ADÉLIE PENGUIN ROOKERIES IN THE LÜTZOW-HOLM BAY AREA AND RELATION OF ROOKERY TO ALGAL BIOMASS IN SOIL

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Abstract: Twelve Adélie penguin rookeries were found in the ice-free areas on the Prince Olav Coast and the Sôya Coast. The population size in each rookery was estimated based on the data collected by the personnel of Japanese Antarctic Research Expedition (JARE) and the authors. In the region surveyed by JARE, the total population of Adélie penguins in the rookeries was about 2000 to 3000.

The distribution of the biomass of microalgae in soil was studied in Ongulkalven. The biomass was high around the presently used rookery and abandoned rookeries and in the wet parts of the depressions. The ratio of chlorophyll-*a* to the sum of chlorophyll-*a* and phaeophytin was high in the areas well supplied with melt water from the snow drifts.

1. Introduction

In order to analyze the coastal ecosystem in a certain region it is necessary to estimate the population size of the Adélie penguin (*Pygoscelis adeliae*) because the penguin occupies a high trophic level in the Antarctic coastal ecosystem. In the region the Japanese Antarctic Research Expedition (JARE) dealt with, some sporadic information on the location of rookeries and on the penguin populations was obtained by the biologists and other expedition members. Part of the information obtained appeared in the scientific publications (MATSUDA, 1964; AOYANAGI, 1973a, b), and the rest was reported either verbally or published in the technical reports issued by the Headquarters of Japanese Antarctic Research Expedition (Publication of the reports was handed over to the National Institute of Polar Research in 1974).

In the early summer of 1975, one of the authors, HOSHIAI surveyed the rookeries along the Sôya Coast with the aircraft, Cessna A 185F. The present data including the previous results by the JARE personnel will suffice to estimate the number of Adélie penguins in the rookeries in the region dealt with by JARE. Therefore, the authors describe the geographical position of the rookeries discovered hitherto and the penguin population in these rookeries.

It is well known that peculiar and remarkable vegetation such as the one dominated by *Prasiola crispa antarctica* is formed near the Adélie penguin rookery. The distribution of the microscopic algae in soil is also influenced by Adélie penguins. The relationship between the penguin rookery and the biomass of microalgae in soil as well as *Prasiola* was investigated in Ongulkalven. The results obtained are also mentioned in the present report.

2. Results and Discussions

2.1. The Adélie penguin rookeries in the vicinity of Lützow-Holm Bay

Since 1957 only two rookeries have been reported from the Prince Olav Coast. However, the survey of penguin rookeries has not been carried out so intensively that further findings on the coast can be expected. In the meantime, 10 rookeries have been recognized along the Sôya Coast, the east coast of Lützow-Holm Bay. The locality of the rookeries is shown in Fig. 1 and the detailed situations of them are given in Fig. 2.

Due to the difficult conditions of ice and logistics, the visits to the rookeries had

