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THE BACTERIA AND PROTOZOA OF SOME SOIL SAMPLES FROM SCORESBY LAND, EAST GREENLAND

BY

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WITH 7 TABLES IN THE TEXT

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INTRODUCTION

Previous reports on soil bacteria from the Arctic have been given by BARTHEL (1922), who worked on soil samples collected by Dr THORILD WULFF from West Greenland (14 samples from Disko and 2 from Kap York) and North Greenland (J. P. Koch Fjord, 2 samples), and by JENSEN (1951), whose nine samples came from Peary Land. SANDON (1927) reported on the protozoa of nine soil samples from Disko, and DIXON (1939) on twelve samples from East Greenland (from Kangerdlugssuaq and Angmagssalik). Although there were considerable differences between different samples which were taken from latitudes 69° to 83°N, the soils showed a flora and fauna resembling those of temperate regions.

The present report adds to the data already published, and is based on 22 samples collected by members of the British East Greenland Expeditions of 1961 and 1962 from Scoresby Land, slightly north of the area studied by DIXON. Besides an assessment of bacterial and protozoan populations, respiratory measurements were carried out with a Warburg apparatus on two samples. The algae were examined by Dr E. A. FLINT Department of Botany, University of Canterbury. The yeasts in these samples have been previously recorded by DI MENNA (1966).

MATERIALS AND METHODS

In September, 1961, samples of *Salix* litter and moss (C1, C2, Table 1) were brought by Dr J. S. EDWARDS, to Cambridge, England, where the author then was, and were cultured and examined for protozoa. A further series of twelve samples (EG 1–12), collected during the 1961 summer season, were subsequently forwarded to New Zealand by ship arriving in June, 1962. They were examined for bacteria and protozoa but as the samples had been held in London for some months and had travelled by ship through the tropics with a delay of about a year between their collection and examination, the significance of the results has to be qualified. During the 1962 summer season, Dr G. HALLIDAY, of the Botany Department of the University of Leicester, collected eight further samples (GM 1–8) near Mestersvig airstrip at an altitude of not more than 160 m. These were flown to New Zealand in a vacuum flask, and arrived only some days after their collection. The samples appeared to be in excellent condition and the presence of such sensitive organisms as copepods and psychrophilic yeasts (DI MENNA, 1966) suggested that the fauna and flora of these samples had suffered no significant change. It was on these samples, therefore, that most of the study was based.

The locality and nature of the samples is summarised in Table 1. Their sites range from soils low in moisture and organic matter with no higher plant cover to peaty samples, and include a sample of algae from a stream. All of them were taken at a latitude of about 72°N. Generally they had a near neutral to alkaline reaction.

For bacterial examination, ten-fold dilution series were prepared and duplicated plates inoculated and poured. The plating medium was glucose (0.5 %)—tryptone (0.4 %)—yeast extract (0.4 %)—agar (1.5%) and the plates were incubated at 24°C. Two series of plates were prepared from each sample: one from dilutions 10^{-3} to 10^{-9} of the sample in distilled water to give a total plate count, and one from dilutions 10^{-1} to 10^{-6} after pasteurisation at 80°C for 5 minutes to determine the number of spores present. Glucose broths (glucose 1%, tryptone 1%, brom-thymol blue), with Durham tubes, were inoculated from each dilution to determine the presence of aerogenic fermenters (producing acid and gas) and acidogenic bacteria (producing acid). Representative

isolates were picked off both series of plates for further study of their cultural characteristics, morphology, reaction in glucose broth, hydrolysis of starch and gelatin, and Voges-Proskauer reaction.

Respiratory measurements were carried out on 3 to 4 g (wet wt.) of two of the fresh samples flown to New Zealand (GM 1 and 5). The experiments were in duplicate, and the following measurements, at 24°C for three hours, were made:

I. of oxygen consumption and carbon dioxide production by the unamended sample on the morning of the first day of the experiment;
II. after the addition of 3 ml of sterile distilled water, on the afternoon of the first day;
III. a similar reading on the morning of the second day;
IV. after the addition of 0.5 ml of 1 % glucose (w/v) on the afternoon of the second day.

