FORAGING DYNAMICS OF SEABIRDS IN THE EASTERN TROPICAL PACIFIC OCEAN

Larry B. Spear, David G. Ainley, and William A. Walker

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Front cover photograph of Great Frigatebird (*Fregata minor*) by R. L. Pitman
Rear cover photograph of Red-footed Booby (*Sula sula*) with flying fish by R. L. Pitman

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LARRY B. SPEAR, DAVID G. AINLEY, AND WILLIAM A. WALKER

Abstract. During a 9-yr period, 1983–1991, we studied the feeding ecology of the marine avifauna of the eastern tropical Pacific Ocean (ETP), defined here as pelagic waters from the coast of the Americas to 170° W and within 20° of the Equator. This is one of few studies of the diet of an entire marine avifauna, including resident breeders and non-breeders as well as passage migrants, and is the first such study for the tropical ocean, which comprises 40% of the Earth's surface. During spring and autumn, while participating in cruises to define the dynamics of equatorial marine climate and its effects on the seabird community, we collected 2,076 specimens representing, on the basis of at-sea surveys, the 30 most-abundant ETP avian species (hereafter; ETP avifauna). These samples contained 10,374 prey, which, using fish otoliths and cephalopod beaks, and whole non-cephalopod invertebrates, were identified to the most specific possible taxon.

The prey mass consumed by the ETP avifauna consisted of 82.5% fishes (57% by number), 17.0% cephalopods (27% by number), and 0.3% non-cephalopod invertebrates (16% by number). Fish were the predominant prey of procellariiforms and larids, but pelecaniforms consumed about equal proportions of fish and cephalopods. Based on behavior observed during at-sea surveys, the ETP avifauna sorted into two groups—15 species that generally fed solitarily and 15 species that generally fed in multispecies flocks. Otherwise, the avifauna used a combination of four feeding strategies: (1) association with surface-feeding piscine predators (primarily tuna [*Thunnus* and *Euthynnus* spp.]), (2) nocturnal feeding on diel, vertically migrating mesopelagic prey, (3) scavenging dead cephalopods, and (4) feeding diurnally on non-cephalopod invertebrates (e.g., scyphozoans, mollusks, crustaceans, and insects) and fish eggs. Because of differential use of the four strategies, diets of the two seabird groups differed; the solitary group obtained most of its prey while feeding nocturnally, primarily on mesopelagic fishes (myctophids, bregmacerotids, diretmids, and melamphaids), and flocking species fed primarily on flying fish (exocoetids and hemirhamphids) and ommastrephid squid (*Sthenoteuthis oualaniensis*) caught when feeding diurnally in association with tuna. Many of the smaller species of solitary feeders, particularly storm-petrels, small gadly petrels and terns, supplemented their diets appreciably by feeding diurnally on epipelagic non-cephalopod invertebrates and by scavenging dead cephalopods. Flock-feeding procellariiforms also supplemented their diet by feeding nocturnally on the same mesopelagic fishes taken by the solitary species, as well as by scavenging dead cephalopods. Some spatial and temporal differences in diet were apparent among different species.

An analysis of otolith condition in relation to hour of day that birds were collected showed that procellariiform species caught mesopelagic fishes primarily between 2000 and 2400 H. Selection of these fishes by size indicates that they occurred at the surface in groups, rather than solitarily. Solitary avian feeders had greater diet diversity than flock-feeders, particularly pelecaniforms. Appreciable diet overlap existed among the solitary and flock-feeding groups. Diet partitioning was evident within each feeding group, primarily exercised by using different feeding strategies and through selection of prey by species and size: larger birds ate larger prey. We classified five of the predominant ETP species, Sooty Shearwater (*Puffinus griseus*), White-necked Petrel (*Pterodroma cervicalis*), Murphy's Petrel (*Pterodroma ultima*), Stejneger's Petrel (*Pterodroma longirostris*), and Parasitic Jaeger (*Stercorarius parasiticus*), as migrants; based on stomach fullness, these species fed less often than the residents and were more opportunistic, using each of the four feeding strategies.

Using generalized additive models and at-sea survey data, we estimated that the ETP avifauna consisted of about 32,000,000 birds (range 28.5–35 million) with a biomass of 8,405 mt (metric tonnes). They consumed about 1,700 mt of food per day. Flock-feeding species were most consistent in choice of foraging strategy. Considering the contribution of each of the four feeding strategies, 78% of prey were obtained when feeding in association with aquatic predators, 14% when feeding nocturnally, and 4% each when scavenging dead cephalopods or feeding diurnally on non-cephalopod invertebrates and fish eggs. Results underscored two important groups of fishes in the ETP upper food web—tunas and vertically migrating mesopelagic fishes. Compared to an analogous study of a polar (Antarctic) marine avifauna that found little prey partitioning, partitioning among the ETP avifauna was dramatic as a function of sex, body size, feeding behavior, habitat and species. In the polar system, partitioning was only by habitat and behavior (foraging depth). The more extensive partitioning, as well as more diverse diets, in the tropics likely was related to much lower prey availability than encountered by polar seabirds. The importance of the association between seabirds and a top-piscine predator in the tropical system was emphasized by its absence in the polar system, affecting the behavior, morphology and diet of ETP seabirds. Further investigation of this association is important for the successful management of the tropical Pacific Ocean ecosystem.

Key Words: cephalopod, diet partitioning, feeding behavior, foraging ecology, myctophid, seabirds, trophic partitioning, tropical ocean, tuna.

DINÁMICAS DE FORRAJE DE AVES MARINAS EN EL ESTE TROPICAL DEL OCÉANO PACÍFICO

Resumen. Durante un período de 9 años, 1983–1991, estudiamos la ecología de alimentación de la avifauna marina del este tropical del océano pacífico (ETP), definida en el presente como aguas pelágicas de la costa de las Américas, 70° W, dentro los 20° del Ecuador. El presente estudio es uno de los pocos sobre la dieta de una avifauna marina entera, incluyendo residentes reproductores y no reproductores, como también migrantes pasajeros; también es el primer estudio de este tipo para el océano tropical, el cual comprende el 40% de la superficie terrestre. Durante la primavera y el otoño, mientras participábamos en cruceros para definir las dinámicas climáticas marinas ecauatorianas y sus efectos en comunidades de aves marinas, colectamos 2,076 especimenes representando estos, basándonos en muestreos de mar, las 30 especies más abundantes del ETP (de aquí en delante; ETP avifauna). Estas muestras contenían 10,374 presas, las cuales, fueron identificadas utilizando otolitos de peces y picos de cefalópodos, e invertebrados completos no cefalópodos fueron identificados al taxa menor posible.

La masa consumida de presa por avifauna ETP consistió de 82.5% peces (57% por número), 17.0% cefalópodos (27% por número), y 0.3% invertebrados no cefalópodos (16% por número). Peces fueron la presa predominante de los Procelariformes y láridos, pero los Pelicaniformes consumieron casi las mismas proporciones de peces y cefalópodos. Con base en el comportamiento observado durante los muestreos de mar, la avifauna ETP se clasificó en dos grupos—15 especies que generalmente se alimentaron solitariamente y 15 especies que generalmente se alimentaban en multitudes de multiespecies. De no ser así, la avifauna utilizó una combinación de cuatro estrategias alimenticias: (1) asociación con depredadores de piscina de alimentación de superficie (primordialmente atún [*Thunnus* and *Euthynnus* spp.]), (2) alimentación nocturna en ciclo regular diario, presa mesopelágica migratoria verticalmente, (3) barrer cefalópodos muertos, y (4) alimentación diurna de invertebrados no cefalópodos (ej., scyphozoanos, moluscos, crustáceos, e insectos) y huevos de peces. Debido a los diferentes usos de las cuatro estrategias, las dietas de dos grupos de aves marinas difirieron; el grupo solitario obtuvo la mayoría de sus presas mientras se alimentaba nocturnamente, principalmente de peces mesopelágicos (mictófidos, bregmacerotidos, diretmidos, y melamfaidos), mientras especies de multitud se alimentaron primordialmente de peces voladores (exocoetidos y hemirhamfidos) y calamar ommastrefido (*Sthenoteuthis oualaniensis*) atrapado durante la alimentación diurna asociada al atún. Muchas de las especies pequeñas solitarias de alimento, particularmente paiños y gaviotas, suplementaron notablemente sus dietas por la alimentación diurna de invertebrados no cefalópodos epipelágicos y por barrer cefalópodos muertos. Procelariformes de alimentación en multitud también suplieron su dieta por alimentación nocturna de los mismos peces mesopelágicos tomados por las especies solitarias, como también por barrer cefalópodos muertos. Algunas diferencias espaciales y temporales en la dieta fueron evidentes en las diferentes especies.

Un análisis de condiciones otolitícas que relacionó la hora del día en que las aves fueron colectadas demostró que las especies procelariformes capturaron peces mesopelágicos principalmente entre 2000 y 2400 H. La selección por tamaño de estos peces indica que ellos aparecen en la superficie en grupos, en vez de solitariamente. Aves que se alimentan solitariamente, tienen una mayor diversidad de dieta que las que se alimentan en multitud, particularmente Pelecaniformes. Existe un evidente traslape en la dieta entre los grupos solitarios y de multitud. La repartición de dieta fue evidente dentro de cada grupo alimenticio, sobre todo al utilizar diferentes estrategias de alimentación y a través de la selección de presa por especie y tamaño: aves más grandes comieron presas más grandes. Clasificamos cinco de las especies ETP predominantes, Pardela gris (*Puffinus griseus*), Petrel, cuello blanco(*Pterodroma cervicalis*), Petrel (*Pterodroma ultima*), Petrel de stejneger (*Pterodroma longirostris*) y Salteador parásito (*Stercorarius parasiticus*), como migratorias; basado en lo lleno del estómago, estas especies se alimentan menos a menudo que las residentes y fueron más oportunísticas, utilizando cada una de las cuatro estrategias alimenticias.

Utilizando modelos aditivos generalizados y datos de muestreos de mar, estimamos que la avifauna ETP consistió de cerca de 32,000,000 aves (rango 28.5–35 millón) con una biomasa de 8,405 tm (toneladas métricas). Consumieron cerca de 1,700 tm de alimento por día. Especies que se alimentan en multitud fueron más consistentes al elegir la estrategia de forraje. Considerando la contribución de cada una de las cuatro estrategias, el 78% de las presas fueron obtenidas al alimentarse con asociación de depredadores acuáticos, 14% al alimentarse nocturnamente, y 4% cuando barrían cefalópodos muertos o se alimentaban durante el día de invertebrados no cefalópodos y huevos de peces. Los resultados resaltaron a dos grupos importantes de peces en la cadena alimenticia más alta de ETP—atunes y peces mesopelágicos verticalmente migratorios. Comparado a un estudio análogo de avifauna marina polar (Antártica) que encontró poca repartición de presa, la repartición entre la avifauna ETP fue dramática como función de sexo, tamaño del cuerpo, comportamiento alimenticio, hábitat, y especies. En el sistema polar, la repartición fue solamente por hábitat y comportamiento (profundidad de forraje). La repartición más extensiva, como dietas más diversas, estaba probablemente relacionado a la disponibilidad mucho más baja de presa, de la encontrada en aves marinas polares. La importancia de la asociación entre aves marinas y depredadores de tope de piscina en el sistema tropical se enfatizó por su ausencia en el sistema polar, afectando el comportamiento, morfología y dieta de aves marinas ETP. Mayor información de dicha asociación es importante para el manejo exitoso de ecosistemas tropicales del Océano Pacífico.

Understanding the factors that affect community organization among seabirds requires detailed information on inter- and intraspecific differences in diet and foraging behavior to define trophic niches and their overlap (Ashmole 1971, Duffy and Jackson 1986). Several studies have examined the diets of entire marine avifaunas during the breeding season at colonies located on a specific group of islands: three tropical (Ashmole and Ashmole 1967, Diamond 1983, Harrison et al. 1983), two temperate (Pearson 1968, Ainley and Boekelheide 1990), and three polar (Belopol'skii 1957, Croxall and Prince 1980, Schneider and Hunt 1984). These studies have provided considerable information on choice of prey fed to nestlings. However, they provided little information on: (1) diet during the remainder of the annual cycle, (2) diet of the non-breeding component of the community, (3) factors that affect prey availability and how these affect diet, or (4) the methods and diel patterns by which seabirds catch prey. Given the logistical difficulties involved in at-sea studies in order to obtain such information, it is not surprising that few of these broader studies have been conducted (Baltz and Morejohn 1977, Ainley et al. 1984, Ainley et al. 1992); those that have have been completed in temperate or polar waters.

Only three studies, as noted above, have been concerned with diet partitioning among seabird communities in the tropics (between 20° N and 20° S), despite the fact that tropical waters cover about 40% of the Earth's surface. Furthermore, none of these studies have considered the highly pelagic component of seabird communities that is not constrained to remain within foraging range of breeding colonies. The results presented herein are the first to examine diets in a tropical, open-ocean avifauna, in this case occupying the 25,000,000 km^2 expanse of the eastern tropical Pacific (ETP) and defined here as pelagic waters within 20° of the Equator and from the Americas to 170° W.

Two factors that characterize pelagic waters, as opposed to coastal, neritic waters, have a major effect on the structure of seabird avifaunas and the strategies used by component species to exploit them (Ballance et al. 1997). The first is the relatively greater patchiness of potential prey over the immense expanses of these oceans (Ainley and Boekelheide 1983, Hunt 1990). These conditions require that tropical seabirds, especially, possess energy-efficient flight to allow them to search for and find food (Ainley 1977, Flint and Nagy 1984, Ballance 1993, Ballance et al. 1997, Spear and Ainley 1997a, Weimirskirch et al. 2004). Another important factor is the minimal structural complexity of the open ocean compared to coastal, neritic areas (McGowan and Walker 1993) and polar waters (Ainley et al. 1992). In regard to the tropics, the intense vertical and horizontal gradients, e.g., water-mass and water-type boundaries and other frontal features that serve to concentrate prey in somewhat predictable locations (Hunt 1988, 1990, Spear et al. 2001) are widely dispersed. For one thing, no tidal fronts or currents occur in the open ocean, which often provide a micro- to meso-scale complexity to coastal waters. The primary frontal feature in the ETP is the Equatorial Front, a boundary on the order of 200 km wide between the South Equatorial Current and the North Equatorial Countercurrent (Murphy and Shomura 1972, Spear et al. 2001; Fig. 1). A second important physical gradient, the thermocline, exists on a vertical scale. This feature has an important effect on the distribution of tuna (*Thunnus*, *Euthynnus* spp.; Murphy and Shomura 1972, Brill et al. 1999), which in turn are important in chasing seabird prey to near the surface (Au and Pitman 1986, Ballance and Pitman 1999).

In fact, the tropical ocean, especially that of the ETP, has the most intense gradients of any ocean area due to the fact that surface waters are very warm but waters as cold as those of subpolar areas lie beneath at less distance than the height of the tallest of trees on continents (Longhurst and Pauly 1987). This water upwells along the equatorial front, bringing a high degree of spatial complexity to mid-ocean surface waters. This complexity and the increased productivity affect the occurrence of seabirds and the prey available to them at multiple spatial scales (Ballance et al. 1997, Spear and Ainley 2007).

Because morphology of tropical seabirds is adapted for efficient flight in order to search large areas for food, nearly all tropical seabirds are able to obtain prey only within a few meters of the ocean surface. This is a result of their large wings, which are not well suited for diving more than a few meters subsurface. In fact, tropical seabirds use four foraging strategies, in part affected by their flight capabilities (Ainley 1977, Imber et al. 1992, Ballance et al.

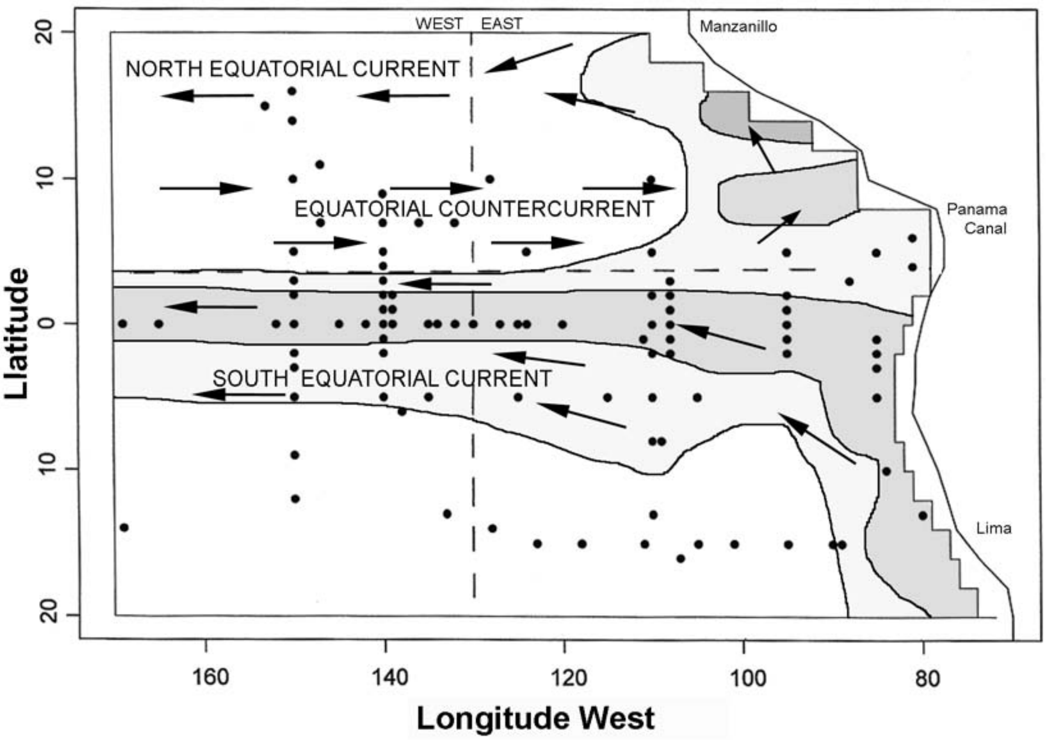

FIGURE 1. The study area in the eastern tropical Pacific Ocean, including locations (shown with dots) where birds were collected. The horizontal dashed line separates the Equatorial Countercurrent from the South Equatorial Current (Tropical Front); and the vertical line separates east from west as referred to in the text. The staircase line effect along the coast on the east side of the study area denotes the boundary separating pelagic waters to the west and coastal waters to the east. Shading indicates large-scale patterns of ocean productivity: the three gradations shown are, darker meaning higher values: <200, 201–300, and >300 mgC m^{-2} d^{-1} (from Longhurst and Pauly 1987, p. 122).

1997, Spear and Ainley 1998, this paper): (1) associating with aquatic predators (especially tuna) that chase prey to the ocean surface during the day, (2) taking advantage of the vertical movement of prey to feed at the ocean surface at night, (3) scavenging of dead prey, particularly cephalopods that die and float on the surface after spawning (Croxall and Prince 1994), and (4) diurnal feeding on non-cephalopod invertebrates (and teleost eggs) that live on or near the ocean surface. The first strategy requires rapid flight to maintain pace with tuna, the fastest and most mobile fish in the ocean (Longhurst and Pauly 1987), but the others require flight that is efficient enough to allow long search patterns.

Our primary objective in this study was to understand better the factors that structure tropical avifaunas, to compare them to the factors underlying community organization among polar avifaunas (Ainley et al. 1984, 1992, 1993, 1994; Spear and Ainley 1998), and to resolve several information gaps in our understanding of tropical seabird ecology. Previous diet studies have consistently shown that diets of seabirds in temperate or polar latitudes are less diverse than those of tropical latitudes and that in both areas there is considerable overlap in diet composition (cf. Harrison et al. 1983, Ainley and Boekelheide 1990). In the absence of data from foraging areas, these patterns have led to questions of whether trophic-niche partitioning exists in tropical waters (Ashmole and Ashmole 1967, Diamond 1983, Harrison and Seki 1987). Such partitioning has been well documented in colder waters, although not necessarily expressed strongly by prey species differences (Ainley and Boekelheide 1990, Ainley et al. 1992). Finally, controversy exists regarding the relative importance of different foraging strategies of tropical seabirds, especially in regard to nocturnal vs. diurnal feeding and solitary vs. flock feeding (Imber 1973, 1976; Imber et al. 1992, Brown 1980, Harrison and Seki 1987, Ballance and Pitman 1999).

None of these questions can be addressed without studies of seabirds at sea. Therefore, we examined niche partitioning by collecting and analyzing data on the species and size of prey taken, and preference for use of the four feeding strategies, including timing of feeding. To do this we examined (1) the effects on diet and its diversity in relation to season, current system, interannual environmental variability (El Niño Southern Oscillation [ENSO] phase), sex, body condition, and predator mass (2) the propensity of the migratory, temperate component of the ETP avifauna to feed in tropical waters rather than merely passing through, and (3) effects on diet due to preferential use of different species of tuna. We were also interested in comparing diets and feeding strategies of seabird species that specialize by foraging in flocks over large aquatic predators vs. birds that feed solitarily, and we were interested in making comparisons to the analogous study we completed in the Southern Ocean (Ainley et al. 1992, 1993, 1994), realizing that we would learn much about the structuring of both communities based on how they differed.

METHODS

Data Collection

Specimens

Beginning in the autumn 1983, seabirds were collected during spring and autumn of each year through 1991. To do this, we participated in 17 cruises designed to study spatial and temporal marine climate variability of the ETP by deploying, retrieving and maintaining weather and ocean buoys as well as obtaining comparative, real-time ocean data (Table 1). Each cruise, sponsored by the U.S. National Oceanographic and Atmospheric Administration (NOAA) lasted 2–3 mo. At locations where an inflatable boat (5-m long with 20–35 hp motor) could be deployed, bird sampling was conducted using a shotgun. These locations included recovery/deployment sites of NOAA buoys and deep CTD (conductivity-temperature-depth) stations (Fig. 1), operations that required most of a day. Sampling in which at least one bird was collected occurred at 96 different locations on 264 d. Thirty-four of the sites were sampled on multiple days (2–29 d/site), but no site was sampled more than once/season/year. Between ocean stations, we conducted surveys to collect data on species composition, at-sea densities, and foraging behavior (Ribic and Ainley 1997, Ribic et al. 1997, Spear et al. 2001).

During each of the 264 sample days, an attempt was made to collect five or six birds of each avian species present in the area. Bird collecting was conducted using two methods. The first was to drive the inflatable boat 2–3 km from the ship where the motor was stopped and a slick was created by pouring fish oil on the water. The slick was freshened periodically by the addition of oil, about every 1–2 hr depending on wind speed (and our drift), which was the primary factor causing the oil slick to break up and disperse. The scent of the oil attracted mainly storm-petrels and gadfly petrels, but generally not shearwaters, larids, or pelecaniforms. Secondly, we also watched for feeding flocks while positioned at slicks. When one was sighted, the boat was moved to the flock where an attempt was made to collect a sample of birds. This allowed us to collect species not attracted to the oil slicks and also to determine the diet of seabirds that foraged over tuna. When at the flocks, we also attempted to determine the species of tuna that were forcing to the surface the prey on which the birds were feeding. We collected 85 birds (Table 2) from 11 flocks foraging over yellowfin (*Thunnus albacares*) and 46 birds from five flocks foraging over skipjack tuna (*Euthynnus pelamis*).

Table 1. Sample sizes, by season and year, of seabirds collected in the ETP and that contained prey [a].

Year	Spring–summer	Autumn–winter	Total
1983	0	74	74
1984	81	57	138
1985	39	91	130
1986	31	144	175
1987	128	211	339
1988	126	229	355
1989	75	115	190
1990	58	207	265
1991	100	55	155
Total	638	1,183	1,821

[a] Shown with respect to season (spring–summer [March–August] and autumn–winter [September–February]) and year; 30 species represented (See Table 3).

TABLE 2. BIRDS COLLECTED IN ASSOCIATION WITH YELLOWFIN AND SKIPJACK TUNAS[a].

Collected over yellowfin tuna		Collected over skipjack tuna	
Juan Fernandez Petrel (*Pterodroma externa*)	26	Sooty Tern (*Onychoprion fuscata*)	24
Wedge-tailed Shearwater (*Puffinus pacificus*)	26	White Tern (*Gygis alba*)	7
Sooty Tern (*Onychoprion fuscata*)	12	Gray-backed Tern (*Onychoprion lunatus*)	4
Phoenix Petrel (*Pterodroma alba*)	4	Black Noody (*Anous tenuirostiris*)	3
Christmas Shearwater (*Puffinus nativitatus*)	3	Blue-gray Noody (*Procelsterna cerulean*)	3
Sooty Shearwater (*Puffinus griseus*)	3	Wedge-tailed Shearwater (*Puffinus pacificus*)	1
Kermadec Petrel (*Pterodroma neglecta*)	2	Flesh-footed Shearwater (*Puffinus carneipes*)	1
Stejneger's Petrel (*Pterodroma longirostris*)	2	Phoenix Petrel (*Pterodroma alba*)	1
Leach's Storm-Petrel (*Oceanodroma leucorhoa*)	2	Great Frigatebird (*Fregata minor*)	1
Masked Booby (*Sula dactylatra*)	1	White-tailed Tropicbird (*Phaethon lepturus*)	1
Buller's Shearwater (*Puffinus bulleri*)	1		
Herald Petrel (*Pterodroma arminjoniana*)	1		
White-winged Petrel (*Pterodroma leucoptera*)	1		
Pomarine Jaeger (*Stercorarius pomarinus*)	1		

[a] Species listed in order of decreasing sample size.

All collected birds were immediately placed in a cooler with ice in plastic bags. Towels covering the ice kept birds dry to facilitate accurate determination of body mass once we returned to the ship. During 1987–1991, the hour of day during which each specimen was collected was recorded.

Once back at the ship, before removing stomachs, birds were weighed (nearest gram for birds <250 g, nearest 5 g for larger birds) and measured. We did not weigh birds that had become wet below the contour (outer) feathers (i.e., had significant water retention). Mean bird-mass values reported are the average mass of each species after having subtracted the mass of the food load (details below: stomach fullness).

One of us (LBS) also examined most individuals to determine sex, breeding status, and fat load. Sex and breeding status were determined by examining gonads. Females were classed as having bred previously (laid an egg) if their oviduct was convoluted as opposed to uniform in width (Johnston 1956a). Testis width of males not having bred previously was considerably smaller than those having bred, because testes do not recede to the original width once an individual has bred (when the testes expand several orders of magnitude; Johnston 1956b). The difference between breeder vs. non-breeder testis width is ≥2 mm among smaller petrels and larids, and ≥3 mm among larger petrels, shearwaters, and pelecaniforms (Johnston 1956b; Spear, unpubl. data). Birds of fledgling status can also be identified during the post-breeding period by their fresh plumage and complete absence of molt compared to older birds that then exhibit considerable flight feather and/or body molt.

The amount of fat covering the pectoral muscles, abdomen and legs was examined, and fat load was scored as 0 = no fat, 1 = light fat, 2 = moderate fat, 3 = moderately heavy fat, and 4 = very heavy fat (validation of this method in Spear and Ainley 1998).

Stomach processing and prey identification

We removed the stomach and gizzard from each bird and sorted fresh prey, otoliths, squid beaks, and non-cephalopod invertebrates. First, an incision was made in the bird's abdomen to expose the stomach. Using tweezers (0.1–0.4 m depending on bird size), a wad of cotton was inserted in the mouth and through the esophagus to the opening of the stomach to make sure that all food items were within the latter. The esophagus was then pinched with two fingers placed just above the cotton wad and was cut just above that point, as was the small intestine at a point just below the gizzard. This procedure allowed the stomach and gizzard to be removed intact.

The stomach was weighed, placed in a pan (the bottom of which had been painted black) and then cut open from one end to the other, so that only the gizzard was left intact. The stomach contents were dumped into the pan and the stomach wall was rinsed clean with water from a squirt bottle and massaging with the fingers. Whole fish and cephalopods, as well as pieces of large cephalopods were rinsed, weighed, and placed in plastic bags with a light covering of water, and then frozen. Otoliths and beaks were removed from partially digested fishes and cephalopods. Some partial fish and cephalopods were also saved in plastic bags and some were discarded after otoliths and beaks had been removed. Loose pieces of flesh left in the pan were covered with a shallow layer of water, massaged into smaller pieces, and, with the pan in hand, swirled around to allow even the tiniest (white) fish otoliths to be seen as they moved over the surface of the black pan. Non-cephalopod invertebrates were measured (total length recorded in mllimeters), weighed, and identified to highest taxon possible. When all non-cephalopod invertebrates, otoliths and visible cephalopod beaks had been removed, pan contents were dumped into a second, white-bottomed pan. The procedure was repeated to find (dark) squid beaks not detected in the black-bottomed pan. Otoliths were saved in slide containers and squid beaks in small plastic bottles with 50% ethanol. After the stomach contents were sorted and saved, the gizzard was cut open with care being taken not to damage the contents (otoliths and squid beaks) with the scissors. The gizzard was rinsed, and all otoliths and beaks were sorted and saved in the manner noted above for specimens from stomachs.

After finishing each cruise, all whole fish and cephalopods (and saved flesh parts) as well as otoliths and squid beaks were identified, enumerated, and measured by one of us (WAW). Measurements of fish were that of the standard length (SL, from the snout to the end of the vertebral column); those of squid were dorsal mantle length (DML). For each bird specimen containing prey, prey number was recorded to the most specific possible taxon for all whole prey, scavenged cephalopod remains, otoliths, and beaks. The minimum number of each cephalopod taxon was determined by the greater number of upper or lower beaks present. Prey size estimates were determined by measuring the lower beak rostral length (squid) or lower beak hood length (octopods), and then applying regression equations. For each bird stomach, the number of teleost prey was determined from the greater number of left or right saggital otoliths. Exceptions to this were when it was obvious that due to differences in otolith size, the left and right otoliths of a given species were from two different individuals. Hereafter, when we refer to otolith and/or beak number, it must be kept in mind that one otolith refers to one fish individual, and one beak refers to one cephalopod individual.

All beaks and otoliths were measured in millimeters; otoliths also were classified into four categories of erosion: (1) none, (2) slight, (3) moderate, and (4) severe. Condition categories scored for cephalopod beaks included: (1) no wear, beak wings and lateral walls (terminology of Clarke 1986) in near perfect condition, often with flesh attached; (2) no flesh present with beaks demonstrating little wing and lateral wall erosion; (3) beak wings absent with some erosion of lateral wall margins; and (4) severe erosion of beak; lateral wall edges ranging from severely eroded to near absent. To avoid positive bias in the importance of cephalopods by the fact that beaks are retained much longer than fish otoliths (Furness et al. 1984), we considered only those beaks of condition 1 and 2 as representing prey ingested within 24 hr of collection. Because an attempt was made to identify all cephalopod beaks to species, regardless of condition, enumeration of cephalopods in the diets of seabirds includes individuals represented by beaks of condition 3 or 4. However, beaks of condition 3 and 4 were not measured and, therefore, were not included in the analysis of prey size/mass and overall contribution to diets.

The sample of 2,076 birds that comprises the basis for the diet analysis in this study is composed of the 30 most abundant species found in the ETP study area (King 1970, Brooke 2004; Table 3). Hereafter, we refer to the 30 species collectively as the ETP avifauna. These birds contained a total of 10,374 prey (Appendix 1). Voucher specimens of prey, their otoliths and beaks were retained by WAW at the NOAA National Marine Mammal Laboratory in Seattle, WA. Seabird specimens were either prepared as study skins or frozen; tissue samples from many were given to Charles Sibley for DNA analyses. All bird skins and skeletons were given to the Los Angeles County Museum or U.S. National Museum.

Feeding behavior

We determined the tendency of birds to feed in flocks as opposed to feeding solitarily. To do this

TABLE 3. COLLECTION DETAILS FOR THE 30 MOST-ABUNDANT AVIAN SPECIES IN THE ETP.

Species	Number collected	Birds w/prey N	Birds w/prey %	Prey/bird $\bar{x} \pm$ SD	Sampling episodes[a]
Hydrobatidae					
Leach's Storm-Petrel (*Oceanodroma leucorhoa*)	503	433	86.1	4.4 ± 5.2	143
Wedge-rumped Storm-Petrel (*O. tethys*)	411	308	74.9	2.2 ± 2.6	128
Markham's Storm-Petrel (*O. markhami*)	15	12	80.0	2.5 ± 4.7	8
White-throated Storm-Petrel (*Nesofregetta fuliginosa*)	22	19	86.4	4.0 ± 4.5	16
White-bellied Storm-Petrel (*Fregetta grallaria*)	22	20	90.9	2.6 ± 1.7	16
White-faced Storm-Petrel (*Pelgaodroma marina*)	15	15	100.0	21.5 ± 15.3	10
Procellariidae					
Sooty Shearwater (*Puffinus griseus*)	43	31	72.1	2.5 ± 5.5	25
Christmas Shearwater (*Puffinus nativitatis*)	7	7	100.0	5.4 ± 3.6	7
Wedge-tailed Shearwater (*Puffinus pacificus*)	112	95	84.8	4.7 ± 5.5	40
Juan Fernandez Petrel (*Pterodroma externa*)	214	204	95.3	6.1 ± 13.4	70
White-necked Petrel (*Pterodroma cervicalis*)	14	12	85.7	2.4 ± 2.6	9
Kermadec Petrel (*Pterodroma neglecta*)	12	11	91.7	3.6 ± 3.0	9
Herald/Henderson Petrel (*P. heraldica/atrata*)[b]	5/8	5/8	100.0	2.5 ± 4.9	4/5
Phoenix Petrel (*Pterodroma alba*)	21	21	100.0	5.4 ± 5.1	11
Murphy's Petrel (*Pterodroma ultima*)	8	8	100.0	4.6 ± 7.2	7
Tahiti Petrel (*Pterodroma rostrata*)	156	154	98.7	6.8 ± 6.5	74
Bulwer's Petrel (*Bulweria bulwerii*)	43	34	79.1	2.9 ± 3.5	29
White-winged Petrel (*Pterodroma leucoptera*)	139	135	97.1	8.0 ± 6.6	56
Black-winged Petrel (*Pterodroma nigripennis*)	89	88	98.9	7.6 ± 5.2	36
Stejneger's Petrel (*Pterodroma longirostris*)	48	46	95.8	8.0 ± 5.7	26
DeFilippi's Petrel (*Pterodroma defilippiana*)	7	7	100.0	17.6 ± 15.0	3
Pelecaniformes					
Red-tailed Tropicbird (*Phaethon rubricauda*)	11	10	90.9	7.6 ± 6.7	9
Red-footed Booby (*Sula sula*)	5	4	80.0	20.2 ± 12.2	3
Masked Booby (*Sula. dactylatra*)	18	18	100.0	8.0 ± 5.1	10
Nazca Booby (*Sula granti*)	5	5	100.0	24.3 ± 14.5	1
Great Frigatebird (*Fregata minor*)	4	4	100.0	6.5 ± 3.3	4
Laridae					
Parasitic Jaeger (*Stercorarius parasiticus*)	9	9	100.0	5.6 ± 3.6	5
Sooty Tern (*Onychoprion fuscata*)	93	82	88.2	4.3 ± 5.6	35
Gray-backed Tern (*Onychoprion lunatus*)	5	5	100.0	10.0 ± 3.5	2
White Tern (*Gygis alba*)	12	11	91.7	4.9 ± 5.4	8
Totals	2,076	1,821	87.7	5.0 ± 7.5	264

Notes: See Appendices 3–32 for prey numbers for each species.
[a] Sampling episodes refer to the dates on which the species was collected, but many sites were visited on more than one date. Therefore, an episode refers to both the date and place of sampling.
[b] The Henderson and Herald petrels were combined into one group because of their close taxonomic and morphological relationships (Brooke et al. 1996, Spear and Ainley 1998), and because of the small sample sizes for those two species.

we used observations gathered during surveys conducted in the ETP when vessels were underway between stations (Fig. 2). These surveys were conducted using 600-m wide transects (details in Spear et al. 2001), in which we recorded 92,696 birds representing the ETP avifauna (69,246 after counts were corrected for the effect of bird flux through the survey strip [Spear et al. 1992]; flight speeds from Spear and Ainley [1997b]). Of the 92,696 birds, 9,472 were recorded in flocks over surface-feeding fishes, and thus, were stationary; these counts required no correction for movement. Other than flock-feeding birds that passed within the survey strip, we also counted those in flocks that would have passed through the survey strip if they had not moved outside of it to avoid the approaching ship when it was within 1 km of the flock (Spear et al. 2005).

We defined a feeding flock as a group of three or more birds milling, or foraging over, surface-feeding fishes (mean flock size was 24.1 ± (SD) 27.7 birds, N = 457 flocks; some flocks contained species other than those of the ETP avifauna). We did not consider a group of birds as having been in a flock if they were in transit, sitting on the water resting, or scavenging (e.g., eating a dead squid). Although we recorded another 57 birds (<0.1% of the flock count) feeding in flocks over cetaceans where no fishes were observed, we excluded these because cetaceans are not important to tropical seabirds (Ballance and Pitman 1999) and because we did not collect any birds over feeding cetaceans. On this basis, we scored a flock index (Fl = the tendency to feed in flocks over piscine predators) for each species. Fl for each species was calculated as the

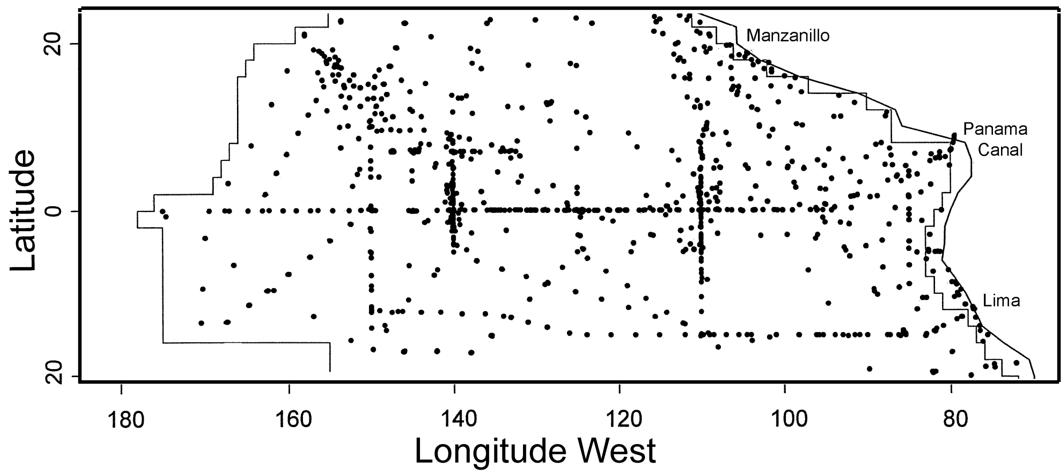

FIGURE 2. The distribution of at-sea survey effort of seabirds in the eastern Pacific Ocean (1983–1991). Each dot represents one noon ship position. The staircase line effect along the coast on the east side of the study area denotes the boundary separating pelagic waters to the west and coastal waters to the east.

number of birds of a given species observed in predatory fish-induced feeding flocks divided by the total number recorded (all behaviors), multiplied by 100, and therefore, is specific to those birds forming flocks over surface-feeding fishes.

We classified the ETP avifauna into two groups—solitary-feeders, those that feed predominantly alone; and flock-feeders, those that feed predominantly in multi-species flocks over surface-feeding fishes. We defined the cutoff between the two groups based on the hiatus in Fl values that occurred between species seldom seen in flocks (Fl = 0.0–4.7) and those regularly seen in them (Fl = 11.0–72.1; Table 4).

We used an adaptation of the feeding methods defined by Ashmole and Ashmole (1967) to classify the primary feeding method of each member of the ETP avifauna observed during our at-sea surveys (Table 4). Feeding methods are: (1) plunging that involves using gravity and momentum to reach a prey that is well beneath the surface, (2) plunging pursuit that involves plunging and then pursuing prey using underwater wing propulsion, (3) surface plunging that rarely involves becoming submerged, (4) contact dipping or swooping, in which only the bill touches the water, (5) aerial pursuit in which volant prey is captured, (6) surface seizing that involves eating dead or live prey while sitting on the water, (7) pattering on ocean surface or briefly stopping—only the feet, bill, and sometimes the breast and belly touch the water, and (8) kleptoparasitizing prey from other birds.

Data Analysis

Comparison of diets

Principal component (PC) analysis in conjunction with ANOVA was used to assess diet differences. For these analyses, the most abundant prey species were grouped into eight categories based on similarities in taxonomy and behavior (Appendix 1): (1) gonostomatids, sternoptychids, and photichthyids, (2) myctophids, (3) bregmacerotids, diretmids, and melamphaids, (4) hemirhamphids and exocoetids, (5) carangids, scombrids, and gempylids, (6) epipelagic cephalopods, (7) mesopelagic cephalopods, and (8) miscellaneous invertebrates (all non-cephalopod) and eggs.

These eight groups made up 90.4% of the prey sample (Appendix 1) with the majority (6.8%) of the remainder being fishes and cephalopods unidentifiable to family level. Thus, only 2.8% of the prey sample was miscellaneous identified fishes. After exclusion of seabirds that did not contain at least one prey item representing the eight prey groups, the sample size was 1,817 birds, or 87.5% of the original sample of the 2,076 birds (Table 3).

For the PC analysis, each bird record was weighted by 1/N, where N was the sample size of the species to which that bird belonged. This was required to control for unequal sample sizes and thus give equal importance to each seabird species in the statistical outcome. For each bird specimen we also converted the prey number it contained to the proportion representing each of the eight prey groups by dividing the number

TABLE 4. FLOCK INDEX, PRIMARY FEEDING METHOD, MEAN MASS (G ± SD), AND PREY-DIVERSITY INDEX (H') FOR THE 30 MOST ABUNDANT AVIAN SPECIES OF THE ETP.

