FEEDING STRATEGY OF YELLOWFIN TUNA (*Thunnus albacares*), AND WAHOO (*Acanthocybium solandri*) IN THE SAINT PETER AND SAINT PAUL ARCHIPELAGO, BRAZIL

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ABSTRACT

Food composition, predator-prey relationships and feeding strategy of yellowfin tuna, *Thunnus albacares,* and wahoo, *Acanthocybium solandri,* in the Saint Peter and Saint Paul Archipelago were studied. A total of 806 stomachs were collected during trolling and hand line commercial fishing from 1994 to 2002. Twenty-five food items were identified for the two predators together, including fifteen fishes, six cephalopods, three crustaceans and one tunicate. A remarkable predation of *T. albacares* and *A. solandri* upon the flying fish *Cypselurus cyanopterus* was observed around Saint Peter and Saint Paul Archipelago, mainly between November and April. This was directly related to the main reproduction period of *C. cyanopterus*. There was no relationship between size and number of food items, and body size of the predators. Food overlapping between predators was 94.8% similar in the number of preys, and 89.9% similar in weigth of preys. The archipelago is a feeding ground for *T. albacares* between November and April, and throughout the year for *A. solandri.*

Key-words: feeding, yellowfin tuna, wahoo, Saint Peter and Saint Paul Archipelago

ESTRATÉGIA ALIMENTAR DA ALBACORA-LAJE (*Thunnus albacares*) E CAVALA-EMPINGE (*Acanthocybium solandri*) NO ARQUIPÉLAGO DE SÃO PEDRO E SÃO PAULO

RESUMO

A composição alimentar, relações presa-predador e estratégia alimentar da albacora-laje, *Thunnus albacares*, e cavala-empinge, *Acanthocybium solandri*, foram estudadas no Arquipélago de São Pedro e São Paulo. Um total de 806 estômagos foram coletados durante a pesca comercial de corrico e linha de mão entre 1994 e 2002. Vinte e cinco itens alimentares foram identificados para ambos os predadores, sendo quinze peixes, seis cefalópodes, três crustáceos e um tunicado. Uma predação notável da albacora-laje e cavala-empinge sobre o peixe-voador *Cypselurus cyanopterus* foi observada nas adjacências do arquipélago, sobretudo entre novembro e abril, diretamente relacionada com o principal período reprodutivo de *C. cyanopterus*. Não houve correlação entre tamanho e número de itens alimentares com o tamanho corporal do predador. A sobreposição alimentar entre os dois predadores foi 94,8% similar em número e 89,9% similar em peso das presas. O arquipélago é um importante local de alimentação para albacora-laje entre novembro e abril, e para cavala-empinge ao longo do ano.

Palavras-chave: alimentação, albacora-laje, cavala-empinge, Arquipélago de São Pedro e São Paulo

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INTRODUCTION

The yellowfin tuna, *Thunnus albacares,* is an oceanic and epipelagic species, although adults also penetrate in mesopelagic layers (ZAVALA-CAMIN,1981). It reaches 2.1 m of total length, and is distributed throughout the tropical and subtropical oceans (COLLETTE and NAUEN 1983), in waters with temperatures between 18º and 31º C (LAEVASTU and ROSA, 1963). *T. albacares* is the main tuna species caught in the Exclusive Economic Zone off Northeastern Brazil, where most captures occur in the first semester (ARAGÃO, 1977; HAZIN, 1986). Annual mean Catch per Unit of Effort (CPUE) in the tuna longline fishery declined from 9.13 fishes per 100 hooks in 1956 to 0.77 in 1971 (PAIVA e LE GALL, 1975). Annual means are between 0.35 and 1.35 fishes per 100 hooks, but reach 3.62 fishes per 100 hooks around the Saint Peter and Saint Paul Archipelago (SPSPA) (HAZIN, 1993). From January 1988, on the CPUE of *T. albacares* more than tripled, changing from 1.5 fishes/100 hooks/year to 5 fishes/100 hooks/year in 1995 (HAZIN *et al*., 1998). Descriptive studies on the diet of *T. albacares* in the tropical Atlantic were analyzed from 1969 to 1998 (DRAGOVICH, 1969; DRAGOVICH and POTTOFF, 1972; MATTHEWS *et al*., 1977; PELCZARSKI, 1990; VALLE *et al*., 1980). ZAVALA-CAMIN (1981,1987) described the diet of *T. albacares* and other pelagic species in the south and southeastern regions of Brazil, and VASKE and CASTELLO (1998) presented the diet composition of *T. albacares* tuna off southern Brazil during winter and spring.

