

# DIET OF EASTERN PACIFIC BROWN BOOBIES *SULA LEUCOGASTER BREWSTERI* ON ISLA SAN JORGE, NORTH-EASTERN GULF OF CALIFORNIA, AND AN APRIL COMPARISON WITH DIETS IN THE MIDDLE GULF OF CALIFORNIA

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## SUMMARY

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During 1998–2000 Eastern Pacific Brown Boobies *Sula leucogaster brewsteri* at Isla San Jorge fed on 30 prey species, including one squid, 14 small pelagic shoaling fishes and 15 benthic fishes. The data suggested that Pacific Anchoveta *Cetengraulis mysticetus* was the food item of choice. By comparing the diet of Brown Boobies at San Jorge with that at Isla San Pedro Mártir and Isla San Ildefonso it seemed that availability of benthic fishes to the Brown Boobies at San Jorge, but not at San Pedro Mártir and San Ildefonso, explains the longer breeding season and residence of this species at San Jorge.

Key words: Brown Booby, *Sula leucogaster*, Gulf of California, diet, distribution, oceanography, Pacific Anchoveta

## INTRODUCTION

The Eastern Pacific Brown Booby *Sula leucogaster brewsteri* is an ubiquitous seabird throughout the Gulf of California, north-western Mexico, where it nests on several islands (Everett & Anderson 1991). On a number of islands it is one of the major nesters, with colonies numbering in the thousands and, on two islands, tens of thousands. Despite being widespread and common, little information about the ecology of Brown Boobies has been published. Knowledge of their diet is important because of their abundance and because of the large numbers of other fish-eating homeotherms with which they share the habitat. It is also important because of the presence of an intensive fishery near some of the breeding colonies.

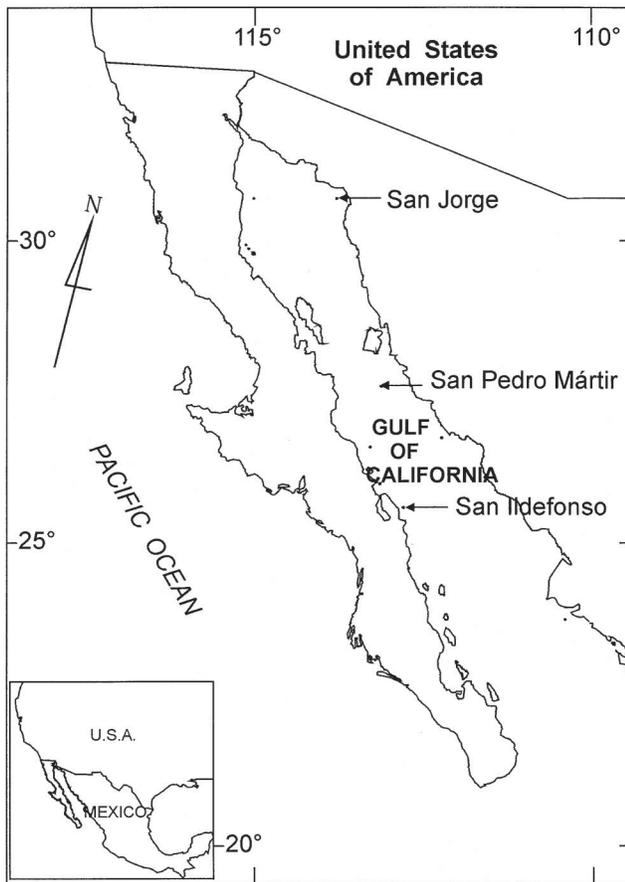
Brown Boobies are near-shore feeders and have been reported to eat mostly flying fish (Exocoetidae) and squid (Dorward 1962, Nelson 1978, Harrison *et al.* 1983). However, they consume many other food items as well, with considerable variation among localities, and make important use of certain seasonal resources (Cramp & Simmons 1977, Nelson 1978). For example, in one study in Hawaii 244 food samples contained over 50 species. Flying fish were second to scads, amber-jacks, and their allies (family Carangidae) as components of the diet, while goatfish (Mullidae) occupied third place (Harrison *et al.* 1983).

