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THE DIET OF THE PERUVIAN DIVING-PETREL AT LA VIEJA AND SAN GALLAN, PERÚ

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Abstract.—The diet of the Peruvian Diving-Petrel (*Pelecanoides garnotii*) was studied from 211 stomach pumpings collected on San Gallan and La Vieja Islands, on the central coast of Peru. Planktonic invertebrates were the dominant food items representing 85.3% and 91.1% of the items ingested on San Gallan and La Vieja, respectively. The remainder of the stomach contents was fish. *Euphausia mucronata* was the principal prey, composing 22.1% by mass of the food ingested on San Gallan and 30% on La Vieja. Fish larval stages represented 23.6% and 19.4% of the ingested food mass on these islands, respectively. Peruvian anchovy was present in only 3.2% of the stomach contents on San Gallan and 7.8% on La Vieja. Prey consumption varied seasonally probably due to changes in resource availability. Planktonic invertebrates were the main prey in summer, while there was a high proportion of fish larval stages during in winter.

LA DIETA DE *PELECANOIDES GARNOTII* A LA VIEJA Y SAN GALLAN, PERÚ

Sinopsis.—Se estudió la dieta del potoyunco peruano (*Pelecanoides garnotii*) en base a 211 lavados estomacales recogidos en las Islas San Gallan y La Vieja en la costa central del Perú. Invertebrados planctónicos fueron el alimento principal representando el 85.3% y el 91.1% de los artículos ingeridos en San Gallan y La Vieja respectivamente. El porcentaje restante de los contenidos estomacales correspondió a peces. La presa principal fue *Euphausia mucronata,* alcanzando el 22.1% y el 30.0% en peso del alimento ingerido en San Gallan y La Vieja, respectivamente. Los estadíos larvales de peces representaron el 23.6% y 19.4% del alimento ingerido en dichas localidades, respectivamente. La anchoveta peruana (*Engraulis ringens*) se presentó en sólo el 3.2% de los contenidos estomacales recolectados en San Gallan y en el 7.8% de los contenidos estomacales recolectados en La Vieja. El consumo de presas varió estacionalmente, debido probablemente, a cambios en la disponibilidad de recursos. Los invertebrados planctónicos fueron la presa principal en verano, en tanto que en invierno se observó una gran proporción de estadíos larvales.

Peruvian Diving-Petrels (*Pelecanoides garnotii*) are endemic birds of the Peruvian current whose distribution is restricted to Peru (Lobos de Tierra Island, 6°S) and Chile (Corral, 37°S). Formerly abundant, their population has been reduced due to habitat destruction by the guano industry and direct capture of birds by fishermen (Coker 1919; Murphy 1936; Hays 1989). Duffy et al. (1984) estimated the breeding population of Peruvian Diving-Petrels in Peru as closer to 10,000 individuals than to 1000 or 100,000. Hays (1989) considered this an overestimation and estimated 4000 breeding individuals. Studies conducted by the Peruvian Marine Re-

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search Institute (Instituto del Mar del Peru, IMARPE) estimated a maximum breeding population of 13,000 pairs in 1996, restricted to only two islands on the central coast of Peru: La Vieja and San Gallan (Jahncke and Goya 1998).

Hays (1989) suggested that Peruvian Diving-Petrels are threatened by industrial fishing activities that limit the availability of their main prey, the Peruvian anchovy (*Engraulis ringens*). However, no studies have been carried out on the diet of this species to support this suggestion. Furthermore, natural history information on this species is scarce. Studies conducted by Payne and Prince (1979) on South Georgia Island have shown that *Pelecanoides georgicus* and *P. urinatrix exsul* feed on crustaceans. *Pelecanoides georgicus* feeds mainly on euphausiids (76% by volume), copepods (20%), and amphipods (4%), while *P. urinatrix exul* feed on copepods (68%), euphausiids (15%), and amphipods (17%).

This paper reports the results of a study designed to determine the diet of Peruvian Diving-Petrels on San Gallan and La Vieja.