The wahoo, *Acanthocybium solandri,* is an epipelagic species in all tropical and subtropical oceans, reaching 2.1 m (COLLETTE and NAUEN, 1983). *A. solandri* represents 3.7% of the mean longline catch in the northeastern region of Brazil (TRAVASSOS, 2002), but represented 99% of SPSPA catches on trolling line fisheries from 1998 to 2002. There are no studies on the feeding habits of *A. solandri* in the Atlantic, with the exception of reports on some observed preys (LAEVASTU and ROSA, 1963; ZAVALA-CAMIN, 1981).

A thorough knowledge of diet is important to understand the aggregation and behavior of the tropical tuna in oceanic areas as well as in the vicinity of islands and offshore banks. The SPSPA has been an important fishing ground since the 1950s for activities aimed at the main target species *T. albacares* and *A. solandri*. In the present study, aspects of the feeding of *T. albacares* and *A. solandri* in the SPSPA are analyzed with regard to food composition in weight, size and number of prey categories; relationships between food and the body size of the fish; and feeding strategy in waters around the SPSPA.

MATERIAL AND METHODS

Samples were obtained between October 1994 and June 2002 from commercial handlines for *T. albacares* and trolling lines for *A. solandri* in adjacent waters two miles around the SPSPA. The stomachs were extracted on board during fishing, preserved in 5% formaline, and stored in 70% ethanol. Food items were identified to the most specific taxonomic level possible. Prey was considered to be a unit of food item; it was measured in total length and weighed in grams when in good condition. Fork length (cm) and date of capture were recorded for each predator sampled. Stomach fullness was visually classified into five categories, as follows: empty - no prey remains in a 1 mm sieve; 25% full; 50% full; 75% full and full.

The importance of each food item in the diet was determined by the Index of Relative Importance (IRI) (PINKAS; OLIPHANT; IVERSON, 1971), modified to weight percentage:

$$IRI_i = (\%N_i + \%W_i) \times \%FO_i$$

Where:

$\%N_i$ = number of taxon i percentage

$\%W_i$ = weight of taxon i percentage

$\%FO_i$ = frequency of occurrence of taxon i percentage

Cephalopod beaks were important to determine the food item diversity, but were not included in number and weight estimations of IRI due to the problem of accumulation in the stomachs, which could lead to an overestimation of the importance of cephalopods in the diet (VASKE and RINCÓN, 1998).

Niche overlap between predators was determined by Pianka's modification of the MacArthur – Levins symmetric measure of overlap (KREBS, 1989):

$$O_{jk} = SS\ p_{ij}\ p_{ik} / v\ (SS\ p_{ij}\ SS\ p_{ik})$$

Where:

O_{jk} = Pianka's measure of niche overlap between species j and species k

p_{ij} = Proportion resource i of the total resource used by species j

p_{ik} = Proportion resource i of the total resource used by species k

RESULTS

Monthly catches of *T. albacares* and *A. solandri* from 1998 to 2002 show that main catches of *T. albacares* occur between November and March, whereas catches of *A. solandri* are irregular throughout the year (Figure 1). Handline fishing takes place at night during new moon when the flying fish *Cypselurus cyanopterus* concentrate at the surface attracted by the light of the fishing boats. Fishing areas of *T. albacares,* both east and west of the SPSPA, are defined by the need of the fishing boats to cast anchor on the platform. The flying fish are caught alive with a dip net and used as live bait to catch *T. albacares*. Trolling is performed during the day around and close to the rocks, capturing only *A. solandri*, using flying fish filet or shark skin as bait (Figure 2). Lengths of *T. albacares* ranged

