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Fisheries catch under-reporting in The Gambia, Liberia and Namibia and the three large marine ecosystems which they represent

Dyhia Belhabib^{a,*}, Asberr Mendy^b, Yevewuo Subah^c, Nasi T. Broh^c, Alvin S. Jueseah^c, Nicolas Nipey^c, William W. Boeh^c, Nico Willemse^d, Dirk Zeller^a, Daniel Pauly^a

^a Sea Around Us, Fisheries Centre, University of British Columbia, 332-2202 Main Mall, Vancouver, B.C., Canada V6T 1Z4

^b Sub-Regional Fisheries Commission, Dakar, Senegal

^c Bureau of National Fisheries, Monrovia, Liberia

^d United Nations Development Programme, Namibia

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ABSTRACT

Fisheries catches from the Exclusive Economic Zones of three West African countries, each representing a Large Marine Ecosystem (LME), were reconstructed to cover all fishing sectors over a 6-decade period. While there are strong differences in terms of target species and the ecosystems within which they are embedded, there are similarities in the manner that domestic catches in The Gambia, Liberia and Namibia are under-reported. For The Gambia, catches by all domestic sectors were assessed to be twice the data supplied by The Gambia to the Food and Agriculture Organization of the United Nations (FAO). This is similar to the trend observed for Liberia, representing the Guinea Current LME, and where there is a larger margin for improvement, as the Liberian small-scale sector on its own is twice the entirety of the catches reported to the FAO. In Namibia, representing the Benguela Current LME, reconstructed catches were only 9% higher than the data reported by the FAO on behalf of Namibia, implying that the drastic measures implemented by Namibia to prevent illegal fishing are bearing fruits. Important lessons can be drawn from the present study for other countries in West Africa, notably for combating illegal foreign fishing, still rampant in the CCLME and the GCLME, and in managing small-scale fisheries, which require, as a starting point a detailed knowledge of their catch. These latter points are illustrated, finally, by catch time series for these three LMEs, reconstructed by taking account of the other 20 West African countries.

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1. Introduction

The western coast of the African continent (Fig. 1) comprises some of the most productive fisheries ecosystems in the world, encompassed within three Large Marine Ecosystems (LME) (Sherman and Hempel, 2008), whose fisheries are sources of employment, revenue, and food (Fao, 2006). LMEs of West Africa comprise the entirety or part of the Exclusive Economic Zone (EEZ) of the countries which border them (Fig. 1).

The Canary Current LME (CCLME, Fig. 1) is known for its geographical diversity, high productivity and fisheries wealth (Arístegui et al., 2009). A seasonal upwelling, a wide continental shelf, and strong river discharge in the south of this LME

* Corresponding author.

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E-mail address: d.belhabib@fisheries.ubc.ca (D. Belhabib).

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Fig. 1. West African Large Marine Ecosystems and the Exclusive Economic Zones of the countries therein. The light blue line in the south represents the boundary of the Agulhas Current Large Marine Ecosystem.

play a major role in enriching the waters of the CCLME (Aristegui et al., 2009). These three factors are all represented in The Gambia, one of Africa's smallest coastal states. The Gambia lies almost entirely in the Savannah-Sahel belt of West Africa, and consists of a strip of land whose width varies from 25 to 50 km on either side of the Gambia River (Horemans et al., 1996). The particular shape of The Gambia implies that most Gambians live along the coast or the banks of the Gambia River, thus making fishing an integral part of their lives, particularly given that a third of them live below the international poverty line.

The Guinea Current Large Marine Ecosystem (GCLME), (Fig. 1) is located in the Eastern Equatorial Atlantic region and is characterized by a relatively wide continental shelf with low lying coastal topography and a large number of estuarine

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systems with strong river inflows (Ukwe et al., 2003). The GCLME region exhibits one of the highest population growth rates of the world, which puts a severe strain on local fisheries, also heavily targeted by important foreign fleets (Ukwe et al., 2003). Moreover, the GCLME encompasses one of the countries (Guinea) most affected by illegal, unreported and unregulated fishing (Godoy, 2010). Liberia, whose population lives principally on the coast, illustrates such patterns. A 1980 *coup d'état* plunged the country into a protracted civil war that killed 250,000 people and caused tremendous damage to the liberian infrastructure (Hendrix and Glaser 2011). As a result, Liberia emerged from this difficult period with 85% of its

Liberian infrastructure (Hendrix and Glaser, 2011). As a result, Liberia emerged from this difficult period with 85% of its population below the poverty line (Anon., 2013). A high unemployment rate caused many Liberians to see fisheries as the only option to secure a livelihood (Glasgow, 2008), a fact that is masked by dubious official fisheries catch statistics (Haakonson, 1992).

The Benguela Current Large Marine Ecosystem (BCLME), (Fig. 1) is located off the southern coast of West Africa and comprises Angola, Namibia and the western coast of South Africa. The BCLME experienced severe over-exploitation by foreign fleets (Crawford et al., 1987, Sumaila and Vasconcellos, 2000), as illustrated by the collapse of several fish stocks during the 1960s and 1970s (Hutchings et al., 2009). These patterns are notably observed in Namibia, whose fleets were, at the time, not controlled by Namibia (Reid et al., 2007). The uncontrolled fishing activity before Namibia's independence in 1990 led to the collapse of several fish stocks (Fergus et al., 2005). Despite this burden of history, after independence, Namibia implemented a policy of rebuilding stocks to their "full potential" (Anon., 2004) using various approaches (Fergus et al., 2005). As a result, fisheries have become the second largest foreign currency earner in the country (Anon., 2004).

Despite obvious differences, a common feature of the fisheries of The Gambia, Liberia and Namibia is the fact that their industrial fisheries are, or were until recently, almost exclusively operated and controlled by foreign interests; also, their catches are barely recorded (Belhabib et al., 2013a, 2013b, Belhabib, 2015c). Artisanal fisheries monitoring efforts vary from good (based on a comprehensive survey) in The Gambia and Liberia to nonexistent in Namibia. Subsistence and recreational fisheries are not monitored and in many cases, are simply assumed to be marginal. Discards are assessed occasionally if at all, whenever industrial vessels carry observers onboard.

Overall, the fisheries statistics of these three countries range from dubious and sometimes outdated in the case of The Gambia (Lazar and Somers, 2011, Horemans et al., 1996, Belhabib et al., 2013a) to very doubtful in the case of Liberia during the civil war (Belhabib et al., 2013b). This also applied to Namibia in the past, before independence, when the uncontrolled nature of the foreign fleets often went along with misreporting of catches (Sumaila et al., 2004; Anon., 2009; Kirchner et al., 2012).

This situation makes it extremely difficult to describe long-term trends of fisheries and thus inform policy makers (Pauly, 1998b; Zeller et al., 2007). Thus, there is an urgent need to reassess more realistic fisheries catches, by adding time series estimates of unreported components to the reported landings baseline, i.e., to the catch statistics supplied by The Gambia (Belhabib et al., 2013a), Liberia (Belhabib et al., 2013b) and Namibia (Belhabib et al., 2015c) and other countries that are part of the CCLME, GCLME and BCLME to the Food and Agriculture Organization of the United Nations (FAO).

2. Methods

We define four separate fishing sectors of either large- or small-scale nature, these being (a) industrial (i.e., large-scale and commercial), (b) artisanal (i.e., small-scale and commercial), (c) subsistence (i.e., small-scale and non-commercial), and (d) recreational (i.e., small-scale and non-commercial).