	Flocking index	Primary feeding method	Mean mass	Prey-diversity index (H')
Flock feeders				
Masked Booby (*Sula dactylatra*)	15.9 (546.3)	1	1,633 ± 75 (16)	1.708 (18)
Nazca Booby (*Sula granti*)	15.9	1	1,487 ± 110 (5)	1.096 (5)
Great Frigatebird (*Fregata minor*)	73.1 (101.3)	4, 5, 8	1,355 ± 59 (4)	1.808 (4)
Red-footed Booby (*Sula sula*)	19.9 (706.7)	1	1,169 ± 145 (5)	0.554 (4)
Juan Fernandez Petrel (*Pterodroma externa*)	16.1 (5,636.4)	5, 3	427 ± 42 (208)	2.919 (204)
White-necked Petrel (*Pterodroma cervicalis*)	11.5 (208.9)	5, 3	414 ± 29 (12)	2.603 (12)
Wedge-tailed Shearwater (*Puffinus pacificus*)	24.8 (5,965.6)	3	381 ± 38 (99)	2.081 (95)
Kermadec Petrel (*Pterodroma neglecta*)	15.4 (149.3)	3, 6, 8	369 ± 34 (12)	2.545 (11)
Parasitic Jaeger (*Stercorarius parasiticus*)	11.0 (481.1)	6, 8	367 ± 81 (6)	1.404 (9)
Christmas Shearwater (*Puffinus nativitatus*)	42.8 (144.9)	2, 3	316 ± 18 (6)	2.148 (7)
Phoenix Petrel (*Pterodroma alba*)	16.7 (131.8)	3, 5	287 ± 34 (19)	2.323 (21)
Herald/Henderson Petrel (*Pterodroma heraldica/atrata*)	21.6 (85.5)	3, 5	280 ± 26 (13)	2.539 (13)
Sooty Tern (*Onychoprion fuscata*)	44.0 (12,744.4)	3, 4	184 ± 14 (68)	2.226 (82)
Gray-backed Tern (*Onychoprion lunatus*)	28.3 (60.0)	3, 4	124 ± 10 (5)	1.370 (5)
White Tern (*Gygis alba*)	44.5 (883.6)	3, 4	97 ± 6 (8)	2.055 (11)
Solitary feeders				
Sooty Shearwater (*Puffinus griseus*)	0.4 (8,642.8)	2, 3	771 ± 85 (36)	2.495 (31)
Red-tailed Tropicbird (*Phaethon rubricauda*)	0.0 (170.3)	3	742 ± 101 (9)	1.296 (10)
Tahiti Petrel (*Pterodroma rostrata*)	3.3 (716.6)	6, 3	413 ± 40 (140)	3.142 (154)
Murphy's Petrel (*Pterodroma ultima*)	1.9 (53.5)	6	374 ± 29 (7)	2.496 (8)
White-winged Petrel (*Pterodroma leucoptera*)	4.2 (1,525.3)	3, 5	160 ± 16 (136)	3.553 (135)
Black-winged Petrel (*Pterodroma nigripennis*)	3.2 (2,104.1)	3, 6	154 ± 12 (78)	3.325 (88)
DeFilippi's Petrel (*Pterodroma defilippiana*)	0.2 (405.9)	3, 6	154 ± 8 (7)	1.792 (7)
Stejneger's Petrel (*Pterodroma longirostris*)	4.7 (569.1)	3, 6	145 ± 10 (47)	3.226 (46)
Bulwer's Petrel (*Bulweria bulwerii*)	2.0 (543.6)	6, 7	94 ± 11 (41)	3.268 (34)
White-throated Storm-Petrel (*Nesofregetta fuliginosa*)	1.8 (56.1)	7, 6	63 ± 3 (18)	2.725 (19)
Markham's Storm-Petrel (*Oceanodroma markhami*)	0.0 (2,338.9)	7, 6	51 ± 4 (15)	2.452 (12)
White-bellied Storm-Petrel (*Fregetta grallaria*)	0.5 (187.5)	7, 6	46 ± 3 (19)	2.872 (20)
Leach's Storm-Petrel (*Oceanodroma leucorhoa*)	0.3 (13.986.7)	7, 6	41 ± 3 (413)	3.465 (433)

TABLE 4. CONTINUED.

	Flocking index	Primary feeding method	Mean mass	Prey-diversity index (H')
White-faced Storm-Petrel (*Pelagodroma marina*)	0.4 (552.4)	7, 6	40 ± 3 (15)	2.487 (15)
Wedge-rumped Storm-Petrel (*Oceanodroma tethys*)	0.3 (9,614.3)	7, 6	25 ± 2 (330)	3.039 (308)

Notes: See Methods for calculation of flock index, species' mass, prey diversity index (H'), and definitions of feeding methods. Peculiarities as follows: flocking index (values in parenthses = total number of birds recorded, corrected for effect of flight movement); mean mass (values in parenthses = sample size); prey diversity index (values in parenthses = sample size). Species with flock index <11.0 were considered to be solitary. Species with samples size of collected birds <9 are not considered in subsequent analyses of H'. Species in each group (flocking and solitary) are listed in order of decreasing mass. Nazca and Masked boobies were distinguished during surveys in only two of our 17 cruises (1983–1991); herein we have assumed that their flocking indices are the same.

of prey representing each group by the total number of prey summed across all eight prey groups, multiplied by 100. The purpose of this was to avoid biases such as that due to larger seabirds being capable of containing larger numbers of prey.

To test for significant differences in diet, we used two one-way ANOVAs (i.e., Sidak multiple comparison tests, an improved version of the Bonferroni test; SAS Institute 1985). In the first, we tested for differences among the PC1 scores of the individuals representing the species composing the ETP avifauna; in the second we compared PC2 scores among those individuals. We considered diet differences between two species to be significant if either or both of their respective PC1 or PC2 scores differed significantly.

Only the first two PC axes were used to assess outcomes of this and the following PC analyses. Although the third and fourth axes explained up to 15% of the variance in PC analyses, our reasoning for using only the first two axes is that they usually explained about 50% of the variance in diet composition, and for presentation of plots, using more than two axes is difficult.

Analysis of temporal, spatial, and demographic factors

PC analyses were also used to compare temporal, spatial, and demographic effects on diet. Because this required sub-sampling, we used only the 10 most abundant avian species representing the ETP avifauna, represented by 1,516 individuals. Included were three species of piscivores that, based on prey size (average >20 g), were subsequently shown to be at or near the top of the trophic scale among ETP seabirds: Juan Fernandez Petrel (*Pterodroma externa*), Wedge-tailed Shearwater (*Puffinus pacificus*), and Sooty Tern (*Onychoprion fuscata*); four that were of intermediate trophic level (prey mass >7 g and <20 g): Tahiti Petrel (*Pterodroma rostrata*), White-winged Petrel (*Pterodroma leucoptera*), Black-winged Petrel (*Pterodroma nigripennis*), and Stejneger's Petrel (*Pterodroma longirostris*); and three that were of lower trophic level (prey mass <7 g): Leach's Storm-Petrel (*Oceanodroma leucorhoa*), Wedge-rumped Storm-Petrel (*Oceanodroma tethys*), and the Bulwer's Petrel (*Bulweria bulwerii*). Diets of each of the 10 species were compared between seasons (spring [March–August] vs. autumn [September–February]); current systems (South Equatorial Current [SEC] vs. the North Equatorial Countercurrent [NECC], where the division between the two systems was assumed to be 4° N; Wyrtki 1966); longitudinal sections (where west was designated as those waters between 135° W and 165° W and east was those waters east of 135° W to the Americas); and ENSO phase. ENSO phases include El Niño, neutral, and La Niña, and were scored by year and season following the guidelines of Trenberth (1997), as 1, 2, and 3, respectively (Table 5). For the PC analysis examining ENSO period, we compared diets of birds collected during El Niño vs. La Niña, and excluded those collected during the neutral phase. We also compared diets between the two sexes.

Prey groups designated for these analyses were the same eight groups as those defined above. Following the PC analysis, one-way ANOVAs also were used to test for significant differences in among species' PC1 and PC2 scores generated in the PC analysis to model diet among individuals of the 10 bird species. Using the one-way ANOVAs, we tested for differences in species' PC1 and PC2 scores compared between two ENSO periods (El Niño vs. La Niña), seasons (spring vs. autumn), current systems (SEC vs. ECC), longitudinal sections (west vs. east), and sexes. In order to examine season, ENSO, current system, longitude, and sex-related effects, data for each of these four environmental, temporal, and sex variables were included in the PC data set, but

TABLE 5. SEASON AND YEAR OF THE OCCURRENCES OF EL NIÑO, NEUTRAL, AND LA NIÑA PHASES OF THE EL NIÑO SOUTHERN OSCILLATION [a].

	Spring–summer (March–August)	Autumn–winter (September–February)
El Niño	1987, 1991	1986, 1987, 1991
Normal	1984, 1986, 1990	1983, 1985, 1989, 1990
La Niña	1985, 1988, 1989	1984, 1988, 1998

[a] Data from Trenberth (1997); for La Niña 1998, see Legeckis (1999).

not included (analyzed) as independent (prey group) variables in the initial PC analysis. Thus, the independent variable in one-way ANOVAs comparing PC scores among species with respect to diet composition was the PC value and the independent variable was bird species. Each ANOVA was constrained to summarize results pertaining to one of the two seasons, ENSO periods, current systems, or sexes.

Multiple regression analyses

With the exception of the use of generalized additive models to estimate the size of the ETP seabird population, most of the analyses summarized below were conducted with ANOVA—either one-way ANOVA (Sidak multiple-comparisons tests) or multiple linear regression (STATA Corporation 1995). The latter was performed using a hierarchical stepwise approach (dependent and independent variables summarized below). For each analysis we confirmed that residuals met assumptions of normality (skewness/kurtosis test for normality of residuals, P > 0.05), and in some cases log-transformation of the dependent variable was required to achieve that.

Diet diversity

Diet diversity of each seabird species was examined using the Shannon-Weiner Index (Shannon 1948; $H' = -\sum p_i \log p_i$, where p_i represents the proportion of each species in the sample). After calculating the index, we used a one-way ANOVA to compare diet diversity among three feeding guilds: (1) small hydrobatids (storm-petrels) that feed solitarily, (2) solitary-feeding procellariids, and (3) procellariids, larids, and pelecaniforms that feed in flocks over predatory fish.

Preliminary analyses demonstrated a significant positive correlation between bird species' sample size (N) and H' (r = 0.538, df = 28, P < 0.01; Table 4), indicating that H' was underestimated among species with smaller sample sizes. This problem has been dealt with elsewhere (Hurtubia 1973, Baltz and Morejohn 1977) using accumulated prey diversity index curves in which H' is computed for increasing N until, at H'_N, an asymptote is reached at which a further increase in N is not expected to cause a change in H'. However, because we had a relatively large number of seabird species, we were able to use an alternative method. In our case, we regressed the predator N on H' to determine what sample size was required to obtain an insignificant (P > 0.05) relationship between H' and N. The predator N required for an insignificant relationship was N = 9. Therefore, we did not calculate H' for predators with N <9, and considered H'-values of predators with N >8 as realistic estimates. To further adjust for the relation between predator N and H', we controlled for predator N in the multiple regression that examined the relationship between H and variables potentially affecting H'.

Prey size

We compared prey size among two species-groups of seabirds. The first group included the five most abundant seabird species that prey solitarily on smaller fishes at night and are, in order of increasing mass, Wedge-rumped and Leach's storm-petrels, and Black-winged, White-winged, and Tahiti petrels (Table 4). Ten prey species most abundant, by number, as well as common to each of these predators, were *Sternoptyx obscura, Vinciguerria lucetia, Diogenichthys laternatus, Symbolophorus evermanni, Myctophum aurolaternatum, Ceratoscopelus warmingii, Diaphus parri, Diaphus schmidti*, *Lampanyctus nobilis*, and *Bregmaceros bathymaster* (see Appendix 1).

The second group included the six flock-feeding seabird species that were either very abundant and/or contained large numbers of prey; each preyed to a large extent on *Exocoetus* spp., *Oxyporhamphus micropterus*, and *Sthenoteuthis oualaniensis*. These predators were, in order of increasing mass, the Sooty Tern, Wedge-tailed Shearwater, Juan Fernandez Petrel, Red-tailed Tropicbird (*Phaethon rubricauda*), Nazca Booby (*Sula granti*), and Masked Booby (*S. dactylatra*). All but the tropicbird are flock-feeders (Table 4).

We used separate multiple regression analyses to examine prey size among the bird species representing each of the two predator groups. The dependent variable was otolith or beak length of prey; beak and otolith lengths are highly correlated with prey size (Appendix 2), and thus, are very reliable for estimating the latter. Independent variables in the regression analyses were predator species, and predator sex, mass, and fat score. We also included prey species in these analyses to control for prey-related differences in otolith or beak length.

In addition, when not known from measurements of intact prey, we calculated standard lengths and mantle lengths for fishes and *Sthenoteuthis oualaniensis*, respectively. We calculated these values only for prey species for which allometric equations were available for conversion of otolith or beak lengths to respective body lengths (Appendix 2). The mean ± SD for these values are presented for the primary prey of the predators listed above.

Scavenging

Most squid are semiparous, short lived and die after spawning (Clarke 1986). Many species that die after spawning float to the ocean surface (Rodhouse et al. 1987, Croxall and Prince 1994). Procellariiforms take advantage of this by scavenging their carcasses (Imber 1976, Imber and Berruti 1981, Croxall and Prince 1994); these birds have strongly hooked beaks for ripping flesh and a well developed sense of smell (Bang 1966, Nevitt 1999). Scavenging of dead cephalopods too large to be swallowed whole consists of eating the parts that are easiest to tear loose: eyes, tentacles, buccal structure including the beak, and then pieces of the mantle if the animal has become decomposed enough so that the mantle is flaccid and can be ripped apart (Imber and Berruti 1981; Spear, pers. obs.).

Cephalopod parts obviously torn from large individuals were considered to have been scavenged. Yet, these parts could usually not be identified to species if only scavenged flesh with no beaks was present in a bird's stomach. Therefore, it was necessary to estimate the proportional number of individual cephalopods of each species scavenged from the total number of lower rostral beaks of condition 1 or 2, representing squid that had been eaten within 24 hr. Thus, beaks of condition 3 and 4 were excluded. To determine if a cephalopod represented by its lower beak had been scavenged, we estimated cephalopod size using lower rostral length applied to allometric equations (Appendix 2), and information provided by M. Imber (pers. comm.) regarding beaks of smaller juveniles and subadults not likely to have had die-offs, and therefore, probably taken alive. Thus, individuals were considered to have been scavenged only if their beaks were too large to represent individuals that could have been swallowed whole. All of these were mesopelagic-bathypelagic species of cephalopods.

Because various amounts of dead cephalopod individuals were eaten by scavenging seabirds, we could not calculate the mass consumed directly from the size of scavenged beaks. We therefore used another method to calculate cephalopod mass consumed by scavenging birds.

Stomach fullness

We consider stomach fullness (SF) as an index for the propensity of a seabird species to feed while in the ETP study area. We calculated these indices as the mass of food in the stomach divided by the mass of the bird multiplied by 100. Mass for each individual was calculated as mass at the time of collection, minus the mass of food in the stomach. Mass of food in the stomach was calculated by subtracting the average mass of empty stomachs from that of the mass of the stomachs containing food. Thus, SF for each bird is the percent of that bird's unfed mass that the mass of food in the stomach represents. In cases when stomachs contained non-food items (e.g., pebbles or plastic), those items were excluded from calculations of food mass. We compare SF among the ETP avifauna except the Nazca Booby. We excluded this species from these analyses because we did not consider our sample as random. All Nazca Boobies were collected as they returned to the Malpelo Island colony, and, not surprisingly, each stomach was very full (SF mean = 26.6%, range = 18–35%).

We used multiple regression analyses to examine factors related to SF using the 10 more abundant seabird species but also included the Phoenix Petrel because of the paucity (three) of flock-feeding species among the 10. The sample unit was one bird. Thus, the analysis for SF included four flock-feeding species and seven solitary-feeding species.

It was necessary to exclude the less-abundant species from these analyses because many were lacking data for the different current systems, ENSO periods, seasons, and/or ETP longitudinal sections. The effects of the latter four variables, as well as sex, age, status, fat load, and mass, were examined (as independent variables) in these regression analyses; SF was the dependent variable and was log transformed so that residuals met assumptions of normality (skewness/kurtosis test, $P > 0.05$). We controlled for species' differences and weighted analyses by the inverse of species N so that outcomes reflect the average effect among species.

Timing of feeding

To determine the time of day when birds were feeding, we regressed the hour-of-day that birds were collected on the condition of otoliths found in their stomachs. We examined feeding time among four groups: (1) storm-petrels, (2) solitary procellariids, (3) flock-feeding procellariids, and (4) all flock-feeding species combined (see Table 3 for species included in each group). For groups 1–3, we examined timing of feeding on myctophids. For all flocking species, we examined timing of feeding on exocoetid and/or hemirhamphids. For these analyses we included several bird specimens representing species within the storm-petrel, larid, and pelecaniform groups that were not included in other analyses. Among storm-petrels we also included eight Wilson's (*Oceanites oceanicus*) and nine Band-rumped storm-petrels (*Oceanodroma castro*); additional larids included two Pomarine Jaegers (*Stercorarius pomarinus*), four Black Noddies (*Anous minutus*), two Brown Noddies (*A. stolidus*), and six Brown Boobies (*Sula leucogaster*).

It should be noted that determination of the proportion of live cephalopods that are taken during the night vs. day is difficult because of confounding caused by occurrence at the surface during the day due to being forced there by tuna vs. occurrence at the surface at night as the result of vertical migration. Because tuna feed during the day, and the only cephalopods eaten by seabirds feeding over them were epipelagic species, we considered all of the latter eaten by flock feeders to have been consumed during the day. However, many of the cephalopods (including epipelagic, mesopelagic, and bathypelagic species) are represented by juveniles and sub-adults that perform vertical migrations to the surface at night (Roper and Young 1975; M. Imber, pers. comm.). Therefore, we considered these smaller mesopelagic-bathypelagic cephalopods found in seabird stomachs to have been consumed at night. We assumed that epipelagic cephalopods consumed by solitary feeders were also eaten at night.

Mass of prey consumed in relation to foraging strategy

We calculated mass of prey consumed as a function of each of the four feeding strategies. Thus, four different complexes of prey were consumed, one complex representing each of the four feeding strategies. The four prey groups were classified based on prey behavior (Weisner 1974, Nesis 1987, Pitman and Ballance 1990; M. Imber, pers. comm.), and the results of this study for timing of feeding and flock composition and prey of birds feeding over tuna. The four groups are: (1) prey eaten by seabirds feeding in association with large aquatic predators during the day—hemirhamphids, exocoetids, carangids, scombrids, gempylids, coryphaenids, nomeids, and epipelagic cephalopods found in seabirds feeding over tuna; (2) prey eaten by seabirds feeding solitarily at night—crustaceans, gonostomatids, sternoptychids, myctophids, bregmacerotids, diretmids, melamphaids, crustaceans, and mesopelagic-bathypelagic cephalopod individuals too small to have been scavenged, (3) live prey eaten by seabirds feeding solitarily during the day—photichthyids, fish eggs, and non-cephalopod invertebrates except crustaceans; and (4) dead cephalopods that were scavenged (i.e., mesopelagic-bathypelagic cephalopods too large to have been eaten whole). We excluded miscellaneous families of fishes as well as fishes and cephalopods unidentified to family level (9.4% of the prey sample; Appendix 1).

Based on these classifications and the diets observed during this study (Appendices 3–32), we estimated the mass of prey consumed using each of the four feeding strategies during one day of foraging by one individual bird representing each of the 30 ETP seabird species. From these values, we could estimate the percent of the daily prey mass consumed when using each of the four feeding strategies.

Calculation of consumption rate for different prey groups

Otolith condition and temporal occurrence of hemiramphid/exocoetid prey indicated that 37.9% of all such otoliths present in seabird stomachs at 0800 H on a given day had actually been eaten between 1600 and 1900 H of the previous day although, due to progressive otolith digestion, the birds eliminated these otoliths by 1200 H the following day. Therefore, we adjusted values for number of hemiramphid/exocoetid prey by multiplying numbers of otoliths of these fish by 0.621 for those in birds collected at 0800, by 0.716 for those collected at 0900, 0.811 for 1000, and 0.906 for 1100 H, and assumed that no otoliths eaten between 0700 and 1800 H had been eliminated before 1800 H. We then calculated mass of hemiramphid/exocoetids using equations for *Exocoetus* spp. and *Oxyporhamphus micropterus* (Appendix 2) applied to all species of respective families of prey. We also used regression equations to calculate biomass of non-scavenged cephalopods (Appendix 2, Clarke 1986) that represented beaks.

Except for whole fishes representing photichthyids, carangids, coryphaenids, scombrids, nomeids, and gempylids, we calculated average mass of these fishes using the average mass of individuals of respective fishes found whole, or nearly so, in seabirds. For the carangids, coryphaenids and *Auxis* spp., we used masses of 25 g, 15 g, and 35 g for individual prey found in large procellariiforms, larids, and pelecaniforms, respectively; for gempylids these values were 12 g, 10 g, and 15 g; and for juvenile *Euthynnus*, 6 g, 6 g, and 7 g. Mean mass of the photichthyid, *Vinciguerria lucetia*, was 1.4 g, and the mass of the nomeid, *Cubiceps carnatus*, was 4.0 g, based on the mass of whole individuals found in bird stomachs and the fact that the otolith lengths of these species were similar among the birds containing them (sample sizes in Appendix 1).

Essentially, all otoliths of prey group 2 (gonostomatids, sternoptychids, myctophids, bregmacerotids, diretmids, and melamphaids) that were identifiable to family level (hereafter = identifiable) were eliminated by seabirds within 24 hr after being consumed. Based on otolith wear, we determined that these otoliths were obtained during the earlier hours of night, and that the proportion remaining in the stomach decreased with hour in such a way that only about 63% of the identifiable otoliths present at about 2000 H the previous night remained at 0800 H the next day, and only about 4% remained in the stomach at 1800 H.

Thus, to estimate the proportion of identifiable prey group 2, otoliths remaining in the stomachs of procellariiforms (essentially the only seabirds to feed on group 2 prey) at different hours of the day (all of those birds collected between 0800–1800 H), we used the regression relationship [Y = a + b (x)] between otolith condition in prey group 2 and hour of day. Hence, we calculated the proportion of identifiable otoliths in group 2 (Y) present in the stomach during the hour that birds were collected as:

$$Y = (1.46 + 0.133\ (\text{hour}/100))/4,$$

where 1.46 is the constant (a), 0.133 is the regression coefficient (b), (hour/100) is (x) (e.g., 0800 H/100 = 8), and 4 = condition of a highly worn (unidentifiable and unmeasured) otolith. We then adjusted prey group-2 otolith values in the stomach samples to estimate the true number eaten in a given night of feeding by multiplying values for number of group-2 otoliths found in bird stomachs in a given hour by the inverse of Y. We calculated mass for all group-2 prey for which we had regression equations relating otolith length to fish mass (Appendix 2). To calculate the mass of group-2 prey for which no regression equations were available, we averaged the mass across all species for which we had regression equations and used that value to estimate the mass of the other group-2 prey species. That is, we assumed that the average mass was similar across all group-2 prey for those in which we could not calculate mass from regression equations.

To calculate the mass of non-cephalopod invertebrate prey, first we calculated the average mass of different species of whole prey weighed during sorting. We then estimated the mass of invertebrate prey species that we did not weigh (either because of time constraints or because they were not whole) by multiplying the counts of these prey by the average values of mass of whole conspecifics. We divided these prey into two groups depending on whether caught at night or during the day (all others). Crustaceans contributed 16% of the prey mass among non-cephalopod invertebrates consumed, and were included with the prey acquired by birds feeding nocturnally.

Because various amounts of dead cephalopod individuals were eaten by scavenging procellariiforms, we could not calculate the mass consumed directly from the size of scavenged beaks. Therefore, to calculate the average mass of prey consumed by each scavenging seabird species, we averaged the mass of animal tissue in the stomachs of individual birds that had been scavenging shortly before being collected (i.e., containing torn off pieces of cephalopods showing little evidence of digestion). The average mass of cephalopod tissue present was 36.1 g for scavenging birds of mass >300 g (N = 41 birds having recently scavenged), 12.3 g for birds <300 g and >100 g (N = 19), and 4.6 g for those <100 g (N = 12). Using these values, we assigned the appropriate mass to the scavenged proportion of the diet of each bird determined to have recently scavenged.

The proportional amount of prey obtained during a 24-hr period when using each of the four foraging strategies was preliminarily estimated for each bird representing each species by: (1) summing prey mass across all prey species representing respective strategies, and (2) dividing the mass estimated to have been obtained when using each strategy by the total prey mass for the four strategies.

Estimation of total prey mass consumed

Estimating the total mass of prey consumed by the ETP avifauna per day first required an estimate of the number of birds representing each of the 30 seabird species present in the study area. To accomplish this, we used generalized additive models (GAMs; Hastie and Tibshirani 1990) and the software and analytical procedure of Clarke et al. (2003) implemented using S-Plus (S-Plus 1997). Inference from model-based methods such as GAMs, unlike sample-based methods, is not dependent on a random survey design and therefore is suited to data from at-sea seabird surveys. GAMs have been used in place of stratified analytical procedures to estimate abundance of marine biota with substantial improvements in precision (Swartzman et al. 1992, Borchers et al. 1997, Augustin et al. 1998). The gains arise because GAMs capture non-linear trends in density while using few parameters. The data used in the GAM for this study were those obtained during the survey portion of cruises. These data included 5,599.8 hr of seabird surveys over 82,440.3 km^2 of ocean surface within the study area (Fig. 2). The 30 species made up 97.3% of the seabirds recorded during the surveys. As explained above, bird counts were corrected for the effects of bird flux. The sample unit was one survey-day and independent variables were latitude, longitude, ocean depth, and distance to mainland. After excluding 20 d when <10 km^2 of ocean area was surveyed (low survey-effort-d can easily result in erroneous densities), the sample size was 807 survey days.

Using the population estimate for all 30 species combined, we then estimated the abundance of each species within the study area by multiplying the total by the percent contribution of a given species, as determined during the corrected survey counts. Using the estimated abundance for each bird species, we then calculated total biomass of each bird species by multiplying the estimated abundance for that species by its respective mean mass as determined in this study (Table 4).

To estimate the mass of prey consumed in one 24-hr period for a given species, we assumed that non-migrant species (species residing in the study area during the breeding season and/or non-breeding season) consumed 25% of their respective mass each day (Nagy 1987). The four species that fed opportunistically while migrating through the ETP were classified as opportunist migrants for this analysis. Because stomach fullness of these species was 50% of that of residents, we assumed a consumption rate of 12.5% of body mass, instead of the 25% used for residents.

Estimated values of average prey mass consumed, using analyses of mass of prey consumed per feeding strategy by each species in a given day, generally yielded masses lower than expected if residents consumed 25% of their mass per day (and migrants 12.5%), we used a second method to estimate the total mass consumed by the ETP avifauna. For the second analysis, we estimated the total mass of prey consumed per species per day by multiplying total bird species mass by 0.25 for resident species and 0.125 for migrants. To estimate the total mass of prey consumed using each foraging strategy for a given species we multiplied the total prey mass consumed by the percent obtained using each strategy calculated using the method described above. Total prey mass consumed by the ETP avifauna was estimated by summing total prey mass across the 30 most-abundant ETP seabird species.

Statistical conventions

Unless otherwise noted all means are expressed with ± 1 SD.

RESULTS

COMPARISON OF SEABIRD DIETS

The prey mass consumed by the ETP avifauna consisted of 82.5% fishes (57% by number), 17.1% cephalopods (27% by number), and 0.4% non-cephalopod invertebrates (16% by number). Fish predominated in the diet of procellariiforms and larids, but both fish and cephalopods were consumed about equally by pelecaniforms.

The first and second PC axes explained 45% of the variance in prey species taken (Table 6). The most important prey groups on the PC1 axis were myctophids with positive scores, and the hemirhamphids/exocoetids and epipelagic cephalopods with negative scores. The 15 seabird species that fed predominantly on myctophids were positioned on the positive side, and those that fed on the others were positioned on the negative side (Fig. 3). The most important prey groups on the PC2 axis were the negatively loaded miscellaneous invertebrates, and the positively loaded epipelagic cephalopods (Table 6).

Species locations on the PC1 axis indicated two distinct feeding groups. The 15 birds on the myctophid side included the six species of storm-petrels, Bulwer's Petrel (Figs. 3, 4), and the eight species of small- to moderately sized *Pterodroma* spp. (Figs. 3, 5). Among these, the White-faced Storm-Petrel (*Pelagodroma marina*) and Tahiti Petrel were the most unique. The storm-petrel was unique due to its more extensive use of miscellaneous invertebrates, which

TABLE 6. PRINCIPAL COMPONENT ANALYSES BY EIGHT GROUPS OF PREY IN THE DIETS OF ETP SEABIRDS.

PC	Eigenvalue cumulative proportion	Prey group [a]	Eigenvector loadings PC1	Eigenvector loadings PC2
1	0.23	gono/ster/phot	0.26	–0.13
2	0.45	myctophid	0.55	0.26
3	0.60	breg/dire/mela	0.38	0.26
4	0.74	hemi/exoc	–0.50	–0.19
5	0.87	cara/scom/gemp	–0.13	0.03
6	0.96	epipelagic ceph	–0.46	0.48
7	1.00	mesopelagic ceph	0.01	0.09
8	1.00	misc. invertebrate	0.10	–0.76

[a] Prey groups: gono = gonostomatids, ster = sternoptychids, myctophids, phot = photichthyids, breg = bregmacerotids, dire = diretmids, mela = melamphaids, hemi = hemirhamphids, exoc = exocoetids, cara = carangids, scom = scombrids, gemp = gempylids, ceph = cephalopods.

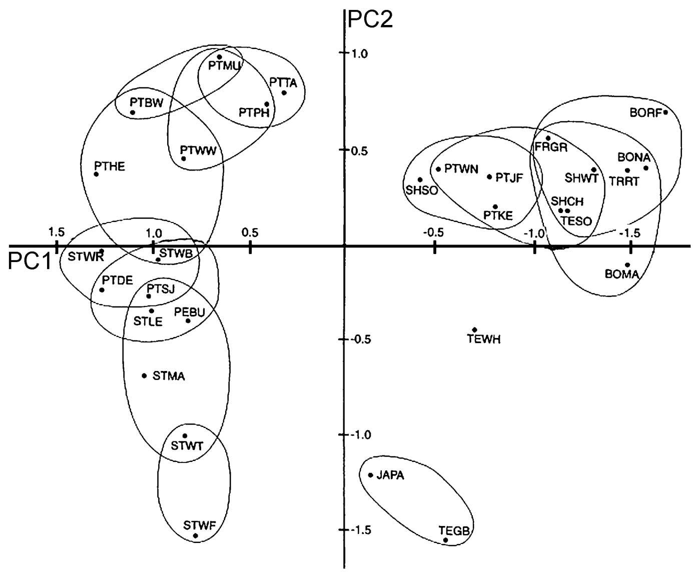

FIGURE 3. Results of the PCA comparing diets among 30 species of seabirds from the ETP. Diets of species enclosed in the same circle were not significantly different (Sidak multiple comparison tests, $P > 0.05$). BORF = Red-footed Booby (*Sula sula*), BOMA = Masked Booby (*S. dactylatra*), BONA = Nazca Booby (*S. granti*), FRGR = Great Frigatebird (*Fregata minor*), JAPA = Parasitic Jaeger (*Stercorarius parasiticus*), PEBU = Bulwer's Petrel (*Bulweria bulwerii*), PTBW = Black-winged Petrel (*Pterodroma nigripennis*), PTDE = DeFilippi's Petrel (*Pterodroma defilippiana*), PTHE = Herald Petrel (*Pterodroma arminjoniana*), PTJF = Juan Fernandez Petrel (*Pterodroma externa*), PTKE = Kermadec Petrel (*Pterodroma neglecta*), PTMU = Murphy's Petrel (*Pterodroma ultima*), PTPH = Phoenix Petrel (*Pterodroma alba*), PTSJ = Stejneger's Petrel (*Pterodroma longirostris*), PTTA = Tahiti Petrel (*Pterodroma rostrata*), PTWN = White-necked Petrel (*Pterodroma cervicalis*), PTWW = White-winged Petrel (*Pterodroma leucoptera*), SHCH = Christmas Shearwater (*Puffinus nativitatus*), SHSO = Sooty Shearwater (*Puffinus griseus*), SHWT = Wedge-tailed Shearwater (*Puffinus pacificus*), STMA = Markham's Storm-Petrel (*Oceanodroma markhami*), STWR = Wedge-rumped Storm-Petrel (*Oceanodroma tethys*), STLE = Leach's Storm-Petrel (*Oceanodroma leucorhoa*), STWB = White-bellied Storm-Petrel (*Fregetta grallaria*), STWF = White-faced Storm-Petrel (*Pelagodroma marina*), STWT = White-throated Storm-Petrel (*Nesofregetta fuliginosa*), TEGB = Gray-backed Tern (*Onychoprion lunatus*), TESO = Sooty Tern (*Onychoprion fuscatus*), TEWH = White Tern (*Gygis alba*), TRRT = Red-tailed Tropicbird (*Phaethon rubricauda*).

differentiated it from all other species except the White-throated Storm-Petrel (*Nesofregetta fuliginosa*), which also fed predominantly on miscellaneous invertebrates. For the Tahiti Petrel, its separation from other species positively loaded on the PC1 axis was related primarily to an extensive use of epipelagic cephalopods, which in conjunction with a high use of myctophids resulted in nearly neutral placement on that axis. The diet of this species was similar only to that of the Murphy's Petrel (*Pterodroma ultima*) and Phoenix Petrel, which also fed heavily on

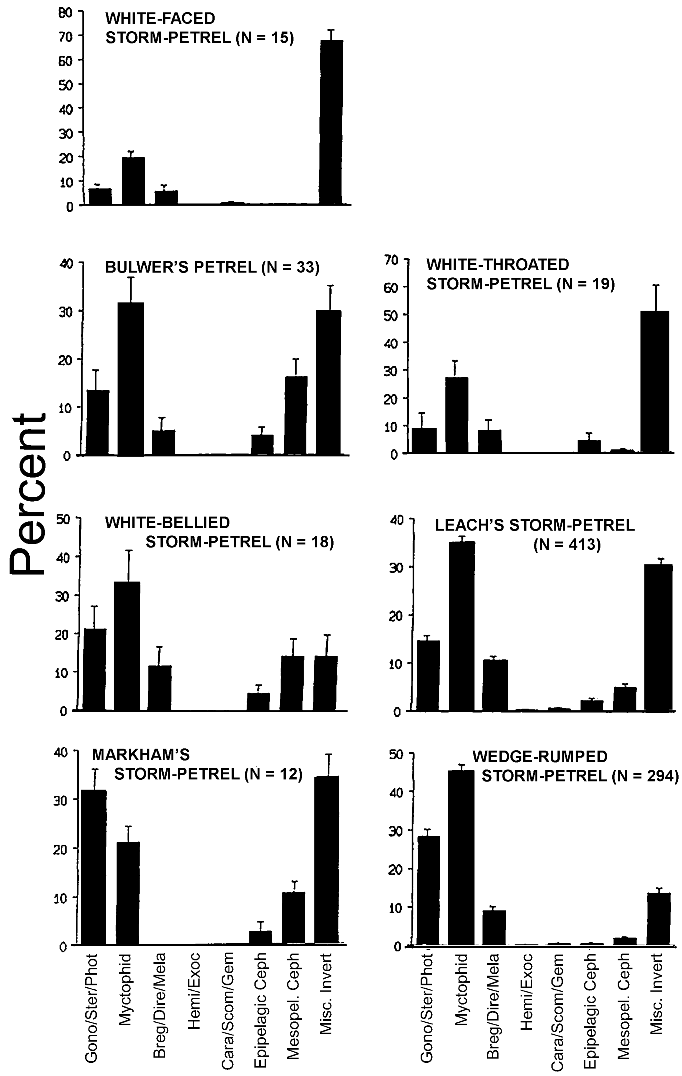

FIGURE 4. Percent of each of eight prey groups in the diet of seven smaller species of petrels, which feed solitarily in the ETP. Percent was calculated as the total number of prey representing a given prey group divided by the total number of prey summed across all eight prey groups in a given seabird species' diet. Values of N (in parentheses) are the number of birds containing at least one prey item. Error bars denote the standard error. See Methods for details on classification of the eight groups of prey species, and Appendices 3–9 for detailed prey lists.

epipelagic cephalopods and myctophids, but which avoided miscellaneous invertebrates. Indeed, the latter three gadfly petrels were the most positively loaded on the PC2 axis. This was due to avoidance of miscellaneous invertebrates in lieu of myctophids, bregmacerotids, diretmids, and melamphaids as well as epipelagic cephalopods.

Among the 15 seabirds occurring on the positive side of the PC1 axis, the nine species occurring on the negative side of the PC2 axis and the six species occurring on the positive side were almost completely separated (Fig. 3). Only one species, the White-bellied Storm-Petrel (*Fregetta grallaria*), essentially neutral on that PC2 axis, differed insignificantly among three of the species on the positive side (Herald Petrel [*Pterodroma arminjoniana*], White-winged, and Black-winged petrels) and five of the species on the negative side (Leach's and Wedge-rumped storm-petrels; Stejneger's, DeFilippi's [*Pterodroma defilippiana*] and Bulwer's petrels).

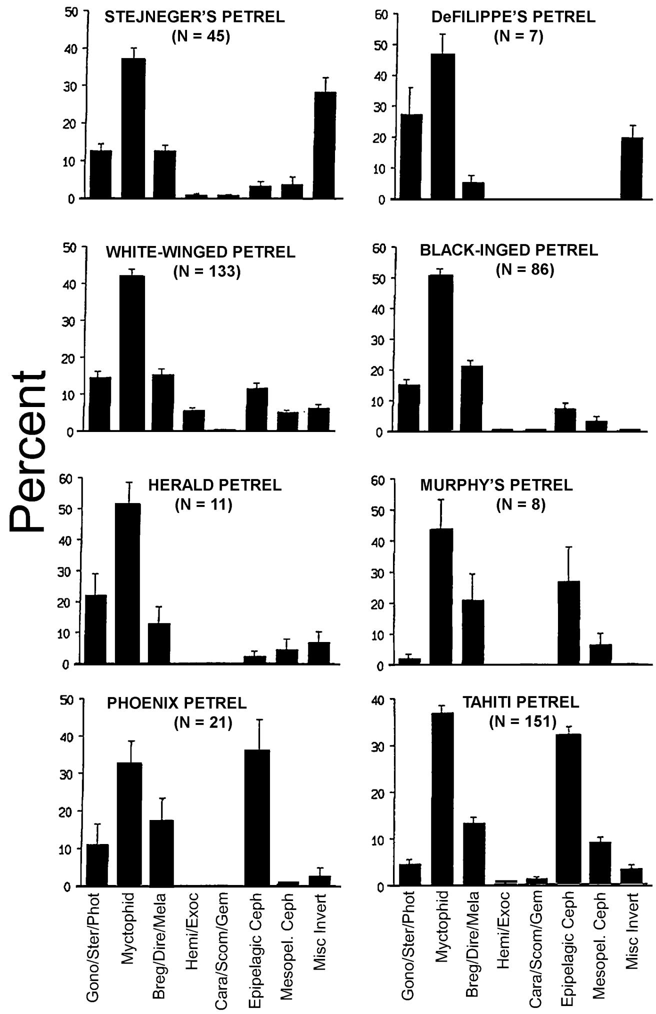

FIGURE 5. Diet composition of the eight medium-sized petrels, most of which feed solitarily in the ETP. For each seabird species, percent was calculated as the total number of prey representing a given prey group divided by the total number of prey summed across the eight prey groups in a given seabird species' diet. Values of N (in parentheses) are the number of birds containing at least one prey item. Error bars denote the standard error. See Methods for details on classification of the eight groups of prey species, and Appendices 10–17 for detailed prey lists and predator sample sizes.

This was primarily due to the lower intake of miscellaneous invertebrates by the White-bellied Storm-Petrel (Figs. 4, 5).

Interestingly, the Wedge-rumped Storm-Petrel, one of the species on the positive side of the PC1 axis, also consumed a low proportion of invertebrates and was also nearly neutral on the PC2 axis (Figs. 3, 4). In fact, the diet of this species was significantly different from that of the Leach's Storm-Petrel, with whom it associated spatially in the ETP. The very large sample sizes for each of the two species notwithstanding, this difference in diet resulted primarily from the higher proportion of myctophids and lower proportion of miscellaneous invertebrates in the diet of the Wedge-rumped Storm-Petrel. Indeed, among all species, this storm-petrel was surpassed only by the DeFilippi's Petrel in the proportion of gonostomatids, sternoptychids, and photichthyids (primarily the photichthyid, *Vinciguerria lucetia*, see Appendix 2), and was surpassed in the proportion of myctophids in its diet only by the Black-winged and Herald/Henderson petrels (Figs. 4, 5). The latter species were separated from the Wedge-rumped Storm-Petrel due to differences on the PC2 axis resulting from the lower proportion of miscellaneous invertebrates in their diets.

The diets of the Stejneger's and DeFilippi's petrels were also significantly different from the other two closely-related Cookilaria (small *Pterodroma*) petrels (Fig. 3). This was mostly due to the higher proportion of miscellaneous invertebrates in the diet of the former (Fig. 5). Among the four Cookilaria, the diet of the White-winged Petrel was noteworthy because of the larger proportions of hemirhamphids, exocoetids, and epipelagic cephalopods compared to the other three.

As noted above, occurring on the negative side of the PC1 axis were seabirds having a high proportion of hemirhamphids, exocoetids, and epipelagic cephalopods and low proportions of myctophids in their diets. Twelve of the 15 species (details on the three exceptions below) occurred in a tight group (Fig. 3). Significant differences consisted only for diets of the Sooty Shearwater (*Puffinus griseus*), and Juan Fernandez, White-necked (*Pterodroma cervicalis*), and Kermadec (*Pterodroma neglecta*) petrels compared with the Red-tailed Tropicbird, and Masked, Nazca, and Red-footed boobies (*Sula sula*). In fact, the Sooty Shearwater's diet differed significantly from all species except the three large *Pterodroma*. These differences resulted from the nearly complete dependence by the four pelecaniforms, the Christmas (*Puffinus nativitatus*) and Wedge-tailed shearwaters and Sooty Tern on hemirhamphids, exocoetids, and epipelagic cephalopods compared to the more diverse diets among the Sooty Shearwater and three large *Pterodroma* (Fig. 6). Indeed, for the PC1 axis, the boobies, tropicbird, and Wedge-tailed Shearwater had the highest negative loadings of the 30 predator species, although the Sooty Tern, Christmas Shearwater, and Great Frigatebird (*Fregata minor*) were not significantly different (Fig. 3). Among the boobies, the diet of the Red-footed Booby differed from that of the Masked Booby primarily because of differences on the PC2 axis resulting from the nearly complete use of epipelagic squid by the former in comparison to the much higher proportion of exocoetid/hemirhamphids in the diet of the latter (Fig. 6)

Two species occurring on the negative side of the PC1 axis, the Gray-backed Tern (*Onychoprion lunatus*) and Parasitic Jaeger (*Stercorarius parasiticus*), were distinct from all other species due to high negative loading on the PC2 axis and nearly neutral loading on the PC1 axis (Fig. 3). For the tern, the cause of divergence was its unique diet consisting almost solely of approximately equal proportions of hemirhamphids/exocoetids and miscellaneous invertebrates (primarily *Halobates* spp.; Fig. 6). Similarly, the diet of the jaeger consisted of 70% miscellaneous invertebrates (primarily barnacles [*Lepas* spp.]) and exocoetid egg bunches, with the remainder being an assortment of small fish and squid (the latter taken mostly by scavenging). Indeed, the proportion of miscellaneous invertebrates in the diet of these two species was similar only to that of the White-faced and White-throated storm-petrels, although the latter had no hemirhamphids/exocoetids in their diets (Fig. 4).

