

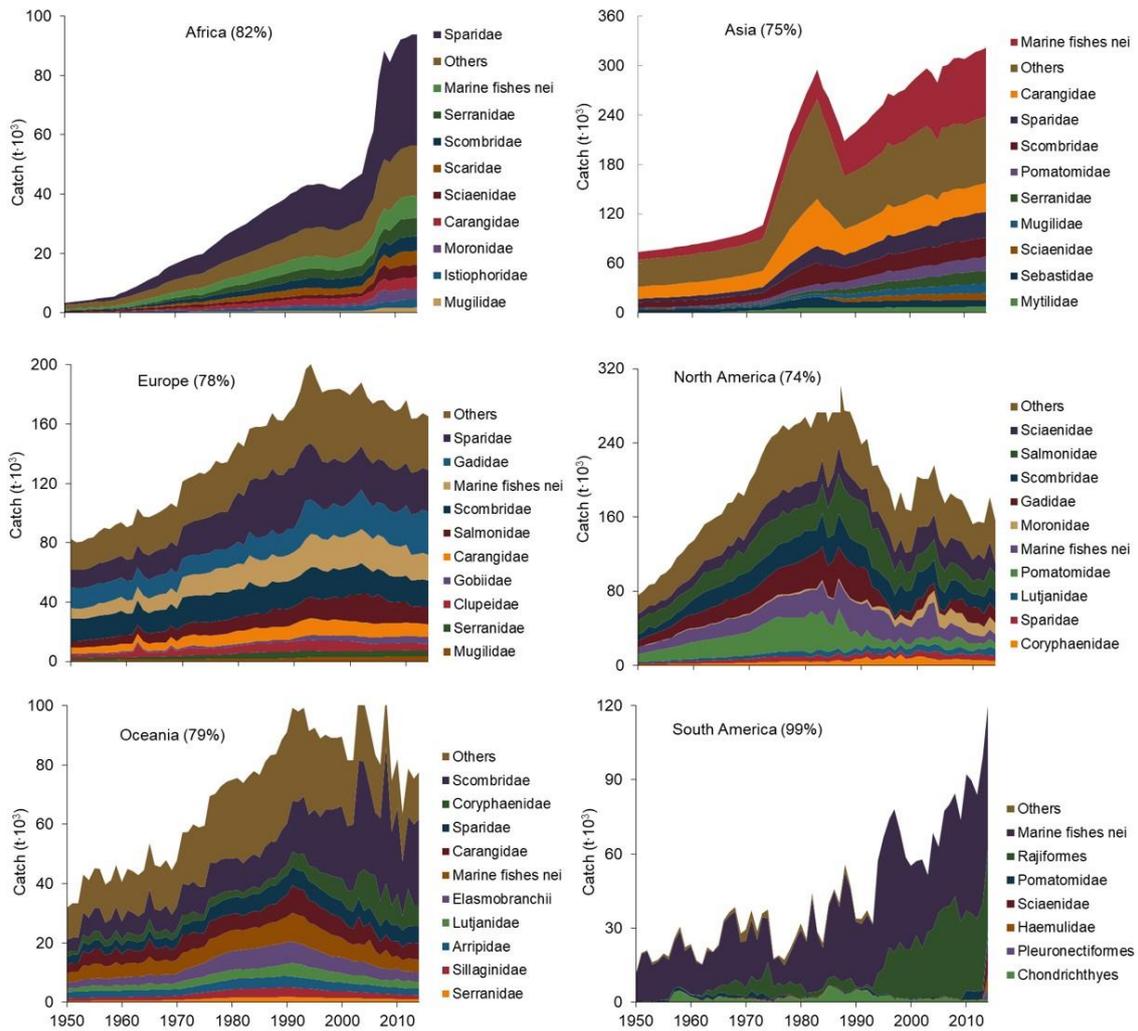
## Supplementary Tables and Figures

### Estimating global catches of marine recreational fisheries

Kátia Meirelles Felizola Freire, Dyhia Belhabib, Jeniffer C. Espedido, Lincoln Hood, Kristin M. Kleisner, Vicky W. L. Lam, Michel L. Machado, Jocemar Tomasino Mendonça, Jessica J. Meeuwig, Pietro S. Moro, Fábio S. Motta, Maria-Lourdes D. Palomares, Nicola Smith, Lydia Teh, Dirk Zeller, Kyrstn Zylich and Daniel Pauly

**Supplementary Table S1:** List of countries and territories included in the reconstruction of global catches from recreational fisheries in the present study. The technical reports and scientific papers underlying each catch reconstruction are listed in Pauly and Zeller (2016b) or can be accessed via [www.seaaroundus.org](http://www.seaaroundus.org).

Algeria	Djibouti	Lebanon	Saba & St. Eustatius (Netherlands)
Angola	Dominican Republic	Lithuania	St Kitts and Nevis
Anguilla (UK)	Egypt	Madeira Isl. (Portugal)	St. Lucia
Antigua and Barbuda	Equatorial Guinea	Malaysia	St. Pierre and Miquelon (France)
Argentina	Estonia	Malta	St. Vincent and the Grenadines
Aruba (Netherlands)	Faeroe Isl. (Denmark)	Martinique (France)	Saudi Arabia
Australia	Finland	Mauritania	Senegal
Azores Isl. (Portugal)	France	Mauritius	Seychelles
Bahamas	Gambia	Mayotte (France)	Singapore
Bahrain	Georgia	Mexico	Sint Maarten
Barbados	Germany	Montenegro	Slovenia
Belgium	Ghana	Morocco	South Africa
Bermuda (UK)	Greece	Namibia	South Cyprus
Bonaire (Netherlands)	Grenada	Netherlands	Spain
Bosnia and Herzegovina	Guadeloupe (France)	New Caledonia (France)	St. Barthélemy (France)
Brazil	Guam (USA)	New Zealand	Sweden
Brit. Indian Ocean Terr. (UK)	Guinea-Bissau	North Cyprus	Syrian Arab Republic
British Virgin Isl. (UK)	Hong Kong	North Marianas (USA)	Taiwan
Brunei Darussalam	Iceland	Norway	Thailand
Bulgaria	Indonesia	Oman	Togo
Canada	Iran	Pakistan	Trinidad and Tobago
Cape Verde	Ireland	Panama	Tunisia
Cayman Isl. (UK)	Israel	Papua New Guinea	Turkey
China	Italy	Peru	Turks and Caicos Isl. (UK)
Christmas Isl. (Australia)	Jamaica	Philippines	Ukraine
Cocos (Keeling) Isl. (Australia)	Japan	Poland	United Arab Emirates
Costa Rica	Jordan	Portugal	United Kingdom
Croatia	Kenya	Puerto Rico (USA)	Uruguay
Cuba	Korea (South)	Qatar	Virgin Isl. (USA)
Curacao	Kuwait	Reunion (France)	USA
Denmark	Latvia	Russian Federation	Vanuatu
			Venezuela



**Supplementary Figure S1:** Taxonomic composition of global recreational catches by geographic region for the top ten taxonomic groupings plus ‘marine fishes nei’. Percentages listed next to each region’s name represent the contribution of the ten taxonomic groups with the highest catches in each region (which may include ‘marine fishes nei’). For some regions, catches for some of the top 10 groups were smaller than 1% and were here grouped under ‘Others’. Nei = not elsewhere included.

## **Supplementary Materials (Part 1)**

### **Estimating global catches of marine recreational fisheries**

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This Supplementary Materials file documents the data sources, methods, assumptions and results underlying the catch data reconstructions for recreational fisheries in the 125 countries and territories listed in Supplementary Table S1 that form the data foundation for the current study. The present materials are based on the original technical reports and, where applicable, the underlying peer-reviewed publications. For more details about data on other fishing sectors (artisanal, industrial, subsistence) please visit [www.seaaroundus.org/data/#/EEZ](http://www.seaaroundus.org/data/#/EEZ) for all EEZ specific data, and for the associated publications. In the following documentation, countries and territories are listed in alphabetical order.

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## Algeria

The original technical reconstruction research was initially documented in Belhabib et al. (2013d) and updated to 2014 by the *Sea Around Us*.

### Methods

Recreational fishing in Algeria includes mainly boat-based line fishing (longline fishing, 80%), handline fishing, and spearfishing using boats of 5 to 7 meters (Boukhalifa and Rambeau 1991). Spearfishing: Spearfishing was rarely practiced until the 1980s<sup>1</sup> and started increasing thereafter. We relied on a field survey targeting spearfishers, electronic qualitative data<sup>2</sup> and literature review (Grau et al. 2009; MATE 2005) to estimate catches by this gear type. We assumed an average number of 381 spearfishers (from 2002 to 2010) based on 28 scuba diving clubs [www.corbusmilchasse.com](http://www.corbusmilchasse.com) [2011]), the estimated number of divers practicing spearfishing per club (14) and a nominal effort of 38 days per year (M. Kharfellah, pers. comm., *Institut des Sciences de la Mer et de l'Aménagement du Littoral*, 2011). We assembled a catch frequency per species per day expressed as a probability of catch ranked from 0 to 1 from the field survey and [www.corbusmilchasse.com](http://www.corbusmilchasse.com) [2011] (Table 1), we multiplied each frequency by the average weight of each species and the number of fishing days per spearfisher (38), then estimated the total catch per year for 1998 (567.32 t·year<sup>-1</sup>) when the total recreational catch per fisher is the product of the number of fishing days by the sum of each species catch per day (1.49 t·year<sup>-1</sup>·fisher<sup>-1</sup>). We obtained the percentage of each species by dividing the weight of each species by the annual recreational catch per fisher for 1998 (Table 1). We reduced the catch frequency (given for 1998) by 80% for groupers (*Epinephelus marginatus*, *E. caninus* and *E. fasciatus*) and 25% for brown meagre (*Sciaena umbra*) for the last decade, beginning from 2002, to represent their decreasing trend (Grau et al. 2009; Kara and Derbal 1999), which led to a total catch of 462.84 t·year<sup>-1</sup> for 2002. From 2003 onwards, we assumed a decreasing rate of recreational catches of 10% per year, then applied it year by year until 2010 to represent the decreasing trend of catches (i.e., recreational catch (2003) = recreational catch 2002 x (100%-10%)). Here, we assumed recreational spearfishing begun in 1970 (10 years after the independence), thus interpolated linearly from zero in 1970 to 567.32 t·year<sup>-1</sup> in 1998, to 462.84 t·year<sup>-1</sup> in 2002, and then completed the time series with a 10% decrease of recreational catches per year.

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

Based on local effort and catch data (MPRH 2011 [www.Algeria.com](http://www.Algeria.com) [2011]) we estimated a catch of 0.5 t·boat<sup>-1</sup>·year<sup>-1</sup> for a total of 1,680 recreational fishing boats per year over the period 2002-2010, resulting in a total catch of 840 t·year<sup>-1</sup> for 2010. To estimate recreational boat-based line catches and allow for species disaggregation, we combined data on the number of fishes per hook per fishing trip (Báez et al. 2009) with weight data per species (obtained from literature or derived from length-weight relationships (Table 2)). We adjusted the estimated catch per species per hook by -50%, to account for the difference in boat efficiency since Báez et al. (2009) described these catches for recreational boats ranging from 5 meters to 12.5 meters of length. By multiplying the sum of

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<sup>1</sup> [www.bainsromains.com](http://www.bainsromains.com) (accessed on June 13th, 2011)

<sup>2</sup> [www.corbusmilchasse.com/corbusmil1/poisson%20miniature.htm](http://www.corbusmilchasse.com/corbusmil1/poisson%20miniature.htm) (accessed on June 13th, 2011).

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

Recreational spearfishing landings are assumed to continue to decline at 10% per year for 2011-2014 while recreational landings from boats are assumed to remain constant at the 2010 amount for 2011-2014.

**Table 1.** Catch per recreational fisher ( $\text{kg}\cdot\text{fisher}^{-1}$ ) and the corresponding catch composition of recreational fishing

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

**Table 2.** Species composition of recreational boat-based fishing.

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

<sup>a</sup>) Derived from length-weight relationship.

<sup>b</sup>) [www.iucnredlist.org/apps/redlist/details/161453/0](http://www.iucnredlist.org/apps/redlist/details/161453/0) (accessed on June 1, 2011).

<sup>c</sup>) Sahi and Bouaicha (2003) and Anon. (2005).

## Results

Recreational catches totaled approximately 31,750 tonnes for the period from 1970 (when recreational fishing began) to 2010. Recreational catches peaked at 1,200 t·year<sup>-1</sup> in 2002, declining thereafter to about 1,000 t·year<sup>-1</sup> in 2010. Reconstructed recreational catches included leerfish (*Lichia amia*) which represented 25% of the catch, and which increased from zero in 1970 to 320 t·year<sup>-1</sup> in the late 1990s, and decreased dramatically afterwards. Swordfish catches (18% of the reconstructed recreational catches) totaled 4,800 tonnes over the period 1970 to 2010, steadily increasing at first until a plateau was reached at about 300 t·year<sup>-1</sup> during the 2000s. Stingrays and blue sharks (7% and 5% of the catches, respectively) amounted to 3,000 tonnes and were caught as bycatch by the swordfish fishery during the period 1970 to 2010, following the same trend as the swordfish fishery. Grouper catches represented 10% of the reconstructed recreational catch, with a total of 2,500 tonnes for the period 1970 to 2010, and included three species: dusky grouper (7%), dogtooth grouper and goldblotch grouper with together 3% of the total recreational catch. Grouper catches were increasing overall from zero in 1970 to a maximum of 150 t·year<sup>-1</sup> in the mid-1990s, and then decreased to 26 t·year<sup>-1</sup> by 2010.

## Angola

The original technical reconstruction research was initially documented in Belhabib & Divovich (2015) and updated to 2014 by the *Sea Around Us*.

## Methods

Although catches and fish sizes are declining, e.g. West Coast dusky kob (*Argyrosomus coronus*) (Potts et al. 2009), suggesting a loss of value of recreational fisheries, there has been increasing interest in Angola's recreational fisheries, illustrated by a growing number of foreign recreational fishers in the recent years (Potts et al. 2009). Fishers spend 6 days fishing per visit (Potts et al. 2011). Catch per fisher data were recorded for 1974-1975 and between 1992 and 2013 (Anon 2014a) published in [www.fapd.co.ao](http://www.fapd.co.ao). Although these data may refer to trophy fish catches (average: 2.83 ± 1.07 kg·fisher<sup>-1</sup>·hour<sup>-1</sup>), these data were not significantly different from the catch per fisher data provided by Potts et al. (2009) between 2005 and 2010 (average: 2.2 ± 0.03 kg·fisher<sup>-1</sup>·hour<sup>-1</sup>). The latter provided the CPUE per species for 2005, 2006 and 2010 for West Coast kob, shad (*Pomatomus saltatrix*) and leerfish (*Lichia amia*) which constituted 87% of the total CPUE. We added 13% to these, interpolated linearly and then compared these to the data provided by Anon. (2014a) for the same period. Earlier records (i.e., for 1974) suggested a predominance of sharks (e.g., hammerheads, *Sphyrna* spp.) and large pelagic species (e.g., Indo-Pacific sailfish, *Istiophorus platypterus*, formerly *I. albicans*) in recreational fishing (Anon 2014a), thus suggesting a distinct shift in recreational targeting.

Similarly, recreational CPUE estimated using nine YouTube videos resulted in similar results (average: 2.56 ± 0.53 kg·fisher<sup>-1</sup>·hour<sup>-1</sup>). Therefore, we derived a trend line which allowed us to obtain the annual CPUE between 1974 and 2010; we extrapolated backwards to complete the dataset for 1950-1973. The CPUE data source for 1974 (catch per fisher) was based on the earlier target taxa (sharks and large pelagics), and it was that CPUE that was used for the pre 1974 period. Given the lack of CPUE information for the 1950s and 1960s, we did make a simplifying assumption

that the 1974 shark and pelagics CPUE rate held constant back to 1950. We assumed this justifiable as the target taxa did not likely change over that time frame (1950-1974) and pelagic stocks were only lightly fished at that time. Thus, the changes in recreational targeting between the pre-civil war period (1950-1974) and the post-civil war period (2000 onwards) was accounted for through the use of different CPUE data sources that were specific to each period and target grouping.

For the number of fishers, the periods where records were absent corresponded to the civil war, i.e., 1975-1991, 1993, 1998, 2001-2002, which shows that the latter was directly related to foreign visits to Angola. On the other hand, the presence of records as early as 1974 reveals that there was recreational fishing during the Portuguese colonial period. There are three main lodges receiving tourists for recreational fishing, Flamingo Lodge ([www.aasafaris.com](http://www.aasafaris.com)), which welcomed 655 recreational fishers with an accommodation capacity of 48 rooms (Potts et al. 2009), Kwanza Lodge, which has a capacity of 24 to 48 people per day, i.e. conservatively 328 tourists (assuming the same proportions as Flamingo Lodge) and Cunene Lodge with a capacity of 15 people per day, i.e., 195 people annually ([www.aasafaris.com](http://www.aasafaris.com)). This provides a total of 1,208 recreational fishers per year for 2010. We assumed the number of recreational fishers in 1950 was half of that in 2010, decreased linearly to 0 in 1975, due to the 1961-1974 War of Independence. During much of the civil war period from 1975-2002, we assumed very little to no recreational fishing occurred. In the earlier, colonial period in Angola, tourism was not as strongly developed and often focused on land based activities, as did much of the economy. Thus, less marine fishing for recreational purposes was assumed to occur, in contrast to marine commercial fishing. The rise of the anticolonial struggles and eventually the civil wars in the early 1960s further decreased any tourism interest. This information formed the knowledge foundation on which we based our assumption of half the number of marine recreational fishers for 1950.

For the years 1992, 1999, and 2000, i.e., the relatively peaceful years during the civil war period, we assumed the number of foreign recreational fishers was 1% of the number in 2010. The number of fishers was zero for the years 1975-1991, 1993, 1998, 2001-2002, and interpolated linearly between 2002 and 2010. Assuming 5 hours of fishing per day, and 6 days per tourist, we multiplied the CPUE by the number of fishers and obtained total recreational catches for Angola.

To disaggregate recreational catches, we calculated the percentage contribution of each documented species between the period 1974 to 2010 using the above mentioned references, interpolated linearly to fill in the gaps and assumed the species disaggregation was constant between 1950 and 1974. The taxonomic breakdown of recreational landings from 2010 (Potts et al. 2009) was used to taxonomically disaggregate recreational catches for all post-1975 years.

The number of recreational fishers were determined for 2011-2014 by extrapolating the interpolated rate of increase in recreational fishers from 2002-2010 forward for 2011-2014. The number of hours, days and catch per hour spent recreational fishing were assumed to remain the same as in 2010 for 2011-2014. The taxonomic breakdown of recreational landings from 2010 was used to disaggregate species for 2011-2014.

Throughout, we conservatively assumed that no recreational fishing was undertaken by local Angolans, i.e., we only estimated foreign or former colonial staff recreational fishing. This conservative assumption may need to be revisited in the future, as with the developing economy in Angola, one can expect increasing interest in domestic recreational fishing (see [www.fapd.co.ao](http://www.fapd.co.ao)).

Given the very strong economic disparity between colonial rulers and the local population during the colonial period, we considered it extremely unlikely that local people that were subjugated with forced labor and deliberately economically disenfranchised would have engaged in recreational fishing during this time. Any non-commercial fishing by local people would most likely have been as subsistence fishing, which was addressed separately in Belhabib & Divovich (2015)

## Results

Recreational catches were estimated at around 180 t in 1950, decreased to 0 in 1975, and generally remained at this level through the civil war, before increasing again to 92 t in 2010. Recreational catches included sailfish and sharks before independence and shifted to leerfish, kob and shad after the civil war, likely due to the change in clientele from Portuguese to South Africans.

## Anguilla (UK)

The original technical reconstruction research was initially documented in Ramdeen et al. (2014b) and updated to 2014 by the *Sea Around Us*.

## Methods

Klausing (1978) conservatively estimated catches from the recreational sector of the Anguilla, which averaged to a rate of about 1.0 kg·tourist<sup>-1</sup>·year<sup>-1</sup>. Assuming participation of tourists in recreational fishing in Anguilla was 10% in 1950 and 20% in 2010, we calculated the number of recreational fishing tourists. Applying the modest rate from Klausing (1978), we conservatively estimated catches from Anguilla's recreational sector for the time period 1950-2010. These may be substantial underestimates.

## Taxonomic composition

Lum Kong (2007) presented a list of marine species targeted by fisheries, but without quantitative information. To further disaggregate finfish catches into more informative taxonomic components, we used the 2000-2010 FAO landings composition breakdown for St. Kitts and Nevis, both neighbouring islands. This was the time period when the most disaggregated species breakdown was available. Conch and lobster data were removed since these were reconstructed separately. Taking the 2000-2010 average species composition from St. Kitts and Nevis, together with some additions from Lum Kong (2007), we derived an assumed taxonomic breakdown for Anguilla reconstructed catches in 2010. For the 1950 anchor point, we re-allotted proportions to each species based on our knowledge of changes in reef species over time (Table 3). We interpolated between these anchor points to derive a taxonomic breakdown for Anguillan finfish catches for the period 1950-2010.

Catches of conch were designated to queen conch, *Strombus gigas*, based on the predominance of this strombid species in Caribbean catches. The Caribbean spiny lobster fishery for *Panulirus argus* was established since the early 1960s (Lum Kong 2007; Olsen and Ogden 1981), but over the past 20 years fishers have also increasingly targeted *Panulirus guttatus* as well (Lum Kong 2007). Since this smaller lobster species averages 2-3 lbs (0.91-1.36 kg), it is preferred by restaurants because of its simpler and more profitable portion control (Gumbs 2003; Hodge 1993). To disaggregate lobster catches by species, we assumed in 1950 that 95% of lobster catches comprised *P. argus*, while 5% comprised *P. guttatus*. From 2000-2010, we assumed a 50:50 split between these two species.

Interpolating between the 1950 anchor point and the 2000 anchor point, we disaggregated catches of lobster for the period 1950-2010.

Recreational landings were updated for 2011-2014 by multiplying the number of stop-over tourists by the recreational fishing participation rate and recreational catch rate from 2010. The 2010 taxonomic breakdown of recreational landings was held constant for 2011-2014.

**Table 3.** Taxonomic breakdown applied to reconstructed catches from Anguilla, based on FAO data for St. Kitts and Nevis as well as Lum Kong (2007).

Taxon	Proportion	
	1950	2010
<i>Acanthocybium solandri</i>	0.005	0.003
Acanthuridae	0.050	0.010
Atherinidae	0.000	0.010
Balistidae	0.000	0.005
Belonidae	0.000	0.013
Carangidae	0.050	0.008
Carangidae	0.050	0.275
Decapterus	0.050	0.126
Clupeidae	0.050	0.172
Corryphaenidae	0.005	0.008
Dasyatidae	0.000	0.010
Engraulidae	0.050	0.126
Exocotidae	0.050	0.011
Haemulidae	0.100	0.006
Holocentridae	0.050	0.003
Lutjanidae	0.150	0.022
<i>Meluccius</i> spp.	0.000	<0.001
Mullidae	0.050	0.015
Myliobatidae	0.000	0.010
Pomacanthidae	0.000	0.010
Scaridae	0.000	0.012
Scombridae	0.010	0.091
Sardinella	0.010	0.037
Serranidae	0.200	0.009
Sparidae	0.050	0.001
Trichiuridae	0.000	0.002
Misc. marine fishes	0.020	0.008

## Results

Domestically-consumed catches were estimated at slightly over 34,100 t, while exported catches amounted to nearly 15,000 t. Examining reconstructed catches by sector, subsistence catches dominated with nearly 22,500 t, while artisanal and recreational catches comprised around 26,400 t and 230 t, respectively for the time period 1950-2010. Thus, total reconstructed catches were approximately 49,000 t for the period 1950-2010, which is 2.75 times the official landings of 17,854 t reported by the FAO on behalf of Anguilla. Total unreported catches from 1950-2010 were around

31,300 t, being on average nearly 510 t·year<sup>-1</sup> for the time period 1950-2010. Catches of lobster were dominant, with *Panulirus argus* comprising 16% and *P. guttatus* 11% of total catches. Groupers (Serranidae; 12%), queen conch (10%), snappers (Lutjanidae; 9%) and grunts (Haemulidae; 6%) were also dominant in catches. Small, schooling pelagic species such as jacks (Carangidae; 6%), clupeids (3%) and sardines (*Sardinella*; 3%) were common as well. The remaining 22% comprised 17 families and a pooled 'marine fishes' category.

## Antigua and Barbuda

The original technical reconstruction research was initially documented in Georges et al. (2015) and updated to 2014 by the *Sea Around Us*.

### Methods

Recreational fishers are primarily sports fishing vessels that operate mainly on weekends and holidays (FAO Fishery Country Profiles; <http://www.fao.org/fishery/facp/ATG/en>; accessed April, 2013). These operators are subject to the same regulations as commercial fishers, however, capture data are rarely recorded as part of the Fisheries Division statistics. Data collection for this sector is difficult and severely limited, since it is often gathered only at tournaments, or when censuses are done. Recreational catch is usually sold directly to restaurants, hotels, supermarkets and housewives. There is no specific national management strategy for the large pelagic species at present. Thus, catches from this sector were reconstructed independently. According to a global recreational study (Cisneros-Montemayor and Sumaila 2010), the proportion of recreational fishers in Antigua & Barbuda in 2003 was 0.23%. Since sport fishing is associated with tourism (Campos and Muñoz-Roure 1986), we assumed all of these fishers were tourists. We applied this rate to the tourist population as a constant from 2000 to 2010. For the year 1950, we assumed a participation rate of 0.11% (half that of the later time period). Linearly interpolating between these two rates, we derived recreational fishing participation rates of the tourist population for the time period 1950-2010. Assuming tourists are likely to participate in just one fishing tour during their stay on the island, and assuming a conservative catch of 4.5 kg·tourist<sup>-1</sup>·year<sup>-1</sup>, we were able to estimate catches from this sector.

### Taxonomic breakdown

Detailed data on catch composition have been reported since 2001. Using available data, the average percentage contribution for each fish species was calculated for the period 2001-2010 (Table 4). Lobster and conch were not included in this breakdown, as they are caught in quantities that are large enough to merit a separate catch reconstruction.

Catch composition has not changed much since the 1990s (Horsford I., pers. comm., April 2013), therefore species composition for 1950-2000 were adjusted based on anecdotal evidence of what species appeared to be more frequently or less frequently caught in the past, and on the development of the fishing boats and gear. Therefore, for 1950 the percentages for serranids, haemulids and lutjanids were increased by 50% compared to the 2001-2010 average (Table 4). Tunas, squirrel fish, box fish, triggerfish, angelfish and barracuda were decreased by 50% and other less significant species were raised or lowered by 5% according to their popularity among locals as

these species are not commercially distributed (Table 4). Molluscs such as cockles (*Cardiidae* family) and whelks (*Cittarium pica*) are collected on a very small scale and generally consumed at home; however cockles are served at a few tourist restaurants. There are no data on quantity collected, therefore based on anecdotal evidence, it was assumed that the catch is comparable to that of other small crustaceans such as the batwing coral crab. Taxonomic break-down for the period 1950-2001 was calculated by interpolating between the adjusted figures for 1950 and the recorded data for 2001 (Table 4).

**Table 4.** Average catch composition of finfish, 2001-2010, in Antigua & Barbuda

Taxon	Percentage composition	
	1950	2001-2010
Snappers, jobfishes nei	25.63%	19.21%
Groupers, seabasses nei	24.79%	19.52%
Grunts, sweetlips nei	17.67%	13.97%
Parrotfishes nei	17.04%	13.03%
Surgeonfishes nei	4.89%	11.47%
Triggerfishes, durgons nei	1.89%	4.72%
Boxfishes nei	1.60%	3.44%
Carangids nei	1.51%	3.39%
Marine fishes nei	1.10%	2.19%
Squirrelfishes nei	0.99%	2.29%
Sharks, rays, skates, etc. nei	0.82%	1.90%
Tuna-like fishes nei	0.55%	1.17%
Porgies, seabreams nei	0.53%	1.28%
Barracudas nei	0.36%	0.85%
Angelfishes nei	0.23%	0.69%
Sea chubs nei	0.20%	0.42%
Filefishes, leatherjackets nei	0.17%	0.46%
Batwing coral crab	0.01%	0.01%
Spanish slipper lobster	0.01%	0.01%

Reported catches of *Strombus gigas* in 2010 were considered to represent total conch landings, and were split into 50% artisanal catches, 40% subsistence catches, and 10% recreational catches. Absent any other information, these assumptions were carried forward to 2014. Artisanal finfish and total conch catches equaled 90% of landings while lobster catches made up the last 10%. The lobster reconstruction was then allocated to different sectors; 90% from artisanal, 7% for subsistence, and 3% from recreational, carrying forward the assumption made for 2010 total lobster catches by Georges et al. (2015).

## Argentina

The original technical reconstruction research was initially documented in Villasante et al. (2015) and updated to 2014 by the *Sea Around Us*.

## Methods

To estimate total fisheries removals, we followed the catch-reconstruction approach developed by Zeller and Pauly (2007) and previously used in various regions of the world's oceans (see [www.seaaroundus.org](http://www.seaaroundus.org)). This approach requires occasional assumptions and interpolations, which are noted in the methods. Despite uncertainties, this method generates results that are preferable to the alternative, where non-reported or missing data are interpreted as zero catch (Zeller and Pauly 2007). Including previously unreported catches is vital, as total fisheries removals are the most fundamental data in assessing the impact of fishing on exploited ecosystems.

For each year, we defined total fisheries removals (TR) as the sum of total fisheries landings (TL) and total discards (TD) for S caught species and F number of fishing fleets as follows:

$$TR = \sum_{s=1, f=1}^{S, N} (TL + TD)$$

TL for S caught species and F number of fishing fleets was composed by the following elements:

$$TL = \sum_{s=1, f=1}^{S, N} (OL + UL) = \sum_{s=1, f=1}^{S, N} (OL + BM + IC + AC + RC + SF)$$

where OL is official landings and UL is unreported landings. UL is composed of unreported catches by the domestic fleet that go to the black market (BM) and illegally caught species (IC) by foreign fleets in the relevant waters. It also includes artisanal catch (AC) not reported in OL, as well as recreational catch (RC) and subsistence fishing (SF), e.g., the personal consumption of seafood by fishers and their families.

TD for S caught species and F number of fishing fleets is estimated by:

$$TD = \sum_{s=1, f=1}^{S, N} (D + PM + GF)$$

where D is direct boat-based discards from fishing activities (Kelleher 2005), PM is underwater discards, of those specimens that die after escaping from fishing nets due to physical damages (Suuronen 2005) and GF is ghost fishing mortality of those specimens that die due to lost or abandoned gear or the loss of fishing gear at sea (Macfadyen et al. 2009).

We considered all the elements of TR that are not included in OL as unreported landings. To calculate TR, we collected and compiled all material available, from primary literature and official sites, final projects report, grey literature, statistics from regional institutions, estimates from experts, observations in harbour areas and markets, and opinions of local fishers and fisheries experts collected through informal interviews. This study does not include catch from aquaculture activities or species of marine mammals, seabirds, marine turtles, worms, or various seaweed species.

This study aims to reconstruct total fisheries removals for Argentina's marine fisheries catches from 1950-2010. First, reported catch data by taxa and year were obtained from Argentinean national data sources. Then, unreported landings and discards were within the commercial, subsistence, and recreational sectors of Argentina using grey literature and other sources as described in the preceding section. The summation of the reported national catch data and unreported catch resulted in total reconstructed catch for Argentina.

Thereafter, the total reconstructed catch was compared to the landings reported to the FAO by Argentina. For the eight major commercial species whose catch accounted for approximately between 80 – 90% of the total catch, i.e., Argentine anchovy, pink cusk-eel (*Genypterus blacodes*), Argentine shortfin squid, Patagonian squid (*Loligo gahi*), Patagonian grenadier, Argentine hake, southern blue whiting, and Argentine red shrimp, we compared the total reconstructed catch and FAO reported catch by species, and found in all cases that total reconstructed catch was higher than the catch reported to the FAO.

For all other species, which jointly contributed the remaining 10-20% of the catch, we noticed that there was a discrepancy in the number of species represented in each data series. Total reconstructed catch (which was based on national data sources) consisted of 53 species in addition to the eight major ones, while the catch reported to FAO had more (92). Also, the catch reported to and by the FAO (which corresponds to the commercial sector) was higher than total reconstructed catch for the commercial sector, due to a multitude of species groups not available in national data.

Hence, we assumed that for the commercial sector, FAO data for the non-major species were actually more comprehensive than reconstructed catch from the national data sources we consulted. Thus, we replaced the reconstructed reported and unreported landings for non-major species with the FAO data. Note, however, that this assumption does not apply to the subsistence sector, the recreational sector, or discards, as these are not included in the data reported by FAO, nor to the eight major commercial species.

#### Data sources

Although the first historical records of fishing in Argentina date back to 1898 (Sánchez et al. 2012), the systematization of information in its current form, disaggregated by species, dates from 1934, thus ensuring that national data from 1950 – 2010 were consistent for the entire time period. Additionally, these data were supplemented by official statistics on landings of the hake fleet, published by the Undersecretary of Fisheries and Aquaculture ([www.minagri.gov.ar](http://www.minagri.gov.ar)).

Data on the level of unreported commercial landings by species were taken from the Secretary of Agriculture, Livestock, Fisheries, and Food, Secretaría de Agricultura, Ganadería, Pesca y Alimentos (SAGPyA) combined with other sources, notably (Agnew et al. 2009), and (Villasante et al. 2014). A synthesis of these data sources enabled us to estimate a percentage of unreported catch by species, varying over time from 1950 – 2010. Estimates for the amount of unreported fisheries catch in the recreational and subsistence fisheries was taken from a compilation of local interviews and data sources (Agnew et al. 2009; SAGPyA; Kelleher 2005). Lastly, estimates for discards were taken from Bezzi et al. (1994); Cañete et al. (2000); Dato et al. (2003); Kelleher (2005); Dato et al. (2006); Villasante et al. (2014) and local interviews.

Landings from recreational and subsistence fisheries were estimated for 2011-2014 based on the proportion between each sector and total reported landings in 2010. The taxonomic breakdown of catch from each sector was maintained at the 2010 proportions for 2011-2014 in order to disaggregate catch by taxa.

## Results

Total fisheries removals were estimated by summing all catch components investigated above: reported landings, unreported landings, and discards. Reconstructed catch began at 67,000 t in 1960 and increased in an exponential trend to reach over 2 million t in 1997, thereafter declining to 1.36 million t-year<sup>-1</sup> in the 2000s.

Total removals in the study area were mainly assigned to the industrial sector, while artisanal, recreational, subsistence fishing and discards removed smaller amounts of catch from the ecosystems. By species, hake accounted for 48% of total reconstructed catch, followed by Argentine shortfin squid at 13%, Southern blue whiting at 5%, Patagonian grenadier at 4%, and the remaining 30% composed of 109 various marine fishes and invertebrates. Clear declines of catch with time are observed for important commercial species such as hake, anchovy, and sardine, while the catch of other species increased in recent years (such as mackerel, blue witting, octopuses and other invertebrates).

Overall, reconstructed catch was 55% higher than FAO reported landings. Of this unreported component, unreported commercial catch accounted for 61.1%, discards accounted for 24.0%, recreational catch accounted for 14.7%, and catch in the subsistence sector was 0.2%.

## Aruba (Netherlands)

The original technical reconstruction research was initially documented in Pauly et al. (2015) and updated to 2014 by the *Sea Around Us*.

### Methods

Aruba's total fisheries catches (artisanal, subsistence, recreational, and foreign/industrial) for the period 1950-2010 following the approach of Zeller et al. (2007).

The landings data in the FAO's Fishstat database, which presents in standardized format the catch statistics submitted by its member countries, including Aruba, were used as the reported catch baseline of this reconstruction. These 'official' data were modified as follows:

To account for tourism-based catches of game fishes (i.e., mostly large pelagics) which, we assume, started in the mid-1970s, we multiplied an assumed average catch per fishing day of recreational fishers with a time series of the number of fishing tourists (see below).

#### Estimation of the recreational catch by tourists

Aruba conducts a "Tourism Survey" whose results are reported by its Central Bureau of Statistics<sup>3</sup>. For 2000-2010, a mean of 712,600 tourists were registered annually, of which about 50% visit two or

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<sup>3</sup> See <http://www.cbs.aw/index.php/statistics/tables-statistics/71-tables/tourism/international-tourism>

more times, and who direct 7% of their expenses toward “entertainment and recreation.” To generate a placeholder for an eventual estimate of catches by tourists, we conservatively assume that 100,000 of these tourists, who usually come for one week (Bryden 1973) spend 5 days each on game fishing, with each catching an extremely conservative 1 kg of fish per fishing day, which generates an annual take of 500 t of oceanic fish such as albacore, bonito, king mackerel, wahoo, billfish, rainbow runner, dolphinfish and ‘others’. Each of these 8 groups was assumed, based on Weidner et al. (2001b), to contribute equally to the catch. The catch of game fish by tourists is assumed to have increased linearly to its 2000- 2010 level from zero in 1974.

Recreational landings were updated for 2011-2014 using the original methods. Updated stop-over tourist arrivals were obtained for 2011-2014 from Central Bureau Statistics Aruba and Aruba Tourism Authority and multiplied by the 2010 recreational fishing participation rate and number of days spent fishing in order to estimate recreational landings.

## Results

Marine landings reported by FAO on behalf of Aruba from 1950-2010, after the adjustments as outlined above, amounted to 20,677 t, all of which pertained to the artisanal sector. When the other sectors (unreported artisanal, recreational, etc.) are taken into account, the reconstructed total catch for Aruba was just over 36,000 t or 75% more than the adjusted amount reported by FAO.

The main components of the reconstructed total landings were reported artisanal catches (20,677 t), recreational catches (11,750 t), subsistence catches (3,100 t), artisanal discards (420 t), and unreported artisanal catches (300 t). The unreported catches grew strongly from 1986 on, and were, in the 2000s, over 76% higher than the landings reported by FAO.

Reconstructed total recreational catches amounted to around 11,750 t from 1950 to 2010. Albacore tuna accounted for around 1,600 t during the entire period, while bonito, wahoo, dolphinfish, king mackerel, rainbow runner and marlin each were assigned an estimated catch of around 1,500 t, while ‘marine fishes nei’ contributed nearly 1,350 t of catches.

## Australia

The original technical reconstruction research was initially documented in Kleisner et al. (2015) and was updated to 2014 by the *Sea Around Us*. It also includes more recent further improvements and corrections from expert feedback that are being implemented for the next *Sea Around Us* data release in the first half of 2020.

## Methods

Recreational fishing is a popular pastime for Australians. The originally used (Kleisner et al. 2015) National Recreational and Indigenous Fishing Survey (NRIFS) estimated a national participation rate of 19.5% in 2000, with recreational fishing from marine waters accounting for 80% of all recreational fishing effort (Henry and Lyle 2003). More recently, additional surveys have been conducted, which will be used in future updates for Australia. Additionally, the recreational sector generates employment to a variety of businesses (Anon 2011a). Here, it was assumed that recreational fishing effort in marine waters likely varied over the 1950-2010 period, mainly due to the growth in coastal population and evolving recreational preferences.

Historically, there has been a paucity of recreational fishing surveys in Australia, thus there is little documentation of recreational fishing effort and catch prior to the 1970s. Moreover, as available surveys were conducted by state fishery agencies, there was rarely a common approach with respect to the spatial and chronological scales of these reports and thus, national catch and effort are difficult to assess by reviewing these surveys alone (Henry and Lyle 2003). The first national recreational survey (Anon 1984), estimated the national participation rate to be 34% in 1984. However, this survey had a rather low sample size, and the resultant participation rate should be viewed with caution.

Historically, fisheries managers assumed that catches from recreational fisheries were much lower than from commercial fisheries (Gartside et al. 1999). However, with an increase in the number of fishers from 1970 to 1990, and the resulting establishment of more frequent state-wide recreational surveys, it became apparent that recreational catches were higher than previously thought. For example, Steffe and Chapman (2003) determined that recreational catches from the coastal lagoon Lake Macquarie were about 295 t over the survey period, while the declared commercial catches over the same period were about 274 t.

Current management of Australia's recreational fisheries is the prerogative of individual state and territory governments, and is considered to represent a well-managed and enforced sector. Management is generally through input controls, but sometimes combines input and output controls, depending on the species targeted. Fishers are often required to adhere to daily bag and possession limits, minimum and/or maximum fish size limits, restrictions on the type, size, and quantity of fishing gear, and seasonal or area fishing closures (Henry and Lyle 2003). The states and territories also regulate fishing licences and provisions.

The NRIFS (Henry and Lyle 2003), conducted in 2000-2001 in response to the substantial increase in recreational fishers over the last few decades, was the first comprehensive national survey to examine recreational fishing in Australia. As such, it is the foundation on which our estimates of recreational catches from 1950 to 2010 are based. Amongst its many objectives, the survey was to assess recreational fishing pressure by quantifying catch, effort, and participation rates. Also, the authors estimated the total numbers of fish caught per species or family, in addition to an estimate of the total tonnage of primary finfish species, resulting in an estimated catch of 27,000 t (Henry and Lyle 2003). More recently, additional surveys have been conducted, which will be used in future updates for Australia.

#### 2011-2014 update

Queensland provided statewide recreational survey catch numbers for 2000, 2010, and 2013 and the numbers of fish were converted to tonnage using the length-weight relationship from FishBase (2019). In cases where 'common length' is specified in FishBase (based on source material), this was used. In cases without 'common length' data, we used ½ of maximum length as the assumed common length for input into the published length-weight relationship to derive assumed average weight per individual. The surveys also provided participation rates during the survey years and the participation rates were interpolated for non-survey years. More recently, additional surveys have been conducted, which will be used in future updates for Australia. The participation rate was multiplied by the state population to determine the number of people participating in recreational fishing each year. The catch rates were determined by calculating the total catch tonnage during

survey years and dividing by the number of people participating and interpolating the catch rates between survey years. The catch rate was held constant from 1950-1989, but we acknowledge that catch rates may have changed over that time period due to changes in gears and fishing access. The catch rate for non-survey years was applied to the number of people participating in recreational fishing to calculate the total recreational catch (t) that year. The 2013 survey taxonomic composition was held constant from 1950-2017, which may introduce time series errors in actual composition due to changes in targeting or availability of taxa over time. Future research needs to examine such changes in composition. In the original reconstruction the “other fishes” category was allocated to other species already in the list. This was corrected here and these catches were retained as “other fishes” but labelled as “Miscellaneous marine fishes”.

Western Australia provided state wide recreational survey data from 2011/12, 2013/14 and 2015/16 and the same methods as used for Queensland were applied.

For the Northern Territories, South Australia, Tasmania, Victoria and New South Wales the participation rates were determined from the respective state wide survey reports and the participation rates were interpolated for non-survey years from 2010-2017. The current *Sea Around Us* recreational sector breakdown was used to calculate the total annual recreational catch (t) from the ABARES reports during survey years. This was used to determine the catch rate during survey years and interpolation was used to determine the catch rate for non-survey years. The catch rate was applied to the number of people recreationally fishing as determined by the participation rate to calculate the recreational catch (t) from 2011-2017. The taxonomic composition from 2010 was held constant.

## Azores Isl. (Portugal)

The original technical reconstruction report (Morato et al. 2001b) was vetted through peer-review in Pham et al. (2013b) and updated to 2014 by the *Sea Around Us*.

### Methods

The methodologies used for reconstruction of the Azores catch were adapted from Pitcher et al. (2002) and Zeller et al. (2006; 2007), and the reported catch baseline was based on the locally reported catch time-series from the National Institute of Statistics of Portugal; Regional Services of Statistics of the Azores.

The main recreational fishing activities in the Azores are spear fishing, boat fishing, coastal rod fishing from shore, and hand collecting (Diogo 2007). The anchor point using 2004 as the reference year of per capita recreational catch and species composition was obtained from Diogo (2007). The estimated spear fishing and boat fishing catch for Faial and Pico was extrapolated for other islands using the number of licenses for both activities. For line fishing from shore and hand harvesting activities (for which licenses are not mandatory), we used an indirect method based on a recreational index calculated for each island (see original supplementary material below). Total estimated catch for these activities in 2004 was 471 t. Using this anchor point, catches from the recreational sector were estimated for other years by modifying two factors from the estimation of Diogo (2007): (i) natural abundance of target species, and (ii) number of fishing events, i.e. fishing

effort. Species abundance was adjusted yearly according to the official commercial landings reported from the artisanal sector for the species that are targeted by recreational activities. The number of operations was adjusted according to the total Azorean population for each year. We also considered time of appearance and relative importance of the three activities to adjust species catch estimates. For example, spear fishing began in the 1970s in the Azores (H. Diogo, pers. comm.), coastal rod fishing was extremely important in the past, whilst boat fishing only appeared after engines were introduced. Therefore, catch by spear fishing was estimated from 1970, whilst the importance of boat fishing was adjusted using the number of commercial boats with engines as a proxy for the importance of recreational boat fishing.

### Big-game fishing

Game fishing for large pelagic fish began in the mid-1980s (Pereira 1988), peaked in the 1990s, with up to eight boats registered on the island of Faial, and is still active today (L. Gallagher, pers. comm.). With the exception of one report briefly describing the activity from 1984–1987 (Pereira 1988), there is little data on total fish removal. In the early days, most of the blue marlin (*Makaira nigricans*) caught were landed, but by 1989, big-game fishing became essentially a catch-and-release activity. For recent years, total blue marlin mortality rarely exceeded two individuals per boat per year. Estimation of total removals by this activity was based on (i) data available from Pereira (1988) for the period 1984–1986; (ii) landings reported by ICCAT for 1987–1988 and 1993–1996; and (iii) information exchanged from Captain Les Gallagher who, since his arrival in the Azores, registered the number of boats conducting this activity on Faial (the main harbour for this activity). For the periods 1989–1992 and 1997–2010, total catch of blue marlin per year was calculated using the number of boats registered by Captain Gallagher and assuming (i) an annual catch of two blue marlin per boat, and (ii) a mean weight of 210 kg (Pereira 1988). White marlin (*Kajikia albida*) biomass was estimated assuming a catch rate of this species to be 20% that of blue marlin (as reported by Pereira 1988) and a mean individual weight of 30 kg (Amorim and Arfelli 2001).

## Results

Total catch by the recreational sector for the entire period was estimated to be 38 900 t (95% CI, 37 900–40 400 t), 6% of the official landing statistics reported by the commercial sector. Catch from the recreational sector was estimated to vary between 300 and 950 t per year. The contribution of each recreational activity towards the total catch varied substantially during the study period. Overall, boat fishing and coastal rod fishing were the most important recreational activities in terms of catch volume, contributing 96% of the total estimated catch. Total catch arising from spear fishing was estimated to fluctuate between 4 and 48 t per year, whilst hand collecting of intertidal invertebrates is the smallest activity (5 t per year average). The most important species in terms of volume are the white seabream (*Diplodus sargus*), with a total catch of 6500 t (220% of official statistics), blacktail comber (*Serranus atricauda*), with a total catch of 4700 t (85% of official statistics), chub mackerel, with a total catch of 3000 t (15% of official statistics), and parrotfish (*Sparisoma cretense*), with a total catch of 2970 t (60% of official statistics).

### Big-game fishing

Total removal of blue and white marlin by the sportfishing sector from 1984–2010 was estimated to be 91 t (95% CI, 71–110 t). ICCAT reported a maximum removal of 10 t of blue marlin by the

sportfishing sector in 1993, a value not present in local fishery statistics. Our estimates suggest that, for the past ten years, the average blue marlin mortality has been 1.5 t per year. Prior to 1990, many blue marlin caught by sportfishers were landed; during that period, the average blue marlin catch was estimated to be 6 t per year.

#### Overall

Therefore, the total reconstructed fishery catch, excluding sperm whales, was 900 000 t for the period 1950–2010. From that amount, 160 000 t (95% CI, 120 000–220 000 t) were not included in official statistics (22% of official statistics) and ranged between 720 and 6600 t per year, with foreign fishing activity being the largest contributor (27%), followed by catches from the recreational sector (25%), discards from the demersal fishing fleet (21%), baitfish for the pole-and-line tuna fishery (11%), discards from pelagic longlining (7%), harvesting of coastal invertebrates (6%), Azorean boats landing outside the Azores (3%), and big-game fishing (0.1%)

In addition, species of recreational interest, such as white seabream, parrot fish, or blacktail comber, had unreported catches up to twofold higher than official amounts.

#### [Original Supplementary Material Methods for the Azores](#)

Based on the work by Diogo (2007)

Estimation of total catches arising from recreational fishing was based on the roving creel survey and interviews conducted by Diogo (2007) between October 2004 and September 2005 in the islands of Faial and Pico. The relatively small area (Faial and Pico have perimeters of 61.15 and 109.50 km and areas of 173.11 and 447.74 km<sup>2</sup>, respectively) allowed accurate surveys, whilst their geographical proximity permitted the work to be done simultaneously in both islands. The islands were divided into nine spatial units (four in Faial and five in Pico). To better understand temporal and spatial patterns of fishing effort and to reduce bias, the survey was designed to collect monthly information at different strata: (i) morning and afternoon (time), (ii) weekends and weekdays (day type), and (iii) different spatial sampling units (McGlennon and Kinloch 1997; Sigler and Sigler 1990). Faial and Pico were sampled 8 and 10 d per month, respectively. The monthly sampling effort was divided between the spatial sampling units in order to obtain two replicates for each combination of day type and time-stratum (Dent and Wagner 1991; Sigler and Sigler 1990).

Effort estimators were based on the count-as-you-go method, where the quantification of recreational fishers outlined the basis for estimating fishing effort for each recreational activity (boat fishing, coastal rod fishing, spear fishing, and hand collecting). For each fishing operation observed, the following variables were recorded: hour, position, fishing method, geomorphology, tide, wind strength (Beaufort scale), and wave length. Interviews were made with randomly chosen recreational fishers. The inquiries covered the following items: (i) inquiry identification, (ii) fisher identification, (iii) activity, and (iv) sampling of the catch and quantification of discards. The interviews were limited to approximately 5 min to minimize underestimation of the fishing effort (Wade et al. 1991). Catch sampling included identification of specimens to the lowest possible taxonomic level along with weight and size measurements. Weight was only taken from specimens that were already eviscerated and from species for which the length–weight relationship was unknown. In all other cases, weight was calculated using the length–weight relationship (Froese and Pauly 2019; Morato et al. 2001a). In the case of fish, total or fork length was measured to the

nearest centimeter, and for molluscs (e.g. squid and octopus), mantle length (ML, cm) was used. The total annual catch was estimated for each island separately. Fishing effort was estimated as the number of fishers observed per hour and estimated per spatial unit for each month and activity. The annual fishing effort in days was estimated as the sum of monthly fishing effort and the associated standard deviation. The annual fishing effort in hours for each fishing activity was calculated as the product of the mean number of fishing hours by the sum of the annual fishing effort of the fishing activity. The catch rate for each fishing activity was calculated using the mean of the individual ratios, as described in Pollock *et al.* (1997). Finally, the catch estimate for each fishing activity was calculated as the product of the fishing effort and the mean catch rate for that activity.

### Key findings

The activity that accounted for the highest number of fishers and the highest fishing effort was coastal rod fishing, followed by recreational boats, hand collecting, spear fishing, and octopus free divers. In terms of catch volume, boat fishing accounted for 70% of the total catch, with the most captures being those of species with high economic value, indicating a high overlap with the commercial coastal fishery. The total annual catch of diurnal recreational fishing activities was estimated to be approximately 138 t for both islands. A total of 32 families and 55 taxa were identified to the lowest possible level. The most captured species in recreational fishing were blacktail comber (*Serranus atricauda*), white seabream (*Diplodus sargus*), blackspot seabream (*Pagellus bogaraveo*), horse mackerel (*Scomber japonicus*), parrot fish (*Sparisoma cretense*), and horse mackerel (*Trachurus picturatus*).

## Bahamas

The original technical reconstruction research was initially documented in Smith and Zeller (2013), and subsequently vetted through peer-review in Smith and Zeller (2015), and then updated to 2014 by the *Sea Around Us*.

### Methods

We divided recreational catches into 2 categories: 1) fish that were caught during major tournaments and 2) fish that were caught for recreation outside of tournaments.

The United States Recreational Billfish Survey (RBS) program recorded total billfish catches (in numbers) and effort data from major fishing tournaments in several parts of the Atlantic, including in The Bahamas during 1972–2007. Data from the RBS also include the fate of fish that were caught (i.e., retained, released, or tagged and released (Diaz et al. 2007)). We used data directly from the RBS program to determine the quantity of blue marlin (*Makaira nigricans*), white marlin (*Kajikia albida*), and sailfish (*Istiophorus platypterus*) that were retained during tournaments during 1972–2006. Before 1972, data for The Bahamas were not collected during the RBS program, and there were also fewer tournaments and, therefore, presumably, lower total tournament catches (Cleare 2007). Hence, we assumed that billfish catches in 1950 were half those in 1972, and we linearly interpolated catches for 1951–1971. In 2007, the quality of the tournament catch data that was reported to the RBS program was likely to have deteriorated; after 2007 organizers stopped

reporting catches for The Bahamas to the RBS program altogether (Venizelos<sup>4</sup>). We, therefore, calculated mean annual tournament catch for the years 2000–2006 and held this value constant for the remainder of the time series, although this calculation could have resulted in an underestimate.

It is important to note that other pelagic species, such as dolphinfish (*Coryphaena hippurus*), wahoo (*Acanthocybium solandri*), and tunas, are also caught during tournaments. We did not, however, have access to any data or information on the quantities of nonbillfish species that were retained during tournaments. Therefore, our estimate of total retained catch during tournaments is limited to billfish species and is highly conservative.

To estimate catches outside of tournaments, we separated data into 2 categories: 1) fish caught by visitors and 2) fish caught by residents.

We relied on 3 information sources to reconstruct visitor catches: 1) visitor arrival data; 2) the Ministry of Tourism visitor activities survey report; and 3) recreational fishing regulations for visitors to The Bahamas. We estimated recreational catch of visitors by combining data on the number of visitors per year with the proportion of visitors that indicated that they fished during their stay (values were based on the Ministry of Tourism 1980 visitor activity survey report, as presented in Thompson (1989)), along with per capita maximum allowable catch for demersal and pelagic species, as stipulated in the Fisheries Resources (Jurisdiction and Conservation) Regulations of 1986 [available at website]. We estimated a per capita recreational catch rate of 54 kg·person<sup>-1</sup>·visit<sup>-1</sup> during 1986–2006. This catch rate was determined with the assumption that the proportion of visitors that fished during their stay remained constant during 1986–2006 (i.e., 6.2%, 5.3%, and 20.0% of stopover visitors to New Providence, Grand Bahama, and the Family Islands, respectively), and this rate represents 80% of the per capita allowable catch for key taxa. This catch rate is conservative given that the number of visitors who have fished in The Bahamas during their stay has increased in recent times and given that catches by visitors to The Bahamas were often thought to exceed maximum catch limits (Cox and Hammerton, J. L. Wilchcombe 2005).

Before 1986, there were no maximum catch limits for recreational fishing in The Bahamas. Moreover, during this period many visitors exploited this lack of regulation by actually fishing commercially (Thompson 1989). We, therefore, assumed (on the basis of the number of stopover visitors per year and the visitor activity survey report) that, during 1950–1985, visitors who fished in The Bahamas during their stay caught and retained twice as much as the maximum per capita catch limits stipulated for key taxa in the 1986 legislation (i.e., ~136 kg·person<sup>-1</sup>·visit<sup>-1</sup>). In 2007, the government of The Bahamas revised the maximum catch limits for key taxa with the aim of reducing total catch. The government assumed that this revision would result in a 50% reduction in catches from the catch rate observed in 1986 (Braynen<sup>5</sup>). In the absence of better data, we accepted this assumption and applied a recreational per capita catch rate of 34 kg·person<sup>-1</sup>·visit<sup>-1</sup>, estimating that visitors caught 50% of the 1986 catch limits for key taxa.

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<sup>4</sup> Venizelos, A. 2012. Personal commun. Southeast Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Miami, FL 33149

<sup>5</sup> Braynen, M. 2011. Personal commun. The Bahamas Department of Marine Resources, Nassau, The Bahamas 3028.

Much less is known about the regular recreational fishing habits of residents. Unlike the existence of legislation for visitors, there is currently no legislation that limits the quantity of fish that may be caught by residents for recreational purposes. Therefore, we relied on 3 sources to estimate catch for this component: 1) resident population data; 2) expert opinion of staff from the Department of Marine Resources; and 3) The Bahamas recreational fishing regulations for visitors. We assumed that, during 1950–1969, 0.5% of residents of the Family Islands fished for recreation 6 times a year and 1% of residents of New Providence and Grand Bahama fished recreationally 4 times a year (Braynen<sup>5</sup>). For each trip, it was assumed that residents caught 50% of the 1986 maximum per capita catch limits for key taxa for visitors (i.e., 34 kg·person<sup>-1</sup>·trip<sup>-1</sup>). This assumption amounts to an annual recreational catch rate of 204 kg·fisherman<sup>-1</sup>·year<sup>-1</sup> and 136 kg·fisherman<sup>-1</sup>·year<sup>-1</sup> for Family Islanders and residents of New Providence and Grand Bahama, respectively.

With increasing economic opportunities in the 1970s, recreational fishing is also likely to have increased, particularly on New Providence and Grand Bahama. According to expert opinion from staff of the Department of Marine Resources (Braynen<sup>5</sup>), during 1970–2010, 2% of residents of New Providence and Grand Bahama fished for recreation 8 times a year. By comparison, although the proportion of residents fishing recreationally in the Family Islands did not change, the frequency with which they fished increased. Hence, it was assumed that during 1970–2010, 0.5% of Family Islanders fished for recreation once a month. A catch rate of 34 kg·person<sup>-1</sup>·trip<sup>-1</sup> translates to annual catches of 272 kg·fisherman<sup>-1</sup>·year<sup>-1</sup> for residents of New Providence and Grand Bahama and to a rate of 408 kg·fisherman<sup>-1</sup>·year<sup>-1</sup> for residents of the Family Islands.

To determine the taxonomic composition for recreational catches from tournaments, we relied on information from the RBS program; for catches outside of tournaments, we relied on 3 sources: 1) recreational fishing regulations; 2) Thompson (1989); and 3) demersal catch composition from commercial fisheries (for details, see Smith and Zeller 2013).

#### Tourist demand for local fishes

We separated tourist demand for local fishes into 2 categories: 1) demand by stopover visitors and 2) demand by visitors who arrived on cruise ships. For our study, we define stopover visitors as tourists that spend at least one night in The Bahamas (Cleare 2007). Most stopover visitors arrive by air, but some of them arrive by other means (e.g., private yacht). Stopover visitors fish recreationally and consume local fishes in restaurants in The Bahamas. In contrast, tourists that arrive by cruise ship, as defined in our study, typically spend only a few hours ashore in The Bahamas and increase demand for local fishes only through seafood consumption during shore visits.

To estimate stopover visitor demand for local fishes through seafood consumption in hotel restaurants, we designed and successfully administered a local seafood consumption survey with 11 major hotels on 5 different island groups. Our study sample represented 37% of all hotel rooms in The Bahamas in 2010. Hotels in our survey ranged in size from 19 to 2932 rooms. In all instances, the purchasing manager or head chef of a hotel restaurant completed the survey, which included requests for information on the type, quantity, origin (i.e., The Bahamas versus imported), and dollar value of fishes supplied to the restaurant on a yearly basis (Smith and Zeller 2013).

In our survey, there was a suspiciously large quantity of seafood that was purported to be of local origin. We, therefore, assumed that 10% of all so-called local seafood was actually imported and we

adjusted consumption accordingly. Visitors to The Bahamas consume both local and imported (e.g., salmon) seafood in hotel restaurants. Our study focused only on local seafood consumption. Overall seafood consumption (i.e., both local and imported products) by visitors to The Bahamas is therefore much greater than our estimates provided here.

Then we combined tourist data (e.g., hotel occupancy rates, number of visitor nights per year) with results from our survey to estimate a consumption rate per stopover visitor for consumption of local seafood. Although staff at hotels provided data for a period that ranged from 2 through 18 years, most hotels provided data for only the last 2 years of our time series (i.e., 2009–2010). We are unaware of any previous estimates of local seafood consumption rates in hotels in The Bahamas.

Hence, we maintained the average consumption rate per stopover visitor for the years 2009–2010 based on our survey results (i.e.,  $0.49 \text{ kg}\cdot\text{visitor}^{-1}\cdot\text{night}^{-1}$  and  $1.08 \text{ kg}\cdot\text{visitor}^{-1}\cdot\text{night}^{-1}$  for visitors to New Providence and Grand Bahama and to the Family Islands, respectively) for the remainder of the time series (i.e., 1950–2008), although this extrapolation may have resulted in a slight overestimate of local seafood consumption rates in the earliest parts of the time series (e.g., the 1950s).

Stopover visitors, by fishing recreationally, also increase local demand on fisheries resources (see the previous Recreational fishery section). However, because our tournament data did not distinguish between resident and tourist individuals that fish, we assumed that 98% of all tournament catch was taken by stopover visitors. The assumption that most tournament catch was taken by tourists is based on the fact that most sport fishing tournaments in The Bahamas are geared toward tourists (Cleare 2007; Thompson 1989) and on the notion that only a small percentage of the Bahamian resident population fishes for recreation (see the previous Recreational fishery section).

We are unaware of any estimates of local seafood consumption by visitors who arrive on cruise ships during their shore visits in The Bahamas. To be conservative, we assumed that, during 1950–2010, 10% of all visitors from cruise ships consumed local seafood equivalent to 1 plate-size snapper during their visit (i.e.,  $0.31 \text{ kg}\cdot\text{visitor}^{-1}\cdot\text{trip}^{-1}$ ).

## Results

### Reconstructed total catch

Reconstructed total catch from 1950 through 2010 was 884,500 t, a level that is 2.6 times the 336,190 t reported by FAO for The Bahamas. Notably, recreational fishing accounted for more than half of the reconstructed total catch over the full time period (i.e., 55% or 490,100 t), followed by the largescale, commercial Caribbean spiny lobster (29%), artisanal (12%), and subsistence (4%) fisheries. In contrast, for the most recent decade (i.e., 2000–2010), recreational catch mainly declined but still accounted for more than one-third (i.e., 39%) of the reconstructed total catch; in the same period, a generally increasing trend was observed for the large-scale, commercial fishery for Caribbean spiny lobster.

### Recreational fishery

Reconstructed recreational catch for the period 1950–2010 was 490,100 t; of this catch, less than 1% (around 420 t) was attributed to major tournaments. Catch increased from 600 t/year in 1950 to a peak of around 16,100 t/year in 1985, before declining rapidly to 7300 t/year in 1986 after the

introduction of maximum catch limits for key taxa for visitors who fish recreationally. A second, but smaller peak occurred in 2006 at 9000 t/year before again declining sharply to just under 5700 t/year in 2010 because of revisions made in 2007 to the recreational fishing regulations for visitors.

#### Tourist demand for local fishes

Tourist demand for local fishes (through recreational fishing and from hotel restaurants) from 1950 through 2010 totaled 661,800 t, accounting for 75% of reconstructed total catches in the entire country. The total number of visitors to The Bahamas each year is in the millions, and visitors have outnumbered the resident population by an order of magnitude for nearly half a century. It is, therefore, not surprising that tourism has such a sizeable effect on fisheries removals in The Bahamas. Demand increased from 660 t/year in 1950 to a peak of more than 19,800 t/year in 1985 before declining to 9100 t/year in 2010. Almost two-thirds of this demand (435,900 t) was driven by recreational fishing by stopover visitors, and the remainder was a result of seafood consumption by stopover visitors (34%) and by visitors from cruise ships (0.3%). Although there were 13% more visitors from cruise ships than stopover visitors during 1950–2010, it is not surprising that less than 1% of demand was attributed to visitors who arrived by cruise ship, given that only a small fraction of them consumed local seafood and that none fished recreationally during their stay.

## Bahrain

The original technical reconstruction research was initially documented in Al-Abdulrazzak (2013), then updated to 2014 by the *Sea Around Us*.

### Methods

Uwate et al. (1994) conducted a survey of recreational fishermen and estimated that recreational catch amounts to 4% of commercial catch. It was assumed that this percentage was the same since the start of reporting and therefore was applied from 1950–2010. Because no data were available on species composition, species composition ratios from Kuwait were applied to the reconstructed recreational catch.

### Results

The catch of recreational fisheries is likely underestimated, for two reasons. First, the study of Uwate et al. (1994), which formed the basis of the estimates presented here, is likely outdated at present. Bahrain's population has strongly increased in recent years leading us to predict that participation has also greatly increased. Second, the study, which was conducted by people working for Bahrain's Fisheries Directorate, was only carried out in selected ports, not all ports that service recreational fisheries. Other sources (e.g., Uwate and Shams 1996; De Young 2006) highlight the significance of recreational catches in Bahrain, but without providing tonnage. However, the study estimates catches to be only 4% of all commercial catches. Ultimately, this value was chosen in order to remain conservative.

## Belgium

The original peer-reviewed reconstruction research was initially documented in Lescauwae et al. (2010), and then updated and vetted through peer-review in Lescauwae et al (2015), and then updated to 2014 by the *Sea Around Us*.

### Methods

#### Recreational (semi-industrial) Crangon fishing

Recreational shrimp fishing occurs with frequency in Belgium and locally regarded as 'semi-commercial' because of their relative importance compared to commercial Crangon landings. However, vessels under 10 m are not required to report catches and the fishery is not part of the official fleet. Prohibitions are on the selling of catch, rather than catch limits. Although considered recreational, due to the fact that the fishery involves towed gear, *Sea Around Us* follows Martin (2012)'s recommendation that such fishing should be considered as large scale and therefore categorizes the activity as industrial.

A conservative estimate was derived based on an average effort of 120 fishing days per vessel, 280 vessels and average catches of 20 kg per fishing trip. The same parameters used to estimate discards by the commercial fleet were applied here.

#### Recreational/subsistence

Other removals that were taken into account are the recreational-subistence (sometimes referred to as artisanal) shrimp fisheries that operate from the beach (on foot and on horseback). We used detailed figures reported during WWII, when these fisheries were widespread practices for subsistence purposes by coastal residents, as a maximum estimate for this component. This fishery was considered to fulfil subsistence needs in the early period but to become mostly a recreational enterprise in the more recent years. Therefore, we applied an assumed breakdown of 80% subsistence/20% recreational in 1950 and interpolated to 10% subsistence/90% recreational in 2010.

Mortality that was not taken into account includes underwater discards such as tow path mortality or escape mortality caused by the gear, effect of changing or decreasing mesh size and other technological developments affecting by-catch of the gear. Ghost fishing caused by lost or abandoned trawl nets was considered negligible or zero (Depestele et al. 2012).

#### Recreational and Subsistence

Recreational fisheries in Belgium include recreational Crangon fishing, fishing from the coastline (angling from the beach, shrimp fishing on feet or on horseback, and the setting of passive nets along the low watermark) and sea angling. Recreational shrimp fishing was considered industrial due to the use of towed gear (Martín 2012) and is addressed in the Crangon fishery above.

#### Sea angling for cod and bass

The magnitude of recreational angling on the Belgian part of the North Sea (BNS) has so far only been addressed in a pilot study which estimated recreational angling for cod on the BNS at 100-200 t per annum (ILVO-Fisheries 2007). The pilot study was based on the outcomes of angling contests organized by the Associations of Anglers (VVHV), which counts approximately 2,000 members as

active sea anglers in 2006. In the present estimate, it was assumed that this form of sea angling has existed since 1970 (0 t), and a linear increase from was applied to a conservative estimate of 50 t in 1975, which remained constant throughout the reconstruction (2,000 anglers, 5 days at sea, 5kg catch). The 50 t-year<sup>-1</sup> was split proportionally between cod (60%) and sea bass (40%) each year. These estimates are in the same order of magnitude as those for the Dutch recreational sea angling for cod and eel (Van der Hammen and de Graaf 2012; Zimmermann et al. 2007).

#### Unreported flatfish catch by 'recreational' or semi-commercial fisheries

As reported for the Crangon fisheries, recreational flatfish fisheries exist in Belgium, which also operate from smaller vessels that are not part of the commercial fishing fleet. Although flatfish are targeted today, it is acceptable to believe that other species may have been targeted over the last few decades depending on their relative abundance on economic value. These fisheries have existed for at least 30 years (E. Hiele, pers. comm.), and for the current estimate it was assumed that they started in the 1970s. Regular surveys suggest that approximately 280 small vessels are involved operating from the 4 ports. A conservative estimate was derived based on an average effort of 120 fishing days per vessel, 280 vessels and average catches of 20kg per fishing trip. The same methods applied to estimate discards by the commercial fleet were applied to estimate discards in the recreational segment.

Reported landings in artisanal/subsistence catches during WWII were negligible for sole (less than 0.5 t per annum) and amounted to 2-19 t of plaice between 1941-1943 (Lescrauwaet et al. 2013 under review). Ghost fishing caused by lost or abandoned trawl nets was considered negligible or zero (Depestele et al. 2012). As in the Crangon fishery although they are generally considered recreational and 'semi-commercial', because the fishery utilizes towed gear, it is considered large scale (Martín 2012) and all catches from it are classified as industrial in this reconstruction.

Unreported catch and associated discards for each component of the *Crangon* fisheries from 2011-2014 were calculated following the assumptions and methods of (Lescrauwaet et al. 2015). For all other fisheries identified in (Lescrauwaet et al. 2015), the methods for estimating unreported catch and associated discards were carried forward to 2014 unchanged. Semi-industrial *Crangon* catches, recreational *Crangon* catches, and recreational catches of cod and bass were allocated 100% to the Belgian EEZ and ICES area 27.4.c.

## Results

Total reconstructed catches in Belgium for 1950-2010 were 1.47 t times the data officially reported by FAO for the same time period. Landings of the industrial sector accounted for nearly 70% of the total catch, with artisanal and recreational catches contributing 0.05% each. Subsistence fishing made up 0.01%. Discards were another major component, making up 30% of the total removals.

There was a small amount of recreational catch estimated for shrimp, Atlantic cod and seabass. Recreational increased slowly from 1.8 t in 1950 to 3.9 t in 1970. Then the cod and seabass fishery started up, causing the catch to jump up to 14 t and then increase to 58 t in 2010.

## Bermuda (UK)

The original technical reconstruction research was initially documented in Divovich et al. (2015), and was updated to 2014 by the *Sea Around Us*.

Bermuda has a long history of recreational fishing which dates back to the 1930s (Smith 1989). Nowadays, recreational fishing remains a popular social activity and also a source of supplemental food for local residents (in essence a modern form of 'subsistence' fishing). Recreational fish catch is not reported in national fisheries statistics and the characteristics of this sector and its impact on the marine environment are still unclear. In 2011, an island-wide survey was undertaken by Bermuda's Department of Environmental Protection's marine resource section to collect data on recreational catch composition and quantity, gear use, fishing platform, and location (DEP 2011). A prior survey conducted in 2008 (Sarkis et al. 2010) estimated that approximately 16,000 local residents of Bermuda participated in recreational fishing, with the majority (70%) fishing from the shoreline while the rest fished from boats. Total annual landings from the recreational sector were estimated at 287 t (DEP 2011), or around 70% of reported commercial landings in the late 2000s.

Recreational fishers are motivated by several factors, including relaxation, spending time with family, as well as the tradition, sport, and subsistence aspects of fishing (DEP 2011). According to the survey, fishing for food was cited as a motivation by 52% of respondents (DEP 2011). We identified this subset of fishers who fish for food as 'subsistence' fishers, which we define as those who fish for personal or family consumption as the primary driver. As such, their catch is allocated to the subsistence sector in this reconstruction. Most recreational fishers fished using hook and line, and targeted fish such as snappers, jacks, wahoo and tunas. The survey specifically omitted recreational fishing from charter fishing boats since they are managed as part of Bermuda's commercial sector, hence their catches are reported as part of commercial landings (Barrett 1991; DEP 2011).

### Charter fishing

Bermuda's sport fishing sector is a major attraction for international fishing enthusiasts, and thus provides high economic benefits. The peak fishing season is usually from May to October, but sport fishing trips occur throughout the year. There are three major billfish tournaments, plus two smaller events that focus on other species<sup>6</sup>. There are also other tournaments that are only open to locals and do not include billfish (Joanna Pitt, pers. comm.). One tournament season was able to generate an estimated USD 3 million in revenue from visiting participants<sup>7</sup>. The Bermuda Fishing Guide's charter directory listed 25 companies that offered charter fishing trips to various locations. The majority of charter fishing trips take place at offshore locations and target blue marlin (*Makaira nigricans*), tunas, wahoo, and dolphinfish (*Coryphaena hippurus*). Three charter fishing companies offered fishing closer to the island, targeting bonefish (*Albula vulpes*), hogfish (*Lachnolaimus maximus*), and other inshore species. Catch and release is practiced during fishing tournaments, and one charter fishing company specified support for tag and release fishing.

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<sup>6</sup> Sport Fishing in Bermuda. Available at: <http://www.gotobermuda.com/sportfishing/> [Accessed 17 February 2015].

<sup>7</sup> The Billfish Foundation. Potential Impacts of Bermuda's Marine Reserve on Sportfishing Tourism. Available at: [www.billfish.org](http://www.billfish.org) [Accessed 24 September 2014]

Local charter boats have been considered part of the ‘commercial’ fleet since 1975 because the retained catch is sold in order to keep the charter fee competitive given the high cost of fuel in Bermuda and because many charter vessels fish commercially when they don’t have charter bookings (Joanna Pitt, pers. comm.). Prior to 1975, charter fishing was more recreational in nature as the pelagic fish that were caught were not usually sold.

## Methods

### Unreported catch

Fishers’ intentional or unintentional misreporting of statistics and the lack of a validation process to monitor self-reporting can distort national fisheries statistics. This can be seen in the recreational fishery of Bermuda, where local catches generally go unreported. Recreational fishing in Bermuda has a strong subsistence component, therefore in this reconstruction we consider recreational fishing to have two subcomponents - ‘leisure’ and ‘subsistence’, whereby ‘leisure’ fishers are those that fish for relaxation, sport, or other social reasons, and ‘subsistence’ fishers are those that fish primarily to supplement their diet. In the following sections, we estimated catch from both the unreported subsistence sector and unreported recreational ‘leisure’ catch from 1950-2010.

Unreported recreational catch in Bermuda is composed of several different subsets of the population and aspects in the fishery, notably, (i) charter catch from 1950 – 1974 (as well as sports catch by locals and military personnel for the same time period), (ii) leisure catch by the local population from 1971-2010, and (iii) catch by foreign visitors who bring their own private vessels to fish in billfish tournaments.

#### (i) Charter boat catch, 1950-1974

Charter boats, as part of the commercial fleet, have reported their catch along with commercial fishing landings since 1975. However, sport fishing has existed in Bermuda since before WWII (Smith 1989), so there is value in accounting for the charter sector prior to 1975, which we have done here.

From 1950 to 1970, we considered estimated local ‘recreational’ catch to come mostly from subsistence fishing. Nonetheless, some fish were caught recreationally by locals and also by personnel stationed at the military bases in the form of sports fishing. It is reasonable to assume that the fishing patterns for this group mirror those for the charter sector of the era (Joanna Pitt, pers. comm.), and hence we have estimated this catch alongside charter catch, from 1950-1974.

Since most, albeit not all, charters catered to foreign visitors, we generated a representative time series of charter boat passengers from 1950 to 1974 using data on visitors to Bermuda. In 1950, there were 60,000 ‘transient visitors’ in Bermuda (Mowbray 1949) but, by the late-1970s (and early 1980s), between 330,000 and 430,000 visitors arrived annually by air alone (Bermuda Government 1973). In recent years, an estimated 10,000 US visitors, roughly 4% of total tourist arrivals, participated in fishing during their stay in Bermuda (Cox 2013), and US visitors made up about 72% of total tourist arrivals to Bermuda in 2010 (Dept. of Statistics 2013). Indeed, based on surveys done in 2008, 4-5% of tourists reported fishing during their visit (Sarkis et al. 2010). This relatively high proportion of tourists who report engaging in fishing can be linked to the cost of visiting Bermuda in recent years, with the market therefore being skewed towards those who can afford expensive activities such as charter fishing (Joanna Pitt, pers. comm.). Although vacationing in Bermuda was

more economically accessible during the tourist boom of the 1980s, Bermuda was considered more of an elite destination from 1950 through 1970 and so a similar rate of 5% of tourists engaging in fishing could be considered representative of this time period as well (Joanna Pitt, pers. comm.).

To model the time series of total tourists visiting Bermuda, we used the anchor points of 60,000 visitors in 1950 and 380,000 visitors in 1980, and for the years in between assumed a growth trend similar to that presented in (Luckhurst et al. 2003). Specifically, we assumed a slight growth in tourism from 1950 to 1960 (interpolated from 60,000 visitors to 90,000 visitors) and then a steep rise from 1960 onward to the estimated 380,000 visitors in 1980. Furthermore, to obtain a time series of the number of visitors engaged in fishing, we applied a variable rate of engagement in fishing to the population of total visitors, interpolated between 4% of visitors engaging in fishing in 1950 to 1% in 1980. We also added several boats of local fishers and military personnel to represent sports fishing from 1950 – 1974. For 1950, we assumed this equated to 100 fishers, increased incrementally to 1960 and 1970 based on the percentage growth of the top two ‘white collar’ occupations with respect to the total population, i.e., to an effort equivalent of approximately 135 fishers in 1960 and 154 in 1970, thereafter remaining constant at 154 until 1974.

Based on photos, which show a typical catch of about a dozen fish, the catch at that time focused on wahoo, yellowfin tuna and blackfin tuna, plus marlin to a rather lesser degree than today, as well as amberjack, Almaco jack, and barracuda (Joanna Pitt, pers. comm.). Virtually all of the fish caught would have been retained during this early time period; however, the catches on typical charters are likely slightly lower than those reported in Barrett (1991) because the boats were generally smaller (80% of registered fishing vessels in 1963 were under 30’ in length) and did not go out as far. In addition, the limited consumption of pelagic fish in those days provided less incentive to catch and retain as many fish as is presently the norm (Joanna Pitt, pers. comm.).

Although Barrett (1991) described average charter vessels catches comprising between 8 - 10 tuna and 8 - 15 wahoo, we used these historical photographs as guidance to estimate catch per fisher during the 1950s and 1960. For this early time period, given that smaller boats would have taken fewer passengers, we assumed each passenger would catch 2 kg of jacks (Carangidae), 7 kg of tunas (Scombridae) and 7 kg of wahoo (i.e., one quarter of a ‘typical’ charter boat catch). In addition, perhaps 40 small sharks (at 20 kg each) and 15 marlin (at 200 kg each – anything larger would likely have been released because it would be too hard to get into the boat) might be caught across the whole charter fleet. This resulted in an individual annual catch rate of 17.6 kg·person<sup>-1</sup>. To obtain estimates of charter catch from 1950 – 1974, we multiplied the catch rates for jacks, tunas, and wahoo by the number of fishers (both charter and local/military), plus total catch of sharks and marlin.

#### (ii) Leisure catch by the local population, 1971-2010

From 1971 onwards, we estimated local leisure catch and local subsistence catch as a whole and then divided catch by sector. Furthermore, we assumed that economic development reduced people’s dependence on subsistence fishing and the proportion of people pursuing the ‘leisure’ aspect of recreational fishing started to increase. Current levels of fishing for subsistence are at 52% (DEP 2011), and we assumed this rate back to 1980 when there was full employment in Bermuda due to the booming tourist trade (Joanna Pitt, pers. comm.). We thus divided total estimates proportionally, assuming the subsistence component decreased from 100% in 1970 to 52% by 1980,

thereafter remaining constant until 2010, with the difference being allocated to the ‘leisure’ (i.e., true recreational fishing) component, yet excluding other recreational activities such as charter operations.

Total recreational catch (including leisure and subsistence) from 1971 onwards was based on the proportion of Bermuda’s population that fished for recreation and an annual catch rate. In 2011, approximately 16,000 people, or about 25% of Bermuda’s resident population, participated in recreational fishing (both leisure and subsistence). We applied this proportion (25%) to calculate the number of recreational fishers in 2010, and kept this proportion constant all the way back to 1971. Population statistics for Bermuda were obtained for the years 1970, 1980, 1990, 2000 and 2010 (Dept. of Statistics 2013). Gap years were filled by linearly interpolating between anchor points, then annual population was multiplied by the proportion of recreational fishers (25%) to obtain a time series of recreational fishers in Bermuda from 1971-2010.

Recreational fishers were further broken down as either shoreline fishers or boat fishers. During the early time period of this study (1950 – 1970), it would appear that all fishing was done from shore due to a lack of resources for the low income population, however fishing from small sailboats or even rowboats was relatively common, and many people were involved in the boat building trade and capable of building their own small vessel (Joanna Pitt, pers. comm.). Hence, we assumed for the year 1970, 25% of the population fished from boats while the remaining 75% fished from shore. Thereafter, we linearly declined the proportion of people fishing from shore from 75% to 70% by 2010.

Average annual catch of shore fishers was 16.5 kg·person<sup>-1</sup>·year<sup>-1</sup> in 2011, while that of boat fishers was 23 kg·person<sup>-1</sup>·year<sup>-1</sup>. While this is representative for the year 2010, it is probable that these figures underestimate the true level of fishing in the earlier time period given that fishing for food was likely still a comparatively stronger motivation and exploitation of marine resources in the past was lower, which corresponds to a higher CPUE (catch per unit effort) in the past. Hence, we used our estimate of total subsistence catch from 1970 (389 t) as a baseline, and using the formula below (where the rates of shore and boat fishing in proportion to one another were held constant) were able to estimate the catch rates for each fishing platform in 1970:

$$Population_{boat} * B + Population_{shore} * S = Total\ subsistence\ catch$$

$$Population_{boat} * \left(\frac{23}{16.5}S\right) + Population_{shore} * S = 431$$

where  $Population_{boat}$  is the number of fishers in 1970 estimated to fish from boats (as stated above, assuming 25% of the population recreationally fished and of that an additional 25% fished from boats),  $Population_{shore}$  is the number of fishers in 1970 estimated to fish from shore,  $BB$  is the catch rate of boat fishers in 1970, and  $SS$  is the catch rate of shore fishers for the same year. By solving the above equations for  $SS$  and  $BB$ , we obtained catch rates in 1970 approximately 80% greater than in 2010, with average annual catch in 1970 of shore fishers estimated at 29.6 kg·person<sup>-1</sup>·year<sup>-1</sup>, while that of boat fishers at 41.3 kg·person<sup>-1</sup>·year<sup>-1</sup>. We linearly interpolated catch rates for shore fishers from 29.6 kg·person<sup>-1</sup>·year<sup>-1</sup> in 1970 to 16.5 kg·person<sup>-1</sup>·year<sup>-1</sup> in 2010 and for boat fishers from 23.0 kg·person<sup>-1</sup>·year<sup>-1</sup> in 1970 to 41.3 kg·person<sup>-1</sup>·year<sup>-1</sup> by 2010. Total recreational catch was then

calculated as the number of shore and boat-based fishers multiplied by annual shore and boat catch rates. Finally, total recreational catch was allocated to each of the subsistence and leisure subcomponents.

In order to allocate the catch to likely species caught, we estimated catch in these recreational and subsistence fisheries (as well as subsistence catch from 1950-1970) by the likely species of which the catch was composed. In a survey of recreational fishers in 2011, fishes that were most commonly targeted and caught included grey snappers (*Lutjanus griseus*), lane snappers (*Lutjanus synagris*), longfin yellowtail (*Seriola rivoliana*), yellowtail snapper (*Ocyurus chrysurus*), little tunny (*Euthynnus alletteratus*), hogfish (*Lachnolaimus maximus*), grunts (Haemulidae), porgies (Sparidae), triggerfishes (Balistidae), coney (*Cephalopholis fulva*), yellowfin tuna, wahoo, and Creole-fish (*Paranthias furcifer*) (DEP 2011). From 1975 to 2010, the percentage contribution of these species to total recreational catch was matched to Bermuda's national landings statistics, i.e., the artisanal sector, including adjustments for over and under-reporting. Table 5 indicates the recreational taxa and their associated artisanal taxa equivalent.

A small recreational lobster diving fishery has also been active since the 1960s, which was likely composed of about 100 divers each catching about 20 lobsters annually (equivalent to about 3 t·year<sup>-1</sup>), as opposed to the current time period where approximately 500 divers catch 5 lobsters per diver, or approximately 3.5 t annually (Joanna Pitt, pers. comm.). Thus, we estimated catch of Caribbean spiny lobster increased from 0 t in 1960 to 3 t in 1965, and then to 3.5 t by 1985. Since then, lobster catch has more or less remained constant except for the early 1990s (1991- 1995) when the commercial spiny lobster fishery was suspended and recreational lobster catch increased dramatically to between 5 to 7 t annually, most of which was likely subsistence in nature due to the lack of available lobster on the market (Joanna Pitt, pers. comm.). Hence, we assumed that from 1991-1995, an additional 2.5 t of lobster was caught annually for subsistence purposes. For all other years we used the equivalent proportions of recreational to subsistence catch as for the other species calculated above.

### (iii) Visiting foreign sports fishing boats

Foreign vessels are not permitted to charter in Bermuda waters. However, a number of elite private vessels visit Bermuda to fish in the three billfish tournaments, and catch from these fishers is not captured by the present reporting system. This is a fairly recent phenomenon, beginning approximately 15 years ago, and numbers have increased to a high of about 25 vessels in the last few years, from about 2 or 3 in the late 1990s (Joanna Pitt, pers. comm.). The start of the Big Game Classic in 2001 and the Billfish Blast in 2005 made it worthwhile for these elite vessels to make the trip from the US east coast, while prior to this there was only one billfish tournament.

**Table 5.** Common species in Bermuda’s recreational and subsistence catch paired with associated taxa names in artisanal landings statistics.

Recreational taxa name	Common name*	Local name(s) if different from common name	Associated taxa in landings data
<i>Acanthocybium solandri</i>	Acanthocybium solandri		<i>Acanthocybium solandri</i>
Balistidae	Triggerfishes		Marine fishes not identified
<i>Seriola rivoliana</i>	Longfin yellowtail	Almaco jack, bonito	<i>Seriola rivoliana</i>
<i>Euthynnus alletteratus</i>	Little tunny		Scombridae
Haemulidae	Haemulidae		Haemulidae
<i>Lachnolaimus maximus</i>	Lachnolaimus maximus		<i>Lachnolaimus maximus</i>
<i>Lutjanus griseus</i>	Lutjanus griseus		<i>Lutjanus griseus</i>
<i>Ocyurus chrysurus</i>	Ocyurus chrysurus		<i>Ocyurus chrysurus</i>
<i>Lutjanus synagris</i>	Lane snapper		<i>Lutjanus</i>
<i>Paranthias furcifer</i>	Paranthias furcifer	Barber	<i>Paranthias furcifer</i>
<i>Cephalopholis fulva</i>	Cephalopholis fulva		<i>Cephalopholis fulva</i>
Sparidae	Sparidae		Sparidae
<i>Thunnus albacares</i>	Thunnus albacares		<i>Thunnus albacares</i>

\*According to FishBase ([fishbase.org](http://fishbase.org))

Although data on the catch of these vessels is not available, a personal communication with Joanna Pitt, estimates the maximum catch from 22 vessels in 2010 (as there were 22 visiting sport fishing vessels in 2011) at 45 kg of tuna and 40 kg of wahoo per boat per day, with a conservative estimated fishing time of five days per visit / year (outside of tournament fishing). This corresponds to 5 tonnes of tunas and 4.4 tonnes of wahoo landed annually. In order to be more conservative, we applied a 75% retention rate to these catches, indicating a tuna catch of 3.7125 t in 2010 and 3.3 t of wahoo. We interpolated between 2 boats in 1997 to 22 boats in 2010, and applied the constant catch rate to this time series.