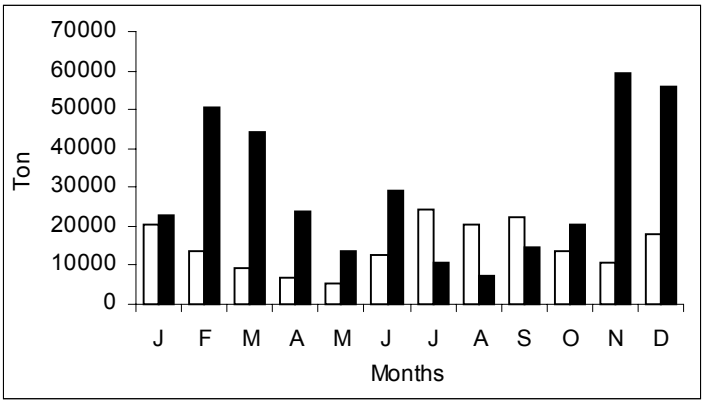

Figure 1. Monthly catches of *Thunnus albacares* (black bar) and *Acanthocybium solandri* (white bar) in the Saint Peter and Saint Paul Archipelago. Source: Nortepesca, Natal-RN

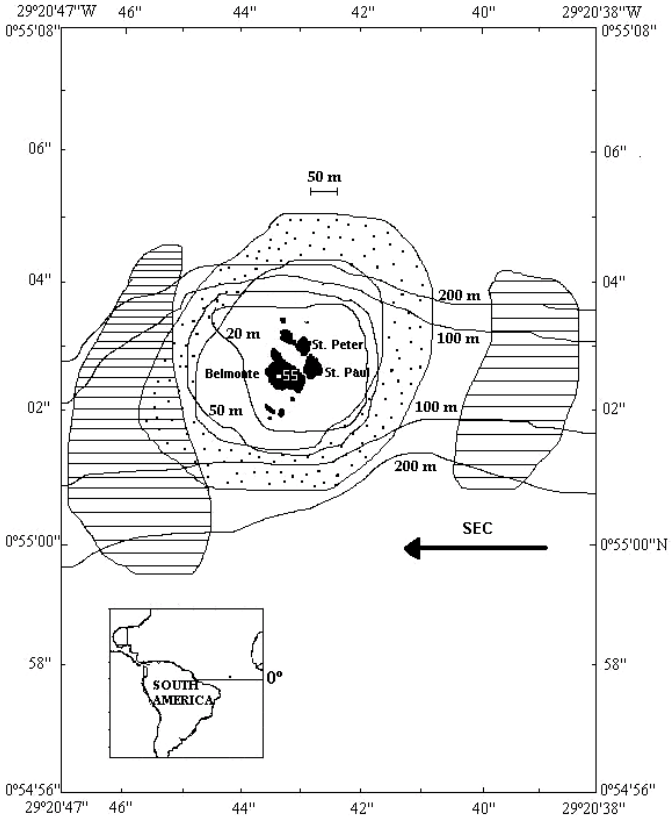

Figure 2. Sample area in the Saint Peter and Saint Paul Archipelago with isobaths. Striped area - *Thunnus albacares* fishing ground. Dotted area – *Acanthocybium solandri* fishing ground. SEC – South Equatorial Current. SS – Scientific Station

from 46 to 148 cm with two modes in 90 and 110 cm (Figure 3). According to ALBARET (1977), *T. albacares* from the tropical Atlantic are sexually mature at 140 cm. Thus, the main catch was of immature individuals. In a review of fish lengths in the tropical Atlantic, HAZIN (1998) found that total lengths of *T. albacares* have been in a continuous decline. In the 1950s, mean lengths were greater than 150 cm; in the 1960s, lengths were 140 cm; and in the 1990s, most fishes were between 80 and 130 cm, coinciding with lengths observed in the present study. Lengths of *A. solandri* ranged between 63 cm and 167 cm, with a narrower distribution for *T. albacares.* Most individuals were between 100 and 150 cm. The sexual maturity of *A. solandri* is not yet known, therefore the impact of fishing efforts on the population is also unknown.