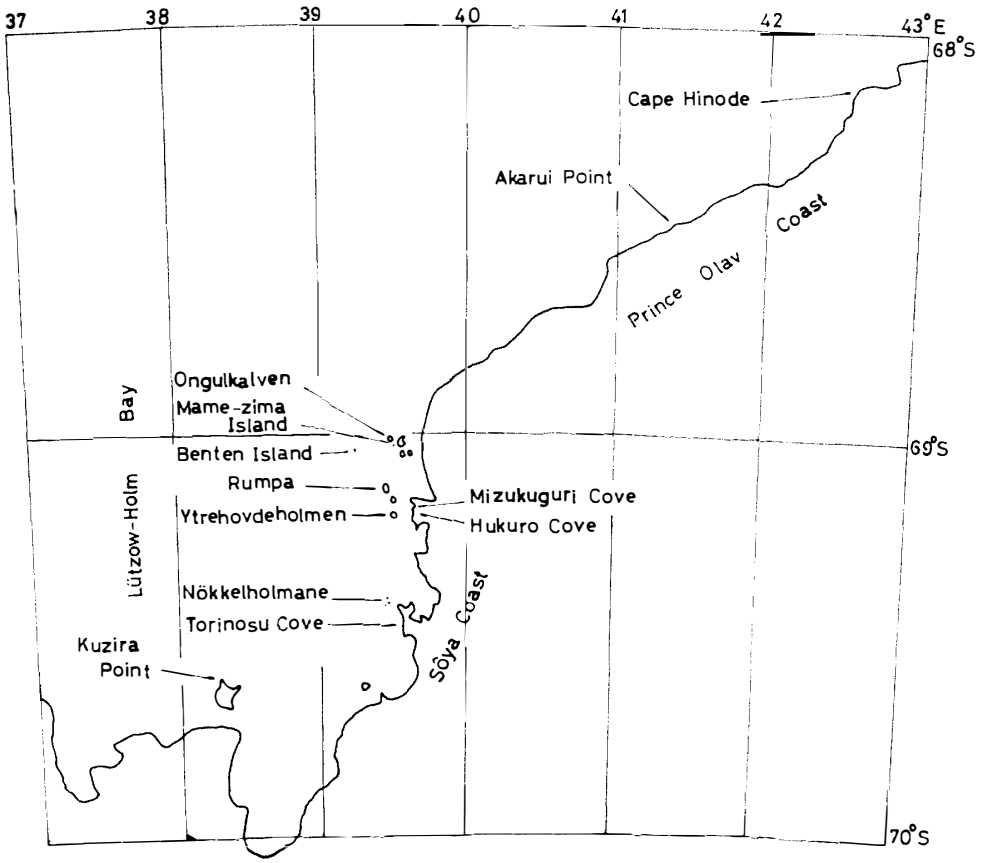

Fig. 1. Distribution of the Adélie penguin rookeries in the vicinity of Lützow-Holm Bay.

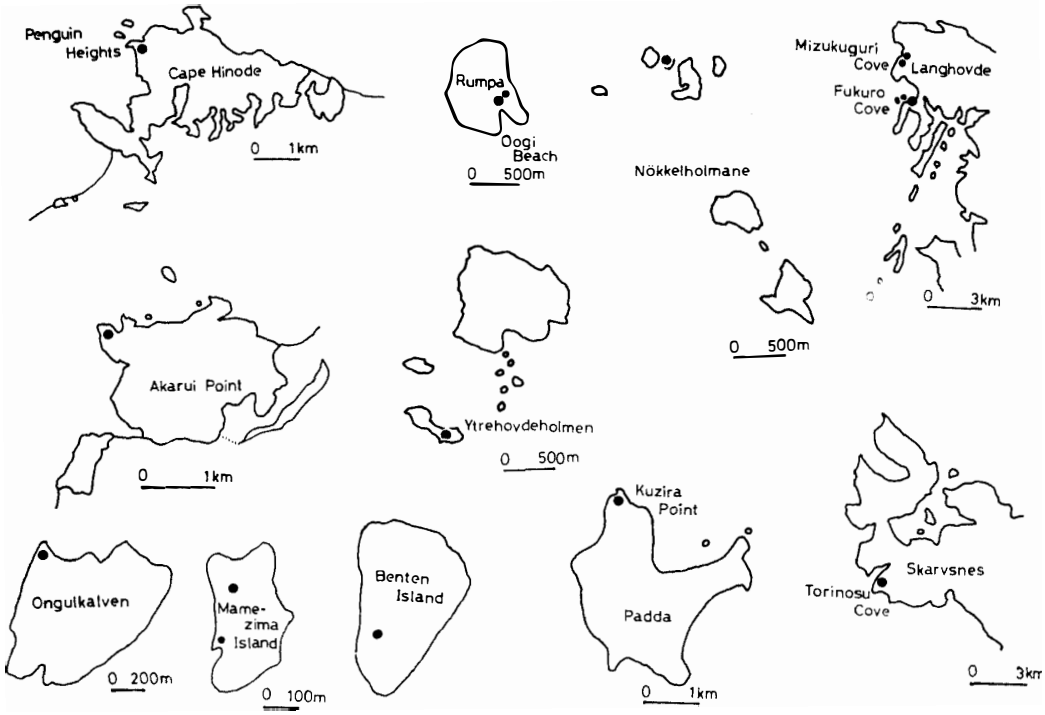

Fig. 2. Detailed situations of the Adélie penguin rookeries.

