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Feeding ecology of *Sula leucogaster*, *Anous stolidus* and *Anous minutus* at Saint Peter and Saint Paul's Rocks, Brazil

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RESUMO. **Ecologia alimentar de *Sula leucogaster, Anous stolidus* e *Anous minutus* no Arquipélago de São Pedro e São Paulo, Brasil.** Regurgitados de três espécies de aves marinhas foram coletados no Arquipélago de São Pedro e São Paulo em três períodos: 07/08-11/09/1998, 20/02-17/03/1999 e 18-30/12/1999. Foram obtidas 90 presas de *S. leucogaster* pertencentes a sete taxa, sendo que 80,0% destas eram peixes-voadores *Exocoetus volitans* e *Paraexocoetus brachypterus* com comprimento total de 80 a 176 mm. Em geral, presas de menor tamanho foram capturadas no mês de dezembro. Foram obtidos oito regurgitados e um conteúdo estomacal de *A. stolidus*, totalizando 50 presas de cinco taxa. Destas, 74,0% eram *Cypselurus cyanopterus* e *Oxyporhamphus micropterus*, a maioria com tamanho de 60 a 80 mm. Em 20 regurgitados de *A. minutus* foram encontrados 13 taxa, totalizando 109 presas, das quais 80,3% eram *Dactylopterus volitans* (8-20 mm), *O. micropterus* (50-90 mm) e *C. cyanopterus* (40-70 mm em dezembro, 10-40 mm em março). Exocoetidae foram as presas mais importantes na dieta das aves, e sua contribuição em número foi diretamente proporcional ao tamanho corporal das espécies: 86,7% em *S. leucogaster*, 46,0% em *A. stolidus* e 25,9% em *A. minutus*. Em comparação com outros locais de ocorrência destas espécies, observou-se que no Arquipélago de São Pedro e São Paulo estas aves consomem pequena quantidade de lulas, e que suas presas possuem maior tamanho. Isto indica que disponibilidade de alimento provavelmente não é um fator limitante de número de aves no arquipélago.
PALAVRAS-CHAVE: *Sula leucogaster*, *Anous stolidus*, *Anous minutus*, Arquipélago de São Pedro e São Paulo, regurgitados, dieta, ecologia.

ABSTRACT. Regurgitation samples in three different species of seabirds were collected on Saint Peter and Saint Paul's Rocks in three periods: 07/08-11/09/1998, 20/02-17/03/1999 and 18-30/12/1999. Ninety prey specimens were sampled in *S. leucogaster* regurgitations. They belonged to seven taxa, of which 80.0% were flying-fishes *Exocoetus volitans* and *Paraexocoetus brachypterus* with total length ranging from 80 to 176 mm. In general, smaller prey was caught in December. Eight regurgitations and one stomach content were sampled in *A. stolidus*, resulting in 50 prey specimens belonging to five taxa. *Cypselurus cyanopterus* and *Oxyporhamphus micropterus* comprised 74.0% of these, mostly with TL from 60 to 80 mm. In 20 *A. minutus* regurgitation samples analysed, 13 taxa were found, totalizing 109 specimens of prey, of which 80.3% were *Dactylopterus volitans* (8-20 mm), *O. micropterus* (50-90 mm) and *C. cyanopterus* (40-70 mm in December, 10-40 mm in March). Exocoetidae were the most important prey in the seabirds' diet, and their numeric proportion was directly related to the body size of the species: 86.7% in *S. leucogaster*, 46.0% in *A. stolidus* and 25.9% in *A. minutus*. When compared to other places where these species occur, birds on Saint Peter and Saint Paul's Rocks consume fewer squid and larger prey. This indicates that the availability of food is probably not a limiting factor to the seabirds' numbers on the islets.
KEY WORDS: *Sula leucogaster*, *Anous stolidus*, *Anous minutus*, Saint Peter and Saint Paul's Rocks, regurgitation, diet, ecology.

Saint Peter and Saint Paul's Rocks (SPSPR – 0º55'10"N 29º20'33"W) are located in the equatorial Atlantic Ocean, 1000 km off the Brazilian coast. It is a small and isolated group of five islets, with a total area of 15.000 m^2 and a highest altitude of 18 m (Lubbock and Edwards 1981). The nearest islands are Fernando de Noronha Archipelago, 630 km away, and Rocas Reef, 760 km away. From December to March, concentrations of spawning flying-fish *Cypselurus cyanopterus* can be observed close to the islets of SPSPR. Migrating Yellowfin Tuna *Thunnus albacares* and other marine and aerial predators are attracted by their heaped occurrence (Lessa *et al.* 1999). There is a commercial fishery of regional importance associated with the high number of tuna and flying-fish (IBAMA 1994).

Birds are the most conspicuous organisms of the emerged portion of SPSPR. Only the Brown Booby *Sula leucogaster*, the Brown Noody *Anous stolidus* and the Black Noody *A. minutus* breed on the islets. Nine other bird species have been recorded flying over the islets and sporadically landing. Mean population numbers are of about 411 *S. leucogaster*, 237 *A. stolidus*, and 309 *A. minutus* (pers. obs.). The number of *S. leucogaster* is fairly constant year round. At least 70% of these birds occur on Belmonte Islet, were there is a dense reproductive colony with about one hundred territories. The other islets are used mainly for roosting. The abundance of the two *Anous* species is higher during the breeding season in the second and in the third quarters of the year. During non-breeding period, the birds which remains on the islets use mainly

Belmont I. for roosting. Territories of *A. stolidus* were found at Belmonte and Challenger islets. Reproductive activities of *A. minutus* takes place on Challenger, Nordeste and Cabral islets. The birds sleep on the islets, moving back and forth from the sea to fish during daytime (pers. obs.; name of islets as Lubbock and Edwards 1981). *Anous stolidus* and *A. minutus* catch their prey at the surface or immediately under or above it by dipping (Ashmole & Ashmole 1967). *Sula leucogaster* fishes plunging from the air (plunge diving), and reaches depths of about 15 m (Nelson 1978).

