Barbados: Reconstructed Fisheries Catches and Fishing Effort, 1940-2000

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ABSTRACT

A time series of catch and effort data was reconstructed for the fisheries of Barbados between 1940 and 2000, based on information from the Barbados fisheries statistical data collection system, published and unpublished reports, and the Barbados fishing boat registration system. Reconstructed catches indicate considerable inter-annual variability with peaks in 1966 (7,908 t) and 1991 (7,563 t) and a slight increasing trend between 1970 (4,081 t) and 2000 (5,003 t). Offshore catches were higher than inshore catches by one order of magnitude. Catches by day-boats and moses boats (dinghies of 3-6 m length, manual propulsion or low-Hp outboard engines) declined by 68.5% between 1967 and 2000, while catches of the ice-boat and longlining fleets increased by 2,647% between 1979 and 2000. Overall, flyingfish contributed up to 89% of total catch, with an annual average of 59% over the sixty year period. The number of boats exploiting the offshore and inshore fisheries increased by 66% and 176%, respectively. Potential effort increased exponentially in both fisheries and was consistently higher in the offshore fishery. Fishing effort increased by a factor of 384 in the offshore fishery and 65 in the inshore fishery. Annual catch per unit area (CPUA) was higher in the inshore than offshore fishery, with high inter-annual variability. CPUA ranged between 0.04 t·km^{-2} (1966, 1991) and 0.015 t·km^{-2} (1985, 1989) in the offshore fishery, and between 2.24 t·km^{-2} (1992) and 0.54 t·km^{-2} (1991) in the inshore fishery. Annual catch per unit effort between 1966 and 2000 declined by 85% and 73% in the offshore and inshore fisheries, respectively. A comparison of reconstructed data with reported statistics incorporated in the FAO FISHSTAT database was made.

INTRODUCTION

Study Area

Barbados is the most easterly of the West Indian islands (Figure 1). It is situated at 13°N and 59°W, and its Exclusive Economic Zone (EEZ) covers an area of 177,346 km^2. 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).

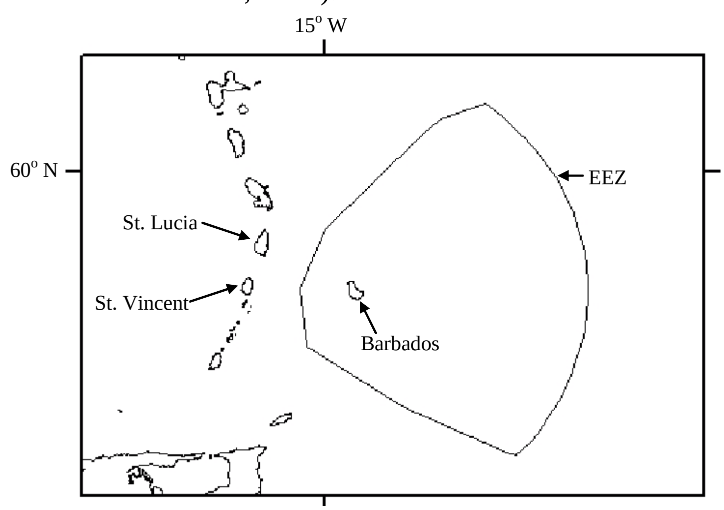


Figure 1: Map of Barbados, Lesser Antilles Islands. Also indicated are the 200 nm EEZ, and the nearest neighbouring islands.

Fishery Description

Detailed descriptions of fisheries development in Barbados are provided in Brown (1942), Hess (1966), Vidaeus (1969), Chakalall (1982), Cecil (1999) and Parker (2000). 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 dolphinfish (*Coryphaena hippurus*), tunas (Scombridae), kingfish (*Scomberomorus cavalla* and *Acanthocybium soalndri*), swordfish (*Istiophorus albicans*) 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 (*Strombus gigas*) are hand 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

In 1944 the Fisheries Division, with responsibility for management and development of fisheries, was formed. Prior to this, a system of fish price control was instituted in 1942 to ensure that fish was affordable to all sections of society. At this time, the fishing fleet was unmechanized, relying on sails and oars for propulsion (Brown, 1942). The fleet was thought to operate below capacity and the introduction of troll gear was promoted to increase catches (Brown, 1942). Mechanization of the fleet was dependent on the increased spatial and temporal availability of flyingfish (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. Flyingfish was traditionally caught using hook and line, or dipnets when plentiful. In 1947 the more efficient gillnet was introduced (Hess, 1966). Following successful fishing trials in the early 1950s, this gear was widely adopted. 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, 1961). Prior to the 1950s only one fish market (primary landing site) was established in 1946 at Cheapside in Bridegtown.

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 since catches were low during the flyingfish off-season (July to October). As a result, fishers also limited their daily catches in favor 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 time (Rose, 1954).

Although development efforts focused on increasing landings, this was 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 production was 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 with ice-boats 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 to 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, 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, whose fishery collapsed in 1987, was banned, 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 Speighstown to meet the demand of increased catches.

Fisheries Statistical data collection

Barbados differs from the rest of the southeastern 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 are 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 and excluded landings during late evening, early morning, Sundays and bank holidays (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, 1961), 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 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 to improve fisheries data collection systems in the region, hosted by the Organization of Eastern Caribbean States (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 in line with recommendations of the OECS workshop of 1988 was undertaken. Data are collected at four primary sites (Bridgetown, Oistins, Speightstown, Weston), seven secondary sites (Conset Bay, Tent Bay, Martins Bay, Skeetes Bay, Fitts Village, Paynes Bay and Half Moon Fort) and ten tertiary sites. 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 were constructed, though not yet operational, at Skeetes Bay and Consett Bay, while another market was 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. The policy for the offshore large pelagic resources is to maximize catches for national and regional fishers, within conservation guidelines, and to ensure fair and equitable distribution of resources. For the flyingfish fishery, the objective is to establish a catch and effort regime aimed at long-term sustainability, optimal economic and social return, and an acceptably low-risk of economic or social disruption as a result of inter-annual variability in catches. The policy for inshore shallow-shelf reef resources is to rebuild fish populations to levels capable of satisfying the requirements of both the commercial fishery, and recreational or tourism non-harvest uses, in order to obtain social and economic benefits from the resource. A precautionary approach to achieving sustainable yield for local consumption is proposed for the deep slope and bank fisheries, while policy aims to optimize catches of target species in the coastal pelagic fishery to meet the demands for bait fisheries, while minimizing by-catch of reef species. Policy aims to rebuild populations of sea urchins and assess the status of queen conch populations as well as institute a co-management arrangement with fishers to maintain population levels that can sustain long term optimum yields for social and economic purposes. For lobsters, the policy is to promote sustainable harvest of the resource for domestic use and the local tourism market aimed at long termed maximum economic gain. Protection, conservation and recovery of sea turtle populations is the management objective.

METHODOLOGY

Catches

Barbados has a long time series of landings data, either hand-written, printed summaries or computerised details of landings by boat trip. There are however, inconsistencies in the level of species disaggregation of landings and aggregation of landings across boat types. Data collected at the primary sites provide the greatest level of detail as far as segregation of species. The associated categories are 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), any other variety of deeper water species (mainly Lutjanidae and Serranidae). Market data are available as monthly summaries of landings as well as the associated categories and numbers of boats. Data for secondary sites during the 1970s are available as monthly summaries of landed weights but aggregated across categories/species, while more recent data (from 1981 onwards) are 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 are reconstructed separately for each fleet, depending on availability of information with the annual catch represented by the sum of individual fleet catches. To correct for missing data, it was assumed, where possible, that all boats of a similar category operating within the same administrative region (parish) exploit the same resource and exhibit the same level of activity.

