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Elizabeth Mohammed, Alasdair Lindop,
Christopher Parker and Stephen Willoughby

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Email: eliza_moham@yahoo.com

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RECONSTRUCTED FISHERIES CATCHES OF BARBADOS, 1950-2010

Elizabeth Mohammed[a], Alasdair Lindop[b], Christopher Parker[c] and Stephen Willoughby[c]

[a] Research and Resource Assessment, Caribbean Regional Fisheries Mechanism Secretariat,
Eastern Caribbean Office, St Vincent and the Grenadines
[b] *Sea Around Us*, Fisheries Centre, University of British Columbia,
2202 Main Mall, Vancouver, Canada, V6T 1Z4
[c] Ministry of Agriculture, Food, Fisheries and Water Resource Management,
Princess Alice Highway, Bridgetown, Barbados

eliza_moham@yahoo.com; alindop@gmail.com; fishbarbados.fb@caribsurf.com; fishbarbados.cfo@caribsurf.com

ABSTRACT

Barbados is a small country in the north Atlantic, lying as the most easterly of the Lesser Antilles. It has a narrow continental shelf, and is surrounded by deeper water. As a small island, fisheries are of high importance to the country, with the artisanal and subsistence sectors being of particular importance. There is also a significant industrial sector, which developed from the introduction of ice-boats equipped with cold storage in the mid-1970s. This report is an update of an earlier study that reconstructed the historical catch and effort of fishing in Barbados for 1940-2000. The update revised and extended the time period to 1950-2010 and found that the reconstructed catch was 1.6 times the data reported to the FAO. Artisanal catches were found to be the most dominant with 63% of the catch, with subsistence and industrial fisheries contributing 20% and 17% of the catch, respectively. Recreational fisheries contributed less than 1%. Flyingfish (Exocoetidae) were the most dominant taxon in the catch, making up almost half (46%), with dolphinfish (Coryphaenidae; 14%), Scombridae (8%) and queen snapper (*Etelis oculatus*; 5%) also major components. Catches increased slightly over time, particularly over the early part of the time period, which can be attributed to advances in gear with the introduction of gillnets, and the mechanization of fleets by the end of the 1960s. The disparity with reported data mostly occurs in the later part of the time period and the underreporting of catch data is likely due to the exclusion of tertiary landing sites in the Fisheries Divisions estimates of total landings.

INTRODUCTION

Study Area

Barbados is the most easterly of the West Indian islands (Figure 2-5-1). It is situated at 13^{o}N and 59^{o}W, and its Exclusive Economic Zone (EEZ) covers an area of 184,000 km^2 (www.seaaroundus.org). The continental shelf is narrow, the 100 fathom line (~180 m) varying between 0.8 and 2.6 nautical miles offshore (Brown 1942), and covers an area of 277 km^2 (Mahon 1986). The deeper and broader sections of this narrow insular shelf occur off the northeast and northwest coasts. An isolated off-shore bank, locally known as the 'London Shallows', exists off the southeast coast (Brown 1942). Actively growing coral reefs are restricted to the west (leeward) coast, between Bridgetown in the south and Shermans, 16 km to the north. Total reef area is 100 km^2 (Oliver and Noordeloos 2002).

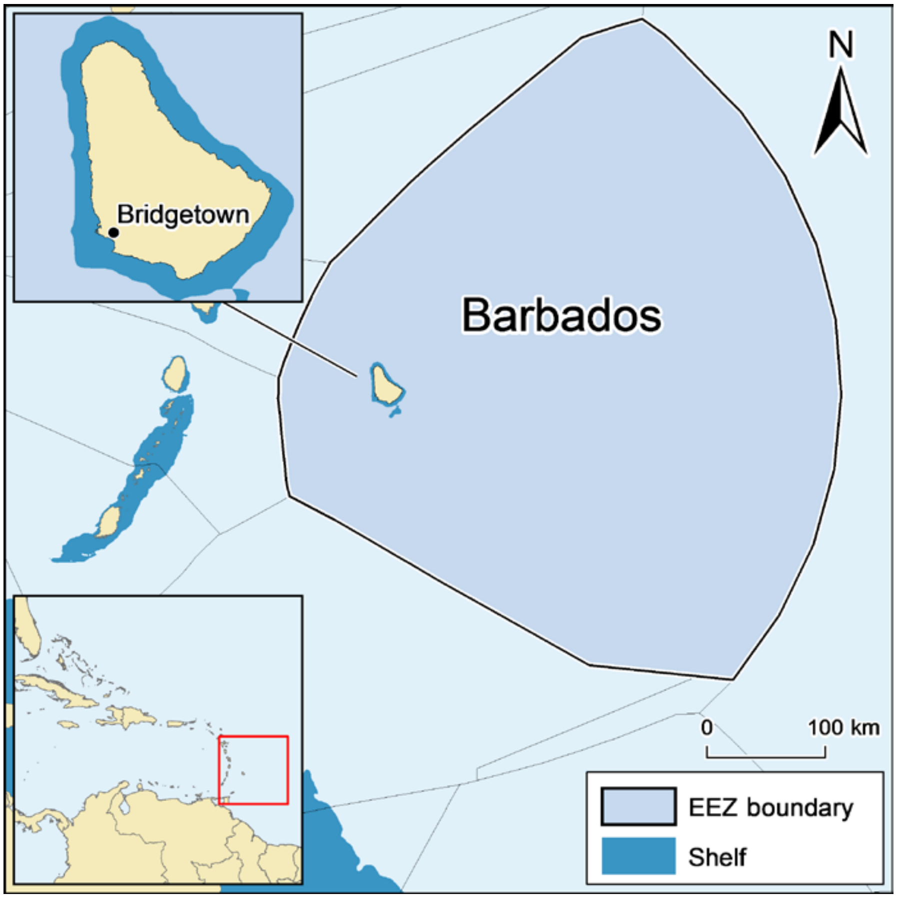

Figure 1: Exclusive Economic Zone (EEZ) and shelf area (to 200 m depth) of Barbados.

Fishery Description

A detailed description of fisheries development in Barbados is provided by a variety of sources (Brown 1942; Hess 1966; Vidaeus 1969; Chakalall 1982; Cecil 1999; Parker 2000; Anon. 2001). The fisheries resources are grouped into nine categories for management by the Barbados Fisheries Division. Two of these categories relate to offshore resources, the large pelagic fishery targeting dolphin fish (*Coryphaena hippurus*), tunas (Scombridae), kingfish (*Scomberomorus cavalla* and *Acanthocybium solandri*), swordfish (*Xiphias gladius*) and sharks (Carcharhinidae) with handlines, troll lines or longlines, and the flyingfish fishery targeting mainly the four-winged flyingfish (*Hirundichthys affinis*) with gillnets, handlines and dip nets. The inshore fishery is comprised of the shallow shelf reef fishes, the deep slope fishes, coastal pelagics, sea urchins, turtles, lobsters and conch. Shallow shelf reef fisheries target parrotfish (Scaridae) and surgeonfish (Acanthuridae) using fish pots, nets and spear guns, while the deep slope fisheries target mainly snappers (Lutjanidae) and groupers (Serranidae) with fish pots and handlines. The coastal pelagic fishery targets herrings (Clupeidae), jacks (Carangidae) and small tunas with handlines, troll lines, seine and cast nets. Sea urchins (*Tripneustes ventricosus*) and queen conch (*Lobatusgigas*[1]) are hand

[1] Previously *Strombus gigas*

collected, while turtles (mainly the hawksbill *Eretmochelys imbricata*) are caught with entangling nets, and lobsters (*Panulirus argus*) with fish traps and hand spears. There has been a moratorium on turtle capture since 1998.

Pre 1950s

Prior to 1942 the fishing fleet was un-mechanized, relying on sails and oars for propulsion (Brown 1942). In the same year the government instituted a price control system on fish to ensure its affordability to all sections of society. The fleet was thought to operate below capacity and therefore the use of troll gear was promoted to increase catches (Brown 1942). Mechanization of the fleet however, was dependent on the increased spatial and temporal availability of flying fish (Brown 1942), the most important species in terms of bulk of catches. Brown (1942) noted the historical decline in catches of the species in 1928, 1930 and 1933. Flying fish was traditionally caught using hook and line, or dip nets when plentiful. Following the 1944 formation of the Fisheries Division as the institution with responsibility for management and development of fisheries a more efficient gear, the gillnet, was introduced in 1947 (Hess 1966). The gear was widely adopted after fishing trials proved extremely successful in the early 1950s. The turtle fishery was lucrative until the early 1950s, but the illegal harvest of eggs on the beaches was thought to result in the decline of the fishery (Hess 1966). Only one fish market or primary landing site existed in Barbados prior to the 1950s (established at Cheapside in Bridgetown in 1946).

