THE DIET OF MARKHAM'S STORM PETREL *OCEANODROMA MARKHAMI* ON THE CENTRAL COAST OF PERU

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Received 2 September 2002, accepted 31 December 2002

SUMMARY

GARCÍA-GODOS, I., GOYA, E. & JAHNCKE, J. 2002. The diet of Markham's Storm Petrel *Oceanodroma markhami* on the central coast of Peru. *Marine Ornithology* 30: 77–83.

We studied the diet of Markham's Storm Petrel *Oceanodroma markhami* on Paracas Peninsula and La Vieja Island, central Peru, in 1996, 1999 and 2000. A total of 95 samples was collected from adults captured in mist nets at breeding colonies, using the water-offloading technique. The diet was composed of fish (54% by mass), cephalopods (36%) and crustaceans (10%). Among the fish, Peruvian Anchovy *Engraulis ringens* was the main prey (27.2% of the total mass), followed by fish of unknown identity (16.7%). The Pelagic Squat Lobster *Pleuroncodes monodon* was the main crustacean prey (9.4%); the oceanic octopus *Japetella* sp. was the most frequent cephalopod eaten. Prey composition varied among years, before and after El Niño 1997/98. Fish was the main prey in samples during 1999, when anchovy was first observed in the diet (43% by mass). Cephalopods were the main prey in 1996 (44%) and 2000 (84%). Fish prey suggests both inshore and offshore feeding, while cephalopods suggest offshore feeding only. The observed pattern of the diet of the Markham's Storm Petrel indicates opportunistic feeding.

Key words: Markham's Storm Petrel, *Oceanodroma markhami,* diet, Peruvian Current, El Niño, Peru

INTRODUCTION

Markham's Storm Petrel *Oceanodroma markhami* is confined to the Peruvian Current and adjacent waters (Murphy 1936, Goodall *et al*. 1951). Breeding areas have been known only since the early 1990s, when discovered at the Paracas National Reserve and La Vieja and San Gallan Islands, on the central Peruvian coast (Jahncke 1993). This storm petrel breeds annually. Egg laying begins in June and fledglings leave their nests between late November and early December (Jahncke 1994). The natural history of this species has been scarcely investigated.

Quantitative dietary data are available for only a few species of storm petrels (Prince & Morgan 1987, Ridoux 1994). However, Croxall *et al*. (1988) emphasized the importance of fish and cephalopods on the diet of Pacific Ocean *Oceanodroma* species and populations as compared to other crustacean feeding genera. Until now the diet of Markham's Storm Petrel has been unknown.

Major food web perturbations in the Peruvian Current result from fluctuations in ocean climate due to warm (El Niño) and cold (La Niña) events (Arntz & Farbach 1996, Morón 2000). This was well shown during El Niño 1997/98, which caused great changes in the diet of Peruvian guano birds (Jahncke & Goya 1998) and other seabirds, mainly because of prey depletion. Due to their breeding schedule Markham's Storm Petrels did not nest during the strongest phase of El Niño in summer 1998, and therefore effects on diet could not be assessed. Because the storm petrel's offshore distribution limits are far from the Peruvian Current, it is probable that El Niño could affect these birds differently to other endemic seabirds. On the other hand, dietary information obtained before and after El Niño 1997/98 could indicate some of the changes brought by that environmental event and its influence on this species. Herein, we report the first findings on the diet of Markham's Storm Petrels.

METHODS

Fieldwork was conducted on the Paracas Peninsula (13°50'S, 76°22'W) in 1996 and at La Vieja Island (14°17'S, 76°11'W) in 1996, 1999 and 2000 (Fig. 1). These areas are located within the Paracas National Reserve, on the Peruvian central coast. Samples were collected during three-day periods during the breeding season (1996: May to September; 1999: August to November and 2000: August).

Birds were captured using mist nets when returning to their colonies after dusk. Stomach contents were obtained by stomach pumping, using the water-offloading technique (Wilson 1984, Montalti & Coria 1993). Flushing was repeated up to three times on each bird to collect the complete stomach contents. Plastic in-

