DIET OF THE PERUVIAN DIVING PETREL *PELECANOIDES GARNOTII* AT LA VIEJA ISLAND, PERU, 1997–2000: POTENTIAL FISHERY INTERACTIONS AND CONSERVATION IMPLICATIONS

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SUMMARY

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Changes in the diet of the Peruvian Diving Petrel *Pelecanoides garnotii* in La Vieja Island were determined from 118 stomach contents collected by the water-offloading technique between 1997 and 2000. Fish were present in 67.8% of samples, crustaceans in 65.3% and squid in 7.6%. By mass, Peruvian Anchovy *Engraulis ringens* (33.9%), the small krill *Euphausia mucronata* (26.8%) and Squat Lobster *Pleuroncodes monodon* (24.3%) were the most important prey species. Other important prey were Mote Sculpin *Normanichthys crockeri* and fish larvae. High monthly variation in the main prey species suggests an opportunistic feeding behaviour associated with prey availability. Sea-surface temperature anomalies were negatively correlated with diet diversity, suggesting that warm conditions decrease prey options. An increased consumption of anchovy occurred between 1997 and 2000, smaller in size than exploited by the legal fishery. There was no overlap in anchovy size between those caught by the fishery and those consumed by diving petrels, discouraging the hypothesis of direct competition. Nevertheless, other factors related to fishery and El Niño events should be evaluated to assure the conservation of this globally Endangered seabird.

Key words: Peruvian Diving Petrel, *Pelecanoides garnotii,* diet, fishery competition, conservation, El Niño

INTRODUCTION

The Peruvian Diving Petrel *Pelecanoides garnotii* is an endemic seabird of the Peruvian or Humboldt Current. Its distribution is restricted to islands from Lobos de Tierra (6°S) in Peru to Corral (37°S) in Chile. Its population was dramatically reduced after the guano industry removed its nesting substratum from the islands off Peru (Coker 1919, Murphy 1936). Peruvian Diving Petrels are considered a Critically Endangered Species (IUCN, 2004) and are protected by Peruvian legislation (Ministerio de Agricultura 2004); they are also considered Endangered by the World Conservation Union (BirdLife International 2004), and they have been included in Appendix I of the Bonn Convention on the Conservation of Migratory Species of Wild Animals (CMS 2002).

Jahncke & Goya (1998a) estimated the population of Peruvian Diving Petrels breeding in Peru as 13 000 pairs, restricted to La Vieja and San Gallán Islands on the central coast of Peru. They recognized guano harvesting and direct mortality by poachers as important threats, disregarding the potential threat that the industrial fishery for anchovies may represent. Hays (1989) had earlier suggested that the commercial fishery endangered Peruvian Diving Petrels by directly competing for the same food sources. However, Jahncke *et al.* (1999) indicated that euphausiids, along with small, unidentified larval fish, formed the most important prey and that competition for food between diving petrels and the industrial fishery should not be seen as a threat.

A well-known example exists of fisheries affecting seabird numbers in Peru during the 1970s. Massive and sustained exploitation of Peruvian Anchovy *Engraulis ringens* for the fishmeal industry, combined with environmental disturbances from El Niño events, caused a severe reduction in fish biomass (Brainard & McLain 1987), resulting in the collapse of the fishery (Clark 1977) and a dramatic decrease in the number of guano-producing seabirds (Duffy 1983, Jahncke 1998, Goya 2000, Jahncke *et al.* 2004). Whether the industrial fishery for anchovies similarly affected the population of Peruvian Diving Petrels is not known. Peruvian Diving Petrels are not known to consume important amounts of Peruvian Anchovy (Jahncke *et al.* 1999), yet changes in community structure resulting from intensive anchovy harvests may have indirectly affected these birds.

Environmental disturbances in the Peruvian upwelling system are generally associated with strongly positive El Niño–Southern Oscillation (ENSO) anomalies which result in decreased production, major food web perturbations and low prey availability for seabirds (Arntz & Farbach 1996, Morón 2000, Fiedler 2002, Chávez *et al.* 2004). ENSO disturbances adversely affected reproductive performance of Peruvian Diving Petrels during the El Niño event of 1997/1998 (Jahncke & Goya 1998b), resulting in massive desertion on La Vieja Island, the largest breeding locality in Peru (IGG pers. obs.).

We present evidence of high variability in the diet of the Peruvian Diving Petrel on La Vieja Island, showing the importance of anchovy and other prey species. We then discuss the role of prey variability and fishery competition in relation to the conservation of this threatened seabird in Peru.

