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Preliminary reconstruction of Bermuda's marine fisheries catches, 1950-2010

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Abstract
We reconstruct marine fisheries catches for Bermuda from 1950-2010 to account for catches that are omitted from official statistics. Annual national landings statistics account for catches from Bermuda's small-scale commercial fisheries, whilst catches from recreational fishing, including fish taken for food (essentially subsistence catch), are not enumerated. This reconstruction thus focuses on quantifying catches that are taken domestically for subsistence and recreational purposes. Reconstructed total catch in Bermuda was 54,200 t from 1950-2010, suggesting that actual catches were around 1.75 times the 30,970 t of domestic catches reported by FAO on behalf of Bermuda for the same time period. Although fisheries play a small part in Bermuda's economy, the magnitude of recreational and subsistence fishing belies its social and cultural significance. Steps should thus be taken to ensure the future sustainability of local fisheries, including comprehensive coverage of fisheries statistics that are essential for informed decision-making.

Introduction
Bermuda is an archipelago of seven main islands and numerous smaller islands located in the central North Atlantic Ocean (Figure 1). This British Overseas Territory has one of the world's highest per capita gross domestic product (GDP) and an economy that is centered on financial services and tourism. Fishing is a minor economic activity, accounting for <1% of total GDP in 2012 (Dept. of Statistics 2013). In comparison, international business activity contributed almost 25% to national GDP (Dept. of Statistics 2013). Reflecting this is the small number of full-time licensed fishers, which totaled around 300 in 2010[1] and was less than 100 in the late 1940s (Mowbray 1949). Local fish catch is not sufficient to support demand from both residents and tourists to the island, and Bermuda imports about two-thirds of its seafood (Dewailly *et al.* 2012).

Bermuda's fisheries are small-scale and multi-species in nature. Historically, fishers used pots to target groupers and other 'white meat' reef species. Up until the late 1960s, the commercial fishery was relatively undeveloped and largely self-regulated by customary tenure (Barrett 1991). There was no formal market for fish - fishers sold their catch to customers at the landing site or directly to hotels and

[1] Government of Bermuda. A Strategy for the Sustainable Use of Bermuda's Living Marine Resources. URL: http://www.caribbeanelections.com/eDocs/strategy/bm_strategy/bm_Fisheries_Strategy.pdf. Accessed 20 September 2014

guest houses (Mowbray 1949). In the 1970s, the government increased efforts to modernize and expand the fishing sector, which, in conjunction with the rise of the global economy, created a market for local fish. With this came the entry of bigger boats and the erosion of customary territorial fishing practices, which ultimately contributed to the rapid decline of reef species such as groupers and snappers by the late 1970s. In response to this decline, the government implemented regulations that restricted the use of pots and limited catch sizes. However, some species of reef fish never recovered fully (Burnett-Herkes and Barnes 1996).

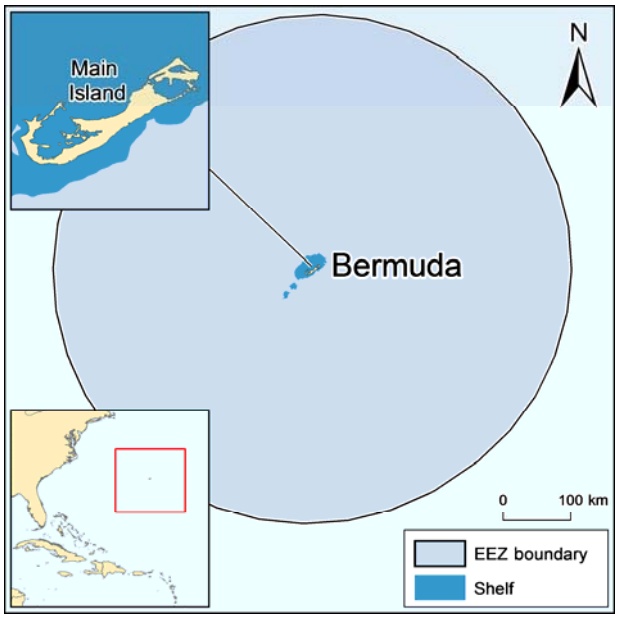

Figure 1. Exclusive Economic Zone (EEZ) and shelf area (to 200 m depth) for Bermuda.

The major demand for fish today continues to be exerted by the tourism industry. As well, recreational fishing is widespread in Bermuda as a leisure activity and also for supplementing local diets. The quantity of fish taken by local recreational fishers and the impact of this activity on domestic fish stocks is not fully known, but initial steps to fill this knowledge gap have been taken (DEP 2011). In addition, catches from tourism driven chartered sport fishing are also likely to be under-reported. Incomplete fisheries statistics hamper well-informed management of Bermuda's fisheries, particularly in the inshore environment where tourism and local fisheries can potentially overlap. This report therefore focusses on reconstructing Bermuda's fish catch from 1950-2010, with a focus on the undocumented subsistence and recreational sectors.