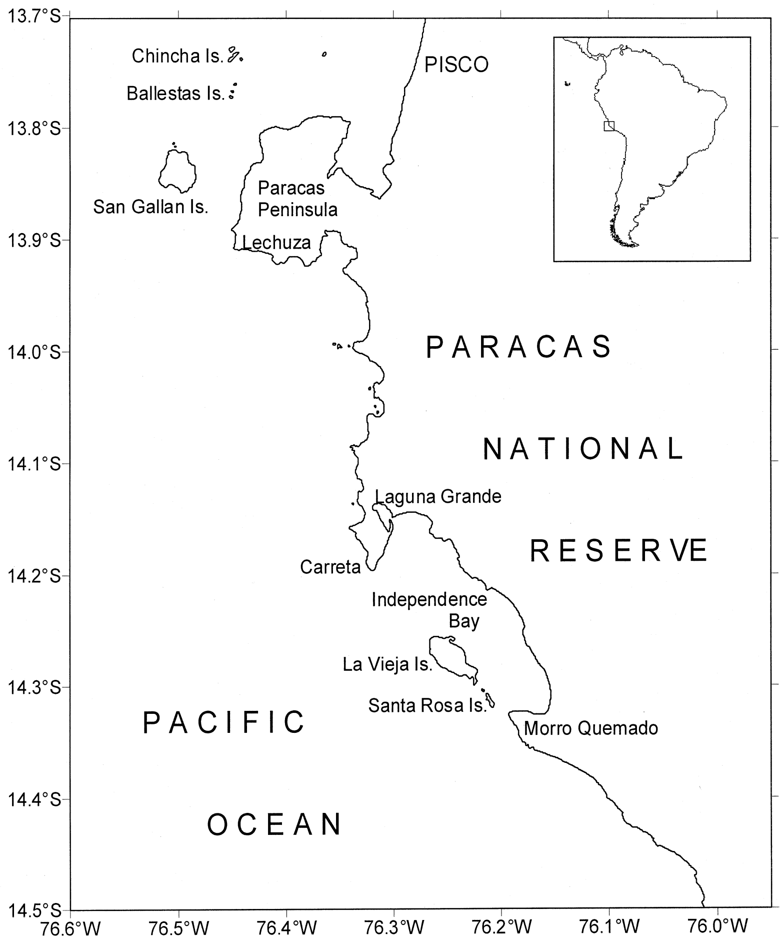

Fig. 1. Location of the study areas, the Paracas Peninsula and La Vieja and San Gallán Islands, the main known breeding grounds of Markham's Storm Petrels.

fant feeding tubes (1 mm in diameter), 20-ml syringes and seawater were used to obtain samples. Stomach contents were preserved with alcohol (70%), and analyzed the day after collection. No mortality of birds was observed. Prey items were identified to the lowest taxonomic level, using Santander *et al.* (1981) and García-Godos (2001). Dr. Unai Markaida (CICESE, Mexico) identified cephalopod beaks.

Fish, cephalopods and crustaceans occurred as whole or fragmented individuals, eye lenses, otoliths and squid beaks. We estimated the minimum number of items in each stomach content using the appropriate remains having the highest number. For example, when both cephalopod beaks and eye-lenses were present, we assumed the minimum number of cephalopods to be the highest number of pairs of beaks or eye-lenses present.

Prey data were transformed to mass for each species, except cephalopods (see below). Because there are no length-mass equations for most of the prey found, we used average mass. For fish, the mass assigned to Peruvian Anchovy *Engraulis ringens* was taken for each given size (IMARPE unpubl. data), which was estimated measuring regurgitated fish or otoliths and applying IMARPE standard equations (unpubl. data). Average mass assigned to Mote Sculpins *Normanichthys crockeri* (6.74 g) was taken from Jahncke *et al.* (1999). The mean mass of the Panama Lightfish *Vinciguerria lucetia* (1.054 g) collected by IMARPE during spring 2000 was used for all other fish species, because of their similar size. Because of the small number of beaks recovered, it was impossible to assign a mass to a particular species of cephalopod. Instead we assigned them a general mass of 1.2 g, that was the mass of the most complete specimen in the sample. The latter did not differ from the mean calculated mass of the few cephalopods beaks identified and measured. Mass used for crustaceans were: 2.15 g for Pelagic Squat Lobster *Pleuroncodes monodon*, 0.011 g for megalopod larvae of Xanthidae crabs and 0.006 g for zoea larvae of Sandcrab *Emerita analoga* (Jahncke *et al.* 1999). Mean mass assigned to Small Krill *Euphausia mucronata* (0.05 g) was taken from Santander *et al.* (1981). For other invertebrates of similar size, we used the same mass assigned to the megalopod larvae of Sandcrab.