1950s to 1980s

The second fish market in Barbados was constructed at Oistins in 1950. The following year a natural disaster, and in 1955 hurricane Janet caused extensive fleet damage (Parker 2000). However, the high number of trees felled by the storm provided the opportunity for extensive fleet development, as these served as a source of timber for boat construction. The government also promoted boat mechanization by facilitating the acquisition of loans (Vidaeus 1969). A safer, more stable boat was designed (day-boat or launch) and by 1954 boat mechanization commenced (Rose 1954). Another fish market was constructed at Speightstown in 1954 and 200 t cold storage provided in Bridegtown. However, the existing cold storage was still inadequate and proved a major problem facing the industry, which tried to stock up to compensate for low catches during the flying fish off-season (July to October). As a result, fishers also limited their daily catches in favour of returning to the landing site early, when there was less competition for sale of their catch. Solutions for short and long term storage of fish were suggested at the (Rose 1954).

Although development efforts focused on increasing landings, these were not matched by similar improvements in handling, distribution, marketing and storage (Hess 1966). In the 1960s government's policy promoted the local fishing industry and welfare of the fishers through improved landing facilities. Although unsatisfactory repayment of loans resulted in the suspension of the scheme in 1964, fishers still benefited from the duty free concessions on fishing gear, diesel engines and spare parts, and subsidization of fuel (Vidaeus 1969). It was also evident that, even though the larger mechanized boats initially operated at a profit, this margin decreased as the number of similar boats entered the fishery. The initial capital investment and operating costs of these boats were greater than the smaller boats, yet the catches were similar (Hess 1966). The government price control system ended in 1972. In 1963 an American-owned company began operations in Barbados. The company caught shrimp off Brazil, and exported the processed catch to the US (Parker 2000). By 1973 this offshore fleet was well established (Kreuzer and Oswald 1978), comprising some 20 trawlers with on-board cold storage (Baker 1976).

During the 1970s, the National Development Plan and policy of the Barbados Development Bank (BDB), newly instituted in the early 1970s and responsible for granting loans to fishers, promoted the use of fishing boats fitted with ice-holds (Parker 2000). These boats became known as ice-boats, with the first being introduced in 1976. During the 1980s the BDB's promotion of development of the offshore fishery resulted in tremendous increase in the number of ice-boats, as well as the introduction of a longlining fleet towards the end of the decade. Increasing trip costs and competition for sale of catch resulted in the conversion of day-boats to ice-boats, by inclusion of an ice-hold (Parker 2002). Ice-boats increased the range of exploitation up to 550 km offshore (Berkes and Shaw 1986) and were equipped for trips of up to 2 weeks duration. The 1980s was marked by considerable improvement in market facilities, including cold storage, with the construction of a fisheries complex at Oistins in 1983 and another at Bridgetown in 1986 (Parker 2000).

1990s

Expansion of the offshore fleet continued into the 1990s. Significant efforts were placed on improving fisheries management initiatives, with the enactment of the Fisheries Act (1993), the drafting of fishery-specific management plans (Anon. 1999) and the enforcement of related fisheries regulations in 1998 (Parker 2000). Exploitation of sea urchins was banned, following a collapse of the fishery in 1987, and a co-management approach instituted for future management. During this decade, there were considerable increases in the number of boats in all fleets except day-boats, which were in the process of conversion to ice-boats. Other infrastructure developments included the construction of the Weston fish market at Reids Bay, formerly a 'secondary landing site' (secondary landing sites are equipped with a shed and running water for processing and selling of fish). The tertiary site at Six Men's Bay had grown in importance as fishers avoided the congestion at the nearby Speightstown market (tertiary sites have no sheds or running water). By 2001 the government planned to construct a market at Six Men's Bay, Payne's Bay and a fisheries complex at Speightstown, to meet the demand of increased catches. Barbados became a Contracting Party to the International Commission for the Conservation of Atlantic Tunas in 2000.

Fisheries statistical data collection

Barbados differs from the rest of the south eastern Caribbean islands of this study in that it instituted a fisheries statistical data collection system in the 1940s, from which a long time series of recorded data is available. Initially, the quantity of fish landed at Bridgetown was recorded and later the system was extended to include landings at

Speightstown and Oistins. The management of the three markets was handed over to the Marketing Division of the Ministry of Agriculture in 1954, while the Fisheries Division, of the same Ministry, retained responsibility for small secondary sites (referred to as 'sheds'). This division of responsibility persists to date. At the time, however, the reliability of statistics collected at the sheds was low (Rose 1954).

By the early 1960s, data were collected at the three markets (Bridgetown, Oistins and Speightstown) and eight secondary sites (beach sheds). The quantities landed were estimated visually, however landings during late evening, early morning, Sundays and bank holidays were excluded (Rose 1954; Hess 1966). The associated gear was also not recorded (Hess 1966). Recorded landings were assumed to represent one third of total landings ('one third' assumption) from some 25 landings sites around the island (Hess 1966), but there was no scientific basis for this assumption. Some fishers avoided landing at the markets to circumvent payment of toll fees. As a result, catches may have been sold across boats. There was also no system for ensuring non-duplication of records, particularly for catches sold at one market and resold at another. By the late 1960s, catches from several fishing centres along the coast e.g., Silver Sands, Conset Bay, Tent Bay and Half Moon Fort, were delivered to the main markets. However, the same assumption that recorded catches represent one third overall total catch was still used in deriving estimates of total catch (Vidaeus 1969). There was little improvement in the data collection system throughout the 1970s and 1980s. Despite developments in the fishing industry, the 'one-third' assumption was still utilized well into the late 1980s (Chakalall 1982; Oxenford 1990).

In the late 1980s, Barbados participated in a workshop, hosted by the Organization of Eastern Caribbean States, to improve fisheries data collection systems in the region (Willoughby *et al.* 1988). Deficiencies in the data collection system were identified, such as non-inclusion of landings from recreational fishing and inadequate coverage of landing sites important for non-fish species. The workshop proposed an improved data collection system, incorporating total census at primary and secondary sites and stratified sampling at tertiary sites, collection of purchase slips from hotels, restaurants and supermarkets to estimate lobster catches and implementation of a logbook system for offshore and charter fleets (Willoughby *et al.* 1988).

Under the CARICOM Fisheries Resource Assessment and Management Program (CFRAMP) restructuring of the data collection program consistent with recommendations of the OECS workshop of 1988 was undertaken. Data are collected at four primary sites (Bridgetown Fisheries Complex, Oistins Fisheries Complex, Speightstown Market and Weston Market), seven secondary sites (Conset Bay, Tent Bay, Martins Bay, Skeetes Bay, Fitts Village, Paynes Bay and Half Moon Fort) and at least ten tertiary sites of a possible seventeen (Stroud Bay, Six Men's Bay, Road View beach, Lower Carlton, Mount Standfast, Holetown, Brooklyn beach, Prospect, Shallow Draft, Bay Street Esplanade, Burkes beach, Worthing, Dover beach, Silver Sands, Foul Bay, Crane beach, Long Bay and Bath beach). Data are recorded at primary and secondary sites five days per week. Since data collectors at the secondary sites reside in the vicinity of landing operations, most of the landings at these sites are captured by the system. Tertiary sites are sampled on a rotational basis. Computerized data management systems were also introduced by the CFRAMP for fisheries catch and effort statistics (Trip Interview Program) and licensing of fishers and boats (Licensing and Registration System).

Since 1997, the 'one third' assumption has been revised. A raising factor of between 1.2 and 1.6 is applied to recorded catches of all species, except tuna and swordfish, for which it is believed that a total census of landings is taken. It is envisaged that greater quantities of total landings would be captured by the data collection system as the Government moves towards increased development of the industry through provision of larger markets or fisheries complexes (primary sites), with increased cold storage and freezing capabilities. Presently (2000-2002), markets have been constructed, though not yet operational, at Skeetes Bay and Conset Bay, while another market is under construction at Paynes Bay. There are also plans to construct markets at Six Men's Bay, Half Moon Fort and a complex at Speightstown.

