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ORIGINAL PAPER

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Terrestrial ciliates (Protozoa, Ciliophora) from two islands (Gough, Marion) in the southern oceans, with description of two new species, *Arcuospathidium cooperi* and *Oxytricha ottowi*

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Abstract Twenty-seven soil and moss samples from Gough Island (40°21′S, 09°53′E) and Marion Island (46°52′S, 37°51′E), two small volcanic elevations in the South Atlantic and southern Indian Oceans, were investigated for ciliated protozoa using the non-flooded Petri dish method. Collections were made from a variety of biotopes covering most principal soil and vegetation types. Sixty species were found, 39 on each of the two islands studied; all are first records for these regions. The mean number of species per sample was markedly higher on Gough (14) than on Marion Island (5.7), reflecting increased climatic severity and decreased soil fertility, respectively. Grassland with a well developed soil cover supported more species than sites with sparse vegetation or heavily eutrophic penguin-influenced habitats. Colpodids dominated the frequency spectrum due to their *r*-selected survival strategy. The most common species were *Colpoda steinii*, a euryoecious bacteria feeder, and *Pseudoplatyophrya nana*, an obligate fungal sucker, also belonging to the Colpodea. Species were very patchily distributed, probably due to the environmental severity allowing few pioneers to establish stable populations. *Hemimastix amphikineta*, a peculiar heterotrophic flagellated organism, was found on Gough Island, an observation that supports the restricted Gondwanian distribution previously proposed for this species. Two new species were found. *Arcuospathidium cooperi* n. sp., a gymnostome ciliate, was discovered on Marion Island and belongs to a small group of spathidiids lacking extrusomes. *Oxytricha ottowi* n. sp., a hypotrichous ciliate, was discovered on Gough Island and is unique in having eight macronuclear nodules.

Key words Sub-Antarctic · Gough Island · Marion Island · Prince Edward Island · Soil ciliates · *Hemimastix amphikineta*

Introduction

Protozoa are an important component of soil ecosystems, because of their large standing crop and high production. Changes in their dynamics and community structure very probably influence soil fertility, as well as the rate and kind of soil formation. Protozoa inhabit and are particularly abundant in soil ecosystems that almost or entirely lack higher organisms due to extreme environmental conditions, e.g., alpine regions above the timberline, Arctic and Antarctic biotopes (Foissner 1987, 1994). However, seen on a global scale, the taxonomy and ecology of most groups of soil protozoa are poorly explored, with the testate amoebae being a notable exception, due to the prolific studies of Bonnet and Schönborn (cited in Foissner 1987).

The present study was concerned with the terrestrial ciliates from two small, isolated islands, Gough and Marion, in the southern oceans. No previous data are available on the ciliates from these volcanic islands, which have never been part of a continental land mass; however, testate amoebae of Marion Island have been studied by Grospietsch (1971). The results show that there is a diverse, but rather patchily distributed, ciliate fauna with few species, mainly *r*-selected colpodids, occurring in a large proportion of samples.

Material and methods

Samples

Samples were collected by Mr. John Cooper (University of Cape Town) between December 1990 and March 1992 on Gough Island and Marion Island, two small, volcanic islands in the southern oceans. Collections were made from a variety of biotopes covering most principal soil and vegetation types.

Dedicated to Professor J.C.G. Ottow on the occasion of his 60th birthday

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Gough Island (samples 1–7) has an area of 65 km^2 and a cool temperate climate. It is located at 40°21′S 09°53′E, about 400 km SSE of Tristan da Cunha, South Atlantic. Block (1994) and Smith (1978) have provided more detailed data on the climate, geology, soils, vegetation, and organisms in general. Samples were collected in October 1990 and investigated in December 1990.

Marion Island (samples 8–27) is one of the Prince Edward Islands and has an area of 290 km^2 and a sub-Antarctic climate. It is located at 46°52′S 37°51′E, about 1920 km SE of Cape Town, South Africa. Grospietsch (1971) has provided general data on climate, geology, etc. Samples were collected in May 1990 (nos. 8–15; investigated in July and August 1990), May 1991 (nos. 16–22; investigated in December 1991), and March 1992 (nos. 23–27; investigated in December 1992). Sample no. 23 is actually from Prince Edward Island (46°38′S, 37°57′E), very near Marion Island. Because only a single sample was obtained, it has been subsumed to Marion Island.

The following sample descriptions are, unfortunately, rather incomplete because few details were provided by the collector and samples were too small for more detailed investigations in my laboratory. No exact measurements of salinity were taken; "slightly" and "heavily" saline mean that few or many salt crystals, respectively, were formed when a small drop (0.1 ml) was evaporated on a slide.

No. 1: Tafelkop; *Sphagnum* spp. moss under mire vegetation; pH 5; 500 m above sea level.

No. 2: Tafelkop; mire vegetation; pH 5.2; 500 m above sea level.

No. 3: Transvaal Bay; moss and soil from river bank; pH 4.3; 50 m above sea level.

No. 4: Tafelkop; moss and mire vegetation; pH 4.5; 500 m above sea level.

No. 5: Tafelkop; grass sward with moss and soil; pH 4.0; 500 m above sea level.

No. 6: Tafelkop; mire vegetation, i.e., almost pure moss with very few soil particles; pH 4.5; 500 m above sea level.

No. 7: Transvaal Bay; fern bush (*Histiopteris incisa*) peat litter, mixed with some soil and moss; pH 4.4; 30 m above sea level.

No. 8: Near meteorological station; mire litter mixed with some soil and moss; pH 4.7; 30 m above sea level.

No. 9: Near meteorological station; fern bush (*Blechnum penna-marina*) material mixed with some soil; pH 5.2; 30 m above sea level.

No. 10: Top of Boulder Beach; mainly moss mixed with some soil; pH 6.3.

No. 11: Near meteorological station, grass (*Poa* sp.) sward with many roots and black soil; pH 6.3.

No. 12: Near meteorological station; soil and litter under *Azorella* spp. plants; pH 5.2.

No. 13: Near meteorological station; mire litter mixed with much soil and some grass residues; pH 6.1.

Nos. 14, 15: Sea cliff top; moss (*Cotula plumosa*) mixed with soil.

No. 16: Archway Bay; soil below *Cotula* sp. clump, 15 m from shore and immediately adjacent to a King Penguin colony; pH 4.6; <5 m above sea level.

No. 17: Archway Bay; gravel substrate to King Penguin (*Aptenodytes patagonicus*) colony, mixed with guano and feathers, no vegetation, within 20 m of sea; pH 7.6; <5 m above sea level.

