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COLONIALISM, CONFLICT, AND FISH: A RECONSTRUCTION OF MARINE FISHERIES CATCHES FOR SIERRA LEONE, 1950-2010

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ABSTRACT

In countries like Sierra Leone, where fisheries-independent stock assessments and complex population models are financially and technically challenging, catch statistics can approximate fluctuations in fish stocks where more precise data is not available. However FAO FishStat, the most widely-used time-series data on global fisheries catch landings, does not account for Illegal, Unreported, and Unregulated (IUU) catches and relies on statistics provided by the internal agencies of each member country. As such, reported FishStat data is vulnerable to changes in monitoring capacity, governmental transitions, and budgetary constraints, and may substantially underestimate the measure of extracted marine resources. In this report, Sierra Leone's total catches by all marine fisheries sectors were estimated for the period 1950-2010, using a catch reconstruction approach incorporating national data, expert knowledge, and published and grey literature. Results demonstrate that a significant amount of marine resource exploitation is not represented in official statistics, and reconstructed catches represent more than 2.6 times the recorded FAO Fishstat values. Reporting has improved over time, with reconstructed catches representing more than thirteen times that of FishStat in 1950, compared to a difference of only 38% in 2010. Notably, the vast majority of industrial catch in Sierra Leone's EEZ is performed by foreign fleets, although the small-scale sector represents the majority of domestic catch. Illegal fishing is also a significant challenge in Sierra Leone, and extracts a large amount of the country's marine fish resources. The results found in the reconstruction present a large discrepancy from FishStat data, with considerable implications for stock assessment and management of Sierra Leone's marine resources.

INTRODUCTION

Sierra Leone is located on the west coast of sub-Saharan Africa, with a land area of 71,620 sq km, and is bordered by Liberia to the southeast and Guinea to the north and northeast (Figure 1). The country is endowed with an abundance of lucrative mineral resources, such as titanium, bauxite, rutile, gold, iron ore and zircon (IMF 2009; S. Sankoh pers. comm.). Additionally, Sierra Leone is the ninth largest producer of diamonds in the world (Kimberley Process Certification Scheme 2010). The country has a tropical climate, lying between 7°N and 10°N latitude, and has a diverse environment, ranging from savannah to rainforest. Though a relatively small country on the African continent, Sierra Leone has over 500 km of coastline, representing approximately one third of its national boundary (Heymans and Vakily 2004). The 27,500 sq km continental shelf in Sierra Leone is characterized by a wider area in the north, at approximately 140 km, tapering to approximately 32 km in the south (Heymans and Vakily 2004). Furthermore, Sierra Leone lies just north of the Gulf of Guinea, at the intersection of the Canary Current in the north and the Guinea Current in the south. This considerable continental shelf, combined with the local currents, creates a substantial upwelling that places Sierra Leone within one of the world's most productive marine ecosystems (Heymans and Vakily 2004; GCLME 2006).

Despite Sierra Leone's wealth of natural resources and optimism for economic development, upon gaining independence from Great Britain in 1961, the country underwent a series of political upheavals. "Extremely poor governance, widespread corruption, and the marginalization and disempowerment of the rural communities" prompted several military coups that culminated in the 11-year Civil War from 1991-2002 (Thorpe *et al.* 2009; Government of Sierra Leone 2008). The Civil War, though attributable to a combination of factors, was at least partially and perhaps in large part driven by the wealth disparities generated by the exploitation of natural resources (UNEP 2010). The conflict, while emerging from a context of environmental degradation, also generated a tremendous amount of environmental destruction, and the country was ranked 163rd of 163 on the 2010 Environmental Performance Index (Yale Center 2010).

Economically, Sierra Leone is also one of the poorest countries in the world, ranked 158 out of 169 countries included in the UN Development Program (UNDP) 2010 Human Development Report. With a per capita GDP of $352 USD and 70% of the population living below the poverty line (UNDP 2010), the fisheries sector is critically important in Sierra Leone as a source of employment, income, and household nutrition (Green et al. 2012; Oceanic Developpement 2008). According to the Ministry of Fisheries and Marine Resources of Sierra Leone (MFMR-SL), approximately 500,000 people are employed in the fisheries sector, which nets the country over 142,000 tonnes (t) of fish annually (Interim Guinea Current Commission 2010; MFMR 2008). Furthermore, the significance of coastal and marine resources to Sierra Leone is demonstrated in the fact that fish represent 75% of dietary animal protein for the country's population, as compared to a 15% global average (FAO 2009), and 11% of Sierra Leone's GDP is derived from marine resources (FAO 2011).

In more developed countries, fishery policies and management decisions may oftentimes be based on robust data from fisheries-independent stock assessments and complex population models. However, in many countries, these techniques are rendered impractical due to the high costs and technical demands involved. In these cases, catch statistics can serve to approximate fluctuations in fish stocks where more precise data is not available (Zeller *et al.* 2007; Costello *et al.* 2008). However, catch statistics do not account for Illegal, Unreported, and Unregulated (IUU) catches, and therefore may substantially underestimate the measure of extracted marine resources (Sumaila *et al.* 2006; Hosch *et al.* 2011). FAO FishStat (FAO 2010) provides time-series data on global fisheries catch landings beginning in 1950. The data relies on statistics provided to the Food and Agriculture Organization (FAO) by the internal agencies of each member country (Garibaldi 2012). However, since many countries do not have the capacity to

monitor remote or decentralized catches—such as those in artisanal or subsistence fisheries—FAO capture production data have been shown to significantly underestimate catch in some countries (Wielgus *et al.* 2010). Variations in data gathering and reporting over time are also of particular concern in self-reported time series (Welcomme and Lymer 2009). Since these data are often used in formulating management structures, these underestimations may lead to inaccurate and detrimental policies and management measures (Jacquet *et al.* 2010).

Here we re-estimated total marine catches by Sierra Leone within its Exclusive Economic Zone (EEZ) between 1950 and 2010. The goal of this reconstruction is to provide a more accurate characterization of all marine capture fisheries sectors in the Sierra Leone EEZ, in order to better inform policy and management measures.

MATERIALS AND METHODS

The catch reconstruction approach utilized here consists of six general steps (based on Zeller *et al.* 2007):

1. Identification of existing reported catch time series, e.g., local reports
2. Identification of sectors, time periods, species, gears, etc. not covered by (1), i.e., missing catch data, via literature searches and consultations;
3. Search for available alternative information sources to supply the missing catch data in (2), through extensive literature searches and consultations with local experts;
4. Development of data anchor points in time for missing data items, and their expansion to country-wide catch estimates;
5. Interpolation of time periods between data anchor points for total catch, generally with per capita catch rates; and
6. Estimation of final total catch time series for total catch, combining reported catches (1) and interpolated, island-expanded missing data series (5).

Human Population Data

Human population data from 1950-1959 was obtained from the Central Intelligence Agency (CIA) World Factbook 2011. Time series population data 1960-2011 was obtained from the World Bank Population Database (www.worldbank.org). Fishers' censuses were conducted as part of the Sierra Leone national frame surveys in 1974, 1981, 1991, 2003, and 2009, from which it was possible to derive the percentage of artisanal fishers in the population at those anchor points. Linear interpolations were made between anchor points, assuming similar proportions to population data.