The unreported component of Bermudian fisheries consist of the recreational and subsistence sectors, often tightly bound together (Pitt and Trott 2013). The method used in (Jovanović et al. 2015) was carried forward unchanged to reconstruct unreported fisheries from 2011 to 2014, as there did not appear to be any large changes in Bermuda’s fisheries sector from 2010 to 2014. The portion of the recreational catch allotted to subsistence fishing remained constant, as well as the unreported recreational catch of *Panulirus argus*.

## Results

Bermuda’s reconstructed domestic catch totaled 53,400 t from 1950-2010, which was nearly twice (1.94 times) the landings reported in national landings data for the same period. Unreported catches were from the subsistence and recreational sectors, which totaled 18,100 t (33.9% of total catch) and 7,830 t (14.6% of total catch), respectively, from 1950-2010, while the remaining 51.5% of catch was reported small-scale commercial catch, i.e., artisanal catch.

## Bonaire (Netherlands)

The original technical reconstruction research was initially documented in Lindop et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

Domestic recreational and subsistence: Twenty-nine percent of Bonaire's households engaged in recreational fishing activities (Lacle et al. 2012). Of these, 15% participate 1-6 times a year, 2% 7-12 times, 8% fish more than once a month and 4% take part more than once a week. To estimate a participation rate, we assumed 15% of the population fished 3.5 times a year, 2% took part 9.5 times a year, 8% engaged 18 times a year (1.5 times per month) and 4% fished 73 times a year (1.5 times per week). We applied these rates to the annual population<sup>8</sup> and assumed the reported average catch rate of 1.5 kg catch per fisher trip from the survey applied to all trips. Lacle et al. (2012) found that 35% of those fishing did so for food, therefore the estimated total each year was split and 65% categorized as recreational (i.e., leisure being the prime driver), with 35% as subsistence (i.e., feeding one's family being the main driver).

Catch composition: According to Lacle et al. (2012), 80% of recreational fishing is from the shore, and consists to 86% of reef fish and 10% of pelagic fish. Lobsters make up 2%, as does baitfish. Species composition for the reconstructed recreational and subsistence catch was calculated using the same breakdown as the artisanal, but adjusted to accommodate the percentages above.

### Tourist recreational

The same protocols for estimating tourist recreational catch in Curaçao was applied to Bonaire, with tourists assumed to have started to arrive from the mid-1940s, when the first pier was built<sup>9</sup>. Tourist numbers were interpolated between 0 in 1945 and 25,200 in 1980, when records started.

For 2011 – 2014 Bonaire's portion of marine fishes nei is all artisanal and split into reef, pelagic, baitfish, and lobster containing 19 separate taxa following the 2010 proportions. The unreported subsistence catch for Bonaire was calculated based on the amount of fish taken home by the artisanal fishermen assuming that 31% of the artisanal catch is taken home. The recreational sector was based on population and tourist numbers and were split equally across 11 different taxa.

## Results

Bonaire's reconstructed catches for 1950-2010 were 2.9 times the data allocated as reported by the FAO on behalf of Bonaire for the same time period. Artisanal fisheries accounted for 56%, with the recreational sector making up 29%, followed by subsistence with 15%. However, the importance and contribution of recreational catches has increased over the last 60 years, while the artisanal contribution has declined. Overall, catches remained relatively constant, decreasing slightly from a peak of around 180 t·year<sup>-1</sup> in the mid 1950s to just under 160 t in 2010.

Pelagic species made up the majority of the catch, with wahoo (15%), great barracuda (*Sphyraena barracuda*; 11%), dolphinfishes (10%), yellowfin tuna (8%) and blackfin tuna (7%) being particularly important. Snappers (*Lutjanidae*; 6%) were the most important demersal taxon. 'Miscellaneous fish' was also a large part of the catch and includes mostly 'potfish' (Dilrosun 2004), which most likely is made up of a variety of reef fish.

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<sup>8</sup> [www.populstat.info](http://www.populstat.info)

<sup>9</sup> <http://bonaireresources.com/aboutbonaire/history.html> 8

## Bosnia and Herzegovina

The original technical reconstruction research was initially documented in Iritani et al. (2015), and updated to 2014 by the *Sea Around Us*.

### Methods

Subsistence and recreational catches made in Bosnia between 1950 and 2010 were estimated by applying half the per capita catch rate of coastal populations in Croatia to the number of coastal inhabitants in Bosnia. For the purpose of this study, areas within 10 km of the coast were considered coastal. Coastal population data for Bosnia were obtained for 1990, 2000, and 2010 from CIESIN (2012), and estimated for years prior to 1990 as the 1990 percentage of coastal to total Bosnian population, while intervening years were interpolated. For 1950 to 1959, total population data were taken from PopulStat (<http://www.populstat.info/>). For 1960 to 2010, population data was taken from The World Bank (<http://www.worldbank.org/>). All subsistence and recreational catches were assigned to family level taxa based on the taxonomic composition found in Croatia

For 2011 – 2014 the subsistence and recreational sectors were calculated using similar methods to Iritani et al. (2015). Since no new coastal population data is available for Bosnia-Herzegovina, we extrapolated the 2000-2010 population trends up to 2014. The recreational and subsistence per capita consumption rate was determined by taking half of the Croatian consumption rate and multiplying it by the coastal population. The family level of the taxonomic composition of the Croatia recreational catch was used, and the same taxonomic composition of the subsistence sector was used.

### Results

Bonaire's reconstructed catches for 1950-2010 were 2.9 times the data allocated as reported by the FAO on behalf of Bonaire for the same time period. Artisanal fisheries accounted for 56%, with the recreational sector making up 29%, followed by subsistence with 15%. However, the importance and contribution of recreational catches has increased over the last 60 years, while the artisanal contribution has declined. Overall, catches remained relatively constant, decreasing slightly from a peak of around 180 t·year<sup>-1</sup> in the mid-1950s to just under 160 t in 2010. Pelagic species made up the majority of the catch, with wahoo (15%), great barracuda (*Sphyraena barracuda*; 11%), dolphinfishes (10%), yellowfin tuna (8%) and blackfin tuna (7%) being particularly important. Snappers (Lutjanidae; 6%) were the most important demersal taxon. 'Miscellaneous fish' was also a large part of the catch and includes mostly 'potfish' (Dilrosun 2004), which most likely is made up of a variety of reef fish.

The total reconstructed marine catches made by Bosnian fisheries were 3,230 t between 1950 and 2010, which was around 35 times the 92 t officially reported by the FAO on behalf of Bosnia. Total catches increased from around 23 t·year<sup>-1</sup> in the 1950s to a peak of 79 t in the 1990. Following a decline during the conflict years, catches increased again to around 82 t in 2002 and have been steadily declining since to reach 73 t by 2010.

The subsistence (i.e., non-commercial) sector accounted for the largest component (72%) of total time series catches, and were all deemed unreported, while unreported recreational (19%) and reported and unreported artisanal landings (3% and 4%, respectively) catches contributed considerably less.

## Brazil

The original technical reconstruction research was initially documented in Freire et al. (2015), and updated to 2014 by the *Sea Around Us*.

### Methods

Brazil has no system of data collection for recreational catches. The reconstruction included catches from competitive events, based on an updated and extended version of the database compiled by Freire (2005). The second component of the reconstruction refers to daily recreational activities. We used data on human population size available in Table 1.4 from IBGE (2010) and fitted a Verhulst logistic equation in the format provided by Miranda and Lima (2010) to estimate the population each year.

Our entry point in the reconstruction is the 2011 national license database, which combines marine and inland recreational fisheries. The number of licenses for recreational fisheries in Brazil increased from 276,500 in 2011 to 400,847 in 2013, most of them issued in the southern states of São Paulo and Paraná. The percentage of licensed recreational fishers *versus* the total number of recreational fishers (licensed and non-licensed) obtained from local studies (Table 6) was then used to conservatively estimate the total number of recreational fishers in each state (Freire et al., 2014). The licensed/total recreational fisher percentages varied from 11% in Bahia to 56% in São Paulo and Paraná (Table 6). For those states where such a ratio was not available, we considered a national mean value of 13.5% (Freire et al. 2012). To adjust the number of recreational fishers, we considered only the proportion of fishers fishing in marine waters (estuarine, coastal, and offshore). This information was collected in a questionnaire answered online in 2009 and required to obtain the license (Table 7). Finally, we estimated total catch multiplying the number of fishers by the number of days fishing and by the mean daily catch for each fisher. The latter information came from local studies, when available, or from neighboring states: Bahia (K.M.F. Freire, unpublished data), Espírito Santo (Chiappani 2006), Rio de Janeiro (Couto 2011), São Paulo and Paraná (Atlantic & Fishing Project), Santa Catarina (Schork et al. 2010) and Rio Grande do Sul (Peres and Klippel 2005).

The start of the time series was originally defined as the year when the first fishing club was established in each state (Freire et al. 2014a). Here, we followed the same procedure but additionally assumed that in 1950 at least 20% of the catches observed in the year of establishment of the fishing club were caught by recreational fishers. Catches were then linearly interpolated in between those years. For those states where clubs were established very early (1950-1955), the same linear trend was used to estimate catches for the first five-six years (to avoid unrealistic sharp increase in catches).

For the states of Rio de Janeiro, São Paulo and Paraná, the procedure was more complex as there was detailed information for different sectors. Thus, we used the proportion among A, B and C license categories (as described in Freire et al. 2012), where category A includes only coastal, shore-based fishers, and B and C categories operating from boats. Category C includes spearfishing. Catches were estimated separately for these categories (A and B/C) considering different number of fishing days per year and CPUE (g/fisher·day) and finally they were added to represent total recreational catch for each state.

**Table 6:** Percentage of licensed recreational fishers fishing in marine waters (mangrove, sandy and rocky beaches, and offshore) by state and region in Brazil, based on the license database for 2009 Table 3: Percentage of licensed recreational fishers fishing in marine waters (mangrove, sandy and rocky beaches, and offshore) by state and region in Brazil, based on the license database for 2009 (Freire et al. 2014a)

Region	State	Percentage in marine waters
North	Amapá	27
	Pará	36
Northeast	Maranhão	39
	Piauí	46
	Ceará	55
	Rio Grande do Norte	83
	Paraíba	80
	Pernambuco	73
	Alagoas	74
	Sergipe	80
	Bahia	56
Southeast	Espírito Santo	69
	Rio de Janeiro	82
	São Paulo	21
South	Paraná	19
	Santa Catarina	66
	Rio Grande do Sul	36

**Table 7:** Marine recreational catch per unit effort (CPUE; g·fisher<sup>-1</sup>·day<sup>-1</sup>) by state in Brazil.

State	CPUE	Source
Amapá to Bahia	732.0	Freire (pers. obs.)
Espírito Santo	18.7	Chiappani (2006)
Rio de Janeiro	200.0	Esparrinha (2011)
São Paulo	200.0	Esparrinha (2011) for Rio de Janeiro
	3,468.8 <sup>a</sup>	Motta et al. (2016)
	4,541.0 <sup>b</sup>	Moro & Motta (pers. obs.)
	5,627.3 <sup>c</sup>	Moro & Motta (pers. obs.)
	200.0	Esparrinha (2011) for Rio de Janeiro
Paraná	3,468.8 <sup>a</sup>	Moro & Motta (pers. obs.)
	4,541.0 <sup>b</sup>	Moro & Motta (pers. obs.)
	5,627.3 <sup>c</sup>	Moro & Motta (pers. obs.)
	533.9 <sup>d</sup>	Peres and Klippel (2005) for Rio Grande do Sul
Santa Catarina	533.9 <sup>d</sup>	Peres and Klippel (2005) for Rio Grande do Sul
	3,325.0 <sup>e</sup>	Schork et al. (2010)
Rio Grande do Sul	533.9	Peres and Klippel (2005)

a. Estuarine; b. Coastal; c. Oceanic/offshore; d. Category A licenses (no boat); e. Category B and C licenses (boats and spearfishing).

Recreational fishers in Brazil spend on average  $15.3 \pm 3.9$  days·year<sup>-1</sup> fishing (mean  $\pm$  SD), with the lowest values in the northern region (8.8-10.6 days·year<sup>-1</sup>) and the highest in the northeastern region (14.6-32.0 days·year<sup>-1</sup>) (Table 6). Catch rates for shore-based fishers varied from 18.7 g·fisher<sup>-1</sup>·day<sup>-1</sup> in the state of Espírito Santo to 732 g·fisher<sup>-1</sup>·day<sup>-1</sup> in the state of Bahia (Table 7). We replaced missing data with the estimate for the closest state with available information. For boat-based fishers, catch rates ranged from 3,468 to 4,541 g·fisher<sup>-1</sup>·day<sup>-1</sup> (data available for the states of

São Paulo, Paraná, and Santa Catarina, Table 7). Thus, the total catch for recreational fishers during normal recreational fishing activities (i.e., not at organized events), here called 'total catch daily activity' (TCDA) in tonnes was estimated as:

$$\text{TCDA (t)} = \text{Number of fishers} \times \text{Number of days fishing in marine waters} \times \text{Catch rate} \cdot 10^{-6}$$

A second component of recreational fisheries consists of organized competitive fishing events (Schramm et al. 1991) that regularly take place across the country. For this component, we used a database that has been compiled since 2001 and updated annually (Freire 2005). For years with events that were missing records, we estimated likely catches using linear interpolation to obtain the 'total catch from fishing events' (TCFE) in tonnes. Thus, total recreational catch (TRC) for each year was estimated as:

$$\text{TRC}_{\text{year}} = \text{TCDA}_{\text{year}} + \text{TCFE}_{\text{year}}$$

This procedure was repeated for each of the 17 coastal states for the period 1950-2010, as detailed in Freire et al. (2014a), and globally integrated with other fisheries sector catches in Pauly and Zeller (2016a; 2016b).

The recreational sector was steadily increasing leading up to 2010, so a linear regression was used to extrapolate up to 2014.

The reconstructed recreational catch tonnages were not taxonomically disaggregated to species level, given the very high diversity of species caught along the very long Brazilian coast that spans three Large Marine Ecosystems (Pauly et al. 2008) and eight Marine Ecoregions (Spalding et al. 2007). Furthermore, studies with representative and reliable information on the taxonomic composition of recreational catches in Brazil are still rare. The well documented complexity and extremely high inconsistency of taxonomic nomenclature in Brazil (by highly localized and inconsistent common names) makes it extremely difficult to obtain reliable and actionable information on taxonomic composition (Freire and Pauly 2005). Results of recreational fishing tournaments usually do not report catch per species but instead total number and total weight of all fishes caught by each fisher in each event (Freire et al. 2016). The only exception is for offshore events, which record catches by species. However, many of these records have been lost or are not available.

## Results

Total estimated catches indicated an increase throughout the period analyzed. Freire (2005) indicated that results of competitive events are lost and earlier results are probably missing. Other sources of error include absence of information on the proportion of license holders in relation to total number of anglers. For many states, a national estimate had to be used (Freire et al. 2012). The same occurred with estimates of daily catch per recreational fisher, as values for neighbor states were used when local data were unavailable. Catches were higher for the southern region, which are dominated by the state of Santa Catarina. The estimates of CPUE may be overestimated and results should be revisited when more local data become available. Finally, for competitive events, there is no national database with catches originating from those events. Thus, there are many missing values that have been only recently reconstructed in other small projects (see, e.g., Freire et al.

2014b). However, for most of the states, this reconstruction is not complete at this point and only results readily available were used.

The national trend was defined mostly by values estimated for southern Brazil. This trend was mainly defined by catches estimated for the state of Santa Catarina where local data available indicated high catch rates for recreational fishers of category B (boatbased) (Schork et al. 2010). Catches for the north region were the lowest, even though it is known that many fishing events are promoted in the state of Pará (Frédou et al. 2008). However, for that region it is expected that most recreational fisheries are practiced in fresh waters. No detail on catch composition was provided, as this information is not available yet for most states, with some exceptions, such as select regions in the states of Bahia, São Paulo, Santa Catarina, and Rio Grande do Sul (Barcellini et al. 2013; Nascimento 2008; Peres and Klippel 2005; Schork et al. 2010).

## British Indian Ocean Territory (UK)

The original technical reconstruction research was initially documented in Zeller and Pauly (2014), and updated to 2014 by the *Sea Around Us*.

### Methods

Recreational fishing occurs in the British Indian Ocean Territory (also called Chagos Archipelago) only in relation to two opportunities: 1) the military personnel and civilian contractors working on the US military installation on the island of Diego Garcia; and 2) recreational yachts that stop off in the Chagos Archipelago during their transit of the Indian Ocean. As (2) consists of a relatively small number of boats with small crew and relatively short stays, we focused our estimation entirely on recreational fishing by personnel on Diego Garcia. Available data on the number of people stationed on Diego Garcia is difficult to obtain, as much relates to operational security by the US military and is thus not readily accessible. However, The CIA factbook states that in 2004 about 4,000 military personnel and civilian contractors were stationed on Diego Garcia<sup>10</sup>. GlobalSecurity.org suggests that normally the island is home to about 1,700 military personnel and 1,500 civilian contractors, i.e., around 3,200 personnel<sup>11</sup>. The British Foreign & Commonwealth Office indicates that in 2012, the population of Diego Garcia amounted to 2,800 personnel<sup>12</sup>.

As construction of the military installation started in 1971 and major developments were completed by the early 1980s, we assumed zero military personnel or civilian contractors in 1971, increasing to 2,000 personnel by 1985 and remaining at that level to the year 2000. We then assumed an increase to 4,000 in 2001 lasting to 2009 (reflecting increased activities during the Iraq and Afghanistan wars), and a subsequent reduction to 2,800 in 2010 (Table 8).

Data made available by the British Indian Ocean Territory authority within the British Foreign & Commonwealth Office indicated the level of recreational catches for some years. We converted these into hypothetical per capita recreational catch rates and applied these to the assumed

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<sup>10</sup> <https://www.cia.gov/library/publications/the-world-factbook/geos/io.html> [Accessed: November 12, 2012]

<sup>11</sup> <http://www.globalsecurity.org/military/facility/diego-garcia.htm> [Accessed: November 12, 2012]

<sup>12</sup> <http://www.fco.gov.uk/en/travel-and-living-abroad/travel-advice-by-country/country-profile/asia-oceania/british-indian-ocean-territory> [Accessed: November 12, 2012]

personnel levels on Diego Garcia to derive a total time series of estimated recreational catches from 1972 to 2010 (Table 8).

The taxonomic composition of the recreational catches was derived based on information in Zeller et al. (2005) which reconstructed recreational catches on Johnston Atoll in the Pacific, that also hosts US government installations with military personnel and civilian contractors (Table 9).

The reconstructed catch data were reconciled with data reported on behalf of the British Indian Ocean Territory (Chagos Archipelago) to the FAO, which consisted only of small tonnages of several species of scombrids and the miscellaneous category ‘marine fishes nei’.

All catches from 1972-2010 previously reconstructed were from the recreational sector of the military forces and their associated contractors currently occupying the islands. The catch was thus carried forward to 2014 assuming the per capita recreational catch rate (24.1 kg·person<sup>-1</sup>·year<sup>-1</sup>) remained constant from 2010-2014. The population of the island was linearly interpolated from the 2010 level of 2,800 residents to the present of 3,000 residents<sup>13</sup>. The taxonomic breakdown of recreational catches was held constant, but was aligned with the current and retroactively updated FAO data where relevant.

**Table 8.** Assumed and derived population (military personnel and civilian contractors), *per capita* recreational catch rates and total recreational catches on Diego Garcia, from first establishment of the military installation in 1972 to 2010. A dash (-) indicates data interpolation.

Year	Population	Catch rate (kg·person <sup>-1</sup> ·year <sup>-1</sup> )	Catch (t)
1971	0	0.0	0.0
1972	-	14.5 <sup>a</sup>	2.1
1973-1984	-	-	-
1985	2,000	-	-
1986-1997	2,000	-	-
2000	2,000	-	47.5
2001	4,000	24.1 <sup>b</sup>	96.4
2002-2009	4,000	24.1	96.4
2010	2,800	24.1	67.5

<sup>a</sup> Assumed *per capita* rate based on recreational catch of 28.9 t reported by the British Foreign & Commonwealth Office for latter years, here assumed to apply also as catch rate to 1972 <sup>b</sup> Based on recreational catch of 96.4 t reported by the British Foreign & Commonwealth Office.

## Results

The catch reconstruction of what can be termed ‘domestic’ catches by Chagos Archipelago fisheries in the EEZ or EEZ-equivalent waters of the British Indian Ocean Territory suggested that over 3,400 t were caught between 1950 and 2010, exclusively by subsistence and recreational fisheries. This contrasts with 286 t being reported by the UK on behalf of the British Indian Ocean Territory to the global community via FAO for the same time period. Thus, total reconstructed domestic catches were likely around 12 times higher than reported data suggest for this time period.

<sup>13</sup> <https://www.cia.gov/library/publications/the-world-factbook/geos/io.html> (Accessed July 6, 2016)

These catches, however, are low compared to the large pelagic catches reported as taken by large-scale fleets from these waters, which were reported as, for example, over 20,000 t in 2004/2005, and an unknown, but potentially significant illegal catch (Koldewey et al. 2010). These large pelagic catches taken from the same waters by foreign vessels through licensed access agreements, or illegally, are not considered here<sup>14</sup>.

The present reconstruction clearly illustrates the fundamental shift from subsistence fishing by the former civilian employees associated with past plantation activities during the first two decades of the present time period, to exclusively recreational fishing by the military and civilian personnel on the only remaining inhabited island (Diego Garcia) over the more recent four decades. Subsistence catches were highest (around 90 t·year<sup>-1</sup>) at the start of the time period (early 1950s) when the largest number of employees still resided on the plantations. Subsistence catches declined thereafter to 50-60 t·year<sup>-1</sup>, in line with the declining population associated with the demise of plantations in the Territory and in preparation of the de-population as part of the UK-US agreement to establish a military installation on Diego Garcia.

With the arrival of military engineers and associated personnel, followed later by civilian contractors

**Table 9.** Assumed and derived taxonomic composition of subsistence and recreational fisheries catches in the Chagos Archipelago. Subsistence catches relate to the civilian population associated with copra plantations between 1950 and 1972, while recreational catches relate to military personnel and civilian contractors associated with the US military installation on Diego Garcia (from 1972 to 2010).

Taxon	Subsistence (%)	Recreational (%) <sup>1</sup>
Carangidae	15	25
Scombridae	-	25
Lutjanidae	10	10
Lethrinidae	10	-
Serranidae	15	20
Cephalopods	15	0
Molluscs	15	0
Crustaceans	15	0
Others	5	20

<sup>1</sup> Composition modified from Zeller *et al.* (2005).

stationed on Diego Garcia, fishing emerged as a recreational activity for residents. This suggested a gradual increase in recreational catches from around 20 t·year<sup>-1</sup> in the early 1980s to over 40 t·year<sup>-1</sup> by the 1990s. Based on the assumption that the number of personnel stationed on Diego Garcia increased substantially with the terrorist events of 2001 and the subsequent wars in Afghanistan and Iraq, we also estimated that recreational catches likely increased to around 90 t·year<sup>-1</sup>, before declining slightly at the end of the time period due to an assumed draw-down of personnel with the approaching end of US military engagements in Afghanistan and Iraq.

<sup>14</sup> *Sea Around Us* is reconstructing global large pelagic catches through a separate process, and the information on this topic derived through the present research, including the information on tuna catches in BIOT presented by Koldewey et al. (2010) will be incorporated in this separate process

Taxonomically, the reconstruction suggested that besides readily caught reef fishes such as serranids, lutjanids, lethrinids and reef-associated pelagic (e.g., carangids), invertebrates dominated early subsistence catches, mainly cephalopods, molluscs and crustaceans. The taxonomic composition of catches changed with recreational fishing, which likely focused more on pelagic species (i.e., reef-associated scombrids and carangids), which are known as challenging species to land on recreational rod-and-reel gears.

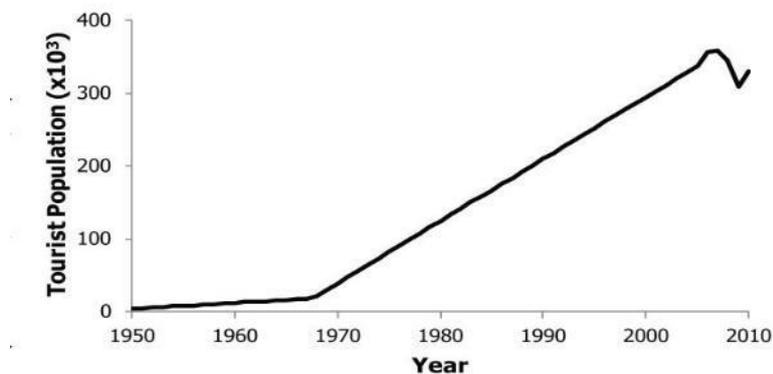
## British Virgin Isl. (UK)

The original technical reconstruction research was initially documented in Ramdeen et al. (2014a), and updated to 2014 by the *Sea Around Us*.

### Methods

We applied a minimal recreational catch per tourist to estimate catches made by the recreational sector.

During the 1975 assessment of BVI fisheries, Klausung (1978) conservatively assumed catches from the recreational sector were 23 t for that year. Assuming the recreational sector is comprised mainly of tourists, we divided this catch of 23 t by the number of stop-over tourists in the BVI5 in 1975 to get an average per capita recreational catch rate of  $0.001 \text{ t} \cdot \text{tourist}^{-1} \cdot \text{year}^{-1}$ . Assuming conservatively that this rate remained constant, we combined this with the number of annual stop-over tourists (Figure 1), to estimate catches from BVI's recreational sector for the period 1950-2010.



**Figure 1.** Stop-over tourist population for the British Virgin Islands during the period 1950-2010.

### Taxonomic composition of catches

Island specific quantitative catch composition data for the near-shore were unavailable in the BVI fisheries literature accessed for this study. FAO data for BVI consists of 15 taxonomic groups from 13 families. A detailed breakdown of catches from Puerto Rico in the year 1975 was presented in the appraisal report on the fisheries of the BVI (CDB 1980). We applied the Puerto Rico catch breakdown to the year 1950 and took the average FAO breakdown for 2001-2010 and applied it to the year 2010. Given that the FAO breakdown only consisted of 13 families, whereas the Puerto Rico

breakdown included 26 families, we further disaggregated the FAO breakdown based on our knowledge of changes in herbivores on Caribbean coral reefs and popularity of certain reef fishes in diets. The assumed and derived taxonomic breakdown of the catch can be seen in Table 10.

For the 2011 – 2014 update the recreational fishery was reconstructed based on the 2010 catch rate by tourists and updated information on the number of tourists obtained from Caribbean tourism statistics.<sup>15</sup> Improved population data is now available and was used to update landings from the near shore fishery sector throughout the time series.<sup>16</sup> The number of fishers was recalculated with the updated population information using the original methods. The sectoral split for the near shore fishery in 2010 was carried forward to 2014. Landings for each sector were disaggregated for 2011-2014 using the taxonomic breakdown from 2010.

**Table 10.** Derived taxonomic breakdown for the near-shore fisheries of British Virgin Islands.

Family	Percentage composition	
	1950	2010
Balistidae	2.00	2.30
Carangidae	1.20	2.30
Carcharhinidae	0.04	0.02
Centropomidae	0.90	0.50
Clupeidae	0.60	2.30
Exocotidae	0.40	0.50
Gereidae	0.40	4.60
Haeumulidae	18.50	4.60
Holocentridae	0.50	2.30
Labridae	1.00	2.30
Lobster	8.30	7.30
Lutjanidae	1.20	7.30
<i>Lutjanus analis</i>	1.50	2.30
<i>Lutjanus synagris</i>	2.90	2.30
<i>Lutjanus vivanus</i>	12.70	6.90
<i>Ocyurus chrysurus</i>	3.90	23.90
Miscellaneous marine fishes	4.80	4.60
Mullidae	7.10	6.90
Octopus	0.90	2.30
Ostraciidae	0.60	3.70
Scaridae	8.30	4.60
Scombridae (Mackerels)	3.30	0.05
Serranidae	11.30	0.50
Shellfish, whelks	0.80	4.60
Sparidae	0.90	0.50
Sphyraenidae	1.00	0.50
Strombidae	4.90	0.30

## Results

Despite increased vigilance in monitoring and enforcement, our reconstructed catches were 2.3 times higher than those reported to the FAO over the 1950-2010 time period, and for the most recent decade the discrepancy was still 940 t-year<sup>-1</sup> (or 65%). Our study of total reconstructed

<sup>15</sup> <http://www.onecaribbean.org/statistics/>

<sup>16</sup> <http://data.worldbank.org>

catches for the BVI contains under-reported catches from the near-shore fishery, which is the major fishing sector in the islands (Alimoso and Overing 1996; CDB 1980), as well as unreported catches from a popular recreational sector. To what extent mis- or under-reporting occurs also in the offshore pelagic sector could not be determined in the present study, but it is likely. Furthermore the discards from this sector should not be overlooked.

There seems to be some distrust by the Conservation and Fisheries Department, which collects near-shore catch data but treats it as confidential, and does not report it to the FAO. Such withholding of data on a public resource is surprising and should be rectified by the responsible authorities. In addition, catches from the recreational sector are not being captured by the present data collection system. Reconstructed recreational catches amounted to approximately 1,800 t for the period 1950-2010. Thus, the impact of tourists is being underestimated. This should be of particular concern for islands such as the BVI, where tourist populations are an order of magnitude greater than local resident populations, and where tourist experience is a major economic factor.

## Brunei Darussalam

The original technical reconstruction research was initially documented in Cinco et al. (2015), and updated to 2014 by the *Sea Around Us*.

### Methods

#### Unreported catch

Total marine fish landings in Brunei that are recorded in national fisheries statistics are only partially reported to the FAO; thus the unreported portion is treated as 'unreported catch' (with respect to FAO data) in this reconstruction. Unreported catches in Brunei originate from the following sources: i) unlicensed and part-time small-scale fishers; ii) the industrial sector; iii) discards; iv) illegal fishing; and v) recreational fishers.

#### Small-scale catch

Small-scale sector catch statistics from 1950-2010 were provided by the DoF. These data account for unregistered fishers, whose numbers have been much reduced in recent years (E. Cinco, pers. obs.). For validation, a second, independent estimate of small-scale catches was conducted.

Total catch from the small-scale sector ( $C_{SS}$ ) from 1950-2010 was also estimated on the basis of local fish consumption as:

$$C_{SS} = P * F * SS$$

where  $P$  is Brunei's total population,  $F$  is the per capita fish consumption, and  $SS$  is the percentage of fish that is caught by the small-scale sector.

Fish consumption was 35 kg·person<sup>-1</sup>·year<sup>-1</sup> and 38 kg·person<sup>-1</sup>·year<sup>-1</sup> in 1985 and 1990 respectively (derived from Silvestre et al. 1992), continued to rise to 40 kg·person<sup>-1</sup>·year<sup>-1</sup> in 2002 (Mohd Ariff and Bakeri 1998) and was 47 kg·person<sup>-1</sup>·year<sup>-1</sup> in 2010 (Lo 2013). We applied the 1985 fish consumption rate to all years from 1950 to 1985, and linearly extrapolated values between these anchor points.

The catch estimated through per capita fish consumption rates was only used to validate the data and was not used in the final database. The proportion of fish caught by the small-scale sector (SS) was calculated from Brunei fish catch data provided by the DoF, where total catch was broken down by small-scale and industrial sectors.

### Recreational fishery

We start accounting for recreational catches in 1970, assuming that the sector established its presence in the same year as that in neighboring Malaysia (Teh and Teh 2014a). Interest in marine sport fishing in Brunei has grown considerably in the past 10 years and the sector is expanding (Airudin 2013). Recreational fishers are required to obtain a license that permits fishing for 3 days, but this requirement does not appear to be strictly enforced. Some recreational fishers may be registered among part-time fishers, who are given a one year fishing license. Data on the number of issued recreational licenses were not readily accessible and limited to 3 years - 2007, 2008 and 2010, in which there were 165, 177, and 165 registered recreational fishers, respectively. We found no strong evidence of catch and release fishing, although it is supported by some local sport fishing operators (Airudin 2013).

The only other indication of the number of recreational fishers we could find was a report of 240 participants in a sport fishing competition in 2009 (Anon 2009a). In the United States, the percentage of recreational fishers who participated in tournaments varied from 3% for catfish anglers in North Carolina in 2011 (Responsive Management 2012), to between 0% and 9% for freshwater fishers in Texas between 1989-1997 (Hunt and Ditton 2002). As we were more interested in recreational fishers' tendency to participate in tournaments rather than the type of fishing that took place, and further due to lack of data on fishing tournament participation rates in Asia, we applied the United States rates to Brunei. We assumed that the number of participants in the 2009 fishing competition represented no more than 10% of recreational fishers in Brunei. This resulted in 2,400 recreational fishers in 2009, or 0.62% of the country's total population. To account for growth in the sport fishing sector in the past decade (Airudin 2013), we halved the proportion of recreational fishers (i.e., 0.3%) in 2000 and linearly increased forward to the anchor point in 2009, which was then kept constant to 2010. We assumed that from 1970 to 1999, the proportion of recreational fishers remained the same as that in 2000.

Recreational catch: We searched the internet for photo documentation of recreational fish catches in Brunei (e.g. Brunei Sport Fishing blog URL: <http://bruneisportfishing.blogspot.ca/>) and estimated the weight of fishes by approximating their length and applying the length-weight relationship ([www.FishBase.org](http://www.FishBase.org)). Fishes caught included brackish water fish such as barramundi (Latidae), mangrove jack (Lutjanidae), grouper (Serranidae), grunts (Haemulidae), jacks (Carangidae), tuna (Thunnidae), mackerels (Scombridae), rays and at least one hammerhead shark. All assessed fishes were caught using fishing lines from shore-based locations along Brunei's coast or from boats in open water. Based on this qualitative assessment, we estimated an overall average catch of 6 kg-fisher<sup>-1</sup>·trip<sup>-1</sup>, and further assumed that recreational fishers fished 2 times per month, 10 months per year<sup>17</sup>, to arrive at an annual recreational catch rate of 120 kg-fisher<sup>-1</sup>. Total annual catch from

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<sup>17</sup> <http://www.fredfishing.com/fishcomp/news2009/bb/bbfishcomp.html>. Accessed 25 March 2014.

the marine recreational sector was then estimated by multiplying the number of recreational fishers by the annual catch rate.

#### Catch composition

Recreational catch composition was approximated on the basis of photos posted on a sport fishing website ([www.bruneifishing.com](http://www.bruneifishing.com)), which suggested that most fishers fished from shore, with typical catches consisting of demersal fishes. Pelagic fishes such as marlins, tunas, jacks, and Spanish mackerels are reportedly abundant in offshore fishing grounds (Bahrum 2009). Given the absence of data, we assumed that a major proportion (i.e., 80%) of recreation catch consisted of demersals from shore-based fishing and the remainder (i.e., 20%) of pelagic fish. We then evenly weighted the major fish groups within the two categories, i.e., 16% to each of sea catfish (Family Ariidae), barramundi (Latidae), emperors (Lethrinidae), snappers (Lutjanidae), groupers (Serranidae); and 5% each to jacks (Carangidae), marlins (Istiophoridae), mackerels (Subfamily Scombrinae) and tunas (Thunninae).

Recreational landings were calculated for 2011-2014 using the 2009 national participation rate of 0.62% and the per capita catch rate of 120 kg/fisher estimated by the original reconstruction. Updated population data was acquired from World Bank for 2011-2014. Total demand for seafood was estimated using the 2010 consumption rate of 47 kg/person/year multiplied by updated population data. Of the total catch consumed by Brunei Darussalam's population, 68% was estimated to be caught by small-scale fisheries as determined by the original reconstruction.

#### Results

Brunei's reconstructed domestic catch increased from an average of 2,900 t·year<sup>-1</sup> in the 1950s to an average of 17,000 t·year<sup>-1</sup> in the 2000s. This estimate is 4 times the landings reported by the FAO on behalf of Brunei. A further 20,600 t was taken illegally from Brunei's waters since the early 1970s.

Unreported domestic catches totalled 369,000 t during the period of the reconstruction, with about 79% stemming from small-scale artisanal and subsistence fishing, followed by industrial fishing (6.5%), discards (14%), and recreational fishing (1.3%). Reconstructed industrial landings (discards not included) grew most between 1977 and 1987, when they comprised on average 41% of reconstructed total catch compared to 20% in the late 2000s. Catches from the 1950s to early 1960s were entirely small-scale in nature, but in the 2000s, this contribution averaged 64% of reconstructed total catch, primarily from artisanal (i.e., small-scale commercial) fishing.

While coarse, this reconstruction provides a first attempt at quantifying the catch of marine recreational fishers in Brunei. The popularity of recreational (sport) fishing has increased in the past decade, but little is known about the impact of this sector on local stocks. Despite a licensing requirement, there are no reliable records of the number of recreational fishers in Brunei, nor their catch (Ebil 2013). We estimated that this sector caught around 4,800 t of fish in the period 1970 to 2010, representing about 1.3% of reconstructed total catch. Besides local recreational fishers, Brunei is moving towards becoming a regional fishing destination (Bahrum 2009) This as yet untapped 'tourism' market segment was not accounted for in this reconstruction, but is likely to become more prominent in the future (Bahrum 2009).

## Bulgaria

The original technical reconstruction research was initially documented in Keskin et al. (2015), and was updated to 2014 by the *Sea Around Us*.

### Methods

Recreational fishing is understood here to mean fishing primarily for sport or enjoyment, while subsistence fishing is understood to mean fishing for the primary purpose of providing protein for self- or family-consumption. While the two sectors are difficult to separate, it is generally understood that subsistence fishing increasingly evolved into recreational fishing, as incomes increased and food security was not a prime concern.

In Bulgaria, recreational fishing is most popular from April to June, and from September to November. It occurs in inshore waters and targets gobies (Gobiidae), grey mullets (Mugilidae), horse mackerel, bluefish, bonito, turbot and Mediterranean horse mackerel and garfish (*Belone belone*). However, no data on the number of fishers and/or their catch rates or amounts have been collected in Bulgaria for this sector for the period 1950-2010.

There has been both recreational and subsistence fishing in Bulgaria for the 1950 to 2010 period. Since no data have been collected in Bulgaria on this topic, estimated catch rates from the neighboring Turkish portion of the Black Sea coast were used as a starting reference point (Ulman et al. 2013b) to estimate recreational and subsistence catches, i.e.  $0.258 \text{ t} \cdot \text{fisher}^{-1} \cdot \text{year}^{-1}$  in 1950 and  $0.129 \text{ t} \cdot \text{fisher}^{-1} \cdot \text{year}^{-1}$  in 2010. To derive the number of recreational/subsistence fishers for Bulgaria, we assumed that in 1950, 2% of the coastal population fished either recreationally and/or for subsistence purposes, and this rate was linearly decreased to 1% of the coastal population by 2010 due to the declining availability of larger fish. To derive the coastal population, we started with total population data from Populstat ([www.populstat.com](http://www.populstat.com)). We assumed that only people living within 20 km from the coast were involved in these fisheries. Coastal population however, was only available for 100 km from the coastline (CIESIN 2012). In order to estimate how much of this population is contained within 20 km of the coast, we conservatively assumed 25% of the 100 km population, as the population will be denser closer to the coast. The catch rates used for Bulgaria were 50% of those used for Turkey in 1950, i.e.,  $0.129 \text{ t} \cdot \text{fisher}^{-1} \cdot \text{year}^{-1}$ , and 80% in 2010, i.e.,  $0.103 \text{ t} \cdot \text{fisher}^{-1} \cdot \text{year}^{-1}$ , since recreational fishing appeared to be less intensive than in Turkey. We also made an adjustment to the catch in the early 1990s, as all fisheries were affected by the ctenophore invasion and the collapse of the pelagic fishery. Therefore, from 1989-1991, we decreased the catch by 75%. We then interpolated between the new 1991 value and 1993 as there was a quick recovery period. In order to assign the catches to the two sectors we assumed that in 1950, 70% of these catches were taken for subsistence purposes, which was linearly decreased to 30% of these totals being taken for subsistence purposes by 2010, and the remaining catches were assigned to the recreational fishery. Sturgeon, bonito, mackerel, bluefish, turbot, horse mackerel, grey mullet and gobies were the main recreational/subsistence taxa for the 1950-2010 period (Table 11).

**Table 11.** Assumed catch composition (%) for recreational and subsistence catches in Bulgaria from 1950 – 2010.

Taxon	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2010
Bonito	35	30	5	1	1	2
Atlantic Mackerel	25	22	5	2	0	0
Bluefish	15	20	10	2	1	2
Horse mackerel	3	3	50	60	50	35
Grey mullet	5	5	15	20	23	30
Goby	2	2	13	15	25	30
Turbot	10	15	1	0	0	1
Sturgeon	5	3	1	0	0	0

The original methods and ratios determined for 2013 by (Keskin et al. 2015) were carried forward to 2014 unaltered. For recreational and subsistence fishing, the trend in landings for 2011-2013 was extrapolated to 2014.

## Results

The reconstructed total catch consisted of reported industrial landings (51.1%), unreported industrial landings (38.3%), industrial discards (3.1%), reported artisanal landings (5.1%), unreported artisanal landings (0.7%), artisanal discards (0.1%), subsistence catches (0.85%), and recreational catches (0.75%).

### Recreational and subsistence sectors

Reconstructed total recreational and subsistence catches each contributed 0.75% and 0.85% to the reconstructed total catch from 1950 to 2010. Recreational catches increased from almost 90 t·year<sup>-1</sup> in 1950 to 120 t·year<sup>-1</sup> in 1988, followed by a rapid decline in the late 1980s to early 1990s. Catches increased again in the mid-1990s up to 110 t·year<sup>-1</sup> in 1993 and decreased slightly to 87 t·year<sup>-1</sup> by 2010. Subsistence catches decreased gradually from just over 200 t·year<sup>-1</sup> in 1950 to 97 t·year<sup>-1</sup> in 1988. Again, catches decreased sharply in the late 1980s to early 1990s but increased again to almost 78 t·year<sup>-1</sup> in 1993. Catches decreased to just less than 40 t·year<sup>-1</sup> by 2010. Both sectors were assumed to have the same species composition. Overall, Mediterranean horse mackerel (*Trachurus mediterraneus*) constituted the largest portion of the catch with 30% over the 1950 to 2010 time period. Mediterranean horse mackerel increased from 3% contribution in the 1950s and 1960s, to 50% and 60% in the 1970s and 1980s, respectively, before decreasing to 35% in the 2000s. Other important contributing taxa were bonito (15%), grey mullet (Mugilidae; 15%), gobies (Gobiidae; 12%), mackerel (*Scomber scombrus*; 11%), bluefish (*Pomatomus saltatrix*; 10%), turbot (6%) and sturgeons (Acipenseridae; 2%).

## Canada

### Pacific Canada

The original peer reviewed reconstruction research for Pacific Canada was initially documented in Ainsworth (2016), and was updated to 2014 by the *Sea Around Us*.

## Methods

“Recreational” fisheries data are compiled from the Department of Fisheries and Oceans (dfo) creel and logbook surveys (DFO 2012a) for salmon and some groundfish, Wallace (1999) for some groundfish, and Hare (2010) for halibut.

All subsistence, artisanal, and recreational catch, as well as discards, is categorized here as unreported.

For the 2011 – 2014 update, recreational fisheries were calculated using 2009 as a reference year for the reconstructed catch and the percentage of BC population that are tidal water fishers (DFO 2012b) and the BC population statistics<sup>18</sup>. A catch rate was thus calculated and multiplied by the number of fishers for the BC population given a constant participation rate and a growing population. The catch was taxonomically disaggregated according to the 2006-2010 average of taxonomic composition (Columbia and Catch 2016). Subsistence fishing was carried forward according to the original reconstruction methods as a proportion of reported catch (Columbia and Catch 2016).

## Results

### Non-Industrial Fisheries

Recreational, artisanal, and subsistence fisheries together capture only a small fraction of the catch of the industrial fleets. Throughout the 1950s and 1960s that fraction was consistently between 2 and 5 percent.

In the 1970s and 1980s, a significant increase in recreational fishing increased that fraction to an average of between 5 and 7 percent, with a peak in 1986 at almost 8 percent. In the mid-1990s, the total recreational catch dropped to about one-third of its size in the previous two decades.

Since the mid-1990s, recreational, artisanal, and subsistence fisheries have accounted for about 4 to 5 percent of total extractions.

### Atlantic Canada

The original technical reconstruction research was initially documented in Divovich et al. (2010), and was updated to 2014 by the *Sea Around Us*.

## Methods

Unreported catches from the recreational sector were reconstructed by compiling anchor points for several years and interpolating between them. The most detailed data on catches were from 1990 to 2010 in the Surveys of Recreational Fishing in Canada (BriLev Consulting 2008; DFO 2010; DFO 2005; DFO 2000; DFO 1995; DFO 1990). The surveys were given to a representative sample of anglers, and then extrapolated to the population at large.

The data were available as the number of fish harvested by specie by province. Only the provinces in scope were included in the analysis, e.g., Newfoundland & Labrador, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Nunavut, and the North West Territories (NWT), prior to 2000. Since

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<sup>18</sup> <http://www.bcstats.gov.bc.ca/StatisticsBySubject/Demography/PopulationEstimates.aspx>

both freshwater and marine recreational fishing was included in the survey, we excluded freshwater species from the analysis. Moreover, since catches were given by the number of fish harvested instead of the weight of fish harvested, we transformed the data by plugging in the average length into the Length-Weight function in FishBase ([www.FishBase.org](http://www.FishBase.org)). The outcome was an average weight for each taxon, which we then multiplied by the number of fish caught.

Additionally, several adjustments were made to the data for the present paper. First, since Nunavut was part of NWT in 1990 and 1995, we averaged the percentage of Nunavut landings to NWT landings (by species for 2000, 2005, and 2010). These percentages were used for 1990 and 1995. Additionally, East Baffin Island is geographically approximately 25% of the entire Nunavut Area, so to obtain catches for this region we multiplied Nunavut catch by 25%. Second, after 2000, data on catches by non-resident anglers in Quebec was no longer available. However, it was stated that non-resident license sales fell at an average annual rate of 2% since 2000. We applied this trend to the data, estimating that non-resident angler catches in 2005 and 2010 were 90% and 82% of the catch in 2000, respectively.

Prior to 1990, Mitchell (1980) provided data on number of resident adult anglers in 1975. We assumed the change in the number of anglers from 1975 to 1990 was proportional to the change in catch. From 1975 to 1990, the number of anglers increased by 72% for the Atlantic (from 246,900 to 424,375 anglers) and by 226% for Quebec (from 484,600 to 1,578,237 anglers). Catch was adjusted commensurate with these changes.

Prior to 1975, data were not available on the number of anglers or recreational catches. Thus, we used the change in the Canadian population from 1950 to 1975 as a proxy for the change in the number of active resident anglers ([www.worldbank.org](http://www.worldbank.org) Statistics Canada 1951). To be conservative, we assumed that active resident participation in 1950 was half that of 1975.

Thus, by compiling all the anchor points and interpolating between them, we reconstructed catches from the recreational fisheries in Eastern Canada. The last adjustments to the data were from additional sources indicating recreational catches of tuna and shark. Between 1967 to 1985, there was a significant bluefin tuna (*Thunnus thynnus*) fishery in North Lake, Prince Edward Island (Island Narratives Program 1995). Data were available from various historical sources, each confirming that the fishery peaked from 1974 to 1976 with 1,000 tons of tuna landed (ASE Consultants 1993; Island Narratives Program 1995; Sutton 2002). These catches were added, along with the recreational catches of blue shark (*Prionace glauca*) from derbies and recreational fishing between 1993 and 2003 (Campana et al. 2006). After 2003, data were also publicly available, but we only considered landings until 2006 due to new rules for derbies where blue sharks are to be released alive after tagging (Canadian Shark Research Laboratory 2014). As in Campana et al. (2006), we assumed that from 2004 to 2006 recreational catch was 66% of derby catch.

For the 2011 – 2014 update, recreational catch was calculated using a per-capita rate of recreational fishing for the provinces of Quebec, Nova Scotia, New Brunswick, Newfoundland and Labrador, and Prince Edward Island, as well as the territory of Nunavut, which were derived from the 2010 recreational catch divided by the population of each province or territory in 2010. This was then carried forward to 2014 by multiplying the per-capita rate with the 2014 populations. The Department of Fisheries and Oceans's (DFO) newest report on recreational fishing in Canada is

expected to be released in 2017- more accurate information will be available from there in the future.

## Results

Recreational catches increased from 8,200 t in 1950 to 74,000 t in 1990 and then decreased to half the pre-moratorium level at about 23,000 t-year<sup>-1</sup> from 1995 to 2010. Most of this catch was from the Newfoundland & Labrador recreational fisheries, followed by Quebec, Nova Scotia, New Brunswick, and Prince Edward Island. Nunavut recreational catches were almost insignificant, ranging from 1- 3 t-year<sup>-1</sup>, which is explained by the relatively few anglers that frequent Nunavut and the even fewer varieties of species. Cod represented the largest portion of the catch with 46%. Trouts were the second most important with 35% of the total recreational catch.

## Arctic Canada

Historically and currently, there are no recreational fisheries in the arctic waters of Canada. All small-scale fisheries in these waters is for subsistence or artisanal purposes, and is documented in the peer-reviewed literature (Zeller et al. 2011a).

## Canary Island (Spain)

The original technical reconstruction research was initially documented in Castro et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

### Population

Data on resident and non-resident population were useful in estimating non-commercial fishery catch for the subsistence and recreational sectors.

### Resident

Data on resident population in the Canary Islands were obtained from the Canarian Government (2004) for the years 1940, 1960, and 1981, and from the Canarian Government Statistics Institute, Instituto Canario de Estadística (ISTAC), for the years 1999-2000. For all other years the population figures were interpolated between the nearest anchor points.

### Tourist

Data on the tourist population were available from 1990 – 2010 from ISTAC's publicly available data (<http://www.gobiernodecanarias.org/istac/>). The expansion of tourism dates back to the 1960s and has been steadily increasing up until the 1990s (Pascual 2004). Thus we interpolated between zero tourists from 1950 – 1959 to over 4.87 million tourists in 1990.

### Recreational catch

Recreational catch was calculated by creating a time series of the number of active anglers and multiplying it by an appropriate variable catch rate per fisher.

### Number of active anglers

In 2005, 16,247 fishing licenses were issued, each valid for three years (MAPyA 2006). This implies that in 2005 the number of active anglers was approximately three times the amount of fishing licenses issued (including those who got their licenses in 2003 and 2004), or approximately 49,000 active anglers. In 2007, the number of valid fishing licenses grew to approximately 60,000, then to 120,000 in 2009 (Pascual-Fernandez and De la Cruz Modino 2011), and then slightly declined to 116,000 in 2011 (MAAyMA 2013).

These recreational licenses included those issued to private individuals and those issued to charter boat captains who take tourists and other individuals without a recreational license to fish. Additionally, Jiménez-Alvarado (2010) reported that approximately 10% of recreational fishers fish without licenses, which is equivalent to unreported fishing licenses at 11.1% of reported ones. It is reasonable to assume those fishing without licenses are individual anglers rather than charter boat captains. Ultimately, we created separate time series for recreational anglers and charter vessels, which would have different catch rates because charter vessels take many passengers at a time and fish all year round.

According to the number of recreational fishing boats registered in the Canary Islands in 2005, MAPyA (2006) indicated that 827 of them were under the “sixth list”, or recreational vessels which are for-profit, i.e. charter vessels, and 22,619 vessels were personal recreational fishing craft under the “seventh list”. It was reasonable to assume that each charter boat would own one license, while there are likely more recreational licenses active than boats, as one boat may belong to a family or some fish without boats on piers. Hence, we assumed that of the 48,741 active anglers in 2005, 827 were charter licenses for taking tourists, and the rest were generally for residents.

We extended this division through time by creating a proxy variable: the number of charter licenses divided by the tourist population, which in 2005 was .009%. We used tourist population because the number of recreational fishers upon charters depends on the influx of tourism and assumedly varies according to the rate of tourist population. We assumed this ratio would be 0% from 1950 to 1959 when tourism had not yet expanded, and interpolated to .009% in 2005 and then continued the linear trend to 2010. This time series of the proxy ratio was multiplied by the tourist population from 1950 – 2010 to obtain an estimated time series of the number of charter boats in operation.

Next we estimated the total number of active recreational anglers, excluding anglers upon charter boats yet including recreational fishers without a license. Since we have data on the total number of active licenses from 2005 – 2010 (with any gap year interpolated) we subtracted the number of charter licenses to obtain the number of (assumedly resident) recreational licenses. For the years prior to 2005, we utilized a similar strategy as that for charter licenses, except we used resident rather than tourist population, obtaining a ratio of resident licenses in 2005 to resident population in 2005 at 2.7%. Since 1950 to 1959 was a time of food shortage (Palmero 2001), implying that subsistence fishing was more likely than recreational fishing among residents, we interpolated between 0% from 1950 – 1959 to the 2005 value. Also, the development of the touristic industry in the 1960s facilitated a better economic position for the local population and, according to this, facilitated the inversions in equipment for recreational fishing, particularly fiberglass boats. This ratio from 1950 – 2004 was multiplied by the resident population to generate a complete time series of reported licenses. Finally, we adjusted this time series to account for the 10% of recreational

anglers fishing without a fishing license by multiplying the reported resident licenses (not charter) by 11.1%.

From comparing boat capacity on recreational charters (from an internet search), it appears that on average, each charter takes between 3 and 4 people at a time. We assumed a very conservative number of trips at two per year per charter, resulting in each charter license accommodating the equivalent of seven private license holders. It is likely that fishing is far more common among charters, who fish all year long to accommodate the waves of tourists; nonetheless, we assume this conservative estimate.

#### Catch rate per angler

According to interviews of anglers, MAPyA (2006) reported a catch rate of  $0.085 \text{ t}\cdot\text{fisher}^{-1}\cdot\text{trip}^{-1}$  when fishing from a boat and  $0.0085 \text{ t}\cdot\text{fisher}^{-1}\cdot\text{trip}^{-1}$  when fishing from the shore. Furthermore, of the new licence holders in 2005, 301 were for fishers fishing from a boat while 16,202 were for those fishing from shore. We weighted these rates by the number of fishers in each category to obtain one representative rate of  $0.0099 \text{ t}\cdot\text{fisher}^{-1}\cdot\text{trip}^{-1}$ . Furthermore, the average number of trips taken was 43 trips annually (MAPyA 2006) so we adjusted this rate obtain a total annual catch rate of  $0.425 \text{ t}\cdot\text{fisher}^{-1}\cdot\text{year}^{-1}$  in 2005.

While this catch rate is appropriate for 2005, we varied catch rates over time using some simple assumptions about changes in the CPUE and technological advancements. Regarding technological advancements, these changes came first for artisanal fishers and then recreational fishers, and we assumed there was a lag of about five years. Throughout the 1970s, most of the artisanal fleet became equipped with onboard engines and hydraulic fishing winches, and in the 1980s and 1990s other technological advancements were also incorporated such as radio, GPS, synthetic nets, echo sounders, etc. Accounting for the five year lag, we assumed a constant level of technology until 1975, thereafter increasing by a factor of four to 100% in 2005, and then remaining constant. The CPUE 2005 value was normalized to 100% as well. The merging of the two trends created a variable trend line of the catch rate before and after the 2005 catch rate.

The time series of catch rate was adjusted accordingly, and this time series was multiplied by the total amount of recreational anglers, counting seven anglers per charter license to obtain the entire time series of recreational catches. For the species composition, we used the percentage of fishers who target certain species as a representative sample of catch (MAPyA 2006). A comprehensive list of species and their contribution to catch is available in Table 12.

For the 2011 – 2014 update, recreational fishing was originally reconstructed based on the number of fishing licenses for both domestic residents and charter operators, and given known catch rate information and effort (MAPyA 2006). Recreational fishing continues to be underestimated and is clearly an important part of the marine fisheries of the Canary Islands (Blanch 2014). Recreational fishing continues to make up a major portion of the Canary Islands' fisheries and has important economic value to the islands' economy (Leon et al. 2003). Therefore, it is important to consider all fisheries sectors when evaluating the importance of fisheries to the Canary Islands (Popescu and Ortega Gras 2013).

**Table 12.** Species composition of recreational catch in the waters of the Canary Islands, 1950 – 2010.

Species name	Spanish common name	English common name	Composition (%)
<i>Diplodus sargus cadenati</i>	Sargo	Moroccan white seabream	10.2
<i>Sparisoma cretense</i>	Vieja	Parrotfish	10.1
<i>Serranus spp.</i>	Cabrilla	Groupers	8.4
<i>Boops boops</i>	Boqa	Boque	8
<i>Sarpa salpa</i>	Salema	Salema	5.8
<i>Mycteroperca fusca</i>	Abade	Island grouper	4.2
<i>Acanthocybium solandri</i>	Peto	Wahoo	3.6
<i>Pagellus erythrinus</i>	Breca	Common pandora	3.3
<i>Trachinotus ovatus</i>	Palometa	Pompano	2.6
<i>Pagrus pagrus</i>	Bocinegro	Red porgy	2.4
<i>Makaira nigricans</i>	Marlin azul	Blue marlin	2.4
<i>Muraena augusti</i>	Morena	N/A	2.3
<i>Seriola dumerilii</i>	Medregal	Greater amberjack	1.7
<i>Coryphaena hippurus</i>	Dorado	Common dolphinfish	1.6
<i>Thunnus obesus</i>	Atún patudo	Bigeye tuna	1.5
<i>Pagellus acarne</i>	Besugo	Adlary seabream	1.5
<i>Spondylosoma cantharus</i>	Chopa	Black seabream	1.5
<i>Sparus aurata</i>	Dorada	Gilthead seabream	1.5
<i>Diplodus vulgaris</i>	Seifia	Common two-banded seabream	1.5
<i>Oblada melanura</i>	Galana	Saddled seabream	1.5
<i>Trachurus picturatus</i>	Chicharro	Blue jack mackerel	1.4
<i>Bodianus scrofa</i>	Pejeperro	Barred hogfish	1.3
<i>Thunnus alalunga</i>	Bonito del norte	Albacore	1.2
<i>Sphyrna viridensis</i>	Bicuda	Yellowmouth barracuda	1.2
<i>Katsuwonus pelamis</i>	Listado	Skipjack tuna	1.2
<i>Stephanolepis hispidus</i>	Gallo verde	Planehead filefish	1.15
<i>Balistes capricus</i>	Gallo moruno	Grey triggerfish	1.15
<i>Helicolenus dactylopterus</i>	Bocanegra	Blackbelly rosefish	1.1
<i>Atherina presbyter</i>	Guelde blanco	Sand smelt	1
<i>Liza aurata</i>	Lisa	Golden grey mullet	1
<i>Lithognathus momyrus</i>	Herrera	Sand steenbras	0.8
<i>Dicentrarchus labrax</i>	Lubina	European seabass	0.8
<i>Mugil cephalus</i>	Lebrancho	Flathead grey mullet	0.7
<i>Pomadasys incisus</i>	Roncador	Bastard grunt	0.7
<i>Dentex gibbosus</i>	Sama	Pink dentex	0.6
<i>Polyprion americanus</i>	Cherne	Wreckfish	0.6
<i>Thalassoma pavo</i>	Pejeverde	Ornate wrasse	0.6
<i>Sarda sarda</i>	Sierra	Atlantic bonito	0.6
<i>Beryx splendens</i>	Alfonsiño	Splendid alfonsino	0.5
<i>Tetrapturus albidus</i>	Marlin blanco	Atlantic white marlin	0.5
<i>Merluccius merluccius</i>	Merluza	European hake	0.5
<i>Belone belone</i>	Aquja	Garfish	0.4
<i>Plectorhinchus mediterraneus</i>	Burro	Rubberlip grunt	0.4
<i>Abudefduf luridus</i>	Fula negra	Canary damsel	0.4
<i>Thunnus albacares</i>	Rabil	Yellowfin tuna	0.4
<i>Trachinus draco</i>	Araña	Greater weever	0.4
<i>Scomber colias</i>	Caballa	Atlantic chub mackerel	0.4
<i>Sphaeroides marmoratus</i>	Tamboril	Guinean puffer	0.4
<i>Synodus saurus</i>	Lagarto	Atlantic lizardfish	0.2
<i>Mora moro</i>	Merluza canaria	Common mora	0.2
<i>Mullus surmuletus</i>	Salmonete	Summullet	0.2
<i>Epinephelus marginatus</i>	Mero	Dusky grouper	0.1
<i>Diplodus annularis</i>	Mugarra	Annular seabream	0.1
<i>Schedophilus ovalis</i>	Pámpano	Imperial blackfish	0.1
<i>Xyrichtys novacula</i>	Pejepeine	Pearly razorfish	0.1
<i>Pagrus auriga</i>	Sama roquera	Redbanded seabream	0.1
<i>Loligo vulgaris</i>	Calamar	European squid	0.1
<i>Heteropriacanthus cruentatus</i>	Catalufa	Glasseye	0.1
<i>Dentex dentex</i>	Dentón	Common dentex	0.1
<i>Beryx splendens</i>	Palometa roja	Splendid alfonsino	0.1
<i>Dentex macrophthalmus</i>	Antoñito	Large-eye dentex	0.1
<i>Thunnus thynnus</i>	Atún rojo	Atlantic bluefin tuna	0.1
<i>Dicentrarchus punctatus</i>	Baila	Spotted seabass	0.1
<i>Phycis blennoides</i>	Briota	Greater forkbeard	0.1
<i>Mustelus mustelus</i>	Cazón	Smooth-hound	0.1
<i>Dasyatis pastinaca</i>	Chucho	Common stingray	0.1
<i>Promethichthys prometheus</i>	Conejo	Roudi escolar	0.1
<i>Conger conger</i>	Congrio	European conger	0.1
<i>Beryx decadactylus</i>	Fula roja	Alfonsino	0.1
<i>Ommastrephes bartramii</i>	Pota	Neon flying squid	0.1
<i>Octopus vulgaris</i>	Pulpo	Common octopus	0.1
<i>Brama brama</i>	Japuta	Atlantic pomfret	0.1
<i>Aphaniopus carbo</i>	Sable negro	Black scabbardfish	0.1
<i>Sepia officinalis</i>	Sepia	Common cuttlefish	0.1
<i>Pontinus kuhlii</i>	Obispo	Offshore rockfish	0.1
			<b>100.0</b>

## Results

For the entire time period, artisanal landings comprised 66% of the total catch, recreational catch was 26%, discards were 6%, and subsistence catch was 2% of the total catch. This composition is not representative for the 2000s, however, and by 2010 artisanal landings had declined to 22% of catch, discards to 4% subsistence to 0.3%, and recreational catch increased to 74% of catch.

Fishing in the Canary Islands consists of a large multi-gear polyvalent small-scale fleet, alternating the exploitation of different fish resources, in a process similar to that of other European small-scale fisheries (Guyader et al. 2013; Maynou et al. 2013; Maynou et al. 2011). Up until the start of the 21st century, most of the approximately 54,000 t·year<sup>-1</sup> of reconstructed catch was taken by this artisanal fishery, including its bait catch and discards, while the remaining 28% were from informal sectors such as recreational and subsistence fishing. Recreational fishing has generally been a larger proportion of catch than subsistence, which has a small catch yet is nonetheless culturally significant.

While in the second half of the 20th century most catch was taken by the artisanal fleet, by the late 2000s, this dynamic shifted from a large increase in recreational fishing, which comprised nearly 70% of total catch and averaged about 40,000 t·year<sup>-1</sup>. This large amount also explains why, from 2006 to 2010 when data were assumedly reported, total reconstructed catch was nearly seven times the reported catch of the FAO. This is troubling for the fishery because in contrast to the artisanal fleet which faces many stringent guidelines limiting effort, there is still no formal management plan to control recreational catch, as can be seen by the abundant charter boat operations and the 10% of recreational fishers who fish without a license. Likewise, the number of recreational anglers grew 230% from 2005 to 2010, while the number of professional fishers decreased by 49% in the same time period. This is a key result for policy makers to attend to, as fish stocks are already depleted. Additionally, there is an increasing trend in recent years of recreational fishers poaching and selling their catches illegally (Pascual-Fernandez and De la Cruz Modino 2011).

## Cape Verde

The original technical reconstruction research was initially documented in Santos et al. (2013) was updated to 2014 by the *Sea Around Us*.

### Methods

Recreational fisheries, which started, along with tourism in 1939 (CVRS 2012; Fialho 2011), are encouraged by the government and have developed alongside the tourism industry (Cabral 2005; ESR 2011; MegaPesca 2004). However, recreational catch data in Cape Verde, as in many other countries (e.g., Zeller et al. 2008), is scarce as the fisheries lacks monitoring.

Cape Verde does not supply any recreational catch data to FAO. Recreational fishing in Cape Verde, a member of the International Game Fish Association (IGFA 2012), started after the first airport opened in 1939 (Fialho 2011), and is practiced exclusively by tourists (MAAP 2004). The total number of tourists was available for 1988, 1990, 1995, and from 2000 to 2010 (CCIT 2010; Table13). We

interpolated linearly from zero tourists in 1939 to 14,000 tourists in 1988 and completed the time series by a series of linear interpolations between 1988 and 2000.

**Table 13.** Recreational fishery estimates for Cape Verde

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

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

The number of recreational fishers (92 tourist·month<sup>-1</sup>), the number of trips (4 trips·tourist<sup>-1</sup>·year<sup>-1</sup>), and catch per tourist (124 kg·tourist<sup>-1</sup>·day<sup>-1</sup> or 0.496 t·tourist<sup>-1</sup>·year<sup>-1</sup>), were available for 2009 from a company offering “fishing safaris” in Cape Verde (Anon 2012a). As these catches were likely highliner catches from the most successful fishers, presented for advertising and promotional purposes, we assumed the actual catch rate to be 25% of the reported catch, i.e., 0.124 t·tourist<sup>-1</sup>·year<sup>-1</sup>. Due to the high development of tourism in the archipelago (Cabral 2005), we conservatively assumed the number of companies offering fishing safaris was 1 per island (9 companies in total), with the same average number of tourists per company, i.e., 828 tourists·month<sup>-1</sup>. Since the number of fishing tourists represents a monthly average over seven months, we conservatively assumed that the number of recreational fishers was five times as high as the previous estimate over a one year period. We estimated the percentage of recreational fishers (4,140) out of the total number of tourists (330,319), i.e., 1.3%, and applied this rate to the total number of tourists from 1950 to 2010 (excluding 2009) to derive a time series of recreational fishers (Table 13).

We assumed the annual catch per tourist from 1950 to 1990 was twice (0.248 t·tourist<sup>-1</sup>·year<sup>-1</sup>) the 2009 and 2010 catch rate (0.124 t·tourist<sup>-1</sup>·year<sup>-1</sup>, Table 13) because of the overexploitation of large pelagic species targeted by tourists in the archipelago and commercial fisheries (Monteiro 2002; Stobberup 2005). A linear interpolation was used between 1991 and 2009 to complete the time series. We then estimated the total annual catch by multiplying the total number of recreational fishers by the catch per tourist for each year (Table 13). Recreational catches were disaggregated using catch data by Anon. (Anon 2012a; Table 14).

**Table 14.** Taxonomic composition of recreational catches

Common name	Taxon name	% <sup>a</sup>
Marlins	<i>Makaira</i> spp.	70
Wahoo	<i>Acanthocybium solandri</i>	7
Yellowfin tuna	<i>Thunnus albacares</i>	10
Sailfish	<i>Istiophorus platypterus</i>	3
Gilthead seabream	<i>Sparus</i> spp.	3
Groupers	<i>Epinephelus</i> spp.	3
Others		3

a) Percentages from Anon (2012).

Recreational landings were carried forward to 2014 with updated tourism data. The total number of tourists visiting Cape Verde in 2011-2014 was obtained from INE (2015). The percentage of tourists participating in recreational fishing and the catch per unit effort (CPUE) of recreational fishers were assumed constant for 2010-2014. Recreational landings were disaggregated by taxa based on the 2010 taxonomic breakdown. Subsistence landings were estimated for 2011-2014 based on the 2010 proportion of subsistence landings to domestic reported landings for each gear-type. The 2010 taxonomic breakdown of subsistence landings for each gear-type was maintained for 2011-2014.

## Results

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

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

## Cayman Isl. (UK)

The original technical reconstruction research was initially documented in Harper et al. (2009a), and was updated to 2014 by the *Sea Around Us*.

## Methods

An offshore recreational fishery for billfishes started in the Cayman Islands in the 1970s and continues today (J. Bothwell, pers. obs., DoECI). This fishery takes place inside the Cayman Islands EEZ. Annual fishing derbies target Blue Marlin (*Makaira nigricans*) and other pelagic sportfish (Brunt

and Davies 1994). Records of catches by this fishery are limited, but Brunt and Davies (1994) present the number of fish caught and retained over the 1983-1991 time period. Thus, fish that were caught and released were ignored here, i.e. assumed to have survived. The numbers of retained fish were converted to wet weight (in tonnes) using average weights for each species presented in FishBase ([www.FishBase.org](http://www.FishBase.org)). Catches over 1970-1980 time period averaged half that of the 1983-1991 period, the 1990s were estimated to have the same average catch as reported for 1983-1991 (35.8 t-year<sup>-1</sup>) and catches in the 2000s were assumed to have decreased by a third (J. Bothwell, pers. obs., DoECI).

For the update, recreational fishing continues to be a popular activity for tourists to the Cayman Islands, particularly to the Cayman Islands International Fishing Tournament held annually in April. One tourist sport fisher estimated more than 30 sport fishing boats during one day of the tournament targeting mahi, wahoo, blue marlin, swordfish, and tuna and reported a catch of 7 dolphinfish for one vessel in one day (Hendricks 2016).

## Results

Catches by the inshore (artisanal) sector totalled 232 t between 1950 and 2007, based on 4 t-year<sup>-1</sup> (the average of the source data of 3-5 t-year<sup>-1</sup>). This total included approximately 58 t of subsistence catches, 58 t of commercial catches and 116 t from the inshore recreational fishery.

Catches by the offshore recreational billfish fishery were estimated to be approximately 1068 t over the 1970-2007 time period. Catches peaked during the 1980s and 1990s and then declined to present day catches of approximately 23 t-year<sup>-1</sup>. The taxonomic breakdown applied throughout the time period was 96% Atlantic blue marlin, 3% Atlantic white marlin, 1% Sailfish and a small number of Longbill spearfish (<0.5%).

## China

The original technical reconstruction research was initially documented in Pauly and Le Manach (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

### Recreational and subsistence fisheries

Shen (2008) writes that, in the marine waters of China, “popular target species include large yellow croaker (*Pseudoscianea crocea*), small yellow croaker (*P. polyactis*), yellow drum (*Nibea albiflora*), genuine porgy (*Pagrosinus major*), red porgy (*Pagrus pagrus*), black porgy (*Sparus macrocephalus*), Japanese sea perch (*Lateolabrax japonicus*), rockfish (*Sebastes schlegeli*) and grouper (e.g., *Epinephelus maculatus*)”. He also writes that “[w]ith rapid development of recreational fishing, many new fishing gear manufacturing plants have been built, and now China is the largest producer and exporter of fishing gear in the world. Furthermore, it is widely recognized that recreational fisheries development drives service businesses such as hotels, inns, cafés, restaurants etc. – but the latter point might more heavily apply to freshwater fisheries, which are indeed very developed in China (Gao 2001; Lin and Hong 2005; Shen 2008).

However, reliable numbers are not available, and thus the catch of marine recreational fishers was estimated as the average of two Fermi solutions (von Baeyer 1993; Pauly 2010). The first method was based on data published by Cisneros-Montemayor and Sumaila (2010), who estimated that the contribution of marine recreational fisheries to global GDP suggested a participation rate of 0.3067% for ‘Eastern Asia’. Given the current population of China, the participation rate generates (1,338 million\*0.003067 =) 4.1 million recreational fishers. Assuming that each recreational fisher catches 1 kg once a month gives (12\*0.001\*(4.1\*10<sup>6</sup>)) approximately 49,000 t as a first estimate of the recreational marine catch of China in 2010.

The second method was based on other reconstructions currently available. We collected estimates of recreational catches for 11 continental countries in 2010, and weighted these catches by each country’s Inshore Fishing Area (www.searounds.org; Table 15)<sup>19</sup>. We then applied the average catch per IFA to China’s IFA (i.e., 358,500 km<sup>2</sup>), which resulted in a catch of around 52,000 t by recreational fishers in 2010.

Given that these two estimates are very close<sup>20</sup>, we accepted their average as the correct value; we also assumed that the recreational fishery only started in 1985 (i.e., we set recreational catch to zero in 1984), which corresponds to the time when the effects of economic reforms initiated by Deng Xiaoping started to be felt. We then fitted a logarithmic regression between the 1984 and 2010 anchor points in order to interpolate data for missing years.

In terms of their taxonomic composition, 50% of the recreational catch is assumed to consist in equal proportion of the 9 species listed above as “popular target species” by Shen (2008) plus a group of ‘other groupers’, while the other 50% was assigned to ‘marine fishes nei’.

**Table 15.** Data and sources used to estimate China’s recreational catch in 2010.

Country	IFA (km <sup>2</sup> )	Catch (t)	IFA catch (t/km <sup>2</sup> )	Source
South Korea	97,000	52,800	0.54	Shon <i>et al.</i> (in press)
Lithuania	3,000	650	0.22	(Rossing <i>et al.</i> 2010; Zeller <i>et al.</i> 2011)
Finland	58,000	9,850	0.17	(Rossing <i>et al.</i> 2010; Zeller <i>et al.</i> 2011)
Denmark	58,000	6,100	0.11	(Rossing <i>et al.</i> 2010; Zeller <i>et al.</i> 2011)
Costa Rica	15,500	1,100	0.07	(Trujillo <i>et al.</i> 2012)
Sweden	101,000	6,600	0.07	(Rossing <i>et al.</i> 2010; Zeller <i>et al.</i> 2011)
Poland	19,500	1,050	0.05	(Rossing <i>et al.</i> 2010; Zeller <i>et al.</i> 2011)
Latvia	14,000	350	0.03	(Rossing <i>et al.</i> 2010; Zeller <i>et al.</i> 2011)
Russia (Baltic Sea)	18,500	450	0.02	(Rossing <i>et al.</i> 2010; Zeller <i>et al.</i> 2011)
China	358,500	50,850	Mean = 0.14	This study

<sup>19</sup> The Inshore Fishing Area is defined as the waters from coast to either 50 km offshore or 200 m depth, whichever comes first (Chuenpagdee *et al.* 2006)

<sup>20</sup> The match between our two estimates of recreational catch is a coincidence.

## Christmas Isl. and Cocos Keeling Isl. (Australia)

The original technical reconstruction research was initially documented in Greer et al. (2012), and was vetted through peer review in Greer et al. (2014), and was updated to 2014 by the *Sea Around Us*.

### Methods

#### Cocos Keeling Island (CKI)

Recreational catch can be defined as fishing where the main motivation is not consumption, trade or sale of the catch, but rather enjoyment. It is unlikely that prior to 1985 there was much recreational fishing occurring due to the absence of non-Cocos-Malay people in the CKI. As such, it was assumed that prior to 1985, the recreational catch was zero. For the remaining time period, two anchor points were found; one in 1993 and another in 2001 (Hender et al. 2001). A linear interpolation between a catch of zero tonnes in 1984 and an average recreational catch of 22.5 t in 1992 (Hender et al. 2001) was done to estimate annual recreational catches for the missing years. Similarly, an interpolation was used between the 1992 recreational catch estimate and a 2001 average recreational estimate of 106.2 t (Hender et al. 2001). The observed increase in recreational catches between these two anchor points is large. It is likely erroneous to assume that recreational catches continued to increase at such a rate past 2001, especially when tourism trends are considered (see below).

The tourism industry in the CKI remains relatively small, with regular flights initiated in the early 1990s. In addition, there have been no major developments to increase the tourist capacity on the island within the last decade. As a result, the recreational catch from 2002 until 2010 was estimated using a per tourist catch rate. Hotel occupancy rates for each state since 2001 are available on the ABS website. In order to estimate the occupancy rate for hotels in the CKI, the state of Western Australia's statistics were used as they are the governing state body of the AIOT. We were able to estimate the number of beds available for tourists on the island (approximately 150) and use the annual average occupancy rate derived from Western Australia statistics to determine the likely number of tourists on the island per year. It was then possible to take the recreational catch known in 2001, divide it by the number of tourists per year to yield a per tourist catch rate of 25 kg assuming that each tourist stays one week. The recreational catch rate from 2002 to 2010 was calculated by multiplying the number of tourists visiting the CKI per year, based on a one-week stay using an average occupancy rate as collected by the Western Australia government. Although the estimated catch of 25 kg per tourist may be high and not all tourists are going to fish, our estimate of recreational catch was considered conservative as the recreational catch of local residents was not estimated in addition to this.

For the 2011-2014 update, recreational catches were calculated by using the same methods as in the original reconstruction. The annual average hotel occupancy rates were obtained from ABS to determine the weekly number of tourists. A rate of 25 kg per tourist catch rate was applied and multiplied by 52 weeks.

#### Christmas Island (CI)

Information on recreational fishing for CI was unavailable. However, it is likely that some recreational fishing does occur, albeit to a lesser extent than on CKI, due to the substantially more

inaccessible coast and coastal waters of Christmas Island. It was assumed that recreational fishing in CI also started in 1985 (as in CKI). However, CI did not experience the changes in the tourism industry that CKI did, and therefore does not exhibit the same increase in catches. Catches were assumed to be zero tonnes in 1984, with a conservative estimate of a constant  $1 \text{ t}\cdot\text{year}^{-1}$  from 1985-2010.

For the 2011-2014 update, population data for Christmas Island was obtained from the 2011 Australian census and was used to carry forward small-scale catch to 2014. The number of small-scale fishers were assumed to remain at 60% of the population and the 2010 consumption rate of 25 kg/person/year was assumed to be constant for 2011-2014. For the years 2011-2014, the 2010 breakdown of small-scale landings into artisanal, recreational and subsistence landings was used to disaggregated catch by sector. Small-scale taxonomic breakdowns were conserved throughout the entire time period.

## Costa Rica

The original technical reconstruction research was initially documented in Trujillo et al. (2006), and was updated to 2014 by the *Sea Around Us*.

Catches of large pelagics have increased during the last decade, now making up around 50% of reported landings. These are dominated by a few families such as Carangidae, including jacks (*Caranx* spp.), moonfish (*Selene* spp.) and amberjacks (*Seriola* spp.); Scombridae, including bonitos (*Sarda* spp.) and skipjack tuna (*Katsuwonus pelamis*); Coryphaenidae (dolphinfish, *Coryphaena hippurus*); and Sphyrnidae (barracudas, *Sphyrna* spp.). In addition to commercial fishing, all of these species are actively targeted by recreational fisheries. Pelagic sharks are also an important target group for this sector, contributing around 15% of reported landings. The principal taxa caught are requiem sharks (Carcharhinidae), mainly silky shark (*Carcharhinus falciformis*) and hammerheads (Sphyrnidae).

## Methods

Recreational fishery Recreational fishing is a rapidly growing sector in Costa Rica, mainly targeting billfish on the Pacific coast. The main species caught are sailfish (*Istiophorus platypterus*), followed by marlins (*Makaira* spp. and *Istiompax indica*) and swordfish (*Xiphias gladius*). Recreational billfish catches were estimated using tourism data and a conservative rate of recreational fishing participation as a percentage of tourist arrivals (~2%; Cisneros-Montemayor and Sumaila 2010; Matarrita-Cascante 2010), and assuming that recreational fishing began around 1980. Catch per angler (~7 fish) was estimated based on a sport fishing catch, catch-release rate (>95%) and catch composition reported for Costa Rica by Ditton and Grimes (1995), and a conservative billfish release mortality rate of 0.25 (based on Cramer 2004; Pine III et al. 2008). Catches including post-release mortality were estimated in tonnes using length-weight conversion parameters for each species (www.FishBase.org). As with other locations, it has been reported that billfish catches in Costa Rica are directly impacted by commercial targeting of billfish (Ehrhardt and Fitchett 2008), so we used commercial billfish catch trends to reflect this observation (i.e., recreational CPUE used in our estimation is directly and inversely correlated with commercial billfish landings as reported by the FAO).

For the 2011 – 2014 update, the 2010 proportions of recreational catches (by species) to tourist population were applied to 2011-2014 tourist populations<sup>21</sup>. The taxonomic breakdown from 2010 was used to disaggregated landings by taxa for each sector for 2011-2014.

## Results

Recreational fishing is an economically important and growing industry in Costa Rica; we focused our efforts on billfishing, the largest sector (Soto-Jiménez et al. 2010). Assuming significant operations began in 1980, we estimate that over 12,500 tonnes of billfish (~85% sailfish) were killed by recreational fishers in Costa Rica from 1980-2010, with an average of almost 750 t·yr<sup>-1</sup> during the last ten years. Almost 94% of this estimate was a result of post-release mortality, highlighting the need to take this factor into account in addition to encouraging catch-and-release.

### Total reconstructed catch

Following the methods described above, our reconstructed catch estimates suggest that, between 1950 and 2010, total fisheries catch in Costa Rica was 2.6 times the total reported to FAO for the same period. The catch increased from 1,600 t in 1950 to a peak of 90,700 t in 1986, before declining to an average of 38,000 t from 2008-2010. The majority of this non-quantified catch, in order from largest to smallest, was discards in shrimp trawls (75%), by-catch in shrimp trawls (13%), under-reported shark landings (8%), subsistence (2%), recreational (1%), and artisanal piangua catches (0.1%). In the more recent period (2000s), we estimate an 83% under-reporting rate relative to FAO statistics. The contribution by sector of the total reconstructed catch is 80.2% industrial, 18.0% artisanal, 1.2% subsistence, and 0.6% recreational. Taxonomically, the total reconstructed catch was dominated by crustaceans with 33% of the catch. Of the crustaceans, 19.3% (of the crustacean total) was from the family Squillidae, Galatheididae was another 17.2%, 15.7% was from Penaeidae and 14% was Panadaliidae. Other taxonomically important groups were sharks (10.8%, this includes groups which may contain rays and chimaeras), and the families Synodontidae (7.7%), Paralichthyidae (5.7%), and Ophidiidae (4.4%).

## Croatia

The original technical reconstruction research was initially documented in Matic-Skoko et al. (2014), and was updated to 2014 by the *Sea Around Us*.

### Methods

No requirements exist for the reporting of recreational fishing in Croatia, despite the substantial proportion of the resident population (and visiting tourists) who engage actively in recreational fishing (Fredotović et al. 2007). As with the subsistence sector, the reconstruction of recreational catches was done indirectly using the available information on the number of fishers. The number of recreational fishers in Croatia was reported to be 25,000 from 1979- 2007 (Basioli 1979; Fredotović et al. 2007; Par et al. 2006; Vodopija 1997). Grubišić (1968) reported a number of 15,338 recreational fishers for 1968, and we assumed that in 1950 there were 10,000 recreational fishers.

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<sup>21</sup> [http://www.visitcostarica.com/ict/pdf/anuario/Statistical\\_Yearly\\_Report\\_2011.pdf](http://www.visitcostarica.com/ict/pdf/anuario/Statistical_Yearly_Report_2011.pdf) (Note: change the year “2011” in the link to access tourist populations in the carry forward years)

Thus, for years when data were unavailable, we estimated the number of fishers using a linear interpolation between the anchor points and carried the 2007 estimate forward to 2010 unchanged. Only Basioli (1979) gave an estimate of total possible recreational catch at about 1,500 t-year<sup>-1</sup>. For years between 1950 and 1978, estimated catch was reduced in accordance with the trend of fishers during that time. From 1980 to 1990, we assumed proportionality with the trend in the number of recreational fishers, and estimated catch was carried forward as a fixed rate. During Croatia's armed conflict for independence between 1991 and 1996, we assumed a decrease in recreational fishing. From 1991 to 1993, we assumed a 25% decrease in recreational catch compared to 1990, and a 75% decrease from 1993 to 1995. Recreational catches for 1996 were increased to 50% of catches made in 1990. The trend from 1980 to 1990 was then carried forward again from 1997 to 2010. In the last couple of years, expert opinion suggests that the number of recreational fishers has increased to around 80,000 (A. Soldo, pers. comm.). However, to remain conservative we did not use this estimate.

Using the species composition given in reported national landings data, we assigned catches to taxa with as much resolution as possible. Catches from the recreational and subsistence sectors were assigned to families, using the same taxonomic information as the industrial and artisanal sectors.

For the 2011 – 2014 update, the subsistence and recreational total catches were held constant from 2014. The taxonomic breakdown for both the reported and unreported components was based on the percentage breakdown in 2014 (calculated separately by sector, catch type, and input)

## Results

Estimates of recreational catches between 1950 and 2010 totalled approximately 72,000. Recreational catches increased steadily from 600 t in 1950 to an estimated 1,500 t-year<sup>-1</sup> from 1980 onward (with a dip in recreational catches to a low of 375 t during the period of armed conflict in the early to mid-1990s).

## Cuba

The original technical reconstruction research was initially documented in Au et al. (2014), and was updated to 2014 by the *Sea Around Us*.

## Methods

National records and FAO landings data do not account for catches generated by subsistence and recreational fisheries. Therefore, we used information from published reports, and assumption-based estimates to determine unreported catches generated by these sectors. Total marine catches in Cuba are equal to the sum of all reported and unreported catches from commercial, subsistence, and recreational fisheries.