2.1. Artisanal fisheries

2.1.1. In The Gambia

Artisanal fisheries in The Gambia operate both off the Atlantic coast of The Gambia and along the Gambia River (Mendy, 2009), and catches were reconstructed by Belhabib et al. (2013a). Artisanal landings documented by the Catch Assessment Surveys (CAS) included largely the marine (Atlantic) component between 1981 and 1992, then expanded to include both marine and river¹ components since then (Anon., 2008a, Anon., 2006). To complete the artisanal catch time series, we first estimated a time series of catch per unit of effort (CPUE). A CPUE of 269 kg boat⁻¹ trip⁻¹ for 1994 was estimated as the mean of values for two landing sites in The Gambia (Horemans et al., 1996). We assumed that the CPUE was 20% higher in 1950 compared to the 1994 CPUE due to over-exploitation, and only 20% lower in 2000, which considers the effect of the drastic decrease in industrial fishing effort since the mid-1990s. Thereafter, we interpolated linearly between these CPUE estimates to fill the gaps. We then followed a series of steps:

2.1.1.1. For the marine component. (1) For the period between 2006 and 2009, we used the data provided by the government of The Gambia, and also assumed the 2010 catch to be the same as in 2009;

(2) For 1993-2005, artisanal marine landings were estimated as 77% of total landings (Anon., 2006), provided by the government of The Gambia;

¹ Recall that Gambia River catches include mostly marine and estuarine species as the lower Gambia River is actually a long estuary.

(3) For the period between 1981 and 1992, we used the data on artisanal landings provided by the government of The Gambia, which only included the marine component;

(4) For 1980, we multiplied the number of canoes operating along the Atlantic coast, i.e., 422 (Belhabib et al., 2013a) by the CPUE for 1980 (286 kg boat⁻¹ days⁻¹), then by the number of days spent fishing for the canoes operating on the Atlantic coast, conservatively assumed to be operating five months per year, i.e., 150 days;

(5) We repeated step (4) for 1974 and 1965 for a number of canoes estimated at 350 and 214, respectively (Everett, 1976), and a CPUE of 294 kg boat⁻¹ day⁻¹ for 1974 and 304 kg boat⁻¹ day⁻¹ for 1965 using the same number of fishing days;

(6) We extrapolated the trend drawn by catches estimated in (4) and (5) backwards to estimate the marine catch for 1950, and then interpolated linearly to fill the gaps.

For the Gambia River component, we:

(7) Repeated step (1) between 2006 and 2010 for the river component;

(8) Estimated river landings as the difference between the total artisanal landing data and the marine component estimated in step (2) between 1992 and 2005;

(9) Multiplied the number of boats operating in the river in 1980 (Lesack and Drammeh, 1980), i.e., 290 canoes, by an interpolated CPUE of 286.1 kg boat⁻¹ trip⁻¹ and 50 fishing trips, and estimated river catches at 6,037 t year⁻¹ for 1980. River catches were then the equivalent of 33% of artisanal catches;

(10) Applied the rate estimated in (9) to artisanal catches and estimated river catches for 1974 and 1965; and

(11) Repeated Step (6) for the Gambia River catch component for 1950–1964.

For inference on the species composition of the catch, we used data from CAS (A. Mendy, unpubl. data), and assumed that the taxonomic breakdown provided for 1992 (which included marine and river catches) applied to total artisanal catches prior to 1981.

2.1.2. In Liberia

Belhabib et al. (2013b) reconstructed the small-scale fishing effort in Liberia based on ethnic affiliations. The *Kru* ethnic group fished typically for subsistence, while the much bigger fisheries operated by *Fanti* canoes and the large Popoh beach seines are for commercial purposes, hence artisanal. Ratcliff and Lindley (1988) estimated a catch of 14,000 t year⁻¹ for 262 *Fanti* canoes, i.e., 53 t canoe⁻¹ year⁻¹ for 1988. We assumed the CPUE for the *Fanti* canoes was 30% lower in 1950 because of the lower effort efficiency (Van Pel, 1954), and decreased by 50% in 2010 due to a generalized over-exploitation pattern (Mees et al., 2011). We assumed that one *Popoh* beach seine (with 8 fishers) would extract 3.2 times as much as one *Kru* fishing boat (with 2.5 fishers on average), i.e., the *Popoh* CPUE was estimated to be the *Kru* CPUE multiplied by 3.2. We performed a series of linear interpolations to fill the gaps for the effort (for *Popoh* and *Fanti* fishers) and CPUEs (see Belhabib et al., 2013b), then multiplied each category of effort by the corresponding CPUE to derive total artisanal catches.

2.1.3. In Namibia

There were no documented artisanal fisheries in Namibia; rather all small-scale activities in this area are directed towards personal consumption in the form of recreational or subsistence activities (see below).

2.2. Subsistence fisheries

Subsistence catches are usually estimated based on the effort exerted, here expressed by the number of fishers (inferred from coastal population data or through field surveys), and the amount of fish they catch or consume. We extracted the total population for The Gambia, Liberia and Namibia from Populstat (www.populstat.info [2013]) for 1950, and from The World Bank database between 1960 and 2010, and interpolated to fill the gaps. We estimated the coastal population using the coastal population rate for 1990 and 2010 extracted from Ciesin (2012). Given the relatively low change in this rate between 1990 and 2010 for The Gambia, we kept the coastal population rate constant for the entire time period. For Namibia, we extrapolated it backwards assuming the same trend. For Liberia, we assumed the 1950 coastal population rate to be 10% lower than the 1990 rate, due to increased migrations towards the coast over time (Belhabib et al., 2013b).

2.2.1. In The Gambia

Subsistence fishing in The Gambia has three components (Anon, 2012): shellfish collection activities undertaken mostly by women, fish given to women for helping men with their fishing activities, and line and net fishing by men and crab gathering by children (Madge, 1994).

A survey covering the entire *Tanbi* National Park area estimated an average of 42 fishers (shellfish collectors) per village in 2012, 30 fishers per village in 2002, and 10 fishers per village in 1982 (Anon, 2012). We extrapolated these figures backwards, and estimated 1.9 fishers per village on average in 1950, and 3.43 for 1962, which we increased by 30% to account for the increase in the coastal population caused by the 1962 drought (Belhabib et al., 2013a). Since the sample provided by Anon (2012) covers the entire *Tanbi* National Park and gives a realistic retrospective of the other mangroves of The Gambia, we assumed that these numbers apply in a similar way to villages located near other mangroves along the Gambia River, notably the eight mangroves studied in Njie and Drammeh (2011), where similar activities occur. We therefore used Google Earth to count 75 villages around these mangroves within a range similar to that of the villages surrounding *Tanbi* National Park. We assumed the number of villages remained constant between 1950 and 2012. We then

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(IPCC criteria from Fig. 1 of Mastrandrea et al. (2010); % intervals adapted from Ainsworth and Pitcher (2005) and Tesfamichael and Pitcher (2007).

Table 1 Table extracted from Zeller, Zylich²¹ representing the 'Score' for evaluating the quality of time series of reconstructed catches, with their uncertainty range

 \pm % Corresponding IPCC criteria Score 10 4 Very high High agreement and robust evidence 3 High 20 High agreement and medium evidence or medium agreement and robust evidence 2 Low 30 High agreement and limited evidence or medium agreement and medium evidence or low agreement and robust evidence 1 Very low 50 Less than high agreement and less than robust evidence

Mastrandrea et al. (2010) note that "confidence increase" (and hence confidence intervals are reduced) "when there are multiple, consistent independent lines of high-quality evidence"

multiplied the number of fishers per village estimated previously for 1950, 1962, 1980, 2002 and 2012 by the total number of villages and estimated total number of fishers for these years (see Table 1 in Belhabib et al., 2013a).