Temporal and Spatial Aspects of Diet

Results of the PC analysis comparing temporal/spatial patterns among diets of the 10 most abundant seabird species were similar to those comparing diets among the remaining 30 abundant species. For the former, the first and second PC axes explained 40% of the variance in prey species intake (Table 7). Similar to the previous analysis, the most important prey groups on the PC1 axis were the positive loading of myctophids, and the negative loadings of hemirhamphids/exocoetids and epipelagic cephalopods. The most important prey groups on the PC2 axis were the miscellaneous invertebrates with negative loadings, and the myctophids with positive loadings. Thus, myctophids had a major effect on both axes, although not nearly as great as miscellaneous invertebrates on the PC2 axis.

Diets of none of the 10 seabirds differed significantly when compared between sexes and seasons (Figs. 7, 8). Similarly, the diet of only one of the 10 species, the Stejneger's Petrel, differed significantly when the 10 species' diets were compared between the SEC and NECC (Fig. 9). This was due to differences primarily on the PC2 axis reflecting a considerably higher intake of invertebrates and lower intake of myctophids in the NECC compared to the SEC (Fig. 10).

The diets of three of nine species differed significantly between the eastern and western waters (Fig. 11). Bulwer's Petrel was excluded because of a small sample in the eastern section. The differing species included Stejneger's Petrel, Leach's Storm-Petrel, and Sooty Tern. The differences occurred primarily on the PC2 axis for Leach's Storm-Petrel and Stejneger's Petrel and on the PC1 axis for Sooty Terns. For the first two species this was mostly due to a higher intake of invertebrates and lower intake of myctophids in the east (Fig. 10). For the Sooty Tern, this was due to a considerably higher intake of gonostomatids, sternoptychids, and photichthyids (particularly *Vinciguerria lucetia*) and lower intake of hemirhamphids/exocoetids and epipelagic cephalopods in the east.

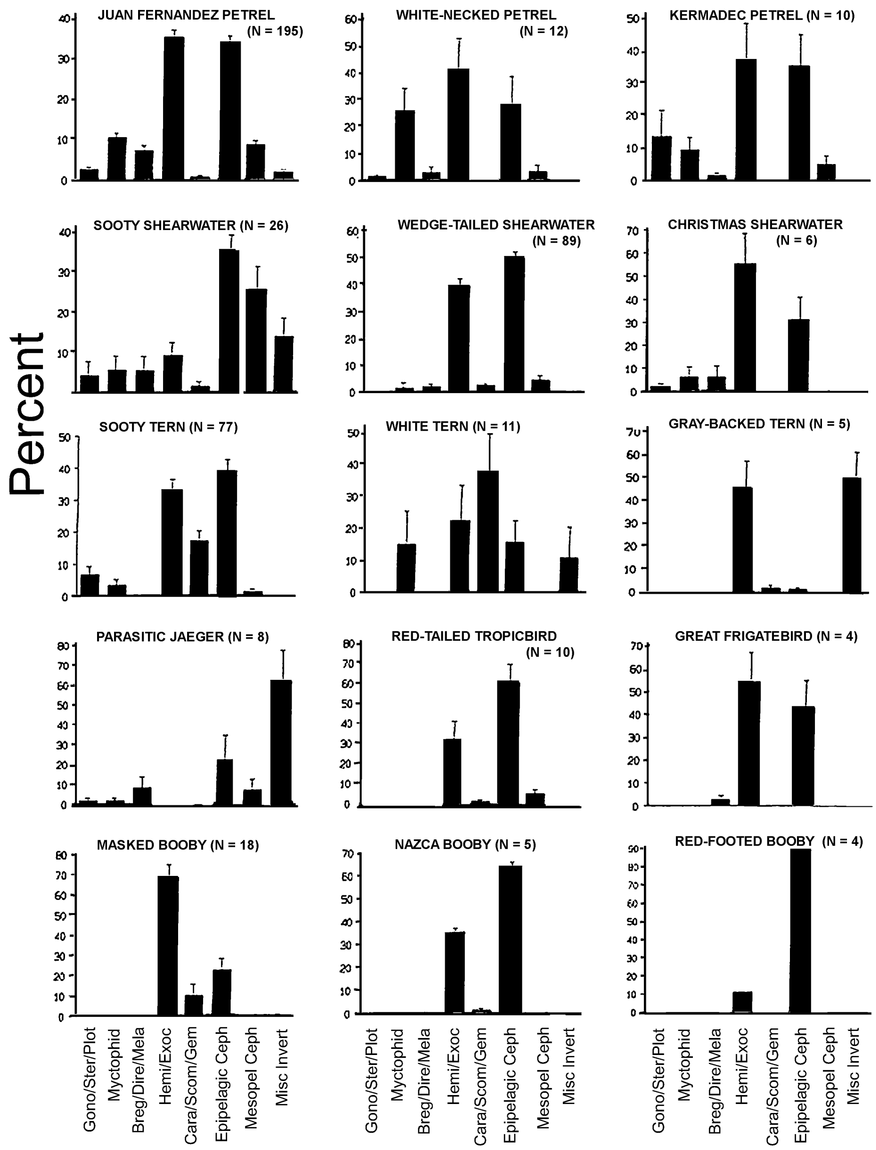

FIGURE 6. Diet composition of the 15 species of birds that generally feed over surface-foraging tuna in the ETP. For each seabird species, percent was calculated as the total number of prey representing a given prey group divided by the total number of prey summed across the eight prey groups in a given seabird species' diet. Values of N (in parentheses) are the number of birds containing at least one prey item. Error bars denote the standard error. See Methods for details on classification of the eight groups of prey species, and Appendices 18–32 for detailed prey lists and predator sample sizes.

The diets of two species—Stejneger's and Bulwer's petrels—differed significantly when compared between the El Niño vs. La Niña phases of ENSO (Fig. 12). This was related mostly to a higher proportion of non-cephalopod invertebrates in the diet of Bulwer's Petrels during El Niño, and in the diet of Stejneger's Petrels during La Niña (Fig 10). The latter also had a much higher proportion of myctophids in their diet during El Niño than La Niña.

Diet Diversity

Diet diversity (H') averaged 2.60 ± 0.62 (N = 23 seabirds species with sample sizes ≥9) and ranged from a high of 3.553 for White-

TABLE 7. PRINCIPAL COMPONENT ANALYSES FOR TEMPORAL/SPATIAL COMPARISONS BY EIGHT GROUPS OF PREY IN THE DIETS OF 10 ETP SEABIRDS.

PC	Eigenvalue cumulative proportion	Prey group [a]	Eigenvector loadings PC1	PC2
1	0.21	gono/ster/phot	–0.21	0.27
2	0.40	myctophid	–0.58	–0.39
3	0.57	breg/dire/mela	–0.31	–0.21
4	0.71	hemi/exoc	0.40	–0.13
5	0.83	cara/scom/gemp	0.21	–0.14
6	0.90	epipelagic ceph	0.55	0.26
7	0.96	mesopelagic ceph	0.07	0.28
8	1.00	misc. invertebrate	–0.03	0.74

[a] Prey groups: gono = gonostomatids, ster = sternoptychids, myctophids, phot = photichthyids, breg = bregmacerotids, dire = diretmids, mela = melamphaids, hemi = hemirhamphids, exoc = exocoetids, cara = carangids, scom = scombrids, gemp = gempylids, ceph = cephalopods.

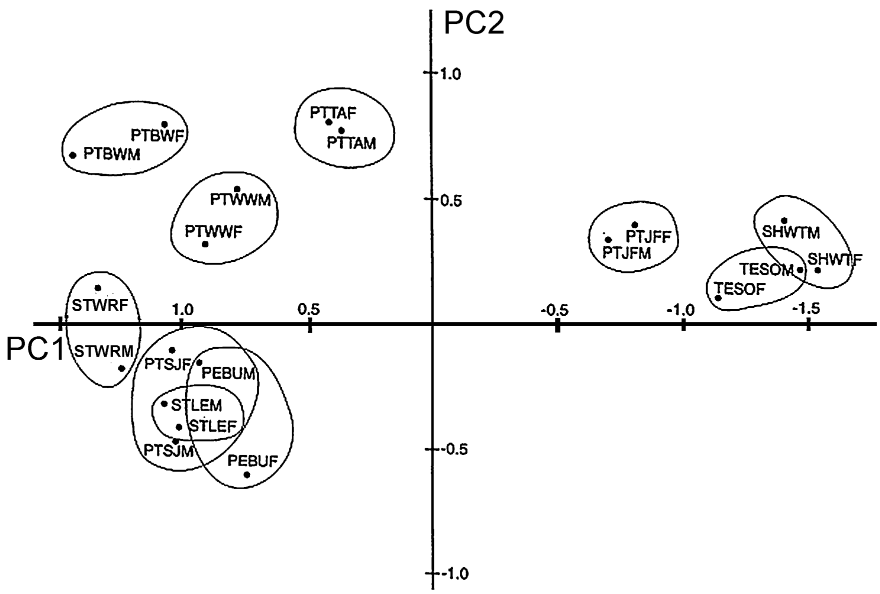

FIGURE 7. Results of the PCA to compare diets between sexes for each of 10 species of seabirds in the ETP. See Fig. 3 for species codes (first four letters). The fifth letter in the code designates female (F) or male (M). Diets of species enclosed in the same circle did not differ significantly between sexes (Sidak multiple comparison tests, all P > 0.05). Difference among species are not shown (see Fig. 3 for those results).

winged Petrels to a low of 1.296 for Red-tailed Tropicbirds (Fig. 13a). Solitary feeders (storm-petrels and certain procellariids) had significantly higher *H′* values than flock-feeding species (flocking procellariids, larids, and pelecaniforms; Sidak tests, all P < 0.025, Fig. 13b). Within the latter, flocking procellariids had significantly higher *H′* values than pelecaniforms (Sidak test, P < 0.001), but not larids (P = 0.3). There was an insignificant tendency for predator mass to be negatively correlated with *H′* in solitary and flock-feeding groups (flocking species, r = -0.503, df = 15, P = 0.06; solitary species, r = -0.499, df = 13, P = 0.06; Table 4).

PREY SIZE

Prey size was estimated using fish otolith and cephalopod beak lengths. The multiple regression conducted to examine factors related to prey size (otolith/beak length = dependent variable) among two storm-petrels, two small *Pterodroma* and one large *Pterodroma* representing the more abundant solitary feeders (all fed extensively on myctophids and other small fishes), explained 74% of the variance in prey size (Table 8; see Table 9 for mean standard lengths of these prey species). Significant main effects (other than prey species) were seabird species, sex, and body mass. Thus, sizes of the

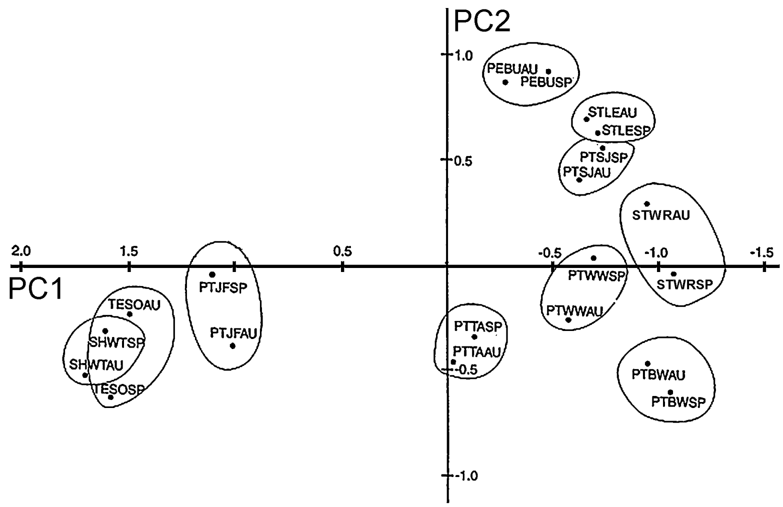

FIGURE 8. Results of the PCA to compare diets between spring and autumn for each of 10 species of seabirds in the ETP. See Fig. 3 for species codes (first four letters). The fifth and sixth letters in the code designates spring (SP) and autumn (AU). Diets of species enclosed in the same circle did not differ significantly between seasons (Sidak multiple comparison tests, all P > 0.05). Difference among species are not shown (see Fig. 3 for those results).

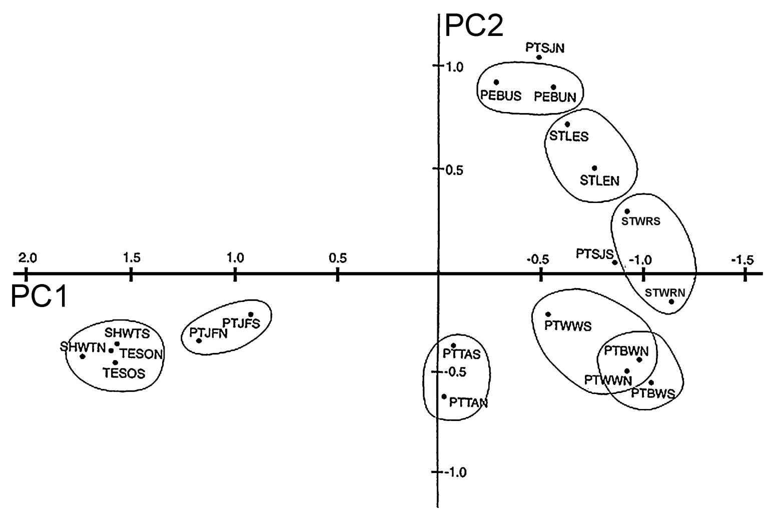

FIGURE 9. Results of the PCA to compare diets of 10 species of seabirds between the South Equatorial Current and North Equatorial Countercurrent. See Fig. 3 for species codes (first four letters). The fifth letter in the code designates current system; S = South Equatorial Current, or N = North Equatorial Countercurrent. Diets of species enclosed in the same circle did not differ significantly between current systems (Sidak multiple comparison tests, all P > 0.05). Difference among species are not shown (see Fig. 3 for those results).

prey representing each prey species differed significantly, and size of prey eaten by a given predator species differed when compared to the size of prey eaten by other petrel species (when controlling for within-predator effects of body mass and sex). In addition, females of a given predator species and of given mass, ate larger prey than males and, for a given predator species and sex, individuals of larger mass ate larger prey. Each of these effects was independent from the others.

An interaction was also found between predator species and prey species (Table 8). However, the difference in prey sizes was apparent in only five of the 10 prey species: *Myctophum aurolaternatum*, *Ceratoscopelus warmingii*, *Diaphus parri*, *Diaphus schmidti*, and *Lampanyctus nobilis* (Fig. 14a), and were

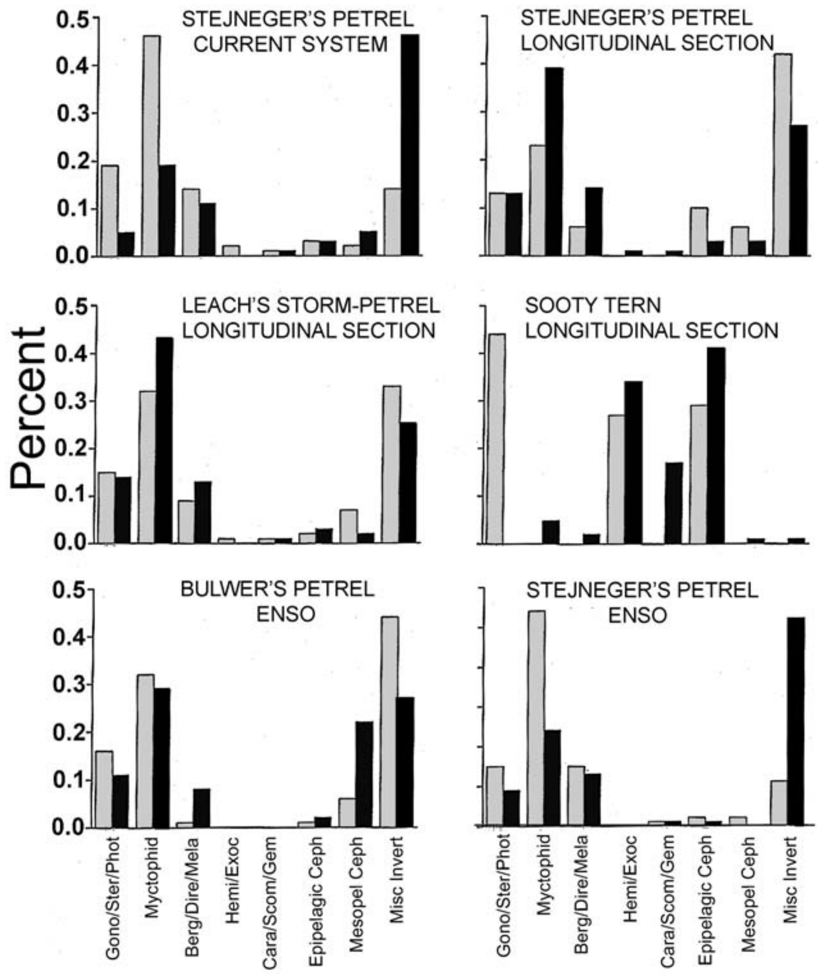

FIGURE 10. Percent of eight different categories of prey in the diets of different species of seabirds occurring within different current systems, longitudinal sections, or during La Niña vs. El Niño. See Methods for details on divisions for these waters or temporal periods. For current system, longitudinal section, and ENSO phase, the light bars designate the SEC, East, and El Niño, respectively; and the dark bar designates the NECC, West, and La Niña.

primarily because Wedge-rumped Storm-Petrel (the smallest species) ate smaller prey than did the other four seabird species. The Tahiti Petrel (the largest of the five predators) ate the largest individuals among five of the 10 prey species.

The multiple regression analyses to examine factors related to prey size among one larid, two procellariids, and three pelecaniform species representing those predators that feed in multispecies flocks and that primarily ate *Exocoetus* spp., *Oxyporhamphus micropterus* and *Sthenoteuthis oualaniensis,* explained 78% of the variance (Table 10; see Table 11 for average prey lengths of these prey species). Other than prey species, significant main effects were seabird species, sex, and fat load. Thus, for a given prey, the six seabird species ate individuals that were of significantly different sizes when controlling for within-predator effects of sex and fat load. In contrast to the solitary petrel group feeding on smaller prey, males ate larger prey than females and, for a given predator species and sex, individuals of lower fat load ate larger prey. Each of these effects was independent from the others.

Five significant interactions were found, including those of seabird species with prey species and seabird mass, sex, and fat load, as well as sex with mass (Table 10). The interaction between predator and prey species reflected the fact that, for a given prey, the size of individuals

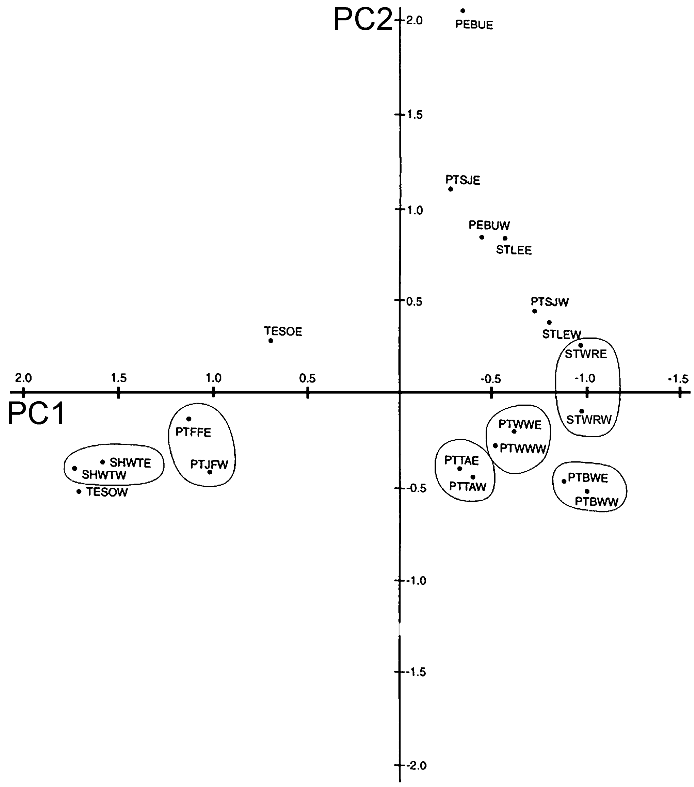

FIGURE 11. Results of the PCA to compare diets between east and west longitudinal portions of the ETP for each of 10 species of seabirds. See Fig. 3 for species codes. The fifth letter in the code designates east (E) or west (W). Diets of species enclosed in the same circle did not differ significantly between longitudinal sections (Sidak multiple comparison tests, all P < 0.05). Differences among species are not shown (see Fig. 3 for those results).

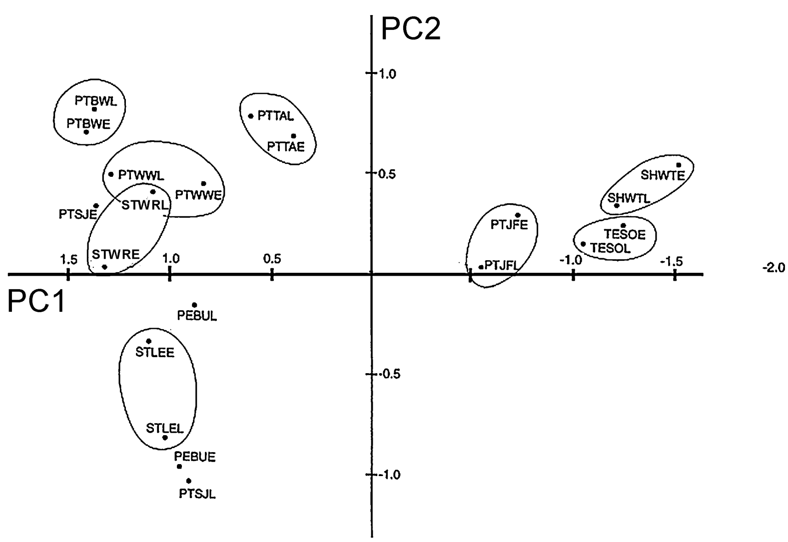

FIGURE 12. Results of the PCA to compare diets between El Niño and La Niña for each of 10 species of seabirds in the ETP. See Fig. 3 for species codes. The fifth letter in the code designates El Niño (E) or La Niña (L). Diets of species enclosed in the same circle did not differ significantly between the two ENSO phases (Sidak multiple comparison tests, all P < 0.05). Difference among species are not shown (see Fig. 3 for those results).

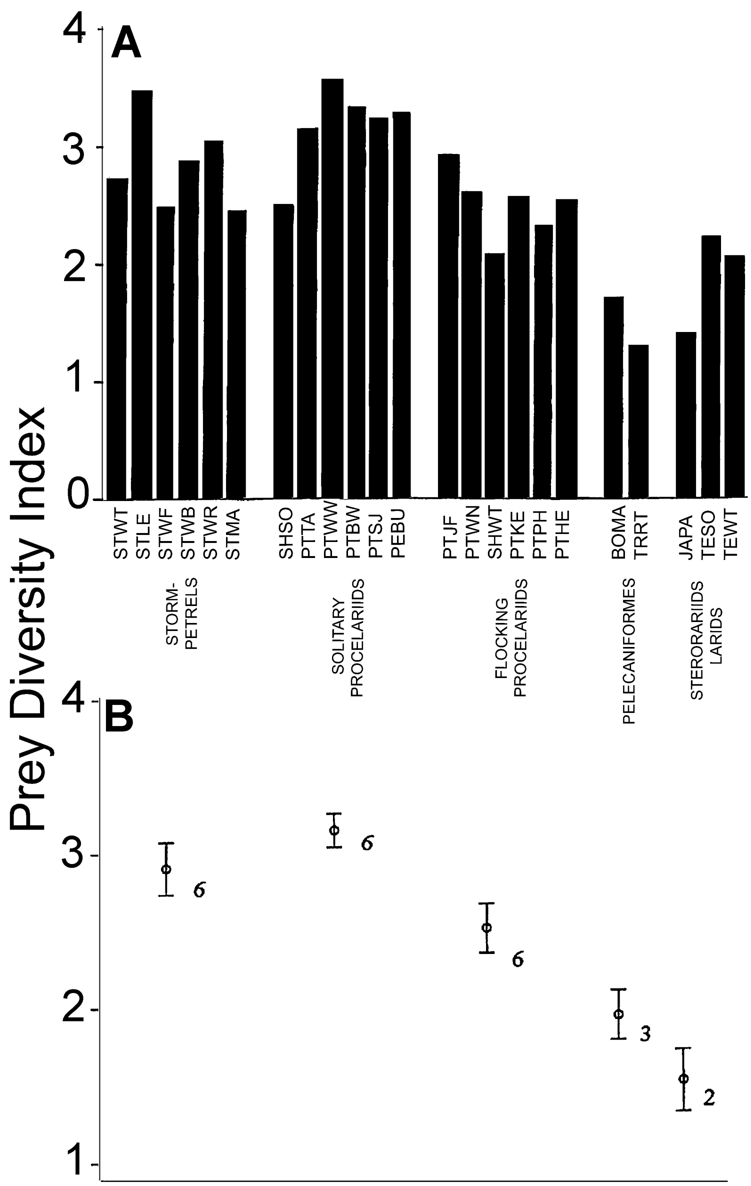

FIGURE 13. (A) Shannon-Wiener diet-diversity indices (H') for species of seabirds in the ETP having sample sizes (number of birds containing prey) ≥9. See Table 3 for species' sample sizes; Fig. 3 for species code definitions. (B) Mean H' ± SD among six groups of ETP seabirds.

eaten increased with predator body mass among the four smaller predators (Sooty Tern, Wedge-tailed Shearwater, Juan Fernandez Petrel, and Red-tailed Tropicbird (given in increasing mass). This interaction was less apparent, and differed in intensity among the three largest predators (Red-tailed Tropicbird, and Nazca and Masked boobies, given in increasing mass; Fig 14b).

The interaction between predator species and predator mass was due to a significant increase in prey size with increase in predator mass among the petrel and shearwater, but not in the tern, tropicbird, or boobies (Table 10). The interaction between seabird species and sex reflected the significantly larger prey taken by males representing the petrel and shearwater, compared to no sex-related prey size differences within

TABLE 8. REGRESSION ANALYSES FOR THE RELATIONSHIP BETWEEN PREY SIZE AND VAROIUS INDEPENDENT VARIABLES.

Term	Coefficient sign	F-value	P-value	df
Main effects				
Predator species	–	3.48	<0.01	4
Prey species	–	343.48	<0.0001	9
Sex	(+)	4.15	<0.05	1
Body mass	(+)	14.25	<0.001	1
Interactions				
Predator sp. X prey sp.	–	4.02	<0.0001	36
Rejected terms				
Fat load	ns	0.02	0.9	1
Prey species X sex	ns	1.10	0.4	9
Prey species X fat load	ns	1.54	0.12	9
Prey species X mass	ns	1.35	0.2	9
Predator species X mass	ns	0.50	0.7	4
Predator species X sex	ns	0.59	0.7	4
Predator species X fat load	ns	0.59	0.7	4
Mass X sex	ns	0.01	0.9	1
Mass X fat load	ns	0.11	0.7	1
Sex X fat load	ns	0.27	0.6	1

Notes: Otolith length = dependent variable; See Methods; independent variables include predator species, mass, sex, and fat load among the five more abundant seabirds that feed solitarily on small fishes (Leach's Storm-Petrel [*Oceanodroma leucorhoa*], Wedge-rumped Storm-Petrel [*O. tethys*], White-winged Petrel [*Pterodroma leucoptera*], Black-winged Petrel [*P. nigripennis*], and Tahiti petrel [*P. rostrata*]). Sample size was 1,449 prey items. Prey size pertains to the 10 more abundant prey species common to the diets of each predator (See Methods, Appendicies). Prey species was controlled for in these analyses to control for differences in size. Predator and prey species were analyzed as categorical; sex, mass, and fat load as continuous. A negative coefficient for sex indicates larger otolith size among males than females. Two terms separated by an asterisk indicate an interaction between respective terms. Model $F_{[51, 1397]}$ = 79.57, 73.6% of variance explained.

TABLE 9. STANDARD LENGTHS OF PHOTICHTHYIDS AND MYCTOPHIDS EATEN BY CERTAIN ETP SEABIRDS.

	Wedge-rumped Storm-Petrel (*Oceanodroma tethys*)	Leach's Storm-Petrel (*O. leucorhoa*)	Black-winged Petrel (*Pterodroma nigripennis*)	White-winged Petrel (*P. leucoptera*)	Tahiti Petrel *P. rostrata*
Vinciguerria lucetia					
$\bar{x}$ ± SD	32 ± 7 (182)	31 ± 6 (204)	30 ± 4 (48)	33 ± 6 (87)	34 ± 2 (9)
Range	19–51	15–53	25–38	19–44	31–39
Myctophum aurolaternatum					
$\bar{x}$ ± SD	42 ± 10 (32)	41 ± 14 (70)	38 ± 12 (13)	41 ± 16 (20)	49 ± 11 (13)
Range	23–60	15–80	21–55	16–75	36–73
Symbolophorus evermanni					
$\bar{x}$ ± SD	39 ± 8 (8)	56 ± 11 (30)	55 ± 8 (10)	50 ± 5 (7)	55 ± 11 (9)
Range	25–64	28–69	43–62	44–59	46–70
Ceratoscopelus warmingii					
$\bar{x}$ ± SD	39 ± 14 (20)	48 ± 11 (74)	51 ± 9 (48)	45 ± 11 (27)	51 ± 7 (10)
Range	17–60	19–67	27–67	24–60	36–69
Lampanyctus nobilis					
$\bar{x}$ ± SD	42 ± 9 (4)	54 ± 10 (7)	91 ± 16 (5)	86 ± 36 (7)	93 ± 24 (10)
Range	30–52	46–75	46–104	28–140	64–134

Notes: Prey sample sizes are given in parentheses. Predator species are given in order of increasing mass. See Appendix 2 for regressions used to calculated standard lengths (in millimeters) from otolith lengths (in millimeters).

the other four seabirds. The interaction between seabird species and fat load occurred because the petrels and shearwaters with a lower fat load ate significantly larger prey than those with a heavy fat load. No such relationship existed among the terns, and for tropicbirds and boobies fat loads did not vary enough to be compared. The interaction between sex and mass reflected a significant increase in prey size with increase in mass among female, but not among male seabirds (Table 10).

SCAVENGING

Species of cephalopods that were scavenged (M. Imber, pers. comm.) were larger individuals of mesopelagic-bathypelagic species—*Octopoteuthis deletron*, *Histioteuthis hoylei* and *H. corona*, *Megalocranchia* sp., *Taonius pavo*, *Galiteuthis pacifica* and *Alloposus mollis* (Table 12). We consider all individuals of smaller size as well as all other species of cephalopods recorded in this study to have been eaten

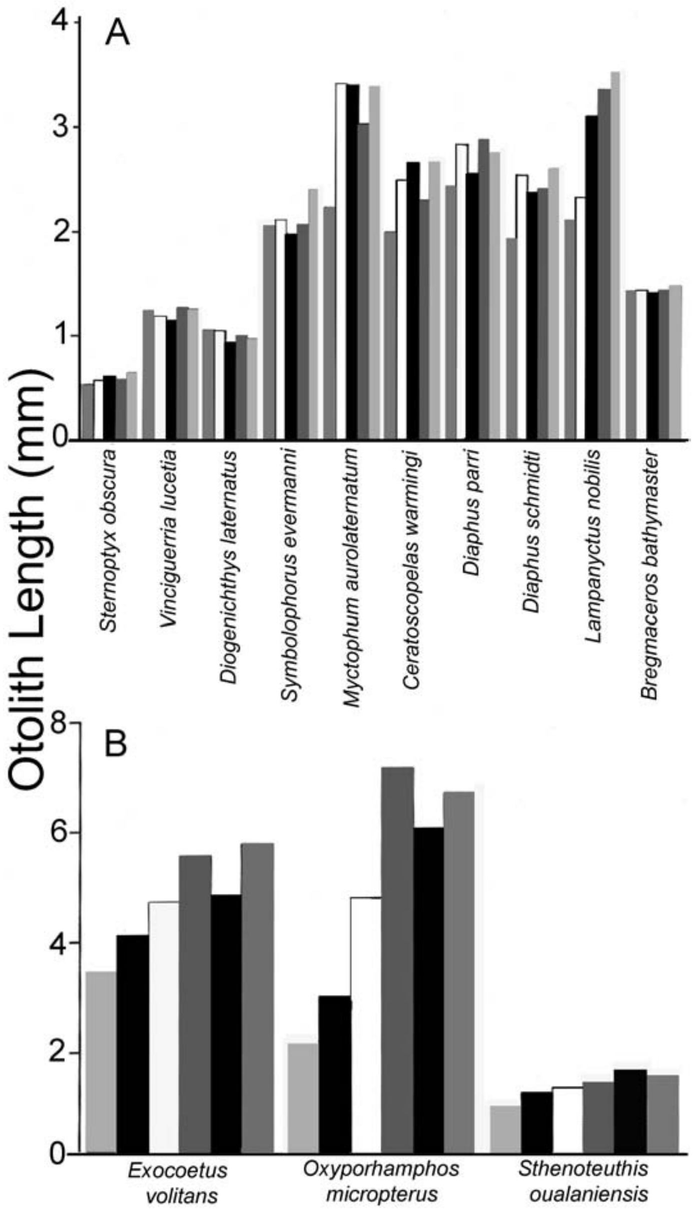

FIGURE 14. (A) Average otolith length (millimeters) of 10 species of prey taken by five species of seabirds that feed on smaller fishes. Predator species' bars for each prey species are from left to right (in order of increasing predator mass): Wedge-rumped Storm-Petrel (*Oceanodroma tethys*), Leach's Storm-Petrel (*O. leucorhoa*), Black-winged Petrel (*Pterodroma nigripennis*), White-winged Petrel (*P. leucoptera*), Tahiti Petrel (*P. rostrata*). (B) Average otolith or beak length (millimeter) of three species of prey taken by six species of seabirds that feed on larger prey. Predator species' bars are from left to right (in order of increasing mass): Sooty Tern (*Onychoprion fuscata*), Wedge-tailed Shearwater (*Puffinus pacificus*), Juan Fernandez Petrel (*Pterodroma externa*), Red-tailed Tropicbird (*Phaethon rubricauda*), Nazca Booby (*Sula granti*), Masked Booby (*Sula dactylatra*). See Appendices for prey sample sizes.

TABLE 10. REGRESSION ANALYSES FOR THE RELATIONSHIP BETWEEN PREY SIZE AND VARIOUS INDEPENDENT VARIABLES.

Term	Coefficient sign	F-value	P-value	df
Main effects				
Predator species	–	25.71	<0.0001	5
Prey species	–	388.46	<0.0001	2
Sex	(-)	4.17	<0.05	1
Fat load	(-)	22.50	<0.0001	1
Interactions				
Predator sp. X prey sp.	–	7.09	<0.0001	10
Predator sp. X mass	–	3.60	<0.01	5
Red-tailed Tropicbird (*Phaethon rubricauda*)	ns	0.59	0.5	1
Nazca Booby (*Sula granti*)	ns	1.73	0.2	1
Masked Booby (*Sula dactylatra*)	ns	0.86	0.4	1
Sooty Tern (*Onychoprion fuscata*)	ns	0.08	0.8	1
Juan Fernandez Petrel (*Pterodroma externa*)	(+)	6.06	<0.02	1
Wedge-tailed Shearwater (*Puffinus pacificus*)	(+)	4.19	0.05	1
Predator sp. X sex	–	2.45	<0.05	5
Red-tailed Tropicbird	ns	0.04	0.9	1
Nazca Booby	ns	1.18	0.2	1
Masked Booby	ns	0.16	0.7	1
Sooty Tern	ns (-)	2.21	0.14	1
Juan Fernandez Petrel	(-)	4.87	<0.03	1
Wedge-tailed Shearwater	(-)	8.56	<0.01	1
Predator sp. X fat load	–	9.37	<0.0001	5
Red-tailed Tropicbird (dropped from model; all fat scores = 1)				
Nazca Booby (dropped; all fat scores = 0)				
Masked Booby (dropped; all fat scores = 0)				
Sooty Tern	ns	0.03	0.5	1
Juan Fernandez Petrel	(-)	5.08	<0.025	1
Wedge-tailed Shearwater	(-)	17.04	<0.0001	1
Sex X mass	–	10.62	<0.01	1
Males	ns	0.31	0.6	1
Females	(+)	6.21	<0.01	1
Rejected terms				
Mass	ns	0.63	0.6	1
Fat load X sex	ns	2.13	0.15	1
Mass X fat load	ns	1.64	0.2	1
Prey sp. X fat load	ns	1.82	0.2	2
Prey sp. X mass	ns	1.72	0.2	2
Prey sp. X sex	ns	0.99	0.4	2

Notes: Otolith length = dependent variable; independent variables include: predator species, mass, sex, and fat load among six of the larger seabirds (Sooty Tern, Wedge-tailed Shearwater, Juan Fernandez Petrel, Red-tailed Tropicbird, Nazca Booby, and Masked Booby) that fed in multispecies flocks and preyed on similar species of prey. Sample size was 567 prey items. Prey size pertains to the three more abundant prey species (see Methods); prey species was controlled for in these analyses to contol for differences in size; see Table 9 for further details. Model $F_{[35, 530]}$ = 59.44, 78.3% of variance explained.

when alive (Roper and Young 1975; M. Imber, pers. comm.). We estimate that about 70%, 21%, and 15% of the squid eaten by Tahiti and Black-winged petrels and Sooty Shearwaters, respectively, were obtained by scavenging. Other procellariids including Stejneger's, Juan Fernandez, White-winged petrels, and Wedge-tailed Shearwaters scavenged 1.8–10.5% of the cephalopods they consumed. All other members of the ETP avifauna consumed 0–1.5% of the cephalopods they ate while scavenging and are not presented in Table 12.

STOMACH FULLNESS

Stomach fullness (SF), a measure of the propensity of different species of seabirds to feed while in the ETP, averaged 4.43 ± 5.58% (N = 1,784 birds; Nazca Booby excluded; Fig. 15). Stomach fullness was significantly different when compared among species ($F_{[26, 1757]}$ = 6.26, P < 0.0001). This difference was primarily due to very low mean SF among four species, which, from the lowest, were the Parasitic Jaeger (SF = 1.26 ± 1.12%, N = 9), White-necked Petrel (1.95 ±

TABLE 11. MEAN (± SD) AND RANGE FOR STANDARD LENGTHS OF THE MORE ABUNDANT PREY CONSUMED BY CERTAIN ETP SEABIRDS THAT FEED IN MULTISPECIES FLOCKS.

	Exocoetus spp.	*Oxyporhamphus Micropterus*	*Sthenoteuthis oualaniensis*
White-winged Petrel	63 ± 10 (18)	–	51 ± 17 (25)
(*Pterodroma leucoptera*)	53–88	–	32–70
Sooty Tern	51 ± 27 (25)	85 ± 17 (17)	54 ± 14 (49)
(*Onychoprion fuscata*)	25–135	46–108	25–84
Wedge-tailed Shearwater	73 ± 32 (74)	103 ± 27 (39)	62 ± 9 (46)
(*Puffinus pacificus*)	28–167	52–155	38–102
Juan Fernandez Petrel	110 ± 44 (59)	120 ± 21 (50)	67 ± 19 (81)
(*Pterodroma externa*)	30–196	133–163	29–117
Red-tailed Tropicbird	153 ± 14 (9)	139 ± 8 (4)	71 ± 12 (13)
(*Phaethon rubricauda*)	130–173	133–144	54–118
Nazca Booby	124 ± 38 (18)	126 ± 20 (29)	77 ± 12 (59)
(*Sula granti*)	75–180	87–171	48–102
Masked Booby	148 ± 20 (54)	145 ± 9 (8)	91 ± 5 (7)
(*Sula dactylatra*)	91–195	133–175	81–121

Notes: Sample sizes are given in parentheses; ranges are given below means. Predator species are given in order of increasing mass. See Appendix 2 for regressions used to calculated standard lengths (in millimeters).

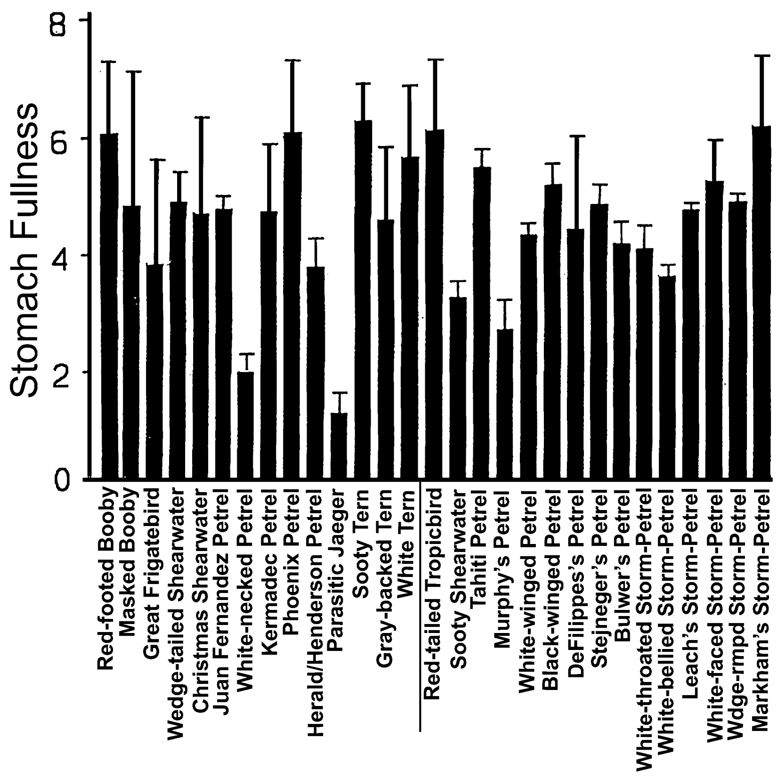

FIGURE 15. Stomach fullness (mean ± SE) of 29 species of seabirds in the ETP (Nazca booby [*Sula granti*] excluded; see Methods). Stomach fullness is the mass of food in the stomach divided by the fresh mass of the predator (minus mass of the food) multiplied by 100. See Table 2 for approximate sample sizes. Verticle line projecting from x-axis separates flock-feeding species (left side) from solitary feeding species (right side)

TABLE 12. MEAN LOWER ROSTRAL LENGTHS (MILLIMETERS) OF CEPHALOPOD BEAKS[a] EATEN BY ETP PROCELLARIIFORMS.