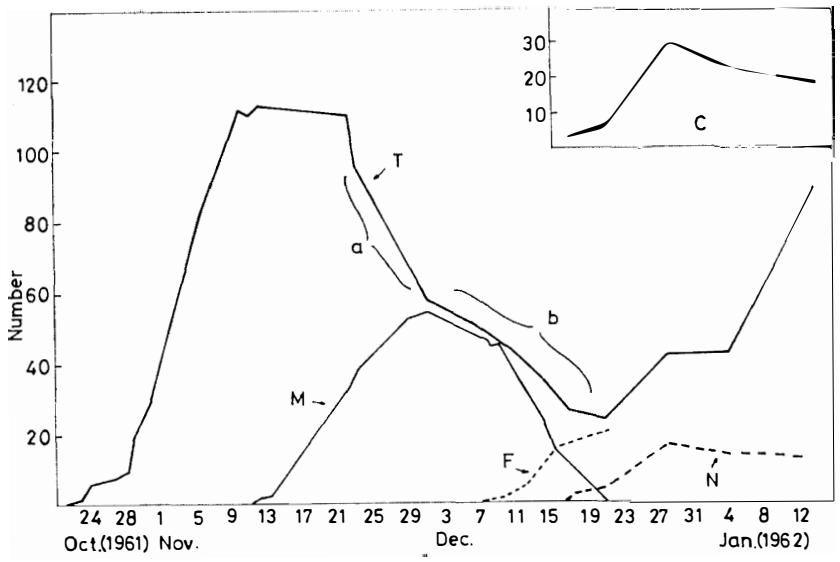

Fig. 3. Change in individual number of Adélie penguins at the rookery.
T: Total number. M: Incubating male. F: Incubating female (replacing male). N: Nest number having chicks. C: Chick number (MATSUDA, 1964).

Table 1. Adélie penguin rookeries in the vicinity of Syowa Station.

Rookeries	Previous records	Present observations	Assumed population size
1. Penguin Heights, Cape Hinode (68°08′47″S, 42°39′48″E)	122 adults, 45 chicks and 12 eggs, 2 Jan. '72 (AOYANAGI pers. commun.) 119 adults, 45 chicks and 12 eggs, 3 Jan. '72 (AOYANAGI pers. commun.) 139 adults, 1 Jan. '73 (AKIYAMA and KURODA, 1974)		200 (AOYANAGI, 1973a) 150±50
2. Akarui Point (68°29′S, 41°23′E)	MORIWAKI found 2 adults and 56 chicks, 6 Feb. '75 (YOSHIDA, 1975)		170±50
3. Ongulkalven (69°01′S, 39°26′E)	110 adults, in the early half of Nov. '61 (MATSUDA, 1964) 113 adults, 13 Nov. '71 (WATANUKI, pers. commun.) 55 adults, 16 chicks and one egg, 17 to 20 Jan. '72 (AOYANAGI, 1973b) 88 adults, 15 Nov. '72 (MIWA, 1973) 59 adults, 39 chicks and 3 eggs, 10 Jan. '73 (AKIYAMA and KURODA, 1974) 73 adults and 12 eggs, 17 Nov. '74 (YAMANAKA, pers. commun.) HOSHIAI found one adult and 29 chicks, 6 Feb. '75 (YOSHIDA, 1975)	27 adults by oblique aerophotograph, 30 Nov. '75 50 adults and 3 eggs, 17 Nov. '75	50–150
4. Mame-zima Island (69°01′S, 39°29′E)	29 adults, 14 chicks and no egg, 31 Jan. '72 (AOYANAGI, pers. commun.) 62 adults, 18 Nov. '72 (MIWA, 1973)	21 adults by oblique aerophotograph, 30 Nov. '75	30–70
5. Benten Island (69°02′28″S, 39°15′11″E)		7 adults, 14 Nov. '77 (FUJISAWA, pers. commun.)	5±5

Table 1. (*Continued*)

Rookeries	Previous records	Present observations	Assumed population size
6. Oogi Beach, Rumpa (69°08′45″S, 39°25′30″E)	1780 both adults and chicks, 1 Feb. '69 (MISHIMA and TAKAHASHI, 1969) 442 individuals by aerophotograph, 14 Feb. '71 (NISHIWAKI, 1972) 209 chicks in 5 creches, 3 Feb. '72 (AOYANAGI, pers. commun.) 58 adults and 380 chicks, 29 Jan. '73 (AKIYAMA and KURODA, 1974)	533 adults by oblique aerophotograph, 30 Nov. '75	1000–1500
7. Ytrehovdeholmen (69°13′S, 39°26′E)		13 adults by olique aerophotograph in the middle of December '75	40±10
8. Nökkelholmane (69°23′30″S, 39°28′E)		32 adults by oblique aerophotograph in the middle of December '75	100±30
9. Mizukuguri Cove, Langhovde (69°11′30″S, 39°38′E)		39 adults by oblique aerophotograph, 30 Nov. '75	80±30
10. Hukuro Cove, Langhovde (69°12′30″S, 39°39′E)	10 adults and 120 chicks, 2 Feb. '73 (AKIYAMA and KURODA, 1974)	142 adults by oblique aerophotograph, 30 Nov. '75	250–400
11. Torinosu Cove, Skarvsnes (69°29′S, 39°33′40″E)	13 adults and 59 chicks, 2 Feb. '73 (AKIYAMA and KURODA, 1974)	50 adults by oblique aerophotograph, 30 Nov. '75	70–200
12. Kuzira Point, Padda (69°36′S, 38°18′E)	Field party of JARE-16 found 14 adults and 10 chicks, in late Jan. '75 (YOSHIDA, 1975)	12 adults by oblique aerophotograph in the middle of December '75	20–40