### Cuban tourism and recreational fishing from 1950-2010

There has been a rapid increase in tourist arrivals to Cuba since the late 1980s (Espino 2008). Recreational fishing is a popular attraction for tourists; however few attempts have been made to quantify the extent of recreational fishing in Cuba (Figueredo Martin et al. 2010). We estimated recreational catches based on the assumption that recreational fishers make up 20% of tourists

arriving to Cuba. We then estimated the number of recreational fishers using available data on tourist arrivals from 1950 to 2010. Tourism data from 1950 to 1961 and 1990 to 2000 were based on estimates made by Jayawardena (2003). We assumed minimal tourist arrivals after the Cuban revolution in 1959, until around 1975 when efforts to promote the tourism industry renewed (Elliott and Neirotti 2008; Taylor and McGlynn 2009). Therefore, we set the number of recreational fishers to a very conservative zero from 1961 to 1975 and interpolated between 1975 and 1982. From 1982 to 1989 and 2001 to 2007, tourist arrivals were based on estimates made by Espino (2008). Tourist arrivals from 2008 to 2010 were obtained from the Cuban National Statistics Office (Anon 2012b). Finally, we assumed a recreational catch rate of 5 kg·recreational fisher<sup>-1</sup>·year<sup>-1</sup> and assigned the estimated recreational catch to four fish families commonly associated with recreational catch: Serranidae (20%), Lutjanidae (30%), Haemulidae (20%), and Scombridae (30%).

Catch-and-release has become an increasingly popular option for recreational fishers, especially if they fish in marine protected areas (Figueredo Martin et al. 2010). This method reduces the impact of recreational fishing on marine ecosystems and has been considered more economically and ecologically favorable compared to recreational fishing for consumption purposes. Catch-and-release is the only permitted form of fishing practiced in the Jardines de la Reina reserve. This is the largest marine reserve in the Caribbean and a popular destination for recreational fishers around the world (Figueredo Martin et al. 2010).

For the 2011 – 2014 update, updated information on tourist arrivals was obtained from the Cuban National Statistics Office for 2008-2014 (ONEI 2015). The recreational fishing participation rate of tourists and recreational catch rate were assumed to remain constant at the 2010 levels for 2011-2014. The original taxonomic breakdowns for recreational and subsistence sectors were maintained for 2011-2014.

## Results

Reconstructed total catches within Cuba's EEZ waters increased from over 10,000 t·year<sup>-1</sup> in 1950 to a peak of 76,700 t·year<sup>-1</sup> in 1985, and then declined to approximately 28,500 t·year<sup>-1</sup> in 2010. Of the reconstructed catch, the artisanal sector constitutes 66% (1.8 million t), industrial 23% (644,500 t), subsistence 10% (268,400 t), and recreational 1% (almost 36,000 t).

**Recreational fisheries** Recreational fishing averaged just over 200 t·year<sup>-1</sup> from 1950-1959, dropping to a mere 4 t after the Cuban revolution. Recreational fishing was non-existent until the late 1970s, after which it increased gradually up until the 1990s. Following 1990, estimated catches increased rapidly to a maximum of 2,500 t·year<sup>-1</sup> in 2010.

## Curaçao

The original technical reconstruction research was initially documented in Lindop et al. (2015) and was updated to 2014 by the *Sea Around Us*.

## Methods

Although Bonaire and Curaçao are similar in size, there are fewer fishers per population, and many of the boats on the island are inactive (Dilrosun 2002). Therefore, using the data from a Lacle *et al.*

(2012) household study in Bonaire by Lacle *et al.* (2012) would be inappropriate and it was determined that domestic recreational catches could not be assessed.

However, some tourist sports fishing occurs, although it appears to not be particularly popular, with less than 1% of tourists engaging in fishing activities (Croes *et al.* 2011). Recreational potential is also limited by the number of available charter vessels, of which there are currently nine. data of overnight stays, which we conservatively assumed began at significant levels in 1945 and interpolated from 0 to 184,700 tourist arrivals that included overnight stays in 1980 when available records began. To the annual visitors, we applied a 1% rate of participation and assumed that the majority of those participating would be primarily there for fishing and would engage in multiple trips, so assumed a multiplication of 2.5. Most fish caught from tournaments and sports operators are catch-and-release (Weidner *et al.* 2001a), so a conservative 1 kg per trip catch rate was applied. It is clear that this relies on many assumptions, and therefore recreational fish catches may be underestimated.<sup>3</sup>

*Recreational:* Weidner *et al.* (2001a) reports that sports fishers across the Netherlands Antilles target blue and white marlin, sailfish, dorado, barracuda, wahoo, amberjack, bonito, blackfin tuna and yellowfin tuna, as well as 'other' species, varying with season and in some cases by island. Without more specific information available, we split the estimated annual recreational catch total evenly amongst all 11 groups.

## Results

The reconstructed catches for 1950-2010 for Curaçao were 2.2 times the data allocated as reported by the FAO on behalf of Curaçao for the same time period. Artisanal fisheries dominated the catch, accounting for 87% of total catches for 1950-2010. Subsistence catches made up 12%, with recreational fishing contributing 0.3% and the industrial sector less than 0.1%.

## Cyprus – North and South

The original technical reconstruction research was initially documented in Ulman *et al.* (2013a), was peer reviewed in Ulman *et al.* (2015) and was updated to 2014 by the *Sea Around Us*.

## Methods

### North

Recreational fishers are referred to as 'amateur' fishers in the north. They are not permitted to use fishing nets >400 m in length or mesh sizes <32 mm. Use of longlines is allowed, but each line is limited to 100 hooks or less. Soon, the use of fishing nets and longlines may also be banned for recreational fishers as the topic is currently under discussion.

Laws were developed for the recreational sector in 2006, and amended in 2010. The following actions are illegal (Anon 2010a): fish sales, use of explosives, use of toxic substances, use of lights or electrical currents, removal of live seagrass, collection of black sponges, removal of shellfish species for decoration purposes, harvesting octopus inshore, the use of monofilament fishing nets (effective as of Jan. 1, 2011), driftnets, and the harvest of female spiny or female European lobsters (*Palinurus vulgaris* and *Homarus gammarus*). Daily catch limits for select species are restricted to 5 kg per

fisher, and/or for any combination of those select species. It is also illegal to scuba dive or use light in Mediterranean monk seal habitats. Seasonal fishing closures include swordfish (Jan. 31-Oct. 1), tuna (Jul. 16-Aug. 15), brown meagre (Apr. 15-July 16), and grouper (June 1-July 15th).

## South

There is a substantial recreational fishery in the south, locally referred to as the 'sports fishery'. A fishing license is always required when fishing from a boat, using lights, spear guns, fishing nets, or longlines (Hadjistephanou and Vassiliades 2004). In the 1980s, there were approximately 300 recreational fishers using boats and several thousand anglers fishing from shore (Pawson et al. 2007). There are six angler clubs, which work in close contact with the Department of Fisheries and Marine Research (DFMR), and the DFMR transfers the relevant rules and regulations to anglers through these clubs. Recreational vessels are encouraged to moor in marinas associated with the Cyprus Tourism Board; the Tourism Board actively supports DFMR initiatives to help increase angling. Boats and tours for sport fishing can be arranged from all harbours, fishing stations and most tourist shops (Pawson et al. 2007). Cyprus is a popular place to purchase fishing gear with the best brands readily available and reasonably priced.

In the early 2000s, there were approximately 2,000 licensed recreational fishers fishing from boats and shore using spearguns, hook and line, nets, longlines, towed lines and jigging lines. Jigging is practiced mainly to target squid and octopus. The vessel-based albacore tuna fishery has recently gained popularity in summer months. Interestingly, the recreational sector is only permitted to fishing on weekends, holidays and Wednesdays (A. Petrou, pers. obs.), which has been the case for many decades. The 2000s have seen the modernization of fishing gear, for example, downriggers now tow lines at 200+ m deep to target benthopelagic species such as the blackspot seabream (*Pagellus bogaraveo*).

There is no legal definition for recreational fishing in the south, although the term 'sport fishing' is commonly used (Pawson et al. 2007). Recreational fishing is defined here as fishing which is not for commercial purposes, and not predominantly for subsistence purposes (Pawson et al. 2007). Much of the recreational fishing in the south occurs in its freshwater reservoirs, but for our purposes, only marine recreational catches have been considered.

Here, recreational fishing is defined as fishing primarily for enjoyment purposes, while subsistence fishing is defined as fishing with the primary purpose of providing food for self- or family-consumption.

In 1960, there were approximately 50 recreational fishing vessels on the island, with an average catch rate of  $0.128 \text{ t}\cdot\text{vessel}^{-1}\cdot\text{year}^{-1}$  and a combined total catch of  $6.4 \text{ t}\cdot\text{year}^{-1}$  (Fodera 1961). Thus, the  $6.4 \text{ t}\cdot\text{year}^{-1}$  recreational catch was held constant from 1950 to 1973, and assigned as 40% to the north and 60% to the south, which equated to  $2.56 \text{ t}\cdot\text{year}^{-1}$  for the north and  $3.84 \text{ t}\cdot\text{year}^{-1}$  for the south.

In the south, the Department of Fisheries and Marine Research (DFMR, Hadjistephanou and Vassiliades 2004) estimated that the recreational catch in the south was equivalent to approximately 15% of the annual reported commercial catches. Thus, for the south, catch was linearly increased from  $3.84 \text{ t}\cdot\text{year}^{-1}$  in 1973 to equate to 15% of the annual reported commercial catches for the south

by 1990, and this rate was held constant to 2010. The south's recreational catch estimation was assumed to include recreational vessel catches, spearfisher catches and shore-based angler catches.

For the north after 1973, recreational catches were calculated by three separate fishing methods: recreational vessels, spearfishers and shore-based fishers. Most vessels registered with the Directorate of Ports and Harbours were known to fish recreationally in 2013 (B.A. Çiçek, pers. obs.), so it was assumed that 80% (i.e., 1425) of registered recreational vessels actively fished in 2010 and the estimated catch rate used was  $0.2 \text{ t}\cdot\text{vessel}^{-1}\cdot\text{year}^{-1}$ , which equated to 285 t of boat-based catches in 2010 (B. A. Çiçek and I. Salihoglu, pers. obs.). For shore-based recreational fishers in 2010, it was assumed that at least 2000 people were engaged in angling for approximately  $20 \text{ weeks}\cdot\text{year}^{-1}$  with a catch rate of  $3 \text{ kg}\cdot\text{fisher}^{-1}\cdot\text{week}^{-1}$  (B. A. Çiçek and I. Salihoglu, pers. obs.), which equated to 120 t of shore-based catches in 2010. There were 368 licensed spearfishers in 2010, 10% of which fished for 150 fishing days $\cdot\text{year}^{-1}$  with an estimated catch rate of  $20 \text{ kg}\cdot\text{fisher}^{-1}\cdot\text{fishing day}^{-1}$  (i.e., they were considered high-liners or expert spearfishers); and 90% of which fished for 75 fishing days $\cdot\text{year}^{-1}$  with a catch rate of  $4 \text{ kg}\cdot\text{fisher}^{-1}\cdot\text{fishing day}^{-1}$  (i.e., average expertise), which equated to 209.4 t of spearfishing catches in 2010. These catch rates were based on expert consultation with about 20 local spearfishers from the north during 2013 (A. Ulman, B. Çiçek, unpublished data). Thus, for 2010, total estimated recreational catches were 614.4 t (i.e., the sum of boat-based, shore-based and spearfishing). For the 1973 to 2010 time period, we linearly interpolated between the 1973 recreational catch (i.e.,  $2.56 \text{ t}\cdot\text{year}^{-1}$ ) and the 2010 value of 614.4 t to establish a time-series of recreational catches in the north.

Furthermore, to differentiate between purely recreational (i.e., primarily for pleasure) and subsistence fishing (i.e., for personal and family consumption) for all 'recreational' catches estimated here, in 1950, 80% of the estimated 'recreational' catches were assumed to be caught for subsistence purposes, and 20% for purely recreational purposes, and by 2010, 40% of catches were assumed to be caught for subsistence purposes and 60% for recreational purposes, with the two rates linearly increased between 1950 and 2010 for both the north and the south.

All recreational and subsistence catches were allocated to the following taxa: rabbitfish (Siganidae, 26%), parrotfish (*Sparisoma cretense* 20%), seabreams (Sparidae, 14%), dusky grouper (*Epinephelus marginatus*, 12%), mottled grouper (*Mycteroperca rubra*, 10%), greater amberjack (*Seriola dumerili*, 6%) and leerfish (*Lichia amia*, 4%). A new target species, albacore tuna (*Thunnus alalunga*) was allocated 2% of recreational and subsistence catches in 2002 which was increased to 10% by 2010, and rabbitfish and parrotfish contributions were proportionality decreased to compensate about 20 local spearfishers from the north during 2013 (A. Ulman, B. Çiçek, unpublished data). Thus, for 2010, total estimated recreational.

For the 2011-2014 update, the recreational and subsistence sectors of North Cyprus were reconstructed assuming a constant number of recreational fishers (anglers, recreational vessels, and spearfishers) from 2010-2014. The total catch from recreational and subsistence sectors of South Cyprus was assumed to continue to be 15% of reported commercial catches for 2011-2014. For both North and South Cyprus, 60% of this reconstructed catch was assigned as recreational and 40% assigned as subsistence.

## Results

For all of Cyprus, the components which had the highest estimated total fishery removals were industrial landings (40%), followed closely by the artisanal landings (36%), while discarded catches (11%), subsistence (7%), and recreational catches (5%) accounted for smaller proportions.

Estimated total recreational and subsistence and catches for the north from 1950-2010 were nearly 6,100 t and 6,050 t, respectively. Estimated subsistence and recreational catches for the south from 1950-2010 were just over 9,400 t and 5,000 t, respectively.

## Denmark

The original technical reconstruction research was initially documented in Gibson et al. (2014), and was updated to 2014 by the *Sea Around Us*.

In 2008, the CFP began to require recreational catch information in addition to discard data (Sparrevohn and Storr-Paulsen 2012a). It is only mandatory to collect Atlantic cod and European eel (*Anguilla anguilla*) catch data for this sector. In addition to this, Denmark began to collect data for sea trout (*Salmo trutta trutta*) in 2010 ((Sparrevohn et al. 2011; Sparrevohn and Storr-Paulsen 2010)). In order to collect recreational catch information, Sparrevohn and Storr-Paulsen (2012a) created an interview-based survey for Danish residents. Nearly 17% of the Danish population identifies themselves as anglers (Sparrevohn and Storr-Paulsen 2012a). Anglers and passive gear fishers between 18 and 65 years old are required to purchase a license (Pawson et al. 2008; Sparrevohn and Storr-Paulsen 2012a).

Recreational fishing began in the 1950s with only few fishers targeting Atlantic cod and European eel from the shore (K. Manniche, pers. comm. Danmarks Sportsfiskerforbund). During this time, there was also a small subsistence fishery on the Wadden Sea coast of Jutland for European plaice (Holm 2005) and likely other flat fish species. With the invention of lighter fishing tackle, the popularity of recreational fishing grew (K. Manniche, pers. comm. Danmarks Sportsfiskerforbund). Recreational fishing peaked in the 1970s with larger catches of Atlantic cod and European eel correlated with higher SSB at the time (K. Manniche, pers. comm. Danmarks Sportsfiskeforbund). In Denmark, there was another historical recreational fishery for Atlantic bluefin tuna (*Thunnus thynnus*)<sup>22</sup>, which ended by 1964 due to the disappearance of stocks in the 1960s (MacKenzie and Ransom 2007). Sea trout fishing has only become more popular with a stock increase in the last 10 years resulting from a stocking initiative of smolts since 1991 (K. Manniche, pers. comm. Danmarks Sportsfiskerforbund).

## Methods

Recreational catch The European Commission's CFP requested member states to begin monitoring and estimating the catches of recreational fisheries in 2008 (Sparrevohn and Storr-Paulsen 2012b; Sparrevohn and Storr-Paulsen 2012a). As a result, Denmark began to estimate catches of Atlantic cod and European eel using a recall survey in 2009 (Sparrevohn et al. 2011; Sparrevohn and Storr-Paulsen 2012b; Sparrevohn and Storr-Paulsen 2010). Sea trout was added to the survey in 2010 (Sparrevohn et al. 2011; Sparrevohn and Storr-Paulsen 2012b). DTU Aqua reports (Sparrevohn et al.

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<sup>22</sup> Tuna club [http://www.tunaclub.dk/viewpage.php?page\\_id=1](http://www.tunaclub.dk/viewpage.php?page_id=1) (Accessed June 12, 2013)

2011; Sparrevohn and Storr-Paulsen 2012b; Sparrevohn and Storr-Paulsen 2010; Storr-Paulsen et al. 2010) provide catch values as well as catch and release numbers for these species since 2009 for various bodies of water surrounding Denmark. Our recreational catch anchor points estimated from these reports include both passive gear and angling catches, as well as DTUs estimate of illegal catches from Kattegat, Skagerrak, the North Sea and Limfjorden (Table 16). Data for cod in 2009 and 2010 (Sparrevohn et al. 2011; Sparrevohn and Storr-Paulsen 2010) are averaged to avoid an unrealistic spike in 2010 recreational catches. The average is used as anchor points for both 2009 and 2010. An ICES report on recreational fishing surveys is used as confirmation for cod and eel catches (ICES 2012a).

**Table 16.** Anchor points to estimate recreational catches (in tonnes) from 1950 – 2010. Dashed line (-) indicates years in which linear interpolations were used.

Year	Atlantic cod	Sea trout	European eel	Garfish	European plaice	European flounder	Common dab	Atlantic bluefin tuna
1950	463	0	195	0	77	77	77	-
1959	-	-	-	-	-	-	-	0.3
1964	-	-	-	-	-	-	-	0.0
1970	926	-	-	-	154	154	154	-
1992	-	167	-	167	-	-	-	-
2009	545	-	39	-	91	91	91	-
2010	545	167	43	167	91	91	91	-

Prior to the European Commission requesting that its member states begin to monitor recreational fisheries, there is little information on Danish recreational catches. Recreational information is often presented qualitatively. Therefore, the anchor point estimates we present are based on DTU Aqua reports and personal communication with fellow researchers and recreational fishers (Table 16). Flatfish species such as European plaice, European flounder (*Platichthys flesus*) and common dab (*Limanda limanda*) as well as garfish (*Belone belone*) are caught in relatively large numbers for sport purposes, but are not included in DTU Aqua surveys (K. Manniche, pers. comm. Danmarks Sportfiskeforbund). For garfish, we use the same anchor points that are used for sea trout (Table 16). For flatfishes, we use half the anchor points for cod and then divide that value equally among the three commonly caught species of flatfish (Table 16).

For the 2011 – 2014 update of Denmark (Baltic) the recreational fishing was carried forward at the 2010 level for 2011-2014 as there were no new statistics on marine recreational fisheries. For the Denmark (North Sea) 2011 – 2014 update the 2015, the Technical University of Denmark (DTU) released a new report on recreational fishing (Olesen and Storr-Paulsen 2015). The major species recreational species outlined in Gibson et al. (2014) were updated to 2012 using the values from this report. The remaining 2013-2014 period was carried forward from 2012, unaltered.

## Results

Recreational catches Denmark's total recreational catch over the time series is estimated at around 86,000 t. Atlantic cod is the most important recreational species, comprising 51% of the total catch. Recreational catches as estimated here remain relatively consistent over the time series; however, they seem to have been declining since the 1970s. However, while the overall trend represented by our data seems appropriate, detailed variation is not well reflected in our data, given the limited data available on this sector, and the assumptions we consequently had to employ. European plaice, European flounder and common dab represent 8% each of the recreational total catch. All flatfishes follow a similar trend to cod; there is an initial increase however, catches have been declining since

the 1970s. European eel represents 8% of the total catch, but demonstrates a gradually declining trend over time. Sea trout has only recently become a more popular species to target since restocking programs beginning in the early 2000s seem to have been successful (K. Manniche, pers. comm. Danmarks Sportsfiskerforbund). They each represent approximately 8% of the total catch and show an increasing trend over the time series.

## Djibouti

The original technical reconstruction research was initially documented in French by Colleter et al. (2015), and was updated to 2014 by the *Sea Around Us*. All material is in French, except for the 2011-2014 update.

### La pêche récréative

La pêche récréative semble encore peu développée et aucune étude concrète n'a encore été réalisée à ce sujet. En 2008–09, trois licences ont été octroyées à des entreprises de pêche sportive (Hosch 2010). Le système des licences fait également état de personnes possédant une licence de pêcheur non-commercial (i.e., pêchant de manière récréative principalement le week-end) au nombre de 60 en 2008 et 50 en 2009 (Hosch 2010). Enfin, il existe également des clubs de pêche au sein des bases militaires étrangères, comme l'ASAC Pêche de Djibouti pour l'armée française. Pour estimer les captures associées à ces trois types de pêches récréatives, nous avons procédé de plusieurs manières.

Concernant la pêche sportive et les entreprises touristiques associées, nous avons pris contact avec la seule entreprise proposant des séjours de pêche à Djibouti pour les touristes étrangers ('Mémoire d'un Fleuve'; [www.memoiredunfleuve.com](http://www.memoiredunfleuve.com)). Cette entreprise a commencé son activité en 2001 et est active 20 semaines par an d'avril à fin juin, puis d'octobre à début novembre. La pratique de pêche est le no kill, c'est-à-dire qu'il y a remise à l'eau systématique des individus pêchés. Cependant, le responsable nous a indiqué que les guides sur place gardaient généralement un ou deux gros *Scomberomorus commerson* (thazards rayés) pêchés chaque semaine, soit environ 25 kg. Nous avons donc estimé que ce type de pêche récréative capturait 0,5 t de thazard par an ( $20 \times 25 = 500$  kg) depuis 2001. Il existe également des hôtels, structures de vacances qui proposent des activités pêche, mais nous ne possédions aucun renseignement précis sur ces acteurs. Nous avons donc considéré que les 500 kg de thazards pêchés annuellement représentaient la moitié des captures de 'Mémoire d'un Fleuve' (l'autre moitié étant allouée au groupe générique 'poissons pélagiques'), et que les autres sources de pêche récréative représentait deux fois ces captures (toutes attribuées au groupe 'poissons pélagiques').

Concernant les pêcheurs récréatifs locaux pratiquant la pêche le week-end, cette pêche est ancienne de par la présence française pré- et post-indépendance, et sa pratique est concentrée à Djibouti. El Gharbi (1987) mentionnait 612 pêcheurs 'amateurs' autorisés à pêcher en 1987. Cependant, ces chiffres semblent être très sur-estimés, étant donné que la distinction entre pêcheurs récréatifs et pêcheurs artisans est difficile à faire à cause du faible coût de l'autorisation et la pratique de la pêche artisanale à mi-temps. En 2008, nous avons donc considéré qu'il y avait 55 pêcheurs récréatifs en 2010, suivant les chiffres proposés par la Direction de la Pêche (60 pêcheurs en 2008 et 50 en

2009). Nous avons ensuite estimé le nombre de pêcheurs récréatifs annuels au pro rata du nombre d'habitants à Djibouti-ville (Guillaume 1979; République de Djibouti). Finalement, nous avons considéré que ces pêcheurs capturaient cinq kilos de 'poissons pélagiques' par sortie, 24 fois par an (i.e., deux week-ends par mois), soit 120 kg·pêcheur<sup>-1</sup>·année<sup>-1</sup>.

Enfin, concernant les clubs de pêche au sein des armées, comme le club ASAC de l'armée française enregistré auprès des Clubs Sportifs et Artistiques de la Défense (CSAD).<sup>9</sup> Ces pêcheurs pratiquent également majoritairement la remise à l'eau, mais les guides locaux gardent une partie des poissons lors des sorties. Ainsi, en 2010, 20% des captures d'un voyage de pêche sont allées aux guides ([www.youtube.com/watch?v=TAjsjWg6o7o](http://www.youtube.com/watch?v=TAjsjWg6o7o)), soit 0,5 t de 'poissons pélagiques' (V. Cressy, comm. pers.). Nous avons donc inclus les clubs de pêche des armées étrangères dans notre reconstruction en estimant la capture à 0,5 t par an depuis 2000, n'ayant pas plus de détails sur les effectifs historiques de l'ensemble des clubs et les pratiques associées.

#### 2011-2014 update

For the 2011 – 2014 update, updated population data from Djibouti National Statistics were used to update the local recreational landings. We maintained the pro-rata catch of 120 kg per local recreational fisher, and the proportion of recreational fishers within the population constant to calculate the local recreational catch from 2015-17. Recreational fishing by visitors were calculated for 'Marines' and 'Memoires d'un Fleuve' separately and have been held constant from 2000 and 2001 respectively, as tourism and foreign military operations are continuing. Future carry forwards should monitor the literature for updates on these fisheries.

## Dominican Republic

The original technical reconstruction research was initially documented in van der Meer et al. (2014), and was updated to 2014 by the *Sea Around Us*.

### Methods

#### Tourist sector

Investigations were done to assess the seafood sources at hotels in the Dominican Republic, which serve both imported and local seafood products on their menus. It is common for fresh seafood catches to be delivered daily by fishers directly to the hotel. Due to the fact that in these instances, fishers bypass landing sites, seafood catches supplying the tourist markets (such as hotels, guest houses and restaurants) are not accounted for and these catches were reconstructed separately. Annual tourist population data (1961-2010) were combined with data on the average length of stay, which was approximately 8.9 days according to the Caribbean Tourism Organisation. Taken together with inferences about the frequency of fresh seafood consumption (i.e., one serving of fresh seafood per day) and a typical serving proportion of 100 g (round weight), we applied the following equation to estimate tourist seafood demand annually:

Tourist seafood demand = # tourist days x average serving size x # servings/day

In this way, we were able to reconstruct small-scale catches satisfying the tourist market from 1961 to 2010.

#### Recreational sector

According to a global recreational study (Cisneros-Montemayor and Sumaila 2010), the number of recreational fishers in the Dominican Republic in 2003 was 19,863. Since sport fishing is an activity that is associated with tourism activities (Campos and Munoz-Roure 1987), we assumed all of these fishers were tourists. Therefore, by dividing the number of recreational fishers by the total number of stop-over tourists in 2003, we calculate the proportion of tourists who fish recreationally during their visit. We applied this rate of 0.006% constantly from 2003 to 2010. For the year 1961, we assumed a participation rate of 0.003% (half that of the later time period). Linearly interpolating between these two rates, we derived recreational fishing participation rates of the tourist population for the entire time period, 1961-2010. Assuming tourists are likely to participate in just one fishing tour during their stay of average 8.9 days<sup>7</sup> and assuming a conservative catch of 4.5 kg-tourist<sup>-1</sup>-year<sup>-1</sup>, we estimate catches from this sector.

#### Species composition

Detailed quantitative data for the taxonomic breakdown for all coastal regions of the Dominican Republic were found in PROPESCA reports for the years 1988 to 1990 and in a report by Appledoorn and Meyers (1993). In these sources, total daily catches by species were reported and classified for 12 months starting in November 1988 until November 1989. These catch amounts were turned into percentages. For all those species and families not mentioned in the above reports, but included in the FAO data, average proportions for the 1990-1995 period (the time period in which the FAO data had the greatest taxonomic disaggregation) were calculated and added to the percentage breakdown provided by the independent reports. Catches of Caribbean spiny lobster and queen conch fisheries have been (and continue to be) an important food source for locals but became even more important in the 1960s with the growth of the tourism sector (Melo and Herrera 2002). Taking the average proportional contribution of spiny lobster and queen conch to total catches in SERCM (Secretaria de estado del medio ambiente y recursos naturales [Secretariat of natural resources and environment]) catch data for 2000-2003, we then also added these two commercially important species to the breakdown. Overall proportions were re-scaled to 100% and applied constantly to the domestically consumed artisanal catches from 1950-2010. A slightly modified version of the artisanal breakdown (i.e., pooled to the family taxonomic level) was applied to the subsistence catches and artisanal catches for tourist consumption.

Information regarding the species composition of the recreational fishery in the Dominican Republic was not available. However, it is known that marlins (Istiophoridae), dolphinfish (*Coryphaena hippurus*), wahoo (*Acanthocybium solandri*), and tunas (Scombridae) are commonly caught species in most marine recreational fisheries. We therefore assumed equal proportionality of 25% for each of these taxonomic groups.

For the 2011 – 2014 update, the consumption rate of tourists and average length of stay per tourist were assumed to remain the same as in 2010 for 2011-2014. The participation rate of tourists in recreational fishing and the recreational catch rate were assumed to remain constant for 2010-2014

in order to calculate recreational landings. The taxonomic breakdowns for each sector were maintained at the 2010 level for 2011-2014

## Results

Reconstructed seafood catches supplying tourist markets, such as hotel, guest houses and restaurants were estimated at 60,000 t for the period 1961-2010. This contributed about 2.4% to the total reconstructed catches.

Reconstructed recreational catches for Dominican Republic were approximately 1,700 t from 1961-2010, accounting for only 0.07% of the total reconstructed catch.

## Egypt

The original technical reconstruction research was initially documented in Tesfamichael and Fahmy Mehanna (2012b), and was updated to 2014 by the *Sea Around Us*. Material for the Red Sea has also been published in a book that was peer-reviewed (Tesfamichael and Pauly 2016).

## Methods

Some form of recreational fishing has been practiced in Egypt for a very long time, starting from the time of the Pharaohs (Pitcher and Hollingworth 2002). The more contemporary recreational fishery started with the growth of tourism in the Egyptian Red Sea, i.e., after the 1967 Arab-Israeli war (Hawkins and Roberts 1994). Both tourists and the local population are involved in recreational fishing. They usually use line fishing (simple hook and line, longline and trolling) and more rarely nets (mainly to catch bait). The catch is usually consumed by the fishers, some given to friends and very rarely, in the case of a big catch, a small portion may be sold in the market. Thus, recreational fishing in Egypt is somewhat confounded with subsistence fishing, although it is not a subsistence-need driven activity. The number of boats involved in the recreational fishery has grown very fast in the last few years (FAO 2010; FAO 2004a).

The presence of a recreational fishery in Egypt is mentioned in many reports, but catch data are very scarce. Indeed, the only quantitative information available for the recreational fishery of Egypt in the Red Sea was that there were 3,013 recreational fishers in 2003 (FAO 2004a) and 5,079 in 2008 (FAO 2010). The term 'recreational fishers' in Egypt refers to full-time operators of boats taking tourists (local and foreign) on day trips of recreational fishing. The 2008 report also gives the number of boats involved in recreational fishing activity. In order to estimate the total catch of the recreational fishery, the numbers of operators from 2003 and 2008 were used. First, the proportion of the recreational fishers from total population (participation rate) was calculated for 2003 and 2008, which were 0.0043% and 0.0067%, respectively. The recreational fishery was assumed to start in 1968, after Egypt's war with Israel in 1967. The tourism industry in the Red Sea started after the war (Hawkins and Roberts 1994) and tourism has major impacts on the recreational fishery. The participation rate for 1967, therefore, was assumed to be zero. The rates were interpolated between 1967 and 2003 and again from 2003 to 2008. The slope of change from 2007 to 2008 was used to calculate the participation rate for 2009 and 2010.

Once the participation rates were estimated from 1967 to 2010, the total number of participants was calculated by multiplying the participation rates by the population of Egypt, obtained from the United Nations, Population Division ([esa.un.org/unpd/wpp/Excel-Data/population.htm](http://esa.un.org/unpd/wpp/Excel-Data/population.htm)). In addition to the number of participants, data on number of days per year and the catch rate per day are needed for the estimation of total catch. The number of days per year we assumed a conservative 250 days-year<sup>-1</sup> based on the report from FAO (FAO 2010), stating that the recreational boats sail on more than 280 days per year. For the catch rate per operator, we assumed 2 kg-day<sup>-1</sup> for 1968 and 1 kg-day<sup>-1</sup> for 2010. This is again a conservative catch rate assumption. The catch rate was interpolated between 1968 and 2010, to mimic the change in catch rate as the intensity of fishing increases and abundance decreases. The total catch was then calculated by multiplying the number of operators by the number of days per year they fish multiplied by the catch rate. Since the estimated number of recreational operators was for the whole of Egypt's EEZ, i.e., both the Mediterranean and the Red Sea, the Red Sea part was calculated by assuming that 75% of the recreational fishery occurs in the Red Sea, based on the report that most of the recreational fishing takes place in the Red Sea (FAO 2010).

The catch composition of the Egyptian recreational fishery in the Red Sea is estimated based on the field observation by the second author. The dominant taxa in catch are groupers (Serranidae), pelagic jacks and mackerels (Carangidae) and snappers (Lutjanidae). Emperors (Lethrinidae) and large sized threadfin breams (Nemipteridae) are also common in the catch, although not as dominant as the three previously listed ones. We assumed a contribution of 20% each for the three dominant taxa, 15% each for emperors and threadfin breams and 10% was allocated to the 'others'.

For the 2011 – 2014 update for Egypt's (Mediterranean Sea), we assumed that the number of recreational fishers decreased by 60% in 2011. The country became a bit more stable during the following years; thus this we assumed that the number of recreational fishers increased by 10% in 2012 and 20% in 2013. The CPUE of 153 kg-person-year<sup>-1</sup> obtained by Mahmoud et al. (2015) for recreational fishery was applied to the number of recreational fishers for each year between 2011 and 2013. For the Red Sea, we assumed that the participation rate in the recreational fishery decreased by 40% in 2011, but increased by 10% in 2012 and by an additional 10% in 2013. We also assumed that the number of fishing days per year decreased from 250 in 2010 (Tsfamichael and Mehanna 2012a) to 150 in 2011 and then increased to 200 in 2012 and 2013. We kept the same per day catch amount of 1 kg used in (Tsfamichael and Mehanna 2012a).

## Results

Overall, from 1950 to 2010, purse seining contributed the largest share to the total catch (42%), followed by trawling (27% discarded and 13% retained catches). The trawl fishery was dominant in the early years, i.e., the 1960s until the mid-1970s, after which it was more or less at par with purse seining, which took over in recent years. The subsistence fishery was the third most important fishery by total catch (14%). The artisanal fishery and recreational fisheries had low contributions (3% and 1%, respectively).

The recreational fishery was the fishery with the least contribution to the total catch and also the fishery that started last. Since then, however, it is the only fishery with a continuously increasing trend. The number of boats involved in recreational fishing has increased considerably as sea-based tourism (both international and local) has increased in Egypt and became economically quite

important. As compared to the other sectors, there was no dominant taxon in this fishery. The recreational fishery does not seem to get attention from the Egyptian fishery authority, possibly because of its limited size and/or that it does not fall into the commonly accepted fisheries in the country: fishing solely done for commercial purposes or to feed one's family (subsistence).

## Equatorial Guinea

The original peer-reviewed reconstruction research was documented in Belhabib et al. (2016c), and was updated to 2014 by the *Sea Around Us*.

### Methods

Recreational fishing is primarily conducted by tourists (Anon 2007a). A hotel in the Parc National de Mont Alen received 200 tourists in 2007 (Anon 2007b) of which 80% fished for 3 days per week, and 60 for 1999 and 192 for 2010 using total tourist expenditure trends (Belhabib et al. 2015a). Data available online suggest the start of tourist activities date back to 1995, but it was assumed here the number of recreational fishers for 1995 was zero. Interpolations were performed. A CPUE of 146.5 kg fisher<sup>-1</sup> trip<sup>-1</sup> was estimated by Belhabib et al. (2015a) and multiplied by the number of fishers and the number of trips per fisher per year to estimate the total recreational marine catch in Equatorial Guinea. The documented catch showed on average 52% of barracudas (*Sphyraena* spp.), 18% of groupers (*Epinephelus* spp.), 9% of jacks (Carangidae) and 21% of other fishes.

Similarly, recreational landings were updated for 2011-2014 based on the proportion of recreational landings to reported landings in 2010. The 2010 proportions of taxa caught recreationally were held constant for 2011-2014.

### Results

Recreational catches increased rapidly from  $1.0 \pm 0.1$  t yr<sup>-1</sup> in 1996 to  $8.0 \pm 1.6$  t yr<sup>-1</sup> in 2010.

Recreational catches consist mostly of barracudas (*Sphyraena* spp.), groupers (*Epinephelus* spp.) and various species of jacks (Carangidae) along with other unidentified fish species.

## Estonia

The original technical reconstruction research was initially documented in Veitch et al. (2010a), was peer reviewed in Zeller et al. (2011b), and updated to 2014 by the *Sea Around Us*.

### Methods

Unreported landings as a rate were applied to landings (i.e. ICES landings statistics + adjustments) to derive tonnage of unreported landings for Estonia from 1950-2007. We assumed that unreported landings for Estonia were zero from 1950-1990, following our conservative assumption-based methodology for all former eastern bloc countries (see Methods in Zeller et al.(2007)). To estimate unreported landings for 1991 and 1992, the years which reflect the transition from a state-controlled economy to a market-based economy, rates were obtained through linear interpolation from 0% in 1990 to the first anchor point established for 1993 (Table 17). Unreported cod landings for the period 1993-2007 were estimated to range from 50-100% (Anon. pers. comm.), and we used

the average of this range (75%) as the rate for unreported cod landings. Unreported landings of salmon were estimated using our default methodology. Baltic-wide unreported landings of salmon were reported for 1981-2007 (ICES 2008) as a minimum, mode and maximum amount, and here we used the mode, following our default approach for countries that did not report recreational catches (see Methods' in Zeller et al.(2007)). The amount of unreported landings was converted to a rate by considering the amount as a proportion of the total landings presented in the same working group report. The Baltic-wide default rate was applied since country specific contributions to unreported landings were lacking. All other taxa had unreported landings based on our default values using anchor points developed from the years 1993, 1994, 2004, and 2005 (see Methods in Zeller et al.(2007)).

**Table 17.** Anchor points for unreported landings (as a %) for cod (LATFRA), salmon (Table 2.1.1. in ICES 2008) and all other taxa. Dashed lines (-) indicate years when the rates were derived through linear interpolation.

<b>Year</b>	<b>Cod</b>	<b>Salmon</b>	<b>Other taxa</b>
1950-1990	0.0 <sup>a</sup>	0.0 <sup>a</sup>	0.0 <sup>a</sup>
1991-1992	-	-	-
1993	75.0	19.4	24.6
1994	75.0	18.7	30.3
1995	75.0	19.5	-
1996	75.0	20.4	-
1997	75.0	20.8	-
1998	75.0	20.1	-
1999	75.0	20.4	-
2000	75.0	19.9	-
2001	75.0	20.4	-
2002	75.0	20.5	-
2003	75.0	20.1	-
2004	75.0	20.6	12.3
2005	75.0	20.7	11.2
2006	75.0	22.2	11.2 <sup>b</sup>
2007	75.0	21.4	11.2 <sup>b</sup>

<sup>a</sup> default assumption based rate; <sup>b</sup> 2005 value carried forward.

Boat-based discard rates for the period 1993-2007 were derived from three sources, the first being the Estonian government provided boatbased discard tonnage for various taxa for 2005. The rates were derived from the total landings presented in the same report, and were estimated for cod (3.7%), herring (3.9%), sprat (3.0%), European flounder - the only reported flatfish - (17.2%), and several other taxa (Table 18) that were included in our grouping others' (Anon 2007c; Anon 2006). The 2005 rate was used as the discard rate throughout the 1993-2007 time period. The second source estimated boat-based discard rates of salmon from ICES stock assessment working group data (ICES 2008), which presents Baltic-wide, boat-based salmon discards (in tonnes) as a minimum, mode and maximum for the 1993-2007 time period (Table 19). The mode was used for Estonia, following our default assumption-based approach for countries that do not report recreational catches (see Methods in Zeller et al. (2007)). These values were converted to rates using the total landings presented in the same working group report. The third source for estimating discards for all remaining individual taxa, included here in our group others', was a boat-based discard rate of 6.2% for all years from 1993-2007, derived from a Danish study (Anon 2006).

Recreational catches for Estonia were considered from 1990 onward, since prior to the 1990s during the USSR period, we assumed that no recreational fishing took place in Estonia (see Methods in Zeller et al. (2007)). Catches for 1991-2007 were estimated from two separate studies done in 2004 and 2007, which had some overlap in species. Thus, anchor points were established for these two years for the taxa reported. Linear interpolations were done between anchor points, but for those taxa that were only reported in 2004, this reported value was used to 2007 (Table 19).

Similarly, recreational landings were updated for 2011-2014 based on the proportion of recreational landings to reported landings in 2010. The 2010 proportions of taxa caught recreationally were held constant for 2011-2014.

**Table 18.** Boat based salmon discard rates for Estonia (ICES 2008) used in all subdivisions except in subdivision 32 when seal-damaged discard rates based on sources were greater (1981-2007). Values in *italics* indicate an interpolated rate

Year	Boat-based	Seal-damaged
1950-1980	2.0	0.0
1981	2.0	<i>6.9</i>
1982	2.0	<i>13.8</i>
1983	2.0	<i>20.7</i>
1984	2.0	<i>27.6</i>
1985	2.0	<i>34.4</i>
1986	2.0	<i>41.3</i>
1987	2.0	<i>48.2</i>
1988	2.0	<i>55.1</i>
1989	2.0	<i>62.0</i>
1990	2.0	<i>68.9</i>
1991	<i>6.0</i>	<i>75.8</i>
1992	<i>10.1</i>	<i>82.7</i>
1993	14.1	<i>89.5</i>
1994	12.9	<i>96.4</i>
1995	13.9	<i>103.3</i>
1996	15.1	<i>110.2</i>
1997	14.9	<i>117.1</i>
1998	14.2	<i>124.0</i>
1999	14.8	<i>130.9</i>
2000	10.3	137.8
2001	15.0	203.4
2002	15.8	255.8
2003	15.4	337.3
2004	15.6	380.5
2005	15.2	113.2
2006	17.4	149.3
2007	14.2	102.7

**Table 19.** Anchor points for recreational catch (t) in Estonia from 1990-2007 obtained from national reports (Anon. 2006, 2007). Dashed line (-) indicates interpolated value.

Year	Herring	Salmon	Flounder	Trout	Perch	Smelt	Bream	Garfish
1990	0	0	0	0	0	0	0	0
1991-2003	-	-	-	-	-	-	-	-
2004	3	6	160	0	4	71	43	61
2005-2006	-	-	-	-	4 <sup>a</sup>	71 <sup>a</sup>	43 <sup>a</sup>	61 <sup>a</sup>
2007	2	2	43	3	4 <sup>a</sup>	71 <sup>a</sup>	43 <sup>a</sup>	61 <sup>a</sup>

<sup>a</sup> 2004 value carried forward.

## Results

Recreational fishing is not accounted for in ICES landing statistics, and in our reconstruction we assumed that no recreational fishing occurred in Estonia prior to 1991. Our recreational catches include salmon, herring, and the groups 'others' and flatfishes. There was an estimated 3,421 t of fish caught by the recreational sector of Estonian fisheries from 1991-2007. The 'others' category was the largest, 1,896 t from 1991 to 2007, accounting for 55% of the total recreational catch. The catches increased from 0 t in 1990 to approximately 183 t in 2007. Recreational catches of flatfish totaled 1,445 t from 1991 to 2007, accounting for 42% of the total recreational catch. Flatfish

catches increased from 1991 to 2004, when they peaked at 160 t, and then decreased to 43 t in 2007. Salmon was estimated to have contributed approximately 1.5% to total recreational catches, with a total of 54 t from 1992 to 2007, and an average yearly recreational catch of 3 t. Recreational herring catches totaled 26 t from 1991-2007.

As recreational fishing in Estonia was illegal during the USSR period, we only considered recreational catches from 1991 onward. We obtained recreational catch data from the Estonian government, but only for selected years in the most recent decade. Recreational catches represented only a minor component of the reconstructed catch, but should be considered significant as these are not included in the ICES landings statistics. Quantifying these catches is important in an ecosystem-based management context as the species targeted recreationally are often different from those caught commercially. For instance perch, pikeperch and pike are important in Estonia's recreational fisheries, particularly since the increase in export opportunities that occurred in the early to mid-1990s (Vetemaa et al. 2006). The high value of these fish in the export market encouraged recreational fishers to sell their catches as opposed to retaining them for personal consumption (Vetemaa et al. 2006).

## Faeroe Isl. (Denmark)

The original technical reconstruction research was initially documented in Gibson et al. (2015b), and was updated to 2014 by the *Sea Around Us*.

### Methods

The Faeroe Islands have a small population and there is not a great deal of tourism. There is likely an overlap of recreational and subsistence catches, in terms of definition, in rural areas over the investigated time series. The Faeroe Islands do not require a license for recreational or subsistence fishing and there is no data collection program for these non-commercial fisheries (E. Magnussen, pers. comm.).

We allocate 70% Atlantic cod (*Gadus morhua*), 15% haddock (*Melanogrammus aeglefinus*), 10% saithe (*Pollachius virens*) and 5% other species to all non-commercial catch (both recreational and subsistence). Due to the importance of demersal fisheries in the Faeroe Islands, much of the subsistence and recreational catch likely consists of demersal targets. The catch of other species (5%) likely consists of flatfishes (European plaice, common dab, etc.), other cod-fishes (whiting, ling and pollock), wolfish, sharks and rays, angler, mackerel and herring<sup>23</sup>.

Our estimate of recreational catch is a fraction of the estimated subsistence catch over time (Gibson et al. 2015b). It is estimated that in 1950, 100% of the non-commercial catch was for subsistence purposes and by 2010; it represents 80% of the non-commercial catch. 20% of the non-commercial catch is designated as recreational in 2010. Proportions of subsistence and recreational catch are interpolated from 1950-2010.

For the 2011 – 2014 update, unreported recreational and subsistence catches were recalculated using updated World Bank population data and the original reconstruction's methods. The

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<sup>23</sup> Magni Blástein <http://fishingwithblastein.com/index.html> (Accessed April 16, 2014)

taxonomic breakdown of unreported small-scale landings was maintained at the 2010 levels for 2011-2014.

## Results

The subsistence catch in the Faeroes increases from 680 t in 1950 to nearly 900 t in 2010. This is a reflection of an increase in population over time. Much of this catch comes from people taking out their individual boats for a trip or fishing crew taking dried fish home for self- and family-consumption (Reinert 2001). We have also estimated recreational catch as an increasing proportion of the subsistence catch over time. There is likely an overlap of the intention of subsistence and recreational catch in the Faeroe Islands, which is why we chose to take recreational catch out of the subsistence estimate. While tourism in the Faeroe Islands isn't significant, there are some fishing trip operators, which operate most of the year (M. Blástein, pers. comm.).

In addition to discards, there is unreported catch in the form of recreational and subsistence catches. The Faeroe Islands do not have much tourism. There are some charter vessels in larger cities and towns throughout the islands (M. Blástein, pers. comm.). These charter vessels target a variety of areas and species, which allow them to remain active all year. There is no licensing program (E. Magnussen, pers. comm.) or data collection program for recreational or subsistence fisheries in the Faeroe Islands. This presents a challenge for estimating tonnages of recreational and subsistence catches. We use Iceland's per capita subsistence rates applied to the Faeroe Islands population for total subsistence and recreational catch. This may be a misrepresentation of subsistence catch, however Iceland and the Faeroe Islands have similar dietary habits, and hence we assume that both have similar subsistence rates. The Faeroe Islands have a much higher rural population proportion than Iceland, which suggests that our estimate is likely on the conservative side. No non-commercial catch is recorded in the official landings in the Faeroe Islands (Reinert 2001a). We suggest that estimates of country-wide non-commercial catches be obtained on a regular basis, and that these are to be included in annual data reporting.

## Finland

The original technical reconstruction research was initially documented in Rossing et al. (2010a), and was vetted through peer-review in Zeller et al. (2011b), and was updated to 2014 by the *Sea Around Us*.

## Methods

The recreational fishing sector is relatively more important in Finland than in other Scandinavian countries as about half of marine landings are accounted for by recreational fishers, when herring catches are excluded (FAO 2005).

### Adjustments to ICES landings statistics

The reported ICES landings statistics were adjusted using Finnish landings data provided by FGFRI for the period from 1953-2007, for most taxa including cod, herring, sprat, salmon, flatfishes and 'others'. For some species in our group flatfishes and 'others', FGFRI data were available for slightly different periods of time (Table 20). Landings reported by FGFRI were considered more reliable than

the ICES landings statistics for two reasons. Firstly, Finland is unique among the Baltic countries in that recreational catches have been estimated and reported nationally since the late 1950s. Secondly, Finland updated its national catch estimation methods in 1988, which led to a revision of reported landings for Finland from 1980-1986 (Ahvonen 2001); yet, the ICES landings statistics database was not amended retroactively to account for these updated landings estimates (E. Aro, pers. comm., FGFRI). Thus, negative adjustments to ICES landings statistics were made to account for the inclusion of recreational catches and also to account for the new catch estimation methods by Finland. These adjustments made to ICES landings statistics to account for the inclusion of Finland's recreational catches made Finland's landings data comparable to all other Baltic countries by reflecting commercial fisheries landings only.

#### Recreational catches

Estimates of Finland's recreational catches from the Baltic Sea were provided by our collaborators at FGFRI. FGFRI has undertaken studies to estimate recreational catches throughout most of the time period considered here (FGRI 2009). Recreational catches were estimated by FGFRI starting in 1953 and since 1986 these estimates have been done every other year with the exception of 1955-1958 and 1960-1961 when recreational catch surveys were not carried out. In years when recreational catch surveys were not done, FGFRI provided estimates of recreational catches for the non-surveyed years. For the period 1950-1952, we estimated annual recreational catches based on the average catch from 1953-1955 as reported by FGFRI. Overall, our total reconstructed catch was the sum of ICES landings statistics, reported landings adjustments and estimates of unreported landings, discards and recreational catches. The estimated total reconstructed catch was then compared to the officially reported data, defined here as the ICES landings statistics.

**Adjustments to ICES landings statistics** Negative adjustments of 180,437 t were made to the ICES landings statistics for Finland using national data sources. These adjustments were, in part, due to recreational catches being included in the ICES landings for some years over the period 1950-2007. Given that we accounted for recreational catches separately, we excluded the recreational component from reported landings here, resulting in negative adjustments. Adjustments to landings were greatest in the late 1970s and throughout the 2000s. The most substantial adjustments to landings were for the group 'others'.

FGFRI carries out surveys to estimate recreational landings in Finnish waters every two years, the results of which were accepted as reported recreational landings. In the time period for this carry forward, 2011-2014, only 2012 recreational data were available from FGFRI (2013). A linear interpolation between 2010 and 2012 FGFRI recreational statistics were used to estimate 2011 data, while the average of 2010-2012 were used to estimate 2013 and 2014. The data were assigned to the same ICES areas as in the FGFRI data.

**Table 20.** Years when landings data provided by FGFRI were used as adjustments to the ICES landings statistics for some taxa included in our grouping of flatfishes and ‘others’.

Common name <sup>a</sup>	Scientific Name	Years
Ide	<i>Leuciscus idus</i>	1969-2007
Flounder	<i>Platichthys flesus</i>	1974-2007
Trout	Salmonidae	1974-2007
Eel	<i>Anguilla anguilla</i>	1976-2007
Roach	<i>Rutilus rutilus</i>	1979-2007
Freshwater species nei	-	1980-2007
Turbot	<i>Psetta maxima</i>	1996-2007
European plaice	<i>Pleuronectes platessa</i>	2006-2007
Whiting	<i>Merlangius merlangus</i>	2006-2007
Other (various)	-	1953-1979

<sup>a</sup>as defined by FGFRI

## Results

Total catches for Finland’s recreational fisheries in the Baltic Sea from 1950-2007 were reported as 456,679 t. Note that Finland reports recreational catches nationally and that the national data set provided by FGFRI had separate accounting for commercial landings and for recreational catches. Recreational catches increased steadily from around 1,600 t·year<sup>-1</sup> in 1950 to between 10,000 and 20,000 t·year<sup>-1</sup> in the 1990s. The majority of recreational catches were of ‘other species’, which represented 80% of the total recreational catch for Finland from 1950-2007. Herring represented 12%, cod 4%, salmon 1%, and sprat contributed less than 0.4% of total recreational catches over the entire study period. Recreational catches of ‘others’ totaled over 366,000 t from 1950-2007 and were most substantial during the 1990s.

Recreational fisheries, dominated by the group ‘others’, accounted for approximately 500,000 t from 1950-2007. The cod fishery in Finland was modest compared to those in other Baltic countries; however, unreported landings, discards and recreational catches of cod together totaled approximately 45,000 t between 1950 and 2007, an increase of 67% to data reported in the ICES landings statistics. Overall, unreported landings, discards and recreational catches represented 12%, 6% and 8% of the total reconstructed catch for Finland, respectively.

## France (Med)

The original research was initially documented in a technical report (Bultel et al. 2008), and was vetted through peer-review in Pauly et al. (2014) and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational fishing in France is defined as non-commercial fishing for self- or family-consumption purposes (Pawson et al. 2008). It is further defined as a motivated by fun, pleasure or sport, and not by a dependence on fish for food (Gaudin and De Young 2007).

Qualitative information regarding recreational fisheries in the French Mediterranean is scarce. However, this activity is known to be expanding in the Mediterranean area and now plays an

important social and economic role, especially with the development of tourism and the enhancement of charter fishing (Gaudin and De Young 2007).

Our reconstruction is mainly based on one set of studies, carried out between 2006 and 2008 (Herfaut et al. 2013; Levrel 2011; Levrel et al. 2009). These studies are based on a combination of telephone and onsite surveys, in collaboration between a statistical institute and the French Research Institute for the Exploitation of the Sea (IFREMER). A total of 15,000 households were surveyed and their results were scaled up to be representative of the entire territory. Results show that 5.1% of the French population beyond 15 years of age is fishing recreationally, i.e., 2.45 million recreational fishers. An overwhelming majority of these recreational fishers are males between 25 and 64 years of age, who actively fish 13 weeks per year on average. It also appears that most fishers live in the coastal area (Levrel et al. 2009).

These studies also illustrate that most fishers feel that the marine resources have been declining over the past years, and that the French recreational fishery has been rapidly expanding for the last 30 years, and is currently catching around 24,000 t·year<sup>-1</sup> of fish, as well as 5,200 t·year<sup>-1</sup> of shellfish, Crustacea and Cephalopoda (Herfaut et al. 2013). Out of these totals, one third are estimated to be caught in the French Mediterranean Sea (Levrel 2011). The most targeted species are seabass (*Dicentrarchus labrax*), Atlantic mackerel (*Scomber scombrus*), and various species of Sparidae and Gadidae (e.g., *Sparus* spp., *Pagrus* spp., *Diplodus* spp., *Pollachius* spp.) (Herfaut et al. 2013; Levrel 2011; Levrel et al. 2009) although Mediterranean rainbow wrasse (*Coris julus*) and comber (*Serranus cabrilla*) make up most of the recreational catches in terms of sheer abundance in Mediterranean marine protected areas (Font et al. 2012). Mugilidae, Blenniidae, Mullidae and Polyprionidae are also reported to be commonly targeted by recreational fishers (Gaudin and De Young 2007).

Based on this information, we considered that the recreational sector truly started to expand in 1976 (i.e., 30 years before the 2006 study), and that the prevalence of recreational fishers in 1976 was 1/4th of that in 2006, i.e., 0.01. We also considered that this ratio had only doubled between 1950 and 1975 (i.e. although growing, the sector truly started to expand afterwards). Furthermore, we considered that the catch per unit of effort in 1976 was twice that of 2006 (and following years), and stable prior to that, as fishers have been noticing a decline in fish per unit of effort. For the taxonomic breakdown, we allocated 75% of the total catch to the most targeted families (Moronidae, Scombridae, Sparidae, Serranidae and Gadidae), and equally distributed the remaining percentage among the other families listed in Font et al. (2012) and Gaudin and De Young (2007) (i.e., Labridae, Carangidae, Scorpaenidae, Mugilidae, Mullidae, Blenniidae, Polyprionidae), as well as a 'marine fishes' category. For the non-fish catch, we allocated 5% to Echinodermata, i.e., sea urchins (Nadaud 1955) and the proportions given by Levrel (2011) to the remaining 95%, i.e., Bivalvia and Gastropoda (36%), marine Crustacea (30%), and Cephalopoda (29%).

For the 2011 – 2014 update, recreational catches were estimated using the same method as in (Bultel et al. 2008), using population data from the Institut National de la Statistique et des Études Économiques (INSEE; <http://www.insee.fr/fr/>) and assumptions on fishery participation and catch per fisher. The total mainland population of France was used to estimate the population over 15 (18.6% of the total mainland population from 2010-2014). The reconstructed recreational catch tonnage for 2010 was used to estimate the number of fishers (assuming the reconstructed Mediterranean catch is equal to 1/3 of total French recreational catch, with a catch rate of 10 kg per

fisher per year),. This allowed the calculation of the proportion of fishers within the population 15 years of age or older, which was kept constant for 2011-2014, and used to estimate the number of fishers, then the recreational catch in the Mediterranean Sea EEZ of France. Subsistence catches were carried forward unaltered from 2010 to 2014.

## Results

Our estimate of the unreported recreational catches for the 1950-2010 period is 286,000 t. They averaged 1,570 t·year<sup>-1</sup> from 1950-1954, and reached an average of 8,980 t·year<sup>-1</sup> by 2006. The only reported recreational catch consisted in the ICCAT tuna catch, which only amounted to 730 t. The recreational catches were distributed by family as follows: Gadidae, Moronidae, Scombridae, Sparidae and Serranidae almost reached 40,600 t, while Blenniidae, Carangidae, Labridae, Mugilidae, Mullidae, Polyprionidae and Scorpaenidae reached over 8,450 t each for the whole period. Seven other taxa accounted for the remaining 8.6%.

Due to the lack of data, it is also important to note that our recreational catch estimates should be improved upon as we did not include any catches taken by tourists. Indeed, since the Mediterranean is a major tourist destination , it can be expected that the high number of tourists can drive the fishing pressure, directly (i.e., fishing by themselves) or indirectly (i.e., willing to eat fresh fish), and therefore have a consequent impact on the resources, especially during summer months (Trumbic 2005). This is a topic to explore, especially as tourism in the region is expected to double by 2025 .

## France (Atlantic)

The original research was initially documented in a technical report (Bultel et al. 2008), and was vetted through peer-review in Pauly et al. (2014) and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational sector Recreational fishing in France is defined as non-commercial fishing for consumption purposes (Pawson et al. 2008) and thus includes what may otherwise be called subsistence fishing. As such, subsistence fisheries consist in sharing and consuming caught fish (or other marine resources) directly with the family and kin of the fishers ([www.fao.org/fishery/topic/12306/en](http://www.fao.org/fishery/topic/12306/en)). However, recreational fishing is also further defined as motivated by fun, pleasure or sport, and not by a dependence on fish for food (Gaudin and De Young 2007), which would exclude subsistence fishing. Nevertheless, Pawson et al. (2008) explained that the term subsistence fishing in France is based more on the “cultural” element of traditional fishing activities rather than on the survival aspect, and most of the hand-picking activities on the exposed intertidal are documented to be traditional and recreational (Lagenette 2001). Moreover, France being a rich country, true subsistence fishing to complement available food supply should be small to nonexistent. Therefore, cultural subsistence fishing, widely carried out on the French Atlantic coasts, is included as part of recreational fishing. Another methodology was applied to the French Mediterranean catch (Bultel et al. 2015; Pauly et al. 2014) in order to fit the local situation.

Quantifying recreational fishing in French marine waters is difficult because this activity does not require a permit, unlike freshwater recreational fishing, leading to few available data (Bolopion et al. 2000; Levrel 2011). However, it is known that this sector contributes substantial catches, and that Atlantic shores have the highest concentration of occasional and regular recreational fishers in France (Levrel 2011).

Our reconstruction is mainly based on one set of studies carried out between 2006 and 2008 (Herfaut et al. 2013; Levrel 2011; Levrel et al. 2009). These studies were based on a combination of phone and on-site surveys about leisure fishing habits, taking into account handpicking, shore fishing, spearfishing and line fishing, and conducted in collaboration with the French Research Institute for the Exploitation of the Sea (IFREMER) and a market research institute (BVA). A total of 15,000 households were surveyed and their results were scaled up to be representative of the entire country. Results show that 5.1% of the metropolitan French population beyond 15 years of age is fishing recreationally, i.e., there are 2.45 million recreational fishers in France. An overwhelming majority of these recreational fishers are males between 25 and 64 years of age, who actively fish 13 weeks per year on average. It also appears that most fishers live in the coastal area (Levrel et al. 2009).

These studies, which documented that most fishers feel that the marine resources have been declining over the past years, also yielded evidence that the French recreational fishery has been rapidly expanding for the last 30 years, and is currently catching around 24,000 t of fish·year<sup>-1</sup>, as well as 5,200 t·year<sup>-1</sup> of Mollusca, Crustacea and Cephalopoda (Herfaut et al. 2013). Out of these totals, two thirds are estimated to be caught outside of the French Mediterranean Sea, i.e., along the Atlantic coast (Levrel 2011). The most targeted species are seabass (*Dicentrarchus labrax*), Atlantic mackerel (*Scomber scombrus*), and various species of Sparidae and Gadidae (e.g., *Sparus* spp., *Pagrus* spp., *Diplodus* spp., *Pollachius* spp.) (Herfaut et al. 2013; Levrel 2011; Levrel et al. 2009), although Mugilidae, Carangidae, Sciaenidae and Clupeidae make up most of the recreational catch in terms of abundance in the South Atlantic (Morandeau 2012; Morandeau 2011a; Morandeau 2011b; Morandeau 2011c; Morandeau 2009). Sepiidae, Labridae, Triglidae and Soleidae are also reported to be commonly caught by recreational fishers in Morbihan (Peronnet et al. 2003). All these species were already reported in 1912 by Cunisset-Carnot (1912) as recreational catches.

In spite of this century-old tradition, we considered that the recreational sector truly started to take off in 1976 (i.e., 30 years before the 2006 study), and that the ratio of recreational fishers in 1976 was 1/4th of that in 2006, i.e., 0.01. We also considered that this ratio had only doubled between 1950 and 1975 (i.e., although growing previously, the sector only expanded after 1975). Furthermore, we considered that the catch per unit of effort in 1976 was twice that of 2006 (and following years), and stable prior to that, as fishers have been noticing a decline in fish per unit of effort.

For the taxonomic breakdown, we allocated 70% of the total catch to the most reported families (Moronidae, Scombridae, Sparidae, Gadidae, Mugilidae, Carangidae, and Sciaenidae) and distributed the remaining percentage equally among the other families (i.e., Clupeidae, Sepiidae, Labridae, Triglidae, Soleidae), as well as a 'marine fishes' category.

For the non-fish catch, we allocated 5% to Echinodermata, i.e. sea urchins (Nadaud 1955) and the proportions given by Levrel (2011) to the remaining 95%, i.e., Bivalvia and Gastropoda (36%), marine Crustacea (30%), and Cephalopoda (29%).

In the context of the *Sea Around Us* database, where 'subsistence' fishing is kept separate from recreational fishing, we suggest that 50% of the recreational catch presented here should be allocated to line fishing, as well as other forms of sport fishing, and the other half to 'subsistence'.

For the 2011 – 2014 update, the same methods were used.

## Results

Recreational catches amounted to almost 600,000 t from 1950 to 2010. They represented about 3,000 t·year<sup>-1</sup> in the early 1950s and increased to reach 20,000 t in 2010. They were mainly composed of Carangidae, Gadidae, Moronidae, Mugilidae, Sciaenidae, Scombridae and Sparidae (9% each), with 11 taxa accounting for the remaining 36% of catch.

## Gambia

The original technical reconstruction research was initially documented in Belhabib et al. (2013c), and was vetted through peer-review in Belhabib et al. (2016d), and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational fishing in The Gambia is conducted by foreign tourists, with the first tourist flight arriving in The Gambia in 1965 (Mendy 2008). The number of tourists (recreational visitors) was reconstructed using anchor points between 1965 and 2010 (Belhabib et al. 2013c). We completed the time series by applying a series of interpolations. We assumed 4.3% of the total number of recreational visitors were recreational fishers (Manel 2008), spending on average 10 days in The Gambia and fishing during 5 days<sup>24</sup>. We assumed the number of visitors in 1981 was half the number of visitors in 1980 to account for disturbance due to the (failed) coup attempt in mid-1981 that would have discouraged foreign tourism (Jabara 1990). However, tourism has grown fast since then (Jabara 1990). To estimate the CPUE of recreational fishers, we combined observations from six YouTube videos posted by tourists and recreational fishing companies in The Gambia with photos of fish catches and their weight provided by [www.african-angling.co.uk](http://www.african-angling.co.uk) [2013] between 2008 and 2010. Overall, 54 observations were collected for 63 tourists. The weighted average CPUE was estimated at 14.5 kg tourist<sup>-1</sup>day<sup>-1</sup>. We assumed this CPUE was constant in the 2000s, and was 20% higher in 1965, i.e., 17.4 kg tourist<sup>-1</sup>day<sup>-1</sup>, due to the generalized over-exploitation of marine resources in the Senegambia region in more recent times. We then interpolated to complete the estimate. We multiplied the CPUE by the number of recreational fishers, then by the number of fishing days and obtained total recreational catches in The Gambia. Finally, we applied the taxonomic breakdown derived from the previous observations.

## Results

Recreational catches, mostly barracudas and stingrays, increased from very low rates in the mid-1960s to around 250 t·year<sup>-1</sup> in the mid-1980s, then fluctuated to reach a peak of 460 t·year<sup>-1</sup> in 2008, driven by the high number of tourists.

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<sup>24</sup> There are two 'Sakumo' lagoons in Ghana, and D. Pauly, who did his field work in 1971, studied the smaller of the two, near Tema.

## Georgia

The original technical reconstruction research was initially documented in Ulman and Divovich (2015), and was updated to 2014 by the *Sea Around Us*.

### Methods

We realized that recreational, subsistence and some aspects of small-scale commercial fisheries form a continuum, and may be hard to separate, however, here recreational and subsistence fisheries are defined and estimated separately.

We are defining the recreational fishery here as fishing primarily for pleasure, and generally neither for commercial sale, nor for the primary purpose of feeding one's self or one's family. The recreational fishery in Georgia is locally referred to as either the 'amateur' or 'sports' fishery and is defined as fishing with any kind of fishing rod, spinning net, throw net, racket net, draught net or the hunting and collection of marine life without the use of scuba gear (Mathews 2007).

Recreational fishing is widespread in Georgia, and the fishers are well-equipped (Khavtasi et al. 2010). Khavtasi et al. (2010) suggested that the number of recreational fishers is high, and their annual catch may be around several hundred tonnes.

To assemble a time-series of Georgian population statistics, the time-series of Tsiklauri and Sulaberidze (2013) was used, which addressed many inconsistencies in the national data, which also included the Abkhaz population.

Given that Georgia has the highest percentage (38.6%) of people living coastally among Black Sea countries, it was assumed that the number of recreational fishers was fixed at a low rate of 0.25% of the total population from 1950-1975 (due to a strong military presence which would have deterred many leisure fishers), after which it was linearly increased to 1% of the population by 1990, and a catch rate of 49 kg·fisher<sup>-1</sup>·year<sup>-1</sup> (verified by local experts for use for the Ukrainian catch reconstruction) was used from 1992-2010, this catch rate was linearly increased by 50% to 73.5 kg·fisher<sup>-1</sup>·year<sup>-1</sup> for the 1950-1975 period (to represent larger and more abundant fish in the earlier Black Sea ecosystem), and then the two catch rates were interpolated between 1976 and 1991. The values from 1989-1992 were reduced by 50% to account for the 'Black Sea fishery crisis' which negatively affected mainly small pelagic catches.

The taxa allocated to the recreational and subsistence sectors were varied to reflect the natural changes in the Black Sea ecosystem, and were derived using a combination of expert (Ukrainian) advice, Turkish fisheries statistics and recreational catch knowledge. In Table 21, each taxon's contribution to the total sum was presented as a percentage for both 1950 and 2010, and were largely interpolated in between following expert advice.

**Table 22.** Recreational and subsistence catch allocation proportions for Georgia, 1950 – 2010.

<b>Common name of species</b>	<b>1950</b>	<b>2010</b>
Bluefish	0.13	0.04
Atlantic mackerel	0.01	0.00
Mediterranean horse mackerel	0.15	0.10
Mediterranean mussel	0.14	0.10
Shrimps	0.05	0.05
European flounder	0.05	0.00
Grey mullets	0.05	0.05
Red mullets	0.05	0.02
Gobies	0.05	0.20
Whiting	0.10	0.10
Groupers and seabream	0.04	0.00
Shi drum	0.04	0.00
Bonito	0.03	0.01
Garfish	0.03	0.00
Dogfish	0.02	0.02
Rays/skates	0.02	0.02
Turbot	0.02	0.02
Sturgeons	0.01	0.00
Crabs/lobsters	0.01	0.00
Sea snail	0.00	0.07
Pacific mullet	0.00	0.20

## Results

Recreational landings (all unreported) averaged 650 t·year<sup>-1</sup> in the early 1950s, peaked in 1988 with 2,400 t, crashed to 1,200 t·year<sup>-1</sup> from 1990-1992, and have since increased to 1,900 t·year<sup>-1</sup> in the late 2000s, but have slowly been declining since 1993. The major taxa which we assumed were caught by the recreational sector from 1950-2010 were Mediterranean horse mackerel (14.4%), Mediterranean mussel (11.6%), bluefish (11.0%), gobies (10.4%), whiting (10.0%), So-iuy mullet (*Liza haematocheila*, 7.6%), sea snails (5.1%), with 14 other taxa accounting for the remaining 30% of catch.

## Germany (North Sea)

The original technical reconstruction research was initially documented in Gibson et al. (2011) was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational fishing in the German North Sea is poorly documented, and generally of low importance. The more significant German recreational fisheries in the Baltic Sea is described separately (Rossing et al. 2010c). It is difficult to estimate how many recreational North Sea fishers there are based on recreational licensing procedures. Much of the information acquired for this reconstruction is personal communication with other researchers and fishers. Recreational fishing in the North Sea in recent times is essentially limited to charter boats, making their catches a useful proxy for annual German recreational catch estimates.

The more historical recreational fisheries were for European eel (*Anguilla anguilla*), blue mussels and other marine molluscs. In the early years, a proportion of these fisheries likely had more a 'subsistence' or 'supplementary subsistence' nature (i.e., feeding one's family) rather than a pure recreational purpose (i.e., pleasure as the major driver). More recent recreational fisheries are for Atlantic cod, Atlantic mackerel, tope sharks (*Galeorhinus galeus*), and European sea bass (*Dicentrarchus labrax*). A government survey of recreational Atlantic cod catches in the North Sea, based on a pilot study in 2004-2006 estimated an annual catch of 30 t (Anon 2011b; Anon 2007d). Data for other recreational species are not readily available. We derive assumed anchor points using qualitative information acquired by personal communication (Table 22). Anchor points for recreational fisheries are based on Anon. (2011b), H. Strehlow (pers. comm., Johann Heinrich von Thünen-Institut) and M. Janke (pers. comm., fisher). Shark values are number of individuals and the other species are estimated tonnages.

Non-commercial fishing with a larger emphasis on sustenance (i.e., subsistence) rather than recreational pleasure for European eel, blue mussel and miscellaneous molluscs was more common in earlier time periods (H. Strehlow, pers. comm., Johann Heinrich von Thünen-Institut). The 1950 anchor point for all non-commercially fished molluscs was arbitrarily estimated at 10% of the commercial blue mussel catch from 1950. This value was then split equally between Blue mussels and miscellaneous molluscs. Miscellaneous molluscs include species such as the surf clam (*Spisula subtruncata*), the American razor clam (*Ensis directus*), common edible cockle (*Cerastoderma edule*), and since 1990, the introduced Pacific oyster (*Crassostrea gigas*) (Lotze 2007; H. Strehlow, pers. comm., Johann Heinrich von Thünen Institut). Thus, after estimating total non-commercial catch time series for eel, blue mussel and miscellaneous molluscs, we split these into assumed subsistence and assumed recreational components equally.

Recreational catch in the original reconstruction heavily relied on personal communication with other researchers and fishers. Consequently, for the 2011 – 2014 update, the increasing or decreasing trends of catch per species were simply interpolated to 2014. For instances where the total catch of a species was already minimal, we conservatively kept the amount constant. Subsistence catch was estimated in the same manner.

## Results

Our approximate estimates of recreational catches total nearly 8,000 t from 1950-2010, and decline steadily over time, from approximately 200 t in 1950 to 44 t by 2010. While small in tonnage compared to commercial catches, our study makes this the first time-series estimate for German recreational fishing in the North Sea. These catches include blue mussels, miscellaneous molluscs, Atlantic cod, European eel, Atlantic mackerel, various sharks and European sea bass.

Blue mussel and miscellaneous molluscs total around 2,800 t each and make up approximately 35% of the total recreational catches each. It is possible that this is an over-representation of molluscs in recreational catches. European eel makes up approximately 8% of the total catch, most of which was likely caught in earlier time periods. Miscellaneous sharks include tope shark (*Galeorhinus galeus*), picked dogfish (*Squalus acanthias*), smooth hound (*Mustelus mustelus*) and small spotted catshark (*Scyliorhinus canicula*) (M. Janke, pers. comm., fisher). Shark catches represent less than 1% of total recreational catches. All of these groups demonstrate a declining trend over time. However,

recreational fisheries for Atlantic mackerel (2% of total catch), Atlantic cod (19% of total catch) and European sea bass (less than 1% of total catch) demonstrate a general increase in catches over time.

**Table 22.** Anchor points to estimate German recreational catches from 1950-2010 in the North Sea. Dashed lines (-) indicate years when linear interpolations were used.

Year	Taxon (tonnes)						Sharks (numbers)			
	European eel	Atlantic cod	Mackerel	Mussels	Misc. molluscs	Sea bass	Tope shark	Picked dogfish	Small spotted catshark	Smooth hound
1950	40	0	0.15	177.5	177.5	0	120	80	60	60
1960	-	-	-	-	-	0	120	40	30	30
1970	-	-	-	-	-	0	100	40	30	30
1990	-	40	-	-	-	0	-	-	-	-
1995	-	-	4.50	-	-	0	-	-	-	-
1999	-	40	-	-	-	0	-	-	-	-
2000	-	35	-	-	-	0	-	-	-	-
2010	1	30	3.00	5.0	5.0	5	20	72	54	54

## Germany (Baltic)

The original technical reconstruction research was initially documented in Rossing et al. (2010c), and was vetted through peer-review in Zeller et al. (2011b) and was updated to 2014 by the *Sea Around Us*.

### Methods

Recreational catches were not estimated for East Germany since it was illegal to participate in this activity (R. Oerberst, pers. comm., Johann Heinrich von Thünen-Institut). Thus, for 1950-1990, recreational catches were estimated for West Germany only, and for the reunified Germany from 1991-2007. The approach taken here is based on the number of fishers and catch rates (i.e., catch-fisher<sup>-1</sup>) for the two states (Länder) bordering the Baltic Sea (Schleswig-Holstein and Mecklenburg-Vorpommern). In 2005 and 2006, the numbers of fishers and the catch of cod, flounder and herring were reported by the Institut für Ostseefischerei Rostock (Zimmermann et al. 2007) for the coastal states of Schleswig-Holstein (a state in former West Germany) and Mecklenburg-Vorpommern (a state in former East Germany). The numbers of fishers in Schleswig-Holstein reported for the two years were averaged (63,500 fishers) and we assumed that the number of fishers in West Germany in 1980 was half this average determined for 2005 and 2006, and in 1950, the numbers of fishers was assumed to be 25% of the average. For the state that was a part of East Germany, the numbers of fishers was also determined (73,500) from the two years of reported data, and for 1990 we set the number of fishers to zero and linear interpolations were done between years. Annual catch rates were held constant and were 23.4 kg-fisher<sup>-1</sup> for cod, 0.5 kg-fisher<sup>-1</sup> for flounder, and 1.8 kg-fisher<sup>-1</sup> for herring.

Recreational fishing catch was extrapolated from 2010 for the 2011-2014 update, as there were no statistics on marine recreational fisheries to be found from the German government.

### Results

Here, recreational catches included cod, herring and flatfishes. Cod made up the majority of recreational catches for Germany in the Baltic Sea. Recreational catches in Germany from 1950-2007 totaled 70,740 t. Recreational catches increased from 410 t-year<sup>-1</sup> in 1950 to over 3,500 t-year<sup>-1</sup> by

2006, with the most significant increase in the early 1990s. With reunification in 1990, recreational fishing in the eastern parts of Germany was permitted and this corresponds to the sharp increase in recreational catches that appears from 1990 onward.

Overall, cod represents over 91% of the total recreational catch for Germany, with herring and flatfishes making up 2% and 7%, respectively. Recreational catches of cod, herring and flatfishes all increased steadily and substantially over the study period. Recreational catches of cod increased from 373 t·year<sup>-1</sup> in 1950 to 3,219 t·year<sup>-1</sup> in 2007, adding a total of 64,210 t to the reported landings over the 1950-2007 study period. Herring catches in Germany's recreational fisheries increased from 8 t·year<sup>-1</sup> in 1950 to 69 t·year<sup>-1</sup> in 2007. Recreational fisheries for flatfish increased from 29 t·year<sup>-1</sup> in 1950 to 250 t·year<sup>-1</sup> in 2007. From 1950-2007, recreational catches of herring added an additional 1,408 t to reported landings and flatfishes added an extra 5,122 t.

Recreational fisheries were only a small contributor to the total reconstructed catch, representing approximately 1%. Recreational fisheries were dominated by cod, which constituted over 90% of Germany's recreational catches. In Germany, cod from the eastern and western stock are caught; however, eastern cod was only considered to have been available recreationally in Germany since reunification in 1990. Prior to 1990, catches of eastern cod were restricted because they were mostly located in East German territory where recreational fishing was illegal, and we considered that West Germans did not have access to this stock. Surveys were conducted in recent years to estimate the amount of cod, herring and flounder caught by recreational anglers in Germany. However, recreational catches are currently not included in stock assessments, which results in under-estimates of TACs (Pramod et al. 2008). In the most recent survey year (2006), recreational catches of cod were a third of the commercial cod catches as presented by ICES landings statistics. To accurately represent the amount of fish being removed from the Baltic Sea, recreational catches must be included in estimations used to allocate catches, particularly for commercially important taxa such as cod.

## Ghana

The original technical reconstruction research was initially documented in Nunoo et al. (2015), and was vetted through peer-review in Nunoo et al. (2014), and was updated to 2014 by the *Sea Around Us*.

### Methods

Recreational fishing in Ghana is a highly popular tourist activity, notably targeting tunas and billfishes<sup>25</sup> (Obeng 2003), although, herein it is assumed this activity began with the creation of the first tourism board in 1974. Recreational catches were estimated by multiplying the estimated number of tourist fishers by the number of fishing trips estimated at 7 days per tourist and by a CPUE obtained from YouTube records. In the absence of recreational catch records, which is a common issue in fisheries catch statistics, data on the CPUE, the species caught and the number of fishing trips per person could be difficult to obtain. Ghana, although an uncommon touristic destination, remains a popular recreational fishing destination (Obeng 2003). Thus, tourists tend to

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<sup>25</sup> <http://www.gipcghana.com/life-leisure/recreation.html> [Accessed on 27/ 08/2013].

document their fishing trips through online fora, blogs, and most commonly YouTube videos. Using the videos posted on YouTube documenting 25 recreational fishers and the species they caught daily, an estimate was made of the average weight caught by each tourist daily at 32.6 kg tourist<sup>-1</sup> day<sup>-1</sup> (details in Nunoo et al. 2014). When the number of tourists was unclear in the videos, the number of lines observed was used as a proxy. This method was used by Belhabib et al. (2014) to estimate recreational catches in Senegal and Angola (Belhabib and Divovich 2015) and found that there was no significant difference between catch per fisher records supplied by recreational fishing clubs, obtained from a sound sampling analysis.

For the 2011 – 2014 update, recreational fishing was reconstructed in the same way as in Nunoo et al. (2014), using tourism data from the World Bank ([www.worldbank.com](http://www.worldbank.com)) for the calculations.

## Results

Total catches from the waters of Ghana were estimated at 20.8 million tonnes between 1950 and 2010, of which 44% were taken by the artisanal fleet (9.2 million t) and 22% by the industrial fleet (notably that reflagged to Ghana), which discarded around 25% of the total (reconstructed) catch (5.2 million tonnes between 1950 and 2010). Non-commercial subsistence and recreational catches contributed 8%, and around 1% was taken illegally by foreign vessels operating in the Ghanaian EEZ.

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

## Greece

The original technical reconstruction research was initially documented in Moutopoulos et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

### Boat-based recreational catches

Two agencies are engaged in collecting data for boat-based recreational fisheries (Table 24). HELSTAT, in the framework of the Annual Agricultural Livestock Survey (Agricultural Statistics of Greece-ASG, 1977-2009), routinely collected for each prefecture between 1975-2005 the number of recreational fishers, the number of recreational vessels and the total landings for all species combined. The data are published in yearly bulletins by ASG (Anon 1977). We note that because in the 1970s, when ASG started recording data from recreational fisheries, the majority of recreational fishers used rowing vessels or vessels equipped with outboard engines, ASG records still refer to rowing vessels. Yet, nowadays, the majority of the recreational vessels are equipped with inboard engines.

The second agency involved in the collection of data for boat-based recreational fisheries is the Ministry of Mercantile Marine that manages port authorities and records each fisher that owns a recreational license. These data were available only for the period 1995-1996 through a field study conducted on Greek recreational fishery (Anagnopoulos et al. 1998).

The representative time series for the reconstruction of the vessel-based recreational landings are those derived from the Ministry of Mercantile Marine, which records all the boat-based recreational licenses (Table 23).

To estimate the boat-based recreational landings for 1950-2010, the number of fishers owning a boat-based recreational license was estimated. This was based on the ratio estimated from the number of fishers owning a boat-based recreational license from the Ministry of Mercantile Marine data to the corresponding data derived from ASG records for the years 1994 and 1995. This ratio was used to estimate the number of boat-based recreational fishers during 1975-1993 and 1996-2005 based on the number of recreational fishers reported by ASG.

**Table 23.** Number of fishers, vessels and engine power per prefecture for recreational fisheries in Greek waters during 1995-1996, based on various sources.

Perfektoures	HELSTAT subareas	HELSTAT		Anagnopoulos et al. (1998)		
		Fishers	Vessels	Fishers	Vessels	HP
Achaia	S5	849	685	2,241	1,654	29,881
Argolida	S8	391	375	1,789	1,011	20,468
Arkadia	S8	52	52	320	289	3,445
Arta	S4	30	30	83	70	-
Chalkidiki	S13	464	249	2,525	1,285	20,540
Chania	S18	262	201	1,849	1,144	22,930
Chios	S15	476	377	771	664	7,727
Dodekanisos	S16	-	-	3,466	2,320	53,516
Etolia and Akarnania	S5	214	210	935	777	12,841
Evia	S10	654	534	1,783	2,635	25,021
Evia	S12	654	534	1,783	2,635	25,021
Evros	S14	69	58	489	486	11,262
Fokida	S9	785	845	658	411	6,593
Fthiotida	S10	459	444	3,519	1,818	33,024
Iliia	S6	156	136	918	432	9,510
Iraklio	S18	1,066	231	1,645	1,009	28,761
Kavala	S14	2,805	703	3,271	1,678	66,213
Kefallinia	S5	597	507	1,479	910	12,658
Kerkyra	S3	1,017	361	935	1,522	21,377
Korinthia	S9	1,513	1,339	4,134	2,241	31,022
Kyklades	S17	98	96	5,278	5,544	45,629
Lakonia	S7	346	360	1,573	722	10,625
Larissa	S13	28	21	667	218	3,426
Lassithi	S18	115	93	1,290	709	17,142
Lefkada	S4	133	112	282	268	5,245
Lesvos	S15	454	393	2,893	1,751	27,751
Magnissia	S11	356	275	5,551	3,642	78,450
Messinia	S6	202	153	3,342	1,063	24,690
Pieria	S13	203	190	1,943	1,011	16,938
Preveza	S4	142	122	286	584	13,271
Rethymno	S18	131	126	285	128	2,954
Rodopi	S14	2	2	387	211	4,221
Samos	S15	448	423	298	295	3,410
Thessalaniki	S13	285	210	7,606	5,280	138,277
Thesprotia	S3	57	58	333	250	5,678
Viotia	S9	379	379	472	308	9,469
Xanthi	S14	29	25	767	1,585	39,420
Zakynthos	S5	838	484	471	336	11,188
Greater Athens	S10	2,164	1,332	27,841	22,319	555,144
Total	-	18,923	12,725	96,158	71,214	1,454,738

The boat-based recreational catches were then calculated using the mean catch per fisher of 0.194 t·fisher<sup>-1</sup> estimated from Anagnopoulos et al. (1998) for the years 1994-1995. This rate was applied to the reconstructed number of boat-based recreational fishers to derive a time series of recreational catches during 1975-2005. Subsequently, this series was expanded to 2010 by fitting a linear trend to the 1995-2005 data. Likewise, for years prior to census data (i.e., 1950-1974), the

boat-based recreational landings were linearly interpolated using an exponential trend fitted to the 1975-1985 data for the number of boat-based recreational fishers, as estimated previously, using also, as an anchor point, a study by Anon. (1977) in which recreational catches ranged between 6,000 and 9,000 t in 1970 (we used the maximum value).

#### Spatial and taxonomic disaggregation of boat-based recreational catches

The spatial allocation of boat-based recreational catches was done using Table 23: (a) the spatial allocation of recreational catches by prefecture as reported by ASG, for the reconstruction of recreational landings during 1950-1993; and (b) the spatial resolution reported in Anagnopoulos et al. (1998), for the reconstruction of recreational catches during 1994-2010. To harmonize the spatial allocation of recreational catches per prefecture during 1950-2010 with the reconstructed catches from all motorized, commercial fishing vessels for the 16 subareas surveyed by HELSTAT during 1950-2010, as described above, we re-allocated the recreational catches based on the ratios per HELSTAT subarea shown in Table 24 and the method presented in Moutopoulos and Stergiou (2012).

The taxonomic disaggregation of the boat-based recreational catches during 1950-2010 was done by using the species composition reported in Anagnopoulos et al. (1998) (shown in Table 25).

#### Shore-based subsistence and recreational catches

Shore-based subsistence and recreational angling in Greece are not easily disaggregated into distinct categories as there is obvious overlap (Anon 2010b; Ünal et al. 2010). Here, the catches of shore-based subsistence and recreational angling per subarea were estimated for 1950-2010 based on interviews conducted in three major coastal areas, which were subsequently extrapolated to the entire country.

Three coastal areas from different parts of Greece (Northern Aegean Sea: Kavala Gulf; Central Aegean Sea: Pagasitikos Gulf; and Ionian Sea: Patraikos Gulf) were surveyed based on personal interviews and local recording from 406 recreational fishers in 2012 (Kavala and Pagasitikos Gulfs) and during 2008-2009 (Patraikos Gulf).

Interviews were conducted through personal questionnaires in which fishers were asked to state their: (a) demographic aspects (i.e., age, sex, marital status, education degree, professional occupation); (b) fishing strategy (i.e., frequency of fishing per year, daily fishing hours, species caught, annual catch in weight); and (c) fishing-related expenditures (i.e., transportation, bait, equipment and other costs).

The mean number of fishing days per year ranged from 180 to 193 days-year<sup>-1</sup> and the average daily catch ranged between 0.711 and 0.861 kg-fisher<sup>-1</sup>·day<sup>-1</sup>. The most representative species (those making up more than 48% of the total catch) for the three studied areas were *Sparus aurata*, Mugilidae and *Diplodus* spp. (Table 26). The yearly catch per fisher for each area was estimated by multiplying the mean number of fishing days with the daily catch per fisher.

