Fisheries Centre

The University of British Columbia

Working Paper Series

Working Paper #2013 - 08

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Nicola S. Smith and Dirk Zeller

Year: 2013

Email: nicola_smith@sfu.ca; d.zeller@fisheries.ubc.ca

BAHAMAS CATCH RECONSTRUCTION: FISHERIES TRENDS IN A TOURISM-DRIVEN ECONOMY (1950-2010)

Nicola S. Smith[1,2] and Dirk Zeller[3]

[1]*Department of Marine Resources, Ministry of Agriculture, Marine Resources & Local Government, East Bay St., P.O. Box N-3028, Nassau, Bahamas*

[2]*Earth to Ocean Research Group, Department of Biological Sciences, Simon Fraser University, 8888 University Drive, Burnaby, B.C., V5A 1S6 (present address)*

[3]*Sea Around Us Project, Fisheries Centre, University of British Columbia, 2202 Main Mall, Vancouver, B.C., V6T 1Z4, Canada*

nicola_smith@sfu.ca; d.zeller@fisheries.ubc.ca

ABSTRACT

Tourism is the primary industry in The Bahamas and is closely linked to fisheries. Fish is an important source of protein for tourists and residents, and both groups expect to catch and eat local fish. Demand for local fish by a burgeoning tourism industry combined with similar demands from a growing resident population, however, raises an important question: Can domestic fisheries satisfy current fishing and seafood consumption patterns of both groups in the long-term? To answer this question, we need to know, among other things, total fisheries removals from all sectors, as well as patterns of fisheries demand by tourists versus residents in the past and present. Using an established catch reconstruction approach, we provide a more comprehensive accounting of Bahamian fisheries catches from commercial and non-commercial sectors from 1950-2010. Results are in marked contrast to national data that are supplied to the Food and Agriculture Organization of the United Nations (FAO), which present only commercial landings. Reconstructed total catches for The Bahamas were over 884,400 t for 1950-2010, and were 2.6 times the landings of 336,190 t presented by the FAO on behalf of The Bahamas. This discrepancy was due to unreported catches from the sport and subsistence fisheries, as well as systematic under-reporting of commercial catches. Moreover, we found that removals from the sport fishery alone represented more than half (55% or 490,000 t) of reconstructed total catches. Yet in The Bahamas, catches from this sector remain unreported. Additionally, we quantified demand for local fish by tourists from 1950-2010, using a combination of tourism industry data, tourist sport fishing regulations, and hotel seafood consumption surveys. We found that nearly 662,000 t, i.e., 75% of reconstructed total catches were attributed to demand by the tourism industry from 1950-2010. Of this, 66% (nearly 436,000 t) was driven by tourist sport fishing activities. In contrast, tourist consumption of local seafood in hotel restaurants accounted for just under 226,000 t from 1950-2010, equating to more than half of reconstructed total commercial catches (including exports) in most years. Thus, tourists consume larger quantities of local fish than reported (or reconstructed) commercial catch data suggest, and substantial amounts of unreported commercial catches end up in hotel restaurants. Further investigations are needed to improve upon these data. Nevertheless, this study provides a preliminary baseline for historic fisheries catches and estimates tourism demand for local fish over the past half century.

INTRODUCTION

The Commonwealth of The Bahamas is an archipelago of more than 3,000 low-lying islands, cays and rocks located east of Florida, USA and northeast of Cuba, between 20-27^{o}N and 72-79^{o}W (Buchan 2000). It has a total land area of just under 14,000 km^2 (Anon. 2002), while its Exclusive Economic Zone (EEZ) is over 629,000 km^2 (www.seaaroundus.org; Figure 1). The Bahamas is a former British colony that obtained internal self-government in 1964, black majority political rule in 1967, and independence in 1973 (Cleare 2007).

Although around 30 islands are inhabited, since the 1950s, roughly 80% of the population resides on the islands of New Providence (where the capital city of Nassau is located) and Grand Bahama (where the nation's second major city of Freeport is located). By convention, The Bahamas is divided into the more urbanized islands of New Providence and Grand Bahama, while the remaining, more rural islands are referred to collectively as the 'Family Islands'.

Based on reported data, tourism is the primary industry in The Bahamas, accounting for 51% of GDP in 2003, followed by banking and financial services, which account for roughly 15% of GDP. By comparison, fisheries and agriculture combined account for around 5% of GDP (Anon. 2002; Sacks 2006).

Despite the notionally small contribution to GDP, fisheries are vital to the Bahamian economy, particularly in the form of exports and job creation (Deleveaux and Higgs 1995; Buchan 2000). For example, The Bahamas has the fourth largest spiny lobster fishery (*Panulirus argus*) in the world, after Australia, Brazil and Cuba (Buchan 2000). In 2006, Bahamian commercial spiny lobster landings alone totaled over 8,000 t live weight and were valued at over 75 million USD (Anon. 2007). In terms of employment, an estimated 9,300 persons are employed fulltime in the fisheries sector based on a 1995 census, representing approximately 7% of the total labour force (Buchan 2000).

Bahamian fisheries consist of: (1) a small-scale, commercial (i.e., artisanal) sector that primarily targets demersal species; (2) a large-scale, commercial (i.e., industrial) spiny lobster fishery; (3) a sport fishery, in which fishing is primarily for recreation and pleasure, and in which catch is not sold or bartered; and (4) a subsistence fishery, defined here as catch that does not enter the formal market, but is taken home and consumed by fishers and their families or that is locally bartered.

Commercial fishing within The Bahamas' EEZ is reserved for Bahamian nationals, and commercial fishing vessels must be 100% Bahamian owned. Only Bahamian citizens can participate in commercial fishing, unless a person has a spousal or work permit that specifically allows fishing (Anon. 2008). Land-based seafood processing and marketing establishments, however, may have up to 40% foreign ownership (BDF 1993). Non-Bahamians from neighboring countries (e.g., Cuba, Dominican Republic, and the USA)

also exploit fisheries resources in the EEZ by poaching, which is a significant problem (BDF 1990, 1991, 1992, 1993; Deleveaux and Higgs 1995; BDF 1996; Cox *et al.* 2005).

Commercial fishing with vessels of 3-30 m in length occurs on the continental shelf, primarily on the Great and Little Bahama Banks, but also on the Cay Sal Bank (BDF 1993; Anon. 2007). The main taxa caught include Caribbean spiny lobster (*Panulirus argus*), Queen conch (*Strombas gigas*), shallow-water fin-fish such as groupers (Serranidae), snappers (Lutjanidae) and jacks (Carangidae), and deep-water fin-fish (mainly snappers, BDF 1993).

In contrast to the commercial fisheries, Bahamians as well as non-Bahamian residents and tourists partake in sport fishing. Catch from this sector is primarily comprised of medium to large sized migratory pelagic fish such as dolphinfish or mahi-mahi (*Coryphaena hippurus*), wahoo (*Acanthocybium solandri*), marlins (Istiophoridae) and tunas (Deleveaux and Higgs 1995). Fishing the shallow flats for bonefish (*Albula vulpes*), tarpon (*Megalops atlanticus*) and permit (*Trachinotus falcatus*) is also popular (Fedler 2010), in addition to coral reef fishing for spiny lobster, groupers and snappers (Thompson 1989).

Fisheries are closely linked to tourism in The Bahamas, although this point is not often made. Tourism increases demand for local fish in the form of removals from sport fishing as well as by consumption of native seafood. Tourism became year-round in The Bahamas in the 1950s with the advent of air-conditioning in local hotels, which made the hotter months of the year bearable for visitors (Cleare 2007). Since then, the number of visitors per year has grown substantially, particularly when compared to growth in the resident population. In 1950, the number of visitors was a meagre 40,000, while the resident population was roughly twice as large. By 2010, however, the number of visitors had swelled to over 5.2 million, and tourists outnumbered the resident population of 350,000 by an order of magnitude (Figure 2a).