	PTTA	PTJF	SHWT	PTPH	PTWW	PTBW	PTSJ	STLE	SHSO[b]
Epipelagic cephalopods									
Sthenoteuthis oualaniensis	1.1	1.3	1.2	1.1	1.1	1.0	0.4	0.7	1.2
Onychoteuthis banksii	2.0	2.1	2.1	–	–	–	–	1.4	2.0
Pterygioteuthis giardi	1.9	1.1	–	–	2.0	–	–	–	–
Abraliopsis affinis	1.7	–	–	–	–	–	–	1.3	1.5
Cranchia scabra	–	–	–	–	1.2	–	–	0.9	–
Helicocranchia sp.	–	0.7	–	–	0.9	–	–	0.8	–
Liocranchia sp.	1.2	–	–	–	–	–	–	–	–
Liocranchia reinhardti	1.3	0.9	1.3	–	1.2	–	–	–	–
Leachia dislocata	–	1.7	–	–	–	–	–	1.2	–
Ocythoe tuberculata	–	2.4	–	–	–	–	–	–	–
Japetella heathi	–	–	–	–	0.9	–	–	–	–
Mesopelagic-bathypelagic cephalopods									
Pholidoteuthis boschmai	2.7	3.1	2.4	–	–	–	–	–	2.4
Ancistrocheirus sp.	**4.7**	**5.2**	–	–	**5.3**	–	–	–	–
Octopoteuthis deletron	**6.4**	–	–	–	2.7	–	–	–	–
Octopoteuthis sp.	–	2.0	–	–	–	–	–	–	–
Histioteuthis hoylei	**4.0**	3.1	1.7	–	2.7	–	–	–	2.6
Histioteuthis sp.	2.6	2.3	–	–	1.7	–	–	–	–
Histioteuthis corona	–	**4.0**	**4.4**	–	–	–	–	–	–
Bathyteuthis bacidifera	–	1.7	–	–	–	–	–	–	–
Mastigoteuthis sp.	–	1.5	–	–	–	–	–	–	–
Chiroteuthis sp.	2.9	–	–	–	–	1.4	–	–	–
Liguriella sp.	1.9	2.3	–	–	2.7	–	–	–	–
Megalocranchia sp.	**4.3**	**3.8**	–	–	**3.6**	**3.8**	**3.9**	–	–
Taonius pavo	**5.2**	**5.4**	–	–	–	–	–	–	**4.8**
Galiteuthis pacifica	–	**3.7**	–	–	**2.8**	**2.7**	**2.9**	–	–
unidentified *Cranchiidae*	3.0	–	–	–	1.8	–	–	–	–
Alloposus mollis	**3.4**	–	–	–	**3.6**	–	–	–	–
Species scavenged	11	12	3	0	9	2	2	3	1
Prey scavenged	352	29	5	0	5	7	0	84	5
Prey eaten	500	487	281	57	136	33	19	0	34
Percent scavenged	70.4	6.0	1.8	0.0	3.7	21.2	10.5	0.0	14.7

[a] Beak lengths given in bold type represent those scavenged, those in standard type represent those taken alive.
[b] See Fig. 3 for bird species' codes, species prey appendices for numbers of prey, Methods for estimation of number scavenged, and Appendix 1 for prey species' families.

1.30%, N = 12), Murphy's Petrel (2.65 ± 1.59%, N = 8), and Sooty Shearwater (3.21 ± 2.10%, N = 36). Thus, the mean SF (2.26%) for the latter four was about 50% of that of the other 25 species, whose SF ranged from 4–6%, except for the Great Frigatebird (3.83%, N = 3), Herald Petrel (3.90%, N = 13), and White-bellied Storm-Petrel (3.85%, N = 19). Species with the highest SF means were the Sooty Tern (6.25%, N = 68), Red-tailed Tropicbird (6.08%, N = 10), and Phoenix Petrel (6.07%, N = 21).

Stomach fullness averaged 5.02 ± 5.14% (N = 1,597) among the 11 seabird species analyzed in the multiple regression examining SF in relation to various biological and environmental factors. The model explained 24% of the variance in SF (Table 13). Significant main effects were current system, ENSO period, and seabird species. For a given species, mean SF was greater in the SEC (5.10 ± 5.02%, N = 1,080) than in the NECC (4.95 ± 4.20%, N = 517), and was also greater during the neutral phase of ENSO (6.36 ± 6.02%, N = 510) than during El Niño (4.66 ± 4.00%, N = 633) or La Niña (4.33 ± 4.12%, N = 454).

The variable, seabird species, was involved in four interactions with other variables (ENSO phase, longitude, fat-load, and age-status; Table 13), indicating that the relationship between SF and each of these variables differed among bird species. For ENSO phase, this was due to (1) highest SF during the neutral phase and lowest SF during La Niña in Wedge-tailed Shearwaters and Juan Fernandez and Phoenix petrels, (2) highest and lowest SF during La Niña and El Niño in Stejneger's Petrel, and (3) lack of a difference in SF with ENSO phase among the other seven species.

The interaction with longitude occurred because SF increased significantly with longitude (i.e., was highest in the western area) among Leach's and Wedge-rumped storm-petrels, but differed little with longitude among the other nine species. The effect of age-status on SF differed among species because (1) breeding adults had higher SF than fledglings among Juan Fernandez and Bulwer's petrels, (2) subadults had higher SF than fledglings in Black-winged Petrels, and (3) no significant age-related differences were found in SF for the other eight species.

Timing of Feeding

Myctophid otoliths became significantly more eroded as the day progressed from dawn among storm-petrels (r = 0.224, N = 709 prey, P < 0.0001), solitary-feeding procellariids (r = 0.120, N = 752, P < 0.001), and flock-feeding procellariids (r = 0.241, N = 171, P < 0.01; Fig. 16). Extrapolation of regression lines of best fit to the point where otolith condition = 1 (freshly eaten fish) indicates that storm-petrels ate myctophids on average at about 2200 H, whereas both groups of procellariids ate them on average at 2000 H, approximately 2 hr after sunset and 10 hr before daybreak the next

Table 13. Results of regression analyses for the relationship between stomach fullness and certain independent variables[a].

Term	Coefficient sign	F-value	P-value	df
Main effects				
Predator species	–	3.82	<0.0001	10
ENSO period	–	13.71	<0.0001	2
Current system	(-)	4.46	<0.05	1
Interactions				
Predator sp. X ENSO period	–	11.27	<0.0001	20
Predator sp. X longitude	–	4.92	<0.0001	10
Predator sp. X fat load	–	2.67	<0.01	10
Predator sp. X age status	–	2.19	<0.01	10
Rejected terms				
Mass	ns	0.00	0.9	1
Season	ns	0.18	0.7	1
Longitude	ns	0.11	0.7	1
Fat load	ns	2.91	0.09	1
Sex	ns	3.65	0.056	1
Predator sp. X current system	ns	0.81	0.6	10
Predator sp. X sex	ns	1.16	0.3	10
Predator sp. X mass	ns	1.31	0.2	10
Predator sp. X season	ns	1.75	0.066	10

Notes: Sample size was 1,315 birds. Predator species and ENSO period analyzed as categorical; all other independent variables analyzed as continuous. Analysis weighted by inverse of species N; see Methods. Model $F_{[66, 1247]}$ = 5.90, 23.8% of variance explained.

[a] Independent variables include season, ENSO period, longitude, current system, predator species, mass, sex, age status and fat load among the 11 more abundant species of ETP seabirds.

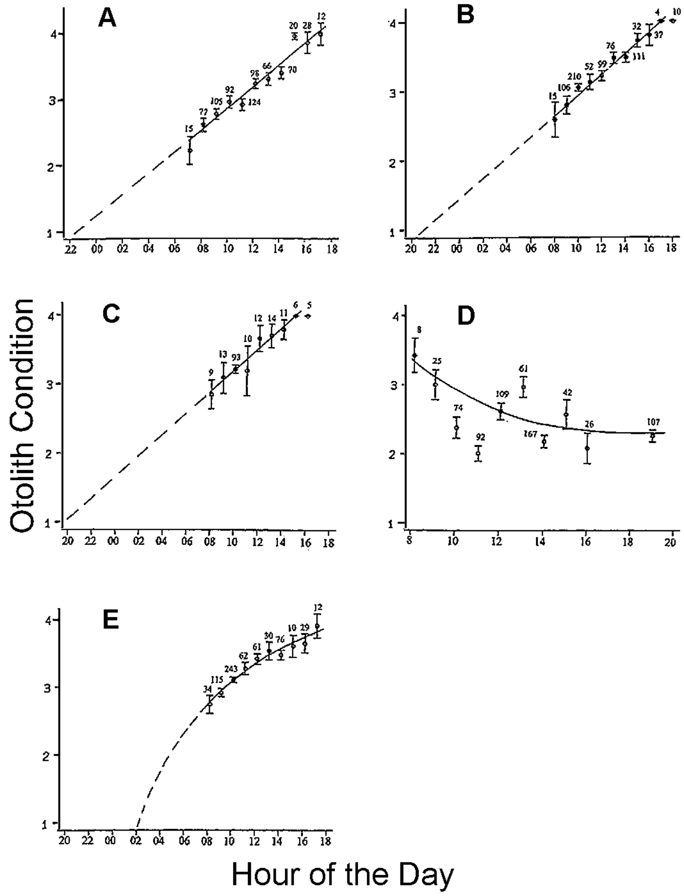

FIGURE 16. Otolith condition (mean ± SE) in relation to hour-of-day among five groups of seabirds: (A), myctophids caught by storm-petrels, (B) myctophids caught by solitary procellariids, (C) myctophids caught by flocking procellariids, (D) exocoetid-hemiramphids caught by flock-feeders, and (E) diretmids, melamphaids, and bregmacerotids caught by all procellariiforms. Otolith condition 1 represents pristine otoliths of freshly caught fish and 4 represents highly-eroded otoliths of well-digested fish. Numbers adjacent to means are otolith sample sizes, where one otolith represents one individual fish (see Methods). For myctophids, diretmids, melamphaids, and bregmacerotids, the line of best fit (solid line) was extrapolated (dashed line) to the x-axis at otolith condition 1, and gives an estimate of the average hour when fish were caught by the seabirds.

day. That nearly (if not) all myctophids were eaten during the night is also indicated by the decline in the number of whole myctophids per bird collected as the day progressed (none after 1000 H; Fig. 17). In addition, the highly-eroded condition of myctophid otoliths in late afternoon, and the absence of heavily-eroded otoliths in the morning (Fig. 16), indicates that few of these otoliths were retained longer than 24 hr.

In contrast, exocoetid/hemirhamphid otolith condition improved as the day progressed among flock-feeding species ($r = -0.188$, $N = 710$, $P < 0.0001$; Fig. 16). The relationship was curvilinear ($P < 0.01$) due to a rapid improvement in otolith condition from 0800–1200 H, followed by leveling of condition thereafter. The highly eroded condition in the first hours of day light compared to the lesser amounts of erosion observed later in the day indicates that some of these (very large) otoliths were retained overnight, and seabirds fed on those two fish families during the day and probably did not feed on them at night.

Otolith condition among flock-feeders (all otoliths considered; mean condition 2.40 ± 1.25, $N = 928$) was significantly better than that of solitary-feeders (all otoliths considered; mean 2.77 ± 1.13, $N = 2,664$; t-test = 8.47, df = 3,590, $P < 0.0001$). This pattern also is consistent with nocturnal feeding among the latter and diurnal feeding among the former.

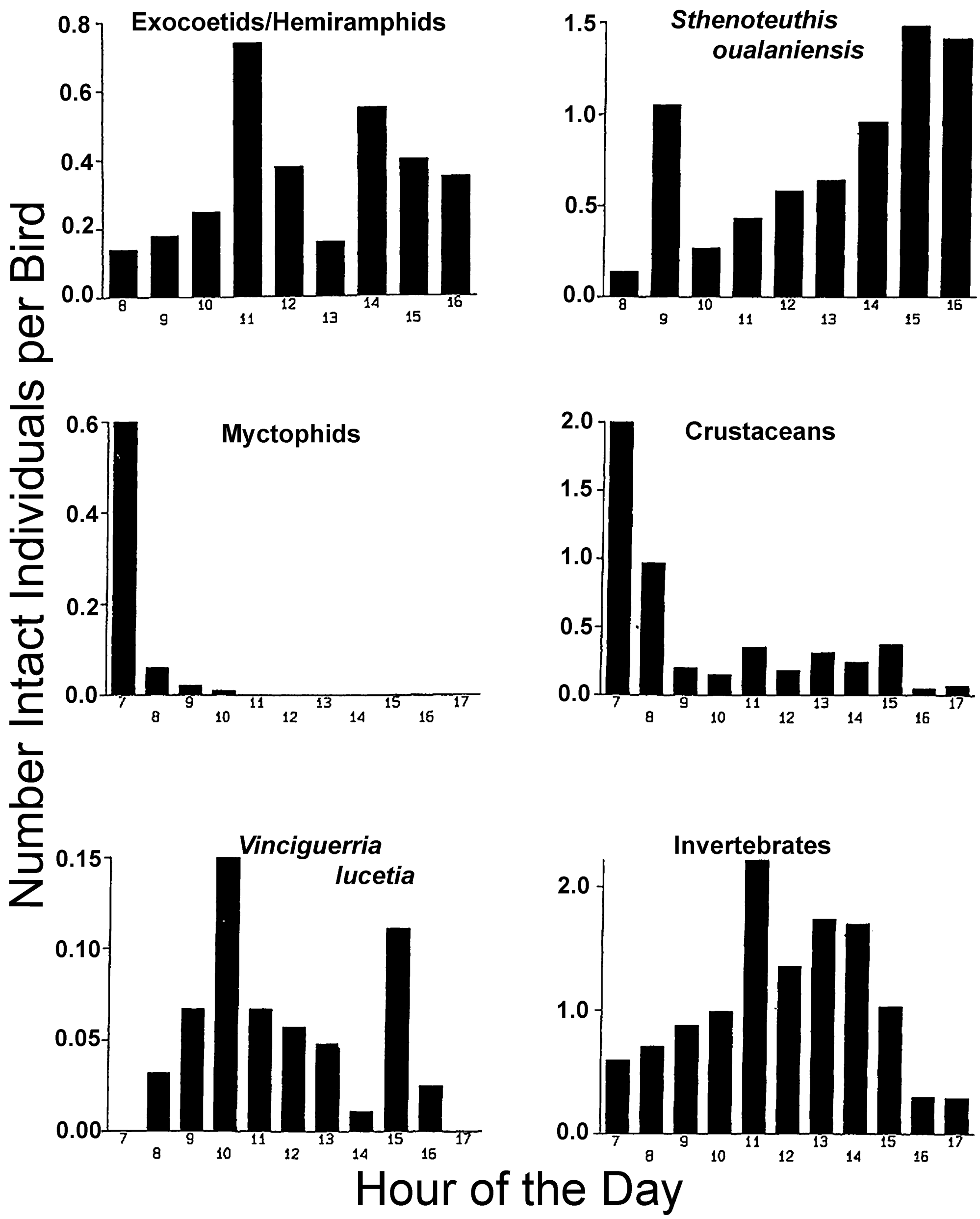

FIGURE 17. Number of intact prey representing six prey groups present in the stomachs of flock-feeding species (top two graphs) and storm-petrels (bottom four) in relation to time-of-day that the birds were collected.

Time-of-day when freshly caught (intact) food items were found in bird stomachs also provided information on feeding schedules (Fig. 17). The number of intact exocoetid/ hemirhamphid individuals per bird among flock-feeders increased between early and mid-morning and then stabilized or declined slightly in the afternoon. Compared to the occurrence pattern of exocoetid/hemirhamphids, acquisition of intact squid (*Sthenoteuthis oualaniensis*) had a significantly different diurnal pattern among flock-feeders in that numbers of squid per bird increased with time of day to a peak in late afternoon (χ^2 = 43.41, df = 8, P < 0.0001; numbers of whole prey by hour, not percentages, compared between the two groups; Fig. 17).

Patterns in the time-of-day that different groups of prey were found intact in the stomachs of storm-petrels and small *Pterodroma* also differed significantly (χ^2 = 134.22, df = 30, P < 0.0001; numbers of whole items per hour compared between the four groups: myctophids, crustaceans, *Vinciguerria lucetia*, and scyphozoans; Fig. 17). This result reflects the following patterns. Intact myctophids were found only during early morning hours and none were found in birds collected after 1000 H. Similarly, crustaceans peaked in early morning although a few continued to be taken throughout the day. On the other hand, *Vinciguerria lucetia* and miscellaneous invertebrate numbers per bird stomach (scyphozoan, *Halobates*, snails, and other mollusks) peaked during mid-day and reached lowest levels during morning and late afternoon.

Flock Composition and Prey among Birds Feeding over Tuna

The 131 seabirds collected while feeding over yellowfin and skipjack tuna contained 702 prey items. All prey species consisted of fishes except for two cephalopod species (*Sthenoteuthis oualaniensis* and *Leocranchia reinhardti*). Seabirds collected from yellowfin- vs. skipjack-induced flocks shared three of the five most abundant prey species found intact in their stomachs (*Sthenoteuthis oualaniensis*, *Exocoetus* spp., and *Gempylus serpens*; Table 14). However, the other two most abundant prey species differed among the two flock types: *Oxyporhamphus micropterus* and *Vinciguerria lucetia* taken in yellowfin-induced flocks, and *Euthynnus* spp. and *Hemirhamphus* spp. taken in skipjack-induced flocks. Comparison of the proportions that the seven prey species represented among diets of the two flock types showed a significant difference in prey made available to birds feeding over yellowfin vs. skipjack tuna (χ^2 = 304.82, df = 6, P < 0.0001; numbers of whole items, not percentages, compared between the two groups; Fig. 18).

Flock composition of seabird species feeding over the two tuna species also differed considerably. In fact, only two seabird species were observed in both flock types: Sooty Tern and Great Frigatebird (Table 15). Flocks feeding over skipjack were composed of 97.8% larids and those over yellowfin were composed of 83.4% procellariiforms. Mean flock size did not differ significantly (t-test = 1.53, df = 32, P = 0.14) between yellowfin-induced (29.4 ± 19.3 birds, N = 23 flocks) and skipjack-induced flocks (42.4 ± 29.5 birds, N = 11 flocks).

Summary of Diet Composition

The majority of prey taken among species of pelecaniforms was composed of cephalopods, although prey composition, by mass, was nearly equally divided among both fishes and cephalopods (Table 16). Numbers of prey taken by large procellariids were nearly equally divided between fishes and cephalopods, although prey mass was dominated by fishes. Small procellariids, hydrobatids, and larids also consumed primarily fishes, both in number and mass, although both the hydrobatids and larids also consumed large numbers of miscellaneous invertebrates and eggs.

Table 14. Composition of whole prey found in the stomachs of seabirds[a] collected while feeding in flocks induced by yellowfin and skipjack tuna[b].

Prey species	Number	(%)	Prey species	Number	(%)
Yellowfin tuna (*Thunnus albacares*) flocks			Skipjack tuna (*Euthynnus pelamis*) flocks		
Sthenoteuthis oualaniensis	343	71.0	*Euthynnus* sp.	90	41.1
Exocoetus spp.	47	9.7	*Sthenoteuthis oualaniensis*	56	25.6
Oxyporhamphus micropterus	40	8.2	*Exocoetus* spp.	32	14.6
Vinciguerria lucetia	24	4.9	*Gempylus serpens*	15	6.9
Gempylus serpens	13	2.7	*Hemirhamphus* sp.	12	5.5
Coryphaena spp.	3	0.6	*Promethichthys prometheus*	7	3.2
Liocranchia reinhardti	3	0.6	*Cubiceps carnatus*	4	1.8
Hemirhamphus sp.	2	0.4	*Oxyporhamphus micropterus*	1	0.5
Euthynnus sp.	2	0.4	*Cypselurus spilopterus*	1	0.5
Naucrates ductor	1	0.2	*Naucrates ductor*	1	0.5
Auxis sp.	1	0.2			
Cypselurus sp.	1	0.2			
Cubiceps carnatus	1	0.2			
Sternoptyx obscura	1	0.2			
Symbolophorus evermanni	1	0.2			

[a] See Table 16 for flock composition.
[b] Yellowfin (N = 11 flocks) and skipjack (N = five flocks); prey species are given in order of decreasing occurrence.

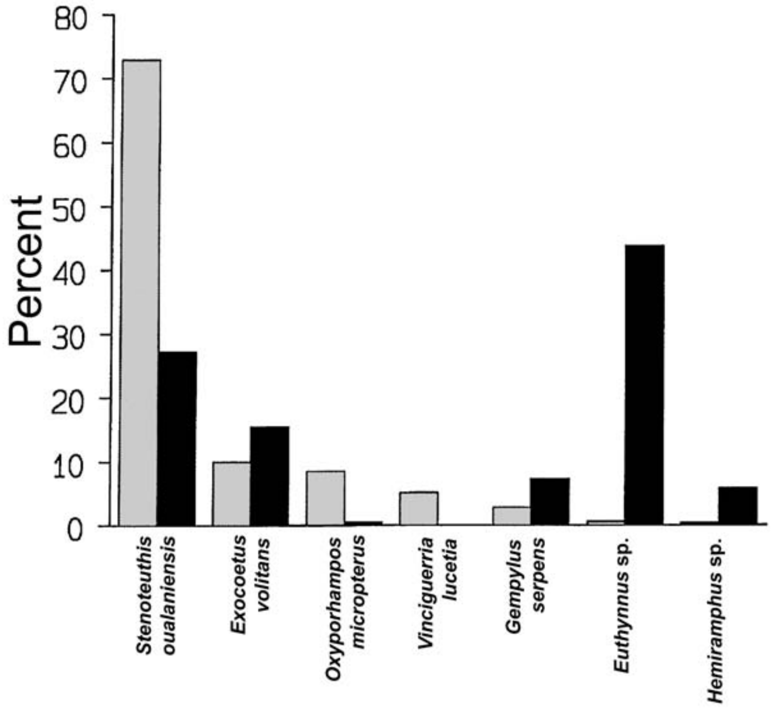

FIGURE 18. Percent composition of the seven most frequently consumed prey species within the diets of seabirds feeding in flocks over yellowfin (*Thunnus albacares*) (light bar, N = 11 flocks) and skipjack tuna (*Euthynnus pelamis*) (dark bar, N = 7 flocks). For a given flock type, percentages are the number of prey of a given prey species divided by the total number of prey representing all seven prey species multiplied by 100. Number of prey for the seven prey species was 471 individuals from birds collected over yellowfin, and 206 prey from birds collected over skipjack tuna.

Proportion of Prey Obtained Using the Four Feeding Strategies

Flocking procellariids, larids, and pelecaniforms obtained an average of 77%, 94%, and 100%, respectively, of the daily prey mass they consumed by flock feeding (Table 17), whereas hydrobatids and solitary and flocking procellariids obtained 78%, 57%, and 20%, respectively, of their daily prey mass by feeding nocturnally. The three groups of procellariiforms also obtained about 17%, 5%, and 1%, respectively, of their daily prey mass by foraging diurnally on non-cephalopod surface-dwelling invertebrates and fish eggs. The three groups obtained 3%, 13%, and 2% of their daily prey mass, respectively, by scavenging. Larids obtained 3% of their daily prey mass by diurnal solitary feeding, and another 3% nocturnally. Hydrobatids obtained 2% of their daily intake by flock feeding, and there was little incidence of scavenging by larids or pelecaniforms. Thus, all procellariids fed nocturnally at least occasionally, 18 of the 21 species (86%) used flock feeding and 15 species scavenged. Solitary, diurnal feeding on surface-dwelling invertebrates and fish eggs was confined to larids, solitary procellariids, and hydrobatids, particularly the latter; the only non-cephalopod invertebrates eaten by pelecaniforms were exocoetid ectoparasitic isopods taken incidentally with those fish.

Size of the Seabird Avifauna and Total Prey Mass Obtained According to Feeding Strategy

The average daily mass of prey obtained per bird representing the 30 ETP avian species when using each of the four feeding strategies (Table 17) is the basis for the following estimates of total daily prey mass obtained by each species.

The GAM used to estimate abundance of the ETP avifauna was very successful in modeling the ETP at-sea survey data as indicated by the very low coefficient of variation (CV = 5.9; details in Clarke et al. 2003). Our estimate for the total number of birds representing the 30 species in the study area was 31,860,300 (95% confidence interval = 28,418,800–35,089,900).

TABLE 15. SPECIES COMPOSITION OF SEABIRD FLOCKS OBSERVED WHILE FEEDING IN FLOCKS INDUCED BY YELLOWFIN AND SKIPJACK TUNA[a].

Species	Number	(%)	Species	Number	(%)
Yellowfin tuna (*Thunnus albacares*) flocks			Skipjack tuna (*Euthynnus pelamis*) flocks		
Wedge-tailed Shearwater (*Puffinus pacificus*)	310	45.9	Sooty Tern (*Onychoprion fuscata*)	365	78.3
Juan Fernandez Petrel (*Pterodroma externa*)	218	32.2	White Tern (*Gygis alba*)	27	5.8
Sooty Tern (*Onychoprion fuscata*)	103	15.2	Gray-backed Tern (*Onychoprion lunatus*)	22	4.7
Phoenix Petrel (*Pterodroma alba*)	12	1.8	Black Noody (*Anous minutus*)	14	3.0
Kermadec Petrel (*Pterodroma neglecta*)	6	0.9	Brown Noody (*Anous stolidus*)	13	2.8
Christmas Shearwater (*Puffinus nativitatus*)	5	0.7	Blue-gray Noody (*Procelsterna cerulea*)	10	2.2
Newell's Shearwater (*Puffinus newelli*)	5	0.7	Great Frigatebird (*Fregata minor*)	9	2.1
Great Frigatebird (*Fregata minor*)	3	0.4	White-tailed Tropicbird (*Phaethon lepturus*)	3	0.6
Parasitic Jaeger (*Stercorarius parasiticus*)	3	0.4	Red-footed Booby (*Sula sula*)	2	0.4
White-winged Petrel (*Pterodroma leucoptera*)	2	0.3	White-throated Storm-Petrel (*Nesofregetta fuliginosa*)	2	0.4
Stejneger's Petrel (*Pterodroma longirostris*)	2	0.3	Black-winged Petrel (*Pterodroma nigripennis*)	1	0.2
Pomarine Jaeger (*Stercorarius pomarinus*)	2	0.3			
Leach's Storm-Petrel (*Oceanodroma leucorhoa*)	2	0.3			
South Polar Skua (*Catharacta maccormicki*)	1	0.2			
Herald Petrel (*Pterodroma heraldica/atrata*)	1	0.2			
Dark-rumped Petrel (*Pterodroma phaeopygia*)	1	0.2			

[a] Species are given in order of decreasing abundance; 676 birds were associated with yellowfin (N = 23 flocks) and 467 were associated with skipjack (N = 11 flocks).

Using the mean mass for each species (Table 4), we estimated the mass of the avifauna to be 6,763 mt (Table 18). The six most abundant species, in decreasing order of abundance, were Leach's Storm-Petrel, Sooty Tern, Wedge-tailed Shearwater, Juan Fernandez Petrel, Wedge-rumped Storm-Petrel, White-winged Petrel, and Black-winged Petrel. These species composed an estimated 85% and 75% of the entire avifauna in terms of numbers and biomass, respectively.

The estimate of the daily prey mass obtained by the ETP avifauna within the study area was 1,588.1 mt (Table 18), 76.3% of which was taken by seabirds feeding over predatory fish, 18.6% by birds feeding nocturnally, 3.3% by scavenging, and 1.8% by feeding on non-cephalopod invertebrates and fish eggs.

In this analysis, we reclassified five of the 17 species previously considered as solitary feeders (Sooty Shearwater, White-necked Petrel, Murphy's Petrel, Stejneger's Petrel, and Parasitic Jaeger) as migrant opportunists, based on low stomach fullness which in turn indicated a propensity to move directly through the study area. We estimated that for each 24-hr period, resident flock feeders consumed 1,198 mt, resident solitary feeders consumed 280 mt, and migrant opportunists consumed 100 mt. However, proportions of the total daily prey mass consumed while using each of the four feeding strategies differed significantly among the three groups ($\chi^2 = 902.75$, df = 6, $P < 0.0001$; mass of prey, not percentages, compared between groups; Fig. 19).

These results were due to: (1) the very high proportion of prey mass obtained by resident flock feeders feeding over large predatory fish (Fig. 19), (2) the high proportion of prey mass obtained nocturnally by the resident solitary group, and (3) the use of all four strategies by the migrant opportunists, although prey consumed by the latter were taken predominantly over large predatory fish.

TABLE 16. PERCENT OF FISHES, CEPHALOPODS, AND NON-CEPHALOPOD INVERTEBRATES IN THE DIETS OF THE 30 MOST-ABUNDANT ETP SEABIRDS[a].

Species	Fishes	Cephalopods	Misc. invertebrates
Pelecaniformes			
Masked Booby (RF) (*Sula dactylatra*)	93.1 (97.4)	4.9 (2.6)	2.1 (0.0)
Nazca Booby (RF) (*Sula granti*)	35.5 (53.1)	63.0 (46.9)	1.4 (0.0)
Red-footed Booby (RF) (*Sula sula*)	10.9 (19.7)	89.1 (80.3)	0.0 (0.0)
Great Frigatebird (RF) (*Fregata minor*)	42.3 (50.4)	53.8 (49.6)	3.8 (0.0)
Red-tailed Tropicbird (RS) (*Phaethon rubricauda*)	23.8 (40.4)	76.2 (59.6)	0.0 (0.0)
Mean	41.1 (52.2)	57.4 (47.8)	1.5 (0.0)
Large Procellariiformes			
Sooty Shearwater (MS) (*Puffinus griseus*)	52.3 (78.8)	57.4 (20.9)	10.3 (0.3)
Christmas Shearwater (RF) (*Puffinus nativitatus*)	52.6 (63.3)	47.4 (36.7)	0.0 (0.0)
Wedge-tailed Shearwater (RF) (*Puffinus pacificus*)	39.1 (67.3)	60.5 (32.6)	0.4 (0.0)
Juan Fernandez Petrel (RF) (*Pterodroma externa*)	47.2 (54.3)	52.0 (45.7)	0.8 (0.0)
White-necked Petrel MF) (*Pterodroma cervicalis*)	66.7 (83.9)	30.3 (16.0)	3.0 (0.1)
Tahiti Petrel (RS) (*Pterodroma rostrata*)	39.1 (44.7)	57.6 (55.2)	3.3 (0.0)
Murphy's Petrel (MS) (*Pterodroma ultima*)	56.8 (57.7)	43.2 (42.3)	0.0 (0.0)
Kermadec Petrel (RF) (*Pterodroma neglecta*)	41.9 (47.7)	58.1 (52.3)	0.0 (0.0)
Phoenix Petrel (RF) (*Pterodroma alba*)	44.2 (33.3)	50.4 (66.6)	5.3 (0.0)
Herald/Henderson Petrel (RF) (*Pterodroma heraldica/atrata*)	72.7 (74.3)	21.2 (25.6)	6.1 (0.0)
Mean	51.3 (60.5)	47.8 (39.4)	2.9 (0.0)
Small procellariids			
White-winged Petrel (RS) (*Pterodroma leucoptera*)	72.6 (89.6)	19.6 (10.2)	7.8 (0.1)
Black-winged Petrel (RS) (*Pterodroma nigripennis*)	85.7 (92.9)	13.6 (7.1)	0.7 (0.0)
DeFillippe's Petrel (RS) (*Pterodroma defilippiana*)	74.8 (94.2)	4.9 (5.4)	20.3 (0.4)
Stejneger's Petrel (MS) (*Pterodroma longirostris*)	62.2 (95.4)	6.8 (3.6)	31.0 (0.1)
Bulwer's Petrel (RS) (*Bulweria bulwerii*)	47.6 (75.2)	25.8 (18.4)	26.6 (6.4)
Mean	68.6 (89.5)	14.1 (8.9)	17.3 (1.4)
Hydrobatids			
White-throated Storm-Petrel (RS) (*Nesofregetta fuliginosa*)	47.1 (87.8)	8.0 (9.9)	44.8 (2.3)
White-bellied Storm-Petrel (RS) (*Fregetta grallaria*)	53.6 (90.9)	26.8 (9.8)	19.6 (0.2)
White-faced Storm-Petrel (RS) (*Pelagodroma marina*)	22.9 (93.6)	0.0 (0.0)	77.1 (6.4)
Markham's Storm-Petrel (RS) (*Oceanodroma markhami*)	53.8 (86.4)	15.4 (7.5)	30.8 (6.1)
Wedge-rumped Storm-Petrel (RS) (*Oceanodroma tethys*)	83.4 (99.1)	3.4 (0.7)	13.2 (0.2)
Mean	52.8 (92.6)	9.9 (4.9)	37.2 (2.3)
Stercorariidae and *Laridae*			
Parasitic Jaeger (MF) (*Stercorarius parasiticus*)	12.2 (36.6)	16.3 (22.1)	71.4 (41.3)

TABLE 16. CONTINUED.

Species	Fishes	Cephalopods	Misc. invertebrates
Sooty Tern (RF) (*Onychoprion fuscata*)	58.1 (59.5)	41.4 (40.5)	0.5 (0.0)
Gray-backed Tern (RF) (*Onychoprion lunatus*)	42.0 (97.5)	2.0 (2.2)	56.0 (0.3)
White Tern (RF) (*Gygis alba*)	62.7 (86.6)	8.5 (13.2)	28.8 (0.2)
Mean	43.7 (70.1)	17.1 (19.5)	39.2 (8.4)

[a] Percentages are given for numbers of prey and prey mass (in parentheses); letters in parentheses are defined as: R = resident, M = migrant, F = flock feeder, S = solitary feeder. See Methods for classification of resident versus migrant seabird.

TABLE 17. AVERAGE PREY MASS IN GRAMS (MEAN ± SE) OBTAINED BY ETP SEABIRDS WHEN USING EACH OF FOUR FEEDING STRATEGIES DURING A GIVEN 24-HR PERIOD[a].

	Flock feeding	Nocturnal feeding	Solitary-diurnal feeding	Scavenging
Hydrobatids				
White-throated Storm-Petrel (*Nesofregetta fuliginosa*)	0.8 ± 0.2 (5)	11.1 ± 1.7 (69)	3.6 ± 1.0 (23)	0.5 ± 0.3 (3)
White-bellied Storm-Petrel (*Fregetta grallaria*)	0.1 ± 0.2 (2)	9.6 ± 1.2 (83)	1.0 ± 0.2 (9)	0.6 ± 0.3 (5)
White-faced Storm-Petrel (*Pelagodroma marina*)	0.1 ± 0.3 (1)	8.8 ± 1.4 (88)	1.1 ± 0.4 (11)	0.0 (0)
Leach's Storm-Petrel (*Oceanodroma leucorhoa*)	0.0 ± 0.0 (0)	9.4 ± 0.4 (92)	0.7 ± 0.1 (7)	0.1 ± 0.0 (1)
Wedge-rumped Storm-Petrel (*Oceanodroma tethys*)	0.1 ± 0.0 (0)	5.3 ± 0.3 (84)	1.0 ± 0.2 (16)	0.0 (0)
Markham's Storm-Petrel (*Oceanodroma markhami*)	0.0 (0)	8.0 ± 1.3 (63)	4.1 ± 1.8 (32)	0.7 ± 0.3 (5)
Mean	0.2 (1.8%)	8.7 (78.4%)	1.9 (17.1%)	0.3 (2.7%)
Solitary procellariids				
Sooty Shearwater (*Puffinus griseus*)	76.8 ± 21.3 (80)	11.8 ± 0.9 (12)	2.2 ± 0.2 (2)	5.5 ± 1.6 (6)
Tahiti Petrel (*Pterodroma rostrata*)	10.3 ± 1.2 (10)	55.3 ± 7.2 (54)	0.1 ± 0.0 (0)	36.4 ± 1.3 (36)
Murphy's Petrel (*Pterodroma ultima*)	9.4 ± 4.2 (20)	32.4 ± 8.4 (70)	0.0 (0)	4.2 ± 1.0 (9)
White-winged Petrel (*Pterodroma leucoptera*)	5.6 ± 0.9 (14)	31.8 ± 3.3 (78)	2.0 ± 0.5 (5)	1.2 ± 0.3 (3)
Black-winged Petrel (*Pterodroma nigripennis*)	1.2 ± 0.7 (3)	34.7 ± 1.9 (89)	1.4 ± 0.4 (3)	1.6 ± 0.3 (4)
DeFilippi's Petrel (*Pterodroma defilippiana*)	0.0 (0)	28.5 ± 4.9 (73)	8.6 ± 4.3 (22)	2.0 ± 1.7 (5)
Stejneger's Petrel (*Pterodroma longirostris*)	1.8 ± 0.9 (5)	30.6 ± 2.0 (85)	2.9 ± 0.8 (8)	0.7 ± 0.4 (2)
Bulwer's Petrel (*Bulweria bulwerii*)	2.6 ± 0.1 (11)	17.3 ± 1.7 (72)	2.2 ± 1.9 (9)	1.9 ± 0.5 (8)
Mean	13.5 (25.4%)	30.5 (57.3%)	2.5 (4.7%)	6.7 (12.6%)
Flocking procellariids				
Wedge-tailed Shearwater (*Puffinus pacificus*)	92.1 ± 12.6 (97)	1.9 ± 0.3 (2)	0.1 (0)	1.0 ± 0.9 (1)
Christmas Shearwater (*Puffinus nativitatus*)	75.0 ± 12.7 (95)	3.9 ± 2.5 (5)	0.0 (0)	0.0 (0)
Juan Fernandez Petrel (*Pterodroma externa*)	92.0 ± 12.5 (86)	9.6 ± 2.5 (9)	0.0 (0)	5.4 ± 0.9 (5)
White-necked Petrel (*Pterodroma cervicalis*)	40.0 ± 14.4 (76)	12.0 ± 2.1 (23)	0.5 (1)	0.0 (0)
Kermadec Petrel (*Pterodroma neglecta*)	75.4 ± 15.7 (82)	15.6 ± 4.6 (17)	0.9 (1)	0.0 (0)
Phoenix Petrel (*Pterodroma alba*)	51.5 ± 11.3 (71)	20.2 ± 1.2 (28)	0.7 ± 0.2 (1)	0.0 (0)

TABLE 17. CONTINUED.

	Flock feeding	Nocturnal feeding	Solitary-diurnal feeding	Scavenging
Herald/Henderson Petrel (*Pterodroma heraldica/atrata*)	10.5 ± 0.7 (15)	52.5 ± 16.3 (76)	2.1 ± 0.5 (3)	4.2 ± 1.5 (6)
Mean	62.4 (77.0%)	16.5 (20.4%)	0.6 (0.7%)	1.5 (1.9%)
Laridae				
Parasitic Jaeger (*Stercorarius parasiticus*)	8.3 ± 0.5 (18)	11.5 ± 3.5 (25)	17.9 ± 7.9 (39)	4.1 ± 0.8 (18)
Sooty Tern (*Onychoprion fuscata*)	44.7 ± 7.8 (97)	0.9 ± 0.3 (2)	0.5 ± 0.3 (1)	0.0 (0)
Gray-backed Tern (*Onychoprion lunatus*)	31.0 ± 9.8 (100)	0.0 (0)	0.2 ± 0.3 (0)	0.0 (0)
White Tern (*Gygis alba*)	22.6 ± 7.0 (94)	1.0 ± 0.6 (4)	0.4 ± 0.2 (2)	0.0 (0)
Mean	27.7 (93.6%)	1.0 (3.4%)	0.8 (2.72%)	0.1 (0.3%)
Pelecaniformes				
Red-tailed Tropicbird (*Phaethon rubricauda*)	186.0 ± 18.2 (100)	0.0 (0)	0.0 (0)	0.0 (0)
Red-footed Booby (*Sula sula*)	292.0 ± 30.5 (100)	0.0 (0)	0.0 (0)	0.0 (0)
Masked Booby (*Sula dactylatra*)	407.0 ± 41.0 (100)	0.0 (0)	1.0 (0)	0.0 (0)
Nazca Booby (*Sula granti*)	372.0 ± 27.8 (100)	0.0 (0)	0.5 (0)	0.0 (0)
Great Frigatebird (*Fregata minor*)	335.6 ± 36.2 (99)	3.1 ± 1.2 (1)	0.3 (0)	0.0 (0)
Mean	318.5 (99.7%)	0.6 (0.2%)	0.4 (0.1%)	0.0

[a] See Table 2 for sample sizes, i.e., total number of birds collected for a given species. Numbers in parentheses are percentages.

TABLE 18. ESTIMATE OF THE TOTAL PREY MASS CONSUMED BY ETP SEABIRDS USING EACH OF FOUR FEEDING STRATEGIES[a].

