Quantifying marine biodiversity changes in the southeastern Caribbean

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ABSTRACT

Quantifying anthropogenic and climatic impacts on fisheries and the biodiversity of associated ecosystems has been the subject of increasing research over the last decade. In the Caribbean region such analyses have focused on region-wide declines in hard corals, phase-shifts in coral reef community structure, declines in pelagic shark populations in the Gulf of Mexico and species extinctions due to historical overfishing. This paper analyses specific ecosystem-based indicators for fisheries management: marine trophic index, mean fish length and fishing-in-balance indices, to quantify changes in biodiversity of species in the marine ecosystem of the southeastern Caribbean region using previously reconstructed time series data (1950 to 2000) on fisheries catches of five countries, Saint Lucia, St Vincent and the Grenadines, Grenada, Barbados and Trinidad and Tobago. Interpretation of trends in the selected indicators considers documented accounts of country specific fishery developmental policies as well as economic, technological and social factors which may impact on the use of fisheries catch data for assessing changes in marine biodiversity. This paper also identifies some anecdotes in historical and anthropological literature as well as scientific and fishery-related surveys conducted in the region which may be useful for examining historical changes in abundance and biodiversity of marine organisms over a longer time series than that based on existing fisheries catch data. Within these sources of information lies the potential for a shift in the current baselines for both fisheries and biodiversity management in the region.

KEY WORDS: abundance, ecosystem-based fisheries management, marine biodiversity, southeastern Caribbean

Cuantificación de los Cambios de Biodiversidad Marina en el Caribe Sudeste

La cuantificación antropogénica e impactos climáticos en las pesquerías y la biodiversidad de ecosistemas ha sido un asunto de investigación creciente sobre la última década. En la región del Caribe tales análisis se han enfocado en declinaciones a lo largo de la región en corales duros, cambios de fases en la estructura de la comunidad de arrecifes de coral, las declinaciones en poblaciones de tiburón pelágico en el Golfo de México y extinciones de especies debido a la sobre pesca histórica. Este documento analiza indicadores basados en ecosistemas específicos para la gerencia de pesquerías: índice trófico marino, longitud de pez medio e índices de pesca en balance, para cuantificar los cambios en la biodiversidad de especies en el ecosistema marino de la región del Caribe sudeste usando series de data de tiempo previamente reconstruido (1950 a 2000) sobre la pesca de cinco países, Santa Lucía, San Vicente y los Granadinas, Granada, Barbados y Trinidad y Tobago. La interpretación de las tendencias en los indicadores seleccionados considera las cuentas documentadas de las políticas de desarrollo de pesquería específica de países tanto como los factores económicos, tecnológicos y sociales que podrían impactar en el uso de la data de la pesca para la evaluación de los cambios en la biodiversidad marina. Este documento también identifica algunas anécdotas en literatura histórica y antropológica tanto como encuestas científicas y relacionadas a las pesquerías realizadas en la región que podrían ser útiles para la reexaminación de cambios históricos en la biodiversidad y abundancia de organismos marinos sobre un período de tiempo más largo que el basado en data de pesca en existencia. Dentro de estos recursos de información resta un cambio potencial para las líneas básicas tanto para pesquerías y la gerencia de biodiversidad en la región.

PALABARAS CLAVES: abundancia, biodiversidad marina, Caribe sudeste, administración de pesquerías basada en el ecosistema.

INTRODUCTION

Quantifying anthropogenic and climatic impacts on fisheries and the biodiversity of associated ecosystems has been the subject of increasing research over the last decade. Among the various human activities fishing has been identified as having the greatest impact on the loss of diversity (Agardy 2000; Kenchington *et al.* 2001). There remains however, imperfect knowledge on marine biodiversity because extinction events and discovery of new species continue in an environment where the total number of species at any given time is not known. Indeed, estimating the total number of species is impractical given the vast expanse of expanse of ocean space which remains unexplored and too costly to explore in future.

The number of fish species listed in the global fish encyclopaedia (FishBase) for countries in the southeastern Caribbean range between 481 (St Vincent and the Grenadines) and 951 (Trinidad and Tobago). The higher number of species in Trinidad and Tobago is a result of the greater diversity in habitat. Due to its location on the South Ameri-

can shelf, Trinidad and Tobago is the only country (island) in the southeastern Caribbean with soft-substrate habitat suitable for shrimp and groundfish fisheries. Like other countries in the region, rocky substrate as well as open-ocean (especially off Tobago) respectively suited to reef and pelagic fisheries also exist in Trinidad and Tobago. With the exception of the extensive banks shared among the Grenadines islands, all other countries possess narrow shelf areas and a vast expanse of open ocean space. The fisheries in the southeastern Caribbean target a wide variety of resources. Exploited fish species include: coral reef and associated fishes (*e.g.* snappers, groupers, parrotfishes, triggerfishes, surgeonfishes, squirrelfishes, grunts); deep-water snappers and groupers which occur along the slopes at the edges of island platforms, on deep banks and along the South American continental shelf; large pelagic fishes which comprise coastal species (*e.g.,* small tunas, mackerels and dolphinfish) and oceanic pelagic species (*e.g.,* tunas, billfishes and swordfish); small coastal pelagics (*e.g.*, herrings, anchovies, small jacks, needlefish and flyingfish); groundfish (*e.g.*, croakers, weakfish, lane snapper); shrimp; lobster and conch. Marine mammals, turtles, squid, sea urchins and seaweed (*Gracilaria* spp.) are also exploited.

Documented evidence of the impacts of fishing in the Caribbean region show that biomass of pelagic shark species such as oceanic whitetip, silk and dusky sharks in the Gulf of Mexico has declined by between 79 and 99 percent of the 1950s estimate (Baum and Myers 2004). As well, only about 10 percent of the pre-industrial levels of biomass of large predatory fishes is currently thought to exist (Myers and Worm 2003), and within the Northwest Atlantic populations of scalloped hammerhead, white and thresher sharks have declined by over 75 percent in the past 15 years (Baum *et al.* 2003). Historical overfishing has also resulted in substantial declines in the biomass of whales, manatees, dugongs, seacows, jewfish, swordfish, sharks and rays in the region (Jackson *et al.* 2001). Due to a combination of overfishing, other anthropogenic, environmental and climatic factors, a massive region-wide decline (80%) of hard corals has been reported in the region over the last three decades (Gardner *et al.* 2003). There is also evidence of phase-shifts from coral to algal dominated reef systems, particularly off Jamaica, with subsequent changes in the overall composition of reef species (Hughes 1994). As well, Hawkins and Roberts (2004) have demonstrated how artisanal fishing has negatively impacted the structural complexity of reef and associated coral cover. Worm *et al.* (2006) investigated how declining biodiversity accelerates the rates of resource collapse and exponentially decreases ecosystem recovery potential and stability as well as water quality. They concluded that the current loss in marine biodiversity is increasingly impairing the ocean's capacity to provide food, maintain water quality and recover from perturbations although it appears that the trends can still be reversed.

