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Alasdair Lindop, Elise Bultel, Kyrstn Zylich
and Dirk Zeller

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Email: alindop@gmail.com

RECONSTRUCTING THE FORMER NETHERLANDS ANTILLES MARINE CATCHES FROM 1950 TO 2010

Alasdair Lindop, Elise Bultel, Kyrstn Zylich and Dirk Zeller

Sea Around Us, Fisheries Centre, University of British Columbia,
2202 Main Mall, Vancouver, Canada, V6T 1Z4

alindop@gmail.com; elise.bultel@gmail.com; k.zylich@fisheries.ubc.ca; d.zeller@fisheries.ubc.ca

ABSTRACT

The former Netherlands Antilles consisted of Aruba, which became a distinct state in 1986, Curaçao and Sint Maarten, which became countries in 2010 with the dissolution of the Netherland Antilles, and Bonaire, Sint Eustatius and Saba, which became special municipalities of the Netherlands. Fisheries management in the Netherlands Antilles has suffered due to a lack of data collection throughout its history and significant declines in fish catches have been seen on most of the islands over recent years. This study reconstructed fish catches for 1950-2010 in the five islands that were part of the Netherlands Antilles at the dissolution (namely Curaçao, Sint Maarten, Bonaire, Sint Eustatius and Saba) including artisanal, subsistence and recreational sectors that may be overlooked in catches officially reported to the FAO. This required disaggregation of FAO reported landings data previously reported only as 'Netherlands Antilles' into their constituent entities, using an assumption based approach. As a result of this process, there were two islands which had a total reconstructed catch that was less than their assumed FAO reported baseline. Overall, Curaçao was 2.2 times its baseline; Bonaire 2.9 times; Saba 6.6 times; Sint Eustatius 0.86 times (i.e., total is smaller than the baseline); and Sint Maarten 0.38 times. However, the total reconstructed catch for all five islands combined was 1.9 times the data reported by the FAO on behalf of the former Netherlands Antilles. In Bonaire and Curaçao, the dominant taxa were wahoo (*Acanthocybium solandri*), dolphinfish (Coryphaenidae) and tunas (*Thunnus albacares* and *Thunnus atlanticus*), with barracuda (*Sphyraena barracuda*) also being important in Bonaire. . In Saba, Sint Eustatius and Sint Maarten, snappers (Lutjanidae) and Caribbean spiny lobster (*Panulirus argus*) were the most dominant taxa, with groupers (Serranidae) also proving to be important. The study emphasizes the need for more comprehensive and accurate fisheries monitoring on all of the islands. Programmes are beginning in Bonaire and Curaçao, although it will be several years before useful trends can be observed.

INTRODUCTION

History

The Netherlands Antilles were originally an autonomous Caribbean country within the Kingdom of the Netherlands, consisting of two geographically distant groups of three more closely clustered islands each: the ABC islands (Aruba, Bonaire and Curaçao) and the SSS islands (Sint Maarten, Saba and Sint Eustatius). The ABC islands are located north of the Venezuelan coast and approximately 800 km from the SSS islands, which are part of the Leeward Islands, located east of Puerto Rico (Figure 1). Sint Maarten encompasses the southern third of the Caribbean island of Saint Martin, while the northern two-thirds of the island constitutes the French overseas collectivity of Saint-Martin. In 1986, Aruba was declared a distinct state and its fisheries catch was reported separately to FAO. Aruba's catch reconstruction was performed previously by Pauly *et al.* (In press). Therefore, in the present report, when mentioning the Netherlands Antilles, we refer to the five remaining islands: Bonaire, Curaçao, Saba, Sint Eustatius and Sint Maarten (Figure 1).

In 2010, the Kingdom of the Netherlands dissolved the Netherlands Antilles, reconstituting Curaçao and Sint Maarten as new countries. Bonaire, Sint Eustatius and Saba (the BES islands) became 'special municipalities' within the Kingdom of the Netherlands. Over several centuries, all of the islands changed

colonial rule several times, eventually coming under stable Dutch rule in 1816. The early Antillean economy during the colonial period involved trade and slavery, with slaves being used to grow sugar, tobacco and cotton. Local economies suffered a set-back with the abolition of slavery (Goslinga 1979). Prosperity returned in the 20th century, with development of oil refineries in Curacao and Aruba (Zaneveld 1962), and later, with the huge growth of international tourism as a profitable industry.

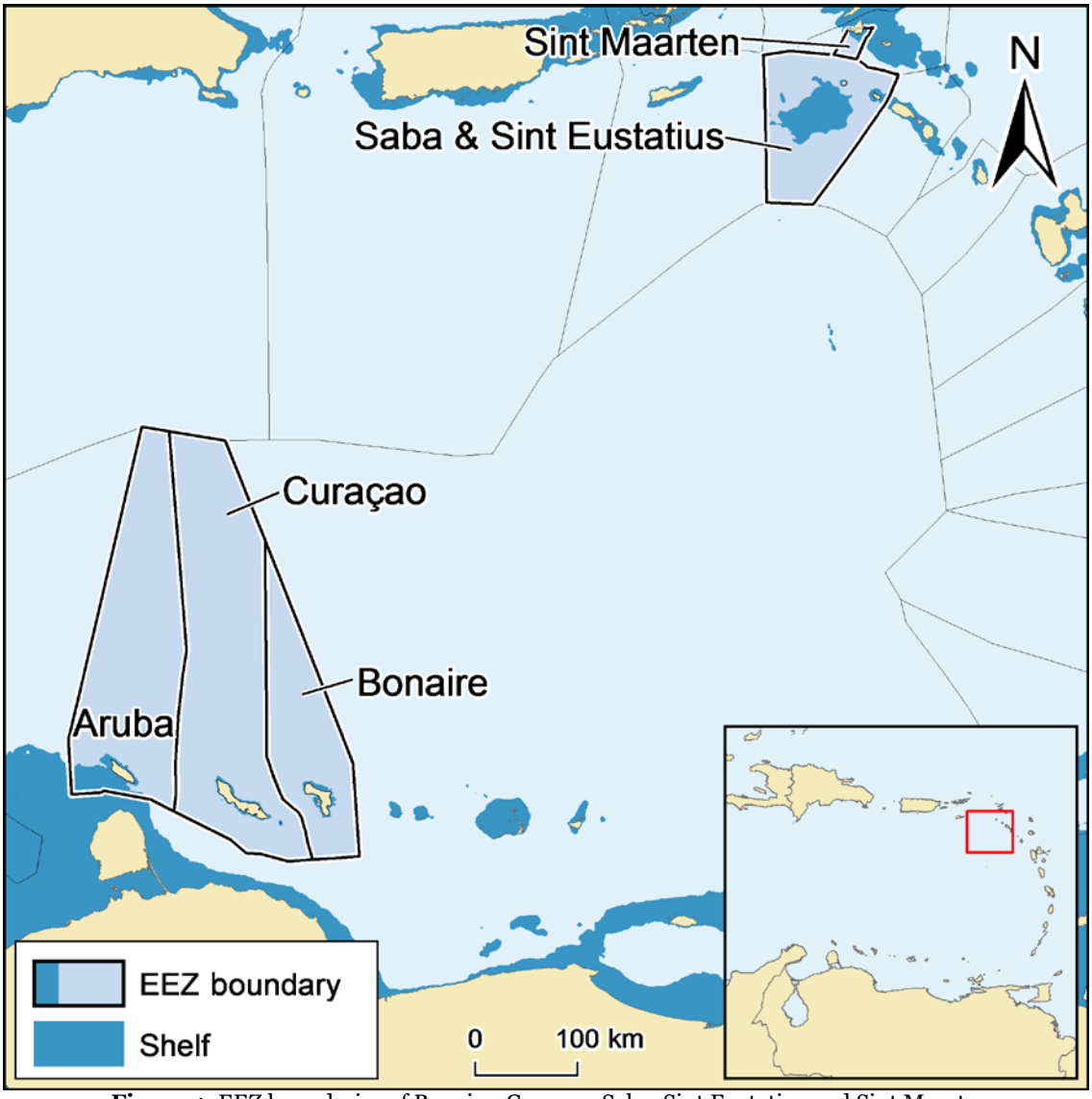

Figure 1. EEZ boundaries of Bonaire, Curacao, Saba, Sint Eustatius and Sint Maarten.

