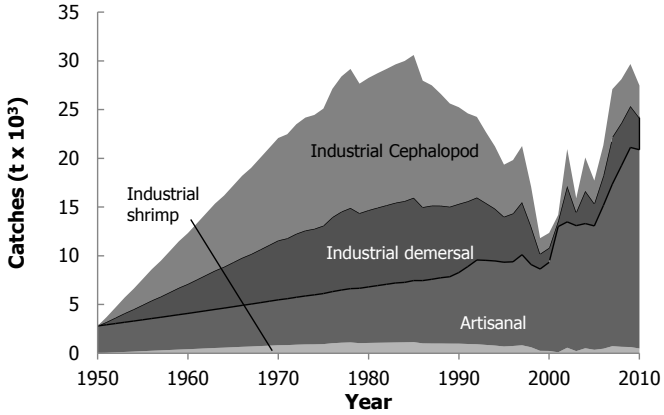

Figure 9. Discards by the domestic sectors in Guinea, 1950-2010.

Discards

Domestic discards were estimated at 1.2 million t between 1950 and 2010 (Figure 9), which is 14% of the total reconstructed domestic catch (Figure 2b). Discards increased from 2,800 t·year^{-1} in 1950 to a peak of 31,000 t·year^{-1} in the mid-1980s, before declining substantially in the late 1990s. By 2010, discards had increased again to around 27,000 t·year^{-1} (Figure 9). Industrial fisheries were responsible for the bulk of discards with 64% (782.171 million t) of the total discards by the Guinean fleet from 1950 to 2010, of which 40% was by the demersal sector. Artisanal discards were estimated at 436,000 t·year^{-1} between 1950 and 2010, i.e., 36% of the total discard by the Guinean fleets (Figure 9).

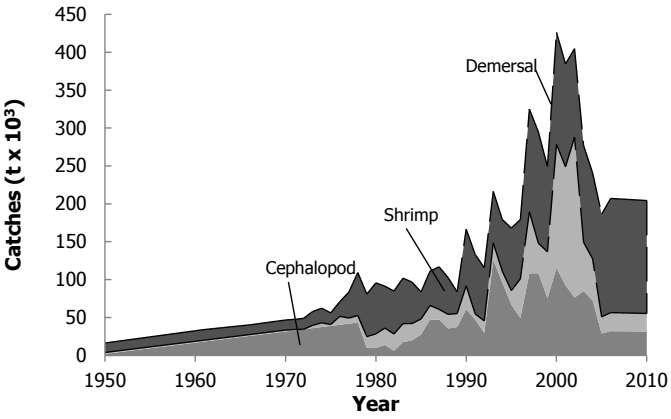

Figure 10. Discards by the foreign fleet by taxonomic group from the waters of Guinea, 1950-2010.

Foreign discards were estimated at 7.2 million t between 1950 and 2010, 48% of which were by demersal trawlers, 20% by shrimpers, and 32% by cephalopod trawlers (Figure 10). Foreign discards increased from 16,300 t·year^{-1} in 1950 to a peak of 426,000 t·year^{-1} in 2000 then decreased to be 205,000 t·year^{-1} by 2010 (Figure 10).

Discussion

This study is the first attempt to reconstruct the recent history of Guinean fisheries catches, including all the sectors that have been identified from 1950 to 2010. Although results were based on a number of assumptions, they were supported by well documented facts, evidence and external expertise. Thus, while uncertainty around these estimates exists, they are probably more accurate than the data provided to the FAO on behalf of Guinea and the distant water

fleet countries that exploit its EEZ. Furthermore, while this study uses CPUEs documented in published literature, in-country discussions with representatives of the artisanal fishing community revealed that the CPUE could be 40% higher than the one used here on average. However, the decreasing CPUE shown in the literature was validated (Aboubacar Kaba, ROPPA, pers. comm.). Along with the over-exploitation of formerly important species such as the giant African threadfin, ray species and snappers; a major decrease in fish size was also reported (Abdullaye Soumah, Artisanal Fishers Association, pers. comm.), which is another sign of over-exploitation.