METHODS

Fieldwork was conducted on La Vieja Island (14°17′S, 76°11′W) from May 1997 to August 2000. The island is located in Independence Bay within the Paracas National Reserve (Fig. 1) along the central coast of Peru. Birds were captured using mist nets set next to the colonies during the night from 18h30 to 22h30, sampling for a total of two days every month. The water-flushing technique (Wilson 1984, Montalti & Coria 1993) was used to obtain stomach contents immediately after the birds were liberated from the net. Flushing was usually undertaken twice to obtain complete samples; three consecutive flushings were made in exceptional cases. No mortality occurred while the birds were being handling. Plastic infant-feeding tubes (1 mm in diameter), 20-mL syringes and seawater were used. Stomach contents were preserved with 70% ethyl alcohol, and analyzed the day after collection. Birds were released beside the colony from which they were captured. No dead birds were found at or near the colonies the day after sampling. Samples were collected in 1997 ($n = 23$), 1998 ($n = 46$), 1999 ($n = 15$) and 2000 ($n = 34$). Prey items were identified using Santander *et al.* (1981) for invertebrates and García-Godos (2001) for fish otoliths. Squid species could not be identified.

The minimum prey number was estimated for each sample. Fish prey and fish larvae numbers were determined by dividing the number of otoliths by two. Euphausiid numbers were determined by counting telsons or the number of eyes divided by two (or both). The number of other crustaceans was determined by counting individuals. Cephalopod numbers were determined by counting of the number of upper or lower beaks. Published and unpublished information was used to transform prey numbers into mass for each prey species.

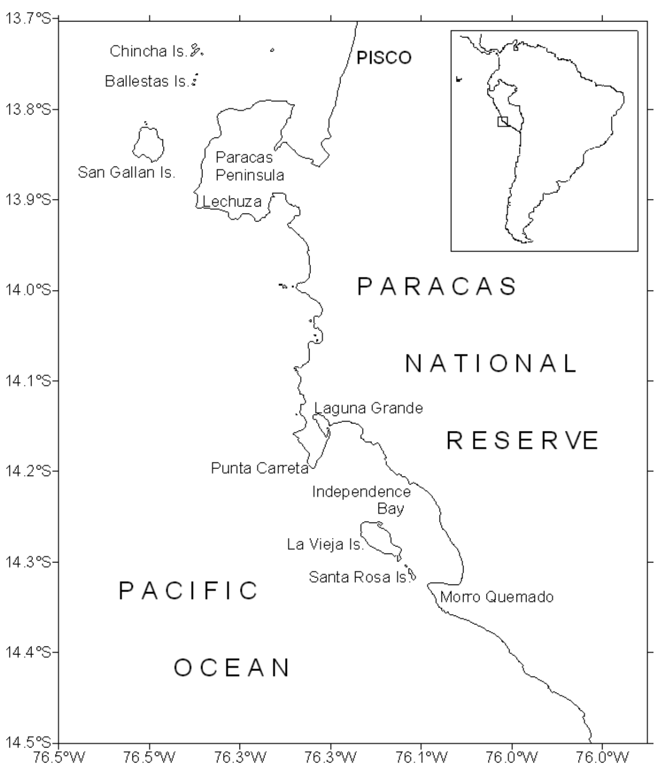

Fig. 1. La Vieja and San Gallán Islands, the main breeding grounds of Peruvian Diving Petrels.

For anchovy, fish length (FL) was obtained from otolith length (OL) measures using the equation $FL = -0.1102 + 4.2229(OL)$ ($r^2 = 0.96$; range: 5.0–17.5 cm) obtained from Laboratorio de Edad y Crecimiento–IMARPE (unpubl. data). Otolith length (OL) was corrected considering 15% erosion for adult otoliths (>2 mm) and 20% erosion for juvenile otoliths (<2 mm), because erosion has an inverse relation with size (Jahncke & Rivas 1998). The IMARPE's unpublished equation $FW = 0.0021 + FL^{3.4221}$ ($n = 173$; $r^2 = 0.98$; range: 2.5–18.5 cm), obtained during a survey of pelagic fish conducted in October/November 2001 was used to estimate anchovy mass.

The mass of Mote Sculpin *Normanichthys crockeri* was obtained from the equation $FW = 0.7867[\mathrm{Ln}\ (OL)] + 2.0018$ ($n = 37$; $r^2 = 0.81$), obtained from direct measures of fish of the same size range as those found in the sample.

Mass assigned to other fish species was the mean of that estimated for anchovy and Mote Sculpin (0.776 g). The mass used for Squat Lobsters *Pleuroncodes monodon* (0.44 g) was the mean value obtained from direct weighing ($n = 292$). Mass of the small krill *Euphausia mucronata* (0.04 g) was obtained from a survey of demersal fish conducted during April/May 2000 (IMARPE unpubl. data). The mass assigned to megalopod larvae of Xanthidae (0.011 g), megalopod larvae of the sand crab *Emerita analoga* (0.007 g), zoea larvae of sand crab (0.006 g), other crustaceans (0.007 g), small squid (0.055 g) and fish larvae (0.33 g) were those of Jahncke *et al.* (1999). Copepod mass (0.002 g) was obtained from Unidad de Producción Secundaria–IMARPE (unpubl. data). Means are expressed plus or minus one standard deviation.