The only published information on the diet of Brown Boobies in Mexico is from Isla San Pedro Mártir, in the middle of the Gulf of California. Here, at the beginning of the 1990 breeding season

(spring), they fed mostly on Pacific Sardines *Sardinops sagax* and Northern Anchovies *Engraulis mordax*. During the summer of that year they included the flying fish *Cheilopogon papilio*, Pacific Mackerel *Scomber japonicus*, and halfbeaks *Hyporhamphus* sp. in their diet (Angeles-Perez *et al.* 1991, Tershy *et al.* 1992). On this island in 1991 and 1992 they consumed mostly Northern Anchovies (Tershy *et al.* 1992). Species composition was similar in regurgitations from males and females, but regurgitations from females were heavier (Angeles-Perez *et al.* 1991).

We studied the diet of Brown Boobies on Isla San Jorge (Fig. 1). This island is located in the shallow northern Gulf of California. Large areas between the island and the nearby coast are less than 16 m deep and waters to the west reach depths of 45 m. The ocean around the island is entirely and year-long Gulf of California Water (Lavín *et al.* 1997). It has a mean salinity of 35.7‰ in winter and 35.4‰ in summer (Maluf 1983). The shallowness of the area creates a complex tide, wind and thermally-driven system of rotary currents which produces winter upwellings around the island (Maluf 1983). Mean surface water temperatures vary from 15.5°C in winter to 30.5°C in summer (Robinson 1973). Tides are mixed semidiurnal and have a maximum range of approximately 5 m (Marinone & Lavín 1997).

The Brown Booby colony at Isla San Jorge is not only large in number of breeding pairs, but it differs in its ecology from other colonies in the Gulf of California except, perhaps, the small colony on Roca Consag, also in the northern gulf. For example, Brown Boobies at San Jorge have a much longer breeding season



**Fig. 1.** The Gulf of California, depicting the islands from which Brown Booby regurgitations were collected, 1998–2000.

than do colonies elsewhere in the gulf (Mellink 2000). Brown Boobies in this colony normally do not abandon the island after the breeding season as they do on other islands in the Gulf of California. Both facts suggest that food is sufficient throughout the year.

Some monitoring of fish larvae in the area has been conducted, and species that potentially occur there can be discerned from general guides (e.g. Fischer *et al.* 1995). However, the composition of the local fish fauna and its dynamics are not known. Neither are the local roles of other piscivores in the marine food web known (a first evaluation of the diet of sea lions has just been completed; Romero-Saavedra & E. Mellink unpubl. data).

Other colonies of Brown Boobies in the Gulf of California exhibit different life-history traits. They are also surrounded by waters with different oceanographic characteristics. By comparing life histories of the boobies in different colonies it may be possible to elucidate the causes of the longer breeding season on San Jorge. To start exploring this issue we obtained some data from two other Brown Booby colonies in the gulf: Isla San Pedro Mártir, and Isla San Ildefonso.

Isla San Pedro Mártir is the southernmost of the Midriff Islands. It rises from the San Pedro Mártir basin and its surrounding waters

are mostly over 180 m deep. Gulf of California Water constitutes the superficial ocean layer around the island year-long (Lavín *et al.* 1997), with a mean salinity of 35.2‰ in winter and 35.1‰ in summer (Maluf 1983). Mean surface water temperatures vary from 15°C in winter to 30°C in summer (Robinson 1973). Tides are mixed semidiurnal and have a maximum range of approximately 1.5 m (Marinone & Lavín 1997).

Isla San Ildefonso is located in the middle Gulf of California. Despite being only 10 km from shore, the waters that surround it are mostly over 90 m deep. Superficial water during the winter is Gulf of California Water, but during the summer the island lies in the region where this water mass meets Superficial Equatorial Water (Lavín *et al.* 1997). The water has a mean salinity of 35.2‰ in winter and 35.4‰ in summer (Maluf 1983). Mean water surface temperatures vary from 17.5°C in winter to 30°C in summer (Robinson 1973). Tides are diurnal and have a maximum range of approximately 1.5 m (Marinone & Lavín 1997).