Foreign fleets can significantly reduce catch opportunities for artisanal fishers, which have been declining over the last decades (EJF 2009). Indeed, the obvious spatial conflict between artisanal and foreign industrial sectors has further reduced the ability of artisanal fishers to improve their livelihoods. The poorly regulated and little monitored or enforced distant water fleets are clearly not helping here, but rather handicapping domestic fisheries and socio-economic development in Guinea. Therefore, the validity of fishing access agreements (let alone the substantial illegal fishery) offered to capture a 'surplus' in the Guinea EEZ is highly questionable, as the benefits to the Guinean population should be seriously considered. Repetitive evidence of illegal fishing, which is considered an international trans-boundary crime (INTERPOL 2010), by European and Asian fleets was available for decades (Anon. 2006). This, along with an obvious lack of monitoring and enforcement of Guinean fisheries (direct exports, trans-shipment, subsistence fisheries, industrial discards, processed fish[3]) (Solie 2004), raises serious concerns about the long term sustainability of Guinean fisheries. Furthermore, catches by foreign fleets are substantially higher than the potential catch of 200,000 t·year^{-1} estimated by the Guinean government (Anon. 2003). Moreover, in the mid-1990s, stocks of targeted and non-targeted species were already over-exploited, and abundance decreased (Figure 2). Therefore, the very recent 60% decrease in IUU catches (Aboubacar Kaba, ROPPA, pers. comm.) is related to the decrease in fishing opportunities for the illegal fleet in terms of ressource availability and surveillance capacity. While decreasing industrial presence is believed to have decreased the conflicts between artisanal and industrial sectors, the increasing presence of Senegalese pirogues fishing in Guinea but landing in Senegal, creates a new type of conflict with the Guinean artisanal fishers (Abdullaye Soumah, Artisanal Fishers Association, pers. comm.).

Another aspect of Guinean fisheries which most likely contributed to the decrease in catches inspite of an increasing capacity, is the high level of corruption involving European fleets (mostly Spanish tuna vessels) and members of the Guinean government, resulting in foraged licenses[4]. These fleets, along with other Asian fleets, were fishing in Guinean waters but exporting catches relabelled as Senegalese, Mauritanian or under the name of any West African country obeying the EU hygiene and health standards (Aboubacar Kaba, ROPPA, pers. comm.), which is now the new fashion in West Africa.

Economically, in the 1980s Guinea received compensation 5 times lower than the ex-vessel value of landings by foreign fleets fishing under Guinean access agreements (Kaczynski 1989), and this has further increased in recent years. As the amount of fish taken from Guinean waters by foreign fleets increased, the compensation decreased from 20% in the 1980s to 3% of the landed value of catches in 2010. While this mirrors a pattern seen elsewhere in West and East Africa (Iheduru 1995; Kaczynski and Fluharty 2002; Le Manach *et al.* in press), the repercussions in Guinea are extensively perceived, since fishing agreements had almost no benefit on local fishing communities, now facing the expansion of their own (over-exploited) fisheries at higher fishing costs. This study highlights the importance of fisheries resources in Guinea; both as protein source and an avenue of livelihood for coastal populations. Fish is more accessible to a large part of the population than any other animal protein sources. With increasing frequency of droughts caused by climate change, this dependency on fish is likely to increase (Allison *et al.* 2009), and therefore the present challenges persist, the economic future of Guinean fisheries is highly uncertain.

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Appendix Table A1. Annual catches by Guinea.