Fisheries Sub-Sectors

The data that served as the baseline for this study was extracted from the FAO FishStat database (FAO 2010). Thorough review of peer-reviewed, government, and non-government organization (NGO) publications, as well as other grey literature, enabled us to identify sectors with missing or incomplete information. To supplement this literature, local and scholarly expertise was sought in each of these sectors, in order to formulate the best possible assumptions. Utilizing these sources, catches were then derived for 1950-2010, based on anchor points in the literature and knowledge-based assumptions.

Small-Scale Fisheries: Subsistence and Artisanal Catches

Artisanal fisheries

For the early artisanal fishery, very little data was available regarding catch, fisher population, or fleet size, although several national data sources were identified from the 1970s onward (Diop and Dossa 2011; Chaytor and Ndomahina 2012; MFMR 2001; Etoh 2012; Golley-Morgan 2012; MFMR 2009; Thorpe *et al.* 2009). While this national catch data was generally higher than that reported to FAO, consultation with local experts indicated that they were likely low, considering the substantial limitations on monitoring and reporting (I. Turay and S. Sankoh, pers. obs.). With this in mind, we estimated catches from the small-scale sector using estimated CPUE rates, summarized in Table 1, based on expert knowledge and national data (I. Turay, pers. obs.; Golley-Morgan 2012; Chaytor and Ndomahina 2012; Ssentongo and Ansa-Emmim 1986). Derived CPUE rates are considered very conservative in comparison to neighboring countries and in-country expert estimates.

Subsistence fisheries

Very little data is available regarding the subsistence aspect of the marine fishery in Sierra Leone, and mention of subsistence fishing is applied solely to inland fisheries (MFMR 2001; Thorpe et al. 2009; Browne 2001). All available per capita consumption estimates were secondarily derived from FAO reported landings, and "very few if any studies have been carried out to determine the per capita intake of fish in Sierra Leone" (Green *et al.* 2012). However, evidence suggests that captured artisanal marine fish are sold to fish processors immediately upon landing the catch, therefore virtually all small-scale catch is landed in local markets, and very little is set aside for household consumption *before* landing (Etoh 2012; Aryeetey 2002; Mason 1993). Therefore, for the purpose of the reconstruction, subsistence was calculated as a subset of reconstructed small-scale landings. As no data was available regarding the quantity of non-market fish consumed by households, estimates were derived using a 1993 study of household consumption, which stated that 95 percent of nationwide respondents consumed fish daily, and 7 percent of those respondents accessed their fish by catching it (Green *et al.* 2012). Applying these percentages to time series population data, we derived an estimate of subsistence fishers, and determined catch estimates by applying an annual per capita consumption rate of 20.8 kg·person^{-1}·year^{-1} from the artisanal marine sector (Oceanic Developpement 2008).

Domestic Industrial Fisheries

The majority of industrial fishing in Sierra Leone has been conducted by foreign vessels. However, beginning in the late 1970s and early 1980s a concerted effort was made to increase the capacity of the national industrial fleet, eventually leading to the establishment of the Sierra Fishing Company (SFC) and the Marine Development Company (MDC) (Payne 1976; Vakily 1992; Ssentongo and Ansa-Emmim 1986; UNCCD 2004). Although both companies are comprised of mixed ownership (i.e., at its conception, SFC's ownership was 25% Government of Sierra Leone, 10% National Development Bank, 20% Franco-Soviet company, and 45% private Sierra Leone entrepreneurs), they are considered to be domestic vessels within the literature and are counted as such in the reconstruction (Ssentongo and Ansa-Emmim 1986; FAO Industries Division 2012). National industrial fleets are comprised primarily of shrimping vessels, with a small number of demersal trawlers active during some years (Ssentongo and Ansa-Emmim 1986; Baio 2009). With this in mind, the reconstruction of the Sierra Leonean industrial fishery was separated into two sectors: the shrimper fleet and demersal fish trawler fleet.

Industrial Shrimp Fishery

Evidence suggests that there was no domestic industrial shrimp fishery in Sierra Leone prior to the late 1970s (Ssentongo and Ansa-Emmim 1986; Cole 2012b; Baio 2009). However, due to its high market value in relation to other fisheries, shrimp and prawns were the subject of numerous studies in the late 1970s

and early 1980s on the potential for further development of the fishery (Chaytor and Okera 1977; Ssentongo and Ansa-Emmim 1986; Showers 1999). Following this rise in interest, the domestic industrial fishery was created, and national statistics on shrimp catches in the domestic fishery are available beginning in 1977 (Showers 2012; Cole 2012b; FAO Industries Division 2012). For 1977-1979 and 1984-1986, reported shrimp catches in national data were utilized for the purposes of the reconstruction. During the years 1980-1983, estimates were created by combining the reported catches of the Sierra Fishing Company and the Marine Development Company, using a headless to head-on conversion ratio of 1.6 (FAO 2000; Kutkuhn 1962; Ssentongo and Ansa-Emmim 1986). For the period 1987-1991, national estimates were only available from the Sierra Fishing Company catches, and FAO FishStat data was considered to be more accurate than reconstructed landings. Similarly, for the period 1992-2010, no national statistics on the catches of the domestic industrial shrimp fishery were available, and FAO FishStat data was retained (Table 2). However, it is notable that several sources mention the virtual disappearance of the domestic industrial fishing fleet from approximately 1994, due to declining catches, declining foreign support (primarily Soviet), logistical challenges, civil war, and poor economic conditions (Baio 2009; Kelleher 2002; B. Cole pers. Comm.). Considering the fact that this period also represents some of the highest reported catches of shrimp in the FAO data, it is likely that the majority of those landings were not caught by a domestic fleet, but rather foreign vessels under joint ventures or access agreements.

Discards for the domestic industrial shrimp fishery were calculated at 1:1.085 (landed shrimp to total discards) from national data sources (MFMR 2001). This discard ratio is considered conservative in comparison to neighboring countries (Kelleher 2005; Sidibe 2003; Weber and Durand 1986), however evidence suggests that discards in Sierra Leone may indeed be lower than the regional average, since industrial vessels are legally obligated to land a portion of bycatch, and a significant amount is in fact locally marketed (Kelleher 2002, 2005; Etoh 2012; M. Vakily pers. obs.; Emanuelsson 2008; Mamie 2008).

Industrial Demersal Trawl Fishery

In addition to the shrimper fleet, a domestic demersal trawler fleet was active during some years in Sierra Leone. Information on the development of the early fishery is limited, however production data from the national demersal fishery is available for the years 1971-1982 (Ssentongo and Ansa-Emmim 1986). For 1983-1986, reconstructed catches are reported catches from the Sierra Fishing Company trawler fleet only, and are considered conservative, as data were unavailable for other participants in the fishery. After 1986, estimates of domestic industrial production—distinct from foreign industrial production—are not available, and estimates were derived from vessel data. Anchor points for domestic industrial demersal fleet size were available for 1988 and 1994 (FAO Industries Division 2012; Kelleher 2002), and fleet size was interpolated between anchor points. We then applied a catch/vessel rate of 446.584 $t \cdot vessel^{-1} \cdot year^{-1}$, which was derived from the average annual rate observed in the entire industrial fleet (foreign and domestic vessels) over the period 1994-2007. This estimate was considered conservative, as several sources indicate a decline in CPUE from the late 1980s to the 1990s (Coutin and Payne 1989)(Table 3). For the subsequent time period (2002-2010), we multiplied the number of domestic demersal trawlers (A. Baio, pers. obs.) by the derived catch rate (446.584 $t \cdot vessel^{-1} \cdot year^{-1}$), assuming that the number of vessels was constant between 2008 and 2010.

