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Protozoa of Lough Neagh, Northern Ireland, UK

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Abstract—This paper made the first records of taxa composition of protozoa in Lough Neagh, the largest freshwater lake in British Isles. One hundred and eight species(genus) were identified from the examinations of approximately 150 PFU artificial substrates and various types of natural substrate from May to December, 1992. Of 108 species or genus, 30 core species were found on PFU substrate and 17 on natural ones. The ecological characteristics of protozoa were studied by showing the variations of species richness and individual abundance as a function of season or water temperature. Protozoa on PFU were compared at two sampling stations as well.

Keywords: Lough Neagh; protozoa; PFU.

1 Introduction

Protozoa usually are taken to include motile algal flagellates, zoofagellates, sarcodines and ciliates. Most protozoan species exhibit a nearly cosmopolitan distribution, occurring in a wide variety of environmental systems around the world. From an ecological viewpoint, protozoa are an interesting group forming virtually self-contained or "model" interacting communities which exhibit many of the characteristics of structure and function of entire aquatic ecosystems (Cairns, 1980). Although often neglected in whole lake studies, it has also been recognized that changes in the protozoan community may significantly affect other components of the aquatic food wed, and thus may influence the distribution and abundance of both lower and higher organisms (Sherr, 1984; Carrick, 1992; Cairns, 1980; Finlay, 1981). For example in Lough Neagh *Mysis relicta*, which exists in very high densities and is a major food source for fish, is frequently found to have guts filled with flagelates and ciliates.

Lough Neagh, with a surface area of 387km^2, is the largest freshwater lake in the British Isles. It is a most valuable resource, supporting a very productive fishery and an important water supply reservoir as well as having great conservation value in its bird life and wetland vegetations. Over the past 25 years Lough Neagh has been extensively studied for a variety of limnological purpose and related problems (Wood, 1989; 1993). However, to the best of our knowledge, no research on freshwater protozoan communities had been carried out in Lough Neagh before. The objective of this investigation was (1) to make the first records of protozoan species composition, variations of species richness and individual abundance as a function of season or water temperature; (2) to compare protozoan colonizers of an artificial substrate (polyurethane foam PFU) with nearby natural substrate protozoans; and (3) using PF to compare the protozoa at two sampling sites.

Artificial substrate, polyurethane foam (PF) was used throughout the study to collect protozoan species from Lough Neagh. Much evidence exists that PF is readily used as ecological islands for colonization by protozoan species. Although providing "unnatural" havens from such as normal predation these sponges offer a very effective method of sampling a new habitat. By comparison with a wide variety of artificial substrates previously used in ecological studies in freshwater ecosystems, Cairns *et al.* found that PF artificial substrate was best suited for collecting complex protozoan communities and that the use of standardized PF units provided many advantages not easily found in natural systems (Cairns, 1979; Yongue, 1971; Pratt, 1985).

2 Methods and procedures

The investigation was made from May to December 1992. Sets of 8cm × 6cm × 5cm cubes (each cube a PF Unit = PFU) of polyurethane foam was anchored 30 cm under the surface of water in the littoral zone of Lough Neagh at two sampling sites, off Traad Point (Series A) and in Ballyronan Bay (series B, Fig. 1). These two sites, although only about 1km apart, are separated by the promontory of Traad Point and the two habitats exhibit notable

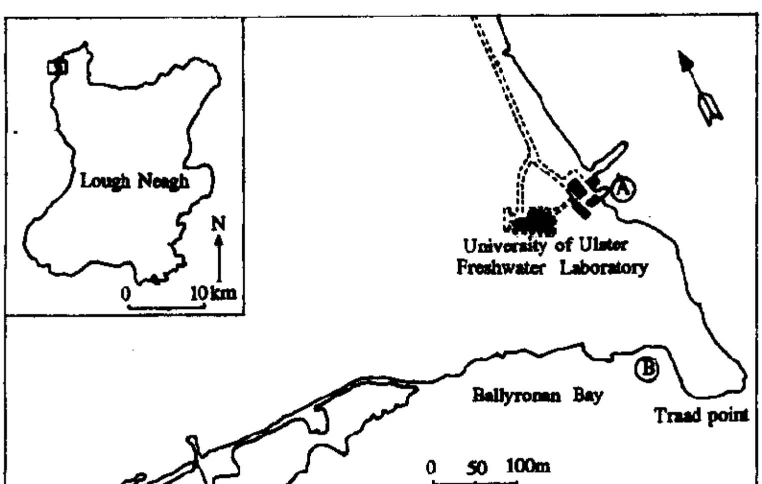

Fig. 1 Location of the Traad Point (A) and Ballyronan Bay (B) Protozoan sampling stations in relation to the Freshwater Laboratory