to be made with the aid of the helicopters of icebreaker FUJI in summer, the latter half of the breeding season, except for the Ongulkalven rookery and two or three rookeries which are easily accessible from Syowa Station in winter. Two aerial observations were carried out on 30 November and in the middle of December, 1975. It was recognized that the number of individual birds counted in two seasons mentioned above is less than the population at the peak time, early November. Therefore, a computation based on an appropriate standard is required for estimating the population size in most of rookeries.

MATSUDA observed the breeding behavior of Adélie penguins at the Ongulkalven rookery in the 1961–1962 season and described the fluctuations of penguin population (MATSUDA, 1964). As shown in Fig. 3, the conspicuous increase in population occurred from late October to 11 November subsequently to the first appearance of the penguins. The highest level of population was maintained during the middle of November. Thereafter the population began to decrease and at the end of November it reached about half of its peak, because female birds after egg-laying went to the open water to feed. The population continued to decrease until the middle of December as males strayed away. Then in January, with an addition of non-breeding adults, the population began to increase and recovered to 50 to 80% of its peak. The information brought by the wintered personnel of JARE substantially agreed with MATSUDA's description.

MATSUDA (1964) pointed out the high mortality in egg and chick population at the Ongulkalven rookery. He mentioned that one-third of the laid eggs succeeded to hatch out and only 17% of them could become juvenile birds, because of the difficulty in seeking the feeding ground in the ice-bound Lützow-Holm Bay area.

Accordingly, the inferred population given in Table 1 is based on an assumption that the population is twice the birds observed on 30 November, three times the birds discovered in the middle of December and also three times the chicks counted in January and February. In estimation, an adequate range of the yearly fluctuations of population was taken into account. Consequently, the total number of adult birds in the rookeries is estimated at 2000 to 3000 in the vicinity of Lützow-Holm Bay. Data on the rookeries discovered before the end of November 1977 are compiled in Table 1. The population of Adélie penguins in this region is extremely low compared with that of the Ross Sea area (TAYLOR, 1964). STONEHOUSE (1967) showed the importance of the open water in the variation of penguin population in McMurdo Sound. The low penguin population may be ascribed to the persistency of fast ice in the Lützow-Holm Bay area.

2.2. Relation between penguin rookery and biomass of algae in soil

The impact of Adélie penguins on the local vegetation was perceptible, though the penguin population is low in the Lützow-Holm Bay area. There was the *Prasiola crispa antarctica* vegetation around the presently occupied rookery in