It is important to distinguish between two types of tourists: stopover visitors and cruise ship visitors. Visitors that spend at least one night in The Bahamas are referred to as stopover visitors (Cleare 2007). Stopover visitors remove fish through sport fishing and consumption at local restaurants. Most air arrivals are stopover visitors, but some also arrive by other means (e.g., private yacht). In contrast, cruise ship visitors typically spend only a few hours in The Bahamas and tend to increase demand for local fish only through seafood consumption. Since the late 1980s, growth in visitor arrivals has been driven by cruise ship visitors (Figure 2b).

Demand for local fish by a burgeoning tourism industry in combination with similar demands from a growing resident population raises an important question: Can domestic fisheries satisfy current fishing and seafood consumption patterns of both groups in the long-term? To address this question, comprehensive statistics on total marine fisheries removals from all sectors, and patterns of local fisheries demand by tourists versus residents are fundamental, as would be assessments of stock status of

main target species. The Bahamian government, however, currently lacks the financial resources and technical expertise needed to adequately assess fish stocks (Anon. 2001), and it does not track local fisheries demand by residents or tourists. Similarly, although some national statistics exist for commercial landings (which are thought to under-report actual landings), catch from other important non-commercial sectors are ignored.

The above challenges result in uncertainty regarding the vulnerability of Bahamian fisheries to overexploitation, and create a bias toward underestimating total fisheries removals and hence demand for local fish. This has serious implications for effective management and conservation. Furthermore, this knowledge deficiency can skew decision makers' understanding of the important contribution of local fisheries to the economy, tourism, local food security and culture.

One objective of this study is to reconstruct total marine fisheries catches for The Bahamas from 1950-2010, following the globally established approach of Zeller *et al.* (2007), which has also been used successfully in non-tropical areas (Zeller *et al.* 2011a; Zeller *et al.* 2011b). We chose the year 1950 as our starting point because this is the start year of the global landings database of the Food and Agriculture Organization of the United Nations (FAO). In some instances, interpolations, cautious extrapolation, and assumptions based on local expert opinion were made *in lieu* of quantitative data. This results in potentially higher uncertainty in some of the data provided here (see also Zeller *et al.* 2011a), but is justifiable due to the unacceptable alternative: namely, catches for missing sectors, species and/or time periods are interpreted as zero catches (Pauly 1998). The second objective of this study is to quantify demand for local fish by the tourism industry over the same time period. As illustrated above, tourism is the primary industry in The Bahamas and is closely linked to fisheries. In order to better understand historical trends in fisheries catches (and predict future trends), we must view these trends in light of changes in local fisheries demand from tourism.

MATERIALS AND METHODS

Human Population

Human population data were used to indirectly estimate catch from various fisheries sectors, as well as to estimate demand for local fish by the tourism industry. Resident population data were obtained from The Bahamas Department of Statistics while data on visitor arrivals were obtained from The Bahamas Ministry of Tourism and from Cleare (2007). For years with no data (e.g., between decadal censuses), we used linear interpolations while for missing data at the start of a time-series, we used cautious extrapolation.

Catch reconstruction

Commercial fishery

Although several fisheries sectors exist in The Bahamas, only landings from the commercial fishery are reported to the FAO based on national data (M. Braynen, Director of Department of Marine Resources, pers. comm.).[1] We compared available national landings statistics (based on National Annual Reports and the British Colonial Reports for The Bahamas, Anon. 1952, 1955, 1957, 1959, 1961, 1963) to FAO Fishstat data. We found that FAO Fishstat data closely matched national statistics for the post-colonial period (i.e., ~1970-2010), and concluded that there was a good transfer of data from national to international level. We accepted FAO Fishstat data as being representative of national statistics, and used FAO data as the basis for further calculations.

National commercial landings statistics from the 1970s onwards are based on two sources: (1) purchasing reports from local seafood processing plants, and (2) sampling of a subset of landing sites, which are not expanded to include non-sampled landing sites (BDF 1993, M. Braynen, Director of Department of Marine Resources, pers. comm.). Due to this latter point, national landings data for the commercial fisheries are systematically under-reported. There are only a few data collectors for the numerous landing sites on many islands in The Bahamas (Anon. 2007). The Department of Marine Resources openly acknowledges that national statistics (and by extension, FAO data) are under-reported: "These figures [i.e., national statistics] are considered to be less than the actual total landings for The Bahamas as there are no fisheries extension officers in many of the Family Islands, some of which have major fishing communities and thus many of the marine product landings are unrecorded" (BDF 1993).

Given the above, we needed to correct for systematic under-reporting of commercial catches during the post-colonial period. The total number of landing sites is unknown, because landing sites are largely unregulated and fishers can land almost anywhere along the coastline (M. Braynen, Director of the Department of Marine Resources, pers. comm.). Therefore, we relied on local expert opinion from the Department of Marine Resources regarding the fraction of commercial catch for each taxon that is likely not reported (Table 1), and retroactively raised FAO Fishstat data from 1970 to 2010 to account for countrywide unreported commercial landings.

Unlike the post-colonial era, FAO Fishstat data did not closely match national statistics (based on the British Colonial Reports for The Bahamas, Anon. 1952, 1955, 1957, 1959, 1961, 1963)[2] from 1950-1969. During this period, national statistics consist almost entirely of exports. Although FAO Fishstat data provide catch estimates for The

[1] The Bahamas Department of Fisheries (BDF) was renamed The Bahamas Department of Marine Resources in 2005, and is responsible for the management and development of fisheries.

[2] We could not locate colonial data from 1962 to 1969.

Bahamas during the entire colonial period, these values are likely lower than the 'actual' tonnage of commercial catches. For example, the FAO reports a total catch of 600 t in 1950. By comparison, the British Colonial Report for The Bahamas states that more than twice that amount (i.e., 1,381 t) was exported as spiny lobster alone in 1950 (Anon. 1952). In order to address the problem of under-reported commercial catches during the colonial period, we calculated the average *per capita* commercial catch rate for the years 1970 to 1975 (based on our expanded, countrywide commercial catch estimates), and applied this catch rate to human population census data from 1950 to 1969. Our method resulted in an 11% increase in total commercial catches for the colonial period when compared to FAO Fishstat data. However, our values are likely still conservative, because in 1950, our estimate of total commercial catches (i.e., 1,221 t) was still less than the spiny lobster exports alone (1,381 t), according to the British Colonial Report.

Spiny lobster fishery

The spiny lobster fishery is the only industrial scale (i.e., large-scale) commercial fishery in The Bahamas, and is classified as such due to the large size of both the vessels and the catches that supply mainly the export market - roughly 90% of all lobsters landed for commercial purposes in The Bahamas are exported (Anon. 2008). The fishery involves large vessels referred to as a 'motherships' (typically 20+ m in length) that support up to eight smaller vessels, including 'dinghies' (typically 5 m in length) and 'roundabouts' (about 8 m in length). Motherships remain at sea for four to five weeks at a time, and will make several trips throughout the lobster season. Motherships have a freezer capacity of about 18,000 kg, but typically land a maximum of just over 9,000 kg during a single trip (Anon. 2008; L. Gittens, Department of Marine Resources, pers. comm.).

It is important to note, however, that small-scale artisanal fishers also engage in the lobster fishery, whose catch is geared mainly toward the local market. These fishers use small vessels (about 5 m in length), typically fish only at the beginning of the lobster season, and usually make single day trips (Anon. 2008; L. Gittens, Department of Marine Resources, pers. comm.).

A variety of gears are used in the lobster fishery, including spears, lobster hooks, compressors, lobster traps, and lobster aggregating devices (locally known as 'condos', 'condominiums', or 'casitas'). A permit is required for the use of compressors and lobster traps (Anon. 2007). The majority of lobsters, however, are caught using condos (Anon. 2008). The lack of regulation and monitoring of condo usage contributes to the situation in which total fishing effort for lobster is unknown. Condos increased in popularity in the late 1980s, generally last for five years and are not typically removed from the seafloor. To date, the total number of condos deployed in the lobster fishery is unknown (Anon. 2008).