CPUEs were estimated in terms of number of 'buckets' of shellfish at 2 buckets fisher⁻¹ trip⁻¹ for 2012, 3.5 buckets fisher⁻¹ trip⁻¹ for 2002 and 7 buckets fisher⁻¹ trip⁻¹ for 1982 (Anon., 2012). This declining trend reflects the over-exploitation status of these fisheries (Njie and Drammeh, 2011). The same authors observed a CPUE of processed, i.e., smoked shellfish of 2.57 kg fisher⁻¹ trip⁻¹, which was when multiplied by a conversion factor of 4.5 (Fao, 2000), which resulted in a wet weight CPUE of 11.55 kg fisher⁻¹ trip⁻¹ for 2011 (assumed constant from 2010 to 2012). Considering two buckets per trip, the catch was averaged at 5.78 kg of wet-weight shellfish per bucket. We multiplied the latter by the number of buckets per year, assuming a constant weight for each bucket, and estimated catch per trip for 2002 and 1982, and extrapolated backwards to estimate catch per trip for 1962 (year of the drought) and 1950 (see Table 1 in Belhabib et al., 2013a). The number of active fishing days was estimated at 120 (Belhabib et al., 2013a). Thus, we obtained shellfish catches by multiplying the CPUE by the number of fishers and the number of fishing days and then disaggregated them taxonomically based on the species composition provided by Niang (2008).

Madge (1994) estimated that, in 1988, non-traded marine fish was consumed on 141 occasions per household of 16.25 people on average. Assuming 1 kg household⁻¹ at each occasion, results in 8.67 kg capita⁻¹ being consumed annually from such fishing activities. Given increasing prices of fish (Njie, 2007), we assumed this quantity was 20% higher in 1950, and 50% lower in 2010, and interpolated linearly to fill in the time series for the intervening years (Belhabib et al., 2013a). Today, a household in The Gambia averages 11.6 members (Jaimovich, 2011). We assumed the size of the household to be constant between 1950 and 1988 at 16.25 people, and interpolated between 1988 and 2011 (11.6 people) to fill the data for the intervening years. Assuming that one woman helps with one canoe on average (which is highly conservative), we multiplied the number of canoes (see Belhabib et al., 2013a) by the number of people supported by these women in each household, and then by the consumption rate per capita, assuming the number of canoes was constant between 1950 and 1964, as data on the number of canoes was missing during this time period.

Another component of subsistence fisheries is the catch that is taken by men and children along the coast of The Gambia, given that around 6% of each household along the coast of The Gambia engage in fishing (Jaimovich, 2011). To estimate catches by men and children, we multiplied per capita fish consumption estimated earlier (see Belhabib et al., 2013a) by the coastal population (after subtraction of the catches generated by women to avoid double-counting).

2.2.2. In Liberia

'Inland' fisheries in Liberia are completely unmonitored, but are believed to be extremely important for food security, given the presumed high catch (Belhabib et al., 2013b). This also applies to fisheries in the coastal, brackish and lagoon waters considered here (freshwater fisheries are not considered), where we will refer to these as 'lagoon catches'. Although the FAO reports a 33-year constant catch time series for inland waters; these non-realistic data are thought to be estimates of the freshwater, rather than the lagoon catch component of Liberian fisheries (Belhabib et al., 2013b).

To estimate lagoon catches, we used the method described in Pauly (1976), i.e., applying a catch rate per surface area to the total lagoon area considered (lagoons within 10 km from the coast). Using Google Maps, we identified 30 lagoons for which we estimated the surface area using GIS. We multiplied the total surface area (18,804 ha) by the catch rate of 150 kg ha⁻¹ year⁻¹ for 1971 (Pauly, 1976), and obtained a total catch of 2821 t year⁻¹ for 1971. We divided the estimated catch by the derived coastal population in 1971 and estimated a per capita lagoon catch rate of 19 kg capita⁻¹ year⁻¹. We assumed this rate was 20% higher in 1950 (i.e., 23.1 kg capita⁻¹ year⁻¹), due to a higher subsistence consumption, and 20% lower in 2010 (i.e., 15 kg capita⁻¹ year⁻¹) due to over-exploitation and declining fish consumption (Delgado et al., 2003). We then interpolated and applied the resulting per capita catch rates to the coastal population data and estimated lagoon catches from 1950 to 2010. Given that most targeted species are tilapias (Cichlidae), and catfishes (Ariidae) along with other species, we assumed 40% of catches were tilapias, 40% were catfishes and 20% were other fish species.

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2.2.3. In Namibia

Historical anecdotes document that a few communities fish for subsistence in the coastal lagoons of the Namib Desert (Odada and Godana, 2002). Barnes and Alberts (2008) reported around 150 subsistence fishers for 2006. We divided the number of fishers for 2006 by the coastal population estimated for the same year and obtained the percentage of subsistence fishers over the coastal population (0.16%, Belhabib et al., 2015c). Given that this percentage was likely higher in the past, we assumed it was 50% higher in 1950, i.e., 0.23%. We interpolated between these rates, and multiplied them by the coastal population to estimate the number of subsistence fishers from 1950 to 2010. We assumed the CPUE between 1996 and 2010 was similar to the recreational fisheries CPUE, i.e., declining from 6.06 kg fisher⁻¹ day⁻¹ in 1996 to 3.23 kg fisher⁻¹ day⁻¹ in 2010 (see below). We assumed the CPUE was 20% higher in the past, because of over-exploitation. We also assumed the same number of fishing days, i.e., 8.2 days for every 19.7 days (Kirchner and Stage, 2005), which is equivalent to a total of 152 days a year, which was held constant between 2005 and 2010. We assumed the number of fishing days was 20% higher in 1950, given the gradual shift to commercial fisheries, and interpolated linearly. We obtained subsistence catches by multiplying the number of subsistence fishers by the number of days and the CPUE.

2.3. Recreational fisheries

2.3.1. In The Gambia

Recreational fishing in The Gambia is conducted by foreign tourists, with the first tourist flight arriving in The Gambia in 1965 (Mendy, 2008). The number of tourists (recreational visitors) was reconstructed using anchor points between 1965 and 2010 (Belhabib et al., 2013a). We completed the time series by applying a series of interpolations. We assumed 4.3% of the total number of recreational visitors were recreational fishers (Manel, 2008), spending on average 10 days in The Gambia and fishing during 5 days². We assumed the number of visitors in 1981 was half the number of visitors in 1980 to account for disturbance due to the (failed) coup attempt in mid-1981 that would have discouraged foreign tourism (Jabara, 1990). However, tourism has grown fast since then (Jabara, 1990). To estimate the CPUE of recreational fishers, we combined observations from six YouTube videos posted by tourists and recreational fishing companies in The Gambia with photos of fish catches and their weight provided by www.african-angling.co.uk [2013] between 2008 and 2010. Overall, 54 observations were collected for 63 tourists. The weighted average CPUE was estimated at 14.5 kg tourist⁻¹ day⁻¹. We assumed this CPUE was constant in the 2000s, and was 20% higher in 1965, i.e., 17.4 kg tourist⁻¹ day⁻¹, due to the generalized over-exploitation of marine resources in the Senegambia region in more recent times. We then interpolated to complete the estimate. We multiplied the CPUE by the number of recreational fishers, then by the number of fishing days and obtained total recreational catches in The Gambia. Finally, we applied the taxonomic breakdown derived from the previous observations.

2.3.2. In Liberia

Although new tourism initiatives are rapidly emerging in Liberia, there do not appear to be any recreational fishing activities in the country.

2.3.3. In Namibia

Recreational angling is a popular activity in Namibia, also famous for shark fishing, sand surfing and wildlife safaris (Huggins, 2011). Angling is practiced by Namibian and foreign anglers (Nghipunya, 2012). However, access to shore is limited as 90% of recreational shore angling occurs in a stretch of only about 260 km of the Namibian coast (Barnes and Alberts, 2008), of which 230 km are available for fishing (Belhabib et al., 2015c). The few surveys performed along the Namibian coast estimate catches as the product of total effort and catch rate (Kirchner and Beyer, 1999), which is the method also used here (Belhabib et al., 2015c).