Amidst growing concern regarding loss of biodiversity

the Conference of Parties to the Convention on Biological Diversity adopted in 2004, a Strategic Plan which included a target "to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth", (CBD 2004). Indicators were required which could effectively communicate trends in biodiversity status, pressures or threats to biodiversity and the impacts on ecosystem goods and services and human well-being. Eight such indicators were selected for immediate testing. Among these indicators was the Marine Trophic Index (MTI) which was to specifically assess the impacts of biodiversity loss on ecosystem integrity and the provision of ecosystem goods and services. The Mean Trophic Level (MTL), synonymous with the MTI, was first developed by Pauly *et al.* (1998). The authors estimated that globally the MTLs of fisheries landings in recent decades have declined at a rate of about 0.1 per decade, without an increase in overall landings. The consequence is a transition in landings, from long-lived, high trophic level, piscivorous fish, towards short-lived, low trophic level invertebrates and planktivorous fish, termed "fishing down the food web". Management measures which focus on rebuilding fish populations within an ecosystem context and which protect the remaining stocks were recommended.

Increasing attention is being given worldwide to the use and assessment of appropriate indicators in fisheries and biodiversity management (Rochet and Trenkel 2003; Cury *et al.* 2005). Such indicators must have an understandable relationship with the state and dynamics of animals in the community, must respond in a predictable direction with increases in fishing, must not vary under any other influence but fishing and must be easily measured and communicated (Rochet and Trenkel 2003). Contributor's to the CBD's review of the MTI expressed concern regarding the varied mechanism which may lead to changes in trophic level of the catch that are inconsistent with changes in the ecosystem (*e.g.,* technological improvements in gear and changing gear selectivity, management measures aimed at reducing catches of specific trophic level animals, changes in fishing area and environmental variation). As a result, an in-depth understanding of the dynamics of the fishery is required to accurately interpret the trends in annual MTI (Cury *et al.* 2005). However, the Fishing-in-Balance Index (Pauly *et al.* 2000), which is used to ascertain whether changes in MTL of the catch are matched by appropriate changes in the biomass, was thought to be less sensitive to this problem.

In the Caribbean region anecdotal reports of declining catch rates and mean sizes of fish caught, along with the scarcity of large, more valuable species in the catch suggest that the "fishing down the food web" may be a feature of Caribbean fisheries, particularly those exploited in inshore waters. However, such a change has never before been quantified in the region. The objectives of this paper are therefore: to examine changes in biodiversity of marine

species harvested in fisheries of the southeastern Caribbean using reconstructed time series data on catches over the period 1950 to 2000 and associated indicators of changes in relative abundance and fish biodiversity (mean trophic level and mean length of fish in the catch, and the fishing-in-balance index) and; to explore possible sources of information from which longer termed changes in marine biodiversity could be investigated.

METHODS

The analyses of annual trends in mean trophic level (MTL) and mean length of fish in the catch and the fishing-in-balance index were conducted separately for the inshore and offshore fisheries to avoid the masking effect due to aggregation of data for species of widely differing distributions (Pauly and Palomares 2005). Offshore fisheries target mainly mackerels, dolphinfish, tunas and billfishes while
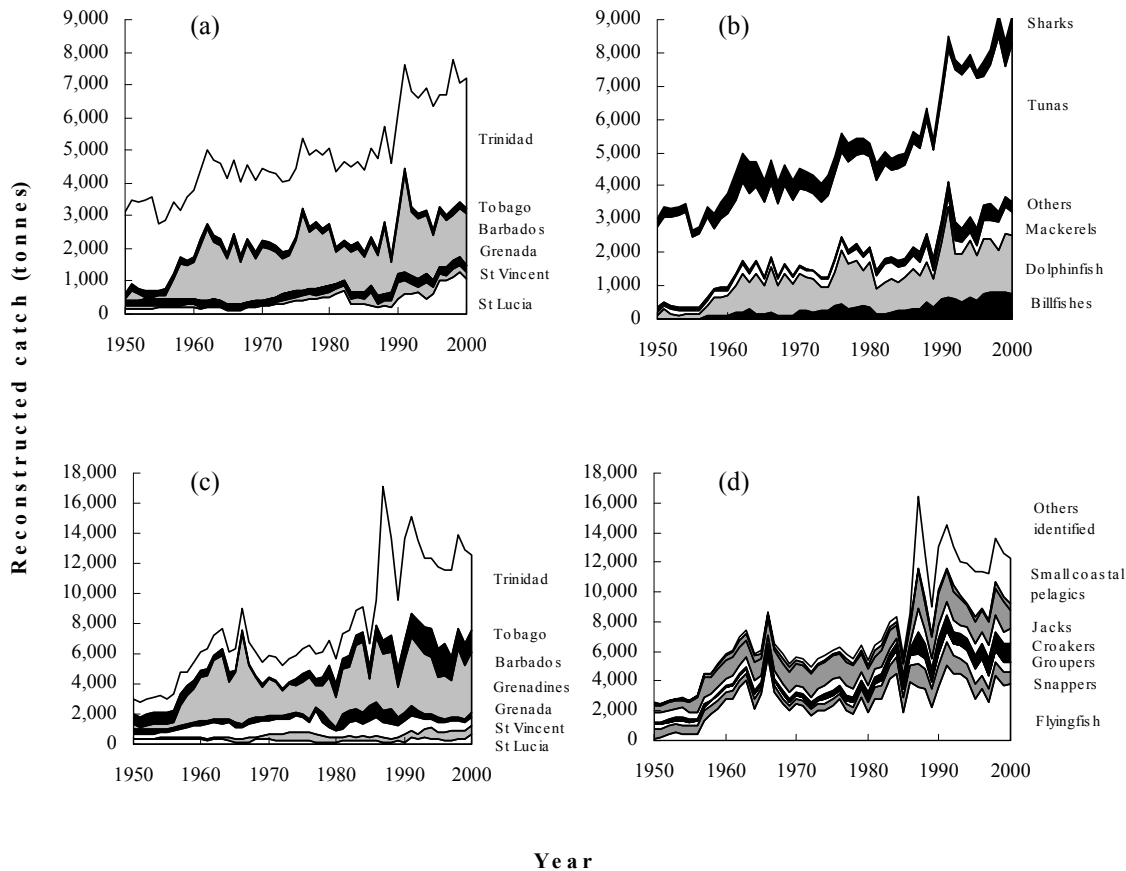

Figure 1. Reconstructed catches of (a) the offshore fishery by country; (b) the offshore fishery by species groups; (c) inshore fishery by country and (d) the inshore fishery by species groups in the Southeastern Caribbean (1950 - 2000).