				Prey mass obtained			
	Proportion	Bird number (1,000s)	Bird mass (mt)	Over aquatic predators	At night	Diurnal NCI[b]	By scavenging
Resident flock feeders							
Red-footed Booby (*Sula sula*)	0.0017	54.2	63.4	10.1	0.0	0.0	0.0
Masked Booby (*Sula dactylatra*)	0.0030	95.6	156.1	38.9	0.0	0.1	0.0
Nazca Booby (*Sula granti*)	0.0004	12.7	18.1	4.7	0.0	0.0	0.0
Great Frigatebird (*Fregata minor*)	0.0011	35.0	47.4	11.7	0.1	0.0	0.0
Juan Fernandez Petrel (*Pterodroma externa*)	0.1178	3,753.1	1,602.6	345.3	36.0	0.0	20.3
Wedge-tailed Shearwater (*Puffinus pacificus*)	0.1195	3,807.3	1,450.6	350.7	7.2	0.4	3.8
Kermadec Petrel (*Pterodroma neglecta*)	0.0030	95.6	35.3	7.2	1.5	0.0	0.0
Christmas Shearwater (*Puffinus pacificus*)	0.0029	92.4	29.2	6.9	0.4	0.0	0.0
Phoenix Petrel (*Pterodroma alba*)	0.0028	89.2	25.6	4.6	1.8	0.1	0.0
Herald/Henderson Petrel (*Pterodroma heraldica/atrata*)	0.0018	57.3	16.0	0.6	3.0	0.1	0.2
Sooty Tern (*Onychoprion fuscata*)	0.2270	7,232.3	1,330.7	323.3	6.5	3.6	0.0
Gray-backed Tern (*Onychoprion lunatus*)	0.0002	6.4	0.8	0.2	0.0	0.0	0.0
White Tern (*Gygis alba*)	0.0110	350.5	34.0	0.9	0.4	0.1	0.0
Total	0.4922	15,681.6	4,810.6	1,112.1	56.9	4.4	24.3

Table 18. Continued.

	Proportion	Bird number (1,000s)	Bird mass (mt)	Prey mass obtained: Over aquatic predators	At night	Diurnal NCI[b]	By scavenging
Resident solitary feeders							
Red-tailed Tropicbird (*Phaethon rubricauda*)	0.0024	76.5	56.8	14.2	0.0	0.0	0.0
Tahiti Petrel (*Pterodroma rostrata*)	0.0146	465.2	192.1	4.8	25.7	0.0	16.9
White-winged Petrel (*Pterodroma leucoptera*)	0.0321	1,022.7	163.6	5.7	32.5	2.0	1.2
Black-winged Petrel (*Pterodroma nigripennis*)	0.0415	1,322.2	203.6	1.6	45.9	1.9	2.1
DeFilippi's Petrel (*Pterodroma defilippiana*)	0.0077	245.3	37.8	0.0	7.0	2.1	0.5
Bulwer's Petrel (*Bulweria bulwerii*)	0.0100	318.6	29.9	0.8	5.5	0.7	0.6
Leach's Storm-Petrel (*Oceanodroma leucorhoa*)	0.2474	7,882.2	323.2	0.0	74.1	5.5	0.8
Wedge-rumped Storm-Petrel (*Oceanodroma tethys*)	0.0653	2,080.5	52.0	0.1	11.0	2.1	0.0
Markham's Storm-Petrel (*Oceanodroma markhami*)	0.0227	723.2	36.9	0.0	5.8	3.0	0.5
White-throated Storm-Petrel (*Nesofregetta fuliginosa*)	0.0011	35.0	2.2	0.0	0.4	0.1	0.1
White-bellied Storm-Petrel (*Fregetta grallaria*)	0.0041	130.6	6.0	0.0	1.3	0.1	0.1
White-faced Storm-Petrel (*Pelagodroma marina*)	0.0094	299.5	12.0	0.0	2.6	0.3	0.0
Migratory opportunists							
Sooty Shearwater (*Puffins griseus*)	0.0265	844.3	651.0	64.8	10.0	1.9	4.6
White-necked Petrel (*Pterodroma cervicalis*)	0.0037	117.9	48.8	4.7	1.4	0.0	0.0
Murphy's Petrel (*Pterodroma ultima*)	0.0012	38.2	14.3	0.4	1.2	0.0	0.2
Stejneger's Petrel (*Pterodroma longirostris*)	0.0123	391.9	56.8	0.7	12.0	1.1	0.3
Parasitic Jaeger (*Stercorarius parasiticus*)	0.0056	178.4	65.5	1.5	2.1	3.2	0.7
Total	0.0493	1570.7	836.4	72.1	26.7	6.2	5.8
Total (all 3 groups)	0.9999	31,860.3	6,763.1	1,211.5	295.4	28.4	52.8

[a] Shown are the proportion of the ETP avifauna contributed by each seabird species, estimates of bird numbers, bird mass, and prey mass eaten (in metric tons [mt]).
[b] NCI = non-cephalopod invertebrates.
Notes: See Methods for details on calculation of prey mass consumed and Table 3 for species' mass.

The seabird species estimated to have taken the most prey mass while feeding nocturnally was the Leach's Storm-Petrel (74.1 mt/d; Table 18). Other species that took large amounts of prey while feeding nocturnally were, in decreasing amounts of prey taken, Black-winged Petrel (45.9 mt/d), White-winged Petrel (32.5 mt/d), Juan Fernandez Petrel (36.0 mt/d), Tahiti Petrel (25.7 mt/d), Stejneger's Petrel (12.0 mt/d), Wedge-rumped Storm-Petrel (11.0 mt/d), Sooty Shearwater (10.0 mt/d) and Sooty Tern (6.5 mt/d).

Species consuming the largest mass of prey while scavenging cephalopods were the Juan Fernandez (20.3 mt/d) and Tahiti petrels (16.9 mt/d; Table 18), as well as the Black-winged and White-winged petrels and Sooty Shearwater (1.2–4.6 mt/d). The species estimated to have taken by far the most prey mass while feeding diurnally on non-cephalopod invertebrates was the Leach's Storm-Petrel (5.5 mt/d), although the Sooty Tern (3.6 mt/d), Parasitic Jaeger (3.2 mt/d), Stejneger's Petrel (3.2 mt/d), and Markham's Storm-Petrel (3.0 mt/d) also took relatively large amounts of these prey.

DISCUSSION

Considering the reduced food availability in tropical oceans compared to those of higher

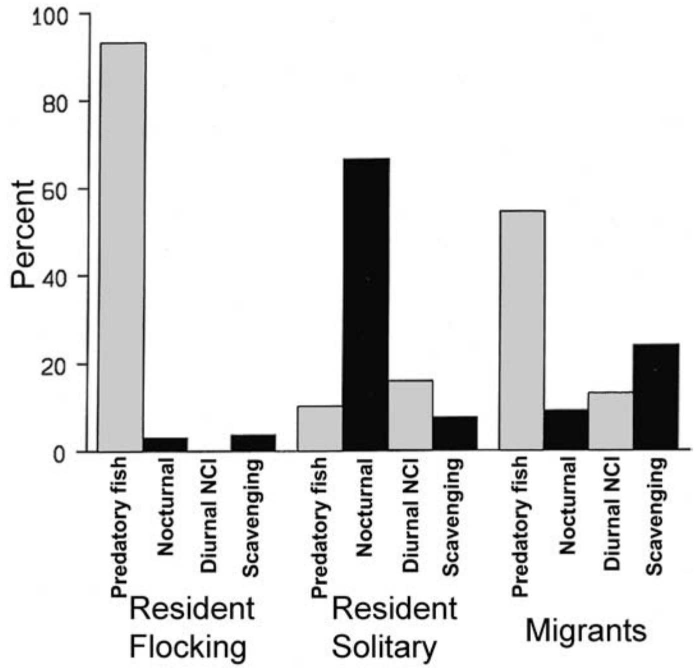

FIGURE 19. Proportion of prey mass obtained by each of three species groups when using four feeding strategies. Feeding over predatory fish is denoted by predatory fish; NCI = non-cephalopod invertebrates.

latitudes (Longhurst and Pauly 1987), it is noteworthy that the majority of seabirds occurring in the ETP breed in higher latitudes (Harrison 1983, Brooke 2004). Reduced prey availability and/or intense competition for resources during the nonbreeding period (Ainley et al. 1994) is indicated in that the majority of individuals, including three of the four most abundant species in the ETP (Leach's Storm-Petrel, Juan Fernandez Petrel, and Wedge-tailed Shearwater), fly considerable distances to the ETP in favor of remaining closer to their higher-latitude breeding areas. These species also have behavioral and morphological characteristics that make them well suited to feed in the ETP (Spear and Ainley 1998). Specifically, lower-latitude procellariids have larger wings, tails, and bills than their higher-latitude counterparts, enabling the former to make use of relatively light winds when foraging over wide ocean expanses to exploit sparse, highly mobile and/or volant prey.

A common finding among many multispecies studies has been that seabirds breeding at a given location have diets that share only a few major prey species, leading to extensive diet overlap (Ashmole and Ashmole 1967, Diamond 1983, Harrison et al. 1983, Furness and Barrett 1985, Schreiber and Hensley 1976, Ainley and Boekelheide 1990). Our findings with respect to the diets among an avifauna of seabirds, primarily nonbreeders, feeding in the pelagic ETP are in some ways consistent with but in others contrary to these patterns. In the following, we summarize our findings on diet diversity and diet overlap among species representing each of five groups of seabird taxa.

Seabird Diets

Pelecaniformes

The five species of this group exhibited the lowest diet diversity (H' = 0.5–1.8) as well as considerable diet overlap; prey mass consumed was almost equally divided among fishes (2–5 families for each pelecaniform species including primarily hemirhamphids, exocoetids, carangids, coryphaenids, and scombrids) and cephalopods (1–4 families for each pelecaniform, but almost exclusively the ommastrephid squid [*Sthenoteuthis oualaniensis*]). These findings are very similar to those of Harrison et al. (1983) for the Hawaiian populations of these species, and also the findings for birds breeding on Christmas Island (Ashmole and Ashmole 1967, Schreiber and Hensley 1976). Also consistent with the findings of Harrison et al. (1983), among the pelecaniforms studied during their as well as our study, the Masked Booby consumed a much greater proportion of fish (97% by mass) than the other pelecaniforms, for which fishes represented 20–53% of their diet mass.

Large Procellariiformes

Diet diversity (*H′*) among the 10 species of large procellariids (mass = 280–430 g) was moderate, ranging from 2.1 in Wedge-tailed and Christmas shearwaters to 2.9 and 3.1 in the Juan Fernandez and Tahiti petrels, respectively. Prey mass consumed was composed of 61% fishes (6–19 families among each large procellariid species), 39% cephalopods (2–12 families among each species), and 3% miscellaneous invertebrates. The predominance of fish in the diets of large ETP procellariids was consistent with the diets of large procellariids feeding in the Southern Ocean (Ainley et al. 1992). However, in the ETP, our results showing heavy use of fish among Murphy's, Phoenix, Herald, and Dark-rumped petrels differed appreciably from that observed at their primary breeding colonies on the Pitcairn and Galapagos islands, where they feed primarily on cephalopods (Imber et al. 1992, Imber 1995). Heavy use of cephalopods also was observed among the Sooty Shearwater and three large *Procellaria* breeding off New Zealand (Imber 1976, Cruz et al. 2001).

As noted by Imber (pers. comm.), studies, such as the above, of petrels' foods at colonies are adversely affected by the birds' behavior. Specifically, in nearly all colony studies of procellariids, biologists obtain food samples from chicks or adults arriving to feed them. Because adults come into the colonies only at night, and usually soon after dusk, any food in their stomachs has been subjected to digestion since the previous night, if eaten at night. This pattern matters less for cephalopods whose beaks are more resilient than fish otoliths, especially the smaller fish species such as myctophids. Thus, colony studies are undoubtedly biased against fish.

The PC analyses indicated high diet overlap among the large flocking procellariids and pelecaniforms that typically fed over predatory fishes. Large procellariids that fed solitarily also had a high degree of diet overlap due to their reliance primarily on vertically migrating myctophids, melamphaids, bregmacerotids, diretmids, and cephalopods. The flocking and solitary procellariid groups also differed in their choice of cephalopods; flock feeders ate primarily ommastrephids and solitary feeders ate mostly onychoteuthids, histioteuthids, mastigoteuthids, chiroteuthids, and cranchiids (findings similar to those of Imber and coworkers; references above). Little diet overlap occurred between large procellariids that feed over predatory fish vs. those that feed solitarily.

Small Procellariiformes

Diet diversity (*H′*) was high among the 11 species of small procellariiform species, including storm-petrels, *Bulweria* and small *Pterodroma* (mass 25–160 g), averaging 2.9 and ranging from 2.5 in the Markham's and White-faced storm-petrels to 3.5 in Leach's Storm-Petrel and White-winged Petrel. The PC analyses also indicated that diet overlap among these 11 species (all solitary feeders) was high. Prey mass was composed of 91% fishes (2–20 families each), 7% cephalopods (0–11 families each), and 2% noncephalopod invertebrates and exocoetid eggs (1–10 taxonomic groups each).

High diet diversity (*H′*) and extensive diet overlap in these species reflected their predominant foraging strategy, nocturnal feeding, in which they ate primarily fishes of the highly speciose family Myctophidae. These results are consistent with those of Imber (1996) for Cook's Petrel. The small Procellariiformes were also highly opportunistic, feeding both nocturnally and diurnally on a diverse array of non-cephalopod invertebrates, occasionally in multispecies flocks over predatory fishes, and scavenging on dead cephalopods (primarily families listed above as cephalopod prey of large solitary procellariids).

Laridae

Diet diversity (*H′*), for the four larids was low, averaging 1.8 and ranging from 1.4 in the Parasitic Jaeger and Gray-backed Tern to 2.1 and 2.2 in the White and Sooty terns, respectively. Prey mass consumed was composed of 70% fishes (3–9 families each), 20% cephalopods (1–4 families), and 8% noncephalopod invertebrates (1–3 taxonomic groups). PC analyses indicated high diet overlap between the Sooty Tern and other flock-feeding species, especially the pelecaniforms and large procellariids. Little diet overlap was found between the Parasitic Jaeger and Gray-backed and White terns, with other ETP species; only the diets of the Gray-backed Tern and Parasitic Jaeger were similar, due to extensive feeding by both on non-cephalopod invertebrates. Heavy use of these prey by Gray-backed Terns on the Hawaiian Islands was also noted by Harrison et al. (1983). Low diet diversity and little diet overlap among the larid species resulted from the fact that each tended to specialize in one or two feeding strategies that differed among them, resulting in the consumption of a distinct group of prey by each species.

Diet Partitioning

Diet partitioning within tropical seabird communities has been demonstrated at their breeding colonies, mainly as a function of prey size (Ashmole and Ashmole 1967). In pelagic waters of the ETP, seabirds also partitioned diet but accomplished this in several ways. First, the foraging strategy used provided access to a distinct group of prey species. The resident flock feeders (composing 71.1% of the biomass of the ETP avifauna) used this one strategy almost exclusively and caught 93% of their prey (by mass) while feeding over large aquatic fish (mainly tuna). Solitary residents (16.5% of the avian biomass) and migratory opportunists (12.4% of the avian biomass) acquired 74% and 69%, respectively, of their prey mass while using both nocturnal feeding and feeding over predatory fish.

Second, the four feeding strategies indirectly provided both temporal (i.e., feeding at night vs. day) and spatial partitioning. Partitioning occurred even among species using a single feeding strategy. For example, among bird species that fed in association with large predatory fishes, spatial partitioning was achieved through differential use of air space, i.e., flying at different elevations above the aquatic predators (Ainley 1977, Ballance and Pitman 1999). Flying height also may have affected the depth to which different species could plunge for prey. Spatial partitioning also occurred among the Red-tailed Tropicbird and boobies that often fed solitarily or in small monospecies groups, sometimes over large dolphinfish [*Coryphaena hippurus*], but usually where no predatory fish were observed (Spear and Ainley 2005; Spear and Ainley, pers. obs.). These Pelecaniformes ate many of the same prey (primarily exocoetids) as did the species that fed in multispecies groups over tuna.

Finally, partitioning by prey size occurred among species feeding over predatory fish and those feeding nocturnally, where larger predators ate larger prey (Ashmole and Ashmole 1967, Harrison et al. 1983). Prey-size partitioning also occurred between sexes of the same species (details below).

Diet Variation with Respect to Environmental Factors

Unlike the findings of Harrison et al. (1983), in which season was the primary factor affecting diet variation among species of seabirds breeding in the Hawaiian Islands, we found no evidence for a seasonal effect (comparing spring vs. autumn) among the 10 most abundant species of seabirds feeding in the pelagic waters of the ETP. However, we found a temporal effect for Stejneger's and Bulwer's petrels, both of which consumed more non-cephalopod invertebrates during El Niño compared to La Niña. The Stejneger's Petrel also consumed a higher proportion of myctophids during El Niño. These results were unexpected because productivity in the ETP within these lower trophic levels is higher during La Niña than El Niño (Fiedler 2002).

Spatial effects on diet variation were detectable in the more abundant species—Stejneger's Petrel, Leach's Storm-Petrel, and Sooty Tern. Such variation must have reflected prey availability. The diets of all three species differed between the eastern and western ETP. The two small petrels had a higher intake of invertebrates and lower intake of myctophids in eastern than western waters; the Sooty Tern had a higher intake of the photichthyid *Vinciguerria lucetia* and lower intake of hemirhamphids, exocoetids, and ommastrephids in the East compared to the West. The Stejneger's Petrel also had a higher intake of invertebrates and lower intake of myctophids in the NECC compared to the SEC. Regarding the tern, higher intake of *Vinciguerria lucetia* in the East is likely due to what appeared to be considerably greater abundance of that prey species there, as it was a major prey in the diets of many seabird species collected east of 130° W (Pitman and Ballance 1990). We can not offer any explanations for the other patterns.

Unexpected were our findings for sex-related differences in prey-size for seven species of procellariiforms—Wedge-rumped and Leach's storm-petrels; White-winged, Black-winged, Tahiti, and Juan Fernandez petrels; and the Wedge-tailed Shearwater. We are aware of only two other procellariiform species in which sex-related dietary differences have been observed: the Northern and Southern giant petrels (*Macronectes halli* and *M. giganteus*, respectively). In these species, males scavenged more penguin and seal carcasses compared to females (Hunter 1983). This author suggested that the difference was probably due to male giant petrels being larger than females, resulting in male dominance when competing for fixed food sources.

In our study, females of the two storm-petrels, as well as Black-winged, White-winged, and Tahiti petrels, ate larger prey than males. In contrast, male Juan Fernandez Petrels and Wedge-tailed Shearwaters ate larger prey than females. The sex-related differences among each of the seven species were not affected by differences in individual bird mass, and therefore, did not appear to be due to size-related competitive dominance, such as in the giant-petrels.

Reliance of ETP Seabirds on Large Predatory Fish

The importance of large predatory fish in making prey available to the ETP avifauna, as well as to cetaceans, is well known (Ashmole and Ashmole 1967, Au and Pitman 1986, Ballance and Pitman 1999), but has not previously been quantified. Indeed, the fact that an estimated 76% of the prey mass consumed by the ETP avifauna was made available by these apex predators (mainly tuna) underscores their importance to the trophodynamics of the ETP ecosystem (Cox et al. 2002, Olson and Watters 2003, Hinke et al. 2004). Moreover, Essington et al. (2002) have shown that the four primary methods of harvesting yellowfin tuna contrast greatly in age selectivity on tuna stocks and also, given current catch rates, in sustainability.

Although the prey of seabirds foraging over tunas was primarily hemirhamphids, exocoetids, carangids, coryphaenids, scombrids, gempylids, and epipelagic cephalopods, several of these families (hemirhamphids, exocoetids, and scombrids) have not been found in the diets of yellowfin tuna (Murphy and Shomura 1972, Bertrand et al. 2002). This was also noted by Ashmole and Ashmole (1967) who were surprised by the lack of correlation between the diets of tuna and that of flock-feeding seabirds. These authors suggested that exocoetids and some hemirhamphids, because of their abilities to leave the water, were more likely to escape fish predators than birds. They also suggested that the lower occurrence of scombrids in the diets of the tuna compared to the birds was not surprising because of the scombrids' ability to swim at high speed (Cairns et al., unpubl. data).

Nocturnal Feeding

An estimated 19% of the prey mass consumed by the ETP avifauna was obtained when feeding at night, making this the second most important feeding strategy. All procellariiform species fed nocturnally at least occasionally. Similar conclusions had been reached by Harrison et al. (1983) regarding small procellariiforms (Bonin Petrel [*Pterodroma hypoleuca*], Bulwer's Petrel, and Sooty Storm-Petrel [*Oceanodroma tristrami*]) breeding on the Hawaiian Islands, for Northern Fulmars (*Fulmarus glacialis*) breeding in Scotland (Furness and Todd 1984), and for many other species of procellariiforms (Imber 1976, 1981, 1995, 1996; Imber and Berruti 1981, Imber et al. 1992, Croxall and Prince 1980, Ainley et al. 1992, Catard and Weimerskirch 1999).

Indeed, in our study, nocturnal feeding was by far the most important feeding strategy of solitary feeders, especially the smaller procellariiform species; the following species are listed in order of increasing importance of nocturnal feeding: Bulwer's Petrel, DeFilippi's Petrel, Herald/Henderson Petrel, White-winged Petrel, White-bellied Storm-Petrel, Wedge-rumped Storm-Petrel, Stejneger's Petrel, White-faced Storm-Petrel, Black-winged Petrel, and Leach's Storm-Petrel. Among the larger species of procellariiforms, nocturnal feeding was used, in order of increasing importance, by Murphy's, Tahiti, Phoenix, White-necked and Kermadec petrels, and Sooty Shearwater (Imber 1981, 1995). Results of this study indicated that non-procellariiform species that occasionally fed nocturnally included the Sooty Tern, White Tern, Parasitic Jaeger, and Great Frigatebird. The inclusion of vertically migrating prey in the diet of the jaeger and frigatebird could represent kleptoparasitism on terns and small procellariids (Spear and Ainley 1993; pers obs.), although nocturnal feeding has been described previously among Sooty Terns (Morzer Bruyns and Voous 1965, Gould 1967).

Nocturnal feeding by seabirds is not surprising; it is well known that many species of smaller mesopelagic fishes (e.g., myctophids, melamphaids, bregmacerotids, and diretmids) and cephalopods ascend to shallow depths at night and descend again during the day (Marshall 1960, Maynard et al. 1975, Roper and Young 1975, Clarke 1978, Gjosaeter and Kawaguchi 1980, Watanabe et al. 1999). Because of this, nocturnal feeding has been inferred by the presence of myctophids and bioluminescent cephalopods in the diets of seabirds, but because of the lack of direct evidence as to when these prey were consumed, this idea has been questioned (Ballance and Pitman 1999). Thus, this is the first study to unequivocally validate nocturnal feeding as an important foraging method among members of a pelagic avifauna.

Specifically, our analyses of otolith condition, number of whole prey, and the hour of day when birds were collected clearly demonstrated that hydrobatids and procellariids (but rarely pelecaniforms, larids, and stercorarids), including both solitary- and flock-feeding species, ate large numbers of myctophids, melamphaids, bregmacerotids, diretmids, and crustaceans, generally caught between 2000 and 2400 H. Otoliths of these fishes were retained no longer than 24 hr, a retention period similar to that found among other species of seabirds when consuming (smaller) shoaling fishes (Uspenski 1956, Duffy and Laurenson 1983, Jackson and Ryan 1986). Furthermore, the occurrence of only a single individual representing these fishes within a sample of 131 seabirds (containing 702 prey) collected while feeding in direct association with surface-feeding yellowfin and skipjack tunas is additional evidence that few of these vertically migrating fishes were caught diurnally (i.e., tunas also are diurnal feeders; Buckley and Miller 1994, Roger 1994). Thus, although vertically migrating fishes are known to occur near the surface during the day on rare occasions (Alverson 1961), the rare occurrence of these fishes in the diets of avian species feeding diurnally is not surprising. This applies also to bird species that feed over large predatory fish, especially yellowfin tuna that feed mostly in the upper 100 m (Bertrand et al. 2002), well above waters where vertical migrating prey aggregate during the day (Kawaguchi et al. 1972).

An exception, however, are the myctophid-sized photichthyids (*Vinciguerria* spp.), which aggregate diurnally at depths from 200 m to the ocean surface (Pitman and Ballance 1990, Marchal and Lebourges 1996). The frequent occurrence of freshly caught *Vinciguerria lucetia* in ETP seabirds collected during the day in our study (Pitman and Ballance 1990) indicates regular diel movements of these fish to the ocean surface, although this could, in part, be related to foraging activities of tuna. This was indicated in another study of *Vinciguerria nimbaria* in the tropical Atlantic, where these fish were frequently eaten by tuna during the day (Marchal and Lebourges 1996).

The evidence from our study also indicates that most of the fish caught at night were caught alive. One indication of this was the pattern in their time of capture. If these fish were occurring at the surface as injured or dead individuals, we would not have expected the tight pattern in timing of capture, i.e., some of these prey would have been consumed during the day. Yet, we found only a single whole myctophid in one seabird collected after 0900 H.

The second line of evidence indicating that these prey were caught alive was their size-related selection by procellariiforms feeding nocturnally. If prey were occurring at the surface mostly as singles, after they had died or become incapacitated, we would not have expected the birds to have consistently had an opportunity to be discriminatory. We believe that prey-based size selection by birds feeding nocturnally indicates that the prey were arriving at the surface in schools, allowing the birds to be selective among groups of individuals. This idea is consistent with the findings of Auster et al. (1992) who observed very densely aggregated monospecific shoals of myctophids representing a very large biomass. Selection among seabirds foraging nocturnally is similar to that of diurnal flock feeders that also select prey by size when schools of the latter are chased to the surface by piscine predators.

The data indicating that many species of fishes including myctophids (particularly *Diaphus* and *Lampanyctus*), melamphaids, bregmacerotids, and diretmids are caught alive at or very near the ocean surface at night presents an enigma in that, with exception of diving-petrels (*Pelecanoides* spp.), procellariiform seabirds seldom pursuit-dive to a depth >10 m (Huin 1994, Prince et al. 1994, Chastel and Bried 1996, Bried 2005) although many of the prey fish and cephalopod species recorded in this study have not been caught at night <90 m from the surface during thousands of kilometers or hours of net tows (Appendix 1 and 33; Hartmann and Clarke 1975, Roper and Young 1975).

Occurrence of the mesopelagic and bathypelagic cephalopods at the ocean surface at night is explainable in that juveniles and subadults (i.e., of the size generally caught alive during this study) of some of these species are known to occur at or near the surface (Roper and Young 1975). However, we can imagine only two possible explanations for the infrequent surface records of the fishes summarized above. First, an idea that also applies to cephalopods, the net-tow methods may be flawed, e.g., due to net avoidance facilitated by factors such as pressure waves preceding towed nets; warning from vibrating lines attached to (and preceding) nets; vibrations/noises from the ship's engines preceding the nets; and/or the ship's lights that usually also precede net tows (Clarke 1966, Wormuth and Roper 1983). A second possibility is that prey that normally do not occur at the ocean surface occasionally stray there after becoming mixed with schools of species that migrate to the surface at night. This idea is consistent with the findings of Auster et al. (1992) who noted that when myctophids occurred in loose aggregations they formed multispecies groups without any affinity for a particular taxon. Upon arriving at the surface, some species possibly not well adapted for surface feeding, may be more vulnerable to predation than others. If this is true, the stragglers should be represented in the diets of seabirds in higher proportions than expected given the proportion represented by these species among fishes occurring at the surface at night.

On the other hand, the idea that myctophids, melamphaids, bregmacerotids, and diretmids being consumed at night by petrels may be represented by a predominance of stragglers is not well supported because it would be expected that scientific sampling methods would have succeed in netting them occasionally near the surface. Nevertheless, the avian consumption of an estimated 252 mt of these fish per night (i.e., after subtraction for the mass of crustaceans also caught at night) represents a consumption rate of 10.0 g (about two individual fish) of these fishes per square kilometer per night, or about 5,000,000 fish caught at or near the surface per night by birds over a surface area of ocean of about 25,000,000 km^2.

Scavenging

Although a large proportion of the diets of procellariids in most parts of the world includes offal scavenged from commercial fisheries (Jackson 1988, Catard et al. 2000), we found little evidence for this in the ETP. Yet, scavenging of dead cephalopods accounted for an estimated 2% of the prey mass consumed by ETP seabirds. Consistent with the findings of Imber and Berruti (1981) and Lipinski and Jackson (1989), this feeding strategy was most prevalent among the 17 procellariiform species, 81% of which scavenged at least occasionally. This behavior is likely to depend largely on these species' well-developed olfactory sense (Wenzel 1980).

Within the ETP avifauna, scavenging was most frequently used by the Tahiti Petrel, a resident that scavenged an estimated average of 36 g of cephalopods/individual petrel/day. Other species that were major scavengers were the Juan Fernandez Petrel and Herald/Henderson's petrels (4.4 g/bird/d), and migrating Sooty Shearwaters and Murphy's Petrels (each scavenging 4.2–5.5 g/bird/d); species of small *Pterodroma* also consistently scavenged cephalopods.

The morphological adaptations of the Tahiti Petrel for scavenging have been noted previously (Spear and Ainley 1997a, 1998). These birds possess wings having the highest aspect ratio among ETP seabirds, an adaptation similar to that of albatrosses (with the highest aspect ratios of all seabirds). The latter forage over wide ocean areas while using minimum amounts of energy, and feed often by scavenging large dead squid (Imber and Russ 1975, Clarke et al. 1981, Croxall and Prince 1994). Tahiti Petrels also have adaptations, unique among ETP seabirds, for consuming dead cephalopods too large to swallow whole—a very large, strongly hooked beak for pulling and ripping, and long legs with heavily clawed feet that are used to brace against the dead floating animal when the beak is pulling flesh in the opposite direction (L. Spear, pers. obs.). In fact, we believe that this species is the ecological counterpart of the larger albatrosses that are essentially absent from tropical waters because of the lack of winds strong enough to provide the mobility needed to forage over wide expanses (Spear and Ainley 1997a).

The only non-procellariiform species that frequently fed as a scavenger was the Parasitic Jaeger, although there was evidence that the Sooty Tern may have done so rarely.

Diurnal Feeding on Non-Cephalopod Invertebrates

Diurnal feeding on non-cephalopod invertebrates accounted for an estimated 3.3% of the prey mass consumed by ETP seabirds, making this the third most important feeding strategy. Resident species for which this strategy was especially important were the Markham's, Leach's and Wedge-rumped storm-petrels. Non-cephalopod invertebrates consumed by these seabirds were primarily scyphozoans (predominantly *Porpida* spp. and *Physalia* spp.), insects (*Halobates* spp.), and mollusks (primarily *Janthina* spp.).

The Sooty Shearwater, a migrant opportunist, consumed twice as much mass of non-cephalopod invertebrates compared to any of the other ETP avian species, although its diet consisted of only 12% by mass of these prey. The Parasitic Jaeger was an exception among the entire avifauna in that 39% of the mass of all prey it consumed was obtained through diurnal feeding on these invertebrates, primarily gooseneck barnacles (*Lepas* spp.).

Summary of Use of the Four Feeding Strategies

The resident flock feeders were the most consistent in their use of a single feeding strategy—association with feeding groups of large predatory fish. Large procellariids using this strategy supplemented their diets by scavenging dead cephalopods and feeding at night on fishes that migrate to the ocean surface. Although nocturnal feeding was by far the most important foraging strategy of the solitary residents, these species supplemented their diets by feeding during the day, using about equal proportions of each of the other three strategies—scavenging, feeding over large aquatic predators, and diurnal feeding on non-cephalopod invertebrates. Migrants were the most opportunistic of the three groups. Although they predominantly associated with large piscine predators, they also obtained appreciable amounts of prey by scavenging, diurnal feeding on non-cephalopods, and by feeding nocturnally (given in increasing order of importance).

Our estimate of the prey mass consumed per day by the ETP avifauna feeding within the study area is about 1,589 mt. Estimates for the mass of prey taken per day by each of the three species' groups was 1,198 mt for resident flock feeders, 280 mt for resident solitary feeders, and 111 mt for migrant opportunists. We are aware of only one other study that has estimated the prey mass consumption rate of an avifauna within an ocean system having well-defined boundaries (Briggs and Chu 1987). These authors estimated that the avifauna residing in the California Current off California (between 32.5° N and 42.0° N, and from the coast to 370 km offshore) consumed 500–600 mt/day within those waters (covering ca. 330,000 km^2). Assuming a value of 550 mt/day, this amounts to a consumption rate of 0.165 mt/100 km^2 per day), compared to 0.0064 mt/100 km^2 per day consumed by the ETP avifauna (1,590 mt/ 25,000,000 km^2 x 100), or a consumption rate about 25 times lower in the latter. This result is consistent with that expected when comparing an eastern boundary current, such as the California Current, with a tropical ocean, due to lower productivity in the latter. Bird densities in the California Current were also much higher, particularly in the upwelling zone over the shelf (11,000 birds/100 km^2; Briggs and Chu 1987) compared to the ETP study area (127.4 birds/100 km^2).

Flock versus Solitary Foraging

The 30 avian species separated into two feeding guilds, one that preyed primarily on exocoetids and hemirhamphids and epipelagic cephalopods during the day by feeding in flocks and the other that was solitary and fed nocturnally, primarily on myctophids. Only two exceptions to this were noted: the Phoenix and Herald petrels, two sibling species (Brooke and Rowe 1996) whose diets were composed of a large proportion of myctophids caught at night. Yet, these species often occurred in feeding flocks (flock indices of 16.7 and 21.6, putting them well into the flock-feeding category) where myctophids were seldom caught.

Species Abundance in Relation to Diet

The most abundant species in the ETP study area were, in increasing order: Wedge-rumped Storm-Petrel, Juan Fernandez Petrel, Wedge-tailed Shearwater, Sooty Tern, and Leach's Storm-Petrel. The predominant prey by mass for each of these species was fishes, contributing an average of 76% of the prey they consumed. Cephalopods composed an average of 35% of the prey mass consumed by the shearwater, petrel, and tern. These findings are similar to those of Harrison et al. (1983), in their study of the diets of breeding Hawaiian seabirds, although these authors concluded that the most abundant Hawaiian seabird species were those that ate cephalopods. Among the above species, the shearwater, petrel, and tern also consumed most of their prey biomass using the flock-feeding strategy, although each of them except the tern supplemented their diet considerably by nocturnal feeding (the strategy used most extensively by the two storm-petrels). With the exception of the two storm-petrels, the more abundant bird species rarely consumed non-cephalopod invertebrates and exocoetid eggs.

Comparison with a Polar Marine Avifauna

An extensive and analogous study to this one was conducted on the foraging dynamics of the open-ocean avifauna of the Scotia and Weddell seas during spring, autumn and winter 1983–1988 (Ainley et al. 1991, 1992, 1993, 1994; Rau et al. 1992, Hopkins et al. 1993). The Scotia-Weddell Confluence is considered to be a highly productive region. As in our ETP study, both breeding and non-breeding portions of the avifauna were sampled. Procellariids (12 species), spheniscids (three species), and larids and stercorarids (four species) made up the polar avifauna. Unlike the tropics, there was no apparent relationship between seabirds and foraging piscine predators, and all foraged solitarily although the avifauna was composed of two distinct assemblages demarcated by habitat: one associated with sea ice and the other with the adjacent open water. Most of the open-water component departed the region during winter, migrating to warmer latitudes (Ainley et al. 1994), and one replaced the other to feed in the same waters on the same prey depending on the daily to seasonal vagaries of ice movement (Ainley et al. 1993). There was some species overlap in the occurrence between the two habitats, but stomach fullness indicated better foraging success for each species when in its preferred habitat.

Similar to the results for the solitary foragers in the ETP study, myctophids, squid, and non-cephalopod invertebrates were by far the predominant prey of the polar avifauna, with a huge degree of overlap in prey species and prey size. This was true regardless of a 1,000-fold difference in predator size, much larger than in the ETP avifauna with only a 65-fold predator size difference. Diet diversity of the polar group was much lower than for ETP species, with the highest Shannon index value being 1.4 among the former, which is about the lowest for ETP species. Only two procellariid species fed predominantly during the day, and in their case by scavenging: Southern Giant Petrel and White-chinned Petrel (*Procellaria aequinoctialis*). The diving species, penguins (*Pygoscelis, Eudyptes,* and *Aptenodytes* spp.) and diving petrels (*Pelecanoides* spp.), fed during the day also, but were capable of deep diving. Otherwise, the majority of species fed at night, or in crepuscular periods in the case of larids and stercorarids, when myctophids and squid rose from meso-depths.

Even though crustaceans were abundant (i.e., krill [*Euphausia* spp.]), the polar birds preyed on the larger fish and squid, which were feeding on the crustaceans (Hopkins et al. 1993). The seabirds, thus, were maximizing their energy intake and minimizing their effort. Any prey selection was in proportion to availability which, in fact, was so high that avian predators were incredibly fat and stomachs were full (Spear and Ainley 1998).

The two studies demonstrate the great importance of the fish family Myctophidae to open-ocean seabirds, a fact that seems to be rarely appreciated. More importantly from an ecological perspective is the high degree of trophic partitioning evident within the tropical avifauna compared to that of the polar region. Unlike the tropics, in the polar avifauna no prey selection occurred by species or size among different predator species or between sexes. Like the tropics, however, a niche divergence was observed in the polar avifauna based on foraging behavior—scavenging, surface feeding, and diving. Unlike the tropics, differences in foraging behavior did not lead to the taking of different species of prey among polar seabirds.

The Importance of Tuna to Tropical Seabirds

The two studies also highlight the great importance of the tunas in tropical oceans (Ashmole and Ashmole 1967, Harrison et al. 1983, Longhurst and Pauly 1987). No such analogous fishes exist in polar regions (Eastman 1993). In fact, as one result of this importance, the niche of the pursuit diver among tropical seabirds is largely absent, at least in part owing to the high wing loading and high cost of flight needed by these birds (Ainley 1977); to keep pace with fast-moving fish, flight efficiency in the tropics is at a premium (Spear and Ainley 1998, Weimirskirch et al. 2004). Several other factors have been proposed to explain this as well (Cairns et al., unpubl. data): (1) the temperature-induced swimming performance of ectothermic animals (fishes) vs. that of endothermic animals—burst speed of thermally adapted fishes increases dramatically as temperature increases above 15 C—results in reduced prey capture success by pursuit diving seabirds in tropical waters; (2) swimming performance of ectothermic sharks also is optimum in tropical waters (Cairns et al., unpubl. data), posing a serious threat to endothermic pursuit divers; and (3) subsurface prey can be taken during the day owing to foraging tuna which force them to within reach of surface feeding birds (Ainley 1977). Thus, only the non-pursuit diving species of seabirds are successful when feeding in tropical oceans (Ainley 1977).

However, regarding the importance of tuna to the ETP avifauna, it is important to note that the tuna catch volume has seen a large increase by commercial fisheries in recent decades (Cox et al. 2002, Myers and Worm 2003, Hinke et al. 2004, Hampton et al. 2005, Maury and Lehodey 2005). Unfortunately, the predation by tuna and other top fish predators has been found to have profound cascading effects on food-web structure of tropical seas (Essington et al. 2002, Schindler et al. 2002). Clearly, risks to seabirds that exploit prey over tunas, should the populations of tuna be greatly reduced by commercial fishing or the density of available schools be reduced, indicates the need for monitoring of tuna stocks, school frequency, size, and density over various spatial scales. Not just catch volumes or catch per unit effort (CPUE) should be monitored, if not by fishery agencies then by wildlife agencies charged with managing seabird populations.

Although not included in the present analysis owing to low population size, but definitely occurring in the study area (Spear et al. 1995), two endangered seabird species, the Hawaiian Petrel (*Pterodroma sandwichensis*) and Newell's Shearwater (*Puffinus auricularis newelli*), are both members of the flocking-feeding group of the ETP. The recovery plans for these species dwell only on colony-related impacts to populations (USDI Fish and Wildlife Service 1983), but given the state of the depleted tuna fisheries and the importance of tuna to these seabirds, further investigation about the relationship between bird population trends and tuna availability is warranted. At the least, a changed food-web structure may require re-definition of how much future growth is possible in these seabird populations. Further monitoring of all ETP seabird populations is important in this regard.

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APPENDIX 1. PREY SPECIES BY NUMBER, MASS (GRAMS), AND PERCENT (BY NUMBER) IN THE DIETS OF 2,076 BIRDS OF 30 SPECIES SAMPLED IN THE ETP, 1983–1991.

	Number	Mass	Percent
Total	10,374	59,661.5	100.0
Fishes	5,885	49,283.6	56.7
Cephalopods	2,785	10,179.9	27.1
Miscellaneous invertebrates	1,704	198.0	16.2
Group 1. Photichthyids, gonostomatids, and sternoptychids	1,254	3,225.3	12.09
Photichthyidae	1,074	1,522.6	10.35
Vinciguerria lucetia	885	1,239.0	8.53
Vinciguerria spp.	138	212.2	1.33
Maurolicus muelleri	2	2.8	0.02
Ichthyococcus irregularis	49	68.6	0.47
Gonostomatidae	19	95.8	0.18
Diplophos taenia	12	59.4	0.12
unidentified Gonostomatidae	7	36.4	0.06
Sternoptychidae	161	1,606.9	1.55
Sternoptyx sp.	1	4.8	0.01
Sternoptyx obscura	83	1,109.9	0.80
Argyropelecus lychnus	36	198.1	0.35
Argyropelecus sp. cf. *A. lychnus*	6	46.2	0.06
Argyropelecus sp.	33	233.9	0.32
Polyipnus sp.	2	14.0	0.02
Group 2. Myctophids	2,371	18,422.3	22.86
Protomyctophum sp.	11	54.0	0.11
Electrona risso	41	223.4	0.40
Hygophum proximum	58	332.8	0.56
Hygophum reinhardti	48	261.9	0.46
Benthosema panamense	5	43.4	0.05
Benthosema suborbitale	1	6.6	0.01
Diogenichthys laternatus	258	3,753.8	2.49
Myctophum nitidulum	26	132.2	0.25
Myctophum lychnobium	8	38.0	0.08
Myctophum spinosum	3	15.0	0.03
Myctophum aurolaternatum	230	1,650.1	2.22
Myctophum sp.	33	187.6	0.32
Symbolophorus evermanni	136	831.5	1.31
Lampadena luminosa	9	44.7	0.09
Bolinichthys photothorax	8	43.7	0.08
Bolinichthys longipes	2	10.9	0.02
Ceratoscopelus warmingii	407	2,914.2	3.92
Lampanyctus nobilis	64	377.3	0.62
Lampanyctus parvicauda	40	252.5	0.39
Lampanyctus idostigma	2	9.4	0.02
Lampanyctus omostigma	2	11.5	0.02
Diaphus parri	178	1,376.6	1.72
Diaphus jenseni	41	220.0	0.40
Diaphus lutkeni	59	386.1	0.57
Diaphus garmani	9	86.5	0.09
Diaphus mollis	28	134.4	0.27
Diaphus lucidus	1	4.8	0.01
Diaphus spp.	77	530.1	0.74
Notoscopelus resplendens	18	114.8	0.18
Gonichthys tenuiculus	17	93.7	0.17
unidentified Myctophidae	492	3,918.9	4.74
Group 3. Bregmacerotids and diretmids			
Melamphaids	829	7,523.5	7.99
Bregmacerotidae	379	4,465.5	3.65
Bregmaceros bathymaster	315	3,987.8	3.04
Bregmaceros sp.	64	477.7	0.62
Diretmidae	169	1,208.9	1.63
Diretmus argenteus	139	1,001.6	1.34
Diretmus pauciradiatus	17	131.3	0.17

APPENDIX 1. CONTINUED.