Day-boats (Launches) and Moses Boats

Except for recent years (1994 to 2000), available catch data for both fleets were aggregated. Although effort (number of boat trips) is recorded separately, it is difficult to disaggregate annual or monthly catches accordingly. As a result, catch reconstruction was conducted 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 and 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.

1940: Brown (1942) provided an estimate of 454 t total catch in 1940.

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 at which data were collected are: Oistins; Skeetes Bay; Pile Bay, Bay Street, Cheapside Market and Bridgetown Complex; Paynes Bay and Reids Bay; Speightstown; Half Moon Fort; Martins Bay and Consett Bay; and Tent Bay. It was assumed that a complete census is taken at recorded sites, that all boats registered at a particular site land catches at that site only and that the average annual catch per boat at recorded sites is 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 (Fisheries Department 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 estimated 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 function similarly and therefore will 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 for parishes for which no data were collected, as well as disaggregation into the respective species components (see below). 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 close proximity of these sites it is assumed that the same boats land 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 land at St Michael, to use the fisheries complex facilities constructed in 1986 in Bridgetown. Thus, average catch per boat across both sites was used in calculations. A considerably lower coverage of landing sites was observed from 1989 to 1991 compared to earlier and later periods. Hence, it was not possible to estimate the average catch per boat from data for the respective years and sites. This 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 Department. The greatest level of disaggregation 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) and then summed across all months, boat categories and parishes to derive the annual total. Although landings data were available separately for each landing site, the Fisheries Department'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, which 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.

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

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

Where 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) and the number of registered boats by parish and type were also estimated, based on the Fisheries Department database. Missing monthly mean CPUE values by parish and boat type were estimated using proportional differences between adjacent months from mean monthly CPUEs calculated for different boat types.

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 by boat type for across all parishes were estimated using the proportional difference 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

Data were available from the Cheapside market in 1942 and the Bridgetown market in 1947 and 1948. However, records were incomplete and could not be used to estimate total catch. Thus, estimates of total catch from 1941 to 1949 were interpolatied between values for 1942 (Brown, 1942) and 1950 (reconstructed). Similarly, 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 (Table 1).

1940 – 1963: Data were only available for up to four landing sites over this period. Thus, composition was estimated using recorded data for all sites combined. The species composition for 1940 and 1941 was assumed the same as for 1942.

1964 – 1992: The average composition of catches at recorded sites of each zone was used to disaggregate the zonal catch into its species components. No data on species composition were available for sites in Zone 3 between 1964 and 1981. 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

Table 1: Species names (taxonomic and common/local) used for disaggregation of reconstructed catches for Barbados.

Scientific Name	Common/Local Name
Hirundichthys affinis	Flyingfish
Coryphaena hippururs	Dolphin
Scomberomorus cavalla; Acanthocybium solandri	Kingfish, Wahoo
Acanthocybium solandri	Wahoo
Scombridae	Mackerel
Sphyraena barracuda	Barracuda
Carcharhinidae	Shark
Thunnus alalunga	Albacore
Thunnus albacares	Yellowfin Tuna
Katsuwonus pelamis	Skipjack Tuna
Scombridae	Tuna
Istiophorus albicans	Sailfish
Tetrapturus albidus	White Marlin
Makaira nigricans	Blue Marlin
Several billfish species	Billfish
Xiphias gladius	Swordfish
Large pelagics unidentified	AOV Large pelagic
Etelis oculatus	Brim
Rhomboplites aurorubens	Snapper
Lutjanidae; Lutjanus synagris, Lutjanus mahogoni	Other snapper
Epinephelus adscensionis	Rock Hind
Epinephelus guttatus	Red hind
Carangidae	Jacks/Johns
Caranx ruber	Cavally
Sarda sarda	Bonito
including conch *Stombus gigas*	Marine molluscs nei[a]
including lobster *Panulirus argus*	Marine crustaceans nei[a]
Mainly hawksbill, *Eretmochelys imbricata*	Turtles
Scaridae	Parrotfish
Haemulidae	Grunts
Holocentrus rufus, Holocentrus adscensionis	Squirrelfish
Cantherhines pullus, Cantherhines macrocerus	Filefish
Chaetodon striatus, Chaetodon capistratus	Butterflyfish
Myripristis jacobus, Plectrypops retrospinis	Soldierfish
Serranidae	Grouper
Acanthuridae	Surgeonfish
Pomacanthus paru	Angelfish
Lactophrys polygonius, Lactophrys triqueter	Cowfish & Trunkfish
Bodianus rufus, Bodianus pulchelles	Hogfish
Pseudopeneus maculatus	Goatfish
Microspathodon chrysurus, Stegastes spp.	Damselfish
Abudefduf saxatilis	Sergeant major
Gymnothorax ocellatus	Spotted moray
Scorpaena plumieri plumieri	Spotted Scorpiofish
Chilomycterus antillarum	Web burrfish
Tylosurus spp.	Garfish
Balistidae	Triggerfish
Canthidermis maculatus	Turpit
Unidentified seine caught fish	AOV Seine
Unidentified pot caught fish	AOV potfish + AOV
Snappers (Lutjanidae) and groupers (Serranidae)	AOV Deep
Unidentified fish	Ninnins

[a] nei = not elsewhere included

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, this was computed 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 1943 to 1946, 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 are 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 between nine and 28 days duration (Parker, 2002), and are equipped with cold storage facilities. Since they fish in specific offshore areas, regardless of their home port or landings site, no differences in CPUE is expected for boats of similar type among landing sites. It is however, impossible to determine the number of fishing days from recorded data (date) as these are indicative of offloading operations rather than fishing. Since this process may span several days, the total catch is 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, b), who assumed an average of 14.5 trips per year with an average of 1808 kg per trip. Mahon estimated total landings as the product of catch per trip, number of trips per year and number of boats. Since there were discrepancies in the number of boats estimated in this study, maximum estimates in Mahon (1990a, b) and Anon. (1986) were used. Using information on the number of longliner boats operating each year (R. Mahon, pers. comm.), and assuming the same annual catch per boat as 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. 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 Department 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, b) assumed a species composition of 60% flyingfish and 40% large pelagics after Hunte and Oxenford (1989). However, data for 1993 indicated other species (including demersals) in the catch, with flyingfish accounting for 67% and large pelagics for 25% of overall catch. Due to the uncertain nature of species composition for the earlier period, the same species composition was based on the 1994-2000 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. A change in the level of detail recorded was evident.

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) were taken from Mahon and Singh-Renton (1993). Since some species are taken by all fleets, catches were disaggregated according to the species composition by fleet of the reconstructed data. Given that ice-boats began operations in 1979 and longliners in 1988, it was assumed that all catches prior to 1979 were attributed to day-boats and moses boats only, and that catches from 1979 to 1987 were attributed to 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 data. Similarly, all catches of skipjack tuna were attributed to day-boats and moses. 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 and estimated catches which exceeded reconstructed data in most years. 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 because of 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. Using conversion factors for the relevant species based on the degree of processing (Mohammed, General Methodology, this volume), species landed weights were adjusted to the corresponding whole weight.