The frequency of occurrence, percent by number and by mass were calculated for each year and for all samples pooled together. Frequency of occurrence was tested statistically using chi-square for independent samples; we used the Mann-Whitney U test (Siegel 1956) to compare prey numbers. The estimated stomach content mass was tested using a single factor ANOVA. Means are expressed ± the standard deviation. In 1999, the total mass of 21 stomach contents and the mass of the floating oil present in 10 samples were measured using a portable digital scale to the nearest 0.1 g.

Prey size could be estimated for some prey. Regurgitated fish was measured to the nearest 1 mm and anchovy otoliths were measured to the nearest 0.01 mm to calculate the standard length (see above). Equations for cephalopod beaks and size of *Leachia* sp. and *Abraliopsis* sp. were taken from Clarke (1986) and Wolff (1984), and for *Loligo gahi* from Pineda *et al.* (1996). These equations were not used in the analysis by mass.

RESULTS

A total of 95 stomach contents of Markham's Storm Petrel was collected, 14 from the Paracas Peninsula and 81 from La Vieja Island (29 in 1996; 41 in 1999; and 11 in 2000). Most samples (77%) contained solid remains that were classified into 13 prey types. Diet was composed of fish, cephalopods and crustaceans (Table 1). Fish was the main prey in 1999, whereas cephalopods were the main prey in 1996 and 2000 (Fig. 2). The percentage by mass of the pooled sample was dominated by the large amount of fish consumed in 1999.

Overall, cephalopods were the main item consumed, representing 35.9% of the diet by mass, followed by Peruvian Anchovy (27.2%), adult Pelagic Squat Lobster (9.4%) and Mote Sculpin (4.5%). Unidentified fish accounted for 17% by mass of the total sample. Other fish found were mesopelagic species having strong diel vertical migration such as Pearly Lanternfish *Mictophum* *nitidulum*, Slimtail Lanternfish *Lampanyctus parvicauda*, Panama Lightfish *Vinciguerria lucetia* and Codlet *Bregmaceros bathymaster* (Wisner 1976, Cohen *et al*. 1990, Castillo *et al*. 1999b).

The few cephalopod beaks identifiable were from *Japetella* sp. (7), *Leachia* sp. (3), *Abraliopsis* sp. (2), *Mastigoteuthis* sp. (1) and *Loligo gahi* (1). Their specific contribution by mass could not be calculated because of the high incidence of cephalopod remains other than beaks (i.e. eye lenses and flesh).

Three stomach contents contained eggs of Peruvian Silverside *Odonthestes regia* and nine contained other remains suggesting scavenging behaviour. Unidentifiable mammal or seabird muscle was found in two samples and eye-lenses (up to 11-mm diameter) from squid much larger than the storm petrels were found in seven stomachs. Small pieces of algae were present in one sample; three samples contained small pieces of plastic and aluminium paper remains.

In 1996 there were no statistical differences in the frequency of occurrence and percentage by number of crustaceans, cephalopods and fish consumed (χ^2_1 and Mann-Whitney test, n.s.) between Paracas Peninsula and La Vieja Island. Therefore, data were pooled for further analyses. Statistical differences existed among years in the occurrence of fish (χ^2_2 = 14.014, $P < 0.01$), but not in the frequency of occurrence of crustaceans and cephalopods. The frequency of occurrence and percentage by number of fish varied strongly between 1996 and 1999 (χ^2_1 = 13.072, $P < 0.01$; Mann-Whitney test, U = 484, $P < 0.01$). Differences were due to an increase in fish and a decrease in squid consumption in 1999 (Table 1). Fish consumption rose considerably in 1999 when Peruvian Anchovy was the main prey. Anchovy was not observed in samples from 1996 and 2000. Other prey species consumed in 1996 such as Pelagic Squat Lobster, Mote Sculpin and Panama Lightfish only accounted for only 3% by mass during 1999, and were not present during 2000 (Table 1).

Fish sizes consumed by Markham's Storm Petrel varied greatly. Peruvian Anchovies directly measured in 1999 ranged in length from 7.5 to 11.0 cm (n = 11), and those estimated from otoliths ranged from 6.1 to 15.2 cm (mean 10.4±3.3 cm, n = 14). The Panama Lightfish ranged from 3.8 to 6.0 cm (n = 5), myctophids were smaller than 7 cm and the single Codlet collected was 6.6 cm. Cephalopod mass could be estimated only for *Leachia* sp. (0.49 to 2.94 g, n = 3) and *Abraliopsis* sp. (2.49 g and 3.24 g, n = 2). The single *Loligo gahi* weighted 55.23 g. *Japetella sp.* was the smallest cephalopod species taken and reached 8.5 cm in mantle length.

