Chemical Composition of Guano of Burrowing Petrel Chicks (Procellariidae) at Marion Island

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Summary. Guano was collected directly from burrowing petrel chicks (Procellariidae) in their nest chambers, throughout their growth periods at Marion Island (46° 54′S, 37° 45′E). Guano production was measured, and concentrations of selected chemical components were determined. Chemical composition of guano was similar to that previously obtained for a wide range of surface-nesting bird species at Marion Island.

1 Introduction

A research programme to determine the roles of marine birds in the transfer of nutrients from the sea to the terrestrial ecosystem at Sub-Antarctic Marion Island was initiated in 1973 (Siegfried 1978). As part of this programme, Burger et al. (1978) determined the chemical composition of guano produced by surface-nesting birds but, until now, no comparable data were available for burrowing petrels (Procellariidae) which are abundant at the island (Williams et al. 1979).

Smith (1976, 1978, 1979) showed that the nutrient contents of plants and soils were higher in areas supporting populations of burrowing petrels than in areas not greatly influenced by manuring by these birds, and that plant species composition was related to manuring. In this paper I describe a method for collecting quantitative samples of guano from burrowing petrel chicks of all ages within their nest chambers, as a preliminary to assessing the contribution of burrowing petrel guano to the terrestrial ecosystem of Marion Island. The chemical composition of the guano is described, emphasis on those elements considered to be of significance as nutrients for plant growth.

2 Methods

Guano was collected from chicks of five species of burrowing petrels at Marion Island (46° 54′S, 37° 45′E) between April 1982 and May 1983. These species were: Blue Petrel, *Halobaena caerulea,* Softplumaged Petrel, *Pterodroma mollis,* Greatwinged Petrel, *P. macroptera,* Grey Petrel, *Procellaria cinerea,* and Whitechinned Petrel, *P. aequinoctialis.*

2.1 Collection of Guano

Occupied burrows were prepared by making a hole into the nest chamber, which was plugged by a turf or stone so that chicks could be removed and replaced easily (Sinclair 1981). Guano was collected directly at regular intervals from chicks of known age throughout their growth periods in their nest chambers, by fitting them with commercially available rubber washing-up gloves with slits in the wrists. The chick was placed in the glove, with its head facing out of the neck of the glove, and its legs and wings were then pulled through the most convenient slits. Loose glove material was gathered up behind the chick's head into a loop, which was held in position by metal staples. For small chicks, the neck of the glove was turned back before stapling. For larger chicks, the glove was extended by material from another glove, and stapled into position. Condensation within the glove was not a serious problem. This method allowed the chick full mobility, and did not affect its being fed by the parents. Chicks were kept in gloves for 24 h periods.

2.2 Chemical Analysis of Guano

Inorganic (available) nitrogen (NH_4-N, NO_3-N, and NO_2-N) was determined by colorimetry (Bremner 1965a). Although these analyses were done at Marion Island, logistical reasons precluded the collection and analysis of guano samples within the 24 h time limit normally required. This problem was overcome by the addition of 5 ml of a streptomycin sulphate solution (0.006 g in 200 ml distilled water) to 0.2 g guano (weighed to an accuracy of 0.001 g) and made up to 500 ml with distilled water (VR Smith, pers comm). The dry wt. of guano collected was recorded after drying samples at 100°C for 72 h in a forced-draught oven. The dried guano samples were later digested (Allen et al. 1974) and total N was determined by the macro-Kjeldahl method (Bremner 1965b), total P by the molybdenum blue method (Murphy and Riley 1962) and Ca, Mg, K, and Na by atomic absorption spectroscopy (Pringle et al. 1968).

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Table 1. Production and chemical composition (selected elements) of guano from five species of burrowing petrel chicks at Marion Island