No. 18: Archway Bay; feather/guano "soup" at back of King Penguin colony, always highly saturated, no vegetation, within 20 m of sea; pH 7.2; <5 m above sea level.

No. 19: Soil from occupied Wandering Albatross (*Diomedea exulans*) nest; pH 4.7.

No. 20: Scree slope of Junior's Kop; red lava/scoria gravel, no vegetation, 2.5 km from sea; pH 6.5; 200 m above sea level.

No. 21: Base of Junior's Kop; red lava/scoria gravel/mud with little vegetation, 2.5 km from sea; pH 6.3; 150 m above sea level.

No. 22: Near base of Junior's Kop; muddy soil from beside grey lava outcrop, some sparse grass vegetation, 2 km from sea; pH 5.9; 125 m above sea level.

No. 23: Coast of Prince Edward Island, Cave Bay (46°38′S, 37°57′E); biologically influenced (i.e., near a penguin colony), *Poa* and *Callitriche* vegetation, sample mainly consisted of moss and was slightly saline; pH 6.3.

No. 24: Boulder Beach; seaward limit of vegetation, grass sward on rock, slightly saline; pH 6.1.

Nos. 25, 26: Boulder Beach; grass, grass roots, moss, and some soil on rock back of beach, heavily saline; pH 5.9.

No. 27: Boulder Beach; seaward limit of vegetation, grass sward, moss and soil on rock, slightly saline; pH 6.0.

Faunistic methods

All samples obtained were air-dried for 4 weeks, then treated with the non-flooded Petri dish method as described by Foissner (1987, 1992). Briefly, this simple method involves placing 10–50 g air-dried moss, litter and/or soil in a Petri dish (10–15 cm in diameter) and saturating but not flooding it with distilled water. Such cultures were analyzed for ciliates on days 2, 7, 14, 21, and 28 by inspecting about 2 ml of the run-off from each sample.

Identification, terminology, and nomenclature are according to the literature cited in Foissner (1987, 1993) and Foissner et al. (1995). Most of the species found were described or redescribed by me and my students. Thus, determinations were done mainly on live specimens using a high-power oil immersion objective. However, species that could not be easily identified from living specimens were checked using various silver-staining techniques (Foissner 1991).

Cytological methods

The species described were studied in vivo using a high-power oil immersion objective and differential interference contrast. The ciliary pattern (infraciliature) was revealed by protargol impregnation as described in Foissner (1991). The descriptions are based on material obtained with the non-flooded Petri dish method mentioned above, i.e., no clonal cultures were set up.

Counts and measurements of silver-stained specimens were performed at a magnification of ×1000. In vivo measurements were conducted at a magnification of ×40–1000. While the latter measurements provide only rough estimates, it is worth giving such data as specimens usually shrink in preparations or contract during fixation. Standard deviations and coefficients of variation were calculated according to statistics textbooks. Illustrations of live specimens are based on free-hand sketches and micrographs; those of impregnated cells were made with a camera lucida. All figures are oriented with the anterior end of the organism directed to the top of the page.

Type slides

Two type slides each of the new species described have been deposited in the Oberösterreichische Landesmuseum in Linz (LI), Austria. The slides contain many protargol-impregnated cells with relevant specimens marked by a black ink circle on the cover glass.

Results and discussion

The culture method used is not perfect, i.e., not all species present can be reactivated from the resting cysts, but is probably the most efficient technique available. Repeated investigations of some soils showed that 2–5 samples distributed over 1 year yielded 50–80% of the species found in 10 samples investigated over 2 years (Foissner 1987). Thus, the samples investigated very likely contain more species than shown in Table 1. A further problem is posed by the different numbers of samples investigated in both the two islands of the present study and the Antarctic regions mentioned in Table 2. This makes a meaningful comparison difficult because the number of species found

Table 1 Species recorded and their frequency (percentage of occurrence in all samples, *F*) in samples from Gough Island (region G; nos. 1–7) and Marion Island (region M; nos. 8–27). +, present; –, absent

Species	*F* (%)	Region		Samples																										
		G	M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Acineria uncinata Tucolesco, 1962	3.7	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
Arcuospathidium cooperi n.sp.	3.7	–	+	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Birojimia muscorum (Kahl, 1932)	7.4	+	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Blepharisma bimicronucleatum Villenneuve-Brachon, 1940	3.7	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Blepharisma hyalinum Perty, 1849	3.7	+	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Blepharisma steini Kahl, 1932	3.7	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Bryometopus pseudochilodon Kahl, 1932	3.7	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Bryometopus sphagni (Penard, 1922)	3.7	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Bryophyllum loxophylliforme Kahl, 1931	3.7	+	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Colpoda aspera Kahl, 1926	18.5	+	+	–	–	+	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	+	+	+	–
Colpoda cucullus (Müller, 1773)	33.3	+	+	–	–	–	–	–	–	+	–	+	–	+	+	+	–	+	–	–	–	–	–	–	–	+	+	+	–	–
Colpoda ecaudata (Liebmann, 1936)	18.5	–	+	–	–	–	–	–	–	–	–	–	+	+	+	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–
Colpoda henneguyi Fabre-Domergue, 1889	3.7	–	+	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Colpoda inflata (Stokes, 1884)	48.1	+	+	+	–	+	+	+	+	+	+	–	+	–	–	+	–	–	–	–	–	–	–	–	–	+	–	+	+	+
Colpoda lucida Greeff, 1888	11.1	+	–	–	–	–	–	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Colpoda maupasi Enriques, 1908	3.7	+	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Colpoda steinii Maupas, 1883	74.0	+	+	+	+	+	+	+	+	+	+	+	–	+	+	–	–	+	+	–	–	–	–	+	+	+	+	+	+	+
Colpoda variabilis Foissner, 1980	3.7	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cyclidium muscicola Kahl, 1931	18.5	+	+	–	–	–	+	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–
Cyrtolophosis mucicola Stokes, 1885	29.6	+	+	+	+	–	+	–	–	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–	+
Dimacrocaryon amphileptoides (Kahl, 1931)	3.7	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Drepanomonas exigua (?) Penard, 1922[a]	3.7	–	+	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Drepanomonas muscicola Foissner, 1987	7.4	+	–	–	–	–	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Drepanomonas pauciciliata Foissner, 1987	11.1	+	–	–	–	+	+	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Drepanomonas revoluta Penard, 1922	3.7	+	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Enchelydium polynucleatum Foissner, 1984	3.7	+	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Epispathidium ascendens (Wenzel, 1955)	7.4	+	+	–	–	+	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Frontonia depressa (Stokes, 1886)	7.4	+	–	–	–	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Fuscheria terricola Berger, Foissner & Adam, 1983	3.7	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Gonostomum affine (Stein, 1859)	11.1	–	+	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	+	–	–	–	–	–	+	–	–
Grossglockneria acuta Foissner, 1980	18.5	+	+	–	+	–	+	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	+	–	–	+	–	+
Haplocaulus terrenus Foissner, 1981	3.7	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–
Hemisincirra gellerti (Foissner, 1982)	3.7	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Holosticha tetracirrata Buitkamp & Wilbert, 1974[b]	7.4	+	+	–	–	–	–	–	–	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Keronopsis muscicola (Kahl, 1932)	3.7	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lamtostyla hyalina Berger, Foissner & Adam, 1984	7.4	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	+	–	–	–	–	–
Lamtostyla islandica Berger & Foissner, 1988	7.4	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–
Leptopharynx costatus Mermod, 1914	44.4	+	+	+	–	+	+	–	+	+	–	+	–	+	+	+	–	–	–	–	–	–	–	–	–	+	–	–	+	+
Microdiaphanosoma arcuatum (Grandori & Grandori, 1934)	33.3	+	+	+	+	+	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	+
Microthorax simulans (Kahl, 1926)	3.7	–	+	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mykophagophrys terricola (Foissner, 1985)	7.4	+	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 1 (continued)

