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Dispersal of algae and Protozoa by antarctic flying birds

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Cyanophyta, Chlorophyta, and Bacillariophyta are the predominate freshwater algae found in the antarctic (Holm-Hansen, 1964; Parker *et al.*, 1972; Cameron, 1972). These species can withstand diurnal freeze-thaw cycles; low humidities, annual precipitation, and magnetic field; and high winds and incoming radiation as well as high sublimation and evaporation rates so typical of the antarctic climate. Organic carbon and nitrogen also are extremely low except in a few areas where algal soil crusts have accumulated (Cameron, 1972). Cameron (1971) listed 14 species of Protozoa and 26 species of algae identified from the antarctic.

It has been well established that in the temperate zone many microalgae and Protozoa are dispersed by air currents (Schlichting, 1969). In contrast, the antarctic air is relatively free of microbes and insects and, therefore, birds probably are the most important agents dispersing microbes within antarctic ecosystems. Blue-green and other algal growth was most abundant where concentrations of guano, such as from skuas, were present (Cameron, 1972). Various studies of dispersal by birds in the temperate zone have been conducted for algae and Protozoa (Atkinson, 1972; McGuire, 1963; Proctor, 1959; Proctor and Malone, 1965; Schlichting, 1958, 1960; Sides, 1973), zooplankton (Loffler, 1963), and fungi (Warner, 1967; Warner and French, 1970). No studies have been conducted on the dispersal of these microorganisms by birds into and out of the Antarctic.

The bird specimens were obtained during the 1976 International Weddell Sea Oceanographic Expedition and earlier at Palmer Station. Specimens were shot, sealed in plastic bags immediately upon retrieval, and frozen for later analysis. The south polar skua (*Catharacta maccormicki*) and southern black backed gull (*Larus dominicanus*) specimens were collected over land at Palmer Station. The other species, arctic tern (*Sterna paradisaea*), cape pigeon (*Daption capense*), and giant fulmar (*Macronetes giganteus*) were collected at various locations in the Weddell Sea with the aid of the USCGC *Glacier*. Birds taken at sea were retrieved from the water within 5 minutes of shooting. Collection dates and localities for each specimen are listed in table 1. The microorganisms cultured are given in table 2.

Although the 15 bird specimens were frozen approximately 3 months prior to taking sample washings, nine birds rendered positive cultures containing nine species of algae, nine Protozoa, and 12 fungi. Three arctic terns, three cape pigeons, two giant fulmars, and one south polar skua transported microalgae and/or Protozoa.

These data are supported by Sides' (1973) findings that gulls more frequently carried microorganisms externally than internally. Atkinson (1972) also found little evidence of phytoplankton organisms transported internally. Schlichting (1960) showed great reductions in both numbers and species of algae and Protozoa carried externally by ducks after exposure to the air for 8 hours.

All species of blue-green algae sampled from the arctic terns collected in Antarctica, *Anacystis marine, A. montana, Nostoc commune*, and *Schizothrix calcicola*, have been collected from pools on Ellesmere Island, Northwest Territories, Canada (83°08'N.), less than 800 kilometers from the North Pole (Croasdale, 1973) and from antarctic soil (Cameron, 1971). This suggests that these blue-green algae, seldom found in atmospheric samples (Schlichting, 1969), may be transported between polar regions by birds. Thomson (1977) suggests that long range dispersal and establishment of bipolar lichens may be occurring. *Usnea sulpharreus*, for example, grows on rocks in northern Greenland and some arctic islands of Canada as well as the antarctic. Explanation for the means of such disjunctive dispersal has been exceedingly controversial. Suggestions include: (1) separate evolution of the species in the two polar regions; and (2) dispersal by birds migrating along such mountain chains as the Rocky Mountains and the Andes. (Possible evidence of such migration routes is certain lichen species at a few intermediate locations in the southern Andes.).

