Preliminary Investigation of the Diets of Large Oceanic Pelagic Species of Importance to the Longline Fishery in Barbados

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ABSTRACT

Increasing attention is now being paid to an ecosystem-based approach to fisheries management, requiring quantitative assessments of feeding habits of the fish species being managed, so that trophic linkages among species, and interactions among fisheries targeting different species within the same ecosystem may be considered. This study focuses on the diets of large pelagic species targeted by the Barbados longline fishery.

Between August 2004 and March 2005, 113 large predators were sampled on commercial longline trips. Diet composition by numerical abundance was, for yellowfin tuna: 47% fishes, 37% squids and 17% crustaceans; for blue marlin: 94% fishes and 6% squids; for white marlin: 83% fishes, 17% squids; for Atlantic sailfish: 47% fishes, 53% squids. A wide range of prey species indicated opportunistic predation and overlap in the diet of these large oceanic predators, although blue marlin appeared to be slightly more selective, and only yellowfin tuna ate crustaceans.

These data have important implications for the ecosystem model and suggest a close interrelationship among the commercial longline fisheries, offshore surface-trolling fleets and sport fisheries, since they target co-competitors in the pelagic food web of the Lesser Antilles.

KEY WORDS: Barbados longline, diet, large pelagics, *Thunnus albacares, Makaira nigricans, Tetrapturus albidus, Istiophorus albicans*

Investigación Preliminar de la Dieta de Especies Pelágicas de Gran Talla Importantes para la Pesca Con Palangre de Barbados

La gestión de pesca con un enfoque basado en el ecosistema esta recibiendo mucha atención. Esta gestión requiere estimaciones cuantitativas de los hábitos alimentarios de las especies que están siendo gestionadas, para que las relaciones tróficas entre especies y las interacciones entre sectores pesqueros de diferentes especies dentro del mismo ecosistema sean tenidas en cuenta. Este estudio documenta las dietas de especies pelágicas de gran talla capturadas por el sector de pesca con palangre de Barbados.

Entre Agosto 2004 y Marzo 2005, 113 depredadores de gran talla fueron examinados durante viajes comerciales de pesca con palangre. La composición de la dieta, por abundancia numérica fue, para el atún aleta amarilla: 47% peces, 37% calamares y 17% crustáceos; para la aguja azul: 94% peces y 6% calamares; para la aguja blanca: 83% peces, 17% calamares; para el pez vela: 47% peces, 53% calamares. La diversidad de presas indica una depredación oportunista con superposición de las dietas de estos depredadores oceánicos, aunque la aguja azul parecía ser ligeramente mas selectiva, y sólo el atún aleta amarilla comía crustaceos.

Estos datos conllevan implicaciones importantes para el modelo de ecosistema, y sugieren la existencia de estrechas interrelaciones entre los sectores de pesca con palangre, el de pesca trolling de superficie y el de pesca deportiva, puesto que pescan especies que compiten entre si en la red trófica de las pequeñas antillas.

PALABRAS CLAVES: Dieta, Barbados, la pesca con palangre, *Thunnus albacares, Makaira nigricans, Tetrapturus albidus, Istiophorus albicans*

INTRODUCTION

Caribbean fishery resources are typically over-exploited or fully exploited, yet fishing pressure is continuing to increase. As such, there is a need for more effective management to ensure long-term sustainable use of these resources. Attention is now being paid to improved management through an ecosystem-based approach, requiring quantitative assessments of feeding habits of the fish species being managed, so that trophic linkages among species, and interactions among fisheries targeting different species within the same ecosystem may be considered (e.g. Browman and Stergiou 2004, Wang 2004).

This study is a part of a larger FAO Lesser Antilles Pelagic Ecosystem (LAPE) Project that is building an ecosystem model to improve fisheries management in the Lesser Antilles. The study assesses, for the first time, the

diets of large oceanic species targeted by the Barbados longline fishery: the billfishes; Atlantic blue marlin (*Makaira nigricans*), white marlin (*Tetrapturus albidus*) and sailfish (*Istiophorus albicans*); and yellowfin tuna (*Thunnus albacares*). Information on the fishing operations of a typical vessel in the Barbados longline fleet is also reported.