The protozoa were cultured by adding 5 to 10 g of the mineral soil samples to a plain agar plate (10 cm petri dishes), together with about 20 ml distilled water. With the organic samples and the algal sample the inoculum was less. These cultures were examined microscopically for some weeks and slides prepared from them.

pH of the samples was determined electrometrically; moisture by oven drying at 105°C; and loss of ignition (L.O.I.), a measure of organic content, by ashing in a muffle furnace at 500°C.

RESULTS

a. Bacteria

The plate counts and reactions in glucose broth are summarised in Table 2. Although comparisons based on depth of sample cannot be drawn, both the old (EG) and the fresh (GM) samples show great variation from the very low counts in dry samples to very high counts in wet samples. Thus moisture, rather than organic content, seems to be of greatest significance in relation to total count. Generally, the spore count is low, and can be related both to moisture and organic content. This appears also to be true of the streptomyces, which appear to be less numerous in the fresh (GM) samples than in the old (EG) samples. A similar situation appears to be true of the moulds, but as the medium was not specifically designed for mould counts they are of only limited significance. The greatest difference between the old and fresh samples is shown by the reaction in glucose broth tubes. Aerogenic fermenters (producing acid and gas) were either absent or present in small numbers (*c.* 200/g or less) in the old samples but were present in all the fresh samples and attained very high numbers in two of the samples (10^8/g). There is less difference in the levels of acidogenic bacteria between the two sets of samples.

About four hundred isolates from the two series of samples were examined and are classified in Table 3. This shows that the majority of the *Bacillus* isolates belong to Group II of SMITH, GORDON and CLARK's (1952) classification particularly the *B. circulans* group (BREED *et al.*, 1957). The large Group I species, *B. megaterium*, *B. cereus*, and *B. mycoides*, common in temperate and tropical soils, are poorly represented and then chiefly by *B. megaterium*. Generally the spore populations of the old and fresh samples are similar but the fresh samples have a higher proportion of the aerogenic fermenter, *B. polymyxa*. There are greater differences in the non-sporing populations of the two sets of samples. The isolates from the old samples are predominantly pleomorphic (*i.e.* *Arthrobacter* and related genera). There are relatively few Gram-negative rods in the old samples. The fresh samples have a much higher proportion of Gram-negative rods, including the aerogenic fermenter *Enterobacter cloacae* (= *Aerobacter cloacae*). Both series had a high proportion of orange

and yellow chromagens including both pleomorphic and Gram-negative rods, and both had Gram-positive cocci or *Sarcina*.

b. Respiration

The results of the respiratory experiments are given in Table 4. They show an initially high rate of oxidation which is depressed by the addition of water but shows a definite response to added glucose. The metabolism appears to be predominantly aerobic but the initial difference in R.Q. between the two samples may be due to the higher population of spores in the peat sample (GM 1). The rate, measured on the basis of organic content (*i.e.*, L.O.I.), shows little difference between the two samples but the rate of the drier sample is less depressed by added water and shows a less marked response to added glucose. This may also be related to differences in population.

c. Protozoa, Algae, and other Microfauna

Only the sarcodina and ciliate protozoa were recorded. The results are summarised in Tables 5 and 6. The occurrence in the samples of the other microfauna and algae is given in Table 7.

There were few sarcodina species in most samples. Exceptions were the two wet, peaty moss samples (EG 6 and 10) and the three fresh peat samples under reeds, rushes and *Salix* (GM 1, 2 and 3), all of which had a high proportion of testacean species. The samples (GM 1 and 2) from peat under reeds and rushes had a large number of *Nebela* species, which were uncommon or absent in the other samples.

The largest number of ciliate species of this series occurred in the two moss samples (EG. 6 and 10) but they were generally not well represented either in the old or the new samples. Exceptions were the *Salix* samples (C 1 and GM 3) and the sample of moss (C 2) that was examined while fresh at Cambridge. The ciliate fauna consisted of typical edaphic taxa, except for the freshwater genera *Colpidium*, *Strombidium*, and *Stylonychia* recorded from the stream algal sample (GM 8) and from the two moss samples (EG 6 and GM 7) taken from the side of the stream. This is an understandable incidence of typical freshwater taxa.

