SECURING SOMALI FISHERIES

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Appendices

METHODOLOGICAL APPENDICES FOR *SECURING SOMALI FISHERIES*

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SECURE FISHERIES
Advancing Sustainable Fisheries

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APPENDIX 1. SURVEYS OF SOMALI FISHERS

In an effort to gain a better understanding of local Somali fisheries, we developed a survey and partnered with another One Earth Future program, Shuraako, to distribute it on the ground in Somalia. The survey covered a range of topics related to the fishing industry, economy, regulations, and perception of foreign fishing. Categories covered included:

1) Respondent personal information such as location, age, sex, number of years in the fishing industry, and occupation (fisher, processor, exporter).
2) Fishing information such as location of fishing, gear and boat types, length of season, species targeted, and typical amount of catch.
3) Economic information such as processing of fish; amount paid for fish after catch, after processing, or at export; who buys the fish, and where it is exported.
4) Information regarding fisheries reporting and regulations such as whether fishers must report catch and to whom, the existence of regulations or management, and the effectiveness of regulations or management.
5) Perception of foreign fishing in Somali waters, including how often they see foreign fishing vessels in their waters, where they are from, if they have licenses, and how Somalis feel about foreign fishers.

The survey protocol received exemption from the Internal Review Board at the University of Denver. The survey was translated from English to Somali. Two employees of Shuraako distributed it to their contacts in the fishing industry in Puntland and Somaliland. We also obtained five completed surveys from other contacts in the Somali fishing industry, for a total of 39 completed surveys. Because of the low sample size and non-randomized locations, the survey is not a quantitative look at the Somali fishing sector. Rather, we used the information to qualitatively understand the market for fish, existence and effectiveness of fishery regulations, and opinions about foreign fishers in Somali waters. Answers were translated back into English (by the same translator) and collated. The questions for which results are reported in *Securing Somali Fisheries* include:

How do you feel about the presence of foreign fishers?

This was an open-ended question. In this report, answers are in the form of quotations throughout Chapters 1 and 5.

Do you know what country they come from? (This was a follow-up question and "they" refers to foreign fishers.) Multiple choice answers included:

1) *Yemen*
2) *Oman*
3) *France*
4) *Seychelles*
5) *Taiwan (Province of China)*
6) *Korea*
7) *Thailand*
8) *India*
9) *Iran*
10) *Other*

"Other" was available to be filled in with unlisted countries. Answers were reported in Chapter 2

What kind of fish do you catch and in which months do you typically catch them? (Check all that apply)

1 What kind of fish do you catch and in which months do you typically catch them?

(See attached species guide for reference - *Check all that apply)*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lobster	○	○	○	○	○	○	○	○	○	○	○	○
Prawns	○	○	○	○	○	○	○	○	○	○	○	○
Sharks & Rays	○	○	○	○	○	○	○	○	○	○	○	○
Tuna	○	○	○	○	○	○	○	○	○	○	○	○
Grouper	○	○	○	○	○	○	○	○	○	○	○	○
Snapper	○	○	○	○	○	○	○	○	○	○	○	○
Jacks	○	○	○	○	○	○	○	○	○	○	○	○
Sardines	○	○	○	○	○	○	○	○	○	○	○	○
Emperors	○	○	○	○	○	○	○	○	○	○	○	○
Scad	○	○	○	○	○	○	○	○	○	○	○	○
King fish (Mackerel)	○	○	○	○	○	○	○	○	○	○	○	○
Squid/Cuttlefish	○	○	○	○	○	○	○	○	○	○	○	○
Goatfish	○	○	○	○	○	○	○	○	○	○	○	○
Sweetlips	○	○	○	○	○	○	○	○	○	○	○	○
Turtle	○	○	○	○	○	○	○	○	○	○	○	○
______ *Other*	○	○	○	○	○	○	○	○	○	○	○	○

Answers were used to guide descriptions of Somali domestic fisheries and inform analyses in Chapters 3 and 4.

How much did you earn for your fish the last time you sold it? (Please enter price/per kilo for all that apply)

The list of fish in the prior question was re-printed, and respondents could fill in the price per kilo for these species. We requested separate prices from the sectors of fishers, processors, and exporters. Many respondents listed prices for more than one sector because many fishers participate in more than one level of the value chain. Answers were included in the collection of data used to estimate prices for fish caught in Somali domestic fisheries (Chapter 3, Table 3.1).

APPENDIX 2. METHODS FOR ESTIMATING FOREIGN FISHING IN SOMALI WATERS

Analysis of IOTC Data

IOTC catch data were analyzed to estimate longline, purse seine, and coastal fishing (primarily gillnet) by vessels from the Seychelles, Taiwan (Province of China), La Réunion, China, Thailand, Spain, Portugal, South Korea, Mauritius, Japan, France, and the former Soviet Union.

Three data sets were obtained from the IOTC catch and effort database:[a] the purse seine set, the longline set, and the coastal set. Combined, these three datasets cover the spatially-disaggregated catch data made available by the IOTC. Each observation reports catch in weight (metric tons) or numbers (or both) for species of concern to the IOTC. Associated metadata for each observation includes fishing nation ("fleet"), gear type, year, month, latitude, longitude, fishing effort and unit, and the cell size resolution for reporting (typically 1 degree by 1 degree for purse seine, 5 degrees by 5 degrees for longline, and non-standard units for coastal, although resolution does vary by fleet). To prepare data for analysis, several pre-processing steps were performed.

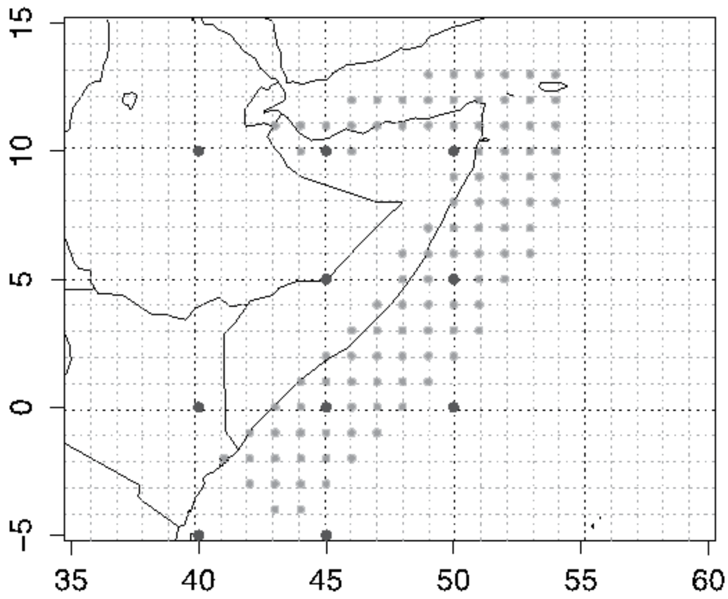
1. All observations of catch were converted from numbers to weight when weight was not reported. Both purse seine and coastal data provided values of weight for all observations, so this conversion was only necessary for the longline dataset. For a given species, the ratio of weight to numbers was calculated for each observation for which both values were available. The mean ratio was then multiplied by observed numbers for observations in which weight was missing. As an example, for yellowfin tuna, there were 72,625 observations of numbers but only 42,634 observations of weight. The average weight:number was 0.035 mt (35 kg) per fish.
2. For the purse seine dataset, separate values were reported for fish caught in different types of schools (free schools, associated schools, or unclassified schools). These three categories were summed. No species-level aggregation was needed for the longline or coastal datasets.
3. Catch was assigned to fall inside or outside Somali waters. Somali waters were defined by EEZ boundaries proclaimed to the United Nations on June 30, 2014.[b] The IOTC grid used for reporting catch data was overlaid on the EEZ boundary line, and grid cells were assigned to fall inside or outside the Somali EEZ as follows (see Figure A2.1):
    a. Purse seine dataset: Purse seine data were reported in 1° × 1° cells. Any cell that touched the Somali EEZ was classified as being "inside" Somali waters. In this regard, then, we may slightly overestimate catch assigned to Somali waters from vessels that fished the line.
    b. Longline dataset: Longline data were reported in 5° × 5° cells (91.8%), 1° × 1° cells (8.2%), or other resolution (<0.1%). No catch from the last category fell within Somali waters. 1° × 1° cells were assigned identically to those in the purse seine fleet. 5° × 5° were disaggregated: total catch in a cell that spanned the Somali EEZ was multiplied by the percentage of the cell area that fell inside the Somali EEZ.
    c. Coastal dataset: Coastal data were reported in 5° × 5° cells (30.9%), 1° × 1° cells (64.2%), or other resolution (4.9%). The latter did not fall within Somali waters. 1° × 1° cells were treated similarly to those in the purse seine fleet, and 5° × 5° were treated similarly to those in the longline fleet.

Following pre-processing, data were summarized by fleet (nation), species, and year.

a IOTC Available Datasets. http://www.iotc.org/data/datasets. Accessed 9 December 2014. Database for *Catch-and-effort by month, species and gear, by vessel flag reporting country.*

b We understand and respect there is disagreement about these boundaries, but we use them for now because they provide concrete boundaries for mapping and analysis purposes. Coordinates defining the EEZ can be found at http://www.un.org/Depts/los/LEGISLATIONANDTREATIES/PDFFILES/SOM_2014_EEZ.pdf.

FIGURE A2.1 Grid cells from the longline (larger dots) and purse seine (smaller dots) fleets used to estimate catch by IOTC vessels in Somali waters. Catch falls in the square grid cell that lies to the north and east of a marked coordinate.



Catch Reconstruction

A reconstruction approach was used to estimate catch for Italy, Yemen, Iran, Egypt, Kenya, Greece, and Thailand. We followed the general approach for catch reconstruction developed by The Sea Around Us at the University of British Columbia. We combined their approaches for estimating IUU or underreported fishing[1, 2] with an approach for estimating catch by a distant water fleet.[3] First, a fishery timeline for Somalia was created (spanning the early 1930s until 2014) from a search of the literature and expert interviews.[c] Second, nations with a presence in Somali waters were identified from this timeline. When available, details of the years fishing occurred, gear used, species targeted, and volumes caught were recorded. Third, catch and associated uncertainty was estimated using Monte Carlo simulations that resampled estimates of numbers of boats and catch volume over a range of values found in reports. These simulations were restricted to time periods for which boat numbers and/or catch volumes were available. Fourth, we extrapolated simulated time series back to 1981 (using linear extrapolation). See exact approaches used for various nations below.