Notes:

Offshore fisheries catch mainly tunas, dolphinfish, mackerels, billfishes and sharks. In the southeastern Caribbean region catches have increased from 3,000 tonnes to just over 7,000 tonnes between 1950 and 2000 (Figure 1a). Trinidad is the major contributor to overall catch, its annual contribution ranging between 40 percent (1976) and 80 percent (1954). Barbados is the second highest contributor to overall catch, with an annual contribution ranging between one percent (1950) and 44 percent (1976) of total catch. Overall, catches are comprised mainly of tunas and dolphinfish. Catches of tuna have increased from 2,425 tonnes in 1950 to 4,763 tonnes in 2000. Similarly catches of dolpinfish have increased from 82 tonnes to 1,747 tonnes over the same period, with peak catch in 1991 (2,701 tonnes). Tunas accounted for between 40 and 60 percent of annual catches between 1960 and 2000, while dolphinfish accounted for between 15 and 30 percent. Mackerels and billfishes feature in lower quantities in the catch. Nevertheless catches of these two groups have increased tenfold; billfishes increasing from five tonnes to 750 tonnes and mackerels increasing from 112 tonnes to 742 tonnes over the fifty years examined.

Inshore fisheries target reef, shelf and small coastal pelagic resources. A wide diversity of fish species is caught, including flyingfish, snapper, groupers, jacks, sharks, croakers, anchovies, herrings, halfbeaks, parrotfish, surgeonfish, squirrelfish and grunts. Catches in the inshore fishery have increased from 2,627 to 12, 279 tonnes between 1950 and 2000. Flyingfish, which accounted for between 20 and 60 percent of overall catch in most years, was the major species caught.

inshore fisheries target snappers, goupers, triggerfishes, parrotfishes, surgeonfishes and other reef species as well as small coastal pelagics such as anchovies, herrings, halfbeaks, needlefishes and small species of jacks. This separation was also necessary due to the differences in life history characteristics of the target species and the overall developmental pattern of the respective fisheries.Catches for which the species were not identified, as well as catches of marine mammals, turtles and other invertebrates were excluded from the analyses. Although invertebrates such as lobster and conch are commercially important the associated catches are not well documented. However, since the associated fisheries are traditional the existence of such species in the catch is and not a result of "fishing down the food web" as is normally thought the case with increasing catches of low trophic level species. Increasing catches of these invertebrates is due mainly to the use of more efficient technology *e.g.*, use of SCUBA gear by divers.

Trends in the annual mean trophic level (MTL) of the catch

The trophic level of an organism identifies its position in the food webs which define the associated ecosystem (Pauly and Palomares 2005). A trophic level of one is attributed to organisms at the bottom of the food web, namely plants and detritus, while first-level consumers such as herbivores and detritivores are attributed a trophic level of two. Second-level consumers (carnivores) have a trophic level that is defined by the mixture of organisms in their diet, thus resulting in non-integer estimates of trophic level. Associated trophic levels may range between 2.0 and 5.0, with organisms at the higher extreme being rare, except for killer whales and polar bears (Pauly and Palomares 2005).

Mean trophic level (Marine Trophic Index) in the catch of a specified area, for a given year, was estimated as:

$$TL_y = \sum_a (TL_a * Y_{ay}) / \sum_a Y_{ay}$$

Where Y_{ay} is the catch of species or group a in year y and TL_a is the trophic level of species or group a.

Reconstructed catches by species or species groups for the five countries (Zeller *et al.* 2003; Figure 1) and estimates of trophic level listed for the species of the respective countries in FishBase (Froese and Pauly 2006) were used. It was assumed that relative abundance of various species groups in the reconstructed catch data correlated with relative abundance of similar groups in the ecosystem. Preference was given to estimates of trophic level derived from diet composition data however it was necessary to use estimates derived from a listing of food items when no other information was available. When several estimates of trophic level were available for a particular species, preference was given to those from the Caribbean or other tropi-

cal regions.

To address the varying levels of species disaggregation in reconstructed catches both within and among countries the following procedure was applied: when species were aggregated at the family level the MTL of available estimates for all the associated species listed for the respective country was used; when species were aggregated at the genus level the MTL of all species of the genus listed for the respective country was used. It was assumed that 'big fish' specified in the catch records of Barbados in the early years of the time series represented all species of tunas, billfish, mackerels and the common dolphinfish listed in Fishbase for the country. Similarly 'AOV Deep' was as-
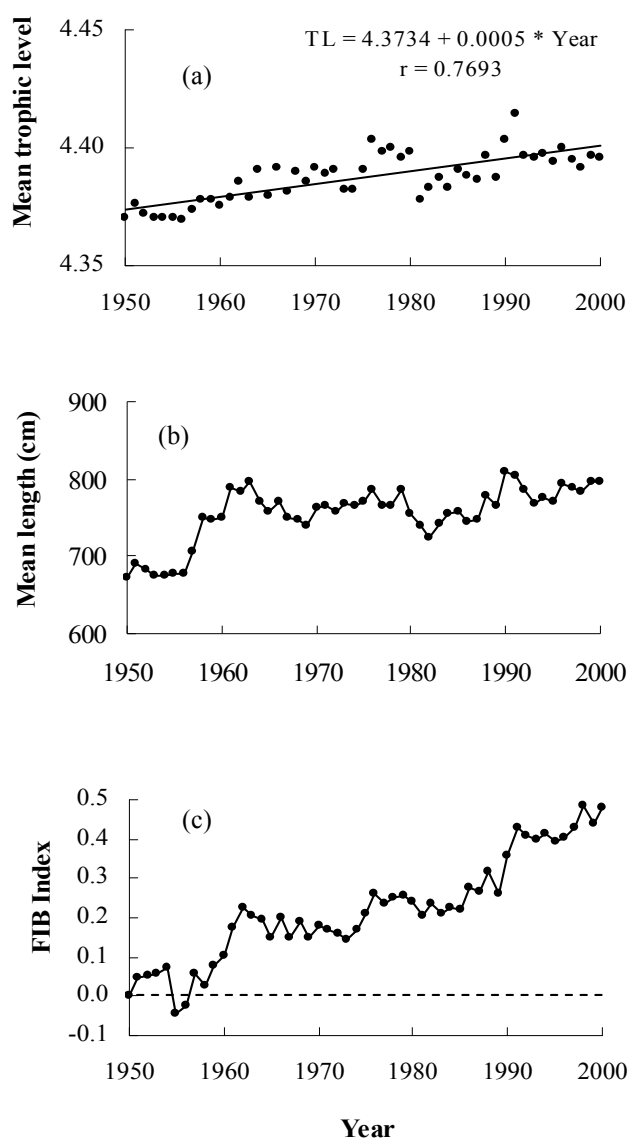

Figure 2. Trends in the offshore fisheries of the southeastern Caribbean: (a) mean trophic level; (b) mean length (cm); (c) Fishing-in-Balance (FiB) Index.

sumed to mean deep water species of snappers and groupers while 'AOV seine' was taken as all species listed in Prescod (1996). Since catches were often specified by local name, there arose the problem where the same local name may have been used for two different species or in extreme cases two species of entirely different families e.g., 'ancho' in Trinidad may refer to either *Pomatomus saltator* or *Mugil trichodon* (Ramjohn 1999). In such cases the MTL of both species was used.

