RIDDLE, O. 1916. Studies on the physiology of reproduction in birds. The occurrence and measurement of a sudden change in rate of growth of avian ova. Amer. J. Physiol. 41: 387–396.

ROMANOFF, A. L., & A. J. ROMANOFF. 1949. The avian egg. New York, John Wiley & Sons.

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## Food of Breeding Leach's Storm-Petrels (*Oceanodroma leucorhoa*)

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Storm-petrels are strictly surface feeders that obtain their food by pattering (Ashmole 1971). Fish, squid, copepods, euphausiids, and amphipods are recorded as their prey (Palmer 1962), although there is no detailed information on prey composition. I studied the prey and seasonal changes in the diet of Leach's Storm-Petrels (*Oceanodroma leucorhoa*) breeding on Daikoku Island (42°56'N, 144°52'E) from May to September 1982. For a description of the island, see Abe et al. (1972). Leach's Storm-Petrels arrive at the island in late April and lay eggs during June. Chicks hatch in mid-July and fledge in September and early October.

Adult petrels were caught on their nesting grounds by hand or with a swooping net from 2100 to 2300. Their stomach contents were drained as much as possible using a stomach pump with a plastic tube (4.5 mm diameter, 15 cm length; Grubb 1971). Petrels with empty or nearly empty (<0.5 cc) stomachs included parents caught just after exchanging incubation duties or feeding chicks, or birds already sampled. These petrels were excluded from the analysis. Undigested items were fixed in 10% formalin and preserved in 70% ethanol. Almost all could be identified to class. Squid were separated from other items by noting the presence of beaks or eye lenses, and fish by the presence of scales or bones. Fish and squid were so digested that they could not be identified further, but copepods and euphausiids were identified to species level. Amphipods were identified to family level by Y. Kamihira.

Samples were collected from 307 stomachs, of which 178 contained recognizable items and 129 only orange oil. Many samples taken in June but few taken in September contained only orange oil (Table 1). The seasonal change in the proportion of samples containing only orange oil was significant ($\chi^2 = 20.24$, df = 4, $P < 0.001$). The stomach oil of petrels is a dietary product (Imber 1976). This suggests that the digestion periods in September are shorter than in earlier months, although seasonal diet changes (see below) also may account for the proportion of orange oil in the samples. Weights of samples varied among the months ($F_{4,302} = 2.53$, $P < 0.05$), but those from June to September were similar ($F_{3,234} = 1.10$, NS; Table 1). Mean weights in August and in September, when many breeders fed chicks, were much lower than the maximum estimate of a food load of a parent to a chick ($\bar{x} = 8.0$ g, Watanuki 1985). This suggests that the stomach pump did not remove large items (as observed with penguins by Volkman et al. 1980).

The diet composition is given in Tables 1 and 2. Petrels fed on squid, amphipods, euphausiids, and copepods in May and June. Most euphausiids eaten in May were *Tysanoessa longipes* and *T. inermis*. In August and September fish and euphausiids (*Euphausia pacifica*) dominated. Fish eggs occurred in July. The percentages of euphausiids and of fish increased later in the breeding season (euphausiids: $\chi^2 = 10.1$, df = 4, $P < 0.05$; fish: $\chi^2 = 21.9$, df = 4, $P < 0.01$; Chi-square test for monthly variation), while those of squid and amphipods did not change seasonally (squid: $\chi^2 = 2.9$, df = 4, NS; amphipods: $\chi^2 = 2.4$, df = 4, NS). Pebbles and plastic were found every month.

When the monthly data were combined, fish, squid, and euphausiids dominated; amphipods, copepods, and fish eggs were the next important; and decapods and isopods were least important. Among euphausiids, *E. pacifica* dominated, while *T. longipes* and *T. inermis* occurred less commonly. *Calanus cristatus* was the only copepod eaten. The mean lower length of squid beaks recovered from stomachs was 2.7 mm ($n = 5$), which corresponds to a weight of about 35–40 g (estimated from Imber 1976: Table 3). The length of the vertebral column of one fish sample was 0.9 mm; the corresponding body length is about 3–6 cm (estimated from Tatara et al. 1962: Table 1). Linton (1978, cited in Brown 1980) found myctophid fish in the diet of Leach's Storm-Petrels, so it is possible that petrels in the northwestern North Pacific also eat lanternfish and fish and squid larvae (Takeuchi 1972).