There have been no studies to date on the diets of these large pelagic species in the Lesser Antilles, except for a single study in Barbados that examined the diet of just 12 yellowfin tuna (Lewis and Axelsen 1967). Many studies have commented on, and a few studies have examined, the diets of these species in more detail in other areas of the Atlantic (e.g. for all of the billfishes and yellowfin tuna: Satoh *et al*. 2004; for blue marlin: Pimenta *et al*. 2001; for white marlin: Mather *et al.* 1972; for yellowfin tuna: Matthews *et al*. 1977, Sabatié *et al*. 2003) but all these are beyond the area of the Lesser Antilles sub-ecosystem.

The pelagic longline fishery in Barbados is a relatively new one, with the first vessel being introduced in 1991. The Barbados longline vessels are generally greater than 12 m in length, have insulated ice-holds for preserving the catch at sea, inboard diesel engines, typically carry 20 – 50 km of subsurface longline, and undertake trips averaging 10 to 14 days (see Hunte *et al.* 1994, Willoughby and Leslie 2000, Fisheries Division 2004). The vessels generally bait with squid and target yellowfin tuna and secondarily billfishes. They also land other non-target species on their return trips, such as; flyingfish (*Hirundichthys affinis)* dolphinfish (*Coryphaena hippurus*) and wahoo (*Acanthocybium solandri*).

METHODS

Field Sampling

Field sampling took place in Barbados from mid-August, 2004 to mid-March, 2005. Large oceanic pelagic fishes (billfishes and tuna) were sampled and stomachs collected from the catch of a commercial longline vessel, operating from the Bridgetown Fisheries Complex, and fishing in an area to the east-southeast of Barbados (Figure 1). A total of 30 - 35 km of longline gear was set to fish during daytime hours at depths between 58 and 70 m below the surface. Collection of samples and preliminary data were completed at sea by the vessel captain during six 1-2 week fishing trips. Preliminary data were recorded on pre-prepared data sheets. For all fish the fork length (for billfishes this was lower jaw fork length) was taken to the nearest 0.5 cm using a measuring tape, and total weight was taken to the nearest kg using a hanging scale.

Stomachs were collected at sea as the fishes were gutted, and each was placed in highly concentrated brine solution in a Ziploc® bag with an identification number. The bags were then carefully stacked in the vessel's ice hold, until docking, and subsequently held in the laboratory freezer.

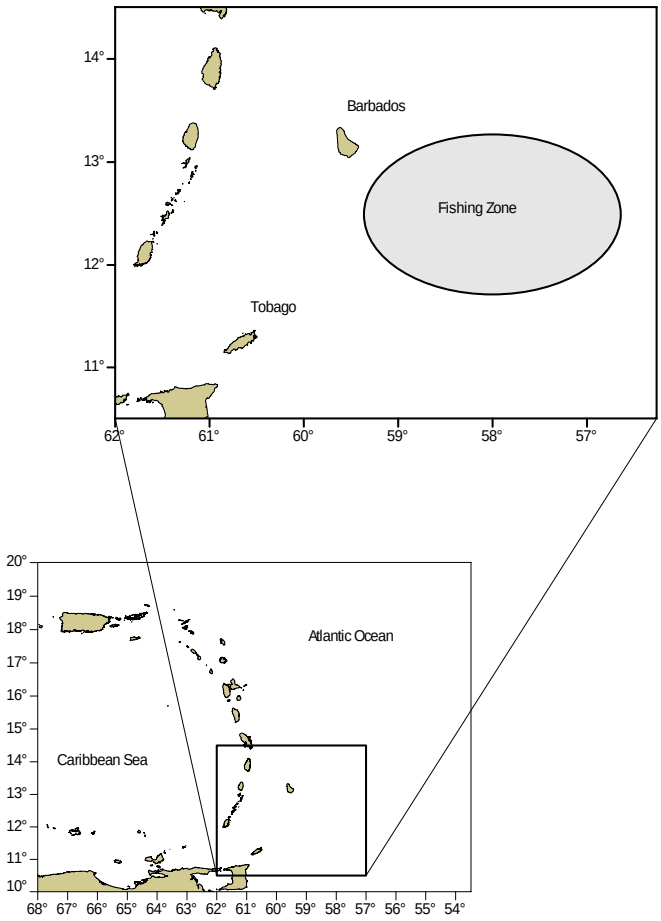

Figure 1. Map of the southeastern Caribbean showing Barbados as a part of the Lesser Antilles ecosystem and the approximate fishing area from which the large pelagic fish samples were taken in this study.