We examined whether there were differences in prey use between months and years. We used the chi-square test for independent samples to test for differences in frequency of occurrence. We used Mann–Whitney and Kruskal–Wallis tests to look for differences in proportions by number or mass (Siegel 1956). We used the Levin standardized index (Krebs 1989) to measure trophic niche breadth to determine how diving petrels use resources. We also estimated trophic diversity for the pooled sample using the Shannon and Wiener index (H), as defined by Krebs (1989). For ease of interpretation we used the standardized form (H_{std}), also called Evenness, which ranges from zero to one (Krebs 1989) and measures how uniformly are prey being used. We examined whether prey use varied with the oceanographic conditions. We used the Spearman rank correlation (Siegel 1956) to relate prey consumption with anomalies in sea surface temperature (SST) from Independence Bay (PROABONOS unpubl. data). We examined whether any size overlap occurred in anchovy caught by the industrial fishery and those consumed by diving petrels. Anchovy sizes from the fishery were measured by observers onboard fishing vessels and correspond to 248 fishing operations within 20 nautical miles of the coast, from 13.5°S to 14.5°S during the months sampled at La Vieja Island (IMARPE unpubl. data.; see Bouchon *et al.* 1998). We used the simplified Morisita index of similarity (Krebs 1989) to determine the level of overlap in anchovy sizes taken by the fishery and by diving petrels. Additional information based on opportunistic sightings of foraging diving petrels is included to permit a discussion of its relevance for the conservation of the species.

RESULTS

We collected a total of 118 stomach contents distributed over 11 months of sampling effort from 1997 to 2000. Solid remains—corresponding to 14 different taxa—were found in 94.9% of the samples. Fish, crustaceans and cephalopods were present in 67.8%, 65.3% and 7.6% of samples respectively (Table 1).

The main taxa consumed were crustacean zooplankton (51.9% by mass) and fish (47.9% by mass). The remaining 0.2% by mass corresponded to cephalopods. We found significant differences in the frequency of occurrence of crustaceans, fish and squid among months (χ^2_{10}, $P < 0.01$) and years sampled (χ^2_3, $P < 0.01$). The most important prey species were Peruvian Anchovy (33.9% by mass), followed by small krill (26.8% by mass) and Squat Lobster (24.3% by mass). Mote Sculpin and fish larvae were also important prey.

We found significant differences in the frequency of occurrence of Peruvian Anchovy, small krill, Squat Lobster, Mote Sculpin, fish larvae and sand crab zoeas between the months (χ^2_{10}, $P < 0.01$) and years (χ^2_3, $P < 0.01$) sampled. No clear seasonality was evident in prey species, and we observed marked shifts from one prey to another between the months and years sampled. Niche breadth estimated for the pooled sample was 0.224. The Shannon and Wiener diversity index was 2.175, with a standardized form (evenness) of 0.571, indicating an elevated variability distribution of prey taxa in the diet.

Table 2 shows prey consumption by mass during each month sampled. Mote Sculpin and fish larvae formed the main prey during 1997. Fish larvae were the main food in early 1998; from July 1998, the food changed to small krill and anchovy. The diet changed to Squat Lobster and anchovy in 1999 and 2000, when no small krill were found in the diet (Fig. 2). Within-year differences in prey consumption were significant for sculpins (Kruskal–Wallis test = 6.816, $P = 0.033$, $df = 2$) and fish larvae (Kruskal-Wallis test = 6.816, $P = 0.033$, $df = 2$) in 1997; anchovy (Kruskal–Wallis test = 42.396, $P < 0.001$, $df = 2$) and small krill (Kruskal–Wallis test = 6.432, $P = 0.04$, $df = 2$) in 1998; sand crab zoeas (Mann–Whitney test = 40.00, $P = 0.038$) and Squat Lobster (Mann–Whitney

TABLE 1
Diet composition of the Peruvian Diving Petrel from 118 stomach contents collected between 1997 and 2000 at La Vieja Island, Peru

Prey taxa	Scientific name	Common name	Frequency (%)	Contribution to diet (%)	
				By number	By mass
PHYLUM MOLLUSCA					
Class Cephalopoda					
Order Teuthoidea	Squid (unidentified)		7.63	0.41	0.24
PHYLUM CRUSTACEA			65.25	88.63	51.88
Class Malacostraca					
Superorder Eucarida					
Order Euphausiacea	*Euphausia mucronata*	Small krill	23.73	72.56	26.83
Order Copepoda	Copepods (unidentified)		7.63	0.79	0.02
Order Decapoda	Decapods (unidentified)		3.39	0.84	0.06
Infraorder Caridea					
Superfamily Galatheidae	*Pleuroncodes monodon*	Squat Lobster	28.81	5.08	24.26
	Porcellanidae (zoea)		0.08	0.09	0.01
Superfamily Hippidae	*Emerita analoga*	Sand crab	15.25	3.09	0.62
Infraorder Brachyura					
Superfamily Xanthidae	Xanthidae (megalopa)		10.17	0.69	0.08
PHYLUM VERTEBRATA			67.80	10.96	47.88
Class Osteichthyes					
Family Engraulidae	*Engraulis ringens*	Peruvian Anchovy	31.47	7.18	33.90
Family Normanichthyidae	*Normanichthys crockeri*	Mote Sculpin	16.10	0.53	8.00
Family Atherinidae	*Odontesthes regia*	Silverside	0.85	0.04	0.19
Family Photichthyidae	*Vinciguerria lucetia*	Lightfish	0.85	0.01	0.05
Fish larvae			24.58	3.19	5.75
Total sample size				118	
Total prey (n)				8502	
Total reconstructed weight of prey (g)				815.6	

test = 42.50, $P = 0.019$) in 1999; and Squat Lobster (Kruskal–Wallis test = 14.738, $P < 0.01$, $df = 2$) and anchovy (Kruskal–Wallis test = 16.270, $P < 0.01$, $df = 2$) in 2000.