METHODS

Study area.—Field work was conducted on La Vieja Island (14°17'S) from October 1995–November 1996 and on San Gallan Island (13°50'S) in March and September of 1996 (Fig. 1). These islands are within the Paracas National Reserve on the central coast of Peru and differ from others of the Peruvian coast because they are high and have soil on their tops and flanks that allow this species to excavate nesting burrows (Murphy 1925).

Sample collection.—Birds were captured using mist nest as they returned to their colonies after sunset. Each bird was measured and banded, and then its stomach was pumped to obtain diet samples (Emison 1968; Wilson 1984; Montalti y Coria 1993). Earlier studies have shown that, while benign, the method of stomach pumping does not always provide high accuracy. The proportion of recovered stomach contents is unknown (Lishman 1985) and may not provide a uniform sample (Croxall and Furse 1980; Croxall and Prince 1980; Lishman 1985). Montalti y Coria (1993) obtained 100% efficiency with all Procellariiforms with which they tried the same method applied in this study. However, it is possible that some otoliths may be retained in the birds' muscular stomach, resulting in a biased estimate of diet. While this method has problems, it is far less dangerous than other methods (Duffy and Jackson 1986) and thus preferable for this endangered species. Nevertheless, five birds of 220 died during its use. We used infant feeding plastic tubes (1 mm in diameter), 20 ml syringes, and sea-water to obtain the samples. The procedure, similar to the one described by Wilson (1984) and Montalti and Coria (1993) was repeated up to three times on each bird. Stomach contents were stored in sea-water, preserved with alcohol (70%), and were analyzed the day after collection.

For each sample we identified the species of each item. Invertebrates

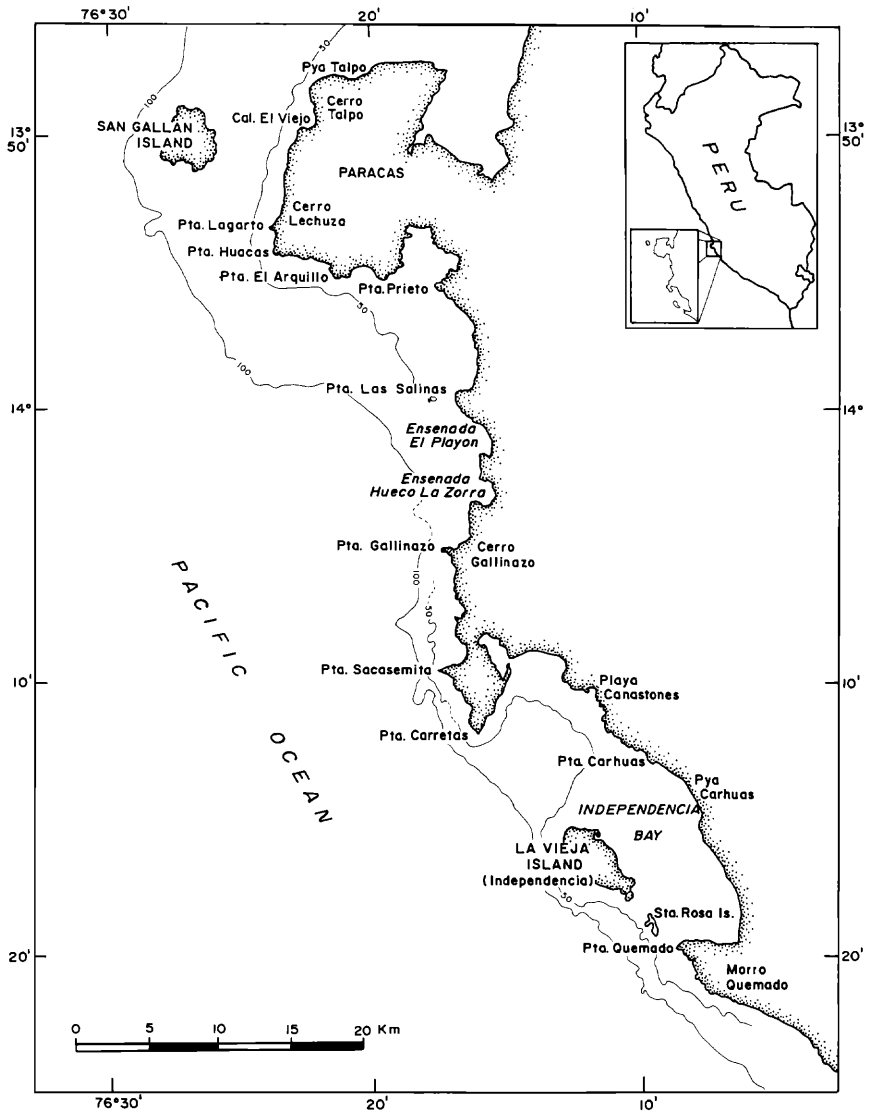

FIGURE 1. Location of San Gallan and La Vieja Island, Perú.