Italy

Catch reconstruction for Italy covered 1981–2006. Italian vessels fished for tuna during the 1930s through 1950s, but data on volume and catch composition was not available. Three trawlers fishing for *Amoroso e Figli* operated during 1978–1979 but volume estimates were not available. We collected reliable information on trawlers operating through the joint ventures SOMITFISH (1981–1983) and SHIFCO (1987–2006).[4, 5] Our reconstruction posits the following: from 1981–1983 three trawlers were operating for SOMITFISH, and from 1987–1989 three trawlers were operating for SHIFCO. In 1987, SHIFCO added two trawlers to its fleet. These vessels were similar in capacity, ranging from 57–66 m in length. Vessels were flagged to Somalia until 1998, and that catch should be attributed to the Somali domestic fleet. Joint venture rules require catch from joint venture vessels be attributed to the flag country. Therefore, catch from these vessels during 1981–1998 should be included in volumes reported by Somalia to the FAO (or covered under the assumptions of the domestic

c The fishery timeline is available at: http://securefisheries.org/report/securing-somali-fisheries.

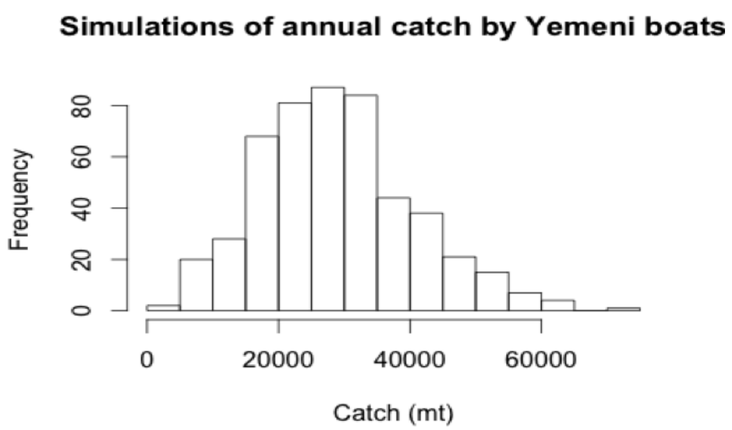
reconstruction in Chapter 3). When SHIFCO vessels were reflagged, catch should be considered foreign. It is unclear under what flag this catch might have been reported to the FAO. We assign it to Italy because of the history of the joint venture and the exclusive purchasing rights of an Italian import company, *Panapesca SpA*.

Records of catch by the five SHIFCO trawlers were obtained from *Panapesca SpA*. Catch was reported in kilograms for various fishery taxa aggregated across all vessels but specific to a fishing campaign (approximately 55 days in length). Records covered August 2000 to September 2006. Annual catch (metric tons) was calculated from these records, and the average catch over the period of observation (3,440 mt) was extrapolated back from 1999 to 1990. Prior to 1990, catch was reduced to 60% of the average observed catch (2,064 mt) because only three trawlers were operating during that period. One trawler, the *Antoinette Madre*, operated in at least 1984.[6] Two trawlers landed fish and lobster in 1985, and values (1,313 mt and 679 mt) were reported by VanZalinge. We used the average catch by these two trawlers to estimate catch for the *Antoinette Madre* in 1984 (996 mt). Finally, records[7] show five additional Italian trawlers operated in 1988 and we applied the average annual catch from the five SHIFCO vessels (3,440 mt) to this datum. This value is bolstered by a report[8] that one SHIFCO trawler landed 1,245 mt in 1987. Catch composition also was obtained from *Panapesca* record sheets. For most reporting periods finfishes were aggregated across species. However, for records from August 2000 and September 2006, we obtained family-level data. We applied this composition breakdown to the larger "fish" categories from remaining reporting periods. All five former SHIFCO vessels stopped operating in Somali waters in 2006 due to high fuel costs.

Yemen

One of the earliest mentions of fishing by Yemen occurs in Yassin in 1981,[9] in which he refers to a concern about shared resource management for the Indian oil sardine. There is no mention of Yemeni boats crossing over into Somali waters; it is implied that the resource spans both territories. Therefore, we take 1981 as an anchor point for which Yemeni catch in Somali waters was zero. Twelve Yemeni vessels were arrested in Somali waters in 2006 (our minimum number of vessels), and the UN[10] claims as many as 300 Yemeni vessels fish in Somali waters each year. Dr. Kulmiye, State Minister for Fisheries and Marine Resources in Puntland, reports that Yemeni vessels carry between 3—7 mt of fish per trip, make 3 trips per month, and visit Somali waters each month out of the year. Therefore, our simulations of catch by Yemeni vessels calculated annual catch by sampling over a triangle distribution limited by minimums of 12 vessels per year and 108 mt per vessel, and maximums of 300 vessels per year and 252 mt per vessel. Monte Carlo simulations estimated an average of 28,970 mt per year, with 90% confidence intervals of 11,094–50,076 mt per year (Figure A2.2). This estimate was applied to 2006–2014, and catch was linearly interpolated back to 1981 (where the anchor point was zero).

FIGURE A2.2 Monte Carlo simulations of catch by Yemeni vessels.

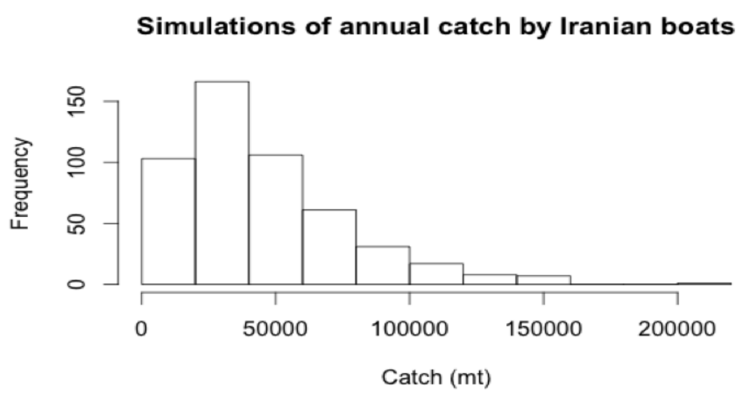


Yemen has reported catch to the IOTC during the period of 2003–2007. It is unclear why data were reported during this period but for no other years. Reported catch is very high: from the Somali EEZ, a total of 313,209 mt were reported, second only to Spain in total catch by IOTC species in Somali waters. Our approach to assigning IOTC-reported catch to Somali waters is particularly vulnerable to inaccuracy in the case of Yemen: Yemen reports catch in 5°×5° cells, and the coordinate that overlaps with Somalia's EEZ also covers a significant portion of Yemen's EEZ. With our approach, there is no way of distinguishing where the catch was made. Consequently, for Yemen we default to our reconstruction, a more conservative approach that results in 29,000 mt of catch annually (compared to an annual average of 62,642 mt per year reached by disaggregating reported IOTC data). However, we use the IOTC data to guide our species composition estimates: yellowfin (48%); other tunas including longtail, narrow-barred Spanish mackerel, frigate tuna, and kawakawa (combined with undifferentiated tuna, 38%); and sharks (5%). All data reported to the IOTC originate from boats deploying handlines.

Iran

Our approach to estimating catch from Iran was identical to that used to estimate catch by Yemen. Reports in the literature indicate Iran has a minimum of 5[11] and a maximum of 180[12] vessels operating in Somali waters. Capacity for fish on each vessel was not available. We therefore used global estimates for gillnet vessels to obtain a range of catch per year. Pauly et al.[13] estimated catch capacity for gillnet vessels as 221 mt per year (average) and 1,211 mt per year (maximum). Waugh[14] estimated the minimum capacity of these vessels to be 16 mt per year. Our simulation therefore resampled triangle distributions estimating number of vessels and fish capacity. Given the wide range of capacities used as input, the estimates of annual catch ranged widely. We estimate total annual catch by Iranian vessels at 44,853 mt with 90% confidence intervals of 8,988–104,150 mt (Figure A2.3).

FIGURE A2.3 Monte Carlo simulations of catch by Iranian vessels.



Egypt

Trawling by Egyptian vessels began in 1981 and continues through today. We therefore reconstructed catch over 1981–2014. Haakonsen reported "a few" and no more than 10 trawlers operating in the early 1980s,[15] split between Italy and Egypt. Knowing Italy had three trawlers operating in 1981, we assigned a conservative three trawlers to an anchorpoint of 1981. Further, we assigned anchor points of 36 trawlers during 2003–2006[16] and 34 trawlers in 2007.[17] Published estimates of catch by these trawlers are 30 mt per trawler per month. We therefore estimate 34 trawlers caught 12,240 mt per year

(2007–2014) and 36 trawlers caught 12,960 mt per year (2003–2006). We extrapolated back to zero catch in 1981. Variable estimates of numbers of boats or capacity were not available, so we did not conduct Monte Carlo simulations to estimate confidence intervals.

Kenya

Kenyan prawn trawlers have operated along the southern Somali border, near the Juba River, since at least 2004.[18] There are reports of 19 illegal trawlers catching 800 mt of prawns each year, for a total of 8,000 tons since 2004.[19] We did not conduct Monte Carlo simulations for Kenyan catch.

Greece

Greek trawlers began operating in Somalia during the 1960s. Haakonsen[20] reported "a few" licensed Greek trawlers operating in the mid-1960s and Bihi[21] noted "a number of" Greek trawlers operating in at least 1983. After 1983 and until recent times, we found no reports of Greek vessels in Somali waters. Today, two Greek trawlers flagged to Belize, the *Greko 1* and *2*, have been operating since 2010. These vessels appear to be licensed and have been fishing off the southern Somali coast. The composition of catch is unknown. To estimate catch by these trawlers, we assumed catch rates per gross tonnage (GT) were similar to the Korean-flagged trawlers operating in recent years. That is, we applied the same catch per gross ton from the Korean trawlers (1.16 mt per GT) to the Greek trawlers (each 193 GT),[22] for a total of 447 mt per year. We assumed two trawlers were present in 1983 and two were present from 2010–2013.