The dominant prey (euphausiids, squid, and fish) remain deep in the sea during the day and rise to the surface at night (Brinton 1967; Kawaguchi 1969; Roper and Young 1975, cited in Naitto et al. 1977), although surface swarming of *E. pacifica* occasionally is observed during the day (Komaki 1967). Less important prey (*C. cristatus* and amphipods) show no such diurnal vertical migration (Sekiguchi 1975, Murano et al. 1976). These facts suggest that the food of the surface-feeding Leach's Storm-Petrels is abundant at night but scarce during the day. The foraging period of the petrels was not determined in this study. Gordon (1955) observed nocturnal activity of Leach's

TABLE 1. Weight of Leach's Storm-Petrel stomach samples ($\bar{x} \pm$ SD), number of samples containing only orange oil, and number and contents of samples containing items. Percentages are given in parentheses (percentages of total stomach samples per month for those containing only orange oil; percentages of samples containing items per month for all others).

| | May | June | July | August | September |
|---|---|---|---|---|---|
| Total stomach samples | 71 | 63 | 69 | 65 | 39 |
| Mean weight (g) | 2.28 ± 1.27 | 1.81 ± 0.85 | 1.84 ± 0.83 | 2.07 ± 1.31 | 1.74 ± 1.22 |
| No. of samples containing only orange oil | 29 (40.8) | 37 (58.7) | 33 (47.8) | 24 (36.9) | 6 (15.4) |
| No. of samples containing items | 42 | 26 | 36 | 41 | 33 |
| Euphausiids | 9 (21.4) | 5 (19.2) | 8 (22.2) | 17 (41.5) | 18 (54.5) |
| Copepods | 8 (19.0) | 2 (7.7) | — | — | — |
| Amphipods | 9 (21.4) | 6 (23.1) | 4 (11.1) | 10 (24.4) | 5 (15.2) |
| Isopods | — | — | 2 (5.6) | 2 (4.9) | — |
| Decapods | 3 (7.1) | — | 1 (2.8) | 2 (4.9) | 1 (3.0) |
| Squid | 16 (38.1) | 11 (42.3) | 13 (36.1) | 10 (24.4) | 8 (24.2) |
| Fish | 5 (11.9) | 5 (19.2) | 12 (33.3) | 18 (43.9) | 24 (72.7) |
| Fish eggs | — | 1 (3.8) | 8 (22.2) | 2 (4.9) | — |
| Pebbles | 3 (7.1) | 4 (15.4) | 4 (11.1) | 8 (19.5) | 1 (3.0) |
| Plastic | 4 (9.5) | 5 (19.2) | 6 (16.7) | 3 (7.3) | 2 (6.0) |

Storm-Petrels at sea and suggested that at least some feeding occurs in the dark, as postulated by Harrison et al. (1983) for the Sooty Storm-Petrel (*O. tristrami*). H. Ogi (pers. comm.) observed daytime feeding activity of Leach's Storm-Petrels. These findings indicate that the petrel is an opportunistic feeder rather than an obligatory nocturnal one.

The quantities of *E. pacifica* in the stomach samples coincide with its abundance in the southern region of the Kurile Islands, the suspected feeding area of this species (Fukuchi 1977). Petrels ate *C. cristatus* in May, when the copepod reaches the sea surface in the northern region of the North Pacific (Sekiguchi 1975). Thus, the occurrence of a prey species in the diet may be correlated with geographical and seasonal changes in the prey's availability. The seasonal changes in the abundance of prey species, however, do not always correlate with changes in the petrel diet. The number of squid larvae rapidly increases beginning in July in the North Pacific north of about 42–43°N (Kubodera and Jefferts 1984). *Euphausia pacifica*, myctophid fish, and *Pleurogrammus* larvae are abundant in this region in April and May but scarce in July and August (Takeuchi 1972). Squid, however, occurs in the petrel diet in every month, and many *E. pacifica* and fish occur in August and September. Breeding adults may feed selectively on euphausiids and fish later in the season when they feed chicks because of the energetic advantages of these prey over squid (Clark and Prince 1980). An alternative hypothesis is that food preferences are different between breeders and nonbreeders, and that seasonal changes in the proportion of nonbreeders in the population contribute to seasonality in the diet composition.

TABLE 2. Composition of crustacean prey.

| Prey taxa | No. prey |
|---|---|
| Euphausiids | |
| *Euphausia pacifica* adult | 290 |
| *Tysanoessa longipes* adult | 6 |
| *T. inermis* adult | 2 |
| Unidentified | 32 |
| Copepods | |
| *Calanus cristatus* adult | 21 |
| Unidentified | 1 |
| Amphipods | |
| Hyperiidae | 2 |
| Melphidipiidae | 2 |
| Calliopiidae | 17 |
| Synoppidae | 2 |
| Unidentified | 21 |

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## LITERATURE CITED

ABE, M., N. ICHIDA, M. SHIMIZU, M. HASHIMOTO, O. YUNOKI, N. OZAWA, & S. OZAWA. 1972. [A new attempt to estimate the number of nesting petrel, *Oceanodroma leucorhoa leucorhoa*, and wildlife on Daikoku Island, Hokkaido.] Tori 21: 346-365.

ASHMOLE, N. P. 1971. Seabird ecology and the marine environment. Pp. 223-287 *in* Avian biology, vol. 1 (D. S. Farner and J. R. King, Eds.). London, Academic Press.

BRINTON, E. 1967. Vertical migration and avoidance capability of euphausiids in the California current. Limnol. Oceanogr. 12: 451-483.