Laboratory Analysis of Stomach Contents

Frozen stomach samples were defrosted and carefully opened to prevent damage. A sieve was used to prevent loss of small items during rinsing. All contents were sorted and identified to the lowest taxonomic level possible. Identification was aided by the use of a low power binocular microscope. Carpenter (2002) and Doroshev and Pearson (1978) were the key references used for fish species identification. Identification of invertebrates was facilitated by Carpenter (2002) and www.cephbase.com. Prey items were also individually measured for length to the nearest mm and weights recorded to the nearest gm. For partially digested individuals the approximate length was reconstructed. The weights however were biased on the low side in these cases.

Data Handling and Analysis

Importance of prey items to the diet was judged using a number of indicators including:

i) Numerical abundance (N) of a prey item calculated as a percentage of the total number of items in all food categories,
ii) Frequency of occurrence (F) of a prey item calculated as a percentage of all stomachs examined which contained one or more of the particular prey item, and
iii) Weight of prey (W) calculated as a percentage of total combined weights of all prey observed.

These values were also used in combination to calculate an overall index of relative importance (IRI) for each of the different food categories observed, using the standard relationship of Pinkas *et al*. (1971):

$$IRI_i = (N_i + W_i) \times F_i.$$

Data were stored electronically in Microsoft Excel spreadsheets and analysed using the Statistical Package for Social Sciences (SPSS ver. 11.0) software.

RESULTS

Sample Sizes and Sex Ratios

The total sample of 113 fish comprised; 29 female and 33 male yellowfin tuna weighing 2,636 kg; 5 female, 11 male and 3 of unknown sex blue marlin weighing 1,086 kg; 5 female, 5 male and 9 of unknown sex white marlin weighing 254 kg; and 6 female, 3 male and 4 of unknown sex Atlantic sailfish weighing 282 kg.

Place of Capture

The position where each fish was caught is shown in Figure 2. These indicate that all fish were caught in the same general fishing area of 64,000 km^2, to the east south-east of Barbados, between 77 and 420 km from shore, and that there was no apparent geographic partitioning of space by the four species.

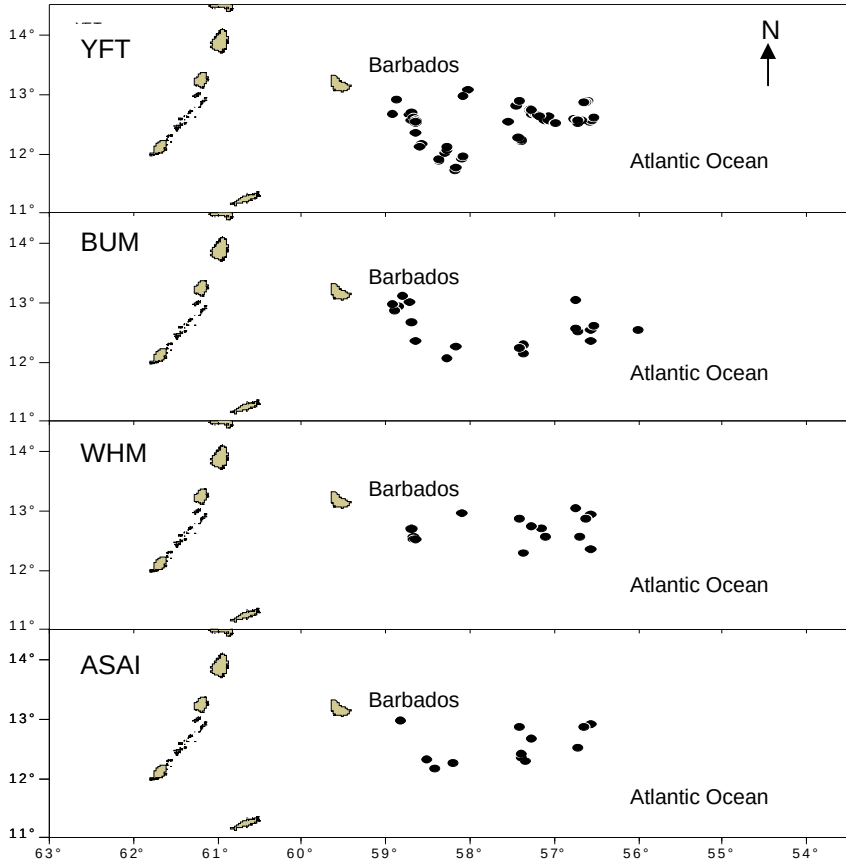

Figure 2. Location of capture for each sampled fish (black dots) shown separately for each species. YFT – yellowfin tuna, BUM – blue marlin, WHM – white marlin, ASAI – Atlantic Sailfish