Fisheries development

Technology

A variety of artisanal fishing gear was used across the Netherlands Antilles in the 1950s, including trolling, bottom hand-lines, coastal beach seines, galvanized chicken wire fishpots, cast nets and hoop nets, with most vessels being unpowered row boats (Zaneveld 1962; Van Buurt and Dienst 2001). Early attempts to establish a more industrial fishery floundered, partly due to insufficient markets for the fish landed (Van Gelderen 1953). This modest level of technology has continued despite advances around the world, with the fishing fleet on each island almost entirely composed of artisanal commercial boats (Weidner *et al.* 2001).

Management

Fisheries management in the Netherlands Antilles has been severely limited by a lack of reliable fisheries data, with very few attempts to estimate accurate catch amounts (Weidner *et al.* 2001). However, there are several examples of management of specific fisheries, as well as marine parks, across the islands. Conch fishing has been restricted since 1985 on Bonaire, but is poorly regulated and heavy poaching occurs (Anon. 2012). There are limitations on the size of Caribbean spiny lobsters allowed to be retained and bans on landing berried or molting lobsters (Dilrosun 2002b), as well as a requirement to include escape panels on all traps used on the Saba Bank. Curaçao has introduced legislation regulating the use of gill nets (Johnson 2011).

Bonaire has established a marine park that encompasses the entire island and extends to 60 m depth where non-traditional fishing is prohibited and conch removal requires a permit. Work is ongoing with stakeholders to identify and manage no-take zones (De Meyer and MacRae 2006). Sint Eustatius also established a marine park surrounding the island from high water to a depth of 30 m, consisting of a general use zone and two no-take areas (White *et al.* 2006) Saba has had a marine park encircling the island extending to 60 m depth since 1987, and in 2008, created a management plan for Saba Bank (Toller and Lundvall 2008). Venezuelan purse seining, trawling and longlining occurred in Bonaire and Curaçao waters, to the frustration of local fishers (Debrot and Nagelkerken 2000; De Meyer and MacRae 2006). According to De Meyer and MacRae (2006), the trawling and longlining is illegal in Bonaire's waters, and although the central government has issued six permits to longlining vessels, by the publication of the management plan in 2006, they still had not yet been used to fish.

Curaçao

Almost all fishing on Curaçao is artisanal; however, since the turn of the century, there have been attempts to introduce longlining as a way to develop local fishing in the Exclusive Fishing Zone (Van Buurt and Dienst 2001). One company, Blue Caribbean, was recorded as operating in 2001 with several vessels, having conducted tests in 1999 and 2000 (Weidner *et al.* 2001; Dilrosun 2002a). However, it was later reported as having ceased operations and, along with another local boat that had attempted to develop the fishery, caught no fish during 2002-2003 (Anon. 2003b). Despite a search, no further records for Blue Caribbean or other longlining enterprises could be found and it appears that so far, no further domestic longlining has occurred.

Other reports of the fishing sector on the island from around the same time only describe reef-fishing, focussing on demersal species, and trolling (Van Buurt and Dienst 2001). Traps and beach seines are also used, but by very few fishers and are only important for elderly or disabled fishers (Debrot and Nagelkerken 2000). Gillnetting for reef species also occurs, mostly by Asian fishers and is poorly regarded by local fishers for its high by-catch rate (Johnson 2011). The island government also employs Fish Aggregation Devices (FADs) to attract pelagic species (Debrot and Nagelkerken 2000).

Pelagic fishing contributes the bulk of the catch, with demersal species only making up 17-22% (Dilrosun 2002a; Anon. 2003b).

Bonaire

The entire coastline of Bonaire is a marine sanctuary to protect coral reefs, and the associated tourism accounts for the majority of economic activity, but fisheries are also significant, both economically and culturally (Lacle *et al.* 2012; Anon. 2013). Bonaire's fisheries are largely artisanal (De Meyer and MacRae 2006); however, the sector has significant value and is currently worth approximately $745,000 annually (Schep *et al.* 2012).

Gears primarily employed include gillnets, spear fishing and fish traps (Johnson 2011), although bottom and trolled hand-lines are the most commonly used gears (Van Buurt 1984). Spearfishing is banned in the marine park (De Meyer and MacRae 2006). Trawling and longlining occurs on the reefs, but it is illegal

and conducted by Venezuelan boats rather than local vessels (De Meyer and MacRae 2006). Larger pelagic trolls on bigger vessels (7-10 m length) account for 80% of catches (Van Buurt 1984). Recreational fishing by the local population is also popular on the island, with 29% of households engaging in the activity at least once a year and most fishing from the shore (Lacle *et al.* 2012).

Saba

Fishing in Saba consists of near-shore fishing and fishing on Saba Bank. Saba Bank is reported to encompass an area of 2,200 km^2, with less than 200 m depth (Meesters *et al.* 1996), and Saban fishers are famed for their excellent seamanship and boat-building abilities.[1] A small fishing fleet of approximately ten vessels, 10-13 m in length, operates from Fort Bay and conducts small-scale commercial fishing on Saba Bank (Toller and Lundvall 2008).

The Saban near-shore fishery can be described as an artisanal trap-fishery. Traps are used to target two different fisheries stocks: lobster and "redfish" (actually a snapper fishery). All Saban fishers participate in the lobster fishery, while less than half of the fishers also participate in the redfish fishery (Toller and Lundvall 2008). Lobster traps are set to capture the Caribbean spiny lobster, *Panulirus argus*, although there are incidental catches of finfish and other invertebrate species in the traps. Redfish landings by Saban trap fishers are dominated by three species of lutjanids: silk snapper (*Lutjanus vivanus*), blackfin snapper (*L. buccanella*), and vermilion snapper (*Rhomboplites aurorubens*). Catches of silk snapper make an important economic contribution to the Saban fishery (Dilrosun 2000; Toller and Lundvall 2007). As special municipalities, Saba shares an EEZ with Sint Eustatius.

Hook and line fishing with hand-lines or with rod and reel is done opportunistically. Fish Aggregating Devices (FADs) are also deployed by some Saban fishers to increase catch rates for pelagic species such as wahoo, tuna, and dolphinfish. Diver-based catch methods, such as the use of SCUBA for capturing lobster and conch or spearing finfish, are absent and there is currently no commercial catch of queen conch (*Strombus gigas*) from Saba Bank (Toller and Lundvall 2008). Presumably, there is some capture of conch in near-shore areas around Saba, as Stromboid conchs are present in official FAO catch records.