The species composition of billfish for 1988-1991 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% of overall billfish catch, while blue marlin and white marlin accounted for 18% and 9%, respectively. Recreational tournament catches were disaggregated by the respective billfish species (white marlin, blue marlin, sailfish). The species composition of billfishes caught commercially from 1992 to 2000 was disaggregated into the species components based on the composition of the recreational catch. The same species composition was used to disaggregate the individual fleet (moses boats, day-boats, ice-boats and longliners) catches.

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

There were no records of catches of molluscs, e.g., Queen conch (*Strombus 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. The associated catches of flyingfish 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 (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 for 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 Department's boat registration system.

Estimation of turtle catches

Fishing is mainly for the hawksbill turtle, though a few green turtles are also taken (Ingle and Smith, 1949). In the 1940s, about 50-60 men harvested turtles between March and July each year using nets, and catches between 1945 and 1948 were taken from Ingle and Smith (1949). Assuming that these were all hawksbill, with a mean individual weight of 51 kg (Witzell, 1994) the equivalent weight was computed. Using annual data on the number of hawksbill turtles associated with quantities of 'bekko' exported to Japan (Milliken and Tokunaga, 1987) and mean individual weight from Witzell (1994), estimates of the weight of hawksbill caught between 1970 and 1986 were derived. Turtle catches were interpolated for years without data.

Fishing Effort

Boats were categorized as sail and/or oar boats, moses boats, day-boats or launches, ice-boats and longliners. In 1947, under the Fishing Industry Control Act, a boat registration system was implemented. This system requires annual re-registration of all boats and continues to date. The Fisheries Department keeps hard copies of these records from 1960 to the present time. In 1995 a Licensing and Registration System was introduced under the CARICOM Fisheries Resource Assessment and Management Program.

Data Sources

Point estimates (representing a single year) were derived for each decade between the 1940s and 1990s. The main data sources were Brown (1942); Rose (1954); Fisheries Department unpublished boat registration statistics available on hard copy for the years 1964, 1974, 1984 and 1994; and the Fisheries Department unpublished statistics available in the Licensing and Registration System for 1995-2000. Fishing effort for years with missing data was estimated by interpolation.

1942: Brown (1942) provided data on the number of boats by size, landing site and fishery, which led to a preliminary identification of landing areas associated with each fishery. Flyingfish and associated large pelagics are caught off all coasts. Since this is the major fishery, there are no clear distinctions in the associated boat designs as all boats target flyingfish. The associated number of boats is 340; while 52 of these target the brim and red fish fishery during the flyingfish off season (July to September). Boats utilising pots to capture demersal and reef species include the large row boats on the west (24) and south east (40) coasts and some small row boats on the west coast (85). It is assumed that large oar boats target the flyingfish and large pelagics fishery from November to June. Some of the small row boats on the west coast target the pot fishery all year, thus it is assumed that these are the boats for which pot fishing is listed as the main fishery (46). It is also assumed that the other 39 small oar boats target the pot fishery during the hurricane season only. The 107 castnets and nine beach seines targeted the inshore small coastal pelagic fishery which also acts as a source of bait. It is assumed that all boats were unmechanised, roughly corresponding to one horsepower.

1952: The number of boats by mooring site and parish, as well as the association of boats to fishery type was available from Rose (1954). There were 400 boats involved in the flyingfish fishery, 18 of which were mechanized with average engines size of 23 Hp (Parker, 2000). During the hurricane season (July to October), only 66 of the flyingfish boats operated in addition to the 18 mechanized ones. It was assumed that these target demersal resources. The inshore pot fishery was exploited by 600 fishers during hurricane season. Based on a mean crew of six (Rose, 1954), the equivalent number of boats was estimated at 100.

1963, 1973, 1983, 1993: Data were available in hard copy from the Fisheries Department's unpublished statistics, and computerized for this analysis. A list of boats and the associated mooring site, length, and engine details, i.e., whether inboard or outboard, brand and horsepower, were extracted for the respective years. The boat registration system requires annual re-registration. However, some fishers may have neglected to register their boat, yet continued to fish (illegally) during the year selected for analysis. Following a review of registration records for the year immediately preceding and following the selected year, boats found to have registered during these years were assumed to have fished during the selected year, and therefore were included. Mean horsepower was estimated from the same database.

1988: Data were available on the number of boats, by type, from Willoughby *et al.* (1988). Engine horsepower was estimated by interpolation between estimates for 1984 and 1994, with resulting estimates of 20 Hp, 53 Hp and 167 Hp for moses, day launches and ice launches, respectively.

1994-2000: Data were available on boat registration, parish, boat length and horsepower and boat type from the Fisheries Department's licensing and registration system (LRS).

Linking fishing effort to fishery type

In Barbados, there is a clear distinction between boat type and the associated fisheries. Prior to mechanization, all boats targeted the flyingfish and large pelagic fishery from November to June/July. During the pelagic off season, some targeted the pot and handline fishery (smaller boats and dinghies or moses boats) to catch bream (*Etelis oculatus*) and other snappers, while others targeted the sea urchin fishery (Brown, 1942; Rose, 1954). Willoughby *et al.* (1988) linked boat design to fishery type. Following mechanization, day-boats targeted the offshore fishery (flyingfish and large pelagics) from November to June, and switched to inshore shallow and deepwater demersals during the hurricane season (coinciding with the flyingfish off-season) from July to October. Ice-boats were designed specifically for targeting the offshore fishery, but were assumed to operate similar to day-boats until 1994, when they targeted the offshore pelagic fishery year round. Longliners target the offshore large pelagic fishery year round, catching flyingfish either incidentally or as bait. During the flyingfish off-season these boats continue targeting large pelagics. Moses boats target inshore shallow and deep water demersal and reef species mainly, though in recent years (1995-2000) records indicate a switch to the offshore pelagic fishery, particularly in the parishes of Christ Church, St John and St Peter.

Assigning fishing days to the respective fleets and fisheries

The assignment of number of fishing days was based on the fishery type and level of fleet mechanization as outlined in Mohammed (this volume). It was assumed that until 1994 ice-boats targeted the offshore pelagic fishery from November to June (130 days), and inshore demersal, reef and slope fisheries from July to October (45 days). Thereafter, ice-boats targeted the offshore pelagic fishery all year (220 days). Moses boats targeted both components of the inshore fishery (small coastal pelagics, and reef, slope and shelf) year round. Based on Mohammed (this volume), 230 fishing days was assumed and this was apportioned equally to each component of the inshore fishery. Between 1995 and 2000, moses boats at Christ Church, St John and St Peter targeted the offshore pelagic fishery. It was assumed that these boats operated similar to the day boats. Longliners target the offshore pelagic fishery year round (220 days).

Annual trends in catch per unit area (CPUA) and catch per unit effort (CPUE)

Using reconstructed catches and estimates of the EEZ (177,346 km^2), reef (100 km^2), and slope and shelf areas (177 km^2), a time series of catch per unit area (CPUA) was derived. The EEZ area was considered offshore and the reef, slope and shelf areas as inshore. Catch per unit effort (CPUE) was estimated as the ratio of reconstructed catch and reconstructed effort for the respective fisheries. Missing data on fishing effort were estimated by interpolation between reconstructed estimates for specific years.