were identified using Santander et al. (1981), and otoliths were identified using the morphological patterns described by Garcia-Godos (1996). We collected 187 samples on La Vieja Island (in 1995: 32 in October; in 1996: 33 in January, 37 in March, 32 in May, 22 in July, 30 in September, and 1 in November). On San Gallan Island, we collected 33 samples (19 in March and 14 in September).

Data analysis.—Diet composition by number overestimates the importance of small prey items, therefore data were transformed to mass for each prey species. Masses assigned to squat lobsters (*Pleuroncodes monodon*; 2.15 g), megalopod larvae of Xanthidae (0.011 g), megalopod larvae of *Emerita* (0.007 g), zoea larvae of *Emerita* (0.006 g), and small squids (0.055 g) were means of our own measurements. Mass assigned to euphausiids (0.05 g) was obtained from literature (Santander et al. 1981). Masses assigned to other invertebrates were the same as those of megalopod larvae of *Emerita,* because of their similar dimensions. The mass assigned to fish larvae (0.33 g) was obtained from unpublished data collected by the SNP-1 Research Vessel of IMARPE in February 1995. The mass assigned to all fish species was the mean mass of mote sculpins (*Normanichtys crockeri*; 6.74 g) captured during the same cruise, because of their similar dimensions.

Niche breadth was measured to assess how diving-petrels use the available resources using Levins' standardized index (Krebs 1989). Trophic niche similarity was measured to determine if resources used were the same on both islands, using the percentage similarity index and the simplified Morisita index (Krebs 1989).

RESULTS

Ninety six percent (95.9%) of the stomach samples (n = 220) contained food remains that could be classified into 18 prey species. Table 1 summarizes diet composition by mass of the 211 samples that contained food remains. Considering only the numbers of individual prey, Peruvian Diving-Petrel diet was dominated by planktonic invertebrates on both islands, representing 85.3% of food items on San Gallan (n = 5070) and 91.1% on La Vieja (n = 31,504). Fish represented only 14.7% of items consumed on San Gallan (n = 5070) and 8.9% on La Vieja (n = 31,504).

Euphausiids (*Euphausia mucronata*) were the main prey item by number, 82.5% on San Gallan and 84.8% on La Vieja. They were present in 67.7% of the samples collected on San Gallan (n = 31) and in 42.8% collected on La Vieja (n = 180). They contributed 22.1% and 30.0% by mass of the ingested food on San Gallan (947.7 g) and La Vieja (4461.1 g), respectively. Other invertebrate species of minor importance were present in the diet on both islands (e.g., squat lobsters, zoea of *Emerita,* megalopod of Xanthidae). Squat lobsters were the second invertebrate species in importance. They were present in 32.3% of the stomach contents collected on San Gallan (n = 31) and on 51.7% collected on La Vieja (n = 180). Squat lobsters constituted 7.3% and 21.4% by mass of the food ingested on San Gallan (947.7 g) and La Vieja (4461.1 g), respectively.

Fish was mostly present as larvae. Species were not determined due to the small size of the otoliths. Fish larvae were present in 32.3% of the contents collected on San Gallan (n = 31) and 29.4% on La Vieja (n = 180). They represented 23.6% (947.7 g) and 19.4% (4461.1 g) by mass of the food ingested on these islands, respectively. Other fish that were

TABLE 1. Peruvian Diving-Petrel diet composition by mass. Diet composition on San Gallan (n = 31) and La Vieja (n = 66) are compared from samples collected in March and September of 1996.