Thailand

In addition to the estimation of Thai purse seine catch (see IOTC estimation above), Thai trawlers operated in Puntland from at least 2005 to 2009. Seven trawlers, owned by Sirichai, operated year-round in Puntland. These vessels were licensed, operated for six consecutive months by transshipping to a Thai freezer ship in Somali waters, and returned twice a year to Salalah (Oman) for repairs and unloading.[23] We were unable to find estimates for the amount of catch by each vessel; consequently, given the location of trawling and type of vessel, we reconstructed catch by these seven trawlers by applying the vessel catch-rate calculated for the Korean trawlers discussed above (785 mt per vessel per year). We believe this is a minimum estimate and likely underestimates the catch by these trawlers. Thai vessels withdrew from Somali waters in 2009.

Automatic Identification System analysis

AIS data were obtained to estimate catch from South Korean trawlers operating in Somali waters during 2006–2014. AIS tracks were obtained for 2010–2014, and estimates thereby derived were carried back to 2006. See Appendix 3 for details on analysis of AIS.

Catch Allocation

We used catch allocated to Somali waters by algorithms[24] developed by The Sea Around Us to estimate catch by Pakistan. We could not find sufficient information about fishing in Somali waters by Pakistan to conduct a catch reconstruction simulation, but interviews with experts indicated their presence was highly likely. Therefore, we used allocations derived from reported catch data published online.[25] Catch was assigned to a Somalia's EEZ by (1) estimating total catch for a given foreign nation using FAO catch statistics, (2) overlaying a species' geographical distribution with Somalia's EEZ, and (3) including consideration of any access agreements between Somalia and the foreign fleet.

TABLE A2.1 Estimates of foreign catch in Somali waters, 1981–2013.

	Italy	Kenya	Yemen	Iran	Egypt	Greece	Thailand	Pakistan	La Rèunion	Seychelles	Taiwan (Province of China)
1981	2,064	0	0	0	1,080	0	0	0	0	0	0
1982	2,064	0	1,159	2,361	1,620	0	0	0	0	0	38
1983	2,064	0	2,318	4,722	2,160	447	0	0	0	0	0
1984	0	0	3,476	7,083	2,700	0	0	0	0	70	0
1985	0	0	4,635	9,444	3,240	0	0	0	0	51	0
1986	0	0	5,794	11,805	3,780	0	0	0	0	0	195
1987	2,064	0	6,953	14,166	4,320	0	0	0	0	0	589
1988	5,504	0	8,112	16,527	4,860	0	0	0	0	0	2,317
1989	2,064	0	9,270	18,888	5,400	0	0	0	0	0	342
1990	3,440	0	10,429	21,249	5,940	0	0	0	0	0	592
1991	3,440	0	11,588	23,610	6,480	0	0	496	0	0	4,101
1992	3,440	0	12,747	25,971	7,020	0	0	88	0	0	408
1993	3,440	0	13,906	28,332	7,560	0	0	1,502	0	0	2,197
1994	3,440	0	15,064	30,693	8,100	0	0	317	0	0	397
1995	3,440	0	16,223	33,054	8,640	0	0	402	0	0	1,368
1996	3,440	0	17,382	35,415	9,180	0	0	716	3	1	2,521
1997	3,440	0	18,541	37,776	9,720	0	0	2,568	163	1,103	4,813
1998	3,440	0	19,700	40,137	10,260	0	0	1,592	158	1,012	6,020
1999	3,440	0	20,859	42,498	10,800	0	0	242	21	4,385	2,396
2000	4,103	0	22,017	44,853	11,340	0	0	1,344	2	4,545	1,877
2001	3,728	0	23,176	44,853	11,880	0	0	152	0	4,102	1,596
2002	3,537	0	24,335	44,853	12,420	0	0	787	0	9,446	5,757
2003	5,059	0	25,494	44,853	12,960	0	0	21,163	0	15,257	9,845
2004	2,780	800	26,653	44,853	12,960	0	0	22,121	0	13,383	8,388
2005	2,275	800	27,811	44,853	12,960	0	5,495	20,389	0	13,367	11,358
2006	2,599	800	28,970	44,853	12,960	0	5,985	0	0	5,653	7,163
2007	0	800	28,970	44,853	12,240	0	5,495	0	0	3,449	2,796
2008	0	800	28,970	44,853	12,240	0	5,495	0	0	1,957	1,719
2009	0	800	28,970	44,853	12,240	0	5,710	0	0	2,907	159
2010	0	800	28,970	44,853	12,240	447	0	0	0	3,910	180
2011	0	800	28,970	44,853	12,240	447	0	0	0	2,825	46
2012	0	800	28,970	44,853	12,240	447	0	0	0	9,032	4,573
2013	0	800	28,970	44,853	12,240	447	35	0	0	9,492	4,642
Sum	74,306	8,000	579,404	1,031,673	286,020	2,235	28,215	73,878	348	105,948	88,393

TABLE A2.1 Estimates of foreign catch in Somali waters, 1981–2013, cont.

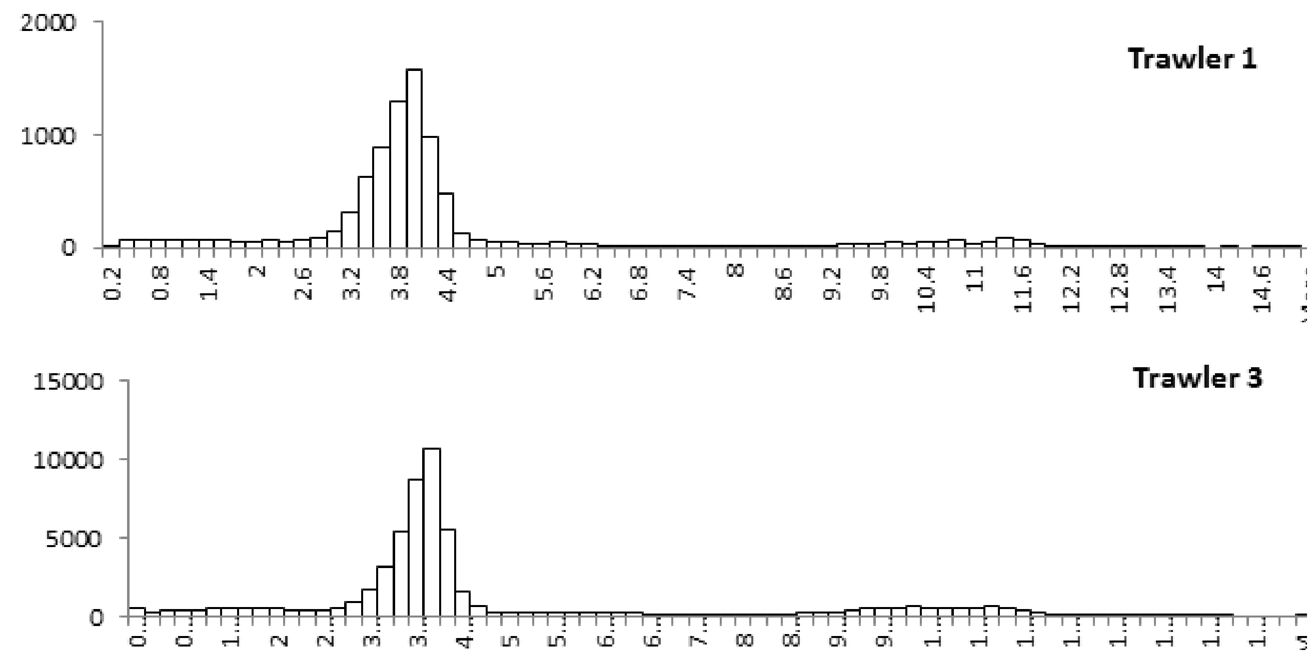
	China	Spain	Portugal	Japan	Korea	Mauritius	France	Ex-Soviet	Other	Sum
1981	0	0	0	1,782	2,089	0	0	0	0	7,016
1982	0	0	0	1,055	4,859	0	0	0	0	13,156
1983	0	0	0	1,172	4,596	0	0	0	0	17,479
1984	0	2,793	0	833	4,268	0	610	0	1,469	23,302
1985	0	4,359	0	737	2,798	0	13,588	0	2,724	41,576
1986	0	933	0	845	5,907	0	5,934	12	17	35,222
1987	0	1,072	0	600	4,028	0	4,258	40	447	38,536
1988	0	1,882	0	323	0	0	5,868	0	367	45,760
1989	0	6,912	0	213	0	0	9,065	0	1,218	53,372
1990	0	4,394	0	729	0	0	3,455	0	1,287	51,515
1991	0	6,775	0	473	0	20	2,307	125	2,418	61,835
1992	0	15,426	0	844	3,162	0	6,814	60	2,922	78,901
1993	0	10,541	0	1,331	3,997	264	3,523	142	4,610	81,346
1994	0	13,670	0	224	1,445	0	3,172	607	6,674	83,805
1995	0	11,718	0	57	1,530	494	6,137	0	3,733	86,797
1996	0	33,074	0	193	2,129	0	13,101	0	9,852	127,007
1997	0	25,789	0	355	1,242	95	9,788	0	8,704	124,097
1998	0	7,194	0	478	0	40	2,928	73	3,340	96,372
1999	0	19,444	0	384	109	470	12,220	477	5,576	123,322
2000	3	24,508	0	544	427	0	13,461	2,730	13,679	145,434
2001	22	10,690	0	473	591	0	5,944	2,159	4,819	114,185
2002	121	27,897	0	999	5	0	26,634	1,643	13,042	171,476
2003	1,136	36,983	0	2,904	214	0	7,547	0	9,890	193,304
2004	2,198	28,582	0	2,288	1,549	0	5,548	0	709	172,812
2005	1,619	16,901	2,043	3,772	922	0	969	0	214	165,748
2006	2,361	7,833	34	3,210	6,150	0	9,457	0	329	138,357
2007	971	4,621	3	2,100	5,651	0	8,954	0	1,194	122,097
2008	754	2,545	0	1,779	5,535	7	600	0	303	107,557
2009	32	1,223	0	21	5,497	0	4,235	0	219	106,865
2010	0	4,818	0	0	5,495	0	6,970	0	0	108,683
2011	0	3,138	0	0	5,495	0	8,236	0	0	107,050
2012	551	11,647	0	350	5,495	0	5,725	0	0	124,684
2013	407	15,935	0	282	5,495	0	8,478	0	0	132,075
Sum	10,174	363,296	2,080	31,348	90,680	1,390	215,529	8,067	99,756	3,100,741