Fifty-one samples contained oil (60.7%). Mean oil mass was 1.8±1.4 g (range = 0.7–4.8 g, n = 10). There was no relationship between oil mass and estimated stomach content mass (r_{Spearman}= 0.158, n = 10, $P > 0.05$). Oil proportion varied from 5.3% to 100%.

DISCUSSION

Markham's Storm Petrels off the Peruvian central coast consumed mainly fish and cephalopods, although prevalence varied by year. Fish was the main taxon by mass in 1999 but cephalopods were the main prey consumed in 1996 and 2000. This general characterization of diet is consistent with studies of diet in other storm petrel species (Prince & Morgan 1987). Croxall *et al*. (1988) hypothesized that all *Oceanodroma* species and populations of the Pacific Ocean feed mainly on fish, with squid as the second-most important prey. Our work partly agrees with that hypothesis, considering the great temporal variation in the main prey. Likely, the diet of Markham's Storm Petrel reflects prey availability, as was suggested for Wilson's Storm Petrel *Oceanites oceanicus* (Quillfeldt 2002). However, the prevalence of some prey species (e.g. pelagic cephalopods) is unknown in the Peruvian Current and adjacent waters.

Changes in the diet of Markham's Storm Petrels were probably influenced by El Niño 1997/98. Cold sea surface temperatures were characteristic in 1996 (Ganoza *et al*. 1997, Pizarro *et al*. 1997). During that year, Mote Sculpin, a coastal pelagic fish associated with sub-Antarctic waters (Quiroz *et al*. 1996), and Pelagic Squat Lobster, a swarming planktonic crustacean associated with cold waters (Segura & Castillo 1996, Paredes & Elliot 1997), were abundant and the diet was comprised mainly of these two species. No anchovy were observed in the diet then, probably because the anchovy population was dispersed, and therefore less available to the birds, during that year (Cárdenas *et al*. 1997, Ganoza *et al*. 1997, Morón *et al*. 1997). The presence of subtropical waters 110 km offshore from the study area (Pizarro *et al*. 1997) could have caused the presence of lightfish and lanternfish, warm water mesopelagic species, in the diet during 1996. Despite the cold sea surface temperatures observed during 1999 (Morón & Crispín 1999, Vásquez & Tello 1999) Mote Sculpin was not present in the area and Pelagic Squat Lobster was present from the coast to 125 km offshore (Castillo *et al*. 1999a,b). During 1999, storm petrel diet was composed mainly of Peruvian Anchovy, which were concentrated from 54 to 145 km offshore of Paracas (Castillo *et al*. 1999a,b). High biomasses of lightfish and lanternfish were recorded off Paracas from 54 to 216 km offshore (Castillo *et al*. 1999a,b). The single Codlet recorded in 1999 was probably associated with El Niño, because it is a common species off Panama (Sánchez *et al*. 1985). During 2000, more average oceanographic conditions predominated in the study area, although subtropical surface waters were unusually close to the coast (IMARPE unpubl. data). Cephalopods were the main prey consumed that year and the only fish recorded was a Slimtail Lanternfish.

Among the cephalopods consumed, *Japetella* sp., a small oceanic octopus, appears to be the main prey, followed by *Leachia* sp. and *Abraliopsis* sp. (Table 1). Unfortunately there are no data on the distribution of these cephalopods off the Peruvian coast. Nevertheless, *Japetella* is a bathypelagic species, while *Abraliopsis* is an epipelagic oceanic species, *Leachia* and *Mastigoteuthis* are mesopelagic, and *Loligo gahi* is neritic (Nesis 1972, Roper & Young 1975, Roper *et al*. 1984, Nesis 1996). Except for *Loligo*, all the cephalopod prey taken by Markham's Storm Petrel suggests feeding in waters deeper than those of the continental shelf.