Most lobsters that are landed in The Bahamas are exported; hence, the Bahamian government assumes that most commercial landings are recorded (Anon. 2007). Nevertheless, we accounted for under-reporting of spiny lobster from 1970 to 2010, by

retroactively raising FAO Fishstat data by 5%, based on local expert opinion (M. Braynen, Director of the Department of Marine Resources, pers. comm.; Table 1). For 1950-1969, we calculated lobster catch based on reconstructed total commercial catches for the colonial period (as described above) and the average proportion of total reconstructed catch attributed to the spiny lobster fishery during the years 1970-1975 (i.e., 53.7%).

Subsistence fishery

Despite its prevalence and importance to local food security, we are unaware of any written reports that quantify the extent of subsistence fishing in The Bahamas. We therefore relied on two sources to estimate total catch from this sector: (1) resident population data, and (2) expert opinion of Department of Marine Resources staff.

From 1950 to 1969, a substantial proportion of the population likely relied on subsistence fishing as a major source of protein for their families. According to the 1950-1951 British colonial report for The Bahamas (Anon. 1952): "…the labourer's staple articles of diet are flour, fish, hominy, meal, sugar and occasionally meat, all of which have risen in price." During this period, few economic opportunities existed for the majority of Bahamians, particularly in the less developed Family Islands. Hence, based on local expert opinion, we assumed that from 1950 to 1969, 40% of Family Island residents ate the equivalent in weight of two plate-sized snappers per week (i.e., ~ 32.55 $kg \cdot person^{-1} \cdot year^{-1}$) that were obtained by subsistence fishing. In contrast, we assumed that 10% of residents of the more developed islands of New Providence and Grand Bahama ate the equivalent in weight of one plate-sized snapper per week (i.e., ~16.29 $kg \cdot person^{-1} \cdot year^{-1}$) that was obtained by subsistence fishing (M. Braynen, Director of the Department of Marine Resources, pers. comm.).

Following black majority rule in 1967 and independence from Britain in 1973, economic opportunities increased considerably for most Bahamians. Hence, reliance on subsistence fisheries likely decreased. Based on local expert opinion, we assumed that the *per capita* subsistence catch rate remained the same as the colonial period, but the percentage of people dependent on subsistence fisheries decreased (M. Braynen, Director of the Department of Marine Resources, pers. comm.). Specifically, we assumed that throughout the 1970s the number of people dependent on subsistence fisheries steadily decreased so that by 1980-2010 only 20% of Family Island residents ate the equivalent in weight of two subsistence –caught plate-sized snappers per week (~ 32.55 $kg \cdot person^{-1} \cdot year^{-1}$), while only 5% of residents of New Providence and Grand Bahama ate the equivalent in weight of one subsistence-caught plate-sized snapper per week (~16.29 $kg \cdot person^{-1} \cdot year^{-1}$).

Sport fishery

Catches from the sport fishery were divided into two categories: (1) fish that were caught and retained during major sport fishing tournaments, and (2) fish that were caught for recreation outside of tournaments.

Catches during tournaments

From 1972 to 2007, the U.S. Recreational Billfish Survey (RBS) program recorded total billfish catches in numbers and effort data from major sport fishing tournaments in several parts of the Atlantic, including The Bahamas. RBS data also include the fate of catches (i.e., retained, released, or tagged and released), and generally consist of two sources: (1) voluntary submissions by tournament organizers, and (2) submissions by scientific observers (Diaz *et al.* 2007). We used RBS data to determine the quantity of blue marlin (*Makaira nigricans*), white marlin (*Tetrapturus albidus*) and sailfish (*Istiophorus albicans*) that were retained during major tournaments in The Bahamas from 1972 to 2007.

Prior to 1972, the RBS program did not collect data for The Bahamas. There were also fewer tournaments during this period. We therefore assumed that the quantity of billfish retained during major tournaments in 1950 was half that of the first year (1972) in which the RBS project began, and linearly interpolated total billfish catches during tournaments for 1951–1971.

After 2007, tournament organizers stopped reporting billfish catches for The Bahamas to the RBS program. Furthermore, the quality of RBS data likely deteriorated in recent years (i.e., 2000s) due to suspected incomplete reporting (A. Venizelos, NOAA NMFS Southeast Fisheries Center, pers. comm.). Thus, we assumed that the total number of billfish species retained during major tournaments remained constant from 2007–2010. This could be an underestimate.

It is important to note that other pelagic species (e.g., dolphinfish, wahoo and tunas) are also caught during sport fishing tournaments. However, we did not have access to any data or information on the quantities of non-billfish species that were retained during tournaments. Thus, our estimate of total retained catch during sport fishing tournaments is limited to billfish species and likely highly conservative.

Catches outside of tournaments

Substantial quantities of fish are caught for recreation outside of tournaments. To estimate catch from this sector, we separated data into two categories: (1) fish caught by stopover visitors, and (2) fish caught by residents.

We relied on three sources to reconstruct total catch from stopover visitors: (1) stopover visitor arrival data, (2) The Bahamas Ministry of Tourism 1980 activities survey report

(presented in Thompson 1989), and (3) sport fishing regulations for visitors to The Bahamas. In order to determine the number of stopover visitors who fish recreationally, we combined stopover visitor arrival data with the 1980 tourist activities survey report. According to the report (presented in Thompson 1989), in 1980, 6.2%, 5.3% and 20% of stopover visitors to New Providence, Grand Bahama and the Family Islands, respectively, fished for recreation at some point during their stay. We did not have access to any other data on the number of stopover visitors who fish recreationally in The Bahamas. Hence, we assumed that the 1980 proportions were representative and remained constant throughout the time-series.

We calculated total catch by stopover visitors by combining estimates of the number of stopover visitors who fish recreationally with *per capita* maximum allowable catch for visitors, as stipulated in Bahamian legislation. In 1986, the Bahamian government introduced sport fishing regulations for visitors (these regulations do not apply to Bahamians) under the Fisheries Resources (Jurisdiction and Conservation) Regulations. This legislation included maximum catch limits per person for pelagic and demersal fisheries, but did not stipulate whether *per capita* maximum catch limits were on a *per day* or *per visit* basis (Appendix 1). In order to remain conservative, we assumed a *per visit* basis.

Maximum allowable catch for demersal fish is specified in terms of weight (i.e., 20 lbs or 9 $kg \cdot person^{-1}$), but maximum catch for lobster (i.e., six individuals), conch (i.e., ten individuals) and pelagic fish (i.e., six individuals) are specified in terms of number of individuals (Appendix 1). Maximum catch specifications are problematic for pelagic species, because total allowable catch (if converted to weight) could vary substantially, from 14 $kg \cdot person^{-1}$ (i.e., six average sized kingfish) to 108 $kg \cdot person^{-1}$ (i.e., six average sized wahoo), depending on catch composition. To remain conservative, we assumed that two average sized individuals of each of the three species listed in the 1986 legislation (i.e., kingfish, dolphinfish and wahoo) constituted maximum allowable catch weight for pelagic species (i.e., 50 $kg \cdot person^{-1}$). In order to further avoid overestimation, we assumed that from 1986 to 2006, recreationally fishing stopover visitors caught and kept on average 80% of the maximum *per capita* allowable catch weight for all taxa per visit (i.e., we assumed a total catch of 54 $kg \cdot person^{-1} \cdot visit^{-1}$). This results in a very conservative estimate, as visitors who fish recreationally in The Bahamas often exceed maximum catch limits (Cox *et al.* 2005).