Species	*F* (%)	Region		Samples																											
		G	M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Nivaliella plana Foissner, 1980[c]	44.4	+	+	+	+	+	+	–	+	+	–	–	–	–	–	–	–	–	+	–	–	+	–	–	+	–	+	+	–	+
Onychodromopsis flexilis Stokes, 1887[d]	7.4	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–
Opercularia arboricola (Biegel, 1954)	3.7	–	+	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Orthoamphisiella grelli Eigner & Foissner, 1993[e]	11.1	+	–	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oxytricha granulifera Foissner & Adam, 1983	3.7	–	+	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oxytricha lanceolata Shibuya, 1930	11.1	+	+	–	–	+	–	–	–	–	–	–	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Oxytricha longigranulosa Berger & Foissner, 1989	3.7	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
Oxytricha ottowi n.sp.	3.7	+	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Platyophrya macrostoma Foissner, 1980	18.5	+	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	+	–	–	+	–	+	+	–	–	–	–	–
Platyophrya spumacola Kahl, 1927	11.1	+	–	–	–	+	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Platyophrya vorax Kahl, 1926	33.3	+	+	+	–	–	+	–	–	–	–	–	–	+	–	–	–	+	+	–	–	+	–	–	–	+	–	–	+	+
Platyophryides dragescoi Foissner, 1987	3.7	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
Protospathidium serpens (Kahl, 1930)	7.4	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	+	–	–	–	–	–	–
Pseudocyrtolophosis alpestris Foissner, 1980	48.1	+	+	+	+	+	+	+	+	+	+	–	–	–	+	–	–	–	–	–	–	–	–	+	+	–	–	–	+	+
Pseudoplatyophrya nana (Kahl, 1926)	63.0	+	+	+	+	+	+	+	+	+	–	+	–	–	+	–	–	+	+	–	–	+	–	–	+	+	–	+	+	+
Pseudoplatyophrya saltans Foissner, 1988	3.7	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sathrophilus muscorum (Kahl, 1931)	18.5	+	+	–	–	+	–	–	–	+	–	–	–	+	–	–	–	–	+	–	–	+	–	–	–	–	–	–	–	–
Sterkiella histriomuscorum (Foissner et al., 1991)	7.4	–	+	–	–	–	–	–	–	–	–	–	+	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Vorticella astyliformis Foissner, 1981	7.4	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	+	–
Number of taxa found (total 60)		39	39	9	7	16	14	8	20	23	3	6	5	10	6	8	2	6	8	0	0	9	2	6	9	9	6	10	9	10

[a] Has a spine also on left side near posterior end; possibly a new species
[b] Very similar to the population described by Blatterer and Foissner (1988) from Australia, i.e., with more than four transverse cirri
[c] Two forms occurred (sometimes in the same sample), one which is very similar to the Austrian type population and another which is less distinctly flattened and more distinctly oviform, resembling *Pseudoplatyophrya saltans*; possibly a new species
[d] Detailed description of Antarctic population in preparation
[e] Description in Eigner and Foissner (1993), i.e, type location is Gough Island

Table 2 Main characteristics of the ciliate communities in cool temperate (Gough Island), sub-Antarctic (Marion Island), and Antarctic (South Orkney Islands, Antarctic Peninsula, South Victoria Land; Foissner 1996) sites. *C/P* ratio of colpodid/polyhymenophorid ciliates (Lüftenegger et al. 1985)

Region	Number of species	Mean species number per sample	Number of new species	C/P quotient	Number of samples investigated
Gough Island	39	14.0	2	2.5	7
Marion Island	39	5.7	2	1.4	20
Gough and Marion Island combined	60	7.8	4	1.4	27
South Orkney Islands	51	9.6	3	1.1	8
Antarctic Peninsula	16	0.9	0	2.7	37
South Victoria Land	14	1.1	1	0.8	14
Antarctic sites combined	64	2.2	4	0.7	59

at a certain area or biotope is generally highly dependent on sampling intensity. However, a few peculiarities are evident and are discussed below in some detail.

Faunistics and community structures

Sixty species were found, 39 in each of the two regions investigated. These figures are comparable to those reported from Antarctic sites (Table 2), alpine grassland and shrub soils above the timberline (Foissner 1981), and spruce forest soils from temperate regions (Aescht and Foissner 1993), but much smaller than those reported from some tropical forests where a single sample may contain 80 species (Foissner 1995). However, the total number of species is an ambiguous measure considering the different sample sizes. Thus, the mean number of species per sample was calculated. This showed that the samples from Gough Island, which has the least severe climate, contained the highest number of species, followed by the South Orkney Islands and Marion Island, which are climatically less severe than the sites from the Antarctic Peninsula and South Victoria Land (Table 2). Thus, the species number for ciliates follows the well-known rule of decreasing with increasing environmental severity (Franz 1975). This is sustained by the *C/P* quotient (ratio of colpodid/polyhymenophorid ciliates) which has been suggested as a measure of biotope extremity (Lüftenegger et al. 1985). Although there was some bias in detail, most quotients were near or above 1, indicating that the biotopes investigated favour *r*-selected "reproducers" (colpodids) rather than *K*-selected "persisters" (polyhymenophorans). Furthermore, colpodids conspicuously dominated the frequency spectrum (see below), whereas at least a few hypotrichs (e.g., *Gonostomum affine, Urosomoida* spp., *Hemisincirra* spp.) were as common as several colpodids in soils from temperate regions (Aescht and Foissner 1993; Foissner et al. 1985; Foissner 1987).