We found no clear relationship between local oceanographic conditions and prey use by Peruvian Diving Petrels. Squat Lobster consumption (percentage by mass) was strongly and negatively related with the SST anomaly from Independence Bay ($r_{\text{Spearman}} = -0.71$, n = 11, $P < 0.01$), but fish larvae consumption showed only a weak negative relationship ($r_{\text{Spearman}} = -0.45$, nonsignificant). Other prey showed no relationship with SST anomalies. We found a negative relationship between Mote Sculpin and fish larvae consumption ($r_{\text{Spearman}} = -0.56$, n = 11, $P = 0.07$), suggesting that fish larvae found in the diet may not belong to this species. The Shannon and Wiener diversity index for diet was negatively correlated with the anomaly of SST by month ($r_{\text{Spearman}} = -0.68$, n = 11, $P < 0.05$).

We found no overlap in the sizes of anchovy captured by the industrial fishery and those consumed by diving petrels (simplified Morisita index of similarity of 0.007). The length-frequency distribution of Peruvian Anchovy consumed by diving petrels indicates a large number of small anchovies in the diet (Fig. 3), some of them at late larval stages. The mean size of Peruvian Anchovies consumed by diving petrels was 45.9 ± 14.6 mm (range: 20.7–149.6 mm), far smaller than the minimum legal commercial size (120 mm). The mean size of anchovy taken by the fishery (Fig. 3) was 149.9 ± 13.9 mm (range: 70–199 mm).

TABLE 2
Average composition by mass of the diet of the Peruvian Diving Petrel during 11 sampling periods between 1997 and 2000 at La Vieja Island, Peru

	1997			**1998**			**1999**		**2000**		
	May	**Jul.**	**Nov.**	**May**	**Jul.**	**Sep.**	**Mar.**	**Nov.**	**Mar.**	**May**	**Aug.**
Crustaceans											
Copepod (undetermined)			1.27	0.05	0.002	0.01					
Decapod (undetermined)				1.72	0.01						
Emerita analoga			0.07			3.29	1.66		0.01		
Ephausia mucronata	0.08			17.09	94.78	10.34			0.02		
Pleuroncodes monodon							44.48		74.34	48.85	2.10
Porcelanidae (undetermined)											0.05
Xanthidae (undetermined)		4.26	0.81		0.02	0.19		0.97	0.01		0.21
Cephalopods (undetermined)				0.74	0.78	0.05					0.05
Fish											
Engraulis ringens	0.70					84.93	41.05	61.06	20.70		94.99
Normanichthys crockeri	99.22		35.36			1.19	8.30		4.04	51.15	1.32
Odontesthes regia									0.72		
Vinciguerria lucetia									0.18		
Fish larvae (undetermined)		95.74	62.49	80.40	4.42		4.51	37.97			1.27
Sample size	10	3	10	12	18	16	10	5	20	3	11