Being a remote and very small group of islets in the mid Atlantic Ocean, SPSPR have peculiar environmental characteristics. The food web and the complex local hydrographic features, which are related to nutrient income, cycling and redistribution, are still poorly understood (Travassos *et al*. 1999). Seabirds are top predators and remineralizers, playing an important role in the population control of several species of ecological and economical importance. The study of seabird trophic ecology is essential to understand their habits and their interactions with other components of the biota, as well as their relationship with environmental variables. Such study also allows the evaluation of the effects of fisheries and other human activities on seabird populations (Zelickman and Golovkin 1972, Furness and Monaghan 1987). Motivated by geopolitical and scientific factors, the Brazilian Comissão Interministerial para os Recursos do Mar – SECIRM has kept a scientific station at SPSPR since June 1998. This initiative has promoted a major advance in the understanding of the physical and biological processes of the area (Anonymous 1998). The study of the role of seabirds in the SPSPR trophic web is very important for the integration of the existing knowledge on other levels of the web. Moreover, the constant human presence in seabird breeding grounds requires measures for the prevention and reduction of disturbances. Such measures depend on the knowledge of the variables that determine the dynamics of the bird populations.

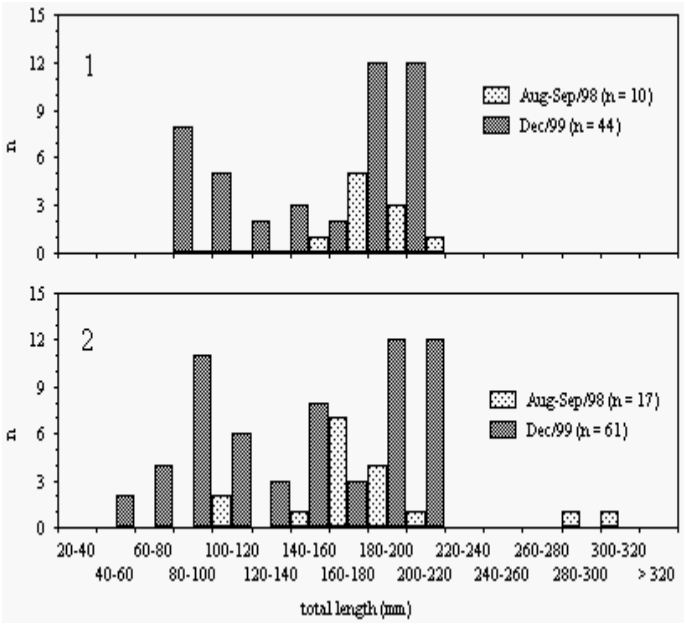
METHODS

We collected regurgitations produced by *S. leucogaster*, *A. stolidus* and *A. minutus* at SPSPR during three periods: 07/08-11/09/1998 (Aug-Sep/98), 20/02-17/03/1999 (Feb-Mar/99) and 18-30/12/1999 (Dec/99). *Sula leucogaster* regurgitation was obtained on the main colony, at roosting places and during banding at Belmont Islet. Regurgitation of *Anous* spp. was collected during banding, and was not found close to nests or at roosting places. Food samples of *A. stolidus* included the stomach content of one bird found dead (table 1). Prey items of *S. leucogaster* were identified right after being sampled according to Figueiredo and Menezes (1978). Regurgitation of *Anous* spp. was kept in alcohol 70% and prey items identified according to Sttaiger (1965), Moser (1984), Matarese *et al*. (1989) and Hunte *et al*. (1995). The diet of *S. leucogaster* was analysed in terms of prey species composition and percentual numeric proportion (N%). In the genus *Anous*, we also analysed the frequency of occurrence (F%) of the prey species in the regurgitation. The total length of the prey (TL, mm) was measured or estimated when it was partially digested. Prey in advanced stages of digestion was treated as "non identified Teleostei".

We used the alometric equation of Birt-Friesen *et al*. (1989) to estimate the daily energy intake of one bird (kj/day) using body mass data (kg), and assuming a digestive efficiency of 75% (Furness 1978, Warham 1996). We used the mean body mass of adult seabirds from SPSPR: 0.199 kg (n = 24) *A. stolidus*, 0.121 kg (n = 10) *A. minutus* and 1.507 kg *S. leucogaster* (considering the sexual dimorphism of this species, the mean body mass was calculated from six males and six females) (pers. obs.). The daily energy intake was converted into daily food intake (g) considering that 1.0 g of fresh fish equals 5.9 kJ (Wiens and Scott 1975). The annual food intake of the three populations was calculated by multiplying the daily food intake of one bird by the mean populations sizes [411 *S. leucogaster*, 237 *A. stolidus* and 309 *A. minutus* (pers. obs.)] and by 365 days.