APPENDIX 3. METHODS FOR ANALYZING AUTOMATIC IDENTIFICATION SYSTEM DATA

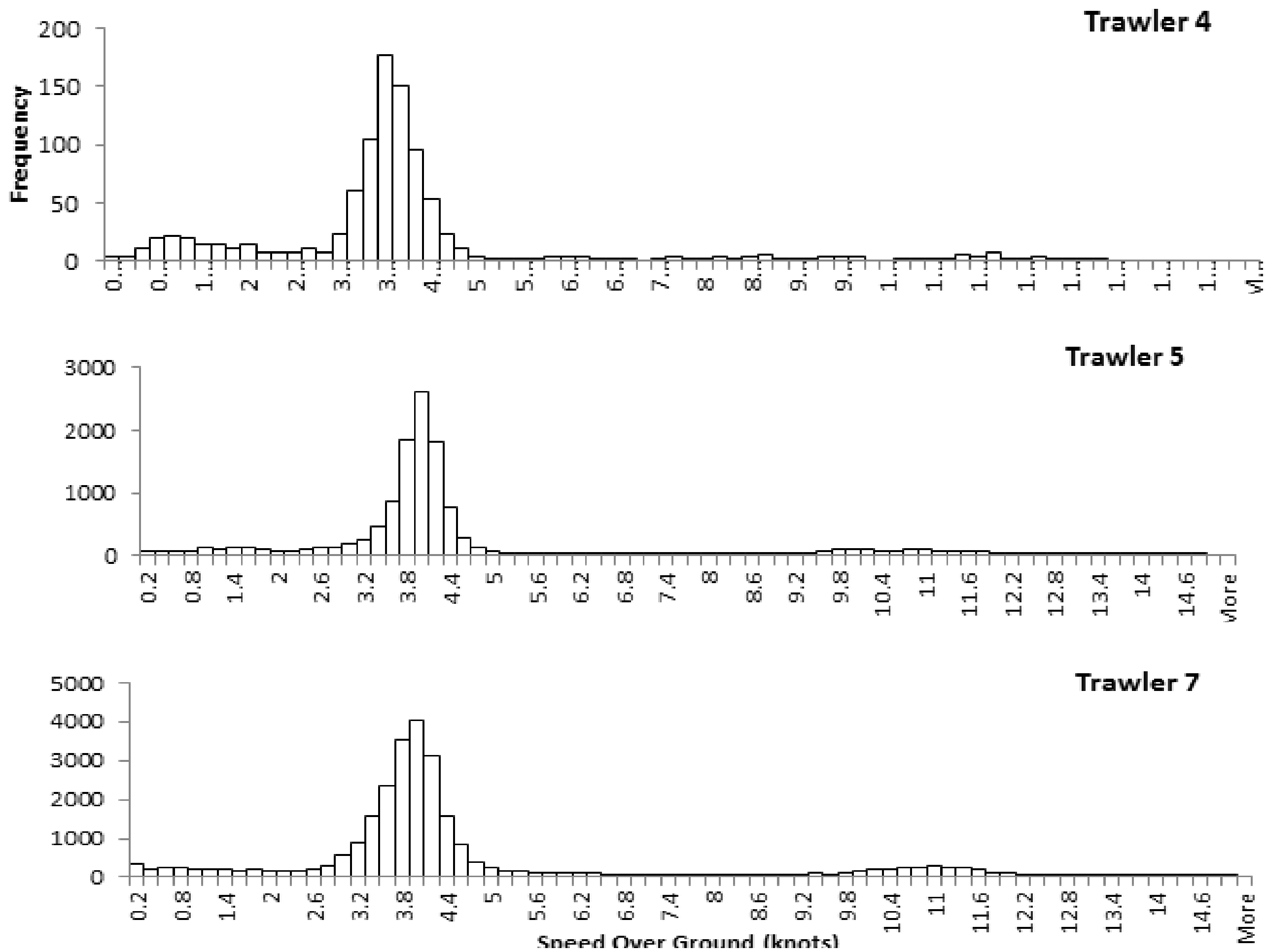
Preliminary analysis of AIS data and expert input[26] identified seven vessels that were likely trawling in Somali waters during the previous decade. Using the MMSI numbers associated with these seven vessels, we purchased satellite Automatic Identification System (AIS) data for all seven boats from exactEarth.[d] These data include every broadcast point from the ship in question during July 2010 through December 2014. Each point includes a position (latitude/longitude) as well as associated vessel information such as IMO number, vessel name, flag, size, date, time, speed over ground (SOG), and course over ground. Vessel operators can control when and what they broadcast. Often there was missing information associated with a ping (e.g., SOG not included in a broadcast) or AIS may have been turned off altogether, creating gaps in the dataset. As a result, estimates made from these data are conservative. Additionally, it is possible that other boats besides those we identified are trawling in Somali waters and fail to broadcast AIS (use of AIS is not mandatory for fishing vessels).

Using ArcGIS 10.3, we determined for each vessel which transmissions were within the boundaries of Somali waters. Then, using SOG during those transmissions, we determined where the vessels were trawling by creating a histogram of SOG and using speeds defining the peak in SOG (see Figure A3.1). This method of using SOG distributions to identify trawling activity has been shown to correctly identify 99% of real trawling activity.[27] Trawlers 2 and 6 were present in Somali waters and were likely trawling, but did not broadcast SOG. They were excluded from this portion of the analysis. One additional vessel for which we had a long time series of data did not broadcast the correct latitude and longitude for most transmissions, and those points were excluded from all analyses.

FIGURE A3.1 Histograms of speed over ground broadcast by trawlers in Somali waters.



d Based in Ontario, Canada.



After identifying coordinates associated with trawling for five of seven vessels, we used the times and dates of the trawling transmissions to calculate the number of days trawled over the time period for which we had data. If there were multiple transmissions at trawling speed in one day, we classified that as a trawling day. The time period covered varied for each boat, so we determined trawling days per boat and then calculated the ratio of days trawling to the number of days for which observations were available. This ratio was then multiplied by 365 (the number of days per year), generating an estimate of days trawling per year, per boat (Main text, Figure 2.24). Using the same procedure, we calculated the mean proportion of days trawled per month across all boats (Main text, Figure 2.25). To obtain estimates of days trawling per month for the two boats that did not broadcast SOG, we determined the number of days per month those two vessels were in the Somali EEZ, then multiplied by the mean proportion the other boats trawled during the associated month.

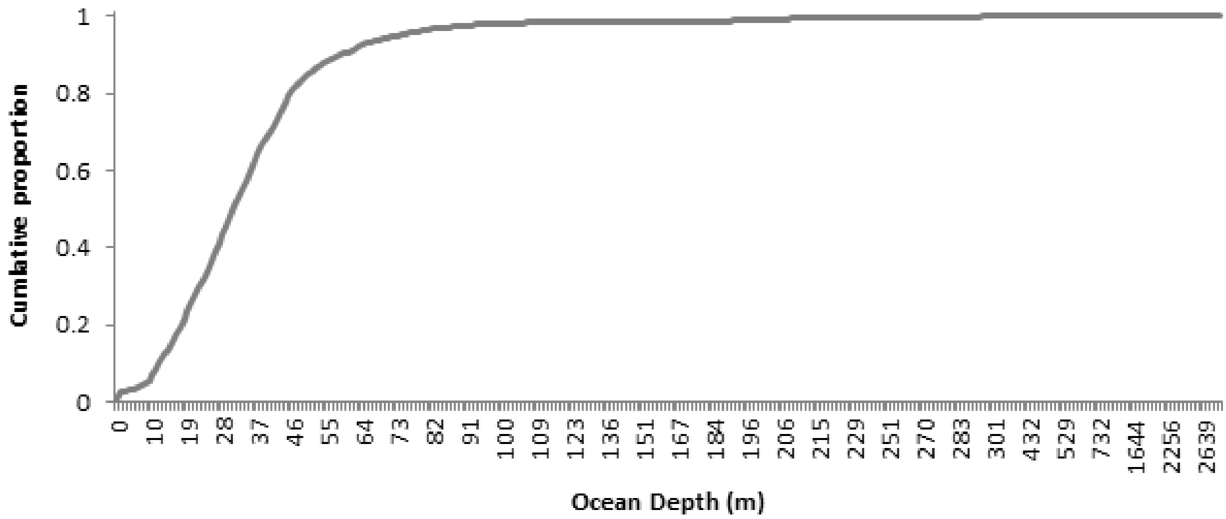
Because the dataset for each boat did not always include an entire year of data at the beginning and end, we used a similar proportional method to estimate days trawling per year for all seven boats. For a single boat, we took the proportion of days trawled to the number of days over which we had data in a given year, then multiplied by the number of days in that year (Table A3.1).

TABLE A3.1 Calculations of days trawling for South Korean vessels in Somali waters.

	Number of days per year for which we have data	Total days trawling in Somali EEZ per year	Proportion of days trawling to total days	Days trawling per year (proportion*365 or 366 in 2012)
Trawler 1				
2013	245	0	0.00	0
2014	334	127	0.38	138
Trawler 2				
2010	140	100	0.71	261
2011	365	73	0.20	73
2012	366	0	0.00	0
2013	365	0	0.00	0
2014	365	0	0.00	0
Trawler 3				
2010	183	152	0.83	303
2011	365	241	0.66	241
2012	366	271	0.74	271
2013	365	270	0.74	270
2014	365	201	0.55	201
Trawler 4				
2010	178	115	0.65	236
2011	192	0	0.00	0
Trawler 5				
2010	184	146	0.79	290
2011	365	253	0.69	253
2012	366	242	0.66	242
2013	365	169	0.46	169
2014	365	188	0.52	188
Trawler 6				
2013	146	0	0	0
2014	365	125	0.34	125
Trawler 7				
2012	231	187	0.81	296
2013	365	280	0.77	280
2014	365	221	0.61	221

We were able to obtain ocean depth at the point of transmission by overlaying the points with a bathymetry raster[e] and using the depth of the cell in which an AIS transmission fell. With these depth data for all boats, we used a cumulative distribution (Figure A3.2) to determine at what depths the majority of trawling was occurring.