BROWN, R. G. B. 1980. Seabirds as marine animals. Pp. 1-39 *in* Behavior of marine animals. Vol. 4, Marine birds (J. Burger, B. L. Olla, and H. E. Winn, Eds.). New York, Plenum Press.

CLARK, A., & P. A. PRINCE. 1980. Chemical composition and calorific value of food fed to Mollymauk chicks *Diomedea melanophris* and *D. chrysostoma* at Bird Island, South Georgia. Ibis 122: 488-494.

FUKUCHI, M. 1977. Regional distribution of amphipoda and euphausiasea in northern North Pacific and Bering sea in summer of 1969. Res. Inst. N. Pacific Fish., Hokkaido Univ. Spec. Vol.: 439-458.

GORDON, M. S. 1955. Summer ecology of oceanic birds off southern New England. Auk 72: 138-147.

GRUBB, T. C. 1971. Stomach oil in Procellariiformes: an extraction technique. Ibis 113: 529.

HARRISON, C. S., T. S. HIDA, & M. P. SEKI. 1983. Hawaiian seabird feeding ecology. Wildl. Monogr. 85: 1-71.

IMBER, M. J. 1976. The origin of petrel stomach oils—a review. Condor 78: 366-369.

KAWAGUCHI, K. 1969. [Diurnal vertical migration of macronektonic fish in the western North Pacific.] Bull. Plankton Soc. Japan 16: 63-66.

KOMAKI, Y. 1967. On surface swarming of euphausiid crustaceans. Pacific Sci. 21: 433-448.

KUBODERA, T., & K. JEFFERTS. 1984. Distribution and abundance of early life stages of squid, primarily Gonatidae (Cephalopoda, Oegopsidae), in the northern North Pacific, part 1. Bull. Natl. Sci. Mus. Tokyo, Ser. A, 10: 91-106.

MURANO, M., R. MARUMO, T. NEMOTO, & Y. AIZAWA. 1976. Vertical distribution of biomass of plankton and micronekton in Kuroshio water off central Japan. Bull. Plankton Soc. Japan 23: 1-12.

NAITTO, M., K. MURAKAMI, T. KOBAYASHI, N. NAKAMURA, & J. OGASAWARA. 1977. [Distribution and migration of oceanic squids (*Ommastrephes bartrami, Onychoteuthis borealijaponicus, Berryteuthis majister*, and *Gonatopsis borealis*) in the western subarctic Pacific region.] Res. Inst. N. Pacific Fish., Hokkaido Univ. Spec. Vol.: 321-337.

PALMER, R. S. 1962. Handbook of North American birds. Pp. 233-234. New Haven, Connecticut, Yale Univ. Press.

SEKIGUCHI, H. 1975. Seasonal and ontogenetic vertical migrations in some common copepods in the northern region of the North Pacific. Bull. Fac. Fish., Mie Univ. 2: 29-38.

TAKEUCHI, I. 1972. [Food animals collected from the stomachs of three salmonid fishes *Oncorhynchus* and their distribution in the natural environments in the northern North Pacific.] Bull. Hokkaido Reg. Fish Res. Lab. 38: 1-119.

TATARA, K., Y. YAMAGUCHI, & T. HAYASHI. 1962. [Study for the restoration of length and weight of prey fishes, found in the stomachs of predators, by graphic estimation using column length of fish vertebrae.] Bull. Naikai Reg. Fish Res. Lab. 16: 199-228.

VOLKMAN, N. J., P. PRESLER, & W. TRIVELPIECE. 1980. Diets of pygoscelid penguins at King George Island, Antarctica. Condor 82: 373-378.

WATANUKI, Y. 1985. Breeding biology of Leach's Storm-Petrels *Oceanodroma leucorhoa* on Daikoku Island, Hokkaido, Japan. J. Yamashina Inst. Ornithol.

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## Stability of Flock Composition in Urban Pigeons

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In temperate urban areas, feral Rock Doves (*Columba livia*) usually feed in flocks (Goodwin 1970). Although the term "flock" can be applied to avian groups that vary in their daily composition (Crook 1965, Morse 1980), it often is assumed that feral pigeon feeding aggregations that are fairly constant in size are made up of the same individuals from one observation to the next. Murton et al. (1972), for example, suggested that the composition of large pigeon flocks feeding on spilled grain in the port of Manchester is stable, but this may not be the case in habitats where pigeons depend on small, unpredictable sources of food. We conducted a study throughout the summer of 1984 on a small flock of urban Rock Doves in central Montréal, Québec to determine the stability of flock composition in this type of habitat. The study was done in the context of work on the cultural diffusion of a novel food-finding behavior (Lefebvre in press). For the cultural diffusion study, it was essential to know to what extent urban Rock Dove flocks are open or closed populations.

Forty-eight Rock Doves were captured with drugged seed (Thearle et al. 1971) at 0600 on 2 mornings in late May on a part of the McGill University