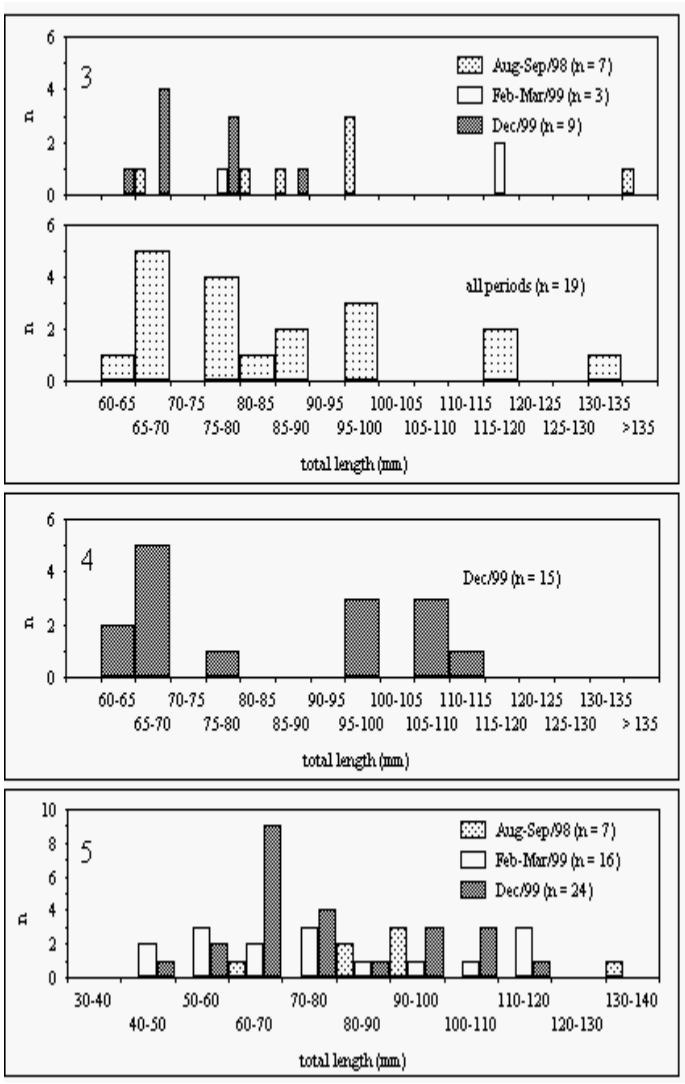
RESULTS

Sula leucogaster. In Dec/99, 26 birds were captured, of which 50.0% regurgitated stomach contents. The weight of the regurgitation ranged between 42.0 and 280.0 g (mean = 117.1 ± 68.1 g, n = 13). The regurgitation was made up of 1 to 9 prey items, with a mean of 4.9 ± 2.5 prey item per regurgitation. In total, 90 prey items of *S. leucogaster* were collected (table 1), belonging to seven taxa: six Teleostei species and one squid, with 91.0% of the fishes being identified to species level (table 2). The TL of prey ranged between 50 and 306 mm (mean = 155.6 ± 51.2 mm, n = 80) and weight varied from 4.0 to 69.0 g (mean = 32.5 ± 22.7 g, n = 21). Exocoetidae represented 86.7% of the total number of prey captured by *S. leucogaster*. *Exocoetus volitans* was the main component of the diet during the three periods studied, representing 71.1% of the 82 identified prey (tables 2 and 3). In Feb-Mar/99, this was the only prey species found. In Aug-Sep/98, *Cypselurus cyanopterus* (N% = 29.4) and *Coryphaena equiselis* (N% = 11.8) also occurred in the diet. In Dec/99, the second most common prey was *Paraexocoetus brachypterus* (N% = 12.7) with TL ranging from 50 to 176 mm (n = 8) (table 3). The TL of *E. volitans* showed a broader range in Dec/99, with two modal classes: 80-100 mm and 180-220 mm (figure 1 and table 3). When all prey species are considered, smaller fishes were captured in Dec/99 (figure 2).



Figures 1-2. Size of *Exocoetus volitans* (1) and Teleostei prey (2) captured by *Sula leucogaster*.

Anous stolidus. Of the 30 birds captured in Feb-Mar/99 and Dec/99, 26.6% (n = 8) regurgitated. The weight of the regurgitation varied from 6.1 to 30.9 g (mean = 13.5 ± 8.5 g, n = 7) and the number of prey per sample ranged from 1 to 12 (mean = 5.6 ± 3.3, n = 9). In eight samples of regurgitation and one stomach content (table 1), 50 Teleostei from five taxa were found (four species and one genus). Flying-fish Exocoetidae represented 46.0% of the total number of prey, followed by Hemirhamphidae *Oxyporhamphus micropterus* (30.0%) and leptocephalus larvae (22.0%). *Cypselurus cyanopterus* and *O. micropterus* had the highest frequency of occurrence and numeric proportion (F% = 88.9 and 44.4, and N% = 44.0 and 30.0, respectively; table 2). The small sample numbers in Aug-Sep/98 (n = 1) and Feb-Mar/99 (n = 2) (tables 1 and 4) make detailed diet analysis impossible in these periods. The stomach content sampled in Aug-Sep/99 was made up of seven *C. cyanopterus* with TL ranging between 70-140 mm. In the two regurgitation samples analysed in Feb-Mar/99, four prey species were found, mainly leptocephalus larvae (F% = 50.0 and N% = 57.8) and *C. cyanopterus* (F% = 100 and N% = 31.6) (table 4). The TL of the prey varied from 50 to 140 mm (mean = 86.2 mm, table 2). *Cypselurus cyanopterus* was present in the diet during the three periods studied, with a lower frequency of occurrence in Dec/99 (F% = 83.3), and a lower numeric proportion in Feb-Mar/99 (N% = 31.6, table 4). *Oxyporhamphus micropterus* was found only in Dec/99 (F% = 66.7, N% = 62.5; table 4). Smaller *C. cyanopterus* were captured in Dec/99, mostly smaller than 80 mm TL. In Aug-Sep/98, the major part of this prey had TL of 80-100 mm (figure 3 and table 4). In Dec/99, *O. micropterus* was found in two class sizes: 60-80 mm and 95-115 mm (figure 4). In general, there was no predominance of any size of prey, but there was a higher abundance of 60-70 mm prey in Dec/99 (figure 5).