The richest sample (23 species) was from site 7 at Gough Island, i.e., the lowland peat. By comparison, the highland mire from Tafelkop showed lower diversity with one sample (no. 3) having only seven ciliate species (Table 1). The lowland peat also supported many more macroinvertebrates than did the highland mire (J. Cooper, personal communication).

The richest Marion Island samples were from sites 11, 19, 22, 23, 25–27, each containing 9–10 species. These samples consisted mainly of grass swards with a lot of adhering litter and soil. Salinity (samples 25, 26) did not negatively influence the ciliate species number, in contrast to the testate amoebae which were poorly developed in saline coastal soils (Grospietsch 1971). The poorest samples were from sites 8, 14, 17, 18, and 20. These were collections from pure moss, a heavily eutrophic penguin-influenced site, and a site without vegetation. Obviously, grassland with a well developed soil cover favoured many more species than sites with little or no vegetation; penguin guano contained only flagellates.

Most species with high frequency (≥18%, Table 1) belong to the class Colpodea, with the highest values reported for *Colpoda steinii* (74%), a very common, euryoecious bacteria feeder (Foissner 1987, 1993), and *Pseudoplatyophrya nana* (63%), an obligate fungal sucker that is also widespread in soils worldwide (Foissner 1987, 1993). As mentioned above, colpodid ciliates generally dominate extreme soil environments due to their *r*-selected survival strategy. Three other species, *Cyclidium muscicola, Sathrophilus muscorum*, and *Leptopharynx costatus*, also had high frequency values (Table 1). These ciliates are small bacteria feeders which may have some preference for acidic soils and mosses, where they are most commonly found.

Another conspicuous peculiarity of the ciliate communities at Gough and Marion Island was the highly patchy distribution of species: 38 out of the 60 species only occurred in 1–2 samples. Very likely, the irregular distribution resulted from the extreme environment allowing few pioneers to establish stable populations.

Special record: *Hemimastix amphikineta* Foissner et al., 1988

Hemimastix amphikineta was found at site 3. It is a peculiar, heterotrophic organism possibly having a common ancestor with euglenoid flagellates (Foissner and Foissner 1993). *Hemimastix amphikineta* has so far been found only in the southern hemisphere, and Foissner and Foissner (1993) thus suggested that it could be a Gondwanian relict. This is not contradicted by its occurrence on a rela-

tively young volcanic island, because the island is surrounded by Gondwanian land masses which are certainly the main species donators for colonization of new land. This is supported by the occurrence of several other Gondwanian protists on Marion Island and other sub-Antarctic islands, viz., certain testate amoebae, e.g., *Nebela vas* (Grospietsch 1971; Smith 1978).

Description of new species

Morphometric data shown in Tables 3 and 4 are repeated in this section only as needed for clarity. All observations are from field material, not from clone cultures. Thus, it remains possible that similar, but different, species were mixed, although this is unlikely because I excluded all specimens which deviated in at least one prominent character. Certainly, this can generate some bias in the data if used too uncritically. However, I usually exclude only such specimens which have, e.g., a different nuclear structure (very likely often postconjugates), a distinctly deviating ciliary pattern (very likely often injured, regenerating, or malformed specimens), or an unusually small size (very likely often degenerating, just excysted, or divided specimens). The inclusion of such individuals, which might sometimes belong to another species, would artificially increase the variability.

Table 3 Morphometric data from *Arcuospathidium cooperi*, based on protargol-impregnated and mounted specimens from raw cultures. Measurements in μm. *CV* coefficient of variation in %, *M* median, *Max* maximum, *Min* minimum, *n* number of individuals investigated, *SD* standard deviation, $SD_{\bar{x}}$ standard deviation of mean, $\bar{x}$ arithmetic mean

Character	$\bar{x}$	M	SD	$SD_{\bar{x}}$	CV	Min	Max	*n*
Body, length	120.1	118	18.4	5.6	15.3	87	153	11
Body, maximum width	18.5	18	1.0	0.3	5.6	17	20	11
Oral bulge, length	29.3	30	3.2	1.0	10.8	24	35	11
Distance anterior end to macronucleus	48.4	50	11.2	3.4	23.2	32	69	11
Macronucleus, length	30.5	30	3.6	1.1	11.9	22	35	11
Macronucleus, width	5.8	6	0.8	0.2	12.9	5	7	11
Micronucleus, length	3.8	4	–	–	–	3	4	11
Micronucleus, width	2.7	3	–	–	–	2	3	11
Brush kinety 1, length	13.5	14	1.7	0.5	12.6	10	16	11
Brush kinety 2, length	14.8	16	1.9	0.6	12.8	12	17	11
Brush kinety 3, length	10.2	10	1.4	0.4	13.7	7	12	11
Brush kinety 1, number of dikinetids	10.3	11	0.9	0.3	8.8	9	11	11
Brush kinety 2, number of dikinetids	10.7	12	1.8	0.5	16.8	7	12	11
Brush kinety 3, number of dikinetids	6.7	7	1.1	0.3	16.5	5	9	11
Somatic kinetics, number	11.2	11	0.9	0.3	7.8	10	13	11
Brush kinetics, number	3.1	3	–	–	–	3	4	11
Kinetids in a right lateral kinety, number	25.5	25	4.6	1.4	17.9	20	35	11
Macronuclei, number	1	1	0.0	0.0	0.0	1	1	100
Micronuclei, number	1	1	0.0	0.0	0.0	1	1	100

Table 4 Morphometric data from *Oxytricha ottowi* (for further explanations, see Table 3)