Formal management of the Saba Bank commercial fishery is minimal owing to limitations of capacity, funding, and infrastructure (Dilrosun 2000). There are no fisheries officers on Saba and there is no program for continuous recording of commercial landings (Toller and Lundvall 2008).

Sint Eustatius

In 1904, Sint Eustatius had a total of 9 fishers and their four fishing boats had been built on Saba (Zaneveld 1962). Today, the Sint Eustatius fishery remains small-scale in nature, with around 24 artisanal fishers and 15 vessels fishing on the narrow shelf surrounding the island (Dilrosun 2004a). The boats are all small wooden-hulled open fishing boats covered with fiber glass and are propelled by outboard engines.

Principal fishing methods used are traps, hook and line trolling and occasionally nets. Fishers target a variety of pelagic and demersal species year-round, including wahoo, tuna, dolphinfish, lobster, conch, snapper, and grouper, with a lobster fishery taking place between September and December (White *et al.* 2006). The lobster fishery is the most important fishery on the island, with each fisher owning 15-20 traps, which are hauled 2 times a week (Dilrosun 2004a).

[1] http://www.thedailyherald.com/index.php?option=com_content&view=article&id=25618:fishing-the-qsaba-bankq&catid=24:weekender&Itemid=37 [Accessed: August 10, 2014]

Sint Maarten

There are about 50 fishers and two main landing sites on Sint Maarten (Dutch side of the island): one at Simpson Bay and one in Great Bay, Philipsburg (Dilrosun 2004b). Three types of fishing vessels are employed in Sint Maarten: small open wooden vessels, large covered fiber-glass vessels equipped with diesel engines and luxury yachts (Dilrosun 2004b). The open boats fish with traps and hand-lines on the Sint Maarten shelf, the larger modern boats fish for snapper on the Saba Bank and the luxury yachts conduct recreational day-charters for tourists.

There is a large demand for fresh fish in Sint Maarten, although pelagic species are only occasionally available at market sites (Dilrosun 2004b). The domestic fishing industry provides much of the local population's needs. Although at the present time fish processors do not export to the US or Europe, the local industry and government are working towards acquiring permission for export to the European Union (Anon. 2003a).

Aims

This report aims to reconstruct the fish catches from 1950 to 2010 for the 5 islands that were part of the Netherlands Antilles when it was dissolved in 2010. The study includes reconstruction of all sectors, including unreported catches. Catches are reconstructed following the approach described by Zeller *et al.* (2007) and compared to the official catch totals reported to the FAO, as allocated to each of the islands using an assumption-based approach.

METHODS

Reported baseline

Reported landings data for marine fisheries from 1950 to 2010 were extracted from the FAO Fishstat database, where the Netherlands Antilles appeared as a single FAO entity until 2010 when the country was dissolved. However, in the 2011 FAO dataset, the new constituent countries and special municipalities were reflected in the reporting entities. The BES islands were reported combined, while Curaçao and Sint Maarten were reported separately.

Industrial catches of large pelagics reported to the FAO were excluded from this study, as they are covered elsewhere by the *Sea Around Us* (Le Manach *et al.* in press). The only remaining classifications were "marine fishes nei" and "stromboid conchs nei". To generate a baseline for the separate islands of the Netherlands Antilles for 1950-2010, we initially applied the proportional split from 2011 of these two taxa into Curaçao, Sint Maarten and Bonaire/Saba/Sint Eustatius. In order to split the Bonaire/Saba/Sint Eustatius portion of the data by island, the 2011 population proportions for those islands was applied to the annual catch totals for the entire time period. We recognize that this is a simplifying assumption.

Curaçao

<u>Industrial, artisanal and subsistence</u>

Other than the attempt to develop a semi-industrial longlining industry at the start of the 2000s (Dilrosun 2002a), all fishing in Curaçao is artisanal, and was categorized as such in the reconstruction. The longline catches as recorded by Dilrosun (2002a) covered a 6 month period and were doubled to account for the full year, whilst the subsistence catches were reconstructed as outlined below.

The total catch for the artisanal and subsistence sectors (i.e., excluding the above estimated longline catch) was estimated using anchor points of 500 t in 1956 (Zaneveld 1962), 850 t in 1984 (Van Buurt 1984), 1,050 t in 2001 (Van Buurt and Dienst 2001) and 200 t in 2008 (Anon. 2008). A ratio was calculated between the 1956, 1984 and 2001 anchor points and the assumed reported annual catch for that year. We interpolated between each ratio to complete the time series and multiplied the reported FAO data by the ratio for the corresponding year to estimate the artisanal catch. Catches prior to 1950-

1956 were estimated using the 1956 anchor point ratio, applied to each year. The anchor point for 2008 was smaller than the FAO reported data for the same year, and assumed to be under-estimated. Therefore we accepted the FAO reported data for 2010 and estimates for 20001-2010 were calculated by interpolation.

To account for subsistence fishing, we followed the protocol used to estimate subsistence catches in Aruba, one of the former Netherlands Antilles (Pauly *et al.* In press). We assumed that the artisanal fishers retain for their own consumption 0.5 kg·day^{-1} on 250 days a year, i.e., that they and/or their families have a consumption of 125 kg·fisher^{-1}·year^{-1}. The number of artisanal fishers was derived by using population trends[2] from 1950-2001, combined with a published fisher to population ratio of 1/190 (Zaneveld 1962). For 2010, it was assumed that only 60% of the 2001 subsistence catch was taken by fishers due to the marked decline in artisanal catches. Subsistence catch was interpolated between 2001 and 2010. This estimated subsistence catch was subtracted from the total catch estimated above and the remainder was considered artisanal.

Recreational

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 2002a). Therefore, using the data from a Lacle *et al.* (2012) household study in Bonaire by Lacle *et al.* (2012) (see below) 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.[3] Therefore, we used tourist 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.[4] 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.* 2001), 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.

Catch composition

Industrial longlining: Catch composition for longliners was reconstructed as reported by Dilrosun (2002a) and only occurred in one year (2001). Dilrosun (2002a) reported that in 2001, longliners caught a total 4.9 t over a 6 month period. This was doubled to estimate the total caught for the year. The estimated total was split by the taxonomic composition of the sampled catch (Table 1). The report gave no comment on whether by-catch was retained or discarded. We assumed that all by-catch was landed, except the undersized tuna and swordfish was discarded.

[2] http://www.cbs.cw/cbs/themes/Population/Data/Population-2014050933620.pdf
[3] http://caribya.com/Curaçao/fishing/ [Accessed: August 10, 2014]
[4] www.onecaribbean.org

Table 1. Composition of industrial longline catch in 2001 (Dilrosun 2002a).