Fisheries policy

The general fisheries management and development policy seeks to "ensure the optimum utilization of the fisheries resources in the waters of Barbados for the benefit of the people of Barbados", (Anon. 2001). Specific management plans have been developed for the respective fisheries. Details of the current fisheries management policy, objectives and regulations are provided in Table 1.

Table 1. Management policy, objectives and regulations for fisheries in Barbados (Anon. 2001).				
Fishery	**Target Species & Gear**	**Stock status**	**Management policy and objectives**	**Regulations**
Shallow-shelf reef fishes	Species: Groupers, parrotfishes, grunts, surgeonfishes, triggerfishes Gear: fish traps (pots) and demersal handlines	Some reef areas believed to be overfished, especially the south and west coasts where fishers report reduced catch rates and fish size	To rebuild reef populations to levels capable of satisfying both the commercial and recreational or tourism non-harvest uses. To optimize associated social and economic benefits.	Prohibition of use of dynamite, poisons, noxious substances, trammel and any other entangling nets. Minimum mesh size for fish traps. Traps must be marked for identification and fitted with escape panels of approved size and design to reduce ghost fishing. Minimum mesh size in seines to reduce reef fish by-catch. Prohibition of coral harvesting and fishing in marine reserves. Regulation of catches of aquarium fish. Co-management promoted.
Deep-slope and bank reef fishes	Species: Snappers (mainly queen snapper, silk snapper and vermillion snapper). By-catch comprises unidentified groupers and large jacks.	Possibly fully exploited in some areas.	Precautionary approach to management with the aim of obtaining a sustainable and optimum yield for local consumption.	Prohibition of use of dynamite, poisons, noxious substances, trammel and any other entangling nets. Minimum mesh size for fish traps. Traps must be marked for identification and fitted with escape panels of approved size and design to reduce ghost fishing. Minimum mesh size in seines to reduce reef fish by-catch. Prohibition of coral harvesting and fishing in marine reserves. Regulation of catches of aquarium fish. Co-management promoted.
Coastal pelagics	Species: Jacks, herrings, silversides, anchovies, ballyhoo, robins or scads (Decapterus spp.), barracudas, garfish, small tunas and young of large tunas such as yellowfin Gear: seines operated from boats, cast nets and trolling	Unknown	To optimize catches of the target species particularly for use as bait, while minimizing by-catch of reef species.	Prohibition of use of dynamite, poisons, noxious substances, trammel and any other entangling nets. Minimum mesh size for seines. Regulation of fishing in marine reserves. Prohibition of use of seines and cast nets near reefs. Integrated coastal zone management implemented as a means to protect fish habitat. Co-management approach promoted.
Large pelagics	Species: Tunas, wahoo, billfishes, dolphinfish, swordfish and mackerels Gear; longline, pelagic lines (trolling and lurk-lining)	Status of small tunas, dolphinfish and mackerels is unknown. ICCAT assessments indicate that large tunas and billfishes are either fully exploited or over exploited.	To maximize catches by national and regional fishers, within regional and international conservation guidelines, through ensuring fair and equitable distribution of resources among users	Prohibition of landing yellowfin and bigeye tuna less than 3.2 kg. Prohibition of use of pelagic drift net greater than 2.5 km. Barbados became Contracting Party to ICCAT in 2000.

Table 1. Management policy, objectives and regulations for fisheries in Barbados (Anon. 2001).

Fishery	Target Species & Gear	Stock status	Management policy and objectives	Regulations
Flyingfish	Species: Four-winged flyingfish Gear: surface set gillnets, handlines and dipnets along with fish attraction devices (palm fronds which serve as a spawning substrate and a basket of rotting fish)	Status unknown but high inter-annual variability in abundance due to changes in spawning stock biomass, environmental factors and predation mortality. High probability of low stock recruitment at low stock size suggests that overfishing in years of low abundance could cause stock collapse.	To establish a catch and effort regime that facilitates resource sustainability over the long term, with an acceptably low risk of economic or social disruption due to catch variability, in order to derive optimal economic and social returns for the fishery.	None
Sea urchins	Species: white sea urchin Gear: collected by hand or using a metal scraper by skin or SCUBA divers	Vulnerable to overexploitation	To rebuild populations and establish a co-management arrangement aimed at maintaining populations for sustainable long term, optimum yields and associated social and economic purposes	Closed season based on stock status. Prohibition of dumping of shell and offal on shallow banks and wanton destruction or injury to animals during open season. Prohibition of use of SCUBA.
Sea turtles	Species: Hawksbill, green, leatherback and loggerhead Gear: Nets used at sea and hand collection of eggs and nesting females on the beach	Severely overexploited and in some cases threatened with extinction.	To promote the protection, conservation and recovery of populations	Barbados is party to the CITES, hence commercial trade is prohibited. Prohibition of sale of turtle or turtle eggs. Fishing or ensnaring turtles, and disturbing or endangering turtle nests or removal of turtle eggs from the nest are prohibited.
Lobsters	Species; Caribbean spiny lobster Gear: free or SCUBA diving using spears or gloves for capture (caught as by-catch in fish pots)	Unknown	To promote sustainable harvest for domestic use and local tourism market in order to achieve maximum economic return from the resource over the long term.	Prohibition of possession, sale or injury to lobsters carrying. Prohibition of removal of berried eggs.
Conch	Species: Queen conch mainly, West Indian fighting conch and milk conch occasionally Gear: Hand collected by skin divers using masks, snorkel and fins or by SCUBA divers	Unknown. Anecdotal information suggests that local populations are much smaller than those of neighbouring islands	To assess current population status and establish a co-management arrangement with fishers to maintain populations at levels that can sustain optimum yields for social and economic purposes.	

Objective

This report is an update and extension to a previous study by Mohammed *et al.* (2003) that presented a time series of catch and effort data for Barbados, from 1940 to 2000, to enable assessment of the ecosystem impacts of fishing. The present extension covers the time period 1950-2010 and provides a sector analysis as well as comparing the reconstructed catches with the data officially reported to the FAO. Small updates were made to the Mohammed *et al.* (2003) data to comply with *Sea Around Us* data protocols and definitions.

METHODOLOGY

Catches

The Barbados Fisheries Division has a long time series of landings data, either hand-written, printed summaries or computerised details of landings by boat trip. However, the level of aggregation of catches across species and fleet types varied throughout the period examined. Data collected at the primary sites (Cheapside, Speightstown, Oistins, Bay Street, Bridgetown market, Bridgetown Fisheries Complex, Oistins Fisheries Complex and Weston market at Six Men's Bay) were the most detailed by individual species. The associated species or groups were: flyingfish (*Hirundichthys affinis*); dolphinfish (*Coryphaena hippurus*); kingfish (*Scomberomorus cavalla* or *Acanthocybium solandri*); shark (Carcharhinidae); tuna (Scombridae); billfish (Istiophoridae); jacks (Carangidae); crevalle jack (*Caranx hippos*); bonito (*Sarda sarda*); pot fish; any other variety (AOV); brim or queen snapper (*Etelis oculatus*); snappers (Lutjanidae) and any other variety of deeper water species (mainly Lutjanidae and Serranidae). Market data were available as monthly summaries of landings by species or groups and the associated number and type of boats. Data for secondary sites during the 1970s were available as monthly summaries of landed weights but aggregated across species, while more recent data (from 1981 onwards) were available in the same species categories as the markets. Catch data from recreational fishing tournaments were also provided by the Barbados Game Fishing Association for the period 1992 to 2001.

Since each fleet is characterized by differences in either level of activity, trip length, fishing area, landing sites or main species targeted, catches were reconstructed separately for each fleet, depending on availability of information. The annual total catch was taken as the sum of individual fleet catches. To correct for missing data, it was assumed, where possible, that all boats of a similar category operating from the same administrative region (parish) exploited the same resources and exhibited the same level of activity.

<u>Day-boats (launches) and moses boats</u>

Except for recent years (1994 to 2000), available catch data were aggregated across both fleets. Although effort (number of boat trips) was recorded separately, it was difficult to disaggregate annual or monthly catches accordingly. As a result, catches were reconstructed for both fleets combined. These fleets make daily fishing trips, are not equipped with on-board cold storage facilities and do not fish in offshore waters outside the EEZ. While the day-boat fleet targets large pelagics mainly, it exploits the inshore demersal and reef resources during the pelagic off-season. The moses fleet (dinghies of 3-6 m length, manual propulsion or low Hp outboard engines) targets mainly inshore demersal and reef species, as well as, coastal pelagic species. Target species are dependent on proximity of mooring sites to fishing areas and landing sites, since this fleet carries engines of low horsepower.