Prior to 1986, there were no maximum catch limits for recreational fishing in The Bahamas. Moreover, during this period visitors exploited this lack of regulation by fishing commercially "…under the guise of sport fishing" (Thompson 1989). From 1950 to 1985, we therefore assumed that stopover visitors who fished recreationally caught and kept twice as much as the maximum *per capita* catch limits stipulated in the 1986 legislation (i.e., ~ 136 $kg \cdot person^{-1} \cdot visit^{-1}$).

In 2007, the Bahamian government revised maximum catch limits for visitors with the aim of reducing total catch from this sector (M. Braynen Director of the Department of

Marine Resources, pers. comm.). However, the 2007 maximum catch limits are expressed in terms of quantity of fish allowed onboard a vessel at any given time (as opposed to per person). The government assumed that this revision would result in a 50% reduction in the 1986 maximum *per capita* catch limits. Because data on the total number of vessels that obtained sport fishing permits from 2007 to 2010 were not available, it was not possible to test this assumption. Hence, we accepted this assumption, and calculated total catch for the period, assuming that stopover visitors who fished caught 50% of the 1986 maximum *per capita* catch limits (i.e., ~ 34 $kg \cdot person^{-1} \cdot visit^{-1}$).

Much less is known about recreational fishing by residents. Legislation pertaining to seasonal closures and minimum size limits now exists for a few species (e.g., spiny lobster and Nassau grouper, *Epinephelus striatus*). However, there is currently no legislation that limits the quantity of fish that may be caught and kept for recreational, non-commercial purposes by Bahamian residents. We therefore relied on three sources to estimate catch from this sector: (1) resident population data, (2) expert opinion of Department of Marine Resources staff, and (3) Bahamian sport fishing regulations as they relate to maximum catch limits for visitors.

From 1950 to 1969, it is generally thought that few Bahamian residents could justify to fish for recreation rather than for subsistence. Based on local expert opinion, we therefore assumed that from 1950 to 1969, 0.5% of Family Island residents fished for recreation six times a year, while 1% of residents of New Providence and Grand Bahama fished for recreation four times a year (M. Braynen, Director of the Department of Marine Resources, pers. comm.). We assumed that for each trip, residents caught and kept a quantity of fish equal to 50% of the 1986 maximum *per capita* catch limits for visitors (i.e., 34 $kg \cdot person^{-1} \cdot trip^{-1}$). This amounts to an annual recreational catch rate of 204 $kg \cdot fisher^{-1} \cdot year^{-1}$and 136 $kg \cdot fisher^{-1} \cdot year^{-1}$ for Family Islanders and New Providence/Grand Bahama residents, respectively.

With increasing economic opportunities in the 1970s, recreation fishing (as opposed to subsistence fishing) also increased, particularly on the more developed islands of New Providence and Grand Bahama. We assumed that from 1970 to 2010, 2% of residents of New Providence and Grand Bahama fished for recreation eight times a year (M. Braynen, Director of the Department of Marine Resources, pers. comm.). By comparison, while the proportion of residents fishing for recreation in the Family Islands likely did not change, the frequency with which they fished likely increased. Hence, we assumed that from 1970 to 2010, 0.5% of Family Islanders fished for recreation once a month (M. Braynen, Director of the Department of Marine Resources, pers. comm.). We assumed the same *per trip* catch rate of 34 $kg \cdot person^{-1} \cdot trip^{-1}$ This results in an annual recreational catch rate of 272 $kg \cdot fisher^{-1} \cdot year^{-1}$ for residents of New Providence and Grand Bahama, and 408 $kg \cdot fisher^{-1} \cdot year^{-1}$ for Family Island residents.

Catch composition

Commercial fishery

We combined FAO Fishstat data with annual national reports and expert knowledge of Department of Marine Resources staff to determine catch composition for the commercial fishery.

From 1970-2010, we used the taxonomic composition of the FAO Fishstat data as our starting point. We disaggregated FAO data for six taxa to species level by using annual national reports, which qualitatively list species that are commonly caught in the commercial fishery (Table 2). We assumed equal distribution of catch among species within each taxon (except for Nassau grouper, see below).

Nassau grouper is one of the most popular and economically valuable species in the commercial fishery. However, Nassau grouper was not reported separately from other species of grouper in the FAO Fishstat dataset until 1994. In order to estimate Nassau grouper catch prior to 1994, we calculated the average proportion of total grouper catch that was attributed to Nassau grouper from 1994-1999 and held that ratio constant throughout the remainder of the time-series in which groupers were reported separately from other catch (i.e., 1993-1965). Pre-1965, we assumed an even distribution of catch among all grouper species, including Nassau grouper.

Taxonomic resolution of FAO Fishstat data during the colonial period is very limited, consisting of two taxa (1950-1964) and six taxa (1965-1969). It is not until 1970, that jacks - a commercially important fish that was likely caught throughout the colonial period - is listed as FAO taxon. Given the generally limited taxonomic resolution of FAO data during this period, we assumed that the types and proportions of fish caught during 1950-1969 were the same as from 1970-1975.

Subsistence fishery

We are unaware of any reports of catch composition for the subsistence fishery. Hence, we assumed the same composition and relative proportions as for commercial shallow water fishery. We excluded deepwater fin-fish, sharks, crabs and sea cucumbers from the assumed subsistence composition.

Sport fishery

For 1972-2007, we used data directly from the US Recreational Billfish Survey program to derive taxonomic compositions for tournament catches. For 2008-2010, we assumed the same composition as for 2007. For the years prior to the survey (1950-1971), we used the average billfish composition for 1972-1979.

In order to determine catch composition for recreational catches outside of tournaments, we relied on three sources: (1) sport fishing regulations; (2) Thompson (1989); and, (3) demersal catch composition from the commercial fishery.

Sport fishing regulations specify maximum allowable catch per fisher for spiny lobster and queen conch. We therefore used these species-specific maximum catch limits (which vary according to time period) to determine the proportion of total recreational catches that was attributed to lobster and conch throughout our time-series.

Sport fishing regulations state maximum allowable catch for pelagic gamefish and demersal fish, but do not specify limits for species within these groups. In order to determine catch composition for pelagic gamefish, we used Thompson (1989), except billfishes, which were included in tournament catch (Table 3).

For demersal fish, we used the broad taxonomic groupings in Thompson (1989) to identify the types of demersal fish that are commonly caught by recreational fishers (e.g., groupers and snappers; Table 3). However, because demersal taxa typically occur year-round in The Bahamas, we could not use frequency of occurrence as per pelagic gamefish. Instead, we used local knowledge of the sport fishery to derive an assumption-based taxonomic distribution. Lastly, we disaggregated taxa to species level by assuming that the types of demersal species caught in the recreational fishery were the same as in the commercial fishery (Table 3).

Tourism demand for local fish

We separated demand for local fish by the tourism industry into two categories: (1) demand by stopover visitors, and (2) demand by cruise visitors.

Demand by stopover visitors

We separated stopover visitor demand into two categories: (1) consumption of local seafood in hotels, and (2) removals from sport fishing.

In order to determine demand in hotels, we designed and administered a seafood consumption survey. In all instances, the purchasing manager or head chef of hotel restaurants completed the survey, which included information on the type, quantity, origin (i.e., Bahamian versus imported) and dollar value of fish supplied to hotel restaurants on a yearly basis (Appendix 2). A total of 11 hotels responded to our survey, representing approximately 8% of all hotels larger than 10 rooms, and 37% of all hotel rooms in The Bahamas as of July 30th, 2010. Hotels in our survey ranged in size from 19 to 2,932 rooms.