**Table 24.** Ratio of the spatial distribution of recreational fisheries landings for each Hellenic Statistical Authority of Greece (HELSTAT) subarea based on Agricultural Statistics of Greece (ASG) records and field studies (Anagnopoulos et al. 1998)

HELSTAT subareas	ASG	Anagnopoulos et al. (1998)
	1975-1992	1995-1996
S3	0.028	0.013
S4	0.013	0.007
S5	0.251	0.053
S6	0.016	0.044
S7	0.020	0.016
S8	0.014	0.022
S9	0.075	0.055
S10	0.161	0.345
S11	0.025	0.058
S12	0.026	0.019
S13	0.047	0.133
S14	0.051	0.051
S15	0.075	0.041
S16	0.082	0.036
S17	0.076	0.055
S18	0.038	0.053

**Table 25.** Ratio of the species composition of recreational fisheries catches in Greek Seas based on the technical report by Anagnopoulos et al. (1998) during 1995-1996.

Species	Ratio
<u>Fishes</u>	
<i>Belone belone</i>	0.0004
Mugilidae	0.0016
<i>Trachurus trachurus</i>	0.0332
<i>Scomber japonicus</i>	0.0063
<i>Serranus spp.</i>	0.0629
<i>Spicara flexuosa</i>	0.0168
<i>Sparus aurata</i>	0.0047
<i>Pagellus erythrinus</i>	0.1219
<i>Pagrus pagrus</i>	0.0051
<i>Boops boops</i>	0.0516
<i>Oblada melanura</i>	0.0113
<i>Spicara maena</i>	0.0008
<i>Lithognathus mormyrus</i>	0.0426
<i>Mullus surmuletus</i>	0.0098
<i>Dentex macrophthalmus</i>	0.0477
<i>Sarpa salpa</i>	0.0063
<i>Trachurus mediterraneus</i>	0.0469
<i>Diplodus sargus sargus</i>	0.2302
<i>Epinephelus marginatus</i>	0.0016
<i>Diplodus annularis</i>	0.1622
<i>Spondyliosoma cantharus</i>	0.0191
Scorpaenidae	0.0461
<i>Dentex dentex</i>	0.0016
Other species	0.0672
<u>Cephalopods</u>	
<i>Octopus vulgaris</i>	0.0023

**Table 26.** Species composition (%) of shore-based subsistence and recreational catches in Greek waters based on interviews in three coastal areas

Species	Pagasetikos	Patraikos	Kavala
<i>Auxis thazard</i>	0.60	-	-
<i>Belone belone</i>	0.62	-	-
<i>Boops boops</i>	0.64	0.38	-
<i>Dentex dentex</i>	0.44	-	1.56
<i>Dicentrarchus labrax</i>	7.78	6.22	11.15
<i>Diplodus annularis</i>	11.26	1.57	18.25
<i>Diplodus sargus sargus</i>	4.46	11.45	3.51
<i>Epinephelus aeneus</i>	0.10	-	-
<i>Epinephelus alexandrinus</i>	0.10	-	0.78
<i>Epinephelus marginatus</i>	0.10	-	-
<i>Euthynus alletteratus</i>	0.63	-	-
<i>Gobius</i> spp.	0.32	-	-
<i>Lithognathus mormyrus</i>	2.24	-	4.68
<i>Merluccius merluccius</i>	0.13	-	-
Mugilidae	18.32	24.54	19.50
<i>Mullus barbatus</i>	0.14	-	-
<i>Mullus surmuletus</i>	0.10	-	-
<i>Oblada melanura</i>	2.03	-	-
<i>Pagellus erythrinus</i>	3.08	0.36	-
<i>Polyprion americanus</i>	0.00	-	0.39
<i>Pomatomus saltatrix</i>	10.28	-	-
<i>Sarda sarda</i>	0.42	-	-
<i>Sarpa salpa</i>	0.77	-	-
<i>Sciaena umbra</i>	0.20	-	-
<i>Scomber japonicus</i>	2.45	-	8.97
<i>Serranus</i> spp.	0.07	-	-
<i>Seriola dumerili</i>	0.00	-	0.78
<i>Solea</i> spp.	0.00	0.63	-
<i>Sparus aurata</i>	15.30	50.46	12.87
<i>Sphyræna sphyraena</i>	0.21	-	-
<i>Spicara flexuosa</i>	2.91	-	-
<i>Spicara maena</i>	1.06	-	-
<i>Spicara smaris</i>	0.07	-	-
<i>Spondyliosoma cantharus</i>	0.17	-	1.17
<i>Thunnus</i> spp.	0.14	-	-
<i>Trachurus mediterraneus</i>	2.09	2.53	7.80
<i>Umbrina cirrhosa</i>	0.07	-	-
<i>Osteichthyes</i>	6.38	1.86	8.58
<b>Cephalopods</b>			
Loliginidae, Ommastrepidae	1.08	-	-
<i>Loligo vulgaris</i>	1.06	-	-
<i>Octopus vulgaris</i>	1.83	-	-
<i>Sepia officinalis</i>	0.35	-	-
<b>List of Osteichthyes species</b>			
<i>Caranx</i> sp.	0.71	-	-
<i>Coryphaena</i> spp.	0.47	-	-
<i>Dentex gibbosus</i>	0.10	-	0.78
<i>Diplodus vulgaris</i>	1.53	0.07	7.80
<i>Diplodus puntazzo</i>	0.00	1.79	-
Labridae	0.07	-	-
<i>Lichia amia</i>	0.34	-	-
<i>Pagellus acarne</i>	1.06	-	-
<i>Pagellus bogaraveo</i>	1.89	-	-
<i>Trachinus</i> spp.	0.21	-	-
<b>Mean number of fishing days</b>	191.00	193.30	180.00
<b>kg·fisher<sup>-1</sup>·day<sup>-1</sup></b>	0.80	0.86	0.71

To estimate the number of shore-based subsistence and recreational fishers, the resident population of each subarea was used, derived from the census of HELSTAT conducted in each prefecture every

decade ([www.statistics.gr](http://www.statistics.gr)) between 1950-2010 (Anon 2012c). This was multiplied by the ratio of shorebased angler to coastal population in each subarea. The latter was conservatively assumed to be 1.5%, because this ratio lies within the values estimated by other studies conducted for subsistence fisheries in the Eastern Mediterranean Seas (ranging between 1% and 3.3% in Turkish waters Ünal et al. 2010; Unal and Franquesa 2010).

#### Spatial and taxonomic disaggregation of shore-based subsistence and recreational catches

To harmonize the spatial allocation of shore-based subsistence and recreational catches per prefecture with the 16 subareas surveyed by HELSTAT, we followed the method described for boat-based recreational fishing (see above). In addition, to re-allocate the spatial distribution of the shore-based subsistence and recreational catches for the three studied areas with the 16 HELSTAT subareas, we considered that Kavala Gulf is representative of the HELSTAT subareas S12 to S15, Pagasitikos Gulf of the HELSTAT subareas S10 to S11 and Patraikos Gulf of the HELSTAT subareas S3 to S9 and also for subareas S16 to S18, for which such data are not available. The taxonomic disaggregation of the shore-based subsistence and recreational catches was done by using the species composition in Table 27.

The shore-based subsistence and recreational catches per species for each HELSTAT subarea from 1950-2010 were estimated from the multiplication of the species ratio to total catches per subarea with the ratio of the number of fishers to the total human population per HELSTAT subarea during 1950-2010.

To split the catches between the subsistence and recreational components, we assumed that the percentage of shore-based recreational catches changed from 10% for 1950 to 90% in 2010. Then, we interpolated this ratio for the years during 1950-2010 using the exponential trend that describes the Greek Gross Domestic Product (GDP; data from World Bank) during the same period.

Thus, two time series of ratios were constructed describing the contribution of the shore-based recreational and subsistence catches during 1950-2010. These time series of ratios were multiplied with the above-estimated combined shore-based subsistence and recreational catches per species for each HELSTAT subarea during 1950-2010, in order to disaggregate the subsistence and shore-based recreational catches.

For the 2011-2014 update, vessel-based recreational fishing catches were reconstructed by extending the linear trend of catches calculated between 2007 and 2010 to 2014. Shore-based recreational and subsistence fishing catches and taxonomic distribution were carried forward to 2014 from 2010 unchanged.

## Results

Boat-based recreational catches increased from just under 1,600 t·year<sup>-1</sup> in 1950 to slightly over 35,600 t·year<sup>-1</sup> in 1986 and then decreased to around 15,000 t·year<sup>-1</sup> by 2010.

Total shore-based subsistence and shore-based recreational catches increased from over 1,800 t·year<sup>-1</sup> in 1950 to slightly over 2,800 t·year<sup>-1</sup> in 2010.

Greek total catches (including discards) are dominated by the small-scale, commercial (i.e., artisanal) fisheries, which accounted for 4.9 million t over the full time period considered here. This compares

to the industrial sector with 3.8 million t and the recreational sector with nearly 987,000 t, while subsistence fishing accounted for just over 87,000 t.

## Grenada

The original technical reconstruction research was initially documented in Mohammed and Lindop (2015), and was updated to 2014 by the *Sea Around Us*.

### Methods

Recreational participation in fishing in Antigua and Barbuda was found to be 0.23% of the population (Cisneros-Montemayor and Sumaila 2010; Cisneros-Montemayor 2010) and the same rate was assumed to be true of Grenada and Grenadines. It was assumed that the vast majority of recreational fishers were tourists, so the participation rate was applied to the tourist population only. Tourist arrivals data were only available from 1952, so estimated tourist numbers for 1950-1994 were calculated by interpolating from 60,000 tourists in 1995 to an assumed 0 tourists in 1945. Recreational participation was then calculated by applying the 0.23% participation rate to the tourist numbers. Ramdeen et al. (2014a) estimated a catch rate of  $0.001 \text{ t} \cdot \text{tourist}^{-1} \cdot \text{year}^{-1}$  for the British Virgin Islands, which we assumed to be representative also for Grenada and applied it to the estimated participation total for each year 1950-2010 to obtain a recreational catch.

### Taxonomic breakdown

Mike and Cowx (1996) reported on the domestic recreational fishery in Trinidad and Tobago and estimated the percentage of each fish taxon sold. This was used as a proxy for the composition of recreational catches in Grenada. The proportion of each taxon sold was estimated from Mike and Cowx (1996) and then all percentages were normalised to give a species breakdown for the recreational sector, which was applied to the estimated total for each year.

For the 2011-2014 update, recreational and subsistence catch for both EEZs together were calculated from the 2010-2012 average percentage of reported catch, and split between Grenada and the Grenadines, then between taxa, according to 2010 proportions

### Results

The total reconstructed catch for 1950-2010 was 1.5 times the data reported for the same period. Artisanal fisheries were the most important sector, contributing 71% of fish removals, with the subsistence sector adding a further 20.5%. The industrial sector made up 8.4% (active only since the 1990s), with recreational catches less than 0.1%.

Reconstructed recreational catches were very small, and contributed less than 0.1% to the total catch. Overall, they gradually rose through the time period, increasing from 0.25 t in 1950 to 2.5 t in 2010.

## Guadeloupe (France)

The original technical reconstruction research was initially documented in Frotte et al. (2009a), and was updated to 2014 by the *Sea Around Us*.

### Methods

Catches for the recreational fisheries sector were based on a preliminary study by Ifremer (2008), which estimated that the 2005 recreational fisheries catch for Guadeloupe was about 323 t, or 0.74 kg·person<sup>-1</sup>. Assuming that recreational catches were zero in 1950, we derived a complete time series by linear interpolation from zero in 1950 to 0.74 kg·person<sup>-1</sup> in 2005. The 2005 value was carried forward unaltered as the per capita recreational fishing rate for 2006 and 2007. This is likely an underestimate of recreational catches as this fishery sector is likely to increase alongside the tourism industry. Of the total recreational catch, 90% were fish and 10% were shellfish. This ratio was used throughout the time series to estimate annual tonnage for these two categories.

Since the initial reconstruction was produced, subsistence and recreational landings have been updated for 1990-2010 with population data available from the French Statistics Institute (INSEE). In order to carry forward unreported landings for 2011-2014, per capita fishing rates of subsistence and recreational fishers were maintained from 2008 to 2014 and multiplied by annual population data from INSEE (2016).

### Results

Recreational catch estimates totaled 8,343 t for the period 1950-2007. Over the time series, we estimated that 7,509 t of fish were caught recreationally and 834 t of shellfish were caught recreationally

The recreational fishing sector is another fisheries component that is currently unaccounted for in most reported landings (e.g., Zeller et al. 2008). Recreational fishing targets large sport fish as a component of the well-developed tourism industry in the Caribbean. Research by the French Research Institute for Exploitation of the Sea (Ifremer) has begun to assess recreational fishing in the region, but the results of this study are only preliminary (O. Guyader, pers. comm., Ifremer). While these preliminary findings were included in our reconstruction, further investigations into recreational fishing may provide a more detailed species breakdown of this fisheries sector.

## Guam (USA)

The original technical reconstruction research was initially documented in Zeller et al. (2005), and was vetted through peer-review in Zeller et al. (2007a), and was updated to 2014 by the *Sea Aournd Us*.

### Methods

Catch data for small boat-based fisheries and shore-based fisheries have been estimated by the Guam Division of Aquatic and Wildlife Resources (DAWR) since the mid-1960s through the use of two separate creel surveys: boat-based fisheries via a marine-based creel survey (the so called 'offshore survey'), and shore-based fisheries via a shore-based creel survey ('inshore survey'). Fish weir catches were mandated for reporting as part of weir-operating permits, but were likely

incomplete. DAWR applied expansion methods to raise the creel survey data to island-wide catch estimates. While, specifics of the method, thoroughness of survey, data handling and analyses have varied, especially during the earlier periods, in one way or another some data existed for almost the entire time period of interest (1950-2002). Since the 1980s, these surveys seemed the most comprehensive procedures for data collection and total catch estimation encountered by this project, with consistent expansion methods applied.

As domestic fisheries in Guam are generally part commercial, part subsistence, part recreational, the reconstruction approach taken was not through commercial and non-commercial differentiation, but rather following the creel survey distinction between boat-based (offshore survey) and shore-based (inshore survey) estimation of catches. Given our focus on bottom- and reef- fisheries (as well as shore-based catches of small, reef associated pelagic species), we ignored the trolling component from the offshore catch reports, while retaining bottom-fishing and boat-based spear-fishing catches.

#### Reported catches

##### Offshore, boat based catches

1950-1964: As no reported information could be obtained for this period, we estimated total likely catch via *per capita* catch rates as part of the supply versus demand approach.

1965-1982: The offshore catch estimates for this time period, which pre-dates WPacFIN reporting, were drawn from the creel survey data as reported in the annual reports of the DAWR (Anderson et al. 1980; Anderson et al. 1979; Anderson and Hosmer 1981; Anon 1978; Anon 1976; Anon 1975; Anon 1974; Anon 1973; Anon 1972; Anon 1971; Anon 1970; Anon 1969; Anon 1968; Anon 1967; Anon 1966; Anon 1965; Anon; Myers 1982). Procedures for expanding the creel surveys data to island-wide catches as used or suggested by the sources at the time, were accepted. Catches were reported by main gear types (trolling, bottom-fishing, spear-fishing), which permitted the removal of large pelagics caught by trolling gear. While the annual reports covered fiscal year periods, they contained monthly reporting of catches for 1978 to 1982, which permitted assembly of calendar year estimates for these years. For 1965-1977, the fiscal year total catch estimates were split in equal parts for allocation to the calendar years incorporated into fiscal accounting periods. In several cases, reports from earlier years acknowledged an assumed under-reporting due to creel survey sampling design by a minimum factor of 2, and recommended adjustments. Thus we adjusted the reported catch estimates by a factor of 2 for these years.

1983-2002: for this latest period, we relied on the island-wide expanded catch estimates as provided by D. Hamm (WPacFIN). These estimates were based on the offshore creel survey as undertaken by the DAWR. These data were reported by taxon, permitting exclusion of large pelagic species.

##### Inshore, shore-based catches

1950-1964: Catches were reconstructed as indicated above in the offshore section and documented in the "supply versus demand" section below.

1965-1981: Similar to the offshore fisheries, the inshore catch data for this period were based on the inshore creel survey data as reported in the annual reports of the DAWR (Anderson and Hosmer

1981; Anon 1978; Anon 1976; Anon 1975; Anon 1974; Anon 1973; Anon 1972; Anon 1971; Anon 1970; Anon 1969; Anon 1968; Anon 1967; Anon 1966; Anon 1965; Anon), with procedures for expanding the catches accepted as reported at the time. Also included in these figures were the often separately reported catch estimates for octopus and shellfish (based on reef gleaning), fish weirs, and the highly irregular, seasonal catches of juvenile rabbitfish (Siganidae) and big-eye scad (*Selar crumenophthalmus*). We applied adjustment factors for non-surveyed periods as indicated for some years (e.g., Anon 1978). Note that the years 1980 and 1981 were deemed poorly reported due to limited survey coverage (Anderson et al. 1980; Anderson and Hosmer 1981). Therefore, we replaced the reported catches for 1980 and 1981 with the average catches for 1978-1979, and 1982-1983, respectively.

1982-1984: WPacFIN reported inshore catches back to 1985, thus the data from Hensley and Sherwood (1993) were used here for the 1982-1984 period. It should be noted that these data did not include night fisheries, and therefore under-represented actual catches (G. Davis, NOAA, pers. Comm.)

1985-2002: For this period, we relied on the island-wide expanded catch estimates from the inshore creel survey, as undertaken by DAWR, and provided to us by D. Hamm (WPacFIN). These data were reported by taxon.

Since completing the carry forward to 2010 (Zeller et al. 2015), new FAO data has become available to 2013. To update the above reconstruction, the 2013 FAO data were accepted as the reported component. Following the original carry forward methods, all catch was assigned as artisanal (36%) or subsistence (64%); subsistence is then further broken down into true subsistence (20%) and recreational (80%). Taxa breakdown from 2009 used. Pelagic species were not included in Guam's catch reconstruction (i.e., blue marlin, common dolphinfish, Indo-Pacific sailfish, skipjack tuna, tuna-like fishes nei, wahoo, yellowfin tuna).

## Guinea-Bissau

The original technical reconstruction research was initially documented in Belhabib and Pauly (2015), and was vetted through peer-review in Francisco Intchama et al. (2018) and was updated to 2014 by the *Sea Around Us*.

### Methods

#### Unregulated Subsistence and Recreational Catches

Some authors report that most of the coastal population practice subsistence fishing (Said 2007), others allude to thousands of women and subsistence fishers operating in Guinea Bissau (Garcia 1992) and providing more animal protein than any other sectors for local consumption (Anon 1994). This is compatible with the observation that almost all the animal protein consumed in Guinea Bissau comes from fish (Anon 2009b). To estimate subsistence catches in Guinea-Bissau (Table 27), we multiplied the population recorded by the World Bank in 2011 to 2015 ([www.worldbank.org](http://www.worldbank.org); Accessed 25/07/2016) by the amount of fish that comes from subsistence fishing per capita, i.e., the consumption derived from Belhabib and Pauly (2015). According to Dia and Bedingar (2001) the rate of consumption of fish in Guinea-Bissau is 26 kg/person/year, but taking into account the industrial

fishing, artisanal fishing imports and exports, the value of consumption derived corresponds to 11 kg/person/year (Belhabib and Pauly 2015), which we assume remained constant. Catches for 2016 and 2017 were projected based on the trend from 2011 to 2015. The 2011-2015 catch trend was then extrapolated to estimate subsistence catches for 2016 and 2017. We chose 2011 as a baseline year, which captures the visible change in the trajectory of subsistence catches.

**Table 27.** Taxonomic breakdown for the recreational fishery in Guinea-Bissau

<b>Common name</b>	<b>Scientific name</b>	<b>%</b>
Barracudas	<i>Sphyraena barracuda</i>	33
Carangids or jacks	Carangidae	14
Cobia	<i>Rachycentron canadum</i>	19
Crevalle jack	<i>Caranx hippos</i>	9
Leerfish	<i>Lichia amia</i>	6
Marine fishes nei	-	5
Guinean snapper	<i>Lutjanus agennes</i>	3
Groupers	<i>Epinephelus</i> spp.	2
Meagre	<i>Argyrosomus regius</i>	2
Blackchin guitarfish	<i>Rhinobatos cemiculus</i>	2
Nurse shark	<i>Ginglymostoma cirratum</i>	2
Sparids	Sparidae	1
Sharks	<i>Selachimorpha</i> spp.	1
Requiem sharks	<i>Carcharhinus</i> spp.	1

#### Unregulated Recreational Fisheries

Sport fishing is apparently a notable segment of tourism in the Bijagos archipelago (Anon, 2010), but little information is available on the number of visitors to the archipelago, or the number of tourists using the services of fishing ‘safaris’ (Belhabib et al. 2016a). For 2012, the camps established for tourists in Guinea Bissau were visited by 1,200 persons, of which only 50% went fishing. There also were between 150 and 350 fishers (250 on average) for each of 4 other camps, and 500 visitors per year to a near-shore hotel, of which only a minority (20%) went fishing (Pierre Campredon, IUCN Guinea Bissau, pers. comm.). Therefore, the overall number of recreational fishers for 2012 was estimated as the sum of fishers for each camp and/or hotel, i.e., 1,500 fishers. Recreational catches were estimated as the product of the number of recreational fishers and the catch per unit of effort – expressed in number of fishers and number of days—extracted from Belhabib et al. (2016a). Using the 2007 anchor point (1,440 fishers) in Belhabib and Pauly (2015), we interpolated the trend between 2007 and 2012 to complete the estimate for 2011. We then calculated the number of fishers for 2013, 2014, and 2015 by multiplying the total number of visitors to Guinea Bissau (obtained from the World Bank database) by 4%, which corresponds to the number of visitors who practice fishing in Guinea Bissau (Belhabib and Pauly 2015). We then multiplied the total number of fishers by a CPUE of 18 kg/tourist/day (Belhabib et al. 2016a). The 2012-2015 catch trend was then extrapolated to estimate recreational catches for 2016 and 2017. We chose 2012 as a baseline year, which captures the visible change in the trajectory of recreational catches. Total catches were estimated as the sum of all catches (industrial, artisanal, recreational, and subsistence) then compared to the reported catch, i.e., the catch submitted by the Government of Guinea Bissau to the Food and Agriculture Organization of the United Nations (FAO) for all domestic catches, and

those reported to the government of Guinea Bissau for all industrial foreign catches, as the law requires all vessels registered or licensed to fish in Guinea Bissau to report their catches to the Government of Guinea Bissau, regardless of their flag. We present below large-scale legal and IUU fisheries catches, and small-scale legal and IUU fisheries catches, which in turn includes artisanal, recreational and subsistence fisheries catch assessment. We then calculate the economic loss from IUU foreign fisheries in Guinea Bissau by multiplying the average annual ex-vessel price of fish by the total IUU industrial foreign catch in the country per year for 2017, as used in various other studies (Belhabib et al. 2014; Doumbouya et al. 2017). This estimate does not include catches by small-scale fisheries sectors, which are in theory captured by the local economy, knowing that small-scale catches are mainly kept for domestic use.

## Results

### Unregulated Subsistence and Recreational Fisheries Catches

Reconstructed subsistence catches for Guinea Bissau illustrate a continued increase from 16,700 t/year in 2010 to 21,236 t/year in 2017. Reconstructed recreational catches were estimated at 200 tons in 2010 increasing to 146 tons in 2017. None of the recreational and subsistence catches are ever reported officially.

## Hawaii (USA)

The original technical reconstruction research was initially documented in Gibson et al. (2015a), and was dated to 2014 by the *Sea Around Us*.

## Methods

The Marine Recreational Information Program (MRIP) data are used for the recreational catch of the Hawaiian Islands from 2003-2010. These data include a detailed species composition for this time. Total estimated annual recreational catch from 1950-2002 is used from Zeller et al. (2007b). The proportion of taxa in the MRIP for each year are averaged and applied to annual totals from Zeller et al. (2007b).

All recreational catches were assumed to originate from the Main Hawaiian Islands because the Northwestern Hawaiian Islands are uninhabited. Marine Recreational Information Program (MRIP) recreational data was converted from number of fish to catch tonnage based on length-weight conversion factors from FishBase. The 1991 anchor point from Hamm and Lund (1992) was used to disaggregate catches into its taxonomic composition from 1950-1991. Composition was interpolated from 1991-2002, when MRIP data becomes available. For the years 2004-2010, an adjustment factor of .82 was applied to account for reporting errors noted by Williams and Ma (2013).

## Results

Recreational catch in the Hawaiian Islands consists of a variety of taxa, with bigeye scad (*Selar crumenophthalmus*) making up the largest single species component, 13% of the catch. Yellowstripe goatfish (*Mulloidichthys flavolineatus*), skipjack tuna, bluestripe herring (*Herklotsichthys quadrimaculatus*), convict surgeonfish (*Acanthurus triostegus*), yellowfin tuna and flagtails (Kuhliidae) represent 40% collectively.

Recreational catch represents 17% of the overall reconstructed catch which is very large for recreational catch. This is likely due to the high levels of marine tourism in the state.

## Hong Kong

The original technical reconstruction research was initially documented in Cheung (2006), and was updated to 2014 by the *Sea Around Us*.

### Methods

The estimation of recreational catch from Hong Kong waters was based on an unpublished survey commissioned by WWF Hong Kong (Andy Cornish, unpublished data) and demographic data. Firstly, the recreational fishing survey estimated the population of Hong Kong residents that participated in recreational fishing in 2001-2002. They divided the frequency of participation into three categories: one time or more per year, four times or more per year, and twelve times or more per year. To be conservative, I used the lower limit of these categories to calculate the total recreational fishing trips per year by Hong Kong residents in 2001-2002. I also calculated the proportion of total population that participated in recreational fishing in each frequency category. Assuming that recreational fishing participation rate and the proportion in different participation frequency remained constant from 1950 to 2010, I multiplied the total population of Hong Kong from 1950 – 2010 with the participation rate to estimate the total number of recreational fishing trips per year. Assuming that the average catch per trip was 500 g of fish (Sumaila et al. 2007), I estimated the annual recreational fishing catch from 1950-2010.

Recreational landings were updated to 2014 using updated population information available from World Bank and the 2010 recreational participation rate and recreational catch rate. Taxonomic breakdowns of unreported landings for each sector were held constant at the 2010 levels

### Results

Surprisingly, recreational fishing contributed a considerable amount of total catches in Hong Kong. I estimated that recreational fishing amounted to approximately 11% of catches from the 2000s. This is partly because of the increased population that participated in recreational fishing and the decreases in commercial catches. The major targeted species, according to the recreational fishing survey (Andy Cornish, unpublished data), were grouper, seabream, snapper, sea perch, rudderfish, trevally, grunt and tuna-like fishes. Currently, marine recreational fishing is not regulated/managed in Hong Kong, except the prohibition of use of destructive methods. As recreational fishing contributed to a large proportion of catches in Hong Kong, it should be managed and regulated.

## Iceland

The original technical reconstruction research was initially documented in Valtýsson (2014), and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational fisheries are popular in Iceland, but are mostly conducted on trout and salmon in rivers and lakes. These are outside the scope of this report. These same species are in turn not the target of any substantial commercial fisheries today. However, recreational fisheries in the ocean have been growing in popularity. Tourists can go on organized trips to fish mainly for cod, and many Icelanders also own small boats that they use to go fishing on good days. However, one can argue that this is rather a subsistence fishery than recreational and is therefore included in the subsistence category. Thus, the recreational fisheries fall roughly into two classes and catch statistics are usually poor.

1) Freshwater fisheries for salmon, arctic char and brown trout. This sector is outside the scope of this study.

2) Recreational marine fisheries for tourists. Several companies offer organized boat tours for tourists where they are provided with equipment and supervision. Each boat can only have 7 fishing rods and only 7 fishes are allowed during a trip. This catch is not registered but the boats need special licenses. Usually medium sized boats (10 GRT) are used. These primarily catch cod.

The other category is the fish Icelanders eat themselves. It can both be from small boat owners that fish for themselves and their family using small boats or from shore, as is allowed without reporting. This is at the border of recreational and subsistence fisheries, but is classified as subsistence fisheries here. Commercial fishers on larger boats can also retain some part of the catch to take home to their families or to eat onboard. A part of this is actually reported and is available as domestic consumption in Statistics Iceland. This has been 5,000 to 6,000 t·year<sup>-1</sup> since 1992, and 98% of this is groundfishes and mostly haddock.

For recreational fisheries, a web search was done in the original methods to determine the number of operators offering sea angling trips to tourist in 2010 and used it as an anchor point for interpolation back to 1995. For this reconstruction, a web search was also conducted and 17 operators were found that offered sea angling trips to tourist in 2019. This number was used as an anchor point to interpolate the number of operators for 2011-2017. As the regulations around the license is the same from 2011-2016 (Anon 2017; Anon 2016; Anon 2015; Anon 2014b; Anon 2013; Anon 2012d), The number of operators was multiplied by the same assumption of each operator for operating 60 days a year, each day taking 7 fishers, each fisher catching 7 fish per day and each fish weighting 2kg to calculate the unreported recreational fisheries amount.

## Results

The reconstructed catches for Iceland's industrial, artisanal, subsistence and recreational fisheries within the EEZ were compared to ICES statistics and national data. The database indicates that the reconstructed total catches by Iceland within its EEZ increased from 411,000 t in 1950 to a maximum of 2.02 million t in 1997, before subsequently declining to 903,000 t in 2010. The reconstructed total catch for Iceland for the period 1950-2010 was estimated around 69.2 million t which is 37% higher than the data reported by ICES (50.6 million t).

## Indonesia

The original technical reconstruction research was initially documented in Pauly and Budimartono (2015), and was updated to 2014 by the *Sea Around Us*.

### Methods

Marine recreational fishing was reported to generate a catch of 5,000 to 10,000 t·year<sup>-1</sup> in the mid-1990s (unpublished update to Willoughby et al. 1999). Given that recreational fishing, in Indonesia, appears to be an urban-based phenomenon, we derived, from the relative population of the 10 largest cities in Indonesia, a key to allocate the midrange (7,500 t) of fish caught recreationally to the three parts of Indonesia identified above, i.e., Central Indonesia (80%; high because of the cumulative populations of Jakarta, Semarang, Bekasi, Tangerang, Depok, Palembang, and Surabaya), Western Indonesia (15%; e.g., Bandung and Medan), and Eastern Indonesia (5%; Makassar). The year 1994 catch of 7,500 t was decreased for previous years and increased to 2010 by making it proportional to the size of the Indonesian population.

Recreational catches for 2011-2014 were estimated based on the 1994 ratio of recreational catch to the total Indonesian population. The taxonomic breakdowns for each area, catch type, and sector were maintained at the 2010 levels.

### Results (Central Indonesia)

The reconstructed total catch for Central Indonesian marine fisheries from 1950 to 2010 was estimated to be 40.3 million t, and increased from around 145,000 t·year<sup>-1</sup> in the 1950s to around 1.34 million t·year<sup>-1</sup> in the 2000s. The total catches are estimated to be around 14.4% higher than the catch reported by FAO and Indonesia (adjusted to Central Indonesia). Industrial domestic fisheries – both reported and unreported - made up 55.6% of the total estimated catch. Discards from both artisanal and industrial fisheries were estimated to be 8% (from artisanal catch, shrimp trawlers catch, and purse-seiners catch) of total catches, while artisanal (34%), subsistence (2%), and recreational fisheries (<1%) made up the rest.

The total reconstructed catch for Eastern Indonesian marine fisheries and increased from around 147,000 t·year<sup>-1</sup> in the 1950s to around 2.42 million t·year<sup>-1</sup> in the 2000s. The total catches of 76.8 million t from 1950 – 2010 are estimated to be around 57% higher than the catch reported by FAO and Indonesia (adjusted to Eastern Indonesia). Industrial and artisanal fisheries catch – both reported and unreported amounts – contributed 43% and 29%, respectively, to total estimated catch. Discards from both artisanal and industrial fisheries were estimated to be 25% (from artisanal catch, shrimp trawlers catch, and purse-seiners catch) of total catches, while subsistence (3%) and recreational fisheries (<1%) made up the rest.

### Results (Western Indonesia)

Marine recreational fishing was reported to generate a catch of 5,000 to 10,000 t·year<sup>-1</sup> in the mid-1990s (pers. comm in Willoughby et al. (1999). Given that recreational fishing, in Indonesia, appears to be an urban-based phenomenon, we derived, from the relative population of the 10 largest cities in Indonesia, a key to allocate the midrange (7,500 t) of fish caught recreationally to the three parts of Indonesia identified above, i.e., Central Indonesia (80%; high because of the cumulative populations of Jakarta, Semarang, Bekasi, Tangerang, Depok, Palembang, and Surabaya), Western Indonesia (15%, e.g., Bandung and Medan), and Eastern Indonesia (5%, Makassar), all assumed for

the year 1994. This 1994 catch of 7,500 t was decreased for previous years and increased to 2010 by making it proportional to the size of the Indonesian population.

Small-scale fisheries catch was estimated to be 13.6 million t from 1950 to 2010, with an average of around 223,000 t·year<sup>-1</sup>. Artisanal (12.9 million t for 1950-2010), subsistence (689,000 t) and recreational catches (54,000 t) were small and relatively stable, with an annual average of around 211,000 t·year<sup>-1</sup>, 11,000 t·year<sup>-1</sup> and 880 t·year<sup>-1</sup>, respectively.

## Iran

The original technical reconstruction research was initially documented in Roshan Moniri et al. (2013), and was updated to 2014 by the *Sea Around Us*.

### Methods

We assumed recreational fishing existed throughout the rule of the Shah, from 1950 to 1979, and after the Iran-Iraq war from 1989 to 2010. We assumed that any personal fishing that occurred during the war years was subsistence fishing and thus we estimated that there was zero recreational fishing during the war years (1980-1988); also, recreational fishing is popular primarily in the Persian Gulf, and hence, we assumed that no recreational fishing occurred in Sistan and Baluchestan. For 2010, it was estimated that around 0.12% of the population in Oman participated in recreational fishing (Cisneros-Montemayor and Sumaila 2010). We assumed this same rate applied to the coastal Iranian population in 2010. We then assumed half of this rate for the pre-war time period (1950-1979), i.e., 0.06%. Participation was set to zero for the years 1980-1988, and then we interpolated from zero in 1988 to 0.12% in 2010. To estimate recreational catches, we assumed that recreational fishers catch 5 kg·trip<sup>-1</sup> and fish for one day per week (i.e., 52 days·year<sup>-1</sup>). Therefore, we multiplied the number of fishers by the number of the fishing days (52 days) and the assumed catch rate (5 kg·trip<sup>-1</sup>) to obtain an approximate time series of recreational catches.

Recreational and subsistence catches were disaggregated using anecdotal data from pictures posted on web-logs of Iranians engaged in recreational fishing ([www.fishingir.blogfa.com](http://www.fishingir.blogfa.com)). The eight most commonly observed taxa by recreational activities are *Sphyraena* spp., *Seriphus* spp., *Chanos chanos*, *Hyporthodus* spp., *Caranx* spp., Sparidae, *Elops* spp. and *Myliobatis* spp., and we allocated recreational and subsistence catches in equal proportions to these taxa.

For the 2011-2014 update, the subsistence and recreational were reconstructed based on 2010 catch and participation rates, with new population data from World Bank.

### Results

Recreational catches (for the Persian Gulf waters only) were estimated at around 28 t·year<sup>-1</sup> in 1950, increasing gradually to 64 t·year<sup>-1</sup> by 1979. After the war years catches steadily increased from 8 t·year<sup>-1</sup> to reach a peak of 265 t·year<sup>-1</sup> in 2010.

## Ireland

The original technical reconstruction research was initially documented in Miller and Zeller (2013), and was updated to 2014 by the *Sea Around Us*.

### Methods

Retained recreational catch In Ireland, there are no reporting requirements for recreational sea angling, either from boat or from shore. In addition, with exception to European seabass (*Dicentrarchus labrax*), there are no regulations to limit catch quantities and no minimum landing size requirements. Sea angling activities in Ireland are currently not monitored and to date, there have been no attempts at estimating the total amount of fish caught through these activities. In order to estimate the likely total amount of fish caught and retained from Irish waters through sea angling for the years 1950 to 2010, a separate reconstruction process was applied to estimate catches made through boat-based and shore-based angling activities.

Estimated values for the total numbers of day trips spent sea angling from boat or shore in Ireland for the years 1996 and 2003 were obtained from a government funded national survey of water-based leisure activities (Marine Institute 2004). These values were converted into per capita rates using Irish population data (CSO (Central Statistics Office) 2012), and rates for the years 1997 to 2002 were estimated through linear interpolation, assuming a constant decreasing (boat days) and increasing (shore days) trend during this time period. The annual numbers of day trips spent sea angling from boat and shore for this time period were then calculated by multiplying the rates for each year by the annual Irish population size (CSO (Central Statistics Office) 2012). The estimated total numbers of day trips spent sea angling from boat and shore were extrapolated forward and backwards through applying the per capita day trips rates from 1996 and 2003, respectively to annual Irish population size data (CSO (Central Statistics Office) 2012). To account for technological advances within the last half of the 20th century that have likely led to improved accessibility of vessels for recreational use, we have assumed that the annual per capita rates for days angling from boats have likely increased and the annual per capita rates for days angling from the shore have likely decreased. As such, prior to 1996, the per capita day trip rates were multiplied by a factor of 0.5 in 1950, extrapolated to 1 in 1996 for angling from boats, and by a factor of 2 in 1950, extrapolated to 1 in 1996 for angling from the shore.

### Boat-based angling activities

The quantity and diversity of fish caught by boat anglers per year was determined through multiplying the estimated annual effort (boat day trips) by estimated average species-specific weights of fish caught per boat angler per day fishing. These latter values were derived from deep sea angling charter boat logbook data from 1978 to 2002, documented within an annual report published by the Central Fisheries Board (CFB) (now Inland Fisheries Ireland (IFI)) (W. Roche, pers. comm., IFI). Species-specific catch rate data (in fish numbers) was available for Atlantic cod, ling, saithe (*Pollachius virens*), white pollack (*Pollachius pollachius*), conger eel (*Conger conger*), greater spotted dogfish (*Squalus acanthias*) and lesser spotted dogfish (*Scyliorhinus canicula*). We decided to omit conger eel and elasmobranch data from this reconstruction as anecdotal evidence (W. Roche, pers. comm., IFI; A. Hayden, pers. comm., [www.anirishanglersworld.com](http://www.anirishanglersworld.com)) suggested they are generally not and never have been retained by anglers in large enough quantities to warrant inclusion in retained catch records.

Average catch rates from the first three years (1978-1980) and from the last three years (2000-2002) of this dataset were applied backwards and forwards, respectively, to each of the remaining years of the dataset not covered by the deep sea angling charter logbook records. The total estimated numbers caught of each species were then multiplied by an estimated 'typical' weight of fish, which was conservatively set at 0.25 of the species' specimen weight, as set by the Irish Specimen Fish Committee (ISFC 2012) to obtain estimated 'typical' species-specific daily catch weights for the year 1950. The specimen weights applied here are 'trophy weights', used by the angling community in Ireland as a threshold measurement for exceptionally large fish that warrant recognition (CSO (Central Statistics Office) 2012). Prior to their application as multiplication factors throughout the dataset, these 'typical' fish weights were extrapolated forwards, declining by 50% for all species from 1950-2010. This conservative estimated trend was applied to account for the decreasing sizes of fish caught over this time period, based on estimates of 50-75% size reductions reported in the North Sea by Jennings (2002). Calculated estimated catch rates by weight were then reduced by 50% for all years, assuming that typical catch rates for all angling activities from boats are not as high as those for angling activities from chartered deep sea angling vessels.

#### Shore-based angling activities

The quantity of fish caught by shore anglers each year was determined through first assuming that occasionally, due to poor luck and inconsistencies in skill, shore anglers have fishing days where they are unsuccessful in catching anything. Thus, to conservatively account for this, we assumed that on 50% of the estimated days spent angling from the shore, zero fish were caught. For the remaining days, in the absence of any other sources of data, the estimated total daily catch rate by weight for all species combined per angler from a boat was also assumed for anglers from the shore. These annual values were multiplied by the total estimated number of days spent angling from shore to obtain a total estimated weight of all species of fish caught per year from shore. Total annual catch weights for sea angling from shore were then disaggregated into species categories based on Scottish angling diversity data (Donnelly 2009). Scottish data were utilised based on the assumption that the diversity of species caught through angling in Ireland is similar to that in Scotland. The Scottish data were from a national survey where individuals were asked which species they typically fished for. For the purposes of this reconstruction, only the species that were mentioned by at least 25% of the respondents were considered, again excluding elasmobranchs (other than rays and skates), and conger eel. The percentage of total respondents that mentioned each species was recorded and these percentage values were used as numerical values, thus approximating the relative catch frequency of each species. These values were converted into proportions of the sum of numerical values for all species mentioned (Atlantic mackerel, Atlantic cod, white pollack, saithe, flatfish, rays and skates, whiting, haddock and European seabass). These proportional values were used to disaggregate the total annual catch weights for all years. In the absence of data suggesting otherwise, it was assumed that the species composition of total shore-based angling catch was consistent throughout the entire time series.

Based on anecdotal quantitative information (W. Roche, pers. comm., IFI; A. Hayden, pers. comm., [www.anirishanglersworld.com](http://www.anirishanglersworld.com)), it was assumed that in 2010, fishers mostly practiced catch and release, whereas during the 1950s, recreational catches were mostly retained. Thus, linear interpolation was used to calculate the final quantities of recreational catches retained from 1950 to 2010 through both boat-based and shore-based angling activities, assuming a 90% retention rate in

1950 and a 10% retention rate in 2010. Lastly, annual retained catch quantities for both boat-based and shore-based angling activities were combined, creating a final dataset of estimated retained catch quantities from all angling activities in Ireland from 1950 to 2010.

Due to limited information on catch rates of Ireland’s recreational anglers, recreational catches were kept constant at 2010 levels for the 2011-2014 update. Spatial and taxa allocations were also kept constant for 2011-2014 recreational catches.

## Results

Reconstructed recreational catch was relatively low and the proportional contribution of this component decreased over time due to increasing catch-and-release behaviour by recreational fishers. For the entire time period, estimated recreational catches accounted for just under 40 000 tonnes and comprised 0.5% of the total reconstructed catches.

## Israel (Red Sea)

The original technical reconstruction research was initially documented in Tesfamichael et al. (2012), and was vetted through peer-review in Tesfamichael and Pauly (2016), and was updated to 2014 by the *Sea Around Us*.

## Methods

Similar to Jordan, the recreational fishery of Israel in the Gulf of Aqaba was calculated based on the population of its largest coastal city in the Red Sea, Eilat (Table 28). The recreational fishery was assumed to start in 1974, after the 1973 war. The participation ratio of 0.12 was used in the calculations (Cisneros-Montemayor and Sumaila 2010) and the number of days fished per year was assumed to be 20. Again, similar to Jordan, the participation ratio was adjusted to the population of Eilat, which had an average of a little less than 1% of the total Israeli population from 1974 to 2010. We assumed 1% and multiplied the participation ratio by 100. The catch rate per day was assumed to be 1 kg·day<sup>-1</sup> for 1974 and 0.5 kg·day<sup>-1</sup> in 2010. Catch rates were interpolated for the intervening years. The catch composition of the recreational fishery was taken from Saudi Arabia’s recreational fishery in the Red Sea, where emperors accounted for 40%, sea breams 30%, groupers 20% and ‘others’ 10% (Tesfamichael and Rossing 2012).

**Table 28.** Population of Eilat.

Year	Pop. (10 <sup>3</sup> )	Year	Pop. (10 <sup>3</sup> )
1972	13	1995	32
1974	14	1999	40
1979	19	2000	41
1983	19	2002	43
1992	30	2008	47
1994	33	2010	48

Source: <http://www.populstat.info/>, except 2008 and 2010 from Wikipedia

Landings from recreational fisheries were updated for 2011-2014 using the same methods as described for 2010 by the original reconstruction. The recreational sector is based on the population of Eilat and so updated population data was sourced from Israel's official statistics. Years between the anchor points of the 2010 population (47,800) and the 2014 population (48,946) were linearly interpolated.

## Results

The artisanal sector had the highest contribution to the reconstructed total catch in the Israeli fishery in the Gulf of Aqaba, contributing 76%. The second was recreational fishery with 18%; the subsistence fishery (6%) was last. Artisanal and subsistence fisheries operated for the entire period, 1950 – 2010; while the recreational fishery began only in 1974.

The total recreational catch estimate for Israel in the Gulf of Aqaba was generally low, a maximum of 63 t·year<sup>-1</sup> in the early 2000s. It increased continuously until it reached its peak and then declined slowly. As compared to the Israeli recreational fishery in Mediterranean, where the catch of recreational fishery was comparable to the that of the artisanal fishery (Edelist et al. 2013), our estimate for the Gulf of Aqaba was very conservative; only 24% of the artisanal catch. The composition of the recreational fishery was dominated by three taxa. The catch composition of the total catch reflected more or less that of the artisanal fishery. The contribution of snappers (Lutjanidae) was reduced from 47% in the artisanal fishery to 38% in the total catch and that of tuna-like fishes was also reduced from 32% to 26%. On the other hand, the contribution of groupers (Serranidae) increased from 12% to 13%. Although, the contribution of the three taxa was moderated by the contribution of the other sectors to the artisanal fishery, they still were the dominant taxa in the total catch.

## Israel (Mediterranean)

The original peer-reviewed reconstruction research was initially documented in Edelist et al. (2013), and was updated to 2014 by the *Sea Around Us*.

## Methods

There has always been some recreational fishing in Israel; however, catches of this sector were never reported and hardly any information exists about the scale of recreational catch or effort. Only recently has a study of this fishery been launched at Tel-Aviv University (SCHULZ et al., 2011) and it sheds some light on the growing scale of this sector. As the population of Israel quadrupled since 1950, the recreational fishery has also grown considerably. However, most of this growth was during the last decade (SCHULZ et al., 2011), and today more than 70,000 Israelis are estimated to contribute significantly to fish extraction from the sea through their recreational activities. From the earliest days of SCUBA diving, there were spear-fishers searching the coastal waters mainly for high-priced groupers. Although this practice was outlawed by a fishery ordinance in 1956, the regulation was very loosely enforced, and the Department of Fisheries has even allowed some 30 SCUBA fishers to keep practicing it legally, through a special permit. These are counted as artisanal fishers in the present study, but we wish to note here that some illegal, unmonitored SCUBA fishing activity is still taking place. Similarly, beach seining, which was outlawed in 1998, is still common on certain beaches. In the recent decades, spear fishing by free divers (not SCUBA) has increased considerably,

and this sector was estimated to land more groupers than the entire commercial fleet (SCHULZ et al., 2011). Angling has also been a traditional pastime for Israelis, mainly as shore-based rod and line fishing, which provides the majority of recreational landings. This sub-sector has, in the last decade, seen a considerable increase in both popularity and use of improved equipment, mirrored by the recent onset of jig-fishing and trolling from kayaks and yachts. In general, recreational fisheries place a growing fishing pressure on the sensitive, scant rocky habitats and especially on shallow rocky nurseries and spawning grounds (SCHULZ et al., 2011).

The catch and effort of recreational fishers were never officially reported or evaluated in Israel. Recently, however, Schulz et al. (2011) conducted extensive in-depth catch and effort surveys for this sector and its sub-sectors. Here, we extrapolated from their survey, conducted during November 2010 to November 2011 along the Israeli Mediterranean coast. Most of the fish in their survey were caught by anglers (81%), a smaller proportion by spear-fishers (14%) and the rest (5%) by other methods such as nets. The estimated catch was 837 t of fish, out of which invasive species contributed 47% of the total biomass. Schulz et al. (2011) also show the growth in the recreational fishing activity along the Israeli Mediterranean coast, as a function of the median experience (8.5 years) and the average age of the fishers ( $48.5 \text{ years} \pm 11$ ) ( $n = 500$ ), suggesting that the recreational fishing effort has doubled during the last 10 years. Therefore, we based the reconstruction on  $837 \text{ t/year}^{-1}$  for the year 2010 and decreased catch exponentially back to  $400 \text{ t/year}^{-1}$  in the year 2000. From 2000 back to 1970, total catch was decreased linearly by  $10 \text{ t/year}^{-1}$  and levelled off at  $100 \text{ t/year}^{-1}$  in 1970 – which we present here as a very approximate and likely conservative estimate for the 1950-1970 period. Species breakdown was extrapolated for the whole period based on information in Schulz et al. (2011). Invasive species were omitted from years preceding their dates of establishment in the Mediterranean (e.g., *Sillago sihama* was omitted prior to 1977 and its share in the previous catch was reassigned to 'other species').

For the 2011-2014 update the recreational sector was reconstructed based on the 2010 catch level of  $837 \text{ t/year}$  carried forward to 2014, with the same taxa being targeted throughout the period.

## Results

the portion of recreational catches have increased substantially over the last decade, and by 2010 ( $837 \text{ t/year}^{-1}$ ) recreational catch estimates accounted for 20% of total catches ( $4,280 \text{ t/year}^{-1}$ ) being taken by Israel in the Mediterranean.

Of substantial interest was the finding that recreational fisheries have taken such a significant role in catches in Israel in the last 10 years, accounting for nearly 20% of total catches (or 28% of landings, if one ignores discarding). While recreational fisheries are of increasing importance in many developed countries (Coleman et al. 2004; Rossing et al. 2010b; Zeller et al. 2011b), at present we know of only one case of higher recreational contribution to catches (i.e., The Bahamas Smith and Zeller 2013). Clearly, this sector requires detailed examination and scrutiny by scientists and focused attention by fisheries managers as well as policy makers in Israel.

## Italy

The original technical reconstruction research was initially documented in Piroddi et al. (2014), and was vetted through peer-review in Piroddi et al. (2015), and was updated to 2014 by the *Sea Around Us*.

### Methods

Until 2010, recreational catches have never been assessed or included in the national fishery statistics. Only in 2010, to fulfill recent EU legislative requirements, the Italian Ministry of Agriculture and Forestry (MIPAAF) first surveyed recreational fishing activities (particularly the number of fishers and gear types) for the marine and freshwater environments. To date, there are only a few sources of information regarding the Italian recreational fisheries. The first preliminary assessment was conducted in 1996 by Anagnopoulos et al. (1998), who described recreational fisheries in Italy and Greece with respect to their fleet size, number of fishers, landings, and fishing effort for 1996. This same estimated number of fishers and fleets for each sub-regional division for the year 1996 was used as a first anchor point. Based on other public sources of data (Cisneros-Montemayor and Sumaila 2010; Gaudin and De Young 2007; Gordoia et al. 2004; Pawson et al. 2007), we were able to obtain three additional anchor points representing the number of fishers for the years 1989, 1993 and 2003, respectively. Population statistics for the 1950-2010 period were extracted from ISTAT (2012) and used to indirectly estimate total catches by local residents. For instance, we used the percentage of observed (from the four anchor points) number of fishers from the total population (1989: 2.2%; 1993: 2.7%; 1996: 2.6% and 2003: 2.7%) to establish a time series of number of recreational fishers for the missing years. Thus, for the 1950-1988 period, it was assumed that 2.2% of the total population were recreational fishers, while for 1990-1992, 1994-1995 and 1997-2002, we interpolated the estimates of the four anchor points, and for the last period (2004-2010), the percentage observed in 2003 (2.7%) was kept constant. Assuming the proportions of recreational fishing fleets per each sub-regional division observed in 1996 was constant throughout the years (Table 29), and two fishers per boat caught  $1.6 \text{ t}\cdot\text{year}^{-1}$  of fish (Anagnopoulos et al. 1998), the total Italian recreational catches for 1950-2010 was derived.

**Table 29.** Percentage of Italian recreational fishing fleets observed in 1996 (Anagnopoulos et al. 1998) per each sub-regional division

Sub-regional division	Recreational fishing fleets (%)
<b>1. Ligurian</b>	13.4
<b>2. Tyrrhenian</b>	
- Northern	12.8
- Central	12.9
- Southern	8.6
<b>3. Ionian</b>	1.2
<b>4. Adriatic</b>	
- Northern	25.6
- Central	9.4
- Southern	6.1
<b>5. Sardinian</b>	5.3
<b>6. Sicilian</b>	4.7
<b>Total</b>	<b>100</b>

To allocate recreational catches to species-level, we kept the ratio found in Anagnopoulos et al. (1998) per each sub-divisional region constant (Table 30).

In addition, since Italian recreational fisheries have been observed catching illegally (e.g., undersized fish, catch above the permitted limits) we added an illegal component to the total reconstructed recreational catches.

For the 2011-2014 update, recreational fishing was reconstructed using updated data from the World Bank to estimate resident population for 2000-2014 and the previous anchor point of 2.7% participation in recreational fishing carried forward to 2014.

## Results

Our catch reconstruction estimated that the total catch was 2.6 times the data presented by FAO with approximately 79% caught by industrial fisheries, 17% by artisanal fisheries, 3% by recreational fisheries and <1% by subsistence fisheries, while discards (7% of the total) were predominantly (95%) from industrial fisheries.

The estimated recreational catches for 1950-2010 were around 1.45 million t of which 87% were unreported and 13% illegal catches. The Adriatic Sea accounted for 597,000 t (41.1%); the Tyrrhenian Sea 497,000 t (34.3%); Ligurian sub-division 194,000 t (13.4%); Sardinia 77,300 t (5.3%); Sicily 68,100 t (4.7%); and the Ionian Sea 16,700 t (1.2%). The major species caught in Italy by the recreational sector throughout the study period were tuna (*Thunnus* spp.) with 223,000 t (15.4%), bogue (*Boops boops*) with 155,000 t (10.7%), Atlantic bonito (*Sarda sarda*) with 107,000 t (7.4%) and Mediterranean horse mackerel (*Trachurus* spp.) with 97,300 t (6.7%). Overall, we observed a slight increase in recreational catches from 1950 to the late 1980s, followed by a more pronounced growth during the last three decades. Catches increased from 19,200 t in 1950 to 29,800 t in 2010. The recreational fishery accounted for 3% of the total reconstructed catches.

**Table 30.** Percentage of recreational species caught (Anagnopoulos et al. 1998) per each sub-regional division: Ligurian (LI); Northern, Central and Southern Tyrrhenian (NT, CT, ST); Sardinian (SAR), Sicilian (SI); Ionian (IO); Southern Northern, Central and Adriatic Sea (NA, CA, SA).

Scientific name	LI	NT	CT	ST	SAR	SI	IO	NA	SA	CA
Carangidae	0	0	10	10	2	3	0	0	0	0
<i>Sarda sarda</i>	4	4	19	19	5	3	8	2	8	8
<i>Boops boops</i>	18	18	0	0	13	22	4	14	4	4
Teuthida	1	1	1	1	1	3	0	0	0	0
<i>Prionace glauca</i>	0	0	0	0	1	0	0	3	0	0
<i>Serranus</i> spp.	2	2	1	1	1	2	1	1	1	1
Sciaenidae	0	0	0	0	1	1	0	2	0	0
<i>Dentex dentex</i>	1	1	11	11	2	1	0	0	0	0
<i>Trachinotus ovatus</i>	1	1	5	5	1	1	0	0	0	0
<i>Coryphaena hippurus</i>	1	1	4	4	1	2	0	0	0	0
<i>Dicentrarchus labrax</i>	0	0	0	0	1	1	3	2	3	3
<i>Platichthys flesus</i>	0	0	0	0	1	0	0	2	0	0
<i>Belone belone</i>	2	2	1	1	6	2	1	15	1	1
<i>Sparus aurata</i>	4	4	0	0	2	0	1	4	1	1
Gobiidae	5	5	0	0	3	0	4	7	4	4
<i>Zosterisessor ophiocephalus</i>	0	0	0	0	1	0	0	3	0	0
<i>Merluccius merluccius</i>	0	0	0	0	1	0	0	2	0	0
<i>Trachurus</i> spp.	15	15	1	1	7	11	7	2	7	7
<i>Scomber</i> spp.	0	0	3	3	7	4	16	7	16	16
Mugilidae	1	1	0	0	3	0	0	9	0	0
<i>Pagellus erythrinus</i>	5	5	6	6	6	14	0	1	0	0
<i>Pagrus pagrus</i>	3	3	0	0	1	0	0	0	0	0
<i>Spicara smaris</i>	2	2	0	0	1	1	0	0	0	0
<i>Mullus barbatus</i>	0	0	0	0	0	0	2	0	2	2
<i>Oblada melanura</i>	7	7	0	0	5	5	2	6	2	2
Scorpaenidae	0	0	2	2	1	2	1	0	1	1
<i>Diplodus</i> spp.	8	8	3	3	7	16	1	2	1	1
<i>Lithognathus mormyrus</i>	0	0	0	0	8	4	28	6	28	28
<i>Xiphias gladius</i>	0	0	3	3	1	1	0	0	0	0
<i>Alopias</i> spp.	0	0	0	0	1	0	2	2	2	2
<i>Chelidonichthys lucerna</i>	0	0	0	0	1	0	7	0	7	7
<i>Thunnus</i> spp.	20	20	30	30	7	1	12	5	12	12
Labridae	0	0	0	0	1	0	0	3	0	0

## Jamaica

The original technical reconstruction research was initially documented in Lingard et al. (2012), and was updated to 2014 by the *Sea Around Us*.

### Methods

A sport tournament fishery has been in operation in Jamaica since 1959 (Harvey et al. 1989). In its early years, the fishery targeted blue marlin (*Makaira nigricans* Harvey et al. 1989). However, in recent years the catch has included a diversity of scombrids and other oceanic pelagic species (Quinn 2005). Tournament catches for the period of 1976-1986 were calculated using the number of fish caught and average weights taken from Ortiz and Farber (2001). Average weight per fish was calculated for the Ortiz and Farber (2001) length data using the FishBase Life History Tool ([www.FishBase.org](http://www.FishBase.org)). The average weights were then multiplied by the total number of *M. nigricans* landed in each year of the tournament fishery as quoted by Harvey et al. (1989). This resulted in estimated landings (in tonnes) for the sport fishery from 1976-1986. We carried the 1976 estimate back unaltered to 1959 as a small tournament fishery has been in operation since this date (Harvey et al. 1989). Quinn (2005) estimated sport fishery landings from tournament records in 2002. Utilizing the taxonomic information from Quinn (2005), we have assigned catches from this sector to

four taxa (*M. nigricans*, *Acanthocybium solandri*, *Coryphaena* spp., and Scombridae) plus an “Others” category of 7.6% (Table 31). We interpolated from a catch composed of 100% *M. nigricans* in 1986 (Harvey et al. 1989) to the taxonomic composition of tournament catches in Quinn (2005) in order to create a complete time series of tournament catches.

No updated information regarding Jamaica’s recreational fisheries was found and as a result, the tonnage estimated for 2008 was held constant for 2009-2014. The taxonomic breakdown was held constant at the 2008 levels.

**Table 31.** Species composition (% of catch) of sport fishery catches, 2002-2010

Taxon name	Common name	Catch (%)
<i>Makaira nigricans</i>	Blue marlin	48.0
<i>Acanthocybium solandri</i>	Wahoo	23.0
Coryphaenidae	Dolphin fish	14.0
Scombridae	Tunas and mackerels	7.6
Others	All other species	7.6

Adapted from Quinn (2005).

## Results

Total reconstructed catches of Jamaica for the 1950-2010 time period were estimated to be 2,960,000 t. The total catches were 4.3 times larger than the FAO reported landings, which were considered to represent only artisanal landings.

## Japan

The original peer-reviewed reconstruction research was initially documented in Swartz and Ishimura (2014), and was updated to 2014 by the *Sea Around Us*.

## Methods

Statistics on the recreational fisheries are limited, although JFA began compiling estimates of catches by recreational fishers in 1998 and has continued to do so every 5 years through its Recreational Fishing Catch Volume Survey (MAFF 2013; MAFF 2008; MAFF 2003). These estimates are based on questionnaires submitted by recreational fishing operators and non-commercial marine vessel owners. As a result, the estimates derived from these surveys are limited to recreational fishing at sea and do not include shore-based recreational fishing activities. Prior to 1998, the statistics on recreational fishing focused on economic data such as the number of participants and operators, again estimated every 5 years via the Fisheries Census, back to 1973. The statistics on the recreational fishers reported by the Fisheries Census vary from year to year, with some years including the number of recreational fishers engaged in shore-based and pier-based fishing as well shellfish collections, while other years simply provide a total figure.

The historical catches by recreational fishers were, therefore, reconstructed by multiplying the species specific per capita catch rate derived from the 2008 statistics and the reported number of recreational fishers. For years between the Fisheries Census (1973–1997) and the Recreational Fishing Catch Volume Surveys (1998–2008), we assumed the changes in the number of recreational

fishers to be linear and computed accordingly. For years prior to 1973, the number of recreational fishers (and, therefore, catches by recreational fishers) was assumed to be equal to that of 1973 and, similarly, for 2009 and 2010 to be that of 2008.

Recreational catches from 2010 were carried forward unchanged to 2014.

## Results

From 1950 to 2010, total fisheries-related biomass removal was estimated at 368 million t, with the commercial fisheries landings (reported industrial, small-scale and subsistence) accounting for almost 87 % of the total (320 million t), discarding at sea 8 % (30 million t), catches by foreign fleets 3 % (13 million t), recreational fishing 1 % (5 million t) and illegal fishing less than 1 % (0.8 million t).

## Jordan

The original technical reconstruction research was initially documented in Tesfamichael et al. (2012), and was vetted through peer-review in Tesfamichael and Pauly (2016), and was updated to 2014 by the *Sea Around Us*.

## Methods

A recreational fishery exists in the Jordanian Gulf of Aqaba and it is growing fast (FAO, 2003). However, data on its size and catches do not exist. The recreational fishery catch was estimated using the population of Aqaba, the main coastal settlement on the Jordanian coast, taken from [www.populstat.info](http://www.populstat.info) and Wikipedia (2012). Data were not available for the whole time series, and interpolation was used to fill the gaps (Table 32). The recreational fishery was assumed to start in 1974, after the war between Israel and Arab countries in 1973, so zero was assigned from 1950 to 1973. From 1974 onward, it was calculated using a participation rate of 8%. To derive this rate we started with the regional participation value of 0.12 (Cisneros-Montemayor and Sumaila 2010). Note the participation ratios in Cisneros-Montemayor and Sumaila (2010) are given for the whole country and as a percentage. In our calculations, we used population size of only Aqaba, the main coastal settlement because the coastal people are the ones to be involved more in recreational fishing than people far from the coast. Therefore the rate of 0.12% was adjusted for the population size of Aqaba using the ratio of Aqaba population to the total Jordanian population from 1974 to 2010, which was 1.5 % (i.e., the total population is 65 times that of Aqaba). Hence the participation ratio was multiplied by 65, making the participation percentage only for Aqaba to be 8%. In addition, we assumed that recreational fishers go fishing a total of 15 days·year<sup>-1</sup>. As for the catch rate, we assumed a rate of 1 kg·day<sup>-1</sup> for 1974 and 0.5 kg·day<sup>-1</sup> for 2010. The rate was interpolated between those two years. Finally, the annual recreational fishery estimate was calculated as a product of population, participation ratio, number of days per year, and catch rate. The catch composition of recreational fishery was taken from Saudi Arabia's recreational fishery in the Red Sea, where emperors accounted for 40%, sea breams 30%, groupers 20% and 'others' 10% (Tesfamichael and Rossing 2012)

**Table 32.** Population of Aqaba.

Year	Pop. (10 <sup>3</sup> )	Year	Pop. (10 <sup>3</sup> )
1970	15	1993	67
1979	27	1994	63
1985	36	1998	80
1986	37	2002	96
1989	44	2007	98
1990	46	2009	109

Source: [www.populstat.info](http://www.populstat.info), except 2007 and 2009 from Wikipedia

## Results

When the reconstructed total catch of Jordan in Jordanian waters is divided into different sectors, the artisanal fishery has the lion's share with 62%, followed by the subsistence fishery at 20% and the recreational fishery at 18%. The recreational fishery started in 1974 and its contribution became important only in the later years.

## Kenya

The original technical reconstruction research was initially documented in Le Manach et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

The nominal catch provided by the Indian Ocean Tuna Commission (IOTC; [www.iotc.org/data/datasets](http://www.iotc.org/data/datasets)) was used to re-allocate the FAO catch of the large pelagics to various sectors. Given that the FAO dataset clearly includes the catch of the longline fleet (targeting swordfish) from 1980 to 1983, we assumed that the catch of this fleet was included in the FAO data for the entire period. When the IOTC catch for a given taxa was higher than the catch of this taxa reported by FAO, we assumed that it was because it was grouped in a more general taxon (due to low catches). We made the same assumption for the sport fishing fleet, thus we also assumed that at least some recreational (i.e., sport) fishing catches were included in the officially reported data. For both these fleets, the re-allocation of the FAO data was done according to Table 33.

**Table 33.** Correspondence between IOTC taxa and their FAO names, from which their catch was reallocated

Fleet	Original IOTC taxon	Reallocated FAO taxon	Period	
Longline (targeting swordfish)	<i>Acanthocybium solandri</i>	Perciformes		
	<i>Alopias</i>	Elasmobranchii	All years these species were reported	
	Carcharhinidae			
	<i>Carcharhinus falciformis</i>			
	<i>C. longimanus</i>			
	<i>C. obscurus</i>			
	<i>Istiompax indica</i>	<i>Makaira indica</i>	1980–83	
	Istiophoridae	<i>Istiophorus platypterus</i>	Istiophoridae	2005 onward
			<i>Istiophorus platypterus</i>	All years these species were reported
	Istiophoridae	<i>Istiophorus platypterus</i>	<i>Istiophorus platypterus</i>	1981–83
			Istiophoridae	2005 onward
	<i>Isurus oxyrinchus</i>	Elasmobranchii		
	<i>I. paucus</i>			
	<i>Kajikia audax</i>	Istiophoridae		
	<i>Katsuwonus pelamis</i>	<i>Katsuwonus pelamis</i>		
	<i>Lamna nasus</i>	Elasmobranchii		
	<i>Makaira nigricans</i>	Istiophoridae		
	Marine fishes not identified <sup>a</sup>	Perciformes		
	<i>Prionace glauca</i>	Osteichthyes <sup>b</sup>		All years these species were reported
	<i>Pseudocarcharias kamoharui</i>	Elasmobranchii		
	Scombridae	Scombroidei		
	<i>Selachimorpha</i>	Elasmobranchii		
	<i>Sphyrna lewini</i>			
	<i>S. zygaena</i>			
	Sphyrnidae			
	<i>Tetrapturus angustirostris</i>	Istiophoridae		
	<i>Thunnus alalunga</i>	<i>Thunnus alalunga</i>	1980–83	
	<i>T. albacares</i>	Perciformes	2005 onward	
		<i>Thunnus albacares</i>	1980–83	
	<i>T. obesus</i>	Perciformes	2007 onward	
		<i>Thunnus obesus</i>	1980–83	
	<i>Xiphias gladius</i>	Perciformes	2005 onward	
		<i>Xiphias gladius</i>	1980–83	
Perciformes		2005–08, 2010		
Sport fishing	<i>Acanthocybium solandri</i>	Osteichthyes	2009	
	<i>Auxis thazard thazard</i>	Perciformes		
	Carcharhinidae	Elasmobranchii	All years these species were reported	
	<i>Carcharhinus longimanus</i>			
	<i>Euthynnus affinis</i>	Perciformes		
	<i>Istiompax indica</i>	Perciformes	1987, 1990–93, 1995, 2008	
	Istiophoridae	Osteichthyes	1994	
		Istiophoridae	2006–07, 2009	
		Perciformes	1995	
	<i>Istiophorus platypterus</i>	Istiophoridae	2000 onward	
		Perciformes	1987, 1989–1993, 1995, 2008	
		Osteichthyes	1994	
	<i>Isurus oxyrinchus</i>	Istiophoridae	1996–2006, 2009–10	
	<i>Kajikia audax</i>	Elasmobranchii	All years these species were reported	
	<i>Katsuwonus pelamis</i>	Perciformes	1987, 1989–1993, 1995	
		Osteichthyes	1994	
	<i>Makaira nigricans</i>	Istiophoridae	1996 onward	
	<i>Makaira nigricans</i>	<i>Katsuwonus pelamis</i>	All years these species were reported	
		Perciformes	1987, 1990–93	
	Marine fishes not identified <sup>a</sup>	Osteichthyes	1994	
		Istiophoridae	1998 onward	
	<i>Prionace glauca</i>	Perciformes		
	Scombridae	Elasmobranchii		
	<i>Selachimorpha</i>	Perciformes		
	<i>Sphyrna zygaena</i>	Elasmobranchii		All years these species were reported
	<i>Sphyrnidae</i>			
	<i>Thunnus albacares</i>	Perciformes		
	<i>T. obesus</i>			
	<i>Xiphias gladius</i>			

<sup>a</sup> Given that the IOTC focuses on large pelagics, we changed this taxon to 'pelagic fishes' in our database.

<sup>b</sup> For some reasons, the catch of that species were very high compared to the other species of sharks. Given that the catch of *Prionace glauca* was even higher than the total catch of sharks reported to FAO, we decided to reallocate it from the higher taxon 'Osteichthyes'.

## Sport fishing fleet

Kenya has been a tourist destination since at least the 1950s (Williams 1970), but mass tourism started in the 1980s (Irandu 2004; Weaver 1999). This sector is now a pillar of the Kenyan economy (Mangi et al. 2007), as there are currently over 1.6 million tourists visiting Kenya every year (Kenya National Bureau of Statistics 2010). Most visitors spend part of their stay visiting places such as the Massai-Mara, Tsavo and Amboseli National Parks for safaris (Weaver 1999), and about one third also visit coastal areas (Williams 1970; Kimani 1995).

Kenyan sport fishing started in the 1950s (Williams 1970) and became much more prominent in the mid-1980s (Marshall 1997), due to increased tourism. According to Marshall (1997), there were about 60 sport fishing boats (5–12m long; 60 to 200 trips each per year) that were registered in the late 1990s, but we can expect this figure to have greatly increased in the 2000s. Indeed, Ndegwa (2010) reported that about 30 centers were registered along the coast in the late 2000s; thus, it is easily imaginable that each center has, on average, more than only two boats. As a matter of fact, Ndegwa (2010) also reports that there are on average nine boats per day at sea at Malindi's resort.

Sport fishing mostly occurs from April to August, the weather being too rough the rest of the year (Abuodha 1999). Boats mainly use hook and line, in contrast with shore-based recreational fishing (mostly trolling, drifting, and spinning)<sup>26</sup>. The sport fishing charters generally operate from all major ports and fish the more distant Kenyan Banks, 35–55 km offshore (Ndegwa 2011). However, it seems that, although resorts occur along the entire Kenyan coast, the resorts of Watamu, Malindi (and offshore Kenya banks), Shimoni and Mombasa make up most of the sport fishing activity (Abuodha 1999; Ndegwa 2010). Ndegwa (2010) reports that 22,000 trips were recorded between 1990 and 2008 in the resort of Malindi alone. This author notes, however, a decrease from 1,600 trips per year in the early 1990s to currently 1,200 (Ndegwa 2010).

Some authors previously believed that FAO data included some recreational fisheries data at some point in the past (de Sousa 1987), but this was later questioned by Ndegwa (2010). According to the latter author, the Kenyan Fisheries Department collected sport fisheries data since 1940, but never computerized them. In 2006, the Indian Ocean Tuna Commission and the Overseas Fishery Cooperation Foundation aimed to collect these data in order to create a historical database and analyze CPUE trends. This database is now available at [41.206.61.142:8080/statbase\\_3](http://41.206.61.142:8080/statbase_3) and has been included in the IOTC catch database. Here, we assumed that these data were now included in the FAO data. These reported catches oscillated between 11 and 182 tonnes and averaged 91 tonnes between 1987 and 2010. However, Ndegwa (2010) reported that recreational catches in Malindi's resort alone consistently ranged around 100 t·year<sup>-1</sup>, making it therefore likely that only a subset of total recreational catches were ever included in the IOTC dataset<sup>27</sup>. As a matter of fact, Maina (2012) reported catches around 206 t·year<sup>-1</sup>, with 318 t in 2009. He also noted that much remains to be

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<sup>26</sup> Although a tag and release project was introduced in 1987 (Abuodha 1999), it seems that most fish are still sold on local markets. When skippers judge the fish to be in good-enough physiological condition, though, they may release it after the photo-shoot.

<sup>27</sup> Pitcher and Hemphill (1989) also collected recreational catch data from 1976 to 1987, showing that several hundred yellowfin tuna (i.e., several tonnes) were caught in the resort of Shimoni alone.

done to improve the quality of these statistics, reinforcing the feeling that official statistics miss a large part of the recreational sector.

To reconstruct this sector, we produced a set of assumptions based on data provided by Williams (1970) for the 1960s:

- Sailfish were weighting on average 29.5 kg;
- Sailfish were making up 30% of the total catch in weight (the author notes that both sailfish and marlin make up a majority of the catch);
- Malindi's area was accounting for half of the recreational catch in Kenya.

A catch of zero tonnes was set for 1950, and data were linearly interpolated to 1958, the first year for which Williams (1970) presented data.

From 1987 to 2006, we used the data published by the IOTC (Ndegwa 2010), filling the gaps with linear interpolations (1988–89 and 2002–04). For 2007–2010, we used the average of the period 1987–2006; excluding interpolations). Further, we considered that this author only managed to collect half of the actual catch in the area of Malindi (Ndegwa [2010] noted that data still needed to be much improved).

To scale these results to the entire Kenyan coastline, we considered that Malindi's resort made 50% of the total catch until 1980, and only 25% from 2000 onward (linearly interpolating in between). This was based on the assumption that other resorts gained a larger portion of the total share due to the tourism expansion in the 1980s.

The taxonomic breakdown for this sector was based on Abuodha (1999), although some modifications were made to accommodate the data reported to FAO: *Istiophorus* sp. (30%) and Scombridae (20%); the rest being equally distributed among *Sphyraena* spp., *Scomberomorus commerson*, *Makaira* spp., *Acanthocybium solandri*, Elasmobranchii, and other pelagic species<sup>28</sup>. The unreported landings were calculated by subtracting the data reported to FAO from the data estimated above (Table 34).

Identical methods from Le Manach et al. (2015) were used to reconstruct the reef gleaning and recreational fisheries: for the latter, while the IOTC's nominal catch database did not record recreational catches for 2011 to 2014, individual national reports submitted by Kenya to the IOTC did (Ndegwa 2015; Wekesa 2014; Wekesa 2013; Wekesa 2012). These catch amounts were considered reported in the FAO data, and portions of FAO reported taxa were disaggregated to the recreational fisheries following these amounts, then evaluated against the reconstructed recreational catch and taxonomic distributions for 2011-2014, which followed the method from Le Manach et al. (2015).

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<sup>28</sup> Noteworthy, it seems that shark sightings decreased over the last few decades (Marshall 1997), similarly to most places in the world.

**Table 34.** Correspondence between the reported taxa and the assumed FAO taxa, from which their catch was subtracted to calculate the ‘unreported landings’.

Reported taxon	Assumed FAO taxon
<i>Acanthocybium solandri</i>	<i>Acanthocybium solandri</i>
Carcharhinidae	
<i>Carcharhinus longimanus</i>	
<i>Isurus oxyrinchus</i>	
<i>Prionace glauca</i>	Elasmobranchii
Selachimorpha	
<i>Sphyrna zygaena</i>	
Sphyrnidae	
<i>Auxis thazard</i>	
<i>Euthynnus affinis</i>	
<i>Katsuwonus pelamis</i>	Scombridae
Scombridae	
<i>Thunnus albacares</i>	
<i>T. obesus</i>	
Istiophoridae	
<i>Istiophorus platypterus</i>	<i>Istiophorus</i> spp.
<i>Istiompax indica</i>	
<i>Kajikia audax</i>	<i>Makaira</i> spp.
<i>Makaira nigricans</i>	
Pelagic fishes	
<i>Xiphias gladius</i>	Pelagic fishes
<i>Sphyrna</i> spp.	
<i>Scorpaenidae</i>	
<i>Scorpaenidae</i>	No reported catch; All 'unreported landing'

## Results

Overall, artisanal, subsistence, industrial, and recreational catches made up 64%, 27%, 5%, and 4%, respectively.

Recreational catches by tourists steadily increased — although fluctuating — from 34 t in 1951 to around 1,300 t by 2010. A substantial decrease occurred in 1997–98 (to around 700 t), which was caused by the collapse of coastal tourism following political riots (Obura 2001). Overall, tourists caught 38,000 t in Kenyan waters, which still only represents around 4% of the total catch. Sailfish represented 28% of the catch and tuna 19%. The rest of the catch was composed of various species of large pelagics.

## Korea (South)

The original technical reconstruction research was initially documented in Shon et al. (2010), and was updated to 2014 by the *Sea Around Us*.

## Methods

Although recreational fishing has occurred in South Korea for more than a century, there is still no monitoring system for recreational fishing activities (Min 2008). Thus, recreational catch data for South Korea are not readily available. Recreational fisheries can be divided into two components, inland and marine; however, available data do not distinguish between these prior to 1970. According to Min (2008), people started to use boats for recreational fishing in 1971. Boats allowed recreational fishers to expand their fishing areas from shore bound activities. In addition, South Korea developed a highway system in the 1970s and ended the midnight curfew in 1982. These factors enabled more people to travel and engage in marine recreational fishing. Thus, we made a

conservative assumption that marine recreational fishing (boat and shore-based) in South Korea started in 1971 and increased gradually thereafter. We also assumed that any ‘recreational’ fishery prior to 1971 was possibly more related to subsistence fishing, and hence assumed to be included in the subsistence catch estimates.

Although the number of people engaged in recreational fishing in South Korea was estimated by several studies with different methods, these estimates were not significantly different from each other and showed an increasing trend. Thus, they were used to estimate marine recreational fish catch (Table 35). According to these sources, approximately 30% of recreational fishers in South Korea are marine fishers prior to 2000 and this increased to 34% by 2004. In 2008, approximately 27% and 36% of recreational fishers are marine specific fishers and general fishers fishing both in inland and marine waters (Lee 2010). The marine specific recreational fishers make an average of 7.5 trips·person<sup>-1</sup>·year<sup>-1</sup>, while general recreational fishers make 4.1 trips·person<sup>-1</sup>·year<sup>-1</sup> for marine fishing.

**Table 35.** Data sources for South Korea’s recreational fisher population

Year	Recreational Fishers	Recreational Sector	Source
1970	0 <sup>a</sup>	Marine only	Min (2008)
1990	3,250,000	Inland and marine <sup>b</sup>	Bae (1992 in Lee <i>et al.</i> 2002)
1994	4,000,000	Inland (70%) and marine (30%)	Anon. (1995 in Lee <i>et al.</i> 2002)
1999	5,000,000	Inland (70%) and marine (30%)	Cho (2000 in Lee <i>et al.</i> 2002)
2004	5,730,000	Inland (66%) and marine (34%)	Anon. (2004 in Kim 2008b)
2008	6,524,000	Inland (37%), Marine (27%), and both (36%)	Lee (2010)

<sup>a</sup> Assumption base on Min (2008) who states that Korea started to use boats for recreational fishing in 1971. <sup>b</sup> Assumed 30% were marine recreational fisheries.

Prior to 2008, we combined the number of marine recreational fishers with the marine specific per capita number of trips per year (7.5 trips·person<sup>-1</sup>·year<sup>-1</sup>) and the average catch per trip (2.33 kg·person<sup>-1</sup>·trip<sup>-1</sup>) (Table 36) to estimate the total marine recreational catch. In 2008, we first calculated the total number of trips per year for both marine specific and general fishers, and then combined the average catch per trip (2.33 kg·person<sup>-1</sup>·trip<sup>-1</sup>) to estimate the total marine recreational catch. Linear interpolations between data anchor points were used for time periods when data were unavailable, and the 2008 estimate was carried forward to 2010 to estimate the total annual marine recreational catch.

**Table 36.** South Korea’s recreational fishing catch

Sources	Average catch (kg·person <sup>-1</sup> ·trip <sup>-1</sup> )
Part <i>et al.</i> (2005)	2.20
Part <i>et al.</i> (2007)	2.45
Averages	2.33

#### Recreational mud flat collecting

Recreational fishing in South Korea not only relates to catching marine fishes from shore or boat, but also to people who catch mud flat species such as clams and crabs during low tide. Recreational mud

flat activities started as events to attract tourists to fishing villages 10 to 20 years ago, and the number of annual participants has increased steadily, reaching 40,000 in 2004 and 46,000 by 2005 (Ryu et al. 2005). Thus, we conservatively assumed that recreational mud flat collecting started in 1994. Since the number of people involved in marine recreational activities such as fishing is increasing, we assumed that the total number of participants in mud flat collecting would continue to grow at the rate observed from 2004-2005 until 2010. We used linear interpolations between 0 in 1994, 40,000 in 2004 and 77,900 in 2010 to obtain the annual number of participants from 1994 to 2010.

However, total participants in recreational mud flat activities do not represent the number of people who catch mud flat species, since the total number of participants includes people who engage in sport activities on mud such as soccer, wrestling and running marathons (Ryu et al. 2005). Thus, we conservatively assumed that only half of the number of total participants would be involved in some collection of marine species.

There were no data available for catch rates on mud flats. However, 3 out of 8 surveyed locations have catch limits of 1 kg per participant (Table 37). We applied this rate to half of the total annual participants to estimate the annual recreational catch of mud flat species.

Recreational landings were held constant at the 2010 amount for 2011-2014 due to the absence of more recent information.

**Table 37.** Surveyed recreational mud flat collecting locations in South Korea.

Locations	Sources	Catch limitation
Baekmiri fishing experience village 백미리 어촌체험마을 (Hwaseong-si 화성시)	<a href="http://www.sugbag.net/jj/baegmiri/enjoy.htm">http://www.sugbag.net/jj/baegmiri/enjoy.htm</a>	not available
Doopo Village mud flat experience centre 도포마을갯벌체험장 (Buan-gun 부안군)	<a href="http://www.dupotown.com/">http://www.dupotown.com/</a>	1kg per person
Jundo mud flat experience centre 전도갯벌체험장 (Namhae-gun 남해군)	<a href="http://cafe.naver.com/nengchun.cafe?iframe_url=/ArticleRead.nhn%3Farticleid=3134">http://cafe.naver.com/nengchun.cafe?iframe_url=/ArticleRead.nhn%3Farticleid=3134</a>	not available
Mohang mud flat experience centre 모항갯벌체험장 (Buan-gun 부안군)	<a href="http://www.mohangmud.com/sub1-1.htm">http://www.mohangmud.com/sub1-1.htm</a>	1kg per person
Nengchun mud flat experience center 냉천갯벌체험장 (Namhae-gun 남해군)	<a href="http://www.getbeol.com/">http://www.getbeol.com/</a>	not available
Taeon ark, salt pan, mud flat experience centre 태안방주염전 갯벌체험장 (Taeon-gun 태안군)	<a href="http://www.xn--vh3bv0ok3cluk.kr/index.html">http://www.xn--vh3bv0ok3cluk.kr/index.html</a>	not available
Tando fishing experience village 탄도어촌체험마을 (Ansan-si 안산시)	<a href="http://www.tando.or.kr/04sea02.html">http://www.tando.or.kr/04sea02.html</a>	1kg per person
Walhaseong mud flat experience centre 월하성 갯벌체험마을 (Seochun-gun 서천군)	<a href="http://cafe.naver.com/01054279292.cafe?iframe_url=/ArticleRead.nhn%3Farticleid=3">http://cafe.naver.com/01054279292.cafe?iframe_url=/ArticleRead.nhn%3Farticleid=3</a>	not available

## Taxonomic composition

The marine recreational catch estimate was broken down using a list of coastal fish species that are commonly targeted by recreational fishers (Ryu et al. 2005) (Table 38). The estimated recreational mud flat catch was assigned to oysters, octopus, crabs, sea cucumbers, miscellaneous crustaceans and miscellaneous mollusks (Table 38).

**Table 38.** Taxonomic composition applied to marine recreational fish catches for South Korea. Percentage data derived through assumption-based consideration of source material (Ryu et al. 2005).

Taxon	Common name	Catch (%)
<i>Acanthopagrus schlegelii</i>	Black porgy	10.0
<i>Chanos chanos</i>	Milkfish	2.5
<i>Girella punctata</i>	Girella punctata	10.0
<i>Nippon spinosus</i>	Ara	2.5
<i>Oplegnathus fasciatus</i>	Barred knifejaw	10.0
<i>Pagrus major</i>	Red seabream	10.0
<i>Sebastes</i> spp.	Redfishes	5.0
Clupeidae	Herrings, shads, sardines	5.0
Hemiramphidae	Halfbeaks	2.5
Lateolabracidae	Asian seaperches	2.5
Mugilidae	Mulletts	5.0
Paralichthyidae	Large-tooth flounders	5.0
Serranidae	Sea basses, groupers	5.0
MMF	Misc. marine fishes	25.0

**Table 39.** Taxonomic composition applied to recreational mud flat collected catches for South Korea. Percentage data derived through assumption-based consideration of source material (Ryu et al. 2005).

Taxon	Common name	Catch (%)
Holothuriidae	Sea cucumbers	5
Octopus	Octopuses	10
Ostreidae	True oysters	10
Portunidae	Swimming crabs	10
MMC	Misc. marine crustaceans	25
MMF	Misc. marine fishes	40

## Results

The estimated total marine recreational catches of South Korea for the 1970-2010 period were 820,000 t, while the estimated recreational mud flat collecting catches for 1994-2008 were 300 tonnes. Total annual recreational catches were around 850 t·year<sup>-1</sup> in 1971 and increased to just under 53,000 t·year<sup>-1</sup> in 2010. The recreational catches were dominated by *Acanthopagrus schlegelii*, *Girella punctata*, *Oplegnathus fasciatus* and *Pagrus major*.

## Kuwait

The original technical reconstruction research was initially documented in Al-Abdulrazzak (2009), and was vetted through peer-review in Al-Abdulrazzak et al. (2015), and was updated to 2014 by the *Sea Around Us*.

### Methods

An active recreational fishery targets demersal species from small speedboats, but no data are available on the number of participants or species landings (FAO 2006). Cisneros-Montemayor and Sumaila (2010) estimate that recreational fisheries involve 0.12% of Kuwait's population. Thus, this ratio was applied to the total population from 1950-2010 to get a time series of number of recreational fishers. As a conservative estimate, it was assumed that recreational fishers catch 1 kg of fish per trip and that they only fish on the weekends. Therefore, the number of fishers was multiplied by the number of fishing days (104 days) and by a catch of 1 kg to obtain a rough time series of recreational catches. The estimated catches for the years during and immediately after the first Gulf War (1990-1992) were eliminated, as it was assumed that no recreational fishing occurred. Rao and Behbahani (1999) estimate that the majority of species caught by recreational fishermen are *Epinephelus chlorostigma*, *Sparidentex hasta*, *Otolithes ruber*, and *Acanthopagrus latus*; thus the recreational catch was evenly distributed among those 4 species.