Anchor points: Total catch

Anchor points are estimates of total catch either taken from the literature or estimated from recorded statistics on fisheries landings.

1950 – 1992: Annual total catch was estimated as the sum of catches across all parishes. Annual catch at each parish was estimated as the product of average catch per boat and number of registered boats. The average catch per boat was estimated using data at recorded sites. Representative sites for each parish (in brackets) at which data were collected are: Oistins (Christ Church); Skeetes Bay (St Phillip); Pile Bay, Bay Street, Cheapside Market and Bridgetown Complex (St Michael); Paynes Bay and Reids Bay (St James); Speightstown (St Peter); Half Moon Fort (St Lucy); Martins Bay and Conset Bay (St John) and Tent Bay (St Joseph). It was assumed that a complete census of catches was taken at recorded sites, that all boats registered at a particular site landed catches at that site only and that the average annual catch per boat at recorded sites was representative of all other, non-recorded, sites within the respective parish. Using the point estimates of number of boats at all landing sites (recorded and non-recorded) in 1942 (Brown 1942), 1954 (Rose 1954) and 1963, 1973, 1983, and 1993 (unpubl. data from Fisheries Division Boat Registration System), and estimating missing values by interpolation, the annual number of boats registered at each recorded site, between 1950 and 1988, was derived. The number of registered boats at each parish was taken as the sum of registered boats at all landing sites, whether recorded or not, within the parish.

Between 1950 and 1953 data were available for the Oistins landing site only. As a result, the average catch per boat at recorded sites in 1954 was assumed the same for similar sites during the 1950 to 1953 period. Because of gaps in the data, it was assumed that boats at adjacent parishes (Christ Church and St Phillip - Zone 1, on the south/south-east coast; St Michael, St James, St Peter and St Lucy - Zone 2, on the west coast and St John and St Joseph - Zone 3, on the east coast) functioned similarly, and therefore would land similar quantities and species. Hence, between 1964 and 1973, the annual catch per boat at St Joseph (not recorded) was assumed the same as that for St John, while the 1992 catch per boat at St John (not recorded) was assumed the same as that for St Joseph. This procedure enabled estimation of total catches as well as disaggregation into the respective species components (see section on Species composition below) for parishes where no data were collected. Since no records of boats at Cheapside Market were available in most of the data sources consulted, the number of boats at Bridgetown was used in the calculations. Because of the proximity of these sites it was assumed that the same boats landed at these two sites.

Between 1984 and 1989 considerably fewer boats were recorded at the sites in St Michael. There was also the anomaly of more boats recorded, than registered, at St Michael during 1992. It was assumed that boats at the neighbouring parish of St James also landed at St Michael, to use the fisheries complex facilities constructed at Bridgetown, in 1986. Thus, average catch per boat across both sites was used in calculations. There was a considerably lower coverage of landing sites from 1989 to 1991, compared to the early 1980s and mid-late 1990s. Hence, it was not possible to estimate the average catch per boat from data for the respective years and sites. The average catch per boat was therefore estimated by interpolation between the 1988 and 1992 estimates.

1994-2000: Computerised data on landings from individual boat trips were provided by the Barbados Fisheries Division (Trip Interview Program). The greatest level of detail was available for this most recent time series. Information for each recorded trip included the catch weight by individual species, date of catch/landing, landing site and the associated boat. The recorded data were used to estimate total monthly landings, for each boat category and parish (as opposed to individual landing site). Total monthly landings were then summed across all months, boat types and parishes to derive the annual total. Although landings data were available separately for each landing site, the Fisheries Division's boat registration records were aggregated for all landing sites within a parish, hence constraining the level of spatial detail of this analysis. Based on similarities of operations of moses boats and day boats, (both make daily trips, fish closer inshore, and land at sites adjacent to the fishing areas), the same procedure was used for estimation of total landings by the two fleets.

Since recorded data did not represent a total census, total catches for the recorded landing sites/parish/boats were estimated by Equation 1:

$$Tc_{\text{parish, boat type, month}} = \text{Mean CPUE} \times \text{FD} \times \text{BR}$$

Where CPUE is the Catch per Unit of Effort; FD is the assumed number of Fishing Days and BR is the number of Boats Registered.

Herein, the basic assumptions are that:

- The CPUE by boat type and month is the same for recorded and non-recorded boats of the same type in similar months;
- That all boats in a parish fish each month; and
- That the average number of fishing days per month, of each boat type, from recorded data is the same for similar boats that are not recorded in other parishes.

For each parish, month and boat type the following details were extracted: catch of each species and total across all species; the number of fishing days; the number of fishing boats; fishing effort, as the product of number of boats and fishing days (boatdays); and mean catch per unit effort (CPUE), where CPUE = total catch/number of boatdays. The mean CPUE by boat type and month (across all parishes) was also estimated and the number of registered boats by parish and type were extracted from the Fisheries Division boat registration database. Missing monthly mean CPUEs, by parish and boat type, were estimated using proportional differences between adjacent months from mean monthly CPUEs calculated for different boat types. The basic assumption here was that seasonal variation in CPUE was the same for all boat types in a given year.

Equation (1) was also used to estimate total catches for non-recorded parishes and boat types, assuming that mean CPUE for the particular boat type across all parishes was representative for non-recorded sites. Missing values of monthly mean CPUE (catch/boat day) by boat type across all parishes were estimated using the relative proportions between adjacent months from mean CPUEs calculated for different boat types across all years (1994-2000). The same procedure was followed for estimating missing cells for average number of fishing days.

The above procedure generated estimates of total catch by parish, month and boat type, which accounted for changes in seasonality of fishing and frequency of trips due to weather or market conditions. Catches were subsequently summed across all months to provide an annual total for day-boats and moses boats.

First interpolation: Total catches

Annual total catch for 1993 was estimated by interpolation between the reconstructed annual estimates for 1992 and 1994.

Species composition

Generally, species composition was estimated directly from recorded data, and species identification was clarified by Fisheries Division staff.

1950 – 1963: Data were only available for up to four landing sites over this period. Thus, species composition was estimated using recorded data for all sites combined.

1964 – 1992: The average composition of catches at recorded sites of each zone was used to disaggregate the total annual zonal catch into its species components. Between 1964 and 1981 no data on species composition were available for sites in Zone 3. During this period, the annual species composition of catches recorded at Oistins (the nearest recorded site) was used. Speightstown was the only landing site for which data were available for 1989. Hence species composition at this site was applied across all sites. Similarly for 1990, the mean species composition at the two recorded sites, Speightstown and Cheapside markets, was applied across all landing sites.

1994 – 2000: The annual species composition from recorded catches was used to disaggregate estimates of total catch of the day-boat fleet into component species. Since day-boats target mainly large pelagics (and the demersal fishery during the flyingfish 'off-season') regardless of their port of registration, the species composition was computed across all parishes. Moses boats generally target inshore resources (small coastal pelagics and reef species); as a result the species composition of the catch may vary at different landing sites. Recent records also show the tendency for some boats to target large pelagics. Since computation of species composition across all parishes may skew the individual species catches towards large pelagics, and underestimate the catches of inshore species, the species composition was estimated separately for each parish and catches of like species summed across parishes to provide the total annual catch by species.

Second interpolation: Species composition

The species composition for 1954 to 1956, and 1993 were estimated by interpolation between the estimates for the years immediately preceding and following these periods.

Ice-boats and longliners

Ice-boats were introduced in the late 1970s, and their catches were offloaded directly at processing plants or to consumers at unmonitored landing sites. During the 1980s, landings of this fleet were not recorded by the Fisheries Division. Longliners were introduced in the late 1980s. Both boat types make fishing trips of several days duration (ice-boats: eight to nine days; longliners: nine to twenty-eight days), and are equipped with cold storage facilities (Parker 2002). Since they fish in specific offshore areas, regardless of their home port or landings site, no differences in CPUE are expected for boats of similar type among landing sites. It was however, impossible to determine the number of fishing days from recorded data (date) in the 1990s as these were indicative of offloading operations rather than fishing. Since this process may span several days, the overall landed trip catch was recorded in batches, corresponding to the quantity offloaded on the respective days. Because of the differences in nature of activity and interpretation of recorded data, a different methodology was employed for estimation of total catches by ice-boats and longliners compared to day-boats and moses boats.