Hotels in our survey were located on five different island groups, representing 28% of all island groups in The Bahamas with hotels. We separated seafood consumption data into hotels located on the more developed islands of New Providence and Grand Bahama

versus the less developed Family Islands. We combined tourism industry data (e.g., hotel occupancy rates, number of visitor nights per year, etc.) with our seafood consumption survey in order to calculate a *per visitor* local seafood consumption rate. Hotels in our survey provided seafood consumption data for a period ranging from two to 18 years. Most hotels, however, only provided data for the last two years in 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 *per capita* consumption rate for the years 2009 and 2010 based on our survey (i.e., 0.49 $kg \cdot visitor^{-1} \cdot night^{-1}$ and 1.08 $kg \cdot visitor^{-1} \cdot night^{-1}$ for New Providence and Grand Bahama versus the Family Islands, respectively) throughout the full time period. Lastly, given the suspiciously large quantity of seafood that was purportedly 'local' in the survey, we assumed that 10% of all so-called 'local' seafood was actually imports that was unrecognized as such, and we adjusted consumption accordingly.

In addition to seafood consumption in hotels, stopover visitors increase demand for local fish by sport fishing (see above). However, because our sport fishing tournament data do not distinguish between resident and tourist fishers, we assumed that 98% of all tournament catch was taken by tourists.

Demand by cruise visitors

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

RESULTS

Catch reconstruction

Commercial fisheries

Reconstructed total catches by the artisanal fishery (which for our purposes excluded spiny lobster) totaled over 103,800 t over the 1950-2010 period, increasing from slightly over 560 $t \cdot year^{-1}$ in 1950 to a peak of over 3,060 $t \cdot year^{-1}$ in 1994 before declining to just under 2,180 $t \cdot year^{-1}$ by 2010 (Figure 3).

Reconstructed spiny lobster catches for the period 1950-2010 were over 257,400 t, increasing from just under 660 $t \cdot year^{-1}$ in 1950 to a peak of nearly 10,900 $t \cdot year^{-1}$ in 2003, before declining slightly to around 10,200 $t \cdot year^{-1}$ in 2010 (Figure 3). Spiny lobster catches dominate commercial fisheries, accounting for roughly 71% of total commercial catches from 1950 to 2010.

Subsistence fishery

Catches from the subsistence fishery totaled nearly 33,100 t over the 1950 to 2010 time period. Catches increased from about 500 t·year^{-1} in 1950 to a peak of around 740 t·year^{-1} in the late 1960s, before declining to just under 590 t·year^{-1} by 2010 (Figure 3). Although roughly 80% of the resident population of The Bahamas lives on New Providence and Grand Bahama, Family Islands' residents accounted for the majority of subsistence catches (69%).

Sport fishery

Reconstructed total sport fishing catches for 1950- 2010 were around 490,100 t; of this, less than 1% (i.e., around 420 t) was attributed to major tournaments. Sport fishing catches increased from just under 600 t·year^{-1} in 1950 to a peak of around 16,100 t·year^{-1} in 1985, before declining rapidly to just over 7,300 t·year^{-1} in 1986 following the introduction of maximum recreational *per capita* catch limits for tourists. A second, but smaller peak in catches occurred in 2006 at around 9,000 t·year^{-1} before again declining sharply to just under 5,700 t·year^{-1} in 2010 due to the revision of sport fishing legislation in 2007 (Figure 3). Although Bahamian residents also partake in sport fishing, tourists remove the majority of fish (i.e., 89%).

Reconstructed total catch

Reconstructed total catches for The Bahamas from 1950 to 2010 were approximately 884,500 t. Catches increased from around 2,300 t·year^{-1} in 1950 to a peak of over 24,700 t·year^{-1} in1985, with a second, smaller peak of around 22,200 t·year^{-1} in 2003, before declining to just over 18,600 t·year^{-1} in 2010. Our reconstructed catches were 2.6 times the official landings of 336,190 t reported by the FAO on behalf of The Bahamas (Figure 3). Significantly, the sport fishing sector accounted for over half of reconstructed total catches (i.e., 55% or over 490,100 t), followed by the commercial spiny lobster (29%), other artisanal (12%), and subsistence fisheries (4%; Figure 3).

In the most recent decade (i.e., 2000-2010), catches from the sport fishery showed a declining trend (mean of 7,555 t·year^{-1}), but still accounted for more than a third of reconstructed total catches (39%). In contrast, catches from the commercial spiny lobster fishery showed a generally increasing trend over the same time period (mean of 8,977 t·year^{-1}, Figure 3).

Taxonomically, from 1950-2010 pelagic gamefish accounted for the greatest amount of reconstructed total catches (41% or around 361,300 t), followed closely by spiny lobster (35% or around 306,300 t). In contrast, conch, groupers and snappers each accounted for less than 10% of reconstructed total catches, i.e., 7%, 7% and 6%, respectively.

Over the last decade (i.e., 2000-2010), spiny lobster catches (51% or around 108,600 t) surpassed pelagic gamefish (29% or 61,000 t) while the proportion of reconstructed total

catches attributed to conch and snapper remained around 7% each. By comparison, the relative proportion of catches attributed to groupers (4%) and miscellaneous marine fishes (2%) declined over the past decade.

Tourism demand for local fish

Demand by stopover versus cruise visitors

From 1950-2010, demand for local fish by stopover visitors totaled over 659,600 t, with around 223,700 t attributed to seafood consumption vs. slightly more than 435,900 t attributed to sport fishing. By comparison, demand by cruise visitors accounted for only 2,200 t for 1950-2010. Although cruise visitor arrivals were 13% higher than stopover visitor arrivals over the full time period (Figure 2b), less than 1% of local fish demand by the tourism industry was attributed to cruise visitors, of which only a small fraction consume native seafood while none fish recreationally during their stay.

Total demand by tourism

Demand for local fish by the tourism industry over the period of study totaled approximately 661,800 t, accounting for 75% of reconstructed total catches (Figure 4). Tourism demand increased from 660 $t \cdot year^{-1}$ in 1950 to a peak of over 19,800 $t \cdot year^{-1}$ in 1985 before declining to around 9,100 $t \cdot year^{-1}$ in 2010 (Figure 4). Almost two thirds (66% or 435,900 t) was driven by sport fishing activities by stopover visitors, while the remainder was due to seafood consumption by stopover (34%) and cruise visitors (0.3%; Figure 4).

DISCUSSION

Reconstructed total catches for The Bahamas from 1950-2010 were 2.6 times larger than the officially reported data presented by the FAO on behalf of The Bahamas would suggest. The source of this discrepancy was twofold. Firstly, only commercial fisheries are accounted for in official data reported for The Bahamas. However, even these data are known to be under-reported by up to 15% per year for some taxa (M. Braynen, Director of the Department of Marine Resources, pers. comm.; Table 1). Secondly, and more importantly, unreported catches from the sport and the subsistence fisheries are substantial and missing in national statistics. Together, these two sectors accounted for nearly 60% of reconstructed total catches from 1950-2010, and thus actually represent a major impact on species and stocks of marine resources that could never be alluded to if one considers official data only.

A second, major discrepancy between reconstructed and official data is the year in which fisheries catches peaked. Based on our reconstruction, total catches likely peaked in the mid 1980s, and not in 2003 as suggested by the official national data presented

by FAO (Figure 3). The peak in reconstructed catches was driven by the sport fishery in which, prior to 1986, no maximum allowable catch legislation existed for tourists. It should be noted that the main reason for the introduction of this legislation was that prior to 1986, tourists were known to remove large quantities of fish from Bahamian waters by essentially engaging in commercial fishing "…under the guise of sport fishing" (Thompson 1989).

Our reconstruction shows that a second peak in fisheries catches did in fact occur in 2003, but at over 22,200 $t \cdot year^{-1}$ as opposed to the reported 12,610 $t \cdot year^{-1}$ (Figure 3). This peak was driven by increased catches in the commercial spiny lobster fishery, which totaled nearly 11,000 $t \cdot year^{-1}$ in 2003. The fact that the commercial spiny lobster fishery had such a large effect on overall trends in fisheries removals is not surprising, as it is the fourth largest spiny lobster fishery in the world after Australia, Brazil and Cuba (Buchan 2000).