For the 2011-2014 update, the same methods were carried forward.

### Results

Total reconstructed catch for Kuwait fisheries was estimated to be 1,997,000 t which is 6.4 times the amount reported by the FAO (312,250 t) on behalf of Kuwait. Kuwait's fisheries were estimated to be 42.8% industrial, 56.8% artisanal, 0.01% subsistence and 0.45% recreational.

## Latvia

The original technical reconstruction research was initially documented in Rossing et al. (2010d), and was vetted through peer-review in Zeller et al. (2011b), and was updated to 2014 by the *Sea Around Us*.

### Methods

Almost no data for recreational catches exist for Latvia except for cod. Therefore, we relied on recreational catch rates from Estonia, and applied these to the coastal population of Latvia to estimate recreational catches for species from 1991-2007.

Three ports have offered boat charters to catch cod recreationally since 2004. In one harbor, Liepaja, 15 boats were estimated to catch between 3-5 tonnes in 2007 (M. Plikshs, unpubl. data). Assuming the same catch rates for the other two harbors, we estimated the recreational catch of cod to be 12 tonnes per year since 2004.

LATFRA reported that Latvian recreational fishers also caught herring, salmon, flounder, garfish, seatrout, perch and smelt. We relied on recreational catch information from Estonia to estimate these catches from 2004-2007. To remain conservative, we used half of the average reported

recreational catch rates from Estonia. These were transformed into per capita catch rates for the coastal population (see Methods in Veitch et al.,(2010b)). We estimated the coastal population for Latvia as the total population of coastal districts to be approximately 1,676,000 inhabitants (Anon., 2006c). Multiplying the estimated coastal population of Latvia with the per capita catch rates, we estimated Latvia’s recreational catches for the above species from 2004-2007 (Table 40). For all species, including cod, we assumed a recreational catch of zero in 1990. Linear interpolations for all Latvian recreational catches were performed in the intervening years from 1991-2003.

For the 2011- 2014 update, recreational catch by each taxon was linearly extrapolated forward to 2014 from the 2010 anchor point and divided into ICES area subdivisions using the 2010 proportions.

**Table 40.** Anchor points for Latvia’s recreational catch for the period 2004-2007, based on half the average Estonian reported recreational catch for 2004 and 2007. (See Veitch et al. 2010b)

<b>Common Recreational catch 2004-2007 t·year<sup>-1</sup></b>	
<b>Name</b>	<b>2007 t·year<sup>-1</sup></b>
Herring	1.24
Salmon	2.04
Flounder	50.67
Garfish	30.73
Sea trout	1.65
Perch	2.17
Smelt	35.48

## Results

It was assumed that there were no recreational catches in Latvia prior to 1991, and in 1991 the total recreational catch was estimated as 16 t. This increased to a peak of 228 t in 2004- 2007. The total estimated recreational catch from 1991-2007 is 2,386 t, and the two groups that made up the majority were ‘others’ and flatfishes, with overall catches of 1,275 t (53% of recreational catch) and 925 t (39% of recreational catch), respectively. Recreational catches of ‘other’ fishes were estimated to be 8 t in 1991, increasing to a peak of 122 t in 2004-2007.

Recreational catches of flatfishes were estimated to have been 6 t in 1991, increasing to a peak of 88 t in 2004-2007. The estimated total recreational catch for cod were 126 t, salmon 38 t and herring 23 t for the period 1991-2007.

ICES landing statistics report 1,211,724 t from 1991-2007, our total reconstructed catch for the same time period was 1,553,914 t, an increase of 28%. For the entire 1950-2007 time period, unreported landings, discards, recreational catches and ICES data source adjustments accounted for 7%, 6%, 0.1% and 87% of total reconstructed IUU. The same components accounted for 69%, 30%, 1% and 0.03% for the 2000-2007 time period.

## Lebanon

The original technical reconstruction research was initially documented in Nader et al. (2014), and was updated to 2014 by the *Sea Around Us*.

### Methods

Due to the lack of available data on recreational fisheries in Lebanon, the recreational catch of Lebanon for 1950-2010 was estimated based on a population participation rate of 0.1181% derived in a global study on marine recreation (Cisneros-Montemayor and Sumaila 2010). To calculate the recreational catches for 1950-2010, it was assumed that this participation rate would only apply to the total coastal population of Lebanon (rural and urban combined) in order to be conservative. An assumption was made that between 1950 and 1974 (before the Lebanese civil war period) recreational fishers would on average go on 1 trip per month and catch 5 kg per trip. Further, for the period 1992-2010 (after the civil war), it was assumed that recreational fishers would make 0.5 trips per month and catch an average of 2.5 kg per trip. For the period of the civil war (1975-1991), it was assumed that recreational fishing immediately declined and that fishing behavior was the same as the period right after the war ended.

### Taxonomic composition

Recreational catches were disaggregated using the information available on a local recreational fishery website ([www.lebanonboats.com/fishing/](http://www.lebanonboats.com/fishing/)). The most common fish captured by recreational fishers in the coastal regions of Lebanon are Serranidae, Scombridae, Haemulidae, Holocentridae, Sparidae, Mugilidae and Sphyraenidae. An assumed breakdown of these taxa was applied to the recreational catches for the whole time period (Table 41).

**Table 41.** Recreational species composition applied to Lebanese recreational catches for 1950-2010.

<b>Taxa</b>	<b>(%)</b>
Haemulidae	20
Mugilidae	20
Sparidae	20
Scombridae	15
Holocentridae	10
Serranidae	10
Sphyraenidae	5

For the update, both recreational and subsistence catch were estimated by applying a per capita consumption rate to the coastal (urban and rural) population of Lebanon. The rural and urban coastal populations in a 10 km range for 2010 were obtained from the Socioeconomic Data and Applications Center (CIESIN, 2012). Using the total population of Lebanon for 2010, it was possible to estimate the percentage of the coastal population to the total population in a 10 km range. This percentage was applied to the total Lebanese population for 2011-2016. This work was completed separately for the urban and rural coastal populations.

Recreational catch was obtained following the same method as 1950 to 2010. According to Cisneros-Montemayor and Sumaila (2010), the percentage of people participating in recreational fisheries is 0.1181%. This percentage was applied to the coastal population (urban and rural) *as per* the 1950 to

2010 methods. Following the same source, the estimate the number of recreational fishers was assumed to complete 0.5 trips per month catching on average 2.5 kg per trip per year.

Subsistence catches were obtained following the same method as Nader et al. (2014). A per capita catch rate of 4 kg·person<sup>-1</sup>·year<sup>-1</sup> (rural) and 0.5 kg·person<sup>-1</sup>·year<sup>-1</sup> (urban) were applied to the rural and the urban coastal populations, respectively.

## Results

Recreational catches for Lebanon were estimated to amount to just under 3,100 t for 1950-2010. Catches increased steadily from around 55 t·year<sup>-1</sup> in the early 1950s to just over 100 t·year<sup>-1</sup> in 1974 before the start of the civil war. During and after the civil war, recreational catches were deemed to remain low at around 26-27 t·year<sup>-1</sup>, and reached around 40 t·year<sup>-1</sup> by the end of the present time period in 2010.

## Lithuania

The original technical reconstruction research was initially documented in Veitch et al. (2010b), and was vetted through peer-review in Zeller et al. (2011b) and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational catches were assumed to be zero until the 1990s as recreational fishing was forbidden during the USSR period, except for in Poland and Russia. From 1990-2007, the years of transition from a state controlled to a market-based economy, little information regarding Lithuania's recreational catches exists. We therefore estimated catches for this period based on the number of fishers and the catch rates of the nearest neighboring countries.

The proportion of Lithuania's coastal population that engages in recreational fishing was based on the proportion of Kaliningrad's coastal population that fishes recreationally (Harper et al. 2010). Using 2002 census data for Kaliningrad and the number of fishers for Kaliningrad, we derived a recreational fishing participation rate for Lithuania. We combined this with the coastal population of Lithuania and estimated that there were 49,000 recreational fishers in Lithuania in 2002. The coastal population of Lithuania was estimated as the sum of the three coastal administrative districts, Klaipėdos, Telsiu and Taurages. Assuming the same catch composition as Germany and half of Germany's catch rate (kg·fisher<sup>-1</sup>) for 2005/2006, as a conservative estimate for Lithuania, we applied this catch rate to the number of recreational fishers in Lithuania and derived recreational catch estimates for cod, herring and flounder. To get a complete time series from 1990-2007, we carried the 2005 values forward, unaltered to 2007 and estimated values for 1990-2005 through linear interpolation.

Overall, total reconstructed catches were obtained as the sum of ICES landings statistics, adjustments, unreported landings estimates, discard estimates, and recreational catch estimates. The estimated total reconstructed catch was then compared to the officially reported data, defined here as the ICES landings statistics.

For the 2011-2014 update, recreational catch by each taxon was linearly extrapolated forward to 2014 from the 2010 anchor point and divided into ICES area subdivisions using the 2010 proportions.

## Results

It is assumed that there were no recreational catches in Lithuania prior to 1991. In 1991, the total recreational catch was approximately 42 t, then increased to 633 t in 2005 and remained stable at this value for the rest of the time period. The total recreational catch for the time period was estimated to be 6,326 t. Cod was the most important species targeted in the recreational fishery, and contributed 5,756 t, or 91% of the recreational catch total. The species with the next largest recreational catch was herring, with a total of 447 t, followed by flatfish with a catch of 123 t for the time period.

Unreported and recreational catches accounted for 21% and 2% of our reconstructed catch from 1991- 2007 (the period that they are estimated to have been operating during). Recreational catches contributed approximately 6,300 t for the 1991- 2007 time period.

## Madeira Isl. (Portugal)

The original technical reconstruction research was initially documented in Shon et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational fisheries contribute, similar to subsistence fishery, to the non-commercial portion of the small-scale marine fisheries, but recreational fishers do not depend on their catches to meet their seafood demand, instead are rather pleasure driven. We assumed that recreational fishing is performed by both locals and tourists. The recreational fishing by tourists is mostly big game fishing and is described below. The recreational catches were neither recorded nor reported; thus, catch data were not readily available. We estimated catches for this sector based on Azorean recreational catch estimates presented by Pham et al. (2013a). The method to calculate the recreational catches of Madeira is similar to that used for the subsistence catches described above, i.e., using population data (Table 42).

**Table 42.** Subsistence and recreational catches (t) of Madeira islands calculated using the subsistence and recreational *per capita* rates estimated from the Azores (Pham et al. 2013).

Year	Azores		Population	Madeira	
	Subsistence (t·person <sup>-1</sup> ·year <sup>-1</sup> )	Recreational (t·person <sup>-1</sup> ·year <sup>-1</sup> )		Subsistence (t)	Recreational (t)
1950	0.0012	0.0001	267,000	329	22
1960	0.0014	0.0003	268,900	378	94
1970	0.0015	0.0011	251,100	376	280
1980	0.0015	0.0017	252,645	388	441
1990	0.0012	0.0022	253,160	315	565
2000	0.0004	0.0012	245,830	88	288
2010	0.0005	0.0016	265,645	127	425

## Big game fishing

Since the 1950s, game fishing has been present in the waters of Madeira; however, it was growing slowly until the early 1970s when the number of tourists started to rise (Graca 2009). Main targets

are largely blue marlins (*Makaira nigricans*), but also swordfish (*Xiphias gladius*), bigeye tuna, bonito (*Sarda sarda*), barracuda (*Sphyraena sphyraena*), hammerhead shark (*Sphyrna corona*), blue shark (*Prionace glauca*), and bluefin (*Thunnus thynnus*), yellowfin (*Thunnus albacares*) and albacore tuna (*Thunnus alalunga*)<sup>29</sup>. While billfishes are not retained due to a catch and release policy, some of the other species are kept for consumption since some big game fishing chapters offer ‘cook your catch’<sup>30</sup>. Although there were estimates of big game fishing catches in the Azores (Pham et al. 2013), there was insufficient and not readily available information to estimate the total catches by this fishing activity in Madeira. Thus, we assumed that catches of big game fishing that were retained for consumption were negligible.

For the 2011 – 2014 update, estimations of unreported subsistence and recreational catches were done with the same rates of per-capita subsistence and recreational catch as in Shon, Delgado et al (2015). Population data was interpolated for 2013 and 2014 using estimated population data from the national statistical institute of Portugal.

## Results

Total unreported catch for the 1950-2010 was 64,700 t (14% of total catch). Unreported catch amounts varied from 400 t·year<sup>-1</sup> to 1,930 t·year<sup>-1</sup>. The total unreported landings (tunas, mackerels, subsistence, recreational, and bait catches) and discards of black scabbardfish fishery contributed close to 13% and 1% of the total reconstructed catches, respectively.

The recreational catches from 1950-2010 were estimated at 20,200 t, presenting 31% of the total unreported catches or 4% of the total reconstructed catches of Madeira. Recreational catches gradually increased from 20 t in 1950 to 550 t·year<sup>-1</sup> in the late 1980s, and then fluctuated between 280 t·year<sup>-1</sup> to 530 t·year<sup>-1</sup> for 1991-2010. The recreational catches were all ‘miscellaneous marine fishes’.

The contribution of the industrial, artisanal, subsistence and recreational sectors towards total reconstructed catches were 67%, 24%, 4% and 4%, respectively.

## Malaysia

The original technical reconstruction research was initially documented in Teh and Teh (2014b) and was updated to 2014 by the *Sea Around Us*.

Recreational fishing is reportedly a growing industry in Malaysia (Tan 2003; Zakariah 2008), but there is very limited information on the marine recreational fishing industry in terms of participation rate and fishing effort. However, the presence of numerous recreational fishing websites and forums, as well as advertisements for chartered fishing trips and game fish competitions suggests that recreational fishing is quite a popular leisure activity in Malaysia.

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<sup>29</sup> <http://www.madeira-web.com/PagesUK/flowers-fruit-fish.html> [Accessed: July 17, 2013]

<sup>30</sup> <http://www.casa-velha.com/en/game-fishing.html> [Accessed: July 15, 2013]

## Methods

### Number of participants

One study in 1997 estimated that there were one million recreational fishers in Malaysia (Nik Mustapha 1997), but did not indicate what proportion of these fishers fished in marine waters. As recreational fishing in inland waters is popular in Malaysia, and we had no other information to go by, we arbitrarily assumed that half of the estimated one million (i.e., 500,000) recreational fishers fished in marine waters in 1997. Su (1985) indicated that people had participated in marine recreational fishing in Sarawak at least since the 1970s. Thus, we started the analysis for marine recreational catches in 1970.

We assumed, given that recreational fishing is a leisure activity, the number of recreational fishers followed the general trend of GDP growth. From the single point estimate of 500,000 marine recreational fishers in 1997, we filled in the time series by extrapolating backward and forward according to the rate of GDP growth or decline per year (Anon. 2012).

### Catch rate

We had no information on fishing effort or catch rates for marine recreational fishers. Recreational fishing surveys conducted in Puerto Rico and Australia led to estimated catch rates of approximately 6 and 8 kg of finfish<sup>4</sup> caught per participant per year in Puerto Rico and Australia, respectively (Garcia-Sais et al. 2008; Henry and Lyle 2003). As both these studies involved tropical water fisheries to some extent, we found it reasonable to apply an average of these rates to Malaysia, given the lack of alternative estimates.

### Annual marine recreational catch

The number of participants was multiplied by the catch rate to estimate the total annual marine recreational catch for 1970-2010 in the whole of Malaysia. The total catch was then allocated to Peninsular Malaysia and Sarawak according to each region's contribution (%) to Malaysia's total annual reported landings.

For the 2011-2014 update, all artisanal, subsistence, and recreational catches were assigned to small-scale gears. The 2010 percent breakdowns for EEZs, sectors, gear types and taxa were held constant for 2011-2014. The same method of determining a proportion of national data to the 2014 FAO FishStatJ dataset for 2010 was used to estimate unreported catch by commercial, subsistence and recreational fisheries and discards for 2011-2014.

## Results

### All of Malaysia

Recreational catches contributed 118,000 t (0.2%).

### Peninsular Malaysia

Discards totaled 808,800 t, while marine recreational catches contributed another 90,900 t (0.16%) to total reconstructed catch.

## Sarawak

Discards added 28,700 t and marine recreational catches contributed about 12,600t to the total reconstructed catch of Sarawak.

## Sabah

We allocated a portion of total Malaysian marine recreational catch to Sabah based on Sabah's percentage contribution to Malaysia's total annual reported landings from 1970-2010. This resulted in reconstructed total catches of 15.8 million t for Sabah from 1950-2010, of which about 56% came from the commercial sector, 32% from the artisanal sector, 11% from the subsistence sector, and 0.1% from the recreational sector.

## Malta

The original technical reconstruction research was initially documented in Khlfallah et al. (2015) and was updated to 2014 by the *Sea Around Us*.

### Methods

Recreational fishing is well developed in Malta and is organised into different organisations and associations in different Maltese port cities, and which are part of the largest amateur fishing club in Malta "Federazzjoni Ghaqda Dilettanti tas-Sajd" (European Commission 2013). This sector can be divided into three types depending on vessel registration:

- (i) The most important group includes vessels on the national fishing fleet register of the Department of Fisheries, which are registered as non-commercial. The main gear used by this class of vessels is trolling lines (Malta Centre for Fisheries Sciences 2006).
- (ii) A second group are small recreational vessels registered with the Ministry of Transport and using sport fishing gears that do not require a license. The main activities of this group are trolling, bottom fishing, swordfish fishing and other small-scale fishing ones (Department of Fisheries and Aquaculture 2013; Malta Centre for Fisheries Sciences 2006).
- (iii) The third group consist of shore-based anglers, who do not require any registration (Malta Centre for Fisheries Sciences 2006).

In 2013, the number of recreational vessels was estimated at 1915 vessels, which represents 65% of the total fishing fleet, compared to only 37% (i.e., 833 recreational vessels) of the total fishing fleet in 2005 (Department of Fisheries and Aquaculture 2013b; European Commission 2013). In Malta, recreational catches cannot be marketed (European Commission 2013).

The reconstruction of the recreational catches is based on a pilot study report following a national fisheries data collection program launched by the Malta Centre for Fisheries Sciences in 2005 (93/2010; EC 1639/2001). This study aimed to identify the activities within the recreational fishing sector and to estimate catches and effort exerted for that year (Malta Centre for Fisheries Sciences 2006). This study showed that total catches from recreational fishing were 1291 kg•day<sup>-1</sup> in 2005, which is equivalent to 471 t•year<sup>-1</sup>. The number of recreational boats in 2005 was around 833

(European Commission 2013), which means that for 2005 the recreational catch rate was  $0.566 \text{ t}\cdot\text{vessel}^{-1}\cdot\text{year}^{-1}$ .

We assumed that, in 1950, only 50 recreational boats were operating, with a vessel catch rate equivalent to twice the vessel catch rate of 2005 (i.e.,  $1.13 \text{ t}\cdot\text{vessel}^{-1}\cdot\text{year}^{-1}$ ) to account for healthier stocks allowing higher catch rates. We also made the assumption that the number of recreational vessels increased to 150 units by 1980 and doubled by 1990 to 300 recreational vessels, the year that marked the start of a boom of recreational vessels in Malta. We interpolated the number of recreational vessels between 1950, 1980 and 1990. For all years between 1950 and 1990, we applied the vessel catch rate as in 1950 (i.e.,  $1.13 \text{ t}\cdot\text{vessel}^{-1}\cdot\text{year}^{-1}$ ).

We then made the assumption that in 2010, the number of recreational vessels was equivalent to 60% of the number of recreational vessels in 2013 (Department of Fisheries and Aquaculture 2013b; European Commission 2013) and that the 2005 vessel catch rate of  $0.566 \text{ t}\cdot\text{vessel}^{-1}\cdot\text{year}^{-1}$  was decreasing by 5% per year after 2005. We interpolated the vessel catch rate from 1990 ( $1.13 \text{ t}\cdot\text{vessel}^{-1}\cdot\text{year}^{-1}$ ) to the 2005 value ( $0.566 \text{ t}\cdot\text{vessel}^{-1}\cdot\text{year}^{-1}$ ).

We then calculated the proportion of each taxon according to their recreational catch amounts in 2005 and multiplied this proportion by the recreational catch estimated for each year. Note that there is no significant catch and release in Malta, only rarely for very small fishes and juveniles, which were here neglected.

For the 2011-2014 update, the same methods were used.

## Results

The main components of the reconstructed catches were artisanal (small-scale commercial) landings (61%), recreational catches (18%), subsistence catches (10%), and industrial landings (6%), while discards (artisanal and industrial) accounted for around 6% of reconstructed total catches. Unreported catches were driven almost exclusively by the growth in the recreational sector.

## Martinique (France)

The original technical reconstruction research was initially documented in Frotte et al. (2009b) and was updated to 2014 by the *Sea Around Us*.

The recreational fishing sector was estimated in 2005 to have 137 fishers who mainly targeted fish in the Labridae and Scaridae families, dolphinfish, crustaceans such as lobster and shellfish such as Conch (Guyader 2008).

## Methods

Recreational catch estimates were based on a preliminary study by Ifremer (2008), which found that the 2005 recreational fisheries catches in Martinique totaled 412 t, or  $1.03 \text{ kg}\cdot\text{person}^{-1}$ . We assumed that recreational catches were zero in 1950 and then derived our time series through linear interpolation from zero in 1950 to  $1.03 \text{ kg}\cdot\text{person}^{-1}$  in 2005. The 2005 per capita recreational fishing rate was carried forward unaltered to 2007. This is likely an underestimate of recreational catches as this fishery sector is likely to increase alongside the tourism industry. Of the total recreational catch

approximately 62% were fish, 19% were shellfish and the remaining 19% were crustaceans (Guyader, 2008). These percentages were used throughout the time series to estimate annual tonnage of fish, shellfish and crustaceans caught recreationally.

The same methods were used for the update.

## Results

Estimated recreational catches totaled approximately 11,400 t over the period 1950-2007. During this period, we estimated that over 7,000 t of fish were caught recreationally and 2,000 t each of shellfish and crustaceans were taken by the recreational sector.

## Mauritania

The original technical reconstruction research was initially documented in Belhabib et al. (2013a), was vetted through peer-review in Belhabib et al. (2016b), and was updated to 2014 by the *Sea Around Us*.

## Methods

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

For the 2011-2014 update, we reconstructed recreational catches by anglers for 2011-2012 following the methods of Belhabib et al. (2013a). To provide a conservative estimate of recreational fisheries catches, we first assembled anchor points for the number of tourists in the Baie de l'étoile fishing center, which hosts European tourists engaged in sport fishing every year. We reconstructed the total number of tourists who visited Mauritania to fish and multiplied it by the average catch per unit effort observed for the years 2011-2014.

## Results

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

## Mauritius

The original technical reconstruction research was initially documented in Boistol et al. (2011), and was updated to 2014 by the *Sea Around Us*.

### Methods

Mauritius is well-known as a tourist destination. While it creates job opportunities for the local population, it also represents a potential threat to marine life (Paul 1987; Sobhee 2004). In Mauritius, the recreational fishery can be divided into two components, namely the extraction of marine resources for leisure purposes inside or close to the lagoon environment, and the pelagic sport fishery, which operates with boats in deeper waters. We estimated these catches separately.

#### Pelagic sport fishery

Mauritius is a popular destination for big game sport fishers. A number of leisure and sports fishers operate successfully around FADs (Roullot et al. 1988; Venkatasami and Sheik Mamode 1995). For this activity, a number of lines are used with rods and outriggers baited for the large migratory carnivorous species. The catch comprises mainly blue marlin (*Makaira mazara*), black marlin (*Makaira indica*), Indo-Pacific sailfish (*Istiophorus platypterus*), striped marlin (*Tetrapturus audax*) and yellowfin tuna (*Thunnus albacares*), albacore (*Thunnus alalunga*) and bigeye tuna (*Thunnus obesus*). Other species like wahoo (*Acanthocybium solandri*), shortbill spearfish (*Tetrapturus augustirostris*), skipjack tuna (*Katsuwonus pelamis*) – used as bait for marlins, sharks (*Sphyrna zygaena*, *Isurus oxyrinchus*, *Carcharinus albimarginatus*, *Carcharinus melanopterus*) and dolphinfishes (*Coryphaena hippurus*) are also caught (Jehangeer 2006; Norungee and Lim Shung 1995). Recently, a system of data collection has been set up at the Albion Fisheries Research Centre (Norungee et al., 2004). However, examination of the Ministry reports showed that the currently reported sport pelagic catches consist of the constant amounts of 400 t from 1977 to 1987 and 650 t from 1988 to 2008. Such amounts do not reflect the increasing trend of the tourist population that reaches the island each year. Thus, catches from the sport fishery were re-estimated. We first extracted catch estimates for the sport fishery from other reliable sources. For each reported value, we calculated a per tourist rate using the time series of number of tourists arrivals. Sport fishery likely already existed in 1950. According to Paul (1987), the sum of the countless amateurs and sport fishermen catches were estimated at 50 t by the officials from 1946 to 1958. However, to remain conservative (and in the absence of more detailed information), we assumed that the pelagic sport fishery catches were null in 1950. For the period 1950-1987, we interpolated linearly between the per tourist rates. Between 1974 and 1988, the calculated per tourist rates declines from 2.9 to 2 kg per tourist arrival. In order to reflect the decreasing catches of pelagic species since the 1990s, we carried this decreasing trend forward from the 1988 catch rate figure to derive the catch rates for the 1988-2008 period. Pelagic sport catches were finally deduced by multiplying the catch rates as estimated above by the number of tourist arrivals.

#### Recreational catches in the lagoon

In addition to the tourists involved in big game fishing, a substantial part of the tourist population is involved in recreational fishing in the lagoon of Mauritius. For 1982, Paul (1987) assumed that a conservative estimate of the total number of fishing tourists involved in the exploitation of the island's waters would be approximately 20,000 people, or about 17% of the tourist arrivals during

the year. We assumed that the number of fishing tourists was proportional to the tourist arrivals, and we carried the 17 percent figures for the whole time period. Thus, using the number of tourist's arrivals time series, we established the number of fishing tourists from 1950 to 2008. For 1982, Paul (1987) estimated the catch rate of a fishing tourist at  $5 \text{ kg}\cdot\text{tourist}^{-1}\cdot\text{year}^{-1}$ . We assumed that this catch rate would not have changed from 1950 to 1982, but that the increasing degradation of marine resources of the island, together with an increasing number of people fishing in the lagoon area, would have caused the tourist's catch rates to decrease from 1982 to 2008. Therefore, we used the proportional decline of 60% between the part time professional fishers catch rates of 1982 and 2008, so that the tourist catch rates decreased from a reported  $5 \text{ kg}\cdot\text{tourist}^{-1}\cdot\text{year}^{-1}$  in 1982 to an assumed  $3 \text{ kg}\cdot\text{tourist}^{-1}\cdot\text{year}^{-1}$  in 2008. We then established the catches using the fishing tourist population time series.

In the absence of updated information, recreational and subsistence components were held constant at the 2008 level for 2010-2014. Unreported landings were taxonomically disaggregated for 2011-2014 based on the 2010 taxonomic breakdown for each sector.

## Results

Our total reconstructed recreational catch for Mauritius from 1950 to 2008 was estimated to be over 30,000 t, which is 1.7 times larger than the reported recreational catch. Pelagic sports fishery catches accounted for approximately 21,800 t and tourist catches from the lagoon fishery representing the remaining 8,700 t. It is worth noting the difference in the overall trend of the reported compared to the reconstructed recreational catch, especially since 1990. Due to the method employed, estimated catches of the fishing tourist population reflected the growing number of tourists visiting the island each year, thus showing an increasing trend for the whole time period. Estimated pelagic sports fishery catches increased constantly from 1950 to a peak of 825 t in 2000, after which catches have been decreasing.

## Mayotte (France)

The original technical reconstruction research was initially documented in Doherty et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

Increased tourism and immigration of French expatriates in recent years has led to an increase of recreational fishing activities (Busson 2011; Guézel et al. 2009). Recreational fishing can be broken down into two sectors: sport fishing and spearfishing.

There are currently only two commercial boats offering sport fishing trips and their annual catch for 2008 was estimated at 4.8 tonnes (Guézel et al. 2009a). This estimate was considered conservative as it did not take into account the catch from individuals who fished recreationally on their own boats, nor tourists who may have rented a boat from locals.

Spearfishing has been regulated since 1991, when it was banned in the interior of the lagoon (Guézel et al. 2009a). It has been practiced for at least 20 years and now mostly takes place on the exterior slope of the barrier reef and in the open ocean. Based on information from Guézel et al. (2009a), a

conservative estimate of 50 spearfishers and an average catch rate of 8.5 kg·fisher<sup>-1</sup>·trip<sup>-1</sup> were used for 2008. An assumption was made that recreational spearfishers were active once every two weeks (i.e., 26 trips per year).

Little recreational fishing took place prior to 1985, as there were few outboard motors at this time (Biais et al. 1987) and few French expatriates living on the island (IEDOM 2006). Due to no other available data, we made a simplifying assumption that recreational catches for 1985 and earlier years were zero, and that catches increased linearly between 1985 and 2010.

Catches were allocated evenly among the target taxa, as no other information is available regarding catch composition. These boats generally target pelagic and demersal species such as barracuda, billfishes, dolphinfish, *Gymnosarda unicolor* (dogtooth tuna), jacks, Lutjanidae (snappers), Lethrinidae (emperors), Selachimorpha (sharks), Serranidae (groupers), Sparidae (sea breams) skipjack tuna, tuna-like species, and wahoo (Guézel et al. 2009a). Spearfishers target dogtooth tuna, groupers, jacks, Scaridae (parrotfish), sharks, snappers, swordfish, tuna-like species, and wahoo (Guézel et al. 2009a).

Recreational fishing was assumed to continue to increase in a linear fashion as in previous years as reconstructed by Doherty et al (2015). The rate of increase was carried forward to 2014, and recreational landings were taxonomically allocated according to 2010 proportions. Unreported industrial fishing rates from *barques* frequenting foreign EEZs were maintained at 2010 levels and taxonomic breakdowns for 2011-2014.

## Results

The total recreational catches were an estimated 220 t, estimated for the 1985–2010 period.

## Mexico

The original technical reconstruction research was initially documented in Cisneros-Montemayor et al. (2015), was peer-reviewed in Cisneros-Montemayor et al. (2013) and was updated to 2014 by the *Sea Around Us*.

## Methods

Subsistence and recreational fisheries have significant catches, yet are relatively small compared with the commercial sector. Recreational catch by species for the billfish fishery were used as reported in Cisneros-Montemayor et al. (2012); it is important to highlight that this does not include other recreational catch, which is often limited at local scales but may prove more significant in the aggregate.

For the 2011-2014 update, Mexico's recreational fishery is still driven largely by tourism and international arrivals to Los Cabos airport were used to update recreational catches to 2014.<sup>31</sup>

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<sup>31</sup> <https://www.aeropuertosgap.com.mx/en/traffic-report.html>

## Results

Preliminary estimates of recreational catches for Mexico are summarized in Table 43.

**Table 43.** Summary of catch statistics by type in Mexico, 1950-2010

Type	1950	2010	Catch by period (t x 10 <sup>3</sup> )	
			Total (1950-2010)	Average/Year (1950-2010)
Reported	89	1,407	46,600	764
Unreported	399	436	19,758	323
Discards	17	258	24,648	404
Subsistence	4	32	808	13
Recreational	9	4	59	1
Total	518	2,137	91,873	1,505

## Montenegro

The original technical reconstruction research was initially documented in Keskin et al. (2014), and was updated to 2014 by the *Sea Around Us*.

### Methods

Recreational fishing is very popular in Montenegro and has been increasingly so in the last 10 years. In 2003, in the marine recreational sector, there were 1,500 registered sport fishers organized in 12 clubs. The national umbrella associations of marine sport fishers are the 'Association for Underwater Activities and Sport Fishing', with its main office in Podgorica, and the 'Association of Marine Sport Fishermen', with its main office in Baosici (FAO 2004b).

Tunas such as Atlantic bluefin tuna (*Thunnus thynnus*), albacore tuna (*T. alalunga*), and little tunny (*Euthynnus alletteratus*) are the most common fishing targets in the Adriatic, but big game fish also include sharks, swordfish (*Xiphias gladius*), amberjacks (*Seriola* spp.), and dorados (*Coryphaena* spp.). Little tunas moving in shoals averaging 10-15 kg in weight are often seen in April. The end of May and the beginning of June marks the shark hunting season (blue sharks and thresher sharks). Bluefin tunas are caught at the beginning of August when they can average between 70-80 kg up to 500 kg in weight. The season for bluefin tunas fall in the best season for recreational fishing (August to November) when chances of catching big game targets are high<sup>32</sup>.

Subsistence and recreational fishing in Montenegro was estimated as entirely unreported catches based on the per capita subsistence and recreational catch made by coastal residents in Croatia from 1950 to 2010 (Matić-Skoko et al. 2014). For the purposes of this report, residents living within 10 km of the coast were considered to engage in subsistence and recreational fishing. Coastal population data for Montenegro for 1990, 2000 and 2010 were taken from CIESIN (2012) and used as anchor points for a time series interpolation. For all years prior to 1990, the 1990 percentage of coastal to total Montenegro population was assumed to be constant. Furthermore, as no single source presented complete population data for Montenegro between 1950 and 2010, two sources were used. For 1950 to 1959, the total population of Montenegro was taken from the United States Census Bureau (<http://www.census.gov>) and for 1960 to 2010, data were taken from The World Bank (<http://www.worldbank.org/>). The taxonomic breakdown of catches made in the subsistence

<sup>32</sup> <http://biggamenmontenegro.com/en/offer/deep-sea-fishing.html> [accessed August 2013]

and recreational sectors were considered on the family level and assumed to be identical to taxa caught in Croatia.

For the 2011-2014 update, the per capita consumption rate of the recreational and subsistence sector from the Croatia reconstruction was calculated for 2011-2013 (see Croatia addendum) and averaged for 2011-2013 for 2014. This per capita consumption rate was applied to the coastal population of Montenegro to determine the recreational and subsistence catch amounts. The taxonomic breakdown followed the species composition of the Croatia recreational and subsistence sectors. For the years 2011-2014, the taxonomic breakdown followed the 2010 composition.

## Results

Total catches (i.e., including discards) by the industrial sector (around 35,200 t) accounted for 51% of total marine catches from 1950-2010. The artisanal sector contributed 22% (15,600 t) of total catches. Catches in the subsistence sector amounted to 14,000 t which corresponds to 20% of total catches. Recreational fishing activities in Montenegro were responsible for 4,800 t, or 7%, of the total reconstructed marine catches.

## Morocco

The original technical reconstruction research was initially documented in Belhabib et al. (2013b), was vetted through peer-review in Belhabib et al. (2016b) and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational fisheries include rod and reel fishing and underwater spear-fishing. In the Mediterranean, these activities are becoming increasingly important (Zahri and Abdelaoui 2010). The number of fishing licenses and the species targeted in the Mediterranean from 2004 to 2009, have been well documented (Abdelaoui 2010; Gaudin and De Young 2007), however, no effort estimate was available for the Atlantic.

The number of spearfishing and rod-fishing licenses for the Mediterranean were available from 2004 to 2009 (Abdelaoui 2010). The number of fishing licenses indicates the number of spearfishers and rod-fishing boats, respectively. To estimate the number of spearfishers and rod-fishing boats for the period from 1950 to 2003, we assumed recreational fisheries started in 1950, i.e., zero spearfishers and zero rod-fishing boats, then interpolated linearly to 100 spearfishers and 1,000 rod-fishing boats in 2004. Since no effort data were available for the central and southern areas, we assumed the effort in the Mediterranean represented 70% of the total effort, 20% in the central areas, and in the southern areas where there was no spearfishing represented 10% of the total number of rod-fishing boats. The number of fishing days was also derived from Abdelaoui (2010) to be conservatively 70 days per year (i.e., during the summer) for the time period from 1950 to 2010, which allowed to estimate the total recreational effort (Table 44). We estimated a CPUE of 58.8 kg·fisher<sup>-1</sup>·day<sup>-1</sup> based on observations from recreational fishers (www.hassan-peche.com [2011]; www.pecheurmarocain.com [2011]) for Atlantic central and southern areas rod-fishing, and assumed a same CPUE for the Mediterranean recreational rod-fishing fleet. We also derived a spearfishing CPUE of 17.14 kg·fisher<sup>-1</sup>·day<sup>-1</sup> (www.hassan-peche.com [2011]) for Atlantic areas, while for the

Mediterranean, the majority of the spearfishing catch per unit of effort (70%) was estimated to be 20.6 kg·day<sup>-1</sup> of seabreams (Zahri and Abdelaoui 2010), i.e., a total CPUE of 28 kg·day<sup>-1</sup>. Thereafter, to reconstruct recreational rod-fishing and spearfishing catches from 1950 to 2010, we applied these CPUE estimates to the effort of each segment in the Mediterranean, Atlantic Morocco and Western Sahara. This approach uses the same CPUE for the 1950 to 2010 time period; therefore, it accounts for the increasing popularity of recreational fishing by Moroccans and tourists (increasing number of fishing days).

The unreported recreational fishery was carried forward from 2010 unchanged for 2011-2014.

**Table 44.** Recreational fishing effort expressed in number of licenses in the northern area<sup>a</sup>.

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

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

## Results

### Northern and Central Areas

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

### Southern Areas

Recreational catches were estimated at 14,000 tonnes for the period 1950 to 2010. Recreational catches in the southern areas increased from 5 t·year<sup>-1</sup> in 1950, when the area was under the Spanish rule, to 1,300 t·year<sup>-1</sup> in 2010.

## Namibia

The original technical reconstruction research was initially documented in Belhabib et al. (2015b), was vetted through peer-review in Belhabib et al. (2016d) and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational angling is a popular activity in Namibia, also famous for wildlife safaris, sand surfing and shark fishing (Huggins 2011). Angling is practiced by Namibian and foreign anglers (Nghipunya 2012). This activity is important on both the resource use and the tourism development aspects. Access to the shore angling is limited in Namibia as it encompasses only about 260 km of the Namibian coast comprised between Sandwich Harbour south of Walvis Bay and the Ugab River in the north, where 90% of recreational fishing occurs (Barnes and Alberts 2008). Besides kob and steenbras, recreational fisheries target species include blacktail, also known as dassie (*Diplodus sargus*), galjoen, snoek (*Thyrsites atun*), barbel (*Galeichthys feliceps*), broadnose sevengill shark (*Notorynchus cepedianus*), spotted gullyshark (*Triakis megalopterus*), smooth-hound (*Mustelus mustelus*) and copper shark (*Carcharhinus brachyurus*), along with a limited amount of Cape rock lobster (*Jasus lalandii*) (Barnes and Alberts 2008; Mavetja Rukoro 2005)

Given the decline in species targeted by recreational fisheries, e.g., silver kob or kabeljou and west coast steenbras (Barnes and Alberts 2008), it is important to assess recreational catches (Kirchner and Beyer 1999). The few surveys performed along the Namibian coast estimate catches as the product of total effort and catch rate (Kirchner and Beyer 1999), the method also used here.

Penhrith and Loutit (1982) surveyed recreational fisheries catches over a period of one year along a 30 km stretch of Terrace Bay (Skeleton Park) and estimated total catches at 50 t·year<sup>-1</sup> for 1980. While 310 km of coast are completely open to recreational shore angling and 85 km under strict regulation with limited access (Kirchner and Beyer 1999), we consider that recreational shore angling is regularly done over a 260 km stretch of coast (Barnes and Alberts 2008). Thus, we extrapolated catches on to the total available coast and estimated a total catch of 436 t·year<sup>-1</sup> for 1980. Similarly we extrapolated catches for each species documented by Penhrith and Loutit (1982). Using the surveyed catch estimate which accounted for 40 anglers per year on average (Penhrith and Loutit 1982) to extrapolate over the entire coast where recreational fishing occurred is conservative. Indeed, Kirchner and Stage (2005) describe that only “some limited” recreational fishing occurs in Terrace Bay (along the Skeleton Coast Park) in contrast to National West Coast Recreation Area where 90% of recreational shore angling occurs (Barnes and Alberts 2008). We used the same method for 1990 when Lenssen et al. (Lenssen et al. 1991) surveyed recreational shore catches along 20 km stretch of Sandwich Shoreline in the Namib-Naukluft Park and estimated a total catch of around 90 t·year<sup>-1</sup> for this stretch of coastline. Since this area is very productive, we extrapolated catches for 230 km of coastline, and adjusted downwards the previous catch rate by 50% to account for lower catches in Terrace Bay (30 km). Thus, we estimated total catches at 1,102 t·year<sup>-1</sup> for 1990. Similarly, the authors provided catches per species, which we extrapolated using the same method.

Kirchner and Beyer (1999) surveyed recreational shore catches along the Namibian coast where most recreational shore fishing occurs and estimated 361 t·year<sup>-1</sup> of silver kob taken by recreational fishers with an error of 5%. This estimate is conservative as it only takes into account catches from easily accessible areas. To estimate total catches, we added other species assuming the same species composition provided by Nghipunya (2012), where kob represented 36% of total catches, steenbras 27%, galjoen 25% and others including copper shark, spotted gully shark and smooth-hound documented by Barnes and Alberts (2008) represented 12%, i.e., herein assumed 4% each. Therefore, we estimated total catches at 1,003 t·year<sup>-1</sup> for 1996. For 2004, Barnes and Novelli (2007) estimated that around 460,000 fishes were taken annually by recreational anglers. We converted

this number to weight using the species disaggregation provided by Nghipunya (2012) and the average weight per fish (Penhrith and Loutit 1982), which translates into a catch of 616 t·year<sup>-1</sup> for 2004.

Barnes et al. (2002) estimated the daily catch per angler at 6.06 kg·angler<sup>-1</sup>·day<sup>-1</sup> for 1996 for 8.2 fishing days over a total of 19.7 visiting days per angler (Kirchner and Stage 2005). The latter argue that the CPUE has strongly declined in the latest years. Assuming the trend remained similar over the last few years, i.e., from 2005 onwards, we assumed a decline of 50% between 1996 and 2011, i.e., the CPUE is estimated at 3.23 kg·angler<sup>-1</sup>·day<sup>-1</sup> for 2010 after interpolation. Nghipunya (2012) reported the number of recreational fishing permits for 2011 and the annual revenue obtained from fishing permits between 2007 and 2011. We obtained the number of permits per year for 2007, 2008, 2009, 2010 by dividing the number of permits for 2011 by the revenue for 2011, then multiplying the result – assuming the ratio was constant - by the revenue per year for the remaining years. We then multiplied the resulting number of fishing permits by the interpolated CPUE and the number of days (8.2). Thereafter we applied the species disaggregation provided by (Nghipunya 2012).

As there was no clear information documenting the beginning of recreational fishing in Namibia or in South West Africa, we assumed the beginning was in the early-1960s given that the first description of Sandwich harbor, where significant recreational fishing occurs, was available in 1963 (Lenssen et al. 1991). We thus interpolated linearly between zero in 1960 and the estimated catches for the subsequent years to fill in the gaps.

Recreational landings were updated for 2011-2014 using the 2010 proportion to reported landings. The 2010 taxonomic breakdown for recreational landings was carried forward unaltered to 2014.

## Results

Recreational catches were estimated at around 20 t in 1961 when recreational fishing began, increased to a first peak of 307 t in 1990, decreased to around 450 t in 2004, and then increased to a peak of 900 t·year<sup>-1</sup> before decreasing to around 200 t in 2010 mainly due to the decrease in the number of visitors. Catches consisted mainly of galjoen in the past, kob, steenbras and blacktail today.

## Netherlands

The original technical reconstruction research was initially documented in Gibson et al. (2015c) and was updated to 2014 by the *Sea Around Us*.

## Methods

The Netherlands collects data for many species through surveys but reports only Atlantic cod and European eel (*Anguilla anguilla*) to ICES (ICES 2012b). We use numbers of recreational fishers (both freshwater and marine) from 1993-2004 (Vriese et al. 2007) and another anchor point of 1.6 million fishers in 2009 (de Graaf 2010). The number of fishers is interpolated between 2004 and 2009 and 1.6 million fishers are carried forward to 2010. The anchor point of 885,000 fishers from 1993 is assumed constant back to 1980. A per capita rate of fishers from the Dutch population is calculated

from 1980 and reduced by 50% and used as a per capita anchor point in 1950. The per capita rate is then interpolated from 1950-1980 and used to calculate number of recreational fishers for the entire time series.

An anchor point of 360 t of cod (ICES 2012b) is divided by number of fishers in 2010 to determine a recreational catch rate. The catch rate is reduced by 50% in 1950 and catch rates are interpolated between to complete the time series. Cod catch is then estimated each year using interpolated catch rates. The same method is used for eel with a 2010 anchor point of 26.5 t (ICES 2012b).

We realize that in using a number of recreational fishers that includes both freshwater and marine, we are likely over estimating the number of fishers and therefore the catch. However, we have only included cod and eel as they were the only two taxa with recorded data. Therefore, we believe that we are underestimating the tonnages of other recreationally important species which are also of commercial importance (Atlantic mackerel, European flounder, European plaice, common dab, common sole, European sea bass etc.) (de Graaf 2010). We assume that the overestimation of fishers and the underestimation of taxa will largely cancel each other out, and that our estimate is likely a conservative representation of total marine recreational catch from 1950-2010 in the Netherlands.

To estimate recreational catch, population totals from 2011-2014 were based on The World Bank<sup>33</sup> while the *per capita* rate of catch of 2010 was carried forward, unaltered. The 2010 anchor points for Atlantic Cod (*Gadus morhua*) and European Eel (*Anguilla anguilla*) were re-calculated using the tonnage in the ICES working group report (ICES 2014) which more closely resembles the expected L-W relationship of these species and were then interpolated to 2014 using the tonnage in the most recent recreational fisheries survey (ICES 2015).

## Results

Dutch recreational catch as estimated here totals just over 9,000 t from 1950-2010. Due to the reconstruction approach taken, Atlantic cod accounts for 93% of the catch and European eel accounts for 7%. Recreational fishing totals approximately 38 t in 1950 and steadily increases to just over 380 t by 2010.

Recreational catch from 1950-2010 is estimated in a similar fashion to subsistence, using anchor points from ICES (2012b) for Atlantic cod and European eel. We use these anchor points to determine a per capita rate based on an estimated number of Dutch recreational fishers from Vriese et al. (2007) and de Graaf (2010), which includes both marine and fresh water fishers. European flounder (*Platichthys flesus*), garfish (*Belone belone*), Atlantic mackerel, common dab, European plaice, common sole, whiting and European seabass (*Cicentrarchus labrax*) are all species known to be targeted by recreational fishers (de Graaf 2010). Therefore, we assume that our over-estimate of fishers and under-estimate of taxa and tonnage will cancel each other out to produce a reasonable estimate of total recreational catch from 1950- 2010.

It is not mandatory to report recreational catch or, in many cases, be in possession of a license (Pawson et al. 2008) in the Netherlands, so it can be difficult to estimate an accurate tonnage to properly represent the catch. However, the Dutch Ministry of Economic Affairs, Agriculture, Nature

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<sup>33</sup> <http://data.worldbank.org/indicator/SP.POP.TOTL?locations=NL>

and Innovation, with the assistance of IMARES Wageningen UR and the Royal Dutch Angling Association (Sportvisserij Nederland), is making efforts to survey recreational fishers for more accurate estimates of catch, both retained and released (de Graaf 2010).

## New Caledonia (France)

The original technical reconstruction research was initially documented in Harper et al. (2009b), was vetted through peer-review in Zeller et al. (2015), and was updated to 2014 by the *Sea Around Us*.

### Methods

#### Human population data

Human population data were used to determine per capita rates for recreational catches and for converting per capita subsistence rates into catch amounts. We obtained census data from an online population statistics database ([www.populstat.info](http://www.populstat.info); Accessed September 2009) for New Caledonia as a whole and for each of the three Provinces of New Caledonia (North Province, South Province and Loyalty Islands Province). In years when census data were not available, a linear interpolation was done to estimate the population for intervening years in order to derive a complete time series of population data from 1950-2007.

Catches were presented by Loubens (1978) for 'la pêche plaisancière' in 1975, which included estimates for both subsistence and recreational sectors. Recreational catches were estimated using the number of registered boats that fished occasionally (3000 boats in 1975) and a catch rate of  $0.6 \text{ t}\cdot\text{boat}^{-1}\cdot\text{year}^{-1}$ . This was used as the 1975 anchor point. Commercial catches presented in Dalzell et al. (1996) assumed to include recreational catches amongst the totals for reef, deep-slope, coastal and/or pelagic fisheries. To derive the recreational catch for 1993, we subtracted the commercial catches (FAO catches) from the total presented by Dalzell et al. (1996). We assumed that recreational fishing started in 1965, around the same time as the artisanal fishery for skipjack (Anon 1985). Recreational catches were, therefore, set at zero in 1964.

The two anchor points for recreational catches (1975 and 1993) were converted to per capita catch rates using population data obtained from Populstat ([www.populstat.info/](http://www.populstat.info/)). Linear interpolations were done from zero in 1965 to the first available anchor point in 1975 and between the 1975 and 1993 anchor points. The 1993 rate was carried forward, unaltered, to 2007. The complete time series of per capita recreational catch rates was then applied to the population of New Caledonia to derive recreational catch amounts from 1965-2007.

According to Dalzell et al. (1996), a large proportion of nearshore pelagics are taken by recreational fishers. Therefore, we applied the breakdown of nearshore pelagics presented in Dalzell et al. (1996) to 70% of our recreational catch estimates across the entire time period considered. Dalzell et al. (1996) describes that in New Caledonia 80% of the catches made by trolling along the coastal margins in the early 1990s are from the Scombridae family (Mackerels, bonitos, and tunas) followed by the Sphyrnaenidae (Barracudas) which make up 10% of the catch (Dalzell et al., 1996). Catches of coastal pelagic species are dominated by Spanish mackerel (*Scomberomorus commerson*), Wahoo (*Acanthocybium solandri*), Kawakawa (*Euthynnus affinis*) and Yellowfin tuna (*Thunnus albacores*). We assumed that the remaining 30% of recreational catches were coral reef and lagoon species. The

taxonomic breakdown for this portion of the recreational catch was estimated to be 10% each from the Serranidae, Lutjanidae and Lethrinidae families.

Recreational catch components were reconstructed for 2011-2014 using the 2009-2010 average per-capita rate of recreational fishing (in tons per person per year). This estimate was calculated by dividing the recreational fishing catches of those years by the municipal population of New Caledonia. The average per-capita rate was multiplied by the municipal population of 2014 to estimate unreported recreational catches.

## Results

Catches by the recreational sector totaled just over 100,000 t from 1965-2007. We assumed that the recreational sector started in the mid-1960s, therefore catches were estimated to be zero from 1950-1964. The main species caught in the recreational sector were from the Scombridae family.

## New Zealand

The original technical reconstruction research was initially documented as a preliminary report in Simmons et al. (2016), and was updated to 2014 by the *Sea Around Us*.

## Methods

To estimate the total recreational catch we used snapper and kahawai (*Arripis trutta*) catch histories, as they were used in their respective stock assessments for Quota Management Area 1 (QMA1).<sup>19</sup> In the 2011-2012 national recreational survey, 50% of the total recreational catch was made up of snapper and kahawai from QMA1. We assume that this proportion of the total catch was consistent over time, and thus all other fish is the sum of SNA1 and KAH1<sup>34</sup>. Nonetheless, recreational fishing can be very important in local areas, at a smaller scale than fishery management zones. Recreational catch can be much greater and socio-economic factors can also influence the behaviour of recreational fishers. We estimate that discard rates and resultant discard mortality was a higher proportion of catches when abundance was high as only a few species were considered worth eating. Recent boat ramp survey-interviews determined the discard mortality rate of returned undersized fish, to be relatively low. They found catch of undersized snapper to be less than 5% by weight. The assumed survival rate of undersized snapper released by recreational fishers is 80% (Ministry of Fisheries 1997, p. 145).

For the present study, customary catch estimates are based on the total customary allowances, which are set to reflect estimated customary catches. An estimated 95% of Māori customary fishers, fish as recreational fishers and take catches within their recreational allowance (Ministry of Fisheries 1997). We assume Māori catch taken under recreational regulations are included in recreational catch estimates, and not included in customary estimates. We estimate unreported customary catch from 1950 to 2010 at 4% of the recreational catch. Note that the *Sea Around Us* considers the

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<sup>34</sup> We recognise that using QMA1 snapper and Kahawai to predict the national average, may not generalise well to locations where other species dominate, such as shellfish areas and blue cod in the Marlborough Sounds.

unreported customary catches calculated here as subsistence catches. Unreported recreational and subsistence catch was carried forward unchanged from 2014.

## Results

Of the total catch from foreign and New Zealand flagged vessels, industrial landings amounted to 46.3%, artisanal landings 14.9%, recreational landings 1.3%, and subsistence (customary plus amateur) catches 0.1%, with commercial discards making up the remaining 37.4%. Unreported landings from the industrial, artisanal, recreational and subsistence sectors made up 18.3%, 6.1%, 1.1% and 0.1% of the total catch, respectively.

For the 1950-2010 period foreign flagged fishing vessels caught approximately 42% of the total New Zealand catch. From 1990, the FAO included an increasing proportion of catch from foreign flagged vessels that fished in New Zealand's EEZ. Thus, more recent FAO data may over-report the amount of catch of New Zealand flagged vessels. If the reconstructed total catch taken by New Zealand flagged vessels is compared to the FAO reported landings for New Zealand flagged vessels only (i.e. excluding that catch reported for foreign flagged vessels), it is 2.4 times that adjusted FAO baseline from 1950-2010. Only an estimated 42.5% of catch by New Zealand flagged vessels was reported. Unreported landings from the industrial, small-scale (artisanal plus subsistence), and recreational (including recreational discards) sectors amounted to 9.9%, 10.7%, and 2.2% of the total New Zealand catch respectively, with commercial discards estimated at 34.8%

The total recreational and subsistence (customary plus amateur) catch for the years 1950 to 2010 was estimated at 512,000 t. Of this 33,700 t was subsistence catch and 479,000 t was recreational catch. For the period 1950 to 2013 the total recreational and subsistence catch was estimated at 549,000 t, comprising 35,100 t subsistence catch and 514,000 t recreational catch.

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## **Supplementary Materials (Part 2)**

### **Estimating global catches of marine recreational fisheries**

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This Supplementary Materials file documents the data sources, methods, assumptions and results underlying the catch data reconstructions for recreational fisheries in the 125 countries and territories listed in Supplementary Table S1 that form the data foundation for the current study. The present materials are based on the original technical reports and, where applicable, the underlying peer-reviewed publications. For more details about data on other fishing sectors (artisanal, industrial, subsistence) please visit [www.seaaroundus.org/data/#/EEZ](http://www.seaaroundus.org/data/#/EEZ) for all EEZ specific data, and for the associated publications. In the following documentation, countries and territories are listed in alphabetical order.

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## Norfolk Island (Australia)

The original technical reconstruction research was initially documented in Kleisner et al. (2015) and was updated to 2014 by the *Sea Around Us*.

### Methods

The total catches of the inshore fishery were available for 2007 and 2008 (Anon 2010a). The average of the 2007 and 2008 catches was 6.34 t. Population figures were obtained from several websites and linear interpolation was used to estimate a complete population time series for 1950 through 2010. Using the estimated population for 2007/2008 and the average catch for 2007 and 2008 (6.34 t) an average per capita catch rate of 3 kg·person<sup>-1</sup>·year<sup>-1</sup> was derived, which was combined with the population figures to estimate total catch from 1980 to 2010. For 1950, we assumed that the per capita catch rate was three times the 1980 per capita catch rate, i.e. 9 kg·person<sup>-1</sup>·year<sup>-1</sup> owing to anecdotal reporting of larger catches prior to 1959 (Anon. 2010), we linearly interpolated annual catches between 1950 and 1980. Using the species composition of the landings in 2007 and 2008 (Anon. 2010), the average proportion of landings per taxon was calculated and this proportion per taxon was applied to each of the annual catch estimates.

Leatherbarrow et al. (2010) mention that the Norfolk Island inshore fishery consists of subsistence, artisanal, and recreational sectors and therefore a ratio of 25:25:50 was used to assign proportions of the estimated total catch to each sector, respectively, under the assumption that recreational fishing is likely the primary sector, and that local demand for seafood is primarily met by imported frozen fish.

For the 2011-2014 update, as in the original reconstruction, fishery landings were estimated by annual seafood consumption by the local population for 2011-2014 and the same consumption rate of 3 kg per person per year was applied to updated population estimates from 2011-2014<sup>1,2</sup>. A linear interpolation between 2011 and 2014 was used to estimate the population size for 2012 and 2013. Taxa were then disaggregated using the same proportions as in 2010.

## Northern Mariana Islands-CNMI (USA)

The original technical reconstruction research was initially documented in Zeller et al. (2006), peer-reviewed in Zeller et al. (2007) and was updated to 2014 by the *Sea Around Us*.

### Methods

The non-commercial sector (subsistence and recreational fishing) in the Commonwealth of the Northern Mariana Islands (CNMI) has seen limited monitoring since 1984 using day-time creel surveys in Saipan lagoon (Graham 1994). While such surveys are useful tools for obtaining information on non-commercial fisheries, to our knowledge, and as confirmed by Graham (1994), these data have not been analyzed or expanded for estimation of CNMI-wide non-commercial

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<sup>1</sup> <https://www.cia.gov/library/publications/the-world-factbook/geos/nf.html>

<sup>2</sup> <https://www.citypopulation.de/Norfolk.html>

catches. We considered two sectors for catch reconstruction: commercial and on-commercial, being cognizant of the fact that most fishing trips might feature some aspects of both components.

Subsistence fishing was an important daily activity in Northern Marianas after WWII. A survey conducted in the late 1940s estimated that the local population of CNMI traditionally consumed nearly 1 lb of fish·person<sup>-1</sup>·day<sup>-1</sup> (0.45 kg·person<sup>-1</sup>·day<sup>-1</sup>) implying an annual *per capita* consumption of over 300 lbs·person<sup>-1</sup>·day<sup>-1</sup>, or 165 kg·person<sup>-1</sup>·day<sup>-1</sup> (Smith 1947). While, on first reflection, this may appear a high estimate, it is worth noting that other Pacific islands have reported similarly high consumption rates as recently as the late 1990s, e.g. Kiribati (183 kg·person<sup>-1</sup>·day<sup>-1</sup>), Palau (124 kg·person<sup>-1</sup>·day<sup>-1</sup>), Federated States of Micronesia (119 kg·person<sup>-1</sup>·day<sup>-1</sup>), or Tuvalu (113 kg·person<sup>-1</sup>·day<sup>-1</sup>) (Gillett 2002). However, in order to remain conservative in our reconstruction approach, we have reduced the consumption rate used in the present study (see this section: 1950-1983). US military support to the local population after WWII included large food subsidies, further supporting our reduced consumption rate. Significantly, given that shortly after the war, virtually no vessels were available for exploitation of offshore resources for subsistence use, we assumed that non-commercial catches in 1950 were based predominantly on inshore resources.

1984-1992: as data point estimate for 1984, we relied on Radtke and Davis (1995), who suggested that non-commercial catches may have accounted for approximately 63% of total catches, which corresponded to a non-commercial to commercial catch ratio of 1.7:1. Thus we assumed higher reliance on non-commercial (e.g., subsistence) fishing in the early 1980s compared to the 1990s (see below). We interpolated the proportion of non-commercial catches between 1984 and 1993 (see below), and expanded using reported commercial catches.

1993-2002: In their analysis of Saipan's seafood market, Radtke and Davis (1995) estimated that by the 1990s, approximately 50% of total catches were not reported, as they formed the non-commercial component. Thus, the non-commercial component of the reconstruction for the time period 1993-2002 was set equal to the total commercial catches as estimated above. In contrast, Graham (1994), leaning on Dalzell (1993), used a ratio of 1.7:1 for subsistence to commercial catches, which is higher than the 1:1 ratio assumed here. However, in order to remain conservative in our estimations, we chose the lower ratio for the 1990s.

2011-2014 methods:

Unreported subsistence and recreational landings

Following methods similar to the original reconstruction, unreported subsistence and recreational landings for 1980-2015 were calculated as a ratio of WPacFIN total commercial landings (both reported and unreported) to unreported non-commercial landings. A 1.7:1 ratio of unreported non-commercial landings to commercial landings, originally estimated by Graham (1994), was applied to the adjusted WPacFIN dataset for the years 1983-1993. For the period 1994-2000, a 1:1 ratio was applied based upon the suggestion by Graham (1994) that the proportion of non-commercial landings may have decreased. In the previous reconstruction (Zeller et al. 2006), these ratios were applied to only non-pelagic catches. Cuentos-Bueno and Houk (2015) suggested that to more accurately estimate unreported non-commercial landings, this ratio should have been applied to *all* commercial catch, including large bodied pelagics. As a result, the 1.7:1 and 1:1 ratios were applied to total commercial catch in order to estimate 1983-2000 non-commercial catch in this

reconstruction update. For the period between 1980 and 1983, the downward trend in catch between 1970 and 1980 was continued.

Following the year 2000, three anchor points summarized by Gillett (2016) were used to estimate rates of underreporting in the CNMI in the 2000s. The first anchor point, calculated by Cuentos-Bueno and Houk (2015) for the “mid 2000s”, was the midpoint between their non-conservative estimate (514 tons of reef fish year<sup>-1</sup>) and their conservative estimate (257 tons of reef fish year<sup>-1</sup>) of total reef fish landings per year: 385.5 tons. This anchor point does not include non-commercial pelagic species landings. As nothing more specific than “mid 2000s” was given, this anchor point was set to 2005 for this reconstruction. While Cuentos-Bueno and Houk also estimated exclusively unreported non-commercial catch in the mid 2000s, their estimate for total catch was more conservative and was therefore chosen over their estimate for only unreported landings. Total landings of non-pelagic fish, including both commercial and non-commercial sectors, was therefore 385.5 tons, resulting in 272 tons of unreported non-commercial catch in 2005.

The 2007 and 2014 commercial and non-commercial landings are presented in Table 24-4 within Gillett (2016) and were used as anchor points in this reconstruction. For the years between 2000, 2005, 2007, and 2014, linear interpolation was used to estimate unreported non-commercial landings.

#### Subsistence-recreational split

As the CNMI are relatively isolated and highly dependent on marine resources, subsistence and recreational fishing are quite common. However, the distinction between subsistence and recreational fishing is often hard to find, and most fishermen engage in roughly equal amounts of both (Hospital and Beavers 2014). As a result, the proportion of subsistence to recreational fishing was set to 50-50 in the year 2000 and the 1980 ratio of 59.94% subsistence to 40.06% recreational was interpolated to 50-50 to fill in the years in between 1980 and 2000. After 2000, the subsistence-recreational split was maintained at 50-50 for the rest of the years in the reconstruction.

## Results

The catch reconstruction for the subsistence/recreational sector suggested the annual catches of around 450 t were likely maintained until the 1970s, but may have declined since to the levels of commercial landings (around 90-135 t) by the early 2000s.

## Norway

The original technical reconstruction research was initially documented in Nedreaas et al. (2015) and was updated to 2014 by the *Sea Around Us*.

### Methods

The recreational catches presented by Norway represent the catches taken by foreign tourists and native Norwegians renting rooms and boats at registered tourist fishing companies. Catches taken by native Norwegians fishing for their households are included in the subsistence catches.

Two main anchor points exist for recreational catches in Norway, i.e., Hallenstvedt and Wulff (2001) and Vølstad et al. (2011). Hallenstvedt and Wulff (2001) base their estimation on official Norwegian

statistics about foreign tourists and their activities in Norway, web-based information from tourist companies and travel agencies and questionnaires among the tourists. The total catch by foreign fishing tourists is estimated to lie between 12,000 and 15,000 tonnes, with an average of 13,400 tonnes. This estimate is not assigned to fish species, but it calculates the ratio between the amount fished by registered tourist fishing companies and the total amount fished by tourists to be about 0.5 in ICES Subareas I/II, and 0.2 in ICES Subareas III/IV. Hallenstvedt and Wulff (2001) do not include Norwegian tourists in Norway, but they provide a time profile on the development of tourist fishing in Norway. Vølstad et al. (2011) used a probability-based survey to estimate annual catch and effort of boats used by anglers associated with 445 tourist-fishing businesses during 2009. The present Norwegian re-construction of recreational catches uses the estimates by Vølstad et al. (2011) as an anchor point for 2009, multiplies it by a factor of 2 and 5 for ICES Subareas I and II, and Subareas III and IV, respectively, to account for the other tourist fishing segments, and finally uses the time profile suggested by Hallenstvedt and Wulff (2001) to account for the development of tourist fishing in Norway. The same procedure has been used for estimating pelagic recreational catches.

For the 2011-2014 update, recreational fishing in Norway continues to rise in importance. However, catch and size limits have been imposed on tourists fishing in Norway since 2010<sup>3</sup>. To reflect the decrease in tourist-driven catches, the average rate of increase in recreational catches between 2008 and 2010 was calculated for each taxon in each ICES area and the largest rate of increase was halved and applied between 2011 and 2014. Catches of *Pollachius virens* and *Sebastes norvegicus* in ICES area IB were estimated for 2011-2014 at the average rate of increase for 2008-2010 and were not halved because catches of these taxa already increased at a slower rate.

## Results

The amount of unreported catch was higher in the earlier time period, averaging 8% of reported catch in the 1950s and 1960s, and lower in the later time period, approximately 4% in the 1990s and 2000s. Catch in subsistence fisheries gradually increased from approximately 40,000 t in 1950 to a peak of almost 60,000 t in 1992, thereafter declining to about 40,000 t by 2010. Recreational fisheries were substantially smaller with minimal catch in the early time period and growth beginning in the late 1990s as a result of the increase in tourism, with catch eventually reaching 10,000 t by 2010.

## Oman

The original technical reconstruction research was initially documented in Khalfallah et al. (2015b), and was updated to 2014 by the *Sea Around Us*.

## Methods

No data could be found on recreational fishing in Oman. However, recreational fisheries do exist, at both local and tourist scales. To regulate and monitor their activities, the government provides two types of licenses for people who want to fish recreationally ([www.oman.om](http://www.oman.om)):

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<sup>3</sup> <http://www.fiskeridir.no/English/Recreational-fishing/Regulations-for-foreign-tourists/Fishing-by-tourists-in-Norway>

- 1) “Non-professional fishing license”: This license is obtained for a period of one year and is available for those who practice recreational fishing using hooks and rods;
- 2) “1-day recreational fishing license”: This license is available for one day only, for recreational fishers who fish with hooks and rods.

However, numbers of these licenses are not available. To roughly estimate the catches of recreational fishers, we applied the recreational fishing participation rate of around 0.12%, estimated for Western Asia in 2003 by Cisneros-Montemayor and Sumaila (2010), to the total population to obtain the number of domestic recreational fishers. Then, we assumed recreational fishing in Oman to be zero in 1960 and reach 5 kg·year<sup>-1</sup> per recreational fisher in 2010, and kept this rate to 2014, and interpolated the catch of 5 kg·fisher<sup>-1</sup>·year<sup>-1</sup> between 1960 and 2014. Finally we multiplied the number of recreational domestic fishers by the annual recreational fishing catch rate for the 1960-2014 period.

#### Taxonomic composition

For the recreational fishery, we identified the most targeted fishes by recreational fishing in Oman according to Fishfishme Inc., which has one of the biggest online platforms allowing tourists to locate and book charter trips around the world ([www.fishfishme.com](http://www.fishfishme.com)). The percentage of each species targeted by this fishery was then assumed according to its importance and popularity in the region (Table 1).

**Table 1.** Taxonomic composition assumed to be caught in the recreational fishery.

Family	%
Carangidae	20
Istiophoridae	30
Scombridae	50

## Results

Total marine fisheries catches in Oman increased from around 53,600 t·year<sup>-1</sup> in the 1950s to almost 200,000 t·year<sup>-1</sup> in the 2000s. This estimated catch is 1.3 times the landings reported by the FAO on behalf of Oman for the period 1950-2010. Reconstructed total catch was dominated by the artisanal sector (74%), followed by subsistence catches (22%), industrial (4%) and recreational (<0.01%).

## Pakistan

The original technical reconstruction research was initially documented in Hornby et al. (2014) and was updated to 2014 by the *Sea Around Us*.

## Methods

A sizable recreational fishery exists in Pakistan that targets fish in three different zones of the EEZ: billfish and tuna fishing out of Karachi, sport fishing in coastal waters, and hand-line (bottom) fishing in near-shore waters (FAO 2009). The only available information on this sector evaluated the fishery at about 900 participants, catching approximately 130 t in 2002 in all activities, and by 2009 it was estimated that 1000 participants were involved in the sector, operating approximately 120-150 non-licensed vessels (FAO 2009; Khan 2006). Despite this information, the total contribution from this sector remains unknown and no official records of catch can be found. We were able to obtain estimates of total catch from 1983-2010 (M.M. Khan, pers. obs.) provided by the Agha Sport Fishing and Angling Headquarters<sup>8</sup>, the largest organized recreational fishing company in Pakistan. As these data only represent catches by one organization, 20% was added to all catches to account for other sports fishing companies in operation, such as the prominent Pakistan Game Fish Association (PGFA).<sup>9</sup> As no records of a recreational fishery exists prior to 1983, a linear interpolation from a catch of zero in 1950 to the first estimate provided by the MFD in 1983, was completed to account for the growth of the recreational sector.

### Taxonomic breakdown

Catch composition for the sports and recreational fishing sector from 1983-2010 was provided by the Agha Sport Fishing and Angling Headquarters in Pakistan. Since total catch of the target family was provided from 1983-2010, the proportion of catch observed in 1983 was extended back to 1950. The taxonomic composition of recreational catch was proportioned into five families (Carangidae, Scombridae, Serranidae, Sparidae and Sphyraenidae) and a 'marine fishes nei' category (Table 2).

For the 2011-2014 update, we maintained the gradual decline in recreational fishing over this update. Both subsistence and recreational fisheries were considered entirely unreported and maintained the 2010 taxa and gear breakdown.

**Table 2.** Derived taxonomic breakdown for recreational catches (1950-2010).

Taxon	1950-1983	1984	1995	2010
	Composition (%)			
Carangidae	4	4	3	6
Serranidae	30	35	23	26
Sparidae	8	8	5	6
Sphyraenidae	15	14	10	18
Marine fishes nei	8	8	10	14
Total	100	100	100	100

## Results

The recreational sector contributed slightly over 8,000 t from 1950-2010. Catches were approximately 160 t·year<sup>-1</sup> in 1983, increasing to 277 t·year<sup>-1</sup> in 1995. Catches then decreased gradually to 120 t·year<sup>-1</sup> in 2010. Catch was dominated by five families and an 'others' category.

## Panama

The original peer-reviewed reconstruction research was initially documented in Harper et al. (2014), and was updated to 2014 by the *Sea Around Us*.

### Methods

Descriptions of game fishing in the Gulf of Panama date back to the 1930's (Fiedler et al. 1943). At that time, the Pacific Sailfish Club had 184 members and there were roughly 23 vessels engaged in this club's activities. While Fiedler et al. (1943) provides an extensive list of species caught by recreational fishermen (68 species), catch amounts or rates are not thoroughly reported. This source does give an estimated number of Indo-Pacific sailfish, *Istiophorus platypterus*, and black marlin, *Istiompax indica*, caught in 1942, which converted to an approximate weight of 4 t using FishBase's life history tool<sup>4</sup>. This was the only quantitative information given for the early time period and was, therefore, used as our first anchor point for estimating recreational fisheries catches. Recreational catch estimates were not readily available for much of the time period; however, the NMFS conducted a Pacific Billfish Angler Survey from 1969–84, which provided estimates of billfish effort and catch (Squire 1987). Catch data were presented for blue marlin *Makaira nigricans*; black marlin; striped marlin, *Kajikia audax*; and swordfish, *Xiphias gladius*. The total for all these species combined ranged from a low of 0.8 t in 1969 to a maximum of 25 t in 1982. Given the substantial year to year variation, we took the average over this time period as the second anchor point, interpolating linearly between our 1942 data point of 4 t and the average catch of 11.2 t set for 1976 (the 1969–84 period). To derive an anchor point for the recent time period, an estimate of 1,000 anglers (Lopez-Alfaro<sup>5</sup>) was used for the year 2010. The number of anglers was then combined with a catch rate of 6.7 billfish per angler per year (Ditton and Grimes 1995), which was converted to weight using the catch composition given in the same report and weights calculated using FishBase length-weight relationships. The resulting catch rate was 0.33 t/ angler/yr, with much of this being released. We assumed a conservative release rate of 70% for Panama (retention of 30%; because release is not mandatory, retention could in fact be higher) and used the number of anglers for 2010 to derive a third anchor point, to which a linear interpolation was used between the 1976 estimate of 11.2 t and this 2010 estimate of 99 t. To assign these catches taxonomically, we calculated the average species composition of billfish catches over the 1969–84 time period presented in Squire (1987). Indo-Pacific sailfish, striped marlin, black marlin, and blue marlin, represented 86%, 6%, 6%, and 2%, respectively of the total recreational catch.

For the 2011-2014 update, the total number of recreational anglers was estimated by Southwick et al. (2013) to be 86 250 in 2011 and the average number of days spent fishing was estimated to be 5.2 days. While the estimate by Southwick et al (2013) includes anglers fishing inland as well as on the coast, it is likely that the original estimate of the number of recreational anglers in 2010 by Harper et al (2014) is an underestimate. In order to remain conservative, recreational catch was carried forward to 2014 using the original estimate for recreational anglers and the rate of increase in recreational catch was extrapolated to 2014. The proportions of taxa caught by recreational fishing remained the same as in the initial reconstruction.

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<sup>4</sup> www.FishBase.org; accessed July 2012

<sup>5</sup> Lopez-Alfaro, L. R. Asociacion de Clubes de Pesca de Panama, Calle Walker, Ancon, Aparta- do 0819-0214, El Dorado, Panama City, Repub- lic of Panama. Personal commun., 4 Apr. 2013

## Results

Recreational billfish catches, considered a minimum estimate, totaled 2,139 t over the 1950–2010 time period. By sector, industrial fisheries (shrimp and associated discards, small pelagics, and tuna) represented 88% of the total reconstructed catch, while artisanal, subsistence, and recreational sectors made up the remaining catch (10%, 1%, and >0.05%, respectively).

## Papua New Guinea

The original technical reconstruction research was initially documented in Teh et al. (2014), and was updated to 2014 by the *Sea Around Us*.

## Methods

Marine recreational fishing as a leisure activity takes place mainly in larger urban areas in PNG, and participants are mostly resident expatriates (FAO 2010). There is no formal management of marine recreational fishing in PNG (FAO 2010; Friedman and Kronen 2008), although the NFA's management plan for barramundi does recognise recreational fishing of the species. Recreational fishers target marlins, trevallies, and tuna, and sport fishing competitions have been held regularly in PNG since the 1970s. While fishing tour operators encourage 'catch and release' fishing, it is up to client's discretion and the rule does not appear to be strictly enforced<sup>6</sup>. On the other hand, sport fishing tournaments do enforce a strict 'catch and release' policy, and marlins, sailfish and barracudas tend to be released by local recreational fishers. We start accounting for marine recreational catch in 1970. Total catch (Rec) is calculated as:

$$\text{Rec} = P_i * e * M * R$$

where

P is PNG population in year I;

e is percentage of expatriates living in PNG;

M is marine recreation sector participation;

R is marine recreational catch rate.

The time series data on the number of expatriates in PNG was based on one anchor point in 2010, when there were approximately 20,000 expatriates<sup>7</sup>. We divided this by total population to derive an expatriate proportion, which was then applied to population time series data starting in 1970 to calculate the number of expatriates. Thus, we assumed proportionality between PNG population and the level of resident expatriates. We then applied a marine recreational angler participation rate for Oceania of 17.7% (Cisneros-Montemayor and Sumaila 2010) to estimate the number of

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<sup>6</sup> Marine Invertebrates of the South Pacific: An Examination of the Trade. A Traffic Network report, October 1995 (unpublished report).

<sup>7</sup> Signature Staff. URL: <http://www.signaturestaff.com.au/job-seekers/jobs-PNG>. Accessed 3 December 2013.

expatriate recreational fishers, assuming that recreational fishing trends among PNG expatriates mirrored those in the Oceania region.

Recreational catch rate was approximated from the second author's (J. Kinch) observations of and participation in recreational fishing in PNG, where a typical catch ranged between 8 to 20 kg·person<sup>1</sup>·trip<sup>-1</sup>. An annual recreational catch rate of 280 kg·person<sup>1</sup>·trip<sup>-1</sup> was then determined on the basis of 2 recreational trips per month for 10 months in a year, assuming an average catch of 14 kg·person<sup>1</sup>·trip<sup>-1</sup>.

#### Catch composition

To estimate marine recreational catch composition, we first listed all fish species that appeared on PNG Game Fishing Association's national records<sup>8</sup>, and categorised them into 8 major groups: barracuda, cobia, Carangidae, dolphin fish, marlins, Scombridae, sharks, and tunas. We then qualitatively assessed whether each species occurred with high, medium, or low frequency in a typical catch, based on the number of species as well as number of records in different weight classes held for individual species within each major group. Out of the 8 major groups, barracuda, Scombridae, marlins, Carangidae and tunas were assessed as 'high', while cobia and dolphin fish were assessed as 'medium' and sharks as 'low'. 'High' groups were assigned a total catch proportion of 29% each, 'medium' groups 7%, and 'low' group 3%. Barracudas, sailfish, and marlins were omitted from the species composition break-down because they are normally released by recreational fishers

Recreational catch was calculated for 2011-2015 using the participation and catch rates determined by the original reconstruction and new population data for 2011-2015 from the World Bank.

#### Results

The subsistence sector accounted for 67% of total reconstructed catches, followed by the artisanal sector at 30% and the industrial fishery at 2%, while the marine recreational sector and fish discards together made up 3% of total reconstructed catches.

#### Peru

The original technical reconstruction research was initially documented in Mendo and Wosnitza-Mendo (2014), and was updated to 2014 by the *Sea Around Us*.

#### Methods

Two main types of recreational fishing occur in Peru, underwater spear-fishing and angling from the beach using fishing rods. Sport fishers engaged in both types of recreational fishing were interviewed in order to obtain estimates about yields in different decades. Underwater fishing started only in the 1960s with the Italian community in Peru, and recreational angling from the beach is performed mainly by Japanese and Chinese migrants. The number of active spear-fishers per year was estimated based on their participation in national competitions organized by groups that promote spear-fishing, e.g., the "Submarine Hunting Federation of Peru", multiplied by the

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<sup>8</sup> Game Fishing Association of Papua New Guinea URL <http://www.gfa.com.pg/>. Accessed 8 Dec 2013.

number of annual competitions. Total catch was estimated using the mean catch per spear-fisher per competition (Table 3), and conservatively assumed to represent the complete spear-fishing catches in Peru. Estimated catch for the last anchor point year (2005) was carried forward to 2010 unchanged, while catch for intervening years was linearly interpolated.

**Table 3.** Data for recreational spear-fishing in Peru, separated by ‘high achievers’ and ‘other’ participants. These data were conservatively assumed to represent total spear-fishing catches in Peru.

Year	‘High achievers’		‘Other participants’		Average number of annual competitions	Annual catch (Kg) <sup>a</sup>
	Mean catch (Kg)	Average number of participants per competition	Mean catch (Kg)	Average number of participants per competition		
1950	0	0	3	0	0	0
1965	30	20	3	30	5	3,450
1975	25	60	3	90	10	17,700
1985	50	80	3	120	10	43,600
1995	25	40	3	40	7	7,840
2005	12	30	3	10	5	1,950

<sup>a</sup> Catch for intervening years was linearly interpolated. Catch in 2005 was carried forward unchanged to 2010.

For beach anglers, we used decadal estimates from interviews in north and central Peru, which provided number of participants, frequency of events per month and mean catch per angler (Table 4). As it is known that there are between 6-8 times more anglers in the south, we increased the number of anglers by 7 to fully represent this group for the whole of Peru. Annual catch was estimated for both recreational fishing activities using the decadal data as representing the mid-point of each decade, and interpolated linearly. Estimated catches for the last year (2005) were carried forward to 2010 unchanged. The total annual catches were allocated to taxa using the catch composition per taxon provided by the interviews (Table 5).

Recreational catches were carried forward to 2014 unchanged from 2010.

**Table 4.** Data for recreational shore anglers in Peru. The number of anglers known for northern and central Peru was expanded to the whole of Peru by assuming a factor of 7 times more anglers in the south (J. Mendo, pers. Obs.). These data were conservatively assumed to represent all shore-based, recreational catches.

Year	Number of anglers in north and central Peru	Total number of anglers in Peru	Catch-fisher <sup>-1</sup> -month <sup>-1</sup> (Kg)	Annual catch (Kg) <sup>a</sup>
1950	15	105	100	126,000
1965	30	210	100	252,000
1975	45	315	200	756,000
1985	50	350	60	252,000
1995	60	420	20	100,800
2005	60	420	5	25,200

<sup>a</sup> Catch for intervening years was linearly interpolated. Catch in 2005 was carried forward unchanged to 2010.

**Table 5.** Taxonomic composition applied to recreational catches, based on interview data.

Spear-fishing			Shore angling		
Common name	Taxon	%	Common name	Taxon	%
Peruvian morwong	<i>Cheilodactylus variegatus</i>	50	Corvina drum	<i>Cilus gilberti</i>	50
Peruvian rock seabass	<i>Paralabrax humeralis</i>	20	Flatfishes	Pleuronectiformes	20
Peruvian grunt	Haemulidae	5	Grunt	Haemulidae	10
Grape-eye seabass	Serranidae	5	Cabinza grunt	<i>Isacia conceptionis</i>	10
Other fishes	Marine fishes nei	20	Lorna drum	Sciaenidae	5
			Other fishes	Marine fishes nei	5

## Results

Yields for recreational fisheries peaked in 1975 with around 770 t·year<sup>-1</sup> annually, and have declined substantially since then. The level of recreational catches is relatively low compared to other counties. In the shore-based angling sector, catches of some species like flatfishes and Peruvian rock seabass have declined drastically over the years and this is attributed to the use of explosives, especially in the southern part of Peru. The main targets of this fishery, besides flatfishes, are sciaenids such as the Corvina drum (*Cilus gilberti*) and haemulids such as the Cabinza grunt (*Isacia conceptionis*). The main targeted species in the spear-fishing sector were Peruvian morwong (*Cheilodactylus variegates*), Peruvian rock seabass (*Paralabrax humeralis*), Peruvian grunt (*Anisotremus scapularis*, Haemulidae) and Grape-eye seabass (*Hemilutjanus macrophthalmos*, Serranidae). Among the 'other fishes', some species have been very heavily targeted over time and show signs of depletion, like Sheepheads (*Semicossyphus darwini*, *Bodianus eclancheri*, *Bodianus diplotaenia*), Halfmoon (*Medialuna ancietae*), Sea Chub (*Graus nigra*), Pacific Beakfish (*Oplegnathus insignis*), groupers (*Mycteroperca xenarcha*, *Epinephelus itajara*, *Epinephelus labriformis*), and Bumphead parrotfish (*Scarus perrico*).

The data used for the reconstruction of recreational catches are approximate. They should be taken as preliminary and a first attempt at assessing such catches. Further research and investigation into recreational fishing should be considered.

## Philippines

The original technical reconstruction research was initially documented in Espedido et al. (2014), and was updated to 2014 by the *Sea Around Us*.

## Methods

The Philippines being an archipelagic country with almost 2,000,000 km<sup>2</sup> of fishing grounds (ADB 1993; Lugten and Andrew 2008), offers numerous sites ideal for sport fishing. Fishing as a recreational activity is associated mostly with the well off, and/or with the expatriate community, as can be deduced from its history. Little is known of the catch from this sector in its early years (1940s-1950s). It is only since the 1960s that sport fishing evolved into a weekend activity, with several tournaments held regularly in various parts of the country, and at least 6 large pelagic species caught year round. Thus, here we reconstruct recreational fisheries catches only for the period 1960-2010.

The recreational fishing sector in the Philippines was assumed to consist of two major components: (1) angling at organized competitive fishing events, mainly for large and medium pelagic fishes; and

(2) reef fishing with spear gun, with and without SCUBA gear. No other form of recreational fishing, e.g., shore-based or boat-based coastal or reef-based angling, is thought to exist to any significant extent in the Philippines, as most such activities would fall under the category of subsistence fishing for food, which is addressed separately in Palomares and Pauly (2014) and not deemed truly recreational. However, with increasing economic development and the expected growth in the middle-class, this may change in the future.

Angling for pelagic ‘gamefish’ or sport fishing started as early as 1936 with the catching of wahoo (*Acanthocybium solandri*) and was practiced mostly by expatriates, i.e., relatively wealthy foreign nationals working in the Philippines. In 1940, members of the Manila Yacht Club established the Philippine Game Fishing Foundation (PGFF). After World War II, the PGFF reestablished itself only in the 1960s, organizing about eight competitive fishing events per year in marine waters. By the mid-1980s, sport fishing became more popular among Filipinos and at least two new clubs were established: the Panay Anglers Association Inc. and the Philippine Sport Fishing Club.

**Table 6.** Sport fishing clubs in the Philippines, year established, website URL, current number of members and number of tournaments hosted each year.

Sport fishing Club (Year founded)	Website	Details
<b>NCR</b>		
Bass Anglers Sportsman Society of the Philippines, BASS (2005)	bassphil-subscribe@yahoogroups.com	members: 57; tournaments per year: 4
Filipino Anglers	filipinoanglers.org/phpBB3/index.php	members: 690
Manila Anglers Club		
Manila Baywalk Anglers Association Inc (2011)	facebook.com/pages/Manila-Baywalk-Anglers-Association-Inc/445589738825485?fref=ts	members: 92
Philippine Game Fishing Foundation, PGFF (1940)	pgff.net/xe/main	member: 162; tournaments per year: 8
Philippine Sport Fishing Club (1985)		tournaments per year: 1
Pinoy Anglers Club Inc., PACI (2010)	pinoyanglersclub.webs.com	members: 211
Navotas Anglers	facebook.com/groups/navotas.anglers/?fref=ts	members: 192
Silver Jack Anglers		
<b>Region I</b>		
Dagupan Anglers Club		
<b>Region III</b>		
Angeles Anglers Club		
Angeles City Fishing Club	angelescityfishingclub.com/fish2/index.html	
Pampanga Anglers Club		
Pampanga Sport fishing Association		
<b>Region IVA</b>		
D Anglers of Laguna, DALag	facebook.com/groups/318928384793963	members: 35
Lucena Anglers Club		
<b>Region VI</b>		
Iloilo Anglers Association (1989)		
Iloilo Game Fishing Association (2007)	igfamunit.blogspot.com	members: 17
Panay Anglers Association Inc. (2007)	facebook.com/pages/Panay-Anglers-Association-Inc/182789708734	members: 450
Negros Sport Fishing Club	facebook.com/groups/191066250927099	members: 153
Sport fishing Or. Negros, SPOON		
<b>Region VII</b>		
Cebu Fish Wars		
Sport Fishing Club of Cebu, SFCC (2009)	facebook.com/pages/Cebu-Sport-Fishing/438335015272	
<b>Region IX</b>		
Baitcaster Association of Zamboanga (2013)	facebook.com/groups/501700826568438	

\*Membership details based mostly on forum/ (Facebook) group page memberships.