The associated microfauna consisted of copepods, nematodes, rotifers and gastrotrichs, all characteristic of such habitats. Rotifers were absent from the old samples but live copepods were recorded from two of the samples (EG 6 and 10), which had remained very moist. Mites were recorded from two of the moss samples (EG 10 and C 2).

The algae of samples GM 3, 4, 6, 7, and 8 were examined by Dr E. A. Flint, Department of Botany, University of Canterbury. As

with the ciliate fauna, terrestrial and aquatic communities could be distinguished among the algae. She found *Ankistrodesmus*, *Coccomyxa* and *Pleurochloris* in GM 3, and *Coccomyxa* and *Stichococcus* in GM 4 which seemed to consist of peaty soil. Both were of probably small populations as they took 2 months to develop in culture; GM 6 contained *Ankistrodesmus*, diatoms and blue-green algae; GM 7 contained the aquatic green algae, *Closterium* and *Oedogonium.* Other algae in the sample includes *Cosmarium*, *Nostoc*, *Tolypothrix* and other blue-green algae; while GM 8 contained *Mougeotia.*

She comments: the algal flora from samples GM 3 and 4 (of soil) differ very much from those PETERSEN (1935) found in two soils from Eskimonæs, East Greenland. He isolated 26 species from one and 13 from the other soil. Barnacle geese, nesting above the spot where these samples were collected, presumably enriched the soil and this could account for the more luxuriant algal flora. The effect of birds on the fauna and flora (excluding algae) of soil below Bird Cliff on Jan Mayen Island has been described by RUSSELL and others (1940).

DISCUSSION

Greenland is of great interest since it supports a very large flora and fauna, despite its high latitudes and polar climate. The collections of Dr THORILD WULFF, described by various authors in Vol. 64 of this journal (BARTHEL, 1922; LIND, 1924), reveal not only a very large flora of higher plants, even at latitudes of 82°–83°N, but also an equally large population of saprophytes which seem to thrive in these conditions. LIND (1924) discusses the fungi; BARTHEL (1922) and JENSEN (1952) present data on the bacterial flora revealing a flora composed of typical soil taxa. The present report confirms this. More critical studies, however, may well reveal significant differences at the specific level, such as are shown by the *Bacillus* isolates. There is one discrepancy between the work of BARTHEL and JENSEN however. BARTHEL recorded typically Gram-negative rods, including *Pseudomonas fluorescens*, but JENSEN concluded that the pleomorphic bacteria were the dominant group. The present studies help to resolve this discrepancy. Pleomorphic bacteria were dominant in the old samples but the fresh samples showed a high population of Gram-negative rods. The total numbers seem to fluctuate little but the numbers of the Gram-negative rods, and particularly the aerogenic fermenters, appear to be subject to great differences depending on the age and condition of the samples. This difference is compatible with the distinction made by WINOGRADSKY (1949) between the autochthonous and zymogenous florae and would help to explain inconsistencies in the results of different authors, such as those of BARTHEL and JENSEN. No colonies of *P. fluorescens* however were observed in any of our cultures. The spore-forming populations are interesting in that, not only are they generally much smaller than those found in temperate and tropical soils, but also the dominant group—the *B. circulans* group—is dominant only in wet or peaty soils in non-polar latitudes. It is curious that the populations of the aerogenic fermenter, *B. polymyxa*, strains of which are known to be able to fix nitrogen, appear to fluctuate like the populations of non-sporing aerogenic fermenters, strengthening WINOGRADSKY's concept of a zymogenous flora.

The respiratory measurements were carried out in the laboratory at a temperature greater than that which would obtain in the field.

