received aboard an aircraft. Their successful utilization during the survey demonstrated that satellite photographs provided by an airborne APT station can be useful in the planning and operation of a subarctic airborne oceanographic survey. In addition, the experiment showed that the photographs collected during the survey can provide valuable data on the regional and local ice and weather conditions for use in the post-survey analysis.

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A Microbiological Study of some Lake Waters and Sediments from the Mackenzie Valley with Special Reference to Cytophagas

INTRODUCTION

The microbial population of arctic lakes has not yet been thoroughly investigated. A few studies have established the presence of cold-tolerant[1] as well as mesophilic and thermophilic bacteria[2,3]. Bunt[1] has recently reviewed the productivity of both aquatic and permafrost environments in polar regions, and although some work has been achieved with green and blue-green algae few bacteriological data are available. Considerably more microbiological work has been done on permafrost soils than on the associated arctic lakes[4].

This paper is a report on the microbial flora of the waters and sediments of five lakes from the Canadian Subarctic, with special emphasis on the genus *Cytophaga.* The cytophagas are long, thin rods which are capable of flexing in liquids and of gliding motility on solid surfaces. They are important in the degradation and recycling of many relatively resistant, macromolecular polysaccharides and proteins such as cellulose, chitin, agar and keratin which occur as structural or storage residues of "higher" plants and animals in the natural environment.

MATERIALS AND METHODS

The samples were collected aseptically during the summer of 1971, flown to Edmonton and stored at 4°C until processed, within two days of sampling time. Three media which allow good growth of cytophagas[5] were used: Cook's cytophaga agar (C.C.A.), tryptone yeast acetate (T.Y.A.), and skim milk acetate (S.M.A.). Duplicate sets of plates were inoculated with dilutions of each sample and incubated at about 25°C for 11 days, and at 10°C for 18 days. General estimations were made of numbers and types of bacteria present. Interesting organisms, including possible cytophagas, were picked and purified for further work. An exhaustive search of one sample (4810 water) was made for possible cytophagas.

Tests, which were carried out at the isolation temperature of each organism (10° or 25°C), were as follows: C.C.A. — growth, spreading, colour, length, width, shape and motility were described at 3-4 days (25°C) or 5-6 days (10°C); S.M.A. — proteolysis (clearing) and silkiness of the liquid culture were noted at 2, 3 and 6 days and length, width, shape, flexing and motility observations were made at 10-14 hrs. and 2 days (25°C) or 24-42 hrs. and 5 days (10°C); S.M.A. — growth at 5° and 30°C, and proteolysis were noted at 6 days. Gram stains and Munsell colour determinations[6,7] were made at 4 days.

Organisms were placed in the genus *Cytophaga* when they possessed at least five of the following seven characteristics: cells $<0.5\mu$M wide, $>6\mu$M long, flexing, silky when culture gently shaken, proteolytic, Munsell colour

within range 7.5-10 YR 6 to 7/8 to 12, spreading growth on C.C.A. However, organisms which did not flex or spread were excluded.

RESULTS AND DISCUSSION

The general growth of bacteria on the three media is summarized in Table 1. As the samples were not refrigerated during transit,

TABLE 1. General growth of bacteria from lake samples.

Sample	Location in N.W.T.	Incubating temp. (°C)	No. of organisms per ml.	Comments
4765 water	106N 9 8-616900-7507900. Deep Lake, 45 miles NE of Arctic Red River	10°	10^4-10^5	About half yellows, half whites and creams.
		25°	10^6-10^7	Mostly yellows.
4765 mud		both	10^4-10^5	Many white, cream, yellow. Some orange, brown pink.
4794 water	106M 6 8-484400-7482950, 15 miles W. of Ft. McPherson.	10°	10^3-10^4	Mostly pink and cream, yeasts and *Chromobacter*. Some large brown mucoid types, and whites with concentric dark rings.
		25°	10^4	Mostly pink and cream yeasts, and *Chromobacter*.
4794 mud		10°	10^4-10^5	Half yellows, half whites and creams.
		25°	10^4-10^5	Mostly cream, a few yellow.
4796 water	106M 7 8-502350-7461200. In flood plain of Peel River, 15 miles S of Ft. McPherson.	both	10^3-10^4	Mostly yellows and oranges, many creams and whites, some pinks.
		10°	10^5-10^6	Mostly yellows and oranges, few whites.
4796 mud		25°	10^5	Many creams and yellows.
4810 water	106M 8 8-526000-7475250. 15 miles E of Ft. McPherson.	both	10^4-10^5	Mostly yellows, very few pinks. Proteolysis good.
4810 mud		10°	10^3-10^4	Mostly whites, (many large mucoid). Very few other.
		25°	10^5	Mostly whites and creams, a few yellows.
4824 water	106K 13 8-551500-740980. 20 miles W. of Martin House.	10°	10^3-10^4	Mostly whites, and creams, some pink, yellow.
		25°	10^3-10^4	Mostly whites and creams, few pinkish.
4824 mud		10°	10^4-10^5	Mostly dirty cream, very few yellow and orange.
		25°	10^6	Mostly cream, some yellow, orange.