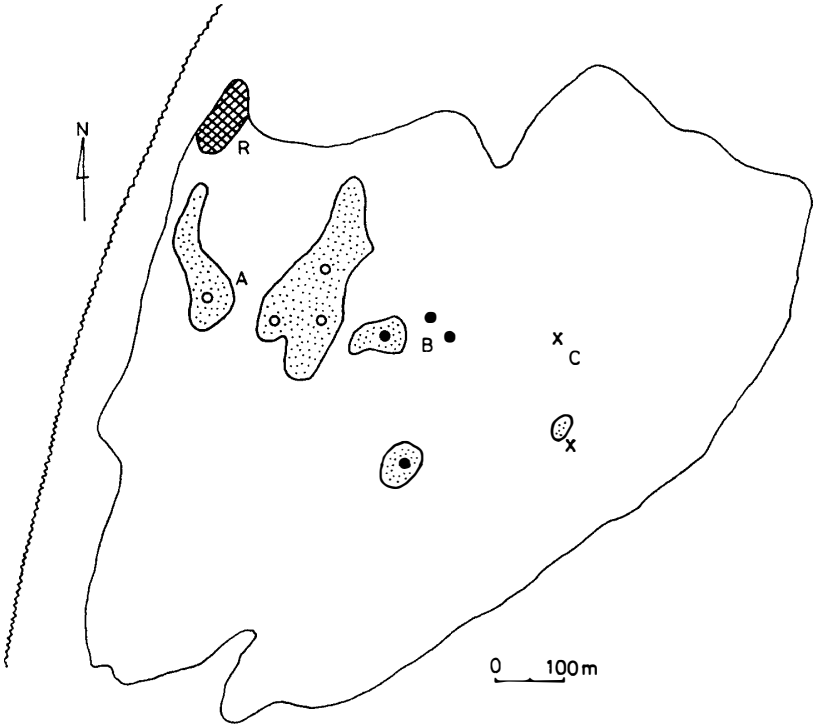

Fig. 4. Relation between the Adélie penguin rookery and algae. R: Presently used rookery. A, B and C: Abandoned rookeries. Dotted parts are algal vegetations (MATSUDA, 1968).

Table 2. Relation between the penguin rookery and the flora and fauna (MATSUDA, 1968).

Penguin rookery	pH	Flora	Number of protozoan species
R: Rookery (now occupied)	7.6–8.3	*Nostoc* sp. (++) *Prasiola crispa antarctica* (+)	1
A: Old rookery (abandoned)	6.3–6.7	*Prasiola crispa antarctica* (++) *Nostoc* sp. (+)	7
B: Oldest rookery (abandoned)	7.0	*Nostoc* sp. (+)	0
C: One or two nests of the penguin (abandoned)	No water		

the northwestern part of Ongulkalven. The vegetation was found not only around the rookery presently in use but also around some rookeries already abandoned. MATSUDA (1968) reported the ecological succession in microfauna and microflora depending on the lapse of time after the abandonment of rookeries. He classified the abandoned rookeries into A, B and C according to the time when the rookeries

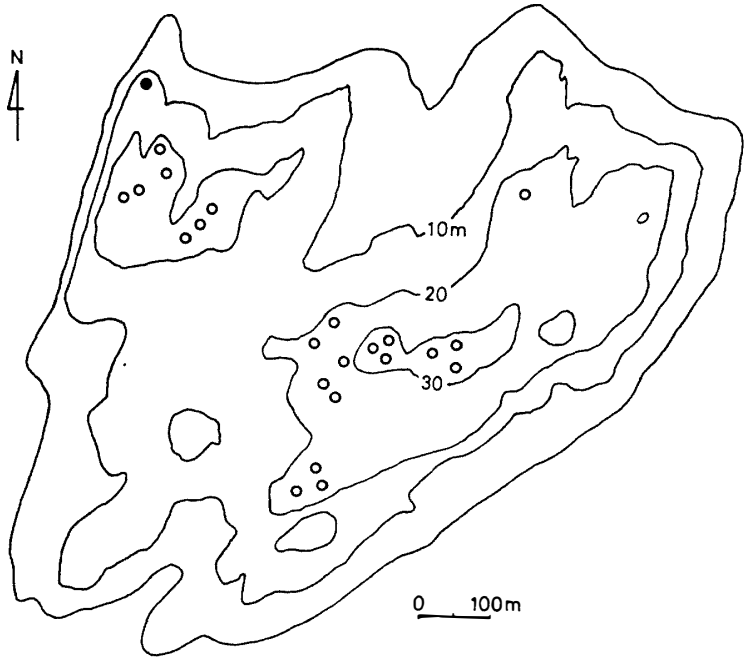

Fig. 5. Presently used rookery (●) and abandoned rookeries (○).