Discards for the demersal trawler fleet were calculated at 1:0.132 (landed fish to total discards) from national data sources (MFMR 2001). Similar to the shrimp fishery, the ratio is considered conservative for the region.

Other Fisheries

Other sectors which were examined for potential reconstruction included shark fisheries, recreational fisheries, and non-shrimp invertebrate fisheries. Although sharks have been caught by artisanal fishers in Sierra Leone for decades, the majority of these landings were incidental bycatch, and targeted shark fishing only emerged in the 1980's, corresponding with the global rise in demand from Southeast Asia (Diop and Dossa 2011; FAO FishStat; Vannuccini 1999). Sharks are primarily targeted by the artisanal sector, and while a specialized artisanal shark fishery has been identified in Sierra Leone for the market of fins, discards are minimal and carcasses are marketed locally or to migrant Ghanaians, Senegalese, and Gambians (Diop and Dossa 2011). Although there has been significant interest in the potential for recreational fishing, and game fish outfitters have operated intermittently in the past, the sector is poorly developed, in large part to the civil war and lack of development and infrastructure (GCLME 2006; Kelleher 2002). Non-shrimp invertebrate fishing and gleaning has occurred throughout Sierra Leone's history, and despite the fact that several species have been observed to be heavily exploited, the characteristics of the fishery are poorly known (Okera 1976; Chaytor and Aleem 1976). Similar to shark fishing, these invertebrates are also targeted for market, and are largely captured in the mixed species of the artisanal catch and industrial bycatch (Mason 1993; FAO Industries Division 2012; Okera 1976). Regarding Sierra Leone, Kelleher states that "there are a number of under-utilized resources which may have a high commercial potential, but commercial exploitation depends on improved shore facilities... these include mangrove crab, bivalve molluscs, shrimp aquaculture, and recreational fishing (Kelleher 2002). While evidence suggests that a specialized sea cucumber fishery has recently emerged in response to the growing Chinese population in Sierra Leone, this represents an acute area of study for the Ministry and no data on catch or effort is currently available (Sawyerr 2011). Utilizing data on sea cucumber dry weight exports (MFMR, unpub. data) covering six months between 2011 and 2012 (Table 4), we converted the figures to wet weight by multiplying by a factor of 9 (Cummins and Wuycheck 1971), and extrapolated catches linearly from the estimated start of the fishery in 2005.

Foreign Fishing in Sierra Leone's Waters

The vast majority of industrial fishing in Sierra Leone's waters has been conducted by foreign vessels, whether through access agreements, joint ventures, reflagging, or IUU activity (Golley-Morgan 2012; Etoh 2012; Coutin and Payne 1989; Kaczynski 1989). Vessels from numerous countries have been documented fishing in Sierra Leone's waters, some as early as the 1940s (MFMR 2001; Cole 2012a; Ssentongo and Ansa-Emmim 1986; Kelleher 2002). In the absence of reliable foreign catch data, estimates of foreign industrial production were derived from vessel data. National sources were available for the demersal trawler fleet from 1958-2007, and anchor points were identified from various sources for the shrimper, longliner, and purse seiner fleets (Table 5). Fleet size was interpolated between anchor points, and domestic fleet estimates were subtracted from the industrial fleet, in order to capture foreign vessels only. Using Kaczynski's (1989) estimate of foreign fleet performance in Guinea of 240 fishing days per vessel, and 10 t per day, we assumed a conservative 100 fishing days per vessel at 8 t per day based on evidence that marine resource exploitation in Sierra Leone is slightly lower than in other states in the region (Chaytor and Ndomahina 2012; Showers 2012; Kaczynski 1989). Additionally, information was gathered from several sources regarding the various flags of vessels fishing in Sierra Leone throughout the time series, and catches were allocated to all nationalities active in each year. A summary of active vessel nationalities is available in Table 6.

Notably, IUU fishing is a significant issue in Sierra Leone, with IUU catches estimated to reach 103,000-127,000 t per year (MRAG 2005). Aerial surveys in 2000-2001 found that 30-51 percent of actively fishing vessels were found to be operating illegally, and some reports have estimated that IUU fishing may account for over 26 percent of total fish catch in Sierra Leone (MRAG 2005; Kelleher 2002; EJF 2009).

While it is not possible to reconstruct illegal catches from observed data, we estimated illegal catches using estimated ratios of illegal to total industrial fishing, summarized in Table 7, based on expert knowledge and published anchor points. The relationship to total industrial catch was considered preferable to other proxies such as illegal activity in neighboring states, licensed vessels, or interdictions, which are subject to both positive and negative relationships with illegal activity based on various factors. Derived ratios are considered very conservative in comparison to other estimates of illegal fishing in Sierra Leone (MRAG 2005; Kelleher 2002).

Catch Composition

Between 1950 and 2010, catches of *Sardinella* spp., *Ethmalosa* spp., *Pseudotolithus elongatus* and "miscellaneous marine fish" (MMF) represented the bulk (average 78%) of FAO FishStat data. The dominance of these species is fairly consistent, and the importance of *Sardinella* and *Ethmalosa* to artisanal fisheries is echoed throughout the literature (Thorpe *et al.* 2009; Brainerd 1978). The significance of the MMF component varied greatly throughout the time series (0-39% of total reported annual catches). With this in mind, the taxonomic distribution in FishStat was maintained for the reported component of the reconstruction. However, a taxonomic distribution available from 2001 national data (Table 8) was applied to the MMF landings in 1972-1975, which represented the greatest proportion (34-39 %) and weight (17,224- 26,300 t·year^{-1}) of reported MMF throughout the time series. The same taxonomic distribution from national data was applied to reconstructed small-scale landings, and the taxonomic distribution for industrial vessels was applied to the reconstructed industrial landings. Additionally, a more detailed taxonomic distribution from Diop and Dossa (2011) was applied to shark and ray landings for both reported and unreported components.

In addition to the reconstructed Sierra Leonean catches, a taxonomic breakdown was performed for the foreign industrial catches as well. For demersal and shrimp trawlers, detailed national data was available in 2001 for species catch composition, which was applied to the percentage of foreign annual catch attributed to demersal and shrimper fleets (Table 9). Since no data was available on catch composition of longliners and purse seiners in Sierra Leone's industrial fishery, catches were classified as large pelagics.