About 10% of samples contained remains that suggest scavenging. It is known that Procellariiforms scavenge dead or moribund squid at the sea surface (e.g. Imber & Berruti 1981, Croxall *et al*. 1988). All cephalopod species recorded in this study have terminal reproduction and some (e.g. Cranchiidae) float on the surface at death, where they could be taken by seabirds (Nesis 1996). The shallowest depth recorded for live *Japetella* sp. is

TABLE 1

Diet composition of Markham's Storm Petrel *Oceanodroma markhami* on the central coast of Peru

	1996			1999		
	Occurrence (%)	**Number (%)**	**Mass (%)**	**Occurrence (%)**	**Number (%)**	**Mass (%)**
Crustaceans	**51.61**	**23.94**	**24.37**	**51.43**	**22.79**	**2.80**
Euphasiacea						
Euphausia mucronata				22.86	11.76	0.47
Decapoda						
Emerita analoga (zoea)	3.23	1.41	0.01			
Pleuroncodes monodon	32.26	15.49	24.32	5.71	1.47	2.29
Phronima sp.	3.23	1.41	0.01			
Fam. Xantidae (megalopa)	6.45	2.82	0.02			
Isopoda				2.86	1.47	0.01
Undetermined crustaceans	6.45	2.82	0.01	31.43	8.09	0.04
Cephalopods*	**70.97**	**50.70**	**44.43**	**65.71**	**32.35**	**28.15**
Enoploteuthidae						
Abraliopsis sp.						
Mastigotheutidae						
Mastigoteuthis sp.						
Cranchiidae						
Leachia sp.						
Loliginiidae						
Loligo gahi						
Bolitaenidae						
Japetella sp.						
Fish	**32.26**	**25.35**	**31.21**	**77.14**	**44.85**	**69.05**
Engrauliidae						
Engraulis ringens				25.71	11.03	43.20
Normanychtiidae						
Normanichthys crockeri	6.45	2.82	13.86			
Photichtyidae						
Vinciguerria lucetia	3.23	5.63	4.34	2.86	0.74	0.56
Myctophidae						
Lampanyctus parvicauda	3.23	1.41	1.08			
Mictophum nitidulum	6.45	2.82	2.17	8.57	4.41	3.37
Bregmacerotiidae						
Bregmaceros bathymaster				2.86	0.74	0.56
Undetermined larval fish	22.58	12.68	9.76	71.43	27.94	21.35
Total prey number		71			136	
Total mass (g)		97.24			187.58	
Sample size		30			36	

*****Obtained from the addition of beaks and unidentifiable remains. Only the number of beaks identified is showed for cephalopod species in the pooled sample.

TABLE 1 (continued)

(Diet composition of Markham's Storm Petrel *Oceanodroma markhami* on the central coast of Peru)

	2000			Pooled		
	Occurrence (%)	**Number (%)**	**Mass (%)**	**Occurrence (%)**	**Number (%)**	**Mass (%)**
Crustaceans	**14.29**	**8.33**	**0.05**	**47.95**	**22.58**	**9.73**
Euphasiacea						
Euphausia mucronata				12.12	7.37	0.30
Decapoda						
Emerita analoga (zoea)				1.37	0.46	0.002
Pleuroncodes monodon				16.44	5.99	9.39
Phronima sp.				1.37	0.46	0.002
Fam. Xantidae (megalopa)				2.74	0.92	0.01
Isopoda				1.37	0.92	0.004
Undetermined crustaceans	14.29	8.33	0.05	19.18	6.45	0.03
Cephalopods*	**85.71**	**75.00**	**83.63**	**69.86**	**41.01**	**35.87**
Enoploteuthidae						
Abraliopsis sp.				**2**		
Mastigotheutidae						
Mastigoteuthis sp.				**1**		
Cranchiidae						
Leachia sp.				**3**		
Loliginiidae						
Loligo gahi				**1**		
Bolitaenidae						
Japetella sp.				**7**		
Fish	**28.57**	**16.67**	**16.32**	**53.42**	**36.41**	**54.40**
Engrauliidae						
Engraulis ringens				12.33	6.91	27.22
Normanychtiidae						
Normanichthys crockeri				2.74	0.92	4.53
Photichtyidae						
Vinciguerria lucetia				2.74	2.30	1.77
Myctophidae						
Lampanyctus parvicauda	14.29	8.33	8.16	2.74	0.92	0.71
Mictophum nitidulum				6.85	3.69	2.83
Bregmacerotiidae						
Bregmaceros bathymaster				1.37	0.46	0.35
Undetermined larval fish	14.29	8.33	8.16	45.21	22.12	16.99
Total prey number		12			219	
Total mass (g)		12.91			297.73	
Sample size		7			73	

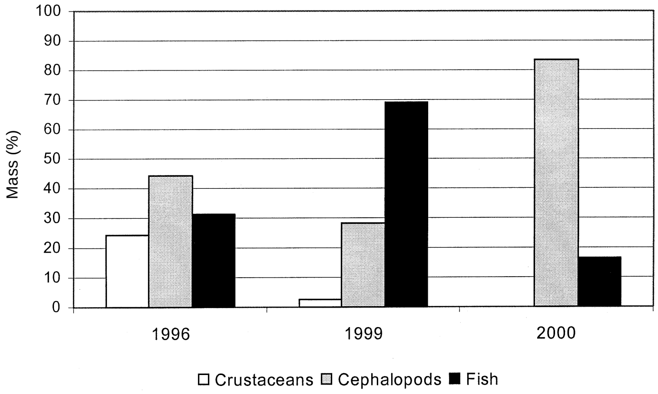

Fig. 2. Annual variation of prey groups in the diet of Markham's Storm Petrels.