Common name	*Taxon*	%
Target		
Swordfish	*Xiphias gladius*	33
Bigeye tuna	*Thunnus obesus*	11
Yellowfin tuna	*Thunnus albacares*	4
Bycatch		
Sharks	Selachimorpha	11
Escola	*Lepidocybium flavobrunneum*	8
Dorado	*Coryphaena hippurus*	3
Marlins	Istiophoridae	3
Jacks	Carangidae	1
Rays	Batoidea	<1
Rainbow runner	*Elagatis bipinnulata*	<1
Discards		
Undersize tuna	Scombridae	9
Undersize swordfish	*Xiphias gladius*	17

Artisanal: The composition of catches was described with a varying degree of taxonomic precision by a number of sources (Zaneveld 1962; Van Buurt and Dienst 2001; Dilrosun 2002a, 2004c). These broadly supported the assertion by Van Buurt (1984) that around 80% of catches are pelagic. Using this information, we derived an estimate of catch composition, based largely on Dilrosun (2002a) which mostly recorded at the family level (Table 2). More recent monitoring suggested a slightly heavier reliance on demersal fishes than in the late 1970s, so we used two anchor points and interpolated between them, leaving the values fixed from 1950-1978 and 2002-2010. Lobster and queen conch are known to be fished in Curaçao and Bonaire (Debrot and Nagelkerken 2000; Oxenford *et al.* 2007; Anon. 2012), however little information exists on catch amounts. While recognising the limitations of such an assumption, 1% of the demersal catch for both taxa was added before normalization. Zaneveld (1962) mentions a large number of taxa and food preferences in the Netherlands Antilles, some of which are not specifically accounted for here, including Carangidae, Clupeidae, Engraulidae and Xiphiidae. These are assumed to be included in the 'other' category.

Table 2. Catch composition used to estimate species breakdown of artisanal catches in Curaçao and Bonaire, based largely on (Dilrosun 2002a).

Category	Common name	Taxon	% of total catch 1978	% of total catch 2002
Demersal	Snappers	Lutjanidae	1.6	2.6
	Great barracuda	*Sphyraena barracuda*	2.7	4.3
	Round scad	*Decapterus punctatus*	0.5	0.8
	Sharks	Carcharhinidae	0.7	1.2
	Grouper	Serranidae	0.2	0.3
	Coney	*Cephalopholis fulva*	1.1	1.8
	Lobster	*Panulirus argus*	0.5	0.8
	Conch	*Strombus spp.*	0.5	0.8
	Potfish	Miscellaneous fish	4.6	7.4
Pelagic	Flyingfish	Exocoetidae	4.9	4.4
	Yellowfin tuna	*Thunnus albacares*	12.7	11.6
	Blackfin tuna	*Thunnus atlanticus*	11.3	10.3
	Bigeye tuna	*Thunnus obesus*	0.9	0.8
	Skipjack tuna	*Katsuwonus pelamis*	1.2	1.1
	Other scombrids	Scombridae	1.9	1.7
	Rainbow runner	*Elagatis bipinnulata*	3.6	3.3
	Wahoo	*Acanthocybium solandri*	24.6	22.5
	Dolphinfish	*Coryphaena spp.*	16	14.6
	Marlin	Istiophoridae	2.4	2.2
	Needlefish	Belonidae	2.6	2.3
	Others	Miscellaneous fish	5.6	5.1

Subsistence: The same species breakdown that was informed by Lacle *et al.* (2012) and used for Bonaire's subsistence and recreational breakdown (see below) was applied to Curaçao's subsistence catches.

Recreational: Weidner *et al.* (2001) 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.

Bonaire

Artisanal and industrial sectors

Few reports describe industrial fishing in Bonaire in detail, other than mention of illegal longlining and trawling occurring in Bonaire's territorial waters, often involving Venezuelan boats (De Meyer and MacRae 2006). Dilrosun (2004c) describes there being 25 '*sleepvissersboten*', which translates as 'towing boats', likely referring to 'trolling vessels' targeting wahoo, dolphinfish and tuna. This contrasts with the only other boat type described as '*rifvissersboten'*, meaning reef-fishing boats. Given the low level of technology in use, for the purposes of the *Sea Around Us* we assumed that no industrial fishing takes place in Bonaire.

Anchor points for artisanal catches were derived as 140 t in 1956 (Zaneveld 1962), 80 t in 1984 (Van Buurt 1984) and 40 t in 2010 (Johnson 2011). Annual catch was interpolated between these anchor points. Artisanal catch was extrapolated back to 1950 following the trend of the FAO data (i.e., there is an increase from 1950 to 1956) as no other information was available.

Catch composition: Virtually no information on the catch composition of Bonaire's artisanal fishery exists, however, in historical accounts the fisheries of Bonaire are often described together without separation from Curaçao and sometimes Aruba (Van Gelderen 1953; Van Buurt 1984). Therefore, we assumed the catch composition to be similar to Curaçao and applied the same taxonomic breakdown protocol (Table 2).

Recreation and subsistence

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[5] 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.[6] Tourist numbers were interpolated between 0 in 1945 and 25,200 in 1980, when records started.

[5] www.populstat.info
[6] http://bonaireresources.com/aboutbonaire/history.html

Saba, Sint Eustatius and Sint Maarten

Studies on fisheries catches of Saba, Sint Eustatius and Sint Maarten have been presented by a variety of authors (Van Gelderen 1953; Zaneveld 1962; Van Buurt 1984; Dilrosun 2000, 2004a, 2004b; Toller and Lundvall 2007, 2008).

Saba Bank

Spiny lobster: Traditionally, fishermen only targeted fish, and lobsters were an associated by-catch. However, in the 1980s, the potential for an extensive targeted fishery was seen, and a lobster fishery grew rapidly. Dilrosun (2000) cited a number of reports which we used as anchor points for several years, and Toller and Lundvall (2008) provided an anchor point for 2007 (Table 3). The anchor points for 1999 and 2000 included catch from Sint Maarten fishers on Saba bank, and so were adjusted using the ratio of vessel numbers from each island (Dilrosun 2000). Catches were assumed to remain the same for 2007-2010, then interpolated between the anchor points and carried back to 1 t in 1950. Toller and Lundvall (2008) report that the lobster traps also catch a 'mixed fish' by-catch, which was calculated to be 20.5% of the lobsters caught in 2007. We therefore applied this by-catch to the annual estimated lobster catch.

Table 3. Anchor points for Saba Bank lobster fishery.

Year	Source	Lobsters (t)
1981	Guidicelli and Villegas (1981; in Dilrosun 2000)	2.00
1992	Propan Consultans Group N.V. (1992; in Dilrosun 2000)	5.00
1995	Framhein (1995; in Dilrosun 2000)	25.50
1996	Meesters et al (1996; in Dilrosun 2000)	36.40
1999	Vomil (1999; in Dilrosun 2000)	70.54
2000	Dilrosun (2000)	70.37
2007	Toller and Lundvall (2008)	83.60

Redfish fishery: Three anchor points of total catch were obtained for the redfish fishery: 15 t for 1959, 13.2 t for 1999 and 41.3 t for 2007 (Zaneveld 1962; Dilrosun 2000; Toller and Lundvall 2008). Catches for 1950-1959 and 2007-2010 were assumed to remain the same, and interpolation was done between the anchor points.

Sint Eustatius

There are relatively few fishers in Sint Eustasius, with Dilrosun (2004a), reporting that only 3 can be considered fulltime. They focus on the narrow shelf around the island, with the lobster fishery being by far the most important.

Lobster fishery: Dilrosun (2004a) estimated a reported 4 t of lobster was caught in 2003, which we used as an anchor point. It was reported that this was an exceptionally bad year, so using this as an anchor point is a conservative estimate. We assumed that the catch remained the same for 2003-2010, and that the fishery started, like in Saba, in 1981. Therefore we interpolated to an estimated 0.5 t in 1981. The same 20.5% rate of 'mixed fish' by-catch used in Saba was applied to the annual estimated lobster catch.