## METHODS

Between 2 June 1998 and 10 April 2000 we collected 195 regurgitations from Brown Boobies on Isla San Jorge on seven occasions (between 8 and 48 samples per visit; Table 1). In addition we collected 11 and 26 regurgitations from Isla San Ildefonso on 12 April 1999 and 10 April 2000, respectively, and 26 regurgitations on Isla San Pedro Mártir on 14 April 2000.

Regurgitations were preserved in 70% ethyl alcohol or 10% formaldehyde and taken to the laboratory where components were identified. Regurgitations that were too digested for the identification of any component were discarded. There were no significant differences in species composition between males, females and, in San Ildefonso in 1999, chicks, so the data were pooled. For each dietary item we present total number of individuals and frequency of occurrence for each sampling date. Other authors have also presented volume (Ashmole & Ashmole 1967, Harrison *et al.* 1983), but because a number of our samples contained large percentages of highly digested and unidentifiable matter, we decided not to use this variable.

## RESULTS

Brown Booby regurgitations from San Jorge contained 30 food items: one squid, 14 small 'pelagic' fishes, and 15 benthic (including reef and sandy-bottom) fishes (Table 1). The diet consisted mostly of small pelagic shoaling species, but on 11 October 1998 the diet was composed entirely of benthic fishes. The most common and abundant item in the diet was the Pacific Anchoveta *Cetengraulis mysticetus*, with a relative frequency of occurrence varying between 0 and 0.90 and averaging 0.47. The frequency of occurrence of Pacific Anchoveta in the diet had a significant negative correlation with the number of food items in the regurgitations (Fig. 2).

In April 1999 scombrid fishes (mackerels), followed by engraulids (sardines), were the most important items in Brown Booby regurgitations at San Ildefonso. In April 2000 the same two families, but in reversed order, were the principal components of the diet at both San Ildefonso and San Pedro Mártir (Table 2).

TABLE 1

Food items in regurgitations from Eastern Pacific Brown Boobies on Isla San Jorge, north-eastern Gulf of California, 1998–2000

Family, species	Frequency of occurrence							Total number of individuals						
	2 Jun. 1998	11 Oct. 1998	19 Jan. 1999	23 Mar. 1999	30 Aug. 1999	20–26 Jan. 2000	10 Apr. 2000	2 Jun. 1998	11 Oct. 1998	19 Jan. 1999	23 Mar. 1999	30 Aug. 1999	20–26 Jan. 2000	10 Apr. 2000
sample size =	20	30	28	28	8	48	38	20	30	28	28	8	48	38
<b>Pelagic</b>														
<b>Squid</b>														
Loliginidae														
Unidentified <sup>1</sup>							0.05							2
<b>Fish</b>														
Atherinidae														
Unidentified <sup>2</sup>							0.05							3
<i>Colpichthys regis</i>							0.03							2
<i>Leuresthes sardina</i>	0.05						0.08	1						6
Clupeidae														
Unidentified				0.18			0.08				29			9
<i>Lile stolifera</i>						0.08	0.03					11		1
<i>Opisthonema libertate</i>			0.04	0.07		0.29				1	4		22	
<i>Sardinops caeruleus</i>							0.03							1
Engraulidae														
<i>Cetengraulis mysticetus</i>	0.90		0.71	0.18	0.87	0.42	0.24	82		331	45	11	78	28
<i>Anchoa</i> sp. <sup>3</sup>	0.15		0.18	0.04			0.13	28		72	10			32
Exocoetidae														
Unidentified							0.03							1
<i>Fodiator acutus</i>					0.12		0.03					1		1
Scombridae														
Unidentified							0.03							1
<i>Scomber japonicus</i>				0.50	0.50		0.21				54	8		12
<i>Scomberomorus concolor</i>			0.07	0.11		0.02	0.29			22	9		1	47
<b>Subtotal</b>	<b>1.10</b>	<b>0</b>	<b>1.00</b>	<b>1.08</b>	<b>1.49</b>	<b>0.81</b>	<b>1.31</b>	<b>111</b>	<b>0</b>	<b>426</b>	<b>151</b>	<b>20</b>	<b>112</b>	<b>146</b>