200 m (Nesis 1972, Roper & Young 1975), so scavenging appears to be the only way by which storm petrels could take them. On the other hand, during the surveys at sea (see below), we recorded Markham's Storm Petrels flying around carcasses of Southern Sea Lions *Otaria byronia*, where Wilson's, Hornby's *Oceanodroma hornbyi* and Wedge-rumped *O. tethys* Storm Petrels were scavenging. This could explain the occurrence of red muscle fibre in some stomach contents.

The diet of Markham's Storm Petrel suggests some nocturnal foraging. The lanternfish and lightfish consumed are mesopelagic species showing diel vertical migration patterns that surface at night (Wisner 1976, Hulley 1990, Paxton *et al.* 1995, Castillo *et al.* 1999b); the presence of photophores in these species may aid storm petrels in locating them. The cephalopods *Japetella, Leachia*, *Abraliopsis* and *Masthigoteuthis* also have photophores (Robinson & Young 1981, Roper *et al*. 1984, Young *et al*. 1998), and exhibit vertical migration. Nocturnal foraging in relation to prey bioluminescence among fish and cephalopods has been discussed by Imber (1973).

Distribution at sea of Markham's Storm Petrel has been recorded during surveys conducted in 1998 and 2000 (Jahncke *et al*. 1998, 1999; J. Pérez & I. García-Godos unpubl. data). Ninety percent of individuals recorded in these surveys were beyond the continental shelf (I. García-Godos unpubl. data) up to 360 km offshore. The wide distribution pattern, the large variations in the diet found in this study, the distribution of their prey and the scavenging habits indicate that Markham's Storm Petrel forages opportunistically on available food occuring near the sea surface.

ACKNOWLEDGEMENTS

We thank José Miguel Pérez, Carlos Mendoza, Carolina Pickens, Silvia Tovar, Liliana Ayala, Elda Cabrera, Katia Balta, Sandra Sampértegui and Doménica Zileri for their help during fieldwork. Special thanks to Unai Markaida (CICESE, Mexico), who identified cephalopod beaks and gave important information. Petra Quillfeldt, Carlos Zavalaga and two referees made helpful comments on the manuscript. PROABONOS authorized our research at La Vieja Island and provided facilities. Fishers from Laguna Grande kindly provided transport to the island.

REFERENCES

ARNTZ, W.E. & FAHRBACH, E. 1996. El Niño: Experimento Climático de la Naturaleza. México: Fondo de Cultura Económica.

CÁRDENAS, G., ESCUDERO, L., ECHEVARRIA, A. & PELLON, J. 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.

CASTILLO, R., GUTIERREZ, M. & PERALTILLA, S. 1999a. Biomasa de los principales recursos pesqueros a finales de otoño 1999, Crucero BIC José Olaya Balandra y BIC Humboldt 9906 de Paita a Punta Infiernillos. *Informe Instituto del Mar del Perú* 149: 19–34.

CASTILLO, R., GUTIERREZ, M., ALIAGA, A. & MARIN, D. 1999b. Distribución de los recursos pelágicos de mayor interés, Crucero BIC Olaya y BIC Humboldt 9906 de Paita a Punta Infiernillos. *Informe Instituto del Mar del Perú* 149: 7–18.

CLARKE, M.R. (Ed.). 1986. A handbook for the identification of cephalopod beaks. Oxford: Clarendon Press.

COHEN, D.M., INADA, T., IWAMOTO, T. & SCIALABBA, N. 1990. FAO Species Catalogue. Vol. 10. Gadiform fishes of the world (Order Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date. FAO Fish. Synop. (125, Vol. 10).

CROXALL, J.P., HILL, H.J., LIDSTONE-SCOTT, R., O'CONNELL, M.J. & PRINCE, P.A. 1988. Food and feeding ecology of Wilson's Storm Petrel *Oceanites oceanicus* at South Georgia. *Journal of Zoology, London* 216: 83–102.