Characteristics of the antarctic soil bacterial species appear to be most similar to those isolated from soils of the Chilean Atacama Desert. *Mycococcus sp.*, found in Antarctica as well as Chile, also occurs in high mountain soils. It exhibits pleomorphism which may aid survival in harsh environments (Cameron *et al.*, 1970). This also may be true of the algae and Protozoa (Schlichting and Bruton, 1970; Trainor *et al.*, 1971).

South polar skuas banded at Palmer Station have been recovered along the coasts of Argentina and western Mexico (Baja, California), and from Greenland (Parmelee *et al.*, 1977). Watson (1975) indicated that skuas regularly disperse northward to the subtropics during the austral winter and less often into the Northern Hemisphere. Thus, the south polar skua as well as the arctic tern may transport micro-organisms between polar regions, although the skuas examined in this study did not have positive tests for these blue-green algal species.

Organisms are not found in all suitable habitats. Their restriction may be attributed to competition in reaching suitable habitats; or repeated invasions may modify the habitat and finally allow for their establishment.

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Table 1. Antarctic birds collected.

Bird	Specimen Number	Species[a]	Collection Location	Date (1976)
1	0306 8	Giant fulmar (*Macronectes giganteus*)	66°52′S.49°56′W.	20 Feb
2	0806 11	Giant fulmar (*Macronectes giganteus*)	59°53′S.52°28′W.	29 Feb
3	0306 10	Cape pigeon (*Daption capense*)		3 Jun
4	0306 9	Cape pigeon (*Daption capense*)	64°15′S.43°56′W.	3 Jun
5	2305 6	Cape pigeon (*Daption capense*)	64°15′S.43°56′W.	12 Feb
6	2305 7	Cape pigeon (*Daption capense*)	59°53′S.52°28′W.	29 Feb
7	1905 1	Arctic tern (*Sterna paradisaea*)	67°12′S.45°35′W.	18 Feb
8	1905 s	Arctic tern (*Sterna paradisaea*)	67°12′S.45°35′W.	18 Feb
9	1905 3	Arctic tern (*Sterna paradisaea*)	67°12′S.45°35′W.	18 Feb
10	2305 4	Arctic tern (*Sterna paradisaea*)	67°12′S.45°35′W.	18 Feb
11	2305 5	Arctic tern (*Sterna paradisaea*)	67°12′S.45°35′W.	18 Feb
12	NA[b]	Southern black backed gull (*Larus dominicanus*)	Old Palmer Station	7 Feb
13	NA	Southern black backed gull (*Larus dominicanus*)	Old Palmer Station	7 Feb
14	NA	South polar skua (*Catharacta maccormicki*)	64°46′S.64°04′W.	7 Feb
15	NA	South polar skua (*Catharacta maccormicki*)	64°46′S.64°04′W.	7 Feb

[a]Taxonomy after Watson (1975)
[b]NA=None assigned.

Table 2. Algae and protozoa cultured from sterile washings of selected antarctic flying birds.

Specimen number	Area of washing	Culture media[a]	Organisms cultured[b]
Arctic tern			
1905 1	Feet	1&2	Anacystis marina
			Schizothrix calcicola
			Tetracystis like
			Uncl. zooflagellate
	Tail Feathers[c]	1&2	Chlorella vulgaris
			Nostoc commune
			Schizothrix calcicola
			Bodo like
			Uncl. zooflagellates (2)
	Wing Feathers	1&2	Chlorella sp.
			Uncl. zooflagellate
	Breast Feathers	3	Schizothrix calcicola
1905 3	Bill	1&2	Anacystis marina
			Chlorella vulgaris
			Nostoc commune
			Tetracystis like
			Mastigamoeba sp.
	Wing	1&2	Chlorella sp.
			Bodo like
			Uncl. zooflagellates (2)
2305 4	Feet	1&2	Chlorella minutisima
			Valkamphia limax type
			Monas sp.
2305 6	Breast Feathers	1&2	Anacystis montana
			Tetracystis like
			Mastigamoeba sp.
			Monas sp.
	Feet	1&2	Anacystis montana
			Chlorella vulgaris
			Chlorella zofingiensis
			Nostoc commune
			Uncl. zooflagellates (2)
Cape pigeon			
0306 8	Tail Feathers	3	Anacystis marina
0306 9	Gullet	1&2	Chlorella sp.
	Wing	1&2	Chlorella sp.
0306 10	Feathers		
0306 10	Feet	1&2	Uncl. zooflagellate
Giant fulmar			
0806 11	Bill	1&2	Anacystis marina
			Monas sp.
			Saccamoeba stagnicola
			Valkamphia spp.
	Gullet	1&2	Anacystis marina
			Monas sp.
			Saccamoeba stanicola
			Vahlkampfia spp.
	Feet	3	Chlorella sp.
			Uncl. zooflagellate
South polar skua[d]			
	Feces	1&2	Chlorella sp.