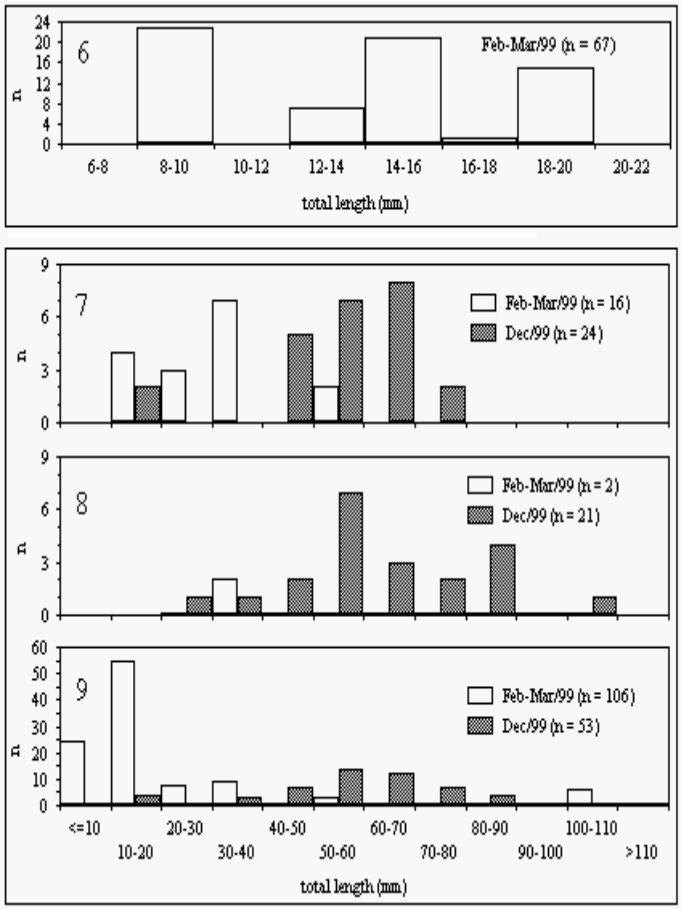
Figures 3-5. Size of *Cypselerus cyanopterus* (3), *Oxyporhamphus micropterus* (4) and Teleostei prey (5) captured by *Anous stolidus*.

Anous minutus. In Feb-Mar/99 and Dec/99, 64.5% of 31 captured birds regurgitated (n = 20, table 1). *Anous minutus* regurgitates more frequently than the other two bird species studied. Regurgitations weighed between 2.0 and 17.4 g (mean = 6.4 ± 4.6 g, n = 9), while number of prey per regurgitation ranged between 2-28 (mean = 8.6 ± 6.6, n = 19). Regurgitation samples collected in Feb-Mar/99 (n = 11) and Dec/99 (n = 9) resulted in 109 prey specimens (table 1) belonging to 10 taxa, of which six were identified to species level. Main prey items in the diet was *Dactylopterus volitans* (F% = 30.0, N% = 41.4), *C. cyanopterus* (F% = 70.0, N% = 24.7) and *O. micropterus* (F% = 45.0, N% = 14.2) (table 2). In Feb-Mar/99, the diet of *A. minutus* was made up mainly of *D. volitans*, *C. cyanopterus*, *Cubiceps* sp. and leptocephalus larvae (table 5). When compared to Feb-Mar/99, in Dec/99 we observed

Table 1. Regurgitation collected during banding (B), and at roosting and nesting places (RN). p: number of prey items, r: number of regurgitations. (*) Stomach content.

Species	Aug-Sep/99		Feb-Mar/99		Dec/99		Total			
	RN	B	RN	B	RN	B	RN	B	p	r
Sula leucogaster	17 p	0	10 p	0	0	13 r, 63 p	27 p	13 r, 63 p	90	13
Anous stolidus	7 p *	0	0	2 r, 19 p	0	6 r, 24 p	7 p *	8 r, 43 p	50	8
Anous minutus	0	0	0	11 r, 109 p	0	9 r, 53 p	0	20 r, 162 p	109	20

an increase in the contribution of *O. micropterus* to the diet (F% = 88.9, N% = 39.6), replacing *D. volitans*, and a lack of *Cubiceps* sp. (table 5). The size of the Teleostei prey varied between 10 and 110 mm (mean = 37.4 mm, table 2). Small prey caught by *A. minutus* included Euphausiacea of c. 2 mm. *Dactylopterus volitans* had a TL of 10-20 mm (figure 6). In Feb-Mar/99, TL of *C. cyanopterus* ranged between 15 and 60 mm, and in Dec/99, 91.7% of this prey had a size from 40 to 80 mm (table 5 and figure 7). Smaller *O. micropterus* was found in Feb-Mar/99 (figure 8), and this is also the pattern for Teleostei prey in general (figure 9).