DUFFY, D.C. & JACKSON, S. 1986. Dietary studies of seabirds: a review of methods. *Colonial Waterbirds* 9: 1–17.

GANOZA, F., VALDIVIA, J., MORÓN, O. & SÁNCHEZ, S. 1997. Distribución, concentración y biomasa de la anchoveta en Primavera 1996. Crucero BIC SNP-1 9610. *Informe Instituto del Mar del Perú* 126: 28–45.

GARCÍA-GODOS, A. 2001. Patrones morfológicos del otolito sagitta de algunos peces del mar peruano. *Boletín Instituto del Mar del Perú 20*: 1–70.

GOODALL, J.A., JOHNSON, A.W. & PHILLIPPI, R.A. 1951. Las Aves de Chile, su Conocimiento y sus Costumbres. Buenos Aires: Platt, Establecimientos gráficos S.A.

HULLEY, P.A. 1990. Myctophidae. In: Quero, J.C., Hureau, J-C., Karrer, C., Post, A. & Saldanha L. (Eds). Check-list of the fishes of the eastern tropical Atlantic (CLOFETA). JNICT, Vol. 1. Lisbon & Paris: SEI & UNESCO. pp. 453–454.

IMBER, M.J. 1973. The food of Grey-faced Petrels (*Pterodroma macroptera gouldi* (Hutton)), with special reference to diurnal vertical migration of their prey. *Journal of Animal Ecology* 42: 645–662.

IMBER, M.J. & BERRUTI, A. 1981. Procellariform seabirds as squid predators. In: Cooper, J. (Ed.). Proceedings of the Symposium of Birds of the Sea and Shore, 1979. Cape Town: African Seabird Group. pp. 43–61.

JAHNCKE, J. 1993. Primer informe del área de anidación de la golondrina de tempestad negra *Oceanodroma markhami* (Salvin 1883). *Proceedings of X Congreso Nacional de Biología, 1992, Lima.* pp. 339–343.

JAHNCKE, J. 1994. Estudio preliminar de la biología reproductiva de la golondrina de tempestad negra *Oceanodroma markhami* en la Península de Paracas, Perú. VII Congreso Iberoamericano de Biodiversidad y Zoología de

Vertebrados. Abstract, p. 52

JAHNCKE, J. & GOYA, E. 1998. Las dietas del guanay y del piquero peruano como indicadoras de la abundancia y distribución de anchoveta. *Boletín del Instituto del Mar Perú* 17: 15–33.

JAHNCKE, J., PEREZ, J. & GARCÍA-GODOS, A. 1998. Abundancia relativa y distribución de aves marinas frente a la costa peruana y su relación con la anchoveta. Crucero BIC Humboldt 9803-05 de Tumbes a Tacna. *Informe Instituto del Mar del Perú* 135: 153–162.

JAHNCKE, J., AYALA, L. & MENDOZA, C. 1998. Abundancia relativa y distribución de aves marinas frente a la costa peruana y su relación con la anchoveta, Crucero BIC Humboldt 9808-09. *Informe Instituto del Mar del Perú* 141: 85–95.

JAHNCKE, J., GARCÍA-GODOS, A. & GOYA, E. 1999. The diet of the Peruvian Diving Petrel at La Vieja and San Gallán, Perú. *Journal of Field Ornithology* 70: 71–79.

MONTALTI, D. & CORIA, N.R. 1993. El uso de la técnica de lavados de estómagos para obtener muestras de contenidos estomacales en aves marinas antárticas. *Revista Italiana de Ornitología Milano.* 63: 69–73.

MORÓN, O. 2000. Características del ambiente marino frente a la costa peruana. *Boletín del Instituto del Mar del Perú* 19: 179–204.

MORÓN, O. & CRISPÍN, A. 1999. Temperatura y salinidad durante la prospección pesquera de reclutamiento de recursos pelágicos LP IMARPE V 9906. *Informe Instituto del Mar del Perú* 149: 75–78.

MORÓN, O., FLORES, G., SANCHEZ, G. & GIRON, M. 1997. Monitoreo oceanográfico pesquero por áreas seleccionadas, Paita, Chimbote, Callao, Pisco, Ilo. Setiembre 1996. *Informe Progresivo del Instituto del Mar del Perú* 50. 80 pp.

MURPHY, R.C. 1936. Oceanic birds of South America. New York: American Museum of Natural History.

NESIS, K.N. 1972. Oceanic cephalopods of Peru current. Horizontal and vertical distribution. *Oceanology* 12: 426–437.