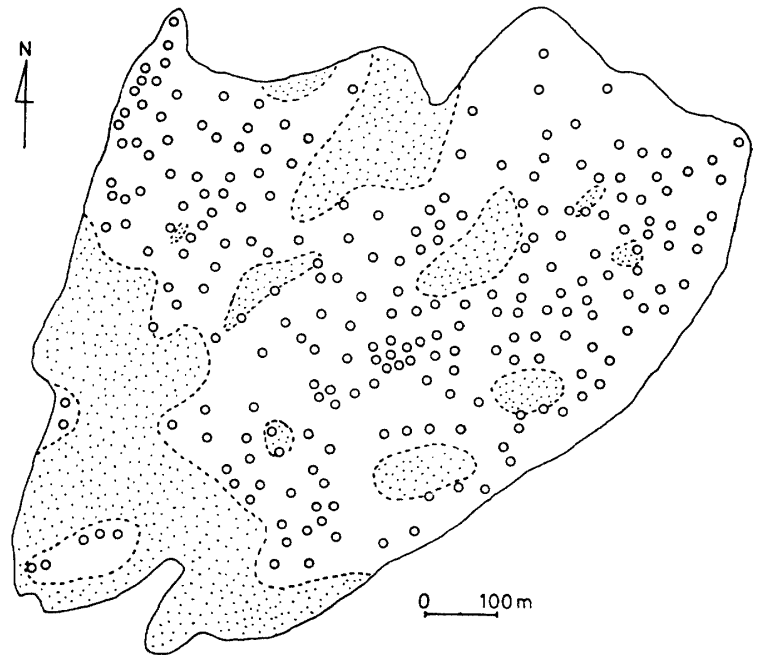

Fig. 6. Soil sampling sites in Ongulkalven. Dotted parts are snow drifts.

were abandoned (Fig. 4). The order of abandonment is C, B and A. As illustrated in Fig. 4 and Table 2, *Nostoc* sp. and *Prasiola crispa antarctica* were abundant around the presently used rookery and the A rookery. The water pools in those

rookeries were also inhabited by ciliated protozoans. Both fauna and flora were scanty around the older rookeries, the B and the C. As the geographical map of this island was not available when MATSUDA's work was carried out, the position of the abandoned rookeries in Fig. 4 was somewhat erroneous. Fig. 5 gives the correct situation of the rookeries in which the A, B and C rookeries designated by MATSUDA are recognizable.

In the present paper, the authors attempted to examine more quantitatively the relationship between the rookeries and the distribution of algae in soil. The chlorophyll-*a* and phaeophytin contents in soil were determined at 229 sites, which cover most part of the ice-free area in this island (Fig. 6).

At each site, 5 m*l* of soil was sampled from the ground surface. Soil sampled was put into 15 m*l* of 90% aqueous acetone. After shaking, it was left for 24 hours in a dark box under room temperature of 15 to 18°C. 12 and 6 hours before the determination, it was repeatedly shaken. The supernatant was centrifuged for 5 minutes at 3000 rpm. Subsequently the initial fluorescence (Fo) was measured. After acidified with two drops of 0.5 N hydrochloric acid, the fluorescence (Fa) was again measured. The fluorometer used was Hitachi FPL-2 Type installed with a red sensitive photomultiplier (Hamamatsu Electric Co. Ltd., R-136). A Hitachi 436 mμ filter was used for excitation and a Toshiba 660 mμ filter was used for the measurement of the emission.

The concentration of chlorophyll-*a* and phaeophytin was calculated with the following equations:

$$\text{Chlorophyll-}a\ (\mu g/ml) = \frac{Fo-Fa}{7.4} \cdot \frac{\text{acetone (m}l)}{\text{soil (m}l)} \cdot \frac{1}{1000}$$

$$\text{Phaeophytin}\ (\mu g/ml) = \frac{5.1\ Fa-Fo}{7.4} \cdot \frac{\text{acetone (m}l)}{\text{soil (m}l)} \cdot \frac{1}{1000}$$

Fo: Fluorescence before acidification
Fa: Fluorescence after acidification

where 5.1 and 7.4 are the constant for this fluorometer.

The distribution of the biomass of microalgae in soil which was indicated by the sum of chlorophyll-*a* and phaeophytin concentration is shown in Fig. 7. Generally, high values of biomass were found around the penguin rookeries. In particular, the values higher than 10 μg/m*l* of biomass were found near the presently used rookery, near the A rookery and in restricted areas of the B rookery. The biomass around the B rookery was intermediate between those near the A and the C rookeries. On the other hand, it is noteworthy that the high biomass was found in some places apart from the penguin rookeries.

The ratio of chlorophyll-*a* to the sum of chlorophyll-*a* and phaeophytin is acceptable as an index to show the amount of the active fraction in the plant pig-