differences. Ballyronan Bay is much more exposed to the prevailing SW winds and its substrate is bare sand. The shore is fringed with *Phragmites* and *Typha* stands. The Traad point site is on the more protected N. Easterly side of the Point, its substrate is small rocks interspersed with soft clay and, in the summer, supports extensive growths of submerged plants such as *Potamogeton* and *Callitriche*. It was considered possible that the protozoan fauna might reflect these habitat differences.

PFUs were retrieved after at least one week's exposure. Protozoan samples from PFUs were obtained by manually squeezing the material and water from the units into a clean glass breaker(200ml). Protozoan species richness was determined from living material by pipetting two or three drops of well-mixed material and examination of the whole field at 100—400x magnification. Identification was made by using standard protozoological keys(Kudo, 1966; Curds, 1982—1983; Lee, 1985; Page, 1976; Patterson, 1992; Shen, 1990) and the examinations of all samples were usually completed within eight hours of collection. Identification of most flagellates and naked amoebae was difficult and was rarely attempted beyond generic level; ciliates were frequently identified to species level, and no attempt was made to identify cysts or other resting stages.

To sample the natural protozoan community for comparison with that in the PFUs, samples from various substrates in the vicinity of the PFUs were taken by a rubber bulb/suction pipette and transported in wide-mouth jars with adequate air rapidly as possible to the laboratory for inspection.

For quantitative analyses, protozoan abundance was measured on a range of water samples in Ballyronan Bay taken throughout a summer-winter season covering an 18℃ temperature range. For each sampling, two replicate 1000 ml water samples were taken from the surface of the water. Vertical profiles were not taken as the bay is shallow and almost invariably well mixed. One liter water samples were first concentrated to 300 ml by filtration through a phytoplankton net as described by Bark(Bark, 1981). This inevitably results in the loss of very small species such as *Bodo*, *Amoeba* and *Monas*. The concentrated sample was then fixed using Lugol's iodine(which of course would on its own have rendered small species and amoebae unidentifiable) and further concentrated to 30 ml by sedimentation for two days in a separating funnel. Four subsamples (0. 1ml) of the final concentrate were placed in a perspex counting chamber and counted under a light microscope at a magnification of 10×20, and the four replicate subsamples from each water sample yielded SE<8% of the mean values of counts.

3 Results and discussion

To data, one hundred and eight protozoan species were identified from the examinations of approximately 150 PF units and various types of natural substrate from May to December 1992. The 108 protozoan species are comprised of 18 species of flagellates, while ciliates and sarcodines contribute 71 and 19, respectively. The species listed in Table 1. This list is almost certainly not exhaustive.