Classification[a]	Prey items	Occurrence (%)	Composition (%)	San Gallan Island (%)	La Vieja Island (%)
Class Cephalopoda					
Order Teuthoidea	Unidentified squid	4.27	<0.01		0.03
Class Malacostraca					
Superorder Eucarida					
Order Euphasiacea	*Euphausia mucronata*	46.44	28.60	22.10	25.24
Order Decapoda					
Infraorder Caridea	Caridae (megalopod)	1.42	<0.01		<0.01
Infraorder Anomura	*Calianassa* spp.	2.37	<0.01	<0.01	<0.01
	Pleuroncodes monodon	48.82	18.90	7.30	19.57
	Porcellanidae (megalopod)	0.95	<0.01		
	Emerita analoga (zoea)	14.22	0.10	<0.01	0.06
	E. analoga (megalopod)	7.11	<0.01	<0.01	0.04
Infraorder Brachyura	Xanthidae (megalopod)	13.74	0.10	0.10	0.27
Superorder Peracaridae					
Order Amphipoda					
Infraord. Physocephalata	*Phronima* spp.	1.42	<0.01		
Class Osteichthyes	Larval stages	29.85	20.10	23.60	27.32
Fam. Scomberesocidae	*Scomberesox saurus*	3.32	1.70	0.70	4.23
Fam. Photichthyidae	*Vinciguerria lucetia*	0.95	0.20		0.70
Fam. Myctophidae	*Mictophum nitidulum*	0.95	3.70		10.57
	unidentified Mictophid	2.37	3.20	15.60	1.41
Fam. Atherinidae	*Odonthestes regia*	1.90	2.70	14.20	0.35
Fam. Engraulididae	*Engraulis ringens*	7.11	9.10	1.40	0.70
Fam. Normanichthyidae	*Normanichthys crockeri*	18.01	11.30	14.90	9.51

[a] Invertebrates classification by Barnes (1989).

present in the diet were mote sculpin (*Normanichthys crockeri*), Peruvian anchovy (*Engraulis ringens*), lightfish (*Vincigerria lucetia*), Peruvian Silverside (*Odontesthes regia*), lanternfish (*Mictophum nitidulum*), and other mictophids of unknown species. Mote sculpins, a coastal pelagic fish associated to subantarctic waters (Bouchon and Quiroz, unpubl. data), were present in 22.6% of the stomach contents collected on San Gallan (n = 31) and in 17.2% collected on La Vieja (n = 180). They contributed 14.9% and 10.6% by mass to the food ingested on San Gallan (947.7 g) and La Vieja (4461.1 g), respectively. Peruvian anchovies on San Gallan were present in only 3.2% of the collected contents (n = 31) and represented 1.4% by mass of the ingested food (947.7 g). On La Vieja, anchovy was present on 7.8% of the stomach contents (n = 180) and represented 10.7% of the food (4461.1 g).

Niche breadth measured for San Gallan was 0.2730 and for La Vieja was 0.2380. Niche breadth estimated for all sample pooled was 0.2640. Peruvian Diving-petrel diet between both islands for March and September (Fig. 2) had percentage overlap values of 49.8% and 49.9%; and simplified Morisita values of 0.6001 and 0.6643, respectively. Comparing the diet for each island between March and September, percentage overlap values were 21.3% and 26.3%; and simplified Morisita values were 0.2196 and 0.2750.

DISCUSSION

Murphy (1936) reported that Peruvian Diving-Petrels congregated with other oceanic birds on shoals of Peruvian anchovies and silversides, and in areas of ocean water discolored by clouds of Munida (squat lobster) or other free-swimming crustaceans. Twelve stomachs contained only traces of gravel and varying amounts of small crustaceans, identified merely as the megalopod stage of a crab (probably Xanthidae) (Murphy 1936). The stomach contents collected during this study have shown the importance of planktonic crustaceans in the diet (specially *Euphausia* and *Pleuroncodes*), confirming Murphy's observations. However, contrary to the suggestion by Hays (1989), the only fish prey items important in the diet were larval stages and mote sculpins.