Although small coastal pelagics such as flyingfish, anchovies, sprats, halfbeaks, needlefish and herring feature prominently in inshore catches, changes in their abundance, due to varying environmental conditions, may mask the overall trend in the fishery. To exclude these environmental impacts Pauly and Watson (2005) suggested that species of trophic level less than 3.25 be excluded from analyses. However, since several low tropic level species besides small coastal pelagics (*e.g.,* parrotfish, surgeonfish, triggerfish) are targeted in inshore (reef) fisheries only the families, species or species groups pertaining specifically to small coastal pelagics were excluded.

Trends in the annual mean length of fish in the catch
Mean length of fish in the catch of a specified area, for a given year, was estimated as:

$$L_y = \sum_a (L_a * Y_{ay}) / \sum_a Y_{ay}$$

Where Y_{ay} is the catch of species or group *a* in year *y* and L_a is the mean maximum length of the species taken from the International Standard Statistical Classification of Aquatic Animals and Plants (ISSCAAP).

Trends in the annual Fishing-in-Balance (FiB) Index
The FiB Index is used to ascertain whether changes in MTL of the catch are matched by appropriate changes in the biomass and as a result catch of the resource *e.g.* a decline in MTL is initially accompanied by an increase in catches due to the higher biological production at lower trophic levels. No change in the index is expected when catches increase, as expected, with a decline in trophic level. An increasing trend in the Index is symptomatic of a geographic expansion in the fishing area or increases in primary production while a declining trend signals either contraction in the fishing range, unrecorded discards in the fishery or impairment of ecosystem functions (Pauly and Palomares 2005; Pauly and Watson 2005).

The FiB index was estimated as:

$$FiB_y = \log [Y_y * (1/TE)^{TL_y}] - \log [Y_0 * (1/TE)^{TL_0}]$$

Where Y is the catch in year *y*, TL is the mean trophic level of fish in the catch, TE is the mean transfer efficiency (here assumed 10 percent between discreet trophic levels) and 0 is the year used as a baseline for normalization of the

Table 1. Trends in annual mean trophic level of fish in the catches of offshore fisheries in the southeastern Caribbean (1980 – 2000).

Fishery	Country	Linear trend in annual mean trophic level (TL) of the catch	R
Offshore fishery			
	St Lucia	TL = 4.4012 + 0.0004 * Year	0.1694
	St Vincent	TL = 4.3606 + 0.0014 * Year	0.2623
	Grenada	TL = 4.3612 + 0.0031 * Year	0.7384
	Barbados	TL = 4.4442 + 0.0012 * Year	0.6579
	Tobago	TL = 4.3548 + 0.0012 * Year	0.3400
	Trinidad	TL = 4.3637 – 0.00006 * Year	0.1643
	All countries combined	TL = 4.3866 + 0.0006 * Year	0.4732
Inshore fishery (excludes invertebrates and small coastal pelagic species)			
	St Lucia	TL = 3.6122 - 0.0101 * Year	0.4233
	St Vincent	TL = 4.2211 - 0.0322 * Year	0.7673
	Grenada	TL = 4.0375 - 0.0126 * Year	0.6754
	The Grenadines *	TL = 3.319 - 0.0042 * Year	0.2638
	Barbados	TL = 3.6624 - 0.0099 * Year	0.3751
	Tobago	TL = 3.9862 - 0.0063 * Year	0.9817
	Trinidad	TL = 3.7009 - 0.002 * Year	0.0651
	All countries combined	TL = 3.747 - 0.0019 * Year	0.2969

Index.

Sources of information for examining changes in species abundance

Based on a search of the Trinidad Fisheries Division's Fisheries Management Information System (FISMIS) a number of potential sources of information for examining changes in species abundance in the Caribbean region were identified. These sources are non-exhaustive, representing only those documents currently available in the FISMIS which may be accessed by other countries in the region

RESULTS

$$TL_{all\ species} = 3.7523 - 0.0017 * Year$$
$$r = 0.6544$$
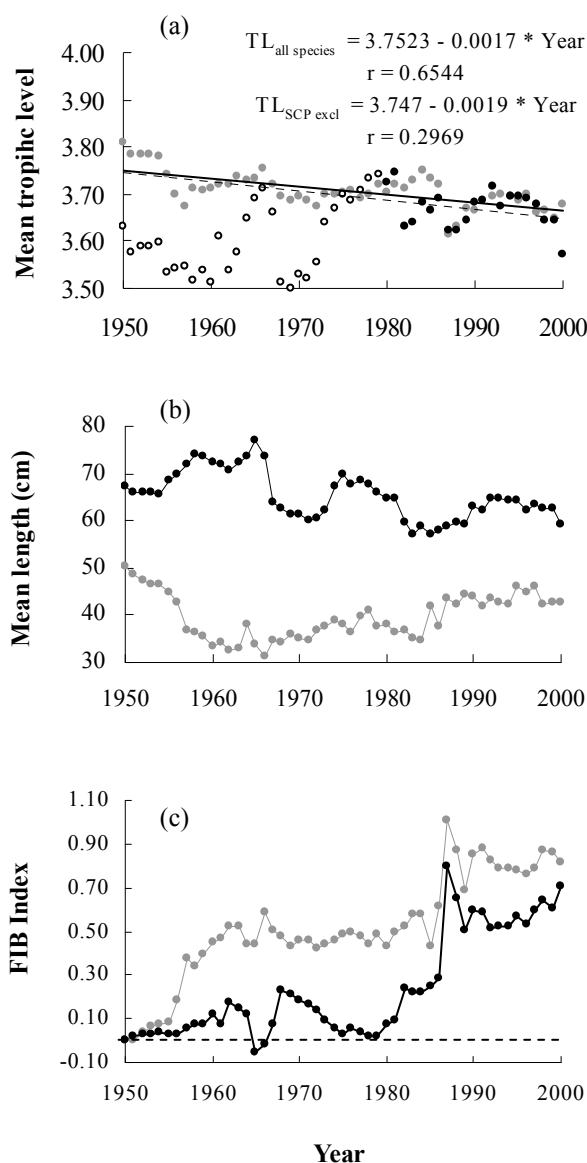$$TL_{SCP\ excl} = 3.747 - 0.0019 * Year$$
$$r = 0.2969$$

Figure 3. Trends in the offshore fisheries of the southeastern Caribbean: (a) mean trophic level; (b) mean length (cm); (c) Fishing-in-Balance (FiB) Index. *Solid, grey circles*: all inshore fish species; *solid, black circles*: small coastal pelagic species excluded ; *open, black circles*: small coastal pelagic species excluded (1950 to 1979 data points).

