DIET OF THE WHITE MARLIN (*TETRAPTURUS ALBIDUS*) FROM THE SOUTHWESTERN EQUATORIAL ATLANTIC OCEAN

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SUMMARY

The aim of this study was to evaluate the diet of white marlin, regarding the number, weight, and frequency of occurrence of the prey items, prey-predator relationships, and feeding strategies in the southwestern equatorial Atlantic Ocean. A total of 257 white marlins were examined, of which 60 (23.3%) were male and 197 (76.7%) were female. Males ranged from 105 to 220 cm low jaw fork length (LJFL) and females ranged from 110 to 236 cm LJFL. Most prey (fish and cephalopods) ranged between 1.0 and 65.0 cm in body length, with a mean length around 10.1 cm. According to the IRI (Index of Relative Importance) ranking, the flying gurnard, Dactylopterus volitans, *was the most important prey item, with 27.9% of occurrence, followed by the squid,* Ornithoteuthis antillarum *(Atlantic bird squid), with 21.2% occurrence.*

RÉSUMÉ

*Cette étude vise à évaluer le régime alimentaire des makaires blancs en ce qui concerne le nombre, poids et fréquence de présence des proies, la relation proie-prédateur et les stratégies trophiques dans l'Océan Atlantique équatorial sud-occidental. Un total de 257 makaires blancs ont été examinés, dont 60 (23,3%) étaient des mâles et 197 (76,7%) des femelles. La taille des mâles oscillait entre 105 et 220 cm (longueur maxillaire inférieur-fourche, LJFL) et celle des femelles entre 110 et 236 cm (LJFL). La taille de la plupart des proies (poissons et céphalopodes) oscillait entre 1,0 et 65,0 cm de longueur du corps, avec une longueur moyenne d'environ 10,1 cm. Selon la classification IRI (Indice d'importance relative), le dactyloptère volant (*Dactylopterus volitans*) était la proie la plus importante avec 27,9% de présence, suivie de l'encornet oiseau (*Ornithoteuthis antillarum*), avec 21,2% de présence.*

RESUMEN

El objetivo de este studio es evaluar la dieta de la aguja blanca, en lo que concierne al número, peso y frecuencia de presencia de las presas, a las relaciones depredador-presa, y a las estrategias tróficas en el océano Atlántico ecuatorial suroccidental. Se examinó un total de 257 agujas blancas de las cuales 60 (23,3%) fueron machos y 197 (76,7%) hembras. Las tallas de los machos oscilaban entre 105 y 220 cm de longitud de mandíbula inferior a horquilla (LJFL) y las de las hembras entre 110 y 236 cm LJFL. La talla de la mayoría de las presas (peces y cefalópodos) oscilaba entre 1,0 y 65,0 cm de longitud de cuerpo, con una longitud media de en torno a 10,1 cm. Según la clasificación IRI (Índice de importancia relativa), el pez volador, Dactylopterus volitans, *se clasificó como la presa más importante con una frecuencia del 27,9%, seguido por el calamar rojo (*Ornithoteuthis antillarum*), con una frecuencia del 21,2%.*

KEYWORDS

Istiophoridae, white marlin, Atlantic Ocean, feeding

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1. Introduction

White marlin, *Tetrapturus albidus*, is an oceanic, pelagic and highly migratory species, found mainly in the mixed layer of equatorial and tropical waters of the Atlantic Ocean. The species is captured by both sport and commercial fisheries, being often caught, as bycatch, in the longline fishery targeting tunas and swordfish. Due to its highly migratory nature, it is captured by several nations, in different areas of the Atlantic Ocean, being thus exposed to a significant fishing pressure, which has resulted in an important decline of its stock. Main commercial catches occur in the first semester in the central Atlantic, between 5°W and 25°W, and 15°N and 10°S, with a CPUE (Catch per Unit of Effort) ranging between 0.02 and 0.16 individuals per 100 hooks, with a mean of 0.025 (Oliveira *et al*., 2007).

Due to its relatively low commercial value, if compared to tunas and swordfish, and to the fact that a great part of its catches happens as by-catch, many specimens are discarded at sea, further hindering accurate catch estimates and studies on its biology. The last stock assessment on the species done by ICCAT (International Commission for the Conservation of Atlantic Tunas) was in 2006. Although this last assessment could not provide an estimate of stock status with certainty, previous results have indicated that the stock has been over-fished for many years (Anon. 2007). Due to a continuing lack of biological information on the species, the ICCAT Standing Committee of Research and Statistics has recommended that research on white marlin biology should be conducted in order to provide better information for future stock assessment.