Predator Sizes

Yellowfin tuna (n = 62) ranged in length from 127 to 170 cm FL with a mean of 148.1 cm FL, and in weight from 26 to 65 kg with a mean of 42.5 kg. Blue marlin (n = 19) were the largest of the billfishes, ranging in length from 175 to 240 cm FL with a mean of 207.5 cm FL, and in weight from 43 to 94 kg with a mean of 57.2 kg. White marlin (n = 19) were the smallest of the billfishes, ranging in length from 140 to 176 cm FL with a mean size of 149.9 cm FL, and in weight from 9 to 20 kg with a mean of 13.4 kg. Atlantic sailfish (n = 13) were longer and heavier than white marlin, ranging in length from 150 to 189 cm FL with a mean size of 168.7 cm FL, and in weight from 17 to 26 kg with a mean of 21.7 kg. These size ranges indicate that most, if not all, of the large predators in this study were young adults (see Beardsley *et al.* 1972, Hunte *et al.* 1994, Froese and Pauly 2005).

Food and Feeding Habits

State of fullness — There was a consistent pattern across all species of a high proportion of samples having empty and/or everted stomachs. Very few of the stomachs examined were ½ full and none was ¾ or $^4/_4$ full. For yellowfin tuna with a reasonable sample size in both sexes, the state of fullness of stomachs was compared between males and females and found to be dependent on sex (Pearson's chi-square test for independence: $\chi^2 = 9.854$, n = 62, p = 0.007). Females had a much higher proportion of empty stomachs and smaller proportion of ¼ full stomachs than males, and none had ½ full stomachs.

State of digestion — Prey items were in varying states of digestion. In a few samples the prey items were in relatively good condition. Most were in poor condition and in some they were in advanced states of digestion. Despite this, it was possible to identify virtually all fish to species level and invertebrates to order by comparing key features with less digested specimens.

Taxonomic composition of diet — A range of prey was taken by all four predator species indicating opportunistic predation. From the 113 stomachs examined there was a total of 467 prey items comprising eight fish species from seven families (82% of the prey items by weight), one squid family and unidentified crustaceans (18% of prey items by weight) (Table 1).

There was considerable overlap in the diet of the large oceanic predators with the most or second most important overall prey family across all predators being Scombridae (tuna) (Table 1). Other families eaten by all four predators were Loliginidae (squid) and Alepisauridae (lancetfish) (Figure 3). Blue marlin appeared to be slightly more selective than the other species, since they appear not to be taking the small pelagic-stage fishes. This may however be an artifact of the small sample size for this predator. Interestingly, only Yellowfin tuna ate crustaceans.

Prey Size — Prey sizes were relatively small, Dactylopteridae (flying gurnards) (size range 0.5 – 9 cm), Bramidae (pomfrets) (size range 0.4 – 9 cm) and Balistidae (triggerfish) (size range 1.8 – 12 cm) were all post-larval or juvenile pelagic stage fishes. Lancetfish and tuna prey had a much wider size range (lancetfish 6 – 36 cm; tuna 5 - 34 cm) indicating juveniles to young immature adults. Interestingly, the size range and mean size of tuna prey was similar across all predators, with the possible exception of blue marlin where slightly larger tuna prey were perhaps being taken. However, sample sizes were considered too small for statistical comparison of prey size among predators. Squid again had similar ranges across all predators of 8 - 11 cm mantle length.

For yellowfin tuna with sufficient sample sizes of all major prey items, a comparison of prey sizes by family was undertaken (Figure 4). The smallest prey were pomfrets and flying gurnards. Lancetfish were the longest prey being consumed up to a total length of 30 cm. Squid and tuna prey had a broad size range.