A total of 395 stomachs of yellowfin, and 411 of wahoo were analyzed with the presence of 25 food items. Fifteen taxa were fishes; 6 were cephalopods; 3 were crustaceans, and 1 was tunicate (Table 1). According to IRI ranking, the main food items of *T. albacares* and *A. solandri* were fishes, of which the margined flying fish *Cypselurus cyanopterus* was the most preyed species, representing 58.7% of the total occurrences of food items for *A. solandri*, and 64.2% for *T. albacares*. Cephalopods were commonly represented by beaks, with the Ommastrephidae

Table 1. Food items list of *Acanthocybium solandri* and *Thunnus albacares* from Saint Peter and Saint Paul Archipelago. IRI - Index of Relative Importance ranging from 1 to 10 in order of importance. %N - percentage in number, %P - percentage in Weight, %FO - frequency of occurrence percentage

	Acanthocybium solandri				***Thunnus albacares***			
	Stomachs with food:			**212**	**Stomachs with food:**			**210**
	Empty stomachs:			**199**	**Empty stomachs:**			**185**
Food items	**%N**	**%W**	**%FO**	**IRI**	**%N**	**%W**	**%FO**	**IRI**
Balistidae	0.5	0.3	1.0					
Carangidae	0.5	0.5	1.0					
Cypselurus cyanopterus	28.7	73.2	58.7	**1**	42.1	98.6	64.2	**1**
Dactylopterus volitans	49.0	1.4	11.2	**2**	1.7		1.8	**8**
Diaphus sp.	0.2		0.5		2.2	0.1	2.4	**6**
Diodon hystrx	4.5	2.6	6.6	**4**				
Gempylus serpens	0.2	0.1	0.5					
Holocentridae					0.8		1.8	**10**
Katsuwonus pelamis	1.4	11.2	3.1	**5**	0.2		0.5	
Monacanthidae	0.5	0.5	1.0	**10**				
Oxyporhamphus micropterus	2.6	0.1	0.5	**9**	1.4	0.2	2.3	**7**
Ranzania laevis	0.7	0.1	1.0					
Remora sp	0.2		0.5					
Scombridae	0.7	2.0	1.5	**6**				
Teleostei	3.8	7.9	8.7	**3**	13.7	0.9	9.0	**2**
FISHES	92.8	99.9	95.8		62.1	99.8	82.0	
Cranchiidae (beak)	0.2							
Japetella diaphana (beak)	0.7		1.0		0.3		0.5	
Ommastrephidae (beak)	0.2	0.1	0.5		3.2		2.3	
Ommastrephidae	2.1		1.0	**7**				
Sthenoteuthis pteropus	3.6		0.5	**8**	21.4	0.2	2.7	**3**
Sthenoteuthis pteropus (beak)					0.2		0.5	
Ornithoteuthis antillarum	0.2		0.5		1.6		4.6	**5**
Onychotheuthidae (beak)					0.1		0.5	
CEPHALOPODS	7.0	0.1	3.0		26.8	0.2	11.1	
Brachyura (megalop)	0.2		0.5		7.9		3.7	**4**
Caridae					1.7		1.8	**9**
Decapoda					0.2		0.5	
CRUSTACEANS	0.2		0.5		9.8		6.0	
Salpidae					1.3		0.9	
TUNICATES					1.3		0.9	

family being dominant. Small individuals of crustaceans and tunicates were preyed mainly by *T. albacares*.

Results from the cumulative prey curve showed stabilization, with 80 stomachs and 16 food items for *T. albacares*; and 65 stomachs and 20 food items for *A. solandri*. Thus, the food items diversity was sampled satisfactorily (Figure 4). Prey lengths ranged from 1cm to 37 cm for *T. albacares* and from 1 cm to 35 cm for *A. solandri* (Figure 5). Small prey items (< 3 cm) were represented by Brachyuran megalopae and cephalopods, and larger prey items were represented mainly by flying fishes.

No relationship was observed between predator size and the occurrence of main prey groups, *i.e.*, fish, cephalopods, and crustaceans. The predominant prey was fish, with the occurrence of crustaceans only in the FL classes of 70 and 90 cm in *T. albacares*; and 110 cm for *A. solandri* (Figure 6).

The proportions of stomach fullness categories were similar for both *T. albacares* and *A. solandri*, with a predominance of 48.4% of empty stomachs in *A. solandri*; and 46.8% in *T. albacares* (Figure 7).

Niche overlap of the diet between predators was 94.8% similar when calculated in number of preys, and 89.9% similar in relation to the weight of preys.