Table 1 Protozoan taxa collected from Lough Neagh, May—December 1992

Flagellates	
Cryptomonas erosa (Ehrenberg)	*Phacus sp.*
Petalomonas mediocanellata (Stein)	*Monas sp.*
Chlamydomonas sp.	*Bodo sp.*
Gonium sp.	*Mastigamoeba limax* (Moroff)
Urceolus parscheri (Skvortzov)	*Codosiga botrytis* (Ehrenberg)
Gymnodinium sp.	*Cercomonas bodo* (Lemm)
Anisonema acinus (Dujardlin)	*Synura sp.*
Euglena sp.	*Monosiga ovata* (Kent)
Peranema trichophorum (Ehrenberg) Stein	*Pandorina morum* (Müller) Bory
Ciliates	
Trochilia minuta (Roux)	*U. dispar* (Stokes)
Cinetochilum margaritaceum (Perty)	*Cristigera vestita* (Kahl)
Halteria grandinella (Müller)	*Cyclidium oblongum* (Kahl)
Mesodinium pulex (Claparede and Lachmann)	*C. granulosum* (Kahl)
Litonotus carinatus (Stokes)	*C. bonneti* (Groliére)
L. obtusus (Maupas)	*C. simulans* (Kahl)
L. lamella (Enrenberg) Schewiakoff	*Uronema nigricans* (Müller) Maupes
L. Cygnus (Müller)	*Acineria uncinata* (Tucolesco)
Dileptus cygnus (Claparede and Lachmann)	
Stylonychia notophora (Stokes)	*Holosticha kessleri* (Wrzesniowski)
S. mytilus (Müller)	*Strobilidium gyrans* (Stokes)
Aspidisca costata (Dujardin)	*Frontonia depressa* (Stokes)
A. lynceus (Ehrenberg)	*F. atra* (Ehrenberg)
Euplotes eurystomus (Wrzesniowski)	*Spathidium spathula* (Müller)
E. affinis (Dujardin)	*Urotricha agilis* (Stokes)
E. patella (Muller)	*Podophrya fixa* (Müller)
E. muscicola (Kahl)	*P. maupasi* (Bütschli)
Tachysoma pellionella (Müller—Stein)	*Opercularia coarctata* (Claparede and Lachmann)
Trithigmostoma srameki (Foissner)	*Epistylis sp.*
Chilodonella uncinata (Ehrenberg)	*Coleps hirtus* (Müller)
C. aplanata (Kahl)	*Hemiophrys fuscidens* (Kahl)
C. turgidula (Penard)	*H. pectinata* (Kahl)
Tetrahymena pyriformis (Ehrenberg)	*Spirostomum ambiguum* (Ehrenberg)
Nassula aurea (Ehrenberg)	*S. minus* (Roux)
N. ornata (Ehrenberg)	*Lembadion bullinum* (Perty)
Pleuronema coronatum (Kent)	*Zoothamnium sp.*
Stentor polymorphus (Müller)	*Lacrymaria pupula* (Müller)

Table 1 (Continued)

S. roeseli (Ehrenberg)	*L. olor*(Müller)
S. coeruleus (Ehrenberg)	*Urocentrum turbo*(Müller)
Paramecium caudatum(Ehrenberg)	*Paruroleptus muscubus* (Kahl)
P. multimicronucleatum(Powers and Mitchell)	*Acineta foetida*(Maupas)
Vorticella microstoma(Ehrenberg)	*Oxytricha saprobia*(Kahl)
V. extensa(Kahl)	*Dichilum platessoides*(Faure—Fremiet)
V. convallaria(L.)	*Urostyla viridis*(Stein)
Urosoma cienkowskii(Kowa lewski)	*Cohnilembus fusiformis*(Kahl)
Uroleptus caudatus (Claparede and Lachmann)	*Histriculus similis* (Quennerstedt)
Sarcodines	
Polychaos dubium(Schaeffer)	*Vahlkampfia sp.*
Saccamoeba limax(Page)	*Actinosphaerium eichhorni* (Ehrenerg)
Hartmannella sp.	*Cyphoderia ampulla*(Ehrenberg)
Centropyxis sp.	*Thecamoeba sp.*
Amoeba sp.	*Trichamoeba villosa*(Wallich)
Mayorella sp.	*Vannella miroides*(Bovee)
Actinophrys sol (Ehrenberg)	*Flamella citrensis* (Bovee)
Chaos carolinense(Wilson)	*Difflugia sp.*
Raphidiophrys sp.	*Arcella sp.*
Acanthocystis sp.	

It would be beyond the scope of this paper to attempt a detailed comparison with all other published protozoan lake faunas but some points of interest can be briefly made. By comparison with Douglas Lake, Michigan, which contained 248 protozoan species in 1977 and 149 species in 1982(Pratt, 1989), the diversity of protozoan species in Lough Neagh is lower. It is premature to offer definite explanations of this but many factors, such as water quality and predation may influence species composition and community development of protozoa in aquatic ecosystems. Lough Neagh is much more eutrophic than Douglas Lake, which is meso (eu) trophic. Also, Lough Neagh supports extremely high densities of *Mysis* relict which , from our casual observations, may use protozoa as one of their main food sources so that those protozoan species susceptible to pollution and predation may have been lost.