FIGURE A3.2 Cumulative distribution of depth of trawling.



To calculate the total area trawled, we used the mean SOG from all boats during trawling (3.9 knots) multiplied by the assumed width of the trawl for vessels of comparable size (49 m)[28] and by the average number of hours trawling per day (8.4 hours). Converted into km^2, we estimated 3 km^2 trawled per boat per day. Multiplied by the estimated number of days trawled per year by each boat, we calculate a total trawled area during 2010–2014 of 120,652 km^2.

To double check our estimate, we also calculated straight-line distance trawled per boat per day over the time period. For each point, we drew a straight line to the next consecutive point, then calculated the combined distance in meters of all of the line segments for a single day. This is an oversimplification and therefore is an underestimate, but it did give us an idea of total distance trawled. Multiplied by the assumed width of the trawl (49m), our second estimate of the trawled area is 113,593 km^2.

We estimated volume and composition of catch for two vessels from catch certificates submitted to the European Union. The dated certificates covered seven months and contained catch by species of fish and invertebrates for each month (Figure A3.3). From the AIS data, we know how many days per month Trawlers 3 and 5 were trawling in Somali waters. Dividing the amount of catch in a month by the number of days trawled in the same month gave us catch per day. We extrapolated that catch rate to the remaining five trawlers and estimated the total catch during 2010–2014 was 27,475 mt (an average of 5,495 mt per year).

e Retrieved from www.gebco.net/data_and_products/gridded_bathymetry_data/

TABLE A3.2 Catch composition (percent of total catch for that month and vessel) from vessels for which we had AIS and catch data

Date	July 2011	Sept 2011	Oct 2011	Nov 2011	Nov 2011	Jan 2012	Feb 2012
Vessel	Trawler 5	Trawler 3	Trawler 3	Trawler 3	Trawler 5	Trawler 3	Trawler 3
Barracudas	0.5	25.8	7.4	26.6	0.2	6.0	14.5
Cobia	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Croakers	1.5	2.6	0.9	1.6	0.0	1.1	1.0
Cuttlefish	77.4	8.1	24.4	1.1	1.0	0.2	0.1
Emperors	5.1	0.4	1.1	26.1	7.3	55.4	29.7
Flounder	0.0	0.0	1.1	0.0	0.0	0.1	0.2
Groupers	3.0	13.1	1.3	6.3	0.4	5.4	11.0
Grunts	1.5	10.8	0.6	14.1	0.3	13.7	20.0
Jacks	3.0	4.0	0.5	2.9	0.4	1.5	3.6
Lobsters	0.8	1.9	0.1	2.8	0.3	0.1	0.2
Mackerel	0.0	0.4	0.6	1.6	1.1	0.8	1.1
Mullets	1.7	7.7	1.3	4.2	0.0	3.9	4.4
Octopi	0.0	1.0	0.2	0.0	0.0	0.0	0.0
Other	0.0	0.0	36.8	0.0	0.0	0.0	0.0
Parrotfishes	0.8	2.4	0.1	4.8	0.2	2.7	3.5
Seabream/ Porgies	3.3	3.5	0.0	0.2	0.0	2.1	1.0
Sharks	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Shrimp and Prawns	0.0	0.0	20.5	0.0	0.0	0.0	0.0
Snappers	1.0	0.8	0.0	5.6	0.6	6.9	9.2
Squid	0.1	17.6	3.0	2.1	88.3	0.2	0.1

APPENDIX 4. METHODS FOR CALCULATING POTENTIAL LICENSE REVENUE FOR FOREIGN TUNA BOATS

Significant numbers of foreign vessels have the incentive and ability to operate within Somali waters (see main text, Chapter 2). Of these, the fisheries for tropical tunas are the most significant and best-documented. These fisheries include tuna longline vessels, predominantly operated by Asian nations targeting yellowfin and bigeye tunas, and tuna purse seine vessels, dominated by European Union member state vessels targeting skipjack and yellowfin tunas. Both fisheries operate widely throughout the Indian Ocean and move into the Somali basin for a few months of the year in pursuit of seasonal fishing opportunities. Demersal fleets from neighboring coastal states, including Yemen, Egypt, Djibouti and Kenya, but also further afield, fish within Somali waters, targeting finfish, lobster and other demersal species (see Chapter 2). However, the activities of these demersal and coastal fisheries, including the number of vessels that operate in Somali waters and their catch, are poorly documented. Given the value and importance of regional tuna fisheries, we estimated the potential revenue that might be generated from tropical tuna resources through the introduction of license fees for foreign tuna fishing vessels within Somali waters, i.e., longline and purse seine tuna fisheries. The sale of licenses to these vessels is a potential source of income to the country.

License fee revenue for the purse seine and longline operations was estimated as a percentage of the annual gross market value of three main commercially important tropical tuna species harvested in Somali waters: yellowfin, bigeye, and skipjack tuna. Ideally such an analysis would calculate license fee revenue directly using vessel catch data and licensing records; however, no data exist on the number and type of licenses sold to tuna fishing vessel operators, nor are there any data on the catch and activities of individual tuna boats fishing in Somali waters. Available Indian Ocean Tuna Commission catch and effort data are aggregated at the scales of month and 1° x 1° cells for purse seine fisheries and 5° x 5° for longline fisheries; therefore, the potential catch per vessel is not available.

While the actual licensing revenues could not be identified, they can be estimated based on examples from other coastal states. For example, the license fees paid by EU tuna boats in all oceans vary markedly between <1% up to 10% of total catch value, with fees being highest in the Indian and Pacific Oceans.[29] In 2012, the western and central Pacific Island States, which arguably have the most advanced tuna fisheries agreements currently in place, had fee rates of between 8.3% and 10.0%.[30] In comparison, in the western Indian Ocean, where agreements are less advanced, fee rates were lower. For example, Kenya's fee rates were estimated to be between 2.6% and 6.8% in the period 2007–2009, and for Tanzania between 2.4% and 3.1% in the period 2008–2009. However, for some countries fee rates were estimated to range as high as 17% in especially productive years (e.g., Madagascar).[31] On this basis, we applied the general assumption that it would be possible to generate a license fee revenue equivalent to 2–10% of the gross value of tuna caught within Somali waters. The upper end of this range is relatively high when compared to most examples in the region, but Somali waters lie within some of the most productive fishing grounds in the Western Indian Ocean, and therefore may be able to command these relatively high license fee annual revenues.[32] This percentage is likely to be influenced by a number of variables, including the (lack of) available monitoring, control and surveillance capacity.

In Somalia, there have been no fisheries access agreements with any distant water fishing nation since 2006, when private access agreements with EU purse seine vessels expired. This means there has been no legal fishing by foreign tuna vessels inside Somali waters in recent years.[f] Additionally, pirate activity increased dramatically in 2006 and peaked in 2010, greatly affecting the willingness of foreign boats to fish in or near Somali waters. Consequently, any catches reported by tuna vessels in Somali waters since 2005 are likely to be anomalous (e.g., incorrect reporting of grid cell coordinates). We have therefore focused on the period 2001–2005 for the analysis as a "best guess" for the amount of tuna fishing that could occur once proper licensing arrangements are secured and if piracy remains at or below 2014 levels.[g]

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f The first fishing license issued to a tuna vessel since 2006 was sold in April 2015.

g This is probably a conservative estimate of possible future fishing activity. During 2004–2005 tuna vessels experienced very large catches of yellowfin tuna in the waters of Tanzania and Kenya, which may have resulted in less fishing than usual in the Somali basin during those years.

Two key sources of data were used in the analysis: First, volumes of tuna catches were estimated using monthly catch of yellowfin, bigeye, and skipjack reported by purse seine and longline vessels within Somali waters for the period 2001–2005.[h] Reported catch was summed from whole or partial IOTC reporting squares (1° x 1° for purse seine vessels; 5° x 5° for longline vessels) falling within Somali waters.[i] Monthly global market price (US$/mt) of yellowfin, bigeye and skipjack tuna for the period 2001–2005 also were used.[j] Prices were adjusted for inflation using the World Bank Consumer Price Index (CPI) for respective countries of import (2013 = 100). Species prices were based on reported import values, and varied for the two fisheries: frozen yellowfin and skipjack from Thailand (purse seine); fresh bigeye and yellowfin from Japan (longline).[k] Thai and Japanese import prices for tropical tuna species represent suitable proxies for the gross market value of catch in a given month. Thailand and Japan, which are major tuna landing and processing sites, tend to lead global prices[33] and therefore import prices of tuna products into these countries (Thailand: frozen yellowfin and skipjack; Japan: fresh bigeye) are commonly used as indicators in the economic analysis of tropical tuna fisheries.[l]

A number of key assumptions were made. First, we assume sufficient administrative and monitoring, control, and surveillance capacity exists to leverage a license fee rate of 2–10% of the gross value of tuna harvested. Second, we assume the reported catch data are representative of the tuna harvested inside Somali waters, particularly for longline vessels where, due to imprecise spatial resolution of reporting, rough estimates of catches have been used. Furthermore, in relation to fishing operations it was assumed that longline vessels are primarily catching for the sashimi market and landing fish fresh whereas purse seine vessels are catching for the canning market and landing fish frozen. This assumption is the basis for selection of either fresh or frozen landing prices.

APPENDIX 5. METHODS FOR ESTIMATING VALUE OF SOMALI DOMESTIC FISHERIES

The lack of robust data from across the country for all stages in the value chains severely constrains estimation of the value of the fisheries in Somali waters. Because data are insufficient for estimating total value (i.e., that calculated at the end of the value chain), our approach was conservative. Instead of total value, our analysis provides an estimate based on the “landed value” (i.e., value of the catch at the first point of sale). These are point estimates, broken down by species/species groupings, for the most recent years for which landings and price data are available.