Feeding studies of Istiophoridae in the Atlantic are scanty, being basically limited to faunistic lists of preys off Venezuela (Garcia-de-los-Salmones *et al*. 1989, Trias *et al*. 1996), Florida (Nakamura 1985), and the Gulf of Mexico (Nakamura 1985). Prey proprotions in the diet of *I. albicans* in the central Atlantic was studied by Maksimov (1971), although the species is cited as *Istiophorus platypterus*, currently the name of the Indo-pacific species (Nakamura 1985). In Brazil, Zavala-Camin (1981) described the identification of partially digested fish specimens in the diet of four Istiophorid species in the southern and southeastern regions, although *I. albicans* is also referred to as *I. platypterus*. Finally, 120 stomachs and predator-prey relationship of four Istiophoridae were analised by Vaske *et al*. (2004), in the northeastern region.

The aim of this study was, therefore, to improve the present knowledge on the feeding habits of *T. albidus* in the Southwestern Equatorial Atlantic Ocean, providing data on the composition of its diet in number, weight, and frequency of occurrence of the prey items, prey-predator relationships, and feeding strategies.

2. Material and methods

The data and samples examined in the present study were collected by observers, of the National Observer Program, on board tuna longliners based in the ports of Recife (PE), Cabedelo (PB) and Natal (RN), located in northeast Brazil, from November 2004 to November 2005. The study area is located between 025°W and 041°W, and 06°N and 25°S (**Figure 1**). All specimens were measured for low jaw-fork length (LJFL), immediately after boarding. After measured, they were dissected for the collection of stomachs, being then frozen and stored in freezers, up to the time of landing. In the laboratory, the stomach content, considered as the material retained in a sieve of 1 mm mesh size, was collected, with the following information being recorded: number of preys of each food item, the mantle length (cm) for cephalopods, the total length for other organisms, and the wet weight (g) of each prey.

The importance of each food item in the diet was obtained by the Index of Relative Importance (IRI) (Pinkas *et al*. 1971), modified to weight in the pooled samples of the species, as follows: $IRI_i = \%FO_i \times (\%N_i \times \%W_i)$, where: $\%FO_i$ – relative frequency of occurrence of each food item; $\%N_i$ – proportion in prey number of each item in the total food; and $\%W_i$ – proportion in weight of each item in the total food.

3. Results

A total of 257 white marlins were examined, of which 60 (23.3%) were males and 197 (76.7%) were females. Males ranged from 105 to 220 cm low jaw-fork length (LJFL) and females from 110 to 236 cm LJFL. Both sexes showed a mode at 150 to 160 cm (**Figure 2**). Mean LJFL was 154.0 cm for males and 154.7 cm for females.

The stabilization of the food items richness was obtained at 54 food items and 150 stomachs, meaning that the number of examined individuals was sufficiently high to obtain the feeding *spectra* of the main prey species

(**Figure 3**). Of the 257 analyzed stomachs, 220 (85.6%) presented some food, and 37 stomachs (14.4%) were empty. A total of 58 items were identified, including 35 teleosteans, 20 cephalopods and two crustaceans (**Table 1**).

According to the IRI ranking, with the exception of unidentified Teleostei and Cephalopods, a remarkable presence of epipelagic fishes and squids was observed. The flying gurnard, *Dactylopterus volitans*, was the most important prey item, with 27.9% of occurrence. Other pelagic fishes, like *G. serpens, C. hippurus, Cubiceps sp.*, and *K. pelamis* were also important. Deep dwellers species like, Chiasmodontidae, *Omosudis lowei*, and *Diretmus argenteus* were occasional. Cephalopods were represented by muscular and vigorous swimmers like Enoploteuthidae, and Ommastrephidae, among which *Ornithoteuthis antillarum* (Atlantic bird squid) was the second most important food item, with 21.2% of occurrence, followed by other ommastrephids like *Ommastrephes bartramii, Hyaloteuthis pelagica, and Sthenoteuthis pteropus*. The epipelagic octopus *Ocythoe tuberculata* was also frequent in the stomachs. Most preys ranged between 1.0 and 65.0 cm in body length, with a mean length around 10.1 cm. Most of them were represented by juvenile stages (**Figure 4**).