Catch information used in this study was gathered from sport fishing club catch records (i.e., name and weight of fish caught, name of fisher, location, and date), photos and videos (sometimes with species name, date and location of catch, length and/or weight) posted in organizational websites (Table 6) and other social media from 2006 to 2013. The PGFF’s website provides, by far, the most

extensive information on sport fishing in the country; it contains record catches by family/species, dating back to the 1980's and tournament records since 2002. For example, the club reported a total catch of over 100 fishes weighing 1.2 t by 18 participants from their annual tournament in 2001 and 31 anglers caught a total of 80 fishes weighing over 0.9 t in 2002. At present, over 25 sport fishing clubs compete in national annual tournaments and as many as 17 countries participate in international tournaments held in the Philippines.

#### Spear gun fisheries (spearfishing)

Data collected for spearfishing is limited because spearfishing is not as popular and organized as line fishing. There is no tournament information or record catches available on the web as this is usually a weekend or holiday recreation activity (Oakley 1984). The bulk of the data for spearfishing are from photos, videos and blogs of a handful of people and personal interviews with some spearfishing enthusiasts. One group openly promoting spearfishing in the Philippines is the Freediving and Spearfishing in the Philippines<sup>9</sup> Facebook group created by Wolfgang Dafert, an Austrian national living in Moalboal, Cebu since 2006 and proprietor of Freediving-Philippines<sup>10</sup>. Spearfishing is offered by Freediving-Philippines together with a free-diving course but there are also groups that use SCUBA when spearfishing, for instance, a group of 8 sportfishers from Davao (Vi de Ocampo pers. comm.).

#### Catch records

Length and/or weight information, when available, were encoded from the website/photo/video records. Otherwise, length was estimated from photos/videos using various indicators, e.g., height of fisher with respect to the length of the fish caught. Fish species was identified to the nearest possible taxon, if not already available from the record. Weight, when not given, was estimated from length-weight parameters of the same species, or of similar species obtained from FishBase ([www.FishBase.org](http://www.FishBase.org)). Line fishing and spearfishing data are presented separately.

The daily catch per line fisher ( $c/f$ ;  $\text{kg}\cdot\text{day}^{-1}\cdot\text{fisher}^{-1}$ ) was estimated as the sum of the weights of fishes caught in a reporting year (which may include several tournament records) divided by the number of fishers, assuming that 1 record = 1 fisher $\cdot\text{day}^{-1}$ . Although most data available from these data sources may represent exceptional ('record') catches rather than average catches, we consider that the total catch tonnages obtained with these data may still be conservative for total annual catch volumes, even if average fish weights or sizes may be overestimated due to perceived 'record' catches likely being documented only.

Thus, the total catch from competitive fishing events, TCFE, was estimated as:

$$\text{TCFE}_{\text{year}} = \text{catch rate (t}\cdot\text{day}^{-1}\cdot\text{angler}^{-1}) \times \text{number of anglers} \times 32 \text{ days}$$

Thus, the total catch from spearfishing, TCS, was estimated as:

$$\text{TCS}_{\text{year}} = \text{catch rate (t}\cdot\text{day}^{-1}\cdot\text{fisher}^{-1}) \times \text{number of fishers} \times 14$$

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<sup>9</sup> Facebook group page of Freediving and Spearfishing in the Philippines at <https://www.facebook.com/groups/23136294001/>

<sup>10</sup> Freediving-Philippines website at <http://www.freediving-philippines.com/>

Finally, the reconstructed total recreational catches (TRC) for the Philippines were obtained as the sum of catches originating from angling in competitive fishing events and spearfishing:

$$TRC_{year} = TCFE_{year} + TCS_{year}$$

A log-linear regression analysis was performed on the data presented in Table 7 to obtain empirical estimates of annual c/f values for 1960-2010. The number of line fishers was estimated from monthly PGFF tournament data from 2002 to 2013 complimented with data from the annual Siargao International Game Fishing Tournament (Table 8). This better represents the number of line fishers who actively participate in tournaments and contribute to the catch. A log-linear regression analysis was performed on the number of tournament participants per year to obtain estimates for 1960-2010, with the 1966 value based on the number of active PGFF members deduced from a historical anecdote (in 1967, a total of 63 members with 17 new members)<sup>11</sup> and the average number of participants of tournament records in 2002-2013, as comparison points. The number of line fishing days per year was estimated from the number and duration (in days) of tournaments per year. Assuming that on the average, tournaments last 4 days, and that there is an average of 8 tournaments per year, the average number of fishing days per year would be 32.

**Table 7.** Catch information obtained from tournament records, photos, and videos grouped by year where catch per unit of effort was computed from the total annual catch (kg) divided by the number of records, which we assume to represent the number of fishers per day.

Year	Recreational fishing			Line fishing			Spearfishing		
	# records	Total catch (kg)	CPUE (kg·day <sup>-1</sup> ·f <sup>-1</sup> )	# records	Total catch (kg)	CPUE (kg·day <sup>-1</sup> ·f <sup>-1</sup> )	# records	Total catch (kg)	CPUE (kg·day <sup>-1</sup> ·f <sup>-1</sup> )
1940*	8	296.91	37.11	8	123.95	296.91	–	–	–
1965*	1	8.10	8.10	–	–	–	1	8.10	8.10
1966*	1	8.60	8.60	–	–	–	1	8.60	8.60
1987	6	607.95	101.33	6	208	607.95	–	–	–
1988	4	200.50	50.13	4	80	200.50	–	–	–
1989	10	777.65	77.77	10	208.26	777.65	–	–	–
1990	11	343.20	31.20	11	93.75	343.20	–	–	–
1991	3	123.60	41.20	3	65.10	123.60	–	–	–
1992	15	389.77	25.98	15	86.25	389.77	–	–	–
1993	18	580.55	32.25	18	145	580.55	–	–	–
1994	5	166.45	33.29	5	78.80	166.45	–	–	–
1995	16	516.89	32.31	16	83	516.89	–	–	–
1996	8	251.05	31.38	8	91.50	251.05	–	–	–
1997	7	147.63	21.09	7	67.25	147.63	–	–	–
1998	18	768.15	42.68	18	575	768.15	–	–	–
1999	7	352.09	50.30	7	236.84	352.09	–	–	–
2000	22	162.76	7.40	22	41	162.76	–	–	–
2001	23	1015.65	44.16	5	59	108.65	–	–	–
2002	40	997.95	24.95	9	30	97.95	–	–	–
2003	19	249.35	13.12	19	69	249.35	–	–	–
2004	15	151.20	10.08	15	43.10	151.20	–	–	–
2005	2	31.47	15.74	2	26.90	31.47	–	–	–
2006	31	559.89	18.06	31	106	559.89	–	–	–
2007	38	910.15	23.95	32	127.22	855.08	–	–	–
2008	71	1062.15	14.96	59	61.13	987.56	12	17.38	74.59
2009	81	1382.47	17.07	77	94.03	1351.26	4	22	31.21
2010	70	934.22	13.35	63	90	862.84	7	25	71.38
2011	69	791.83	11.48	57	140	706.08	12	31.63	85.74
2012	56	467.83	8.35	55	48.90	466.98	1	0.85	0.85
2013	69	1391.49	20.17	40	318	1163.71	29	57.13	227.79

\*Records not used, as they appear to have been outliers

The daily catch per spear fisher was estimated as the average c/f computed from the catch data for spear fishers in Table 7, again following the assumption that 1 record = 1 fisher·day<sup>-1</sup>. A log-linear regression analysis was performed on the 1965-2013 spear fisher records to obtain empirical estimates of the number of spear fishers for 1960-2010. The number of (spear) fishing days per year

<sup>11</sup> <http://pgff.net/x/about>

was obtained assuming that: 1) the sport fishing season in the Philippines is April-October (7 months); 2) spearfishers go out 2/4 weekends in a month; and 3) 1/2 days in a weekend. This results in an average spear fishing of 14 days in a year.

The reconstructed catch (t) of line/spear fishers was obtained as the product of daily catch per fisher, number of fishers and number of fishing days. The total reconstructed recreational fisheries catch is then the sum of line and spear fishing catches. Composition of the catch was analyzed using the rank and percentile method (described in Parducho and Palomares (2014)). The official statistics,

**Table 8.** Membership and/or tournament participants of Philippine game Fishing Foundation (PGFF)<sup>81</sup> and Siargo International game Fishing tournament (SIGFT).

Year	PGFF <sup>81</sup>		SIGFT <sup>82</sup>
	#Members	Total tournament participants	Total tournament participants
1940	6	–	–
1966	46	–	–
1967	63	–	–
1984	120	–	–
1991	71*	–	–
1992	114	–	–
1993	46*	–	–
1994	103	–	–
1995	104	–	–
1996	65*	–	–
2001	–	18**	–
2002	100	203	–
2003	–	78**	–
2004	–	13**	–
2005	–	28**	–
2006	–	59	–
2007	–	93	–
2008	54*	77	76
2009	–	86	65
2010	55*	41	41
2011	45*	61	52
2012	64*	100	46
2013	62*	88	36

\*Number of members based on Angler of the Year records and not on actual membership list, data not used

\*\* Number of participants is from less than 3 tournaments that year, data not used.

were used to get the annual % composition of each taxon. Missing data for a taxon (e.g., for 1950-1980, 1983, 1985-1987, and 2007-2010) were inter/extrapolated using the following rules: 1) if % catch data is interpolated between  $Y_1$  and  $Y_2$ , corresponding to years  $X_1$  and  $X_2$ , then  $Y_{i+1} = Y_i + [(Y_1 - Y_2)/(X_1 - X_2)]$ , where  $Y_{i+1}$  is the missing % catch data; 2) if % catch data is (forward or backward) extrapolated from  $Y_i$  corresponding to year  $X_i$ , then  $Y_{i+1} = (\sum Y_i \dots Y_{i+3})/3$  or  $Y_{i-1} = (\sum Y_i \dots Y_{i-3})/3$ .

The most important species in the catch were obtained from the sums of the catch for all years with official landing statistics using rank and percentile analysis and are presented in Table 9.

The number of recreational fishers was updated to 2014 by extending the original regression equations for spear and line fishers and catch per day by line fishers calculated by Espedido et al. (2014) to 2014. The number of days spent fishing was assumed to remain constant at the 2010 amount and the catch per spear fisher per day was carried forward unaltered to 2014. The taxonomic breakdown of recreational landings was maintained at the 2010 levels for each gear.

**Table 9.** Results of the rank and percentile analysis of sport fishing catches in the Philippine based on accumulated data from 1987-2013.

Rank	Percent	Taxa	Popular Species
1	100	Sailfish	<i>Istiophorus platypterus</i> , <i>Xiphias gladius</i>
2	96.9	Marlin	<i>Istiompax indica</i> , <i>Makaira indica</i> , <i>Makaira mazara</i> , <i>Makaira nigricans</i>
3	93.9	sharks and rays	<i>Alopias pelagicus</i> , <i>Carcharhinus falciformis</i> , <i>Dasyatis</i> , <i>Galeocerdo curvier</i> , <i>Isurus oxyrinchus</i> , <i>Prionace glauca</i> , <i>Sphyrna tiburo</i> , <i>Sphyrna zygaena</i>
4	90.9	yellowfin tuna	<i>Thunnus albacares</i>
5	87.8	Trevally	<i>Alectis indica</i> , <i>Carangoides dinema</i> , <i>Carangoides orthogrammus</i> , <i>Caranx ignobilis</i> , <i>Caranx melampygus</i> , <i>Caranx papuensis</i> , <i>Caranx sexfasciatus</i> , <i>Gnathanodon speciosus</i> , <i>Ulua mentalis</i>
6	84.8	Dolphinfish	<i>Coryphaena hippurus</i>
7	81.8	Wahoo	<i>Acanthocybium solandri</i>
8	78.7	dogtooth tuna	<i>Gymnosarda unicolor</i>
9	75.7	Barracuda	<i>Sphyraena barracuda</i>
10	72.7	Spanish mackerel	<i>Grammatorcynus bicarinatus</i> , <i>Scomberomorus cavalla</i> , <i>Scomberomorus commerson</i>
11	69.6	bigeye tuna	<i>Auxis rochei rochei</i> , <i>Thunnus obesus</i>
12	66.6	Grouper	<i>Cephalopholis boenak</i> , <i>Cephalopholis cyanostigma</i> , <i>Epinephelus coioides</i> , <i>Epinephelus malabaricus</i>
13	63.6	Snapper	<i>Etelis carbunculus</i> , <i>Lutjanus decussatus</i> , <i>Lutjanus griseus</i> , <i>Symphoricthys spilurus</i> , <i>Symphorus nematophorus</i>
14	60.6	Oilfish	<i>Ruvettus pretiosus</i> , <i>Thyrsitoides marleyi</i>
15	57.5	Jacks	<i>Elagatis bipinnulata</i> , <i>Scomberoides lysan</i> , <i>Seriola</i>
16	54.5	Skipjack	<i>Katsuwonus pelamis</i>
17	51.5	misc. demersal perch-like	<i>Evoxymetopon poeyi</i> , <i>Lates calcarifer</i>
18	48.4	other fish	<i>Pseudorhombus duplicioccellatus</i> , <i>Rachycentron canadum</i>
19	45.4	Pompano	<i>Alectis ciliaris</i> , <i>Trachinotus blochii</i>
20	42.4	Bluefish	<i>Pomatomus saltatrix</i>
21	39.3	Jobfish	<i>Aphareus rutilans</i> , <i>Pristipomoides filamentosus</i> , <i>Pristipomoides multidentis</i>
22	36.3	Triggerfish	<i>Balistoides viridescens</i>
23	33.3	misc. coastal fishes	<i>Lagocephalus lagocephalus</i>
24	30.3	Salmon	<i>Eleutheronema tetradactylum</i> , <i>Polydactylus sexfilis</i>
25	27.2	Mackerel	<i>Megalaspis cordyla</i>
26	24.2	misc. coastal perch-like	<i>Cheilinus fasciatus</i> , <i>Chlorurus bowersi</i> , <i>Gerres erythrourus</i> , <i>Mesopristes cancellatus</i> , <i>Parupeneus heptacanthus</i> , <i>Platax orbicularis</i> , <i>Priacanthus tayenus</i> , <i>Seriphus politus</i> , <i>Terapon jarbua</i>
27	21.2	Ladyfish	<i>Elops hawaiiensis</i>
28	18.1	Sweetlips	<i>Plectorhinchus pictus</i>
29	15.1	emperor fish	<i>Gymnocranius elongatus</i> , <i>Lethrinus harak</i> , <i>Lethrinus lentjan</i> , <i>Lethrinus olivaceus</i>
30	12.1	Needlefish	<i>Strongylura gigantea</i> , <i>Strongylura leiura</i>
31	9	other non-fish	<i>Dosidicus gigas</i> , <i>Panulirus ornatus</i>
32	6	Tripletail	<i>Lobotes</i>
33	3	Surgeonfish	<i>Acanthurus gahhm</i>
34	< .01	Rabbitfish	<i>Siganus canaliculatus</i> , <i>Siganus guttatus</i>

## Results

A total of 689 catch records (622 line fishing; 67 spear fishing) were collated, describing a 27-year history of recreational fisheries catches in the Philippines, from 1987 to 2013 (kg·day<sup>-1</sup>·fisher<sup>-1</sup>; standard error of X/Y pairs at 15.7).

### Line fishing (angling)

The log-linear regression analysis of the annual sums of line fishing catches explains 0.55 of the variability and is presented in equation (1):

$$\log_{10}(\text{kg}\cdot\text{day}^{-1}\cdot\text{fisher}^{-1}) = 243.3 - 73.32\cdot\log_{10}(\text{year})\dots(1)$$

The log-linear regression analysis of the annual number of line fishing tournament participants (standard error of X/Y pairs at 45.1) compared with the base value for 1966 of 46 PGFF members, and the geometric mean of 118 line fishers in 2009 is presented in equation (2):

$$\text{Line fishers} = 43.74\cdot\log_{10}(\text{year})^{-1}42.4 \dots (2)$$

The product of the estimates produced by equations (1) and (2) and the average number of 32 line fishing tournament days a year is the reconstructed time series of line fishing total catches.

Spear gun fisheries (spearfishing)

The 67 spear fishing records resulted to an average of  $8 \text{ kg}\cdot\text{day}^{-1}\cdot\text{fisher}^{-1}$  (s.e.=1.5). The log-linear regression analysis of the annual number of spear fishers explains 0.57 of the variability and is presented in equation (3):

$$\text{Spearfishers} = 76 \log_{10}(\text{year}) - 250 \dots (3)$$

The product of the estimates produced by equation (3), the average daily catch per fisher and the average number of spear fishing days of 14 is presented as the reconstructed time series of spear fishing total catches.

Catch composition

Rank and percentile analyses of the data gathered from 1987-2013 are presented in Table 9. Some of the frequent game fishes caught during these years include the IndoPacific sailfish (*Istiophorus platypterus*), the biggest, caught from Sta. Ana, Cagayan in 2007 weighed more than 127 kg; wahoo (*Acanthocybium solandri*) with a record specimen of more than 30 kg from Bolinao, Pangasinan in 2003; the giant trevally (*Caranx ignobilis*), with a 37 kg record specimen from Camiguin Island, Cagayan in 1995; dolphinfishes were also very common and a large 32 kg specimen was caught near Siargao during the 2008 International Game Fishing Tournament.

Recalculated catch composition for the years 1950 to 2010 shows 7 dominant taxon groups comprising 80% of the total catch. The 1965 and 1966 catch records were not used in the catch composition calculations as these contained single records which created a bias.

The results of this study are very approximate as we used mainly tournament data, especially to estimate the number of fishers per year. Nonetheless, it gives a projection of how much sport fishing contributes to the local fisheries in the country. We believe that, though of great potential for the tourism industry, this sector is highly dependent on the status of fish stocks, i.e., overexploitation implies less (in number) and smaller (in size) game fishes.

## Poland

The original technical reconstruction research was initially documented in Bale et al. (2010), was vetted through peer-review in Zeller et al. (2011) and was updated to 2014 by the *Sea Around Us*.

## Methods

Sport and recreational fishing in Poland began in the late 1980s (Radtke and Dabrowski, 2007). Recreational catches were estimated for Poland by using a combination of Polish data regarding the number of recreational fishers between 1999 and 2007 (Anon 1989), with taxon-specific, per capita catch data for Germany in 2005-2006 (Anon 2007a) Recreational catch rates were presented by (1999) for cod, herring and flounder. To remain conservative, we applied half of the German recreational catch rates (Table 10) to the estimated number of recreational fishers in Poland (Table 11), to estimate recreational catches of cod, herring and flounder from 1986-2007.

Because the original reconstruction used Polish population data to calculate recreational catch, trends in yearly population changes for Poland from 2011-2014 were matched using the 2010 recreational catch number as an anchor point. Percent increases or decreases in Poland's population were then applied to the anchor point catch for the years 2011-2012 using data from Poland's Central Statistics Office (Stańczyk et al. 2016).

**Table 10.** Recreational catch rates (t-fisher<sup>-1</sup>) by species used to estimate Poland's recreational catches (Anon., 2007).

Common name	Catch rate (t-fisher <sup>-1</sup> )
Cod	0.011746
Herring	0.000251
Flounder	0.000912

**Table 11.** The number of Polish recreational fishers from 1986-2007 in Poland. Dashed lines (-) indicate interpolated values.

Year	Polish fishers
1986	0
1987-1998	-
1999	6,300
2000	13,700
2001	16,100
2002	21,500
2003	26,500
2004	31,500
2005	38,000
2006	79,043
2007	79,043 <sup>a</sup>

<sup>a</sup>2006 value carried forward.

## Results

Since the mid-1980s when recreational fishing began, the predominant species caught was cod. Since this time, annual catches of cod have increased to approximately 928 t (2006-2007), totaling 4,105 t over the entire period of study (1950-2007). Recreational catches of cod accounted for approximately 0.3% of our total catch reconstruction for cod between 1986 and 2007 (the period in which recreational fishing occurred), and 0.11% of our total reconstructed catch for cod over the period of study (1950- 2007). Recreational catches of herring and flatfishes totaled only about 407 t between 1986 and 2007, comprising about 9% of all recreational catches combined. Due to increasing numbers of recreational fishers, recreational catches of all species appear to have increased dramatically since the onset of recreational fishing in the 1990s.

Considering previously reported landings and our additional estimates of IUU, each component comprised the following proportion of our total catch reconstruction (1950-2007): reported data

from ICES landings statistics, 74%; adjustments, 3.5%; unreported landings, 17.3%; discards, 5.1%, and recreational catches, 0.05%

## Portugal

The original technical reconstruction research was initially documented in Leitao et al. (2010), was vetted through peer-review in Leitao et al. (2014), and was updated to 2014 by the *Sea Around Us*.

### Methods

Until recently, little attention has been paid by fisheries scientists and managers to the economic importance and potential impacts of saltwater recreational fisheries in European Community waters and in Portugal (Veiga et al. 2010). Subsistence fishing has always taken place throughout Portugal, for daily livelihood (food provision) or as a source of additional, casual income. Prior to 2006, no recreational angling license was required. According to official statistics, a total of 201,522 saltwater fishing licenses were issued in 2007, with 141,046 (70%) for shore angling. However, many people with recreational licenses (legal anglers) use recreational fishing as an additional source of subsistence despite daily recreational bag limits. This implies that in Portugal subsistence fishing is confounded with recreational angling. Recreational/subsistence fisheries are legal, as long as the daily bag limit of 10 kg per angler is respected. However, recreational/subsistence catches are entirely unreported. For our purposes, we are not concerned with legality or adherence to bag limits, we are only concerned with estimating the potential total catches being taken (Veiga et al. 2010).

**Pelagic sport fishery:** The Portuguese Federation for Boat Sport Fisheries was created in October 1980. On the Portuguese mainland, sport fishing has become more popular over the last 15 years and includes big game sport fishing, targeting large pelagics and sharks, as well as bottom fishing for demersal fish in coastal waters. Although there is no data collection system, big game fishing is regulated by the International Game Fishing Association (IGFA), with catch and release being common practice, and only suspected record-breaking fish being retained and landed. Thus, retained catches were deemed negligible.

For bottom sport fishing, the main targets are sea breams (Sparidae) as well as cephalopods (squid, cuttlefish). Given the lack of catch data and the fact that quantities caught probably reflect trends in tourism, it was not possible to rebuild sport fishing catches.

For the subsistence/recreational catches, we used the estimates of Veiga et al. (2010) for the percentage contribution of recreational/subsistence catches in relation to total annual national reported landings as a proxy of these unreported catches. This study covered the Algarve and a significant proportion of the southwest coast, or approximately 1/3 of the Portuguese coast. In the absence of more reliable information for the remaining southwestern and northwestern coasts, we assumed that the proportions of subsistence/recreational catches in relation to total landings is equal to those determined by Veiga et al. (2010).

In order to separate, at least approximately, subsistence (i.e., the main driver is self- or family consumption as a cost-effective protein alternative) from recreational (i.e., main driver is pleasure) we applied the following generalized assumptions to the estimated combined catch time series. For

1950, we assumed 80% was subsistence and 20% was recreational, while for 2010 we assumed 90% recreational and 10% subsistence. Percentages were interpolated for intervening years. Both subsistence and recreational sectors were assumed to catch identical taxa.

For the 2011-2014 update, the subsistence and recreational sectors were calculated following the same methods outlined by Leitão et al. 2014 which estimates 8% of total landings is contributed to both sectors. The division of these sectors uses the same proportion as 2010 (10% subsistence and 90% recreational). The taxonomic breakdown remains constant for the entire time series.

## Results

Recreational and subsistence catches accounted for 58,000 t and 54,000 t between 1950 and 2010, respectively. Recreational/subsistence fisheries account for only 1.5% of the unreported catches with an average, minimum and maximum of 1,791, 1,344 and 2,239 t·year<sup>-1</sup>.

## Puerto Rico (USA)

The original technical reconstruction research was initially documented in Appeldoorn et al. (2015) and was updated to 2014 by the *Sea Around Us*.

## Methods

Baitfish catch was studied by Kimmel (1987), who compared his estimates to those of reported landings from the previous three years. His study only surveyed and compared two months of the year; we multiplied his result by six to obtain yearly estimates. Kimmel (1987) found in his study that the mean reported baitfish landings over the three years were only 14.4%. Since baitfish are used for both commercial and recreational fishing, we indexed the reported and observed baitfish catch to the sum of the commercial and recreational catches for the years of the study, which indicated that unreported baitfish represented 5.65% of the combined catch. This estimate was used as a correction factor for the entire catch history.

The recreational fishery in Puerto Rico consists of boat-based fishing, shore fishing, charter boat fishing and tournament fishing, the latter specifically targeting highly migratory and coastal pelagic fishes such as blue marlin (*Makaira nigricans*) and dolphinfish. Recreational finfish catch has been routinely monitored since 2000 through the US Marine Recreational Fisheries Statistics Survey (MRFSS) ([www.st.nmfs.noaa.gov/recreational-fisheries/index](http://www.st.nmfs.noaa.gov/recreational-fisheries/index)), which can be partitioned into the above groups. These data only include finfish, so they were adjusted upward by the percent weight of shellfish recorded in the recreational survey by Appeldoorn and ValdezPizzini (1996), see below. Before 2000, there is limited information on recreational fishing outside the small tournament fishery. Appeldoorn and Valdez-Pizzini (1996) conducted a three month survey of the boat-based fishery through interviews conducted at boat ramps. Over 300 boats were surveyed, of which 13.4% had been engaged in fishing activities. The catch of these were measured, and converted to weight using published length-weight conversions (Bohnsack and Harper 1988; [www.FishBase.org](http://www.FishBase.org)). Average catch per boat fishing was 4.221 kg, with 3.96% being shellfish, and participants indicated that they made an average of 40 trips per year. Using these data and the reported number of boats in 1996 (37,351), an overall estimate of the boat-based catch of 1,858,809 lbs (or 843 t) was derived. Valdez-Pizzini (1987) reported on a small survey of recreational fishing boats, which indicated that the

average number of trips per year was 72. Using these data jointly with those from Appeldoorn and Valdez-Pizzini (1996) and reported number of boats for 1987 (22,699) resulted in an estimated catch of 2,033,395 lbs, i.e., 922 t.

One study of the shore line fishery was available. For 1988, Berrios et al. (1989) estimated the catch from the shore fishery at six locations around Puerto Rico, representing 65% of the coast. Their resultant total catch was scaled up to the entire coast to yield 12,936 kg. We assumed a linear trend in the shore fishery from this point until 2000 and 2001, when the reported shore catch was 25,614 and 91,662 kg, respectively. We thus assumed a value for 1999 of 27,215 kg (60,000 lbs) and decreased the catch by 1,360 kg (3,000 lbs) each year back to 1989 and further assumed a shore catch of 13,607 kg (30,000 lbs) for 1986.

Based on studies by Valdez-Pizzini (1987), the charter boat fishery at that time was quite small. We chose a base for that year of 2,000 lbs (907 kg) and increased that amount by 1,360 kg each year until 1995, after which it was increased by 1,360 kg annually until 1999. For 1987 to 1999, total recreational catch was estimated as the sum of the boat-based, shore line and charter boat catch estimates. The above calculations for the boat-based, shoreline and charter boat recreational catches were summed for the years in which at least some data were available for the boat-based fishery (1986 and 1989), since that represented the vast majority of the catch.

Two other estimates of total recreational catch were available for years prior to 1986. Suárez Caabro (1979) reported that total recreational catch was 1 million lbs (453.6 t) for 1971 with a fleet of 2,500 boats. Schmeid and Burgess (1987) reported that for 1979, the total recreational catch was 1,910,065 lbs of which 58% was landed. We assumed no discard mortality, and thus the catch was 1,107,838 lbs (502.5 t).

One method of estimating of total recreational catch in other years is to relate catch to the number of recreational boats. Data on the number of boats was incomplete; however, from the available data, we only included data on powered vessels not counting personal water craft (e.g., jet skis). Garcia (2003) reported the number of recreational boats from 1986-2001, which showed a relatively linear increase. More recent data (2007-2009) were available from the Department of Natural and Environmental Resources, which showed that the number of vessels had leveled off from earlier years. Finally, there is also the above estimate for 1971 from Suárez Caabro (1979). The number of vessels for early years without data was estimated by modeling a four parameter S-shaped function to the data. This was based on the knowledge that recreational boats increased markedly after the mid-1980s due to the increase in US Federal funding for Puerto Rico, the number of boats would level off in later years, and that the number of predicted boats during the 1960s could not fall to zero. The number of boats from 1971 and 1986-2001 was used, which resulted in the following equation:

$$\text{Number of Boats} = 70871(1 - e^{-0.638(0.0881(\text{Year} - 1944))})^{1/0.638} \quad (1)$$

Six values of recreational catch and number of boats were used to model the relationship between the two. These included the first two years of recreational catch available from the MRRFS database (2000-2001), which varied substantially, and the values as above for 1996, 1986, 1979 and 1971. The number of boats for 1979 was estimated from Equation (1). A plot of these data indicated a straight line relationship between the  $\ln(\text{recreational catch})$  and number of boats as follows:

$$\ln(\text{recreational catch}) = 5.986 + 0.0000305(\text{number of boats}) \quad r^2 = 0.823 \quad (2)$$

Based on the estimation of the number of boats from Equation (1), the total recreational catch was estimated from Equation (2) for all remaining years back to 1950.

For the recreational catches, the above equations (1 and 2) were not applicable to reconstruct the catches until 1950, as the predicted numbers of boats and resultant catches were too high to be reasonable. Thus we accepted the catches of 1971, 1979, 1987 and 1996 at face value and assumed for 1950 a total recreational catch of 400 t. Interpolations were then performed between these anchor values to fill-in catches for the missing years. The values from 2000 onwards were adopted since from this time on there was routine monitoring of the recreational fishery.

#### Taxonomic breakdown

The taxonomic breakdown of the artisanal landings and discards was derived by using the values presented by Valle-Esquivel et al. (2011) and Matos-Caraballo (2008) with the assumption that since 1995, the fraction of pelagic fish and invertebrates in the total catch increased. We assumed that invertebrates made up 20% of the total catch in 1950-1990 and 30% from 2000 onwards. The composition of the invertebrates also changed during the period 1990-2000. Queen conch decreased from 36.5% to 27% and spiny lobster from 39.5% to 29.7% of the total invertebrates. The rest of this proportion was divided equally between the remaining invertebrate groups. The pelagic fish were 7% and 12.2% of the total catch in 1950-1990 and 2000, respectively. The species breakdown of the pelagic fish portion was derived from Valle-Esquivel et al. (2011) and was kept constant from 1950 to 2010. The proportion for the miscellaneous tuna group was equally divided into the 3 tuna species, i.e., yellowfin (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*) and blackfin tuna (*T. atlanticus*; Matos-Caraballo 2008).

For reef fish, a proportions of 73% and 57.8% of the total catch were assumed for the years 1950-1990 and 2000, respectively. Deep-water snappers were 0% of the reef fish catch in 1950. The value was steadily increased to 16.3% in 2000 and kept constant to 2010. Groupers, in 1950, were 22.9% of the reef fish catch and decreased to 5% in 2000. All the other reef fishes were kept constant from 1950 to 1990, then interpolated from 1991-99 and stayed constant again from 2000 to 2010. We assumed a constant contribution of 'miscellaneous marine fish' of 15% to the total catch throughout the years.

For the recreational and subsistence catch a breakdown was derived from the artisanal composition but at the family level. For the recreational catches the invertebrates, parrotfishes (Scaridae) and boxfishes (Ostraciidae) were excluded. The percentages of the remaining taxa were renormalized.

For baitfish catches, we assumed that mostly Engraulidae were caught.

Data for total recreational catches in Puerto Rico was obtained from the Marine Recreational Information Program (MRIP) of the NOAA and carried forward for 2011-2014.

## Results

There was an absolute rise in the recreational catch with a peak in 2000 (2,200 t, around 40% of the total catch). Not included was the catch from the tournament fishery prior to 2000, when recreational landings began to be systematically collected. While this fishery is both economically

and socially important, overall catch was always less than 1% of total estimated catch (Rodriguez-Ferrer et al. 2007).

From 1982 to 1994, the recreational catch was the largest source of discrepancy between estimated catch and reporting landings. After this time, reported landings, while still underestimating total catch, seem to track total estimated catch fairly well. By 2001 both data sets were in general agreement as recreational catch statistics became readily available. The growth and magnitude of the recreational fishery during the late 1980s through the 1990s represents a fundamental change in the fishery in terms of total impact, species composition, data collection and assessment, and potential management options. This increase was modeled to follow the large increase in recreational boats. Interestingly, our best fit to the data indicated that recreational catch/boat actually increased across the time series. This could be explained by increases in both the size (range) and gear sophistication of recreational vessels and the disproportional expansion of the fishery (relative to the commercial fishery) into pelagic fisheries.

## Qatar

The original technical reconstruction research was initially documented in Al-Abdulrazzak (2013a), was vetted through peer-review in Al-Abdulrazzak et al. (2015), and was updated to 2014 by the *Sea Around Us*.

### Methods

To estimate recreational catch, the same method as was used in the Kuwait reconstruction, was applied, where a 0.12% participation rate was applied to total population from 1960-2010 to obtain a time series of recreational fishers, and a conservative estimate of 1 kg of fish per trip, along with 104 fishing days per year (See Kuwait, (Al-Abdulrazzak 2009)). Similarly, Kuwait's reconstructed recreational catch species composition ratios were applied.

### Results

Given the country's rapidly growing population, the corresponding increase in recreational fishing is unsurprising. However, Morgan (2004) predicts that the catch of the recreational sector (which is unmonitored) could one day exceed that of the commercial sector. Thus, management issues for this growing sector must be addressed.

## Reunion (France)

The original technical reconstruction research was initially documented in Le Manach et al. (2015a) and was updated to 2014 by the *Sea Around Us*.

### Methods

IOTC species

The FAO data follow a similar pattern and are very close to those provided by Biais (1991), Biais and Taquet (1992), and DMSOI/SIH since 1980 (FAO data slightly higher in the 1970s, and slightly lower

in the 1990s-early 2000s;  $r^2 = 0.89$ ). Here, we kept the FAO data for reasons of consistency, but applied two corrections:

- From 1950 to 1966, the total FAO catch data were replaced with the data from Tessier and Poisson (1997), to which the FAO species breakdown was applied (the catch in excess, when any, was re-allocated to the generic 'groundfishes' grouping and allocated to the distant-bank fishery; see below);
- Catches data in 1970 steeply dropped, and as we found no evidence to support such a large decline in catch, we assumed that this was an issue of underreporting and disregarded the 1970 FAO data. We estimated the 1970 catch as the average of 1969 and 1971 catches.

Several authors have also reported that 'informal fishers' (i.e., non-registered commercial fishers; labeled as 'artisanal' for the purpose of the *Sea Around Us* database) and recreational fishers using the same gears and targeting the same species frequently used the a-FAD network (Biais and Taquet 1992). Non-professional and tourism boats were estimated to represent 57% and 16%, respectively, of the total fleet in the late 1990s (Bouchard 2009; CRPMEM 2006). Although these non-registered artisanal and recreational fishers are allowed to fish on a-FADs during weekends (Roos et al. 1998), it seems that this regulation is not really enforced (Rey 1998; Tessier and Poisson 1997), and that their total catch is of the same magnitude of the registered fishers (Guyomard et al. 2012). Thus, they form an entirely cryptic component of the artisanal sector, for which no data are reported (Biais and Taquet 1992; Chavance et al. 2012; Tessier and Poisson 1997).

These fishers are also known to target deep-water demersal species (mostly snappers; between 200 and 600 m) with electric reels, and sell most of their catches. Large commercial stocks of such species were identified at the end of the 1990s, and numerous fishers (mostly non-registered) started employing electric reels to exploit them (around 100 tonnes were caught in 2006 by the only registered professional fisher). However, as deep demersal stocks are fragile, their biomass rapidly decreased. A study conducted in 2011 confirmed their overexploited status in the western and northern part of La Réunion (Guyomard et al. 2012).

We assumed that non-registered artisanal and recreational fishers occupied half of the total fishing effort (e.g. number of total boat fishing days) as that of registered artisanal fishers, and half of the annual CPUE of registered fishers (D. Guyomard, pers. obs.). We reconstructed these two missing sectors by multiplying the FAO catch of the registered artisanal fishers by 0.5 (to account for reduced fishing effort) and another 0.5 (to account for reduced CPUE), maintaining the same taxonomic breakdown. For the 2007–2010 period, though, we considered that the effort of both non-registered and recreational fishers doubled compared to the previous period, since the end of fuel subsidies resulted in an important exit from the registered fleet towards the informal one. Finally, we also considered that the unreported catch of the registered artisanal fishers was representing 10% of their reported catch (D. Guyomard, pers. obs.).

#### Non-IOTC species

For this sector, we used demersal and small pelagic total catch data extracted from previous studies (Biais and Taquet 1992), which we believe are the one that were transmitted to FAO.

The taxonomic breakdown provided in several studies was used to disaggregate these totals from 1950 to 1969 (Biais 1991; Biais and Taquet 1992; Tessier and Poisson 1997; DMSOI/SIH, unpub. data). From 1970 to 1998, crabs and Clupeidae were excluded from this breakdown, as they were already included in FAO data. Two adjustments were also made to correct unexplained drops in FAO catches:

- From 1950 to 1953, the average catch and breakdown of the next five years was carried backward;
- For 1965, an interpolation was done between 1964 and 1966.

For the 1999–2010 period, the total catch of demersal species that was extracted from the various studies cited above were proportionately re-allocated from the remaining FAO data. For small pelagics (Carangidae and Clupeoids), we kept the FAO data for consistency, since trends and values of the two datasets were very similar.

We used the same set of assumptions used for the IOTC species (see above) to estimate the unreported catch of nonregistered and recreational fishers. For the registered fleet, we assumed 25% of the declared catch was unreported (D. Guyomard, pers. obs.).

#### Sport fishing by tourists

The tourist population is currently a third of that of the residents and given the nature of the island, an overwhelming part of these tourists stay on the coast during their trip. From the plethora of internet fora describing and praising La Réunion's sport fishing activities, there is no doubt that this sector is important in terms of its economic contribution, as well as in terms of its catch. However, skippers working for sport fishing centers are required to own a professional license; therefore, catches of this sector are thought to be included in the artisanal sector, although usually sold to restaurants and fishmongers (where tourists can therefore enjoy a small piece of their trophies). Here, we conservatively assumed that the sport (i.e., recreational) catch by tourists was included in the reported artisanal statistics (since professional licenses are required to operate sport fishing boats), and as such, we did not reconstruct any catches.

#### Shorefishing and spearfishing by residents

La Réunion only has slightly over 1,000 hectares of coral reef, exclusively along the southern coast (80% of this reef is protected since 2007 via the Réserve Naturelle Marine; [www.reservemarinereunion.fr](http://www.reservemarinereunion.fr)). The recreational reef fishing and gleaning sectors have therefore always been limited. However, reef gleaners are active on these reefs and target most edible fish (over 200 species of commercial interest; Deschamps 2005), but also invertebrates such as crabs, clams and octopuses, locally called 'zourites' (David and Mirault 2006). Fleury et al. (Fleury et al. 2012) described the recent activity of this sector in the MPA, which can provide us with a general idea of fishing practices and impact on shore resources. Four fishing techniques are authorized within the protected area (Fleury et al. 2012):

- Beach-seines to catch *Mulloidichthys flavolineatus* (yellowstripe goatfish);
- Sticks to catch octopuses ('zourites');
- Handlines (from the shore) and spearguns (external slope) to catch various reef species.

These techniques (especially handlines) are also used elsewhere along the coast. There is very little information regarding historical catches of this recreational sector, but Bertrand (1985) reported that this sector was substantial, although not included in reported data (authorities only report commercial activities). Here, we applied a simple Fermi solution as a first approximation of this sector (von Baeyer 1993; Pauly 2010). Population data were extracted from Sandron (2007) and INSEE (2014), and we conservatively assumed that 1% of the population was catching 20 kg of fish per person and per year. Due to the rather low total resulting from this set of assumptions, we did not apply any taxonomic breakdown.

For the 2011-2014 update, local recreational shore fishing rates were calculated for La Réunion by calculating the ratio of population to shore fishing landings for 2008 to 2010: this relationship was carried forward to 2014 with population data from INSEE (2016). Catches from this sector were allocated to “Marine fishes not identified”, as in Le Manach et al (2015a).

## Results

The most prominent sector is by far the industrial one, with almost 60.7% of the total catch from 1950 to 2010. The artisanal sector comes second with 31.2%, whereas the recreational sector makes up the remaining 8.1%.

## Russia (Barents Sea)

The peer-reviewed reconstruction research was documented in Popov and Zeller (2018).

## Methods

Recreational fishing has historically been popular in Russia (FAO 2007a), particularly for salmon on the Kola Peninsula in the Barents Sea region (ICES 2015; ICES 2012). The ICES planning group on recreational fishing indicates that on average, recreational fishing accounts for 2–8% of a country’s total reported landings (ICES 2010). However, as there is little to no data on recreational fishing in the Barents Sea region prior to 1990, a likely conservative recreational fishing rate of 0.5% of reported landings was applied for the period 1950–1990. 1990 was likely the year when recreational fishing was first “officially” opened to foreign tourists, and it is assumed that recreational fishing increased in popularity with the increase in tourism to the region after the fall of the Soviet Union. Thus, it was assumed that from 1991 onwards, the lower end estimate of 2% from ICES (2010) was chosen for calculating recreational catch.

The exception to the data-poor recreational sector in Russia’s Barents Sea waters is recreationally caught Atlantic salmon (*S. salar*). Recreational catches of salmon after 1991 are exceptionally well documented by the Working Group on North Atlantic salmon (WGNAS; ICES, 2015). Data on the number of salmon that were caught and then retained each year in the recreational fishery were obtained from the 2015 Working Group report (ICES, 2015). The average annual mean fork lengths and whole weights of Atlantic salmon, for all sea ages, for each year from 1991 to 2012, were published by the National Oceanic and Atmospheric Administration (NOAA) and used to convert the number of salmon caught to the weight of salmon caught (Sheehan et al. 2013). For the years 2013 and 2014, the same weight as in 2012 was used.

After calculating the total recreational landings per year, the estimated catch of salmon for that year was subtracted from the total. The recreational catch without salmon was then split evenly between seven commonly targeted recreational species described on numerous Russian fishing websites: cod (*G. morhua*), navaga (*Eleginus nawaga*), polar cod (*B. saida*), wolffish (*Anarhicas lupus*), haddock (*M. aeglefinus*), saithe (*P. virens*), and pollack (*Pollachius pollachius*).

## Results

A relatively small fraction of reconstructed landings was deemed to be small-scale in nature, these being artisanal, recreational, and subsistence landings (all deemed unreported). Combined, these three small-scale sectors averaged less than 1% of the total reconstructed landings. Landings in these three sectors remained relatively steady at an average of 1,700 t·year<sup>-1</sup> until 1991, which was the year the Russian Federation was declared open to outsiders. At this point, recreational fishing increased dramatically to a total of nearly 12,000 tons in 1992; thereafter, unreported small-scale landings, while varying widely, averaged around 5,600 t·year<sup>-1</sup>.

## Russia (Far East)

The original technical reconstruction research was initially documented in Sobolevskaya and Divovich (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

### Subsistence and recreational fisheries

Subsistence and recreational fisheries are small-scale sectors with effort exerted by nonprofessional fishers who fish for consumption or fun. Total catch is unreported and was reconstructed by modelling the number of anglers and their catch rate. Thus, in the following section we first estimated the population of the relevant Russian Far East regions and then use this information to assess the number of anglers.

### Population

For the present paper, population data for the Russian Far East were only modelled for the six coastal federal subjects, as opposed to the ten federal subjects belonging to the RFE Federal District, four of which lie in the interior and have no access to the Sea of Okhotsk or the Bering Sea. The relevant coastal federal subjects are the Chukotka Autonomous Okrug, Kamchatka Oblast, Khabarovsk Krai, Magadan Oblast, Primorsky Krai, and Sakhalin Oblast.

### Resident

Resident population data for the above mentioned subjects of the Russian Federation were obtained from the Soviet and Russian Federation censuses. The population of each federal subject was modelled separately using a compilation of 'anchor points' for years with population data. Between any years with missing population data, a series of interpolations were performed.

In 1989, the population of the relevant federal subject was made available by (Демоскоп Weekly 1989) and for the years 1991 (Magadan Oblast only), 2002, 2008 (Magadan Oblast only), and 2010,

from the Russian Federal State Statistics Service ([www.gks.ru](http://www.gks.ru)). For the years prior to 1989, we obtained the population trend for the Russian Far East District as a whole, with census data present for the years 1939, 1959, 1970, and 1979 (Minakir and Freeze 1994). This trend was applied to scale back the 1989 data for each federal subject.

#### Urban and rural populations

The distinction between urban and rural populations was also modelled separately for each federal subject. As was done for the overall population, we compiled anchor points for years where data were available and interpolated between years with data. The final result was a comprehensive time series of urban and rural population for the six coastal federal subjects of the Russian Far East.

The earliest available data on the proportion of urban versus rural population were available for census years, i.e., 1939, 1959, 1970, 1979, and 1989 for the Russian Far East District as a whole (Minakir and Freeze 1994). Since the aim is to reconstruct the proportion of urban and rural separately for each federal subject, we first obtained such specific estimates for years where data were available, and then utilized the data from (Minakir and Freeze 1994) only as a trend for the unique composition of each subject.

Such specific data on the six relevant subjects were available for 2000 (Newell 2004) as well as for 2010 through the Russian Federal State Statistics Service ([www.gks.ru](http://www.gks.ru)). Additionally, there were data available on the change in urban population from 1989 and 1999 in major regional centers of the relevant subjects (Bradshaw 2013). With the dissolution of the Soviet Union, both rural and urban populations of the Russian Far East declined proportionally to their population share. On the federal subject scale, however, rural population in the Magadan Oblast declined more dramatically than urban population (Bradshaw 2013) and to this day “entire villages are disappearing as the countryside empties” (Scott Polar Research Institute 2014).

Hence, we utilized the data from 2000 and 2010 and estimated an additional data point for 1989 by assuming the change in population of the major regional centers from 1989 – 1999 was representative of the change in urban population from 1989 - 2000. With the 1989 unique composition for each federal subject, we then applied the trend implied in (Minakir and Freeze 1994) back to 1950. Through a series of interpolations for years where data were missing, we developed a comprehensive time series of urban and rural population for the six coastal federal subjects of the Russian Far East, as well as the cumulative representation of urban and rural population in all six subjects.

#### Tourist

We estimated a time series of the (minimum) amount of foreign tourists who visit the Russian Far East in order to later estimate annual recreational fisheries catch by these tourists. The tourist industry of the Russian Far East has immense potential due to its rich resources, however due to certain factors, e.g., lack of infrastructure, it is presently underdeveloped. Nonetheless, tourism is present, especially for nature-lovers and those who enjoy hunting and fishing. Likewise, due to the proximity of Primorsky Krai and Khabarovsk Krai to heavily-populated countries like China, Japan, and South Korea, tourism in these two federal subjects is more developed than in others. In 2004,

Primorsky Krai had 195,000 foreign tourists while the Khabarovsk Krai had 25,124, which would grow to 29,420 in 2005 (Anon 2007b)

Foreign travel was tightly restricted during the former-USSR, and hence we assumed the volume of tourists was zero in the Russian Far East from 1950 to 1991. We then interpolated to the tourist data available in 2004 for both Primorsky Krai and Khabarovsk Krai.

Thereafter, we assumed the number of tourists remained constant at 195,000 for Primorsky Krai and at 29,420 for the Khabarovsk Krai from 2005 to 2010.

Sakhalin Oblast is also a southern federal subject in close proximity to Japan, yet due to long-standing territorial disputes, most of the island is restricted to foreign tourists. Travelling to its capital city, Yuzhno-Sakhalinsk, has less restrictions, but since data were not present we conservatively assumed zero tourists in Sakhalin Oblast, especially as those visiting this larger city are not in rural environments where they can freely engage in recreational fishing.

For the northern federal subjects which are colder and even more remote, data on tourism only existed for Kamchatka. Some occasional tourists may visit Magadan and the Chukotka Autonomous Okrug, but as no data were available we assumed no foreign tourists for the entire time period. After 1991, the Kamchatka peninsula became 'open' for foreign tourists and began to attract amateur fishers from around the world. At the same time, the number of companies that provide services to fishing tourists grew steadily. In 2008, approximately 1,700 websites featured advertisements for recreational fishing in Kamchatka, 1,000 of them in Russian and 700 in English (Леман 2008). While there is 'catch-release' scheme of fishing activities in place, it is unclear how well this is adhered to in terms of salmon fishing. Moreover, companies that provide services on fishing tourism often times act unlawfully, i.e. they do not obtain licenses that could authorise their activities (Шатило and Леман 2008).

Data were available on fishing tourism expressed as the number of fishers per day in Kamchatka from 1995 to 2007 (Шатило and Леман 2008). We converted these figures to the number of fishers present per year, and then assumed an average trip was 10 days for these tourists, so that we could obtain an estimated time series of the number of tourists who visited annually. Between 1991 to the 1995 data point we performed an interpolation, and after 2007 we assumed the number of fishers in persons per day remained constant at 1,421. Since this tourist data only reflect the number of tourists engaged in recreational fishing, the true number of tourists is undoubtedly higher.

## Recreational fisheries

### Catch by resident anglers

Amateur and sport fishing are, perhaps, ones of the most popular hobbies for Russian people. According to different sources, the number of amateur fishers in Russia is estimated between 20 and 25 million people (Леман 2008), though this figure was not disaggregated by region; thus, the number of amateur fishers in the RFE is not known. However, the fact that seven of the nine of the RFE constituent entities that represent more than 90% of the territory and about 83% of the population in the Far East have direct access to the sea may would support the assumption that these numbers is high (ЕСИМО 2014).

### Number of recreational fishers

The first data source available on this topic suggest that in the 1980s, there were 100,000 amateur fishers in Primorsky Region, 50,000-70,000 in Sakhalin, and 15,000-20,000 in Kamchatka, who caught 4000, 2000, and 1000 t·year<sup>-1</sup>, respectively (Фетинов 1982). Фетинов (1982) implied that amateur fishers include both recreational and subsistence fishers for whom fishing is a hobby, although catch of indigenous peoples was not included. With these numbers into account, it can be estimated that approximately 5% of the total population of Primorsky Region (where 2,046,000 persons resided in 1982) and Kamchatka (369,000 persons), and 9% of that of Sakhalin (676,000 persons) were engaged in fishing for leisure and diet supplementation. For the three remaining federal subjects where data on the proportion of amateur fishers was not available, we assumed an average of the three federal subjects with available data (amounting to 6% of the resident population).

Based upon the total number of amateur fishers in the 1980s, we estimated that 80% of them were resident recreational fishers and the remaining 20% were subsistence fishers, as in the Soviet Union planned economy limited the need for a subsistence fishery, yet not entirely. We assumed that the resulting proportion of amateur fishers in each federal subjects resident population were representative for the entire period, from 1950 – 2010, as the popularity of recreational fishing among residents shows little change throughout time.

### Catch rate per amateur fisher

The catch rate of amateur fishers in Primorsky Region, Sakhalin and Kamchatka in the 1980s was 40 kg, 33.3 kg and 57 kg·year<sup>-1</sup> per fisher, respectively (Фетинов 1982). Since these are the earliest catch rates available and are also the only available benchmark during the Soviet years, we assumed these catch rates were representative up until the late 1980s, hence from 1950 – 1989.

According to interview with amateurs who fished during 2000-2010, their catches ranged between 70 and 80 kg·year<sup>-1</sup> per person, with their increased catches are attributed to more advanced fishing gear and their greater affordability comparing to the previous times. Therefore, we assumed that the Kamchatka catch rate, which was the highest of the three other regions, increased to 80 kg·year<sup>-1</sup> in 2000 from 57 kg·year<sup>-1</sup> in 1989, while Sakhalin, which had the lowest catch rate in Soviet times increased to 70 kg·year<sup>-1</sup> in 2000 from 33.3 kg·year<sup>-1</sup> in 1989. Assuming that the ratio of catch rates in 1989 from each region remained constant, this implied that the catch rate for the Primorsky region increased to 73 kg·year<sup>-1</sup> in 2000 from 40 kg·year<sup>-1</sup> in 1989. From 2000 to 2010 we assumed the catch rates remained constant. For the three remaining federal subjects with no catch rate data, we took an average of the per capita catch rates for each year from 1950 to 2010.

### Species composition

While the basic composition of the catches for recreational and subsistence fishing depends on the season and is divisible into few main species, their exact proportions of catch remain unclear. In Sakhalin, the Fisheries Agency of the region cites that winter catches mainly consists of smelts (Osmeridae), saffron cod (*Eleginus gracilis*) and white-spotted char ((СахНИРО 2011). In spring, coastal flounders (Pleuronectidae), white-spotted char, Pacific redfin (*Tribolodon brandti*) and masu salmon dominate the catch (СахНИРО 2011). In summer season, pink salmon, white-spotted char, Pacific redfin, starry and smooth flounders (Pleuronectidae) make up the catch of amateur fishers

(СaxНИРО 2011). Finally, the main species in autumn catch are chum and coho salmon, white-spotted char, and Dolly Varden (*Salvelinus malma*) (СaxНИРО 2011). Salmon species account for about 55% of all catches (СaxНИРО 2011).

We used this description as a baseline, assuming that 55% of all recreational catch was various salmon species of the genus *Oncorhynchus*. For the other species we made several assumptions about the proportion of species caught in various seasons, as well as assigned 10% of catch to miscellaneous marine species which can be seen in Appendix 4.

#### Catch by foreign anglers (tourists)

Using the time series generated on the number of foreign tourists who visit each federal subject per year, we converted these estimates to the number of recreational fishers per year. For Kamchatka, 100% of the tourists were fishers, as the data were derived from a study on fishing tourism. For the other federal subjects, we assumed 5% of the foreign tourist population engaged in recreational fishing. Furthermore, we assumed that a foreign recreational fisher fished only 25% of the total time that a resident recreational fisher would fish. This was based on the simplistic assumptions that while a foreign fisher may fish for 10 days in a row, the resident recreational fisher likely fishes 40 days sporadically throughout the year. This estimate is speculative and should be revised upon future data. Thus, we adjusted the recreational catch rate per fisher for residents for tourists by dividing it by four. Total catch was obtained by multiplying the adjusted recreational catch rates by the number of foreign fishers. The species distribution was assumed to be identical to that caught by resident recreational fishers.

## Results

Recreational and subsistence catches began at 6,300 t and 6,000 t in 1950, respectively, both gradually increasing into the 1980s as a result of population growth.

Recreational catch increased in the 1990s, peaking in 2003 with 29,300 t of catch and in 2005 with 29,800 t of catch before stabilizing at about 19,800 t·year<sup>-1</sup> in the late-2000s.

Recreational and subsistence catch each account for 0.54% and 0.47% the magnitude of reported catch, respectively, which is quite small in proportion to commercial catch, but nonetheless of great social importance.

## Saba & Sint Eustasius (Netherlands)

The original technical reconstruction research was initially documented in Lindop et al. (2015), and was updated to 2014 by the *Sea Around Us*.

### Methods

Studies into fishing behaviour on Sint Maarten and Sint Eustatius reported that 15% of the population in 2010 engaged in recreational fishing (Bervoets 2010a; Bervoets 2010b). We assumed that the same was true for Saba, and that this activity level was constant throughout the time period. Therefore, we applied 15% to the annual population to determine participation rates. To be conservative, we assumed a low level of recreational fishing, i.e., once every two months, and a low

catch rate of 1 kg per trip. The estimate catch total was divided equally between the taxa in the reef 'redfish' catch and large pelagics. The large pelagic breakdown included the 11 species listed for recreational fisheries in Bonaire and Curacao, split equally. The majority of fish caught from tourist charter vessels are catch and release<sup>12</sup>, thus retained catches from such vessels were determined to be minimal and therefore are not reconstructed.

## Saba

The total reconstructed catch for 1950-2010 in Saba was 6.6 times the data assumed to be reported to the FAO on behalf of Saba for the same time period. Artisanal catches were the largest, accounting for 58%, with subsistence making up 39% and recreational catches 3%.

Caribbean spiny lobster (*Panulirus argus*) was the largest component of the catch, with 47%, followed by snappers (Lutjanidae; 44%). Sea basses/groupers (Serranidae; 4%) and grunts (Haemulidae; 2%) were the most important taxa of the rest of the catch.

## Sint Eustatius

The reconstructed catches from Sint Eustatius were only 86% of what the data assumed to be reported to the FAO on behalf of Sint Eustatius for the same time period. However, this may simply be due to the assumptions used to disaggregate the FAO data for the former Netherlands Antilles into the separate islands. Artisanal fisheries made up 50% of the catch, with subsistence fisheries contributing 33% and recreational catches making up 17%. After a stable 1950s, averaging just under 12 t·year<sup>-1</sup>, catches declined slightly to a low of 10 t in 1981. Catches then increased to almost 13 t in 2010. Snappers made up the largest part of the catch, with 70%, followed by lobsters with 14%, Serranidae and Scombridae were the most important taxa of the rest of the catch, contributing 5.3% and 3.2%, respectively.

## Saint Kitts & Nevis

The original technical reconstruction research was initially documented in Ramdeen et al. (2014b), and was updated to 2014 by the *Sea Around Us*.

### Methods

We also estimated consumption by visiting tourists and catches from the small recreational sector.

According to a global study of recreational fishing (Cisneros-Montemayor and Sumaila 2010), the proportion of recreational fishers in St. Kitts and Nevis in 2003 was 0.23%. Since sport fishing is an activity that is associated with tourism (Campos 1984), we assumed all of these fishers were tourists. We applied this rate constantly from 2000 to 2010. For the year 1950, we assumed a participation rate of 0.11% (half that of the later time period) of the tourist population. Linearly interpolating between these two rates, we derived recreational fishing participation rates of the tourist population for the time period 1950-2010. Assuming tourists are likely to participate in just one

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<sup>12</sup> <https://www.stmaartencruiseexcursions.com/StmaartenDeepSeaFishing.htm>;  
<http://www.goldenrockdive.com/fishing-charters.php> Accessed: August 15 2010

fishing trip during their stay, and assuming a conservative catch rate of  $4.5 \text{ kg}\cdot\text{tourist}^{-1}\cdot\text{year}^{-1}$ , we were able to estimate catches from this sector.

### Catches satisfying tourist demand

In many parts of the world, fishers have so-called 'direct' customers, such as hoteliers and restaurateurs, whom they supply directly with fresh seafood catches, which often bypass landings sites and monitoring procedures. Community reports from Jessups, Nevis and Dieppe Bay, St. Kitts, state that most fishers sell their catch to hotels (FORCE 2012a; FORCE 2012b). Thus, seafood supplying the tourist market, such as hotels and restaurants, were reconstructed separately. Annual tourist population data were combined with data on the average length of stay, i.e., approximately 10 days according to the Caribbean Tourism Organization. Taken together with inferences about the frequency of seafood consumption (i.e., one serving of seafood per day) and a typical serving proportion of 250 g (round weight), we applied the following equation to estimate tourist seafood demand annually. Using this calculation, we were able to reconstruct small-scale catches provided directly to the tourist market from 1950 to 2010, which we assumed did not enter the reporting system.

For the 2011-2014 update, updated population numbers for Saba were used to estimate the recreational sector, which was then disaggregated into taxa using the same proportions as 2010.

## Results

From 1950 to 2010, reconstructed catches for St. Kitts and Nevis for the artisanal (i.e., small-scale, commercial) sector contributed 39% of the catch, the subsistence sector amounted to almost 61% of the catch and the recreational sector in St. Kitts and Nevis contributed less than 0.1% to the total reconstructed catch.

Recreational catches have increased over the time period, for the most part. Catches increased slowly from just over  $0.02 \text{ t}\cdot\text{year}^{-1}$  in 1950 to  $0.17 \text{ t}\cdot\text{year}^{-1}$  in the late 1970s, and increased faster after that up to  $0.86 \text{ t}\cdot\text{year}^{-1}$  in the mid- to late-1990s. After exhibiting a slight decline to  $0.70 \text{ t}\cdot\text{year}^{-1}$  in 2001, catches rapidly increased to a peak of  $1.36 \text{ t}\cdot\text{year}^{-1}$  in 2006, followed by a decline to just over  $1.0 \text{ t}\cdot\text{year}^{-1}$  in 2010.

## Saint Lucia

The original technical reconstruction research was initially documented in Mohammed and Lindop (2015a), and was updated to 2014 by the *Sea Around Us*.

## Methods

A study on recreational participation in Antigua and Barbuda (Cisneros-Montemayor and Sumaila 2010; Cisneros-Montemayor 2010) documented a participation rate of 0.23% of the total population, and this rate was assumed to also hold for St. Lucia. It was assumed that the vast majority of recreational fishers were tourists, so the participation rate was applied to the tourist population only. Tourist arrivals data was only available from 1995 so estimated tourist numbers for 1950-1994 were calculated by interpolating from 231,000 tourists in 1995 to an assumed 0 tourists in 1945. Recreational participation for 1950 to 2010 was then calculated by applying the 0.23% participation

rate to the tourist numbers. Ramdeen et al. (2014a) estimated a consumption rate of 0.001 t·tourist<sup>-1</sup>·year<sup>-1</sup> for the British Virgin Islands, which we assumed to be the same for St. Lucia and applied it to the estimated participation total for each year 1950-2010 to obtain a recreational catch for both islands combined.

#### Taxonomic breakdown

Mike and Cowx (1996) reported on the domestic recreational fishery in Trinidad and Tobago and estimated the percentage of each fish taxa sold. This was used as a proxy for the composition of recreational catches in St. Lucia. The proportion of each taxa sold was estimated from Mike and Cowx (1996) and then all percentages were normalised to give a species breakdown for the recreational sector, which was applied to the estimated total for each year.

Recreational landings were reconstructed for 2011-2014 using the rate of recreational catch per fisher in 2010 multiplied by the number of tourist fishers for 2011-2014. The number of tourists fishing was determined by multiplying the total tourist arrivals by the original reconstruction participation rate.

### Results

Artisanal and subsistence fisheries were the most important to the total reconstructed catch, contributing more than 90% combined, with artisanal fisheries making up 59% of the total. Industrial fisheries contribute 8.5%, with the recreational sector only making up 0.3%.

## Saint Maarten

The original technical reconstruction research was initially documented in Lindop et al. (2015), and was updated to 2014 by the *Sea Around Us*.

### Methods

Sint Maarten does not have rich fishing grounds and because local fishers are restricted from activities in neighbouring islands, they are limited to the Anguilla and Saba banks (Dilrosun 2004a). Dilrosun (2004) reported catches by Saint Maarten vessels over a week, where from 9 landings, a total of 227 kg was caught, with a CPUE of 30.7kg/trip. Dilrosun (2004) also reported that there are 7 active vessels fishing Sint Maarten's waters, hauling fish traps twice a week. Applying this to the catch effort estimated above resulted in an estimated 490 kg total catch per week. We assumed effort remained constant throughout the year and thus applied an anchor point of 22.4 t for 2004. As the report made no mention of specific lobster catches, we assumed there was only a targeted snapper fishery.

For the lobster fishery on all the SSS islands, we applied a catch composition from the Saban lobster trap fishery as detailed in Toller and Lundvall (2007). The contribution of species other than lobster was normalized and applied to the by-catch. For the redfish fisheries, we assumed similar catch compositions across all islands and used the catch composition provide by Toller and Lundvall (2008). A percentage of conch was added to both fisheries to allow for the few fishers who target conch, which is often illegal (Dilrosun 2004a; Dilrosun 2004b).

Studies into fishing behaviour on Sint Maarten and Sint Eustatius reported that 15% of the population in 2010 engaged in recreational fishing (Bervoets 2010a; Bervoets 2010b). We assumed that the same was true for Saba, and that this activity level was constant throughout the time period. Therefore, we applied 15% to the annual population to determine participation rates. To be conservative, we assumed a low level of recreational fishing, i.e., once every two months, and a low catch rate of 1 kg per trip. The estimate catch total was divided equally between the taxa in the reef 'redfish' catch and large pelagics. The large pelagic breakdown included the 11 species listed for recreational fisheries in Bonaire and Curacao, split equally. The majority of fish caught from tourist charter vessels are catch and release, thus retained catches from such vessels were determined to be minimal and therefore are not reconstructed.

For the 2011-2014 update for Saba, Sint Eustatius and Sint Maarten, the marine fishes nei is split into three catch types: Lobster, Lobster by-catch and Redfish. Saba's portion of the reported marine fishes nei category is all artisanal and assigned to 13 different taxa following the same proportions as 2010. The total reconstructed catch for lobster, lobster by-catch and redfish remained constant since 2007, so this amount was used up to 2014. The reported amount was subtracted from the total reconstructed amount and the remainder was considered unreported and split into sector and taxa using the same proportions as 2010. Updated population numbers<sup>3</sup> for Saba were used to estimate the recreational sector, which was then disaggregated into taxa using the same proportions as 2010.

## Results

Reconstructed catches of Sint Maarten were also deemed to be less than the data we assumed (based on our disaggregation assumptions) to be reported by the FAO on behalf of Sint Maarten. Reconstructed catches are only 38% of the assumed baseline. Artisanal catches were 39% of the total, including fishing by Sint Maarten fishers on Saba Bank, followed by subsistence catches, with 26% and the recreational sector with 36%. Snappers dominated the catch, contributing 69%. Of the remaining catch, Scombridae, lobster, Serranidae, and Istiophoridae (marlins and sailfish) were the most important, contributing 6.55%, 6.1%, 5.1% and 4.9% of the total catch, respectively.

## Saint Pierre and Miquelon (France)

The original technical reconstruction research was initially documented in Bultel and Zylich (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational fishing plays an important role in Saint-Pierre and Miquelon and recreational boats are reported to be especially interested in lobster fishing<sup>13</sup>. Evidence of a recreational fishery for Atlantic salmon was also found and catches were available from 1990-2010 (Herle 2010). We assumed the fishery started in 1987, together with the legislation, and that the catches from 1987 to 1989 were equal to those of 1990. As we could not find information on the beginning of the lobster recreational fishery, it was assumed to have started in 1987 as well, and, as the reported catch seemed to be low,

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<sup>13</sup> <http://www.profilspm.fr/en/in-detail/economic-profile/main-economic-activities.html>

we estimated the recreational catch to match the annual average of reported catch from 1987 to 2010 (i.e., 1 t·year<sup>-1</sup>).

Recreational catches of salmon, as well as the number of recreational salmon fishing licenses issued, from 2011 to 2014 were extracted from a NASCO report and the average recreational catch of 2012-2014 was used to estimate the recreational catch of salmon in 2015 (de Guillebon 2015).

New information regarding the recreational lobster fishery prompted its complete reconstruction from 1987 to 2015. The recreational lobster fishery is poorly documented in official sources, which mainly focus on the regulations controlling the lobster fishery or rough estimates of fishing activity in the archipelago (D'Aboville 2007; Lebrun 2009). However, it is estimated that individual fishers (of which there are hundreds across the archipelago) could each catch, on average, 300 kg of lobster per year, especially in the last twenty years (F. Teletchea 2016, *pers. comm.*). Fishing activity in this sector is also likely to have occurred before 1987, when the first regulations on lobster fishing were put into place (Guellec 1987), but there are no data available on the number of fishers, fishing effort, or even catches of lobster from that time. To better reconstruct this fishery, it was assumed that the number of recreational lobster fishers climbed from 0 to 5% of the total population of the archipelago from 1986 to 1992, and remained at this percentage from then onwards (more recreational fishers may have targeted lobster after the collapse of the cod fishery). The average annual catch rate of 300 kg per year per fisher was multiplied by the estimated number of fishers to reconstruct recreational lobster catches. This reconstruction is highly uncertain and should be updated with better data if and when it becomes available.

## Results

Catches estimated for the recreational sector started in 1987 at about 730 t and oscillated throughout the study period, reaching a minimum of 450 t in 1995 and a maximum of 1,800 t in 2008. They were almost exclusively composed of Atlantic salmon (99.9%).

## Saint Vincent and the Grenadines

The original technical reconstruction research was initially documented in Mohammed and Lindop (2015b), and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational participation in Antigua and Barbuda was found to be 0.23% of the total population (Cisneros-Montemayor 2010; Cisneros-Montemayor and Sumaila 2010) and the same rate was assumed to be true of St. Vincent and Grenadines. It was assumed that the vast majority of recreational fishers were tourists, so the rate was applied to the tourist population. Tourist arrivals data was only available from 1995<sup>14</sup>, so estimated tourist numbers for 1950-1994 were calculated by interpolating from 60,000 tourists in 1995 to an assumed 0 tourists in 1945. Recreational participation was then calculated by applying the 0.23% participation rate to the tourist numbers. Ramdeen et al. (2014a) estimated a consumption rate of 0.001 t·tourist<sup>-1</sup>·year<sup>-1</sup> for the British Virgin Islands, which we assumed to be the same for St. Vincent and the Grenadines and applied it to the

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<sup>14</sup> <http://data.worldbank.org/indicator/ST.INT.ARVL?page=3>

estimated participation total for each year 1950-2010 to obtain a recreational catch for both islands combined.

#### Taxonomic breakdown

Mike and Cowx (1996) reported on the domestic recreational fishery in Trinidad and Tobago and estimated the percentage of each fish taxa sold. This was used as a proxy for the composition of recreational catches in St. Vincent and the Grenadines. The proportion of each taxa sold was estimated from Mike and Cowx (1996) and then all percentages were normalised to give a species breakdown for the recreational sector, which was applied to the estimated total for each year.

Unreported recreational catches were updated for 2011-2014 by assuming the same participation rate in recreational fishing by tourists suggested in the original work above and deriving the 2014 fishing rate of those recreational fishers as the average of the 2011-2013 rates.

### Results

Reconstructed total catches for St. Vincent and the Grenadines were 1.6 times the total reported to the FAO for the period 1950-2010. The majority of the reconstructed catch was artisanal, making up 62.1%, with subsistence fishing contributing a further 36.2%. Industrial fisheries and recreational fisheries made up only 1.6% and 0.1% of the total catch, respectively.

The recreational fishery was minimal throughout the time period and, although catches gradually increased each year, the sector contributed less than 1 t·year<sup>-1</sup> until the early 1980s. Throughout the 2000s, catches averaged 1.9 t·year<sup>-1</sup>. Serra Spanish mackerel (18%), king mackerel (16%), snappers (13%) and jacks (12%) were major contributors.

### Saudi Arabia (Red Sea)

The original technical reconstruction research was initially documented in Tesfamichael and Rossing (2012), was vetted through peer-review in Tesfamichael and Pauly (2016), and was updated to 2014 by the *Sea Around Us*.

#### Methods

Very little data were available for Saudi Arabia's recreational fishery catches. They have not traditionally been accounted for in the reported fisheries statistics, possibly because their catch is very small compared with artisanal or industrial fisheries. The only catch estimate available was 1,500 t for 1998 (MAW 2000). This tonnage was used as anchor point. We assumed, in lack of other data, that recreational catches had been ongoing since the beginning of 1970s. This is the time the oil wealth started to have effect in the fishing sector. Many Saudi citizens started to buy fiberglass boats and hired foreigners to do the fishing (Sakurai 1998; Sanders and Morgan 1989) while they would go fishing for pleasure usually in the weekend. Thus, the catch was assumed to be zero until 1969 and interpolated between 1969 and the anchor in 1998. The population size of Saudi Arabia was used as a proxy to calculate the recreational fishery catch from 1998 to 2010 using the 1998 catch as anchor.

Recreational catches were reported to consist mostly of emperors, then sea breams followed by groupers (MAW 2000). We transformed this qualitative information (using 10% steps between the ranked groups) into percent contributions, which yielded: emperors (Lethrinidae) = 40%; sea breams (Sparidae) = 30%; groupers (Serranidae) = 20% and 'others' = 10%.

For the 2011-2014 update, recreational catch was estimated by a per capita rate from an anchor point in 1998, and applied to population data from World Bank. Taxa were assigned using the estimated rates from the original reconstruction.

## Results

Overall, artisanal fishery contributed to the highest to the total catch from 1950 to 2010 (64%), followed by industrial fishery (12%), discards (11%), subsistence catch (10%) and recreational fishery (3%).

## Saudi Arabia (Persian Gulf)

The original technical reconstruction research was initially documented in Tesfamichael and Pauly (2013), was vetted through peer-review in Al-Abdulrazzak et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

The other sector not included in official reporting is the recreational fishery, which started with the oil boom, when Saudi citizens started fishing for pleasure. Although recreational fishing occurs in Saudi Arabia's Gulf waters, the only data available were for 1996, when it was reported that there were 2,528 boats involved in the recreational fishery in the Gulf, while in the Red Sea there were 2,446 (Sakurai 1998). Thus, the recreational fishery and its composition for the Gulf were calculated using the ratio of boats for 1996 and the reconstructed recreational fishery of the Red Sea (Tesfamichael and Rossing 2012).

For the 2011-2014 update, recreational catch was estimated by a per capita rate from an anchor point in 1998, and applied to population data from World Bank. Taxa were assigned using the estimated rates from the Red Sea reconstruction.

## Results

Of all the sectors, the recreational fishery was the smallest contributor to the total reconstructed catch at 2.4%. The recreational fishery of Saudi Gulf has the least contribution to the total catch; and is also the youngest fishery. This fishery is not regulated at all, except that fishers are not allowed to use any gear besides handlining; its catch is not recorded at all.

## Senegal

The original technical reconstruction research was initially documented in Belhabib et al. (2013), was vetted through peer-review in Belhabib et al. (2014), and was updated to 2014 by the *Sea Around Us*.

## Methods

The first accounts of tourism in Senegal date back to the post-independence period in the 1960s, when tourists visited Senegal for recreational fishing. Manel (2008) estimated that 4% of tourists were visiting Senegal for that purpose. Their average time of stay was estimated at 10 days per year per tourist in 2008 (Manel 2008) including 5 days spent fishing. The number of visitors to Senegal was given by different sources (Table 12), which however, include the short-term stays of visitors other than tourists. ANSD (2011) provided the number of leisure tourists per year for the period between 2008 and 2010 (Table 12), i.e., 25% of the visitors to Senegal, a fraction which was assumed constant during the 1960-2010 time period. We applied this fraction to the total number of short-term visitors to Senegal and obtained the number of leisure tourists (Table 12), and then calculated the number of recreational fishers as the product of the percentage of tourists going exclusively to fish (4%) and the total number of leisure tourists (Table 12). Although the CPUE per fishing trip ranged between 35 and 350 kg per day, (M. Mamadou Sow, President of the Senegal Federation for Recreational Fishing, pers. comm.) using the minimum CPUE per day allows for a more conservative estimate. We assumed the CPUE was 10% higher in 1950 relatively to 2010 to reflect –at least symbolically- on the general over-exploitation pattern of near-shore species observed in Senegal, then interpolated linearly. We multiplied the resulting CPUE by the number of fishing trips and the estimated number of recreational fishers to estimate total tourist-based recreational catches in Senegal.

There is also a recreational fishery operated by Senegalese recreational fishers rather than tourists. However, it appears to be difficult to separate from a subsistence fishery. We have no attempt here to quantify this component, although it could be substantial.

**Table 12.** Estimation of the number of recreational tourist fishers in Senegal. Interpolations (other than those shown in *italic* here) were performed to fill in the gaps for the missing years.

Year	Tourists	Reference	Leisure tourists	Fishers
<i>1950-1959</i>	0	-	-	0
<i>1960</i>	<i>7,573</i>	Fishing started here (Manel 2008)	<i>1,893</i>	81
<i>1988</i>	219,609	Dehoorne and Diagne (2011)	<i>54,902</i>	2,347
<i>1992</i>	267,878	Dehoorne and Diagne (2011)	<i>66,969</i>	2,863
<i>1995</i>	279,635	Tchitou (2005)	<i>69,909</i>	2,989
<i>1996</i>	282,169	Tchitou (2005)	<i>70,542</i>	3,016
<i>1997</i>	313,642	Tchitou (2005)	<i>78,411</i>	3,352
<i>1998</i>	352,389	Tchitou (2005)	<i>88,097</i>	3,766
<i>1999</i>	369,116	Tchitou (2005)	<i>92,279</i>	3,945
<i>2000</i>	389,433	Tchitou (2005)	<i>97,358</i>	4,162
<i>2001</i>	396,254	Tchitou (2005)	<i>99,064</i>	4,235
<i>2002</i>	426,825	Tchitou (2005)	<i>106,706</i>	4,562
<i>2003</i>	495,000	Index Mundi (2013)	<i>123,750</i>	5,290
<i>2004</i>	667,000	Index Mundi (2013)	<i>166,750</i>	7,129
<i>2005</i>	769,000	Index Mundi (2013)	<i>192,250</i>	8,219
<i>2006</i>	866,000	Index Mundi (2013)	<i>216,500</i>	9,255
<i>2007</i>	875,000	Index Mundi (2013)	<i>218,750</i>	9,352
<i>2010</i>	900,000	Deiry Diallo (2011)	<i>220,000</i>	9,405

## Results

Recreational catches increased from zero in 1960, when recreational fishing began, to 1,600 t-year<sup>-1</sup> in 2006, after which they remained relatively constant, at around 1,650 t-year<sup>-1</sup>.

## Seychelles

The original technical reconstruction research was initially documented in Le Manach et al. (2015b), and was updated to 2014 by the *Sea Around Us*.

### Methods

Until 2002, annual SFA reports included estimates of catch by recreational fishers. The number of boats was low in the 1980s, ranging from 4–7 (Payet 1996).<sup>15</sup> During the 1990s, their number steeply increased, to reach 40 by 2000 (SFA 2005). Since 2003, logbooks are poorly transmitted, precluding catch data from being estimated and included in national data (SFA 2014; SFA 2008; SFA 2007; SFA 2006). To date, there are no real estimates with regards to the number of vessels participating in this activity (SFA 2014; SFA 2013).

For the purpose of this reconstruction, and in order to produce a time-series reflecting the aforementioned trends in this sector, we assumed that recreational fisheries started in 1971 (opening of the airport; i.e., no catch in 1970), reached 10% of the unreported artisanal fleet catches by 1990, and 25% by 2010 (proportion held constant afterward). We reallocated part of the unreported artisanal fleet catches rather than adding a whole new sector in order to avoid double-counting, as a portion of the recreational fishery's catch might have been included in official statistics, at least prior to 2003.

For the 2011-2014 update, reporting on recreational fishing in the Seychelles continued to be affected by poor logbook returns (SFA 2015). Unreported recreational fishing was calculated for 2011-2014 as 25% of total unreported artisanal catches for each taxon and then subtracted from the unreported artisanal catch to avoid double-counting.

## Results

The artisanal has dominated the total catch, with an overwhelming 95.6% since 1950. The recreational sector, however, has increased its share (around 3.5% in 2010), similarly to the semi-industrial longline fleet, which made up on average 8.5% of the annual catch.

## Singapore

The original technical reconstruction research was initially documented in Corpus (2014), and was updated to 2014 by the *Sea Around Us*.

### Methods

Weekends and public holidays are the usual days for recreational fishing in Singapore. For example, in June 2013, a photograph of a 40 kg giant trevally (*Caranx ignobilis*) caught and released within the local waters of Singapore was posted. The earliest report of recreational fishing found in the present

study was a feature in 'The Straits Times', 24 July 1938, mentioning catches of almost 100 catties (60.5kg) from Singapore Straits. Highlights of the day's catch were a 24 lbs (10.8 kg) bass and an 8 lbs painted sweetlip (3.6 kg). Presently, boats vary from 23 ft fiberglass open deck (outboard) to 53 ft wooden (inboard) boats<sup>15</sup> and they can be chartered for fishing any day of the week. Average number of anglers that could be taken is 8. Up to 50 boats with anglers may be seen around Singapore on weekends. 6 On 31 January 1971, the The Straits Times columnist Clement Mesenas wrote that 40,000 of Singapore's population of two million people are anglers of one kind or other.

The recreational catch Singapore was estimated of by combining information gathered from two fishing supplies stores with information from groups in Singapore. Photographs found within these websites (posted within the years 2009-2013 by months) that had fish from which the length could be estimated were selected (n =450), the fish they displayed websites of fishing interest were measured, and length-weight relationships (from [www .FishBase.org](http://www.FishBase.org)) were used to compute individual weights. Data generated from the photos were used to determine a mean monthly catch estimate (n=19). To generate an annual catch estimate, mean monthly catch was multiplied by the number of charter boats (n=50), months in a year (n=12), and then doubled to provide for shore/beach catches, as the managers of fishing supplies stores interviewed estimated that the number of boat-based fishers is twice the number of regular shore-based fishers and equal to the number of irregularly fishing shore-based fishers. Finally, the numbers of recreational fishers from 1950 through 2010 were estimated by interpolation using the published 40,000 anglers in 1971 as anchor point, related to the population size of Singapore from 1950 to 2010.

The annual recreational catch estimated for 2009-2012<sup>7</sup> was divided by the mean of the number of fishers estimated above to generate an estimated catch per recreational fisher. This estimate of individual recreational fish catch was in turn multiplied with the estimated number of recreational fishers for each year from 1950-2010 to generate the recreational catch data series. Crab catch reports were available from postings of shore/beach fishers. Production of a recreational crabber was set at 10% of a commercial crabber following a comment that suggests commercial crabbers deploy at least 50 traps while recreational crabbers deploy 4-6 traps<sup>16</sup>. The number of recreational crabbers was estimated by first determining the proportion of online discussion threads on crabbing in relation to those on total marine fishing (P). The proportion (P) was applied to the mean number of fishers in 2009-2012, and their catch was extended backward to 1950 in the same manner as the recreational fish catch.

#### Taxonomic composition

The taxonomic composition of the estimated recreational catch was assumed to be the same as that of the inshore commercial catch for the corresponding years (but without 'Indo-Pacific swamp crab' and 'marine crabs nei').

The number of recreational fishers was updated for 2011-2014 based on the percentage of total population that participated in recreational fishing in 2010. The 2010 recreational catch rate was maintained for 2011-2014 and used to calculate landings by recreational fishers. Recreational landings were disaggregated using the taxonomic breakdown of reported landings in 2011-2014 for

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<sup>15</sup> <http://www.handlinefishing.com/whosfishing/fishingcharters.htm>

<sup>16</sup> <http://www.fishingkaki.com/forum/viewtopic.php?t=170558&highlight=crabbing>

all taxa except for marine and swamp crabs. Recreational crab landings were estimated based on the proportion of commercial crab landings to recreational crab landings in 2010 for each species.

## Results

Examining reconstructed total catches of Singapore by sector, industrial catches dominated with nearly 49% (all of which is taken outside the EEZ), while artisanal and recreational catches comprised approximately 42% and 8%, respectively

The number of recreational fishers, however, can be expected to continue growing. It was even reported that some 950 recreational sized speedboats were sold in 2012, about 200 more than in 2011.<sup>10</sup> The growing significance of marine recreational catches complement the commercial production for a sum of catches that hovered above 4,000 t. As expected, given the assumed trend in the number of recreational fishers and their assumed constant individual catch, the lowest and highest estimated recreational catch of 539 t and 2,137 t were obtained for 1950 and 2010, respectively.

## Slovenia

The original technical reconstruction research was initially documented in Bolje et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational data was available in the national database for 2011 and 2012. Therefore we assumed that recreational catch was 0 in 1945 and interpolated linearly to the data point for 2011. Species breakdown was based on the percentage contribution of each taxa in 2011, which we applied to the estimated recreational total for 1950-2010. These methods were carried forward to 2014.

## South Africa

The original technical reconstruction research was initially documented in Baust et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

Human population data<sup>17</sup>

The various components of recreational fisheries have been subject to numerous individual studies and offer information for estimating the total recreational marine catch if one accepts some assumptions. Available information included data on catches, catch rates and targeted species composition, geographic and socio-economic information, as well as historical and general background information

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<sup>17</sup> Population data for South Africa were obtained from the United Nations World Population Division (United Nations 2009) and the World Bank (World Bank 2010).

## Marine inshore surf and rock recreational fisheries

In general, shore angling data are sparse for South Africa. An exception to this is the province Kwa-Zulu Natal, where several investigations have been undertaken to estimate catches and effort, species compositions, the economic importance of recreational shore fishing, and anglers' attitudes towards and compliance with fishery regulation (Brouwer et al. 1997). Information obtained from government shore patrols, voluntary catch and effort data, and inspections, are collected in the National Marine Linefish System (NMLS; Brouwer et al. 1997). Due to the fact that almost no recreational data are collected for provinces other than Kwa-Zulu Natal, the flexibility of data sources and the unreliability of voluntary and compulsory catch data from individual fishers; the NMLS is unfortunately perceived as being a poor and unrepresentative data source (Sauer et al. 1997). Therefore, the focus has been on obtaining additional data from individual studies, reports and scientific papers.

## Boat-based marine inshore recreational fisheries

Gears used are the same as in the shore angling sector, i.e., rod and reel or handlines. Even though there are varying levels of competition between all recreational fishing sectors and the commercial linefishery sector, the commercial and recreational boat sectors compete most directly. Similar vessels and gear are used and the same fish species are targeted in the same geographic regions and marine environments. The resulting user conflicts were reported in the literature, which highlighted the difficulty in distinguishing between recreational and commercial fishers due to the fact that many operate in both sectors, depending on seasonal availability of fish and the availability of supplementary incomes (Sauer et al. 1997). Collection of information about catch rates, effort, total catches and targeted species started in the 1970s, similarly to the shore angling sector. Data on commercial and recreational boat-based fisheries were separate until 1982, when the NMLS database was initiated. As with the other recreational sectors, numerous scientific studies have been done, which reveal important information on the nature of recreational boat-based fisheries in South Africa.

## Spearfishing

Spearfishing is regarded as one of the most dangerous forms of fishing in South Africa, as it often occurs in challenging underwater conditions, requiring excellent mental and physical fitness of its participants. Nevertheless, this form of fishing has enjoyed great popularity since the 1950s along the South African coast, where fishers operate both from shore or from boats (Mann et al. 1997).

## Estuarine recreational angling

Along the South African coastline, there are approximately 250 well-defined estuaries and many are used as recreational fishing sites. Due to the lack of inlets and bays in South Africa, estuaries offer popular fishing grounds, as they are sheltered from rough seas and are productive fishing grounds attracting mainly recreational boat-based and shore-based fishers who also use cast nets to catch baitfish such as mullet. Linefishing and netfishing (mostly gillnets and seine netting) for commercial and subsistence purposes also occurs in estuaries (Lamberth and Turpie 2003). The most important ecological role of estuaries is that they provide nursery areas for many fish, contributing to healthy fish stocks and a healthy marine environment (Whitfield 1994). It is estimated that the estuarine

catch in the early 2000s totalled 2,480 tonnes per year (including commercial, subsistence and recreational catches), and that recreational fisheries generate by far the biggest share of the GDP value in comparison to the commercial fisheries within estuaries (Lamberth and Turpie 2003).