Sport fishery

Overall, the magnitude of recreational catches in The Bahamas over the study period is astounding, accounting for 55% of total catches. Yet, catches from this sector remain unaccounted for. Reconstructed recreational catches from 1950-2010 were 1.4 times the commercial catches, yet worldwide, commercial fisheries are commonly perceived to remove the greatest quantity of fish, and deemed the most important fisheries. Our findings, however, debunk this notion that catches from recreational fisheries are generally relatively small, and thus negligible when compared to other major sectors.

The fact that in 1986 and again in 2007, The Bahamian government introduced maximum recreational catch limits for tourists, suggests that even in the absence of quantitative catch statistics, there was (and remains) a perception that catches from this sector are substantial and in need of regulation. This study briefly highlighted some of the shortcomings of existing Bahamian sport fishing regulations, and we suggest that these regulations are thoroughly reviewed and where necessary, further revised and closely monitored. The cost of any monitoring program will likely be challenging, but not prohibitive for a small islands developing state like The Bahamas. Costs can be reduced if monitoring and reporting are initially conducted annually for the first five years, and subsequently reduced to once every 4-6 years and interpolated between surveys (see also Zeller *et al.* 2007). The cost of implementing such a program certainly outweighs the economic, social and cultural losses that would be associated with a collapse of this fishery.

Tourism demand for local fish

Another way to examine this is through the very high demand for local fish by the tourism industry in The Bahamas, which accounts for 75% of reconstructed total catches. The total number of visitors to The Bahamas each year counts in the millions, and has outnumbered the resident population by an order of magnitude for more than half a century. It is therefore not surprising that tourism has such a sizeable effect on fisheries removals.

Although total fisheries removals through tourist seafood consumption (i.e., 255,900 t) were considerably less than removals through sport fishing (i.e., 436,000 t), our estimates of tourist consumption (based on empirical data) equate to more than half of total reconstructed commercial fishery catches (including exports) in most years. This suggests that tourists consume larger quantities of local fish than commercial catch data suggest, and that substantial amounts of unreported commercial catches likely end up in hotel restaurants. Given the obvious implications of this finding for local food security, fisheries management, and the equitable distribution of a finite natural resource, we recommend that comprehensive surveys on country-wide total commercial landings, and tourist versus resident seafood consumption patterns are undertaken.

Study limitations

This study provides a baseline for historic fisheries catches in The Bahamas derived from the 'best available' data. This study is useful insomuch as it serves as a means of comparison for current and future fisheries trends. However, it should not be interpreted as a complete representation of all historic fisheries removals in The Bahamas. Due to lack of access to sufficient data, we have not included illegal catches, which are considerable, especially due to poaching by citizens from neighboring countries (BDF 1990, 1991, 1992, 1993; Deleveaux and Higgs 1995; BDF 1996; Cox *et al.* 2005). We have also excluded discards, although these are likely low in comparison to other global fisheries, mainly due to the artisanal nature of many of the gears used in The Bahamas. We also did not estimate removals from the recreational flats fishing sector, which generates roughly $141 million (USD) in total economic benefits to the Bahamian economy each year (Fedler 2010). Hopefully, future investigations will be conducted to improve and expand on these data and the trends they represent.

Conclusion

Numerous catch reconstruction studies have revealed that official landings data for most countries are incomplete (e.g., Zeller *et al.* 2006; Zeller *et al.* 2007; Wielgus *et al.* 2010; Zeller *et al.* 2011a; Zeller *et al.* 2011b; Le Manach *et al.* 2012). This study shows that The Bahamas can be added to the growing list of countries with inadequate reporting. We should be concerned because incomplete reporting creates a bias toward

underestimating total fisheries removals, which in turn, has serious implications for effective management and resource conservation. Furthermore, underestimating total fisheries removals can skew decision makers' understanding of the importance of local fisheries to the economy, local food security, culture, and in the case of The Bahamas, tourism.

Tourism is one of the largest and fastest growing industries globally (UNWTO 2013). In the wider Caribbean, total visitor arrivals now outnumber resident populations in many countries, including The Bahamas (Table 4). The trends in tourism demand for local fish shown here for The Bahamas are therefore likely shared by many Caribbean countries. Incomplete or missing reporting of fisheries removals by the tourism industry (and consequently, inadequate fisheries management) creates a situation in which continued population growth and rising fisheries demands by residents and tourists will likely place unsustainable pressure on fisheries resources in the future.

ACKNOWLEDGEMENTS

We thank The Bahamas Department of Marine Resources, particularly M. Braynen and L. Gittens for data, expert opinion and helpful discussions. We also thank The Bahamas Ministry of Tourism, particularly G. Delancy, and The Bahamas Department of Statistics for data. We are grateful to the following hotels for participating in our seafood consumption survey: The Atlantis Royal Towers; The Atlantis Cove; The Atlantis Reef; Bimini Sands Resort and Marina; Corner Hotel; One & Only Ocean Club; Sandals Royal Bahamian Spa, Resort and Offshore Island; Small Hope Bay Lodge; Stella Maris Resort Club; Superclubs Breezes; and, Wyndham Nassau Resort. Data provided by A. Venizelos from NOAA NMFS Southeast Fisheries Center are also greatly appreciated. We thank Daniel Pauly and the *Sea Around Us* project, a scientific collaboration between the University of British Columbia and The Pew Charitable Trusts, for support. The statements, findings, conclusions and recommendations presented here are those of the authors and do not necessarily reflect the views of the aforementioned persons or organizations.

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Tables:

Table 1. Fraction of commercial catch by major taxa that were deemed unreported from 1970 to 2010 (M. Braynen, Director of the Department of Marine Resources, pers. comm.).

Taxon	Fraction
Grunts	0.10
Jacks	0.15
Nassau grouper	0.10
Other groupers	0.10
Misc. marine fishes	0.15
Queen conch	0.15
Sharks	0.05
Snappers	0.15
Spiny lobster	0.05
Black stone crab	0.03

Table 2. FAO taxonomic disaggregation based on qualitative information in BDF (1990, 1993).

Original FAO taxa	**Disaggregated taxa**
Carangids	*Caranx bartholomaci*
	Caranx fusus
	Selar crumenophthalmus
Groupers	*Epinephelus adscensionis*
	Epinephelus morio
	Epinephelus mystacinus
	Mycteroperca bonaci
	Mycteroperca venenosa
Grunts, sweetlips	*Haemulon album*
	Haemulon perrai
	Haemulon plumieri
	Haemulon sciurus
Marine fishes nei[1]	*Sphyraena barracuda*
	Lachnolaimus maximus
	Balistes vetula
Sea cucumbers	*Astichopus multifidus*
	Holothuria mexicana
Snappers	*Apsilus dentatus*
	Lutjanus analis
	Lutjanus apodus
	Lutjanus buccanella
	Lutjanus griseus
	Lutjanus synagris
	Lutjanus vivanus
	Ocyurus chrysurus
Stromboid conchs	*Strombus gigas*

[1] Numerous species are caught in relatively small amounts in the commercial fishery. We retained 'marine fishes nei' for 25% of reconstructed catch to account for less common species.

Table 3. Taxonomic breakdown of reconstructed catch for the sport fishery, modified from Thompson (1989).