RESULTS

Small-Scale Fisheries: Subsistence and Artisanal Catches

Reconstructed catches from the small-scale fishery in Sierra Leone rose steadily from 1950 to 1960, until the influx of several thousand refugee Ghanaian fishers led to a sharp increase in small-scale landings in the early 1960s. Catches remained high until the repatriation of the Ghanaians led to a drop in catch from 116,300 t in 1966 to 103,500 t in 1969. However, catch levels continued to increase in the following years, reaching a peak of 133,900 t in 1977, before declining again into the 1980s (Figure 2). This decline is largely attributed to increased technology and motorization, which led to overcompetition, overcapitalization and decline in CPUE in the 1980s (Chaytor and Ndomahina 2012, Golley-Morgan 2012, Baio 2009, Thorpe et al. 2009). Furthermore, catches declined significantly during the period of Sierra Leone's Civil War from 123,400 t in 1990 to 77,900 t in 1999, due largely to population displacement and labor redeployment (Thorpe et al. 2009, Hendrix and Glaser 2011, I. Turay pers comm.). However, a tremendous increase in post-conflict development support to the small-scale fishery sector led to dramatic increases in effort, and increases in catch from 122,600 t in 2000 to 241,200 t in 2010 (Baio 2009, I. Turay, S. Sei, and B. Cole pers. comm.).

Sea Cucumber catches were estimated at 94 t·year^{-1} in 2005, declining steadily to 40 t·year^{-1} in 2010. While this demonstrates a declining trend, data used in the extrapolation are highly incomplete and

should be considered a first step in estimating sea cucumber exploitation rather than a conclusive estimate of catch trends.

Industrial Shrimp Fishery

Sierra Leone's industrial shrimp fishery was established in the 1970s and shrimp landings rose to a peak of 1,740 t in 1982, as domestic companies increasingly invested in vessels and infrastructure. However, following the initial investment, the active domestic fleet declined due to decreasing CPUE, scarcity of foreign exchange, lack of local maintenance infrastructure, and increases in license and royalty fees from the 1990 Fisheries Regulations (Cole 2012b). Catches steadily declined to a low of 170 t in 1994, the same year in which sources indicate the virtual disappearance of the domestic industrial fleet. Although several sources suggest that a true domestic shrimper fleet has still not reemerged from this decline, FAO data was retained for the purposes of the reconstruction, and represents an increase to 2,155 t in 1999. Following this spike, however, catches again declined to 1,020 t in the 2010 FAO FishStat data. Discards followed a similar trend, peaking at 1,890 t in 1982, declining, and peaking in 1999 at 2,340 t (Figure 3).

Industrial demersal trawl fishery

The domestic demersal trawl fleet in Sierra Leone emerged in the 1970s, in response to growing international interest in the sector. Landings from the industrial demersal trawl fishery peaked in 1978 at 5,700 t[1], spiked again in 1985 at 4,300 t, and declined steadily to the mid-1990s. Catches remained at 0 for the period 1994-2001 (Figure 4), as evidence suggests that there was no domestic industrial trawl fishery active during the civil war (Baio 2009; Kelleher 2002). Landings then steadily increased from 450 t in 2002 to 4,500 t in 2010 (Figure 4). Discards followed the same trend as the landings and added almost 10,700 t to the reconstructed catch.

Total reconstructed catches

Over the period 1950-2010, total reconstructed catches of the domestic fishery within the Sierra Leone EEZ amounts to just over 8 million tonnes, which is 1.6 times the reported FAO data (Figure 5).

Foreign fishing in Sierra Leone's waters

In contrast to the minimal domestic industrial fishing, foreign fleets have been active in the Sierra Leone EEZ and wider Eastern Central Atlantic (CECAF) region for decades. Although foreign vessels have been documented in the area since at least the 1940s, foreign activity is said to have increased substantially in the late 1960s, in response to UN exploratory surveys of the fishing resources (Golley-Morgan 2012; Cole 2012a). Effort from foreign fishing vessels again increased in the late 1970s, and the number of foreign vessels licensed in Sierra Leone peaked in 1987 (Ssentongo and Ansa-Emmim 1986) with associated catches estimated at 200,800 t. After this peak, vessel numbers again declined, due principally to declining catches, the withdrawal of Russian vessels following the dissolution of the Soviet Union, and the 1991 onset of the Sierra Leonean Civil War (Thorpe *et al.* 2009; MFMR 2001) (Figure 6).

Estimated illegal fishing remained low through the 1950s-1960s, but increased from 5,740 t in 1969 to a peak of 86,000 t in 1989 following UN exploratory surveys of the fishing resources (Golley-Morgan 2012; Cole 2012a) and the subsequent rise of foreign interest in the area (Figure 7). With the exception of 1991 (19,500 t), when monitoring, control, and surveillance activities were increased for a short time, illegal catches vascillated between 86,000-21,000 $t \cdot year^{-1}$ from the 1980s through 2001 with the end of the civil war. Following the war, decreases in licensed vessels coupled with increases in enforcement against illegal vessels led to a decline in the estimated amount of estimated illegal fishing from previous levels (15,300-

19,700 t·year^{-1}). Estimated illegal foreign industrial fishing reached its lowest point since the 1960s at 9,928 t·year^{-1} in 2010, when significant MCS efforts led to a reported decline in illegal activity.

Catch Composition

The taxonomic compostion of Sierra Leone's reconstructed catches is available in Figure 8. Bonga shad (*Ethmalosa fimbriata*) represents the largest contribution to overall catches (54%), followed by *Sardinella* spp. (24%). The family Sciaenidae was also significant (3.3%), and was largely comprised of bobo croaker, and law croaker. Baraccuda (Sphyraenidae.), jacks (Carangidae), grunts (Haemulidae.), and threadfins (Polynemidae) also represented 2-3% of annual catches (Figure 8).

DISCUSSION

Sierra Leone's historical marine fisheries are particularly difficult to assess. That data which did exist regarding the social, ecological, and economic aspects of exploitation in past decades were largely destroyed in the burning of the Ministry of Fisheries and the Institutute of Marine Biology and Oceanography (IMBO) during the civil war (Kelleher 2002; Thorpe *et al.* 2009). Although efforts have been exerted in the past by various colonial and international powers to assess the marine fisheries potential in Sierra Leone (Steven 1945; Longhurst 1963; Ssentongo and Ansa-Emmim 1986)—and several recent endeavors have produced stock assessments and biomass estimations (ISFM 2009)—actual data on the characteristics of historical exploitation are largely absent or destroyed.

However, despite limited quantitative information, three primary issues emerge from the literature as having a major impact on the domestic fisheries of Sierra Leone. First, evidence suggests that the civil war had a diverse array of consequences for marine resource exploitation, including: migration both into and out of coastal areas, displacement of traditional fishers, increases in foreign illegal fishing, decline of fishing infrastructure, decreases in commercial fishing, the dissolution of the domestic industrial fishing fleet, and increases in subsistence harvesting (S. Sankoh pers. comm.; Baio 2009; Hendrix and Glaser 2011). The second issue is the prominent role of foreign fishing in Sierra Leone, and the challenges of discerning the legal from the illegal. The case of Sierra Fishing Company highlights the increasingly confusing ownership, licensing, and ultimate beneficiaries of Sierra Leone's domestic resource, and renders realistic assessment of stocks and effort highly challenging. Third, following the civil war, there has been a dramatic increase in effort in the small-scale sector. This is attributed to massive increases development aid as well as the commercial incentive that small-scale fishers face to illegally act as nearshore extensions of the foreign industrial fleet (Baio 2009; H. Seilert pers. obs.).