Redfish fishery: Zaneveld (1962) reported 10 t of fish caught and estimated a catch rate of 0.5 t per fisherman in 1958, and also provided data that allowed for an estimate of 0.7 t per fishermen in 1956. These fishermen were reported to fish for both fish and lobster; however, the lobster season ends in April and begins in July, suggesting a targeted fishing season of only 4 months. Dilrosun (2004a) reported 24 fishermen in 2004, which assuming a similar catch rate, would catch a total 14.4 t. Applying the targeted fishery for only a third of the year gives 4.8 t, which we used as an anchor point and interpolated to the 10 t in 1958 (Zaneveld 1962). We assumed catches 1950-1958 and 2004-2010 remained the same.

Sint Maarten

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 2004b). Dilrosun (2004b) reported catches by Sint Maarten vessels over a week, where from 9 landings, a total of 227 kg was caught, with a CPUE of 30.7kg/trip. Dilrosun (2004b) 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.

Subsistence (all SSS islands)

Bultel *et al.* (2015) reported that over 40% of catches in French Saint-Martin were retained for consumption. Given the proximity of Saint-Martin to Sint Maarten and the other SSS islands, we used this as a proxy and categorized 40% of all catches as subsistence.

Catch composition (all SSS islands)

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) (Table 4). 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) (Table 5). A percentage of conch was added to both fisheries to allow for the few fishers who target conch, which is often illegal (Dilrosun 2004a, 2004b).

Table 4. Saban lobster-fishery catch composition (Toller and Lundvall 2007).

Species	Proportion
Lobster	0.610
Redfish (Snapper)	0.210
Hind	0.042
Moonfish	0.025
Grunts	0.079
Other[1]	0.034

[1] 50% of the 'other' category was allotted to *Strombus gigas*.

Table 5. Saban 'redfish' fishery catch composition (Toller and Lundvall 2008).

Species	Proportion
Silk Snapper	0.560
Blackfin Snapper	0.300
Vermillion	0.040
Red Hind	0.038
Groupers	0.028
Lane Snapper	0.014
Other[1]	0.020

[1] 50% of this category was allotted to *Strombus gigas*.

Recreational (all SSS islands)

Studies into fishing behaviour on Sint Maarten and Sint Eustatius reported that 15% of the population in 2010 engaged in recreational fishing (Bervoets 2010a, 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 (Table 4) 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,[7] thus retained catches from such vessels were determined to be minimal and therefore are not reconstructed.

Fishing on Saba Bank

Saba Bank is a prime fishing area in the region of the SSS islands, and is exploited by fishers from Saba, Sint Eustatius and Sint Maarten (Dilrosun 2002b). Saba Bank lies in the Saba/Sint Eustatius EEZ, and therefore any fishing by fishers from Sint Maarten is classed as 'foreign fishing', as it is outside Sint Maarten's domestic EEZ. However, given the lack of information on catches on Saba Bank, estimating the extent of Sint Maarten fishing there is difficult. Dilrosun (2000) reported that only two boats from Sint Maarten fished there, whilst Kadison *et al.* (2009) states that fishers from Sint Maarten fish the bank heavily. Earlier in the time period, during the eighties and nineties, the Bank was a refuge for foreign vessels that had been expelled from other countries, which resulted in reduced participation by local fishers due to intimidation and perceived over-exploitation, with only 4 local vessels in total remaining by 1996 (Dilrosun 2000; Hoetjes and Carpenter 2010).

To estimate Sint Maarten catch on Saba Bank for the reconstruction, we used the number of vessels reported by Dilrosun (2000), who stated that a total of 14 vessels fished the bank, two of which (14%) were from Sint Maarten. We assumed that Sint Maarten fishing didn't begin until 1996 and applied 14% of the total reported catches from the Saban anchor points in 1996, 2000 and 2007, interpolating between them and assuming that catches for 2007-2010 remained the same. We performed this for both the lobster and redfish fisheries, and applied the same species breakdown as described above.

Discards

Kelleher (2005) reported that the fisheries of the small island states in the Caribbean are considered to have discard rates of zero. While zero discards are unlikely (species that cannot be eaten are likely discarded), discarding is deemed negligible, therefore we did not estimate discards for any of the reconstructions.

RESULTS

Curaçao

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 (Figure 2a). 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% (Figure 2a). Catches increased steadily throughout the period from 330 t in 1950 to a peak of 1,060 t in 2001, before decreasing rapidly to a low of 470 t in 2010.

[7] https://www.stmaartencruiseexcursions.com/StmaartenDeepSeaFishing.htm; http://www.goldenrockdive.com/fishing-charters.php Accessed: August 15 2010

Wahoo (*Acanthocybium solandri*) was the most important species caught, making up 21% of the catch, followed by dolphinfish (Coryphaenidae; 14%), yellowfin tuna (*Thunnus albacares*; 11%) and blackfin tuna (*Thunnus atlanticus*; 10%; Figure 2b).

Bonaire

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% (Figure 3a). However, the importance and contribution of recreational catches has increased over the last 60 years, while the artisanal contribution has declined (Figure 3a). Overall, catches remained relatively constant, decreasing slightly from a peak of around 180 t·year^{-1} 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 (Figure 3b). 'Miscellaneous fish' was also a large part of the catch and includes mostly 'potfish' (Dilrosun 2004c), which most likely is made up of a variety of reef fish.

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% (Figure 4a).

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 (Figure 4b).

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% (Figure 5a). After a stable 1950s, averaging just under 12 t·year^{-1}, catches declined slightly to a low of 10 t in 1981. Catches then increased 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 (Figure 5b.).

Sint Maarten

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 (Figure 6a). 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% (Figure 6a).

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 (Figure 6c).

Foreign fishing on Saba Bank

It was assumed that fishers from Sint Maarten begun exploiting Saba Bank in 1996. The catch from Saba's EEZ increased from 9 t in 1996 to almost 23 t in 2010. Catches by Sint Maarten represented almost 14% of the total catch in Saba's EEZ for the 1996-2010 time period.

All former Netherlands Antilles islands

As previously mentioned, for the 1950-2010 time period, catches for the five islands were all reported together in the FAO data under 'Netherlands Antilles'. Only starting in 2011 is there any disaggregation of the islands and even then, three of the five islands are still grouped. Therefore, comparisons of total reconstructed data to the reported baseline data for individual islands are only approximations as we can only estimate how much of the data comes from each island. Therefore, for this analysis it is more appropriate to look at the islands as a whole. The total reconstructed catch of all five islands (Bonaire, Curaçao, Saba, Sint Eustatius and Sint Maarten) is 88% higher than the data reported by the FAO on behalf of the former Netherlands Antilles (Figure 7). Artisanal fisheries dominated the overall catch with 78%, followed by subsistence and recreational fisheries which contributed 15% and 7%, respectively (Figure 7). There was only one year of industrial data which amounted to less than 0.1% of the total reconstructed catch.

DISCUSSION

The reconstructions support the observations that a large portion of reef fish catches never pass through the main fish landing sites (Debrot and Nagelkerken 2000) and are therefore highly unlikely to be included in the reported data. The reported data was extremely limited in scope, accounting for only 'miscellaneous fish' and 'stromboid conchs' after the industrial pelagic catch had been discounted. Whilst the splitting of FAO data into individual islands to account for the political changes in the last decade made some assumptions about the quantity of catch each island reported, our reconstructions clearly demonstrate that there is not adequate inclusion of all fisheries in the reporting process.