4. Discussion

The majority of white marlin individuals analyzed were adults, according to the size of first sexual maturity (148.8 cm) estimated by Oliveira *et al.* (2007). The mean length of white marlin specimens caught by the Brazilian tuna longline fleet, from 1971 to 1985, estimated by Goodyear *et al.* (2003), ranged from 162 to 172 cm, which is a little larger than the lengths observed in the present sample.

The results showed that *T. albidus* feeds on a variety of prey, mostly small sized epipelagic species of fish and cephalopods. The feeding activity seems to be continuous, due to its high metabolism and reduced size of stomach, which would force them to feed constantly, to restore the energy required to its migratory movements. This feeding activity implies a strategy of foraging wide ocean areas to find scarce prey that are commonly distributed isolated in the water column. According to Vaske Jr. *et al.* (2004), the occurrence of small crustaceans in the stomachs of istiophorids is considered accidental, since istiophorids do not have gill rakers, and thus crustaceans are not potential prey due to their small size. In this study, only 1.7% of occurrence of small crustaceans was observed.

The presence of several seamounts off Ceará and Rio Grande do Norte (Brazil), and along Vitória-Trindade Chain, as well as the islands of Rocas Atoll, Fernando de Noronha and Saint Peter and Saint Paul Archipelago in the region where *Tetrapturus albidus* specimens were predominantly caught, is the possible cause for the occurrence of young shallow water fish in their diet, represented mainly by *Dactilopterus volitans* (Vaske & Lessa, 2004; Vaske *et al*., 2004). Considered a brephoepipelagic species, *i.e*., a coastal species which juveniles are pelagic, juveniles of *Dactylopterus volitans* (2.0 up to 7.0 cm) were frequent in the stomachs, as were also Balistidae, Diodontidae, Holocentridae and Carangidae. Seamounts provide shelter, food, and reproduction ground to phytoplankton, microzooplankton, micronekton, fishes, and cephalopods (Roden 1987, Fonteneau 1991, Rogers 1994). *Dactylopterus volitans* found in the white marlin stomachs ranged between 5.0 and 10.0 cm, showing that its larval form is epipelagic. Trias *et al* (1996), in the central region of Venezuela, also observed small sized *D. volitans* (0.5 at 6.0 cm) in the stomachs of white marlins. The great amount of brephoepipelagic fishes as food item of white marlin indicates the wide range of spawning ground of some coastal species, especially *D. volitans*, which becomes an important food supply of epipelagic predators being even the main food resource in some cases, as seen in the present study. The results of this study indicate that fish and cephalopods were the most important preys of white marlin in the southwestern equatorial Atlantic Ocean, and that this species, therefore, can be classified as carnivorous of first and second order.

5. References

Anon. 2007, Report of the 2006 ICCAT Billfish Stock Assessment (Madrid, Spain, May 15-19, 2006). Collect. Vol. Sci. Pap. ICCAT, 60(5): 1431-1546.

Fonteneau, A. 1991, Seamounts and tuna in the tropical eastern Atlantic. Aquat. Living Res. 4: 13–25.

Garcia-de-Los-Salmones, R., Infante, O. and Alio, J. 1989, Reproducción y alimentación de los peces de pico *istiophorus albicans, Tetrapturus albidus* y *Makaira nigricans*, en la costa central de Venezuela. Collect. Vol. Sci. Pap. ICCAT, 30(2): 436-439.

Goodyear, C.P. 2003, Spatio-temporal distribution of longline catch per unit effort, sea surface temperature and Atlantic marlin. Marine and Freshwater Research, 59: 409-417.

Hazin, F.H.V. 1993, Fisheries-oceanographical study on tunas, billfishes and sharks in the southwestern equatorial Atlantic Ocean. Tese de doutorado. Universidade de Pesca de Tóquio, Japão. 286 p.

ICCAT, 2007, Report for Bienal Period, 2006-07, International Commission for the Conservation of Atlantic Tunas, 224p., Madrid, 2007.

Maksimov, V.P. 1971, The biology of the sailfish *Istiophorus platypterus* (Shaw & Nadder) in the Atlantic Ocean. J. Ichthyol. 6: 850-855.