TABLE 2. Bacterial types found in lake samples.

Sample	Numbers													
	Isolates	5° Growth[1] Total	5° Growth[1] Cytophagas	Motile	Gram+	Proteolytic	Bacilli	Cocci and Coccobacilli	Vibrios	Spirilla	Spreaders	Cytophagas	Yeasts	Other Pinks[2]
4765 water	8	0	0	5	2	3	8	0	0	0	2	1	0	0
mud	9	2	1	5	2	3	9	0	0	0	1[3]	2[4]	0	0
4794 water	7	1	0	4	3	5	5	2	0	0	0	0	2	0
mud	4	1	1	0	2	2	3	1	0	0	1	2	0	0
4796 water	15	4	2	6	5	8	13	2	0	0	6	2	0	3
mud	9	8	4	2	2	7	9	0	0	0	1	5	0	0
4810 water	37	2	2	4	5	23	34	1	0	2	18	21	0	2
mud	23	7	3	6	9	16	18	4	1	0	2	10	3	2
4824 water	27	1	1	6	5	17	20	6	1	0	11	10	1	3
mud	11	1	0	6	4	4	7	2	1	1	0	0	1	0

1. Growth at 5°C equal or better than growth at 30°C.
2. Other than yeasts and cytophagas.
3. Not cytophagas.
4. Not spreaders.

detailed enumeration was not justified, since some bacteria prevalent at the lake temperature could easily have died and minor constituents of the flora could have multiplied. An analysis of the types found amongst the 147 organisms, including 52 *Cytophaga* spp. selected for further study, is given in Table 2.

The small number of samples used does not permit large-scale generalization; nevertheless some useful observations can be made. The three media and two temperatures used for isolation should screen the samples exhaustively for cytophagas[5] (with the exception of any as yet unknown psychrophiles), as well as support the growth of various other micro-organisms. Very likely, other organisms could be found if a greater selection of media and conditions were used.

The uniqueness of the microbial community of each site is noteworthy. The number and variety of bacterial types present varied widely. It is reasonable to conclude that those sites possessing a greater range of morphological types are likely to have a greater range of biochemical capacity in the degradation of organic molecules too.

Of the total isolates 65% grew better at 30° than at 5°C, 13% showed similar growth at both temperatures, and 16% showed no growth at 5°C, whilst only 1% showed no growth at 30°C, and 5% better growth at 5°C than at 30°C. The results for the *Cytophaga* cultures followed this trend, giving 61%, 13%, 15%, 4% and 6% respectively. This scarcity of psychrophiles should not be interpreted as necessarily reflecting the situation in the lakes, since the transit temperature and the temperatures of culture isolation were all higher than those in situ. The results do show a good potential for mesophilic growth if these areas were ever heated (by an oil pipeline for example), and turnover of materials could be expected to be fairly rapid.

The genus *Cytophaga*, members of which spread by gliding motility on nutritionally weak media, were well represented in these lakes. Spreading on C.C.A. should not, however, be taken as an infallible criterion for the identification of a cytophaga[8,9]. Only 56% of the cytophagas studied here spread on this medium, and there were also other organisms exhibiting superficially similar behaviour, notably flagellated bacteria and those producing copious mucilaginous material.

Members of the genus *Cytophaga*, with their potential for waste polymer degradation, were recovered from all five lakes examined, and very large numbers were present in samples 4796 water and mud and 4810 water. The Munsell colours of 96% of the *Cytophaga* isolates fell within a narrow, distinctive range of deep orange-yellow (7.5 to 10 YR 6 to 7/8 to 12) and so their identification was aided. The cytophagas found in these subarctic lakes seem to differ very little from those present in more temperate regions of Canada[6].

ACKNOWLEDGEMENTS

My thanks are due to Dr. F. D. Cook for his constructive criticism of this work, to R. L. Hare and W. G. M. Gattinger of the Inland Waters Branch for collection of samples, and to the National Research Council of Canada who provided financial assistance.

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