Of 108 protozoan species, 30 core species were found on PFUs and 17 on natural substrate(Table 2). These core species were almost always found in all samples and their individual abundance also was highest.

Table 3 records the number of species identified from PFUs and natural substrate during four sampling periods of time. There were obvious differences in the number of species collected from the different substrate. The number of species collected from PFUs at each time was higher than that from natural substrate. This study confirms for Lough Neagh the pre-

Table 2 Occurrence of core protozoan species on artificial and natural substrate

Presence is denoted by (+), absence by (−)

Taxa	Artificial substrate	Natural substrate
Flagellates		
Anisonema acinus	+	+
Peranema trichophorum	+	+
Monas sp.	+	+
Bodo sp.	+	+
Cryptomonas erosa	+	−
Chlamydomonas sp.	+	+
Ciliates		
Aspidisca costata	+	−
A. lynceus	+	+
Cinetochilum margaritaceum	+	+
Chilodonella uncinata	+	−
Halteria grandinella	+	−
Litonotus lamella	+	−
Stylonychia mytilus	+	+
Euplotes patella	+	+
Tachysoma pellionella	+	−
Nassula aurea	+	−
Pleuronema coronatum	+	−
Stentor polymorphus	+	+
S. coeruleus	+	−
Paramecium caudatum	+	+
Vorticella convallaria	+	+
Cyclidium simulans	+	+
Strobilidum gyrans	+	−
Coleps hirtus	+	−
Uroleptus caudatus	+	+
Sarcodines		
Amoeba sp.	+	+
Actinophrys sol	+	+
Cyphoderia ampulla	+	−
Chaos carolinense	+	−
Acanthocystis sp.	+	+
Total number of core species	30	17

vious findings that PFUs collect more protozoan species than natural substrate. Polyurethane foam offers an attractive generalized substrate for protozoa from virtually every microhabitat because the lattice arrangement of the polyurethane foam provides both a relatively large surface area for attachment of sessile and crawling protozoans, and much open space for habitation by planktonic forms. Natural substrate are far more selective for particular species and usually collect a much lower diversity of organisms (Cairns, 1974—1976; Plafkin, 1979; Henebry, 1980). Also, some organisms which prey on protozoa, such as snails, many insect larvae and crustaceans (cladocera, copepods) are excluded from the interior of the PFUs. Such predators have also been found on flat artificial substrates, such as glass slides and plastic petri dishes-surfaces commonly used to collect protozoa from natural aquatic environments (Spoon, 1975). Cairns *et al.* (Cairns, 1974) found that PFUs collect appreciably more protozoan species than eight other types of natural and artificial substrate suspended in its epilimnion of Douglas Lake. In addition, Lough Neagh almost always is very rough due to being exposed to strong wind action, and has vast areas of open water. It may thus be difficult for protozoa to attach to natural substrate, such as vegetation (both living and dead), stone, scum and the like. In contrast, the PFUs provide a protective space for species colonization and community development of protozoans.

Table 3 Numbers of protozoan species recorded from concurrently sampled artificial and natural substrates

Date	Artificial substrate*	Natural substrate**
25/05/92	32	27
15/06/92	37	24
03/07/92	42	28
15/10/92	39	30

* Collected from artificial substrate which had been submerged for 14 days;

** protozoa samples from a variety of natural substrate (i. e. stones and aquatic vegetation)

Results obtained during concurrent collection of samples from the Traad Point and Ballyronan series are shown in Table 4. There were no major differences between the number of species and the species overlap was between 79% and 98%. Clearly the proximity of the two sites and the well mixed state of Lough Neagh override any differences in substrate surface and protection which the two sites offer.