The sharp crash in Curaçao's total catches has not been widely commented on in the literature and a simple explanation is hard to find. It may be that the effect of a crash is a result of the interpolation between two anchor points in the 2000s. Significant overfishing is unlikely as the reliance on fishing on Curaçao is not high and significant amounts of fish are imported; however, the increase in tourism and population will certainly increase pressure on the resources available. It is also possible that some of the decline is from a reduction in effort, as fisher numbers have significantly reduced. However, the extent to which reduced effort has an impact on catches is difficult to determine as fisher numbers have been decreasing across the whole time period, not just the last decade (Zaneveld 1962; Anon. 2008). Furthermore, less fishing may occur as catch per unit effort decreases and fishers look for other sources of income.

The decline of artisanal catches in Bonaire supports observations by local fishers that catches have reduced significantly in recent years (Johnson 2011). The temporary increase in the recreational and subsistence catches at the end of the 1990s are more likely to be artifacts of census methodology, which the reconstruction estimates were based on, than sudden increases in activity.

The reconstructions of the Windward Islands (Saba, Sint Eustatius and Sint Maarten) were the most heavily reliant on assumptions. The Saba Bank is the largest submarine atoll in the Atlantic Ocean and has some of the richest diversity of marine life in the Caribbean Sea. Yet there are no fisheries officers on Saba and there is no program for continuous recording of commercial landings (Toller and Lundvall 2008). In view of the recognized importance of catch statistics for management and the state of data monitoring in the Caribbean, alternative methods, such as catch reconstructions, must be sought to provide more comprehensive estimates.

The assumed reported catch in Sint Maarten is significantly higher throughout the entire time series, and Sint Eustatius also shows a discrepancy, albeit not as large. An explanation is that the assumptions used

to disaggregate the FAO data did not appropriately relate to the distribution of catch between the 5 islands. However, Sint Maarten has its own reported catch to the FAO in 2011, which is much higher than the total 2010 estimate. An increase this large in one year would be unlikely. It is very possible that the data submitted to the FAO for Sint Maarten in 2011 was an estimate and does not accurately reflect the catch of that island. Another reason for this may be that surveys possibly quantified the fish available at markets rather than actual catches by Sint Maarten fishers. Under this explanation, extra catch that informed the 2011 FAO data point may have been landed in Sint Maarten by vessels from other countries. This explanation emphasises the need to focus on the specific catches of local boats, rather than just the fish at the market, which is often harder to trace a source for.

Overall, the lack of nuance in the reconstructions reflects our limited ability to accurately piece together historical fishing in the Netherlands Antilles, as no systematic records have ever been kept (Weidner *et al.* 2001). This will hopefully improve with Bonaire starting official fisheries monitoring in late 2013, and the first results available in 2015, and a similar programme is planned on Curaçao in 2015 (de Graaf, pers. comm.). However, it is likely that a time series of at least five years of data collection will be required to be useful for identifying trends (Toller and Lundvall 2008).

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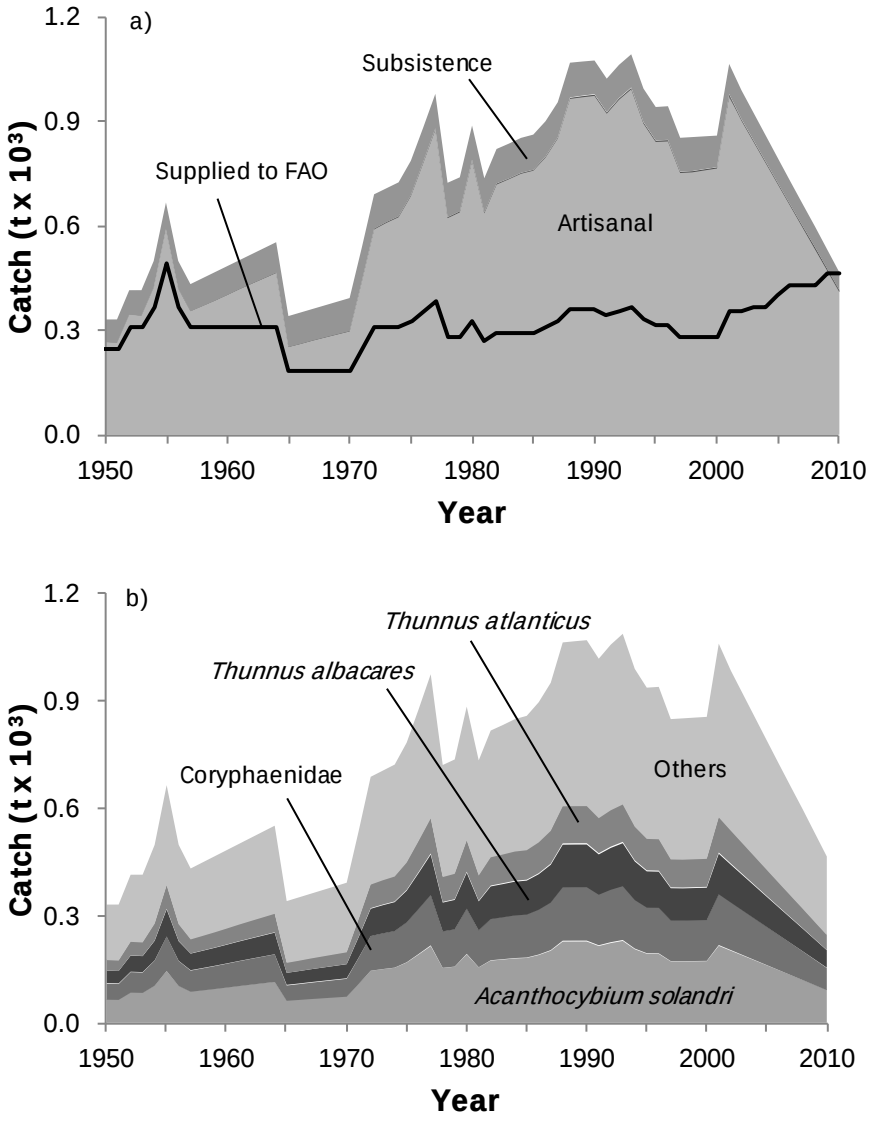

Figure 2. Reconstructed catch of Curaçao fisheries, 1950-2010, a) by sector, with catches deemed to be reported by the FAO on behalf of Bonaire overlaid as a line graph (note that industrial and recreational catches are too small to visualize), and b) primary taxa of the Curaçao catch. 'Others' includes 29 additional taxonomic categories.