### Abalone

Recreational diving for abalone has a long tradition in South Africa and has become a highly sought-after marine resource for illegal poachers in organized crime networks in recent years. The increasing pressure on the abalone stocks both in western and eastern provinces of South Africa led to the closure of recreational fisheries for abalone in 2003 (Raemaekers and Britz 2009). Before the increase of illegal abalone poaching activities in South Africa in the early 1990s, recreational and commercial abalone fisheries in the Western Cape provinces were stable (Raemaekers and Britz 2009). Nevertheless, early concern over declining commercial catch rates resulted in stricter management regulations, introduced in 1970. The regulations included annual catch quotas (total allowable catch), which have been gradually lowered (Cockcroft et al. 1999).

### Rock lobster

There are several different species of rock lobster that are targeted by recreational divers or trappers. The main species, however, are the West Coast rock lobster, which inhabit near shore areas from about 23° S (Walvis Bay, Namibia) to about 28° S near East London, and the East Coast rock lobster, which inhabit shallow reef habitats from Port Elisabeth to north to Mozambique (Cockcroft and Payne 1999). This report focused on the recreational fisheries for West Coast rock lobster, since it is the largest recreational rock lobster fishery in South Africa, both in terms of catches and number of fishers (Okes and Burgener 2011).

According to Cockcroft and Mackenzie (1997), commercial exploitation of West Coast rock lobster began in the late 19th century. By 1933, the same regulations applied to both the recreational and commercial sectors, and it was not until 1961 that the authorities differentiated these sectors by introducing a bag limit for recreational fishers. The selling of recreational catches was prohibited and non-conformity continues to be heavily penalized. Over the years, regulations regarding the recreational fishery were steadily updated as fishing pressure increased, e.g., legal minimum sizes and catch bans for specific times of the day were implemented. Legal obligations for the possession of catch permits was introduced in the 1983–84 season (Cockcroft and Mackenzie 1997). In comparison to the recreational abalone fishery, which has been banned since 2003, the recreational rock lobster fishery continues to be a popular pastime for South Africans (Okes and Burgener 2011).

### Charter boat fishing

Charter boat fishing was practiced in South Africa before 1950, and gained popularity during the apartheid period (1948–1994). During this time, mainly wealthy white South Africans went fishing for marlin, swordfish and tuna along the South African coast (Schoeman 1962). Today, hundreds of different operators offer fishing trips to customers in South Africa, particularly in the Kwa-Zulu Natal Province<sup>18</sup>. According to Pradervand and van der Elst (2008), the introduction of stricter legal

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<sup>18</sup> However, these operators do not restrict their activities to South African waters. See, e.g., Le Manach and Pauly (this volume) and their discussion on recreational fishing by South Africans in the EEZ and Bassas da India (France).

obligations and resulting economic disincentives for commercial fishing has led some commercial fishers to switch to operating charter boat trips. In comparison to the commercial linefish industry, income from the charter boat business is not directly linked to total catch but rather to the experience. Since estimates of annual participation in South Africa are sparse, this report quantified total retained catch only, based on the assumption that at least 50% of nationwide total annual catches were made in Kwa-Zulu Natal, the province where charter boat fishing has been the most popular.

#### Number of recreational fishers

The number of fishers was derived from the literature (Griffiths and Lamberth 2002; Lamberth and Turpie 2003; Mann et al. 1997; Sauer et al. 1997). For the years when the number of fishers were missing, linear interpolations were used between time spans of known data, or missing data were derived by applying compound annual growth rates.

Information on the number of participants in the charter boat sector was not available. Thus, the focus was on deriving estimates for total annual retained catches. Abalone and rock lobster fisheries participation was derived from the number of licenses sold and directly translated into the number of fishers or divers, thus assuming one license equaled one fisher or diver. Missing data were derived by applying a ratio of total population to number of licenses sold, based on respective years, and linear interpolation between years of known data.

The purpose of deriving the number of recreational fishers by sector was to determine an estimate of the total number of recreational fishers, in order to calculate the proportion of recreational fishers in the total population, and to derive total catches for each sector using catch rates per fisher.

#### Recreational catch rates

The annual average fishing effort per fisher was assumed to have remained stable in the recreational fishing sector over the study period. Catch rates varied significantly over-time for the recreational boat-based, estuarine, shore and rock fisheries. Catch rates for abalone and West Coast rock lobster did not experience significant changes and therefore were kept at a constant rate, based on estimates obtained from the literature. Information and data from scientific papers and grey literature suggested trends of decreasing catch rates over-time (Coetzee et al. 1989; Guastella 1994; Pradervand and Baird 2002) and states that many important linefish stocks have been heavily overfished and in a state of overexploitation (Griffiths 2000; Griffiths 1997a; Griffiths 1997b; Griffiths and Lamberth 2002). According to Griffiths (2000) and Griffiths and Lamberth (2002), most of the overexploitation of linefish already occurred in the 1970s. Therefore, a catch trend scenario was developed reflecting these changes.

The nationwide catch rates for the shore and rock, boat-based and estuarine recreational fisheries were adjusted conservatively, in relation to documented catch rates for 1995 (Lamberth and Turpie 2003). Catch rates for 1950 were set 25% higher than the 1995 rate, based on the assumption that stocks were much less exploited and not overfished in the 1950s. The technological advances in fishing gear, boats, knowledge and fishing methods, as well as the increasing popularity of fishing as a pastime (Schoeman 1962), was reflected in the assumption that from the 1950s onwards, catch

rates increased steadily, peaking in 1970 at a rate 50% higher than in 1995. Catch rates for missing years between 1950 and 1970, as well as for the period 1970–95, were derived through linear interpolation. The decreasing trend was carried forward unaltered to 2010.

#### Shore and rock anglers

Shore and rock angling is considered the most popular form of recreational angling in South Africa and is practiced all along the South African coast and, therefore, is the biggest recreational sector in terms of number of participants. It was estimated that in 1991, there were roughly 365,000 recreational shore fishers (Van der Elst 1993), increasing to 412,000 by 1995 (McGrath et al. 1997). Contrary to the suggested annual compound growth rate of 6% by van der Elst (1993), a slightly smaller rate of 2% annual compound growth was suggested by McGrath et al. (1997). Estimates of shore anglers were based on those data anchor points. Missing numbers of participants were estimated for 1950–91 and from 1995–2010 by applying an annual compound growth rate of 2%, backward (declining) and forward (increasing), respectively. A linear interpolation between 1991 and 1995 provided estimates for the number of anglers in this time-period. Using the 2% growth rate (McGrath et al. 1997) supported a conservative approach in estimating the number of recreational fishers, especially for the post-1995 period.

An annual average catch rate of 7.37 kg·fisher<sup>-1</sup>·year<sup>-1</sup> was calculated for the year 1995 based on the total catch estimates (3,037 tonnes) for the recreational shore angling sector (Brouwer et al. 1997; Lamberth and Turpie 2003). The same logic as mentioned above was applied in order to construct a time-series of catch rates. Catch rates for 1950 and 1970 were set 25% and 50% higher than the 1995 rate, respectively. The trend was carried forward unaltered to estimate likely catch rates for recent times.

#### Boat-based inshore anglers

Numbers of recreational boat-based inshore marine fishers for similar periods varied in the literature. Sauer et al. (1997) suggested that there were 13,800 fishers in 1996. For this report, the more conservative estimate of 12,000 participants in 1995 was chosen as an anchor point (Lamberth and Turpie 2003). It was assumed that the development and popularity of boat-based recreational fishing in South Africa followed the same consistent growth trend as the shore and rock sector. Therefore, the same annual compound growth rate of 2% (McGrath et al. 1997) was applied to calculate missing numbers of fishers over the period 1950 to 2010.

An annual average catch rate of 106.92 kg·fisher<sup>-1</sup>·year<sup>-1</sup> for the year 1995 was calculated, based on 12,000 fishers catching 1,283 tonnes (Lamberth and Turpie 2003). The same logic as mentioned above was applied in order to construct a time-series of catch rates. Catch rates for 1950 and 1970 were set 25% and 50% higher than the 1995 rate, respectively. The trend was carried forward unaltered to estimate likely catch rates for recent times.

#### Spearfishers

It was estimated that in 1987, there were 4,000 recreational spearfishers in South Africa (Van der Elst 1989). The number of participants rose to 7,000 in 1995 and an annual growth rate of approximately 6% was suggested (Mann et al. 1997). For the time-period of 1987–95, linear

interpolation provided the missing data, whereas a growth rate of 6% was applied to calculate the remaining years.

Mann et al. (1997) report that there was neither evidence for declining catch rates, nor a change in species composition between 1984 and 1995 for the recreational spearfishing sector in Kwa-Zulu Natal (i.e., where most spearfishing activity is occurring). Thus, it was assumed that no significant changes in catch rates between 1950 and 2010 occurred. The respective annual catch rate per fisher for 1995 was estimated at  $30 \text{ kg}\cdot\text{spearfisher}^{-1}\cdot\text{year}^{-1}$ , based on 7,000 spearfishers catching 210 tonnes in 1995 (Mann et al. 1997; Lamberth and Turpie 2003). Consequently, this constant catch rate was applied to the estimated number of recreational spearfishers in order to derive total annual catches.

#### Estuarine boat-based & shore anglers

It was estimated that there were 72,000 recreational estuarine fishers in 1995 (Griffiths and Lamberth 2002; Lamberth and Turpie 2003). The reconstructed number of fishers for the period 1950–2010 was derived by applying an annual compound growth rate of 2% (McGrath et al. 1997) to the fixed data point of 1995 (Lamberth and Turpie 2003), based on the assumption that the development of recreational estuarine fisheries followed a similar trend as inshore marine shore and rock angling.

In 1995 an estimated 72,000 recreational estuarine fishers were catching roughly 1,068 tonnes of fish and other marine organisms from boats or the shore, using handlines, rods and reels, or nets (Griffiths and Lamberth 2002; Lamberth and Turpie 2003). This translated into an average catch rate of  $14.83 \text{ kg}\cdot\text{fisher}^{-1}\cdot\text{year}^{-1}$ , which was used here. The 1995 catch rate was adjusted for 1950 (25% higher) and 1970 (50% higher), and the declining trend was carried forward from 1995 to 2010 by linear interpolation.

#### Abalone

Participation in the abalone fisheries was represented in the literature by the annual number of licenses sold, and for the purpose of this report, was directly translated into actual number of fishers using a ratio of 1 to 1 (one license equalled to one fisher). The period 1989–2003 was fairly well documented in scientific reports in regards to annual number of licenses and the associated total catch. From 2003 onwards, recreational permits were no longer sold due to the closure of the fisheries. In order to estimate participation before 1989, a ratio of total population to abalone fishers was derived for the year 1989 (total population of 34,490,549) in which 20,000 recreational licenses were sold (Cockcroft et al. 1999). This ratio of 0.0006 was applied to the total South African population in the years prior to pre-1989, to estimate likely numbers of participants.

For abalone, a catch rate of  $14.80 \text{ kg}\cdot\text{fisher}^{-1}\cdot\text{year}^{-1}$  for the year 1989 was calculated from reports stating that 20,000 individual recreational divers and fishers caught 296 tonnes of abalone in that respective season (Cockcroft et al. 1999). This rate was held constant from 1950 to 1989 and applied to the reconstructed number of participants in order to derive total annual catches for the period 1950–1989.

## West Coast rock lobster

Due to the fact that permit requirements were nonexistent before 1983, it was difficult to estimate the actual amount of fishers before this period. The most reliable data found in the literature involve voluntary cooperation of fishers and indirect estimation methods such as questionnaires (Cockcroft et al. 1999; Cockcroft and Mackenzie 1997).

A total population to licenses ratio was established based on the fixed data point of 38,000 sold licenses in 1989 (total population of 34,490,549). This ratio of 0.0011 was applied to population data over the period 1950–89 in order to reconstruct participation. From 1989 to 1998, the actual number of licenses purchased, and thus the number of fishers/divers, was known (using the same approach as abalone where the ratio of one license equalled to one fisher). From 1999 onwards, the number of permits sold was unknown and thus not represented, but annual catch estimates were available from government reports (Anon. 2010a,b).

For the rock lobster sector, an annual catch rate of  $6.2 \text{ kg}\cdot\text{fisher}^{-1}\cdot\text{year}^{-1}$  in 1995 was derived based on 54,000 participants catching 336 tonnes and applied to the reconstructed number of participants for times, in which data were unavailable (Cockcroft and Mackenzie 1997; Cockcroft et al. 1999; Cockcroft and Payne 1999). For the period 1999–2010, government estimates for recreational catches were available (Anon 2010b).

## Charter boat fishing

Estimates of retained catch for the charter boat sector in Kwa-Zulu Natal in 2003 amounted to approximately 200 t (Pradervand and Van der Elst 2008). Based on the estimated number of operators throughout South Africa, it was assumed that this represented only 50% of the total annual retained charter boat catch (Africa 2010; Directory 2010). Consequently, it was assumed that the nationwide retained catch totalled 400 t in 2003. Assuming that this industry was still underdeveloped in the early 1940s (Schoeman 1962), the total catch for the year 1945 was set at zero and a linear interpolation for the period 1945–2003 provided annual, nationwide catch estimates for 1950–2002. The increasing trend was carried forward to 2010.

## Targeted species

The development of sound fisheries management policies and the process of assessing the fisheries impact on marine ecosystems were not solely based on improvements of spatial and quantitative information. Another vital part was the improvement of taxonomic information about the overall catches. Griffiths and Lamberth (2002) collected catch contribution information from various sources and assigned the most important species by weight, targeted by recreational anglers (grouped into shore angling, boat angling, estuarine angling and spearfishing) to the five main coastal geographical regions, namely Western Cape, Southern Cape, Eastern Cape, Transkei and Kwa-Zulu Natal. Recreational fish catch was broken down according to the percentage contribution of species.

## Results

The total number of recreational fishers in South Africa increased substantially over the 1950–2010 time-period. In 1950, the total estimated number of recreational fishers was more than 225,000 actively targeting marine organisms on a regular basis in various subsectors. This represented

roughly 1.65% of the total population. The biggest sector in terms of participants in the past was shore- and rock-based angling with more than 160,000 participants. This is not surprising, given that this type of fishing would have required less technological expertise and equipment than for the relatively small boat-based sector, with an estimated 4,000 participants in 1950. Spearfishing was only practiced by very few recreational divers at that time, but the number steadily increased at a rate of 6% per year, and in 2010 it was estimated that there were 16,000 recreational spearfishers operating throughout South Africa. The second biggest sector was, and still is, estuarine fisheries with nearly 30,000 fishers in 1950 and almost 100,000 estimated recreational estuary anglers today.

Participation in abalone and West Coast rock lobster fisheries was relatively low in 1950 with 9,000 and 19,000 fishers, respectively. Both sectors experienced peak participation in the 1990s. The abalone sector was shut down in 2003 which slowed down the overall rate of increase in total number of fishers.

It is estimated that there were approximately 250,000 recreational fishers in South Africa in the early 1960s (Schoeman 1962). This estimate, which is mostly based on fishing club membership data, supports our estimates suggesting a total of 280,000 recreational fishers among all sectors for the same period.

We found that in the mid-1990s there were nearly 600,000 recreational fishers, which seems to be an underestimate compared to government appraisals at more than 750,000 marine recreational fishers for the same period (Anon. 1997). Furthermore, government information reported on one million individual participants in 2010 (Anon. 2010), whereas our estimates suggest a more conservative number of 700,000. Our estimates suggest that approximately 1.5% of the total population of South Africa participate in recreational fishery activities of various kinds. Griffith and Lamberth (2002) suggest that approximately 0.5% of South Africans engage in recreational linefishing only. In other countries, recreational fishing seems to be more popular. The average participation in Europe is estimated at 4.7% of the total population. In Germany, roughly 2.1% of the total population are fishing recreationally in freshwater only, whereas in some northern European countries such as Norway, participation reaches up to 50% (Toivonen 2002). In Australia, estimates vary from 4% to 26% (Kearney 2002; Lyle et al. 2002). Hence, our estimates for South Africa appear to be realistic and may even be an underestimate due to conservative assumptions.

The actual number of recreational fishers is difficult to obtain and official government estimations vary greatly and lack comprehensible statements and references. For the purpose of deriving long-term estimates and growth trends for the period 1950–2010, more conservative choices were made. Furthermore, there is a certain degree of overlap between the individual sectors. For instance, it is impossible to distinguish between recreational fishers who fish from the shore on a regular basis, but sometimes also participate in boat-based recreational fishery activity. The exclusive categorization of fishers is impossible to attain and therefore conservative choices are more sensible and consequently more meaningful if it comes to reconstructing catches landed in the past.

Estimated recreational catches for the shore- and rock-based sector totalled approximately 157,000 t over the 1950–2010 period. Estimated at roughly 1,500 t in 1950, the annual total catches increased due to growing participation and catch rates, and peaked in 1995 at 3,040 t. Since 1996, a decreasing trend in annual catches is noticeable, mainly due to diminishing individual catch rates.

Estimated recreational catches for the boat-based sector totalled approximately 68,000 t for the 1950–2010 period. While the catches totalled 658 t in 1950, they peaked in the early 1990s at 1,283 t. It is estimated that even with continuously increasing number of participants over the entire period, landings were relatively stable at approximately 1,200 t·year<sup>-1</sup>, due to decreasing individual catch rates. As stated earlier, many linefish species targeted by recreational boat fishers are heavily overexploited and some stocks have even collapsed. Many of those species are also targeted by the commercial linefish sector and direct user conflict and competition is reported in the literature (Griffiths and Lamberth 2002). This recreational sector has the highest per fisher catch rate, estimated at 75 kg·fisher<sup>-1</sup>·year<sup>-1</sup> in 2010. The precarious stock conditions of some main targeted species raises concerns for the future of this specific sector.

The total spearfishing catches for the 1950–2010 period was estimated at 8,440 t. In 1950, annual catches were very small due to the fact that spearfishing was not commonly practiced in South Africa. Increasing availability of equipment (e.g., masks and spear guns) resulted in a sharp increase in the number of participants and an estimated 38-fold increase in annual catches between 1950 and 2010, estimated at around 14 t and 503 t, respectively. The time series shows a nearly exponential growth trend of annual spearfishing catches.

Estimated recreational catches for the estuary sector totalled approximately 57,000 t over the 1950–2010 period, making this the third most important recreational sector in terms of landed tonnage. In 1950, an estimated 29,000 fishers landed around 550 t of fish. Total catches peaked in 1995 at 1,070 t and decreased slightly to an estimated 1,000 t in 2010.

The total estimated recreational catch for abalone was approximately 12,100 t of whole weight for the period 1950 to 2003. Recreational catches were estimated at around 120 t in 1950. Total annual catches increased steadily with rising rates of participation, peaking in 1994 at 540 t. The sharp decrease of catches in 1997–1998 was a result of declining effort because a moratorium was placed on the sale of recreational permits in order to allocate catch quotas to subsistence fishers in line with the implementation of the new Marine Living Resources Act 18 (MLRA) in 1998; the new post-apartheid regulation scheme regarding marine management (Cockcroft et al. 1999). Downward adjustments with respect to permits sold to compensate for over exploitation since 2000, exacerbated by illegal harvesting, ended in the closure of the recreational abalone sector in 2003. Illegal activity continues to thrive and puts additional pressure on the already heavily exploited resource.

Estimated recreational catches of lobster totalled approximately 13,300 t over the 1950–2010 period. Starting off at around 100 t·year<sup>-1</sup> in the 1950s, catches increased steadily until the 1990s. Catches fluctuated in the 1990s, peaking at nearly 600 t in the 2002–2003 season. The increase in catches in the mid-1990s is related to the decrease of the legal minimum size for recreationally-caught lobster, as well as an increased season length in that period (Cockcroft et al. 1999).

The total retained catch for the charter boat sector was estimated at 14,700 t over the 1950–2010 period. In 1950, catches were estimated to be very low (35 t), accounting for its recent introduction and assumed slow evolution. Technological advances in tackle and gear and greater availability of boats since the end of World War II are reflected in the expansion of the industry and continuous increase of annual catches. Due to the lack of sufficient data and information, reconstructed catches for this sector may underlie the highest degree of uncertainty. Furthermore, estimating retained

catches exclusively may under represent actual mortality in this sector. Post-release mortality and severe impairments of released fish due to barotrauma-induced stress is believed to be very high (Bartholomew and Bohnsack 2005; Gravel and Cooke 2008). It is estimated that approximately 37% of the total catch in this sector in Natal is released, with the remaining 63% retained (Pradervand and Van der Elst 2008). The reasons for releasing catch are varied, including unwanted species, undersized or protected fish or the general underlying catch-and-release policy, which is common in this industry with respect to sharks, sailfish and swordfish. Therefore, the reconstructed catch estimates are conservative and if also accounting for mortality of released catch, estimates would likely be much higher.

Estimated recreational catches for all sectors totalled approximately 332,000 t over the 1950–2010 period. In 1950, catches totalled just under 3,000 t, increasing rapidly to 5,400 t in 1970. The overall reduction in catch rates due to overfishing is reflected in the decreased growth rate of total catches from 1970 onwards. Total catches peaked in 1997 at nearly 7,000 t and decreased to an estimated 6,300 t in 2010. This decrease is mainly due to the closure of the abalone sector in 2003 and the decreased effort for West Coast rock lobster. Based on increasing participation and overall population growth, catches are likely to continue to increase.

In comparison to the landings of several hundred thousand tonnes each year by the commercial fishing fleet in South Africa, the reconstructed catch estimates for the recreational sector seem to be negligible in terms of weight. For most years, this amount represented less than 1% of the overall industrial landings. So far, these catches are not reported to the FAO and therefore not represented in official reports. Nevertheless, with regards to the overall sustainability of the marine ecosystems and its productivity, these catches play an important role. Bearing in mind that many endemic fish species are fully or nearly fully exploited, severely overexploited or have even collapsed, the influence and effects of recreational fishing becomes apparent. According to Griffiths and Lamberth (2002), recreational fishers are directly responsible for the depletion of many species. Additionally, for some user groups such as subsistence and artisanal fishers, who rely on fish for monetary income and as their primary source of protein, decreased availability of marine resources threatens their livelihood and food security.

The estimated catches in this report may be under reported due to various facts. As a result of the multi-sector nature of this industry, smaller categories such as the east coast rock lobster fisheries were excluded. Additionally, individual effort and catch rates were solely based on diurnal fishing activity in all sectors. Night fishing, which is commonly practiced in South Africa, was excluded in all scientific studies used and therefore not represented in this report. Furthermore, rather conservative choices for catch rate trends and number of recreational fishers were made.

## Spain (Mediterranean and Gulf of Cadiz)

The original technical reconstruction research was initially documented in Coll et al. (2015), was vetted through peer-review in Coll et al. (2014), and was updated to 2014 by the *Sea Around Us*.

### Methods

Taxonomic composition of the Spanish Mediterranean Sea and Gulf of Cadiz recreational fisheries

The taxonomic breakdown of the Spanish Mediterranean Sea recreational catch was derived from Gordo et al. (2004) who presented data on the species composition (by percent of presence and weight) of recreational catches according to fishing modality. For each species, the percentage by weight for all fishing modalities was summed and then re-scaled to 100%. The final percentage contribution of each species was then applied to the total Spanish recreational catch from 1950 to 2010.

Despite recreational fishing being a popular activity in the Gulf of Cadiz, there is little information regarding the catch composition of recreational fisheries. Thus, we used the Spanish Mediterranean Sea recreational catch composition to disaggregate the total catch from recreational fisheries in the Gulf of Cadiz from 1950 to 2010.

From the literature, we identified the key components of unreported catches, such as (i) illegal catch, (ii) illegal fishing techniques, (iii) misreported legal catch, and (iv) catch not reported in the official statistics, such as recreational fishing. All the available information was used to estimate unreported catches by region and main species for time periods available (see sections below).

Interviews with fishers in different regions of the study area enabled us to verify the existence of unreported catches, to identify principal sources of non-reporting and provide a first quantification.

Data from fishers interviews was also used to estimate the total amount of artisanal catches (i.e., small-scale commercial) that are unreported. In principle, artisanal fisheries should get registered in official statistics as other fisheries, but this is not always the case. Of all fishers interviewed, 44% identified artisanal fisheries as important in terms of unreported catches. Fishers indicated that, on average, non-reporting of artisanal fisheries may represent an additional 20±3% in addition to official landings.

Another important source of unreported catches is the catch from recreational fishing (Table 13). This catch can represent an important amount and it is not captured in official statistics. In Spain, recreational fishing needs to be associated with a recreational fishing licence. It is a well-established economic activity in the study area. It represents a highly diversified activity (Franquesa et al. 2004; Gaudin and De Young 2007; Gordo et al. 2004), comprising both shore-based fishing (e.g., pole and line, or diving) and boat-based fishing (including diving). Different types of recreational fisheries exist: (i) shore fishing with pole and line, (ii) fishing when diving, both from coast or from a vessel, (iii) diving competitions, (iv) charter activities that include fishing as a tourist attraction, and (v) fishing from rented vessels (Franquesa et al. 2004).

**Table 13.** Sources of data on recreational fisheries from the Spanish Mediterranean and Gulf of Cadiz regions.

Regions	Recreational fisheries	
	Coastal	Open sea
<b>Catalonia</b>	2000-2004: (Franquesa and Bellini 2006) Ebro Delta area 2002-2006: (Gordoa 2009) All region 2004: (Soliva 2006) All region 2004-2007: (Anonymous 2008) All region 2006: (Lloret <i>et al.</i> 2008b) MPA 2007: (Lloret <i>et al.</i> 2008a) MPA 2007-2008: (Ribalta 2009) Southern Catalan Sea 2004: (TRAGSATEC 2005) Mediterranean 2005-2006: (Franquesa 2006) Mediterranean	1990s-2000s: (Gordoa 2003) Mediterranean
<b>Valencia</b>		1990s-2000s: (Gordoa 2003) Mediterranean 2004: (TRAGSATEC 2005) Mediterranean 2005-2006: (Franquesa 2006) Mediterranean
<b>Balearic Islands</b>	1975-2001: (Coll <i>et al.</i> 2004) Balearic islands 2001: (Morales-Nin <i>et al.</i> 2005) 2004: (TRAGSATEC 2005) Mediterranean 2005-2006: (Franquesa 2006) Mediterranean	1990s-2000s: (Gordoa 2003) Mediterranean
<b>Murcia</b>		1990s-2000s: (Gordoa 2003) Mediterranean 2004: (TRAGSATEC 2005) Mediterranean 2005-2006: (Franquesa 2006) Mediterranean
<b>Andalusia-Mediterranean</b>		1990s-2000s: (Gordoa 2003) Mediterranean 2004: (TRAGSATEC 2005) Mediterranean 2005-2006: (Franquesa 2006) Mediterranean
<b>Andalusia-Gulf of Cadiz</b>	no information found	no information found

Boat-based species caught during competitions are mainly bluefin tuna, little tunny, bonito, skipjack tuna and albacore tuna. Main species for shore-based fishing are more diverse and include table fish such as the gilthead seabream (*Sparus aurata*), white seabream (*Diplodus sargus*), European seabass (*Dicentrarchus labrax*), sand steenbras (*Lithognathus mormyrus*), conger eel (*Conger conger*), octopuses (mainly the common octopus *Octopus vulgaris*), and salema (*Sarpa salpa*) (Franquesa *et al.* 2004; Gordoa *et al.* 2004).

Despite the importance of recreational fisheries in the Mediterranean Sea (Gaudin and de Young 2007), little information on total removals from these activities exists to date (Franquesa *et al.* 2004) (Table 13), although preliminary studies from the mid-2000s for our study area (including Spanish Mediterranean and Andalusia region) estimated a total annual fish harvest of 19,740 t (Gordoa *et al.*

2004; Franquesa 2006; Gaudin and de Young 2007). By region, Andalusia and Catalonia are the regions with largest absolute values of recreational removals, followed by the Balearic Islands, Valencia and Murcia. If recreational removals are compared to commercial catches, the Balearic Islands are the region with the largest recreational catches relative to commercial fisheries, followed by Catalonia and Murcia. Overall, recreational catch represented 13.2% of that from commercial fisheries in the mid-2000s. Since historical data on the importance of recreational fisheries were not available, we assumed that its importance was similar back to the 1980s, but was lower from the 1950s to the 1970s (accounting for half of the amount in terms of landings, thus 6.6%).

When we included recreational catches in total catches of the region, we observed that the overall trends of total catches peaked in 1958 with approximately 413,000 t·year<sup>-1</sup>, then fluctuated to 1982 and declined to a minimum value of 180,000 t·year<sup>-1</sup> in the late 2000s.

## Results

Total reconstructed fisheries removals in the Spanish Mediterranean and Gulf of Cadiz were estimated by summing all catch components investigated here: official reported landings, discards and unreported catches. Overall, the total reconstructed catch is 1.7 times that of the available reported catch for the same time period. Reported landings represented 58.5% of the total reconstructed catch, followed by IUU landings (22%) and discards (19.5%) Unreported landings were investigated in terms of black market and subsistence fishing, artisanal fishing and recreational fishing. They also included a small portion of illegal catch. Of these elements of unreported catch, in 2008 recreational fisheries were the most important (~36%), followed by black market (~32%), subsistence fishing (~17%), artisanal (~12%) and illegal catch (~2%).

## Spain (Northwest)

The original technical reconstruction research was initially documented in Villasante et al. (2008), and was updated to 2014 by the *Sea Around Us*.

## Methods

Calculations of catch for the subsistence and recreational fisheries were gleaned from fisher interviews for Galicia. This was extended to the entire northwest coast (as to include Asturias, Cantabria, and the Basque Country) by using population as a proxy for magnitude of catch. Population anchor points were used for the years 1981, 1991, 2001, and 2011 from (<http://www.citypopulation.de/Spain-Cities.html>) and in between these years population was interpolated. We then constructed a ratio of the population in northwest of Spain to population in Galicia alone. Prior to 1981 this ratio was assumed to be the same as in 1981. Then this ratio was applied to the estimated recreational and subsistence catch that was calculated for Galicia.

For the recreational and subsistence fisheries, we assumed the per capita catch rate in Galicia was representative of the entire northwest Spanish coast due to similar cultural norms in the catch and consumption of fish.

For the 2011-2014 update, unreported recreational and subsistence catches were calculated by dividing the 2008-2010 total recreational and subsistence catch for divisions 27.8.c and 27.9.a by the

combined population of the provinces of Galicia, Asturias, Cantabria and Basque Country. The average of the north coast per-capita recreational and subsistence catch was averaged from 2008-2010, and multiplied by the north coast population for 2011 to 2014, to obtain an estimate of recreational and subsistence catch, allocated to the two divisions according to 2010 proportions. These catches were taxonomically allocated following 2008-2010 proportions for both divisions.

## Results

Reconstructed total catch increased from 484,000 t·year<sup>-1</sup> in the 1950s to an average of 631,000 t·year<sup>-1</sup> in the 1960s annually, thereafter declining throughout the 1970s to a level of 273,000 t·year<sup>-1</sup> from 1980 to 2010. Reconstructed catch for northwest Spain was nearly twice (188%) the reported amount deemed within the Spanish EEZ. Unreported industrial landings account for about 41% of the unreported amount, unreported artisanal landings are just under 4%, discards account for 54%, recreational catch for 1%, and subsistence was existent yet negligible (<1%) in total unreported catch.

## St Barthélemy (France)

The original technical reconstruction research was initially documented in Bultel et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational fishing within the Caribbean targets a range of large pelagic species, and the region also attracts a multitude of international anglers wishing to target the large migratory tunas and billfishes<sup>19</sup>

In Dutch Sint Maarten, recreational fishing takes place through casual shore fishing and sport fishing whose species targeted are marlin, tuna, wahoo, sailfish and other large pelagics (MacRae 2011). Queen conch is also reported to be a species of interest for recreational fishers, but legislation from 2002 allowed only professional to collect the marine mollusc (Anon 2012). Dolphinfinch are targeted throughout the Western Central Atlantic region by recreational fishers (Mahon 1999).

As 15% of the local population in Sint Maarten engages in some form of recreational fishing (Bervoets 2010), we applied the same percentages to the population estimated through data found for St. Barts and St. Martin. Population data were available from INSEE for 1967, 1974, 1982, 1990, 1999 and 2010; we interpolated population data between those years and from 1950 to 1966, we used the trend of the population growth from 1967 to 1980. Assuming that each person involved in recreational fishing would catch 20 kilos per year, we estimated the amount potentially caught by recreational fishers for each year and then equally allocated this amount among the families of the targeted taxa.

As noted in Bultel et al (2015), statistics on the fisheries of St. Barthélemy are lacking, and no new information has been produced about them. However, FAO reported data for St. Barthélemy in 2007-2014 from have doubled from 50 to 100 t reported per year since the previous version of FAO

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<sup>19</sup> <http://clmeproject.org/casestud2.html>

data. Thus, the methods of Bultel et al (2015) have been applied unaltered on the updated FAO landings data from 2011 to 2014, including the calculation of discards for the artisanal fishery.

## Results

Reconstructed removals for St. Barts between 1950 and 2010 were 5.4 times the data we deemed reported for St. Barts through extraction from the reported FAO catch of Guadeloupe over the same time period. Artisanal and subsistence landings were most important, with 46.5% and 41.9% of the catch respectively. Recreational catches made up 7.7% and discards from the artisanal fishery contributed 3.9%.

## St Martin (France)

The original technical reconstruction research was initially documented in Bultel et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational fishing within the Caribbean targets a range of large pelagic species, and the region also attracts a multitude of international anglers wishing to target the large migratory tunas and billfishes<sup>20</sup>

In Dutch Sint Maarten, recreational fishing takes place through casual shore fishing and sport fishing whose species targeted are marlin, tuna, wahoo, sailfish and other large pelagics (MacRae 2011). Queen conch is also reported to be a species of interest for recreational fishers, but legislation from 2002 allowed only professional to collect the marine mollusc (Anon. 2012). Dolphinfish are targeted throughout the Western Central Atlantic region by recreational fishers (Mahon 1999).

As 15% of the local population in Sint Maarten engages in some form of recreational fishing (Bervoets 2010), we applied the same percentages to the population estimated through data found for St. Barts and St. Martin. Population data were available from INSEE for 1967, 1974, 1982, 1990, 1999 and 2010; we interpolated population data between those years and from 1950 to 1966, we used the trend of the population growth from 1967 to 1980. Assuming that each person involved in recreational fishing would catch 20 kilos per year, we estimated the amount potentially caught by recreational fishers for each year and then equally allocated this amount among the families of the targeted taxa.

As noted in Bultel et al (2015), statistics on the fisheries of St Martin are lacking, and no new information has been produced about them. However, FAO reported data for St Barthélemy from 2007 to 2010 have decreased since the last reconstruction, from 200 t to 90 t per year. The methods of Bultel et al (2015) have been applied unaltered on the updated FAO landings data from 2011 to 2014, including the calculation of discards for the artisanal fishery.

## Results

The reconstructed total catch for 1950-2010 in St. Martin was 5.4 times the data deemed reported for St. Martin through extraction from the reported FAO catch of Guadeloupe over the same time

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<sup>20</sup> <http://clmeproject.org/casestud2.html>

period. The artisanal landings contributed 46.7%, with subsistence fisheries making up 42.1%. Recreational fishing contributed 7.3%, whilst discards from the artisanal fishery made up a further 3.9%.

## Sweden (Baltic)

The original technical reconstruction research was initially documented in Persson (2015), was vetted through peer-review in Zeller et al. (2011), and was updated to 2014 by the *Sea Around Us*.

### Methods

Salmon: Information about the so-called 'Midsummer salmon' (i.e., sales that are not reported; Hultkrantz, 1997), and illegal fishing activities during closed salmon run periods (U. Steinbash, pers. comm., Swedish Coast Guard) was obtained, but was not detailed enough for deriving anchor points. Instead, estimated total unreported catches of salmon in the Baltic Sea, including rivers, from 1981 to 2007 from the ICES salmon and trout working group report (Table 2.1.1. in ICES 2008) were used. In this source, estimates of recreational catches were included in the Swedish reported landings from 1988 onwards, and could not be distinguished from commercial landings. Therefore, in order to avoid double accounting and remain conservative, Sweden's fraction of the total Baltic Sea catch per year was multiplied by the lower limit of the 95 % probability interval (see Table 2.1.1. in ICES, 2008) to derive Sweden's unreported landings (see next paragraph for example). The unreported landings were then converted into percentages based on Sweden's reported landings, and used as anchor points between 1981 and 2007 (Table 14). The average of the first three years of data (1981-83) was used as anchor point for 1980 (Table 14), and carried back fixed to 1950 to derive a complete time series.

To more clearly illustrate the approach, for example, in 1990 Sweden's reported landings of salmon (including river catch and estimated recreational catch) was 1,468 t, and the total reported landings for the Baltic Sea was 5,636 t (as reported in Table 2.1.1. in ICES, 2008). The 95 % Confidence Interval of the estimated unreported landings was 324 t – 2,512 t (Table 2.1.1. in ICES, 2008). Therefore, Sweden's fraction of the total landings ( $1,468 \text{ t} / 5,636 \text{ t} = 0.26$ ) was multiplied with the lower 95% Confidence Interval value ( $0.26 \times 324 \text{ t} = 84.4 \text{ t}$ ) to derive estimated unreported salmon landings of 84.4 t for Sweden in 1990. Sweden's reported marine landings in 1990 was 1,249 t (ICES landings statistics), and the unreported landings were converted into a percentage ( $84.4 \text{ t} / 1,249 \text{ t} = 6.8\%$ ), which was used as an anchor point for unreported marine salmon landings in 1990 (Table 14).

Swedish national studies from 1977, 1990, 1995, 2000, 2005, and 2007, estimating the extent of recreational fishing, were used to derive anchor points for recreational catches (Anon 2007c; Anon 2005; Anon 1977a; Anon 1977b; Nilsson 1991; Norström et al. 2000). These studies were carried out as questionnaires-based surveys to between 5,000 and 11,000 people at a time, and are known to have their own sets of uncertainties and methodological problems. It is recognized that an individual's interest in fishing increases the willingness to answer the questionnaires, and this can lead to overestimation of results if the fraction of the questionnaires that is not answered is not accounted for differently (Anon 2005; Bratt and Jansson 2007). The 1977 study focused on possession of different gear and fishing effort rather than catch, which was addressed by Anon. (1977b), and is considered to be reliable due to the large sample size (11,000 participants), and a

93% participation rate (Anon., 1977a; A. Paulrud, pers. comm., Swedish Board of Fisheries). Among the 1990-2007 studies, the 2007 study is thought to be most reliable because it adjusts for the variation in willingness to participate based on personal fishing interest (Anon., 2007a). The 2005 study (Anon., 2005c) has been similarly adjusted (A. Paulrud, pers. comm., Swedish Board of Fisheries), and the resultant adjustment factors were used to improve the other studies (Table 14)

**Table 14.** Unreported landings anchor points (% of reported landings). Dashes (-) indicate interpolated or expanded values.

Year	Cod	Herring & sprat	Salmon <sup>a</sup>	Eel	Vendace	Others <sup>b</sup>
1950	5.0 <sup>b</sup>	5.0 <sup>b</sup>	-	5.0 <sup>b</sup>	5.0 <sup>b</sup>	5.0 <sup>b</sup>
1951-1979	-	-	-	-	-	-
1980	15.5 <sup>b</sup>	12.5 <sup>b</sup>	6.7 <sup>c</sup>	9.9 <sup>b</sup>	10.0 <sup>b</sup>	6.8 <sup>b</sup>
1981	-	-	9.1	-	-	-
1982	-	-	5.4	-	-	-
1983	-	-	5.6	-	-	-
1984	-	-	5.6	-	-	-
1985	-	-	4.8	-	-	-
1986	-	-	5.7	-	-	-
1987	31.0	-	5.3	-	-	-
1988	-	-	6.3	-	-	-
1989	-	-	6.6	-	-	-
1990	-	-	6.8	-	-	13.5
1991	-	-	7.1	-	-	-
1992	-	-	6.9	-	-	-
1993	-	25.0	7.1	-	-	-
1994	-	-	7.2	-	-	-
1995	-	-	7.8	-	-	-
1996	-	-	7.8	-	-	-
1997	-	-	8.0	-	-	-
1998	-	-	9.0	-	-	-
1999	-	-	9.4	-	-	-
2000	-	-	8.9	-	-	-
2001	-	-	8.8	-	-	-
2002	-	-	9.8	-	-	-
2003	-	13.0	9.6	-	-	-
2004	-	-	7.8	-	-	-
2005	-	10.0	8.7	-	20.0	-
2006	13.1	-	8.5	19.8	-	-
2007	13.1	-	9.4	15.0	-	6.8

<sup>a</sup> based on ICES stock assessment working group report (Table 2.1.1 in Anon., 2008c). <sup>b</sup> assumption based anchor points, see text. <sup>c</sup> average of the three first years of data, based on general assumptions.

The recreational catches in the studies from 2000 and 2005 (Norström et al., 2000; Anon., 2005c) were reported as the total Swedish marine recreational catches, hence had to be adjusted for west coast catches. These adjustments were based on Anon. (2005c; 2007a), due to their spatial area reporting, which allowed west coast catches to be excluded and adjustments factors to be derived as follows; for cod, flatfishes, sea trout, and ‘other species’ individual adjustment factors could be calculated. Mackerel, crab, lobster, mussels, and ‘other cod fish’ were thought to be entirely caught on the west coast (Anon., 1978; Anon., 2007a). For species without individual adjustment factors, a general adjustment factor was based on the fraction of west coast catches reported in Anon. (2005c) excluding above mentioned species and species categories with specific information (Table 15).

After adjustments, the numbers of country-wide recreational fishers from each study as well as for 1947 (200,000 fishers; Anon., 1978), were used in conjunction with Swedish population numbers (Statistics Sweden 2008) to derive the percentage of the total population that were recreational

fishers for these years. Linear interpolation between derived percentage rates was done to fill missing years, and then the percentage for each year was applied to the total population number to derive a complete time series of number of recreational fishers. For example, the number of fishers in 1975 was 2 million, and given a total Swedish population of 8.2 million, the percentage of recreational fishers was 24.4%.

**Table 15.** Swedish recreational catches for 2005 (Anon., 2005d), both the originally reported amount and the amounts adjusted for willingness to participate based on fishing interest. The difference was used to adjust for overestimation of catches in the studies from 1995 and 2000. The west coast adjustment is based on Anon. (2007b), and was used to exclude west coast catches.

Common name	Recreational catch (t)		Adjustment factor	West coast adjustment
	Original	Adjusted		
Atlantic cod	1,730	1,127	1.54	0.78
Herring	3,454	2,043	1.69	0.87
Atlantic mackerel	2,851	1,313	2.17	0.00
Atlantic salmon	569	318	1.79	0.87
Cyprinids nei	380	128	2.97	0.87
Edible crab	1,258	355	3.54	0.00
European eel	388	183	2.12	0.87
European perch	2,360	1,346	1.75	0.87
European whitefish	911	578	1.58	0.87
Flatfish	954	621	1.54	0.81
Lobster	228	189	1.21	0.00
Mussels	76	47	1.62	0.00
Northern pike	2,236	1,294	1.73	0.87
Other cod fish	364	242	1.50	0.00
Sea trout	729	461	1.58	0.72
Other species	896	395	2.27	0.79
Fishers	1,800,000	1,400,000	1.29	n/a
Fishing days	29,000,000	22,000,000	1.32	n/a

The above recreational surveys were used to derive effort estimates (number of fishing days per fisher per year), and a recreational catch rate per fisher per day. The number of recreational fishing days in 1975 was 25 million, which implies that the average number of fishing days per fisher in 1975 was 12.5. The recreational catch in 1975 was 13,334 t, which gives a catch rate of  $0.00053 \text{ t} \cdot \text{fisher}^{-1} \cdot \text{day}^{-1}$ . The 1975 number of fishing days and catch rate per fisher were carried back fixed to 1950. Thus, the recreational catch per year from 1950-2007 was estimated as the product of estimated number of recreational fishers, their average fishing time in days, and daily catch rate. The species specific catch for each study was used to derive a fraction of total recreational catch per species where it was possible. These fractions were then interpolated and applied to the calculated total recreational catch.

For the 2011-2014 update, Statistics Sweden provided data for 2013 recreational catch in Swedish waters (2014). While Statistics Sweden differentiates between marine and freshwater recreational catch, they do not indicate which ICES subarea catch originated from. Reported national recreational

catch from 2013 was therefore split between sectors 24-31 according to the average split between those areas from 1950-2010. While previous reconstructions have assigned catch to areas 22, 23, and 32, that catch was assigned to “Outside of EEZ”, and those areas were therefore not included in the 1950-2010 catch split. For the years 2011-2012, a linear interpolation was performed for each taxon between the 2010 reconstruction and the 2013 national data, unless the taxon was not present in the 2010 reconstruction but was present in the 2013 data. In those cases, the catch was simply reported in the year 2013 and not added in the years 2011 or 2012. For 2014, a linear projection was performed for species that were in both the 2010 reconstruction and 2013 data to carry forward the trend. For species that were present in the 2013 data but not the 2010 reconstruction, 2013 statistics were simply held constant for the year 2014.

## Results

The recreational catches of cod were relatively low, except possibly during the 1990s when the total estimated decadal recreational catch was around 32,600 t. According to the available information, which does not include the cod-boom 1980's, the historically highest annual recreational catch of cod was around 3,600 t in 1996.

Prior to 1980, the unreported landings, discards, and recreational catches of herring were relatively small (averaging 3,600, 1,400, and 1,000 t·year<sup>-1</sup>, respectively). During the 1980s and the 1990s, unreported landings of between 7,000 and 21,800 t·year<sup>-1</sup> made up a substantial proportion of the unaccounted herring catches. In recent years the unreported herring landings were around 6,300 t·year<sup>-1</sup>.

The estimated recreational catches of herring were small for the whole time period, with peak catches in 1994 of about 3,900 t·year<sup>-1</sup>. For the most recent period (2000-2007), recreational catches averaged around 2,200 t·year<sup>-1</sup>.

The estimated recreational catches of salmon increased steadily from 20 t in 1950, to the peak catches of about 300 t in 2002. Thereafter, recreational catches declined to about 140 t in 2007.

Estimated recreational flatfish catches made up a substantial part of the reconstructed likely total catch. The average recreational catches were 600 t·year<sup>-1</sup> prior to 1980, 1,600 t·year<sup>-1</sup> during the 1980s, and 2,400 t·year<sup>-1</sup> during the 1990s when they peaked. In recent years (2003-2007), the estimated recreational catches were, on average, 500 t·year<sup>-1</sup>.

The estimated total recreational sea trout catches were more than 8 times larger than ICES landings statistics suggested for 1950-2007. Estimated recreational catches increased from around 130 t in 1950 to a peak of about 730 t in 1975, before declining during the 1980s. In the most recent years, recreational catches declined to around 230 t by 2007.

Due to the substantial recreational catches of sea trout, the total estimated reconstructed catches were about 10 times larger than ICES landings statistics from 1950-2007, and almost 12 times larger for the most recent 2003-2007 period.

The estimated recreational catches of eel were larger than both unreported landings and discards combined, and made up a substantial part of IUU catches. The largest recreational catches were taken during the 1970s with average catches of 460 t·year<sup>-1</sup> (55% of ICES landings statistics in the

1970s). Between 2000 and 2006, before the regulation of eel fishing in 2007, the recreational catch was on average 210 t·year<sup>-1</sup>, equaling approximately 70% of reported ICES landings for 2000-2006.

The estimated recreational whitefish catches were very large compared to reported landings, being about 4.5 times larger than reported landings from 1950-2007. Recreational catches increased from an estimated 300 t in 1950 to a peak of 1,600 t in 1975. Thereafter, the recreational catches declined from an average of 1,500 t·year<sup>-1</sup> in the 1970s to annual catches of around 1,000 t·year<sup>-1</sup> during the 1990s. The recreational catches declined even more during the 2000s to about 500 t·year<sup>-1</sup>.

The estimated recreational catch was about 0.6 million t from 1950-2007, which was 7% of the estimated total reconstructed catches. Recreational fishing in Sweden is one of the biggest recreational activities and for some species the recreational catch is several times larger than the commercial landings (Anon., 2007a). If one excludes the three major commercial species, cod, herring, and sprat (which account for 94% of reported ICES landings statistics), the recreational catches made up nearly 50% of the remaining total reconstructed catches, none of which is appropriately represented by ICES data. Similar recreational contributions to total catches have been reported in the USA (e.g., Coleman et al., 2004). Even though the recreational part of catches is often substantial, the data on recreational fishing in Sweden are very poor, especially prior to 2006. Hence, better data are needed for recreational fisheries, including species- and area-specific catch and effort data. These could possibly be obtained through well designed, country-wide surveys, conducted at least every 3-5 years, with all data for intervening years being interpolated. Emphasis should also be placed on incorporating these data (surveyed and interpolated) in all annual reports to ICES.

## Sweden (West Coast)

The original technical reconstruction research was initially documented in Persson (2015), and was updated to 2014 by the *Sea Around Us*.

### Methods

Swedish national studies from 1977 (SOU 1977), 1995 (Nilsson 1996), 2000 (Norström et al. 2000), 2005 (Anon. 2005a), and 2007 (Anon. 2007c), were used to derive anchor points for recreational catches. The studies were not equally reliable due to variations in study- and analytical methods. The 1977 study (SOU 1977) was deemed to be reliable due to a large sample size, and the values were used without adjustments. The study from 2007 (Anon. 2007c) was also deemed reliable due to analyze and study method and values were used without adjustments. The studies from 1995 (Nilsson 1996), 2000 (Norström et al. 2000), and 2005 (Anon. 2005a) were adjusted for overestimation and also split into different catch areas (see Persson 2010), based on the ratio in the 2007 study (Anon. 2007c). Swedish population data from Statistics Sweden (available at [www.scb.se](http://www.scb.se), accessed October 2012) and a calculated catch rate were used to extrapolate the non-commercial catch to 2010.

Information about recreational cod catches of the same magnitude as the coastal fisheries (minus trawl catches) was found in Phil and Ulmstrand (1988). Between 1980 and 1986, this information replaced the interpolated recreational cod catches.

To separate subsistence and recreational catches the ratio of handheld gear and other gear types was used. Recreational fishing was defined as fishing carried out with handheld gear with relaxation and pleasure as the main driver, while subsistence fishing was defined as fishing with other types of gear and self- or family-consumption as the main driver rather than pleasure only. Some fishers use both handheld and other types of gear, and some subsistence fishing is carried out with handheld gear, but this method for separating catches was assumed to be the best given the information available. For 1975, the ratio was about 40% recreational and 60% subsistence (SOU 1978). In 2006, it was about 70% recreational and 30% subsistence fishing (Thörnqvist 2009). As the recreational part of the catches has been increasing over time (SOU 1978; Thörnqvist 2009), 30% recreational and 70% subsistence catches were therefore assumed as anchor points for 1950. It should be noted that 85% of the catch in both recreational and subsistence fisheries was used for home consumption (Thörnqvist 2009).

For the 2011-2014 update, recreational and subsistence catch were extrapolated to 2014 while maintaining the 70%-30% split between recreational and subsistence catch, respectively.

## Results

The reconstructed total catch for Sweden within the EEZ in the North Sea, 1950-2010 of 1.5 million t was 29% higher than the ICES reported landings for the same time period and area. Total catches were estimated to be over 29,000 t·year<sup>-1</sup> in the 1950s, compared to the just under 25,000 t·year<sup>-1</sup> reported by ICES. Reconstructed total catches peaked in the mid-1960s and early 1990s with an average of 47,000 t·year<sup>-1</sup> and over 46,000 t·year<sup>-1</sup>, respectively. Comparative reported catches from ICES for those time periods were only 39,000 t·year<sup>-1</sup> and just under 35,000 t·year<sup>-1</sup>, respectively. Catches have decreased drastically in the last decade, with reconstructed total catches averaging 9,000 t·year<sup>-1</sup> in 2009-2010, and an average of 6,700 t·year<sup>-1</sup> reported by ICES for the same years. The unreported commercial catches accounted for 49% of the difference for the 1950-2010 time period (unreported landings 40% and discards 9%). Recreational and subsistence catches accounted for the rest with 24% and 27%, respectively.

The industrial sector made up 69% of the reconstructed total catch. The artisanal sector contributed 19% to the reconstructed total catch, and recreational and subsistence accounted for 5% and 6% of the remaining catches, respectively.

Recreational catches increased from 340 t in 1950 to 2,470 t in 1975. Catches declined gradually until 1990 and then shot back up to a peak of 2,700 t in 1999. Catches have decreased since to 1,260 t in 2010.

## Syrian Arab Republic

The original peer reviewed reconstruction research was initially documented in Ulman et al. (2015a), and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational fishing is defined here as fishing primarily for pleasure without the intention for commercial sale. Subsistence fishing is defined here as catch for self- or family-consumption, as fish

prices are high in Syria<sup>21</sup>. Since the reported data only include commercial sectors, the amount of fish caught for pleasure and/or self-consumption has gone unreported. In Syria, a license is required to fish recreationally either from a boat or the shore (Gaudin and De Young 2007). The recreational fishing sector is limited to angling, and is to use a maximum of three hooks per fishing line. In 2006, 148 marine recreational licenses were issued.

To conservatively account for recreational and subsistence catches, we assumed that these two sectors amounted to the equivalent of 5% of total reported and unreported commercial landings. For 1950, we assumed that 80% of the combined recreational/subsistence catches represented the subsistence sector, and 20% the recreational sector. In 2010, the opposite was assumed, with 20% being subsistence, and 80% recreational. Percentages were interpolated for intervening years. The taxa allocated to these catches were mullet (*Mullidae*, 40%); bonito (*Sarda sarda*, 30%); common pandora (*Pagellus erythrinus*, 20%); and seabream (*Sparidae*, 10%).

For the 2011-2014 update, recreational fishing in Syria has likely ground to a halt due to the civil unrest, while those subsistence fishers that continue their activities may be experiencing higher levels of catch due to the drop in fishing pressure by commercial and recreational fishers. Recreational fishing had been calculated as 4% of total commercial fishing catches in 2010: this percentage was halved to 2% for 2011, halved again for 2012, and reduced to 0% for 2013 and 2014. Subsistence fishing rates per capita for the coastal rural population was calculated for 2010: this per-capita rate was increased by 10% per year and multiplied by the coastal rural population of 2011-2014 to obtain an estimate of subsistence fishing catches for those years.

## Results

Recreational catches were low, but increased slightly over the time period from approximately 9 t · year<sup>-1</sup> in the early 1950s to about 240 t · year<sup>-1</sup> in the late 2000s.

Total catches in Syria were dominated by the artisanal sector with almost 67%. Industrial, recreational, and subsistence catches accounted for 29%, 3%, and 2%, respectively.

## Taiwan

The original technical reconstruction research was initially documented in Divovich et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

To estimate catch from recreational fisheries, we utilized data by Cisneros-Montemayor and Sumaila (2010) who estimate a participation rate in recreational fishing of 0.3067% of the population for Eastern Asia. We assumed that the recreational fishery in Taiwan began in 1985, with the participation rate growing from 0% in 1984 to 0.3067% by 1990 and thereafter remaining constant. We applied the participation rate to a time series of Taiwanese population. For the per capita catch rate in the recreational fishery, we made a similar assumption as in Pauly and Le Manach (2014) that each recreational fisher catches 1 kg·month<sup>-1</sup>, equivalent to 12 kg·year<sup>-1</sup>.

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<sup>21</sup> <http://stats.oecd.org/glossary/detail.asp?ID=2600>

This per capita catch rate was multiplied by the population time series of recreational fishers to obtain a time series of recreational catch. We assumed ‘marine fishes nei’ accounted for 50% of the catch, and the remaining 50% were equally split between 10 commonly targeted species in recreational fishing: large yellow croaker (*Larimichthys crocea*), small yellow croaker (*Pseudosciaena polyactis*), yellow drum (*Nibea albiflora*), red seabream (*Pagrosomus major*), red porgy (*Pagrus pagrus*), blackhead seabream (*Acanthopagrus schlegelii*), Japanese seaperch (*Lateolabrax japonicus*), Korean rockfish (*Sebastes schlegelii*), highfin grouper (*Epinephelus maculatus*), and other groupers (Serranidae).

Recreational landings were updated to 2014 using updated population statistics from Taiwan’s national Statistical Bureau<sup>22</sup> multiplied by a participation rate of 0.3067% and a per capita catch rate of 12 kg/year as described by the original reconstruction.

## Results

Total reconstructed catch within FAO Area 61 by Taiwan was 55% higher than the 23.2 million tonnes of catch FAO reported on behalf of Taiwan from 1950-2010. The difference of 12.8 million t between the two time series is predominantly composed of unreported commercial catches (63.8%), followed by discards (26.5%), subsistence catch (9.5%), and recreational catch (0.2%).

## Thailand

The original technical reconstruction research was initially documented in Teh et al. (2015), and was vetted and updated through peer-review in Derrick et al. (2017).

## Methods

Recreational fishing is performed by both tourists and Thai anglers. The approximate catch from recreational fishing was estimated by multiplying the number of recreational fishers by an average catch rate. Coastal recreational fishing by tourists and Thai citizens were estimated separately from “big game” fishing for tuna and billfishes.

Recreational fishing by locals was assumed to begin in 1980. In a global study of marine recreational fishing, the average participation rate of recreational fishers in Asia was 18.2% (Cisneros-Montemayor and Sumaila, 2010). Because most of Thailand’s recreational fishing is performed by tourists, and to remain conservative, the national participation rate was assumed to be half the rate estimated by Cisneros-Montemayor and Sumaila (2010), i.e., 9.1% for 2010. Because recreational fishing is unlikely to be undertaken by people living under the poverty level (who would engage in subsistence fishing, see above) or far from the coast, local recreational catch per year  $n$  from 2010-2014 was estimated as:

$$C_{\text{local},n} = (P_{\text{coastal}} - P_{\text{poverty}})_n * T * C_t$$

Where  $C_{\text{local},n}$  is local recreation catch in year  $n$ ,  $P_{\text{coastal}}$  is the number of people living within 100 km from the coast,  $P_{\text{poverty}}$  is the number of people living under the poverty level (UNCTAD, 2012),  $T$  is the participation rate (here 9.1%), and  $C_t$  is the average annual recreational catch rate (kg·fisher<sup>-1</sup>

<sup>22</sup> <http://eng.stat.gov.tw/lp.asp?ctNode=2265&CtUnit=1072&BaseDSD=36>

·year<sup>-1</sup>). The number of recreational fishers for each year  $n$  prior to 2010 was estimated by adjusting the number of recreational fishers for year  $n$  by the relative changes to Thailand's per capita annual average GDP growth from year  $n-1$  to year  $n$ . GDP values were obtained from the United Nations Conference on Trade and Development (UNCTAD 2012). No estimates of Thailand's per fisher recreational catch rates were found and so the recreational catch rate estimated for Malaysia (7 kg·fisher<sup>-1</sup>·year<sup>-1</sup>) was used as it was expected to be similar in Thailand (Teh and Teh, 2014). This catch rate was assumed constant from 1980 to 2014.

Recreational fishing by tourists was assumed to have only begun in earnest in 1990 (Kontogeorgopoulos 1998). The number of coastal tourists that fish was multiplied by a tourist recreational catch rate for 1990–2014. The total number of tourists that participated in recreational fishing was determined for 2007 by multiplying the number of fishing operators by the number of clients per trip and number of fishing trips taken per year. In 2007, the number of big game operators and coastal fishing operators were assumed to be the same. An average of 22 big game operators was estimated for the Andaman Coast and half as many in the Gulf of Thailand based on available anecdotal accounts<sup>23</sup> Based on written reports and photos of tourist coastal fishing trips, an average of 4 clients per trip was assumed. Coastal fishing operators were assumed to run five fishing trips per week during peak months of November to March and half as many during non-peak months.

Estimates of tourist arrivals to Phuket for 1989–2005<sup>24</sup>, 2008–2010<sup>25</sup> and 2014<sup>26</sup> were obtained and linear interpolation was used to estimate years without data. The change in tourist arrivals per year was used to estimate the number of coastal tourist fishers before and after 2007. Catches varied widely from 0 fish to 40 tunas caught by 7 participants in a single day<sup>27</sup>. As a result, a likely conservative catch rate of 3 kg·fisher<sup>-1</sup>·trip<sup>-1</sup> was assumed for 1990–2014, assuming each tourist who fished participated in one fishing trip per year.

Recreational catch composition was different for big game fishing and coastal fishing trips. Big game catches included marlins and sailfishes (Istiophoridae), tunas (Scombridae), dolphinfish (*Coryphaena hippurus*), barracudas (Sphyraenidae), and giant trevally (*Caranx ignobilis*) based on reports from fishing trips. Coastal recreational catch was composed of Scombridae, Carangidae, Sphyraenidae and demersal fish including Serranidae, Lutjanidae, Nemipteridae, Holocentridae, Lethrinidae and Dasyatidae. All taxa were assigned equal proportions except for Scombridae and demersal fish taxa, which were weighted double because catches were likely more common.

## Results

Reconstructed total catches increased from just over 400,000 t·year<sup>-1</sup> in 1950 to a peak of nearly 10 million tons in 1996, before declining to just over 5.5 million t·year<sup>-1</sup> by 2014. Of the total reconstructed catch, 84% was attributed to the industrial sector, approximately 5% of which was

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<sup>23</sup> <http://megafishingthailand.com/guided-fishing-in-thailand/deep-sea-fishinggulf-of-thailand-koh-chang-koh-kut/>

<sup>24</sup> [http://phuketland.com/phuket\\_links/touristinfo.htm](http://phuketland.com/phuket_links/touristinfo.htm)

<sup>25</sup> <http://www.c9hotelworks.com/press-best-year-ever-for-phuket-tourismarrivals.htm>

<sup>26</sup> <http://www.thephuketnews.com/phuket-sees-over-seven-per-cent-increase-intourist-arrivals-on-2014-51903.php>; <http://www.c9hotelworks.com/downloads/phuket-hotel-market-update-2014-09.pdf>

<sup>27</sup> [http://www.tripadvisor.com/ShowUserReviews-g1389361-d1873466-r126026076-Phuket\\_Fishing\\_Charters\\_Chalong\\_Phuket.html#REVIEWS](http://www.tripadvisor.com/ShowUserReviews-g1389361-d1873466-r126026076-Phuket_Fishing_Charters_Chalong_Phuket.html#REVIEWS)

discarded, 16% was assigned as small-scale fisheries (artisanal and subsistence) and less than 1% was deemed from recreational fishing. The industrial, artisanal, subsistence and recreational sectors contributed 154, 14, 12, and 0.3 million tons of unreported landings respectively, while 13 million tons were discarded over the entire time period.

## Togo

The original technical reconstruction research was initially documented in Belhabib et al. (2010), and was updated to 2014 by the *Sea Around Us*.

### Methods

While growing up in Togo, V.K did not observe significant recreational fishing activities; however a few recreational fishing clubs were created by expatriates, notably during the last 16 years. Three clubs were documented, the first in 1997, the second in 2004 and the third in 2007 (FAO 2007b). These clubs often sell their catches to restaurants. We assumed that the number of fishers per club was 20, i.e., that they was a total of 20 fishers in 1997, 40 fishers in 2004 and 60 fishers in 2007. We extrapolated the trend and estimated the number of recreational fishers at 68 for 2010. We assumed the number of trips to be 4 per month (i.e., one day per week end) during six months of the year corresponding to the dry season (24 trips·fisher<sup>-1</sup>·year<sup>-1</sup>). We estimated the CPUE based on four YouTube videos posted by recreational fishers/clubs from Togo, which showed the species caught and the number of recreational fishers (5). We approximated the weight for each species, then estimated the mean CPUE as 13.6 kg·fisher<sup>-1</sup>·trip<sup>-1</sup>. We multiplied the number of fishers by the number of trips and the CPUEs and obtained a catch of 6.5 t for 1997, 13.1 t for 2004, 19.6 t for 2007 and 22.2 t for 2010. We interpolated linearly assuming recreational fishing began after the last coup d'état in 1967, which was followed by a certain political stability. We obtained the species breakdown by averaging the total catch by species by the total for all species (by all fishers), i.e., 515 of wahoo (*Acanthocybium solandri*), 21% of groupers (Fam. Serranidae), 7% of Carangidae, 7% of Muraenidae, 7% of dolphinfish (*Coryphaena hippurus*) and 7% of other species.

Recreational fisheries were updated using the original methods. The percentage of recreational fishers in the total Togolese population for 2010 was used to estimate recreational fishers for 2011-2014. The number of recreational fishing trips per fisher per year in 2010 and CPUE for 2010 were held constant for 2011-2014. The 2010 taxonomic breakdown of recreational landings and subsistence landings was assumed to remain constant for 2011-2014.

### Results

Recreational catches were estimated at 287 t between 1950 and 2010. Recreational catches increased from zero in 1967 to 22 t in 2010 and included mostly wahoo, carangids and groupers.

## Trinidad and Tobago

The original technical reconstruction research was initially documented in Mohammed and Lindop (2015c), and was updated to 2014 by the *Sea Around Us*.

## Methods

Sector disaggregation for Trinidad's industrial, semi-industrial and artisanal fleets, including landed by-catch and discards of the shrimp industry, and tournament recreational fishing, as well as for the artisanal fleet for Tobago, were provided by Mohammed and Chan A Shing (2003) for the period 1950-2001. To estimate the catch in each sector for 2002-2010, the average contribution of each to the total catch in 1997-2001 was applied to the estimated total for each year.

### Domestic

#### Taxonomic breakdown

Mike and Cowx (1996) reported on the domestic recreational fishery in Trinidad and Tobago and estimated that in 1992, 1,000 t of fish were caught in the north-west Trinidad domestic recreational fishery. This was used as an anchor point and it was assumed that 1,000 t·year<sup>-1</sup> remained the catch until the end of the time period; it was also assumed that 100 t was caught by recreational fishers in 1950. Catch totals were interpolated between 1950 and 1992 to estimate landings for the intervening years. Mike and Cowx (1996) also reported that many of the fish caught were sold and estimated the proportion sold in each taxa. We used this as a proxy for the catch composition and the percentages were normalised to give a species breakdown sector, which was applied to the estimated total for each year. Again, this is considered to be a conservative estimation for the total fish caught recreationally in the islands.

### Tourist

Recreational participation in Antigua and Barbuda was found to be 0.23% of the total population (Cisneros-Montemayor 2010) and the same rate was assumed to be true of tourists in Trinidad and Tobago. Tourist arrivals data were only available from 1995, 1 so estimated tourist numbers for 1950-1994 were calculated by interpolating from 260,000 tourists in 1995 to an assumed 0 tourists in 1945. Recreational participation was then calculated by applying the 0.23% participation rate to the tourist numbers. Ramdeen et al. (2014) estimated a consumption rate of 0.001 t·tourist<sup>-1</sup>·year<sup>-1</sup> for the British Virgin Islands, which we assumed to be the same for Trinidad and Tobago and applied it to the estimated participation total for each year 1950-2010 to obtain a recreational catch for both islands combined.

#### Taxonomic breakdown

The catch composition for the tourist recreational fishery was calculated using the same methods as for the domestic recreational fishery.

#### Tournament recreational fishing taxonomic breakdown

The average species contribution for the years 1997-2001 was applied to the estimated 2002-2010 totals for the tournament fishing calculated above.

The 2006-2010 average ratio of total reconstructed catches to reported catches was used to estimate the unreported catches for 2011-2014. These unreported catches were split between the EEZs of Trinidad & Tobago and Venezuela, between landings and discards, and between sectors

according to the average proportion of unreported catches assigned to each between 2006 and 2010.

## Results

Total reconstructed catches by Trinidad and Tobago between 1950 and 2010 were 2.6 times larger than those reported to the FAO over the same period. The catches were dominated by the artisanal sector, which made up 37.7% of the overall catch, followed by the landings of the subsistence and industrial sectors, with 26.5% and 7.9%, respectively. The recreational sector contributed 4% of the total catch.

Catches in the recreational sector increased steadily from 100 t in 1950 to a peak of 1,000 t in 1992 and plateaued thereafter.

In Trinidad alone, artisanal landings were again most important, contributing 37%. Subsistence fisheries made up 28.6%, with recreational fisheries making up 4.5%. Industrial landings were 7.1% of the total, with discards contributing 22.7%.

Artisanal fisheries in Tobago made up 71.7% of catches, with subsistence contributing 28.2%. Recreational fisheries made up less than 0.1%.

## Tunisia

The original technical reconstruction research was initially documented in Halouani et al. (2015) and was updated to 2014 by the *Sea Around Us*.

### Methods

With the sophistication of the recreational fishing gears, which became cheaper and more affordable to a wider public, the recreational fishery in Tunisia is gaining in popularity. However, there is almost no data or studies on fisheries catches by this sector. The most important organization of the recreational fishery is the Tunisian Federation of Sport fishing, which was created in 2005 for better controls and regulations, as well as promotion of activities within the sector, e.g., underwater fishing, line fishing, etc. This organization thus became a hub for recreational fishing clubs of the country ([www.ftps.org.tn](http://www.ftps.org.tn)). To estimate recreational fishery catches, we used information from previous works on recreational fishing in Tunisia, surveys of recreational fishers, as well as information provided directly by the Tunisian Federation of Sport Fishing.

Based on the number of recreational fishers who are members of Tunisian recreational fishing clubs in 2013 and on the recreational fishing effort, i.e., numbers of trips per season and mean catch per trip, we estimate the recreational catch for the year 2013, when the fishing clubs had 3,000 members (Tunisian Federation of Sport fishing pers. comm.). Earlier catches were interpolated between the 2013 estimate and a catch of zero in 1960, assuming that recreational fishing started in the early 1960s.

There are two different fishing seasons for this sector: summer (June/July/August) and “non-summer”. Recreational fishers go fishing on average twice a week in summer and once a month in “non-summer”. However, on average each fisher returns empty-handed following 3 trips out of 5 in

summer and 1 trip out of 5 in “non-summer”. During the trips where there are catches, the average catch amount per trip per fisher in summer is 3.5 kg and in “non-summer” 1.8 kg (Khalfallah 2013). Following Khalfallah (2013), we consider (A) number of recreational fishers in 2013; (B) number of trips per fisher in summer; (C) number of trips per fisher in “non-summer”; (D) recreational catch amounts per trip per fisher in summer; (E) recreational catch amounts per trip per fisher in “non-summer”; and (F) total estimated recreational catch amounts in 2013, i.e.,  $F = A \cdot [(B \cdot D) + (C \cdot E)]$ .

The taxonomic disaggregation of artisanal discards and recreational catches, which includes individual species, was pooled to the family level. Then, the percentage of each family was applied to the artisanal catches for the 1950-2010 time period, while the percentages of families for the recreational catches were adjusted according to the popularity of some species of fish among recreational fishers.

Recreational fishing was estimated for 1960, when recreational fishing began in Tunisia, to 2010 by linearly interpolating from zero to a data point from 2013. This linear trend was continued for 2014.

## Results

Reconstructed total catch was dominated by the industrial sector with 66%, followed by artisanal (34%) and recreational (0.1%).

## Turkey

The original peer-reviewed reconstruction research was initially documented in Ulman et al. (2013), and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational catches have never been included in the collection of fishery statistics for Turkey. The first study of recreational fisheries activities in Turkey by Ünal et al. (2010), from the Çanakkale region, provided valuable insight and data; specifically, the number of recreational fishers, catch rates, and species composition.

At a recent workshop of the General Fisheries Commission for the Mediterranean (GFCM) on recreational fisheries (GFCM 2011), a standardized definition of recreational fishing was produced. In this definition recreational fisheries are: “Fishing activities exploiting marine living aquatic resources from which it is prohibited to sell or trade the catches obtained.” Subsistence fishing is generally understood as the exploitation of marine aquatic resources for personal consumption (stats.oecd.org/glossary). Subsistence and recreational fishing are not easily separated into distinct categories but rather form part of a continuum. Here we estimate these components separately but recognize that catches from one sector may encompass some catches of the other. Subsistence fishing (for necessity) developed into recreational fishing (for leisure and to supplement the diet) as social and economic conditions evolved. Although the legal framework for these sectors is defined in ‘Fisheries Law No. 1380 Aquaculture and Fisheries Communiqué’, the majority of fishers in these sectors are unaware of these rules. Anyone can obtain an Amateur Fishing Certificate, although it is not legally required in order to fish, which leads to incapacity of monitoring this sector (M. Zengin, unpublished data). Here we estimate recreational and subsistence fisheries catches for Turkey using a detailed

account of fishing in Çanakkale (Ünal et al., 2010) in combination with assumption-based estimates to expand this estimate to the entire country.

### Çanakkale

Çanakkale, with a population of 70,000, is increasingly becoming a popular coastal city for both recreational and commercial fisheries. In the Ünal et al. (2010) study, 190 recreational fishers were surveyed, and then total catches were scaled up to reflect total catches of the recreational fishers in the region. The percentage of recreational fishers from this region was found to represent 9.9% of the population and their average number of recreational fishing days was 77 per year. Their catch rate resulted in an average of  $0.645 \text{ t} \cdot \text{fisher}^{-1} \cdot \text{year}^{-1}$ . The study also suggested that most recreational fishers are neither subsistence nor 'true sport' fishers, since 45% of shore-based, 73% of underwater fishers and 75% of boat-based recreational fishers sell their catches. Conflicts often arise between commercial and recreational fishers for this reason (ICES 2006). The total number of recreational fishers estimated for this study was greater than the reported number of commercial fishers (6,922 and 5,987, respectively).

The total human population of the region was obtained from Populstat data ([www.populstat.info](http://www.populstat.info)) for the period 1950-2010, and the data were interpolated between the closest available years. The annual population amount was divided by 9.9%, to represent the percentage of fishers in the study (Ünal et al., 2010), which was then multiplied by the calculated catch rate to get annual recreational catch totals. The catch rate per fisher for 1950 was obtained by doubling the catch rate for 2010, which yielded  $1.29 \text{ t} \cdot \text{year}^{-1}$ , the intermediate values were then obtained by interpolating linearly to the 2010 values ( $0.645 \text{ t} \cdot \text{year}^{-1}$ , see above). This higher catch rate in the past was attributable to higher fish abundances and also larger mean fish sizes resulting from less competition in 1950. Recreational catches were assigned taxonomically using the same species composition as the Ünal et al. (2010) study.

### İstanbul

İstanbul is, by far, the most populated city in the country. From 1950 to 2010, the city of İstanbul has grown in population from 1.18 million people to 13.3 million people ([www.turkstat.gov.tr](http://www.turkstat.gov.tr)), and it is now the 22nd largest city in the world.

İstanbul has thousands of anglers fishing daily on the Bosphorus Strait, which is a very prominent fishing corridor. Many pelagic stocks make their annual migrations from the Aegean Sea, through the Sea of Marmara and then the Bosphorus Strait, to the Black Sea, and return via the same route back to the Mediterranean Sea. To calculate the number of recreational fishers for this area, the assumption that 1% of the population fishes recreationally was used (S. Bekişoğlu, pers. obs.), changing with population trends over time so that in 1950, İstanbul had an estimated 11,665 recreational fishers, and in 2010 an estimated 129,000 recreational fishers.

In earlier years, fishers in İstanbul were richly rewarded for their efforts. An angler could finish a fishing 'day' in one hour in the 1960s, and each fish weighed between 4-6 kg (M. Ulman, pers. comm.). The average catch rate at present is about  $1 \text{ kg} \cdot \text{fisher}^{-1} \cdot \text{day}^{-1}$ , although considerable day-to-day variation occurs (A. Safahi, pers. comm., recreational angler from İstanbul). In 1950, we conservatively assumed a catch rate of  $2 \text{ kg} \cdot \text{day}^{-1}$  (due to more abundant fish stocks, and less

overall fishing pressure). A linear interpolation was used to derive a time series of catch rates from the 1950 rate of  $2 \text{ kg} \cdot \text{person}^{-1} \cdot \text{day}^{-1}$  and the rate in 1999 of  $1 \text{ kg} \cdot \text{person}^{-1} \cdot \text{day}^{-1}$ . The 1999 catch rate was held constant to 2010. The increasing population of İstanbul and associated increase in fishing effort likely resulted in lower catch rates per person, due to lowered abundance and the availability of smaller-sized fish, which is reflected in our assumption based estimated catch rate. We assumed the same number of fishing days per year as presented in Ünal et al. (2010) of 77 fishing days  $\cdot \text{year}^{-1}$ . Although higher catch rates ( $5 \text{ kg} \cdot \text{day}^{-1}$ ) are presented for recreational anglers catching horse mackerel from a Galata Bridge survey (Zengin 2011), experience of fishers and timing of survey likely influenced these high catch rates and, thus, our estimation remains conservative in comparison.

The Çanakkale species breakdown (based on Ünal et al., 2010) was also used to disaggregate the recreational catches of the İstanbul (Bosphorus) fishing area, since both areas share similar taxa.

The entire Turkish coast

Recreational catches

To estimate the number of recreational fishers in Turkey (excluding the Çanakkale and İstanbul provinces, which have been estimated separately), human population data from Populstat data's provincial dataset was used. The population of the coastal provinces in each of the four regions considered here (Black Sea, Marmara Sea, Aegean Sea, and Levantine Sea) was calculated based on census data (as presented by Populstat) for the period 1950-2000. For 2001-2010, the total known population trend was inferred to each coastal region. The percentages of the population living coastally (Çanakkale and İstanbul provinces excluded) ranged from 40.2% in 1997 to 45.0% in 1950.

To account for the number of recreational fishers in the coastal population, we assumed that 2% of the coastal population fishes recreationally in both the Aegean Sea and Levant Sea, to account for less productive seas than the study area, which equals 1/5th the percentage of recreational fishers of the Ünal et al. (2010) study on recreational fishers. For the Sea of Marmara, we assumed 3.3% of the coastal population fished recreationally; and for the Black Sea region, 1% of the coastal population was assumed to recreationally fish since subsistence/ recreational fisheries are known to be much lower in this region. The amount of recreational fishers varied over time along with population trends for each of the provinces.

The recreational catch rates applied to the coastal populations of the Black Sea, Aegean Sea and Levant Sea were one fifth that of the Çanakkale study site, or  $0.129 \text{ t} \cdot \text{fisher}^{-1} \cdot \text{year}^{-1}$  in 2010. The catch rate was doubled to  $0.258 \text{ t} \cdot \text{fisher}^{-1} \cdot \text{year}^{-1}$  in 1950. A linear interpolation between catch rates of  $0.258 \text{ t} \cdot \text{fisher}^{-1} \cdot \text{year}^{-1}$  in 1950 and  $0.129 \text{ t} \cdot \text{fisher}^{-1} \cdot \text{year}^{-1}$  in 2010 was applied.

The catch rate applied to the Marmara Sea was three quarters that of the study site, since the productivity of these regions are more similar, or  $0.483 \text{ t} \cdot \text{fisher}^{-1} \cdot \text{year}^{-1}$  in 1950 (to remain conservative), which was reduced by half in 2010 to  $0.241 \text{ t} \cdot \text{fisher}^{-1} \cdot \text{year}^{-1}$  and the catch rate was interpolated between 1950-2010.

## Taxonomic allocation of recreational/subsistence catches

To allocate recreational/subsistence catches to individual fish species/groups for the Aegean, Marmara and Levant Seas, the species composition from the reported TURKSTAT 1980 commercial catch data was used as a baseline to assign catches to the same percentage of occurrence per species.

Some of these individual species ratios were slightly adjusted after consultation with local experts, fishers and analyzing all the peer-reviewed literature to account for different target species between commercial and recreational fisheries. For example, anchovy and other small pelagics are not caught by the recreational sector (S. Knudsen, pers. obs.), so these were excluded from recreational catches for all seas. For the Black Sea, annual trends in the catch data as well as expert knowledge were used. For the years between 1950 and 1966, the species composition was averaged from the closest available statistical years (1967-1971). Select popular recreationally caught taxa were given a higher allocation percentage for recreational catches (Table 16).

**Table 16.** Taxonomic allocation of recreational/subsistence catches (%) in Turkey, from 1950-2010.

Taxa	1950-1980	1981-2010
<b>Aegean &amp; Levantine Sea:<sup>a</sup></b>		
Grouper (Serranidae)	20	10
European seabass ( <i>Dicentrarchus labrax</i> )	20	10
Common dentex ( <i>Dentex dentex</i> )	5	10
<b>BlackSea:<sup>b</sup></b>		
Bonito ( <i>Sarda sarda</i> )	40 (1950-1968)	3-49 (1969-2010)

<sup>a</sup>From Ünal and Erdem (2009); <sup>b</sup>From S. Knudsen, unpublished data.

For the 2011-2014 update, the recreational and subsistence sector are entirely unreported and were calculated with updated population values multiplied by the 2010 catch rates. Population data were available for two cities (Istanbul and Canakkale)<sup>28</sup> for 2011-2015 and were estimated based on the national population growth trend of 8% since 2010 for other regions (Black Sea, Marmara Sea, Aegean Sea and Levantine Sea coastal populations)<sup>29</sup>. The 2010 taxonomic breakdown of catch from each sector was carried forward unaltered for 2011-2015.

## Results

Total estimated Black Sea recreational and subsistence catches totaled slightly over 77,500 t, or specifically ~39,300 t for the recreational and ~38,200 for the subsistence sectors, for the 1950-2010 period. The portion of this attributed to the subsistence sector was much higher (90%) at the beginning of the study period than at the end (10% in 2010). Recreational catches had the opposite trend, whereby in 1950, they accounted for 10% which increased to 90% by 2010. The dominant species caught in the Black Sea by the recreational sector over the 1950-2010 time period were:

<sup>28</sup> <http://www.citypopulation.de/Turkey-C20.html>

<sup>29</sup> <http://data.worldbank.org/country/turkey>

bonito (28%); Mediterranean horse mackerel (16%); Atlantic horse mackerel (12%); bluefish (7%); grey mullet (7%); and seabream (4%).

The total reconstructed catch for the entire Marmara Sea region for the recreational and subsistence sectors for the 1950-2010 period was ~2.28 million t, or specifically, ~1.28 million t for the recreational and ~1 million for the subsistence sector, for the 1950-2010 period.

The catch is distributed between the three different sub-areas in the following manner: the total reconstructed catch for the recreational sector in the Marmara Sea region (excluding İstanbul and Çanakkale) for the 1950-2010 period totalled ~1.7 million t (75% of the regions total catch); the recreational/subsistence catches for the Çanakkale region for the entire 1950-2010 period totalled nearly ~233,500 t; and the recreational/subsistence catches for the İstanbul region for the same period totalled ~328,300 t.

Recreational catches for the Çanakkale region were dominated by bluefish (15%), picarel (*Spicara smaris* 12%), sea snail (10%), mussel (6.8%), sea cucumber (6.7%), axillary seabream (*Pagellus acarne*; 6.2%), grey mullet (4.6%), horse mackerel (3.6%), gilthead seabream (*Sparus aurata*; 3.35%), Atlantic mackerel (3%), and smooth-hound shark (*Mustelus mustelus*; 2.92%).

The dominant recreationally-caught species in the rest of the Marmara Sea region by the recreational for the 1950-2010 period were: bluefish (15.9%); bonito (7%); Mediterranean horse mackerel (6.9%); picarel (6.5%); chub mackerel (5.9%); mullet (5.4%); sea snail (5.4%); horse mackerel (4.9%); mussel (3.8%); and 'other' marine species (38.3%).

The total reconstructed catch for the recreational and subsistence sectors from the Aegean Sea for the entire 1950-2010 period was ~143,450 t, (on average, 3,700 t · year<sup>-1</sup> in the 2000s). Total recreational catches amounted to ~79,900 t (59%) over the 1950-2010 period, while subsistence catches accounted for ~63,550 t (41%).

The dominant taxa caught in the Aegean Sea by the recreational and subsistence sectors were groupers (13%); grey mullet (11%); seabream (12%); horse mackerel (12%); European seabass (12%); common dentex (11%); bogue (6%); and Mediterranean horse mackerel (5%).

The reconstructed catch for the recreational and subsistence sectors from the Levantine Sea region for the entire 1950-2010 period was ~95,750 t (on average, just over 2,000 t · year<sup>-1</sup> in the 2000s). Total recreational catches amounted to just above 53,500 t over the 1950- 2010 study period, while subsistence catches accounted for ~43,600 t.

The major taxa caught in the Levantine Sea by the recreational and subsistence sectors through the 1950- 2010 period were European barracuda (~14,250 t); grouper (nearly 13,200 t); picarel (just over 12,400 t); common dentex (~9,550 t); European seabass (~9,550); gobies (~7,200 t); shark (~6,150 t); and leerfish (~2,100 t).

#### Turkey as a whole

The estimated recreational and subsistence catches for the 1950-2010 period were just over 2.6 million t. Of this amount 1.45 million tonnes was from the recreational sector and 1.15 million tonnes was from the subsistence sector. Of the total reconstructed catch, the Marmara Sea region

(including both İstanbul and Çanakkale regions) accounted for ~2.3 million tonnes (88%); the Aegean Sea accounted for ~139,000 t (5%); the Levantine Sea accounted for ~251,000 t (10%); and the Black Sea region accounted for ~76,000 t (2%).

The major species caught by the recreational sector throughout the 1950-2010 period were bluefish (~590,000 t); bonito (~288,000 t); Mediterranean horse mackerel (~272,000 t); picarel (~239,000 t); and chub mackerel (~229,000 t). Overall, recreational and subsistence catches as a fraction of total reconstructed catches accounted for nearly 9% of the total reconstructed catch.

## Turks and Caicos (UK)

The original peer reviewed reconstruction research was initially documented in Ulman et al. (2016), and was updated to 2014 by the *Sea Around Us*.

### Methods

Recreational catches are defined here as catches taken for the primary purpose of sport or pleasure. A sport fishery was assumed to have begun with the onset of tourism in 1965. Surveys suggested that 0.02% of all tourists in 2002, and 0.04% in 2004, came to the TCI primarily to fish (TCI Tourist Board, 2003, 2005). From 1965–1980, 0.01% of tourists were assumed to come primarily to fish, from 1990–2002, 0.02%, and from 2004–2013, 0.04%. The percentage of tourists assumed to be recreational fishers was linearly interpolated between the three time-series anchor points. All tourists with a focus on fishing were assumed to catch 10 kg·visit<sup>-1</sup> (visits average 6 days). The following species were allocated at 10% of catches each: bonefish, blue marlin, sailfish (*Istiophorus albicans*), wahoo (*Acanthocybium solandri*), bigeye tuna, blackfin tuna, swordfish (*Xiphias gladius*), shark (Elasmobranchii), barracuda (Sphyraenidae), and dolphinfish (*Coryphaena hippurus*).

For the 2013-2014 update, updated data on stopover tourists and cruise ship tourists were obtained from several sources.<sup>30</sup> The recreational fishing participation rate of 4% of stopover tourists and recreational catch from 2010 were held constant to 2014. Taxonomic breakdowns from the original reconstruction were maintained for domestic and tourist consumption of reef-fish and game fish.