Figures 6-9. Size of *Dactylopterus volitans* captured by *Anous minutus* (6), size of *Cypselerus cyanopterus* (7), *Oxyporhamphus micropterus* (8) and Teleostei prey (9) captured by *Anous minutus*.

Overlap in the diet of the seabirds of Saint Peter and Saint Paul's Rocks. A higher diversity of prey was found in the diet of *A. minutus* (10 taxa), followed by *S. leucogaster* (6 taxa) and *A. stolidus* (5 taxa). According to the data shown in table 2, there is a minor overlap in prey species composition of the diet of the seabirds studied. At species level, *C. cyanopterus* was the only prey shared by the three seabirds. The diet of the two *Anous* species had four prey types in common: leptocephalus, *C. cyanopterus*, *O. micropterus* and *R. pretiosus*. The size of prey captured by *S. leucogaster*, *A. stolidus* and *A. minutus* matched in the TL interval from 40 to 120 mm, which corresponds to the smaller prey of *S. leucogaster*, caught mainly in Dec/99 (figures 2 and 10). *Anous stolidus* and *A. minutus* caught prey with a TL of up to 120 mm (figure 10). Despite their small body size, *A. minutus* had a greater proportion of prey with a TL of 100-120 mm in the diet. However, *A. minutus* also captures a great quantity of prey with a TL shorter than 20 mm, represented mainly by *D. volitans*.

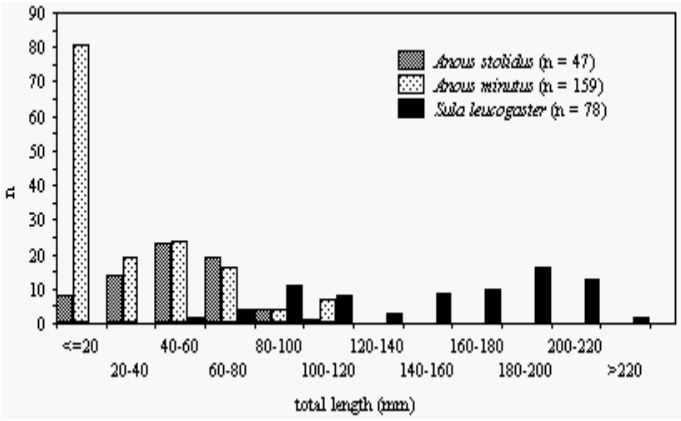


Figure 10. Size of Teleostei prey captured by *Sula leucogaster*, *Anous stolidus* and *Anous minutus* off Saint Peter and Saint Paul's Rocks.

This is corroborated by the fact that the regurgitation of *A. minutus* has approximately half the weight and twice as much prey as those of *A. stolidus*. In Dec/99, *C. cyanopterus* and *O. micropterus* were the predominant prey in the diet of *A. stolidus* (table 4; TL: mean = 73.3 ± 11.2 mm, n = 9; TL: mean = 86.1 ± 20.1 mm, n = 15, respectively). These two species were also the prevailing

Table 2. Prey species of *Sula leucogaster*, *Anous stolidus* and *A. minutus*. (N) Number, (N%) numeric proportion, (F%) frequency of occurrence, (TL) total length (mm), (SD) standard deviation, (W) weight (g), (*) lack of information.

	Sula leucogaster						*Anous stolidus*					*Anous minutus*				
	N	N%	TL range	TL mean ± SD; (n)	W range	W mean ± SD; (n)	N	N%	F%	TL range	TL mean ± SD; (n)	N	N%	F%	TL range	TL mean ± SD; (n)
Teleostei	89	98.9	50-306	155.6±51.2; (80)	4-69	32.5±22.7; (21)	50	100	100	50-140	86.2±21.3; (31)	160	98.8	100	10-110	37.4±28.7; (154)
leptocephalus	0	0					11	22.0	11.1	50-120	86.4±21.1; (11)	9	5.7	30	75-110	99.4±15.9; (9)
Alepisauridae	0	0					0	0				1	0.6	5	60	
Alepisaurus ferox	0	0					0	0				1	0.6	5	60	
Exocoetidae	78	86.7	50-220		4-69		23	46.0	100	50-140	86.1±22.0; (20)	42	25.9	75	15-80	49.6±19.1; (40)
Cypselurus cyanopterus	6	6.7	110-200		*	*	22	44.0	88.9	50-140	87.5±21.7; (19)	40	24.7	70	15-80	49.6±19.1; (40)
Exocoetus volitans	64	71.1	83-215	165.0±41.1; (54)	4-69	35.4±20.8; (26)	1	2.0	11.1	60		0	0			
Paraexocoetus brachypterus	8	8.9	50-176	120.5±46.0; (8)	12-19	15.5±5.0; (2)	0	0				0	0			
Hemirhamphidae	0	0					15	30.0	44.4	60-112	86.1±20.1; (15)	25	15.4	55	30-110	64.4±20.1; (24)
Hyporhamphus sp.	0	0					0	0				1	0.6	5	40	
Oxyporhamphus micropterus	0	0					15	30.0	44.4	60-112	86.1±20.1; (15)	23	14.2	45	30-110	65.4±19.8; (23)
Dactylopteridae	0	0					0	0				67	41.4	30	10-20	14.2±3.8; (67)
Dactylopterus volitans	0	0					0	0				67	41.4	30	10-20	14.2±3.8; (67)
Coryphaenidae	2	2.2	290-306	*	*	*	0	0				0	0			
Coryphaena equiselis	2	2.2	290-306	*	*	*	0	0				0	0			
Bramidae	1	1.1	30		*		0	0				0	0			
Brama brama	1	1.1	30		*		0	0				0	0			
Gempylidae	0	0					1	2.0	11.1	60		2	1.2	10	70	
Gempylus serpens	0	0					0	0				1	0.6	5	70	
Ruvettus pretiosus	0	0					1	2.0	11.1	60		1	0.6	5	70	
Nomeidae	0	0					0	0				13	8.0	10	10-30	21.9±7.2; (13)
Cubiceps sp.	0	0					0	0				13	8.0	10	10-30	21.9±7.2; (13)
Non identified Teleostei	8	8.9	*	*	*	*	0	0				1	0.6	5	*	*
Euphasiacea	0	0					0	0				2	1.2	10	*	*
Loliginidae	1	1.1	*		*		0	0				0	0			
Total	90	100					50	100				162	100			