Data acquired through publications was supplemented by enquires to experts familiar with regional fisheries of the Gulf of Aden, Arabian Sea, and Indian Ocean. Price data[m] for fish and fish commodities were collated for analysis. To create supply/value chains, the distribution pathways of fish and fish commodities from fisher to final in-country consumers or exporters were mapped using available information from the literature and from key contacts.

1.1 Estimating the value of fish landed to domestic markets

The current value of wild capture fisheries resources landed to domestic markets was based on calculations of the annual revenue[n] generated domestically from the fisheries resources. For annual landing figures, we used an average of the most recent years for which both fish price and landings data were available.

h Derived from IOTC datasets.
i See detailed methods in Appendix 2
j Derived from Thai and Japanese customs import datasets and COMTRADE website: http://comtrade.un.org/data/.
k Derived from Thai and Japanese customs import datasets and COMTRADE website: http://comtrade.un.org/data/.
l See e.g., Miyake et al., 2010
m Global prices indexes such as Globefish/Infofish were considered but were eliminated as proxies for local prices due to a poor match with “Priority Species” selected for study. See Section 2.1.
n The analysis is limited to assigning revenues (benefits) but not costs as a formal cost-benefit analysis was limited by data availability.

Appendices

Landings data[o]

Landings data were based on reconstructed catches (accounting for reported and unreported landings and discards) produced by Persson et al.[34] We averaged landings (mt) for a five-year period (2005–2009)[p] chosen to match the most comprehensive data available for fish prices for Somali fish commodities (exports) available from FAO.[35] Landings were combined into species groups and, where possible, associated commodities were identified (e.g., fresh/chilled/frozen, dried, salted, smoked, whole/fillet/minced, shark fins, lobster tails). Species groupings were based on available landings and price data and an analysis of supply/value chains from the literature (see main text Chapter 3). Best available price data for the fish and associated fish commodities were then used to estimate the revenue that could be generated at the first point of sale of domestic landings (often referred to as "landed value"[q]). This represents the direct economic value of fisheries sector output.[36]

Landings data were provided for species caught by three fishing sectors: small-scale fisheries, disaggregated into artisanal and subsistence activities,[r] and industrial fisheries. Of these, small-scale artisanal is the main domestic commercial fishing activity. Industrial fishing activities are largely assumed to be carried out by foreign-owned vessels fishing in Somali waters that land their fishery products outside the country.[37, 38, 39] Our analysis therefore focused on the revenue generated by the artisanal sector and the associated domestic markets that are supplied. We have, however, considered what value the industrial landings would have if all were landed and sold through the domestic supply chain.

For all taxonomic groups except sharks, the total landings were calculated by summing the landings for species within each group (see Table A5.1). Species groupings were based on available landings and price data and an analysis of supply/value chains from the literature.

For sharks, three distinct products were identified: whole shark, shark meat, and shark fins. Sharks represent an important focus of Somali artisanal fisher activity because fins fetch a high price, meat and fins are highly marketable, and both shark meat and fins can be salted and dried, thus avoiding freezer needs.[40] Shark fins are the most valuable product from sharks and value is based on the grade.[s] We assumed landed weight for fins was roughly 2% of total landed body weight, a conservative fin-to-weight estimate used by the International Union for Conservation of Nature.[41] In the case of Somalia, validating evidence comes from Eyl, where 200 mt of shark fins was produced from approximately 10,000 mt of live-weight sharks.[42] An additional scaling factor of 0.25 was also applied to account for the difference in the conversion of wet to dry weight for fins.[43]

Shark fins can be further divided based on their marketable characteristics into higher quality "white" fins and lower quality "black" fins. The classification into white and black can be based on a number of factors but, in general, white fins have a higher percentage of fin needles and a better flavor and command higher prices.[44] We assumed landings consist of approximately 12% white and 88% black fins.[45]

o While the original data from Persson et al. (2015) is reconstructed catch, and not landings, we refer to the data as landings throughout because discards from the domestic fishery are minimal.

p The selected period (2005–2009) for domestic revenue analysis is different from the selected period (2011–2013) for the analysis of potential revenue that could be generated from licensing foreign fishing vessels for tropical tuna resources within Somalia's EEZ. This is due to constraints from price data for the domestic analyses. Domestic landings data does not change significantly beyond 2009 and so the periods selected should be fairly comparable in terms of catch volumes.

q See e.g. Sumaila et al. 2007; Dyck and Sumaila 2010.

r Artisanal fisheries represent fish landed for sale by small-scale operators while fish landed by subsistence fishers are not for sale but for direct consumption or local barter.

s Fin grade is based on a combination of cut quality, color, and size. A basic distinction is between "white" fins that are high quality and lower quality "black" fins.

TABLE A5.1 Fishery species groupings and percent of landing for each group by sector

	Artisanal		Subsistence		Industrial	
Fish Grouping	Species in group	% of grouping	Species in group	% of grouping	Species in group	% of grouping
Billfish	Swordfish	50	n/a	n/a	Indo-Pacific blue marlin	20
	Misc. billfish	50			Striped marlin	47
					Swordfish	27
					Misc. billfish	6
Clupeids	Indian oil sardine	80	Indian oil sardine	80	Indian oil sardine	70
	Misc. clupeids	20	Misc. clupeids	20	Round herring	30
Cuttlefish	Misc. cuttlefish	100	Misc. cuttlefish	100	n/a	
Dolphinfish	Common dolphinfish	100	n/a		n/a	
Groupers	Areolate grouper	80	Areolate grouper	80	Areolate grouper	80
	Misc. groupers	20	Misc. groupers	20	Misc. groupers	20
Jacks	Arabian scad	40	Arabian scad	40	Misc. scads	100
	Bigeye scad	40	Bigeye scad	40		
	Misc. jacks	20	Misc. jacks	20		
Goatfish	Misc. goatfish	100	Misc. goatfish	100	Indian goatfish	100
Rays and Mantas	Misc. rays and mantas	100	n/a	n/a	n/a	n/a
Sharks (meat)	Blacktip reef shark	20	n/a	n/a	n/a	n/a
	Grey reef shark	10				
	Hammerhead shark	20				
	Mako shark	20				
	Thintail thresher	20				
	Misc. sharks	10				
Sharks (fins)	Blacktip reef shark	20	n/a	n/a	n/a	n/a
	Grey reef shark	10				
	Hammerhead shark	20				
	Mako shark	20				
	Thintail thresher	20				
	Misc. sharks	10				
Snappers	Blue-green snappers	40	Blue-green snappers	33	Blue-green snappers	40
	Red snappers	40	Misc. snappers	67	Red snappers	40
	Misc. snappers	20			Misc. snappers	20
Yellowfin tuna	Yellowfin tuna	100	n/a	n/a	Yellowfin tuna	100
All other tuna	Kawakawa	33	Misc. tunas	100	Bigeye tuna	100
	Longtail tuna	33	n/a	n/a	n/a	n/a
	Misc. tunas	33				

Emperors	Longfaced emperor	20	Longfaced emperor	20	Longfaced emperor	20
	Pink ear emperor	20	Pink ear emperor	20	Pink ear emperor	20
	Spangled emperor	40	Spangled emperor	40	Spangled emperor	10
	Misc. emperors	20	Misc. emperors	20	Misc. emperors	20
Grunts	n/a	n/a	n/a	n/a	Painted sweetlips	100
Spiny lobster	Spiny lobster	100	n/a	n/a	Spiny lobster	100
Mackerel	Narrow-barred Spanish mackerel	100	n/a	n/a	Chub mackerel	100
Misc. fish	Misc. marine fish	100	Misc. marine fish	100	Misc. marine fish	100

Price data

The availability of price data, and in particular price data at each stage of the value chain, was limited and there are serious quality considerations with data that do exist. Prices were most often presented as US$ per kg. Information on the proportions of fish or processed commodities going to each stage in the supply chain was virtually nonexistent within the existing literature, and price information for fish and identified commodities was patchy. Despite having a good spread of species-commodity data, even the FAO FishStatJ commodity data over the five-year period (2005–2009) contained numerous missing data points, and values between years were in some cases highly variable. Annual FAO data was considered low-quality and it was not possible to identify the seasonal effects that are known to occur. To supplement the FAO data, a range of point-value market prices for fish and fish commodities were also sourced from the available literature and from local sources (see data sources in main text, Table 3.1). Results are presented below for each of the sectors and fish groups (Table A5.2).

Given the paucity and low quality of available price data for different steps in the supply chain, we estimated the revenue that could be generated from fish landed at first point of sale and supplemented with qualitative assessments of the value added along the supply chains to the final point of sale for actors involved in the domestic market. The final point of sale was assumed to be the last point in the supply chain where Somali businesses were involved in the trade of the fish commodity. Beyond this point it was assumed the value obtained for the commodity in the international market by non-national individuals/companies would unlikely be a direct benefit in terms of revenue for Somali operators. There are significant difficulties in tracing fish beyond this.[46]

In many cases, price data for species groups were used as it was not possible to obtain price data at individual species level. To account for the variation in prices within and across locations, we chose to use and present the minimum, mean, and maximum prices. These prices were used to calculate the minimum, mean, and maximum revenue that could be generated for each species group by multiplying by the mean estimated landings volume from the years 2005–2009. However, the importance of fisheries to the economy may be understated by considering only the landed value. For this reason economic multipliers were used to account for the linkages throughout the sector. Economic multipliers provide a raising factor for the landed value to estimate the contribution to economic output, including activities directly and indirectly dependent on it.[47, 48] Multipliers have been used in a number of cases[t] to provide estimates of economic value that incorporate value added. While these figures represent approximations, they can provide an indication of the scale of the additional value added.[49] Dyck and Sumaila[50] undertook an analysis of global production statistics and, from this, calculated that the multiplier with Somali fisheries was 2.95 and the average figure for Africa is 2.59. Given the uncertainties with Somali statistics, we chose to use the more conservative average figure.

t Teh et al., 2011; Dyck and Sumaila, 2010.