### Results

The main fisheries catch in the TCI was from the artisanal sector, which contributed around 85% to the reconstructed total catch. The artisanal catch consisted mainly of conch (89%) and lobster (6%), while various fish taxa (over 20 taxa) each made minor contributions. The subsistence sector contributed 15% to the reconstructed total catch, and consisted of conch (85%) and lobster (11%), with various fish taxa making minor contributions. The recreational catches contributed only around 0.1%, or about 1,000 t in total, to the reconstructed catch.

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<sup>30</sup> <http://turksandcaicostourism.com/wp-content/uploads/2015/03/Turks-Caicos-Tourism-Statistics-2014.pdf> ; <http://turksandcaicostourism.com/turks-and-caicos-islands-tourism-statistics-2013/> ; <http://www.tcinewsnow.com/headline-Tourist-Board-announces-visitor-arrival-numbers-for-2012-5712.html>

Recreational catches from sports fishing commenced in 1965 with 0.025 t of fish caught, which gradually increased to average 130 t·year<sup>-1</sup> from 2011–2012.

## Ukraine

The original peer reviewed reconstruction research was initially documented in Ulman et al. (2015b), and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational and subsistence fisheries share a common feature: their catch is not sold, or at least is not supposed to be. Here, they are initially estimated as one item, then later disaggregated into fish caught primarily for pleasure (i.e., recreational fishing) and fish caught primarily for household consumption (i.e., subsistence fishing).

An estimated 1 to 3 million people were engaged in either full-time or part-time recreational/subsistence fishing, including freshwater fishing (FAO 2004). Subsistence fishing dominates rural areas, and recreational and sports fishing dominates urban areas with > 1 million inhabitants. The catch of recreational fisheries is partly collected and involve 15 taxa, but these data are incomplete due to monitoring limitations, and represent less than 5% of the fishery.

However, the results showed that in 2006, 54,000 recreational fishers landed a total of 509 t of fish of the 15 taxa monitored, equating to 9.4 kg·fisher<sup>-1</sup>·year<sup>-1</sup> (V. Shlyakhov, unpubl. data).

The Ukraine has the highest coastal population living along the Black Sea coast, estimated at 6.8 million people (Zaitsev and Mamaev 1997), or 15% of the total population. Given the economic situation of the country, the high national unemployment rate and Ukraine's extensive coastline, we assumed that the number of coastal marine recreational/subsistence fishers was 1% of the total population after independence, and 0.25% of the total population from 1950- 1989. The lower proportion of marine recreational/subsistence fishers pre-independence was due to the strict control of the coastal zone by the Soviet regime, thus making access and fishing more difficult (V. Shlyakhov, pers. obs.). The 0.25% rate was linearly increased to 1% from 1990-1992.

This leads to an estimate of about 450,000 recreational/subsistence fishers in 2010, which is much lower than the FAO estimate of 1-3 million (which, however, includes freshwater anglers). We used this estimate of marine recreational/subsistence fishers in conjunction with the only published recreational catch rate per fisher of 49 kg·fisher<sup>-1</sup>·year<sup>-1</sup> for the early 2000s (FAO 2004) to derive a catch estimate. Given the changes in taxonomic assemblages over time in the Black Sea, in which most of the large predatory fish had been removed from the Black Sea ecosystem, the catch rate was increased by 50% for 1950-1970, i.e., to 73.5 kg·fisher<sup>-1</sup>·year<sup>-1</sup>, and was linearly decreased to 49 kg·fisher<sup>-1</sup>·year<sup>-1</sup> by 2000.

To differentiate between recreational and subsistence sectors, it was assumed that for the entire 1950-2010 period, 70% of all estimated recreational/subsistence catches were caught for subsistence purposes (i.e., primarily as a protein source), and 30% of catches were caught for recreational purposes (i.e., primarily for fun or enjoyment).

The catch composition of the recreational and subsistence catches were modified from our artisanal catch composition (V. Shyakhov, pers. obs.), in combination with Turkish western Black Sea catch data to understand when the absence of certain species began. As the Black Sea species composition changed strongly over time, a different taxonomic breakdown was applied for each year (see Table 17), and the amounts were interpolated between 1950 and 2010. Although sturgeon catches were prohibited for the recreational sector, they were still allotted 1% of total recreational/subsistence catches from 1950- 1990 due to the existence of a ‘Black market’ for prohibited species.

Recreational and subsistence fisheries were reconstructed for 2011-2014 as described by the original reconstruction with updated number of fishers calculated based on World Bank population data. The catch rate (49 kg per fisher per year) and taxonomic disaggregation of 2010 were carried forward to 2017. The subsistence and recreational catches were split 30% and 70% respectively for 2011-2014 based on 2010 figures.

**Table 17.** Recreational and subsistence catch allocation for 1950 and 2010, percentages mostly interpolated and adjusted based on expert advice.

Common name of species	Scientific name	1950	2010
		%	%
Bluefish	<i>Pomatomus saltatrix</i>	13	4
Atlantic mackerel	<i>Scomber scombrus</i>	1	0
Mediterranean horse mackerel	<i>Trachurus mediterraneus</i>	15	10
Mediterranean mussel	<i>Mytilus galloprovincialis</i>	14	10
Shrimps	Penaeidae	5	5
European flounder	<i>Platichthys flesus</i>	5	0
Grey mullets	Mugilidae	5	5
Red mullets	Mullidae	5	2
Gobies	Gobiidae	5	20
Whiting	<i>Merlangius merlangus</i>	10	10
Groupers and seabream	Epinephelinae and Sparidae	4	0
Shi drum	<i>Umbrina cirrosa</i>	4	0
Bonito	<i>Sarda sarda</i>	3	1
Garfish	<i>Belone belone</i>	3	0
Dogfish	<i>Squalus acanthias</i>	2	2
Rays/skates	Rajidae	2	2
Turbot	<i>Scophthalmus maetocis</i>	2	2
Sturgeons	Acipenseridae	1	0
Crabs/lobsters	Decapoda	1	0
Sea snail	<i>Rapana venosa</i>	0	7
Pacific mullet	<i>Mugil soiyu</i>	0	20

## Results

Previously unreported recreational landings averaged just over 2,000 t·year<sup>-1</sup> in the early 1950s, peaked in 1992 at 16,500 t, and then decreased slightly, averaging nearly 16,000 t·year<sup>-1</sup> in the late 2000s. The major species caught by the recreational sector for the 1950-2010 period were Mediterranean horse mackerel (14%), gobies (12%), Mediterranean mussel (11%), so-iuy mullet, bluefish, and whiting (each at 10%), and sea snail (6%), with 14 other taxa making up the remaining 27%.

For the Ukraine as a whole from 1950-2010, the sectors which had the highest contributions to the total reconstructed catch were the industrial sector (70%), followed by the artisanal sector (11%), the subsistence sector (7%), the recreational sector (9%), and discards of both the industrial (2%) and artisanal sectors (1%).

## United Arab Emirates

The original technical reconstruction research was initially documented in Al-Abdulrazzak (2013b), was vetted through peer-review in Al-Abdulrazzak et al. (2015) and was updated to 2014 by the *Sea Around Us*.

### Methods

The UAE has a growing recreational fishery, and although (free) recreational fishing licenses are required in Dubai and Abu Dhabi, no data on the number of participants or quantity of catches exist (Morgan 2004). Therefore, to estimate this sector, methods originally developed for Kuwait were used: it was assumed that recreational fishing began in 1960, a 0.12% participation rate was applied to the total population from 1960-2010 to obtain a time series of recreational fishers, and a conservative catch rate estimate of 1 kg-trip<sup>-1</sup>, along with 104 fishing trips per person per year was used to calculate total recreational catch (see Kuwait,(Al-Abdulrazzak 2009)). UAE's recreational fishers target Spanish mackerel, tuna, sailfish and demersal species (Bishop 2002; Morgan 2004) and this species composition was applied in equal ratios to disaggregate the recreational catch.

The telosts *Lethrinus borbonicus*, *Lethrinus microdon*, *Pomacanthus maculosus*, and *Scolopsis taeniata* are caught as incidental and generally discarded bycatch by gargoor targeting emperors, groupers, jacks, and sweetlips (Grandcourt et al. 2010; Morgan 2004). Weizhong et al. (2012) estimate gargoor discard rates to be 2.56%, and this figure was used to extrapolate total discards for the fishery. The species composition was applied in equal ratios among the above species.

Despite the UAE's high GDP, subsistence fishing occurs by the industry's foreign labourers. Foreign fishers make up 0.0046% of the country's total population, and it was assumed that fishers take home an average of 5 kg of fish per week, starting with the oil boom in 1960 until 2010. Because these take home catches are made up of less desirable species (which lack a targeted fishery), the ratios from species discarded from the gargoor fishery was applied.

For the 2011-2014 update the same methods were carried forward.

### Results

For the 1950-2010 time period, artisanal catches accounted for 99.5% of the total reconstructed catch, while the subsistence and recreational sectors contributed 0.05% and 0.45%, respectively.

## United Arab Emirates (Fujirah)

The original technical reconstruction research was initially documented in Khalfallah et al. (2015a), and was updated to 2014 by the *Sea Around Us*.

## Methods

Two types of recreational fishing were considered in this study, i.e., domestic recreational fishing, and recreational fishing by foreign tourists. Their catch was estimated separately then both estimates were added to obtain total recreational catch.

To estimate the domestic recreational catches, i.e., recreational catches by UAE citizens, we converted the total recreational catches for the UAE estimated by Al-Abdulrazzak (2013c) to a per capita catch applied to the whole population of the country for each year, beginning from 1960 (i.e., we assumed UAE citizen began fishing recreationally in 1960). This per capita was then multiplied by the regional population for each year for the period 1960-2010 (Table 18).

To estimate the recreational catches by foreign tourists, we identified the number of recreational fishing licenses obtained by tourists from 2006 to 2010 from the national official reports ([www.uaestatistics.gov.ae](http://www.uaestatistics.gov.ae)) which are assumed to be 'fishing tourists'. The number of tourist fishing licenses was held constant between 2006 and 2010, at 1,311. We assumed that prior to 1960, there was no tourist fishing, and that the increase in foreign tourism was linear from 1961 to 2006. Then, we assumed that each fishing tourist stays an average of two weeks in Fujairah, corresponding to 5 days of fishing with a catch rate of 5 kg·fishing day<sup>-1</sup>.

### Taxonomic disaggregation

For recreational catches, we identified the most commonly targeted fishes by recreational fishing in Fujairah according to Fishfishme Inc., which has one of the biggest online platforms allowing finding and booking charter trips around the world ([www.fishfishme.com](http://www.fishfishme.com)), we assumed their percentages according to their importance and popularity in the region (Table 19). For the 2011-2014 update the same methods were carried forward.

**Table 18.** Data used to estimate domestic and foreign recreational catches (in tonnes) in Fujairah. Values in brackets indicate estimated populations in the years with missing data.

Years	Total UAE Population (A)	Regional population (B)	Recreational domestic national catches (C)	Recreational Domestic catches (D) D=C/A* B	Fishing tourists in Fujairah	Recreational catches by foreign tourists
1960	90,000	(4,823)	11	0.60	(0)	0.0
1961	98,000	(5,252)	12	0.66	(29)	0.7
1962	109,000	(5,841)	14	0.73	(57)	1.4
1963	122,000	(6,538)	15	0.81	(86)	2.1
1964	134,000	(7,181)	17	0.90	(114)	2.9
1965	146,000	(7,824)	18	0.98	(143)	3.6
1966	157,000	(8,414)	20	1.05	(171)	4.3
1967	167,000	(8,950)	21	1.12	(200)	5.0
1968	181,000	9,700	23	1.21	(228)	5.7
1969	201,000	10,000	25	1.25	(257)	6.4
1970	232,000	(10,770)	29	1.34	(285)	7.1
1971	272,000	(11,722)	34	1.47	(314)	7.8
1972	322,000	(12,805)	40	1.60	(342)	8.6
1973	383,000	(13,957)	48	1.74	(371)	9.3
1974	453,000	15,000	57	1.87	(399)	10.0
1975	533,000	16,655	67	2.08	(428)	10.7
1976	623,000	26,500	78	3.31	(456)	11.4
1977	724,000	(28,837)	90	3.60	(485)	12.1
1978	827,000	(30,702)	103	3.84	(513)	12.8
1979	926,000	(31,872)	116	3.98	(542)	13.5
1980	1,015,000	32,189	127	4.02	(570)	14.3
1981	1,091,000	(35,231)	136	4.40	(599)	15.0
1982	1,156,000	38,000	144	4.75	(627)	15.7
1983	1,215,000	(42,983)	152	5.37	(656)	16.4
1984	1,277,000	(48,374)	160	6.05	(684)	17.1
1985	1,347,000	54,400	168	6.80	(713)	17.8
1986	1,427,000	(55,879)	178	6.98	(741)	18.5
1987	1,515,000	(57,464)	189	7.18	(770)	19.2
1988	1,609,000	(59,054)	201	7.38	(798)	20.0
1989	1,707,000	(60,555)	213	7.57	(827)	20.7
1990	1,806,000	(61,850)	226	7.73	(855)	21.4
1991	1,908,000	63,000	238	7.87	(884)	22.1
1992	2,013,000	(65,502)	251	8.18	(912)	22.8
1993	2,121,000	68,000	265	8.49	(941)	23.5
1994	2,232,000	(72,018)	279	8.99	(969)	24.2
1995	2,346,000	76,180	293	9.52	(998)	24.9
1996	2,471,000	(79,424)	309	9.92	(1,026)	25.7
1997	2,609,000	83,000	326	10.37	(1,055)	26.4
1998	2,753,000	(87,059)	344	10.87	(1,083)	27.1
1999	2,894,000	(90,969)	362	11.36	(1,112)	27.8
2000	3,026,000	(94,545)	379	11.83	(1,140)	28.5
2001	3,132,000	(97,263)	393	12.21	(1,169)	29.2
2002	3,224,000	(99,508)	406	12.54	(1,197)	29.9
2003	3,369,000	(103,345)	424	13.02	(1,226)	30.6
2004	3,659,000	(111,547)	457	13.92	(1,254)	31.4
2005	4,149,000	125,698	508	15.39	(1,283)	32.1
2006	4,876,000	(132,667)	582	15.83	1,311	32.8
2007	5,797,000	(139,826)	675	16.27	1,311	32.8
2008	6,799,000	143,000	775	16.29	1,311	32.8
2009	7,718,000	152,000	866	17.05	1,311	32.8
2010	8,442,000	163,751	937	18.18	1,311	32.8

**Table 19.** Assumed catch composition of the recreational fishery of Fujairah.

Scientific name	Common name	%
<i>Istiompax indica</i>	Black marlin	5
<i>Kajikia audax</i>	Striped marlin	5
<i>Istiophorus platypterus</i>	Sailfish	5
<i>Coryphaena hippurus</i>	Dorado	20
<i>Thunnus albacares</i>	Yellowfin tuna	20
<i>Seriola dumerili</i>	Amberjack	10
<i>Sphyrna barracuda</i>	Baracuda	10
Lutjanidae	Red snapper	10
Istiophoridae	Other marlins	5
Others	Marine fishes nei	10

## Results

Until the late 1990s, unreported catches were lower than the reported catches, but this has changed since then, mainly because of the increase of unreported artisanal fishing. Despite the importance of recreational fishing as an attraction for local and international tourists, the recreational catch amounts remain relatively low.

## United Kingdom

The original technical reconstruction research was initially documented in Gibson et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

We use the recreational catch estimates from the reconstruction of Irelands' fisheries (Miller and Zeller 2013). The UK and Ireland are culturally similar and neither has reporting requirements for their recreational catch (Miller and Zeller 2013). Therefore, we consider Ireland to be a good proxy for estimating the UK's recreational catch. In Ireland, 1.76% of the population is considered a marine recreational fisher and 1.84% of the UK's population are marine recreational fishers, therefore our estimate is a conservative one (Pawson et al. 2007). Ireland's total recreational catch by year is converted into a per capita rate and then that per capita rate is applied to total UK population using data from Populstat<sup>31</sup> and Worldbank<sup>32</sup>. The recreational catch for the UK is assumed to exclude the Isle of Man, Jersey and Guernsey because, as dependencies, their populations are likely not included in UK population data.

Once there is a complete time line of total annual recreational catch, the catch is split into 70% whitefish, 10% European flounder (*Platichthys flesus*) and 20% Atlantic mackerel (Pawson et al. 2007). The whitefish catch is split equally between pollock (*Pollachius virens*), Atlantic cod (*Gadus morhua*), whiting (*Merlangius merlangus*), European seabass (*Dicentrarchus labrax*) and Norway pout (*Trisopterus esmarkii*) (Pawson et al. 2007).

For the 2011-2014 update, recreational fisheries were reconstructed following the original reconstruction based on similar participation rates in recreational fishing in Ireland

<sup>31</sup> Populstat <http://www.populstat.info/>

<sup>32</sup> Worldbank <http://www.worldbank.org/>

## Results

Recreational catch for the UK is based on Irish recreational per capita rates. Catch decreases from 20,000 t in 1950 to 3,000 t in 2010. Recreational fishing in the UK is a popular activity, but this popularity has decreased over time. Many species are targeted; however Atlantic mackerel is the most commonly caught (20%). Freshwater angling has remained quite popular over the years; however these species are not included in our estimates.

It should be noted that there is recreational fishing in Jersey and Guernsey but no statistics of catch or licenses so not estimate is made at this time. There is some use of nets and lines for gadids as well as flatfishes and mackerel (Jonathan Shrives, pers. comm., Jersey Department of the Environment). There is also some potting for lobster and crabs in Jersey (Jonathan Shrives, pers. comm., Jersey Department of the Environment).

Unreported commercial landings comprise the largest portion of the reconstructed catch at 17% over the whole time series, with discards representing 7% and recreational catch 2%.

## Uruguay

The original technical reconstruction research was initially documented in Lorenzo et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

A small recreational fishery exists in Uruguay. In a study on global recreational marine fishing participation, Cisneros-Montemayor and Sumaila (2010) approximated the recreational marine fishing participation rate in Uruguay as 0.78% of the population. This translates to 26,000 people in 2003. If we conservatively assume that each person fishes once per month for six months of the year, and catches 1 kg per trip, this would equate to 156 t·year<sup>-1</sup>. We set this as our 2010 anchor point and assume that recreational fishing began in the early 1950s. We interpolate the tonnage from zero tonnes in 1950 to 156 tonnes in 2010 to estimate a time series of recreational catch. It is known that *Micropogonias furnieri*, *Pogonias cromis*, *Brevoortia aurea*, *Mugil platanus*, *Menticirrhus americanus*, and *Macrodon ancylodon* are the main targets of recreational fishing. The relative proportions of these species within the artisanal species breakdown is used as a proxy breakdown for the recreational fishery (Table 20).

For the 2011 – 2014 update, updated population information was available from World Bank and was used to calculate the number of recreational fishers based on the 2010 percentage of the total population that engaged in recreational fishing. The 2010 recreational catch rate was maintained at

**Table 20.** Assumed species composition of the recreational catch.

Species	%
<i>Brevoortia aurea</i>	6.30
<i>Macrodon ancylodon</i>	1.64
<i>Menticirrhus americanus</i>	0.22
<i>Micropogonias furnieri</i>	89.80
<i>Mugil platanus</i>	1.41
<i>Pogonias cromis</i>	0.63

the 2010 level in order to calculate recreational landings for 2011-2014. The taxonomic breakdown of recreational landings was assumed to remain the same as in 2010.

## Results

The reported data does not fully account for the small-scale fisheries, which include the artisanal, subsistence and recreational sectors. Although industrial fisheries account for 90% of the total catch (including discards), artisanal and subsistence fisheries (8% and 2%, respectively) are important for the economic stability and food security of the artisanal fishers. Unreported recreational catches seem a minor contributor to total national catches.

## Virgin Isl. (USA)

The original technical reconstruction research was initially documented in Ramdeen et al. (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

Using information on the number of fishers from various sources together with catch per unit (CPUE) effort information from Fiedler and Jarvis (1932), Swingle et al. (1970) and Williams (1976), we reconstructed the small-scale catches made in the US Virgin Islands from 1950-2010. Using effort information from a 2004 survey of resident participation in recreational fisheries (Mateo 2004), we estimated the recreational catches made by locals. Combined with effort information from García-Moliner et al. (2002) on recreational chartered fishing activity in the U.S. Caribbean we reconstructed the tourist recreational catches.

The USVI Division of Fish and Wildlife's recreational fisheries assessment program conducted a telephone survey from December 1998 to July 1999. Based on this survey, 11% households in St. Croix and 13.5% households in St. Thomas/St. John had at least one recreational angler. The study estimated a total recreational catch of 78 tonnes in the USVI in the year 1999. Thus taking the average of 12% resident participation in recreational fishing, and a typical household size of 4 persons, we reconstructed a time series of local recreational anglers in the USVI from 1950-2010. Taking this together with a CPUE of 0.024 t·fisher<sup>-1</sup>·year<sup>-1</sup> (the 1999 rate) we reconstructed the recreational catches made by local anglers from 1950-2010.

Taking the average per capita recreational catch rate of 0.001 t·tourist<sup>-1</sup>·year<sup>-1</sup> (Klausing 1978), we conservatively estimated catches from USVI's recreational sector for the period 1950-2010.

Recreational catches by locals and tourists were divided equally into 4 categories: wahoo, tuna, dolphinfish and marlin.

For the 2011-2014 update, the recreational fishery was reconstructed for both tourists and the resident population. Current population data was sourced from the same sources as the original reconstruction, the World Bank<sup>33</sup> for residents, and One Caribbean<sup>34</sup> for stop-over tourists. The

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<sup>33</sup> <http://data.worldbank.org/indicator/SP.POP.TOTL?locations=VI>

<sup>34</sup> [www.onecaribbean.org](http://www.onecaribbean.org)

residential recreational fishing rate and catch per unit effort was kept constant for residents and tourists at  $0.024 \text{ t}\cdot\text{fisher}^{-1}\cdot\text{year}^{-1}$  and  $0.0001 \text{ t}\cdot\text{tourist}^{-1}\cdot\text{year}^{-1}$ , respectively

## Results

Reconstructed catches from the USVI for the time period 1950-2010 were composed of artisanal catches of 40,100 t, subsistence catches of 34,100 t and recreational catches of 3,100 t.

## United States of America (Atlantic and Gulf of Mexico)

The original technical reconstruction research was initially documented in McCrea-Strub (2015), and was updated to 2014 by the *Sea Around Us*.

## Methods

Recreational catch and effort data collected at a national or regional scale are scant for the 1950s to the 1970s prior to the official implementation of MRFSS in 1981. Two alternative methods were used to reconstruct recreational landings in the Atlantic and Gulf of Mexico during these three decades, and the results of each were compared. The first method used data from Saltwater Angling Survey reports published in 1960, 1965, and 1970 to reconstruct catch for 1960 to 1980 (Clark 1962; Deuel 1973; Deuel and Clark 1968). The reports include catch in weight (reported in pounds) for each species group in the Northeast (Maine to New York), Middle Atlantic (New Jersey to Cape Hatteras, North Carolina), South Atlantic (Cape Hatteras to the Florida Keys) and Gulf of Mexico (Florida Gulf coast to Texas). These data were recorded, and weight in pounds was converted to tonnes. Due to the fact that average fish weight was likely to have been overestimated by 200% in each survey, as suggest by Wheeland (1973), catches in weight for each species group were corrected for this bias. Total annual catch obtained from these three surveys provided anchor points for the years 1960, 1965 and 1970. To predict the magnitude of total landings in the 1950s, a linear model was fitted to the SWAS data points. Total landings reported from the first year of MRFSS in 1981 provided the final anchor point. Linear interpolation was then used to estimate total catch during the remaining years for which there were no available data (i.e., 1951-1959, 1961-1964, 1966-1969, 1971-1980).

Alternatively, a second method based on estimates of recreational effort was also used to reconstruct probable recreational landings for 1950 to 1980. Overall, mean catch-per-unit-effort was estimated from the earliest five years of the MRFSS dataset and applied to estimates of annual recreational effort derived from the National Surveys of Fishing, Hunting and Wildlife Associated Recreation (FHWAR) for the years 1955, 1960, 1965, 1970, 1975, and 1980. To begin, the FHWAR surveys provided nationwide estimates of the total number of saltwater and freshwater anglers and the total number of days spent fishing in saltwater and freshwater, as well as regional estimates of the combined number of saltwater and freshwater anglers. For each year of the survey, the nationwide ratio of saltwater anglers to total anglers was applied to the total anglers in each region to estimate the number of saltwater anglers in each region. In the absence of better information, it was assumed that the number of days spent fishing in each region was proportional to the number of saltwater anglers in each region. Thus, total days spent fishing in saltwater was broken down by region by applying the proportion of saltwater anglers in each region to the nationwide total number of saltwater days.

Annual estimates of landings and effort by species for 1981 to 1985 were extracted from the MRFSS database. In this case, effort is defined as the estimated number of saltwater fishing trips taken by individual anglers (including coastal, non-coastal, and out-of-state residents). However, each fishing trip may last multiple days, so the number of days spent fishing is not directly equal to the number of fishing trips. To apply CPUE estimates from the MRFSS database to estimates of effort from the FHWAR surveys, the annual number of days spent saltwater fishing was converted to trips using the mean ratio of trips to days. FHWAR surveys from 1955 and 1960 as well as more recent years (starting in the 1990s) provided annual estimates of both saltwater days and trips nationwide. The mean ratio of trips to days for 1955, 1960, 1991, and 1996 was equal to 0.86 (range: 0.840 – 0.885). Additionally, the spatial definition of regions in the FHWAR survey data differed from the definition used in this study, so region-specific estimates of effort from FHWAR surveys were adjusted as needed using the average ratio of state trips to region trips calculated from the MRFSS database for 1981 to 1985.

To ensure that MRFSS estimates of effort for 1981 to 1985 were compatible with effort estimated from the FHWAR surveys, the total number of saltwater trips was estimated for the 1985 FHWAR survey and compared to the total saltwater trips estimated by the MRFSS in 1985. For this common year, the FHWAR survey data resulted in an estimate that was 2.6 times greater than that from the MRFSS database. This result is not surprising given the issues of inaccuracies and bias described by Wheeland (1973). To avoid overestimating catch for 1950 to 1980, the calculated number of trips from the FHWAR surveys were adjusted using the ratio of the MRFSS total trips to the FHWAR survey total in 1985 (ratio = 0.384).

It was necessary to estimate the likely number of fishing trips taken during 1950, even though no data were available for this year. As the annual number of trips estimated from FHWAR survey data clearly increased in a linear fashion, a linear model was fitted to these data and used to predict the number of trips in 1950. The number of trips during the missing years (i.e., 1951-1954, 1956-1959, 1961-1964, 1966-1969, 1971-1974, 1976-1979) was then estimated using linear interpolation.

Mean CPUE for 1981 to 1985 was calculated for each species in the MRFSS database. For each species, annual landings were summed over multiple states to produce region-specific estimates. Annual landings of each species in each region were divided by the total number of trips summed over all species in the corresponding region and year. Regions were defined according to the management jurisdictions of the regional Fisheries Management Councils. Estimates of likely landings of each species in each region were then calculated for 1950 to 1980 by multiplying the species-specific mean CPUE for each region by the total number of estimated trips in each year.

The initiation of the MRFSS in 1981 facilitated access to more reliable, publicly available data regarding recreational catch and effort in the Atlantic and Gulf of Mexico, as well as Pacific regions of the US. Estimates of annual, taxon-specific landings (in terms of weight) by region for 1981 to 2004 were kindly supplied by Will Figueria and Felicia Coleman (Coleman et al. 2004). This database is based primarily on the MRFSS, and data gaps were filled using information provided by the Texas Department of Fish and Wildlife and the NMFS headboat survey program.

Recreational landings for 2005 to 2010 were obtained from the Marine Recreational Information Program (MRIP). For each species or higher-order taxonomic group, annual landings (in terms of weight and number of fish) by state were downloaded from the publically accessible website. The

MRIP database does not include party or headboat data from North Carolina to Florida and the Gulf of Mexico states. These data were provided by the NMFS Southeast Region Headboat Survey program.

For all higher-order taxonomic groups and some species, some or all of the data records indicated only landings in terms of fish; the weight of the landings was not calculated. This represented approximately 8.5% of the total landings in terms of fish for 2005 to 2010. To estimate landings in terms of weight when this information was missing for a particular species, the mean weight of an individual fish was calculated for each region for 2005-2010 using those species-specific records in which both landings in number and weight were known. When possible, missing annual landings in terms of weight of a species in a given state were estimated by multiplying the mean individual weight in the corresponding region by the number of fish landed. To fill in the gaps in the records of higher-order genus or family groups, mean individual fish weight was computed over all member species for which this information was available in a particular region for 2005-2010. Annual landings of each genus or family in a particular state were approximated by multiplying the number of fish landed by the mean genus or family fish weight.

#### 2011-2014 update

##### Recreational landings

In 2018, the Marine Recreational Information Program completely revised their dataset from 1981-2017 which resulted in estimates several times higher (NOAA 2018). The revision was due to the recent transition from the Coastal Household Telephone Survey to the new, mail-based Fishing Effort Survey, which is a more accurate method of collecting recreational fishing data. As a result of this revision, the recreational sector has been completely replaced by the revised MRIP data from 1981-2017. Since there was an interpolation done from the last anchor point in 1975 to the first year MRIP reports their data in 1981, a new interpolation had to be done to the new 1981 amount. Some data from MRIP only gives estimates in numbers of fish and not by weight, so a weight/fish ratio was needed for each species. This was done by taking the sum of the known weights and dividing that by the sum of the known numbers of fish for each taxon. For taxa without any known weights, the average weight/fish for the associated genus or family was used.

##### Recreational discards

The recreational discards are derived from the number of fish released, as reported by MRIP. Following the methods by McCrea-Strub (2015), 23 taxa were had calculated discards and the remaining taxa were grouped into marine fishes nei. Of these 23 taxa, some mortality rates were found from Bartholomew (2005) and Muoneke (1994), and an average was taken of these known mortality rates and applied to the remaining taxa. Since the released fish are assumed to be smaller than the retained ones (too small to legally keep) a new weight/fish is needed for these 23 taxa. This was determined by using the total discarded weight from Harrington (2005) and dividing it by the total number of released fish for each species. The discard amounts can be calculated using the following equation:

$$\text{Discard amount} = (\# \text{ or fish released}) * (\text{Mortality rate}) * (\text{Weight/fish})$$

The discards of the remaining taxa (all fish minus the 23 taxa above) used the same equation and were grouped together as marine fishes nei. The mortality rate used for the marine fishes nei discards was a conservative half the average mortality rate of the 23 species (7.5%). The weight/fish for marine fishes nei was the average by region and year.

## Results

Initial reconstruction of recreational landings using raw data from the 1960, 1965, and 1970 Salt-Walter Angling Surveys (Clark 1962; Deuel and Clark 1968; Deuel 1973) predicted that landings increased from over 400,000 t in 1950 to a maximum of almost 620,000 t in 1970 and then declined to approximately 435,000 t in 1980. After adjusting these data to account for the problem of overestimation (Wheeland 1973), landings were estimated to have increased from 134,000 t in 1950 to a maximum of over 206,000 t in 1970 and then decreased to approximately 145,000 t in 1980. While landings of this magnitude appear more reasonable than those initially predicted, the idea that recreational fishing achieved its maximum catch during the 1970s and has since declined is not consistent with general perception regarding trends in saltwater fishing popularity and effort. The reconstruction of recreational landings based on raw effort data obtained from the 1955, 1960, 1965, and 1970 FHWAR surveys result in a more realistic, increasing trend over 1950 to 1980; however, the magnitude of landings are also high. Recreational landings were estimated to have increased from over 93,000 t in 1950 to a maximum of nearly 400,000 t in 1975. After adjusting effort estimates due to the likely problem of overestimation, predicted recreational landings appear more realistic when compared to previous predicted trends, and were consequently used in the final reconstruction. Landings were estimated to have increased from almost 36,000 t in 1950 to 153,000 t in 1975, reaching a peak of over 178,000 t in 1986, before declining to 83,000 t by 2010.

It was estimated that 6.3 million t of fish were landed by recreational fishers in the Atlantic and GOM between 1950 and 2010. This amount is 3.2% of the total reconstructed catch estimated for these areas over the same time period and 95% less than the magnitude of total commercial landings. Of this total, 55% was landed by fishers in Northeast and Middle Atlantic states combined, 15% in the South Atlantic, and 30% in the GOM. Reported landings include 599 taxa (including individual species and aggregated groups of similar species), which was reduced to 368 taxa in accordance with the Sea Around Us taxon list. Recreational catches consisted primarily of bluefish (19%), summer flounder (5%), spotted seatrout (5%), Atlantic cod (4%) and red drum (4%).

When analyzed together, the greatest percentage of recreational landings occurred in the Northeast and Middle Atlantic regions. Over 3.4 million t were landed along the coast between Maine and Virginia between 1950 and 2010.

During this time, bluefish were heavily targeted by recreational fishers, and landings amounted to an estimated 1.09 million t (i.e., nearly one third of the times series total). Summer flounder, Atlantic cod, striped bass and winter flounder were also dominant species in the landings, equaling 9%, 6%, 5% and 5% of the total, respectively. While landings of bluefish, summer flounder, Atlantic cod, and winter flounder have generally declined since their peak in the early 1980s, landings of striped bass have increased by an order of magnitude. In fact, striped bass landings have exceeded those of all other species since 1996.

It was estimated that approximately 0.92 million t were landed by recreational fishers in the South Atlantic over 1950 to 2010. These landings were primarily composed of dolphinfish (13%), king mackerel (10%), bluefish (6%), spotted seatrout (3%), and sheepshead (3%). With the exception of bluefish, landings of these species did not exhibit a clear increasing or decreasing trend in the years since the early 1980s. In contrast, bluefish landings fell from a peak of nearly 2,600 t in 1981 to less than 150 t in 1996 before increasing to over 1,100 t in 2010. The marked rise in total South Atlantic landings during the final 10 years is primarily the result of high landings of yellowfin tuna and mullet.

Almost 2 million t of fish were recreationally landed in the GOM between 1950 and 2010. The dominant species targeted included spotted seatrout (13% of the total landings during this time period), red drum (10%), king mackerel (5%), red snapper (4%) and sheepshead (4%). While total landings in this region remained relatively stable between 1980 and 2010, spotted seatrout and red drum accounted for increasingly larger proportions of the total. Landings of seatrout increased from a low of 8.5% of total landings in 1985 to a high of nearly 20% in 2009, and red drum landings rose from only 4% of the total in 1988 to also reach 20% in 2010.

#### Recreational discards

It was estimated that total recreational catch in the Atlantic and GOM increased from a minimum of over 46,000 t in 1950 to a height of nearly 240,000 t in 2004. The discarded proportion of this catch more than doubled from 1950 to 2010, increasing from approximately 23% during the 1950s through 1980 to over 56% in 2010. Of these discards, it was estimated that 87% was released alive while 13% of discards died as a result of the fishing activity. For the purposes of this reconstruction, only dead discards were included in estimates of total catch over all fishing sectors in the Atlantic and GOM.

Recreational fishers in the Northeast and Middle Atlantic regions combined caught nearly 4.5 million t of fish over 1950 to 2010. Approximately 20% of this catch was released alive while 3% was discarded dead. It was estimated that dead discards in these regions reached a maximum of nearly 6,300 t in 2006. Total recreational catch in the South Atlantic amounted to over 1.4 million t during 1950 to 2010, of which 31% was caught and released and 4.6% was discarded dead. Dead discards in the South Atlantic were highest in 2010, reaching nearly 2,700 t. In the GOM, 3.7 million t of fish were caught during 1950 to 2010, of which 41% was released alive and 6% was discarded dead. Peak dead discards in the GOM occurred in 2008 and equaled 8,000 t.

Overall, it is clear that merely considering recreational landings in the Atlantic and GOM masks the actual trend in total recreational catch over 1950 to 2010. While total recreational landings in the Atlantic and GOM declined during the 1980s and remained relatively stable thereafter, discards due to catch and release fishing steadily increased over the study period.

## United States of America (West Coast)

The original technical reconstruction research was initially documented in Doherty et al. (2015b), and was updated to 2014 by the *Sea Around Us*.

## Methods

A variety of data sources were used to reconstruct recreational catches from 1950-2010 for the western United States (Tables 21-23). We used the Recreational Fisheries Information Network (RecFIN) database ([www.recfin.org](http://www.recfin.org)) and unpublished catch data from Figueira and Coleman (2010) to estimate recreational catch of most fish species for the years 1980-2010. Catch data from Figueira and Coleman (2010) were used where available (1981-1989, 1993-2002) and RecFIN for 1980 and 2003-2010. Linear interpolations were used to approximate catches for the years 1990 to 1992 where no additional data were available.

Additionally, estimates of catches from some of the major recreational fisheries, such as Pacific halibut and salmonids relied more heavily on additional data available from the California Department of Fish and Wildlife<sup>35</sup> (CDFW), the Oregon Department of Fish and Wildlife (ODFW), the Washington Department of Fish and Wildlife (WDFW), the International Pacific Halibut Commission (IPHC) and the Pacific Fishery Management Council (PFMC), which are considered more accurate than RecFIN estimates for these species (P. Mirick, ODFW, pers. comm.). For species with overlapping years in different catch datasets, we used only one dataset for the overlapping time period to avoid any double-counting.

There were limited data available for recreational catch during the earlier period from 1950-1979. The reconstructed catch for species during this time was developed from a variety of sources, as well as linear interpolations, linear regression and the backwards extrapolation of more recent catch trends to estimate catch for years and species with zero data (Tables 21-23). Where available, data prior to 1980 were often recorded as numbers of fish, and we converted these numbers to wet weights. The weight conversion factors ( $\text{kg}\cdot\text{fish}^{-1}$ ) used are found in Doherty et al. (2015b) and were mostly taken from:

- The 1960 saltwater angling survey (Clark 1960); and
- Mean RecFIN weights for landed fish for CA, OR, and WA.

In some cases, where there were missing or incomplete data, we estimated catch based on average annual catches in the preceding or succeeding years. When this was done for salmonids, we took into account the life cycles of individual species and used an average, which would encompass an even amount of different year-classes. For most species of salmon, there is some overlap between the stocks of different years, as not all individuals born in one year will return to spawn on the same year. This is rarely the case for pink salmon (*O. gorbuscha*), which have a 2-year life cycle and often return to spawn in much different run strength in even and odd years (Hard et al. 1996; Hart and Clemens 1973; Turner and Bilton 1968). Thus, when this method was employed to estimate pink salmon catches, we looked at odd and even years separately.

In the cases with anadromous species, which migrate between saltwater and freshwater water bodies throughout their lifecycles (such as salmonids and sturgeon), precise catch locations were not always available. We excluded all steelhead catch, as most catches were from rivers well inland. For the case of Columbia River sturgeon, we only included catch from WDFW Reporting Area 1A at the mouth of the Columbia River, located at the ocean-river interface. For other salmon (chinook, coho,

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<sup>35</sup> Formerly the California Department of fish and Game

pink, chum and sockeye) species, we included landings originating from ocean and freshwater recreational fisheries as both are considered to be the result of ocean productivity.

**Table 21.** Sources of recreational catch estimates for marine fish in California.

Years	Chinook & coho salmon	Taxa		
		Rockfish	Pacific halibut	All Others
1950-1957	INPFC (1979)	California reconstruction project (Ralston <i>et al.</i> 2010) <sup>a</sup>	<i>Assumed catch of 0.1 t based on 1958-1960 catch</i>	CPFV data <sup>d</sup>
1958-1960			Miller and Gotshall (1965) <sup>b</sup>	
1961				
1962-1973			<i>Linear interpolation</i>	
1974	Skud (1975) <sup>b</sup>			
1975-1976	<i>Linear interpolation</i>			
1977-1979	PFMC data	Figueira and Coleman (2010)	IPHC RARAs <sup>c</sup>	RecFIN
1980				Figueira and Coleman (2010)
1981-1989				<i>Linear interpolation</i>
1990-1992				Figueira and Coleman (2010)
1993-2002				RecFIN
2003-2010				

<sup>a</sup> Ralston *et al.* (2010) compiled estimates of catch for 6 different species of rockfish, as well as catch that was aggregated at the genus level, that are based on CPFV logbook and other historical data. These data were used instead of the 1980 RecFIN data, which is considered questionable for CA rockfish (Ralston *et al.* 2010)

<sup>b</sup> Skud (1975) and Miller and Gotshall (1965) estimates are for CA and OR. Based on proportions observed in IPHC estimates from 1991-2010, we assigned 3% of this catch to CA and 97% to OR

<sup>c</sup> IPHC catch estimates from 1999-2010 include catch caught in southern OR waters (South of Humburg) that was assumed landed in CA and classified as CA catch

<sup>d</sup> Sources of CPFV data include: (Chadwick 1962; Young 1969; Mckechnie and Miller 1971; Collins *et al.* 1980; White 1986; Crone *et al.* 2009; CDFG 2011) and the unpublished CDFG database (provided by J. Robertson). This method was used to reconstruct catches for 68 taxonomic groupings, minor deviations from this method were used for select species (see Appendix B for details)

We found historical time series for the 1950-1979 period to reconstruct catches for most of the species that are frequently targeted by recreational anglers and comprise substantial portions of statewide recreational catches in recent years. These taxa are outlined in Tables 21-23 and represented 99%, 90% and 42% of reconstructed recreational catches from 1980-2010 for CA, WA and OR, respectively. Other taxa landed by recreational fishers are bycatch or less frequently targeted species and assumed to occur in a similar proportion to the overall annual catches. An additional 10% (WA) and 58% (OR) were subsequently added to the annual reconstructed recreational catches of WA and OR for 1950-1979, and assigned proportionally to these less frequently targeted taxa. The assumption is that species without any data for the 1950-1979 period, occupied the same annual proportions of total state catch as their proportion in the total catch over the 1980-2010 period.

**Table 22.** Sources of recreational catch estimates for marine fish in Washington State.

Years	Ocean chinook, coho & pink salmon	Chum and sockeye salmon	Pacific halibut	Taxa Rockfish <sup>c</sup> , lingcod, spotted spiny dogfish, walleye pollock, Pacific cod, sturgeon & albacore <sup>d</sup>	All others		
1950-1961	INPFC (1979)	Average annual catch from 1965-1974	Assumed 5 t based on 1965 catch	Average annual catch from last 5 years, 1975-1979	Estimated as 10% of total marine catch <sup>e</sup>		
1962-1964							
1965-1966							
1967-1974	WDFW unpub. data	WDFW unpub. data	Skud (1975)	WDFW unpub. data			
1975-1976			WDFW unpub. data				
1977-1979			IPHC RARAs <sup>b</sup>	RecFIN		RecFIN	
1980				Figueira and Coleman (2010)		Figueira and Coleman (2010)	
1981-1989				WDFW data when available and otherwise linear interpolation		Linear interpolation	
1990				Figueira and Coleman (2010)		Figueira and Coleman (2010)	
1991-1992				RecFIN		RecFIN	RecFIN
1993-1995							
1996-2002							
2003-2009							
2010	RecFIN <sup>a</sup>						

<sup>a</sup> PFMC (2013) landings do not include Puget Sound, and thus we accepted the reported landings from RecFIN for 2010 for chinook and coho, for which we did not have data from WDFW. See appendix for details on coastal river catches of Coho and Chinook. <sup>b</sup> IPHC statistics were converted from net weights to wet weights using a conversion factor of 1.3 (FAO 2000; Williams 2012). <sup>c</sup> All catch was assigned as *Sebastes* spp. from 1950-1974, as there was little species specific information for this period. Catch between 1975 and 2010 was assigned to 11 major species (See Appendix B), with less commonly caught species being grouped as *Sebastes* spp. <sup>d</sup> Catch data from Holts (1985) was used for albacore catches from 1950-1982. Small deviations from this method were also used for estimations of black rockfish (*Sebastes melanops*), spotted spiny dogfish (*Squalus suckleyi*) and sturgeon (*Acipenser* spp.) for select years, the details of which are listed in Appendix B. <sup>e</sup> Other species accounted for another 10% of total reconstructed marine catch estimates from 1980-2010. We thus assumed an additional 10% of catch annually which was allocated proportionally to 20 taxonomic groupings based on the average catch composition from 1980-2010.

**Table 23.** Sources of recreational catch estimates for marine fish in Oregon.

Years	Taxa						
	Chinook & coho salmon	Pink & chum salmon	Pacific halibut	All others <sup>e</sup>			
1950-1957	INPFC (1979)	Average of annual catch from 1976-1982 (for even years) and from 1973-1979 (for odd years)	Assumed 2 t based on 1958-1960 catch	Estimated as 58% of total marine catch <sup>f</sup>			
1958-1960			Miller and Gotshall (1965) <sup>d</sup>				
1961-1966			Linear interpolation				
1967	INPFC (1979) & ODFW (1977) <sup>a</sup>	Linear interpolation					
1968-1972	ODFW (1977)	ODFW data <sup>c</sup>	Skud (1975) <sup>d</sup>				
1973			Linear interpolation				
1974							
1975-1976							
1977							
1978-1979	ODFW Sport Catch Statistics <sup>b</sup>	ODFW data <sup>c</sup>	IPHC RARAS		RecFIN		
1980							
1981							
1982-1989							
1990							
1991-1992							
1993-2002							
2003-2010							
							Figueira and Coleman (2010)
							Linear interpolation
				Figueira and Coleman (2010)			
				RecFIN			

<sup>a</sup> INPFC (1979) data was used for freshwater landings and ODFW (1977) was used for marine landings.

<sup>b</sup> Available at: <http://www.dfw.state.or.us/resources/fishing/sportcatch>. No data was available for 1994 coastal and Columbia river fall chinook catch and these were estimated using the average of annual landings from 1990-1994 and 1995-1998 for fall chinook. <sup>c</sup> Pink and chum salmon (*Oncorhynchus* spp.) are grouped together in ODFW data from 1978-2009. These catches are not disaggregated to individual species in our estimates. <sup>d</sup> Skud (1975) and Miller and Gotshall (1965) estimates are for CA and OR. Based on proportions observed in IPHC estimates from 1991-2010, we assigned 3% of this catch to CA and 97% to OR. <sup>e</sup> Albacore catch between 1975-1991 and for 2003 is estimated based on ODFW data (ODFW 1977; [www.dfw.state.or.us/MRP/sportalbacore](http://www.dfw.state.or.us/MRP/sportalbacore)); as it was unreported in Figueira and Coleman (2010) and RecFIN catch statistics. <sup>f</sup> Other species account for another 58% of total reconstructed marine catches from 1980-2010. We thus assumed an additional 58% of catch annually which was allocated proportionally to 23 taxonomic groupings based on the average catch composition from 1980-2010. The recreational albacore fishery began circa 1975 and had low catches at this time (Holts 1985), and thus we did not allocate any catch as albacore from 1950-1974.

Recreational fishing for shellfish such as crabs and a variety of clams are popular activities along the U.S. west coast and were also estimated from 1950-2010. Shellfish harvests are not included in the RecFIN database nor are they in the estimates by Figueira and Coleman (2010); however some data were available from the respective state departments of fish and wildlife and in the scientific literature.

Many of these data were listed as numbers of individuals collected and were converted into wet weights (See (Doherty et al. 2015b) for conversion factors). Often shellfish estimates were only available for select years or for certain areas and thus assumptions were required to estimate statewide time series from 1950-2010. We used these data as anchor points and generated per-license catch estimates to estimate harvests for years without data. U.S. Fish and Wildlife Service historical fishing license data were available from 1958-2013 ([wsfrprograms.fws.gov](http://wsfrprograms.fws.gov)) and were used as an indicator of overall shellfish collection effort to estimate catch based on catch per-license rates for years with data.

## California

Recreational catch data are available from logbooks of California's commercial passenger fishing vessels (CPFVs) or 'party boats', which have been collected by the California Department of Fish and Game (CDFG) since 1936 (Hill and Schneider 1999). Party boat logbook data are the basis for many recreational catch estimates reported in the scientific literature (Chadwick 1962; Collins et al. 1980; McKechnie and Miller 1971) and were also used in this study as the main source to reconstruct recreational catches from 1950-1979 (Table 20)).

Historical records of recreational fisheries in California were also available for Chinook and Coho salmon (INPFC 1979; PFMC 2013; PFMC 1993), rockfish (Ralston et al. 2010), and Pacific Halibut (Blood; Hare 2012; Miller and Gotshall 1965; Skud 1975; Williams 2012; Williams 2011; Williams 2010). These estimates were more robust for these taxa and were used instead of the CPFV logbook information.

Three main sources of CPFV data were used; 1) Young (1969), 2) CDFG (2001) and 3) the CDFW CPFV database (CDFW, unpubl. data, provided by J. Robertson). These data sets correlated well for 1957 and later for most major species. However, from 1950 to 1957, landings from the CDFG database were substantially lower than those reported by Young (1969) and CDFG (2001). Landings from CDFG (2001) and Young (1969) matched well for major groups between 1950-1957, and were used where available, and when not available, data from the unpublished CDFW database were used.

The party boat logbook data represent a large component of recreational catch; however it is not a complete estimate of total recreational catch as there are also anglers who fish on private boats and from shore (Chadwick 1962; Collins et al. 1980; Deuel 1973; Deuel and Clark 1968; Stevens 1977; White 1986). It was necessary to increase party boat catches by a factor (KCA) to estimate the total recreational catch. The values selected for KCA varied for different species and years and were calculated as:

$$\text{KCA} = \text{total recreational catch} / \text{total charter boat catch}$$

Data used to calculate KCA were obtained from the following sources, the values of which are shown in Appendix B:

- Catch data from the 1965 and 1970 salt water angling surveys (Guel 1973; Guel and Clark 1968);
- Unpublished catch data from Figueira and Coleman (2010); and
- Independent sources for specific species (Collins et al. 1980; Crone et al. 2009; White 1986).

In general, we used the more conservative of the two K values calculated from the 1965 and 1970 salt water angling surveys. The K value from Figueira and Coleman (2010) was calculated based on the ratio of total recreational catch to charter boat catch observed from 1981-2002. K values for years in between were linearly interpolated (see (Doherty et al. 2015b) for details). For a few taxa, where estimates of K were unavailable, we assumed a value of 2 (i.e., party boat catch accounted for half of the total recreational catch). This is considered conservative, given that the majority of the species in Figueira and Coleman (2010) have a value for K that is greater than 2 and that the K ratio for total catch from 1981-2002 is 2.6.

All party boat catch was recorded in numbers of fish and needed to be converted into weights (see Appendix B for specific conversions used) and thus the calculation of total recreational catch was:

Total recreational catch = KCA x party boat catch no. x weight/fish

Recreational shellfish catch estimates for CA were made for abalone (*Haliotis* spp.), California spiny lobster (*Panulirus interruptus*), crabs and a variety of clams (Doherty et al. 2015b). In general, statewide and historical time series of shellfish catch estimates for California are sparse.

Catch estimates of abalone (*Haliotis* spp.) were available for select years from 1960-2010 (CDFG 2010; Haaker et al. 2004; Haaker et al. 2001). Estimates prior to 1983 include only the catch obtained by diving from boats (Haaker et al. 2001; Payne et al. 2017) and thus were adjusted to include the proportion from shore pickers and shore divers. Surveys from 1989-2007 (CDFG 2010), show that shore picking and divers from shore are an important component of the recreational abalone fishery, accounting for 75-92% of catch. We assumed estimates prior to 1983 accounted for only 25% of the recreational catch and adjusted them accordingly. This is considered conservative, given that catch estimates of red abalone account for as much as 7 times the commercial catch in the 1980s and that recreational catch estimates by Frey (1971) are nearly the same as the commercial landings.

Recreational clamming is a popular activity among the intertidal bays of California and for many species makes up the bulk of the total catch (Moore 2001a; Moore 2001b). Catch estimates of clams are available for Humboldt Bay for 1975, 1977-1989 and 2008 (McVeigh et al. 2010), for Tomales Bay for 1962-1963 and 1989-1997 (CDFW, unpubl. data, provided by P. Kalvass) and for Morro Bay for 1979-1980 (Mello 1981). These data were used as anchor points to generate estimates of clam catches for 1950-2010 for Humboldt, Tomales and Morro Bay (see Doherty et al. 2015b). Estimates of effort and catches are not available for several other bays such as Bodega Bay, Drakes Estero and Elkhorn Slough, which also provide good recreational catches (Moore 2001a; Moore 2001b; Spratt 1982) and are not included in our estimates.

## Washington

In addition to RecFIN and the data in Figueira and Coleman (2010), the following sources were used to reconstruct recreational catches for WA and are summarized in Table 22:

- Historical records of salmon and marine fish landed by the recreational fishery (WDFW, unpubl. data, provided by E. Kraig) for 1967-2010;
- Historical salmon landings data from the INPFC (1979) for 1946-1976, and the PFMC (PFMC 2013; PFMC 1993) for 1950-2010;
- Historical records of recreational albacore catch from US CPFVs (Holts 1985); and
- Historical estimates of recreational Pacific Halibut landings from reports (Miller and Gotshall 1965; Skud 1975) and IPHC reports of assessment and research activities (RARAs) for 1991-2012 (Blood; Hare 2012; Williams 2011; Williams 2010).

The PFMC (1993) has historical records of the number of chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*) and pink (*O. gorbuscha*) salmon landed at four major WA ports (Neah Bay, Le Push,

Westport, and Ilwaco) from 1950 to 1990. Landings from these areas match with those from the same areas reported by the WDFW from 1967 to 1990; however, the PFMC historical records do not include landings from another nine sites in the Puget Sound Area. WDFW data indicate that landings from Puget Sound account on average for approximately 50% and 17% of annual landings of chinook and coho, respectively, between 1967-1976. INPFC catch statistics include landings from Puget Sound and the San Juan Islands and thus were used instead of the PFMC statistics from 1950-1965.

Coastal river catch for coho and chinook were available from 1976-2010 (WDFW, unpubl. data, provided by E. Kraig) and accounted for 1% of average annual landings for both species between 1976-1980. We thus assumed they account for 1% of total landings from 1950-1975 where there were no species-specific data available. This is may be a conservative assumption, as records from 1964-1976 (IPFNC 1979) show higher annual freshwater salmon landings for WA than our estimate. However, we chose not to use the IPFNC (1979) time series for 1964-1976 for two reasons: (1) This time series did not include a species breakdown and thus we were uncertain of what proportion was composed of coho and chinook; and (2) the IPFNC freshwater salmon totals for 1976 were 100,600 individuals and differed greatly from the freshwater totals of 16,000 individuals from WDFW for the same year.

The proportion of salmon caught in freshwater has steadily increased since the 1970s and it is unclear if this is primarily due to improved reporting of landings from river fisheries or management changes that have increased river landings over this period.

A variety of recreational shellfish data exist for WA and was obtained from WDFW:

- Dungeness crab (*Metacarcinus magister*) and red rock crab (*Cancer productus*) catches for select years between 1976-1995 (WDFW, unpubl. data, provided by E. Kraig ) and for Dungeness crab from 1996-2010 ([wdfw.wa.gov](http://wdfw.wa.gov));
- Spot prawn (*Pandalus platyceros*) catches from 1977 and 1980-2002 for Hood Canal and Puget Sound, Pacific oyster (*Crassostrea gigas*) catches from 1972-2001, and clam catches from 1972- 1986 and 1990-2007 (WDFW, unpubl. data, provided by E. Kraig); and
- Pacific razor clam (*Siliqua patula*) catches for 1950-2010 (WDFW, unpubl. data, provided by D. Ayres).

These data were used in conjunction with U.S. Fish and Wildlife Service historical fishing license data to generate recreational estimates for WA from 1950-2010 (see Doherty et al. 2015b).

## Oregon

Many of the same data sources used for WA were also used to reconstruct recreational catches for OR and are summarized in Table 23. Chinook and coho have historically accounted for the majority of the OR recreational fishery (Schindler et al. 2012). Sport catch statistics for salmon from 1978-2010 are available on the ODFW website ([www.dfw.state.or.us/resources/fishing/sportcatch](http://www.dfw.state.or.us/resources/fishing/sportcatch)). These data along with ODFW (1977) summarize records of the number of chinook and coho landed in coastal rivers, the Columbia river and from ocean areas for 1967-2010. IPNFC (1979) provide similar estimates for inland and ocean salmon catch for 1949-1976 that were used to reconstruct coho and chinook catch for 1950-1966 (1950-1967 for freshwater catch).

The IPNFC (1979) data only report total salmon landings from the 1956-1963 and does not distinguish between freshwater or marine catch. We performed this separation of freshwater and marine catch based on the average proportions from 1950-1954 (27% marine and 73% freshwater) and the average proportions from 1964-1968 (68% marine and 32% freshwater). We used the 1950-1954 average proportion for 1955 and the 1964-1968 average proportion for 1963, and linearly interpolated between these ratios to estimate the proportion of freshwater and marine landed salmon for the intervening years. We applied a similar method to estimate the proportion of coho and chinook in the ocean landings from 1956-1963. We used the 1952-1955 average proportion for 1956 (51% coho and 49% chinook) and the 1964-1968 average proportion for 1963 (87% coho and 13% chinook), and linearly interpolated between these ratios to estimate the proportion of coho and chinook in the ocean landings for years in between.

INPFC (1979) statistics do not provide a species breakdown for inland salmon landings. To divide total freshwater salmon landings from 1950-1967 between coho and chinook, we used the average annual ratio of these species in the freshwater landings from the 1968-1977 ODFW (ODFW 1977) statistics (i.e., the first 10 years of freshwater catch with a species breakdown) of 22% coho and 78% chinook. This ratio seems reasonable, given that the proportion of coho and chinook in freshwater landings is fairly consistent between 1967-1977, ranging from 15-31% for coho and 69-85% for chinook.

A variety of recreational shellfish data exist for OR and were obtained from ODFW:

- Dungeness crab catch for 1971 (ODFW 1977) and 2007-2011 (Ainsworth et al. 2012);
- Pacific razor clam catch from 1955-2010 (Link 2000; Hunter 2008; ODFW, unpubl. data, provided by M. Hunter); and
- OR bay clam catches for 1970-1983 (Gaumer 1984) and for 2008 (Ainsworth et al. 2012).

These data were used in conjunction with U.S. Fish and Wildlife Service historical fishing license data to generate recreational estimates for OR from 1950-2010 (see Doherty et al. 2015b)

#### Discards

In the context of this study, discards are defined as any catch of a fishery, recreational or commercial, that is not landed. We include discards of fish that are released both alive and dead, and where possible have incorporated post-release mortality rates. We estimated discards for several major US west coast fisheries, which were divided into the following groups:

- Non-hake groundfish bottom trawl;
- California halibut;
- Sablefish fixed gear;
- Pacific halibut;
- Pacific hake;
- Ocean shrimp;

- Salmon; and
- Non-salmon recreational fisheries.

Comprehensive discard mortality estimates of groundfish and some non-groundfish species are available for most of the above fisheries from 2005-2011 (Bellman et al. 2012; Bellman et al. 2011; Bellman et al. 2010a; Bellman et al. 2010b; Bellman et al. 2008; Hastie and Bellman 2007; Hastie and Bellman 2006) and for Pacific halibut from 2002- 2011 (Jannot et al. 2012). These data are provided by the Northwest Fisheries Science Center (NWFSC) and are referred to throughout as the NWFSC discard estimates. Discard estimates for Pacific halibut are available in multiple reports. Here we use discard mortality estimates from groundfish fisheries by Jannot et al. (2012) for 2002-2010 and from the IPHC (Hare 2012) for the Pacific halibut fishery. Estimates of mortality from incidental bycatch and selective fisheries from commercial and recreational salmon fisheries are available from 1999-2012 from the PFMC stock assessment and Fishery Evaluation (SAFE) documents (PFMC). Detailed observer discard data are also available from NMFS Southwest Fisheries Science Centre (SWFSC) for the swordfish drift gillnet fishery from 1990-2010 and the longline fishery from 2001-2004 ([swr.nmfs.noaa.gov](http://swr.nmfs.noaa.gov)). Otherwise, limited information regarding discards or bycatch is available for most west coast fisheries and, where available, additional sources of information used are discussed in the relevant sections.

NWFSC discard estimates apply mortality rates to discards of sablefish, lingcod and Pacific halibut in the groundfish bottom trawl, California halibut and sablefish fixed gear fisheries. We use the NWFSC discard mortality estimates where available, rather than total discards, and adjust bycatch rates for earlier years accordingly. Commercial and recreational bycatch estimates by the PFMC also apply estimates of mortality rates for incidental bycatch and mark selective fisheries, and these estimates were also used rather than total discards. We also applied discard mortality rates to recreational catch-and release discards (Table 24). For other species and fisheries, where there was little information about the proportion of discards released alive or dead, we did not apply any post-release mortality rates, essentially assuming 100% mortality. This is clearly not the case for all the fisheries assessed (particularly the sablefish and halibut fixed gear fisheries) and species in the discards; however, a detailed analysis of post-release mortalities for all fisheries is beyond the scope of the present work.

**Table 24.** Discard mortality rates (%) in US west coast fisheries considered in discard estimates.

Fishery & gear	Bycatch species	Discard mortality (%)	Source
Non-hake groundfish	Pacific halibut	20-90	1
	Sablefish & lingcod	50	2
Sablefish pots	Pacific halibut	18	1
	Sablefish	20	2
Sablefish longlines	Pacific halibut	16	1
	Sablefish	20	2
California halibut	Lingcod	50	2
Pacific halibut	Pacific halibut	25	3
Commercial troll salmon	Salmon	26	4
Recreational salmon	Salmon	14-28	4
Non-salmon recreational	All species	2-66	See Table 23

Sources: 1. Jannot *et al.* (2012). Discard mortalities for groundfish bottom trawl are based on assessments of viability by the observer. 2. Hastie and Bellman (2006, 2007); Bellman *et al.* (2008); Bellman *et al.* (2010a); Bellman *et al.* (2010b); Bellman *et al.* (2011, 2012). 3. Gilroy and Hare (2012). 4. PFMC (2000-2013).

We calculated fishery specific discards to landings (D/L) ratios from the NWFSC discard and landings data and other available sources. We used these D/L ratios to estimate discards for years where discard data were not available (thus assuming proportionality), the methods of which are summarized in the relevant sections. D/L ratios were calculated as follows:

$$D/L = \text{Total dead discarded weight} / \text{Landed weight of target species}$$

Over the last six decades, management, economic and technological changes have influenced these fisheries and impacted the amount of fish discarded. We attempted to consider these changes in our discard estimates; however, we acknowledge that there is considerable uncertainty for many years in which data are limited. This is particularly the case prior to 1979, where we found zero records of discard or bycatch information.

Most discard estimates available (e.g., IPHC RARAs; Harrington *et al.* 2005; NWFSC estimates; Bellman and Heery 2013) do not specify the uncertainty involved therein. Since these discard data were used to calculate D/L ratios that were extrapolated to the earlier period, it is thus difficult to quantify uncertainty using traditional statistical methods. Alternatively, we quantify high and low ranges of the reconstructed discards by applying the lowest and highest D/L ratios observed for a given period for the various fisheries assessed.

### Salmon

Salmon are discarded for three main reasons in commercial trolling and recreational fisheries: (1) regulatory discards of salmon that are below the legal size limit, (2) regulatory discards of legal sized fish in directed fisheries for other species (i.e., coho caught in chinook-directed fisheries), and (3) discards of non-marked fish in mark-selective fisheries which allow only for the retention of hatchery fish. Discarding of other non-salmon species is low (Harrington *et al.* 2005).

Estimates of bycatch mortality (in numbers of fish) from commercial troll and recreational salmon fisheries are available in the PFMC Stock Assessment and Fishery Evaluation (SAFE) reports from 1999- 2012 (PFMC 2000-2013). These reports provide estimates of all three of the above sources of discards and apply a post-release mortality rate to estimate the portion of dead discards (Table 24).

They also assume a drop-off mortality rate of 5% of all encounters, to account for predation of hooked fish that do not reach the boat.

We summed the total annual discards and landings for recreational and commercial sectors from 1999- 2012 divided total discards by total landings to estimated D/L ratios for coho and chinook fisheries. Coho landings were reported in both tables for mark-selective and incidental discards for select areas, and were carefully assessed to avoid double counting of landings when estimating D/L ratios for all discards. We took the median value of these D/L ratios, and multiplied these by the commercial troll landings (obtained from the NMFS database) and reconstructed recreational landings of coho and chinook to estimate discards from the salmon fishery for earlier years where no discard estimates were available. As we had no way of distinguishing between fish caught in mark-selective fisheries, we applied the D/L values calculated from total discards.

It is possible that as regulations in U.S. fisheries have tightened, the amount of regulatory discards from salmon fisheries will have increased in recent years, in which case our D/L ratios would overestimate discards in the earlier period. However, size regulations for salmon fisheries have existed throughout most of the period assessed (PFMC 1985), and we found little information on discards from salmon fisheries prior to the late 1990s. Managers with more detailed knowledge of the history of specific salmon fisheries may provide better estimate for certain areas; however, this is currently beyond the scope of our work.

The D/L ratios are in a similar range as those estimated by Harrington et al. (2005) and PSC (2011) for salmon fisheries on the Pacific west coast during the same time period. We feel this is a reasonable estimate and that total salmon discards are conservative given that we do not include discards from salmon fisheries using gillnets, seines and other gears, which account for nearly half of NMFS commercial coho and chinook landings from 1950-2010. We assumed average weights of 5.5 kg and 2.4 kg for chinook and coho discards, respectively, (based on RecFIN mean weights of released fish from 2004- 2010 for WA) to convert the 1999-2010 PFMC discards into weights.

#### Non-salmon recreational fisheries

In general, there is thought to be low discards in the recreational sector and that discards are composed mainly of unwanted species, such as sharks (PFMC 2011a) and fish of sub-legal sizes (Harrington et al. 2005). Estimates of discards are recorded in the RecFIN database in two ways: (1) B1 catch; fish that are released dead, used for bait or filleted on board, and (2) B2 catch; fish that are released alive. The B1 catch estimates were included in the recreational landings estimates, as it was not possible to disaggregate dead discards from filleted or bait fish.

Estimates of fish that are released alive (B2) by recreational anglers are available from 1980<sup>1</sup>1989 and 1993-2010 from the RecFIN database. Estimates by weight and the number of released fish are available from 2004-2010, while estimates from 1980-1989 and 1993-2003 include only the number of released fish. Average weights of different species or higher order taxa of released fish are available by year and state from 2004-2010. We used the mean average weights from 2004-2010 for specific taxa to convert the 1980-2003 estimates from numbers of released fish into weights. State specific mean weights were used where available, and when not available we used the mean weight for total west coast landings. Where mean weights were not available for released species we used the mean weight of landed fish from 1989- 2003 (RecFIN). This is an important distinction as anglers

are likely to discard smaller fish than those landed and thus one would expect the mean weights of landed fish to be larger. This is not expected to have substantially influenced our results, since the portion of total B2 catch that was converted this way accounted for only 1% of our total estimated weight of discards from 1981-2003. We excluded the data from 1980, as estimates for this year were over 20 times the average from 1981-2003, suggesting that there may be an error in the 1980 values.

We then applied post-release mortalities to estimate the portion of released fish (B2) that do not survive. There is little known about the long-term survival of many fish species that are caught and released in recreational fisheries. Discard mortalities vary by species depending on many factors such as: gear type, handling and release techniques, playing time, hook size, hook type, fish size, water temperature, and capture depth. For example, discard mortalities for sharks are thought to be low (PFMC 2011a), whereas discard mortalities for some species of rockfish may be higher than 60% due to barotrauma (Jarvis and Lowe 2008; PFMC and NMFS 2009). A meta-analysis of 274 catch-and-release mortality estimates for 48 species targeted by recreational fisheries in the U.S. found estimates ranging from 0-95% (Bartholomew and Bohnsack 2005; Muoneke and Childress 1994)

Given all of these factors, we recognize that there is uncertainty with estimating post-release survival rates that may be applied to west coast recreational fisheries from 1950-2010. Furthermore, many of the studies that are available are based on limited sample sizes and thus there is risk with extrapolating these results to larger populations. Nonetheless, this exercise has been attempted here as we feel this provides more valuable information than the alternative of listing only total discards (dead and alive).

Estimates of post-release mortality were compiled from a variety of sources (Table 25) Where available, we applied species-specific post-release mortality rates for hook and line fisheries to the major taxa discarded by recreational fisheries. When these were not available, we used a median value of 11% for teleost species, obtained from the meta-analysis of the 274 studies conducted by Bartholomew and Bohnsack (2005) and Muoneke and Childress (1994).

With the exception of leopard sharks, we were able to find species-specific post-release mortality estimates for hook and line fisheries for major elasmobranch species (Table 25) that were present in RecFIN B2 discards. Post-release mortality rates ranged between 15-26% for four species of shark commonly present in the discards and we applied a median value of 22% to estimate post-release survival of the remaining shark species in the discards.

For skate and ray species, we found no studies estimating post-release discard mortality from hook and line fisheries, however several studies estimating post-release mortality from trawling (Enever et al. 2009; Laptikhovsky 2004) and gillnet fisheries (Braccini et al. 2012). We applied the post-release mortality rates from the study by Braccini et al. (2012) for the Southern eagle ray (*Myliobatis australis*) to bat rays, as these species are from the same genus, and used the median value from the three Batoidea species in this study (7%) to estimate discard mortalities for other skate and ray species. We found no estimates of post-release mortalities for chimaeras from recreational fisheries, and thus we also applied the 11% median value for teleosts to spotted rattail (*Hydrolagus colliei*).

**Table 25.** Post-release mortality rates used to estimate mortality from catch-and-release discards in CA, OR, and WA non-salmon recreational fisheries from 1981-1989 and 1993-2010.

Scientific name	Common Name	Release mortality (%)	Source	% of B2 catch
<b>Teleosts and Acipenseriformes</b>				
<i>Acipenser transmontanus</i>	White Sturgeon <sup>a,b</sup>	3	6	3.7
<i>Ophiodon elongatus</i>	Lingcod	2	1	4.0
<i>Morone saxatilis</i>	Striped Bass	17	1	1.0
<i>Hippoglossus stenolepis</i>	Pacific Halibut	16	1	0.4
<i>Atractoscion nobilis</i>	White weakfish	10	4	0.9
<i>Thunnus albacares</i>	Yellowfin tuna	30	1	0.0
<i>Sebastes</i> spp.	Rockfish	16-66 <sup>c</sup>	5	3.6
Other teleost species	Median value (n=274)	11	1	59.3 <sup>d</sup>
<b>Elasmobranchs</b>				
<i>Alopias vulpinus</i>	Thresher shark	26	7	0.9
<i>Prionace glauca</i>	Blue shark	15	3	2.5
<i>Isurus oxyrinchus</i>	Shortfin mako shark	20	9	0.5
<i>Myliobatis californica</i>	Bat ray <sup>e</sup>	15	8	3.1
<i>Squalus acanthias</i>	Spiny dogfish <sup>b</sup>	24	2	8.1
Other Batoidea	Median value (n=3)	7	8	3.1
Other Selachimorpha	Median value (n=4)	22	10	8.8

<sup>a</sup> This mortality rate was applied to all *Acipenser* spp. discards. <sup>b</sup> Mortality rates may be an overestimate due to the holding conditions used (Robichaud *et al.* 2006; Mandelman and Farrington 2007). <sup>c</sup> Range shows mortality rate for 8 rockfish species, a median value of 31.5% was used for all other rockfish species. <sup>d</sup> Includes 126 tonnes of spotted rattail (*Hydrolagus collie*). <sup>e</sup> This rate was an estimate for the Southern Eagle Ray (*Myliobatis australis*) of the same genus. Sources: 1. Average release mortality calculated from meta-analyses by Bartholomew and Bohnsack (2005) and Muoneke and Childress (1994), 2. Mandelman and Farrington (2007), 3. Musyl *et al.* (2011), 4. Aalbers *et al.* (2004), 5. PFMC and NMFS (2009) 6. Robichaud *et al.* (2006), 7. Heberer *et al.* (2010), 8. Braccini *et al.* (2012), 9. Hight *et al.* (2007), 10. Median value of rates from 4 species shown in table.

Using these estimates of dead catch-and-release fish from 1981-1989 and reconstructed estimates of recreational fisheries, we calculated an average annual D/L ratio for each state (Table 25). The landings denominator included all recreational fish catch (i.e., excluding shellfish and crustacean taxa), with the exception of salmon caught in coastal rivers, as we assumed these would be associated with less non-salmon bycatch. We did not have CA salmon separated by marine and freshwater landings and thus all salmon catch was included in the denominator used to calculate the CA D/L ratios. We then multiplied these ratios by the reconstructed recreational ocean fish landings (excluding river salmon catches) for each state, to estimate the portion of dead catch-and-release catches from 1950-1980 and 1990-1992 (1990-1995 for WA). Discards for WA from 2004-2010 do not include spotted spiny dogfish, which is the most commonly discarded taxon, contributing 71% of total WA discards from 1980-2003. The average annual D/L ratio from 1981-2003 for spotted spiny dogfish in WA is 0.07 (ranging between 0.02- 0.13), and we used this ratio to estimate dogfish discards in WA from 2004-2010.

#### Tribal fisheries

Since 1970, WDFW commercial catch statistics are classified as treaty and non-treaty landings. The NMFS commercial landings for WA used as the baseline to reconstruct commercial landings does not separate the landings as such, but based on the total catches reported by WDFW and NMFS, it was inferred that both WA treaty and non-treaty commercial landings are included in NMFS commercial statistics. Since 1983, a breakdown of subsistence and ceremonial catches is also present in the WDFW data (unpubl. data, provided by T. Gibbs). Reported ceremonial catch ranges from 3-300 t-year<sup>-1</sup> for 1984-2010, with salmonid species representing 94% of the catch. These catches represent less than 0.1% of the overall commercial landings during this period.

Commercial tribal landings in OR are recorded on fish landing receipts (P. Mirick, ODFW, pers. comm.) and thus would be reported in the commercial datasets. Tribal catches are also included in

state estimates of total recreational shellfish catch; however, are not available separated from the overall catch (M. Vance, ODFW, pers. comm.).

**Table 26.** Summary of tribal seafood consumption rates from various

State	Tribe	Year	kg·year <sup>-1</sup> <sup>a</sup>	Study
WA	Squaxin			
	Island	1994	27	Toy <i>et al.</i> (1996)
	Tulalip	1994	27	Toy <i>et al.</i> (1996)
	CRITFC	1991-1992	21	CRITFC (1994)
	Suquamish	1998	78	Suquamish Tribe (2000)
	Lummi	1985	140 <sup>b</sup>	Freimund <i>et al.</i> (2012)
	Makah	1998	46	Sepez (2001)
OR	Various	1800s <sup>c</sup>	140-270 <sup>c</sup>	Hewes (1947)
	Various	1800s <sup>c</sup>	140-180 <sup>c</sup>	Hewes (1947)
CA	Various	1800s <sup>c</sup>	90-200 <sup>c</sup>	Hewes (1947)

<sup>a</sup> When consumption rates were presented as g/day per body weight of consumer, consumption rates were converted to kg·year<sup>-1</sup> using the mean weight of survey respondents. <sup>b</sup> includes only the male population. <sup>c</sup> Consumption rates from Hewes (1947) are noted in the source material as being from "aboriginal" times, which we assumed are representative of consumption rates in the 1800s. They include only salmon consumption.

We found little information on treaties for commercial tribal fishing rights in CA, but we assume potential tribal catches would be reported in the commercial database as is the case for OR and WA. The survey designs for recreational finfish fisheries in CA since 1980 account for unlicensed anglers (A. Sadrozinski, CDFW, pers. comm.).

There are a variety of consumption surveys that have also been conducted for tribal fisheries along the west coast of the U.S. (Table 26). These estimates range between 22-140 kg·year<sup>-1</sup> for various tribes in WA in recent years, and were much higher in the earlier period (Hewes 1947). To obtain an indication of the total amount of tribal consumption, we extracted population data for ages 18 and over for populations listed as "American Indian or Alaska Native" from the 2010 U.S. Census. We included only populations from counties in coastal areas and those that were adjacent to Puget Sound, which summed to 82,000 people. Extrapolating the low and high consumption rates observed for WA tribes to this population yields estimates of tribal consumption ranging from 1,800–11,000 t·year<sup>-1</sup>. This is substantially lower than the portion of subsistence and ceremonial catch reported in the official statistics.

It is often not clear in these reports whether tribal seafood consumed is caught commercially or recreationally. Some of the catch is reportedly gifted but otherwise there is little information to indicate whether this catch might be included in official catch statistics. It is thus very difficult to ascertain what portion (if any) of tribal subsistence catch is unreported. Furthermore, consumption studies caution against extrapolating these consumption rates to a wider population as has been done here (CRITFC 1994; Suquamish Tribe 2000; Toy *et al.* 1996).

Due to this uncertainty and to avoid double counting, we do not include any additional catch for tribal fisheries above what has been estimated from recreational and commercial catch. It is possible that there are unreported tribal catches; however, a more detailed assessment of catch by individual tribes and time series of tribal populations, and an evaluation of their integration into national data systems would be required to make such an estimate.

For the 2011-2014 update, updated data and the same methods were used.

## Results

Total catch for the 61-year period is composed primarily of commercial landings (87%), followed by discards (8%) and recreational landings (4%).

Recreational catch ranged from nearly 17,000 t in 1950 to just over 12,000 t in 2010, peaking at nearly 31,000 t in 1980. Total recreational catch for the 1950-2010 period was over 1.3 million tonnes and averaged about 22,000 t annually. CA, WA and OR accounted for 63%, 24% and 13%, respectively, of total recreational catch.

RecFIN landings totalled around 381,000 t for years reported from 1980-1989 and 1993-2010. In comparison, reconstructed catch for this period was 565,000 t, about 1.5 times what is reported by RecFIN. The difference is largely due to coho and chinook landings, for which we used state data considered to be more accurate, and due to shellfish and crustaceans, which are almost completely unreported by RecFIN. Salmon (20%), rockfish (16%), and tunas and mackerels (16%) were the most important contributors to the recreational catch from 1950-2010.

Most of the reconstructed recreational catch (84%) was compiled from existing historical catch data from a variety of sources, and was either accepted as is or multiplied by some proxy to account for an unreported component of the catch (e.g., CPFV logbook data). Data from RecFIN and Figueira and Coleman (2010) accounted for 25% of total reconstructed catch, while estimates derived from CPFV logbooks and State agencies (WDFW, ODFW, CDFW) accounted for another 24% and 19%, respectively

## Discards

Total discards were estimated at over 2.5 million t for commercial and recreational fisheries in CA, WA and OR, with discards from the groundfish bottom trawl (54%) and ocean shrimp fishery (27%) contributing the most. Discards peaked at nearly 86,000 t in 1989 prior to the introduction of BRDs in the ocean shrimp fishery, and ranged from around 24,000 t in 1950 to around 14,000 t in 2010. The most common taxonomic groups in the discards were Pacific hake (23%), flatfish (17%), rockfish (12%), spotted spiny dogfish (9%), and skates and rays (8%).

## United States of America (Subarctic, Alaska)

The original technical reconstruction research was initially documented in Doherty et al. (2015a), and was updated to 2014 by the *Sea Around Us*.

## Methods

The Alaska Department of Fish and Game has conducted statewide estimates of recreational “catch” (retained catch and discarded catch) and “harvest” (retained catch) since 1977; recorded as the number of individual fish for different species. Data from these statewide surveys were compiled from historical reports (Howe et al. 1996; Mills 1986) and data readily available on the ADFG website ([www.adfg.alaska.gov/sf/sportfishingsurvey](http://www.adfg.alaska.gov/sf/sportfishingsurvey)), and were converted into fish weights (Table 27). We included only marine species in our estimates and excluded species more commonly found in freshwater such as Rainbow trout, Arctic grayling, whitefish, Sheefish, Burbot, Brook trout, lake

trout, Kokanee and other land-locked salmon. These data were used to reconstruct recreational retained catch from 1977-2010.

**Table 27.** Conversion factors used to convert retained recreational catch from 1977-2010 ADFG surveys from numbers of individuals into weight.

Taxa	Kg·fish <sup>-1</sup>	Source
Chinook salmon	13.6	1
Coho salmon	4.5	1
Sockeye salmon	2.7	1
Pink salmon	1.9	1
Chum salmon	5.2	1
Cutthroat trout	1.6	2
Dolly Varden	1.4	3
Smelt	0.2	4
Shark	2.2	4
Rockfish	1.1	4
Lingcod	3.7	4
Pacific cod	2.3	5
Sablefish	0.6	4
Razor clams	0.09	6
Other fish	1.0	4

Sources: 1. Average range from species information provided on ADFG website ([www.adfg.alaska.gov/index.cfm?adfg=animals.listfish](http://www.adfg.alaska.gov/index.cfm?adfg=animals.listfish)), 2. Behnke *et al.* (2002), 3. Estimated based on information from recreational fishing websites, 4. Estimated based on average weights recorded in the Recreational Fisheries Information Network ([www.recfin.org](http://www.recfin.org)) 5. Clark (1960), 6. Hirschhorn (1962)

Recreational catch estimates for Pacific halibut in Alaska are available from the International Pacific Halibut Commission since 1977 (Williams 2012) and were used to reconstruct recreational catch from 1977-2010, converting net weights into round weights using a conversion factor of 1.3. Skud (1975) provides estimates of recreational catch for 1973-1975 in numbers of fish, which were converted into weights using a conversion of 7.1 kg·fish<sup>-1</sup> (Skud 1975).

Due to the lack of data prior to 1977, the numbers of fishing licenses issued in Alaska from 1950-1976 ([wsfrprograms.fws.gov](http://wsfrprograms.fws.gov)) was used as a proxy for annual fishing effort. We calculated the average annual amount of fish caught per license per year from 1977-1981. This ratio was then used to estimate the recreational catch from 1950-1976. We used the average annual catch of halibut per license from 1973-1975 to estimate halibut catch from 1950-1972, and the average annual catch from 1975 and 1977 to estimate halibut catch in 1976.

#### 2011-2014 update

Alaska's recreational fisheries are reported by the Alaska Department of Fish and Game and by the International Pacific Halibut Commission (IPHC), and these numbers of fish caught were used to estimate recreational catches for 2011-2014. The live weight of these catches were calculated based on conversion factors from the original reconstruction. Alaska's subsistence fisheries were calculated for 2011-2014 based on subsistence fishing rates for non-salmon taxa. Subsistence catch rates were carried forward from 2010 unchanged. Because no new census data were available since the 2010 update, the population trend from the 2006-2010 period was assumed to continue and was used to inform the population in the 2011-2015 period.

## Results

Strictly domestic commercial landings (e.g. NMFS commercial landings, excluding joint ventures) constitute 55% of the total reconstructed catch, while foreign catches and joint venture landings accounted for 34% and 5%, respectively. Discards from joint ventures and domestic fisheries contribute an additional 5%. Reconstructed subsistence and recreational catches represent 0.3% and 0.2%, respectively, of the total reconstructed catch.

Total estimated recreational catches from 1950-2010 were 207,000 t. The 3 species that contributed the most to these catches were Pacific halibut (*Hippoglossus stenolepis*) with 51% of total catch, Coho (20%), and Chinook salmon (16%). Recreational catches have steadily increased from about 160 t in 1950 to a peak of nearly 11,000 t in 2005.

## Vanuatu

The original technical reconstruction research was initially documented in Zyllich et al. (2014), was vetted through peer-review in Leopold et al. (2017), and was updated to 2014 by the *Sea Around Us*.

## Methods

Vanuatu is a well-known game fishing location and hosts numerous game fishing tournaments, including the Vanuatu Marlin Classic and the Blue Marlin World Cup (Gentner 2009). Recreational fishing is not only limited to tournaments though. Hotels and resorts also hire boats to take guests out fishing and charter boats are available for hire to take tourists out on the water. Data on total number of boats used for recreational purposes was inconsistent across sources. Also, catch rates for smaller boats operating out of resorts were not available. However, it is known that when charter boats take people out for fishing, the boat retains all fish caught and then sells these to hotels, resorts, or restaurants, thus partially supplying fish for the tourist consumption demand. A catch rate of 48-64 t caught annually by the charter fleet was given for 2008 (Gay 2008). Taking the average gives an anchor point of 56 t in 2008. Chapman (Chapman 2004) stated that charter fishing vessels began operating out of Port Vila in the late 1980s. We assumed that the very first charter fishing vessels began operating in 1980 and set the catch to zero t in 1979. Interpolation was done between the zero anchor point and the point of 56 t in 2008. The rate of increase in catch was carried forward to 2010.

No detailed information regarding species composition of recreational catches was readily available. However, it is known that recreational catches mainly consist of billfishes and tuna-like fishes. Thus an assumed composition of 90% family Istiophoridae and 10% family Scombridae was applied.

For the 2011-2014 update, a linear regression was used to carry the original trend forward.

## Results

The reconstructed total catch for Vanuatu was estimated to be 886,750 t over the 1950-2010 time period. This is 9.5% higher than the 810,021 t of landings reported by the FAO on behalf of Vanuatu. Of the total reconstructed catch, the industrial sector constitutes 81.5%, artisanal 2.9%, subsistence 15.5% and recreational 0.1%.

Recreational catches began in 1980 and increased gradually from zero to 21 t·year<sup>-1</sup> in 1999. From 1999 to 2010 the rate of recreational catch increased and catch was estimated to be 64 t·year<sup>-1</sup> by 2010.

## Venezuela

The original technical reconstruction research was initially documented in Mendoza (2015), and was updated to 2014 by the *Sea Around Us*.

### Methods

Landings of recreational fisheries for billfishes (Family Istiophoridae) during the period 1961-1996 have been reported to ICCAT, but since the mid-1990s, the fishery has become exclusively catch and release and there are no records of landings. However, this fishery began in the early 1940s (Alio 2012) and therefore, linear interpolation was used (assuming a catch of zero in 1945) in order to estimate unreported catches for the period 1950-1960.

There has been no recreational catch reported since 1996 and therefore this sector was left out of the carry forward reconstruction.

### Results

The majority of Venezuelan catches come from the western central Atlantic, which contributes 90% to the total catch. The eastern central Pacific constitutes 6% of the total catch and the remaining 4% comes from the southeast Pacific. Within the western central Atlantic 80% of the catch is artisanal, followed by 18% industrial, 2% subsistence, and 0.01% recreational. Catches in the two Pacific FAO areas are 100% industrial.

Artisanal fisheries catches constitute 97.2% of the small-scale catch with subsistence equating to only 2.8% and recreational fisheries less than 0.1%.

Recreational catches were estimated to be only 770 t over the 1950-1996 time period. Catches have fluctuated over the time period, peaking in 1969 with 50 t. A second peak was reached in the early 1990s with an average of 31 t·year<sup>-1</sup> from 1992-1994. Catches fell to 15 t·year<sup>-1</sup> in 1995-1996, after which the fishery became catch and release. Catches consisted of 38% Atlantic white marlin, 35% Atlantic sailfish, and 27% Atlantic blue marlin.

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