[a]Media utilized: 1. Bold's basal medium & soil water extract (50/50)
2. Bold's basal medium, soil water extract and 3 drops sodium silicate per 100 milliliter
3. Erdschreiber's medium & 20 percent soil water extract
[b]Algal taxonomy after Bold (1970), Drouet (1968), Drouet and Daily (1956), Fott (1964), and Kantz and Bold (1969). Some protozoan identifications were made by Eugene Bovee, University of Kansas.
[c]The three longest feathers on the wing and tail were sampled.
[d]Only bills and fecal matter were studied.

taxonomic study of the Protozoa; Clifford M. Wetmore provided laboratory facilities; and John W. Thomson, Department of Botany, University of Wisconsin, Madison, critically read the manuscript.

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Behavioral and ecological adaptations in pygoscelid penguins

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The objective of our work was to determine if and how sympatrically breeding pygoscelid penguins partition critical resources, *i.e.*, time, breeding habitat, and food. During the 1977-78 field season, we collected a second season's data on breeding success, predator-prey dynamics, interspecific interactions, breeding habitat, food utilization, and rate of chick growth of three pygoscelids.

From 1 November 1977 to 20 February 1978, W. Trivelpiece and N.J. Volkman stayed at the Polish Academy of Sciences, Henryk Arctowski Research Station, in Admiralty Bay near Point Thomas, King George Island, South Shetland Islands (62°10'S. 58°30'W.).

In Admiralty Bay there are two rookeries, Point Thomas and "Llano Point," (unofficial name) with breeding penguins of all three pygoscelid species—the Adēlie penguin (*Pygoscelis adeliae*), the chinstrap penguin (*P. antarctica*), and the gentoo penguin (*P. papua*).

Egg-laying began about 10 days later in 1977 than in 1976, probably because of unusually heavy sea ice during the 1977 austral winter. Adēlies began egg-laying in late October (exact dates unknown due to late arrival of investigators), chinstraps on 19 November and gentoos on 7 November. Peak egg-laying dates for Adēlies and gentoos were 2 weeks apart; those of gentoos and chinstraps were 8 days apart. A similar spacing of egg-laying dates was observed during 1976.

We studied the food utilization in collaboration with Piotr Presler, biologist at the Polish Academy of Sciences and Lodz University. Whole and partial stomach samples were collected throughout the breeding season. *Euphausia suberba* constituted 99.7 percent of the diet of *P. adeliae* and *P. antarctica* by volume, and fish and amphipods comprised the remaining 0.3 percent. *P. papua* stomachs were found to contain 85 percent *E. superba*, 14 percent fish, and 1 percent amphipods. White and Conroy (1975), sampling in the South Orkneys, also found that *E. superba* made up nearly 100 percent of the diet of Adēlies and chinstraps. In contrast, they found that fish constituted 100 percent of the gentoo's diet. The sex, length, and weight of *Euphausia* in the stomach samples are presently being analyzed.

The competition for breeding habitat between Adēlie and chinstrap penguins was monitored for a second season. In the Pt. Thomas rookery, about 300 of the approximately 750 breeding chinstrap penguins obtained their nest site by actively displacing established Adēlie pairs. Observations at Llano Pt. indicated that about 50 percent of the chinstraps used nests previously occupied by Adēlies. The male chinstraps arrived 1-4 days before their mates and competed for nest sites with Adēlies. As chinstraps began nesting 15 to