TABLE A5.2 Range of prices for fish products caught by Somali domestic sectors, and the estimated value (first point of sale) of those products based on landed weight

Sector	Fish Grouping	Catch (kg)	Low Price (US$/kg)	High Price (US$/kg)	Avg. Price (US$/kg)	1st Point of Sale - Low	1st Point of Sale - High	1st POS - Average
Industrial	All Emperors	3,925,269	$0.50	$2.30	$1.35	$1,962,634	$9,028,118	$5,310,658
	All Groupers	1,796,778	$0.25	$2.50	$1.22	$449,194	$4,491,945	$2,194,636
	All Snappers	1,409,780	$0.20	$2.50	$0.86	$281,956	$3,524,449	$1,214,579
	Indian Goatfish	1,299,209	$0.30	$2.30	$1.08	$389,763	$2,988,180	$1,401,289
	Painted Sweetlips	2,626,060	$0.40	$2.30	$1.04	$1,050,424	$6,039,938	$2,721,553
	All Mackerel	110,571	$1.00	$5.00	$1.93	$110,571	$552,855	$213,450
	All Clupeids	373,177	$0.20	$2.30	$0.70	$74,635	$858,307	$261,224
	All Billfish	207,321	$0.40	$2.00	$1.20	$82,928	$414,641	$248,785
	Yellowfin Tuna	1,064,245	$0.80	$4.00	$2.40	$851,396	$4,256,982	$2,554,189
	All other Tuna	815,461	$0.40	$3.00	$1.44	$326,184	$2,446,382	$1,174,868
	Misc. Scads	41,464	$0.15	$2.30	$0.84	$6,220	$95,367	$34,926
	Misc. Marine Fish	152,035	$0.98	$0.98	$0.98	$149,564	$149,564	$149,564
	Spiny Lobsters	234,260	$5.00	$20.57	$12.92	$1,171,302	$4,819,073	$3,026,701
Subsistence	All Emperors	3,422,961	$0.50	$2.30	$1.35	$1,711,480	$7,872,810	$4,631,065
	All Groupers	855,740	$0.25	$2.50	$1.22	$213,935	$2,139,351	$1,045,226
	All Snappers	513,444	$0.20	$2.50	$0.86	$102,689	$1,283,610	$442,352
	Misc. Goatfish	427,870	$0.30	$2.30	$1.08	$128,361	$984,101	$461,488
	All Clupeids	855,740	$0.20	$2.30	$0.70	$171,148	$1,968,203	$599,018
	Misc. Tunas	840,181	$0.40	$3.00	$1.44	$336,073	$2,520,544	$1,210,483
	All Jacks & Scads	855,740	$0.15	$2.30	$0.84	$128,361	$1,968,203	$720,797
	Misc. Marine fish	630,136	$0.98	$0.98	$0.98	$619,896	$619,896	$619,896
	Misc. Cuttlefish	121,667	$0.25	$3.00	$1.06	$30,417	$365,000	$128,779
Artisanal	All Emperors	3,636,117	$0.50	$2.30	$1.35	$1,818,058	$8,363,068	$4,919,452
	All Groupers	909,029	$0.25	$2.50	$1.22	$227,257	$2,272,573	$1,110,314
	All Snappers	909,029	$0.20	$2.50	$0.86	$181,806	$2,272,573	$783,164
	Misc. Goatfish	454,515	$0.30	$2.30	$1.08	$136,354	$1,045,384	$490,226
	Common Dolphin-fish	909,029	$0.98	$0.98	$0.98	$890,849	$890,849	$890,849
	All Mackerel	1,818,058	$1.00	$5.00	$1.93	$1,818,058	$9,090,291	$3,509,643
	All Clupeids	909,029	$0.20	$2.30	$0.70	$181,806	$2,090,767	$636,320
	All Billfish	909,029	$0.40	$2.00	$1.20	$363,612	$1,818,058	$1,090,835
	Yellowfin Tuna	2,727,087	$0.80	$4.00	$2.40	$2,181,670	$10,908,350	$6,545,010
	All other Tuna	2,727,087	$0.40	$3.00	$1.44	$1,090,835	$8,181,262	$3,929,026
	All Jacks & Scads	909,029	$0.15	$2.30	$0.84	$136,354	$2,090,767	$765,682
	All Rays and Mantas	3,470,984	$1.50	$1.50	$1.50	$5,206,476	$5,206,476	$5,206,476
	Shark fins (black)	36,663	$51.00	$55.60	$53.66	$1,869,801	$2,038,449	$1,967,219
	Shark fins (white)	4,999	$87.00	$100.00	$91.43	$434,954	$499,947	$457,094
	Sharks (meat)	8,165,796	$0.20	$2.50	$1.42	$1,633,159	$20,414,490	$11,603,282
	Misc. Marine Fish	905,210	$0.98	$0.98	$0.98	$890,501	$890,501	$890,501
	All Cuttlefish	458,333	$0.25	$3.00	$1.06	$114,583	$1,375,000	$485,128
	Spiny Lobsters	245,740	$5.00	$20.57	$12.92	$1,228,698	$5,055,213	$3,175,013

APPENDIX 6. SUSTAINABILITY ANALYSIS

We used the panel regression model developed by Costello et al.[51] to estimate B/B_{MSY} for various fish groups in Somali waters: dolphinfish, emperors, goatfish, jacks, clupeids, snappers, sharks, rays, groupers, and grunts. Where catch time series were reported for species, they were aggregated up to the family (or near-family) level. We combined catch reconstructions of Somali domestic fisheries with our estimates of foreign fishing to create estimates of total catch for these species groups.

B/B_{MSY} is a measure of the current standing stock (biomass, B) of a fish stock compared to the biomass needed to support maximum sustainable yield (MSY). For $B/B_{MSY} < 1.0$, biomass is below that needed for MSY, and fishing should be reduced to improve sustainability. For $B/B_{MSY} > 1.0$, biomass is above that needed for MSY, and fishing levels should stay the same or potentially increase. B/B_{MSY} is a function of a suite of fishery characteristics, including (but not limited to) life history characteristics such as size, growth patterns,[u] or age at reproductive maturity, and catch characteristics such as how quickly a fishery developed, how long it has existed, or whether catch has peaked. Costello et al. created a regression model that relates B/B_{MSY} to these characteristics. Coefficients were estimated using data from 204 assessed (data-rich) stocks from around the world. The B/B_{MSY} calculated for these stocks was validated by independent stock assessments. Six nested models, each containing a different set of explanatory variables to accommodate varying data availability, were generated. Next, the coefficients estimated for these 204 stocks were then applied to 1,793 unassessed (data-poor) stocks to estimate B/B_{MSY}. We used their published coefficients on each catch time series mentioned above.

Specifically, for fishery i, family type j,[v] and calendar year t, a multivariate panel regression model estimates B/B_{MSY} as:

$$\log(B/B_{MSY})_{ijt} = \alpha + \beta X_{ijt} + \gamma_I + \delta t + \varepsilon_{ijt}$$

where α is a constant term, β relates the fishery characteristic X_{ijt} to B/B_{MSY}, γ_i is a family fixed effect, δ is a time trend effect, and ε_{ijt} is an error term. For the fish groups we included, data for fish maximum length were available[52] but von Bertalanffy K, geographic distribution, and temperature preference were not uniformly available. We therefore chose Model 5 published in Costello et al.'s supplementary materials.[53] Table A6.1 gives the model parameters and coefficients used in our model.

u Von Bertalanffy K

v Family types were associated with fixed effects and listed in Table A6.1.

TABLE A6.1 Regression coefficients used in model for sustainability analysis. Reprinted from Costello et al.[54]

Coefficient	Variable	Estimate	p-value
a	Constant	-95.563	0.477
b	Inverse age of fishery	0.049	0.46
b	Scaled harvest 4 years ago	-0.101	0.165
b	Scaled harvest 3 years ago	-0.003	0.952
b	Scaled harvest 2 years ago	0.136	0.067*
b	Scaled harvest 1 year ago***	0.426	0***
b	Scaled harvest in current year	-0.393	0.327
b	Years to max harvest	0.007	0.288
b	Initial slope of harvest	0.106	0.332
b	Maximum harvest	0	0.174
b	Running harvest ratio***	1.184	0***
b	Mean scaled harvest	-0.357	0.669
b	Maximum length*	-0.003	0.024**
g	Cods, hakes, haddocks fixed effect	0.379	0.076*
g	Misc. coastal fishes fixed effect	-0.618	0.335
g	Misc. demersal fishes fixed effect***	0.755	0.001***
g	Herrings, sardines, anchovies fixed effect	0.058	0.77
g	Tuna, bonito, billfish fixed effect	0.943	0.027**
g	Misc. pelagic fish fixed effect	0.492	0.085*
g	Flounders fixed effect	0	0***
d	Time effect	0.047	0.482