Character	$\bar{x}$	M	SD	$SD_{\bar{x}}$	CV	Min	Max	*n*
Body, length	92.2	92.0	8.4	2.2	9.1	78	103	14
Body, maximum width	32.8	32.5	5.4	1.4	16.3	23	40	14
Anterior somatic end to proximal end of adoral zone, distance	31.3	31.5	3.6	1.0	11.4	24	35	14
Nuclear figure, length	52.9	51.0	8.2	2.2	15.6	41	65	14
Macronuclear nodules, length	7.9	8.0	0.9	0.3	12.0	6	9	14
Macronuclear nodules, width	6.0	6.0	0.9	0.3	14.6	4	7	14
Micronuclei, largest diameter	2.3	2.2	0.3	0.1	12.5	2	3	14
Macronuclear nodules, number	8.0	8.0	0.0	0.0	0.0	8	8	19
Micronuclei, number	3.2	3.0	1.3	0.3	41.1	0	5	19
Adoral membranelles, number	25.5	25.5	2.7	0.7	10.4	21	29	14
Right marginal cirri, number	24.6	24.5	1.8	0.5	7.4	22	27	14
Left marginal cirri, number	22.5	22.0	2.2	0.6	10.0	19	26	14
Anterior frontal cirri, number	3.0	3.0	0.0	0.0	0.0	3	3	14
Posterior frontal cirri, number	4.0	4.0	0.0	0.0	0.0	4	4	14
Buccal cirri, number	1.0	1.0	0.0	0.0	0.0	1	1	14
Postoral cirri, number	3.0	3.0	–	–	–	3	4	14
Ventral cirri ahead of transverse cirri, number	2.0	2.0	–	–	–	1	2	14
Transverse cirri, number	4.9	5.0	–	–	–	4	5	14
Caudal cirri, number	3.0	3.0	0.0	0.0	0.0	3	3	14
Dorsal kineties, number	6.0	6.0	0.0	0.0	0.0	6	6	14

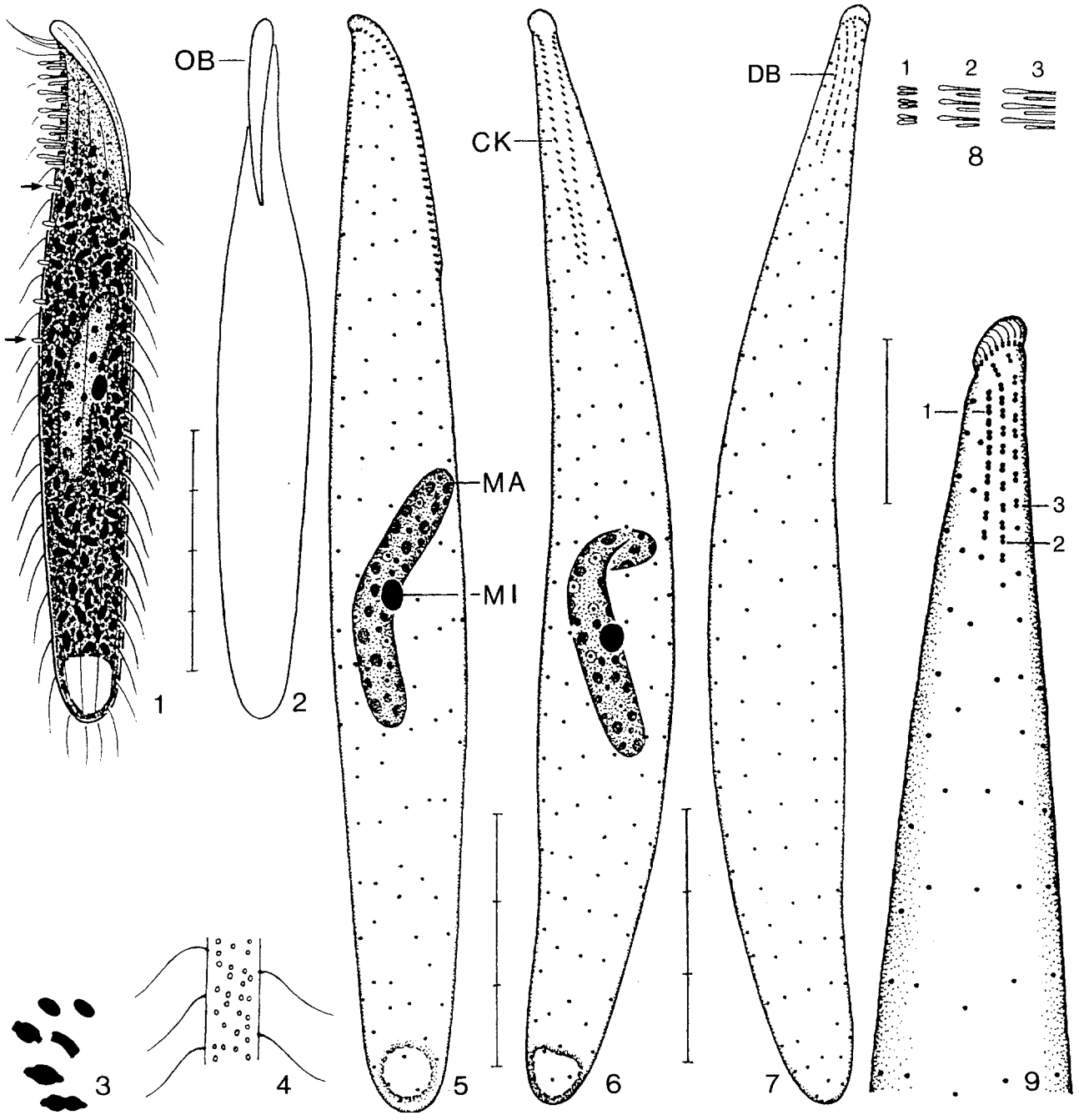
Arcuospathidium cooperi n. sp. (Figs. 1–13, Table 3)

Diagnosis: Size in vivo about 90–160×20–25 µm. Macronucleus slenderly reniform, 30×6 µm on average. Oral bulge short, i.e., about $\frac{1}{4}$ of body length. 11 somatic kineties on average.