Despite these difficulties, some recent developments have given cause for optimism. In very recent years, many Sierra Leonean fishers have noted an increase in both the availability and size of catches, which are attributed to the decreased competition resulting from the introduction of a vessel monitoring system (VMS) in 2011 and the extension of the Inshore Exclusion Zone (IEZ) beyond 5 nm in 2012 (Fisheries Decree 1994, Thorpe *et al.* 2009, Fisheries and Aquaculture Bill 2011). Furthermore, support from international partners has led to improved enforcement of the IEZ (S. Sankoh pers. obs.), and Sierra Leone has demonstrated steady improvement in reporting over the time series. While these developments are the result of tremendous effort, and represent major achievements in the management of Sierra Leone's marine resources, continued commitment to monitoring, surveillance, enforcement, and reporting will be critical in ensuring the persistence of the resources.

The landed value of total reconstructed catches generated by the domestic sectors (excluding discards), is herein estimated at $195 million US annually (one tonne generates a landed value of $785 US,

see www.seaaroundus.org [2013]). Applying the average economic multiplier in Africa of 2.59 (Dyck and Sumaila 2010), fisheries in Sierra leone induce an economic impact of over $505 million US annually to the economy, representing 20% of the country's GDP in 2010, more than 10 times the contribution of mining and the quarrying in the same year (AfDB et al. 2012). Sierra leone has a history of abundant fisheries coupled with low surveillance and enforcement, that in the past has generated an estimated loss of over $28 million US annually to illegal fisheries (MRAG 2005). The present study suggests that the recent improvements in monitoring have decreased this amount by up to $20 million US in less than five years. While this is significant, the benefits of fisheries to Sierra Leone are not limited to the economic output they generate, but also act as an important source of food, income, and cultural identity.

While fisheries management in Sierra Leone is hindered by a lack of data and historical documentation, this study sought to aggregate various data sources in order to create them most accurate representation of Sierra Leone's historical marine resource exploitation. The results of this reconstruction have been validated by extensive in-country consultation with the Ministry of Fisheries and Marine Resources, fishers, and various stakeholders, and may hopefully contribute to the growing literature on Sierra Leone's marine resources.

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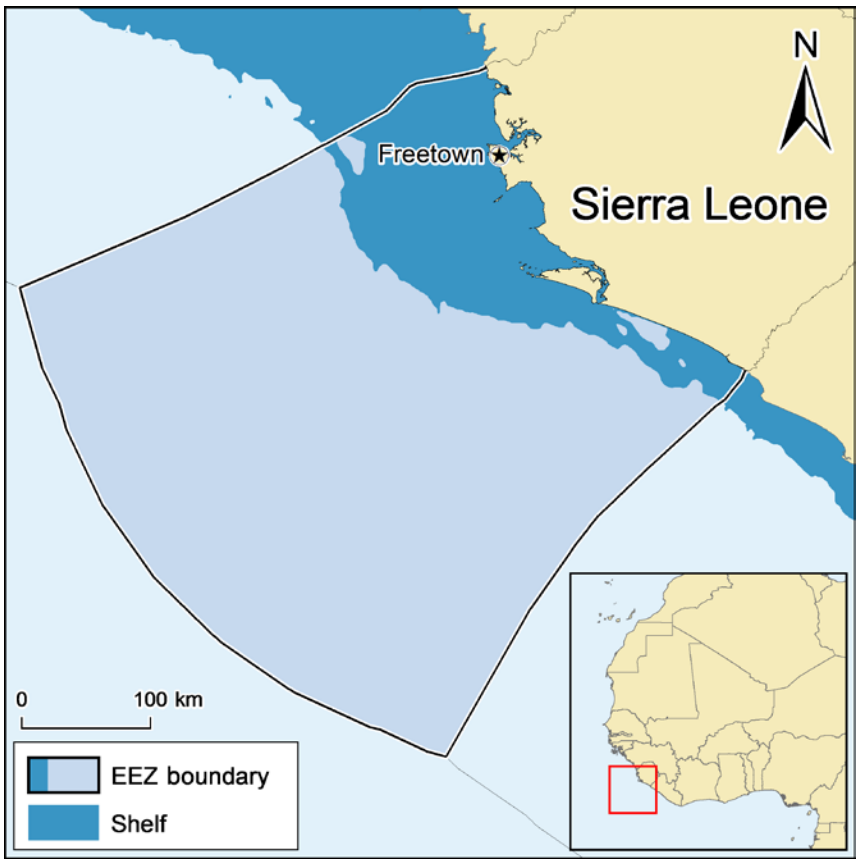

Figure 1. Map of Sierra Leone and it's EEZ boundaries.

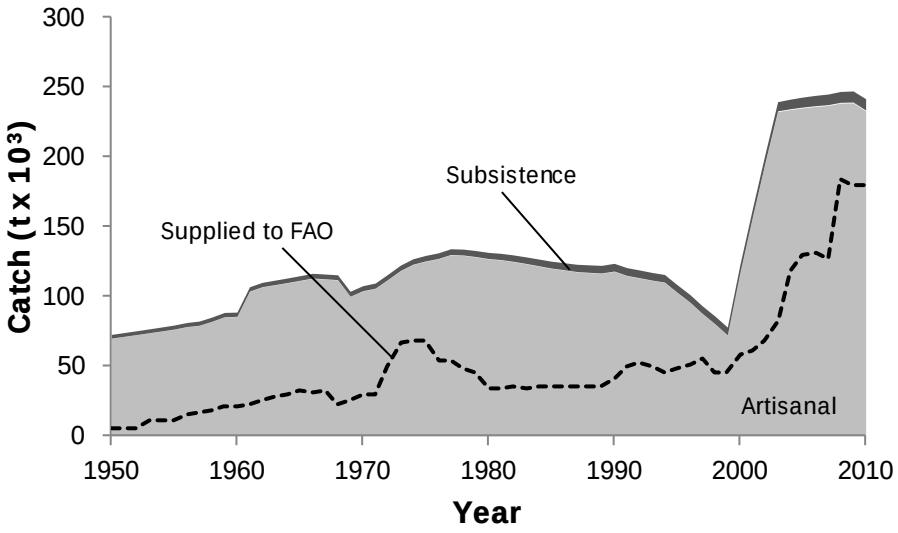

Figure 2. Total reconstructed small-scale catch of Sierra Leone, 1950-2010, by sector, with total data reported by FAO on behalf of Sierra Leone overlaid as a line graph.