The respiratory rates recorded are high, suggesting that temperature and not moisture, is the principal factor limiting biological activity and subsequent organic decomposition in the field. It is this limited organic decomposition that leads to the formation of peat where there is appreciable plant growth in well-watered situations. The respiratory rates of the populations also show an appreciable response to added glucose but they are not restored to the initial level. The R.Q. suggests there is a predominantly aerobic microflora, despite the populations of aerogenic fermenters that are present.

SANDON (1927) recorded seven species of non-testate sarcodina and eleven testacea. DIXON (1939) more than doubled this list, with 17 and 25 species, respectively, but some of the amoeba species are undoubtedly synonyms. The present fauna is very similar to that of DIXON's but adds a number of testacean species, particularly of *Nebela*. DIXON pointed out that the testacea were particularly abundant in the samples with rich vegetation and accumulating organic matter, and that this factor rather than pH, controlled their distribution. I concur in these conclusions for the East Greenland peaty soils are remarkable for their near neutral to alkaline reaction and the relatively raw state of the humus, whether of peat or of samples under *Salix*, and these conditions appear to favour the development of the testacea irrespective of pH or latitude.

SANDON only recorded 12 species of ciliates. DIXON recorded 20, but the present list doubles this number. There is clearly a rich edaphic ciliate fauna though it is restricted, like the testacea, to favourable sites. Most of the species are those commonly found in forest litter, peat and mineral soil in temperature or tropical regions. The only notable exception is *Stylonychia* which was recorded in two instances from samples of moss bordering streams (EG 6, GM 7). This is not an edaphic but a fresh-water genus and its presence indicates that the prevailing moisture conditions of the moss provide virtually a fresh-water environment at these sites. This also explains the recording of *Colpidium* (in GM 8) and *Strombidium* (in GM 7), two other fresh-water genera.

The presence of algae, particularly diatoms, in most of these samples is noteworthy. They would be favoured by the near neutral to alkaline reaction and lack of ground cover by higher plants.

The present paper gives some indication of the survival of the various organisms in the soil samples under conditions generally very different from those obtaining in the field, and also of fluctuations in populations. It is remarkable, for example, that copepods remained viable in samples cultured a year after collection, whereas the rotifers disappeared, and that generally the microfaunal population, including the protozoa, should show such consistency between samples of the same type of habit but of very different sampling age. On the other

hand, the microflora shows more striking differences but these are confined generally to the fast-growing zymogenous flora, populations that would have the greatest capacity to recover under favourable soil conditions. They are best represented, moreover, as is the microfauna, in the samples from well-watered sites where plant growth is not inhibited by lack of moisture. At such sites, an organic cycle—of soil, plant, and micro-organisms, is well established, and it is known that in the summer large populations of Collembola may occur in the *Salix* litter. Therefore, an ecosystem exists there which, though dormant during the long arctic winter, in summer is comparable to those of temperate regions, particularly cold regions such as the sub-antarctic islands of Macquarie (Bunt and Rovira, 1955) and Signy (Heal, Bailey and Latter, 1967); the climate of these islands is, however, cold and damp throughout the year with relatively little seasonal variation. In the poorly watered sites, though higher plants may be absent, algae appear to be present in most samples but generally the microfauna and microflora are more limited than at the wet sites. There is no marked accumulation of organic matter and conditions appear to parallel those of polar deserts, such as occur in Antarctica (*cf.* Flint and Stout, 1960) where the aridity and very low temperatures greatly limit biological activity. Thus lack of moisture appears to limit plant growth while low temperature may limit the rate of organic decomposition and therefore lead, even in polar regions, to the accumulation of raw humus or peat. This accumulated organic matter in turn supports a fauna characteristic of such microhabitats in polar, as well as other climatic zones.