Anchor Points: Total Catch

1979 – 1993: Estimates of annual total catch for this fleet were derived using the methodology of Mahon (1990a), who assumed an average of 14.5 trips per year and used an average of 1,808 kg per trip from Hunte and Oxenford (1989). Mahon (1990a) estimated total landings as the product of catch per trip, number of trips per year and number of boats. Since there were differences among the number of boats in initial reconstructed data, (Mahon) and Anon. (1986), the estimate of all three sources was used in any given year. Using information on the number of longliners operating each year (R. Mahon, pers. comm.), and assuming the same annual catch per boat as in 1994, estimates of total annual catch were derived for 1988 to 1993.

1994 – 2000: Monthly catch per boat (C_{BM}) and monthly number of boats recorded (B_{RM}) were extracted from the fisheries landing database (Trip Interview Program). Using the total number of unique boats of each type, recorded in the respective year (T_{RY}), the fraction operating each month was estimated (B_{RM}/T_{RY}). Based on the overall number of registered boats by type, available in the Fisheries Division Licensing and Registration database, the number of boats operating each month (B_{AM}) was estimated, assuming the same proportion from recorded data. The total monthly catch was estimated as the product of the average catch per boat and the number of boats operating (C_{BM} x B_{AM}). Monthly catches were summed for an estimate of total catch.

First interpolation: Total catches

Annual total catch of ice-boats for 1990-1993 was estimated by interpolation between estimates for 1989 and 1994.

Species composition

1979 – 1993: No data were available for the ice-boat fleet. Mahon (1990a) assumed a species composition of 60 percent flyingfish and 40 percent large pelagics after Hunte and Oxenford (1989). However, data for 1993 indicated other species (including demersals) in the catch, with flyingfish accounting for 67 percent and large pelagics for 25 percent of overall catch. Due to the uncertain nature of species composition for the earlier period, the same species composition as in 1994 was assumed. The species composition from 1994 to 2000 was taken directly from recorded data.

Data on species composition of the longliner fleet was not available for 1988 to 1993. Thus, the species composition for 1994 was assumed for this period, and species composition for 1994 to 2000 was taken directly from recorded data.

Catches from sport fishing tournaments

The recreational fishing industry has grown over the years, particularly because of its association with tourism and the introduction of local and international fishing tournaments. Raw data sheets, with details on catch weight by boat, were provided by the Barbados Game Fishing Association for the period 1992-2001. However, there was evidence of a change in the level of detail recorded. Records of earlier years provided information on individual fish weights by species, with a total weight for those fish below the size limit, summed for each species. It is not known when this method of recording changed, however by 2000 only the weights of those fish meeting the minimum weight criteria for the competition were recorded. While additional information indicated the overall number of fish caught by each boat, no information was provided on the fish caught that were not satisfying the minimum weight criterion.

Species catch adjustments

Between 1970 and 1990, catches of kingfish (*Scomberomorus cavalla*), yellowfin tuna (*Thunnus albacares*), skipjack tuna (*Katsuwonus pelamis*) and billfish (Istiophoridae) from Mahon and Singh-Renton (1993) exceeded reconstructed data most years. Consistent with the precautionary management approach, reconstructed catches were replaced by estimates from Mahon and Singh-Renton (1993) for the relevant species. Since some of these species were taken by all fleets, catches were disaggregated according to the species composition by fleet in the initial reconstructed data. Given that ice-boats began operations in 1979 and longliners in 1988, it was assumed that all catches prior to 1979 were from day-boats and moses boats only, and that catches from 1979 to 1987 were from day-boats, moses and ice-boats. Catches from 1988 to 1990 were attributed to all fleets. Catches of yellowfin tuna from 1970 to 1978 were attributed solely to day-boats and moses boats. However, from 1979 to 1988 yellowfin tuna catches were attributed solely to ice-boats. From 1988 onwards, catches of yellowfin tuna were divided between ice-boats and longliners according to species compositions in the initial reconstructed data. Similarly, all catches of skipjack tuna were attributed to day-boats and moses boats. The 1991 yellowfin tuna catch was taken from Mahon *et al.* (1994) and was disaggregated among fleets as previously described.

Swordfish (*Xiphias gladius*) catches from 1994 to 1998 were provided by R. Mahon (pers. comm.), who investigated the swordfish fishery of Barbados. Mahon's estimated catches exceeded reconstructed data most years and replaced initial reconstructed data for the reason given previously. Catches were distributed to respective fleets based on the contribution of each fleet to total catch and the percentage composition of each fleet in the overall catch in the initial reconstructed data.

Data for kingfish (*Scomberomorus cavalla*) and Wahoo (*Acanthocybium solandri*) were grouped due to uncertainty in species identification (wahoo is referred to as 'kingfish' in Barbados). Also, the estimated catch of 'bigfish' for 1981 and 1982 (166 t and 6 t, respectively) was assumed to be incorporated in estimates of yellowfin tuna and billfishes from (Mahon and Singh-Renton 1993).

Because of the extended trip lengths of ice-boats and longliners, it was assumed that some degree of processing occurred on board to avoid spoilage. Using conversion factors for the relevant species based on the degree of processing (Mohammed 2003), species landed weights were adjusted to the corresponding whole weight.

The species composition of the general billfish category for 1988 to 1991 was taken from (Oxenford 1994); assuming no differences across fleet types, this was applied across catches for all relevant fleets. Sailfish and spearfish accounted for 73 percent of overall billfish catch, while blue marlin and white marlin accounted for 18 percent and 9 percent, respectively. Recreational tournament catches between 1992 and 2001 were disaggregated into the respective billfish species (white marlin, blue marlin, sailfish). Commercial catches of billfish over the same period were disaggregated into the species components based on the composition of tournament catches, assuming no differences across individual fleet types (moses boats, day-boats, ice-boats and longliners).

An 'AOV' (any other variety) category, comprising mainly fish caught in pots, was listed as a separate category to 'AOV potfish' or 'Potfish' in statistics from the Fisheries Division. Since all three categories refer to the same fishery, associated reconstructed catches were combined into one 'AOV Potfish' category. The species compositions of catches in the commercial, artisanal, pot fishery were available for 1986, 1990, 1991 and 1996 from D. Robichaud and R. Mahon (pers. comm.) and (Robichaud *et al.* 1999). The species compositions for 1987 to 1989 and 1992 to 1995 were estimated by interpolation, while the species composition for 1997 to 2000 was assumed the same as that for 1996.

There were no records of catches of molluscs, e.g., Queen conch (*Lobatus gigas*) or crustaceans, e.g., spiny lobster (*Panulirus argus*), in the literature or databases consulted for this study. The respective catches in FAO FISHSTAT were therefore included as presented.

Estimation of flyingfish caught as bait

Longliners utilize flyingfish as bait; however, the associated catches are not accounted for in the data collected at landing sites. Estimation of annual landings of flyingfish caught as bait uses information on the number of hooks per main line from R. Mahon (pers. comm.), the mean individual weight of flyingfish (0.15 kg) from personal observation and an assumed 110 fishing days per year. The assumed number of fishing days is a conservative estimate since longliners have the potential to operate about 220 days per year. However, R. Mahon (pers. comm.) outlined the slow start-up of activities and ongoing maintenance problems of this fleet. Since introduction of longliners to the fishery in 1986 the number of hooks has increased from 200 per mainline to about 400 (R. Mahon, pers. comm.). The number of hooks per mainline between 1986 and 1999 was estimated by interpolation. It was assumed that hooks were baited once each fishing day and that one flyingfish was used per hook. The estimated annual quantity of flyingfish utilized as bait was taken as the product of number of hooks per mainline, number of fishing days, the mean individual weight of flyingfish and the number of longliners estimated from the Fisheries Division's boat registration system.

Update

Calculating totals

1950-1960

Initial reconstructed catches for the early part of the time period were anomalously low, so were adjusted to align with FAO data for the same years.

2002-2010:

For the update, catches were extrapolated forward to 2010. This was achieved by first calculating the ratio of overall reconstructed catches to the FAO total for each year and taking an average of the ratios 1997-2001. The average ratio was applied to the FAO total annually for 2002-2010 to estimate an overall catch for the country in each year.

Species breakdown

1950-2010

The percentage contribution of each species to the reconstructed annual total 1950-1960 was calculated, and then applied to each taxon against the FAO total for each of the years.

2002-2010

A taxonomic breakdown was estimated by applying the average catch contribution of each species in 1997-2001 to the total catches in each year 2002-2010.