Year	Data reported to FAO	Artisanal	Industrial	Subsistence	Discards	Reconstructed catches
1950	900	22,357	0	22,357	2,795	47,509
1951	900	23,013	1,445	23,013	3,709	51,180
1952	900	23,690	3,022	23,690	4,708	55,111
1953	900	24,376	4,599	24,376	5,713	59,064
1954	1,800	25,069	6,176	25,069	6,616	62,931
1955	1,800	25,771	7,753	25,771	7,611	66,906
1956	1,800	26,481	9,330	26,481	8,612	70,904
1957	2,600	27,199	10,907	27,199	9,480	74,785
1958	2,600	27,925	12,484	27,925	10,479	78,813
1959	2,600	28,659	14,061	28,659	11,483	82,862
1960	3,400	29,401	15,638	29,401	12,325	86,766
1961	3,400	30,152	17,215	30,152	13,329	90,848
1962	3,400	30,910	18,792	30,910	14,338	94,950
1963	3,400	31,677	20,369	31,677	15,350	99,073
1964	4,200	32,451	21,946	32,451	16,173	103,022
1965	4,200	33,234	23,523	33,234	17,187	107,178
1966	4,200	34,025	25,100	34,025	18,204	111,354
1967	5,000	34,824	26,677	34,824	19,016	115,342
1968	5,000	35,631	28,254	35,631	20,035	119,552
1969	5,000	36,446	29,831	36,446	21,057	123,781
1970	5,000	37,270	31,408	37,270	22,082	128,030
1971	7,300	38,101	32,985	38,101	22,471	131,658
1972	7,300	38,941	34,562	38,941	23,493	135,936
1973	8,500	39,788	36,139	39,788	24,175	139,891
1974	11,100	40,644	37,716	40,644	24,450	143,454
1975	12,370	41,508	39,293	41,508	25,099	147,408
1976	8,920	42,380	40,870	42,380	27,130	152,760
1977	8,120	43,260	42,447	43,260	28,398	157,365
1978	9,000	44,148	44,024	44,148	29,170	161,490
1979	17,453	45,044	45,601	45,044	27,661	163,351
1980	18,900	45,949	47,219	45,989	28,250	167,406
1981	20,700	46,861	48,837	44,830	28,729	169,256
1982	22,600	47,782	50,454	43,592	29,174	171,002
1983	24,400	48,728	52,031	42,255	29,643	172,656
1984	26,200	49,053	53,649	40,356	29,989	173,047
1985	28,000	50,229	55,524	39,179	30,601	175,532
1986	30,500	50,988	51,733	37,636	27,967	168,324
1987	32,000	51,753	50,698	36,117	27,489	166,058
1988	35,000	52,524	49,745	34,549	26,602	163,420
1989	38,000	53,300	48,465	32,677	25,624	160,065
1990	41,000	56,899	46,898	32,115	25,239	161,152
1991	46,000	62,355	45,206	32,115	24,603	164,279
1992	51,000	67,755	43,955	31,824	24,245	167,779
1993	56,000	67,798	42,727	28,807	22,685	162,017
1994	60,000	67,787	41,380	25,695	21,218	156,080
1995	64,760	67,623	39,879	22,480	19,345	149,327
1996	60,580	67,683	38,377	19,360	19,819	145,238
1997	58,841	73,088	36,806	17,482	21,256	148,633
1998	65,764	66,782	35,307	12,900	17,086	132,075
1999	83,314	66,055	34,038	9,741	11,802	121,637
2000	87,513	71,498	32,665	7,276	12,343	123,782
2001	101,227	98,735	31,464	9,806	14,189	154,193
2002	87,358	101,511	32,575	9,296	20,947	164,329
2003	114,845	101,154	31,638	8,757	15,890	157,439
2004	88,550	100,637	30,534	8,190	20,082	159,443
2005	98,566	100,121	30,793	7,629	17,712	156,255
2006	94,489	113,524	31,367	8,224	21,331	174,445
2007	70,823	128,280	31,895	8,651	27,095	195,922
2008	81,240	141,722	32,511	8,915	28,108	211,256
2009	81,000	155,868	33,083	9,015	29,676	227,642
2010	93,000	154,045	33,810	8,159	27,010	223,024

Appendix Table A2. Total reconstructed catches by taxon caught by the domestic fisheries of Guinea, 1950-2010.

