



Rumen protozoa in South African sheep with a summary of the worldwide distribution of sheep protozoa

Authors:

Dirk Booyse¹
Burk A. Dehority²

Affiliations:

¹Department of Anatomy and Physiology, University of Pretoria, South Africa

²Department of Animal Sciences, Ohio State University, USA

Correspondence to:

Dirk Booyse

Email:

dbooyse@op.un.ac.za

Postal address:

Private Bag X04,
Onderstepoort 0110,
South Africa

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Protozoa species were identified in rumen contents of four domestic sheep (*Ovis aries*) from South Africa. All animals were fed a forage diet which consisted of 50% lucerne and 50% teff hay. Ten new host records were identified, bringing the total number of species and forms observed in sheep in South Africa to 30. The occurrence and geographic distribution of ciliate protozoa in both domestic and wild sheep from around the world are summarised. It was found that 15 genera and 131 species occur in domestic sheep globally.

Introduction

Other than several early reports from South Africa on rumen ciliate protozoa in domestic sheep (Fantham 1920, 1921, 1926; Van der Wath & Myburgh 1941), no additional research in this respect has been published. These previous studies identified a total of only 12 species and forms. Studies from other areas of Africa are also limited (see, e.g. Selim *et al.* [1996] for Egypt and Selim *et al.* [1999] for Libya). To date only 17 species have been observed in domestic sheep across Africa.

Materials and methods

During August 2009 samples of rumen contents were obtained from four fistulated male domestic sheep (*Ovis aries*), which were all housed together in 6 m x 10 m pens at the Department of Anatomy and Physiology, University of Pretoria (Onderstepoort), South Africa. Half of each pen was covered by a concrete floor, whilst the other half was an open-air dirt floor. The animals were rotated to a clean pen every week. The sheep were fed a 50:50 mixture of lucerne (*Medicago sativa*) and teff hay (*Eragrostis tef*) each morning, after which they were allowed free access to kikuyu grass (*Pennisetum clandestinum*) pasture for the rest of the day. Rumen samples of 200 mL each were collected through rumen fistulas and 200 mL warm saline was added immediately to each sample. This helped to extend the cilia of the protozoa for easier identification. The sample was then preserved by adding 70% alcohol (100 mL).

Each sample was washed in a Pitchford-Visser filter, similar to the one used for trematode egg counts. The outer sieve had an aperture of 37 µm, whilst apertures in the inner sieve were 110 µm. This procedure retained all the coarse material in the inner sieve and the protozoa were captured in the outer sieve. The sample was recovered from the outer sieve by means of a drain tap. The washed sample was drained into a container, allowed to stand and settle for 15 min and then most of the supernatant was decanted. This allowed concentration of the sample to a final volume of 40 mL. A measured volume of alcohol was added to preserve the sample. A few drops of methyl blue stain were added to stain the protozoa and nucleus (Booyse, Boomker & Dehority 2010).

A 0.1-mL aliquot of stained sample was transferred onto a glass microscope slide using a 'Finnpipette', commonly used in chemistry laboratories. The sample was covered with a glass cover slip and examined with a standard Nikon microscope fitted with a Panasonic digital camera. Photographs were taken to aid identification. Each sample was examined in triplicate.

Owing to the observed lack of *Entodinium* spp. in the washed samples, additional samples of rumen contents from the four sheep were obtained. Sub-samples (0.1 mL) of these samples were stained and examined under the microscope to verify the presence of *Entodinium* spp., which had been lost through the 37-µm filter.

Ethical considerations

Housing and care of fistulated animals in the Department of Anatomy and Physiology were approved on an ongoing basis by the University of Pretoria Animal Care and Use Committee, as sheep are routinely used as rumen fluid donors, both for experimental and for teaching purposes.