Marine mammals and turtles

Earlier work by Mohammed *et al.* (2003) contained reconstructions of marine mammal and turtle catches. However, the *Sea Around Us* does not include these taxa, thus marine mammal and turtle data from Mohammed *et al.* (2003) were excluded from the database and final reconstruction totals.

Sector breakdowns

Industrial and artisanal catches

The proportional contribution of the industrial and artisanal sectors to the total reconstructed catch was calculated and averaged for 1996-2000. This was applied to the total reconstructed catch for the years 2001-2010.

Taxonomic breakdown

No taxonomic disaggregation by sector was provided in the original study, so one was estimated for the industrial sector by calculating the percentage contribution of each taxon in the offshore catch to the reconstructed offshore catch total for the years 1950-2010 and applying it to the reconstructed industrial catch annual totals. A breakdown for the artisanal offshore catches was achieved by applying the same percentage contributions to the artisanal offshore catch totals for each year. All inshore catches were classified as artisanal.

Subsistence

The reconstruction may already address part of the subsistence contribution for the islands, in terms of parts of reported catch that was landed through reporting stations but taken home, but it is likely that fishing purely for subsistence bypassed the reporting process. Using case studies from Martinique, Dominica, Guadeloupe, Montserrat and St Kitts and Nevis (Frotté *et al.* 2009a, 2009b; Ramdeen *et al.* 2012; Ramdeen *et al.* 2014a; Ramdeen *et al.* 2014c), similar small Caribbean islands, we derived a per capita subsistence rate of 0.013 $t \cdot capita^{-1}$ in 1950 and 0.006 $t \cdot capita^{-1}$ in 2010. We conservatively applied 50% of this to the population for Barbados and interpolated the rate for the intervening years to estimate a subsistence catch. This is a highly simplified approach and it is likely that subsistence catches are underestimated.

Taxonomic breakdown

A taxonomic disaggregation was achieved by assuming that the subsistence catch composition was proportionally similar to the inshore catch and applying the same percentage breakdown for each year to the estimated subsistence annual totals.

Recreational

Recreational participation in Antigua and Barbuda was found to be 0.23% of the total population (Cisneros-Montemayor 2010; Cisneros-Montemayor and Sumaila 2010) and the same rate was assumed to be true of Barbados. It was assumed that the vast majority of recreational fishers were tourists, so the participation rate was applied to the tourist population. Tourist arrivals data was only available from 1995[2], so estimated tourist numbers for 1950-1994 were calculated by interpolating from 231,000 tourists in 1995 to an assumed 0 tourists in 1945. Recreational participation was than calculated by applying the 0.23% participation rate to the tourist numbers. Ramdeen *et al.* (2014b) estimated a consumption rate of 0.001 $t \cdot tourist^{-1} \cdot year^{-1}$ for the British Virgin Islands, which we assumed to be the same for Barbados and applied it to the calculated participation total for each year 1950-2010 to obtain a recreational catch estimate.

[2] http://data.worldbank.org/indicator/ST.INT.ARVL?page=3

Taxonomic breakdown

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

RESULTS

Reconstructed catches in Barbados for 1950-2010 were 1.6 times the data reported to the FAO for the same time period. Most catches were from the artisanal sector (63.2%), with subsistence (20.1%) and industrial (16.7%) fisheries contributing similar amounts overall. Recreational fishing made up less than 0.2% of the total (Figure 2a). Catches grew slightly over the time period, increasing from 4,300 t in 1950 to 5,800 t in 2010. However, the trend was characterized by several large spikes and inter-annual variation. Particularly notable were spikes in 1966 (9,200 t), 1988 (8,900 t) and 1991 (8,700 t), where the catch quickly increased by over 50%, before declining just as swiftly over the following years (Figure 2a).

Flyingfish (Exocoetidae) were by far the most dominant fish in the catch, making up 45.5% of the total removals. Dolphinfish (Coryphaenidae*;* 14.2%), Scombridae (7.6%) and queen snapper (*Etelis oculatus*; 5.0%) were also important taxa, with 38 other taxa making up the remaining 27.7% (Figure 2b).

<u>Industrial</u>

The industrial sector began in 1979, and contributed 16.6% of the overall catch. Overall, the catches grew throughout the time period, from just over 100 t in 1979, to peaks of 3,000 $t \cdot year^{-1}$ from 1998-2000 and 2008-2009. The trend was characterized by a decline of almost 50% from 2000 to 2006, when 1,700 t was caught. Flyingfish made up two thirds of the catch (66.5%), with dolphinfish contributing another 20%. Overall, a clear shift from the artisanal to the industrial sector was observed starting in the mid-1980s (Figure 2a).

Artisanal

The artisanal fishery initially grew significantly in the early part of the time period, increasing from 2,900 t in 1950 to a peak of 7,900 t in 1966. However, there was an immediate decline reaching 3,300 t by 1969, after which catches stabilized until the mid-80s, before slowly declining. Throughout the decline, there was much variation, with a spike in 1991 reaching almost 6,000 t, but by 2007 catches had reduced to 1,500 t. A small recovery at the end of the time period saw total artisanal catches in 2010 at 2,200 t. More than half of the catch was flyingfish (54.5%), with dolphinfish making up a further 17.2%.

Subsistence

The subsistence catch initially declined by almost 40%, dropping from 1,350 t in 1950 to 820 t in 1953, before recovering back to 1,300 t by 1957. The catch averaged 1,300 t·year^{-1} throughout the 1960s and slowly declined thereafter, following a gradual and steady trajectory with catches at 830 t by 2010. Families Lutjanidae (24.4%), Carangidae (11.2%) and Scombridae (8.0%) dominated the subsistence catch.

Recreational

Although the recreational catch was small, and never reached more than 13 t·year^{-1}, it grew over the time period, from 1 t in 1950 to 12 t in 2010. Serra Spanish mackerel (*Scomberomorus brasiliensis*; 18.0%) and king mackerel (*S. Cavalla;* 16.2%) were the most prevalent taxa.

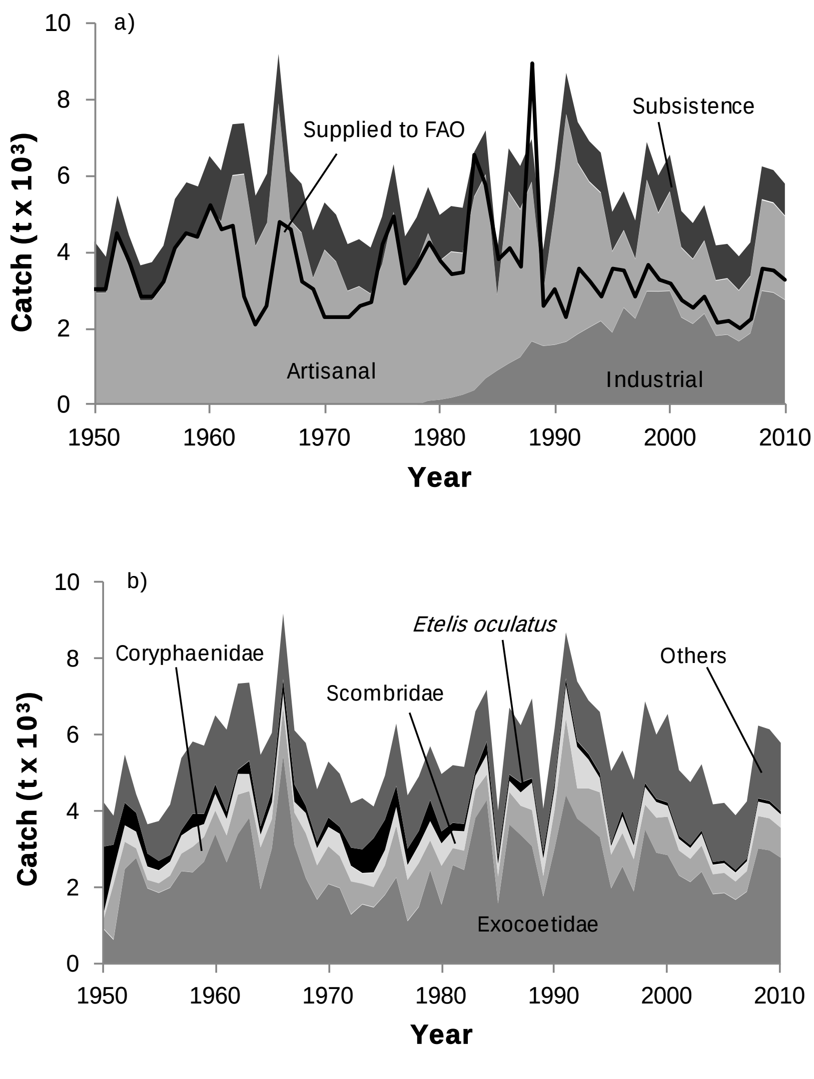

Figure 2. Reconstructed catches for Barbados from 1950-2010 by a) fishing sector, with data officially reported to FAO overlaid as line graph; and b) major taxa, with 'others' accounting for an additional 38 taxonomic categories.