	Number	Mass	Percent
Melamphaidae	281	1,844.5	2.71
Melamphaes longivelis	37	201.9	0.36
Melamphaes sp.	25	160.0	0.24
Scopeloberyx robusta	122	817.5	1.18
Poromitra sp.	2	9.7	0.02
unidentified Melamphaidae	95	655.4	0.92
Group 4. Hemirhamphids and exocoetids	851	17,625.0	8.20
Hemirhamphidae	273	5,705.0	2.63
Hemirhamphus sp.	6	62.5	0.05
Oxyporhamphus micropterus	254	5,425.0	2.45
unidentified Hemirhamphidae	13	217.5	0.13
Exocoetidae	578	11,920.0	5.57
Exocoetus spp.	358	7,682.5	3.45
Hirudichthys sp. cf. *H. speculiger*	9	232.5	0.09
Cypselurus sp. cf. *C. spilopterus*	2	42.5	0.02
Cypselurus sp. cf. *C. exilens*	2	50.0	0.02
Cypselurus sp. cf. *C. spilonotopterus*	1	20.0	0.01
Cypselurus spp.	17	390.0	0.17
Prognichthys sp.	3	90.0	0.03
unidentified Exocoetidae	186	3,412.5	1.79
Group 5. Carangids, coryphaenids, scombrids, gempylids, and nomeids	218	2,087.0	2.10
Carangidae	4	70.0	0.04
Naucrates ductor	4	70.0	0.04
Coryphaenidae	13	345.0	0.13
Coryphaena spp.	13	345.0	0.13
Scombridae	104	707.0	1.00
Auxis spp.	3	105.0	0.03
Euthynnus sp.	101	602.0	0.97
Gempylidae	62	583.0	0.60
Nesiarchus nasutus	7	63.0	0.07
Promethichthys prometheus	8	74.0	0.08
Gempylus serpens	36	388.0	0.35
unidentified Gempylidae	10	46.0	0.10
Nomeidae	35	382.0	0.34
Psenes anomala	1	5.0	0.01
Cubiceps carnatus	34	377.0	0.33
Group 6. Epipelagic cephalapods	1,947	8,569.5	18.77
Ommastrephidae	1,283	8,073.8	12.37
Sthenoteuthis oualaniensis	936	7,704.8	9.02
Hyaloteuthis pelagica	7	71.0	0.07
unidentified Ommastrephidae	340	298.0	3.28
Onychoteuthidae	519	180.0	5.00
Onychoteuthis banksii	519	180.0	5.00
Enoploteuthidae	53	58.4	0.51
Pterygioteuthis giardi	16	20.2	0.15
Abraliopsis affinis	12	28.6	0.12
Abraliopsis sp.	25	9.6	0.24
Cranchiidae	77	169.1	0.74
Cranchia scabra	14	34.5	0.13
Leachia dislocata	27	20.7	0.26
Liocranchia sp.	5	25.1	0.05
Liocranchia reinhardti	8	66.0	0.08
Helicocranchia sp.	23	22.8	0.22
Octopods			
Bolitaneidae	4	21.9	0.04
Japetella heathi	4	21.9	0.04
Tremoctopodidae	2	8.5	0.02
Tremoctopus violaceus	2	8.5	0.02
Ocythoidae	7	47.8	0.07
Ocythoe tuberculata	7	47.8	0.07

APPENDIX 1. CONTINUED.

	Number	Mass	Percent
Group 7. Mesopelagic-bathypelagic cephalopods	298	1,610.4	2.87
Ommastrephidae	6	36.8	0.06
Ornithoteuthis volatilus	6	36.8	0.06
Pholidoteuthidae	10	134.0	0.10
Pholidoteuthis boschmai	10	134.0	0.10
Enoploteuthidae	11	33.9	0.11
Ancistrocheirus lesueuri	11	33.9	0.11
Octopoteuthidae	27	98.0	0.26
Octopoteuthis deletron	4	52.5	0.04
Octopoteuthis sp.	23	45.5	0.22
Histioteuthidae	65	491.1	0.63
Histioteuthis spp.	24	36.0	0.23
Histioteuthis hoylei	26	228.0	0.25
Histioteuthis sp. B	7	120.0	0.07
Histioteuthis reversa	2	18.5	0.02
Histioteuthis corona	6	88.6	0.06
Bathyteuthidae	4	36.0	0.04
Bathyteuthis bacidifera	4	36.0	0.04
Mastigoteuthidae	27	48.0	0.26
Mastigoteuthis sp.	25	0.0	0.24
Idioteuthis sp.	2	0.0	0.02
Chiroteuthidae	42	192.5	0.40
Chiroteuthis calyx	8	0.0	0.08
Chiroteuthis sp. A (different from next species)	13	132.0	0.13
Chiroteuthis sp.	19	48.0	0.18
Valbyteuthis sp.	2	12.5	0.02
Cranchiidae	104	521.0	1.00
Liguriella sp.	12	0.0	0.12
Megalocranchia sp.	14	5.05	0.13
Taonius pavo	52	0.0	0.50
Taonius sp. A	1	0.0	0.01
Taonius pavo B	2	0.0	0.02
Galiteuthis pacifica	13	96.0	0.12
unidentified Cranchiidae	10	0.0	0.10
Octopods			
Alloposidae	2	19.2	0.02
Alloposus mollis	2	19.2	0.02
Argonautidae	2	10.0	0.02
Argonauta argo	2	10.0	0.02
Group 8. Misc. invertebrates and eggs	1,704	210.3	16.63
eggs[a]	14 (2,525)	64.1	0.13
Lepas sp.	72	13.0	0.69
Crustacea	323	34.3	3.16
Euphausiid (12–20 mm)	184	17.5	1.77
unidentified medium shrimp (21–30 mm)	31	2.9	0.29
unidentified large shrimp (31–50 mm)	8	0.8	0.08
Grammarid-hyperiid amphipod (4–7 mm)	45	5.1	0.43
Isopod (8 mm)	2	0.2	0.02
Cymothoid (*Nerocila* sp.)[b] (25–35 mm)	16	5.8	0.35
Portunid crab	1	0.1	0.01
unidentified crab megalops (3–5 mm)	5	0.6	0.05
Mysid sp.	1	0.2	0.02
unidentified crustacean	30	3.4	0.29
Scyphozoan	703	59.2	6.75
Porpida sp.	563	47.8	5.43
Vellella sp.	59	4.8	0.57
Physalia sp.	81	6.6	0.78
Gerrid insect	286	8.7	2.76
Halobates sp. (orange body)	9	0.3	0.09
Halobates sp. (black body)	38	1.1	0.37
Halobates sp.	239	7.3	2.30

APPENDIX 1. CONTINUED.

	Number	Mass	Percent
Pelagic nudibranch	13	1.0	0.13
Snail	136	14.2	1.31
Janthina sp. (5–12 mm)	113	10.8	1.09
Unidentified snail sp. (2–3 mm)	23	1.1	0.07
Pteropod	6	0.3	0.06
Pteropod sp.	6	0.3	0.06
Bryzoan	4	0.3	0.07
Unidentified mollusc	145	2.9	1.40
Group 9. Misc. fishes	295	400.5	2.84
Engraulidae	192	30.0	1.85
Engraulis ringens	186	29.1	1.79
Stolephorus apiensis	5	0.6	0.05
unidentified Engraulidae	1	0.3	0.01
Argentinidae	14	89.4	0.13
Microstoma microstoma	11	71.5	0.11
Nansenia sp.	3	17.9	0.03
Bathylagidae.	4	18.0	0.04
Bathylagus sp.	4	18.0	0.04
Alepocephalidae	1	5.5	0.01
unidentified Alepocephalidae (juv.)	1	5.5	0.01
Chauliodontidae	8	46.1	0.08
Chauliodus sloani	8	46.1	0.08
Synodontidae	2	10.8	0.02
Saurida sp.	2	10.8	0.02
Chloropthalmidae	2	9.6	0.02
Chloropthalmus sp.	2	9.6	0.02
Paralepididae	2	10.5	0.02
unidentified Paralepididae	2	10.5	0.02
Evermanellidae	1	7.5	0.01
Evermanella ahlstromi	1	7.5	0.01
Scomberosocidae	3	10.0	0.03
Scomberesox scombroides	3	10.0	0.03
Macrouridae	3	15.6	0.03
unidentified Macrouridae (juv.)	3	15.6	0.03
Moridae	7	41.9	0.07
unidentified Moridae (juv.)	7	41.9	0.07
Echeneididae	1	4.8	0.01
Remora sp.	1	4.8	0.01
Trachipteridae	3	13.9	0.03
Trachipterus sp.	3	13.9	0.03
Percichthyidae	14	66.5	0.13
Howella sp.	14	66.5	0.13
Trichiuridae	2	9.5	0.02
Trichiurus sp. cf. *T. nitens*	2	9.5	0.02
Holocentridae	1	4.6	0.01
Adioryx sp.	1	4.6	0.01
Tetradontidae	2	6.3	0.01
Lagocephalus sp.	2	6.3	0.01
Teleosts unidentifiable to family	100	0.0	0.96
Cephalopoda unidentifiable to family	147	0.0	1.42
Teuthoids unidentifiable to family	395	0.0	3.81
Octopods unidentifiable to family	1	0.0	0.01

Notes: Prey species are given by species group as used in the diet analyses; numbers preceding family names are group numbers also used when presenting each of the 30 seabird species' diets (Appendices 3–32). Cephalopods having mass = 0 were those that were unmeasured or unidentifiable. Most eggs were probably from exocoetids.

[a] The number 14 is number of egg bunches, where each individual bird contained no more than one bunch. Total number of eggs is given parentheses.

[b] Isopod ectoparasite caught incidentally; isopod attached to exocoetid host.

APPENDIX 2. REGRESSION EQUATIONS USED TO CALCULATE STANDARD LENGTHS (SL), DORSAL MANTLE LENGTHS (DML), AND MASS (W) OF 19 SPECIES OF FISHES AND 17 SPECIES OF CEPHALOPODS EATEN BY ETP SEABIRDS.

Prey species	Regression equation	Mean ± SD	Range	N	Adjusted r^2	Source
Fishes						
Photichthyidae						
Vinciguerria lucetia	SL = 6.22 + 21.05ot	37.4 ± 7.2	25–52	35	0.81	this study
Myctophidae						
Symbolophorus evermanni	SL = 8.78 + 13.70ot	NA	NA	33	0.80	Ohizumi et al. (2001)
	$W = 1.32 - 0.101SL + 0.0022SL^2$	37.4 ± 7.2	20.4–82.0	608	0.97	RLP[a], SWFSC (unpubl. data)
Myctophum nitidilum	SL = 4.86 + 19.42ot	?	?	?	?	J. Caretta, SWFSC (unpubl. data)
	$W = 1.34 - 0.107SL + 0.0024SL^2$	?	17.6–78.8	568	0.97	RLP, SWFSC (unpubl. data)
Myctophum spinosum	SL = 2.19 + 19.00ot	NA	NA	8	0.98	Ohizumi et al. (2001)
	$W_{log10} = -1.00 + 3.67ot_{log10}$	NA	NA	8	0.97	
Myctophum aurolaturnam	SL = –12.94 + 25.95ot	36.0 ± 23.1	25-65	7	0.89	this study
	$W = 3.41 - 0.180SL + 0.0031SL^2$	?	18.3-110.1	328	0.99	RLP, SWFSC (unpubl. data)
Lampadena luminosa	SL = -19.31 + 16.51ot	NA	NA	7	0.97	Ohizumi et al. (2001)
	$W_{log10} = -2.67 + 4.53\ ot_{log10}$	NA	NA	7	0.94	
Lampanyctus nobilis	SL = –29.40 + 35.95ot	92.8 ± 38.7	47-140	6	0.61	this study
Bolinichthys longipes	SL = -9.29 + 23.25ot	NA	NA	7	0.91	Ohizumi et al. (2001)
	$W_{log10} = -0.81 + 2.26ot_{log10}$	NA	NA	7	0.77	
Ceratoscopelus warmingii	SL = 4.60 + 17.4ot	NA	NA	23	0.97	Ohizumi et al. (2001)
	$W_{log10} = -1.01 + 2.97ot_{log10}$	NA	NA	23	0.94	
Diaphus garmani	SL = 4.21 + 11.73 ot	NA	NA	9	0.74	Ohizumi et al. (2001)
	$W_{log10} = -1.51 + 3.13\ ot_{log10}$	NA	NA	9	0.87	
Diaphus mollis	lnSL = 3.00 + 0.79 *ln*ot	NA	NA	22	0.96	Smale et al. (1995)
Electrona risso	lnSL = 2.48 + 1.15 *ln*ot	NA	NA	13	0.94	Smale et al. (1995)
	lnW = -3.78 + 3.93 *ln*ot	NA	NA	9	0.98	
Hygophum proximum	SL = -0.75 + 21.29ot	NA	NA	18	0.89	Ohizumi et al. (2001)
	$W_{log10} = -0.69 + 1.37\ ot_{log10}$	NA	NA	18	0.90	

APPENDIX 2. CONTINUED.

Prey species	Regression equation	Mean ± SD	Range	N	Adjusted r^2	Source
Diretmidae						
Diretmus argenteus	$\ln SL = 2.02 + 1.19 \ln ot$	NA	NA	18	0.99	Smale et al. (1995)
	$\ln W = -3.11 + 3.20 \ln ot$	NA	NA	17	0.99	
Hemirhamphidae						
Oxyporhamphus micropterus	$SL = 11.13 + 22.97ot$	121.8 ± 27.7	65-194	47	0.81	this study
	$W = 25.32 - 19.14ot + 3.13ot^2$	21.4 ± 12.7	4.2-68.4	22	0.88	
Exocoetidae						
Exocoetus spp.	$SL = 11.77 + 20.73ot$	88.9 ± 51.3	24–180	60	0.94	this study
	$W = 6.63 - 5.16ot + 1.52ot^2$	27.5 ± 20.9	1.7–65.0	23	0.92	
Scombridae						
Euthynnus sp.	$SL = 15.28 + 39.40ot - 5.65ot^2$	53.5 ± 9.7	38-85	24	0.94	this study
Gempylidae						
Gempylus serpens	$SL = -8.99 + 110.91ot$	113.1 ± 39.1	90–190	11	0.92	this study
Cephalopods						
Ommastrephidae						
Sthenoteuthis oualaniensis	$DML = 20.18 + 37.27r$	70.8 ± 13.9	45–118	120	0.87	this study
	$W = 1.81 - 5.81r + 9.28r^2$	11.7 ± 7.4	3.5–34	64	0.82	this study
	$DML = 6.98 + 39.25r$	NA	NA	NA	0.93	Wolff (1982)
Dosidicus gigas	$DML = 44.20 + 35.79r$	NA	NA	NA	0.84	Wolff (1982)
	$\ln W = 7.4 + 2.48 \ln r$	NA	NA	NA	0.91	
Hyaloteuthis pelagica	$DML = 17.81 + 28.55r$	NA	NA	NA	0.86	Wolff (1984)
	$\ln W = 5.87 + 2.12 \ln r$	NA	NA	NA	0.84	
Onycoteuthidae						
Onychoteuthis banksii	$DML = -28.90 + 60.01r$	NA	NA	NA	0.95	Wolff (1982)
	$\ln W = 9.1 + 3.70 \ln r$	NA	NA	NA	0.89	
Pholidoteuthidae						
Pholidoteuthis bochmai	$DML = 11.3 + 41.09r$	NA	NA	NA	NA	Clarke (1986)
	$\ln W = 0.976 + 2.83 \ln r$	NA	NA	NA	NA	
Enoploteutyhidae						
Abrailiopsis affinis	$DML = 9.80 + 19.28r$	NA	NA	NA	0.88	Wolff (1982)
	$\ln W = 5.5 + 2.1 \ln r$	NA	NA	NA	0.81	
Pterygioteuthis giardi	$DML = 6.20 + 33.16r$	NA	NA	NA	0.41	Wolff (1982)
	$\ln W = 7.6 + 2.6 \ln r$	NA	NA	NA	0.70	
Octopoteuthidae						
Octopoteuthis sp.	$DML = -0.4- + 17.33r$	NA	NA	NA	NA	Clarke (1986)
	$\ln W = 0.166 + 2.31 \ln r$	NA	NA	NA	NA	
Histioteuthidae						
Histioteuthis hoylei	$DML = 7.69 + 14.55r$	NA	NA	NA	0.97	Wolff (1984)
	$\ln W = 6.96 + 2.44 \ln r$	NA	NA	NA	0.98	

APPENDIX 2. CONTINUED.

Prey species	Regression equation	Mean ± SD	Range	N	Adjusted r^2	Source
Bathyteuthidae						
Bathyteuthis sp.	DML = 1.68 + 51.59r	NA	NA	17	0.56	Clarke (1986)
	lnW = 2.855 + 3.38*ln*r	NA	NA	17	0.68	
Mastigoteuthidae						
Mastigoteuthis sp.	DML = -1.80 + 29.08r	NA	NA	47	0.91	Clarke (1986)
	lnW = 0.184 + 2.88*ln*r	NA	NA	45	0.94	
Chiroteuthidae						
Chiroteuthis sp.	DML = 11.4 + 24.46r	NA	NA	23	NA	Clarke (1986)
	lnW = -0.241 + 2.70*ln*r	NA	NA	14	NA	
Cranchiidae						
Cranchia scabra	DML = 17.7 + 28.03r	NA	NA	22	NA	Clarke (1986)
	LnW = 1.623 + 1.70*ln*r	NA	NA	23	NA	
Leachia dislocata	DML = 18.22 + 67.94r	NA	NA	10	NA	Wolff (1982)
	lnW = 0.627 + 2.39*ln*r	NA	NA	10	NA	
Liocranchia reinhardti	DML = –1.90 + 80.22rl	NA	NA	NA	0.89	Wolff (1982)
	lnW = 6.7 + 2.11*ln*r	NA	NA	NA	0.80	
Megalocranchia sp.	lnW = -0.108 + 2.73*ln*r	NA	NA	20	NA	Clarke (1986)
Taonius pavo	DML = 45.29 + 40.53r	NA	NA	158	0.94	Walker et al. (2002)

Notes: Calculations made from measured otoliths lengths (OT) and lower rostral length (R; see Methods for details); r^2 = adjusted correlation coefficient. All lengths in millimeters; mass in grams.
[a] RLP = Robert L. Pitman.

Appendices 3–32. Number and occurrence frequency of prey species in the diets of the 30 most abundant ETP seabird species

Notes: These appendices are presented in the following order: Hydrobatids and *Bulweria*, Appendices 3–9; *Pterodroma*, Appendices 10–20; *Puffinus*, Appendices 21–23; Larids, Appendices 24–27; Pelecaniformes, Appendices 28–32. Numbers of prey (N) reported for fishes and cephalopods do not include prey not identified to family level. Counts of eggs refer to number of stomachs containing eggs, not total number of eggs (those values given using subscripts). In these appendices, and throughout this monograph, a prey identifiable only to genus was designated as genus spp.; a prey identified to genus, but which had a distinctive otolith or beak, was designated as genus sp.; and prey identified to genus, but having a distinctive otolith or beak that had been described in a previous study was designated as genus sp. A (the living animal possessing this otolith or beak has yet to be caught).

APPENDIX 3. DIET OF BULWER'S PETREL (*BULWERIA BULWERII*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	53	44.9	355.2	22	51.2
Cephalopods	26	22.9	87.0	18	41.9
Misc. invertebrates/eggs	38	32.2	30.4	16	37.2
Gonostomatidae	1	0.9	4.6	1	2.3
Diplophos taenia	1	–	4.6	–	–
Sternoptychidae	7	6.0	36.2	5	11.6
Sternoptyx diaphana	2	1.7	8.9	1	2.3
Argyropelecus sladeni	2	1.7	9.2	2	4.7
Argyropelecus sp.	3	2.6	18.1	2	4.7
Photichthyidae	7	6.0	9.8	3	7.0
Viniguerria lucetia	5	4.3	7.0	2	4.7
Vinciguerria sp.	2	1.7	2.8	1	2.3
Myctophidae	32	27.3	272.6	15	34.9
Hygophum sp.	1	0.9	4.6	1	2.3
Diogenichthys laternatus	1	0.9	8.5	1	2.3
Myctophum cf. M. lychnobium	1	0.9	4.8	1	2.3
Symbolophorus evermanni	3	2.6	22.0	3	7.0
Ceratoscopelus warmingii	11	9.4	117.8	5	11.6
Diaphus parri	2	1.7	23.9	1	2.3
Diaphus jenseni	2	1.7	18.3	1	2.3
Diaphus lutkeni	2	1.7	18.3	1	2.3
Diaphus schmidti	3	2.6	16.1	3	7.0
Gonichthys tenuiculus	2	1.7	8.4	2	4.7
unident. Myctophidae	4	3.4	29.9	3	7.0
Bregmacerotidae	3	2.6	14.4	2	4.7
Bregmaceros bathymaster	3	–	14.4	–	–
Melamphaidae	2	1.7	12.6	2	4.7
Melamphaes longivelis	1	0.9	6.6	1	2.3
Scopeloberyx sp.	1	0.9	6.0	1	2.3
Nomeidae	1	0.9	5.0	1	2.3
Cubiceps carnatus	1	–	5.0	–	–
Unidentified teleosts	1	0.0	0.0	1	2.3
Ommastrephidae	8	6.8	45.0	5	11.6
Sthenoteuthis oualaniensis	6	5.1	45.0	3	7.0
Unidentified Ommastrephidae	2	1.7	0.0	2	4.7
Histioteuthidae	4	3.4	0.0	3	7.0
Histioteuthis sp.	2	1.7	0.0	2	4.7
Histioteuthis sp. cf. *H. hoylei*	2	1.7	0.0	1	2.3
Mastigoteuthidae	3	2.6	12.0	3	7.0
Mastigoteuthis sp.	3	–	12.0	–	–
Chiroteuthidae	3	2.6	18.0	1	2.3
Chiroteuthis calyx	1	0.9	6.0	–	–
Chiroteuthis sp. A	2	1.7	12.0	–	–
Cranchiidae	8	6.8	12.0	7	16.3
Cranchia scabra	2	1.7	6.0	1	2.3
Leachia dislocata	1	0.9	6.0	1	2.3
Helicocranchia sp.	4	3.4	0.0	4	9.3
Galiteuthis pacifica	1	0.9	0.0	1	2.3
Unidentifified Cephalopoda	5	0.0	0.0	5	11.6
Unidentifified Teuthoidea	1	0.0	0.0	1	2.3
Crustacea	13	11.1	1.0	1	2.3
Euphausiid	3	2.6	0.3	–	–
Gammarid/hyperiid amphipod	10	8.5	0.7	–	–
Scyphozoan	2	1.7	0.16	2	4.7
Porpida sp.	2	–	0.16	–	–
Gerrid insect	18	15.4	0.54	8	18.6
Halobates (black body)	1	0.9	0.03	1	2.3
Halobates sp.	17	14.5	0.51	7	16.3
[a]eggs	5	4.3	28.7	5	11.6

Note: Sample size of petrels, N = 43, with prey 34; prey sample, N = 117.
[a]Five egg bunches consisted of approximately 400, 400, 75, 50, and 30 eggs.

Appendix 4. Diet of White-faced Storm-Petrel (*Pelagodroma marina*).

	Number of prey	%	Mass (g)	Prey occurrence	
				Frequency	%
Fishes	70	21.9	412.6	15	100.0
Cephalopods	0	0.0	0.0	0	0.0
Misc. invertebrates/eggs	249	78.1	28.1	15	100.0
Sternoptychidae	1	0.3	6.0	1	6.7
Argyropelecus sp.	1	–	6.0	–	–
Photichthyidae	14	4.4	19.6	7	46.7
Viniguerria lucetia	5	1.6	7.0	3	20.0
Vinciguerria sp.	8	2.5	11.2	3	20.0
Ichthyococcus sp.	1	0.3	1.4	1	6.7
Myctophidae	44	13.8	325.1	15	100.0
Hygophum cf. *H. proximum*	1	0.3	6.0	1	6.7
Hygophum sp.	2	0.6	9.7	2	13.3
Benthosema suborbitale	1	0.3	6.6	1	6.7
Diogenichthys laternatus	6	1.9	30.7	4	26.7
Myctophum aurolaternatum	3	0.9	18.9	1	6.7
Symbolophorus evermanni	4	1.3	21.1	4	26.7
Ceratoscopelus warmingii	9	2.8	88.7	6	40.0
Diaphus parri	8	2.5	78.2	5	33.3
Diaphus lutkeni	1	0.3	4.9	1	6.7
Diaphus schmidti	4	1.3	32.8	3	20.0
Diaphus sp.	1	0.3	4.9	1	6.7
Gonichthys tenuiculus	1	0.3	5.5	1	6.7
Unidentified Myctophidae	3	0.9	17.1	3	20.0
Bregmacerotidae	3	0.9	16.3	3	20.0
Bregmaceros bathymaster	3	–	16.3	–	–
Diretmidae	3	0.9	20.4	3	20.0
Diretmus argenteus	3	–	20.4	–	–
Melamphaidae	4	1.3	20.2	3	20.0
Scopeloberyx sp.	1	0.3	4.2	1	6.7
Unidentified Melamphaidae	3	0.9	16.0	3	20.0
Gempylidae	1	0.3	5.0	1	6.7
Nesiarchus nasutus	1	–	5.0	–	–
Unidentified teleosts	4	0.0	0.0	1	6.7
Lepas barnacle	13	4.1	0.65	3	20.0
Lepas sp.	13	–	0.65	–	–
Crustacea	30	9.4	15.17	8	53.3
Euphausiid	2	0.6	0.16	1	6.7
Gammarid/hyperiid amphipod	24	7.5	2.25	4	26.7
Crab megalops	2	0.6	0.24	2	13.3
unidentified crustacean	2	0.6	2.89	2	13.3
Scyphozoan	3	0.9	0.3	1	6.7
Porpida sp.	3	–	0.3	–	–
Gerrid insect	104	32.6	3.12	14	93.3
Halobates (orange body)	7	2.2	0.21	1	6.7
Halobates (black body)	10	3.1	0.30	1	6.7
Halobates sp.	87	27.3	2.61	13	86.7
Snail	98	30.7	8.82	9	60.0
Janthina	93	29.1	8.37	9	60.0
Small snail	5	1.6	0.45	2	13.3
Pteropod	1	0.3	0.04	1	6.7
Pteropod sp.	1	0.3	0.04	–	–

Note: Sample size of storm-petrels, N = 15, all with prey; prey sample, N = 319.

APPENDIX 5. DIET OF WHITE-THROATED STORM-PETREL (*NESOFREGETTA FULIGINOSA*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	41	42.8	124.7	15	68.2
Cephalopods	5	5.9	14.1	6	27.3
Misc. invertebrates/eggs	39	45.9	3.2	12	54.5
Photichthyidae	21	24.7	29.4	2	9.1
Viniguerria lucetia	20	23.5	28.0	2	9.1
Ichthyococcus sp.	1	1.2	1.4	1	4.5
Myctophidae	15	17.6	71.4	11	50.0
Electrona risso	3	3.5	13.1	3	13.6
Myctophum aurolaternatum	1	1.2	4.6	1	4.5
Symbolophorus evermanni	4	4.7	19.1	4	18.2
Lampadena luminosa	1	1.2	4.8	1	4.5
Ceratoscopelus warmingii	1	1.2	4.9	1	4.5
Diaphus parri	2	2.4	11.1	2	9.1
Diaphus sp.	1	1.2	4.8	1	4.5
Unidentified Myctophidae	2	2.4	9.0	2	9.1
Diretmidae	3	3.5	14.5	2	9.1
Diretmus argenteus	2	2.4	9.6	1	4.5
Diretmus pauciradiatus	1	1.2	4.9	1	4.5
Melamphaidae	2	2.4	9.4	2	9.1
Scopeloberyx robusta	1	1.2	4.6	1	4.5
Scopeloberyx sp.	1	1.2	4.8	1	4.5
Ommastrephidae	3	3.5	6.6	2	9.1
Sthenoteuthis oualaniensis	1	1.2	6.6	1	4.5
Unidentified Ommastrephidae	2	2.4	0.0	1	4.5
Cranchiidae	2	2.4	7.5	2	9.1
Helicocranchia sp.	2	–	7.5	–	–
Unidentified Cephalopoda	2	0.0	0.0	2	9.1
Crustacea	16	18.8	1.6	5	22.7
Euphausiid	15	17.6	1.5	4	19.2
Small isopod	1	1.2	0.1	1	4.5
Scyphozoan	19	22.4	1.40	8	36.4
Porpida sp.	3	3.5	0.12	2	9.1
Velella sp.	5	5.9	0.4	2	9.1
Physalia sp.	11	12.9	0.88	8	36.4
Gerrid insect	2	2.4	0.06	1	4.5
Halobates sp.	2	–	0.06	–	–
Nudibranch	1	1.2	0.05	1	4.5
Pelagic nudibranch sp.	1	–	0.05	–	–
Snail	1	1.2	0.12	1	4.5
Small snail	1	–	0.12	–	–

Note: Sample size of storm-petrels, N = 15, all with prey; prey sample, N = 319.

APPENDIX 6. DIET OF WHITE-BELLIED STORM-PETREL (*FREGETTA GRALLARIA*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	29	53.7	146.5	19	86.4
Cephalopods	14	25.9	14.3	8	36.4
Misc. invertebrates/eggs	11	12.4	0.33	5	22.7
Photichthyidae	10	18.5	14.0	8	36.4
Viniguerria lucetia	4	7.4	5.6	3	13.6
Vinciguerria sp.	6	11.1	8.4	5	22.7
Myctophidae	13	24.1	86.8	9	40.9
Hygophum sp.	1	1.9	6.6	1	4.5
Diogenichthys laternatus	1	1.9	4.6	1	4.5
Myctophum sp. cf. *M. nitidulum*	1	1.9	8.5	1	4.5
Myctophum aurolaternatum	2	3.7	9.6	1	4.5
Ceratoscopelus warmingii	5	9.3	35.1	4	18.2
Diaphus parri	1	1.9	8.5	1	4.5
Unidentified Myctophidae	2	3.7	14.1	2	9.0
Bregmacerotidae	3	5.6	21.2	3	13.6
Bregmaceros bathymaster	3	–	21.2	–	–
Melamphaidae	2	3.7	17.0	2	9.0
Unidentified Melamphaidae	2	–	17.0	–	–
Percichthyidae	1	1.9	7.5	1	4.5
Howella sp. cf. *H. brodei*	1	–	7.5	–	–
Unidentified teleosts	1	0.0	0.0	1	4.5
Ommastrephidae	2	3.7	5.0	2	2.7
Unidentified Ommastrephidae	2	–	5.0	–	–
Onychoteuthidae	1	1.9	0.0	1	4.5
Onychoteuthis banksii	1	–	0.0	–	–
Histioteuthidae	1	1.9	4.5	1	4.5
Histioteuthis corona	1	–	4.5	–	–
Mastigoteuthidae	1	1.9	0.0	1	4.5
Mastigoteuthis sp.	1	–	0.0	–	–
Cranchiidae	9	16.7	4.8	5	22.7
Leachia dislocata	3	5.6	0.0	2	9.0
Helicocranchia sp.	1	1.9	4.8	1	4.5
Liguriella sp.	1	1.9	0.0	1	4.5
Megalocranchia sp.	3	5.6	0.0	1	4.5
Unidentified Cranchiidae	1	1.9	0.0	1	4.5
Unidentified teuthoids	1	0.0	0.0	1	4.5
Gerrid insect	11	20.4	0.33	5	22.7
Halobates sp.	11	–	0.33	–	–

Note: Sample size of storm-petrels, N = 22; with prey 20; prey sample, N = 54.

APPENDIX 7. DIET OF LEACH'S STORM-PETREL (*OCEANODROMA LEUCORHOA*).

	Number of Prey	%	Otolith or beak/ body length mean ± SD (N)	Occurrence frequency %	Mass (g)
Fishes	1,219	56.9		335 (66.6)	7,276.0
Cephalopods	84	3.9		109 (21.7)	92.6
Invertebrates/eggs	838	39.1		186 (37.0)	74.3
Engraulidae	3	0.1		1 (0.2)	10.0
Engraulis ringens	3	–		–	10.0
Argentinidae	2	0.1		2 (0.4)	12.3
Microstoma microstoma	2	–		–	12.3
Bathylagidae.	1	<0.1		1 (0.2)	4.2
Bathylagus sp.	1	–		–	4.2
Alepocephalidae	1	<0.1		1 (0.2)	5.5
Unidentified Alepocephalidae	1	–		–	5.5
Gonostomatidae	9	0.4		7 (1.4)	50.0
Diplophos taenia	6	0.3		6 (1.2)	28.0
Unidentified Gonostomatidae	3	0.1		2 (0.4)	22.2
Sternoptychidae	35	1.6		24 (4.8)	268.3
Sternoptyx sp.	1	<0.1		1 (0.2)	4.8
Sternoptyx obscura	26	1.2	0.57 ± 0.08 (26)	18 (3.6)	214.8
Argyropelecus lynchnus	4	0.2		3 (0.6)	25.3
Argyropelecus sp.	2	0.1		2 (0.4)	9.4
Polyipnus sp.	2	0.1		2 (0.2)	14.0
Photichthyidae	283	13.2	118	(23.5)	415.6
Vinciguerria lucetia	241	11.3	1.18 ± 0.28 (201)	95 (18.9)	337.4
Vinciguerria sp.	36	1.9	23	4.6	69.4
Woodsia nonsuchae	1	<0.1	0.2	1.8	–
Ichthyococcus irregularis	5	0.2		5 (1.0)	7.0
Chauliodontidae	3	0.1		3 (0.6)	20.0
Chauliodus macouni	3	–		–	20.0
Synodontidae	1	<0.1		1 (0.2)	6.6
Saurida sp.	1	–		–	6.6
Myctophidae	638	29.8		265 (52.7)	4,237.7
Protomyctophum sp.	4	0.2		3 (0.6)	19.1
Electrona risso	9	0.3		8 (1.6)	43.2
Hygophum proximum	18	0.8		16 (3.2)	104.2
Hygophum reinhardti	12	0.5		10 (2.0)	64.4
Benthosema panamense	3	0.1		3 (0.6)	13.3
Diogenichthys laternatus	53	2.5	1.04 ± 0.15 (33)	36 (7.0)	366.4
Myctophum nitidulum	7	0.3		7 (1.4)	30.9
Myctophum lychnobium	2	0.1		2 (0.4)	10.3
Myctophum aurolaternatum	86	4.0	2.11 ± 0.49 (70)	51 (10.1)	733.0
Myctophum sp.	10	0.5		9 (1.8)	63.2
Symbolophorus evermanni	48	2.2	3.40 ± 0.77 (30)	40 (8.0)	351.1
Bolinichthys photothorax	6	0.3		4 (0.8)	34.6
Bolinichthys longipes	1	<0.1		1 (0.2)	6.0
Ceratoscopelus warmingii	106	5.0	2.49 ± 0.64 (74)	64 (12.7)	719.6
Lampanyctus nobilis	7	0.3		6 (1.2)	34.1
Lampanyctus parvicauda	18	0.8		15 (3.0)	142.9
Lampanyctus omostigma	2	0.1		2 (0.4)	11.5
Diaphus parri	56	2.6	2.83 ± 0.94 (44)	40 (8.0)	350.9
Diaphus jenseni	13	0.6		10 (2.0)	63.2
Diaphus lutkeni	12	0.6		10 (2.0)	53.3
Diaphus garmani	1	<0.1		1 (0.2)	3.9
Diaphus schmidti	23	1.1	2.54 ± 0.27 (22)	16 (3.2)	126.8
Diaphus spp.	27	1.3		21 (4.2)	196.2
Notoscopelus resplendens	7	0.3		7 (1.4)	31.7
Gonichthys tenuiculus	2	0.1		2 (0.4)	9.1
Unidentified Myctophidae	105	4.9		87 (17.3)	654.8
Scomberosocidae	1	<0.1		1 (0.2)	5.0
Scomberesox scombroides	1	–		–	5.0
Exocoetidae	1	<0.1		1 (0.2)	5.0
Exocoetus spp.	1	–		–	5.0

APPENDIX 7. CONTINUED.

	Number of Prey	%	Otolith or beak/ body length mean ± SD (N)	Occurrence frequency %	Mass (g)
Bregmacerotidae	128	6.0		72 (14.3)	1,340.0
Bregmaceros bathymaster	117	5.5	1.44 ± 0.35 (102)	63 (12.5)	1,248.1
Bregmaceros sp.	11	0.5		9 (1.8)	91.9
Diretmidae	23	1.1		19 (3.8)	123.4
Diretmus argenteus	14	0.7		14 (2.8)	70.4
Diretmus pauciradiatus	4	0.2		3 (0.6)	22.9
Diretmus sp.	5	0.2		2 (0.4)	30.1
Melamphaidae	77	3.6		48 (9.5)	681.4
Melamphaes longivelis	10	0.5		7 (1.4)	55.4
Melamphaes sp.	3	0.1		3 (0.6)	20.1
Scopeloberyx robusta	9	0.4		8 (1.6)	50.7
Scopeloberyx sp.	31	1.4		16 (3.2)	382.9
Unidentified Melamphaidae	24	1.1		19 (3.8)	192.4
Percichthyidae	7	0.3		6 (1.2)	30.0
Howella pammelas	7	–		–	30.0
Coryphaenidae	2	0.1		2 (0.4)	10.0
Coryphaena sp.	1	<0.1		1 0.2	5.0
Naucrates ductor	1	<0.1		1 (0.2)	5.0
Scombridae	2	0.1		1 (0.2)	10.0
Euthynnus sp.	2	–		–	10.0
Gempylidae	8	0.4		8 (1.6)	36.0
Pronethichthys prometheus	2	0.1		2 (0.4)	9.0
Gempylus serpens	4	0.2		4 (0.8)	18.0
Unidentified Gempylidae	2	0.1		2 (0.2)	9.0
Nomeidae	1	<0.1		1 (0.2)	5.0
Cubiceps carnatus	1	–		–	5.0
Unidentified teleosts	13	0.0		12 (2.4)	0.0
Ommastrephidae	19	0.9		18 (3.6)	20.0
Sthenoteuthis oualaniensis	4	0.2		3 (0.6)	15.0
Unidentified Ommastrephidae	15	0.7		13 (2.6)	5.0
Onychoteuthidae	9	0.4		9 (1.8)	7.5
Onychoteuthis banksii	9	–		–	7.5
Enoploteuthidae	9	0.4		7 (1.4)	14.4
Pterygioteuthis giardi	4	0.2		3 (0.6)	0.0
Abraliopsis affinis	4	0.2		4 (0.8)	14.4
Abraliopsis sp.	1	<0.1		1 (0.2)	0.0
Octopoteuthidae	5	0.2		5 (1.0)	9.0
Octopoteuthis deletron	1	<0.1		1 (0.2)	4.5
Octopoteuthis sp.	4	0.2		4 (0.8)	4.5
Histioteuthidae	4	0.2		4 (0.8)	0.0
Histioteuthis sp.	2	0.1		2 (0.2)	0.0
Histioteuthis hoylei	1	<0.1		1 (0.2)	0.0
Histioteuthis reversa	1	<0.1		1 (0.2)	0.0
Mastigoteuthidae	2	0.1		2 (0.4)	0.0
Mastigoteuthis sp.	1	<0.1		1 (0.2)	0.0
Idioteuthis sp.	1	<0.1		1 (0.2)	0.0
Chiroteuthidae	5	0.2		3 (0.6)	0.0
Chiroteuthis calyx	2	0.1		1 (0.2)	0.0
Chiroteuthis sp.	1	<0.1		1 (0.2)	0.0
Valbyteuthis sp.	2	0.1		1 (0.2)	0.0
Cranchiidae	29	1.3		22 (4.4)	36.7
Cranchia scabra	5	0.2		4 (0.8)	27.0
Leachia dislocata	12	0.6		7 (1.4)	4.2
Helicocranchia sp.	10	0.5		9 (1.8)	5.5
Unidentified Cranchiidae	2	0.1		2 (0.4)	0.0
Argonautidae	2	0.1		1 (0.2)	5.0
Argonauta argo	2	–		–	5.0
Unidentified cephalopods	46	0.0		45 (8.9)	0.0
Unidentified teuthoids	3	0.0		2 (0.4)	0.0

APPENDIX 7. CONTINUED.

	Number of Prey	%	Otolith or beak/ body length mean ± SD (N)	Occurrence frequency %	Mass (g)
Lepas barnacle	10	0.5		1 (0.2)	5.0
Lepas sp.	10	–		–	5.0
Crustacea	108	5.0		54 (10.7)	12.96
Unidentified crustacean	14	0.6		12 (2.4)	1.14
Euphausiid	87	4.1	14.9 ± 8.8 (75)	40 (8.0)	10.44
Gammarid/hyperiid amphipod	5	0.2		3 (0.6)	0.6
Cymothoid, *Nerocila* sp.	1	<0.1		1 (0.2)	0.12
Unidenified shrimp	1	<0.1		1 (0.2)	0.12
Scyphozoan	510	23.8		134 (26.6)	42.6
Porpida sp.	399	18.6	9.3 ± 6.7 (277)	92 (18.3)	32.6
Velella sp.	43	2.1	18.4 ± 18.9 (42)	17 (3.4)	3.4
Physalia sp.	58	2.7	18.1 ± 5.5 (43)	48 (9.5)	4.6
Unidentified scyphozoan	10	0.5		2 (0.4)	2.0
Gerrid insect	35	1.6		19 (3.8)	1.05
Halobates (black body)	14	0.7		5 (1.0)	0.42
Halobates sp.	21	1.0		14 (2.8)	0.63
Nudibranch	12	0.6		3 (0.6)	0.96
Pelagic nudibranch	12	–		–	0.96
Snail	12	0.6		7 (1.4)	1.3
Janthina sp.	11	0.5		6 (1.2)	1.2
Small snail	1	<0.1		1 (0.2)	0.1
Pteropod	1	<0.1		1 (0.2)	0.06
Pteropod sp.	1	–		–	0.06
[a]Eggs	1	<0.1		1 (0.2)	4.2
Other molluscs	145	6.8		2 (0.4)	5.8
Unidentified mollusc	145	–		–	5.8
Bryzoan	4	0.2		2 (0.4)	0.4
Unidentified bryzoan	4	–		–	0.4

Notes: Sample size of storm-petrels, N = 503, with prey 433; prey sample, N = 2,141. Total length data are given in mm; body lengths given for misc. invertebrates only.
[a]13 eggs in one clump.