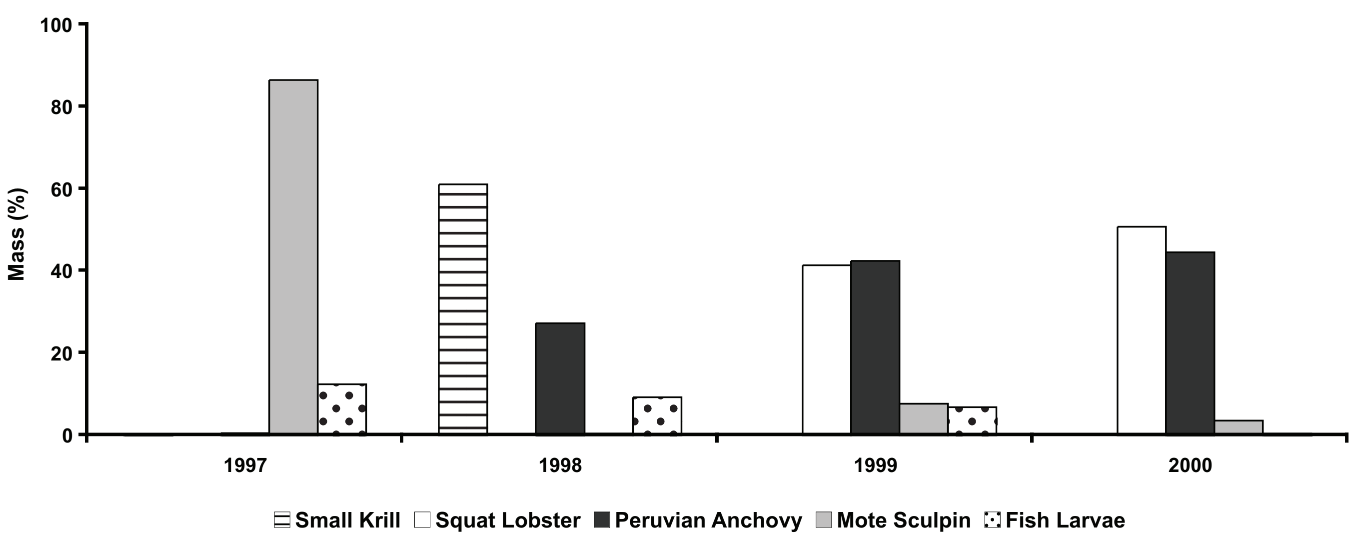

Fig. 2. Annual changes in composition by mass of the diet of the Peruvian Diving Petrel at La Vieja Island between 1997 and 2000.

Opportunistic sighting of foraging Peruvian Diving Petrels suggest the presence of small foraging flocks inside Independence Bay. Approximately 5000 diving petrels and 100 Dusky Dolphins *Lagenorhynchus obscurus* were observed foraging two nautical miles off Punta Carreta by IGG in November 2000 (Fig. 1). The echo sounder at this location showed strong backscatter from a depth of 8–40 m, suggesting the presence of a large concentration of fish, likely to be Mote Sculpins near the surface.

DISCUSSION

Peruvian Anchovy, small krill and Squat Lobster were the three dominant prey species consumed by Peruvian Diving Petrels in this study, according with observations by Jahncke *et al.* (1999) between 1995 and 1996. This diet is different from that of the higher-latitude diving petrels. Common *P. urinatrix* and South Georgian *P. georgicus* Diving Petrels have diets dominated by single crustacean species, with fish being unimportant. They also show differences in prey and foraging areas during breeding, with the Common species foraging in coastal waters close their colonies and the South Georgian species occurring in more offshore waters (Reid *et al.* 1997, Bocher *et al.* 2000). No dietary information is available for the Magellanic Diving Petrel *P. magellani.*

Peruvian Anchovy was the main prey species consumed during the present study, followed closely by small krill and Squat Lobster. Jahncke *et al.* (1999) found that small krill, Squat Lobsters and fish larvae formed the main food in 1995 and 1996, with little contribution from anchovy. In the present study, the occurrence of anchovy was three times higher and that of fish larvae was slightly

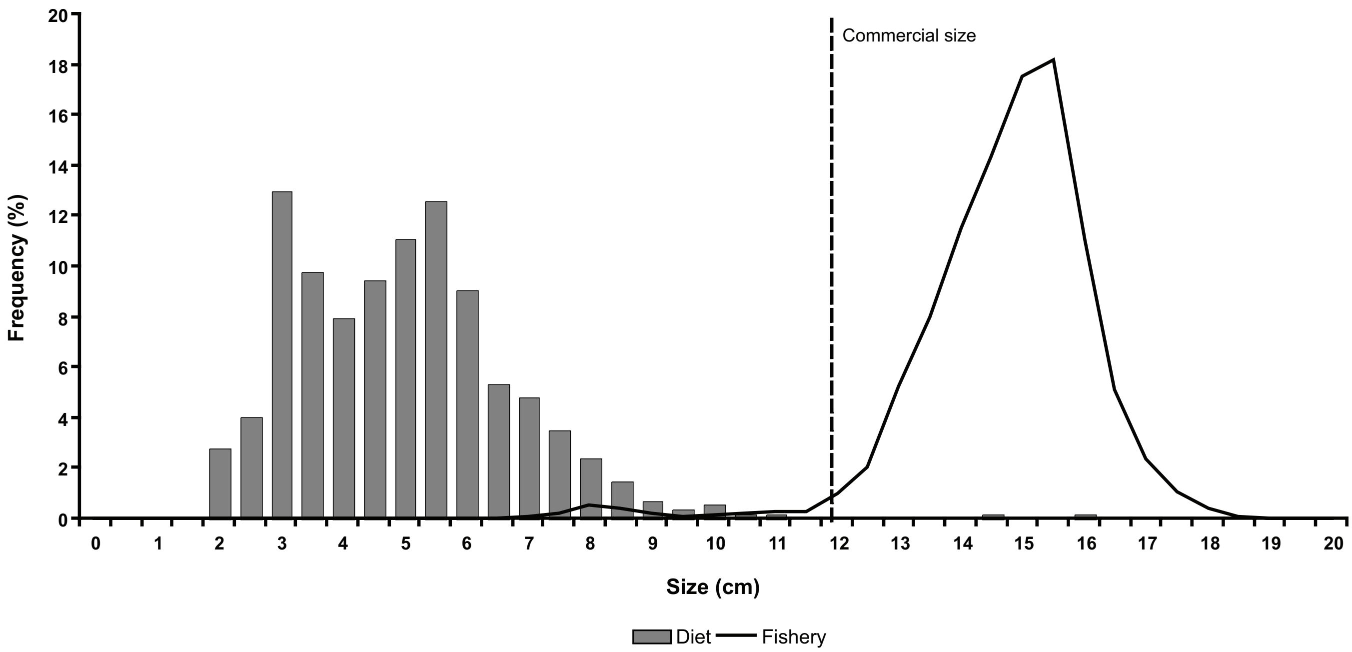

Fig. 3. Length–frequency distribution of Peruvian Anchovy consumed by Peruvian Diving Petrels at La Vieja Island, Peru. The dotted line indicates the minimum commercial size, solid line indicates anchovy size taken by fishery in the area.