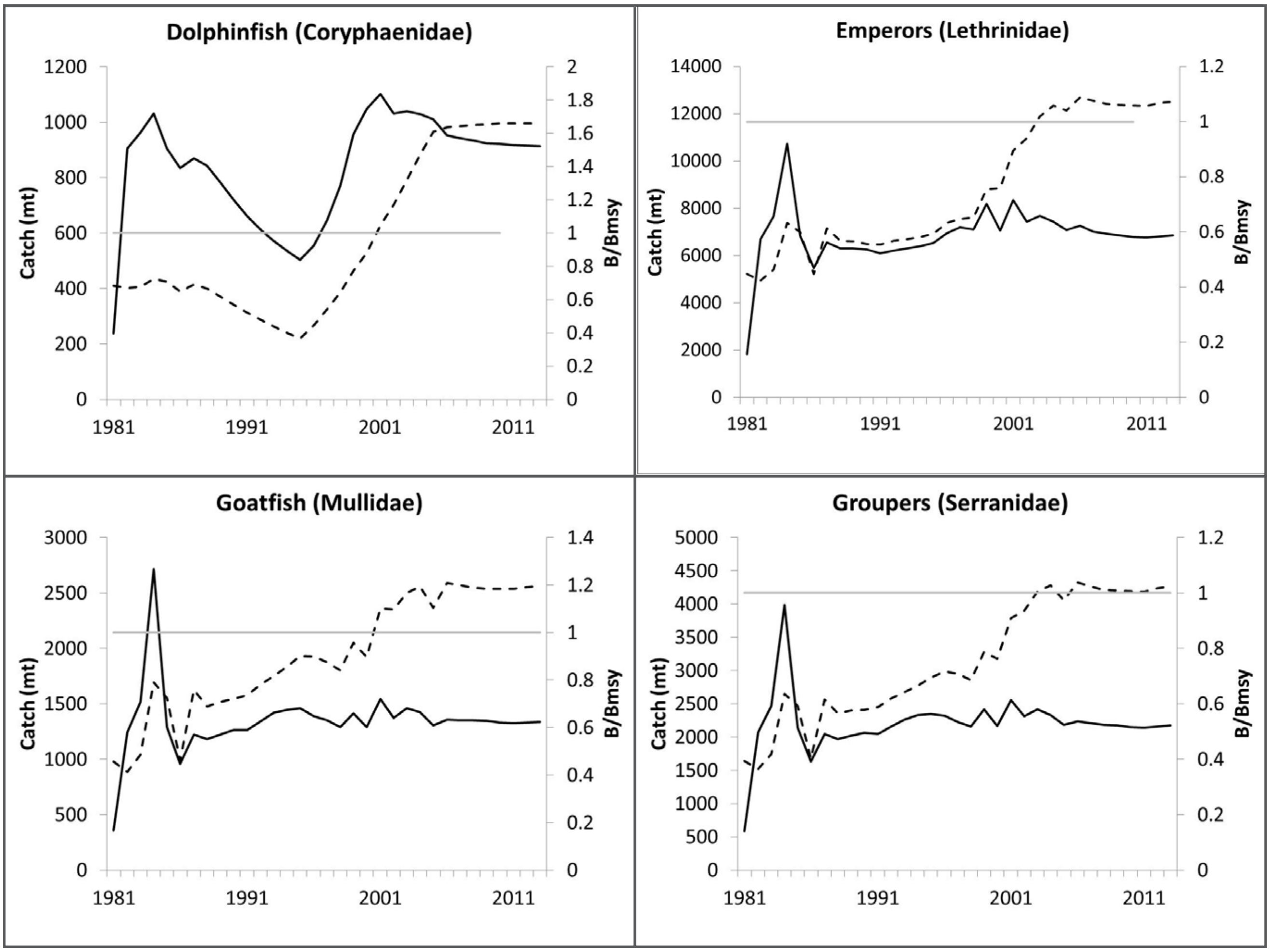
The vast majority of these parameters were calculated directly from the time series of catch. Maximum length data were obtained from FishBase.[55] We created a database[w] of over 800 species known to occur in Somali waters and these species guided our choice of length values to select from FishBase. To calculate a length value to include in the regression model, for a given family/species group, we averaged maximum length values for the species that occur in Somali waters. Although the Sea Around Us reconstruction extends back to 1950, we truncated the time series to cover only 1981–2013. Catch data were most robust from 1981–1987 due to relatively more reliable data collection and reporting by the Ministry of Fisheries under the Siad Barre regime.[56] For the foreign fleet, reconstructions extended only back to 1981. Following Costello et al., we further truncated catch time series to begin once catch reached 15% of the maximum value in the record. This reduces noise associated with behavior attributed to fishery "ramp-up" in the early years of a fishery. For most series, the value in 1981 was greater than 15% of maximum catch, so no further truncation was applied. All analyzed catch time series had at least seven years of continuous data, the minimum required by Costello et al. to make the approach valid.

Costello et al. performed rigorous model validation. Of relevance to our approach are their findings of model robustness to poor data. Estimation was not biased by the size of the fishery (total volume of landings included), reporting errors (missing data), or chronic underreporting of landings (their Supplementary Materials).[57] We present the group-level results in Figure A6.1.

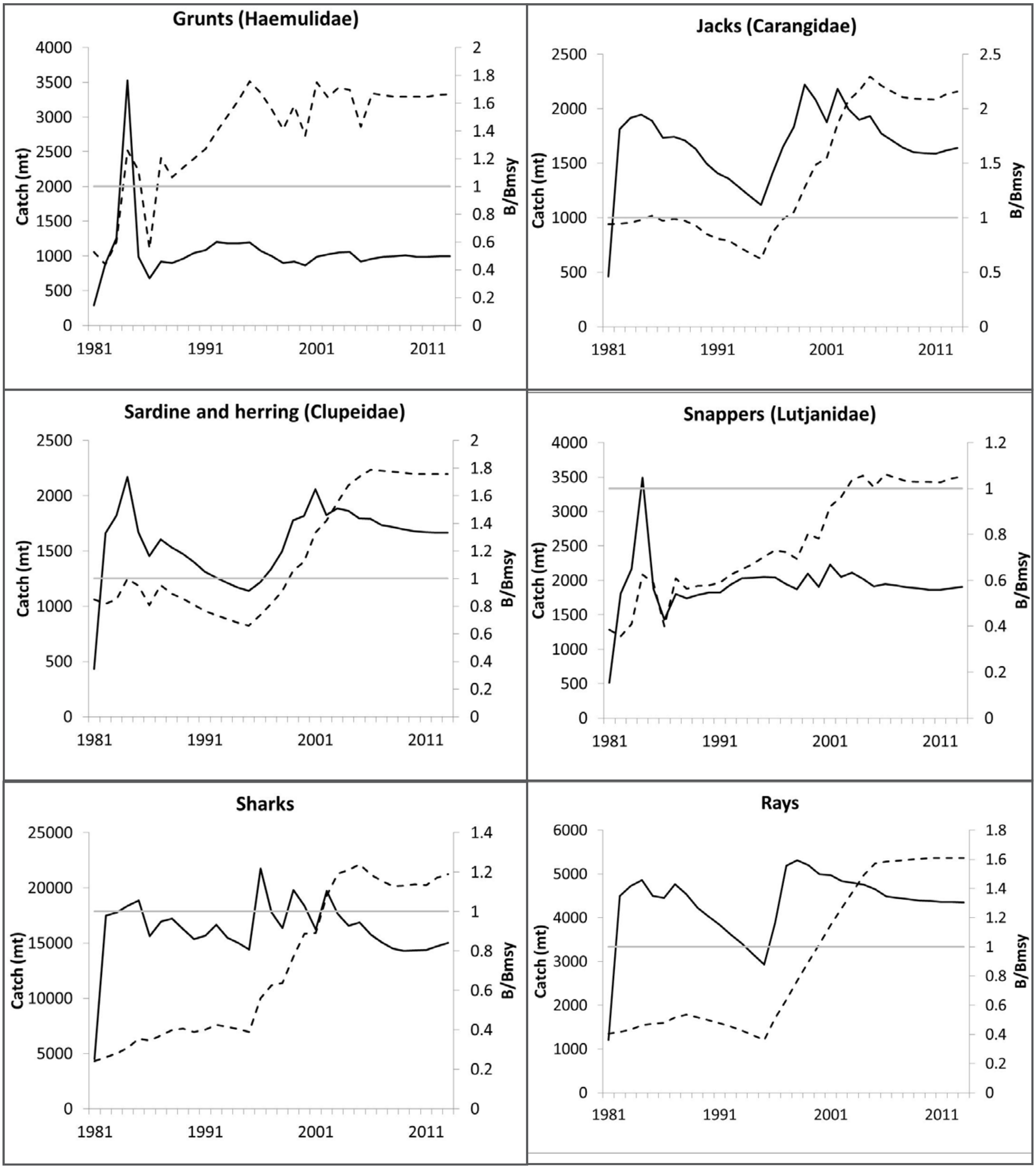
w Available at: http://securefisheries.org/report/securing-somali-fisheries.

To include sustainability classifications for IOTC species (yellowfin tuna, bigeye tuna, skipjack tuna, swordfish, longtail tuna, blue marlin, and striped marlin), we turned to formal stock assessments conducted by the IOTC. Given these highly migratory species are in Somali waters only part of the year, our estimates of annual catch for them in Somali waters are not appropriate for the panel regression approach to classification. Additionally, IOTC brings expert analysis and knowledge to bear on these species. Their approach calculates B/B_{MSY} as well as F/F_{MSY} (where *F* is fishing mortality). They classify sustainability according to a red-orange-yellow-green 4-cell contingency[x] that incorporates B/B_{MSY} and F/F_{MSY}. To make their analysis comparable to ours, we translated those species classified as orange to green, and those classified as yellow to red.[k]

FIGURE A6.1 Sustainability analysis of Somali domestic fisheries. Full results from panel regression model after Costello et al.[58] Dashed lines represent catch (input) data from catch reconstructions of Somali fisheries. Solid lines are the time-varying estimates of B/BMSY. Gray lines are the 1.0 reference line for B/BMSY: values of B/BMSY above 1.0 denote sustainable fishing, while values below 1.0 denote unsustainable fishing.



x See, for example, their approach and 2 x 2 contingency classification outlined in the Report of the 18th Session of the Indian Ocean Tuna Commission, Colombo, Sri Lanka, 1–5 June 2014. IOTC-2014-S18-R[E]. p. 58.



Grunts (Haemulidae)
Catch (mt)
B/Bmsy
0
500
1000
1500
2000
2500
3000
3500
4000
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
1981
1991
2001
2011
Jacks (Carangidae)
Catch (mt)
B/Bmsy
0
500
1000
1500
2000
2500
0
0.5
1
1.5
2
2.5
1981
1991
2001
2011
Sardine and herring (Clupeidae)
Catch (mt)
B/Bmsy
0
500
1000
1500
2000
2500
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
1981
1991
2001
2011
Snappers (Lutjanidae)
Catch (mt)
B/Bmsy
0
500
1000
1500
2000
2500
3000
3500
4000
0
0.2
0.4
0.6
0.8
1
1.2
1981
1991
2001
2011
Sharks
Catch (mt)
B/Bmsy
0
5000
10000
15000
20000
25000
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1981
1991
2001
2011
Rays
Catch (mt)
B/Bmsy
0
1000
2000
3000
4000
5000
6000
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
1981
1991
2001
2011

Appendices

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