Background

Bermuda lies on top of a seamount and has a total coral reef area of about 1,000 km^2 (Burnett-Herkes and Barnes 1996). Most fishing occurs in shallow inshore waters and is artisanal (i.e., small-scale commercial) in nature. In the past, fishing effort was directed mainly at reef species, the local food fish of choice, but is now shifting to pelagic species. Since the mid-1980s, pelagics have become more important in the commercial fishery and now comprise more than half of total landings, while reef fish landings have declined to about half their average levels of the mid-1970s and 1980s. Yellowfin tuna (*Thunnus albacares*) and wahoo (*Acanthocybium solandri*) make up approximately 83% of total pelagic landings. A small, limited entry commercial fishery for spiny lobster (*Panulirus argus*) was established in 1996 and is

relatively stable (Trott *et al.* 2002). Licenses are also issued to recreational lobster divers, who are required to report their catches (Trott *et al.* 2002). There is a significant non-commercial, recreational fishery that is not monitored. Recreational fishers fish mainly with handlines, although trolling rods, spears, lobster noose, and cast nets are also used. Frequently caught species include lane snappers (*Lutjanus synagris*), carangids, and hogfish (*Lachnolaimus maximus*), and total catch by recreational fishers is estimated to be close to two-thirds of total commercial landings (DEP 2011).

Recreational fishing

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). According to the survey, 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 on average 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 self- 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 (international tourists)

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. Bermuda hosts at least 5 major big-game tournaments annually, most of which focus on billfish[2]. One tournament season was able to generate an estimated USD 3 million in revenue from visiting participants[3]. 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*), tuna, 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. Nonetheless, anecdotal evidence suggests that most fish caught on non-tournament charter fishing trips are kept, therefore are accounted for in this reconstruction.

[2] Bermuda Tourism Authority. Bermuda Fishing Guide. URL:http://www.gotobermuda.com. Accessed 24 September 2014.

[3] The Billfish Foundation. Potential Impacts of Bermuda's Marine Reserve on Sportfishing Tourism. URL:www.billfish.org. Accessed 24 September 2014.

Fisheries management

Management of Bermuda's marine resources and fisheries falls under the responsibility of the Marine Resources and Fisheries Enforcement Section of the Department of Environmental Protection. This section conducts fisheries monitoring and research and enforces fisheries regulations. Bermuda has a long history of fisheries management dating back to the 1600s, which included gear, species, temporal, and spatial restrictions (Luckhurst *et al.* 2003). In 1972, parliament passed the Fisheries Act which made provisions for controlling foreign fishing and protecting selected species within Bermuda's exclusive fishing zone (Burnett-Herkes and Barnes 1996).This series of regulations included a requirement for all commercial fishers to be licensed and to submit statistics on fish landings, fishing effort, and fishing location. During this period, entry to the pot fishery was restricted to licensed commercial fishers only (Barrett 1991). Further regulations to control entry and effort in the pot fishery ensued in the 1980s as fishing levels reached unsustainable levels, culminating in the 1990 ban on fish pots. An unintended side effect of these policies was the creation of conflict between full-time and part-time fishers, as well as between fishers and the government. Past fisheries interventions have thus tended to be reactionary rather than precautionary in nature.

The commercial fishing sector is separated into two categories, full-time and part-time fishers, where full-time status is defined as being a minimum of 800 hours at sea per year. Only full-time fishers are eligible for concessions (subsidies) such as fuel rebates. Participation in specialized fisheries, such as the spiny lobster fishery, is also restricted to full-time fishers only. Specialized fisheries include the guinea chick (*Panulirus guttatus*), offshore, and deep-water fisheries, which are managed on a limited entry basis. Scientific knowledge about the status of fish stocks in Bermuda is still limited; however, improving management of key fish stocks, along with that of commercial and non-commercial fisheries, including the collection of catch, effort, and biological data, is a key target in Bermuda's roadmap for marine resource management in the next decade[1]. Currently, the government is considering an ambitious marine reserve, which will be the largest addition to Bermuda's existing 29 marine protected areas. The proposed 'Blue Halo' reserve will be a fully protected marine reserve surrounding Bermuda, extending from 50 miles offshore outwards to 200 miles. Supporters claim that commercial fishers will not be negatively affected by the reserve due to the continued availability of the areas within 50 miles from shore (McFadden 2013), but it has faced opposition from the sport fishing community (Cox 2013).

Bermuda's national fisheries statistical program has been in operation since 1975 and relies on commercial fishers to gather catch and effort data (Luckhurst and Ward 1996). Fishers' intentional or unintentional misreporting of statistics and the lack of a validation process to monitor self-reporting can distort national fisheries statistics. Fisheries landings reported by the FAO on behalf of Bermuda were inconsistent with national fisheries statistics from 1950 to the mid-1970s; this issue is addressed in detail by Luckhurst *et al.* (2003), who adjusted FAO landings for total catch and modified the species composition of landings with more detailed national datasets.

Methods

Reported landings

Annual reported marine fisheries landings from 1950-2010 were extracted from FishStat (FAO 2012) and represent the reported baseline as used here. From 1950 to 1975, FAO landings for Bermuda were reported in only two groups, 'marine fishes nei' and 'Caribbean spiny lobster', with the majority of landed catch being in the former group. This suggest that the corrections by Luckhurst *et al.* (2003) have not been implemented by FAO to date.

Unreported catch

Unreported catches in Bermuda originate from recreational fishing. 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.