Trends in the offshore fishery

Annual mean trophic level of species in the combined offshore catches of all countries increased steadily between 1950 and 2000 (Figure 2a). This rate of increase was 5 x 10^{-4} per year. Catches from the St Vincent fishery, between 1950 and 1966, were excluded from the analyses as the species composition of the catch could not be ascertained. Within the last twenty years of the period examined the MTL of catches from the respective countries increased at a rate of between 4 x 10^{-4} per year (St Lucia) and 3.1 x 10^{-3} per year (Grenada), (Table 1.). The mean length of fish in the catch has also increased (Figure 2b), from about 673 cm in 1950 to 796 cm in 2000. As well, the FiB Index has increased steadily over the period (Figure 2c).

Trends in the inshore fishery

Annual mean trophic level of species in the combined inshore catches of all countries decreased at a rate of 1.7 x 10^{-3} per year between 1950 and 2000 (Figure 3a). Catches from St Vincent, between 1950 and 1966, were excluded from the analysis for the reason described previously. When small coastal pelagics were excluded from the analysis the trend in annual MTL of earlier years (1950 to 1979) was unclear, but declined at a rate of 1.9 x 10^{-3} per year within the last twenty years of the time series (Figure 3a). Over the same period, the annual MTL of catches from the respective countries decreased at a rate of between 2.0 x 10^{-3} per year (Trinidad) and 3.0 x 10^{-2} per year (St Vincent), (Table 1).

When small coastal pelagics were included in the analyses the mean length of fish in the catch decreased from 50 cm in 1950 to 31 cm by 1975, but subsequently increased to 43 cm by 2000 (Figure 3b). Conversely when small coastal pelagics were excluded from the analyses mean length of fish in the catch declined steadily over the fifty years, from 67 cm in 1950 to 59 cm by 2000. There was a general increase in the FiB Index (Figure 3c) of combined catches of all countries. When examined individually however, only the catches of the Grenadines showed a decline in the FiB Index over the last twenty years of the time series examined (Figure 4).

Sources of information for examining historical changes in abundance and biodiversity

A search of the STOCK database incorporated in the Fisheries Management Information System (FISMIS) of the Trinidad Fisheries revealed some historical documents dating to the early 1900s, from which inferences can be made regarding marine biodiversity at the time. Among these documents were the historical and natural history reports of Duerden (1901), Vincent (1910) and Guppy (1922). Duerden (1901) gave a detailed account of fisheries in the British West Indies. Vincent (1910) identified, giving the scientific name, local name, habitat and sometimes a qualitative description of abundance for 85 species of food fish and 31 species of other fish in Trinidad. The au-

thor provided useful information for both terrestrial as well as marine flora and fauna. Subsequently Guppy (1922) estimated 240 species of fish in Trinidad and 180 species in Tobago. He gave detailed descriptions of several species, including the local and scientific names and provided a detailed description of fishing gear. Selected statements on abundance from these authors are provided in Table 2,

purely to demonstrate the potential usefulness of what may be deemed "unscientific" information.

A search of the CRUISE database of FISMIS identified several scientific and fishery surveys conducted in the region between 1944 and 1988. Whiteleather and Brown (1945) explored the fishery resources off Trinidad and British Guiana in 1944 to gather information on gear efficiency
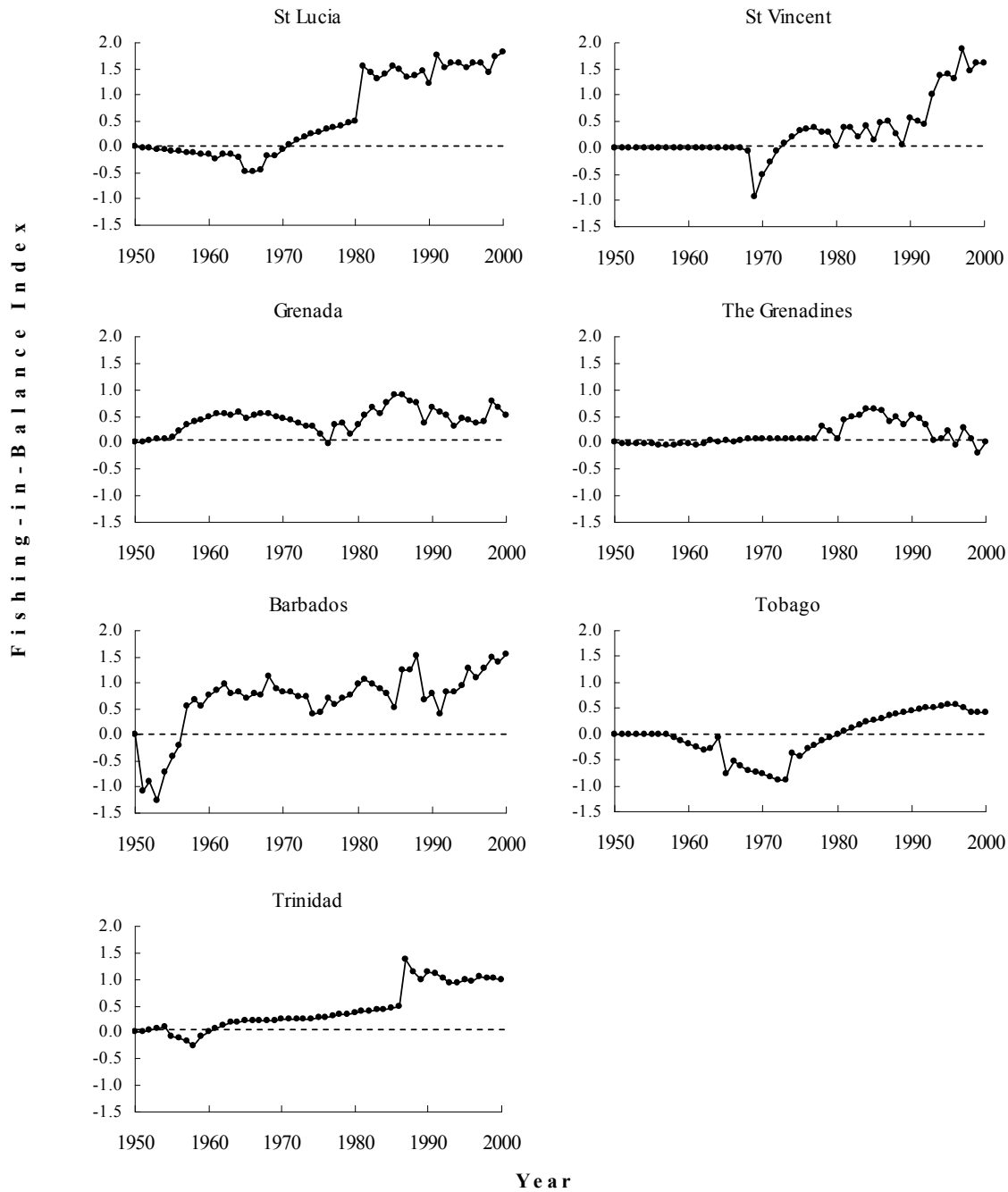