(TABLE 1 continued)

Family, species	Frequency of occurrence							Total number of individuals						
	2 Jun. 1998	11 Oct. 1998	19 Jan. 1999	23 Mar. 1999	30 Aug. 1999	20–26 Jan. 2000	10 Apr. 2000	2 Jun. 1998	11 Oct. 1998	19 Jan. 1999	23 Mar. 1999	30 Aug. 1999	20–26 Jan. 2000	10 Apr. 2000
<b>Benthic</b>														
<b>Fish</b>														
Batrachoididae														
<i>Porichthys analis</i>		0.07		0.04		0.04			6		3		4	
Carangidae														
<i>Oligoplites refulgens</i>	0.05	0.03						1	22					
Gerreidae														
<i>Eucinostomus argenteus</i>		0.43		0.04		0.15			34		1		20	
Haemulidae														
<i>Haemulopsis</i> sp.		0.07							3					
<i>Haemulopsis nitidus</i>		0.17				0.06			7				3	
<i>Orthopristis reddingi</i>		0.13							4					
Mullidae														
<i>Pseudupeneus grandisquamis</i>						0.02							1	
Paralichthyidae														
<i>Etropus</i> sp.		0.07				0.04			2				2	
Sciaenidae														
<i>Cynoscion reticulatus</i>		0.17							5					
<i>Micropogonias megalops</i>		0.23							12					
<i>Umbrina</i> sp.	0.05							1						
Serranidae														
<i>Paralabrax</i> sp.						0.02	0.03						1	1
<i>Diplectrum labarum</i>					0.12	0.06							1	5
Synodontidae														
<i>Synodus</i> sp.		0.10		0.04		0.12	0.03		3		2		6	1
Triglidae														
<i>Bellator</i> sp.				0.04							3			
<b>Subtotal</b>	0.10	1.40	0	0.16	0.12	0.51	0.06	2	98	0	9	1	42	2
	0						6							
<b>Total taxa</b>	5	10	4	10	4	12	16							

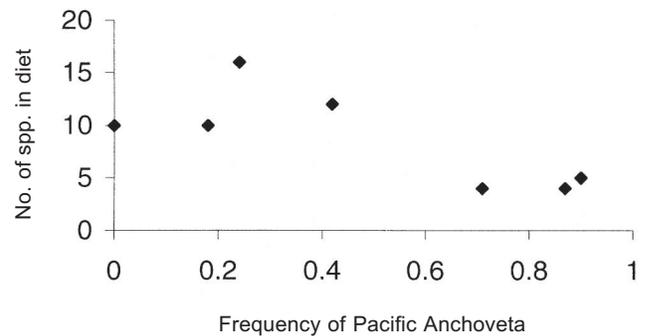
<sup>1</sup> The only species of squid that we have documented in the area is *Lolliguncula panamensis*.<sup>2</sup> When both species and 'unidentified' are included under a given family, the latter, although unidentified, was different from the species listed.<sup>3</sup> *Anchoa helleri* was positively identified, but very digested remnants could include other species of *Anchoa* as well.

## DISCUSSION

Diet composition on San Jorge was clearly different on different dates (Table 1), and no coincidences between sampled years were evident. Also, during the spring and summer of 1998 Brown Boobies interrupted their breeding season and most adults abandoned the area, whereas in 1999 the breeding season developed normally (Mellink 2000). The reason for these differences in diet and breeding season might be that during late 1997 to mid-1998 nearby waters were under the influence of El Niño conditions, whereas during late 1998 to mid-1999 they were under those of La Niña. During late 1999 to mid-2000 conditions were intermediate (normal). As found by other authors, on San Jorge Brown Boobies are generalists capable of exploiting 'any prey that becomes available in near-shore water' (Harrison *et al.* 1984).