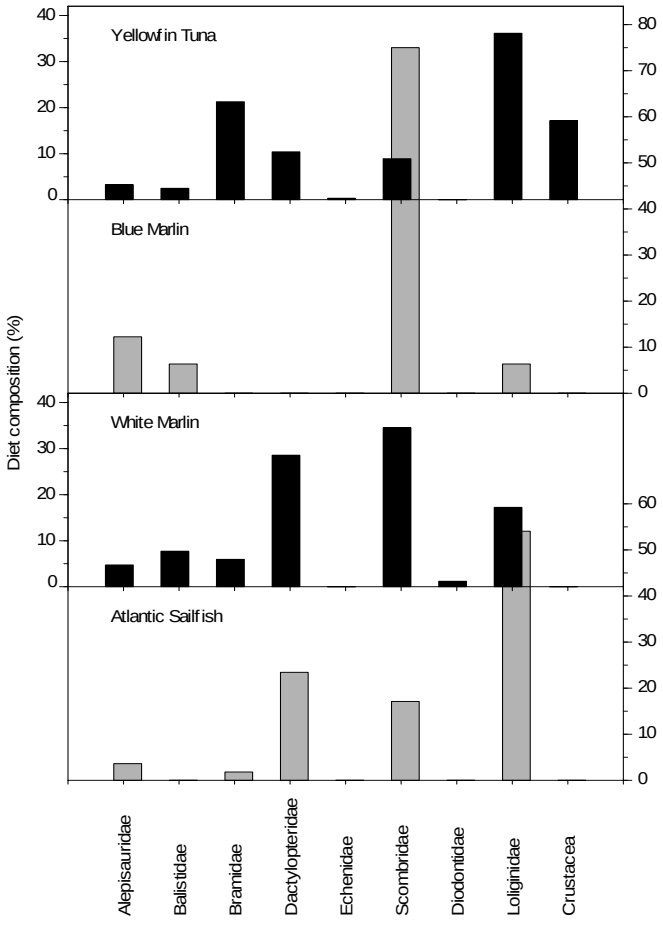

Figure 3. Percent numerical abundance of prey families found in all four large oceanic pelagic species caught by a longline vessel from Barbados between mid-August 2004 and mid-March 2005.

Table 1. Summary of prey items found in the stomachs of large oceanic predators sampled off Barbados, between mid-August 2004 and mid-March 2005. Sample size (n) refers to the number of non-empty stomachs. Frequency of occurrence refers to the number of predators in which a particular prey item occurred. IRI refers to the Index of Relative Importance of items to the diet and is ranked here by prey family/group.

Prey Species			Predator Species															
			Yellowfin tuna (n = 34)				Blue marlin (n = 7)				White marlin (n = 14)				Atlantic sailfish (n = 8)			
Category	Family	Prey Species	No	Wt (g)	Freq. occur.	IRI rank	No	Wt (g)	Freq. occur.	IRI rank	No	Wt (g)	Freq. occur.	IRI rank	No	Wt (g)	Freq. occur.	IRI rank
FISHES																		
Reef	Balistidae	*Xanthichthys ringens*	6	21	4	7	1	12	1	3	7	60	3	4	0	0	0	-
	Dactylopteridae	*Dactylopterus olitans*	37	64	10	4	0	0	0	-	22	35	4	3	14	35	4	3
	Diodontidae	Unknown	0	0	0	-	0	0	0	-	1	10	1	7	0	0	0	-
Oceanic pelagic	Scombridae	*Auxis thazard*	14	1381	11	2	7	1324	5	1	7	557	6	1	8	429	5	1
		Katsuwonus pelamis	14	369	9		5	144	4		22	360	5		2	45	2	
	Echenidae	*Remora* sp.	1	25	1	8	0	0	0	-	0	0	0	-	0	0	0	-
Pelagic	Bramidae	*Brama* sp.	62	119	12	3	0	0	0	-	5	8	2	6	1	4	1	5
	Alepisauridae	*Alepisaurus ferox*	11	209	8	6	2	25	0	2	4	39	4	5	2	47	2	4
INVERTEBRATES																		
Crusta-ceans	Shrimp	Unknown	50	40	3	5	0	0	0	-	0	0	0	-	0	0	0	-
	Crab larvae	Unknown	2	n/a	2		0	0	0		0	0	0		0	0	0	
Cephalo-pods	Loliginidae	*Loligo* sp.	114	982	26	1	1	10	1	4	14	85	5	2	31	48	3	2
TOTAL FOOD ITEMS			314	3211	-	-	16	1515	-	-	82	1154	-	-	58	608	-	-