LIST OF TABLES

Table 1. *List of samples examined*

	pH	Moisture	L.O.I.	Vegetation	Description of Sample	Locality
EG 1	6.7	13	13	None	Flush soil on hillside	Schaffhavaerdden Camp 72°14′N 25°30′W
2	6.8	3	19	*Betula nanna* and *Vaccinium*	- - -	-
3	7.9	2	3	None	Pale sandy, 'peaty' looking soil Solifluction area, polygons forming	Kap Petersens 72°25′N 24°30′W
4	7.7	5	5	None	Outwash sands by the side of stream	- -
5	6.65	4	5	*Cassiope*, *Salix arctica* and *Carex*	Comparatively dry area	- -
6	6.0	76	37	Moss	At side of the stream	- -
7	7.3	11	8	None	Dolomitic soil	- -
8	7.7	11	11	None	'Peaty' soil	- -
9	7.8	42	34	Lichen and algae	On shore of a tarn	Base camp 72°20′N 24°15′W
10	6.45	63	39	Moss	- - - - -	- - - -
11	7.95	40	52	Submerged algae and other plants	At edge of the tarn	- - - -
12	7.0	2	6	None	Typical of the col	SW of base camp
GM 1	6.6	41	89	Reeds and rushes *Carex microglochin*, *C. atrofusca*, *Kobresia simpliciuscula*, *Juncus castaneus*	2–4 cm below surface of wet peat	72°14′N 23°55′W Low dolerite hills, alt. 160 m.
2	7.7	12	99	*Sphagnum girgensohnii*, *Eriophorum triste* and *Vaccinium uliginosum*	10 cm below tussock of peat	- -
3	6.6	33	59	*Salix arctica*, with *Vaccinium* and *Dryas*	Depth 0–3 cm	Warm S-facing slope *c.* 5°
4	6.8	5	23	*Salix arctica*, with *Vaccinium* and *Dryas*	Depth 7–15 cm from below 200 cm high bank irrigated by melt water throughout the summer	- - - -
5	6.8	57	21	Herbs *Potentilla cranzii*, *Polygonum viviparum*, *Melandrium apetalum*, *Poa alpina*, *Erigeron humilis*	Depth 2–8 cm Soil probably derived from sandstone underlying dolerite	Warm E-facing slope *c.* 5°
6	7.5	2	15	Scattered *Salix arctica* and *Equisetum variegatum*	Silt from small stream (non-glacial)	- - - -
7	7.5	47	7	Moss	Margin of stream	- - - -
8	nd	nd	nd	Algae	From stream	- - - -
C 1	7.2	nd	nd	*Salix* litter		
2	7.2	nd	nd	Moss		

Moisture, % wet wt.; L.O.I. loss on ignition % dry wt.; nd not done

Table 2. *Plate counts and reaction in glucose tubes*

	Plate Counts/g wet wt.				Reaction in Glucose Tubes log no/g wet wt.	
	Bacteria		Streptomyces	Moulds		
	Total $\times 10^6$	Spores $\times 10^3$	$\times 10^6$	$\times 10^4$	A & G	A
EG 1.....	30	1.5	1.5	3	1	4
2.....	0.08	3	<0.0001	25	0	5
3.....	0.2	0.02	<0.0001	1	0	5
4.....	30	4	0.5	0.2	0	1
5.....	20	0.07	0.3	0.35	1	4
6.....	200	250	<0.001	20	2	5
7.....	2.5	3.5	0.01	1.5	1	5
8.....	2	4	10	70	1	5
9.....	350	0.2	450	2.5	1	7
10.....	400	400	<0.001	20	0	6
11.....	400	0.75	150	<0.1	2	7
12.....	0.15	0.015	0.05	250	0	4
GM 1.....	4	2000	<0.001	0.2	3	6
2.....	4	5	<0.001	0.1	4	6
3.....	30	35	<0.001	20	2	4
4.....	0.5	4	0.1	1	1	5
5.....	60	300	1	2	4	6
6.....	0.3	1	0.001	0.15	1	4
7.....	250	40	<0.001	1	8	8
8.....	900	350	<0.001	< 0.1	8	8