Penhrith and Loutit (1982) surveyed recreational fisheries catches over a one year period along a 30 km stretch of Terrace Bay (Skeleton Park) and estimated total catches at 50 t year⁻¹ for 1980. We extrapolated these catches to the total available coast, i.e., 230 km, (i.e., 230 km, Belhabib et al., 2015c) and thus estimated a total recreational catch of 436 t year⁻¹ for 1980. We used the same method for 1990, when Lenssen et al. (1991) surveyed recreational shore catches along 20 km stretch of Sandwich Shoreline in the Namib-Naukluft Park and estimated a total catch of around 90 t year⁻¹ for this stretch of coast. Since this area is very productive, we extrapolated catches for 230 km of coastline, and adjusted downwards the previous catch rate by 50% to account for lower catches in Terrace Bay (30 km). Thus, we estimated total catches at 1102 t year⁻¹ for 1990. Kirchner and Beyer (1999) estimated 361 t year⁻¹ of silver kob (*Argyrosomus inodorus*) taken by recreational fishers. To estimate total catches, we added other species assuming the same species composition provided by Nghipunya (2012), wherein kob represented 36% of total catches, steenbras (*Lithognathus* spp.) 27%, galjoen (*Dichistius* spp.) 25% and others including copper shark, spotted gully shark and smooth-hound documented by Barnes and Alberts (2008) represented 12%, i.e., herein assumed 4% each. Therefore, we estimated total catches at 1,003 t year⁻¹ for 1996. For 2004, Barnes and Novelli (2007) estimated that around 460,000 fishes were taken annually by recreational anglers. We converted this number to weight using the species disaggregation provided by Nghipunya (2012) and the average weight per fish (Penhrith and Loutit,

² http://www.african-angling.co.uk/latest_gambia_fish_catches_Mar_April_May_2010.htm (accessed on 09.03.15).

1982), which translates into a catch of 616 t year⁻¹ for 2004.

Barnes et al. (2002) estimated the daily catch at 6.06 kg angler⁻¹ day⁻¹ for 1996 for 8.2 fishing days over a total of 19.7 visiting days per angler (Kirchner and Stage, 2005). The latter argue that the CPUE has strongly declined in the latest years. Assuming the trend remained similar from 2005 onwards, we assumed a decline of 50% between 1996 and 2011, i.e., the CPUE is estimated at 3.23 kg angler⁻¹ day⁻¹ for 2010 after interpolation. Nghipunya (2012) reported the number of recreational fishing permits for 2011 and the annual revenue obtained from fishing permits between 2007 and 2011. We obtained the number of permits for the years 2007–2010 by dividing the number of permits for 2011 by the revenue for 2011, then multiplying the result-assuming the ratio was constant-by the revenue per year for the remaining years. We then multiplied the resulting number of fishing permits by the interpolated CPUE and the number of days (8.2). Taking all these sources into account, we ended up with recreational catches of 436 and 1200 t year⁻¹ for 1980 and 2010, respectively, and interpolated linearly between these dates. Thereafter we applied the species disaggregation provided by Nghipunya (2012).

As there was no clear information documenting the beginning of recreational fishing in Namibia (or the former South West Africa), we assumed that recreational fishing began in 1960, given that the first description of Sandwich harbor, the site of an important recreational fishing activity, was available in 1963 (Lenssen et al., 1991). Thus, we interpolated linearly between zero in 1960 and the estimated catches for the subsequent years to fill in the gaps.

2.4. Industrial fisheries

2.4.1. In The Gambia

The mostly Gambian-flagged (but foreign owned) industrial fisheries are monitored through on-board observers. Catch data for other vessels (notably those from the EU) were then added, assuming that vessels with the same capacity and the same gear would perform similarly (Mendy, 2004).

A comprehensive list of fishing vessels and the reported GRT between 1998 and 2013 was gathered by Belhabib et al. (2013a). We assumed vessels with similar GRT will have similar catches, an assumption also used by The Gambian Department of Fisheries.

We obtained the capacity of vessels operating in The Gambian EEZ by entering either the name of the vessel or the call sign (when these were consistent) into online databases such as www.grosstonnage.com [2013] and www.vessel-finder.com [2013] which documented the GRT, the history of reflagging, and the residence of the owner and/or management company. Then, the average real GRT per country of origin (or beneficial ownership) was estimated.

The effort for the remaining time period was obtained from various sources (Beaudry et al., 1993, Weber and Durand, 1986, Everett, 1976, Ndiaye, 2011) summarized in Belhabib et al. (2013a), with an associated conservative assumption that fishing effort was zero before an agreement began and after it ended. CPUE estimates were derived from catch and effort data from Senegambia (Caverivière and Rabarison andriamirado 1988) and Senegal (Belhabib et al., 2014b) as 20.2 kg GRT⁻¹ day⁻¹ between 1988 and 1990, as 14.78 kg GRT⁻¹ day⁻¹ for the 2000s, and was assumed to be 20% higher in 1950 relatively to 1988. We interpolated linearly to complete the time series.

In the past, foreign fleets were operating in Senegal and The Gambia during the same licensing period (Caverivière and Rabarison andriamirado 1988, Lhomme et al., 1975). The number of fishing days of a trawler operating in The Gambia represented 41% of the number of fishing days in Senegal by the same trawler (Lhomme et al., 1975). Therefore, we assumed that the number of fishing days between 1968 and 1971 (a period covered by the previous study), was equivalent to 41% of the number of fishing days reconstructed by Belhabib et al. (2014b) for Senegal, i.e., 64.1 days year⁻¹. We then interpolated linearly to 165 days in 2000, which was kept constant between 2000 and 2010. For domestic trawl and purse-seine fleets and the Ghanaian purse-seine fleet based in The Gambia, we assumed the number of days was constant at 165 days, as they were likely to operate in The Gambia only. For Japanese tuna vessels, we assumed the number of fishing days was around 50% of the recorded licence period, which is the average duration of operation by licence period in Mbye (2005), i.e., 90 days.

We used the same species breakdown provided by Mendy (unpubl. data) to all industrial catches excluding Ghana, Norway, Bermuda, South Africa and Japan. For Ghana, 13,000 t year⁻¹ consisted of sardinellas and bonga shad (Freon et al., 1978); the remainder was allocated to "marine fishes nei". Similarly, we assumed all catches by Norway, Bermuda and South Africa to be clupeoids, as these were operating small pelagic purse-seiners. For Japan, we assumed all catches were scombrids, i.e., tuna.

2.4.2. In Liberia

Industrial fishing in Liberia began in 1955 (Haakonson, 1992). The industrial sector is operated by foreign companies under access agreements, joint ventures with Liberian shell companies or by flying the Liberian flag of convenience (Belhabib et al., 2013b). Catches were grossly under-estimated as vessels are engaged in unmonitored, offshore transhipping (Glasgow, 2008, Nepad, 2006). Even the recent presence of poorly paid observers on board is suspected to be "ineffectual" (Glasgow, 2008, Anon, 2008b)³. Braimah (2012) showed that around 38% of industrial vessels were under-reporting catches, while Mees et al. (2011) illustrated that the coverage of fishing days by observers was very low. Moreover, when observers

³ In some instances, vessel owners lock observers under deck while pursuing an illegal operation (http://www.stopillegalfishing.com/sifnews_article.php?ID=71) (accessed on 09.03.15).

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are onboard, they tend to disregard and misreport transhipping practices, which were legalized only recently (Mees et al., 2011), and therefore under-report the high catches they imply (Anon, 2008b).