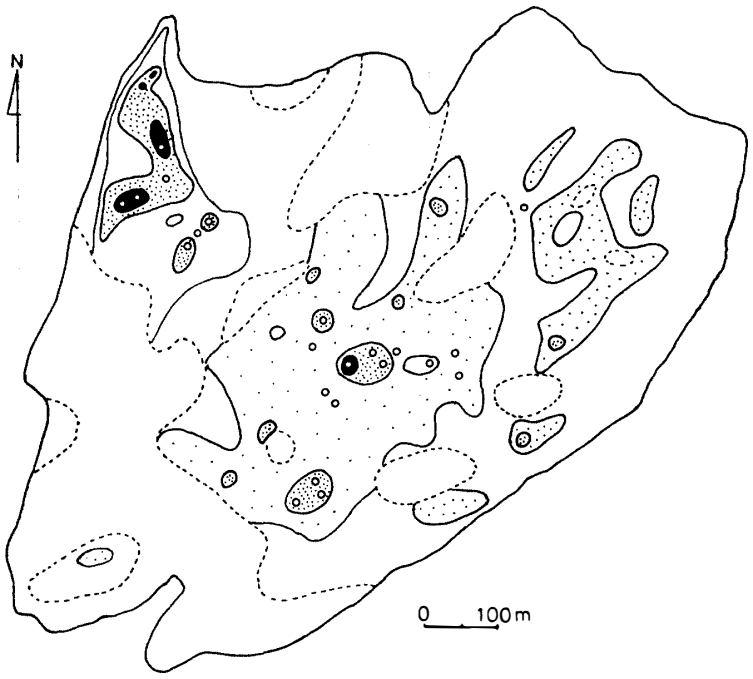

Fig. 7. Distribution of the biomass of microalgae in soil. Black part: above 10 μg/ml in the sum of chlorophyll-a and phaeophytin. Thick dotted part: between 10 and 1.0μg/ml. Thin dotted part: between 1.0 and 0.1 μg/ml. White part: below 0.1 μg/ml and snow drifts shown by broken line.

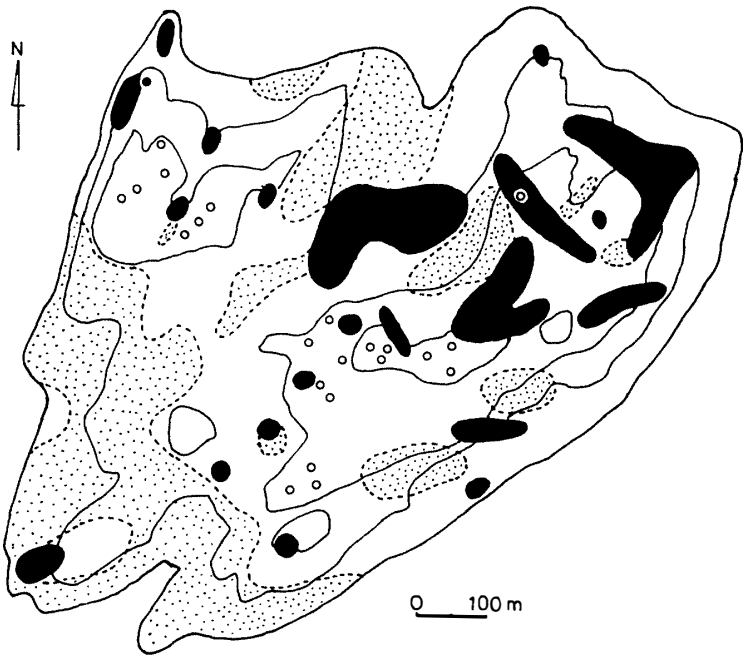

Fig. 8. Areas of higher values in the ratio of chlorophyll-a to the sum of chlorophyll-a and phaeophytin. The ratio of chlorophyll-a exceeds 30% in the black parts. (●) Presently used rookery, (○) abandoned rookeries.

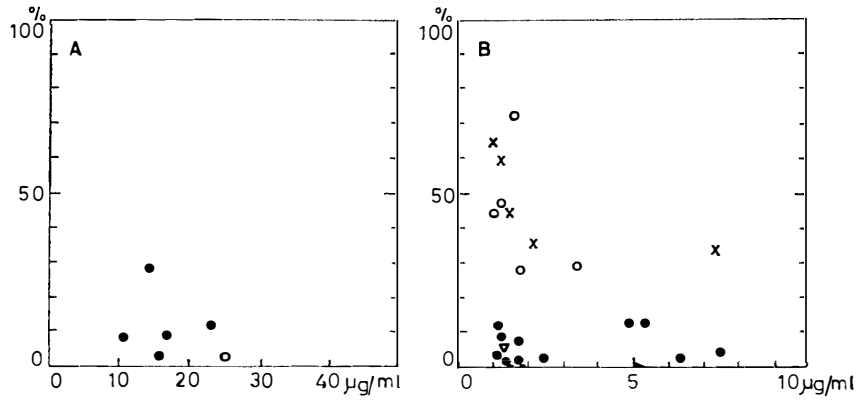

Fig. 9. Relation between the chlorophyll-a ratio and the topography in the areas of high biomass. (○) Presently used rookery. (●) Abandoned rookery. (×) Depression. (△) Hill.