Figure 4. Trends in the Fishing-in-Balance (FiB) Index of catches in the southeastern Caribbean (1967 base year for St Vincent and 1950 base year for other countries).

in tropical fisheries. They provided estimates of catch rates and species distributions. A fleet of vessels from the US Fish and Wildlife Service conducted exploratory fishing in the Caribbean region between 1957 and 1987. These vessels included: OREGON I, GERONIMO, UNDAUNTED and OREGON II. Some cruises investigated the biology of selected species, distribution and species compositions in the region and gave estimates of catch rates for selected gears. As well, during the period of the Caribbean Fishery Development Project (late 1960s) the ALCYON, CALAMAR and FREGATA conducted exploratory fishing activity and reported similar information as the US vessels. In 1988 the R/V Fridtjof Nansen conducted a fishery survey off the South American shelf. The survey sought to describe the species composition, distribution and abundance of small pelagic and demersal fish, and crustaceans, to estimate stock status and fishing potential, to collect biological samples of most important species for growth, maturity and other biological analyses and to conduct taxonomic studies for a regional species guide. A more detailed historical account is outlined in Bayer (1969) who provided a list of research vessels conducting exploratory, geological, biological, and hydrographic investigations in the Caribbean region between the early 1500s and 1968. The author provided details on specific geographical areas explored, the names of the commanding officers and ships along with the titles or authors of expedition reports and possible locations where the associated raw data may be stored.

DISCUSSION
Trends in annual mean trophic level (MTL), mean length of fish and FiB index of catches

Two contrasting trends were observed in catches of the offshore and inshore fisheries in the southeastern Caribbean. In the offshore fishery generally, the annual mean trophic level, mean length and FiB index of the catches all increased steadily between 1950 and 2000. These trends reflect the prevailing policy in the region since the early 1980s. This policy promoted development of the offshore fishery in an attempt to fully utilize the resources within the extended jurisdiction conferred under the 1982 United Nations Law of the Sea. As well, the policy aimed to improve food security in the region, in light of declining catches in the inshore fishery. The sizes and number of boats targeting the offshore fishery increased, more powerful engines were used and new fishing gear (longlines and vertical longlines) were introduced (Mohammed and Chan A Shing 2003; Mohammed and Joseph 2003; Mohammed *et al.* 2003a; Mohammed *et al.* 2003b; Mohammed and Rennie 2003). The number of semi-industrial longliners increased from about four vessels in the early 1980s to 80 vessels by the end of the 1990s while the number of semi-industrial ice-boats in Barbados increased from 12 in 1983 to 156 by 2000. Tobago increased its ice-boat fleet from one vessel in the early 1990s to 10 vessels by 2001. In contrast to the artisanal fleet, which comprises mainly pirogues

or canoes, not exceeding 10.6 m with engines of less than 100 Hp, semi-industrial vessels range between 11 and 20 m and carry engines which often exceed 250 Hp, and sometimes range between 300 and 400 Hp.

The trends observed in the offshore fishery of the southeastern Caribbean do not reflect worldwide trends in similar fisheries. According to assessments of the International Commission for the Conservation of Atlantic Tunas, stocks of yellowfin tuna, big-eye tuna and albacore are either fully or over-exploited, while stocks of Atlantic blue marlin and Atlantic white marlin are overfished. The North Atlantic stock of swordfish is also fully exploited. The likely consequence of overexploitation is a decline in catches and changes in the size structure of the catch towards one dominated by smaller individuals. Since the distribution ranges of large tunas and billfishes extend far beyond the southeastern Caribbean such trends in MTL and mean length of fish in the catch are not reflected in the associated data. Pauly and Palomares (2005) demonstrated that worldwide, MTL of catches of tunas and billfishes have declined at a rate of 2.1×10^{-3} per year between 1950 and 2000.

In the inshore fishery the declining annual MTL and annual mean length of fish in the catch are symptomatic of unsustainable fisheries. Previously, fishers have expressed concern about the smaller sizes of fish and decreasing amounts of previously important commercial fish species in the catch (Mahon 1990; Singh-Renton and Mahon 1996). Results of this study scientifically confirm these anecdotes and quantify the impacts of fishing and other anthropogenic activities on the biodiversity of marine fish species in the catches of the region. Annual MTL of the catch has declined at a rate of between 0.3 per decade (St Vincent) and 0.02 per decade (Trinidad) over the last twenty years of the time series (1980 to 2000). Prior to 1975 catches were dominated by snappers, groupers, jacks and croakers. The declining trends are attributable mainly to the capture of other species of previously lesser commercial importance as well as the inclusion of by-catch from the trawl fishery in Trinidad. It appears therefore, that the region has experienced the "fishing down the food web" effect, at an overall rate of 0.019 per decade. Although the overall rate of decline in MTL is much less than the global estimate of 0.1 per decade (Pauly *et al.* 1998), the rates of decline in the St Lucia and Grenada inshore fisheries are comparable to the global estimate, while the rate of decline in the St Vincent inshore fishery is three times the global estimate.

Previous studies also support the changes in species composition and size structure of the marine fish population in the Caribbean. Using a trophic model of the Gulf of Paria, a system exploited by both Trinidad and Venezuela, Manickchand-Heileman *et al.* (2004) demonstrated that with the exception of carangids, penaeids and possibly clupeoids, biomass of groups at higher trophic levels were significantly higher prior to the 1950s (when trawling was

introduced) than biomass in the early 2000s. The authors suggested that there may have been a shift towards a system dominated by lower trophic levels. Wing and Wing (2001) estimated a decline in MTL from 3.46 to 3.77 between the early (1,850 – 1,280 years B.P.) and late (1,415 – 560 years B.P.) periods of the Ceramic Age by examinations of faunal remains from archaeological sites at Puerto Rico, St Thomas, St Martin, Saba and Nevis. The authors demonstrated significant declines in individual fish weight and size distribution of reef taxa (Scaridae, Acanthuridae, Serranidae and Lutjanidae), as well as a decline in the percentage contribution of reef fish biomass to overall aquatic vertebrate biomass. Overall there was a greater decline in biomass of predatory fish (serranids, lutjanids and haemulids) compared to omnivores and herbivores (scarids and chaetodonths).