	Blue Petrel	Greatwinged Petrel	Softplumaged Petrel	Grey Petrel	Whitechinned Petrel
Guano production (g dry wt. d^{-1})	0.6 ± 0.5 n = 30	0.8 ± 0.7 n = 32	0.6 ± 0.5 n = 7	1.7 ± 1.3 n = 47	1.8 ± 1.5 n = 32
Water content (% dry wt.)	1000 ± 1316 n = 22	740 ± 496 n = 28	960 ± 450 n = 11	1254 ± 725 n = 14	2036 ± 3087 n = 30
NH_4-N (mg g^{-1} dry wt.)	26.2 ± 18.6 n = 22	15.3 ± 19.9 n = 28	35.3 ± 20.6 n = 11	30.6 ± 30.9 n = 16	44.8 ± 21.8 n = 30
NO_3-N (mg g^{-1} dry wt.)	1.1 ± 1.1 n = 22	0.3 ± 0.8 n = 28	0.3 ± 0.6 n = 11	< 0.1 n = 18	5.3 ± 9.8 n = 30
NO_2-N (mg g^{-1} dry wt.)	0.1 ± 0.2 n = 22	2.6 ± 8.0 n = 28	< 0.1 n = 11	< 0.1 n = 18	< 0.1 n = 30
N (mg g^{-1} dry wt.)	158.3 ± 56.7 n = 15	162.0 ± 53.1 n = 8	173.9 ± 67.8 n = 7	196.6 ± 49.1 n = 9	147.2 ± 74.8 n = 21
P (mg g^{-1} dry wt.)	20.8 ± 12.5 n = 14	11.4 ± 4.8 n = 9	17.9 ± 8.1 n = 7	13.6 ± 5.5 n = 9	25.7 ± 14.7 n = 21
Ca (mg g^{-1} dry wt.)	61.4 ± 56.8 n = 14	25.3 ± 32.9 n = 9	91.8 ± 89.3 n = 7	31.1 ± 32.6 n = 9	41.0 ± 42.0 n = 21
Mg (mg g^{-1} dry wt.)	3.4 ± 1.1 n = 15	4.3 ± 1.6 n = 9	4.1 ± 2.2 n = 7	6.1 ± 2.8 n = 9	3.5 ± 1.5 n = 21
K (mg g^{-1} dry wt.)	13.4 ± 8.9 n = 15	16.3 ± 11.0 n = 9	8.8 ± 13.2 n = 7	16.3 ± 4.7 n = 9	18.3 ± 14.2 n = 21
Na (mg g^{-1} dry wt.)	8.2 ± 10.3 n = 15	30.0 ± 22.2 n = 9	23.2 ± 11.5 n = 7	17.8 ± 14.0 n = 9	20.7 ± 14.9 n = 21

Figures are means ± 1 S.D. integrated over the whole chick-growth period.

2.3 Statistical Methods

To identify possible relationships between age, amount of guano produced, and selected nutrients, regression analyses (linear, $\log_e$-linear and $\log_e$-$\log_e$, models) were done on all possible pair-wise combinations of variables (Dixon 1981).

3 Results

Large species produced most guano, ranging from a mean of 0.6 g guano (dry wt.) d^{-1} for the Blue Petrel and Softplumaged Petrel to 1.8 g d^{-1} for the Whitechinned Petrel (Table 1). In the Blue Petrel and Greatwinged Petrel, guano production increased with increasing age of the chicks (Table 2).

The guano of the 5 species was liquid in consistency (Table 1). Water content (expressed as % dry wt.) ranged from 740 (Greatwinged Petrel) to 2036 (Whitechinned Petrel). Most available N was in the form of ammonia (NH_4-N) (15.3–44.8 mg g^{-1}). Total N was higher (147.1–196 mg g^{-1}) than total P (11.4–25.7 mg g^{-1}) for each of the five species. Of the remaining selected elements, Ca was present in highest concentrations (25.3–91.8 mg g^{-1}) except for the Greatwinged Petrel; the concentration of Na being higher and Mg lower than for any other species (Table 1). Only two significant correlations between chick-age and a selected guano nutrient were found (Table 2).

4 Discussion

The chemical composition of burrowing petrel guano at Marion Island is essentially similar to that of surface-nesting seabirds breeding at the same locality (Table 1; Burger et al. 1978). However, the Na content of Greatwinged Petrel chick guano is the highest of all Marion Island seabirds.