NESIS, K.N. 1996. Mating, spawning and death in oceanic cephalopods: a review. *Ruthenica* 6: 23–64.

PAREDES, F. & ELLIOT, W. 1997. Estudio biológico pesquero del "camaroncito rojo" o "munida" *Pleuroncodes monodon* frente a Pucusana, Lima. *Informe Progresivo del Instituto del Mar del Perú*. 57: 21–34.

PAXTON, J.R., LAVENBERG, R.J. & SOMMER, C. 1995. Myctophidae. Linternillas. In: Fisher, W., Krupp, F., Schneider, W., Sommer, C., Carpenter, K.E. & Niem, V. (Eds). Guía FAO para identificación de especies para los fines de la pesca. Pacífico Centro – Oriental. 3 Vols. pp. 1315–1321.

PINEDA, S.E., AUBONE, A. & BRUNETTI, N.E. 1996. Identificación y morfometría comparada de las mandíbulas de *Loligo gahi* y *Loligo sanpaulensis* (Cephalopoda, Loliginidae) del Atlántico sudoccidental. *Revista de Investigación y Desarrollo Pesquero* 10: 85–99.

PIZARRO, L., FLORES, G. & SOLÍS, J. 1997. Condiciones oceanográficas frente a la costa norte – centro del Perú durante el invierno 1996, Crucero BIC Humboldt 9608-09. *Informe Progresivo del Instituto del Mar del Perú* 123: 47–66.

PRINCE, P.A. & MORGAN, R.A. 1987. Diet and feeding ecology of Procellariiformes. In: Croxall, J.P. (Ed.). Seabirds: feeding ecology and role in marine ecosystems. Cambridge: Cambridge University Press. pp. 135–171.

QUILLFELDT, P. 2002. Seasonal and annual variation in the diet of breeding and non-breeding Wilson's Storm Petrels on King George Island, South Shetland Islands. *Polar Biology* 25: 216–221.

QUIROZ, M., ZAMBRANO, M. & CARDENAS, F. 1996. El recurso camotillo (*Normanichthys crockeri*) en la zona sur del Perú, abril 1995 a enero 1996. I *Informe Progresivo del Instituto del Mar del Perú* 46: 19–29.

RIDOUX, V. 1994. The diets and dietary segregation of seabirds at the subantarctic Crozet Islands. *Marine Ornithology* 22: 1–192.

ROBINSON, F.G. &. YOUNG, R.E. 1981. Bioluminescence in pelagic octopods. *Pacific Science* 35: 39–44.

ROPER, C.F.E. & YOUNG, R.E. 1975. Vertical distribution of pelagic cephalopods. *Smithsonian Contributions in Zoology* 209. 51 pp.

ROPER, C.F.E., SWEENEY, M.J. & NAUEN, C.E. 1984. FAO Species Catalogue. Vol. 3. Cephalopods of the world. An annotated and illustrated catalogue of species of interest to fisheries. FAO Fish. Synop. (125) Vol. 3. 227 pp.

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

SÁNCHEZ, G., VELEZ-DIEGUEZ, J. & CHIPOLLINI, A. 1985. Un pez panameño en aguas peruanas: *Bregmaceros bathymaster* durante "El Niño" 1982–83. *Boletín de Lima* 38: 92–96.

SEGURA, M. & CASTILLO, R. 1996. Distribución y concentración de la "múnida" en el verano 1996. *Informe Instituto del Mar del Perú* 122.

SIEGEL, S. 1956. Nonparametric statistics for the behavioral sciences. New York: McGraw-Hill Book Company.

VÁSQUEZ, L. & TELLO, E. 1999. Condiciones oceanográficas del mar peruano durante el Crucero BIC José Olaya Balandra 9902-03, de Tumbes a Tacna. *Informe Instituto del Mar del Perú* 147: 71–82.

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

WISNER, L.R. 1976. The taxonomy and distribution of lanternfishes (Family Myctophidae) of eastern Pacific Ocean. Norda Report 3. St. Louis: Office of Naval Research.

WOLFF, G.A. 1984. Identification and estimation of size from the beaks of 18 species of cephalopods from the Pacific Ocean. *NOAA Technical Report*. *NMFS* 17: 1–50.

YOUNG, R.E., BURGESS, L.A., ROPER, C.F. & SWEENEY, M.J. 1998. Classification of the Enoplotheutidae, Pyroteuthidae and Anchistrocheiridae. *Smithsonian Contributions in Zoology* 586: 239–256.