Subsistence catch

From 1950 to 1970, we considered all estimated local 'recreational' catch to come from subsistence fishing only (Figure 1). Up until the late 1960s, the market for fish was weak given low wages and limited job opportunities, especially for Bermuda's black population (Barrett 1991). People thus worked a variety of jobs to earn a livelihood and fished on a part-time subsistence basis when they required fish to eat. We assumed that from 1950-1970, subsistence fishing in Bermuda was primarily carried out by the black population. The rate of fish consumption is high in the Caribbean, with rates up to 77 $kg \cdot person^{-1} \cdot year^{-1}$ in places like Antigua and Barbuda[4]. We used the Caribbean wide consumption rate of 30 $kg \cdot person^{-1} \cdot year^{-1}$ to be representative of subsistence-based fish consumption in Bermuda from 1950-1970. The black population in Bermuda was 37,403, 42,640, and 52,976 in 1950, 1960, and 1970 respectively (Dept. of Statistics 2013). These were used as anchor points, and data gaps between these points were filled by linear interpolation. Total subsistence catch from 1950 to 1970 was then calculated as Bermuda's black population multiplied by the annual *per capita* subsistence fish consumption rate. From 1966 to 2010, a portion of total recreational catch (which includes both leisure and subsistence components) was allocated to the subsistence sector.

Recreational catch

From 1971 onwards 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. We thus started to decrease the subsistence component from 100% in 1970 to 52% in 2010 (DEP 2011), with the difference being allocated to the 'leisure' (i.e., true recreational fishing) component. To smooth out subsistence catch from 1970 to 1971, we started to linearly decrease the catch value from 1966 to the end point in 1971, which was calculated as described in the next paragraph.

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 160,000 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 (Figure 2). We assumed that prior to 1970 all fishing was done from shore given the dominance of low technology subsistence fishing. Starting in 1971, we started to linearly decrease shore fishing from 100% to 70% by

[4] Caribbean 360. Caribbean per capita fish consumption results in high imports. URL: http://www.caribbean360.com/news/caribbean-per-capita-fish-consumption-results-in-high-imports. Accessed 24 September 2014.

2010 (Pitt and Trott 2011). Average annual catch of shore fishers was 16.5 kg·person^{-1}·year^{-1} in 2011, while that of boat fishers was 23 kg·person^{-1}·year^{-1}. Due to lack of other data we applied these same catch rates to 1971, although it is probable that these figures under estimate the true level of fishing in the earlier time period given that fishing for food was likely still a comparatively stronger motivation. 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.

Up to this point, we have accounted for recreational fishing by locals. However, Bermuda is also a popular sport fishing destination for international visitors, whose catches are likely under-represented in Bermuda's fisheries landings statistics. As such, we considered the 'leisure' subcomponent to have 'local' and 'international' fishers, of which the catch of 'international' fishers is calculated separately (Figure 2). We assume that all international visitors take fishing trips using charter fishing boats, and account for their catch in the following section.

Charter boat fishing (international visitors)

Sport fishing has existed in Bermuda since before WW II (Smith 1989). Nonetheless, common sport fishing target species such as wahoo, swordfish (*Xiphias gladius*), yellowfin tuna, and marlins did not appear in FAO landing statistics until 1975. To account for this, we added a quantity of unreported sport fishing catch from 1950-1974, which was estimated as:

$$C_{charter} = P_{charter} * E_{charter} * R$$

Where C is total catch from charter fishing; P is the population of charter fishers; E is the catch rate; and R is the portion of catch that is retained.

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). US visitors made up about 72% of total tourist arrivals to Bermuda in 2010 (Dept. of Statistics 2013). Nonetheless, we remained conservative by using the number of US fishing visitors only as the 2010 anchor point for charter fishers, and assumed that the proportion of fishing visitors has remained constant since 1950. In 1950, there were 60,000 'transient visitors' (Mowbray 1949) in Bermuda, and we linearly increased this to 232,000, the number of tourist arrivals in 2010.

During an average charter fishing trip, between 8 - 10 tuna and 8 - 15 wahoo could be caught (Barrett 1991). An online search of charter fishing trip reports in Bermuda[5] showed that fishers were still catching the same quantity, or more fish. Using an average of 12 wahoo weighing 7kg per fish, and 9 tuna weighing an average of 4kg, we derived a total boat catch of 120 kg per charter fishing trip. In general, each charter boat takes between 3 to 6 fishers per trip; assuming an average of 5 fishers per trip, the individual catch rate is 24 kg·person^{-1}. We maintained this catch rate from 1950 to 2010. Not all fish that are caught by recreational fishers are retained. Fishing tournaments stipulate a catch and release policy, with the exception of fish that are large enough to be tournament winners. In a personal account, 73 blue marlin out of 132 blue marlin caught in Bermuda during the late 1980s were retained (Smith 1989). On the other hand, recent online trip reports suggest that it is common for most, if not all of the fish that are caught on

[5] For example, see URL: http://www.tripadvisor.ca/Attraction_Review-g147261-d3423693-Reviews-Paradise_One_Sports_Fishing_Charters-Southampton_Parish_Bermuda.html. Accessed 24 September 2014.

charter fishing trip to be brought back to shore. Therefore, we increased the retention ratio from 55% in 1985 to 80% in 2010.

Unreported charter fishing catch from 1950 to 2010 was then calculated by subtracting reported charter landings from $C_{charter}$.