The inshore fishery in the Grenadines appeared to be the most affected by fishing, marked by a decline in the annual FiB index between 1980 and 2000. While associated catches were not well documented prior to 1980, reconstructed catches decreased from 944 tonnes in 1981 to 320 tonnes in 2000 (Mohammed and Rennie 2003, Mohammed *et al*. 2003b). Apart from the shelf area of Trinidad and Tobago, the reef and shelf areas of the Grenadines are the most extensive in the southeastern Caribbean region, slightly less than 3,395 km for the islands of St Vincent and Grenada combined (Mahon 1993). As a result the apparent ecosystem change is cause for concern. The main difference between fisheries in the Grenadines and those in other southeastern Caribbean countries is the target resource. The inshore reef, slope and shelf resources are the mainstay of the Grenadines fishery. In contrast, other countries (except Trinidad) focus on the offshore fishery, and switch to the inshore fishery between July and September, mainly to supplement the drop in catches associated with the seasonality of offshore species. The inshore resources in the Grenadines have also experienced considerable fishing pressure since the early 1950s to support markets in Martinique and Guadeloupe (Mohammed *et al*. 2003b). A possible explanation for the increasing trend in the annual FiB Index of all other countries is an expansion of the range of fishing, which due to the narrow shelf area, can only be attributed to fishing at greater depths or to fishing in the waters of other countries *e.g.* the Grenadines.

Study limitations

The main limitations associated with this study relate to the species composition of reconstructed catches, catches and discards of foreign fleets, illegal, unregulated and unreported catches as well as the capture of juvenile fish in both the offshore and inshore fisheries.

There is a wide variation in the taxonomic specification of the catch due mainly to the grouping of catches of similar species as well as the use of local names which either complicate species identification or conflict with the established FishBase common name and corresponding

scientific names. The variation occurs both within and among countries. The species grouping may be broad *e.g.*, "AOV Pot" meaning all species harvested by fishpots or at varying levels of specificity *e.g.*, the family, genus or species level. The lower the level of taxonomic disaggregation the less specific is the estimate of trophic level (estimated as the mean of all possible species for the group). This serves to weaken any possible signals of changing biodiversity in the catch. The situation is complicated by the general tendency to explicitly record catches of commercially important species while grouping catch data across broad categories for a number of species of lesser commercial importance (Zeller *et al.* 2003). When the species of previously lesser importance achieve a higher commercial status, and is then explicitly recorded, the historical trends in catches cannot be ascertained as the catches were previously recorded in an aggregate category.   The overaggregation of catches across species is particularly prevalent in the inshore fishery where numerous species are landed at several small landing sites dispersed along the coast and human and financial resources are inadequate to implement a stratified system of sampling to generate more accurate estimates of species catches.

Catches and discards of foreign fleets and illegal, unregulated and unreported catches were not considered in the analyses. This is another possible explanation for the deviation in MTL trends and observations by Pauly and Palomares (2005). Regional and international distant water fleets include those from Venezuela, Cuba, Japan, Korea, Taiwan and the United States (Mahon and Rosenberg 1988; Singh-Renton and Mahon 1996). These industrial fleets comprising mainly longliners, exert relatively greater fishing pressure, (*e.g.,* Venezuelan fleets are between 24 and 95m with GRT ranging between 95 and 1904), and as a result account for a greater proportion of the total catch than the artisanal and semi-industrial fleets of the southeastern Caribbean countries. They target the large tunas and billfish in the offshore fishery however smaller species of commercial importance in the region (dolphinfish, small tunas and mackerels) are taken as by-catch.

Catch data in the southeastern Caribbean region do not reflect the relative proportions attributable to juveniles and adults of the associated species. Since trophic level usually increases during ontogeny as larvae and juvenile fish are likely to feed at lower trophic levels than conspecific adults (Pauly *et al.* 2001) increasing contribution of juveniles to overall catch would also contribute to the decline in MTL. However, due to the limitations of existing data ontogenetic changes in diet could not be considered in this study. As a result, any decline in MTL reflects solely variations among species groups. Pauly and Palomares (2005) however, citing an example from Eastern Canada, concluded that although ontogenetic changes accentuate the decline in MTL it is the change in species composition that is the major contributor to this decline. Changes in population structure, *e.g.* growth rate and size at maturity, are a direct

consequence of exploitation. The proportion of young fish in the catch increases as growth and recruitment overfishing are almost always inevitable. As a result the maximum length of fish decreases with time. This change was however, not considered in the analysis.

The use of diet composition data to estimate trophic levels (currently listed in FishBase) has been criticized because such data provides solely a "snap-shot" of the overall diet of the organism and estimates tend to be biased in favour of higher values. The bias arises because soft-bodied animals are quickly digested and therefore do not feature in stomach content analyses. Although more accurate estimates of trophic level may be derived from stable nitrogen isotope analysis such technology is not readily available, nor affordable, to the southeastern Caribbean region. Instead estimates derived from diet composition and which are available in the global database on fishes (FishBase) were used. This also facilitates repetition of the study.

Factors which challenge the main assumption

Throughout the fifty-year period examined there were several factors impacting on the fishing industry which challenge the assumption that the species composition of the catch is representative of the species composition in the ecosystem. This assumption is critical to interpretation of MTL analyses. The regulation of fish prices in many countries after World War II may have influenced the species targeted by fishers. As well, the preference for flyingfish and redhind grouper in the fish export policy of Grenada and the Grenadines during the 1970s would have negatively impacted catches in the offshore fishery (Mohammed and Rennie 2003). Apart from the introduction of longlines, most gears utilized in the region had already been introduced by the early 1950s so that there is negligible impact of changing gear. However, during the 1960s, following the introduction of trawl nets in the 1950s, many boats fishing off the southwestern Peninsular of Trinidad switched their target from fish to shrimp. The consequent decline in fish and increase in shrimp catches (serving to reduce the annual MTL of the catch) therefore are not reflective of changes in the ecosystem. Some social factors may also affect interpretation of the trends in MTL *e.g.*, young fishers in Grenada prefer boats of faster speed and therefore tend to target the offshore fishery while older, more skilled fishers target the inshore reef, shelf and slope fisheries (Mohammed and Rennie 2003). As the number of older fishers decreases it is expected that the contribution of offshore species to overall catch would increase.

RECOMMENDATIONS

If the trends in annual MTL, mean length of fish and the F*i*B index are to be used to assess changes in species abundance and marine biodiversity in the future, improvement of the current fisheries catch and effort data collection systems is of paramount importance. The focus of data

collection systems has changed over the fifty-year period examined in this analysis. Initially, between the 1940s and 1970s, data collection supported proposals for infrastructural development in the fishing industry, while more recently (early 1980s), the focus has shifted to include resource assessment, a requirement upon ratification of the United Nations Convention on the Law of the Sea. To address the complexity of fisheries in the region greater attention should be given to species identification and to more accurately representing the mix of species in the catch, particularly in the inshore fishery. All removals from the ecosystem e.g., foreign catches, illegal, unregulated and unreported catches, as well as catches of bait species and catches from recreational fisheries must be considered within given ecosystem and management areas to fully account for the ecosystem impacts of fishing. Since recorded data is often a sub-sample of the landings a methodology for estimating total catches should be developed and customized to suit the data collection systems in the respective countries.