RESULTS

Catches

A literature review indicated considerable variability in estimates of catches from different sources (Figure 2). Both, reconstructed data and statistics for Barbados in the FAO FISHSTAT indicate considerable inter-annual variability in catches (Figure 3a). Between 1950 and 2000, catch statistics in FISHSTAT varied between 2,101 t (1964) and 6,523 t (1983), with an unusually high catch of 8,929 t in 1988. Greatest deviation between reconstructed catches and FISHSTAT statistics occurred pre-1960 and post-1990. Except for the 1990s, periods of peak catches coincided in both data sources, although magnitude differed.

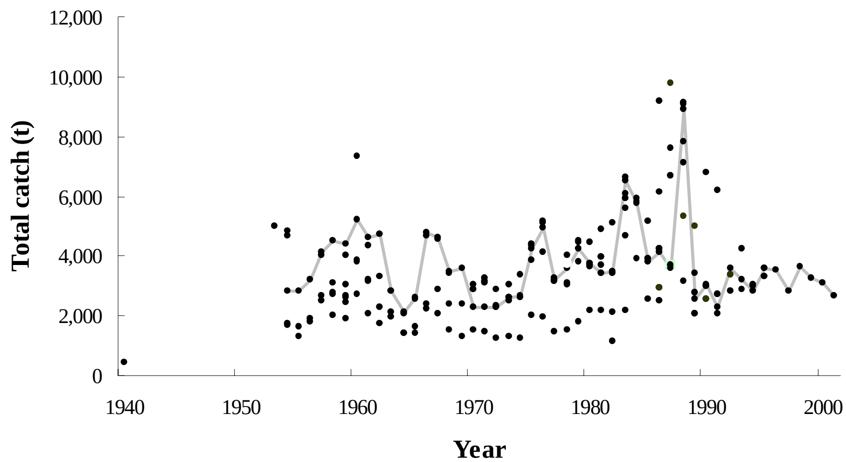


Figure 2: Estimates of total catch for Barbados from a literature review. Sources: Brown (1942); Howard (1950); Rose (1954); Fiedler *et al.* (1957); Smyth (1957); Bair (1962); Vidaeus (1969); Villegas (1979); Kreuzer and Oswald (1978); Chakalall (1982, 1992); St. Hill (1984); Berkes and Shaw (1986); McConney (1987, 1996); Anon. (1990); Oxenford (1990); Willoughby *et al.* (1990); Prescod *et al.* (1991); Prescod (1996); and the Barbados Fisheries Division. The line indicates data from FAO FISHSTAT for Barbados.

Reconstructed statistics indicate periods of peak catches in 1966 (7,908 t) and 1991(7,563 t). There is also a slightly increasing trend from 1970 (4,081 t) to 2000 (5,003 t), with annual catches fluctuating between 2,886 t (1985) and 7,562 t (1991). Inter-annual variability is evident in both the offshore and inshore fisheries (Figure 3b). Offshore catches were higher than inshore catches by one order of magnitude, and varied between 7,394 t (1966) and 2,670 t (1985), while inshore catches varied between 204 t (1991) and 843 t (1992). A comparison of catches between artisanal (day-boats and moses boats) and semi-industrial (ice-boats and longliners) fleets between 1964 and 2000 indicates an overall 68.5% decline in catches of the artisanal fleet, from a high of 7,889 t in 1967 to a low of 2,482 t in 2000 (Figure 4). Conversely, from 1979 to 2000, catches of the semi-industrial fleet have increased from 105 t to 2,884 t, a 2,647% increase. Overall, flyingfish contributed up to 89% of the total catch, with an annual average of 59%.

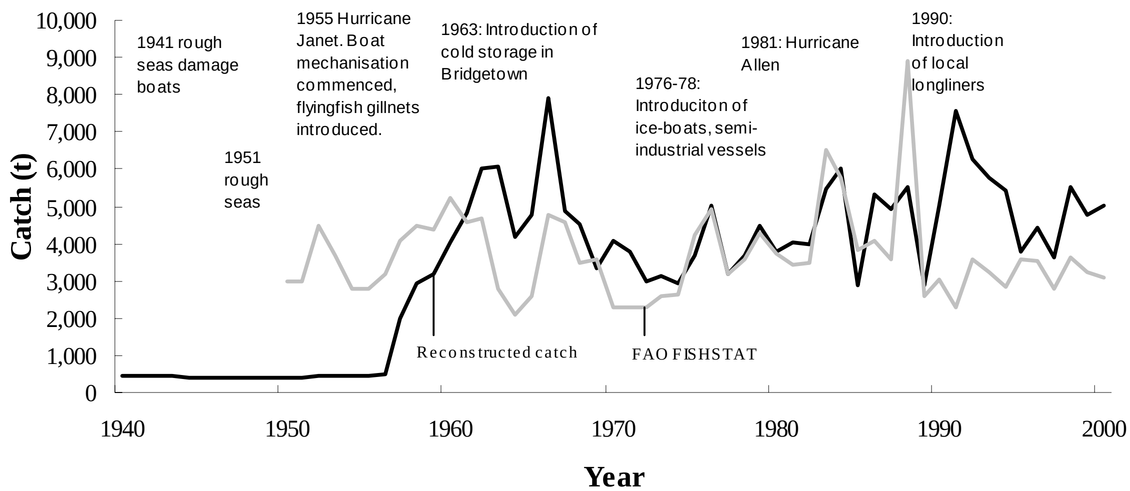
Over the 50 year period catch statistics in FISHSTAT were disaggregated into up to 20 species/groups, while reconstructed catches were disaggregated into 37 species/groups (Figure 5a). The percentage of overall catch attributed to the FAO aggregate category ('Miscellaneous Fishes nei') remained at or below 5% in most years for data in FAO FISHSTAT (Figure 5b). Notable exceptions occurred between 1965 and 1970 when this increased to 15%, and in 1980 when 42% of overall catch was attributed to the aggregate category. In reconstructed statistics the greatest contribution of the aggregate category, comprising 'AOV seine', 'AOV large pelagics', 'AOV potfish', 'AOV' and 'ninnins', to total catch was 9% in 1968 and 1981. In other years this category contributed at most 7% to overall catch (Figure 5b).

Catches of large pelagics from recreational tournaments were insignificant compared to commercial catches. Between 1992 and 2001, landings from tournaments declined from about 11 t to 2 t (Table 2). Catches of flyingfish as bait for the longline fishery has increased from 7 t in 1986 to 205 t in 2000 (Table 3). Marine turtle catches increased from 5 t (1945) to 20 t (1970), followed by a general decline (Figure 6).