Sector allocation

Bermuda's commercial landings are from 3 licensed groups – the charter sport fishing fleet, pot fishery, and non-pot commercial fishery (Barrett 1991). Landings statistics reported by the FAO are not segregated by gear or boat type. To take out the charter fishing boat catch (since we deem these to be 'recreational'), we identified landed species that are commonly targeted by sport fishers - marlins, blackfin tuna (*Thunnus atlanticus*), yellowfin tuna, and wahoo (Table 1). The main pelagic species targeted by Bermuda's commercial sector are yellowfin tuna and wahoo. Therefore, we assumed that all landed marlins and blackfin tuna were from charter fishing boats (i.e., recreational), while only a portion of landed wahoo and yellowfin tuna were taken by charter fishers. In the past two decades, marlins have made up approximately 2% of total commercial landings. Marlins are caught relatively less frequently than tuna and wahoo on charter fishing trips, but with an average blue marlin weighing 400 to 600 lbs[2], are much heavier. In the absence of other data, we simplistically assumed that quantity and weight balanced out, and allocated 2% of yellowfin tuna and wahoo landings to charter fishing boats (i.e., recreational) rather than artisanal (i.e., commercial) fishers. All remaining landings were allocated to the artisanal sector.

A portion of unreported total resident recreational catch was allocated to the subsistence sector. From 1950 to 1970, all resident recreational catch was assumed to be from subsistence fishing, based on the rationale that there was an existing tradition of fishing, and prevailing poor socio-economic conditions compelled people to rely on fishing to supplement their diet (Barrett 1991). From 1970 onwards, we linearly decreased the subsistence fishing proportion from 100% until the 2010 anchor point of 52% of resident recreational fishing, which is the average percentage of resident recreational fishers who fished for food in 2011 (DEP 2011).

Species composition

Marine fishes nei

1) 1950-1990: The composition of foodfish landings from 1950-1980 is shown in Table 2. In 1950, fishes such as jacks, tunas, mackerels and other pelagics were grouped together in the category 'jacks, tuna etc.' that comprised 9% of landings (Burnett-Herkes and Barnes 1996). This category was broken down into carangids and pelagics. Pelagics only started appearing in landings in 1975 and were included with 'jacks' (carangids) prior to this time. In 1979, the ratio of pelagics to carangid landings was roughly 2:1. We assumed that this ratio had remained constant since 1950, and set pelagics and carangids to comprise 6% and 3% of total catch, respectively, in 1950.

2) Snappers and groupers started to be reported in landings in 1981, and carangids in 1990, thus were taken out of the breakdown for 'marine fishes nei' from those respective years onwards. The proportions allocated to the remaining groups in 1980 and 1990 were subsequently scaled-up to make up for the removal of first, snappers and groupers, then carangids, and carried forward to 2000. From 2001 to 2010, landings were reported in finer taxonomic detail and 'marine fishes nei' quantities were minimal, therefore we did not disaggregate further.

3) Pelagic catches were further broken down into 5 major taxon groups: Yellowfin tuna, blackfin tuna, wahoo, barracuda (*Sphyraena* spp.), and all others. We matched the composition of pelagic catches to that reported in Bermuda's national landings statistics, which were available from 1975 onwards. Due to lack of other data sources, we applied the 1975 catch composition to all years prior, starting from 1950.

4) Miscellaneous catches were further broken down to 5 major taxon groups (Table 3). Parrotfish (Scaridae), which were previously an undesired food fish, increased from zero catch in 1975 to 36% of total miscellaneous reef fish catch in 1987 (Butler *et al.* 1993). As we had no data on the proportion of other miscellaneous taxa in 1950 and 1987, we averaged the non-parrotfish catch proportion evenly across the remaining 5 miscellaneous fish groups. The 1990 composition was carried forward to 2000, after which miscellaneous reef fish catches were no longer disaggregated with the start of finer taxonomic reporting.

Recreational catch

In a survey of recreational fishers in 2011, fishes that were most commonly targeted and caught included grey snappers (*Lutjanus griseus*), lane snappers (*L. synagris*), bonita (*Seriola rivoliana*), yellowtail snappers (*Ocyurus chrysurus*), mackerel/little tunny (*Euthynnus alleteratus*), hogfish (*Lachnolaimus maximus*), grunts (Haemulidae), bream (Sparidae), robin (*Decapterus macarellus*) triggerfish (Balistidae), coney (*Cephalopholis fulva*), yellowfin tuna, wahoo, and barber (*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. Due to lack of earlier time series data, we applied the 1975 catch composition to the period 1950-1974.

Charter fishing catch

Unreported catches from charter fishing boats were broken down according to the composition of FAO landings identified as being from charter fishing boats as described above.

RESULTS

Bermuda's reconstructed domestic catch totalled 54,200 t from 1950-2010, which was 1.75 times the landings reported to the FAO for the same period. Unreported catches were from the recreational and subsistence sectors, which totalled around 8,000 t and 16,800 t, respectively from 1950-2010, compared to landings of 30,974 t reported for the same time period (Figure 3). Reconstructed catches averaged 850 $t \cdot year^{-1}$ in the 1950s, peaked at 1,300 $t \cdot year^{-1}$ in 1987, and dropped to about 820 $t \cdot year^{-1}$ in the 2000s. Artisanal catches (i.e., small-scale commercial) made up 53% of total catch, while subsistence and recreational fishing contributed 32% and 16%, respectively (Figure 4). Within the recreational sector, 67% of total catch came from tourist charter fishing boats and the remainder from local shore- and boat-based fishers. The taxonomic composition of reconstructed catches shifted from primarily high trophic level reef fishes such as groupers and snappers in the 1950s to being dominated by pelagics in the 1980s (Figure 5).

DISCUSSION

This reconstruction provides a preliminary estimate of Bermuda's total domestic marine fisheries catches. Tuna catches totalling 48,190 t from 1971-1983 that were caught outside of Bermuda's EEZ were not

considered in this reconstruction. From 1950 to 2010, Bermuda's total estimated fish catch of 54,200 t was approximately 1.75 times the data reported by the FAO.