Nakamura, I. 1985, FAO Species Catalogue. Vol. 5. Billfishes of the World. An annotated and illustrated catalogue of marlins, sailfishes, spearfishes and swordfishes know to date. FAO Fish. Synop. (125) 5: 65 pp.

Oliveira, I.M, Hazin, F.H.V., Travassos, P., Pinheiro, P.B. and Hazin, H.G. 2007, Preliminary results on the reproductive biology of the white marlin, *Tetrapturus albidus* Poey 1960, in the western equatorial Atlantic Ocean. Collect. Vol. Sci. Pap. ICCAT, 60(5): 1738-1745.

Pinkas, L., Oliphant, M.S. and Iverson, I.L.K. 1971, Food habits of albacore, bluefin tuna, and bonito in Californian waters. Calif. Dep. Fish Game, Fish. Bull. 152: 105 p.

Roden, G.I. 1987, Effect of seamounts and seamount chains on ocean circulation and thermohaline structure. pp. 335–354. *In*: B.H. Keating, P. Fryer, R. Batiza & G.W. Boehlert, (ed.) Seamounts, Islands and Atolls. Geophysical Monography 43, American Geophysical Union, Washington.

Rogers, A D. 1994, The biology of seamounts. Adv. Mar. Biol.30: 306-330.

Trias, J.O., Marcano, L.A. and Alio, J.J. 1996, Alimentación de peces istioforidos de la region nororiental del central de Venezuela. Collect. Vol. Sci. Pap. ICCAT, 45(2): 288-294.

Vaske Jr., T. and Rincón Fo, G. 1998, Conteúdo estomacal dos tubarões azul (*Prionace glauca*) e anequim (*Isurus oxyrinchus*) em águas oceânicas no sul do Brasil. Rev. Bras. Biol. Vol 58 (3): 443-450.

Vaske Jr., T.; C.M. Vooren; R. P. Lessa. 2004. Feeding habits of four species of Istiophoridae (Pisces: Perciformes) from northeastern Brazil. Env. Biol. Fishes 70: 293-304.

Vaske Jr., T. and Lessa, R.P. 2004, Feeding habits of the common dolphinfish (*Coryphaena hippurus*), in the Northeastern Brazilian Exclusive Economic Zone. *Arq. Ciênc. Mar*. 37:131-138.

Zavala-Camin, L.A. 1981, Hábitos alimentares e distribuição dos atuns e afins (Osteichthyes - Teleostei) e suas relações ecológicas com outras espécies pelágicas das regiões sudeste e sul do Brasil. 237 p. Tese de doutorado, Instituto de Biociências da Universidade de São Paulo, Brasil.

Table 1. Percentages in number, weight, and frequency of occurrence (FO) of food items of *Tetrapturus albidus.* IRI importance according from first (1) most important item, to tenth item (10). (N=total number; W=total weight; B=beak)