Mees et al. (2011) estimated a CPUE of 6 t boat⁻¹ day⁻¹ in 1998, 2 t boat⁻¹ day⁻¹ in 2010, and we assumed the CPUE was 50% higher in 1955 compared to the 1998 CPUE, i.e., 9 t boat⁻¹ day⁻¹, given the documented over-exploitation and over-capacity in the more recent time period. We interpolated linearly the CPUE rates to complete the CPUE time series from 1950 to 2010. We multiplied the CPUE rates by 75% of the 225 authorized fishing days for the industrial fleet, i.e., 169 days vessel⁻¹ year⁻¹ (Mees et al., 2011) and estimated the annual CPUEs by multiplying the number of days, assumed constant between 1950 and 2010, by the estimated daily CPUE. Although, many officials claim Liberia has had a proper Liberian fishing fleet in the past, it appears a company based in Liberia and owned by a Liberian operates foreign owned vessels flagged to Liberia. Therefore, to estimate catches by actual country of origin (or true beneficial ownership), we interpolated the available effort per flag data (Belhabib et al., 2013b) and then estimated the total catch as the product of this effort by the annual CPUE.

We then applied the species breakdown provided for industrial fisheries by Glasgow (2008) for the 2000s. Pair-trawlers are known to have high catch rates; thus, we added the authorized Chinese pair-trawlers since 2003 separately. Around 8 Chinese pair-trawlers were authorized to fish in 2007 (USAID, 2008), before the ban of pair-trawling, while the number of authorized Chinese trawlers was 4 in 2010/2011 (Thiao, 2011). We interpolated linearly from zero in 2003 when China started fishing legally in Liberia. We then applied the CPUE of 1,200 t boat⁻¹ year⁻¹ estimated by Pauly et al. (2014) and Belhabib and Pauly (2015b) for trawlers and estimated total Chinese legal catches.

2.4.3. In Namibia

Many authors provided sets of landing data for Namibia that were overall similar (Sumaila and Vasconcellos, 2000; Bonfil et al., 1998; Roux and Shannon, 2004; de Astrola, 2002; Crawford, 2007; Cram, 1976; Japp, 2011; Midgley, 2012; Oelofsen, 1999; Akawa and Nashima, 2013; Kirchner et al., 2012; Huggins, 2011), as well as the profile of the fleet and the number of fishing vessels (Paterson et al., 2013; Lees, 1969; Anon, 1965; Sumaila, 2000; Midgley, 2012; Akawa and Nashima, 2013; Esau, 2013; Nichols, 2006; Goodisan, 2000; Bonfil et al., 1998; Beaudry et al., 1993; Anon, 2009; Deepfishman, 2010). Although these data are seen as providing a baseline for assessments, it appears that prior to Namibian independence, there was a major bias in the assessment, notably those of the FAO catches from the Namibian EEZ equivalent waters landed in, e.g., South Africa were barely assessed (Thomesen, 1978).

Another kind of bias was related to the fact that landing statistics of some species, e.g. west coast sole (*Austroglossus microlepis*), were recorded only in South Africa prior to 1987 (de Astrola, 2002), along with other species (Binet, 2012). Massive uncontrolled extractions also resulted in under-reporting. The reporting bias of catch and effort is "suspected to have played a major role in the decline in Cape hake stocks" (Roux and Shannon, 2004; Oelofsen, 1999) as foreign fishing effort in the southeast Atlantic was mostly unregulated prior to 1972 (Paterson et al., 2013). Further evidence related to the sudden collapse of some stocks, e.g., horse mackerel (*Trachurus capensis*) stocks, highlight that the chartered vessels might have been exceeding their quotas (Grobler, 2008). Moreover, foreign fishing vessels routinely exceeded their quota and were reported to report less than half of their real catches (Grobler, 2008). In addition, after the creation of the International Commission for the South East South Atlantic Fisheries (ICSEAF) in 1971, the foreign fleet hake fishery intensified (Binet, 2012) and quotas were not allocated on a scientific basis (Cram, 1976).

Therefore, although the evidence at hand suggests that under-reporting was common, we remained conservative by considering that it applied only to the hake and pilchard fisheries. We conservatively assumed that actual pilchard catches between 1950 and 1980 were 50% higher than the reported landings, and that under-reporting declined to zero after Namibia regained full control of its fisheries in 1994. We applied the same under-reporting rates for the hake fishery, as quota abuses were common.

For snoek (*Thyrsites atun*), Lees (1969) reported that a fleet of around 20 boats were catching "more than a million snoek" per year during the 1950s. Using an average weight of 3 kg fish⁻¹, we estimated 3000 t year⁻¹ for that period, then interpolated to zero unreported catches in 1987, when reporting for this species began.

The quotas levies offered to vessels by the Namibian government has encouraged the 'Namibianization' of vessels (Oelofsen, 1999), which are now mostly Namibian-owned (Anon, 2004). In addition, all access agreements, notably with the EU, were canceled (Mavetja Rukoro, 2005). Therefore, we assumed that after 1994, all catches reported by Namibia were domestic.

We cross-matched different fleets (Belhabib and Pauly, 2015c) with the data extracted from FAO for hake and then converted the hake catch to percentages, which we applied later onto the data from 1963, when hake fishing in Namibia began to 1990, when Namibia became independent. We also applied this approach to West Coast sole, whose catches as reported by Israel, Spain and Namibia from FAO area 47, likely refer to the northern stock, i.e., Namibia (de Astrola, 2002). We applied the same approach for Cape rock lobster and southern anchovies, caught by South Africa, and later by South Africa and Namibia. We also applied this approach for monkfish, which was a by-catch of the hake fishery at the beginning, and was caught by Bulgaria, Cuba, France, Germany, Israel, Namibia, Portugal, Spain and the former Soviet Union (mainly Russia). Similarly, West African unreported catches (reported at a national level, but not submitted to FAO) of deep-sea crabs (*Chaceon* spp.) were actually catches taken by Japan, Namibia, Portugal, South Africa and Spain; combined with the best evidence (Paterson et al., 2013, Anon, 1965), these catches could be allocated per country, while reported catches were all allocated to Namibia.

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Almost all of the fleet targeting Cape horse mackerel is composed of Russian vessels flying flags of convenience (FoCs) of St Vincent & the Grenadines, Mauritius and Belize (Grobler, 2008). Therefore, although the catch is reported to FAO as Namibian, it is highly likely that Namibia has but a small share of it. Thus, we estimated that 64% of this catch had been caught by Russian vessels flagged to FoC countries (but actually Russian beneficial ownership), this percentage being obtained by dividing the catch of the by Russian Federation by the total catch taken by fleets that are foreign to FAO's area 47.

Tuna catches were all allocated to South Africa, as the entire tuna fleet is based in South Africa; this applies to bigeye tuna (*Thunnus obesus*), albacore (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*), and southern bluefin (*Thunnus maccoyii*) that are reported by Namibia as 'domestic', although they are caught by the South African fleet (Bonfil et al., 1998).

We compared the national data to the data supplied to FAO for orange roughy (*Hoplostethus atlanticus*), blue sharks (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*), and found some inconsistencies. However, their catches were small and began to be reported only after independence (Oelofsen and Staby, 2004); thus, we used the FAO data as baseline.

2.5. Discards

Discards were estimated as the product of discard rates obtained from the literature and the reconstructed industrial catch. Thus, we only address major discards as taken by industrial fleets.