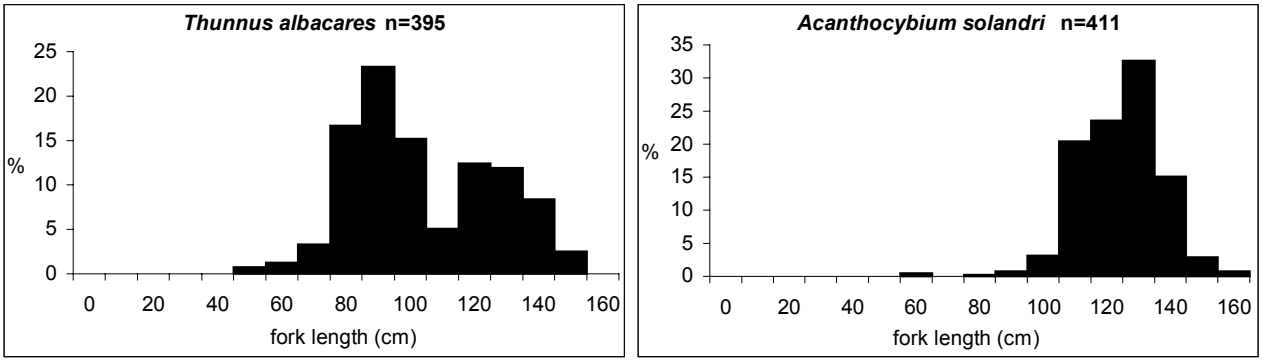

Figure 3. Fork length distributions for males and females of *T. albacares* and *A. solandri*

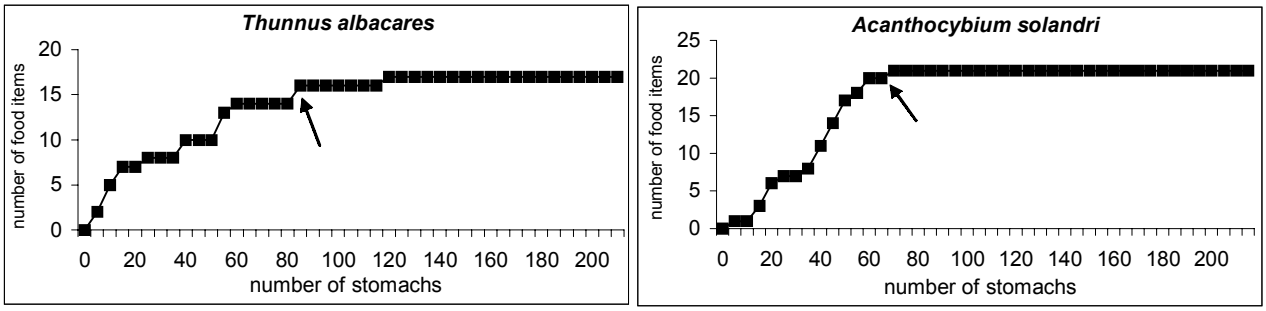

Figure 4. Number of food items per number of stomachs for *A.solandri* and *T. albacares* in th Saint Peter and Saint Paul Archipelago. (Arrows indicate stabilization)