Table 3. Prey species of *Sula leucogaster*. (N) Number, (N%) numeric proportion, (TL) total length, (*) lack of information.

	N			N%			TL range (mm)			Weight range (g)		
	Aug-Sep	Feb-Mar	Dec	Aug-Sep	Feb-Mar	Dec	Aug-Sep	Feb-Mar	Dec	Aug-Sep	Feb-Mar	Dec
Teleostei	17	10	62	100	100	98.4	157-306	157-206	50-215	27-226	31-62	4-69
Cypselurus cyanopterus	5	0	1	29.4	0	1.6	110-200		80	*		*
Exocoetus volitans	10	10	44	58.8	100	69.8	157-206	157-206	83-215	27-62	31-62	4-69
Paraexocoetus brachypterus	0	0	8	0	0	12.7			50-176			12-19
Coryphaena equiselis	2	0	0	11.8	0	0	290-306			*		
Brama brama	0	0	1	0	0	1.6			30			*
Non identified Teleostei	0	0	8	0	0	12.7			*			*
Loliginidae	0	0	1	0	0	1.6			*			*
Total	17	10	63	100	100	100						

Table 4. Prey species of *Anous stolidus*. (N) Number, (F%) frequency of occurrence, (N%) numeric proportion, (TL) total length.

	N			F%			N%			TL range (mm)		
	Aug-Sep	Feb-Mar	Dec	Aug-Sep	Feb-Mar	Dec	Aug-Sep	Feb-Mar	Dec	Aug-Sep	Feb-Mar	Dec
Teleostei	7	19	24	100	100	100	100	100	100	70-140	50-120	50-112
leptocephalus	0	11	0	0	50	0	0	57.8	0		50-120	
Cypselurus cyanopterus	7	6	9	100	100	83.3	100	31.6	37.5	70-140	80-120	50-90
Exocoetus volitans	0	1	0	0	50	0	0	5.3	0		60	
Oxyporhamphus micropterus	0	0	15	0	0	66.7	0	0	62.5			60-112
Ruvettus pretiosus	0	1	0	0	50	0	0	5.3	0		60	
Total	7	19	24				100	100	100			

type of prey in the diet of *A. minutus* (table 5), but were of shorter length (TL: mean = 59.6 ± 15.2 mm, n = 24; TL: mean = 67.9 ± 19.0 mm, n = 21, respectively). In Feb-Mar/99 we observed a greater difference between the diets of the two species of *Anous* spp. In *A. minutus*, the most common type of prey was *D. volitans* (TL between 10-20 mm, table 5). This species was absent from the regurgitation of *A. stolidus*, which caught a greater amount of leptocephalus (TL between 50-120 mm, table 4). The number of Exocoetidae found in the diet was directly proportional to the bird body size: 86.7% in *S. leucogaster*, 46.0% in *A. stolidus* and 25.9% in *A. minutus* (table 2).

Food intake. Using the alometric equation of Birt-Friesen *et al.* (1989), we calculated that the daily food consumption of *S. leucogaster*, *A. stolidus* and *A. minutus* was 356.3 g, 92.3 g and 66.3 g, respectively. Considering these values, food intake of the three resident species throughout the year is around 70 t, of which at least 15 t are larvae and juveniles caught by *Anous* spp. (table 6).

DISCUSSION

In southern Brazil, the availability of fishery bycatch results in a great amount of demersal fish and higher prey

Table 5. Prey species of *Anous minutus*. (N) Number, (F%) frequency of occurrence, (N%) numeric proportion, (TL) total length, (*) lack of information.

	N		F%		N%		TL range (mm)	
	Fev-Mar	Dec	Fev-Mar	Dec	Fev-Mar	Dec	Fev-Mar	Dec
Teleostei	107	53	100	100	98.2	100	10-110	30-110
leptocephalus	6	3	27.3	33.3	5.5	5.7	110	75-80
Alepisaurus ferox	1	0	9.1	0	0.9	0	60	
Exocoetidae	0	2	0	11.1	0	3.8		15-20
Cypselurus cyanopterus	16	24	63.6	77.8	14.8	45.2	15-60	20-80
Hemirhamphidae	0	1	0	11.1	0	1.9		40
Hyporhamphus sp.	0	1	0	11.1	0	1.9		40
Oxyporhamphus micropterus	2	21	9.1	88.9	1.8	39.6	40	30-110
Dactylopterus volitans	67	0	54.6	0	61.5	0	10-20	
Gempylus serpens	0	1	0	11.1	0	1.9		70
Ruvettus pretiosus	1	0	9.1	0	0.9	0	70	
Cubiceps sp.	13	0	18.2	0	11.9	0	10-30	
Non identified Teleostei	1	0	9.1	0	0.9	0	*	
Euphausiacea	2	0	18.2	0	1.8	0	2	
Total	109	53			100	100		

Table 6. Estimates of energy and food intake by the birds on Saint Peter and Saint Paul's Rocks.