Type	Common name	Scientific name
Pelagic	Allison tuna	*Thunnus albacares*
	Blackfin tuna	*Thunnus atlanticus*
	Bluefin tuna	*Thunnus thynnus*
	Blue marlin	*Makaira nigricans*
	Dolphin	*Coryphaena hippurus*
	Great amberjack	*Seriola dumerili*
	Kingfish	*Scomberomorus cavalla*
	Mackerel	*Scomberomorus* spp.
	Oceanic bonito	*Katsuwonus pelamis*
	Sailfish	*Istiophorus albicans*
	Wahoo	*Acanthocybium solandri*
	White marlin	*Tetrapturus albidus*
Demersal[1]	Barracuda	*Sphyraena barracuda*
	Groupers	*Epinephelus adscensionis*
		Epinephelus morio
		Epinephelus mystacinus
		Epinephelus striatus
		Mycteroperca bonaci
		Mycteroperca venenosa
	Jacks[2]	Carangids
	Queen conch	*Strombus gigas*
	Snappers	*Apsilus dentatus*
		Lutjanus analis
		Lutjanus apodus
		Lutjanus buccanella
		Lutjanus griseus
		Lutjanus synagris
		Lutjanus vivanus
		Ocyurus chrysurus
	Spiny lobster	*Panulirus argus*

[1] Species commonly associated with the Bahamian flats fishery, i.e., bonefish, tarpon and permit, are also frequently caught by recreational fishers. These species, however, were not included in our reconstruction due to insufficient available information on flats fishing, which is primarily a catch-and-release fishery. [2] Although jacks were not explicitly listed in Thompson (1989), we included them based on local knowledge of the fishery.

Table 4. Tourist arrivals compared to resident populations in 2007 for Caribbean countries that reported some of the greatest number of tourists that year, according to the Caribbean Tourism Organization.

Country	Stopover visitor arrivals ('000s)[1]	Cruise visitor arrivals ('000s) [1]	Total arrivals ('000s)	Resident population ('000s)[2]	Stopovers as % of resident population
Aruba	772	482	1,253	104	742
Barbados	573	616	1,189	294	195
Bahamas	**1,528**	**2,971**	**4,498**	**331**	**462**
Dominican Republic	3,980	385	4,364	9,760	41
Jamaica	1,701	1,180	2,880	2,714	63
Puerto Rico	1,356	1,437	2,794	3,991	34
US Virgin Islands	693	1,918	2,611	111	625

[1] Caribbean Tourism Organization. [2] United Nations World Population Prospects.

Figures:

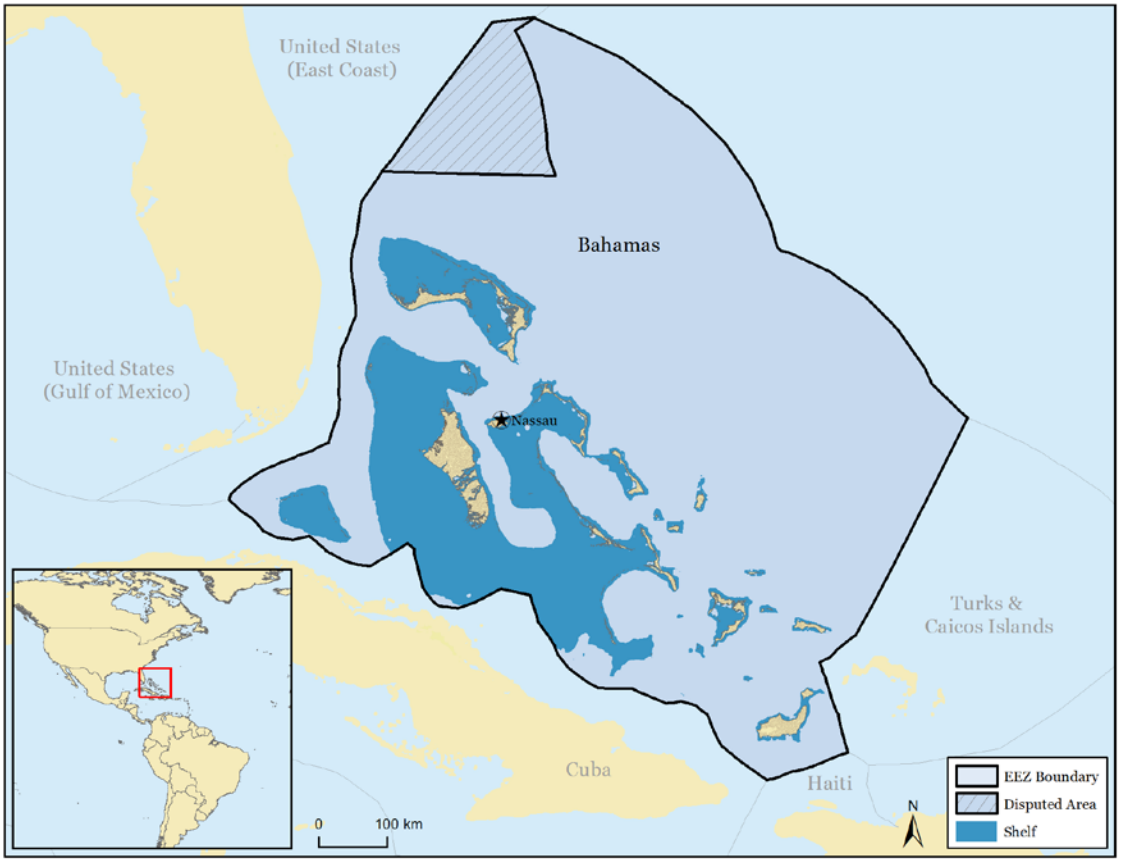
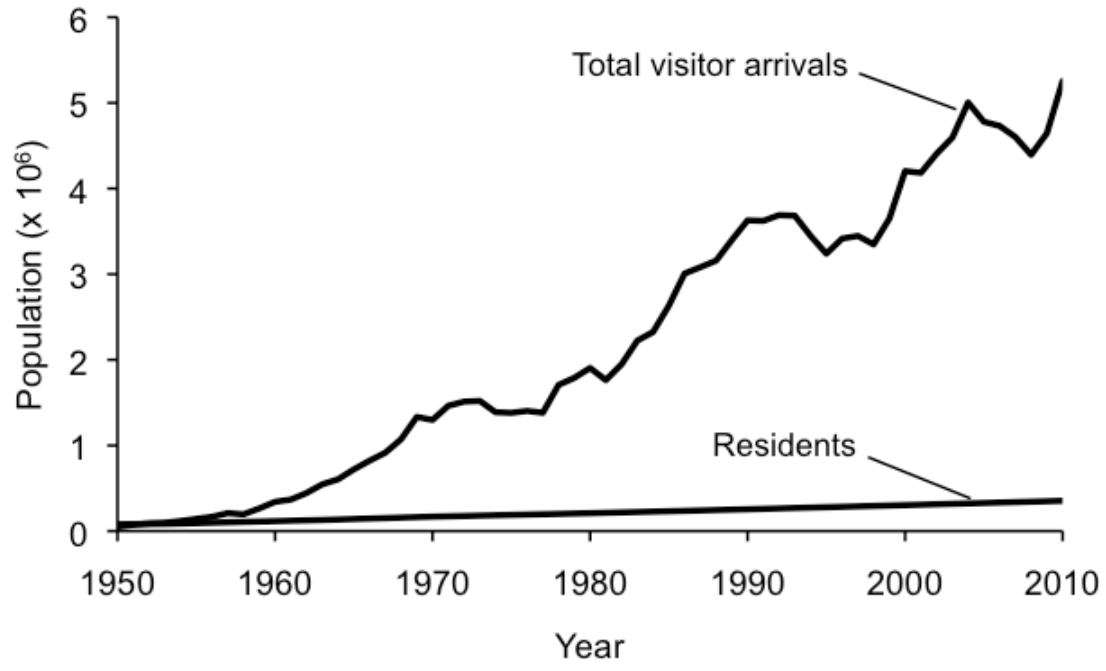


Figure 1. Map of The Commonwealth of The Bahamas, illustrating the size of its Exclusive Economic Zone (EEZ) as well as the shelf area to 200 m depth.