Bermuda's fisheries have shifted from being dominated by valuable demersal reef species such as groupers and snappers to a more variable mix consisting mainly of pelagics. During the late 1960s and 1970s, uncontrolled fishing pressure driven by local and tourist demand contributed to the rapid decline of groupers in less than 10 years. Fisheries landings statistics reported by the FAO for the period 1950 to 1975 only reported two categories of catch, 'marine fishes nei' and 'spiny lobster', which is not helpful for alerting managers to dynamics at the species level. These early landings were disaggregated to lower taxonomic classes (Luckhurst et al. 2003), which showed the clear trend that later alerted managers to the decline in reef species catches. Although fishing effort restrictions were put in place in response to this situation, they were not enough to help grouper stocks recover. The responsibility is with the government reporting agency in Bermuda (likely the Marine Resources and Fisheries Enforcement Section of the Department of Environmental Protection) to request from FAO and ensure that all FAO data are retroactively corrected for the uninformative taxonomic pooling, especially in the earlier years. Bermuda could also request the inclusion of all recreational and subsistence catches in the data they report to FAO, since recreational as well as subsistence catches are included in data reported to FAO by other countries (Zeller *et al.* 2011; Zeller *et al.* 2014), a reasonable and necessary step given increasing predominance of ecosystem-based consideration in fisheries and fisheries management (Pikitch *et al.* 2004). FAO's data mandate explicitly permits countries to retroactively request such data corrections.

Bermuda keeps landing statistics of commercially valuable fish, but overlooks fish that are taken for food and recreation. We estimated that in the 2000s, around 170 t of subsistence catch is taken annually to supplement local diets, which at 20% of total reconstructed catch is a significant amount of unreported catch. In addition, recreational catch is up to 300 $t \cdot year^{-1}$(Appendix 1), more than half of which is taken by international visitors fishing in Bermuda's waters. Bermuda has been a destination for sport fishers since the first half of the 20th century (Mowbray 1949, Smith 1989) and continues to attract tourists who generate large financial benefits for the local economy. However, the impact of their fishing on the local ecosystem has not been investigated and this type of fishing is highly under-reported. Based on this reconstruction's segregation of charter fishing from total landings, about 7% of charter fishing catch is reported, with unreported charter fishing catches being up to 13 times more than reported catch. Although the high discrepancy may be explained in part by the segregation method we applied, our estimate nonetheless suggests that catches from charter fishing are not low. Without a better understanding of the magnitude of this sector's impact on local fisheries, the government should be cautious in over-promoting sport fishing, despite the high revenues it attracts.

As this reconstruction focuses on documenting catches in domestic waters taken by domestic fishers, we omitted foreign fishing (authorized or unauthorized) within Bermudan waters. However, it should be noted that foreign industrial longline vessels that were capable of holding 80 to 120 t of frozen fish and that were fishing under Japanese, Korean, and Taiwanese flags, fished for albacore tuna in Bermuda's offshore waters from the 1960s through the 1980s[6]. This activity was uncontrolled until 1977 when Bermuda declared its 200 mile Exclusive Fishing Zone, after which licensing conditions for foreign vessels were set. In the early 1980s, there were 68 registered foreign vessels, which besides tuna, were also very likely taking substantial bycatch of sharks. Longlining in Bermudan waters ended when the government stopped issuing licenses to any foreign vessels in 1994.

[6] Marine Resources Section, Department of Environmental Protection. Pelagic Longline Fishing in Bermuda's Exclusive Economic Zone. Unpublished report.

CONCLUSION

Fisheries play a small role in Bermuda's economy but have high social and cultural value. As much as 75% of Bermuda's food is imported, therefore artisanal, subsistence and recreational fisheries are particularly important for supporting local food security and consumption habits. Sustainable fisheries management should therefore be a priority for the government so that society can continue to benefit from this valuable marine resource which also acts as a major attractor for tourism. The government's long-term outlook includes introducing small-scale longlining and aquaculture to increase fish production, as well as improved research and monitoring programmes for commercial and non-commercial (i.e., recreational) sectors. As the Bermuda government moves towards these targets, it should also address social dynamics within the fisheries so as to avoid the breakdown in customary practices and fisher relationships that led to the decline of Bermuda's once valuable reef fisheries.

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Table 1. Landed species that are allocated to the recreational sector's charter fishing fleet.

Atlantic white marlin
Blue marlin
Blackfin tuna
Marlins, sailfishes, etc.
Swordfish
Wahoo
Yellowfin tuna

Table 2. Composition (%) of FAO's 'marine fishes nei' category, 1950-2000.

	Snappers	Groupers	Carangids	Pelagics	Miscellaneous
1950[a]	20	70	3	6	1
1965[b]	20	60	5	10	5
1980[b]	9	40	11	20	10
1990[b]	11	16	14	24	35
1991[b]	12	13	20	41	14

[a] Burnett-Herkes and Barnes (1996)
[b] Butler et al. (1993)

Table 3. Composition (%) of miscellaneous reef fish catches, 1950-2000.