2.5.1. In The Gambia

Discards were included in the official national statistics for the years 1998, 2000, 2004, 2008, and 2009 for the reported domestic industrial catches at a rate of 3–15% (Mendy, unpubl. data). Thus, The Gambia is exceptional in having included part of discarded catch in the data they report to FAO. We extrapolated the trend backwards and estimated a discard rate of 32% when trawling began in The Gambia in 1968. We interpolated linearly between 32% in 1968 to 9.3% in 1998 (reported by observers on-board Gambian vessels), and then to 15% in 2000, 12.2% in 2004, 2.6% in 2007 and 2.8% in 2009, keeping this rate constant to 2010. We multiplied these rates by the total industrial 'domestic' reflagged catch.

The profile of trawl discards of foreign fleets is similar to that of Senegal (Belhabib et al., 2014b), with much higher unreported discards (Anon, 1979). We therefore applied discard rates reconstructed by Belhabib et al. (2014b) to the estimated demersal catches. These discard rates range from 38 to 85% and are declining over time, which is further illustrated by the relatively new development of cooperation between artisanal fishers and industrial vessels, with industrial vessels exchanging discards for commodities (Mbye, 2005). We exclude tuna catches from present consideration; Norway, Ghana, Bermuda and South Africa caught small pelagic species, and these countries' catches were also excluded from the estimation of discards.

2.5.2. In Liberia

Based on at-sea observations, discards of the industrial fleet were estimated at 30% of total catches (Glasgow, 2008), i.e., 42% of landings, as also observed by crew members of the industrial fleets (Larry George, SEAMEN Union, pers. comm.). Therefore, we applied this rate to the total estimated industrial catch from the start of industrial fishing in 1955–2010. We applied a similar discard rate to the illegal industrial fleets from South Korea, Spain, Portugal and Greece and a higher discard rate to the Chinese illegal pair-trawling fleet (Larry George, SEAMEN Union, pers. comm.), estimated at 80% of catches (Yevewuo Subah, Deputy Project coordinator, BNF, pers. comm.).

2.5.3. In Namibia

Discarding in Namibia is prohibited by the present regulations, and a discard levy has been implemented (Mavetja Rukoro, 2005). Although this is believed to have reduced discard rates to as low as 2% (Pramod and Pitcher, 2006), there is scarce information on actual discarding practices and discard rates on Namibian fisheries. Before the implementation of the ban, discards, particularly those of the hake fishery were estimated at about 35% of Cape hake catches, and of monkfish in the 1960s (Binet, 2012); this declined after the ban to between 5% and 15% of hake and monkfish catches in the 2000s, i.e., to a mean of 10% (Pramod and Pitcher, 2006). We assumed that the discard rate was constant between 1950 and the mid-1960s at 35% of catches, then declined linearly to 10% in 2006, which we kept constant from then on.

Prior to the decline in southern African pilchard catches, discards were believed to be around 15%, consisting mostly of anchovies caught as bycatch (Midgley, 2012), which then started to be landed in the early 1980s. Therefore, we kept the discard rate constant at 15% between 1950 and 1980, then interpolated to 2% for 2006 (Pramod and Pitcher, 2006), which we held constant to 2010.

The horse mackerel fishery has a discard rate of around 2% (Pramod and Pitcher, 2006), which we kept constant between 1950 and 2010. We applied the previous discard rates to each fishery to obtain total discards.

2.6. Unregulated and illegal fisheries

Here, unregulated fishing is defined as industrial foreign fishing within the EEZ-equivalent waters of The Gambia, Liberia and Namibia prior the establishment of the EEZs in 1982, 2008, and 1990, respectively. Illegal fishing is defined as unlicensed fishing within these EEZs after their declaration, and in the territorial waters of these countries (within 12 nm of the coast) at any time.

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2.6.1. In The Gambia

Illegal catches were estimated to be 12% of legal catches in 2010 (Agnew et al., 2010). The level of monitoring, control and surveillance increased in recent decades, and thus the level of sighted illegal activities decreased by 9% between 1996 and 2000, and by 2% between 2000 and 2001 (Agnew et al., 2010). We extrapolated this rate of change backwards and forwards, and then derived the rate of illegal fishing between 1950⁴ (194%) and 2010 from the initial anchor point (12% in 2010) by multiplying this rate by the estimated annual rate of change. We then multiplied the estimated illegal fishing rates by the reconstructed legal industrial catch. The Gambia declared its EEZ in 1982; thus, prior to 1982, all catches estimated herein are considered unregulated rather than illegal. Illegal and unregulated catches were assigned to Belgium, Belize, Cameroon, Canada, China, Cyprus, France, Germany, Ghana, Greece, Guinea-Bissau, Italy, Japan, Korea, Nigeria, Panama, Russia, Senegal, Sierra Leone, Spain, St. Vincent and Grenadines, Taiwan, United Kingdom, Brazil, Honduras, Ukraine, Latvia, Morocco, Portugal, USA, Norway, Bermuda and South Africa based on the percentage contribution to legal catches. Catches deemed to be of the former USSR were assumed to be Russian between 1968 and 1982, based on the frequent occurrence of Russian vessels in neighboring Senegal (Belhabib et al., 2014b). The remainder was assigned to China, as it was the only country documented to be illegally fishing in The Gambia after the early 1980s (Dobo, 2009, Pauly et al., 2014).

2.6.2. In Liberia

(Mrag 2005) estimated illegal fishing to be 59.4% of total catches, i.e., 146% of landings for about 150–200 vessels, of which 53% were targeting tuna species. Braimah (2012) reported the total number of illegal vessels at 200–300. It is noted that the monitoring capacity of Liberia before, during and after the civil war were almost non-existent (MRAG, 2005). (Mcconnell, 2008) reported that some 250 boats were fishing illegally in Liberian waters, including trawlers from China, South Korea, Spain, Portugal and Greece, as well as large motorized pirogues from Senegal and Ghana. To estimate total unregulated/illegal catches, we assumed the rate of unregulated fishing was a third in 1950–1988, i.e., 49%, then increased to 146% of landings in 2005 due to the lack of monitoring during the civil war. We then separately estimated Chinese illegal fishing, since effort data were available, with 8 pair-trawlers fishing illegally in Liberian waters from 2008 to 2010 (Glasgow, 2008). It is fair to assume that Chinese illegal fishing started in 1990 at the beginning of the civil war, taking advantage of the complete absence of governance structure (Agnew et al., 2009) on the one hand, and the expansion of the Chinese distantwater fleet on the other hand (Pauly et al., 2014). We interpolated the fishing effort, then multiplied the latter by a CPUE of 1200 t boat⁻¹ year⁻¹ (Pauly et al., 2014), which would correspond to a higher catch by pair trawlers. Then we allocated the difference between the total illegal catch and the Chinese illegal catch to the remaining countries, assuming that Ghana took 30% from 1950 to 1988 prior the beginning of the civil war, which then decreased to 25% by 2010, that Senegal took 10% from 1950 to 1988, increasing to 15% in 2010, and that he remainder could be distributed evenly between Spain, Portugal, Greece and South Korea (McConnell, 2008).

2.6.3. In Namibia

There is significant concern about the presence of unlicensed vessels fishing illegally in Namibian waters (Mavetja Rukoro, 2005), which is considered a serious offence in Namibia along with catch misreporting and exceeding by-catch allowances (Stop Illegal Fishing, 2008). For example, 11 large trawlers were arrested between 1990 and 1991 (Anon, 2004). In 2004–2005, Chinese vessels targeting mussels and limpets in inshore waters were arrested (Pramod and Pitcher, 2006). Nevertheless, the monitoring efforts since independence have largely proven efficient in deterring foreign illegal fishing (Anon, 2004). Furthermore, as Namibian fishers themselves monitor and enforce fishing regulations (e.g., fishers chartering helicopters to detected illegal activities, Huggins, 2011), any observed attempt to fish illegally within Namibian waters is reported.