Food items	*N*	*%N*	*W*	*%W*	*FO*	*%FO*	*IRI*
Dactylopterus volitans (Linnaeus, 1758)	437	29.37	972	5.07	50	27.93	**1**
Teleostei (others)	56	3.76	3610	18.84	58	32.40	**2**
Gempylus serpens (Cuvier, 1829)	137	9.21	1194	6.23	25	13.97	**4**
Coryphaena hippurus (Linnaeus, 1758)	11	0.74	1776	9.27	10	5.59	**6**
Thunnus sp.	11	0.74	917	4.79	9	5.03	**7**
Cubiceps sp.	118	7.93	373	1.95	4	2.23	**9**
Katsuwonus pelamis (Linnaeus, 1758)	3	0.20	1601	8.35	3	1.68	**10**
Holocentridae	32	2.15	71	0.37	8	4.47	
Brama caribbea (Mead, 1972)	11	0.74	681	3.55	4	2.23	
Ranzania laevis (Pennant, 1776)	3	0.20	264	1.38	4	2.23	
Brama brama (Bonnaterre, 1788)	12	0.81	48	0.25	5	2.79	
Exocoetus volitans (Linnaeus, 1758)	4	0.27	176	0.92	3	1.68	
Decapterus sp.	5	0.34	152	0.79	3	1.68	
Auxis sp.	6	0.40	103	0.54	3	1.68	
Monacanthidae	1	0.07	510	2.66	1	0.56	
Mola mola (Linnaeus, 1758)	3	0.20	128	0.67	2	1.12	
Synagrops sp.	3	0.20	48	0.25	3	1.68	
Istiophoridae	2	0.13	73	0.38	2	1.12	
Decapterus tabl (Berry, 1968)	2	0.13	69	0.36	2	1.12	
Diodontidae	8	0.54	48	0.25	1	0.56	
Oxyporhamphus micropterus (Valenciennes, 1847)	4	0.27	91	0.47	1	0.56	
Balistes sp.	2	0.13	20	0.10	3	1.68	
Chiasmodontidae	3	0.20	6	0.03	3	1.68	
Omosudis loweii (Günther, 1887)	2	0.13	93	0.49	1	0.56	
Balistidae	3	0.20	15	0.08	2	1.12	
Scombridae	1	0.07	73	0.38	1	0.56	
Paralepididae	3	0.20	30	0.16	1	0.56	
Lagocephalus sp.	1	0.07	38	0.20	1	0.56	
Belonidae	1	0.07	23	0.12	1	0.56	
Diretmus argenteus (Johnson, 1864)	2	0.13	7	0.04	1	0.56	
Diodon sp.	1	0.07	14	0.07	1	0.56	
Carangidae	1	0.07	12	0.06	1	0.56	
Bramidae	1	0.07	5	0.03	1	0.56	
Lestidiops jayakari (Boulenger, 1889)	2	0.14	4	0.02	2	1.12	
TELEOSTEI	**892**	**59.95**	**13245**	**69.11**			
Ornithoteuthis antillarum (Adam, 1957)	150	10.08	818	4.27	38	21.23	**3**
Ommastrephidae	185	12.43	470	2.45	18	10.06	**5**
Hyaloteuthis pelagica (Bosc, 1802)	33	2.28	243	1.26	14	7.82	
Cephalopoda	26	1.75	28	0.15	8	4.47	
Ommastrephes bartramii (Lesueur, 1821)	16	1.08	229	1.19	6	3.35	
Cranchiidae	5	0.34	42	0.22	2	1.12	
Sthenoteuthis pteropus (Steenstrup, 1855)	1	0.07	69	0.36	1	0.56	
Cranchiidae	4	0.27	28	0.15	1	0.56	
Liocranchia reinhardti (Steenstrup, 1856)	2	0.13	2	0.01	1	0.56	
Argonauta nodosa (Lightfoot, 1786)	1	0.07	10	0.05	1	0.56	
Enoploteuthidae (B)	55	3.70			10	5.59	
Ocythoe turberculata (Rafinenque, 1814) (B)	27	1.81			11	6.15	
Ornithoteuthis antillarum (Adam, 1957) (B)	10	0.67			2	1.12	
Japetella diaphana (Hoyle, 1885) (B)	2	0.13			2	1.12	
Cranchiidae (B)	2	0.13			2	1.12	

Onychoteuthis sp. (B)	1	0.07			2	1.12
Taonius pavo (Lesueur, 1821) (B)	1	0.07			1	0.56
Sthenoteuthis pteropus (Steenstrup, 1855) (B)	1	0.07			1	0.56
Tremoctopus violaceus (Chiaie, 1830) (B)	1	0.07			1	0.56
CEPHALOPODS	**524**	**35.22**	**1939**	**10.11**		
Caridea	20	1.34			1	0.56
Megalopa de Brachyura	6	0.40	1	0.01	1	0.56
CRUSTACEANS	**26**	**1.75**	**1**	**0.01**		
BAIT	**43**	**2.89**	**3958**	**20,65**	40	22.35
TOTAL	**1485**	**100.00**	**19164**	**100.00**		