Appendix 8. Diet of Wedge-rumped Storm-Petrel (*Oceanodroma tethys*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	723	84.3	80.1	281	68.4
Cephalopods	16	1.9	20.5	30	7.3
Misc. invertebrates/eggs	119	13.9	6.3	66	16.1
Engraulidae	1	0.1)	5.0	1	0.2
Unidentified Engraulidae	1	–	5.0	–	–
Argentinidae	4	0.5	27.5	3	0.7
Microstoma microstoma	4	–	27.5	–	–
Gonostomatidae	1	0.1	4.5	1	0.2
Unidentified Gonostomatidae	1	–	4.5	–	–
Sternoptychidae	8	0.9	38.7	7	1.7
Sternoptyx obscura	7	0.8	33.9	6	1.5
Argyropelecus sp.	1	0.1	4.8	1	0.2
Photichthyidae	280	32.6	392.0	120	29.2
Viniguerria lucetia	244	28.4	341.6	91	22.1
Vinciguerria sp.	24	2.8	33.6	20	4.9
Ichthyococcus sp.	12	1.4	16.8	11	2.7
Chauliodontidae					
Chauliodus macouni	1	0.1	4.6	1	0.2
Myctophidae	352	41.0	2,094.0	191	46.5
Protomyctophum sp.	3	0.3	14.3	3	0.7
Electrona risso	3	0.3	16.2	3	0.7
Hygophum sp. cf. *H. proximum*	12	1.4	71.6	11	2.7
Hygophum sp.	11	1.3	55.9	11	2.7
Benthosema panamense	2	0.2	30.1	1	0.2
Diogenichthys laternatus	72	8.4	570.2	51	12.4
Myctophum sp. cf. *M. nitidulum*	6	0.7	33.5	6	1.5
Myctophum sp. cf. *M. spinosum*	1	0.1	4.2	1	0.2
Myctophum aurolaternatum	36	4.2	191.0	29	7.1
Myctophum sp.	1	0.1	6.7	1	0.2
Symbolophorus evermanni	14	1.6	78.3	14	3.4
Ceratoscopelus warmingii	33	3.8	188.5	30	7.3
Lampanyctus nobilis	4	0.5	4.2	4	1.0
Lampanyctus parvicauda	5	0.6	27.0	5	1.2
Diaphus parri	19	2.2	98.6	19	4.6
Diaphus jenseni	3	0.3	14.4	2	0.5
Diaphus lutkeni	6	0.7	30.0	4	1.0
Diaphus schmidti	2	0.2	11.1	2	0.5
Diaphus sp. cf. *D. mollis*	28	3.3	134.4	4	1.0
Diaphus spp.	12	1.4	58.8	12	2.9
Notoscopelus resplendens	6	0.7	30.0	2	0.5
Gonichthys tenuiculus	8	0.9	47.6	8	2.0
Unidentified Myctophidae	65	7.5	377.4	58	14.1
Exocoetidae	1	0.1	5.0	1	0.2
Unidentified Exocoetidae	1	–	5.0	–	–
Bregmacerotidae	42	4.9	329.9	31	7.5
Bregmaceros bathymaster	36	4.2	283.9	27	6.6
Bregmaceros sp.	6	0.7	46.0	5	1.2
Diretmidae	2	0.2	9.0	2	0.5
Diretmus argenteus	2	–	9.0	–	–
Melamphaidae	25	2.9	139.9	20	4.9
Melamphaes longivelis	2	0.2	13.0	2	0.5
Melamphaes sp.	1	0.1	4.8	1	0.2
Scopeloberyx sp.	11	1.3	62.4	9	2.2
Unidentified Melamphaidae	11	1.3	59.7	8	2.0
Gempylidae	6	0.7	30.0	6	1.5
Nesiarchus nasutus	1	0.1	5.0	1	0.2
Gempylus serpens	1	0.1	5.0	1	0.2
Unidentified Gempylidae	4	0.5	20.0	4	1.0
Unidentifiable teleosts	20	0.0	0.0	19	4.6

APPENDIX 8. CONTINUED.

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Ommastrephidae	4	0.5	4.0	4	1.0
Sthenoteuthis oualaniensis	3	0.3	0.0	3	0.7
Unidentified Ommastrephidae	1	0.1	4.0	1	0.2
Onychoteuthidae	2	0.2	0.0	2	0.2
Onychoteuthis banksii	2	–	0.0	–	–
Enoploteuthidae	3	0.3	4.8	3	0.7
Abraliopsis affinis	3	–	4.8	–	–
Octopoteuthidae	1	0.1	0.0	1	0.2
Octopoteuthis sp.	1	–	0.0	–	–
Mastigoteuthidae	1	0.1	0.0	1	0.2
Mastigoteuthis sp.	1	–	0.0	–	–
Chiroteuthidae	1	0.1	0.0	1	0.2
Chiroteuthis sp.	1	–	0.0	–	–
Cranchiidae	3	0.3	11.7	3	0.7
Cranchia scabra	1	0.1	7.5	1	0.2
Leachia dislocata	1	0.1	4.2	1	0.2
Galiteuthis pacifica	1	0.1	0.0	1	0.2
Octopods	1	0.1	0.0	1	0.2
Ocythoidae	1	0.1	0.0	1	0.2
Ocythoe tuberculata	1	–	0.0	–	–
Unidentified cephalopods	9	0.0	0.0	9	2.2
Unidetified teuthoids	5	0.0	0.0	5	1.2
Crustacea	94	11.0	5.5	51	12.4
Unidentified crustacean	5	0.6	0.3	5	1.2
Euphausiid	69	8.0	4.1	32	7.8
Gammarid/hyperiid amphipod	3	0.3	0.12	3	0.7
Unidentified medium shrimp	12	1.4	0.7	9	2.2
Unidentified large shrimp	3	0.3	0.18	3	0.7
Small unidentified isopod	1	0.1	0.04	1	0.2
Mysid sp.	1	0.1	0.03	1	0.2
Scyphozoan	3	0.3	0.14	3	0.7
Porpida sp.	1	0.1	0.04	1	0.2
Velella sp.	1	0.1	0.05	1	0.2
Physalia sp.	1	0.1	0.05	1	0.2
Gerrid insect	20	2.3	0.6	13	3.2
Halobates (black body)	1	0.1	0.03	1	0.2
Halobates sp.	19	2.2	0.57	12	2.9
Snail	1	0.1	0.05	1	0.2
Small snail	1	–	0.05	–	–
[a]Eggs	1	0.1	10.0	1	0.2

Note: Sample size of storm-petrels, N = 411, with prey 308; prey sample, N = 858.
[a] One bunch of 500 eggs.

APPENDIX 9. DIET OF MARKHAM'S STORM-PETREL (*OCEANODROMA MARKHAMI*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	Prey occurrence %
Fishes	20	57.1	55.1	9	60.0
Cephalopods	2	5.7	4.8	5	33.3
Misc. invertebrates/eggs	13	37.1	3.9	9	60.0
Photichthyidae	12	34.3	16.8	5	33.3
Vinciguerria lucetia	12	–	16.8	–	–
Myctophidae	8	22.9	38.3	3	20.0
Diogenichthys laternatus	7	20.0	32.9	3	20.0
Ceratoscopelus warmingii	1	2.9	5.5	1	6.7
Cranchiidae	2	5.7	4.8	2	13.3
Leachia dislocata	1	2.9	4.8	1	6.7
Galiteuthis pacifica	1	2.9	0.0	1	6.7
Unidentified cephalopods	4	0.0	0.0	3	20.0
Crustacea	2	5.7	0.24	2	13.3
Euphausiid	1	2.9	0.06	1	6.7
Unidentified medium shrimp	1	2.9	0.18	1	6.7
Scyphozoan	4	10.3	0.2	3	20.0
Porpida sp.	2	5.7	0.1	1	6.7
Velella sp.	1	2.9	0.05	1	6.7
Physalia sp.	1	2.9	0.05	1	6.7
Insect	4	11.4	0.12	3	20.0
Halobates sp.	4	–	0.12	–	–
Snail	2	5.7	0.36	2	13.3
Janthina sp.	2	–	0.36	–	–
[a]Eggs	1	2.9	3.0	1	6.7

Note: Sample size of storm-petrels, N = 15, with prey 12; prey sample, N = 35.
[a] One clump of 150 eggs.

APPENDIX 10. DIET OF STEJNEGER'S PETREL (*PTERODROMA LONGIROSTRIS*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	231	60.2	1,633.8	40	83.3
Cephalopods	30	7.8	61.1	18	37.5
Misc. Invertebrates/eggs	120	31.3	17.2	26	54.2
Bathylagidae.	1	0.3	4.2	1	2.1
Bathylagus sp.	1	–	4.2	–	–
Gonostomatidae	4	1.0	22.1	3	6.3
Diplophos taenia	3	0.8	17.3	2	4.2
Unidentified Gonostomatidae	1	0.3	4.8	1	2.1
Sternoptychidae	8	2.1	45.4	7	14.6
Sternoptyx diaphana	1	0.3	6.6	1	2.1
Argyropelecus sladeni	4	1.0	23.1	4	8.3
Argyropelecus cf. *lychnus*	2	0.5	9.7	1	2.1
Argyropelecus sp.	1	0.3	6.0	1	2.1
Photichthyidae	28	7.3	39.2	16	33.3
Viniguerria lucetia	21	5.5	29.4	8	16.7
Vinciguerria sp.	2	0.5	2.8	2	4.2
Woodsia nonsuchae	1	0.3	1.4	1	2.1
Ichthyococcus sp.	5	1.3	7.0	5	10.4
Chauliodontidae	1	0.3	6.6	1	2.1
Chauliodus macouni	1	–	6.6	–	–
Myctophidae	132	34.4	1,075.2	35	72.9
Electrona risso	1	0.3	4.2	1	2.1
Hygophum sp. cf. *H. proximum*	3	0.8	21.6	2	4.2
Hygophum sp.	1	0.3	4.8	1	2.1
Diogenichthys laternatus	9	2.3	73.4	6	12.5
Myctophum aurolaternatum	17	4.4	103.4	11	22.9
Myctophum sp.	3	0.8	13.8	2	4.2
Symbolophorus evermanni	9	2.3	45.9	7	14.6
Lampadena luminosa	2	0.5	11.9	1	2.1
Ceratoscopelus warmingii	36	9.4	349.3	18	37.5
Lampanyctus nobilis	3	0.8	21.0	2	4.2
Lampanyctus parvicauda	1	0.3	6.0	1	2.1
Lampanyctus idostigma	1	0.3	4.8	1	2.1
Diaphus parri	17	4.4	178.5	11	22.9
Diaphus lutkeni	4	1.0	33.2	3	6.3
Diaphus schmidti	2	0.5	8.8	2	4.2
Diaphus sp.	2	0.5	9.4	2	4.2
Unidentified Myctophidae	21	5.5	208.6	14	29.2
Paralepididae	1	0.3	3.9	1	2.1
Unidentified Paralepididae	1	–	3.9	–	–
Exocoetidae	4	1.0	40.0	1	2.1
Exocoetus spp.	4	–	40.0	–	–
Bregmacerotidae	26	6.8	215.4	15	31.3
Bregmaceros bathymaster	22	5.7	187.1	11	22.9
Bregmaceros sp.	4	1.0	27.7	4	8.3
Diretmidae	13	3.4	113.3	7	14.6
Diretmus argenteus	12	3.1	104.4	7	14.6
Diretmus pauciradiatus	1	0.3	8.9	1	2.1
Melamphaidae	11	2.9	53.5	7	14.6
Melamphaes longivelis	5	1.3	24.9	4	8.3
Scopeloberyx robusta	2	0.5	9.6	1	2.1
Scopeloberyx sp.	1	0.3	4.6	1	2.1
Unidentified Melamphaidae	3	0.8	14.4	3	6.3
Scombridae	2	0.5	10.0	1	2.1
Euthynnus sp.	2	–	10.0	–	–
Gempylidae	3	0.8	5.0	1	2.1
Unidentified Gempylidae	3	–	5.0	–	–
Unidentified teleosts	2	0.5	0.0	2	4.2
Ommastrephidae	12	3.1	32.0	4	8.3
Sthenoteuthis oualaniensis	7	1.8	8.0	2	4.2

Appendix 10. Continued.

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Ornithoteuthis volatilus	3	0.8	16.0	1	2.1
Unidentified Ommastrephidae	2	0.5	8.0	2	4.2
Onychoteuthidae	1	0.3	0.0	1	2.1
Onychoteuthis banksii	1	–	0.0	–	–
Enoploteuthidae	1	0.3	4.8	1	2.1
Abraliopsis sp.	1	–	4.8	–	–
Octopoteuthidae	1	0.3	0.0	1	2.1
Octopoteuthis sp.	1	–	0.0	–	–
Chiroteuthidae	1	0.3	12.0	1	2.1
Chiroteuthis sp. A	1	–	12.0	–	–
Cranchiidae	2	0.5	4.8	2	4.2
Megalocranchia sp.	1	0.3	0.0	1	–
Galiteuthis pacifica	1	0.3	4.8	1	–
Octopoda	1	0.3	7.5	1	2.1
Bolitaneidae	1	0.3	7.5	1	–
Japetella heathi	1	–	7.5	1	–
Unidentified Cephalopods	5	0.0	0.0	5	10.4
Unidetified Teuthoids	2	0.0	0.0	2	4.2
Lepas barnacle	3	0.8	0.3	3	6.3
Lepas sp.	3	–	0.3	–	–
Crustacea	11	2.9	1.14	6	12.5
Unidentified crustacean	2	0.5	0.24	2	4.2
Euphausiid	3	0.8	0.3	2	4.2
Unidentified crab megalops	2	0.5	0.2	1	2.1
Unidentified medium shrimp	4	1.0	0.4	2	4.2
Scyphozoan	101	26.3	10.5	20	41.7
Porpida sp.	90	23.4	9.0	18	37.5
Velella sp.	1	0.3	0.1	1	2.1
Physalia sp.	10	2.6	1.4	4	8.3
Gerrid insect	1	0.3	0.03	1	2.1
Halobates sp.	1	–	0.03	–	–
Snail	1	0.3	0.12	1	2.1
Janthina sp.	1	–	0.12	–	–
Pteropod	2	0.5	0.1	1	2.1
Pteropod sp.	2	–	0.1	–	–
[a]Eggs	3	0.8	5.3	3	6.3
Exocoetid eggs	2	0.5	3.3	2	4.2
Unidentified eggs	1	0.3	2.0	1	2.1

Note: Sample size of petrels, N = 48, with prey 46; prey sample, N = 384.
[a] Three clumps of eggs: exocetid eggs, N = 75, 7; unidentified eggs, N = 50.

APPENDIX 11. DIET OF DEFILLIPPE'S PETREL (*PTERODROMA DEFILIPPIANA*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	Prey occurrence %
Fishes	92	78.0	292.4	7	100.0
Cephalopods	1	0.8	16.8	4	57.1
Invertebrates	25	21.2	1.3	6	85.7
Sternoptychidae	2	1.7	9.8	1	14.3
Sternoptyx obscura	2	–	9.8	–	–
Photichthyidae	48	40.7	67.2	5	71.4
Vinciguerria lucetia	48	–	67.2	–	–
Myctophidae	38	32.2	181.8	7	100.0
Diogenichthys laternatus	27	22.9	116.1	4	57.1
Ceratoscopelus warmingii	2	1.7	10.3	2	28.6
Diaphus schmidti	4	3.4	31.4	2	28.6
Unidentified Myctophidae	5	4.2	24.0	3	42.9
Bregmacerotidae	4	4.2	33.6	2	28.6
Bregmaceros bathymaster	4	–	33.6	–	–
Pholidoteuthidae	1	0.8	12.0	1	14.3
Pholidoteuthis boschmai	1	–	12.0	–	–
Octopoda	1	0.8	4.8	1	14.3
Bolitaneidae	1	0.8	4.8	1	14.3
Japetella heathi	1	–	4.8	–	–
Unidentified Teuthoids	4	0.0	0.0	2	28.6
Lepas barnacle	4	3.4	0.4	1	14.3
Lepas sp.	4	–	0.4	–	–
Crustacea	1	0.8	0.15	1	14.3
Crab megalops	1	–	0.15	–	–
Gerrid insect	18	15.3	0.54	3	42.9
Halobates sp.	18	–	0.54	–	–
Snail	2	1.7	0.24	2	28.6
Janthina sp	2	–	0.24	–	–

Note: Sample size of petrels, N = 7, all with prey; prey sample, N = 118.

Appendix 12. Diet of White-winged Petrel (*Pterodroma leucoptera*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	797	78.4	5,502.8	128	92.1
Cephalopods	133	13.1	627.7	76	54.7
Misc. invertebrates	87	8.6	8.7	22	15.8
Argentinidae	3	0.3	13.8	2	1.4
Microstoma microstoma	3	–	13.8	–	–
Gonostomatidae	2	0.2	8.4	2	1.4
Diplophos taenia	1	0.1	4.2	1	0.7
Unidentified Gonostomatidae	1	0.1	4.2	1	0.7
Sternoptychidae	30	2.9	176.0	25	18.0
Sternoptyx obscura	13	1.3	76.7	12	8.6
Argyropelecus sladeni	10	1.0	56.9	8	5.7
Argyropelecus sp. cf. *A. lychnus*	2	0.2	15.3	2	1.4
Argyropelecus sp.	5	0.5	27.1	5	3.6
Photichthyidae	191	18.8	267.4	40	28.8
Viniguerria lucetia	140	13.8	196.0	26	18.7
Vinciguerria sp.	44	4.3	61.6	12	8.6
Ichthyococcus sp.	7	0.7	9.8	6	4.3
Myctophidae	370	36.4	3,322.6	110	79.1
Electrona risso	7	0.7	39.4	7	5.0
Hygophum sp. cf. *H. proximum*	5	0.5	24.7	5	3.6
Hygophum sp.	6	0.6	28.6	5	3.6
Diogenichthys laternatus	54	5.3	1,028.6	28	20.1
Myctophum sp. cf. *M. nitidulum*	3	0.3	16.8	3	2.2
Myctophum sp. cf. *M. lychnobium*	1	0.1	4.6	1	0.7
Myctophum aurolaternatum	36	3.5	260.5	23	16.5
Myctophum sp.	4	0.4	20.1	3	2.2
Symbolophorus evermanni	18	1.8	100.2	15	10.8
Ceratoscopelus warmingii	54	5.3	356.3	54	38.8
Lampanyctus nobilis	9	0.9	44.2	9	6.5
Lampanyctus parvicauda	6	0.6	28.5	6	4.3
Lampanyctus idostigma	1	0.1	4.6	1	0.7
Diaphus parri	37	3.6	405.1	23	16.5
Diaphus jenseni	5	0.5	35.6	4	2.9
Diaphus lutkeni	10	1.0	64.4	5	3.6
Diaphus garmani	6	0.6	73.4	4	2.9
Diaphus schmidti	7	0.7	31.7	6	4.3
Diaphus spp.	6	0.6	31.9	5	3.6
Notoscopelus resplendens	5	0.5	44.1	4	2.9
Gonichthys tenuiculus	2	0.2	10.0	2	1.4
Unidentified Myctophidae	88	8.7	669.3	55	39.6
Paralepididae	1	0.1	6.6	1	0.7
Unidentified Paralepididae	1	–	6.6	–	–
Exocoetidae	51	5.0	510.0	29	20.9
Exocoetus spp.	17	1.7	170.0	8	5.7
Cypselurus sp.	3	0.3	30.0	2	1.4
unidentified Exocoetidae	31	3.0	310.0	21	15.1
Bregmacerotidae	53	5.2	509.8	31	22.3
Bregmaceros bathymaster	36	3.5	384.2	18	12.9
Bregmaceros sp.	17	1.7	125.6	13	9.4
Diretmidae	42	3.8		22	15.8
Diretmus argenteus	36	3.5	322.4	19	13.7
Diretmus pauciradiatus	5	0.5	24.7	3	2.2
Diretmus sp.	1	0.1	4.8	1	0.7
Melamphaidae	45	4.4	297.0	29	20.9
Melamphaes longivelis	1	0.1	4.8	1	0.7
Melamphaes sp.	6	0.6	37.3	4	2.9
Scopeloberyx robusta	7	0.7	48.2	4	2.9
Scopeloberyx sp.	21	2.1	149.4	15	10.8
Poromitra sp.	1	0.1	5.5	1	0.7
Unidentified Melamphaidae	9	0.9	51.8	7	5.0
Trachipteridae	2	0.2	9.7	2	1.4
Trachipterus sp.	2	–	9.7	–	–
Percichthyidae	2	0.2	9.6	1	0.7
Howella sp. cf. *H. brodei*	2	–	9.6	–	–

APPENDIX 12. CONTINUED.

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Coryphaenidae	1	0.1	5.0	1	0.7
Coryphaena sp.	1	–	5.0	–	–
Gempylidae	1	0.1	5.0	1	0.7
Pronethichthys prometheus	1	–	5.0	–	–
Nomeidae	3	0.3	10.0	2	1.4
Cubiceps carnatus	3	–	10.0	–	–
Unidentified teleosts	11	0.0	0.0	11	7.9
Ommastrephidae	70	6.3	280.0	23	16.5
Sthenoteuthis oualaniensis	47	4.2	264.0	15	10.8
Unidentified Ommastrephidae	23	2.1	16.0	11	7.9
Onychoteuthidae	27	2.4	112.0	17	12.2
Onychoteuthis banksii	27	–	112.0	–	–
Enoploteuthidae	8	0.7	38.5	7	5.0
Pterygioteuthis giardi	2	0.2	9.7	2	1.4
Abraliopsis affinis	1	0.1	4.8	1	0.7
Abraliopsis sp.	4	0.4	19.2	3	2.2
Ancistrocheirus lesueuri	1	0.1	4.8	1	0.7
Octopoteuthidae	4	0.4	24.0	4	2.9
Octopoteuthis deletron	1	0.1	12.0	1	0.7
Octopoteuthis sp.	3	0.3	12.0	3	2.2
Histioteuthidae	11	1.0	72.0	9	6.5
Histioteuthis sp.	6	0.5	36.0	5	3.6
Histioteuthis sp. cf. *H. hoylei*	2	0.2	12.0	2	1.4
Histioteuthis sp. B	1	0.1	12.0	1	0.7
Histioteuthis corona	2	0.2	12.0	1	0.7
Bathyteuthidae	1	0.1	12.0	1	0.7
Bathyteuthis bacidifera	1	–	12.0	–	–
Chiroteuthidae	1	0.1	12.0	1	0.7
Chiroteuthis sp.	1	–	12.0	–	–
Cranchiidae	9	0.8	42.0	8	5.8
Cranchia scabra	2	0.2	24.0	2	1.4
Liocranchia reinhardti	1	0.1	12.0	1	0.7
Helicocranchia sp.	1	0.1	0.0	1	0.7
Megalocranchia sp.	1	0.1	0.0	1	0.7
Galiteuthis pacifica	2	0.2	6.0	2	1.4
Unidentified Cranchiidae	2	0.2	0.0	2	1.4
Octopoda	3	0.3	25.6	3	2.2
Tremoctopodidae	1	0.3	6.0	1	0.7
Tremoctopus violaceus	1	–	6.0	–	–
Ocythoidae	1	0.1	4.8	1	0.7
Ocythoe tuberculata	1	–	4.8	–	–
Bolitaneidae	1	0.1	4.8	1	0.7
Japetella heathi	1	–	4.8	–	–
Alloposidae	1	0.1	4.8	1	0.7
Alloposus mollis	1	–	4.8	–	0.7
Unidentified Cephalopods	16	0.0	0.0	13	9.4
Unidentified Teuthoids	68	0.0	0.0	15	10.8
Lepas barnacle	12	1.2	1.2	1	0.7
Lepas sp.	12	–	1.2	–	–
Crustacea	16	1.6	1.9	13	9.4
Unidentified crustacean	6	0.6	0.7	6	4.3
Euphausiid	4	0.4	0.5	2	1.4
Gammarid/hyperiid amphipod	2	0.2	0.2	1	0.7
Unidentified medium shrimp	3	0.3	0.4	3	2.2
Unidentified large shrimp	1	0.1	0.1	1	0.7
Scyphozoan	52	5.1	5.2	7	5.0
Porpida sp.	52	–	5.2	–	–
Gerrid insect	6	0.6	0.2	3	2.2
Halobates sp.	6	–	0.2	–	–
Snail	1	0.1	0.2	1	0.7
Small snail	1	–	0.2	–	–

Note: Sample size of petrels, N = 139, with prey 135; prey sample, N = 1,017.

APPENDIX 13. DIET OF BLACK-WINGED PETREL (*PTERODROMA NIGRIPENNIS*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	573	87.3	3,673.9	80	90.9
Cephalopods	77	11.7	285.7	40	45.5
Misc. invertebrates/eggs	6	0.9	4.0	6	6.8
Engraulidae	1	0.1	5.0	1	1.1
Engraulis ringens	1	–	5.0	–	–
Argentinidae	1	0.1	4.8	1	1.1
Nansenia sp.	1	–	4.8	–	–
Sternoptychidae	32	4.9	187.4	15	16.9
Sternoptyx obscura	21	3.2	123.9	7	7.9
Argyropelecus sladeni	5	0.8	27.4	5	5.6
Argyropelecus sp. cf. *A. lychnus*	1	0.1	6.6	1	1.1
Argyropelecus sp.	5	0.7	29.5	3	3.4
Photichthyidae	86	13.1	120.4	29	32.6
Viniguerria lucetia	68	10.4	95.2	20	22.5
Vinciguerria sp.	11	1.7	15.4	6	6.7
Ichthyococcus sp.	7	1.1	9.8	6	6.7
Myctophidae	316	48.2	2,272.7	74	83.1
Protomyctophum sp.	3	0.5	16.1	3	3.4
Electrona risso	6	0.9	30.0	5	5.6
Hygophum sp. cf. *H. proximum*	11	1.7	66.1	10	11.2
Hygophum sp.	6	0.9	37.1	5	5.6
Diogenichthys laternatus	22	3.4	115.9	9	10.1
Myctophum sp. cf. *M. nitidulum*	7	1.1	33.4	5	5.6
Myctophum sp. cf. *M. lychnobium*	3	0.5	13.6	3	3.4
Myctophum sp. cf. *M. spinosum*	1	0.1	6.6	1	1.1
Myctophum aurolaternatum	21	3.2	132.4	14	15.7
Myctophum sp.	5	0.8	29.5	3	3.4
Symbolophorus evermanni	17	2.6	92.9	16	18.0
Lampadena luminosa	1	0.1	4.6	1	1.1
Bolinichthys sp. cf. *B. pyrsobolus*	1	0.1	4.6	1	1.1
Bolinichthys sp. cf. *B. longipes*	1	0.1	4.9	1	1.1
Ceratoscopelus warmingii	72	11.0	595.6	38	42.7
Lampanyctus nobilis	9	1.4	54.6	8	9.0
Lampanyctus parvicauda	2	0.3	9.0	2	2.2
Diaphus parri	17	2.6	121.2	13	14.6
Diaphus jenseni	10	1.5	47.6	7	7.9
Diaphus lutkeni	11	1.7	109.8	7	7.9
Diaphus garmani	1	0.1	4.6	1	1.1
Diaphus schmidti	12	1.8	94.3	9	10.1
Diaphus spp.	10	1.5	65.4	7	7.9
Unidentified Myctophidae	67	10.2	582.9	36	40.4
Exocoetidae	2	0.3	20.0	2	2.2
Exocoetus sp.	1	0.1	10.0	1	1.1
Unidentified Exocoetidae	1	0.1	10.0	1	1.1
Moridae	1	0.1	4.6	1	1.1
Unidentified Moridae	1	–	4.6	–	–
Bregmacerotidae	79	12.1	655.9	35	39.3
Bregmaceros bathymaster	64	9.8	530.8	25	28.1
Bregmaceros sp.	15	2.3	125.1	11	12.4
Diretmidae	8	1.2	48.0	7	7.9
Diretmus argenteus	6	0.9	38.6	6	6.7
Diretmus sp.	2	0.3	9.4	2	2.2
Melamphaidae	43	6.6	331.5	27	30.3
Melamphaes longivelis	8	1.2	46.5	8	9.0
Melamphaes sp.	3	0.5	14.2	2	2.2
Scopeloberyx sp.	16	2.4	147.4	9	10.1
Unidentified Melamphaidae	16	2.4	123.4	11	12.4
Gempylidae	2	0.3	10.0	2	2.2
Nesiarchus nasutus	1	0.1	5.0	1	1.1
Gempylus serpens	1	0.1	5.0	1	1.1

APPENDIX 13. CONTINUED.

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Trichiuridae	1	0.1	4.8	1	1.1
Trichiurus sp. cf. *T. nitens*	1	–	4.8	–	–
Nomeidae	1	0.1	5.0	1	1.1
Cubiceps carnatus	1	–	5.0	–	–
Unidentified teleosts	6	0.9	0.0	4	4.5
Ommastrephidae	44	6.7	182.5	18	20.2
Sthenoteuthis oualaniensis	24	3.7	144.0	13	14.6
Unidentified Ommastrephidae	20	3.1	38.5	6	6.7
Onychoteuthidae	9	1.4	24.0	7	7.9
Onychoteuthis banksii	9	–	24.0	–	–
Enoploteuthidae	3	0.5	9.2	2	2.9
Abraliopsis sp.	2	–	4.8	–	–
Ancistrocheirus lesueuri	1	0.1	4.8	1	0.7
Octopoteuthidae	1	0.1	4.8	1	1.1
Octopoteuthis sp.	1	–	4.8	–	–
Histioteuthidae	2	0.3	9.6	2	2.2
Histioteuthis sp.	2	–	9.6	–	–
Mastigoteuthidae	5	0.8	0.0	3	3.4
Mastigoteuthis sp.	5	–	0.0	–	–
Chiroteuthidae	1	0.1	4.8	1	1.1
Chiroteuthis sp. A	1	–	4.8	–	–
Cranchiidae	10	1.5	36.0	6	6.7
Helicocranchia sp.	3	0.5	0.0	1	1.1
Megalocranchia sp.	3	0.5	24.0	3	3.4
Galiteuthis pacifica	4	0.6	12.0	2	2.2
Octopods	2	0.3	9.6	2	2.2
Ocythoidae	1	0.1	4.8	1	1.1
Ocythoe tuberculata	1	–	4.8	–	–
Alloposidae	1	0.1	4.8	1	1.1
Alloposus mollis	1	–	4.8	–	–
Unidentified cephalopods	9	0.0	0.0	9	10.1
Unidentified teuthoids	7	0.0	0.0	3	3.4
Crustacea	3	0.5	0.3	3	3.4
Unidentified medium shrimp	2	0.3	0.12	2	2.2
Portunid crab	1	0.1	0.1	1	1.1
Gerrid insect	1	0.1	0.03	1	1.1
Halobates sp.	1	–	0.03	–	–
Snail	1	0.1	0.15	1	1.1
Small snail	1	–	0.15	–	–
[a]Eggs	1	0.1	3.8	1	1.1
Unidentified fish eggs	1	–	3.8	–	–

Note: Sample size of petrels, N = 89, with prey 88; prey sample, N = 655.
[a] One clump of 125 eggs.

Appendix 14. Diet of Herald Petrel (*Pterodroma arminjoniana*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	26	86.7	129.1	11	84.6
Cephalopods	2	6.7	44.5	7	53.8
Misc. invertebrates/eggs	2	6.7	0.1	2	15.4
Sternoptychidae	1	3.3	6.0	1	7.7
Sternoptyx diaphana	1	–	6.0	–	–
Photichthyidae	4	13.3	5.6	4	30.8
Viniguerria lucetia	4	–	5.6	–	–
Myctophidae	14	46.7	91.7	8	61.5
Hygophum proximum	1	3.3	4.6	1	7.7
Myctophum aurolaternatum	1	3.3	6.0	1	7.7
Myctophum sp.	2	6.7	12.5	2	15.4
Ceratoscopelus warmingii	1	3.3	5.5	1	7.7
Diaphus parri	3	10.0	18.0	3	23.1
Unidentied Myctophidae	6	20.0	45.1	5	38.5
Moridae	1	3.3	6.0	1	7.7
Unidentied Moridae	1	–	6.0	–	–
Bregmacerotidae	1	3.3	6.0	1	7.7
Bregmaceros bathymaster	1	–	6.0	–	–
Diretmidae	1	3.3	4.6	1	7.7
Diretmus argenteus	1	–	4.6	–	–
Melamphaidae	4	6.7	9.2	2	15.4
Melamphaes longivelis	2	–	4.6	–	–
Unidentied Melamphaidae	2	6.7	6.6	2	15.4
Onychoteuthidae	1	3.3	8.5	1	7.7
Onychoteuthis banksii	1	–	8.5	–	–
Chiroteuthidae	1	3.3	36.0	1	7.7
Chiroteuthis sp. A	1	–	36.0	–	–
Unidentified Cephalopoda	4	0.0	0.0	4	30.8
Unidentified Teuthoidea	1	0.0	0.0	1	7.7
Gerrid insect	2	6.7	0.06	2	15.4
Halobates sp.	2	–	0.06	–	–

Note: Sample size of petrels, N = 13, all with prey; prey sample, N = 30.

APPENDIX 15. DIET OF MURPHY'S PETREL (*PTERODROMA ULTIMA*).

	Number of prey	%	Mass (g)	Prey occurrence	
				Frequency	%
Fishes	21	56.8	127.3	7	87.5
Cephalopods	16	43.2	93.5	5	62.5
Sternoptychidae	1	2.7	5.9	1	12.5
Sternoptyx diaphana	1	–	5.9	–	–
Myctophidae	11	29.7	82.9	7	87.5
Ceratoscopelus warmingii	4	10.8	29.6	4	50.0
Lampanyctus nobilis	4	10.8	35.9	3	37.5
Lampanyctus parvicauda	1	2.7	4.9	1	12.5
Myctophidae	2	5.4	12.5	2	25.0
Evermanellidae	1	2.7	7.5	1	12.5
Evermanella ahlstromi	1	–	7.5	–	–
Bregmacerotidae	1	2.7	4.9	1	12.5
Bregmaceros bathymaster	1	–	4.9	–	–
Diretmidae	1	2.7	4.6	1	12.5
Diretmus argenteus	1	–	4.6	–	–
Melamphaidae	4	10.8	21.5	3	37.5
Scopeloberyx robusta	1	2.7	4.8	1	12.5
Unidentified Melamphaidae	3	8.1	16.7	2	25.0
Unidentified teleosts	2	5.4	0.0	2	25.0
Ommastrephidae	8	21.6	76.5	3	37.5
Ornithoteuthis volatilus	1	2.7	10.0	1	12.5
Ommastrephidae	7	18.9	66.5	2	25.0
Onychoteuthidae	2	5.4	17.0	2	25.0
Onychoteuthis banksii	2	–	17.0	–	–
Mastigoteuthidae	1	2.7	0.0	1	12.5
Mastigoteuthis sp.	1	–	0.0	–	–
Chiroteuthidae	1	2.7	0.0	1	12.5
Chiroteuthis calyx	1	–	0.0	–	–
Cranchiidae	1	2.7	0.0	1	12.5
Taonius pavo	1	–	0.0	–	–
Unidentified Cephalopoda	1	2.7	0.0	1	12.5
Unidentified Teuthoidea	2	5.4	0.0	2	–

Note: Sample size of petrels, N = 8, all with prey; prey sample, N = 32.

APPENDIX 16. DIET OF PHOENIX PETREL (*PTERODROMA ALBA*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	Prey occurrence %
Fishes	50	44.2	283.5	18	85.7
Cephalopods	57	50.4	566.0	10	47.6
Invertebrates	6	5.3	0.7	1	4.8
Sternoptychidae	2	1.8	9.2	2	9.5
Sternoptyx diaphana	2	–	9.2	–	–
Photichthyidae	6	5.3	7.0	3	14.3
Vinciguerria lucetia	6	–	7.0	–	–
Myctophidae	27	23.9	153.9	14	66.7
Electrona risso	1	0.9	8.5	1	4.8
Hygophum sp. cf. *H. proximum*	1	0.9	4.2	1	4.8
Myctophum sp. cf. *M. spinosum*	1	0.9	4.2	1	4.8
Myctophum aurolaternatum	3	2.7	22.5	1	4.8
Symbolophorus evermanni	2	1.8	8.8	2	9.5
Lampadena luminosa	2	1.8	9.6	1	4.8
Ceratoscopelus warmingii	3	2.7	13.8	2	9.5
Lampanyctus nobilis	1	0.9	4.6	1	4.8
Diaphus parri	1	0.9	4.8	1	4.8
Diaphus sp.	3	2.7	21.2	1	4.8
Unidentified Myctophidae	9	8.0	51.7	7	33.3
Moridae	1	0.9	6.0	1	4.8
Unidentified Moridae	1	–	6.0	–	–
Bregmacerotidae	7	6.2	49.9	5	23.8
Bregmaceros bathymaster	7	–	49.9	–	–
Diretmidae	1	0.9	4.2	1	4.8
Diretmus argenteus	1	–	4.2	–	–
Melamphaidae	3	2.7	17.3	3	14.3
Scopeloberyx sp.	1	0.9	4.6	1	4.8
Unidentified Melamphaidae	2	1.8	12.7	2	9.5
Nomeidae	3	2.7	36.0	2	4.8
Cubiceps carnatus	3	–	36.0	–	–
Ommastrephidae	54	47.8	539.0	9	42.9
Sthenoteuthis oualaniensis	54	–	539.0	–	–
Onychoteuthidae	2	1.8	15.0	1	4.8
Onychoteuthis banksii	2	–	15.0	–	–
Cranchiidae	1	0.9	12.0	1	4.8
Galiteuthis pacifica	1	–	12.0	–	–
Crustacea	6	5.3	0.7	1	4.8
Unidentified medium shrimp	6	–	0.7	–	–

Note: Sample size of petrels, N = 21, all with prey; prey sample, N = 113.

APPENDIX 17. DIET OF TAHITI PETREL (*PTERODROMA ROSTRATA*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	403	43.1	2,623.2	127	81.4
Cephalopods	498	53.2	3,241.5	126	80.8
Misc. invertebrates/eggs	35	3.7	2.7	9	5.8
Argentinidae	1	0.1	6.6	1	0.6
Nansenia sp.	1	–	6.6	–	–
Bathylagidae.	1	0.1	4.8	1	0.6
Bathylagus sp.	1	–	4.8	–	–
Sternoptychidae	15	1.6	93.5	11	7.1
Sternoptyx obscura	7	0.7	53.8	6	3.8
Argyropelecus sladeni	6	0.6	28.9	4	2.6
Argyropelecus sp. cf. *A. lychnus*	1	0.1	6.0	1	0.6
Argyropelecus sp.	1	0.1	4.8	1	0.6
Photichthyidae	14	1.5	19.6	12	7.7
Viniguerria lucetia	9	1.0	7.0	9	5.8
Ichthyococcus sp.	5	0.5	12.6	3	1.9
Chauliodontidae	2	0.2	10.8	2	1.3
Chauliodus macouni	2	–	10.8	–	–
Synodontidae	1	0.1	4.2	1	0.6
Saurida sp.	1	–	4.2	–	–
Chloropthalmidae	1	0.1	4.8	1	0.6
Chloropthalmus sp.	1	–	4.8	–	–
Myctophidae	257	27.5	1,732.4	110	70.5
Electrona risso	10	1.1	63.5	9	5.8
Hygophum sp. cf. *H. proximum*	3	0.3	14.4	3	1.9
Hygophum sp.	6	0.6	29.8	5	3.2
Diogenichthys laternatus	5	0.5	21.8	5	3.2
Myctophum sp. cf. *M. nitidulum*	2	0.2	9.1	2	1.3
Myctophum sp. cf. *M. lychnobium*	1	0.1	4.8	1	0.6
Myctophum aurolaternatum	15	1.6	85.9	14	9.0
Myctophum sp.	4	0.4	23.7	4	2.6
Symbolophorus evermanni	9	1.0	49.6	9	5.8
Lampadena luminosa	2	0.2	9.6	1	0.6
Bolinichthys sp. cf. *B. pyrsobolus*	1	0.1	4.6	1	0.6
Ceratoscopelus warmingii	53	5.7	274.7	36	23.1
Lampanyctus nobilis	18	1.9	111.5	14	9.0
Lampanyctus parvicauda	5	0.5	25.2	5	3.2
Diaphus parri	12	1.3	63.9	11	7.1
Diaphus jenseni	1	0.1	4.6	1	0.6
Diaphus lutkeni	5	0.5	26.5	5	3.2
Diaphus garmani	1	0.1	4.2	1	0.6
Diaphus schmidti	11	1.2	75.5	6	3.8
Diaphus lucidus	1	0.1	4.8	1	0.6
Diaphus spp.	11	1.2	71.5	8	5.1
Unidentified Myctophidae	81	8.7	753.2	57	36.5
Exocoetidae	2	0.2	40.0	2	1.3
Exocoetus sp.	1	0.1	20.0	1	0.6
Unidentified Exocoetidae	1	0.1	20.0	1	0.6
Moridae	2	0.2	11.4	2	1.3
Unidentified Moridae	2	–	11.4	–	–
Bregmacerotidae	18	1.9	120.8	15	9.6
Bregmaceros bathymaster	10	1.1	73.6	8	5.1
Bregmaceros sp.	8	0.9	47.2	7	4.5
Macrouridae	1	0.1	6.0	1	0.6
Unidentified Macrouridae	1	–	6.0	–	–
Diretmidae	38	4.1	247.2	31	19.9
Diretmus argenteus	28	3.0	153.2	24	15.4
Diretmus pauciradiatus	6	0.6	67.2	4	2.6
Diretmus sp.	4	0.4	26.8	3	1.9
Melamphaidae	41	4.4	231.1	31	19.9
Melamphaes longivelis	6	0.6	32.8	6	3.8

Appendix 17. Continued.