	Porgies	Bermuda chub	Hogfish	Parrotfish	Grunts	Triggerfish
1950	20.0	20.0	20.0	0	20.0	20.0
1987	12.8	12.8	12.8	36	12.8	12.8
1989[a]	17.0	10.0	11.0	33	16.0	13.0
1990[a]	24.0	16.0	7.0	18	11.0	24.0

[a] Luckhurst and Ward (1996)

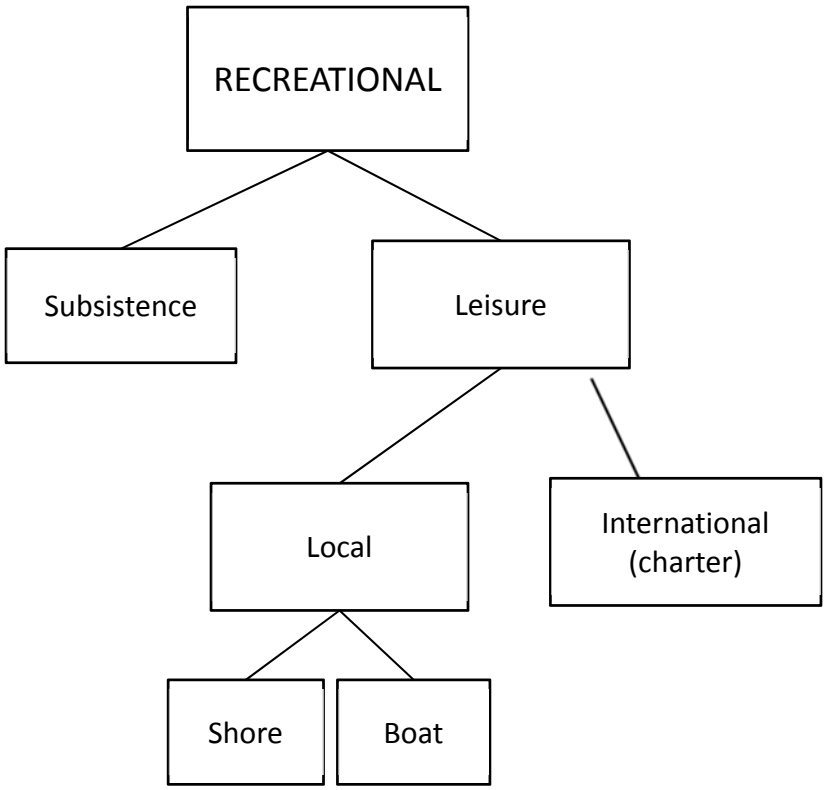

Figure 2. Subcomponents of recreational fishing as defined in this reconstruction. Subsistence catches are allocated to the subsistence sector while catches from all other subcomponents are treated as recreational catch.

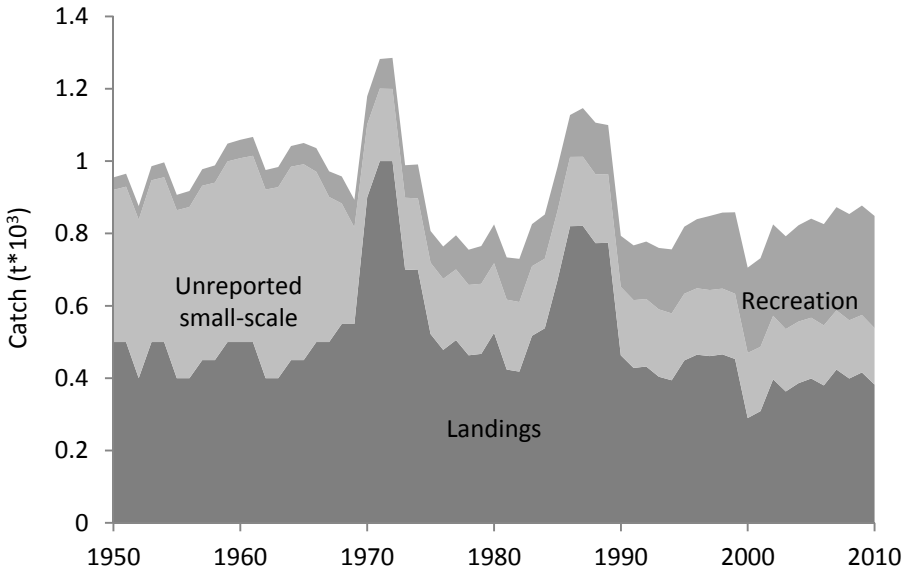

Figure 3. Bermuda's reconstructed total catches from 1950-2010, showing unreported catches from small-scale and recreational fishing added to the reported landings.

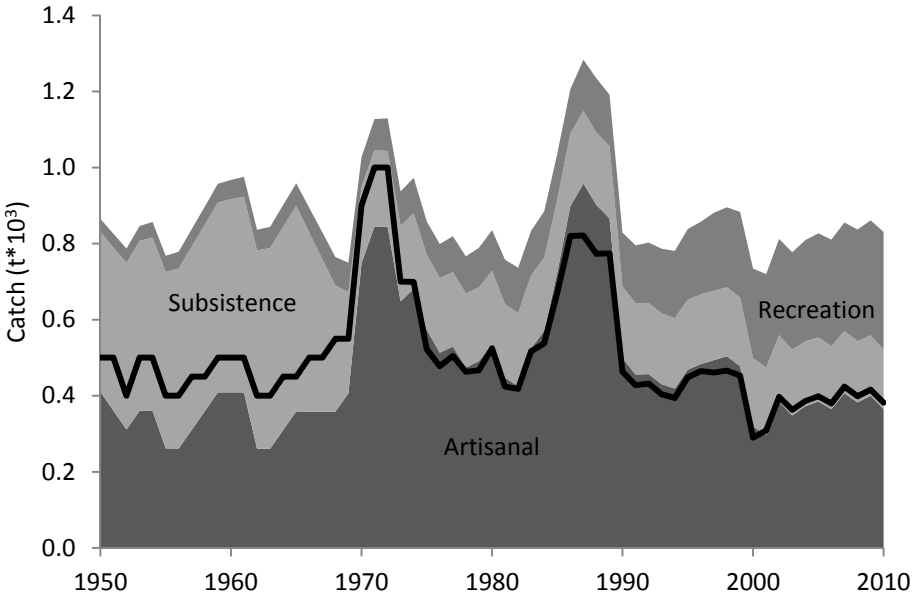

Figure 4. Reconstructed catches showing contribution of different fisheries sectors as defined here. The solid overlaid line represents FAO reported landings.