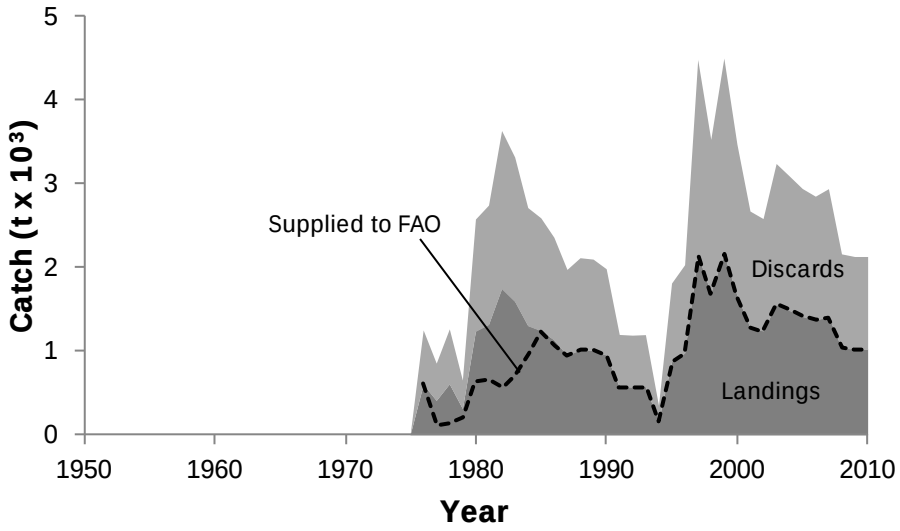

Figure 3. Reconstructed shrimp catch from domestic industrial trawlers for Sierra Leone, 1950-2010, with shrimp data reported by FAO on behalf of Sierra Leone overlaid as a line graph.

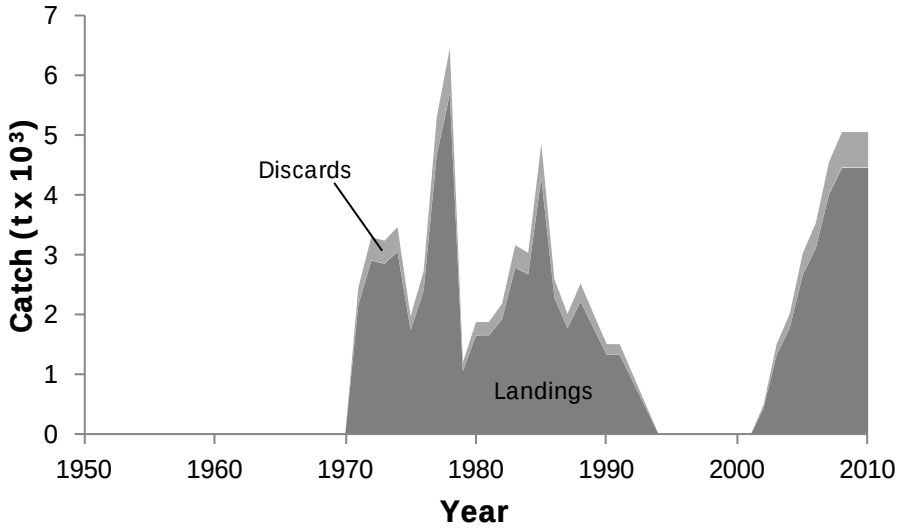

Figure 4. Reconstructed demersal catch from domestic industrial trawlers for Sierra Leone, 1950-2010.

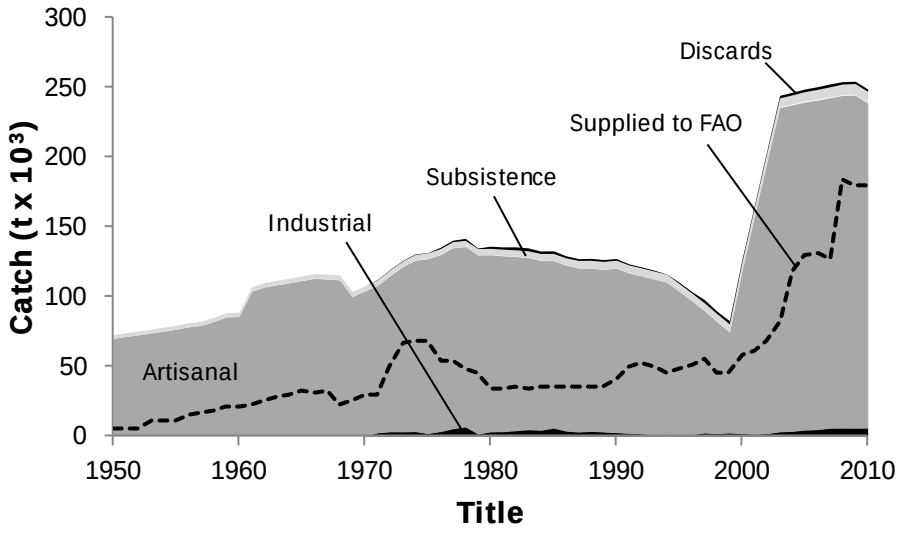

Figure 5. Total reconstructed domestic catches for Sierra Leone, 1950-2010, by sector, with the data reported by FAO on behalf of Sierra Leone overlaid as a line graph.

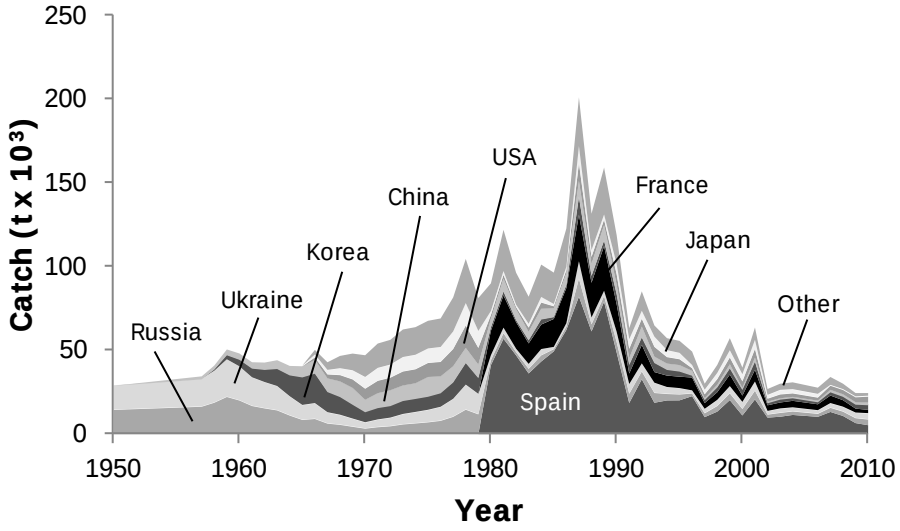

Figure 6. Total estimated foreign catch in Sierra Leone EEZ waters, 1950-2010, by country. 'Other' includes catches estimated for Greece, Liberia, former Yugoslavia, Italy and Portugal.