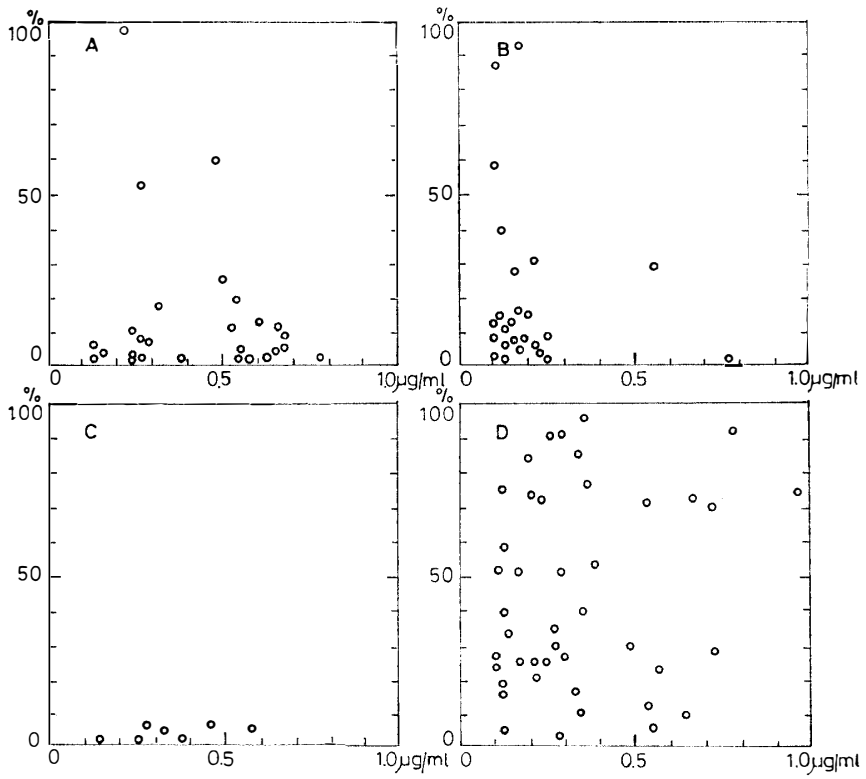

Fig. 10. Relation between the chlorophyll-a ratio and the topography in the areas of medium amount of biomass. A: Abandoned rookery. B: Hill. C: Head of depression. D: Depression.

ments. The areas where the ratio of chlorophyll-*a* exceeded 30% are shown in Fig. 8. The areas of high values in the ratio of chlorophyll-*a* are distributed in the northeastern part of the island. These areas are hardly influenced by penguins,

but are well supplied with melt water from the adjacent snow drifts. The relations of the biomass and the chlorophyll-*a* ratio to the effects of penguins and melt water were examined. The chlorophyll-*a* ratio was low at six sites where the biomass exceeded 10 μg/m*l* (Fig. 9) and five out of six were situated around the abandoned rookeries. The rest was at the presently used rookery. The sites where the biomass was between 1.0 μg/m*l* and 10 μg/m*l* were divided into two groups with respect to the ratio of chlorophyll-*a*. Some of the sites belonging to the high ratio group were situated near the presently used rookery and were supplied with melt water from snow patches accumulated in the lee of rocks around the rookery. Four sites in the high chlorophyll-*a* ratio group were located in the depressions which were distant from the rookeries but were supplied with water from the snow drifts. However, it must be mentioned that there were abandoned rookeries at the top of these drifts behind the four sites mentioned above. This shows the possibility that the melted snow carries some nutrients from the rookeries. Sometimes the plumage of penguins was found embedded in the drifts distant from the presently used rookery, which suggests that the excremental substances are transported with feather from the presently occupied rookery by wind. On the other hand, as shown in Fig. 10, the sampling sites where the ratio of chlorophyll-*a* was high but the biomass was lower than 1.0 μg/m*l* are frequently in the depressions but occassionally in the abandoned rookeries at the head of the depressions and the hills. Therefore, it is concluded that the present activity of microalgae in soil depends upon the degree of water supply and the biomass is influenced by the fertility of soil which is increased by excrements of penguins.

Acknowledgments

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