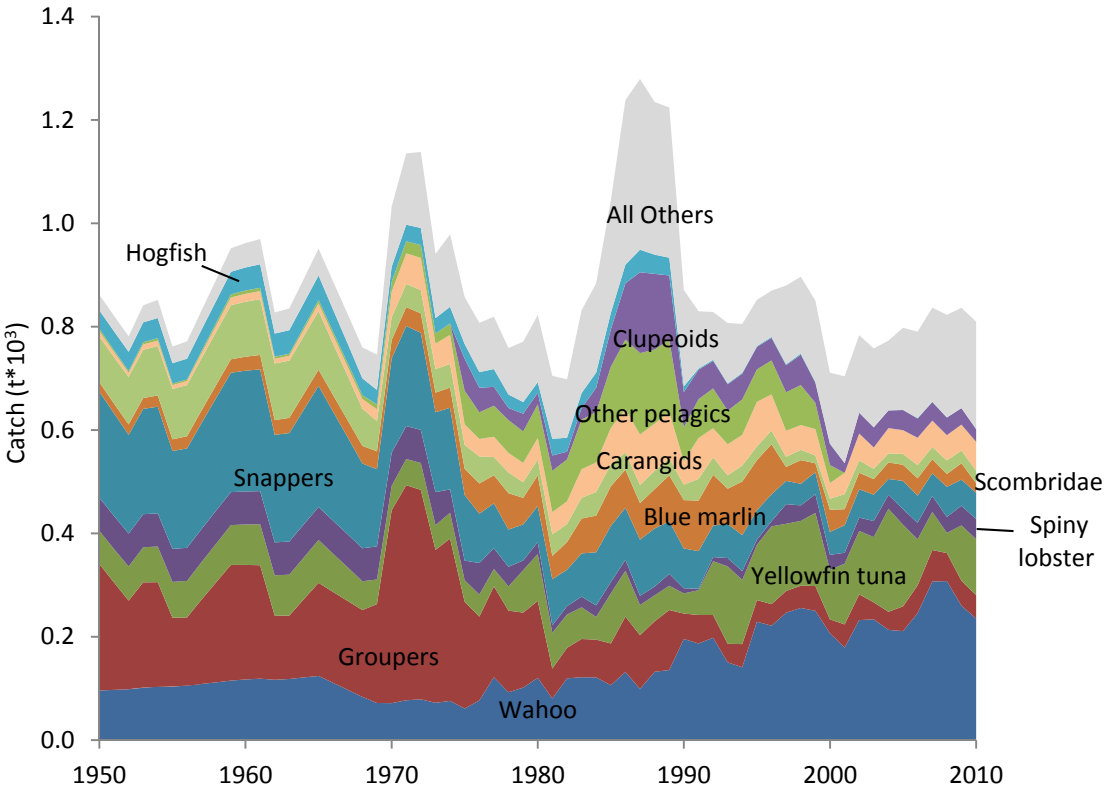

Figure 5. Total reconstructed catch broken down by major taxon groups.

Appendix 1. Reported landings and reconstructed catches (t) for Bermuda, 1950-2010.

Year	Reported			Reconstructed		
	Landings	Artisanal	Recreational	Artisanal	Subsistence	Recreational
1950	500	346		64	421	34
1951	500	297		64	429	36
1952	400	247		64	438	37
1953	500	296		64	447	39
1954	500	296		64	456	40
1955	400	197		64	464	42
1956	400	197		64	473	44
1957	450	246		64	482	46
1958	450	296		64	491	47
1959	500	345		64	499	49
1960	500	345		64	508	51
1961	500	345		64	515	52
1962	400	197		64	521	54
1963	400	197		64	528	56
1964	450	246		64	534	57
1965	450	295		64	541	59
1966	500	295		64	470	64
1967	500	294		64	401	70
1968	550	294		64	333	74
1969	550	342		64	266	77
1970	900	684		64	201	78
1971	1,000	781		64	200	81
1972	1,000	780		64	200	85
1973	700	584		64	199	89
1974	699	681		62	198	94
1975	522	512	10	48	197	87
1976	478	465	12	37	197	89
1977	505	493	12	24	196	93
1978	463	450	12	34	195	97
1979	467	457	10	22	194	104
1980	525	513	12	30	193	106
1981	424	418	5	15	193	117
1982	418	410	8	23	193	119
1983	517	502	15	47	192	116
1984	538	524	14	72	192	122
1985	670	650	20	109	192	121
1986	820	789	31	156	191	116
1987	821	802	19	146	191	134
1988	773	755	17	124	190	143
1989	774	742	31	68	190	135
1990	463	430	32	57	189	141
1991	428	399	28	53	188	152
1992	432	404	28	51	187	159
1993	404	380	24	50	186	170
1994	394	369	25	44	185	177
1995	449	425	24	44	184	185
1996	465	440	25	52	183	191
1997	461	442	19	59	182	205
1998	466	445	21	39	181	210
1999	453	439	14	41	180	225
2000	290	278	12	-	180	236
2001	309	297	10	-	177	245
2002	397	384	10	-	175	253
2003	363	348	14	-	173	256
2004	386	373	11	-	171	266
2005	399	385	12	-	168	273
2006	380	365	13	-	166	279
2007	424	407	16	-	164	284
2008	399	382	15	-	161	293
2009	416	400	15	-	159	302
2010	382	365	15	-	156	310