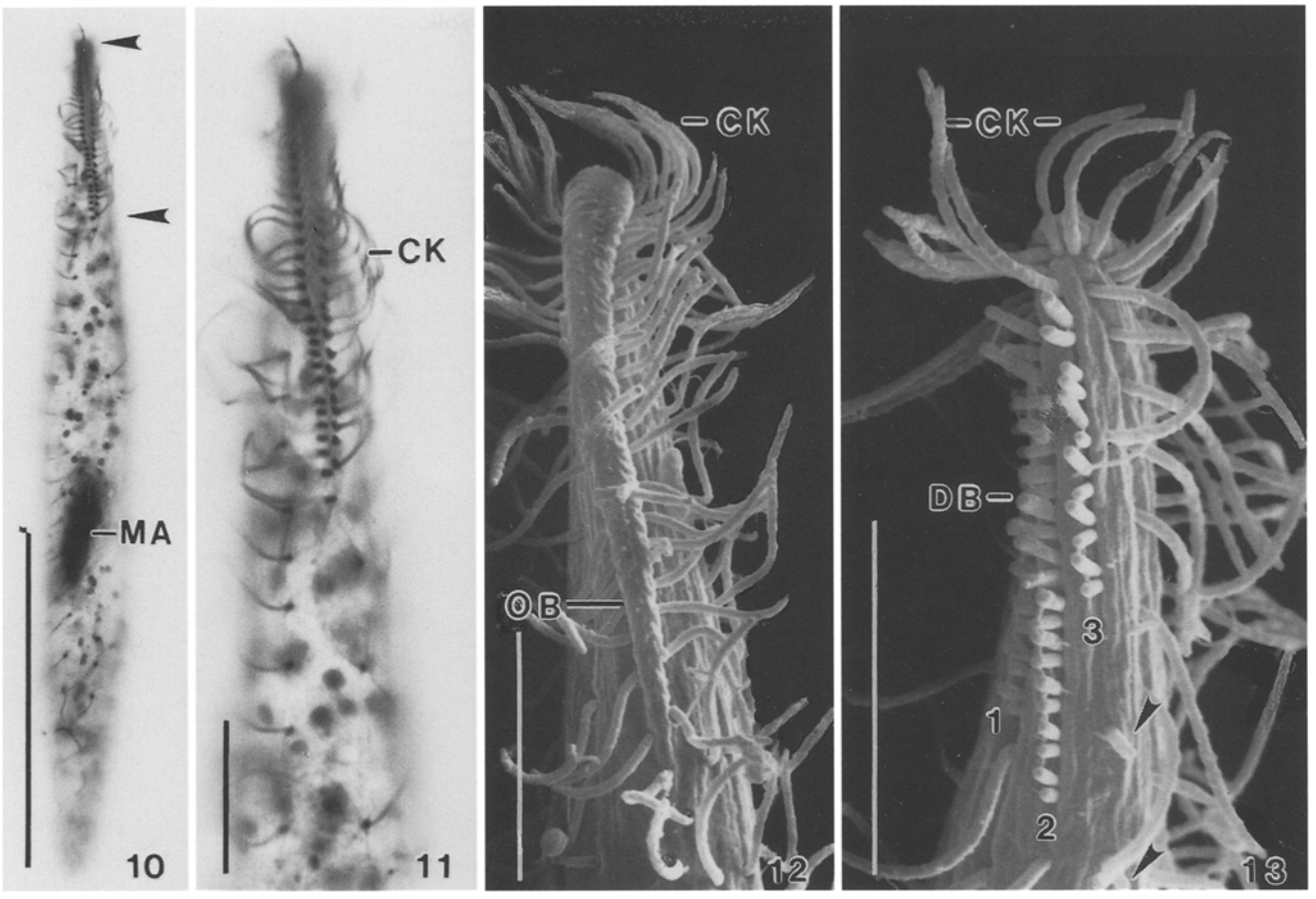
Type location: In moss and soil from Marion Island, Prince Edward Islands, southern Indian Ocean (46°52′S, 37°51′E).

Dedication: Named after Mr. John Cooper (University of Cape Town, South Africa), who provided the samples investigated in this study.

Description: Shape slightly fusiform to slenderly cylindroid, flattened only in oral region, widest usually close



Figs. 1–9 *Arcuospathidium cooperi* from life (1–4, 8) and after protargol impregnation (5–7, 9). **1–3** Right lateral and ventral view of typical specimen. Cells appear blackish due to many highly refractile, crystalline inclusions (Fig. 3). *Arrows* mark bristles at posterior end of third dorsal brush row. **4** Surface view showing loosely arranged cortical granules. **5–7** Somatic and oral infraciliature (ciliary pattern) of right, ventral, and dorsal side. **8, 9** Anterior dorsal portion at higher magnification. The dorsal brush consists of three rows (*numbers* 1–3) having paired, short cilia. Row 3 continues posteriorly with single, short bristles (cp. Figs. 1, 13). *CK* circumoral kinety, *DB* dorsal brush, *MA* macronucleus, *MI* micronucleus, *OB* oral bulge. Scale bar division 10 µm



Figs. 10–13 *Arcuospathidium cooperi* after protargol impregnation (**10, 11**) and in the scanning electron microscope (**12, 13**). **10, 11** Ventral views showing oral bulge (*arrowheads*), circumoral kinety (*CK*) and macronucleus (*MA*). **12, 13** Anterior ventral and dorsal portion showing oral bulge (*OB*), circumoral kinety (*CK*) and dorsal brush (*DB*) consisting of three rows (*numbers* 1–3). Row 3 continues posteriorly with single, short bristles (*arrowheads*; cp. Fig. 1). Scale bars 50 μm (Fig. 10) and 10 μm (Figs. 11-13), respectively

below proximal end of oral bulge. Macronucleus slenderly reniform to boomerang-shaped, near centre of body, with many roundish nucleoli. Micronucleus globular, attached to macronucleus. Single contractile vacuole in posterior end. No extrusomes recognizable in oral bulge and cytoplasm. Cortex flexible, colourless, contains loose rows of 0.5–1 μm sized granules (Fig. 4). Cytoplasm conspicuously dark at ×100 due to innumerable, highly refractile crystalline inclusions; macronucleus and contractile vacuole thus stand out as bright blisters (Fig. 1); crystals 3–5 μm long, of variable shape (Fig. 3), do not dissolve in water when cell is disrupted. Movement serpentine and slow.