Nichols (2006) estimated that around 100 vessels were fishing illegally in Namibian waters in 1990. World Wildlife Fund (1998) reported that this number declined sharply in 1991, as only 12 vessels were arrested in 1991, of which 11 were Spanish-the most recurrent offender (Freeman, 1992)-and 1 from the Congo (Mavetja Rukoro, 2005). In 2004, 6 out of 16 inspected vessels were arrested (Stop Illegal Fishing, 2008). Assuming that only 10% (in 2004) to 5% (2010) of these were fishing without a license, and expanding this to the entire fleet operating in Namibia between 2004 and 2010, the number of vessels fishing illegally is estimated at 8 in 2004, 10 in 2005, 8 in 2006 and 2007, 7 in 2008 and 5 in 2009 and 2010. These number seem high for Namibia, however, they revolve around the 2004 estimate. We then multiplied the number of vessels (2004–2010) by the average CPUE ($1573 \text{ t vessel}^{-1} \text{ year}^{-1}$), i.e., the total legal catch divided by the number of legal vessels, averaged between 2004 and 2010. Similarly, we conservatively used this CPUE for the previous years, and multiplied it by the effort for 1990 and 1991. We then interpolated from zero at the introduction of ICSEAF in 1971, set as the beginning of unregulated (later illegal) fisheries in Namibia.

2.7. Assessing uncertainty

The procedure to assess uncertainty of catches is described in Zeller et al. (2015) and uses the criteria inspired by the Intergovernmental Panel on Climate Change (IPCC) which attributes to each fishing sector a 'score' that evaluates their

⁴ Here we treat the water up to 200 nm from the coast for years prior to declaration of the EEZ as EEZ-equivalent waters of The Gambia.

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quality within a given time as (4) 'very high', (3) 'high', (2) 'low', and (1) 'very low' (Table 1). Each score is assigned a confidence interval (with a uniform distribution), who ranges were calibrated based on Ainsworth and pitcher (2005); Tesfamichael and Pitcher (2007). These intervals were then used for Monte Carlo simulations, which yielded confidence bands for total and sectoral catches by countries (Table 1).

2.8. Catch reconstructions for other west African countries

The catch reconstructions for the 19 other countries in West Africa in Fig. 1 were performed based on methods and assumptions similar to those presented above for The Gambia, Liberia and Namibia. Details can be found in Belhabib et al. (2012c, 2012d) for Morocco; Belhabib et al. (2012b) for Mauritania; Belhabib et al. (2014b) for Senegal; Santos et al. (2012) for Cape Verde; Belhabib and Pauly (2015b) for Guinea Bissau; Belhabib et al. (2012a) for Guinea; Seto et al. (2015) for Sierra Leone; Belhabib (2015a) for Côte d'Ivoire; Nunoo et al. (2014) for Ghana; Belhabib et al. (2014a) for Togo; Belhabib and Pauly (2015a) for Benin; Etim et al. (2015) for Nigeria; Belhabib and Pauly (2015d) for Cameroon; Belhabib et al. (2015a) for Congo (Brazzaville); Belhabib (2015b) for Sao Tome and Principe; Belhabib (2015c) for Gabon; Belhabib and Pauly (2015c) for Congo (Brazzaville); Belhabib et al. (2015b) for Congo (ex-Zaire); Belhabib and Divovich (2014) for Angola; and Baust et al. (2015) for the Atlantic coast of South Africa. Once reconstructed, these catches were allocated to the three LME to which they belong. Finally, the reconstructed total catches of the CCLME, GCLME and BCLME were obtained by simply adding their national components.

3. Results

3.1. Reconstructed total catches in The Gambia

Artisanal fisheries of The Gambia represented around 20% of total catches, while the bulk of fish removals were taken by



Fig. 2. Reconstructed marine catches off The Gambia by (a) fishing sectors. Note the solid black line, representing the data officially reported by FAO on behalf of The Gambia shows domestic catches only; (b) taxon; and (c) domestic and foreign fleets (thick lines) and their respective confidence intervals (thin lines), 1950–2010.

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Fig. 3. Reconstructed marine catches off Liberia by (a) fishing sectors. Note the solid black line, representing the data officially reported by FAO on behalf of Liberia shows domestic catches only; (b) taxon; and (c) domestic and foreign fleets (thick lines) and their respective confidence intervals (thin lines), 1950–2010.

industrial, notably foreign fleets; of this, more than 40% are either discarded or caught illegally. Total catches increased from 5700 t year^{-1} in 1950, at the time all were deemed small-scale, to a peak of 308,000 t year⁻¹ in 1990, driven by a sharp increase in industrial fisheries, which altogether (i.e., reported and unreported landings, discards and illegal catches) represented 75% of the total catch (Fig. 2(a)). Catches declined thereafter, probably due to the departure of a number of foreign industrial fishing vessels, to less than 76,700 t year⁻¹ in 2010. Taxonomically, total catches taken by all countries fishing within The Gambian EEZ were dominated by sardinellas, bonga shad and other clupeoids, (Fig. 2(b)).

Domestic catches were 2.5 times the data supplied by The Gambia to FAO. Domestic catches increased rapidly between 1950 and 1980, when they reached 48,000 t year⁻¹, of which 78% were unreported. Domestic catches remained relatively steady, with slight variations, at least compared to the increasing pattern in official datasets, between 1980 and the 2000s. Domestic catches were at their maximum in 2003 at 68,000 t year⁻¹ compared to 34,200 t year⁻¹ officially reported (50%), which shows a decrease in underreporting (Fig. 2(a)).

3.2. Reconstructed total catches in Liberia

Liberian small-scale artisanal and subsistence fisheries catches represented around 20% of total removals from Liberia (Fig. 3). The small-scale sectors represent the truly Liberian domestic fisheries catch made available to the local population. This sector alone is 66% higher than the data supplied by Liberia to FAO (337,900 t) covering only the marine component, and twice as high when also accounting for lagoon catches. The legal industrial sector accounted for around 1.8 million t from 1950 to 2010, while the unregulated/illegal foreign catch was responsible for over 1.3 million t in the same period, along with 249,000 t of illegal discards. Total removals from Liberian waters increased from around 9900 t year⁻¹ in 1950 to a peak of about 112,000 t year⁻¹ in 1988, then decreased to around 89,000 t year⁻¹ in 2010 (Fig. 3(a)). Taxonomically, although over 140 taxonomic groups were identified and caught by the different sectors operating in Liberia, catfishes and small pelagic fishes, mainly clupeoids, dominated catches (Fig. 3(b)).



Fig. 4. Total reconstructed catches off Namibia, 1950–2010, by (a) sector (with the solid black line, representing the data officially reported by FAO on behalf of Namibia showing only domestic catches), and (b) taxon; and (c) distinguishing between domestic and foreign fleets. The thin lines are confidence intervals.

3.3. Reconstructed total catches in Namibia

Total catches were estimated at around 90,300 t in 1950, increased to a peak of 3.7 million t in 1968 and then declined sharply after the collapse of the southern African pilchard fishery to 435,300 t in 2010 (Fig. 4(a)). Less than 0.1% of the catch was domestic before the late 1980s, in contrast to almost 100% today. Domestic catches increased from 60 t year⁻¹ in 1950, all of which were for subsistence purposes, to a first peak of around 444,000 t in 1990 compared to 261,000 t reported to FAO, declined slightly before increasing to a second peak of 838,000 t in 1993 compared to 789,000 t reported to FAO. Domestic catches declined later on to 427,000 t in 2010 compared to 367,000 t reported to the FAO (Fig. 4(a)).

Since catches were, in the past, mostly taken by foreign fleets, the bulk of these were unreported. This changed when Namibia gained independence and took control of its fisheries, after which only 9% of catches were left unreported.