Appendix 2. Bermuda reconstructed catches by major taxa, 1950-2010. 'All Others' includes 25 other taxa.

	Wahoo	Groupers	Yellowfin tuna	Spiny lobster	Snappers	Blue marlin	Scombridae	Carangids	Other pelagics	Clupeoids	Hogfish	All Others
1950	99	245	66	64	205	11	88	11	4	-	36	41
1951	100	208	67	64	198	11	90	9	4	-	36	41
1952	102	172	67	64	191	12	92	8	3	-	37	42
1953	105	204	69	64	204	12	94	10	4	-	38	45
1954	107	202	71	64	207	13	96	11	4	-	39	47
1955	107	133	71	64	189	13	97	7	3	-	40	45
1956	109	132	73	64	192	14	99	8	3	-	40	47
1957	113	163	75	64	205	14	101	10	4	-	41	51
1958	116	194	77	64	218	15	103	12	5	-	43	56
1959	119	224	79	64	231	15	105	15	6	-	44	61
1960	122	222	81	64	234	16	107	15	6	-	45	63
1961	124	219	82	64	236	16	108	16	7	-	45	65
1962	121	124	80	64	208	17	109	9	4	-	45	58
1963	123	123	82	64	210	17	111	9	4	-	45	59
1964	126	152	84	64	222	18	112	12	5	-	47	65
1965	129	180	86	64	234	18	114	15	6	-	48	70
1966	116	176	77	64	211	19	100	16	7	-	43	73
1967	103	172	68	64	187	19	86	17	7	-	38	76
1968	89	168	59	64	164	20	72	19	8	-	33	79
1969	78	191	51	64	149	20	58	23	9	-	28	88
1970	77	373	50	64	183	21	44	49	20	-	29	137
1971	83	416	54	64	194	21	45	59	24	-	32	159
1972	85	405	55	64	188	22	45	62	25	-	33	169
1973	78	296	51	64	155	22	45	49	19	-	30	146
1974	82	314	53	45	158	23	46	56	22	-	32	163
1975	63	207	43	38	127	7	46	40	65	62	28	146
1976	79	162	44	61	95	12	52	34	52	48	30	146
1977	126	176	35	40	87	13	35	39	60	37	35	154
1978	95	158	48	38	72	32	40	38	64	24	26	150
1979	106	145	86	19	69	16	30	37	61	34	22	178
1980	126	149	95	23	70	29	31	41	65	22	21	179
1981	87	58	75	14	90	14	42	43	80	30	32	201
1982	127	59	69	16	71	21	35	44	81	15	27	183
1983	127	74	62	21	83	41	40	55	96	23	29	201
1984	126	73	45	22	103	51	46	57	98	47	30	206
1985	110	81	100	22	109	42	42	70	119	72	32	263
1986	135	107	91	21	101	34	33	84	134	109	36	367
1987	103	104	60	18	109	30	35	98	158	156	44	400
1988	138	98	52	17	112	46	35	91	143	146	37	348
1989	139	116	48	23	101	50	33	89	140	124	34	341
1990	199	49	40	10	77	56	30	45	66	68	11	221

Appendix 2. Bermuda reconstructed catches by major taxa, 1950-2010. 'All Others' includes 25 other taxa.

	Wahoo	Groupers	Yellowfin tuna	Spiny lobster	Snappers	Blue marlin	Scombridae	Carangids	Other pelagics	Clupeoids	Hogfish	All Others
1991	191	55	49	3	73	71	42	79	75	57	2	135
1992	203	44	107	8	61	78	34	56	77	53	2	112
1993	155	36	154	16	66	54	26	60	65	51	2	131
1994	145	45	128	17	70	75	31	59	69	50	2	123
1995	237	42	111	10	57	81	27	86	63	44	2	108
1996	230	42	156	10	52	78	27	70	66	44	2	113
1997	259	42	137	38	45	21	20	50	75	52	2	167
1998	268	43	131	30	42	33	20	48	77	59	2	172
1999	269	48	152	36	43	10	15	51	51	39	2	188
2000	221	27	103	29	44	25	21	30	35	41	1	175
2001	195	45	128	21	53	31	29	41	-	19	0	174
2002	259	50	137	26	55	32	24	52	-	40	0	152
2003	252	33	136	31	51	23	20	41	-	39	0	166
2004	237	35	221	27	31	29	18	49	-	34	0	144
2005	233	48	174	30	55	28	21	46	-	39	0	168
2006	266	54	96	32	53	26	26	53	-	37	1	183
2007	332	61	80	31	44	22	24	51	-	36	0	196
2008	333	54	42	31	58	23	26	49	-	34	0	207
2009	284	48	117	38	50	25	25	50	-	32	0	211
2010	254	45	117	39	51	13	24	56	-	24	0	228