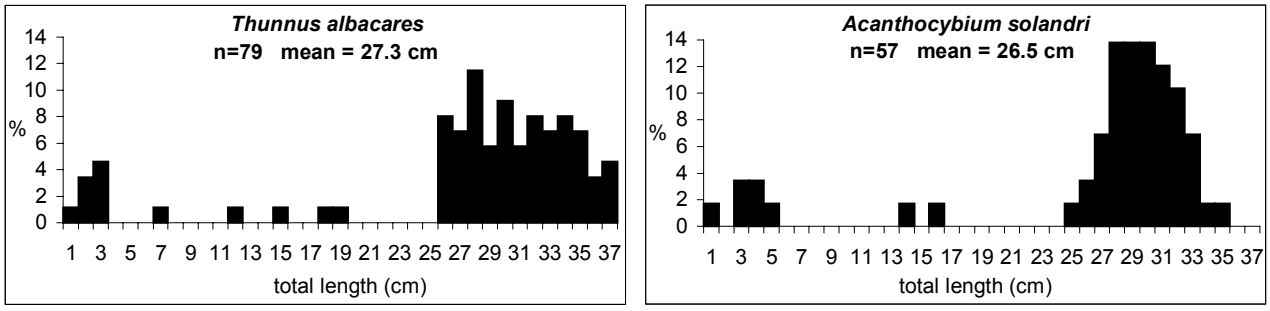

Figure 5. Prey length of *Thunnus albacares* and *Acanthocybium solandri*

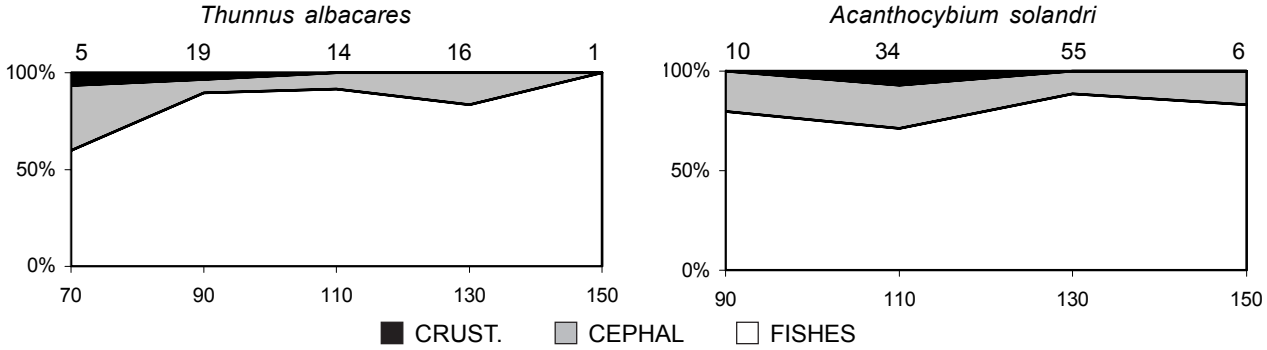

Figure 6. Proportions of main items in the ocurrence of prey frequency per fork length of *T. albacares* and *A. solandri* in the Saint Peter and Saint Paul Archipelago. (Values at the top refer to the number of analyzed stomachs in the respective length classes)

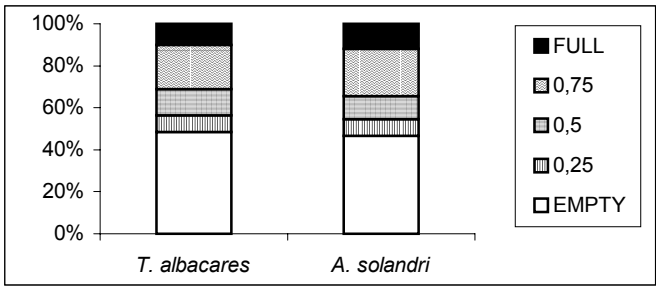

Figure 7. Proportions of stomach fullness of *T. albacares* and *A. solandri* in the Saint Peter and Saint Paul Archipelago

DISCUSSION

The daily period of observed predatory activity of *T. albacares* is more intense at dawn and sunset (ROGER and GRANDPERRIN, 1976; ZAVALA-CAMIN, 1981), when the flying fish *C. cyanopterus* begin to concentrate near the surface. Fishermen take advantage of this fact for fishing. *C. cyanopterus* is very abundant around the SPSPA, mainly between November and March, when fishes gather for reproduction and utilize the rocks for egg attachment (MONTEIRO *et al*., 1998; LESSA *et al*., 1999). In turn, *A. solandri* is captured throughout the day, with better catches at dawn and sunset. The occurrence in the stomachs of brephoepipelagic fishes such as *Dactylopterus volitans*, Holocentridae and Monacanthidae indicates that there is dispersion of eggs from these families in oceanic waters, and that young forms are also preyed on by *T. albacares* and *A. solandri* before they reach adulthood and migrate to coastal waters. In surveys about the distribution and abundance of icthyoneuston in the SPSPA surroundings, the dominant family was Exocoetidae (81.3% in number), of which *C. cyanopterus* represented 73.2% of the total (LESSA *et al*., 1999). Hemiramphidae represented 14.4% and 0.05% were represented by Tetraodontidae, Dactylopteridae and Myctophidae. Quantitative species composition of the icthyoneuston was similar to that of fishes in the stomach contents of *T. albacares* and *A. solandri,* where the dominant fish was also *C. cyanopterus*. Flying fishes are also the main food items of the seabirds inhabiting the islands. NAVES *et al*. (2002) pointed out the importance of Exocoetidae in the diet of seabirds in the SPSPA, which share resources with pelagic predators, though they do not compete directly. Exocoetidae represented 86.7% of total occurrences in regurgitation samples of *S. leucogaster*; 46% in the brown noody, *Anous stolidus*; and 25.9% in the black noody, *A. minutus* (NAVES *et al*., 2002). BOTH (2001) found that diet composition of the brown booby (*Sula leucogaster*) in the SPSPA is represented by *C. cyanopterus* (53.4%), and *O. micropterus* (36.6% of the total occurrences in the diet).