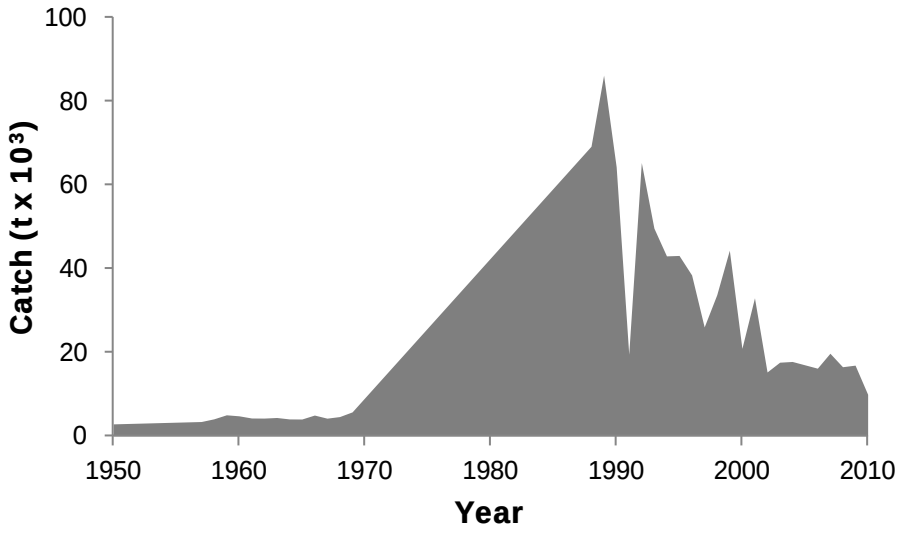

Figure 7. Estimated illegal industrial fishing in Sierra Leone's EEZ, 1950-2010.

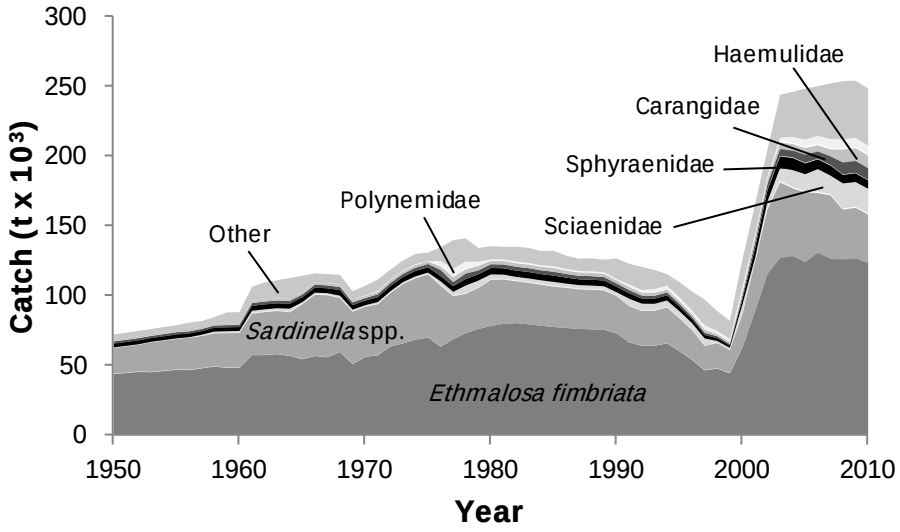

Figure 8. Total reconstructed domestic catches by major taxon. 'Other' consists of 52 additional taxonomic categories.

Table 1. Summary of data, assumptions & sources used for CPUE estimates of small-scale fishing in Sierra Leone.

Year	Number of fishers	Catch (t)	CPUE ($t \cdot fisher^{-1} \cdot year^{-1}$)	Comments	Source(s)
1950-1957	12,033-13,626	72,201-81,758	6.0	Pelagic stocks virtually un-fished except by a few drift and cast netters, artisanal exploited demersal species only by hook and line, traps, and weirs	Golley-Morgan 2012
1962-1966	16,884 -17,882	109,747-116,235	6.5	2-3000 Ghanaian fishers immigrated in the early 60s, specialized with pelagic stocks, introduced ring nets, gill nets, and larger boats	Chaytor and Ndomahina 2012; Golley-Morgan 2012
1968	18,436	115,228	6.25	Ghanaians repatriated in late 60s, fish production dropped	Chaytor and Ndomahina 2012
1970	16,519	107,376	6.5	Fish production reported to have reached prior levels within approx. 3 years of Ghanaian repatriation	Chaytor and Ndomahina 2012
1977	17,857	133,930	7.5	increase in motorization in the 1970s which is reported to have greatly increased the total landings	Chaytor and Ndomahina 2012
1987-1989	17,654 -17,551	123,583-122,859	7.0	under pressure and intense competition from the foreign mechanized fleet, the small- scale fishery showed a decline in their contribution of *Sardinella* but increased its *Ethmalosa* landings.	Chaytor and Ndomahina 2012; Baio 2009
1999-2000	10,000-15453	80,000-123,624	8.0	following the RUF entrance into Freetown in 1997, international support projects were halted, boats were destroyed, and fishing as a coping strategy simply ceased to exist at in many sites, following the prohibition of all fishing activity on 27th May 1998	Thorpe et al. 2009, Baio 2009
2010	37,053	240,845	6.5	post-war recovery programmes reactivated artisanal fishing activities, and it is widely believed that the small-scale fishery is now well over capacity	Thorpe et al. 2009, FAO 2001, Baio 2009; Heiko pers. Comm.
1958-1961, 1967, 1969, 1970-1976 1978-1986 1990-1998 2001-2009	13,870-16,655 18,155 16,224 16,519-17,830 17,884-17,706 17,500-11,069 20,906-37,053		interpolation		

Table 2. Summary of data, assumptions and sources used for the reconstruction of the domestic shrimp trawler catches in Sierra Leone.

Time Period	Industrial Shrimp Catches (t/year)	Parameters	Sources
1977-1979, 1984-1986	313-1,300		FAO Industries Division 2012
1980-1983	1,234-1,741	1.6[a]	Cole 2012b, Ssentongo and Ansa-Emmim 1986, FAO 2000, Kutkuhn 1962
1976, 1987-2010	600-2,147		FAO FishStat data
1977-2010	340-2,329	1:1.085[b]	MFMR 2001

a) Headless to Head-on Conversion Ratio
b) Shrimp catch:discard ratio

Table 3. Summary of data, assumptions and sources used for the reconstruction of the domestic demersal fish trawler catches in Sierra Leone.

Time Period	Industrial Demersal Trawl Catches (t/year)	Parameters	Sources
1971-1982	1,071-5,699		Ssentongo and Ansa-Emmim 1986
1983-1986	2,686-4,295		FAO Industries Division 2012
1987-1993	0-4,466	446.584[a]	MFMR 2009, Baio 2009, FAO Industries Division 2012, Kelleher 2002
1971-1993	59-753	1:0.132[b]	MFMR 2001
2002-2010	447-4,466	446.584[a]	MFMR 2009, Baio 2009, FAO Industries Division 2012, Kelleher 2002

[a] Derived Catch Rate (t/vessel/year)
[b] Landed demersal catch: discard ratio

Table 4. Sea cucumber exports in dry weight (kg).