Catches were composed mostly of southern African pilchard and Cape hakes in the past; their catches declined drastically in the 1980s and were slowly replaced by Cape horse mackerel, which today contributes most of the catch (Fig. 4(b)). This contrasts with official data reported for Namibia, which show a decrease in Cape horse mackerel catches since the 1990s, and roughly constant catches of Cape hakes.

3.4. Reconstructed total catches in the three west African LMEs

The 3 panels of Fig. 5, finally present the reconstructed and reported domestic catches by LME, each representing a convenient framework for large-scale comparison (Duda and Sherman, 2002; Pauly, 1998a). Total catches from the Canary Current (CCLME, Fig. 1) increased from 819,000 t in 1950 to a peak of 7.9 m t in 1977 and declined to 7.4 m t in 2010 (Fig. 5 (a)). Domestic catches were twice the data reported by West African countries to the FAO. Foreign catches represented over half (55%) of total removals from the CCLME, however, their contribution declined from around 80% in 1977, i.e., when catches in the CCLME peaked, to less than 40% in 2010. This was accompanied by an increase in industrial domestic fisheries by two folds, likely driven by increased re-flagging drives of vessels with continued majority foreign beneficial ownership.



Fig. 5. Total catches, 1950–2010 from three West African LMEs, i.e., (a) Canary Current LME; (b) Guinea Current LME, and (c) Benguela Current LME, compared (for the domestic catch) to the data reported by the FAO on behalf of the countries encompassed by each LME.

Small-scale commercial and non-commercial fisheries within the CCLME increased from 185,000 t in 1950 to a peak of 839,000 t in 2004 after which they declined to 779,000 t in 2010 (Fig. 5a).

Catches from the Guinea Current Large Marine Ecosystem (GCLME, Fig. 1) increased from 567,000 t in 1950 to a peak of 4.8 m t in 2000 after which they declined to less than 4.4 m t in 2010 (Fig. 5(b)). Domestic catches were 2.3 times the data reported by West African countries to the FAO. Small-scale fisheries, which represented around one third of total removals from the GCLME, increased from 381,000 t in 1950 to a peak of 1.4 m t in 2004, after which they remained relatively constant (Fig. 5(b)).

Total catches from the Benguela Current Large Marine Ecosystem (BCLME, Fig. 1), which were mostly industrial, increased from 1.1 million t in 1950 to a historical peak of 10.4 million t in 1968, after which they declined to 2.8 million t in 2010 (Fig. 5(c)), a continuous decline that was long attributed to over-exploitation resulting from uncontrolled foreign fishing. Domestic catches were overall 20% higher than the catch data reported by West African countries to the FAO.

4. Discussion

Overall, fisheries catches in the waters of the three LMEs considered here, and by extension in all of West African shelf waters, were historically dominated by foreign fleets. Only more recently has this slowly begun to change as foreign catches are declining while domestic catches increase. However, we must note the increasing re-flagging to West African countries along with joint venture and charter operations, in contrast to "real" domestic ownership, may have contributed to this perception. These ownership patterns do not contribute much, if at all, to the food security and economic development of local populations, the true owners of the marine resources along West African coastlines.

Domestic catches in the different LMEs followed the same pattern: they grew, peaked and then declined, despite or rather because of increasing effort. Under-reporting which ranged between 20% and 133% of reported landings declined as countries improved their fisheries monitoring system.

Corroboration of these catch reconstruction results within LMEs and across LMEs could be done by comparing catch by

unit area of shelf to productivity estimated for the same area. For example, Caddy et al. (1998) provided estimates of productivity based on landings, which in principle could be compared with our results. However, their non-inclusion of distant water catches, of discards, and part of small-scale fisheries makes such comparisons moot. However, our finding of higher catches imply higher catch per area and much higher system productivity than assumed hitherto, a topic which warrants further study.

While total domestic catches in Liberia and The Gambia, despite significant improvement in monitoring, control and surveillance, are within the West African the neighborhood of twice the amount supplied to the FAO, Namibia more recently underreported its catches by only 9% (Belhabib, 2014). In addition, as opposed to The Gambia and Liberia, whose fisheries were mainly foreign operated, Namibia has now gained almost full control of its fisheries.

Indeed, Namibian policy has been quoted as "one of the most successful in the world" (Esau, 2013) with reference to the way it tackled the issues inherited from its colonial economy (Boyer and Boyer, 2005). For example, fisheries are subjected to some of the highest taxes in the country, while remaining profitable (Reid et al., 2007).

On the other hand, the importance of domestic fisheries in The Gambia and Liberia for food security, illustrated through the composition of the species they catch, along with the high level of unmonitored and uncontrolled foreign fishing, is of serious concern. Also, we noted that in recent years, licenses are granted to foreign vessels directly or through joint ventures, and that information about these (in contrast, e.g., to EU access agreements) are accessible only through requests to the government of The Gambia (Department of Fisheries)⁵. Thus, the very nature of this information contributes to the relative lack of visibility of the foreign fisheries in The Gambia, and makes their contribution to the economy and food security of the country less visible or accountable. Fisheries in The Gambia support poverty alleviation by providing an alternative for better livelihoods for women and their households. Indeed, in the past, subsistence fishers (e.g., shellfish collection) were 80% women, while today, this has increased to over 90% (Njie and Drammeh, 2011; Ngaido, 1990).

The present study shows a lack of reliable information on Liberian fisheries. For example, while scientific research shows that the artisanal sector collapsed to 10% of its previous size during the civil war (Haakonson, 1992), official data do not reflect the impact of the civil war on artisanal catches. Therefore, it is reasonable to conclude that landings data reported by FAO on behalf of Liberia may over-estimate artisanal catches in Liberian waters during the civil war. They also illustrates a clear disconnect between 'reporting' data and the reality on the ground, something also encountered elsewhere, e.g., with regards to natural disasters that impact fisheries but do not show up in reported data (e.g., cyclones, Lingrad et al., 2012, or volcanic events, Ramdeen et al., 2012)

This study also shows a shift from legal to illegal operations in Liberia. The legal industrial sector decreased and the unregulated sector increased during the civil war, while one would suspect that the same vessels would stay in the same fishing grounds in the absence of monitoring and control. This is illustrated by Chinese pair trawlers being banned from Liberian waters, but still operating there, if illegally, from bases in Guinea or Sierra Leone (Belhabib et al., 2013b).

Liberia remains, however, one of the very few African countries that demonstrate a clear improvement in both conflict reduction between artisanal and industrial fisheries and tackling illegal fishing practices. Indeed, the Liberian government answered to the increasing conflicts between artisanal and industrial fleets by increasing the size of the areas reserved for artisanal fishing. Monitoring has also strongly increased in most recent years (D. Copeland, Bureau of National Fisheries, Government of Liberia, pers. comm.). Under-reporting of legal industrial catches is also believed to have decreased, as currently, all industrial vessels have observers onboard, at sea trans-shipments (now legal) are being reported, as are discards (including garbage, plastic and fishing nets), and landings. The very fact that there are more at sea-observers than fisheries inspectors on land shows an improvement in industrial data reporting.

Underreporting occurs in many countries in West Africa, with an average under-reporting rate of 200% to 300% of the data reported by the FAO on their behalf (Belhabib, 2014), particularly in the CCLME and the GCLME (See Fig. 5). A crucial recommendation to improve this situation can be inferred from our three case studies: better reporting and catch ownership (i.e., landing, processing and other value added activities are encouraged locally) can be achieved by (a) improving vessel ownership; (b) enforcing landing requirements; (c) increasing monitoring, control and surveillance activities by following a participative approach; and (d) providing better protection for the more sustainable small-scale fisheries, which however, require dedicated management.

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