Discussion

Catches

The literature review showed that most authors neglected to indicate the methods used for arriving at their estimates of total catch, while others simply quoted recorded data or estimates of total landings from other documents. This has resulted in tremendous variation in the figures presented, making it difficult to ascertain which estimate is most representative of true catches. Often, there were discrepancies in estimates even within the same document. Traditionally, annual total catch has been estimated by raising recorded landings by a factor of three (Rose 1954; Vidaeus 1969; Chakalall 1982; Oxenford 1990). These estimates have been submitted for inclusion in the FAO FISHSTAT database between 1950 and 1996. The methodology, however, gives no consideration to changes in the coverage of the data collection system, associated infra-structure development and changes in fleet characteristics. While some have criticized the methodology used to adjust recorded data to total catch (Hess 1961; Vidaeus 1969; Chakalall 1982; Oxenford 1990), there has been little effort to provide an alternative approach. Mahon (1990a) estimated catches of flyingfish and dolphinfish by the day-boat and ice-boat fleets, between 1962 and 1989, using information on the catch per trip, number of boats and an assumed number of trips per year. The resulting catches showed an increase from 1,750 t in 1962 to 7,104 t in 1989. This trend is not reflected in the data of FAO FISHSTAT (reported to FAO by Barbados) nor the present reconstructed statistics. It also does not indicate the high inter-annual variability in catches documented in the literature (Mahon *et al.* 1982). While Mahon (1990a) represented inter-annual variability in the estimates of catch per trip for day-boats, he assumed a constant estimate for the ice-boats, from 1979 to 1989.

The methodology used in this study assumed similar average annual catches per boat for all non-recorded sites within a parish as for the corresponding recorded sites, and estimated an annual total catch for each parish based on the number of registered boats (point estimates for specific years and interpolated values for years with missing data). This estimate was disaggregated into species components based on the composition of catches at recorded sites within the parish. This process accounted for site-specific differences in species composition. The reconstruction over the most recent period before the update extrapolation (1994 to 2000) used a more refined methodology, which accounted for between-site differences in average annual catch rates of the respective fleets, the associated number of fishing days and number of boats. The species composition was estimated separately by parish, for the moses fleet only, to account for recent trends towards targeting offshore pelagics, instead of the traditional inshore reef and shelf demersals and coastal pelagics.

There are however, some limitations, based on the assumptions made in the present study. For the earlier period (1950 to 1992), it was assumed that a total census of landings at recorded sites was taken, and that boats landed only at their associated registered landing sites. Vidaeus (1969), however, commented on the limitations of the data collection system in the 1960s, and indicated that, at the time, early morning and late evening catches were not recorded. Double recording of landings being taken from one market to another occurred, and catches sold at beaches were also not recorded. Hence, recorded data may not have represented a total census at the respective landing sites. Bair (1962) reported on the movement of fishing boats, particularly during the early months of the year, when seas on the windward coast are rough. At that time, boats from Tent Bay relocated to Bridgetown, and those from Foul Bay operated from Crane, Silver Sands or Oistins. Between December and March, boats from Crab Hill also moved to Speightstown or Half Moon Fort. These movements of boats were not considered in the reconstruction analysis, because estimations were made annually. It may be possible however, to refine the estimates of total catch accordingly, if annual changes in movements of boats throughout the entire study period are known. Another limitation was that estimates of catches were not derived for months with missing data. This was largely due to uncertainty in interpretation of statistics provided by the Barbados Fisheries Division, i.e., whether a blank or zero entry reflected no catch taken on the fishing trip, no fishing trip was made or that catches were not recorded.

The reconstructed statistics can be refined further by disaggregation of catches taken in fish pots using the species composition after Wilson (1983) and Selliah (2000). These documents were not available during the course of this study and species disaggregation was estimated using composition of previous years instead. Estimation of recreational catches, apart from tournament catches, may also be possible using data in Antia *et al.* (2002). Future research, rather than simply an update, will focus on estimating adjustment factors for historic data which can account for the difference in methodology used, compared to the most recent period (1994 to 2000). Catches by foreign fleets may also be estimated using data organized by fishing area, from the International Commission for the Conservation of Atlantic Tunas (ICCAT) for the relevant fleets.

The comparison of reconstructed catches and FAO statistics indicated major deviations between the two data sources in the pre-1960 and post-1990 periods. In the initial Mohammed *et al.* (2003) study, the reconstructed catch was below 500 t $year^{-1}$ from 1950-1956, before a dramatic sudden increase to almost 2,000 t in 1957 and reaching 6,000 t by 1962. For the *Sea Around Us* update, it was considered that this rate of increase was too steep and sudden to be realistic. We assumed that given the number of assumptions in the early part of the reconstruction, coupled with the small number of available data points, the FAO reported data may well include other data not available to us and therefore the reconstruction totals were adapted to the FAO total for 1950-1960. However, it was still evident that a combination of gillnet introduction in the flyingfish fishery, and complete mechanization of the fleet by the end of the 1960s resulted in considerable increases in catches compared to the early 1950s (Hess 1966).

Hess (1966) commented on the increased productivity per boat and per crew member since the mid-1940s. He cited Hall (1955), who estimated an increase from 150 to 240 average daily catch of flyingfish per boat, and a fivefold increase in overall catch with the introduction of gillnets. An increase in reconstructed catch was evident from the mid-1950s, however, the magnitude of this increase far exceeded the fivefold estimate by (Hall 1955). This increase was also not reflected in the trends in FAO FISHSTAT statistics, which do not indicate any increases, outside of the normal inter-annual variation, which may be considered a result of technological development at the time. Further, the catches in FAO FISHSTAT seem high, ranging between 2,800 t and 4,500 t in the mid to late 1950s, for a fleet that was experiencing the initial transition from sail to engine power at the time. There are, however, factors which also contributed to a decline in catches, including price control on fish between 1942 and (Parker 2000), the lack of cold storage facilities which resulted in fishers limiting their catch (Parker 2002), and increasing cost of fishing due to boat mechanization and rising fuel prices in the 1970s. The extent to which specific factors contributed to a net increase in catches is not known.

There is greater confidence in reconstructed data for the post-1990 period because of the considerations outlined above. Since 1997, the Fisheries Division has applied a raising factor of 1.2, instead of the traditional three, to estimate total catch from recorded data (C. Parker, pers. Comm.). It is interesting to note that the Planning Division of the same Ministry has applied a raising factor of 1.6 to the same data in its estimation of total catches. Further, data from tertiary sites have not yet been incorporated in the Fisheries Division's estimates of total landings (C. Parker, pers. Comm.). Tertiary sites are important landing sites for pot and small coastal pelagic fisheries, and the estimates of landings for these fisheries are therefore underestimated by the Fisheries Division. In contrast, landings at these sites were considered in the present study.

Bair (1962) alluded to the possible influence of environmental factors on catches. She noted the increase of 2,550 t between 1959 and 1960, which could not be attributed to technological developments alone. This increase, however, is not reflected in reconstructed data or the FAO FISHSTAT database. The introduction of cold storage facilities may explain the increase in catches to a peak in 1960. The decline that followed is consistent with rising fuel prices, globally, in the early 1970s. The introduction of ice-boats in the late 1970s and longliners in the late 1980s have contributed to an overall increase in catches over the years. However, there have been periods of tremendous fluctuation. One such period occurred in 1988-1989, when the fishing community reported a tremendous decline in catch rates, prompting a detailed study to investigate the reasons for and impacts of the decline (Mahon 1990a, 1990b). There were no unusual environmental factors or foreign fleet activity identified in the region which explained the decline. It seems that fishers responded in this manner because 1989 was a year of low abundance that immediately followed a year of unusually high abundance. The decline is reflected in FAO FISHSTAT, with the 1988 catch of about 9,000 t plummeting to 2,500 t by 1989. A somewhat smaller decline, from 5,500 t to 2,900 t, is reflected in reconstructed statistics. This, however, is not unusual, compared to the normal inter-annual variability. In fact, a decline of greater magnitude occurred between 1984 and 1985. R. Mahon (pers. comm.) indicated that two US longliners landed catches in Barbados during 1988, possibly accounting for the high 1988 observed catch. However, this does not entirely explain the 1988 peak. Reconstructed catches indicated higher variability in annual catches, which is consistent with observations in Hunte and Oxenford (1989).