Fishing Effort

The number of boats in the offshore fishery ranged between 370 (1984) and 631 (2000) over the sixty year period (Figure 7a). No definite trend towards increased numbers of boats was observed in the earlier period (1940 to 1988), with the overall increase between 1940 and 2000 being 66%. The number of boats exploiting the inshore fishery ranged between 184 (1952) and 878 (2000), with a 176% increase between 1940 and 2000 (Figure 7b). Generally, effort increased exponentially between 1940 and 2000, with effort in the offshore fishery far exceeding that in the inshore fishery. The 2000 estimate was 11,667 x 10^3 Hp- days for the offshore fishery,

(a)



(b)

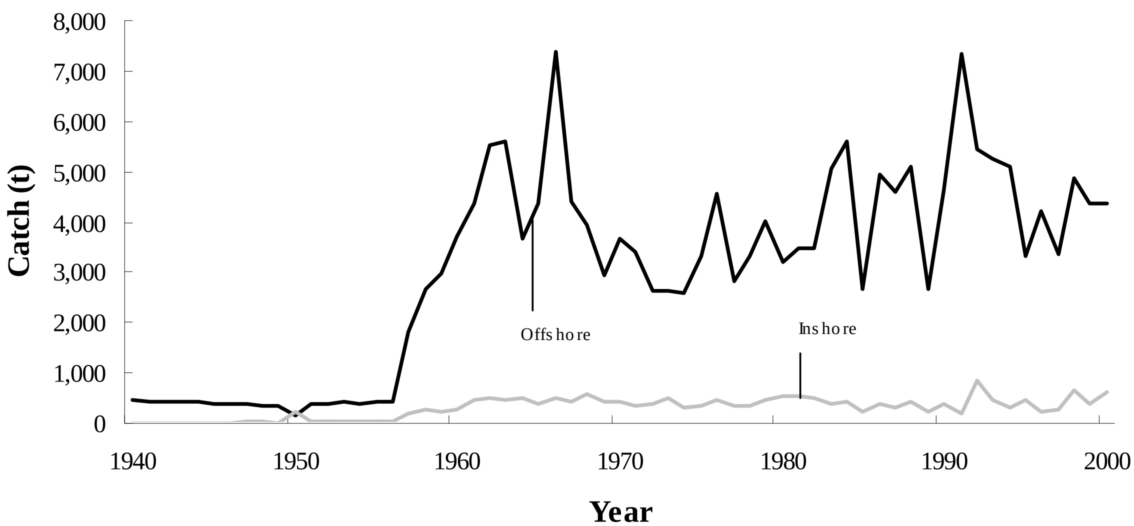


Figure 3: Catches in Barbados: (a) reconstructed catches (1940 – 2000) and FAO FISHSTAT (1950-2001); (b) reconstructed catches dis-aggregated for offshore and inshore fisheries (1940-2000).

compared to 2,690 x 10^3 Hp-days for the inshore fishery.Over the 60 year period, fishing effort increased by a factor of 384 and 65 in the offshore and inshore fishery, respectively. This increase was more pronounced in the most recent years (1994 to 2000) for both fisheries.

A summary of number of boats and mean engine size by boat type between 1963 and 2000 (Table 4) indicates a general increase in the overall number of boats and engine size. The increase in numbers of boats is attributed mainly to increases in moses and ice-boats, and longliners to a lesser extent in recent years. However, the number of day-boats has gradually declined over the period.

Annual trends in catch per unit area (CPUA) and catch per unit effort (CPUE)

Generally CPUA was greater, by about two orders of magnitude, in the inshore compared to the offshore fishery (Figure 8). Between 1956 and 1962, both fisheries experienced considerable increases in CPUA, from 0.13 $t{\cdot}km^{-2}$ to 1.30 $t{\cdot}km^{-2}$, and from 0.002 $t{\cdot}km^{-2}$ to 0.031 $t{\cdot}km^{-2}$ in the inshore and offshore fisheries, respectively. Thereafter, CPUA remained relatively stable, although still varying between years.

Catch per unit effort in the inshore fishery was considerably lower than in the offshore fishery (Figure 9). Two different patterns in CPUE were observed in both fisheries between 1940 and

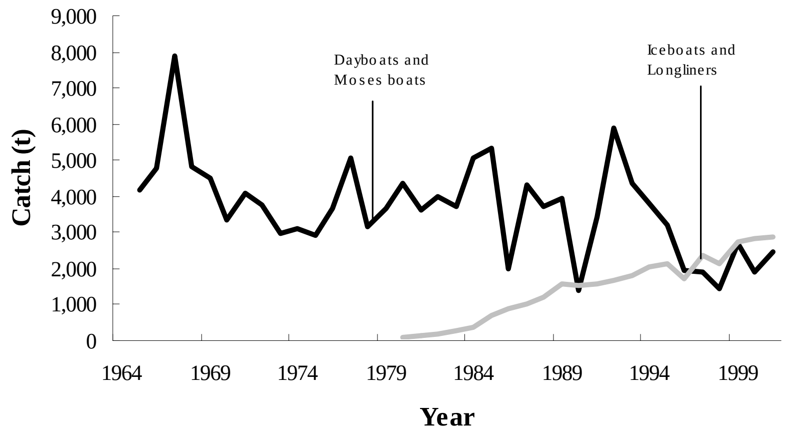


Figure 4: A comparison of annual reconstructed catches for artisanal boats (day-boats and moses boats), and semi-industrial boats (ice-boats and longliners) from 1964 to 2000.

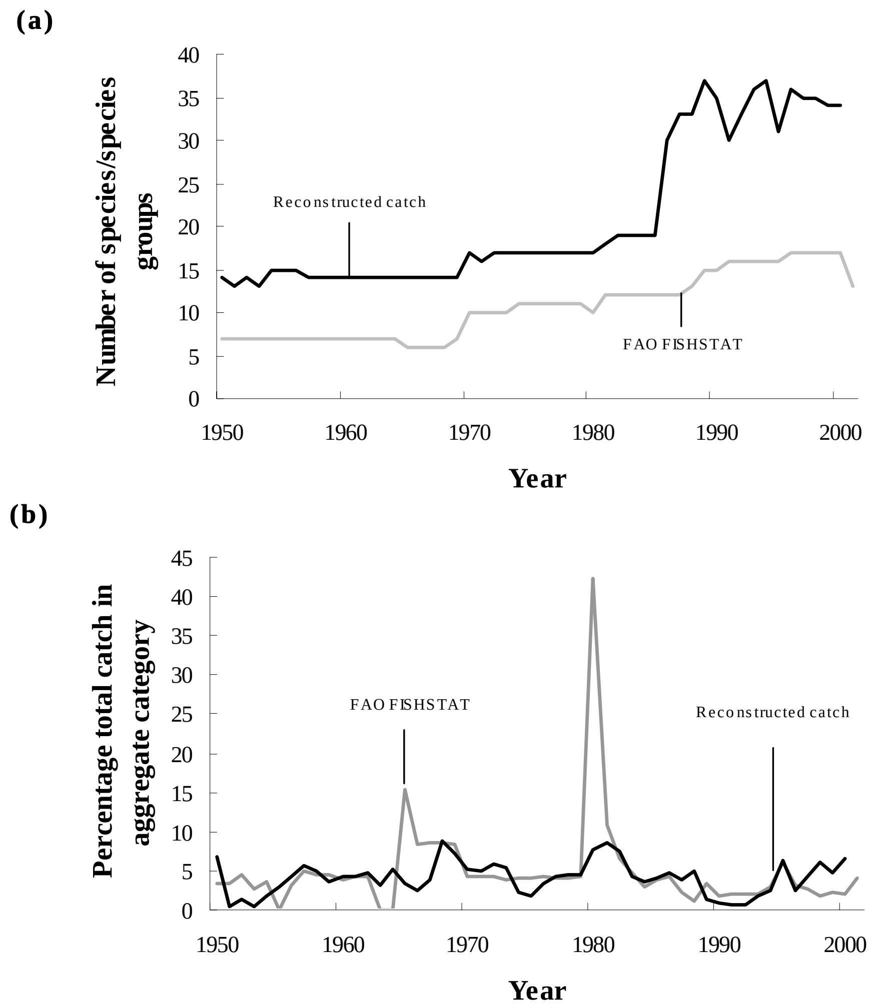


Figure 5: A comparison of reconstructed catch data and statistics in FAO FISHSTAT for Barbados between 1950 and 2000: (a) number of species/species groups and (b) percentage of total catch in aggregate category

.