Peruvian Diving-Petrel diving capabilities were studied by Zavalaga and Jahncke (1997). They found mean maximum dive depth of this species was 31.06 ± 3.6 m (range = 10–83 m, n = 22), and that 91% of the maximum dives were between 10 and 50 m (Zavalaga and Jahncke 1997). Euphausiids are widespread to at least depths of 300 m (Santander et al. 1981), whereas larvae of Peruvian anchovy and Peruvian Pacific sardine (*Sardinops sagax*) are confined to the upper 60 m, and mictophids larvae to the upper 100 m (Sameoto 1981). All prey show diel vertical migration, remaining in deeper waters during the day and rising the surface by night (Santander et al. 1981; Sameoto 1981). Because Peruvian Diving-Petrels are mainly diumal foragers (Jahncke, unpubl. data), it is expected that these birds need to reach deep water strata to catch their main prey. Peruvian Anchovy schools during 1996 were available above 30 m depth

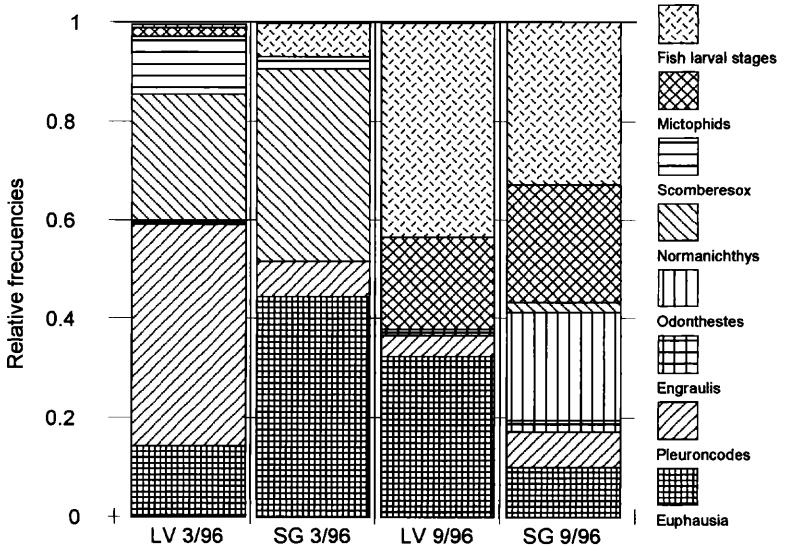

FIGURE 2. Peruvian Diving-Petrel diet composition on San Gallan (SG) and La Vieja (LV) from contents collected in March and September 1996.

in summer (February–March) and 60 m depth in winter (August–September) (Segura et al. 1996; Cárdenas et al. 1997). Eighty percent of the schools were distributed over 15 m depth in summer and 20 m in winter, no differences were observed between day and night vertical distribution (Segura et al. 1996; Cárdenas et al. 1997). However, Peruvian anchovy was present in only 7.1% of the stomach contents, representing 9.1% by mass of the ingested food.

The niche breadth of the Peruvian Diving-Petrel on San Gallan and La Vieja islands is quite narrow. Only a few of the items were consumed in large quantities. Similarities in resources used on San Gallan and La Vieja, and differences in diet between months for each island, suggest that consumption of preys varies seasonally. Variations are probably related to changes in the availability of resources. In summer, planktonic invertebrates represented almost 60% of the ingested food, followed by mote sculpin and south pacific saury. In winter, invertebrates were only 30% of the food, with a high proportion of fish larval stages (40%), besides mictophids (Fig. 2). Low niche breadth values and seasonal diet variations, suggest that Peruvian Diving-Petrels are opportunistic feeders that prey on plankton (zooplankton and ichthyoplancton) but can switch to temporarily abundant small sized schooling fishes depending on their availability.

Anchovy fishing activities were thought to be the main threat to the conservation of seabirds in Peru (Duffy et al. 1984; Hays 1989). However, our results show that Peruvian Diving-Petrels are mainly planktonic feed-

ers and that they feed on minimal amounts of Peruvian anchovies. Therefore, competition for food between this species and industrial fishing activity should not be seen as a threat to this seabird population.

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LITERATURE CITED

BARNES, R. D. 1989. Zoología de los invertebrados. Quinta edición. Interamericana Mc Graw-Hill, Mexico. 957 pp.