Results and discussion

A total of 20 species and forms of protozoa were observed in the four sheep used in the present study. Of these species, 10 were identified in South Africa for the first time (Table 1). This brings the total number of species and forms reported from sheep in South Africa to 30. All *Entodinium* species listed in Table 1 were identified in whole rumen content (i.e. unfiltered samples). It is noteworthy that for these new host records in South Africa at least three of the *Entodinium* species are closely related or possibly similar to *Entodinium dubardi* (Dehority 1994). These are *Entodinium caudatum* f. *dubardi*, *Entodinium parvum* and *Entodinium simplex*. *Entodinium nanellum* would have been included in this group, but had been observed previously. Two of the other *Entodinium* species reported as a new host record, namely *Entodinium exiguum* and *Entodinium longinucleatum*, can occur on a variation line with *E. dubardi*. However, two rather distinctive features allow identification as a separate species: for *E. exiguum*, a straight oesophagus that does not curve towards the macronucleus, and for *E. longinucleatum*, a macronucleus extending the entire length of the cell.

The number of species and forms observed for other geographical locations range from fewer than 10 to 49, as shown in Table 2. The number found in the present study is about halfway between these extremes. In general, several reports where only a limited number of species were observed, appear not to be comprehensive studies; that is, only a few species were identified rather than a complete listing of all species present. Göçmen *et al.* (1999) observed that the protozoan fauna of sheep in Turkey and Far Eastern areas (e.g. China and Japan) appeared to be more diverse than in European and American sheep.

A number of the studies listed in Table 2 were reported between 1920 and 1985, before the most widely used classification scheme of Lee, Hutner and Bovee (1985) was published. Therefore, the older species names in the subfamily Diplodiniinae listed in the original reports have been corrected according to the more recent classification scheme. For example, *Eodinium* spp. are now classified under *Diplodinium* and *Eremoplastron* spp. under *Eudiplodinium*. *Diploplastron affine* is now classified as *Metadinium affine*. In more recent studies by Göçmen (1999a, 1999b), classification

TABLE 1: Rumen ciliate protozoa observed in domestic sheep (*Ovis aries*) in South Africa.

Species and forms	Present study	Fantham (1920)	Fantham (1921)	Fantham (1926)	Van der Wath and Myburgh (1941)
<i>Isotricha intestinalis</i>	+	+	-	-	-
<i>Isotricha prostoma</i>	+	+	-	-	-
<i>Dasytricha ruminantium</i>	+	+	-	-	-
<i>Entodinium bursa</i>	-	+	-	-	-
<i>Entodinium caudatum</i>	-	-	-	-	-
f. <i>caudatum</i>	+	-	+	-	-
f. <i>dubardi</i>	++	-	-	-	-
<i>Entodinium dubardi</i>	+	-	-	+	+
<i>Entodinium elongatum</i>	-	-	-	-	+
<i>Entodinium exiguum</i>	++	-	-	-	-
<i>Entodinium furca</i>	-	-	-	-	+
<i>Entodinium longinucleatum</i>	++	-	-	-	-
<i>Entodinium minimum</i>	-	-	-	+	-
<i>Entodinium nanellum</i>	+	-	-	+	+
<i>Entodinium parvum</i>	++	-	-	-	-
<i>Entodinium simplex</i>	++	-	-	-	-
<i>Diplodinium dentatum</i>	+	-	-	+	-
<i>Diplodinium polygonale</i>	-	-	-	+	-
<i>Ostracodinium crassum</i>	-	-	-	+	-
<i>Ostracodinium gracile</i>	++	-	-	-	-
<i>Ostracodinium trivesiculatum</i>	++	-	-	-	-
<i>Eudiplodinium neglectum</i>	-	-	-	+	-
<i>Enoploplastron triloricatum</i>	++	-	-	-	-
<i>Polyplastron multivesiculatum</i>	++	-	-	-	-
<i>Epidinium ecaudatum</i>	-	-	-	-	-
f. <i>ecaudatum</i>	-	+	-	-	-
f. <i>caudatum</i>	+	+	-	-	-
f. <i>bicaudatum</i>	-	+	-	-	-
f. <i>tricaudatum</i>	-	+	-	-	-
<i>Ophryoscolex caudatus</i>	+	-	-	+	-
<i>Ophryoscolex purkynjei</i>	-	-	-	-	-
f. <i>bicoronatus</i>	+	-	-	+	-
f. <i>purkynjei</i>	++	-	-	-	-
Total species and forms	20	8	1	9	4

Note: Please see the full reference list of the article, Booysse, D. & Dehority, B.A., 2011, 'Rumen protozoa in South African sheep with a summary of the worldwide distribution of sheep protozoa', *Onderstepoort Journal of Veterinary Research* 78(1), Art. #307, 7 pages. doi:10.4102/ojvr.v78i1.307, for more information.