Table 2: Catches (t) from recreational fishing tournaments (1992 – 2001).

Year	Dolphin-fish	Wahoo	Sailfish	White marlin	Blue marlin	Yellowfin tuna	King-fish	Other pelagics	Total
1992	6.21	3.62	0.32	0.08	0.40	0.12	-	0.04	10.79
1993	2.82	4.26	0.18	0.10	0.59	0.01	-	0.03	7.99
1994	3.42	1.99	0.15	0.03	0.47	0.19	-	0.05	6.30
1995	4.11	3.58	0.07	0.08	0.75	0.18	-	0.13	8.89
1996	5.33	4.88	0.05	0.04	1.06	0.08	0.02	0.11	11.58
1997	3.84	1.15	0.29	-	0.35	0.08	-	0.01	5.72
1998	1.79	0.70	0.11	0.02	0.32	0.06	-	0.01	3.02
1999	1.18	0.96	0.07	-	0.10	0.05	-	0.02	2.37
2000	0.54	0.44	0.05	0.02	0.43	0.04	-	0.13	1.66
2001	0.81	0.48	0.05	0.07	0.70	0.17	-	-	2.30

1952. Catch per unit effort in the inshore fishery increased from 0.176 x 10^{-3} t·Hp-days^{-1} in 1940 to 1.60 x 10^{-3} t·Hp-days^{-1} in 1952, while offshore CPUE declined from 14.74 x 10^{-3} t·Hp-days^{-1} to 1.59 x 10^{-3} t·Hp-days^{-1} over the same period. An unusually high inshore CPUE in 1950 was attributed to high catches of queen snapper (*Etelis oculatus*). Generally between 1956 and 1966, CPUE increased from 0.79 x 10^{-3} t·Hp-days^{-1} to 5.29 x 10^{-3} t·Hp-days^{-1} in the offshore fishery. Over the same period, the increase in CPUE was much smaller for the inshore fishery, from 0.20 x 10^{-3} t·Hp-days^{-1} to 0.86 x 10^{-3} t·Hp-days^{-1}. Thereafter, CPUE declined to 0.38 x 10^{-3} t·Hp-days^{-1} and 0.23 x 10^{-3} t·Hp-days^{-1} by 2000, for offshore and inshore fisheries, respectively.

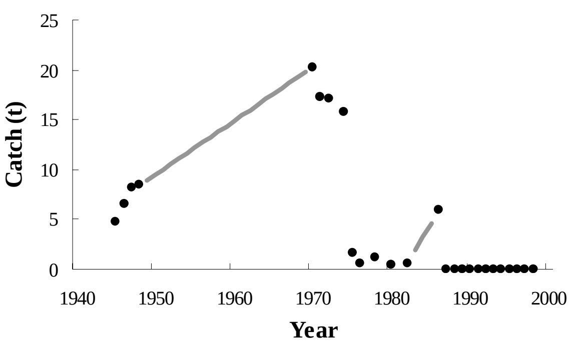


Figure 6: Reconstructed catches of hawksbill turtle (*Eretmochelys imbricata*) in Barbados (1945 – 1998). Solid circles represent reconstructed data and solid lines are interpolated values.

DISCUSSION

Catches

Our review of the literature 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, b) 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

Table 3: Estimated catch of flyingfish caught as bait (1986-2000).

Year	Number of hooks per main line	Number longliners	Estimated catch (t)
1986	200	2	6.60
1987	214	2	7.07
1988	29	3	11.31
1989	243	3	12.02
1990	257	3	12.73
1991	271	6	26.87
1992	286	9	42.43
1993	300	10	49.50
1994	314	13	67.41
1995	329	13	70.48
1996	343	19	107.49
1997	357	24	141.43
1998	371	24	147.09
1999	386	29	184.56
2000	400	31	204.60

Table 4: Number of boats (N) and mean engine horsepower (Hp) in the Barbados fishery (1963-2000).

Boat Type	Details	1963	1973	1983	1993	1994	1995	1996	1997	1998	1999	2000
Day-boat	N	484	370	356	303	327	326	316	301	301	288	290
	Hp	18	25	53	56	53	52	52	54	54	62	62
Moses	N	71	51	82	208	250	271	290	320	333	401	434
	Hp	13	15	19	20	21	21	21	23	25	26	27
Ice-boat	N	-	-	12	75	89	100	120	134	144	145	156
	Hp	-	-	174	173	159	158	161	160	167	173	192
Longliner	N	-	-	-	10	13	14	19	24	24	29	31
	Hp	-	-	-	348	262	265	302	308	314	334	325
Pirogue	N	9	15	2	-	-	-	-	-	-	-	-
	Hp	185	156	115	-	-	-	-	-	-	-	-
Total N		564	436	452	596	679	711	745	779	802	863	911

not indicate the high inter-annual variability in catches documented in the literature (Mahon *et al.*, 1982). While Mahon (1990a, b) 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. He also assumed no change in the number of day-boats over the time period examined, however, our reconstructed fishing effort shows otherwise.

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. This estimate was disaggregated into species components based on the composition of catches at recorded sites within the parish. This process accounts for site-specific differences in species composition. The reconstruction over the most recent period (1994 to 2000) provides a more refined methodology, accounting 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 is estimated separately by parish for the moses fleet only, because of 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 (1940 to 1992), it was assumed that a total census of landings at recorded sites was taken, and that only boats registered at the respective sites landed there. 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 represent 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 this 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 of movements of boats throughout the entire study period are known. Another limitation is that estimates of catches were not derived for months with missing data. This is largely due to uncertainty in interpretation of statistics, i.e., whether a blank or zero entry reflects no catch taken on the fishing trip, no fishing trips made or that catches were not recorded.

The reconstructed statistics can be refined further by disaggregation of catches taken by fishing pots according to the species composition after Wilson (1983) and Selliah (2000). These documents were not available during the course of this study. Estimation of recreational catches, apart from tournament catches, may also be possible using data in Antia *et al.* (2002). Future research 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 by fishing area from the International Commission for the Conservation of Atlantic Tunas (ICCAT) for the relevant fleets.