In spite of the refinements mentioned earlier, there are still several limitations in the data presented here. These relate to incomplete records of catches in the recreational fishery, lack of data on catches by foreign fleets, quantities of bait fish and sea urchins utilized in inshore fisheries, and catches in the inshore reef, slope and shelf fishery. Juveniles of large and small tunas are also caught in the inshore fishery. However, the associated proportion of total catch is not known. As a result, all catches of these species were attributed solely to the offshore fishery. Although there is by-catch in several fisheries (Anon. 2001), nearly all fish are landed, so discarding is not a problem.

The recreational fishery has grown because of its association with tourism. By 2000 there were 12 charter boats (R. Mahon, pers. comm.), targeting barracudas, tunas, wahoo, dolphinfish and billfish, and with the capacity to fish 25-50 km offshore. Catches of these and smaller recreational boats were not recorded. Catches from fishing tournaments were also incomplete, since fish which did not meet the minimum size requirements were not recorded. Furthermore, foreign fleets from the US and Asia fished in the EEZ of Barbados (Cecil 1999), but the associated data were not recorded. It may be possible, however, to estimate the magnitude of foreign fishing using catch data, available by fishing area, from ICCAT. Bait is also utilized in the fishpot fishery, but the associated species and quantities were not recorded. Traditionally, the data collection system has also not incorporated landing sites of importance to the lobster and conch fishery.

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Appendix Table A1. Total reconstructed catch vs. FAO landings for Barbados, 1950-2010, as well as catch by sector.

Year	FAO landings	Total reconstructed catch	Industrial	Artisanal	Subsistence	Recreational
1950	3,010	4,280	0	2,930	1,340	1
1951	3,010	3,880	0	2,940	940	1
1952	4,510	5,480	0	4,400	1,070	1
1953	3,710	4,440	0	3,620	820	2
1954	2,810	3,650	0	2,730	920	2
1955	2,810	3,730	0	2,740	1,000	2
1956	3,210	4,170	0	3,130	1,040	2
1957	4,110	5,390	0	4,080	1,300	2
1958	4,510	5,820	0	4,490	1,330	3
1959	4,410	5,720	0	4,390	1,320	3
1960	5,210	6,510	0	5,190	1,320	3
1961	4,610	6,140	0	4,800	1,330	3
1962	4,710	7,340	0	6,010	1,330	3
1963	2,811	7,370	0	6,050	1,320	4
1964	2,111	5,470	0	4,160	1,310	4
1965	2,610	6,050	0	4,760	1,290	4
1966	4,810	9,180	0	7,890	1,290	4
1967	4,610	6,120	0	4,840	1,270	4
1968	3,210	5,790	0	4,510	1,270	5
1969	3,010	4,570	0	3,320	1,240	5
1970	2,311	5,300	0	4,060	1,230	5
1971	2,311	4,980	0	3,750	1,220	5
1972	2,311	4,210	0	2,980	1,220	5
1973	2,611	4,340	0	3,100	1,230	6
1974	2,666	4,120	0	2,910	1,200	6
1975	4,221	4,930	0	3,670	1,250	6
1976	4,950	6,290	0	5,050	1,240	6
1977	3,186	4,410	0	3,170	1,230	7
1978	3,595	4,910	0	3,690	1,220	7
1979	4,265	5,700	110	4,380	1,200	7
1980	3,745	4,970	130	3,630	1,190	7
1981	3,421	5,200	190	3,830	1,180	7
1982	3,490	5,160	270	3,710	1,170	8
1983	6,532	6,610	380	5,070	1,160	8
1984	5,782	7,180	700	5,330	1,150	8
1985	3,830	4,010	900	1,980	1,120	8
1986	4,110	6,710	1,090	4,490	1,120	8
1987	3,608	6,250	1,250	3,870	1,120	9
1988	6,945	6,950	1,670	4,160	1,110	9
1989	2,583	4,060	1,550	1,400	1,100	9
1990	3,027	6,170	1,580	3,490	1,090	9
1991	2,290	8,690	1,660	5,940	1,070	9
1992	3,583	7,400	1,860	4,470	1,060	10
1993	3,223	6,900	2,040	3,810	1,050	10
1994	2,827	6,600	2,210	3,350	1,030	10
1995	3,590	5,050	1,900	2,120	1,020	10
1996	3,521	5,590	2,560	2,010	1,010	10
1997	2,818	4,830	2,270	1,550	990	11
1998	3,653	6,880	2,990	2,900	980	12
1999	3,279	6,000	2,990	2,040	970	12
2000	3,183	6,550	3,000	2,580	960	13
2001	2,729	5,070	2,300	1,820	940	12
2002	2,528	4,760	2,130	1,680	930	11
2003	2,846	5,230	2,400	1,900	920	12
2004	2,156	4,170	1,820	1,440	910	13
2005	2,190	4,210	1,850	1,460	890	13
2006	1,983	3,890	1,670	1,320	880	13
2007	2,232	4,250	1,880	1,490	870	13
2008	3,558	6,240	3,000	2,370	860	13
2009	3,503	6,140	2,960	2,330	840	12
2010	3,276	5,790	2,760	2,180	830	12

Appendix Table A2. Total reconstructed catch for Barbados, 1950-2010, by major taxa. 'Others' accounted for 38 taxa.

Year	Exocoetidae	Coryphaenidae	Scombridae	*Etelis oculatus*	Others
1950	960	78	117	1,906	1,220
1951	640	1,447	358	668	760
1952	2,490	713	426	592	1,260
1953	2,780	252	429	497	480
1954	1,980	220	338	340	770
1955	1,870	249	326	245	1,050
1956	2,000	318	357	172	1,320
1957	2,430	459	467	138	1,890
1958	2,400	670	489	368	1,890
1959	2,680	649	330	267	1,790
1960	3,400	627	434	247	1,810
1961	2,660	708	427	189	2,150
1962	3,400	1,046	541	104	2,260
1963	3,830	709	445	341	2,050
1964	1,960	1,094	326	214	1,880
1965	3,030	774	433	279	1,540
1966	5,450	1,269	400	344	1,720
1967	3,120	851	278	455	1,420
1968	2,260	1,173	524	188	1,640
1969	1,690	898	441	166	1,380
1970	2,100	990	500	246	1,460
1971	1,990	834	580	179	1,390
1972	1,300	866	397	475	1,170
1973	1,570	539	267	620	1,340
1974	1,490	530	372	897	830
1975	1,810	774	389	798	1,160
1976	2,270	1,354	492	547	1,630
1977	1,130	1,074	381	426	1,400
1978	1,500	1,148	467	362	1,430
1979	2,460	781	501	553	1,410
1980	1,560	1,012	581	314	1,500
1981	2,590	445	447	207	1,510
1982	2,460	506	500	192	1,500
1983	3,820	742	369	142	1,540
1984	4,290	680	525	334	1,350
1985	1,590	699	323	191	1,210
1986	3,650	860	288	165	1,750
1987	3,380	771	346	252	1,500
1988	3,090	954	713	110	2,090
1989	1,770	531	453	172	1,130
1990	3,030	1,014	563	139	1,420
1991	4,420	2,027	879	157	1,210
1992	3,810	803	1,089	145	1,560
1993	3,570	1,038	755	144	1,390
1994	3,320	1,184	373	126	1,600
1995	1,980	879	222	63	1,900
1996	2,560	878	433	138	1,580
1997	1,900	839	355	76	1,650
1998	3,520	660	461	99	2,140
1999	2,910	923	407	82	1,680
2000	2,850	1,010	281	83	2,320
2001	2,320	656	295	76	1,730
2002	2,150	608	276	73	1,650
2003	2,420	684	306	77	1,740
2004	1,830	519	240	68	1,510
2005	1,860	527	243	68	1,510
2006	1,690	477	223	65	1,440
2007	1,900	537	246	67	1,500
2008	3,020	855	373	82	1,910
2009	2,980	842	367	81	1,880
2010	2,780	788	345	78	1,790