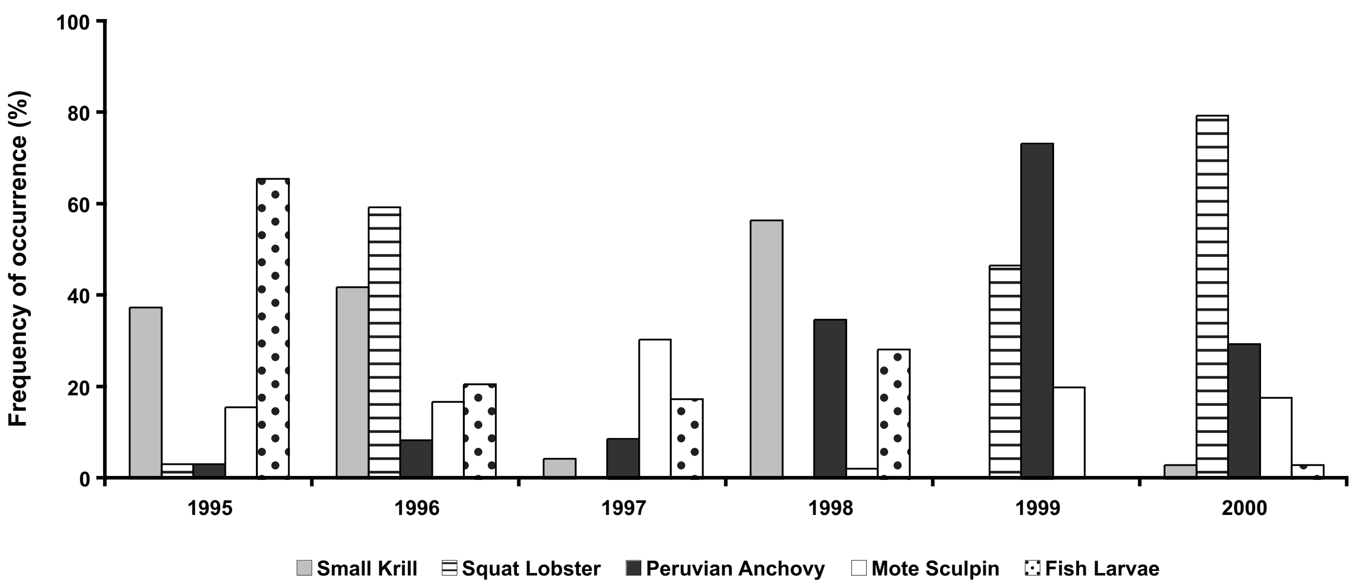

Fig. 4. Annual variation in the occurrence of prey of the Peruvian Diving Petrel at La Vieja Island, between 1995 and 2000. Information from 1995 and 1996 was taken from original data used by Jahncke et al. (1999).

lower (25%). In addition to the main prey types, Mote Sculpin and fish larvae had temporal importance, being the main prey consumed during some sampling periods (Table 2). Fig. 4 shows the prey occurrence at La Vieja Island between 1995 and 2000, which includes data used by Jahncke *et al.* (1999).

Jahncke *et al.* (1999) overestimated the mass of anchovy and other prey. Nevertheless, the percentage-by-mass of anchovy remained low because of that prey's scarce occurrence in their samples. In the present study, the mass of anchovy was more carefully calculated, resulting in masses lower than those assumed by Jahncke *et al.* (1999), but the high occurrence of the fish produced an increased contribution by mass. Fish consumption could be favoured by its availability in the area (see below) and its higher energetic value as compared with other prey (Clarke & Prince 1980, Quillfeldt 2002).

On the basis of samples collected during 1995 and 1996 "cold years," Jahncke *et al.* (1999) suggested seasonality related to availability of food. In the present work no evidence of seasonality could be noted. However, a growing annual tendency for the occurrence of Peruvian Anchovy was observed during 1995–1999 (Fig. 4). Occurrence of Mote Sculpin showed a temporal pattern related to El Niño years (Fig. 4). No other prey species showed annual patterns in occurrence, although it would be necessary to obtain a longer time series for better quantitative analysis. On the other hand, to improve the detection of seasonality in the diet, seasonal sampling should be more uniform in future investigations.