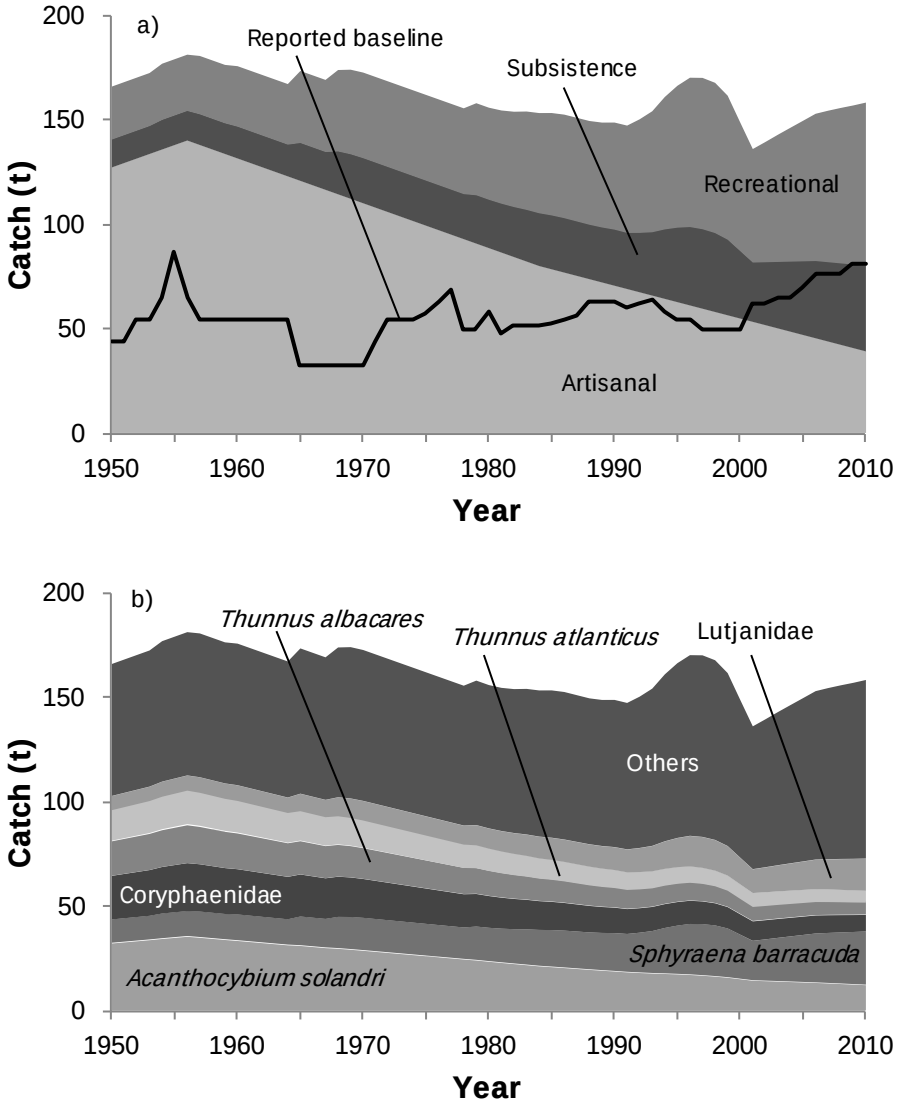

Figure 3. Reconstructed catch of Bonaire fisheries, 1950-2010, a) by sector, with catches deemed to be reported by the FAO on behalf of Bonaire overlaid as a line graph, and b) primary taxa of Bonaire's total catch. 'Others' includes 18 additional taxonomic categories.

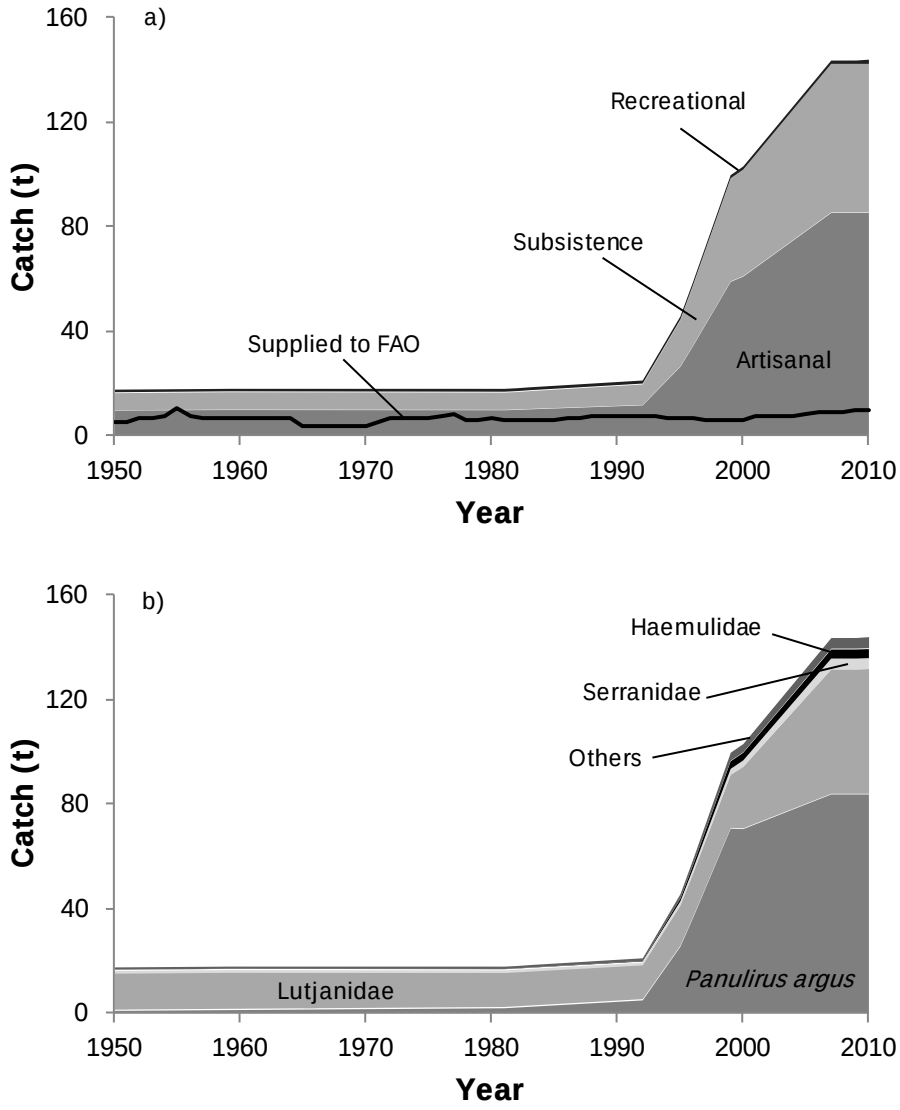

Figure 4. Reconstruction of Saba Island fisheries, 1950-2010, a) by sector, with catches deemed to be reported by the FAO on behalf of Saba Island overlaid as a line graph, and b) primary taxa of Saba Island's total catch. 'Others' includes 13 additional taxonomic categories.