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Melamphaes sp.	6	0.6	29.2	6	3.8
Scopeloberyx robusta	4	0.4	22.5	4	2.6
Scopeloberyx sp.	6	0.6	30.5	6	3.8
Unidentified Melamphaidae	19	2.0	116.1	16	10.3
Trachipteridae	1	0.1	4.2	1	0.6
Trachipterus sp.	1	–	4.2	–	–
Percichthyidae	2	0.2	8.0	2	1.3
Howella sp. cf. *H. brodei*	2	–	8.0	–	–
Coryphaenaidae	1	0.1	25.0	1	0.6
Coryphaena sp.	1	–	25.0	–	–
Gempylidae	4	0.4	48.0	4	2.6
Nesiarchus nasutus	2	0.2	24.0	2	1.3
Rexea solandri	1	0.1	12.0	1	0.6
Gempylus serpens	1	0.1	12.0	1	0.6
Trichiuridae	1	0.1	4.8	1	0.6
Trichiurus sp. cf. *T. nitens*	1	–	4.8	–	–
Unidentified teleosts	11	0.0	0.0	11	7.1
Ommastrephidae	91	9.7	441.0	22	14.1
Sthenoteuthis oualaniensis	32	3.4	254.8	10	6.4
Ornithoteuthis volatilus	1	0.1	9.8	1	0.6
Unidentified Ommastrephidae	58	6.2	176.4	11	7.1
Onychoteuthidae	286	30.6	1,744.6	87	55.8
Onychoteuthis banksii	286	–	1,744.6	–	–
Pholidoteuthidae	2	0.2	36.0	2	1.3
Pholidoteuthis bochmai	2	–	36.0	–	–
Enoploteuthidae	16	1.7	36.0	14	9.0
Pterygioteuthis giardi	7	0.7	6.0	6	3.8
Abraliopsis sp.	4	0.2	4.8	3	1.9
Ancistrocheirus lesueuri	5	0.5	25.2	5	3.2
Octopoteuthidae	5	0.5	60.0	4	2.6
Octopoteuthis deletron	2	0.2	24.0	1	0.6
Octopoteuthis sp.	3	0.3	36.0	3	1.9
Histioteuthidae	19	2.0	312.0	15	9.6
Histioteuthis sp.	7	0.7	36.0	6	3.8
Histioteuthis hoylei	11	1.2	264.0	8	5.1
Histioteuthis sp. B	1	0.1	12.0	1	0.6
Bathyteuthidae	2	0.2	24.0	2	1.3
Bathyteuthis bacidifera	2	–	24.0	–	–
Mastigoteuthidae	10	1.1	36.0	8	5.1
Mastigoteuthis sp.	10	–	36.0	–	–
Chiroteuthidae	20	2.1	240.0	13	8.3
Chiroteuthis calyx	4	0.4	48.0	4	2.6
Chiroteuthis sp. A	3	0.3	36.0	1	0.6
Chiroteuthis spp.	13	1.4	156.0	8	5.1
Cranchiidae	47	5.0	297.5	29	18.6
Cranchia scabra	1	0.1	12.0	1	0.6
Liocranchia sp.	1	0.1	5.5	1	0.6
Liocranchia reinhardti	2	0.2	22.0	5	3.2
Leachia dislocata	5	0.5	60.0	2	1.3
Helicocranchia sp.	1	0.1	12.0	1	0.6
Liguriella sp.	5	0.5	36.0	4	2.6
Megalocranchia sp.	2	0.2	36.0	2	1.3
Taonius pavo	26	2.8	108.0	15	9.6
Taonius sp. A	1	0.1	6.0	1	0.6
Unidentified Cranchiidae	3	0.3	0.0	3	1.9
Octopoda	2	0.2	9.6	2	1.3
Bolitaneidae	1	0.1	4.8	1	0.6
Japetella heathi	1	–	4.8	–	–
Alloposidae	1	0.1	4.8	1	0.6
Alloposus mollis	1	–	4.8	–	–

APPENDIX 17. CONTINUED.

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Unidentified Cephalopoda	16	0.0	0.0	16	10.3
Unidentified Teuthoidea	94	0.0	0.0	94	60.3
Unidentified octopod	1	0.0	0.0	1	0.6
Crustacea	2	0.2	0.27	2	1.3
Unidentified crustacean	1	0.1	0.12	1	0.6
Unidentified large shrimp	1	0.1	0.15	1	0.6
Gerrid insect	20	2.1	0.6	5	3.2
Halobates sp.	20	–	0.6	–	–
Snail	13	1.4	1.8	3	1.9
Small snail	13	–	1.8	–	–

Note: Sample size of petrels, N = 156, with prey 154; prey sample, N = 936.

APPENDIX 18. DIET OF JUAN FERNANDEZ PETREL (*PTERODROMA EXTERNA*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	599	54.7	6,338.6	167	78.0
Cephalopods	485	44.3	5,335.0	148	69.2
Misc. invertebrates/eggs	10	0.9	1.5	10	4.7
Engraulidae	187	17.1	261.8	1	0.5
Unidentified Engraulidae	187	–	261.8	–	–
Argentinidae	3	0.3	15.3	2	0.9
Microstoma microstoma	2	0.2	8.8	1	0.5
Nansenia sp.	1	0.1	6.5	1	0.5
Bathylagidae.	1	0.1	4.8	1	0.5
Bathylagus sp.	1	–	4.8	–	–
Sternoptychidae	16	1.5	94.7	13	6.1
Sternoptyx diaphana	5	0.5	35.6	3	1.4
Argyropelecus sladeni	3	0.3	14.6	3	1.4
Argyropelecus sp.	8	0.7	44.5	7	3.3
Photichthyidae	2	0.2	2.8	2	0.9
Vinciguerria lucetia	1	0.1	1.4	1	0.5
Ichthyococcus sp.	1	0.1	1.4	1	0.5
Chloropthalmidae	1	0.1	4.8	1	0.5
Chloropthalmus sp.	1	–	4.8	–	–
Myctophidae	68	6.2	324.8	54	25.2
Protomyctophum sp.	1	0.1	4.6	1	0.5
Hygophum sp. cf. *H. proximum*	3	0.3	15.5	3	1.4
Hygophum sp.	2	0.3	10.5	2	0.9
Diogenichthys laternatus	1	0.1	4.6	1	0.5
Myctophum aurolaternatum	7	0.6	33.2	7	3.3
Symbolophorus evermanni	4	0.4	22.1	4	1.9
Lampadena luminosa	1	0.1	4.2	1	0.5
Ceratoscopelus warmingii	8	0.7	39.1	7	3.3
Lampanyctus nobilis	6	0.5	27.7	6	2.8
Lampanyctus parvicauda	2	0.2	9.0	2	0.9
Diaphus parri	2	0.2	9.4	2	0.9
Diaphus lutkeni	2	0.2	8.7	2	0.9
Diaphus sp.	4	0.4	17.4	2	0.9
Gonichthys tenuiculus	1	0.1	4.6	1	0.5
Unidentified Myctophidae	24	2.2	114.2	18	8.4
Scomberosocidae	2	0.2	9.8	1	0.5
Scomberesox scombroides	2	0.2	9.8	–	–
Hemirhamphidae	107	9.8	2,140.0	59	27.6
Oxyporhamphus micropterus	104	9.5	2,080.0	56	26.2
Unidentified Hemirhamphidae	3	0.3	60.0	3	1.4
Exocoetidae	155	14.2	3,100.0	90	42.1
Exocoetus spp.	92	8.4	1,840.0	55	25.7
Cypselurus exilens	1	0.1	20.0	1	0.5
Cypselurus spilonotopterus	1	0.1	20.0	1	0.5
Cypselurus sp.	1	0.1	20.0	1	0.5
Unidentified Exocoetidae	60	5.5	1,200.0	46	21.5
Moridae	1	0.1	6.6	1	0.5
Unidentified Moridae	1	–	6.6	–	–
Bregmacerotidae	9	0.8	45.7	8	3.7
Bregmaceros bathymaster	8	0.7	40.9	7	3.3
Bregmaceros sp.	1	0.1	4.8	1	0.5
Macrouridae	2	0.2	9.6	2	0.9
Unidentified Macrouridae	2	–	9.6	–	–
Diretmidae	25	2.3	193.3	15	7.0
Diretmus argenteus	24	2.2	188.4	14	6.5
Diretmus sp.	1	0.1	4.9	1	0.5
Melamphaidae	16	1.5	89.2	14	6.5
Melamphaes longivelis	3	0.3	13.4	3	1.4
Melamphaes sp.	4	0.4	31.0	3	1.4
Scopeloberyx robusta	3	0.3	15.2	3	1.4
Scopeloberyx sp.	4	0.4	20.8	4	1.9
Unidentified Melamphaidae	2	0.2	8.8	2	0.9

APPENDIX 18. CONTINUED.

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Percichthyidae	2	0.2	11.4	2	0.9
Howella sp. cf. *H. brodei*	2	–	11.4	–	–
Gempylidae	2	0.2	24.0	2	0.9
Nesiarchus nasutus	1	0.1	12.0	1	0.5
Gempylus serpens	1	0.1	12.0	1	0.5
Unidentified teleosts	15	1.4	0.0	12	5.6
Ommastrephidae	279	25.5	3,047.0	74	34.6
Sthenoteuthis oualaniensis	181	16.5	1,991.0	58	27.1
Dosidicus gigas	3	0.3	11.0	1	0.5
Hyaloteuthis pelagica	2	0.2	22.0	2	0.9
Ornithoteuthis volatilus	1	0.1	11.0	1	0.5
Unidentified Ommastrephidae	92	8.4	154.0	21	9.8
Onychoteuthidae	122	11.1	1,307.9	55	25.7
Onychoteuthis banksii	122	–	1,307.9	–	–
Pholidoteuthidae	3	0.3	36.0	3	1.4
Pholidoteuthis boschmai	3	–	36.0	–	–
Enoploteuthidae	15	1.4	3.9	9	4.2
Pterygioteuthis giardi	2	0.1	0.0	2	0.9
Abraliopsis affinis	2	0.2	0.0	1	0.5
Abraliopsis sp.	7	0.6	0.0	3	1.4
Ancistrocheirus lesueuri	4	0.4	3.9	4	1.9
Octopoteuthidae	3	0.3	36.0	3	1.4
Octopoteuthis sp.	3	–	36.0	–	–
Histioteuthidae	16	1.5	216.0	13	6.1
Histioteuthis sp.	3	0.3	36.0	3	1.4
Histioteuthis sp. cf. *H. hoylei*	6	0.5	36.0	5	2.3
Histioteuthis sp. B	5	0.5	108.0	3	1.4
Histioteuthis corona	2	0.2	36.0	2	0.9
Bathyteuthidae	1	0.1	36.0	1	0.5
Bathyteuthis bacidifera	1	–	36.0	–	–
Mastigoteuthidae	3	0.3	108.0	3	1.4
Mastigoteuthis sp.	2	0.2	72.0	2	0.9
Mastigoteuthis sp. A	1	0.1	36.0	1	0.5
Chiroteuthidae	7	0.6	72.0	3	1.4
Chiroteuthis sp. A	5	0.5	36.0	1	0.5
Chiroteuthis sp.	2	0.2	36.0	2	0.9
Cranchiidae	33	3.0	415.7	23	10.7
Liocranchia sp.	3	0.3	19.7	2	0.9
Liocranchia reinhardti	1	0.1	36.0	1	0.5
Leachia dislocata	1	0.1	36.0	1	0.5
Liguriella sp.	3	0.3	72.0	3	1.4
Megalocranchia sp.	4	0.4	72.0	4	1.9
Taonius pavo	17	1.6	144.0	12	5.6
Galiteuthis pacifica	2	0.2	36.0	2	0.9
Unidentified Cranchiidae	2	0.2	0.0	1	0.5
Octopoda	3	0.3	32.5	2	0.9
Tremoctopodidae	1	0.1	8.5	1	0.5
Tremoctopus violaceus	1	–	8.5	–	–
Ocythoidae	2	0.2	24.0	1	0.5
Ocythoe tuberculata	2	–	24.0	–	–
Unidentified Cephalopoda	17	0.0	0.0	17	7.9
Unidentified Teuthoidea	172	0.0	0.0	23	10.7
Crustacea	9	0.8	1.5	9	4.2
Unidentified crustacean	2	0.2	0.3	2	0.9
Gammarid/hyperiid amphipod	1	<0.1	0.2	1	0.5
Cymothoid, *Nerocila* sp.	4	0.4	0.8	4	1.9
Unidentified large shrimp	2	0.2	0.2	2	0.9
Gerrid insect	1	0.1	0.03	1	0.5
Halobates sp.	1	–	0.03	–	–

Note: Sample size of petrels, N = 214, with prey 204; prey sample, N = 1094.

APPENDIX 19. DIET OF WHITE-NECKED PETREL (*PTERODROMA CERVICALIS*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	21	70.0	248.3	11	78.6
Cephalopods	8	26.7	47.3	6	42.9
Invertebrates	1	3.3	0.2	1	7.1
Photichthyidae	1	3.3	1.4	1	7.1
Ichthyococcus regularis	1	–	1.4	–	–
Myctophidae	8	26.7	52.9	5	35.7
Myctophum aurolaternatum	1	3.3	11.4	1	7.1
Ceratoscopelus warmingii	2	6.7	9.4	2	14.3
Lampanyctus nobilis	3	10.0	22.9	2	14.3
Diaphus parri	1	3.3	4.6	1	7.1
Unidentified Myctophidae	1	3.3	4.6	1	7.1
Hemirhamphidae	2	6.7	40.0	2	14.3
Oxyporhamphus micropterus	2	–	40.0	–	–
Exocoetidae	7	23.3	140.0	5	35.7
Exocoetus spp.	5	16.7	100.0	4	28.6
Unidentified Exocoetidae	2	6.7	40.0	2	14.3
Diretmidae	2	6.7	9.4	2	14.3
Diretmus argenteus	2	–	9.4	–	–
Melamphaidae	1	3.3	4.6	1	7.1
Melamphaes longivelis	1	–	4.6	–	–
Unidentified teleosts	1	0.0	0.0	1	7.1
Ommastrephidae	6	20.0	41.3	3	21.4
Sthenoteuthis oualaniensis	4	13.3	33.0	2	14.3
Unidentified Ommastrephidae	2	6.7	8.3	1	7.1
Onychoteuthidae	1	3.3	6.0	1	7.1
Onychoteuthis banksii	1	–	6.0	–	–
Cranchiidae	1	3.3	0.0	1	7.1
Liocranchia sp.	1	–	0.0	–	–
Unidentified Teuthoidea	2	0.0	0.0	2	14.3
Crustacea	1	3.3	0.2	1	7.1
Cymothoidae, *Nerocila* sp.	1	–	0.2	–	–

Note: Sample size of petrels, N = 14, with prey 12; prey sample, N = 30.

APPENDIX 20. DIET OF KERMEDEC PETREL (*PTERODROMA NEGLECTA*).

	Number of prey	%	Mass (g)	Prey occurrence	
				Frequency	%
Fishes	18	43.9	172.4	9	75.0
Cephalopods	23	56.1	189.2	9	75.0
Invertebrates	0	0.0	0.0	0	0.0
Sternoptychidae	2	4.9	8.8	1	8.3
Sternoptyx diaphana	1	2.4	4.4	1	8.3
Argyropelecus sladeni	1	2.4	4.4	1	–
Photichthyidae	3	7.3	4.2	1	8.3
Viniguerria lucetia	3	–	4.2	–	–
Myctophidae	5	12.2	35.3	4	33.3
Myctophum aurolaternatum	1	2.4	4.6	1	8.3
Unidentified Myctophidae	4	9.8	30.7	3	16.7
Hemirhamphidae	3	7.3	60.0	3	25.0
Oxyporhamphus micropterus	3	–	60.0	–	–
Exocoetidae	2	4.9	40.0	2	16.7
Exocoetus sp.	1	2.4	20.0	1	8.3
Cypselurus sp.	1	2.4	20.0	1	8.3
Moridae	1	2.4	7.5	1	8.3
Unidentified juvenile Moridae	1	–	7.5	–	–
Diretmidae	1	2.4	4.6	1	8.3
Diretmus argenteus	1	–	4.6	–	–
Nomeidae	1	2.4	12.0	1	8.3
Cubiceps carnatus	1	–	12.0	–	–
Ommastrephidae	12	29.3	132.0	4	33.3
Sthenoteuthis oualaniensis	7	17.1	77.0	3	25.0
Unidentified Ommastrephidae	5	12.2	55.0	1	8.3
Onychoteuthidae	7	17.1	24.5	4	33.3
Onychoteuthis banksii	7	–	24.5	–	–
Pholidoteuthidae	1	2.4	10.2	1	8.3
Pholidoteuthis boschmai	1	–	10.2	–	–
Cranchiidae	3	7.3	22.5	3	25.0
Leachia dislocata	1	2.4	7.5	1	8.3
Leachia sp. B	1	2.4	7.5	1	8.3
Helicocranchia sp.	1	2.4	7.5	1	8.3
Unidentified Cephalopoda	2	0.0	0.0	2	16.7

Note: Sample size of petrels, N = 12, with prey 11; prey sample, N = 41.

APPENDIX 21. DIET OF SOOTY SHEARWATER (*PUFFINUS GRISEUS*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	53	53.5	301.6	11	26.2
Cephalopods	35	35.4	80.0	27	64.3
Invertebrates	11	11.1	1.1	5	11.9
Photichthyidae	34	34.3	47.6	1	2.4
Vinciguerria lucetia	34	–	47.6	–	–
Chauliodontidae	1	1.0	4.2	1	2.4
Chauliodus macouni	1	–	4.2	–	–
Myctophidae	4	4.0	12.0	4	9.5
Lampanyctus nobilis	3	3.0	8.2	3	7.1
Diaphus schmidti	1	1.0	3.8	1	2.4
Hemirhamphidae	2	2.0	40.0	2	4.8
Oxyporhamphus micropterus	2	–	40.0	–	–
Exocoetidae	7	7.1	140.0	3	7.1
Exocoetus spp.	4	4.0	80.0	3	7.1
Hirudichthys sp. cf. *H. speculiger*	2	2.0	40.0	1	2.4
Unidentified Exocoetidae	1	1.0	20.0	1	2.4
Diretmidae	2	2.0	8.8	2	4.8
Diretmus argenteus	2	–	8.8	–	–
Coryphaenidae	1	1.0	25.0	1	2.4
Coryphaena sp.	1	–	25.0	–	–
Gempylidae	1	1.0	12.0	1	2.4
Nesiarchus nasutus	1	–	12.0	–	–
Nomeidae	1	1.0	12.0	1	2.4
Cubiceps carnatus	1	–	12.0	–	–
Unidentified teleosts	2	2.0	0.0	1	2.4
Ommastrephidae	8	8.1	66.0	4	9.5
Sthenoteuthis oualaniensis	8	–	66.0	–	–
Onychoteuthidae	13	13.1	4.8	12	28.6
Onychoteuthis banksii	13	–	4.8	–	–
Pholidoteuthidae	1	1.0	0.0	1	2.4
Pholidoteuthis boschmai	1	0.0	–	–	–
Enoploteuthidae	2	2.0	9.2	2	4.8
Pterygioteuthis giardi	1	1.0	4.6	1	2.4
Abraliopsis affinis	1	1.0	4.6	1	2.4
Histioteuthidae	3	3.0	0.0	2	4.8
Histioteuthis sp.	1	1.0	0.0	1	2.4
Histioteuthis hoylei	2	2.0	0.0	1	2.4
Chiroteuthidae	1	1.0	0.0	1	2.4
Chiroteuthis sp.	1	–	0.0	–	–
Cranchiidae	7	7.1	0.0	6	14.3
Cranchia scabra	1	0.9	0.0	1	2.4
Liguriella sp.	1	0.9	0.0	1	2.4
Taonius pavo	3	2.8	0.0	3	7.1
Taonius pavo B	2	1.9	0.0	1	2.4
Unidentified Cephalopoda	5	0.0	0.0	5	11.9
Crustacea	3	3.0	0.36	2	4.8
Unidentified crustacean	2	2.0	0.24	1	2.4
Cymothoidae, *Nerocila* sp.	1	1.0	0.12	1	2.4
Scyphozoan	8	8.1	0.72	3	7.1
Velella sp.	8	–	0.72	–	–

Note: Sample size of shearwaters, N = 43, with prey 31; prey sample, N = 99.

APPENDIX 22. DIET OF WEDGE-TAILED SHEARWATER (*PUFFINUS PACIFICUS*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	199	41.1	3,680.8	63	56.3
Cephalopods	283	58.5	1,784.7	71	63.4
Invertebrates	2	0.4	0.3	2	1.8
Photichthyidae	4	0.8	5.6	1	0.9
Viniguerria lucetia	4	–	5.6	–	–
Myctophidae	3	0.6	18.1	3	2.7
Ceratoscopelus warmingii	1	0.2	4.8	1	0.9
Gonichthys tenuiculus	1	0.2	8.5	1	0.9
Unidentified Myctophidae	1	0.2	4.8	1	0.9
Hemirhamphidae	52	10.7	1,040.0	27	24.1
Oxyporhamphus micropterus	50	10.3	1,000.0	25	22.3
Unidentified Hemirhamphidae	2	0.4	40.0	2	1.8
Exocoetidae	116	24.0	2,320.0	33	29.5
Exocoetus spp.	92	19.0	1,840.0	24	21.4
Cypselurus sp.	2	0.4	40.0	2	1.8
Unidentified Exocoetidae	22	4.5	440.0	15	13.4
Diretmidae	1	0.2	4.8	1	0.9
Diretmus argenteus	1	–	4.8	–	–
Melamphaidae	1	0.2	4.6	1	0.9
Melamphaes sp.	1	–	4.6	–	–
Holocentridae	1	0.2	4.7	1	0.9
Adioryx sp. cf. *A. microstomus*	1	–	4.7	–	–
Coryphaenidae	3	0.6	75.0	3	2.7
Coryphaena spp.	3	–	75.0	–	–
Carangidae	1	0.2	22.0	1	0.9
Naucrates ductor	1	–	22.0	–	–
Scombridae	3	0.6	18.0	3	2.7
Euthynnus sp.	3	–	18.0	–	–
Gempylidae	8	1.7	96.0	6	5.4
Gempylus serpens	8	–	96.0	–	–
Nomeidae	6	1.2	72.0	4	3.6
Cubiceps carnatus	6	–	72.0	–	–
Unidentified teleosts	7	1.4	0.0	6	5.4
Ommastrephidae	234	48.3	1,661.0	47	42.0
Sthenoteuthis oualaniensis	175	36.2	1,617.0	40	35.7
Unidentified Ommastrephidae	59	12.2	44.0	1	9.8
Onychoteuthidae	29	6.0	15.7	15	13.4
Onychoteuthis banksii	29	–	15.7	–	–
Pholidoteuthidae	1	0.2	36.0	1	0.9
Pholidoteuthis boschmai	1	–	36.0	–	–
Enoploteuthidae	1	0.2	0.0	1	0.9
Abraliopsis sp.	1	–	0.0	1	–
Octopoteuthidae	3	0.6	0.0	2	1.8
Octopoteuthis sp.	3	–	0.0	–	–
Histioteuthidae	5	1.0	72.0	4	3.6
Histioteuthis sp.	1	0.2	0.0	1	0.9
Histioteuthis sp. cf. *H. hoylei*	2	0.4	36.0	2	1.8
Histioteuthis sp. B	1	0.2	0.0	1	0.9
Histioteuthis corona	1	0.2	36.0	1	0.9
Mastigoteuthidae	1	0.2	0.0	1	0.9
Mastigoteuthis sp.	1	–	0.0	–	–
Cranchiidae	9	1.9	0.0	6	5.4
Cranchia scabra	1	0.2	0.0	1	0.9
Liguriella sp.	1	0.2	0.0	1	0.9
Liocranchia reinhardti	4	0.8	0.0	2	1.8
Taonius pavo	3	0.6	0.0	2	1.8
Unidentified Cephalopoda	6	1.2	0.0	5	4.5
Unidetified Teuthoidea	30	6.2	0.0	9	8.0
Crustacea	1	0.2	0.2	1	0.9
Cymothoid, *Nerocila* sp.	1	0.2	0.2	–	–
Scyphozoan	1	0.2	0.1	1	0.9
Porpida sp.	1	–	0.1	–	–

Note: Sample size of shearwaters, N = 112, with prey 95; prey sample, N = 484.

APPENDIX 23. DIET OF CHRISTMAS SHEARWATER (*PUFFINUS NATIVITATUS*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	19	51.4	270.2	7	100.0
Cephalopods	18	48.6	156.5	6	83.3
Invertebrates	0	0.0	0.0	0	0.0
Sternoptychidae	1	2.7	4.2	1	16.7
Argyropelecus sladeni	1	–	4.2	–	–
Myctophidae	3	8.1	13.1	1	16.7
Ceratoscopelus warmingii	3	–	13.1	–	–
Hemirhamphidae	1	2.7	20.0	1	16.7
Oxyporhamphus micropterus	1	–	20.0	–	–
Exocoetidae	11	29.7	220.0	5	66.7
Exocoetus spp.	5	13.5	100.0	3	50.0
Cypselurus sp.	2	5.4	40.0	1	16.7
Unidentified Exocoetidae	4	10.8	80.0	2	16.7
Bregmacerotidae	2	5.4	8.5	1	16.7
Bregmaceros bathymaster	2	–	8.5	–	–
Melamphaidae	1	2.7	4.4	1	16.7
Scopeloberyx robusta	1	–	4.4	–	–
Unidentified teleosts	1	2.7	0.0	1	16.7
Ommastrephidae	16	43.2	143.0	4	50.0
Sthenoteuthis oualaniensis	11	29.7	88.0	4	–
Unidentified Ommastrephidae	5	13.5	55.0	1	–
Onychoteuthidae	1	2.7	7.5	1	16.7
Onychoteuthis banksii	1	–	7.5	–	–
Octopoda	1	2.7	6.0	1	16.7
Ocythoidae	1	2.7	6.0	1	16.7
Ocythoe tuberculata	1	–	6.0	–	–

Note: Sample size of shearwaters, N = 7, all with prey; prey sample, N = 37.

Appendix 24. Diet of Sooty Tern (*Onychoprion fuscata*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	227	58.1	1816.4	9	74.2
Cephalopods	162	41.4	1,237.0	9	52.7
Invertebrates	2	0.5	0.2	1	1.1
Photichthyidae	24	6.1	33.6	4	4.3
Viniguerria lucetia	24	–	33.6	–	–
Myctophidae	9	2.3	50.5	4	4.3
Symbolophorus evermanni	4	1.0	20.4	2	2.2
Ceratoscopelus warmingii	2	0.5	15.7	1	1.1
Diaphus jenseni	3	0.8	14.4	1	1.1
Hemirhamphidae	34	8.7	425.0	17	18.7
Hemirhamphus sp.	5	1.3	62.5	2	2.2
Oxyporhamphus micropterus	25	6.4	312.5	12	12.9
Unidentified Hemirhamphidae	4	1.0	50.0	3	3.2
Exocoetidae	49	12.5	412.5	29	31.2
Exocoetus spp.	25	6.4	112.5	12	12.9
Hirudichthys sp. cf. *H. speculiger*	1	0.3	12.5	1	1.1
Unidentified Exocoetidae	23	5.9	287.5	18	19.4
Diretmidae	1	0.3	4.8	1	1.1
Diretmus argenteus	1	–	4.8	–	–
Carangidae	1	0.3	20.0	1	1.1
Naucrates ductor	1	0.3	20.0	–	–
Scombridae	73	18.7	438.0	11	11.8
Euthynnus sp.	73	18.7	438.0	–	–
Gempylidae	21	5.4	252.0	13	14.0
Pronethichthys prometheus	3	0.8	36.0	3	3.2
Gempylus serpens	17	4.3	204.0	11	11.8
Unidentified Gempylidae	1	0.3	12.0	1	1.1
Nomeidae	15	3.8	180.0	5	5.4
Cubiceps carnatus	15	–	180.0	–	–
Unidentified teleosts	3	0.0	0.0	3	3.2
Ommastrephidae	157	40.1	1,232.0	46	49.5
Sthenoteuthis oualaniensis	132	33.8	1,166.0	41	44.1
Unidentified Ommastrephidae	25	6.4	66.0	10	10.8
Octopoteuthidae	4	1.0	5.0	1	1.1
Octopoteuthis sp.	4	–	5.0	–	–
Cranchiidae	1	0.3	0.0	1	1.1
Taonius pavo	1	–	0.0	–	–
UnidentifiedTeuthoidea	2	0.5	0.0	2	2.2
Crustacea	1	0.3	0.15	1	1.1
Mysid sp.	1	–	0.15	–	–
Gerrid insect	1	0.3	0.03	1	1.1
Halobates sp.	1	–	0.03	–	–

Note: Sample size of terns, N = 93, with prey 82; prey sample, N = 391.

APPENDIX 25. DIET OF WHITE TERN (*GYGIS ALBA*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	37	62.7	295.9	10	83.3
Cephalopods	5	8.5	45.0	4	33.3
Invertebrates	17	28.8	0.7	2	16.7
Myctophidae	3	5.1	17.6	2	16.7
Electrona risso	1	1.7	5.5	1	8.3
Unidentified Myctophidae	2	3.4	12.1	1	8.3
Exocoetidae	7	11.9	87.5	4	33.3
Exocoetus spp.	3	5.1	37.5	2	16.7
Unidentified Exocoetidae	4	6.8	50.0	3	25.0
Scombridae	21	35.6	126.0	5	41.7
Euthynnus sp.	21	–	126.0	–	–
Gempylidae	5	8.5	60.0	3	25.0
Pronethichthys prometheus	2	3.4	24.0	1	18.3
Gempylus serpens	3	5.1	36.0	2	16.7
Tetradontidae	1	1.7	4.8	1	8.3
Lagocephalus sp.	1	–	4.8	–	–
Ommastrephidae	5	8.5	45.0	4	33.3
Sthenoteuthis oualaniensis	5	–	45.0	–	–
Gerrid insect	14	23.7	0.42	1	8.3
Halobates (orange body)	2	3.4	0.06	1	8.3
Halobates (black body)	12	20.3	0.36	1	8.3
Snail	1	1.7	0.15	1	8.3
Janthina sp.	1	–	0.15	–	–
Pteropod	2	3.4	0.1	1	8.3
Pteropod sp.	2	–	0.1	–	–

Note: Sample size of terns, N = 12, with prey 11; prey sample, N = 59.

APPENDIX 26. DIET OF GRAY-BACKED TERN (*ONYCHOPRION LUNATUS*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	21	42.0	270.6	5	100.0
Cephalopods	1	2.0	6.0	1	20.0
Invertebrates	28	56.0	0.8	4	80.0
Hemirhamphidae	4	8.0	50.0	2	40.0
Hemirhamphus sp.	3	6.0	37.5	2	40.0
Oxyporhamphus micropterus	1	2.0	12.5	1	20.0
Exocoetidae	16	32.0	200.0	4	80.0
Exocoetus spp.	9	18.0	112.5	3	60.0
Cypselurus sp. cf. *C. spilopterus*	1	2.0	12.5	1	20.0
Unidentified Exocoetidae	6	12.0	75.0	3	60.0
Carangidae	1	2.0	20.0	1	20.0
Naucrates ductor	1	–	20.0	–	–
Ommastrephidae	1	2.0	6.0	1	20.0
Sthenoteuthis oualaniensis	1	–	6.0	–	–
Gerrid insect	28	56.0	0.84	4	80.0
Halobates sp.	28	–	0.84	–	–

Note: Sample size of terns, N = 5, all with prey; prey sample, N = 50.

APPENDIX 27. DIET OF PARASITIC JAEGER (*STERCORARIUS PARASITICUS*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	5	10.4	16.6	4	44.4
Cephalopods	8	16.7	10.0	4	44.4
Misc. Invertebrates/eggs	35	72.9	18.7	5	55.6
Photichthyidae	2	4.2	2.8	1	11.1
Viniguerria lucetia	2	–	2.8	–	–
Myctophidae	1	2.1	4.8	1	11.1
Myctophum sp.	1	–	4.8	–	–
Diretmidae	1	2.1	4.8	1	11.1
Diretmus argenteus	1	–	4.8	–	–
Melamphaidae	1	2.1	4.2	1	11.1
Poromitra sp.	1	–	4.2	–	–
Unidentified teleosts	2	0.0	0.0	2	22.2
Ommastrephidae	1	2.1	10.0	1	11.1
Sthenoteuthis oualaniensis	1	–	10.0	–	–
Pholidoteuthidae	1	2.1	5.0	1	11.1
Pholidoteuthis boschmai	1	–	5.0	–	–
Enoploteuthidae	5	10.4	0.0	2	22.2
Abraliopsis sp.	5	–	0.0	–	–
Cranchiidae	1	2.1	5.0	1	11.1
Liguriella sp.	1	–	5.0	–	--
Lepas barnacle	30	62.5	5.4	4	44.4
Lepas sp.	30	–	5.4	–	–
Snail	3	6.3	0.3	1	11.1
Janthina sp.	3	–	0.3	–	–
[a]Eggs	2	4.2	13.0	2	22.2
Exocoetid eggs	2	–	13.0	–	–

Note: Sample size of jaegers, N = 9, all with prey; prey sample, N = 48.
[a]Two egg bunches consisting of approximately 400 and 250 eggs.

APPENDIX 28. DIET OF RED-TAILED TROPICBIRD (*PHAETHON RUBRICAUDA*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	20	23.8	610.0	9	81.9
Cephalopods	64	76.2	900.2	8	72.7
Invertebrates	0	0.0	0.0	0	0.0
Hemirhamphidae	4	4.8	120.0	2	18.2
Oxyporhamphus micropterus	4		120.0	–	–
Exocoetidae	14	16.7	420.0	6	54.5
Exocoetus spp.	11	13.1	330.0	6	54.5
Unidentified Exocoetidae	3	3.6	90.0	2	18.2
Corphaenidae	1	1.2	35.0	1	9.1
Coryphaena sp.	1	–	35.0	–	–
Scombridae	1	1.2	35.0	1	9.1
Auxis sp.	1	–	35.0	–	–
Ommastrephidae	60	71.4	885.0	8	72.7
Sthenoteuthis oualaniensis	55	65.5	825.0	7	63.6
Hyaloteuthis pelagica	5	6.0	60.0	2	18.2
Enoploteuthidae	2	2.4	10.4	2	18.2
Abraliopsis affinis	1	1.2	4.8	1	9.1
Ancistrocheirus lesueuri	1	1.2	5.6	1	9.1
Cranchiidae	1	1.2		1	9.1
Cranchia scabra	1	–	0.0	–	–
Octopods	1	1.2	4.8	1	9.1
Ocythoidae	1	1.2	4.8	1	9.1
Ocythoe tuberculata	1	–	4.8	–	–

Note: Sample size of tropicbirds, N = 11, with prey 10; prey sample, N = 84.

APPENDIX 29. DIET OF GREAT FRIGATEBIRD (*FREGATA MINOR*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	11	42.3	304.8	4	100
Cephalopods	14	53.8	210.0	2	50
Invertebrates	1	3.8	0.2	1	25
Hemirhamphidae	3	11.5	90.0	3	75
Oxyporhamphus micropterus	3	–	90.0	–	–
Exocoetidae	7	26.9	210.0	3	75
Exocoetus spp.	4	15.4	120.0	2	50
Cypselurus sp.	1	3.8	30.0	1	25
Unidentied Exocoetidae	2	7.7	60.0	1	25
Diretmidae	1	3.8	4.8	1	25
Diretmus argenteus	1	–	4.8	–	–
Ommastrephidae	8	30.8	120.0	2	50
Sthenoteuthis oualaniensis	8	–	120.0	–	–
Onychoteuthidae	6	23.1	90.0	2	25
Onychoteuthis banksii	6	–	90.0	–	–
Crustacea	1	3.8	0.2	1	25
Cymothoid, *Nerocila* sp.	1	–	0.2	–	–

Note: Sample size of frigatebirds, N = 4, all with prey; prey sample, N = 26.

APPENDIX 30. DIET OF MASKED BOOBY (*SULA DACTYLATRA*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	134	93.1	3,885.0	18	100.0
Cephalopods	7	4.9	105.0	2	11.1
Invertebrates	3	2.1	0.5	3	16.7
Hemirhamphidae	28	19.4	690.0	10	55.6
Oxyporhamphus micropterus	27	18.8	660.0	9	50.0
Unidentified Hemirhamphidae	1	0.7	30.0	1	5.6
Exocoetidae	97	67.4	2,940.0	16	88.9
Exocoetus spp.	64	44.4	1,920.0	12	66.7
Hirudichthys sp. cf. *H. speculiger*	5	3.5	150.0	3	16.7
Cypselurus sp. cf. *C. spilopterus*	1	0.7	30.0	1	5.6
Cypselurus sp. cf. *C. exilens*	1	0.7	30.0	1	5.6
Cypselurus sp.	5	3.5	150.0	1	5.6
Prognichthys sp.	3	2.1	90.0	2	11.1
Unidentified Exocoetidae	19	13.2	570.0	7	38.9
Coryphaenidae	4	2.8	140.0	3	16.7
Coryphaena spp.	4	–	140.0	–	–
Scombridae	2	1.4	70.0	2	11.1
Auxis sp.	2	–	70.0	–	–
Nomeidae	3	2.1	45.0	2	11.1
Cubiceps carnatus	3	–	45.0	–	–
Ommastrephidae	7	4.9	105.0	2	11.1
Sthenoteuthis oualaniensis	7	–	105.0	–	–
Crustacea	3	2.1	0.5	3	16.7
Cymothoid, *Nerocila* sp.	3	–	0.5	–	–

Note: Sample size of boobies, N = 18, all with prey; prey sample, N = 144.

APPENDIX 31. DIET OF NAZCA BOOBY (*SULA GRANTI*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	52	35.6	1,565.0	5	100.0
Cephalopods	92	63.0	1,380.0	5	100.0
Invertebrates	2	1.4	0.4	2	40.0
Hemirhamphidae	27	18.5	810.0	5	100.0
Oxyporhamphus micropterus	27	–	810.0	–	–
Exocoetidae	24	16.4	720.0	5	100.0
Exocoetus spp.	20	13.7	600.0	5	100.0
Hirudichthys sp. cf. *H. speculiger*	1	0.7	30.0	1	20.0
Cypselurus sp.	2	1.4	60.0	2	40.0
Unidentified Exocoetidae	1	0.7	30.0	1	20.0
Coryphaenidae	1	0.7	35.0	1	20.0
Coryphaena sp.	1	–	35.0	–	–
Ommastrephidae	92	63.0	1,380.0	5	100.0
Sthenoteuthis oualaniensis	92	–	1,380.0	–	–
Crustacea	2	1.4	0.4	2	40.0
Cymothoid, *Nerocila* sp.	2	–	0.4	–	–

Note: Sample size of boobies, N = 5, all with prey; prey sample, N = 146.

APPENDIX 32. DIET OF RED-FOOTED BOOBY (*SULA SULA*).

	Number of prey	%	Mass (g)	Prey occurrence Frequency	%
Fishes	11	10.9	330.0	3	60.0
Cephalopods	90	89.1	1,344.5	3	60.0
Invertebrates	0	0.0	0.0	0	0.0
Hemirhamphidae	6	5.9	180.0	2	40.0
Oxyporhamphus micropterus	6	–	180.0	–	–
Exocoetidae	5	5.0	150.0	1	20.0
Exocoetus spp.	5	4.0	150.0	1	–
Ommastrephidae	88	87.1	1,320.0	3	60.0
Sthenoteuthis oualaniensis	88	–	1,320.0	–	–
Cranchiidae	2	2.0	24.5	2	40.0
Leachia dislocata	1	1.0	12.5	1	20.0
Taonius pavo	1	1.0	12.0	1	20.0

Note: Sample size of boobies, N = 5, with prey 4; prey sample, N = 101.

APPENDIX 33. MINIMUM DEPTH DISTRIBUTIONS OF MYCTOPHIDS DURING NOCTURNAL VERTICAL MIGRATIONS.

Prey species	Depth at night (m)	Information source	Maximum standard length (mm)
Electrona risso	surface	Wisner (1974)	90
Hygophum proximum	surface	Wisner (1974), R. L. Pitman (unpubl. data)	50
Hygophum reinhardti	surface	Wisner (1974)	55
Benthosema panamense	surface	Wisner (1974), R. L. Pitman (unpubl. data)	55
Benthosema suborbitale	unknown	Wisner (1974)	33
Diogenichthys laternatus	100	Wisner (1974), R. L. Pitman (unpubl. data)	25
Myctophum nitidulum	surface	Wisner (1974), R. L. Pitman (unpubl. data)	79
Myctophum lychnobium	surface	Wisner (1974), R. L. Pitman (unpubl. data)	116
Myctophum spinosum	surface	Wisner (1974), R. L. Pitman (unpubl. data)	90
Myctophum aurolaternatum	surface	Wisner (1974), R. L. Pitman (unpubl. data)	110
Symbolophorus evermanni	surface	Wisner (1974), R. L. Pitman (unpubl. data)	82
Lampadena luminosa	60	Wisner (1974)	150
Bolinichthys photothorax	50–150	Wisner (1974)	68
Bolinichthys longipes	50–150	Wisner (1974)	49
Ceratoscopelus warmingi	100	Wisner (1974)	75
Lampanyctus nobilis	100–200	Wisner (1974)	140
Lampanyctus parvicauda	surface	Wisner (1974), R. L. Pitman (unpubl. data)	110
Lampanyctus idostigma	unknown	Wisner (1974)	90
Lampanyctus omostigma	surface	Wisner (1974)	65
Diaphus parri	200	Wisner (1974) as *Diaphus longleyi*	55
Diaphus jenseni	85	Wisner (1974)	40
Diaphus lutkeni	90	Wisner (1974)	60
Diaphus garmani	surface	Nakamura (1970), Wisner (1974)	55
Diaphus schmidti	100	Wisner (1974)	40
Diaphus mollis	surface	Wisner (1974)	65
Diaphus lucidus	175	Wisner (1974)	78
Notoscopelus resplendens	200	Wisner (1974)	80
Gonichthys tenuiculus	surface	Wisner (1974), R. L. Pitman (unpubl. data)	58