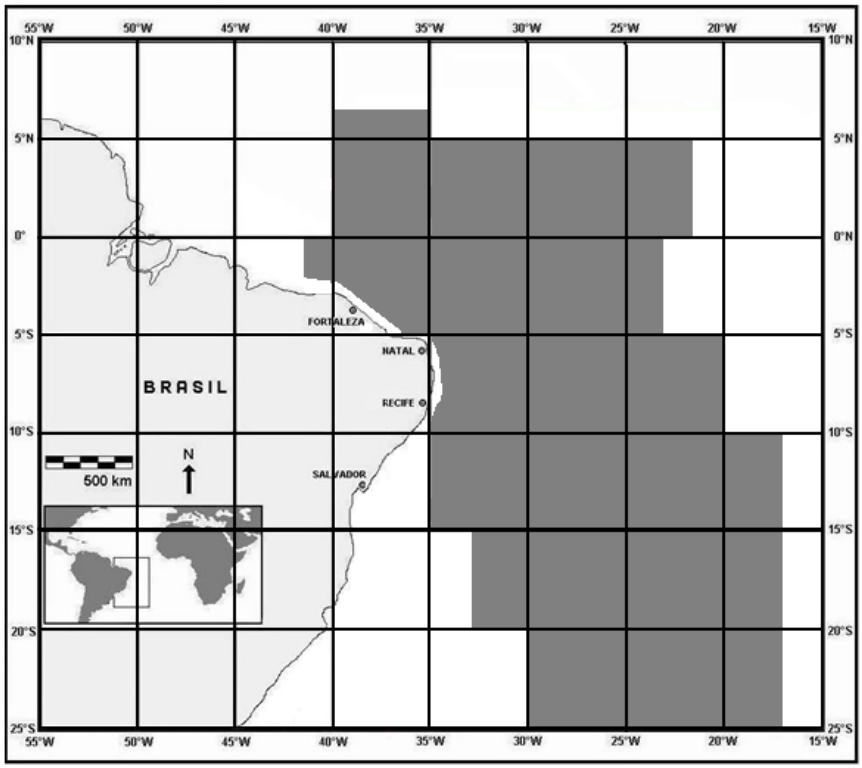

Figure 1. Sample area of *Tetrapturus albidus* specimens caught in the southwestern equatorial Atlantic Ocean.

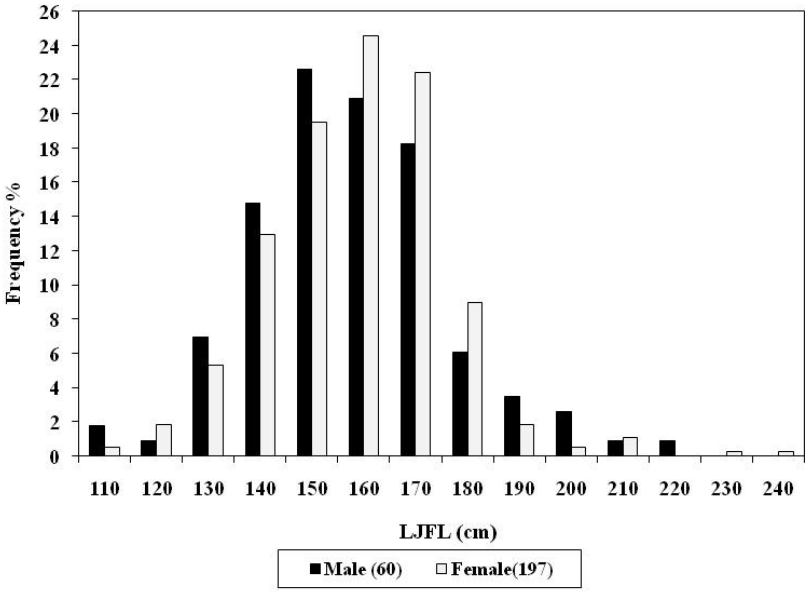

Figure 2. Low-jaw-fork-length (LJFL) frequency distribution of the white marlin, *T. albidus*, in the Southwestern Equatorial Atlantic Ocean, for males and females.