A)



B)

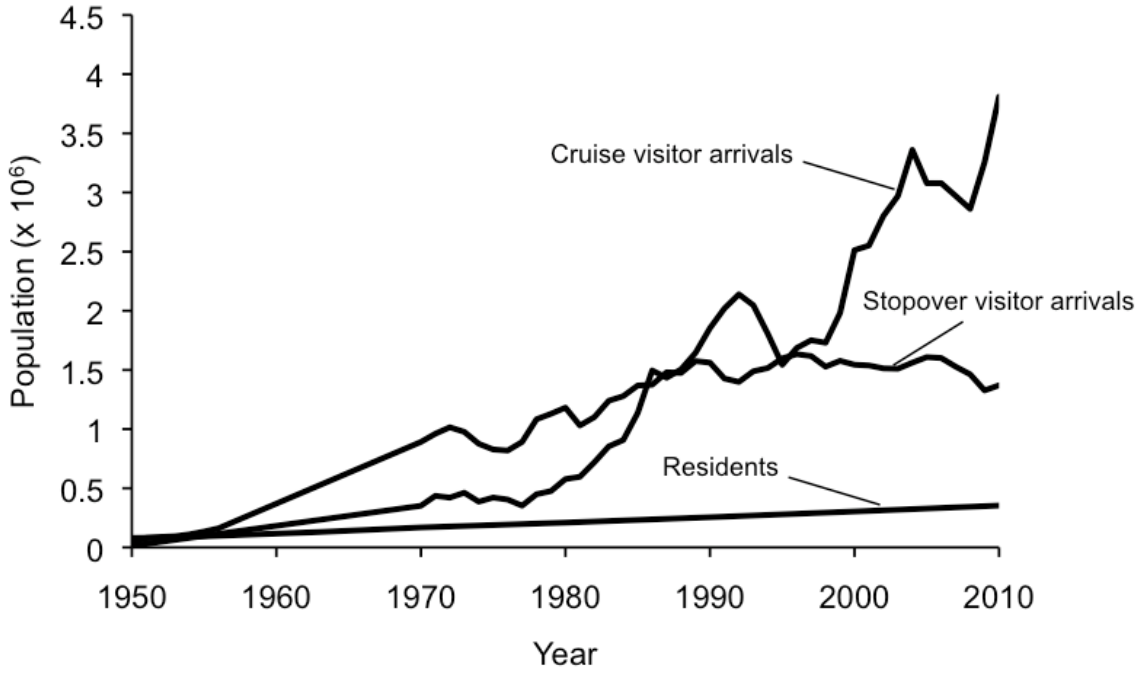


Figure 2. Human population data for The Bahamas, showing (A) resident population and total number of visitor arrivals; and (B) resident population compared to total number of stopover and cruise visitor arrivals, 1950-2010.

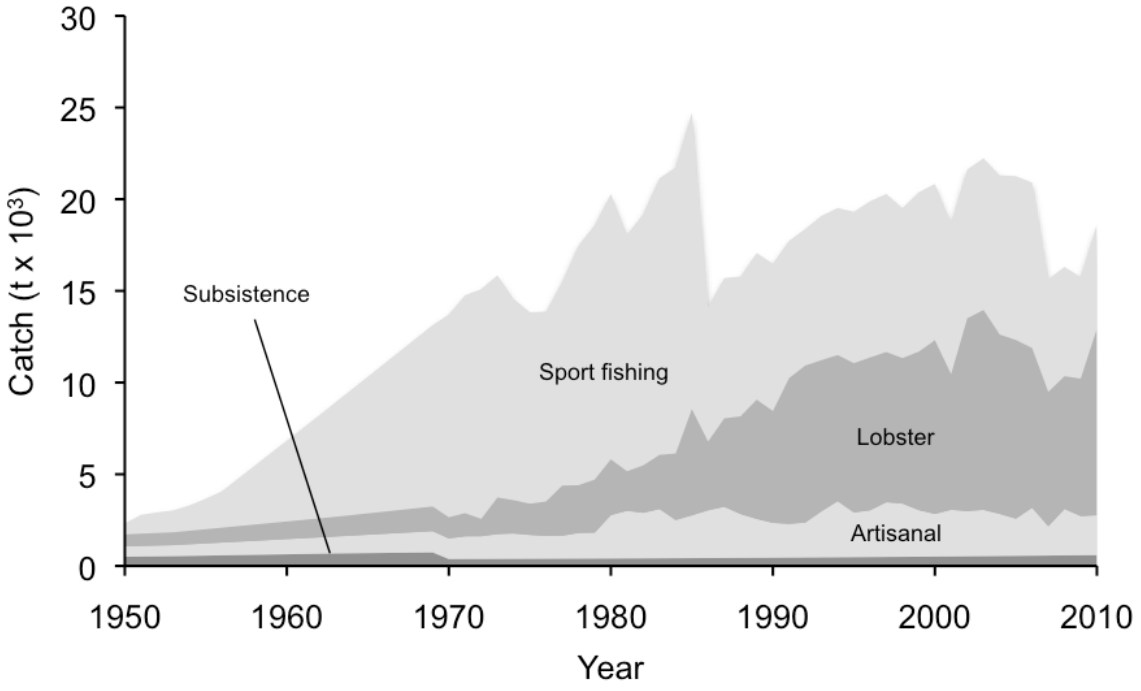


Figure 3. Total reconstructed catches for The Bahamas for 1950-2010, by major fisheries component.

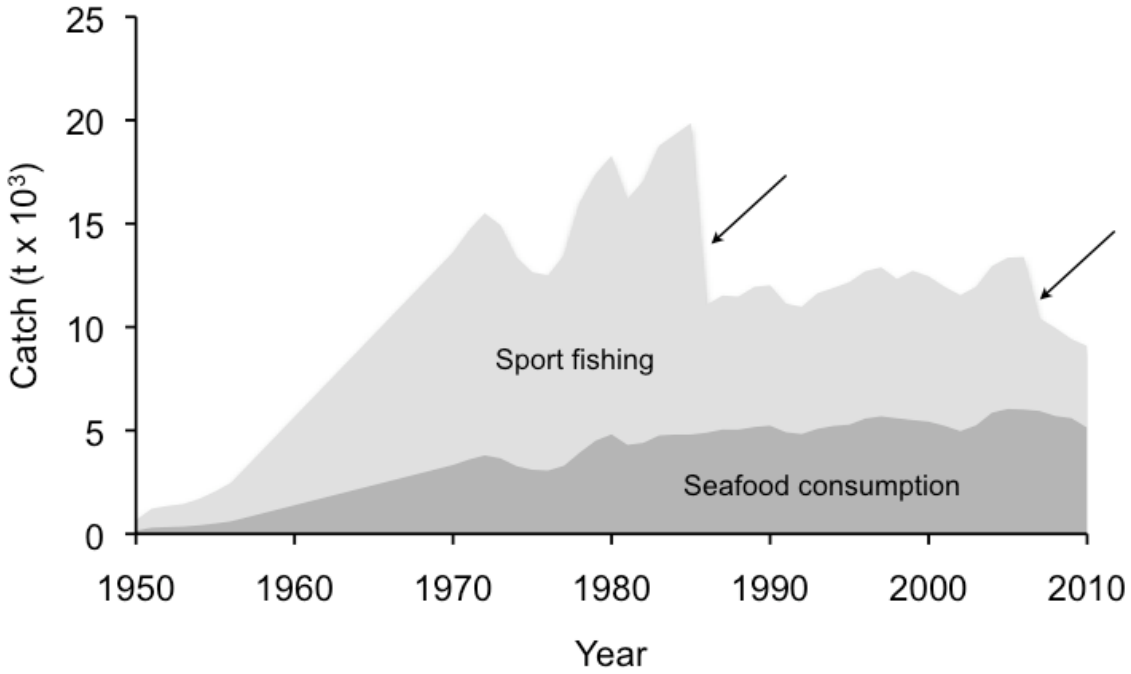


Figure 4. Demand for local fish by the tourism industry (i.e., both stopover and cruise visitors) in The Bahamas, 1950-2010. Arrows indicate the effects of changes in maximum allowable catch regulations for tourists engaged in sport fishing.