A & G, acid and gas produced: A, acid produced

Table 3. *Classification of bacterial isolates*

	Gram-negative rods			*Spore-forming rods*						*Pleomorphic rods*	*Cocci*	*Yeasts*	*Total (isolates)*
	Reaction in glucose broth			Groups									
	A & G	A	n–A	Ia	Ib	IIa	IIb	IIc	III				
EG 1...	2	2	..	2(1)	..	..	..	2	..	12			21
2...	..	2	..	..	2	..	..	3	..	5	..	..	12
3...	..	..	..	..	..	..	..	1	..	9	..	..	10
4...	..	..	..	..	..	..	..	5	..	15	..	..	20
5...	..	1	..	..	..	1	1	3	..	8	..	..	14
6...	6	×	..	1	2	..	..	4	..	8	..	..	21
7...	×	1	2	5	..	..	..	3	..	16	1	..	29
8...	8	2	..	..	1	..	3	3	..	4	2	..	23
9...	3	1	1	..	..	..	..	5	..	8	..	..	18
10...	2	9	..	..	..	..	..	8	..	1	..	..	20
11...	1	7	..	..	1	..	..	5	..	2	..	..	16
12...	..	..	..	..	..	..	..	5	..	3	..	..	8
Total...	23	25	3	8(1)	6	1	4	47	0	91	3	0	212
GM 1...	2	10	7	2	..	5	2	7	..	1	1	..	37
2...	4	4	..	1	..	..	1	3	1	..	..	..	14
3...	1	5	6	..	..	..	..	6	..	..	1	..	19
4...	..	7	1	..	..	..	5	..	..	3	..	..	16
5...	1	10	4	7	..	5	2	4	..	1	1	1	36
6...	2	5	2	..	1	..	1	6	..	3	..	..	20
7...	7	1	..	..	..	..	..	7	..	..	..	..	15
8...	5	1	..	..	..	..	..	6	..	1	..	..	13
Total...	22	43	20	10	1	10	11	39	1	9	3	1	170
Total No. of Isolates	45	68	23	18(1)	7	11	15	86	1	100	6	1	382

Gram negative-rods:
A & G —producing acid and gas from glucose
A —producing acid from glucose
n–A —producing alkali or no change from glucose

Spore-forming rods:
Ia —*B. megaterium* (*B. cereus*)
Ib —*B. subtilis* group
IIa —*B. polymyxa*
IIb —*B. circulans* group, growing in glucose broth
IIc —*B. circulans* group, not growing in glucose broth
III —*B. sphaericus*

Table 4. *Respiratory rates for samples GM 1 (from peat) and GM 5 (from soil)*

(a) μl CO_2/g dry wt/hr and (b) μl CO_2/g L.O.I./hr at 24°C

	Stage	GM 1			GM 5		
		a	b	R.Q.	a	b	R.Q.
First day							
Unamended sample	I	152	172	0.90	39	184	0.66
With addition of water	II	23	26	0.56	20	93	0.55
Second day	III	21	23	0.46	21	101	0.62
With addition of glucose ..	IV	67	75	0.65	30	144	0.61
	IV/III	3.2			1.4		
	IV/I–III	1.1			1.1		