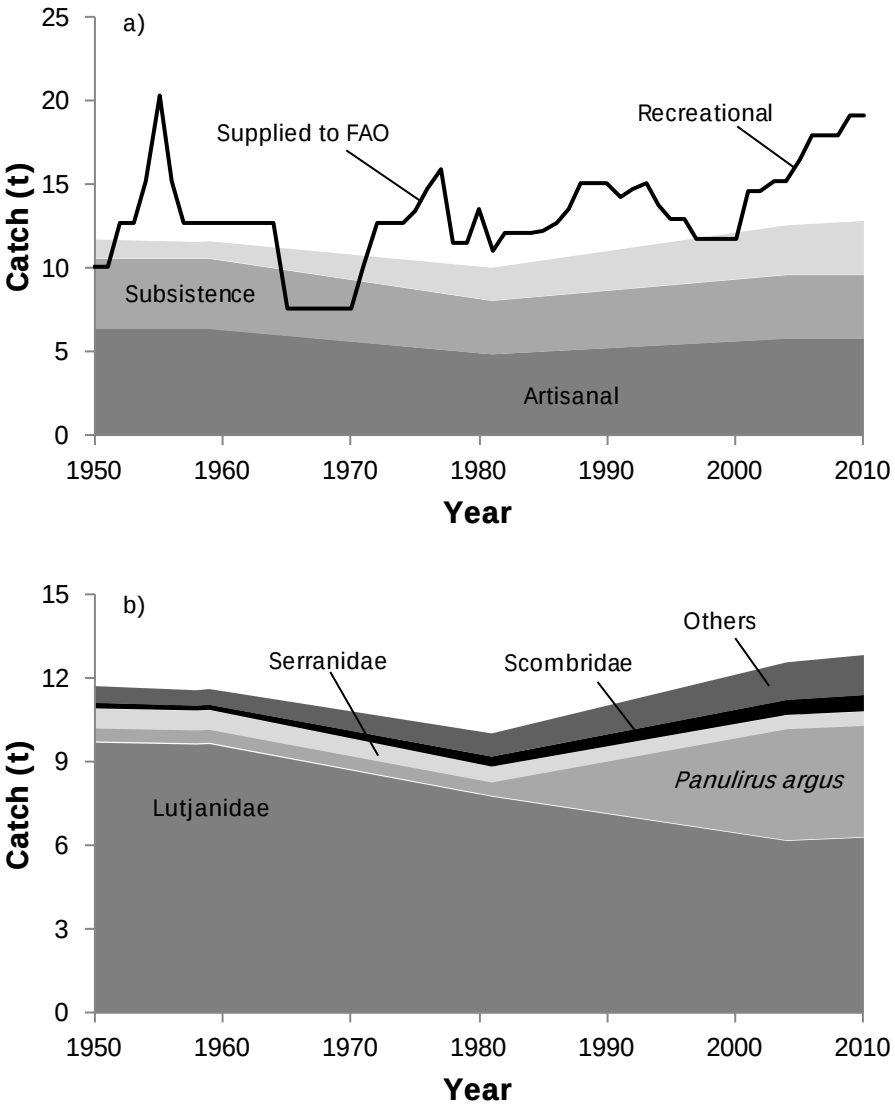

Figure 5. Reconstruction of Sint Eustatius' fisheries, 1950-2010, a) by sector, with catches deemed to be reported by the FAO on behalf of Sint Eustatius overlaid as a line graph, and b) primary taxa of Sint Eustatius' total catch. 'Others' includes 10 additional taxonomic categories.

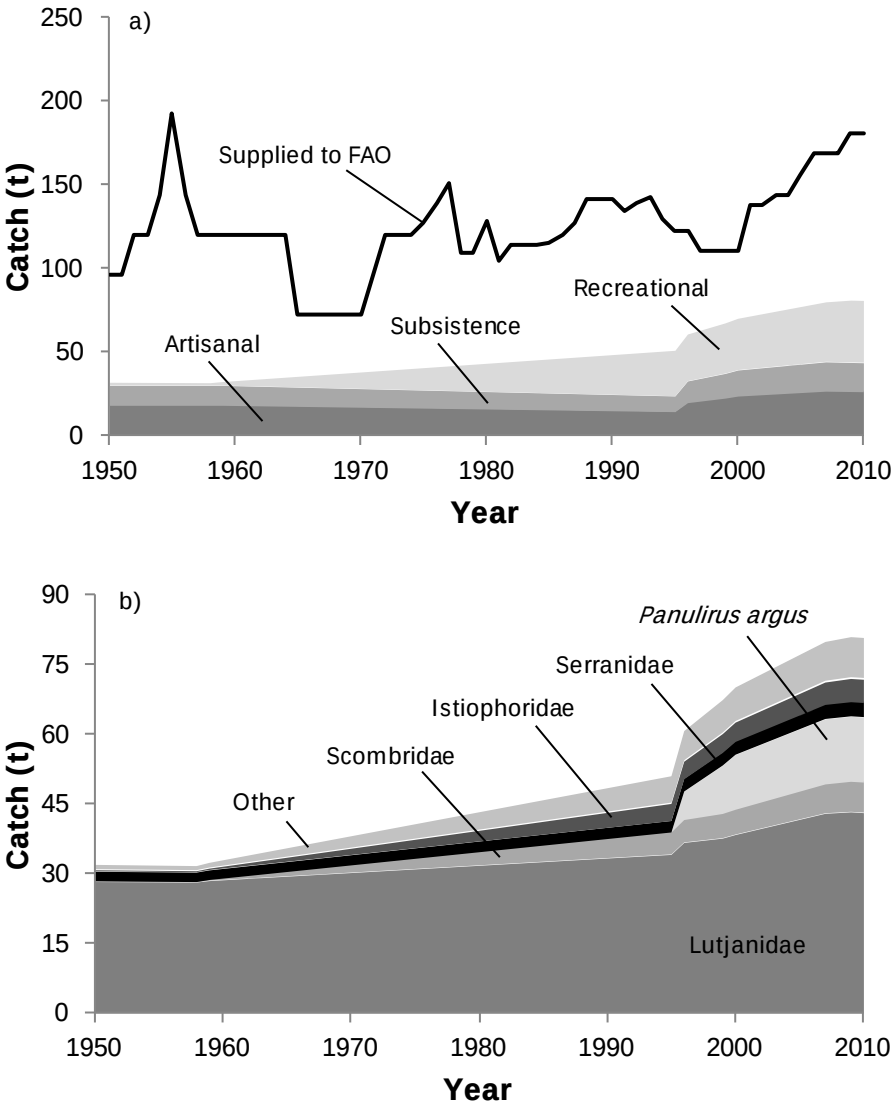

Figure 6. Reconstruction of Sint Maarten's fisheries, 1950-2010, a) by sector, with catches deemed to be reported by the FAO on behalf of Sint Maarten overlaid as a line graph, and b) primary taxa of Sint Maarten's total catch. 'Others' includes 7 additional taxonomic categories.

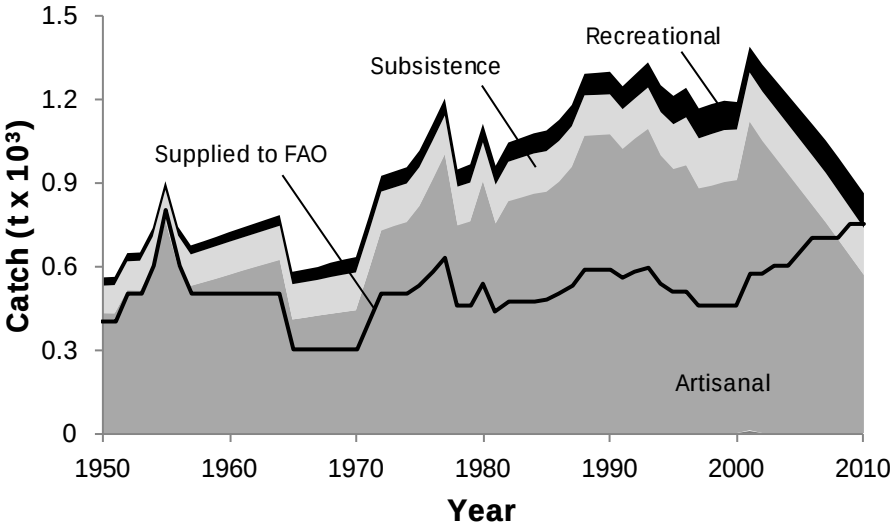

Figure 7. Total reconstructed catch of all five islands (Bonaire, Curaçao, Saba, Sint Eustatius and Sint Maarten), 1950-2010, by sector, with the data reported by FAO on behalf of the former Netherlands Antilles overlaid as a line graph. Note that this FAO total still excludes the large pelagics which were not considered in this reconstruction.