The ENSO is a cyclic climatic fluctuation with consequences around the world (Barber & Chávez 1983, Arntz & Farbach 1996, Fiedler 2002). Peruvian waters are the first observed locality of this large-scale process, producing important changes in the community structure of the Peruvian waters. During strong El Niño events, upwelling off Peru ceases and productivity decreases dramatically, producing a reduction in anchovy biomass followed by a dramatic decrease in seabird populations (Jahncke 2004) and an increase in warm-water species (Arntz & Farbach 1996). During El Niño events, SST can increase by 8°C because of intrusion by warm oceanic and tropical waters and weakening of the Peruvian Current (Arntz & Farbach 1996). In contrast, during the cold part of the fluctuation, known as La Niña, upwelled cool water dominates the system, productivity increases and anchovy and its predators, including seabirds, increase their biomass (Arntz & Farbach 1996, Fiedler 2002).

The effect of El Niño events on Peruvian Diving Petrels has not yet been studied. However, the effects would probably be similar to those suffered by guano-producing seabirds: serious population reductions from mortality and migration (Jahncke 1998, Jahncke *et al.* 2004) and important shifts in the diet (Duffy 1990, Jahncke and Goya 1998c). During the 1997/1998 El Niño, extreme positive anomalies in Independence Bay occurred simultaneously with the complete failure of the 1998 summer reproductive season of Peruvian Diving Petrels at La Vieja Island (IGG pers. obs.). The cause of this reproductive failure has not been investigated, but we believe that food scarcity and heat stress may have had an effect.

Peruvian Diving Petrels show a remarkable plasticity in their diet in the context of a highly variable environment such as the Peruvian Current, in contrast with other diving petrel species. Observed changes in their main prey suggest an opportunistic feeding strategy probably related to cycles of local availability of prey. High fluctuation of oceanographic conditions (Fig. 5) at Independence Bay as a product of the ENSO could be the cause of such variability in resource availability and diet. The anomaly of SST in Independence Bay has ranged between –1.9°C and 6.8°C, with maximum values corresponding to the strong 1997/1998 El Niño event. Our analysis suggests that negative values of the SST anomaly increase the consumption of Squat Lobster and fish larvae by Peruvian Diving Petrels, but that positive anomalies produced by El Niño do not appear to result in the consumption of particular prey, although a reduction in diet variability presumably follows a reduction in prey availability. With fewer alternative prey types in the area, the options for foraging decrease, thus decreasing the diet's diversity.

Oceanographic conditions between 1995 and 2000 changed off Peru because of the ENSO, showing no consistent pattern with prey consumption except for anchovy and Squat Lobster. The years 1995 and 1996 sampled by Jahncke *et al.* (1999) were characterized by low SST in Peru (Pizarro & Tello 1996, Ganoza *et al.* 1997, Pizarro *et al.* 1997), and 1997 and 1998 were warm years because of El

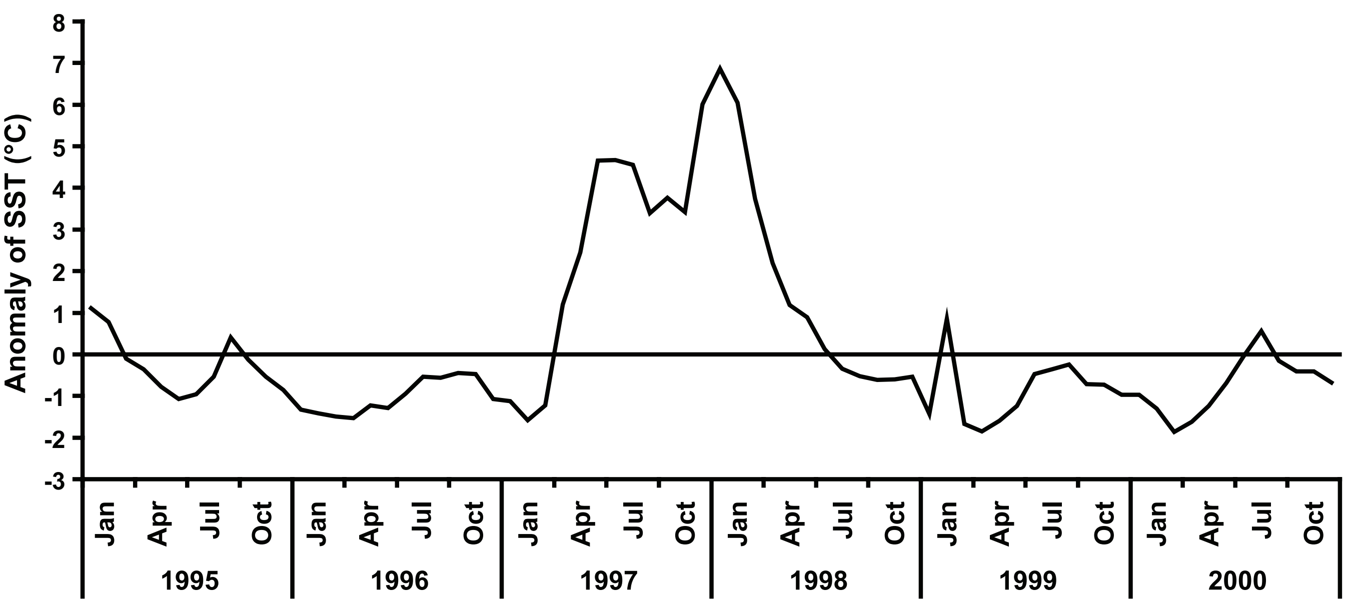

Fig. 5. Anomaly of sea surface temperature in Independence Bay between 1995 and 2000.