CÁRDENAS, G., L. ESCUDERO, A. ECHEVARRÍA, AND J. PELLÓN. 1997. Distribución, concentración y aspectos biológico pesqueros de los principales recursos pelágicos. Crucero BIC Humboldt 9608-09. Informe Instituto del Mar del Perú 123:28–37.

COKER, R. E. 1919. Habits and economic relations of the guano birds of Peru. Proceedings of the United States National Museum 56:449–511.

CROXALL, J. P., AND R. J. FURSE. 1980. Food of the chinstrap penguins *Pygoscelis antarctica* and macaroni penguins *Eudyptes chrysolophus* at Elephant Island, South Sheetland Islands. Ibis 122:237–245.

———, AND P. A. PRINCE. 1980. The food of gentoo penguins *Pygoscelys papua* and macaroni penguins *Eudyptes chrysolophus* at South Georgia. Ibis 122:245–253.

DUFFY, D. C., C. HAYS AND M. A. PLENGE. 1984. The conservation status of Peruvian seabirds. Pp. 245–259, *in* Croxall, J. P., P. G. H. Evans, and R. W. Schreiber, eds. Status and conservation of the world's seabirds. ICBP Technical Publication No. 2.

———, AND S. JACKSON. 1986. Dietary studies of seabirds: A review of methods. Colonial Waterbirds 9:1–17.

EMISON, W. B. 1968. Feeding preferences of the Adelie penguin at Cape Crozier, Ross Island. Antarctic Res. Ser. Wash. 12:191–212.

GARCÍA-GODOS, A. 1996. Patrones morfológicos del otolito sagitta de los peces de la costa central de Peru. Informe final. Concejo Nacional de Ciencia y Tecnología CONCYTEC. Lima. 90 pp.

HAYS, C. 1989. The Peruvian diving-petrel in Peru. Oryx 23:102–105.

JAHNCKE, J., AND E. GOYA. 1998. Status of the Peruvian Diving-Petrel population at the main breeding areas along the cost of Peru. Colonial Waterbirds 21: in press.

KREBS, C. J. 1989. Ecological methodology. Harper and Row Publishers, New York. 654 pp.

LISHMAN, G. S. 1985. The food and feeding ecology of the Adelie penguins (*Pygoscelis adeliae*) and Chinstrap penguins (*P. antarctica*) at Signy Island, South Orkney Islands. J. Zool. Lond. (A) 205:245–263.

MONTALTI, D., AND N. R. CORIA. 1993. El uso de la técnica de lavados de estómagos para obtener muestras de contenidos estomacales en aves marinas antárticas. Riv. ital. Om. Milano. 63:69–73.

MURPHY, R. C. 1925. Bird islands of Peru. G. P. Putnam's Sons. The Knickerbocker Press. New York. 362 pp.

———. 1936. Oceanic birds of South America, volume II. The Macmillian Company, New York. 1245 pp.

PAYNE, M. R., AND P. A. PRINCE. 1979. Identification and breeding biology of the diving-petrels *Pelecanoides georgicus* and *P. urinatrix* at South Georgia. New Zealand Journal of Zoology 6:299–318.

SANTANDER, H., G. LUYO, S. CARRASCO, M. VÉLIZ, AND O. S. DE CASTILLO. 1981. Catálogo de zooplancton en el mar peruano. Primera parte: área Pisco-San Juan. Boletín Instituto del Mar del Peru, vol. 6. 75 pp.

SAMEOTO, D. 1981. Distribution and abundance of six species of fish larvae in Peruvian waters and their relationship with the physical and biological environment. Boletín Instituto del Mar del Perú. Volumen Extraordinario: 171–179.

SEGURA, M., M. GUTIERREZ AND R. CASTILLO. 1996. Distribución, concentración y biomasa de los principales recursos pelágicos durante el verano de 1996. Crucero BIC SNP-1 9602-04. Informe Instituto del Mar del Perú 122:9–26.

WILSON, R. P. 1984. An improved stomach pump for penguins and other seabirds. J. Field Ornithology 55:109–112.

ZAVALAGA, C. B. AND J. JAHNCKE. 1997. Maximum dive depths of the Peruvian Diving-Petrel. Condor 99:1002–1004.

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