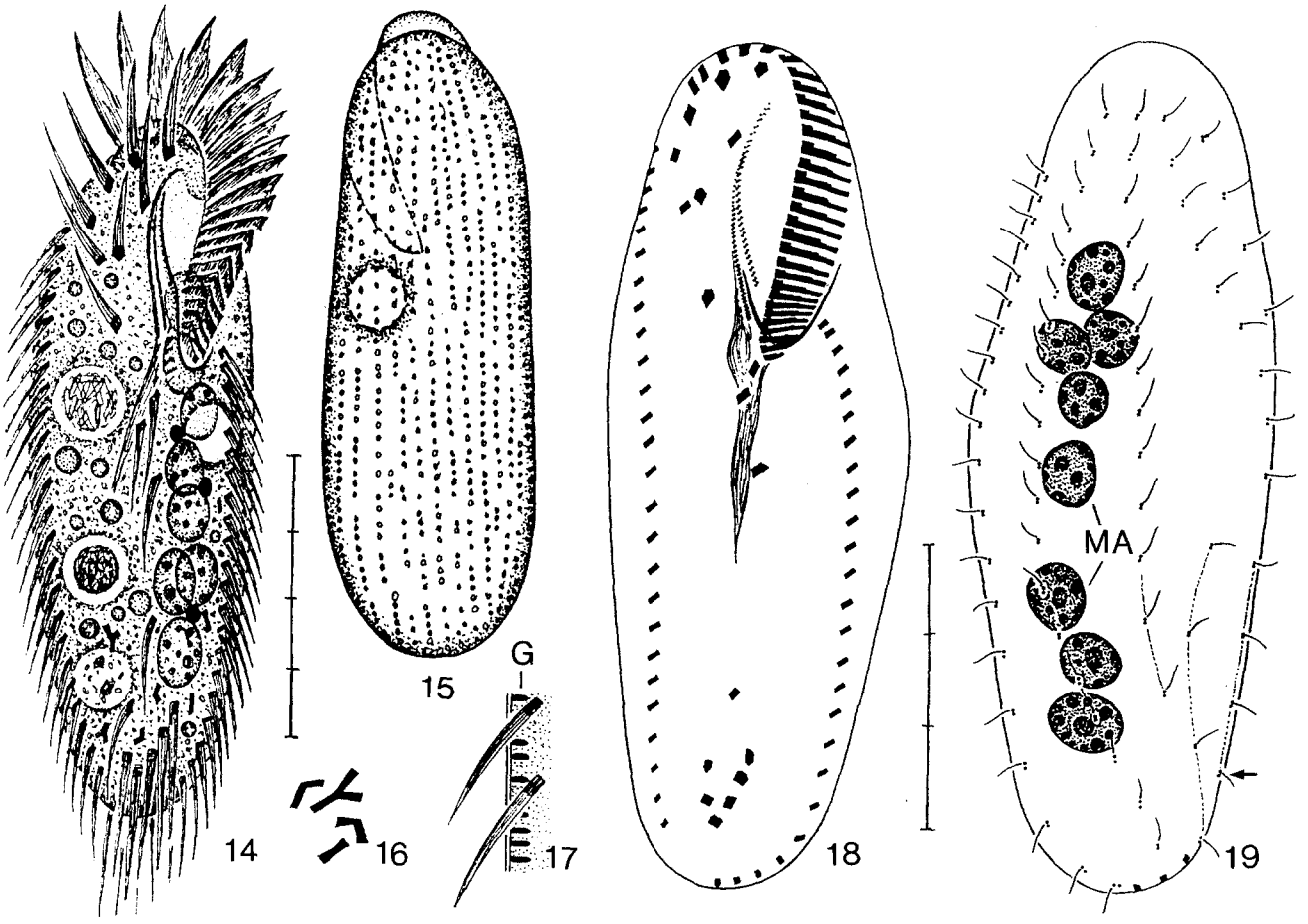
Somatic cilia 8–10 μm long, widely spaced, arranged as in other members of genus (Foissner 1984), i.e., in longitudinal rows distinctly separate from circumoral kinety. Dorsal brush short, usually consisting of 3 (rarely 4) rows of paired cilia with slightly inflated distal end; cilia of row 1 about 2 μm long, those of rows 2 and 3 up to 5 μm long, row 3 continues with single, about 2 μm long bristles to mid-body (Figs. 1, 8, 9, 13).

Oral bulge distinctly oblique and slenderly cuneate, hyaline, inconspicuous, base surrounded by cuneate circumoral kinety composed of rather widely spaced dikinetids having only one basal body ciliated (Figs. 6, 10–12).

Comparison with related species: Size, shape, ciliary pattern, and terrestrial habitat of *A. cooperi* highly resemble *A. vermiforme* Foissner, 1984 which, however, has two ellipsoid macronuclear nodules. These species also share another, however negative, character, viz., the absence of extrusomes, at least in the light microscope. I checked this very carefully in many specimens and with optimum technical equipment. No *Spathidium* species was found in the older literature which might be identical with *A. cooperi*.

Oxytricha ottowi n. sp. (Figs. 14–19, Table 4)

Diagnosis: Size in vivo about 85–110×25–35 μm. 8 macronuclear nodules forming conspicuous row left of cell median. Cortical granules about 2×0.5 μm, colourless, arranged in many, loose rows. On average 25 adoral membranelles, 24 right and 22 left marginal cirri, and 5 transverse cirri. 6 dorsal kineties with 1 caudal cirrus each associated with kineties 1, 2, 4.



Figs. 14–19 *Oxytricha ottowi* from life (**14–17**) and after protargol impregnation (**18, 19**). **14** Ventral view of typical specimen. **15** Dorsal view showing rows of cortical granules. **16** Cytoplasmic crystals. **17** Lateral optical section through cortex showing that cortical granules (*G*) are rod-shaped. **18, 19** Infraciliature of ventral and dorsal side. *Arrow* marks posterior end of dorsal kinety 5. The main species character of *O. ottowi* is the macronucleus (*MA*) which consists of eight nodules. Scale bar division 10 μm

Type location: Peat at Transvaal Bay, Gough Island (40°21′S, 09°53′E), South Atlantic Ocean.

Dedication: Named in honour of Professor Dr. J.C.G. Ottow (Giessen University, Germany), founder and successful Managing Editor of *Biology and Fertility of Soils*, on the occasion of his 60th birthday.

Description: Shape ellipsoidal, both ends broadly rounded, dorsoventrally flattened up to 2:1. Very flexible, like e.g., *Oxytricha granulifera*. Macronuclear nodules globular to ellipsoid, number very constant (Table 4). Micronuclei globular, number highly variable, most specimens have 3 (Table 4). Contractile vacuole slightly above mid-body at left margin of cell, without conspicuous collecting canals. Cortical granules elongate, stain deep-blue with methyl green-pyronin and light-brown with protargol (Figs. 15, 17). Cytoplasm colourless, with few to many 3–4 μm sized crystals (Fig. 16), some 2–4 μm sized fat globules, and food vacuoles containing residues of bacteria, heterotrophic flagellates, and coccal cyanobacteria. Movement moderately rapid, without peculiarities.