Species	One bird			Population	
	kj/day	g/day	% body mass	kg/day	kg/year
Sula leucogaster	2102.1	356.3	23.6	146.4	53436.0
Anous stolidus	544.7	92.3	46.4	21.9	7993.5
Anous minutus	390.9	66.3	54.8	20.5	7482.5
Total				356.2	68912.0

diversity in the diet of *S. leucogaster*. On Moleques do Sul Islands, prey size ranged between 50-213 mm (Bege and Pauli 1989). On Currais Islands, 30 prey species were found in the diet of *S. leucogaster*, and these fishes had mean TL of 104 mm (33-344 mm) and weighed 18.6 g (0.6-280.6 g) (Krul 1999). The mean weight of prey on SPSPR (32.5 g, table 2) is almost twice this value (even though 70.0% of the prey were sampled in Dec/99, when a greater proportion of small prey occurred in the diet), and only seven prey species were found. The mean weight of the regurgitation on SPSPR (117.1 g) is similar to that measured in southern Brazil (112.9 g) (Krul 1999), but the larger size of prey on SPSPR results in a smaller number of prey items per regurgitation (1-9, mean = 4.9). On Currais and Moleques do Sul islands, the number of prey items per regurgitation varies, respectively, between 1 to 35 (mean of 6.4, Krul 1999) and 1 to 53 (Bege and Pauli 1989). In the Abrolhos Archipelago, *S. leucogaster* prey

mainly on beakfish *Hemirhamphus brasiliensis* (Alves *et al*. 1997). In northern Australia, Blaber *et al*. (1995) found prey with a standard length ranging between 20 and 370 mm. On Hawaii, the diet of *S. leucogaster* comprised 18 families of fish and one family of squid (representing 5% of the volume of food consumed), with mean TL of 94 mm (ranging between 3-319 mm) (Harrison *et al*. 1983). On SPSPR, mean prey size (155.6 mm, table 2) indicates the capture, and thus, the availability of larger prey.

Diet composition and prey size of *A. stolidus* on SPSPR are different from what was found by Ashmole and Ashmole (1967) on the Christmas Islands, Pacific Ocean. In this location, fish and squid had the same importance in terms of volume, and fish smaller than 40 mm represented 44% of prey items (most measuring between 20 to 40 mm). Prey captured on SPSPR are bigger than 40 mm (figure 5) and do not include squid. On Hawaii, Harrison *et al*. (1983) found 7.7 prey per regurgitation (mean standard length = 48 mm, range between 3-185 mm), including 33 families of fish, two families of squid (representing 33% of food volume), two groups of crustaceans and one group of insects.

The information about the diet of *A. minutus* on SPSPR is similar to that presented by Ashmole and Ashmole (1967) for *Anous tenuirostris* on the Christmas Islands, a species that has a mean weight 24.9% (90.9 g) smaller than *A. minutus* on SPSPR (121 g; pers. obs.). Ashmole and Ashmole (1967) recorded 17 families of fish in the diet of *A. tenuirostris*, of which 10 were significantly important, especially Exocoetidae, Scombridae and Blenniidae. On the above-mentioned locality, fish smaller than 40 mm represent 90% of *A. tenuirostris* prey items. In *A. minutus* on SPSPR, prey of this size represent 64.9% of the total. On Hawaii, Harrison *et al*. (1983) found an average number of 12.6 prey per regurgitation in *A. minutus*. These authors identified 36 families of fish, 2 families of squid and three groups of crustaceans, with mean prey size of 34 mm (range between 5-137 mm, standard length). The diet of *A. tenuirostris* on Hawaii was characterized by the presence of *Cirripectus* sp. (Blenniidae), an abundant fish found among calcareous algae (genus *Lithothamnion*) in the outer limit of atolls (Strasburg pers. comm., *apud* Ashmole and Ashmole 1967). On SPSPR, a single *A. minutus* was observed collecting food over calcareous algae on 06 March 1999. The bird touched the ground with its feet, but remained in the air with its wings beating. This is probably the same behaviour used by *A. tenuirostris* to capture *Cirripectus* sp.

The size of prey caught by *S. leucogaster*, *A. stolidus* and *A. minutus* on SPSPR is larger than what has been observed in other places where these species occur. Bigger prey means greater energy intake per prey captured (Erwin 1977). Thus the ability to obtain energy easily suggests that there is less intra and interspecific competition for food, and that food availability is not a limiting factor to the seabirds' numbers on SPSPR.

The great amount of Exocoetidae in the diet of seabirds on SPSPR confirms the importance of flying-fish as an essential species for the epipelagic trophic chain in the region, as shown for other trophic levels (Monteiro *et al*. 1998, Lessa *et al*. 1999, Vaske Junior 2001). The main difference in the composition of the diet of seabirds on SPSPR when compared to other locations was the small amount of squid in the former (Ashmole and Ashmole 1967, Harrison *et al*. 1983).