Month	Exports (kg)	Wet weight (t)
01/03/2011	500	4.5
01/04/2011	500	4.5
01/05/2011	500	4.5
01/02/2012	148	1.3
01/05/2012	100	0.9
01/08/2012	100	0.9

Table 5. Summary of vessel data and sources used to estimate foreign catches in Sierra Leone.[a]

Years	Fleet	Number Vessels	Sources
1958-2010	Demersal Trawl Vessels	7-140	Chaytor and Ndomahina 2012, MFMR 2009, Baio 2009
1968-2010	Shrimp Vessels	1-67	Cole 2012b, Chaytor and Ndomahina 2012, MFMR 2009, MFMR 2001, Baio 2009, MFMR 2001
1950-2010	Purse Seine Vessels	4-59	Ssentongo and Ansa-Emmim 1986, Baio 2009, MFMR 2009, Chaytor and Ndomahina 2012, MFMR 2001, Cole 2012a
1950-2010	Longline Vessels	0-32	MFMR 2009, MFMR 2001, Chaytor and Ndomahina 2012, Ssentongo and Ansa-Emmim 1986

[a] Assumptions: 100 fishing days, 8t/day (Kaczynski 1989).

Table 6. Flag allocation of foreign catch estimates.

Foreign Flag	Derived Years present in Sierra Leone EEZ	Sources
USA	1959-1963	Cole 2012a
China	1985-2010	MFMR (2001); Kelleher (2002); Baio (2009); Wildman (1993); Mallory (2012a); Mallory (2012b); Dobo (2009)
France	1952-1969	Cole (2012a)
Ghana	1977-1981	MFMR (2001)
Guinea	2002	Kelleher (2002)
Guinea-Bissau	2002	Kelleher (2002)
Greece	1977-2010	MFMR (2001); Ssentongo and Ansa-Emmim (1986); Kelleher (2002); Baio (2009)
Italy	1952-1981	MFMR (2001); Ssentongo and Ansa-Emmim (1986)
Japan	1950-1998	Cole 2012a, Weber and Durand (1986); Anon. (1998); Swartz (2004)
Korea	1964-2010	MFMR (2001); Cole (2012a), Kelleher (2002); Baio (2009)
Liberia (Korea)[a]	1977-1981	MFMR (2001); Ssentongo and Ansa-Emmim (1986); Anon. (1998); www.grosstonnage.com Accessed on 27/08/2013
Libya	1988-1993	Anon. (1998)
Nigeria	1991-1995	Beaudry *et al.* (1993)
Norway	2002	Kelleher (2002)
Panama (Korea)[a]	1976-1981	MFMR (2001); EJF (2009), www.grosstonnage.com Accessed on 27/08/2013
Senegal[b]	1976-1981	MFMR (2001); Ssentongo and Ansa-Emmim (1986)
Ukraine	1959-1993	Ssentongo and Ansa-Emmim (1986); Cole (2012a); MFMR (2001); Weber and Durand (1986); Anon. (1998); Wang 1992
Russia	1959-1993	Ssentongo and Ansa-Emmim (1986); Cole (2012a); MFMR (2001); Weber and Durand (1986); Anon. (1998); Wang (1992)
Spain	1955-2009	Cole (2012a); Ssentongo and Ansa-Emmim (1986); Baio (2009)
Yugoslavia	1973-1977	Weber and Durand (1986)

[a] Sources indicate that ships flagged to Panama and Liberia are generally under Korean ownership and operation (www.grosstonnage.com Accessed on 27/08/2013).

[b] Although there is some indication that Senegalese small-scale fishers exploit significant amounts of fish as far as Sierra Leone, estimates of these catches are considered a different classification of foreign fishing, and are not included in this estimate (Binet *et al.* 2012).

Table 7. Summary of data, assumptions and sources used for estimating illegal foreign industrial catches in Sierra Leone.

Year	Total Estimated Industrial Catch (Domestic + Foreign)	Percent of Total Industrial Fleet operating Illegally	Estimated Illegal Catch	Comments	Source(s)
1950-1968	28,800-46,200	0.10	2,880-4,620	Industrial fishing begins in the early 1950s with a small number of foreign vessels	Etoh (2012)
1969-1988	47,600-135,405	Interpolation	5,736-69,056	1969 surveys reveal rich fish resources, leads to massive increase in legal and illegal industrial fishing	Etoh (2012); Elliott (1993); Sierra Leone Fisheries Department (1993); Alder and Sumaila (2004)
1989	162,252	0.53[a]	85,993	-	Etoh (2012)
1990	121,107	0.53	64,168	-	Etoh (2012)
1991	64,930	0.30	19,479	Increases in monitoring, control, and surveillance activities led to a temporary decrease in illegal activity	Graham and Booth (2012)
1992-1999	86,897-59,028	0.75	65,173-44,272	Illegal fishing increased during the civil war, when foreign investors withdrew and monitoring, control, and surveillance activity was impeded	A. Baio pers. obs.; Thorpe *et al.* (2009); MRAG (2005)
2000	40,937	0.51[a]	20,878	-	Kelleher (2002)
2001-2009	64,554-33,094	0.51	32,922-16,878	Illegal activity remained high through the 2000s	Thorpe *et al.* (2009)
2010	33,094	0.30	9,928	Increases in monitoring, control, and surveillance activities and implementation of VMS technology led to a decrease in illegal activity	EJF pers. comm.

[a] Sources provide anchor points of ratios for illegal vessels: total industrial fishing vessels.

Table 8. Taxonomic distribution of the 2001 artisanal fishery catches (Source: MFMR 2009).

Local name	Scientific Name	Catches (t)	Catches (%)
Awefu & Bonga	*Ethmalosa spp.*	24,790	62.05
Bonita	*Rachycentron canadium*	214	0.53
Catfish	*Arius spp*	53	0.13
Couta & Kinni	*Sphyraena spp*	1,704	4.26
Cowreh	*Caranx spp*	230	0.58
Crab	*Portunidae*	4	0.01
Crocus	*Pomadasys spp*	678	1.7
Grouper	*Lutjanus spp*	70	0.17
Gwangwa, Lady, & Whiting	*Pseudotolithus spp*	300	0.75
Herring & Mina	*Sardinella spp*	9,849	24.65
Joefish	*Trachinotus spp*	522	1.31
Kente	*Chloroscombrus chrysurus*	227	0.57
Lati	*Ilisha africana*	4	0.01
Mackerel	*Scomber spp*	352	0.88
Others	*Mixed species*	307	0.77
Pomp	*Alectes alexandrinus*	11	0.03
Shark	*Sphyrna spp*	45	0.11
Sheephead	*Drepane africana*	11	0.03
Shinenose	*Galeoides decadactylus*	64	0.16
Shrimp	*Penaeidae*	4	0.01
Silverfish	*Trichurus lepturus*	9	0.02
Skate	*Dasyatidae*	9	0.02
Snapper	*Sparidae*	354	0.89
Sole	*Cynoglossidae*	10	0.02
Spanish	*Polydactylus spp*	128	0.32

Table 9. Taxonomic breakdown applied to foreign demersal and shrimper catches (Source: MFMR 2009).

Local name	Scientific name	%
Couta/Kinni	*Sphyraena* spp.	6.41
Crocus	*Pomadasys* spp.	7.90
Cuttlefish	*Sepia* spp.	3.23
Gwangwa	*Pseudotolithus* spp.	3.29
Ladyfish	*Pseudotolithus* spp.	6.12
Pollock	*Decapterus* spp.	2.64
Shinenose	*Galeoides decadactylus*	5.17
Shrimp	*Penaeus* spp.	7.77
Snails	*Cybium* spp.	3.82
Snapper	*Sparidae*	5.09
Others	-	48.56