Ventral cirral pattern as in other members of genus (Fig. 18). Marginal rows open widely at posterior end, gap occupied by caudal cirri right of cell median. Anterior frontal and marginal cirri about 15 μm long in vivo, transverse cirri 20 μm long, project distinctly above posterior body margin. Dorsal cilia about 3 μm long, rows 1 and 2 as long as body, rows 3 and 5 slightly shortened posteriorly, row 4 distinctly shortened anteriorly, row 6 markedly shortened posteriorly, both consisting of about 4 dikinetids only (Fig. 19); row 4 very likely originates by fragmentation from row 3, as e.g. in *O. granulifera* (Foissner and Adam 1983).

Oral apparatus and adoral zone of membranelles rather conspicuous, occupy about 34% of body length. Buccal cavity comparatively large and deep, right third covered by hyaline lip. Paroral and endoral membrane curved and tightly spaced, i.e., in parallel and/or intersecting optically only in anterior third, both composed of dikinetids arranged in zigzag. Pharyngeal fibres conspicuous (Figs. 14, 18).

Comparison with related species: The general organization of *O. ottowi* is very similar to that of other members of the genus, especially *O. granulifera* Foissner and Adam, 1983 and *O. longigranulosa* Berger and Foissner, 1989. However, these species and most congeners have only two macronuclear nodules; few have four, e.g., *Oxy-*

tricha islandica Berger and Foissner, 1987, but none eight like *O. ottowi*. The number of macronuclear nodules is highly constant in oxytrichids and thus a reliable species character. Species with eight macronuclear nodules are found also in genera closely related to *Oxytricha*, e.g., *Urosoma* and *Australocirrus*. These species have, however, a different ventral and/or dorsal infraciliature and thus cannot be confused with *O. ottowi*.

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References

Aescht E, Foissner W (1993) Effects of organically enriched magnesite fertilizers on the soil ciliates of a spruce forest. Pedobiologia 37:321–335

Berger H, Foissner W (1987) Morphology and biometry of some soil hypotrichs (Protozoa, Ciliophora). Zool Jb Syst 114:193–239

Berger H, Foissner W (1989) Morphology and biometry of some soil hypotrichs (Protozoa, Ciliophora) from Europe and Japan. Bull Br Mus Nat Hist (Zool) 55:19–46

Blatterer H, Foissner W (1988) Beitrag zur terricolen Ciliatenfauna (Protozoa, Ciliophora) Australiens. Stapfia (Linz) 17:1–84

Block W (1994) Terrestrial ecosystems: Antarctica. Polar Biol 14:293–300

Eigner P, Foissner W (1993) Divisional morphogenesis in *Orthoamphisiella stramenticola* Eigner & Foissner, 1991 and *O. grelli* nov. spec. (Ciliophora, Hypotrichida). Arch Protistenk 143:337–345

Foissner I, Foissner W (1993) Revision of the family Spironemidae Doflein (Protista, Hemimastigophora), with description of two new species, *Spironema terricola* n. sp. and *Stereonema geiseri* n. g., n. sp. J Euk Microbiol 40:422–438

Foissner W (1981) Die Gemeinschaftsstruktur der Ciliatenzönose in alpinen Böden (Hohe Tauern, Österreich) und Grundlagen für eine Synökologie der terricolen Ciliaten (Protozoa, Ciliophora). Veröff Österr MaB-Programms 4:7–52

Foissner W (1984) Infraciliatur, Silberliniensystem und Biometrie einiger neuer und wenig bekannter terrestrischer, limnischer und mariner Ciliaten (Protozoa: Ciliophora) aus den Klassen Kinetofragminophora, Colpodea und Polyhymenophora. Stapfia (Linz) 12:1–165

Foissner W (1987) Soil protozoa: fundamental problems, ecological significance, adaptations in ciliates and testaceans, bioindicators, and guide to the literature. Progr Protistol 2:69–212

Foissner W (1991) Basic light and scanning electron microscopic methods for taxonomic studies of ciliated protozoa. Eur J Protistol 27:313–330

Foissner W (1992) Estimating the species richness of soil protozoa using the "non-flooded Petri dish method". In: Lee JJ, Soldo AT (eds) Protocols in protozoology. Society of Protozoologists, Allen Press, Lawrence, Kansas, pp B-10.1–B-10.2

Foissner W (1993) Colpodea (Ciliophora). Fischer, Stuttgart Jena

Foissner W (1994) Soil protozoa as bioindicators in ecosystems under human influence. In: Darbyshire JF (ed) Soil protozoa. CAB International, Wallingford, Oxon, pp 147–193

Foissner W (1995) Tropical protozoan diversity: 80 ciliate species (Protozoa, Ciliophora) in a soil sample from a tropical dry forest of Costa Rica, with descriptions of four new genera and seven new species. Arch Protistenk 145:37–79

Foissner W (1996) Faunistics, taxonomy and ecology of moss and soil ciliates (Protozoa, Ciliophora) from Antarctica, with description of new species, including *Pleuroplitoides smithi* gen. n., sp. n. Acta Protozool 35:95–123

Foissner W, Adam H (1983) Morphologie und Morphogenese des Bodenciliaten *Oxytricha granulifera* sp. n. (Ciliophora, Oxytrichidae). Zool Scr 12:1–11

Foissner W, Peer T, Adam H (1985) Pedologische und protozoologische Untersuchung einiger Böden des Tullnerfeldes (Österreich). Mitt Österr Bodenkd Ges 30:77–117

Foissner W, Blatterer H, Foissner I (1988) The Hemimastigophora (*Hemimastix amphikineta* nov. gen., nov. spec.), a new protistan phylum from Gondwanian soils. Europ J Protistol 23:361–383

Foissner W, Berger H, Blatterer H, Kohmann F (1995) Taxonomische und ökologische Revision der Ciliaten des Saprobiensystems – Band IV: Gymnostomatea, *Loxodes*, Suctoria. Informationsberichte des Bayer. Landesamtes für Wasserwirtschaft 1/95:1–540

Franz H (1975) Die Bodenfauna der Erde in biozönotischer Betrachtung, Teil 1: Textband, Teil 2: Tabellenband. Steiner, Wiesbaden

Grospietsch T (1971) Beitrag zur Ökologie der Testaceen Rhizopoden von Marion Island. In: Bakker EMZ, Winterbottom JM, Dyer RA (eds) Marion and Prince Edward Islands. Balkema, Cape Town, pp 411-423

Lüftenegger G, Foissner W, Adam H (1985) *r*- and *K*-selection in soil ciliates: a field and experimental approach. Oecologia (Berlin) 66: 574–579

Smith HG (1978) The distribution and ecology of terrestrial protozoa of sub-Antarctic and maritime Antarctic islands. Br Antarct Surv Sci Rep 95:1–104