A comparison of reconstructed catches and FISHSTAT statistics indicated major deviations between the two data sources in the pre-1960 and post-1990 periods. While few data points

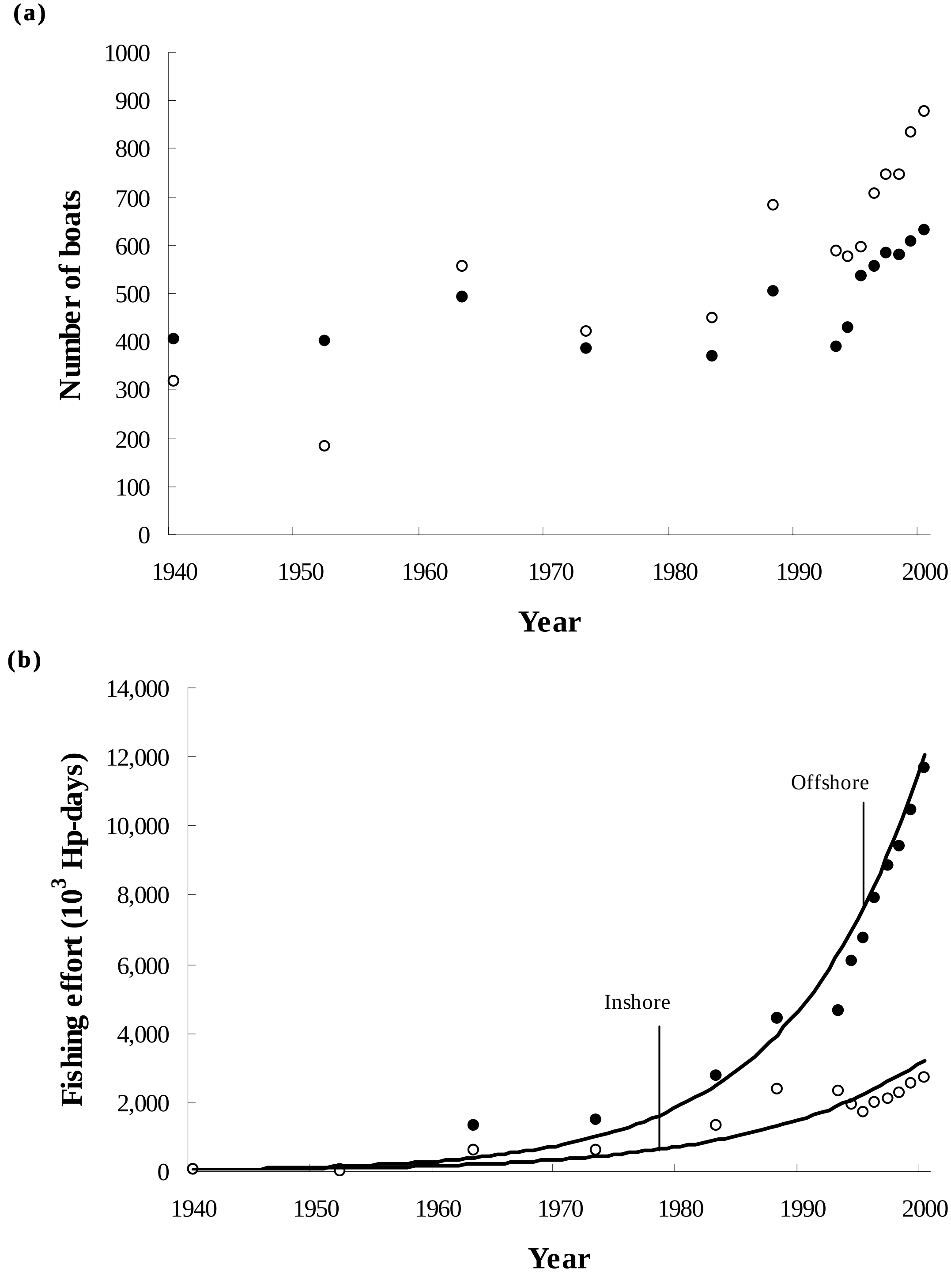


Figure 7: Reconstructed number of boats (a) and fishing effort (b) in the Barbados fisheries (1940 to 2000). Solid and open circles represent the offshore and inshore fishery, respectively.

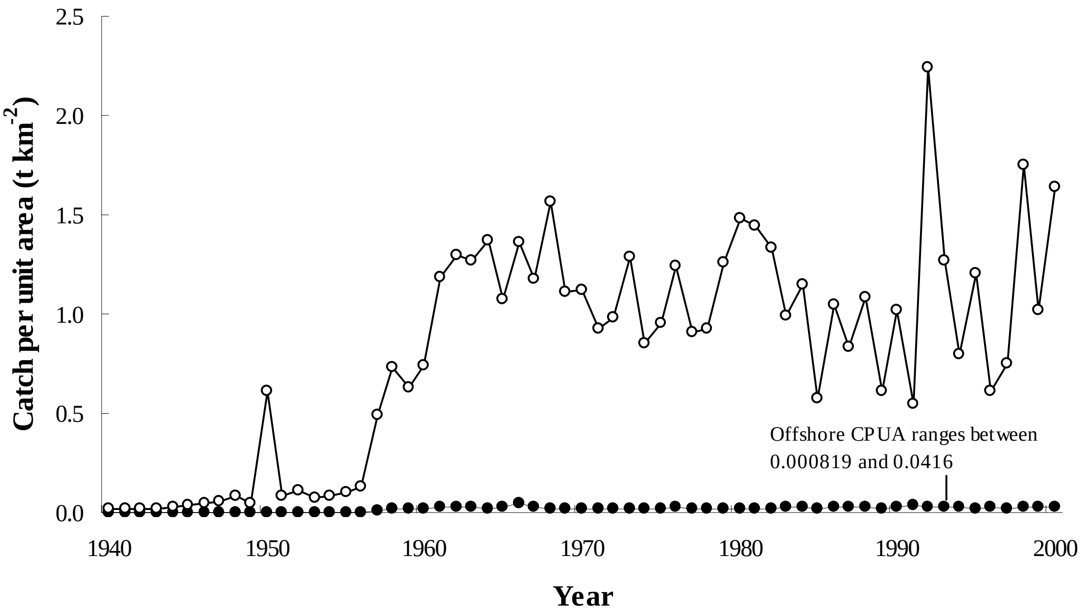


Figure 8: Annual trends in catch per unit area (t·km^{-2}) in the fisheries of Barbados (1940 – 2000). Solid and open circles represent offshore and inshore fishery, respectively.

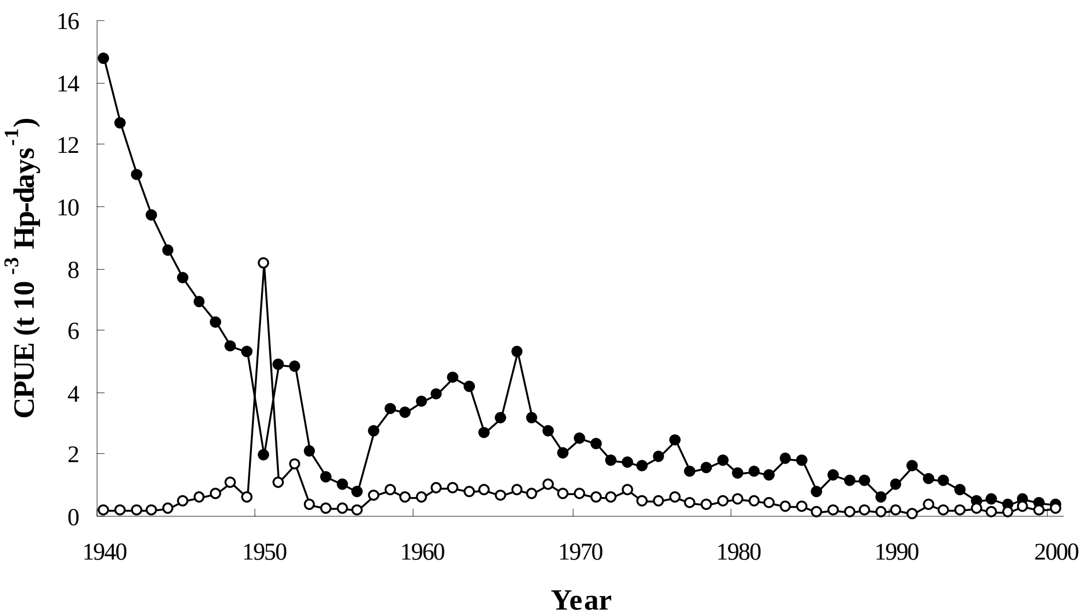


Figure 9: Annual trends in catch per unit effort (10^{-3} t·Hp-days^{-1}) in the fisheries of Barbados (1940 – 2000). Solid and open circles represent offshore and inshore fishery, respectively.