Table 5. *List of sarcodina*

	C1	2	EG1	2	3	4	5	6
HELIOZOA								
Actinophrys sol Ehrb.	..	..	..	..	..	..	..	+
Raphidiophrys Archer	..	..	+	+	..	..	..	..
PROTEOMYXA								
Nuclearia Cienkowski	..	..	+	..	..	..	..	..
Biomyxa vagans Leidy	+	..	..	..	..	..	..	..
Penardia Cash	..	..	..	..	..	..	..	..
AMOEBINA								
Naegleria gruberi (Schardinger)	+	..	..	..	..	..	..	..
Hartmanella Alex	+	..	..	+	..	..	..	+
Hyalodiscus Hertwig & Lesser	..	..	..	..	..	..	..	+
Mayorella vespertilio (Penard)	..	+	..	..	..	..	..	+
Trichamoeba Fromentel	..	..	..	..	..	..	..	..
Trichamoeba Fromentel	..	..	..	..	..	..	..	..
Trichamoeba Fromentel	..	..	..	..	..	..	..	..
Metachaos Schaeffer	..	..	..	..	..	..	..	..
Thecamoeba verrucosa (Ehrb.)	..	..	..	..	..	..	..	+
Thecamoeba striata (Penard)	+	..	..	..	..	..	..	..
TESTACEA								
Centropyxis aerophila Deflandre	..	..	..	..	..	..	+	+
Centropyxis orbicularis Deflandre	..	..	..	..	..	..	..	..
Centropyxis sylvatica (Deflandre)	+	..	..	..	..	..	+	+
Cyclopyxis Deflandre	..	..	..	..	..	..	..	+
Difflugia lucida Penard	..	..	..	..	..	..	..	+
Heleopora sylvatica Penard	..	..	..	..	..	..	..	+
Hyalosphenia minor Cash	..	..	..	..	..	..	..	..
Nebela collaris (Ehrb.)	..	..	..	..	..	..	+	+
Nebela galeata Penard	..	..	..	..	..	..	..	..
Nebela lageniformis Penard	..	..	..	..	..	..	+	..
Nebela minor Penard	..	..	..	..	..	..	..	..
Nebela penardiana Deflandre	..	..	..	..	..	..	..	..
Nebela dentistoma Penard	..	..	..	..	..	..	..	..
Nebela militaris Penard	..	..	..	..	..	..	..	..
Difflugiella oviformis (Penard)	..	..	..	..	..	..	..	..
Phryganella acropodia (Hertwig & Lesser)	..	..	..	..	..	..	+	..
Pseudochlamys patella Clap & Lach	..	..	..	..	..	..	..	+
Assulina muscorum Greeff	..	..	..	..	..	..	..	..
Corythion dubium Taranek	..	..	..	..	..	..	..	..
Euglypha ciliata (Ehrb.)	..	..	..	..	..	..	..	..
Euglypha compressa Wailes	..	+	..	..	..	..	..	..
Euglypha laevis (Ehrb.)	..	..	..	..	..	..	..	..
Euglypha rotunda Wailes & Penard	..	..	..	..	..	..	..	+
Tracheleuglypha dentata (Moniez)	..	..	..	..	..	..	..	+
Sphenoderia fissirostris Penard	..	..	..	..	..	..	..	+
Trinema enchelys (Ehrb.)	..	..	..	..	..	..	..	+
Trinema galeata (Penard)	..	+	..	..	..	..	..	..
Trinema lineare Penard	+	+	..	+	..	..	+	+
Pseudodifflugia gracilis Schlumberger	..	..	..	..	..	..	..	+
Total No. species (44 total)	6	4	2	3	0	0	6	18

recorded in the cultures

7	8	9	10	11	12	GM1	2	3	4	5	6	7	8
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..	+	+	+	..	..	+	+	+	..	..	..	+	..
..	+	..	+	..	..	+	..	..	..	..	..	..	..
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..	..	..	+	..	..	+	..	..	..	..	..	..	..
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..	..	..	+	..	..	..	..	..	..	+	..	..	..
0	3	1	15	0	1	18	8	12	1	4	2	7	1