Niño events (Gutiérrez *et al.* 1998, Vásquez & Tello 1998). The post-1999 and -2000 El Niño years had slightly cold conditions off Paracas (Vásquez & Tello 1999, Morón & Crispín 1999, IMARPE 2000), and negative anomalies occurred in Independence Bay. In accord with these oceanographic conditions, the distribution of anchovy and other main prey changed over the years of the present study, showing an increase in anchovy consumption. During 1997, anchovy were dispersed away from the study area (Chipollini *et al.* 1997, Gutiérrez *et al.* 1998), but in 1998, they were concentrated there (Castillo *et al.* 1998a,b). In 1999, anchovy had high biomass values around Independence Bay (Castillo *et al.* 1999) and during 2000 anchovy and Squat Lobster were concentrated in the area (IMARPE 2000). The increased consumption of anchovy and Squat Lobster found could thus be related to their availability near the shore as a response to the cooling after El Niño observed by Morón (1998). The large quantity of Mote Sculpin in the diet during 1997 could be linked to the presence of cold waters around the study area, reported by Vásquez (1997).

During the El Niño event of 1997/1998 the ichthyoplankton community experienced great changes off Peru, with a decreased distribution and abundance of anchovy larvae and introduction of other species into the system (Ayón *et al.* 1998, Ayón & Quesquén 1998). In 1997/1998 fish larvae of anchovy and other fish were present in the study area (Ayón *et al.* 1998, Ayón & Quesquén 1998, Girón 1998) and were thus available to diving petrels. In 2000, anchovy and sculpins were the main larval species in Independence Bay (Vélez *et al.* 2005), and adult forms were the main prey for diving petrels that year. This shows the importance of the association of adult fish and fish larvae, which could be alternative preys depending of their availability, in the diet of diving petrels. Vélez *et al.* 2005 found that the main ichthyoplankton species in Independence Bay are Peruvian Anchovy and Mote Sculpin. The negative relationship between fish larvae and Mote Sculpins observed in the diet suggests that fish larvae consumed by diving petrels were Peruvian Anchovy.

The Peruvian Diving Petrel is restricted to coastal cold waters (Murphy 1936). Distribution of prey and frequent sightings of foraging flocks around La Vieja Island and Independence Bay during vessel trips to the island also suggest inshore foraging. In this sense, the tendency of diving petrels to forage in large aggregations in inshore waters would make this species vulnerable to bycatch during fishing operations, as occurs with Peruvian guano-producing seabirds and Humboldt Penguins *Spheniscus humboldti* (Duffy *et al.* 1984, Majluf *et al.* 2002). Mortality of foraging diving petrels has been observed during artisanal beach-seining at Independence Bay (J.C. Márquez, IMARPE, pers. comm.). This issue must be considered for further conservation measures.

The role of commercial fishery competition for anchovy on the conservation of the Peruvian Diving Petrel is not clear at the moment. Hays (1989) suggested that competition with the commercial fishery endangers the species. However, Jahncke *et al.* (1999) indicated that competition for food should not be seen as a threat, given the small amount of anchovy found in the birds' diet. In contrast, we found anchovy to be a major prey species. However, the anchovy consumed by diving petrels were smaller than those taken by the fishery (Fig. 3) in the area, showing that no direct competition for anchovy occurs between them. Because anchovy is an important prey species for diving petrels and the only main prey species that is commercially exploited in Peru, it remains necessary to maintain adequate levels of exploitation in the area with the purpose of not decreasing the availability and diversity of prey. Moreover, the indirect effects of the fishery on zooplankton and fish larvae production should be investigated.

Although guano harvesting was mainly responsible for the current Endangered status of Peruvian Diving Petrels (Jahncke & Goya 1998a), strong El Niño events and overfishing, plus their interactions, occurring during the last century must have produced a negative impact on this species. Future management should aim to maintain fishery interaction as low as possible and to reduce any indirect effects of fishing on secondary production in Independence Bay and the surrounding area. Currently the area within 10 nautical miles of Independence Bay is not an important fishing ground for the fish-meal industry, contributing only 1.3% of the Peruvian Anchovy landings between 1997 and 2000 and forming 3.7% of fishing operations sampled by the Peruvian Fishery Logbooks Project (IMARPE unpubl. data). To assure the continuity of this relative isolation of the Peruvian Diving Petrel's habitat from the anchovy fishery, the status of the Paracas National Reserve as the only Peruvian marine protected area must be reinforced and monitored permanently to guarantee the conservation of the Peruvian Diving Petrel, considering that almost 85% of its world population breeds at La Vieja Island.

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