Whenever Brown Boobies on San Jorge did not feed on Pacific Anchoveta, their diet became more diverse. They substituted not just one but several other species: the fewer Pacific Anchovetas they consumed, the more species they added to their diet (Fig. 2). This suggests that when Pacific Anchoveta is available it is the food of choice. Also, the generally low consumption of benthic fishes suggests that Brown Boobies turn to them when suitable small pelagic species are in low supply. Although the species that we found in diets at San Ildefonso and San Pedro Mártir were different from those found in the early 1990s (Ángeles-Perez *et al.* 1991, Tershy *et al.* 1992), in both cases small pelagic shoaling species predominated. The differences between the two sets of data cannot be explained at present.

Despite the rather limited data, there was an important difference between the boobies' feeding ecology on the islands that we studied. In the central part of the Gulf of California and the Midriff region many seabirds consume almost exclusively small pelagic shoaling species, at least during the spring. In addition to the data that we obtained, such reports exist for Brown Boobies in other studies, Blue-footed Boobies *Sula nebouxii*, Brown Pelicans



**Fig. 2.** Relationship between the relative frequency of Pacific Anchoveta in regurgitations of Brown Boobies from Isla San Jorge and the total number of species found in regurgitations, 1998–2000.  $R^2=0.58$ ,  $P = 0.047$ .

*Pelecanus occidentalis*, Elegant Terns *Sterna elegans* and Heermann's Gulls *Larus heermanni* (Tershy *et al.* 1992, Velarde *et al.* 1995, E. Mellink unpubl. data).

At San Jorge, Brown Boobies incorporated both more species and an important component of benthic fishes. Even when pelagic species accounted for most of the diet at San Jorge, the diet could be more diverse there than at San Ildefonso and San Pedro Mártir. Samples taken during the same week in April 2000 rendered 16 species in the diet of Brown Boobies at San Jorge, but only six on San Ildefonso and San Pedro Mártir (five species being the same on both of these islands).

The higher food diversity for Brown Boobies at San Jorge was in part due to 15 benthic fishes that were consumed. The shallow waters that surround this island allow the boobies to forage widely on benthic species if they need to. Benthic fishes are probably out of reach for birds nesting on San Pedro Mártir and San Ildefonso,

**TABLE 2**

**Prey items in Brown Booby regurgitations from two islands in the central Gulf of California, April 1999 and 2000 (columns 1 & 4 = San Ildefonso 1999; columns 2 & 5 = San Ildefonso 2000; columns 3 & 6 = San Pedro Mártir 2000)**

	Frequency of occurrence			Total number of individuals			
	Sample size =	12	26	26	12	26	26
<b>Fish</b>							
Sardine Clupeidae		0.08	0.04	0.15	3	4	8
Pacific Anchoveta <i>Cetengraulis mysticetus</i>		0.08	0.61	0.54	2	62	68
Anchovy <i>Anchoa</i> sp.		0.42	0.04	0.04	25	20	3
Flying fish Exocoetidae			0.08			3	
Chub Mackerel <i>Scomber japonicus</i>		0.58	0.15	0.04	21	12	2
Monterey Spanish Mackerel <i>Scomberomorus concolor</i>		0.17		0.19	4		13
Unidentified 'mackerel' Scombridae			0.11	0.04		16	1
<b>Total</b>		<b>1.33</b>	<b>1.03</b>	<b>1.00</b>	<b>55</b>	<b>117</b>	<b>95</b>
<b>Total Taxa</b>		<b>5</b>	<b>6</b>	<b>6</b>			

except very close to shore. Its likely that the wider food spectrum is responsible for the longer breeding season and residency (under non-El Niño conditions) of Brown Boobies at Isla San Jorge.

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