Table 6. *List of ciliates*

	C1	2	EG1	2	3	4	5	6
Enchelys O.F.M.	..	..	..	..	..	..	..	..
Chaenea Quennerstedt	..	..	..	+	..	..	..	..
Prorodon Ehrb.	..	+	..	..	..	..	..	..
Spathidium muscicola Kahl	+	..	..	..	..	+	..	..
Chilodonella gouraudi (Certes)	+	+	..	..	..	..	..	..
Chilodonella wisconsinensis Kahl	..	..	..	..	..	..	..	..
Litonotus Wrzes	+	..	..	..	..	..	..	..
Gastronauta membranaceus Englm.	..	..	..	..	..	..	..	..
Chilodontopsis muscorum Kahl	+	..	..	..	..	..	..	..
Sonderia Kahl	+	+	..	..	..	..	..	..
Mycterothrix tuamotuensis Balbiani	..	..	..	..	..	..	..	..
Colpoda steinii Maupas	..	..	..	..	..	..	..	..
Colpoda inflata (Stokes)	+	..	..	..	..	+	..	..
Colpoda cucullus O.F.M.	+	..	+	..	..	..	..	..
Woodruffia sinistromembranellata Gellért	..	..	..	..	..	..	..	..
Leptopharynx sphagnetorum (Levander)	+	+	..	..	..	..	..	..
Microthorax simulans (Kahl)	..	..	..	..	..	..	..	..
Drepanomonas Fresenius	+	+	..	..	..	..	..	..
Pseudoglaucoma muscorum Kahl	..	..	..	..	..	..	..	..
Cyrtolophosis mucicola Stokes	+	..	+	+	..	+	+	+
Cinetochilum margaritaceum Perty	+	+	..	..	..	..	..	..
Sathrophilus muscorum (Kahl)	+	..	..	..	..	..	..	..
Cyclidium muscicola Kahl	+	..	..	..	..	..	..	..
Homologastra setosa Kahl	+	..	..	..	..	..	..	..
Tetrahymena rostrata (Kahl)	+	..	..	..	..	..	..	..
Colpidium Stein	..	..	..	..	..	..	..	..
Strombidium Clap & Lach.	..	..	..	..	..	..	..	..
Halteria grandinella (O.F.M.)	+	+	..	+	..	..	..	+
Blepharisma hyalinum Perty	..	..	..	..	..	..	..	..
Phacodinium metschnicoffi Prowazek	..	..	..	..	..	..	..	..
Gonostomum affine (Stein)	+	+	..	..	+	+	..	+
Oxytricha setigera (Stokes)	+	+	..	+	..	+	..	+
Oxytricha pellionella (Stokes)	+	..	+	+	..	..	..	..
Oxytricha fallax Stein	..	+	+	+	+	..	..	+
Oxytricha Bory	..	..	..	..	..	..	+	..
Stylonychia mytilus Ehrb.	..	..	..	..	..	..	..	+
Uroleptus piscis Ehrb.	..	+	..	..	..	..	..	..
Uroleptus mobilis Englm.	..	..	..	..	..	+	..	+
Onychodromus Stein	..	+	..	..	..	..	..	..
Keronopsis muscorum Kahl	+	+	+	+	..	..	..	+
Aspidisca Ehrb.	..	..	..	..	..	..	..	..
Vorticella striata Stokes	+	+	..	..	..	..	..	+
Vorticella muralis Penard	..	..	..	..	..	..	..	..
Vorticella Linn.	..	..	..	..	..	..	..	..
Suctorida	..	..	..	..	..	..	..	+
Total No. species (45 total)	21	14	5	7	2	6	2	10

recorded from the cultures

7	8	9	10	11	12	GM1	2	3	4	5	6	7	8
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3	5	1	8	0	1	10	4	22	3	5	5	16	2

Table 7. *Other microfauna and algae recorded from the cultures*

Cultures	Nematoda	Rotifera	Gastrotricha	Harpacticid Copepoda	Algae			
					Diatoms	Yellow/Brown	Green Filamentous	Green
C 1	+	+	..	..	+	..	..	+
2	+	+	..	..	+	..	..	..
EG 1	..	..	..	..	+	..	..	..
2	+	..	..	..	+	..	+	..
3	..	..	..	..	..	+	..	..
4	..	..	..	..	..	..	..	..
5	+	..	..	..	..	..	+	..
6	+	..	+	+	+	..	..	..
7	+	..	..	..	..	..	..	+
8	..	..	+	..	..	..	..	..
9	..	..	..	..	+	+	..	..
10	+	..	+	+	+	..	..	..
11	..	..	..	..	+	..	..	..
12	..	..	+	..	..	..	..	..
GM 1	+	+	+	+	+	..	..	..
2	+	+	+	..	..	..	..	..
3	+	+	..	..	..	..	..	..
4	..	..	..	..	..	..	..	..
5	+	+	..	+	+	..	..	..
6	..	..	..	..	+	..	..	..
7	..	+	..	..	+	..	..	+
8	..	..	..	..	..	..	+	..

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