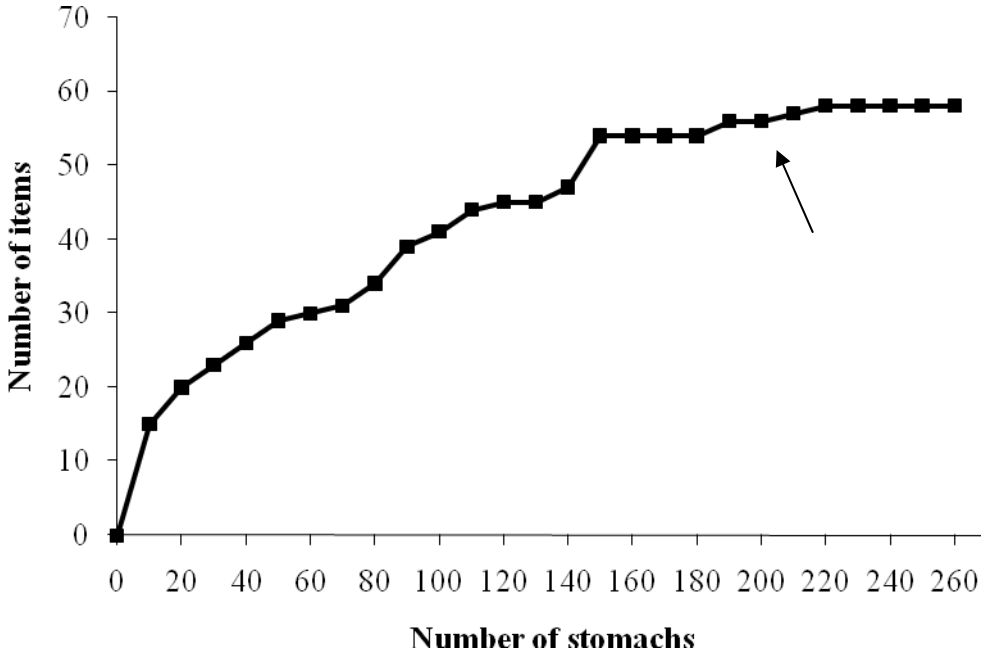

Figure 3. Number of stomachs analyzed in relation to the number of food items in the stomachs of *Tetrapturus albidus* from the southwestern equatorial Atlantic Ocean. Arrow indicates the beginning of stabilization.

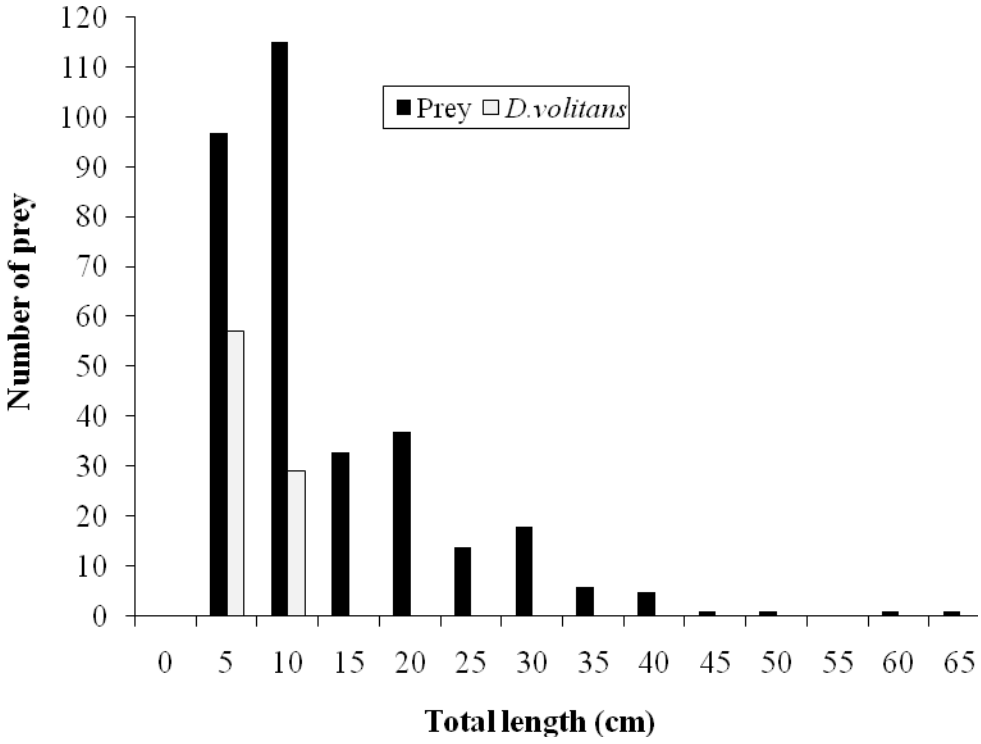

Figure 4. Lengths of prey items found in the stomachs of *Tetrapturus albidus* from the southwestern equatorial Atlantic Ocean. White bar = *Dactylopterus volitans*; black bar = other prey.