Bedard et al. (1980), working in the St. Lawrence Estuary, Canada, studied soluble N content of guano of the

Table 2. Significant correlations from all possible pair-wise combinations of measured variables for guano of five species of burrowing petrel chicks

	Pair-wise combination	Correlation coefficient (r)	n	P
Blue Petrel	AGE vs GUANO	0.491	30	0.01
	AGE vs NO_3	0.560	22	0.01
	H_2O vs ln NO_3	0.855	15	0.001
	H_2O vs ln NH_4	0.596	22	0.01
	H_2O vs ln NO_2	0.795	12	0.01
	P vs Na	0.712	14	0.01
Greatwinged Petrel	ln AGE vs ln GUANO	0.477	37	0.01
	Na vs Mg	0.928	9	0.001
	ln K vs N	0.780	8	0.05
Softplumaged Petrel	H_2O vs ln N	0.903	7	0.01
	H_2O vs ln NH_4	0.689	11	0.05
Grey Petrel	AGE vs ln NH_4	0.532	18	0.05
Whitechinned Petrel	GUANO vs NO_2	0.547	30	0.01
	GUANO vs Ca	0.580	21	0.01
	H_2O vs NO_3	0.915	29	0.001
	Mg vs NO_3	0.817	9	0.01
	Mg vs Ca	0.634	21	0.01

Abbreviations: GUANO = guano production (g dry wt. d^{-1}); AGE = chicks in days; H_2O = water content (% dry wt.); for units of nutrients see Table 1.

Herring Gull, *Larus argentatus,* Great Blackbacked Gull, *L. marinus,* Ringbilled Gull, *L. delawarensis,* and the Common Eider Duck, *Somateria mollissima.* Bedard et al. (1980) suggested that seabird guano did not differ greatly in chemical composition with taxonomic grouping or with diet, although their data do not support this conclusion since the concentrations of soluble nutrients in Common Eider Duck guano were much lower than the concentrations of these nutrients in gull guano. This study and that of Burger et al. (1978) show that the chemical composition of seabird guano at Marion Island does not vary greatly between species or, at least in the case of burrowing petrels, with the age of chicks.

Most of the guano brought onto Marion Island by surface-nesting birds is deposited on bare rocks in penguin colonies where it is washed into the sea (Burger et al. 1978). Guano deposited in vegetated areas is more important to the terrestrial ecosystem of the Island, and burrowing petrels are the most important source of terrestrial manuring (Lindeboom 1979). Future reports will include seasonal estimates of the quantities of guano and nutrients deposited by burrowing petrels in different habitats at the Prince Edward Islands.

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References

Allen SE, Grimshaw HM, Parkinson JA, Quarmley C (1974) Chemical analysis of ecological materials. Blackwell, Oxford

Bedard J, Therriault JC, Berube J (1980) Assessment of the importance of nutrient recycling by seabirds in the St. Lawrence Estuary. Can J Fish Aquat Sci 37:583–588

Bremner JM (1965a) Inorganic forms of nitrogen. In: Black CA (ed) Methods of soil analysis. Am Soc Agron, Wisconsin (vol 2, pp 1178–1237)

Bremner JM (1965b) Total nitrogen. In: Black CA (ed) Methods of soil analysis. Am Soc Agron, Wisconsin (vol 2, pp 1149–1179)

Burger AE, Lindeboom HJ, Williams AJ (1978) The mineral and energy contributions of guano of selected species of birds to the Marion Island terrestrial ecosystem. S Afr J Antarct Res 8:59–70

Dixon WJ (ed) (1981) BMDP Statistical software. University of California Los Angeles

Lindeboom HJ (1979) Chemical and microbiological aspects of the nitrogen cycle on Marion Island (sub-Antarctic). PhD thesis, Univ Groningen

Murphy J, Riley JP (1962) A modified single solution method for the determination of phosphate in natural waters. Analytica Chim Acta 27:31–36

Pringle BH, Hissong DE, Katz B, Mulawka S (1968) Trace element accumulation by estuarine molluscs. J Sanit Eng Div Proc Am Soc Civ Eng 94:455–475

Siegfried WR (1978) Ornithological research at the Prince Edward Islands: a review of progress. S Afr J Antarct Res 8:30–33

Sinclair JC (1981) Techniques for observing Subantarctic burrowing petrels at the nest. Cormorant 9:67–71

Smith VR (1976) The effect of burrowing species of *Procellariidae* on the nutrient status of inland tussock grasslands on Marion Island. J S Afr Bot 42:265–272

Smith VR (1978) Animal-plant-soil nutrient relationships on Marion Island (Subantarctic). Oecologia (Berl) 32:239–253

Smith VR (1979) The influence of seabird manuring on the phosphorus status of Marion Island (Subantarctic) soils. Oecologia (Berl) 41:123–126

Williams AJ, Siegfried WR, Burger AE (1979) The Prince Edward Islands: a sanctuary for seabirds in the Southern Ocean. Biol Conserv 15:59–70