Anous stolidus and *A. minutus* feed on fish larvae and juveniles. Therefore the composition of their diets depends on the reproductive cycle of the prey species. Larvae and juveniles usually present rapid growth. For this reason, *Anous* spp. takes advantage of different food resources according to their availability in space and time, which can be stochastic and of short duration. Several authors have reported a strong relationship between the feeding habits of *A. stolidus* and *A. minutus* and the predatory activity of fish, such as tuna, which force their prey to surface (Ashmole and Ashmole 1967, Harrison *et al*. 1983). This type of association remains unknown on SPSPR. The difference in the size of prey caught by *A. minutus* and *A. stolidus* is probably due to the considerable difference in body size between the species, since *A. stolidus* is 39.2% heavier and 4.8% larger in culmen length (pers. obs.). Small differences in the width and depth of the beak may dramatically alter its format and function, even without any alteration in culmen length (Ashmole 1968). The longer and thinner beak of *A. minutus* allows it to handle items of reduced size, although these birds are able to capture bigger prey. Considering that on SPSPR the two species probably have similar seasonal cycles of abundance and reproduction (pers. obs.), the difference in prey size caught by *A. minutus* and *A. stolidus* leads to ecological segregation, thus decreasing interspecific competition.

The frequency at which birds regurgitate when captured may be interpreted as a measure of sensitivity to disturbance. The 50.0% value observed in *S. leucogaster* (see Results) may be related to the high density of the species on the ground. This situation results in frequent interaction, struggles between individuals and higher aggression, which could condition birds to regurgitate more easily. Considering the great difference in values obtained for *A. stolidus* and *A. minutus* (i.e., 26.6% and 64.5% respectively, see Results), we conclude that *A. minutus* is more sensitive to disturbance. This information is relevant for the conservation of the seabird populations and control of human activities on SPSPR.

Fish-eating birds can also regurgitate "pellets". As a result of specific feeding habits, pellets of seabirds are composed of scales, eye lenses, otoliths, fish bones and fragments of crustacean and insect shells (Jordán 1959,

Harris and Wanless 1993). Pellets of *A. stolidus* (n = 412) and *S. leucogaster* (n = 11) were collected by Blaber *et al*. (1995) in northern Australia, proofing that these species are capable of doing that. On SPSPR, despite the effort to find such samples, pellets were never found.

The information available about the fish fauna in the region of SPSPR is related to larval (Lessa *et al*. 1999) and adult stages (Monteiro *et al*. 1998, Vaske Junior 2001). In such context, the study of the diet of *Anous* spp. is an important source of information about the occurrence, the distribution and the abundance of juvenile fish in the area of SPSPR. It is relevant to highlight the occurrence of *Alepisaurus ferox* in the regurgitation of *A. minutus*, since this is the first record of Alepsauridae larvae in the region (Vaske Junior *et al*. 1998, Lessa *et al*. 1999). Squids were absent from the diet of *A. stolidus* and *A. minutus*, and only one individual was found in the regurgitation of *S. leucogaster* in SPSPR. This indicates that squid, especially small individuals, are poorly abundant in the region. Among the species of flying-fish, predominance in numbers of *Cypselurus cyanopterus* has been recorded (Monteiro *et al*. 1998, Lessa *et al*. 1999). Juveniles of *Exocoetus volitans* with sizes ranging from 24 to 182 mm were collected near to SPSPR in September by Monteiro *et al*. (1998). Lubbock and Edwards (1981) observed a high abundance of this species off the islets. The predominance of *E. volitans* in the diet of *S. leucogaster* may either reflect poorly known fluctuations in the occurrence and abundance of this fish, or, although less probable, indicate a selection of prey species by the avian predator.

The amount of *E. volitans* found in the diet of *S. leucogaster* and its seasonal variation has no parallel in the diets of *Anous* spp. This prey species caught by *S. leucogaster* (mean TL 165.0 mm) was, on average, bigger than the mean size of Teleostei prey of *A. stolidus* (mean TL 86.2 mm) and *A. minutus* (mean TL 37.4 mm) (table 2, figure 10). The smaller amount of *E. volitans* in the diet of *Anous* spp. indicates a low availability of individuals smaller than 165 mm in the birds' feeding ground. Otherwise, it may indicate the selection of prey species by *Anous* spp. In the stomach content of *A. stolidus* collected in Aug-Sep/98, seven *C. cyanopterus* were found, with TL between 70 and 140 mm (table 4). This was the same period when the highest amount of this prey species was found in the diet of *S. leucogaster* (TL 110-200 mm, table 3). In Dec/99, smaller individuals (TL 20-80 mm) were the main prey of *A. minutus* (N% = 45.2) (table 5).

Vaske Junior (2001) studied the diet of 19 large pelagic fish species caught by long-liners off the north-east coast of Brazil and SPSPR area. He found *Dactylopterus volitans* and *Cypselurus* spp. as important prey of *Thunnus albacares*, *Tetrapturus albidus*, *Istiophorus albicans* and *Coryphaena hippurus*. At SPSPR area, *T. albacares* preys upon *Cypselurus* spp. from 260 to 350 mm of TL, larger than the 110-200 mm fishes captured by *S. leucogaster*. It can be said that the seabirds and the pelagic fishes mentioned share resources, though they do not compete directly. The annual food intake of the three resident species on SPSPR is around 70 t, of which at least 15 t are larvae and juveniles caught by *Anous* spp. (table 6). To feed on a great number of small prey means a higher energetic cost to the predator and a higher mortality rate to the prey. Such aspects of prey and predators population dynamics are still poorly understood and quantified (Koslow 1992, Cairns 1992). SPSPR is considered to be a reproductive ground of *C. cyanopterus* probably isolated from the Fernando de Noronha Archipelago due to hydrographic conditions (Lessa *et al*. 1999). However, the predation of eggs and larvae by fish and seabirds may contribute to the reduced flow of young flying-fish to areas outside the SPSPR region.

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