exist for the earlier period, it is 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 (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 in average daily catch per boat from 150 to 240 flyingfish, and a fivefold increase in overall catch with the introduction of gillnets. An increase in reconstructed catch is evident from the mid-1950s, however, the magnitude of this increase far exceeds the fivefold estimate. This increase is also not reflected in the trends in 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 1972 (Parker, 2000), the lack of cold storage facilities resulting in fishers limiting their catch (Parker, 2002), and increasing cost of fishing due to vessel mechanization and rising fuel prices in the 1970s. The extent to which specific factors contributed to a net increase in catches is not known.

For the post-1990 period, greater confidence is placed on estimates derived from reconstructed data, because of the considerations outlined above. Since 1997, the Fisheries Department has applied a raising factor of 1.2, instead of the traditional three, to estimate total catch from recorded data. 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. 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 Department. In contrast, landings at these sites were considered in the present study.

Bair (1962) alluded to the possible influence of environmental factors on catches. He 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 nor the FAO FISHSTAT. The introduction of cold storage facilities may explain the increase in catches to a peak in 1960. The decline that followed is consistent with the global period of rising fuel prices 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 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, b). There was 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 is reflected in reconstructed statistics. This, however, is not unusual, compared to the normal inter-annual variability. In fact a decline of greater magnitude appears to have 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 indicate 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. Juvenile large tunas 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, 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 vessels are not recorded. Catches from fishing tournaments are also incomplete, since individuals which do not meet the minimum size requirements are not recorded. Furthermore, foreign fleets from the US and Asia are reported to fish in the EEZ of Barbados (Cecil, 1999). It may be possible 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 are not recorded. Traditionally, the data collection system has also not incorporated landing sites of importance to the lobster and conch fishery.

Fishing effort

The number of boats in the offshore fishery ranged between 370 (1984) and 631 (2000) over the sixty year period. No definite trend towards increased numbers of boats was observed between 1940 and 1988, however, the overall increase between 1940 and 2000 was 66%. The number of boats exploiting the inshore fishery ranged between 184 (1952) and 878 (2000), with a 176% total increase. Generally, effort in the offshore fishery far exceeded that in the inshore fishery, increasing by a factor of 384 in the offshore fishery and 65 in the inshore fishery. This increase was more pronounced in recent years (1994-2000) for both fisheries, and results from increases in number of boats (except day-boats) and engine size.

The recent decline in number of day-boats reflects their conversion to ice-boats. These boats were considered over-mechanized for their size (Parker, 2000). The main advantage of increasing horsepower was to enable boats to return from fishing prior to the closure of markets and arrival of ice-boats. Ice-boats were found to flood the markets resulting in declining prices which adversely affected the day-boat fleet (Horemans, 1988). Increasing horsepower eventually led to economic inefficiency (Oxenford and Hunte, 1998) and finally to conversion to the more efficient ice-boat fleet.

The unit of fishing effort used here allowed comparison across fishery and fleet types regardless of gear types. As a result, the increase in fishing efficiency associated with the introduction of gillnets for the capture of flyingfish in the 1950s, and the introduction of longlining gear in the late 1980s are not reflected in this analysis. Neither is the increase in effort directed at specific inshore resources, e.g., lobsters, conch and sea urchins, which may be measured by the number of fishers rather than boat or gear units. Further, boat mechanization is reported to have extended daily fishing time by about two hours. Although the increase in boat horsepower associated with introduction of the ice-boats and longliners is incorporated in the unit of effort, the increased range of fishing, including areas inaccessible by the artisanal fleet of Barbados and other islands, is not considered.

Annual trends in catch per unit area (CPUA) and catch per unit effort (CPUE)

Generally CPUA in the inshore fishery was greater, by about two orders of magnitude, then in the offshore fishery. Between 1956 and 1962, both fisheries experienced considerable increases in CPUA. Thereafter, CPUA remained stable but showed high inter-annual variability. The higher inshore CPUA is a result of concentration of the resources within a narrow shelf and reef area. Compared to the entire area considered in this study for Barbados, the inshore component accounts for only 0.15% of the total area. The increase in CPUA between 1956-1962 quite likely results from increased catches due to boat mechanization and introduction of gillnets in the flyingfish fishery. Essentially, factors accounting for the trends in catches also explain the trends in CPUA. From the late 1970s onwards, however, CPUA seems over-estimated. Introduction of the ice-boat and longline fleets have considerably increased the fishing range. Ice-boats can fish as far as 650 km offshore. They operate as far south as Trinidad and Tobago, and Grenada (Potts *et al.*, 1988; R. Mahon, pers. comm.). Longliners also operate in the EEZ of the windward islands, e.g., St Vincent and the Grenadines (Morris *et al.*, 1988), and St Lucia (Murray *et al.*, 1988), in the Atlantic waters outside the Barbados EEZ and as far south as Surinam and Guyana. Some boats are also reported to fish as far as the southern coast of the Dominican Republic. This increase in fishing range is not incorporated here.

Generally CPUE in the inshore fishery was considerably lower than in the offshore fishery. Between 1956 and 1966, CPUE increased dramatically in the offshore fishery, while the increase in CPUE was much smaller for the inshore fishery. Between 1966 and 2000, CPUE decreased exponentially, with a drastic 85% decline in the offshore fishery, and a 73% decline in inshore CPUE over the same period.

Factors contributing to the increase in CPUE between 1956 and 1966 include the introduction of the gillnet in the flyingfish fishery and loans for boat mechanization during the previous decade, along with government subsides on gear and fuel (Hess, 1966). The decline in CPUE from the late 1960s is consistent with increasing fishing effort associated with offshore and inshore fisheries. This increase in effort is not balanced by similar increases in catch. As indicated earlier, the over-mechanization day-boats was solely for the purpose of achieving greater speeds, thereby reducing return time to the markets and winning the intense competition for the sale of the catch (Parker, 2000). However, this also indirectly contributed to an increase in fishing time and overall fishing effort. Flyingfish account for the major portion of the catch (about 60%), and as such has a great influence on overall CPUE. It is also a major prey of the dolphinfish (Oxenford and Hunte, 1998) and other large pelagics. The abundance of flyingfish is also highly influenced by environmental conditions (Mahon, 1986). McConney (1996) identified several economic, social and ecological factors impacting on estimates of CPUE. However, it is difficult to identify which of these exerts the greatest influence on CPUE at any point in time.

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