Possible sources of information for examination of historical changes in abundance and marine biodiversity

The time series of catch data examined in this study represents but a small period in the history of fishing in the region. Subsistence fishing was a common practice on Caribbean islands since about 2,000 years ago (Wing and Wing, 2001). Records of catch and effort data in the southeastern Caribbean are however, quite recent (dating back to 1945) and therefore cannot give an accurate representation of the associated long-termed changes in marine biodiversity and relative species abundance. To fully appreciate these changes and to alleviate the "shifting baseline syndrome" (Pauly 1995) more historical information is required. Although lack of information has been commonly cited as a severe limitation in management of fisheries and biodiversity in the Caribbean region it is, rather, the access to existing information that has been the major problem.

Possible sources of information from which changes in marine biodiversity can be quantified include, but are not limited to:

◊ Natural history and logbook accounts of historical expeditions *e.g.*, as was done for the Falkland islands (Palomares *et al.* 2005);

◊ Natural history and specimen collections of research institutions *e.g.*, the Smithsonian Institute; British Museum;

◊ Natural history accounts of individuals *e.g.*, Duerden (1901); Vincent (1910); Guppy (1922);

◊ Scientific reports and databases of research surveys *e.g.*, those listed in Bayer (1967);

◊ Scientific reports of research conducted by foreign institutions and individuals;

◊ Archaeological studies on marine fauna and flora *e.g.*, see Wing and Wing (2001);

◊ Administrative reports of colonial governments *e.g.*, as

kept by the Public Record Office in Britain.

Although there are limitations associated with the use and standardization of information across a variety of sources due to the varying methods of collection and quality of information correlation of trends from various sources may reveal the likely changes in marine biodiversity over time (Jackson *et al.* 2000). Proxies *e.g.*, barrels of whale oil exported, weights of turtle shells exported, are useful for estimating removals of animals from the ecosystem in the absence of catch data.

Much of the historical records of countries in the southeastern Caribbean however, reside outside of the region, in the archives of European countries. Since some countries were colonies of several European nations over the course of their history the associated archival records may be further divided among several Colonial governments. Except for the US territories, there exists no centralized repository or coordination among relevant institutions for the management and dissemination of fisheries and biodiversity information in the region. This remains a major obstacle to quantifying changes in marine biodiversity.

ACKNOWLEDGEMENTS

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Table 2. Anecdotes of abundance of marine organisms in the waters of Trinidad and Tobago.

Species/Group	Anecdotal text	Source
Oysters, manatees and whales	*Oysters are plentiful, and are said to be good eating. The manatee or 'sea-cow' is occasionally caught. A large quantity of whale oil is sent to the London markets, where it is used for various commercial purposes. It is worth from 14 Pounds Sterling to 18 Pounds Sterling per ton.*	Duerden (1901); p. 125
Red snapper	*As regards fishing, I have always found at Chacachacare that the "ligne dormante," a process I shall describe later on, is the most successful, as the waters there abound with the big red snappers, locally called "sorbs'.*	Vincent, 1910; p.13
	Monos …There are innumerable banks round the island that used to afford good sport, bit I have noticed for the past five years they have deteriorated greatly both in the size and quantity of the fish obtainable…	Vincent, 1910; p.15
King mackerel	*…off Cape La Pena, that part of the Venezuelan mainland, nearest to Trinidad…At 6 A.M. You can then troll until 10 A.M., by which time you have got all you want in more ways than one, as your hands and arms will tell you. The king-fish there average from 30 lbs. to 50 lbs. and often larger…*	Vincent, 1910; p.18
King-fish and mackerel	*…and as a matter of fact we neither of us got anything of consequence until reaching Matura Point and there we had some glorious sport, especially near the rocky islets off the headland. Here we were kept busy, as the water simply teemed with king-fish and mackerel, some of the former being of great size,…*	Vincent, 1910; p.69
Seabirds	*From Scylla into Charybdis, for immediately above them the air is darkened with gulls, boobies, pelicans, kittiwakes and man-o'-war birds, who cram their maws to satiety with the jumping fugitives.*	Vincent, 1910; p.70
Bivalves	*In places, torn up and spread out by the tide were heaps of chip-chip, a small shell-fish with which the East coast cooks concoct a most delicious and nutritious soup, pretty, rose-tinted shells attached to the end of a corraline 15 ins., or 18 ins. Long, purple bivalves, with graceful spines projecting from them (Cytherea Dione), and numberless other objects of joy to the curiosity hunter.*	Vincent, 1910; p.70
Manatee	*L.E.B. told us that some four weeks previously, his men had harpooned and killed a "manatee" or sea-cow in the mouth of the river, about 600 lbs. in weight, and showed us the hide,…*	Vincent, 1910; p.76
Seaweeds	*Students of the sea-shore will be glad to hear that they can get seaweed of many and varied hues, the best I have seen in the tropics, on the Western arm of Guayaguayare Bay,…*	Vincent, 1910; p.81
Porpoises	*I have alluded to porpoises and the mysterious manner they disappear before the 'remous'. Now the sea in the vicinity of the Bocas is nearly always being occupied, both as a playing and hunting ground by these ocean shikarees. There are two varieties that are exceedingly common, the "marsouen blanc" (local name) or white porpoise, a small greyish-brown porpoise weighing but a few hundred weight, and the other "marsouen canale" or canal porpoise, a dark-brown variety, averaging somewhere about a ton in weight. […] I have seen a veritable army of the big porpoise marching in this fashion through the sea…*	Vincent, 1910; p.90
Giant ray	A photograph of a Giant ay or Devil Fish (Manta birostris) with a 12 ft "wing-span" is printed	Vincent, 1910; p.91
Ocean gar	*After rowing round some time, one of the crew, seeing a huge object rise in the immediate vicinity of Pointe Rouge, raised a shout of "Baleine" (whale), but on getting nearer, they espied the large fan-like fin of a monster "Maman-Balaou," or "Ocean Gar," the largest of the Scomberoides. Nearer still, they could make out the gigantic beak or bill, possibly 10 to 12 ft. in length, …*	Vincent, 1910; p.94

Table 2. Continued.

Sharks	*This blood had already attracted hordes of predaceous fish, conspicuous amongst them being the dreaded "tintorelles" or spotted sharks, the most fearless and voracious of all.*	Vincent, 1910; p.95
Flatfish	*Sometimes rare and peculiar fishes are brught in, also a few of the delicious soles or flounders, or "aileronde." There are no fewer than five different kinds of these flatfishes that have both eyes on one side of the head; three species are rare, but unfortunately none is plentiful…*	Guppy, 1922
Scombrids	*It is a wonderful sight to see the seine hauled in with a big catch of bonito…Hundreds are to be seen…This fish is very abundant..*	Guppy, 1922
Spadefish	*A very common fish at certain seasons in the Gulf of Paria is the "Paoua" or "Spade" fish (*Chaetodipterus (Ephippus) faber)*, which is caught in the early part of the year…*	Guppy, 1922