Year	*Pseudotolithus* spp.	Threadfins	*Arius* spp.	*Ethmalosa fimbriata*	Clupeoids	*Pomadasys* spp.	*Cynoglossus* spp.	Cephalopods	Scombroids	Sparidae	Others[a]
1950	3,062	356	1,464	19,225	16,432	127	0	0	347	1,238	5,258
1951	3,659	590	1,746	19,831	16,920	239	161	675	359	1,312	5,690
1952	4,308	846	2,052	20,453	17,423	360	337	1,415	371	1,391	6,156
1953	4,959	1,103	2,360	21,075	17,931	483	514	2,160	382	1,470	6,627
1954	5,446	1,321	2,589	21,870	18,396	588	672	2,821	382	1,503	7,342
1955	6,096	1,576	2,896	22,523	18,918	709	847	3,556	395	1,583	7,809
1956	6,748	1,832	3,204	23,176	19,445	831	1,022	4,295	407	1,664	8,280
1957	7,240	2,043	3,435	24,166	19,939	932	1,173	4,926	410	1,706	8,815
1958	7,893	2,298	3,744	24,836	20,479	1,054	1,348	5,662	423	1,788	9,290
1959	8,549	2,554	4,053	25,507	21,024	1,175	1,524	6,401	436	1,870	9,769
1960	9,034	2,759	4,282	26,397	21,539	1,273	1,668	7,008	440	1,915	10,451
1961	9,691	3,015	4,592	27,086	22,097	1,395	1,844	7,745	453	1,998	10,931
1962	10,351	3,272	4,904	27,777	22,660	1,518	2,020	8,486	466	2,081	11,416
1963	11,013	3,530	5,216	28,471	23,228	1,640	2,197	9,228	479	2,165	11,904
1964	11,494	3,730	5,443	29,277	23,770	1,735	2,337	9,816	485	2,214	12,721
1965	12,158	3,988	5,757	29,988	24,351	1,858	2,513	10,558	498	2,298	13,211
1966	12,824	4,247	6,071	30,703	24,937	1,981	2,690	11,302	512	2,383	13,704
1967	13,304	4,443	6,297	32,339	25,498	2,075	2,828	11,879	518	2,434	13,725
1968	13,972	4,702	6,613	33,063	26,097	2,198	3,005	12,623	532	2,520	14,227
1969	14,643	4,962	6,929	33,792	26,701	2,322	3,182	13,369	546	2,606	14,731
1970	15,315	5,222	7,247	34,665	27,310	2,445	3,360	14,115	559	2,693	15,098
1971	15,432	5,292	7,302	36,704	27,843	2,480	3,415	14,346	554	2,683	15,609
1972	16,104	5,551	7,619	37,456	28,465	2,603	3,592	15,089	568	2,771	16,119
1973	16,485	5,709	7,799	38,875	29,051	2,678	3,703	15,556	572	2,809	16,654
1974	16,521	5,747	7,815	41,071	29,594	2,697	3,735	15,692	565	2,790	17,227
1975	16,882	5,896	7,985	42,559	30,191	2,768	3,840	16,130	569	2,827	17,762
1976	18,411	6,453	8,708	41,407	30,957	3,031	4,210	17,688	613	3,059	18,223
1977	19,289	6,784	9,123	41,738	31,636	3,188	4,434	18,625	634	3,182	18,732
1978	19,752	6,968	9,341	43,023	32,263	3,276	4,561	19,161	642	3,236	19,267
1979	18,319	6,481	8,663	48,410	32,642	3,048	4,249	17,848	589	2,982	20,119
1980	18,651	6,617	8,817	50,050	33,293	3,111	4,339	18,229	593	3,016	20,691
1981	18,894	6,719	8,929	51,198	32,523	3,158	4,409	18,520	595	3,036	21,276
1982	19,112	6,812	9,028	52,403	31,698	3,200	4,471	18,784	596	3,053	21,845
1983	19,340	6,908	9,136	53,517	30,811	3,246	4,539	19,068	598	3,075	22,420
1984	19,477	6,986	9,198	54,181	29,513	3,283	4,597	19,312	592	3,064	22,845
1985	19,853	7,131	9,364	55,477	28,750	3,343	4,683	19,671	598	3,105	23,557
1986	18,380	6,413	8,678	55,508	27,813	2,984	4,151	17,436	580	3,082	23,299
1987	17,854	6,181	8,397	55,622	26,778	2,848	3,945	16,977	576	3,024	23,854
1988	17,760	5,894	8,376	54,476	26,167	2,658	3,665	16,143	559	3,355	24,367
1989	17,542	5,557	8,331	53,179	25,335	2,466	3,387	15,266	541	3,691	24,771
1990	17,490	5,290	8,350	52,979	25,378	2,326	3,170	14,611	557	4,005	26,995
1991	17,495	4,945	8,424	54,721	25,987	2,141	2,881	13,680	581	4,479	28,946
1992	18,469	4,734	9,005	54,762	26,879	1,989	2,643	12,858	599	5,406	30,434
1993	17,875	4,292	8,809	53,036	25,225	1,758	2,326	11,618	544	5,671	30,862
1994	16,705	3,838	8,272	52,758	23,060	1,550	2,041	10,272	828	5,541	31,215
1995	17,383	3,496	8,807	47,271	22,198	1,307	1,708	8,936	896	6,645	30,682
1996	16,307	3,604	8,237	48,957	21,096	1,349	1,750	9,204	2,834	5,897	26,004
1997	15,983	3,606	7,561	55,084	18,237	1,435	1,838	9,894	1,998	6,032	26,963
1998	13,152	2,372	6,220	46,931	16,621	1,013	1,296	7,653	1,652	4,725	30,439
1999	7,352	1,042	3,965	48,496	16,270	413	510	4,078	500	4,083	34,928
2000	10,796	1,047	6,150	41,596	19,003	396	483	2,873	427	2,654	38,356
2001	13,419	835	8,391	59,830	16,429	290	190	1,378	1,481	6,162	45,789
2002	20,036	2,484	10,023	61,268	14,942	1,005	1,180	6,510	1,159	4,866	40,857
2003	16,484	1,985	13,446	67,130	10,471	378	440	2,435	225	2,254	42,191
2004	18,568	3,655	9,823	57,452	9,112	905	1,056	5,876	533	3,052	49,412
2005	21,186	3,373	7,946	35,800	7,480	637	720	4,021	3,306	2,027	69,760
2006	25,597	4,233	9,406	57,665	10,376	898	951	5,337	1,257	3,240	55,484
2007	24,136	4,340	11,331	73,962	13,406	1,449	1,488	8,380	1,224	6,456	49,748
2008	27,864	4,313	16,440	81,826	13,076	1,385	1,348	7,624	1,757	5,875	49,749
2009	29,827	4,488	17,336	89,873	14,184	1,439	1,292	7,332	1,993	6,742	53,136
2010	27,175	3,767	16,173	84,100	20,521	1,173	987	5,417	4,289	6,081	53,339

a) include Elasmobranchii, Carangidae, Mugilidae, Sparidae, *Drepane africana*, *P. notialis*, *Penaeus kerathurus*, and various fishes.

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