Among fishes, only the myctophid *Diaphus* sp. reaches the inferior mesopelagic layer (LEGAND *et al*., 1972). All others are epipelagic. *Diaphus* sp. performs

vertical migration, staying in the epipelagic at night, when the *T. albacares* feeding activity is low (ROGER and GRANDPERRIN, 1976; LEGAND *et al*., 1972). This is the probable cause of the few occurrences of myctophids. Among cephalopods, all identified taxa perform vertical migration (ROPER and YOUNG, 1975). Considering that both *T. albacares* and *A. solandri* feed preferentially at the dawn and sunset, the cephalopods would be preyed during these periods of vertical movement. The occurrence of Brachyuran megalopae is probably derived from the shores of the Archipelago, which shelter Brachyura, particularly the crab *Grapsus grapsus* (OLIVEIRA *et al*., 1996). The occurrence of small prey (1 to 2 cm), such as crustaceans and salps, was probably related to the food selectivity of the gill rakers. MAGNUSON and HEITZ (1971) have demonstrated that in scombrids with no gill rakers, like *A. solandri*, crustaceans were absent, whereas in scombrids with gill rakers (*Thunnus* spp. and *Katsuwonus pelamis*), crustaceans and small cephalopods made up 40 to 67 % of the diet.

According to ROGER (1988), in areas of low prey density, *T. albacares* feeds in small schools eating any kind of prey, with an average of 6 to 12 preys in the stomach. Around the SPSPA, the number of preys per non-empty stomach was low, ranging from 1 to 5. This is attributed not to low prey density, but to the large size of the dominant prey *C. cyanopterus* (27 cm in average), which take up more room in the stomach. The high proportion of empty stomachs of *T. albacares* and *A. solandri* can be attributed to prey dispersion in the adjacent sea, where food is not heaped, as it is around the islands. Although stomachs were collected during fishing activity, it can be assumed that during the day *T. albacares* and *A. solandri* have low feeding activities and, therefore, empty stomachs. When predatory activity begins at dawn and sunset, about 10% of stomachs are full due to the presence of two or more flying fishes, which were preyed before the predator was caught. A maximum of eleven flying fishes (2.7 kg) was found in the stomach of a *T. albacares* of 138 cm FL, and even so, the fish was hooked when swallowing yet another flying fish. This implies that predators with high metabolism, like tuna and wahoo, are constantly hungry due to fast digestion (SMITH, 1991) and need to continuously seek for food.

FONTENEAU (1991) and HOLLAND *et al*. (1999) pointed out the importance of residence time and aggregations of tuna over seamounts as earth's magnetic field orientation points and prey densities, as in this case. With regard to the diet composition of oceanic tunas, the prey spectrum for both *T. albacares* and *A. solandri* can be described as a narrow trophic spectrum closely associated with the presence of the high concentration of *C. cyanopterus* in the SPSPA environment. *T. albacares* perform east-west migrations in the tropical Atlantic from the Gulf of Mexico to the Gulf of Guinea (HONMA and HISADA, 1971), and may utilize the high concentration of flying fish in the SPSPA for feeding and energy storage for migration during the main period between November and April. The decrease of catches of *T. albacares* by hand lines between April and October is attributed to the fact that flying fish are much fewer during these months and probably disperse in the open ocean. At this time, handline fishing activity is substituted for longlines in the adjacent waters of the SPSPA, aiming at sharks, billfishes and other tunas. However, trolling line fishing targeting *A.solandri* is performed throughout the year, with no clear seasonal tendencies regarding captures. Among the 25 food items preyed on by both predators, *A. solandri* preyed 21 items, and *T. albacares* preyed 16 food items. This implies a more constant presence throughout the year of *A. solandri* feeding on a greater diversity of prey groups around the islands.

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