DISCUSSION

Sample Sizes and Condition

This study was conducted outside of the periods of peak abundance for yellowfin tuna but at least within a part of the period for billfishes (Hunte *et al.* 1994). The frequency of fishing trips was reduced by a very active hurricane season and continued low catches. Attempts to involve other longline vessels in data collection were unsuccessful. All of these factors resulted in a much smaller sample size of large pelagics than desired and a much longer study period than planned. However, total sample size was considered adequate for this preliminary study, given that many previous diet studies have also utilized small sample sizes (see Rawlins 2005 for review). The sample size of stomachs suitable for analysis of diet was further reduced by the high incidence of everted or empty stomachs, as can be expected when sampling bait-caught fish (e.g. Bard 2001, Sabatié *et al.* 2003). The number of prey items found was also constrained by the low level of repletion of stomachs, although this is reported normal for large oceanic pelagics sampled by longline (e.g. Bard 2001).

Examination and identification of prey is a difficult task, especially if the stomach contents are partially or fully digested. In this study, the advanced state of digestion of prey resulted from the long soak time of the gear (12 hours) and the storage conditions of stomach samples in the vessel hold before docking. Despite the well digested samples however, there were still remains of various hard parts that allowed for identification.

Prey Species

The variety of prey species and similarity in the diets of the four predator species gives an indication of available forage species in the geographic area sampled. Furthermore, the species composition of the diets of the four predators off Barbados were similar to the diets of these species in the Atlantic reported in previous studies (Rawlins 2005). These results support the suggestion that many large oceanic pelagic species are opportunistic predators, eating what is present and easiest to catch, a foraging mode that is suited to tropical oceans where food is often scarce and unevenly distributed (e.g. Beardsley *et al.* 1972, Mather *et al.* 1972, Oxenford and Hunte 1999).

In general, yellowfin tuna appear to be opportunistic predators, but with a fairly consistent preference for squid (see Rawlins 2005). Also consistent with this study, crustaceans feature in the diets of yellowfin tuna from all locations except Brazil (Rawlins 2005). Blue marlin can be considered specialized but opportunistic, with tuna prey consistently accounting for a large part of their diet, even in studies where predator sample sizes were much larger than the current study (see Rawlins 2005, also Parin 1968, Nakamura 1985). In the current study, tuna are also the most important prey for white marlin, although previous studies in the Caribbean have found squid to be more abundant in their diet. Tuna and squid also appear to be the most important components of the diet of Atlantic sailfish in the Caribbean, although in Brazil, porcupinefishes, flyingfishes, and jacks were more important (see Rawlins 2005). Also consistent with the findings of this study, crustaceans are not important prey of the billfishes (Rawlins 2005).

Overall, the diets of the large pelagic species reported in this study are very similar to those reported by previous studies of the same predator species from the NW Atlantic and Caribbean, and less similar to those reported from Brazil (South Atlantic).

Prey Size

Maximum prey size is determined by the mouth gape of the predator, whilst minimum prey size is determined by the gap width between gill rakers (e.g. Magnuson and Heitz, 1971). Preference for the largest prey a predator can ingest is supported on theoretical grounds (see Olson and Glavan-Magana 2002). However, for the oceanic predators studied here, prey size was generally quite small when compared to the size of the predators. This seems to be a general feature of the diets of tropical oceanic predators (e.g. Matthews *et al.* 1977, Fonteneau and Marcille 1993, Oxenford and Hunte 1999, Olson and Glayan-Magana 2002) and likely reflects a genuine preference for small forage items. There seems to be a reliance on the pelagic, post-larval and juvenile stages of neritic benthic species (such as coral reef species) as well as juvenile or immature stages of pelagic species of fish (especially tunas) and squid.

Ecosystem Interactions

These data have important implications for ecosystem modeling in the Lesser Antilles, since they suggest broadly overlapping diets and thus some level of competition among the large predators for forage species. A close interrelationship among the commercial longline fisheries, offshore surface-trolling fleets, and sport fisheries is also indicated, since they target co-competitors in the pelagic food web of the Lesser Antilles. Although the species appear to be opportunistic predators and also to feed on early life history stages of many species, attention should still be given to management of prey species for which fisheries exist. Of particular importance is the likely impact of excessive tuna fishing on the billfishes, particularly the blue marlin, that show a strong preference for scombrids in their diet.

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