Table 4 Numbers of species of protozoa colonizing artificial substrate anchored at Traad Point (A) and Ballyronan Bay (B)

Exposure time, weeks	A	B	No. of species common to A+B
1	30	34	27
2	59	56	50
3	47	52	41
4	43	49	42
5	56	58	48

Fig. 2(a) illustrates the variations in the number of species colonizing PFUs and the abundance of protozoa taken from water samples of Lough Neagh from May to December, 1992. The two sites sampled were restricted to the Traad Point area of Lough Neagh but it is likely that more spatially comprehensive sampling would show essentially the same result.

Other studies of phytoplankton, zooplankton, chemistry and benthic organisms have all indicated the well-mixed overall uniformity of the water mass.

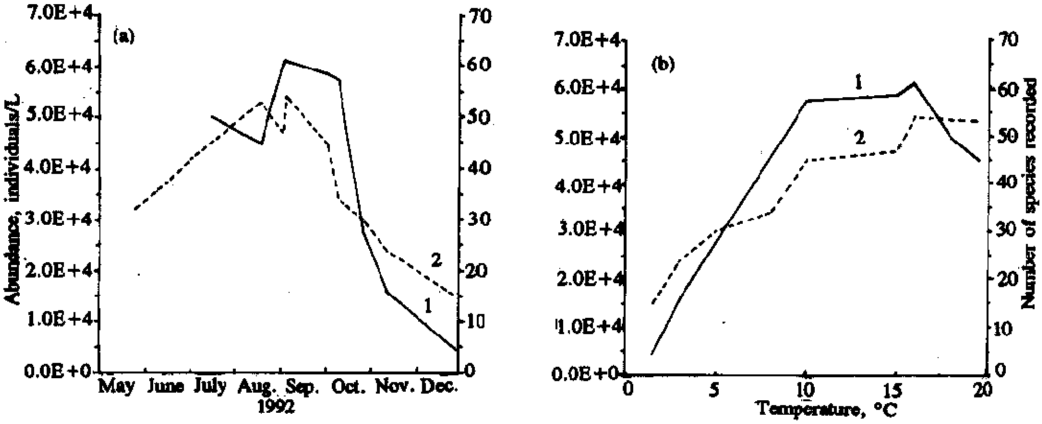

Fig. 2 (a) Variations in the open water abundance(1) and the number of PFU-colonizing species (2) collected from Lough Neagh from May to December 1992. (b) The same data as (a) plotted as a function of water temperature

There is a broad indication in Fig. 2(a) of peak values in September followed by rapid decline with onset of winter conditions. We have no information on early season values but it is likely that the annual cycle would show spring and autumn peaks of abundance separated by lower values in mid/late summer. This is an extremely common pattern found elsewhere, the mid-summer fall often caused by peak zooplankton grazing in Lough Neagh. For example, Lake Donghu (China), which is temperate, shallow and eutrophic like Lough Neagh though slightly smaller in area, exhibited in 1961 a spring peak of 6480 individuals/L and a larger autumn peak of 15270 individuals/L. The yearly average of 4270 protozoan cells/L and the autumn peak rose, with increasing eutrophication, to 9873 and 47820 individuals/L in 1981(Gong, 1986).

Although Lough Neagh is responding to phosphate reduction in recent years (Gibson, 1986), it is still highly eutrophic and it may be that the smaller overall populations found here, compared with Lake Donghu, may at least partly result from heavy predation by *Mysis relicta* throughout the year. Although quantitative protozoa samples were taken only from Ballyronan Bay, the results may well be indicative of the overall Lough Neagh population. Other studies of phytoplankton, zooplankton, benthic organisms and chemistry have all indicated the well-mixed overall uniformity of the water mass.

Fig. 2(b) plots the same data as a function of water temperature, essentially illustrating populations dating autumn/winter cooling from 19.5℃ to 1.5℃. Although Lough Neagh exhibits a fairly wide temperature range there is little reason to suggest that species diversity is much constrained by temperature intolerance especially in view of extreme tolerance in the encysted state (Kudo, 1966).

This half-year investigation of protozoa can best be considered as a guide to further work and lines of inquiry, and would need to be continued for several years to establish the pattern of variation within and between adjacent years and to integrate the very active and important population of protozoa into the food webs and overall ecology of Lough Neagh.

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