A total of 30 species and forms have been observed in South Africa (+), of which 10 new ones (++) were observed in the present study.



TABLE 2: Compilation of the protozoan fauna reported for domestic sheep (*Ovis aries*) from numerous geographical locations around the world. The numbers in each locality refers to the references listed below the table.

Species or form	South Africa	Egypt	Libya	Iceland	Canada	China	Europe	India	Italy	Iran	Pakistan	Russia	Scotland	Siberia	Turkey	USA	Yugoslavia	Cyprus	Portugal	Alaska	France	USSR	Britain
<i>Isotricha intestinalis</i>	1	2	3	-	4	-	-	-	-	-	5	-	-	-	30	6	7	-	-	-	-	-	-
<i>Isotricha prostoma</i>	1	2	-	10	4	24	-	-	9	-	5	-	31	-	30	6	7	-	-	-	-	-	-
<i>Dasytricha ruminantium</i>	1	2	3	10	4	6	-	-	9	-	5	-	31	-	30	6	7	-	-	-	-	-	-
<i>Parasotricha colpoidea</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-
<i>Charon venticuli</i>	-	-	-	10	-	24	-	-	-	-	5	-	-	-	-	-	7	-	-	-	-	-	-
<i>Buetschliella neglecta</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-
<i>Buetschliella parva</i>	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	6	7	-	-	-	-	-	-
<i>Entodinium acutum</i>	-	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Entodinium amphicostatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-
<i>Entodinium angustatum</i>	-	-	-	-	-	14	14	-	-	-	-	-	-	-	-	-	-	-	-	32	-	-	-
<i>Entodinium anteronucleatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>f. dilobum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-	-	-	-
<i>f. laeve</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	8	32	33	-	-
<i>Entodinium babici</i>	-	-	-	-	-	-	-	-	-	-	-	-	31	-	-	-	-	-	-	-	-	-	-
<i>Entodinium bicaudatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	-	-	-	33	-	-	-
<i>Entodinium bicornutum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32	-	-	-
<i>Entodinium biconcavum</i>	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	30	-	-	-
<i>Entodinium bimastus</i>	-	-	-	-	4	24	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-
<i>Entodinium bursa</i>	1	-	-	-	4	-	-	-	9	-	5	-	-	-	30	-	7	34	24	-	-	-	-
<i>Entodinium caudatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>f. caudatum</i>	15	2	3	10	4	24	-	-	9	-	5	17	-	35	30	22	7	34	32	-	-	-	-
<i>f. dubardi</i>	TS	2	3	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-
<i>f. lobosopinosum</i>	-	-	-	-	4	24	-	-	-	-	5	-	-	31	30	-	-	34	-	-	-	-	-
<i>Entodinium constrictum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	36	-	33	-	-	-
<i>Entodinium costatum</i>	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	7	34	32	-	-	-	-
<i>Entodinium cypriensis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-	-	-	-
<i>Entodinium dalli</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-
<i>f. rudidorsospinatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	34	-	-	-	-	-
<i>Entodinium damae</i>	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Entodinium dilobum</i>	-	2	3	10	-	24	-	-	9	-	5	-	-	-	30	-	7	34	32	-	-	-	-
<i>Entodinium dubardi</i>	38	2	3	10	-	24	-	13	9	-	5	-	31	-	30	6	7	34	32	-	-	-	-
<i>Entodinium elendrae</i>	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	34	32	-	-	-	-
<i>Entodinium elipsoidum</i>	-	-	-	-	-	-	-	-	-	-	-	-	31	-	30	-	-	-	-	-	-	-	-
<i>Entodinium elongatum</i>	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Entodinium exiguum</i>	TS	2	3	10	4	-	-	-	9	-	5	-	31	-	30	-	-	36	32	33	-	-	-
<i>Entodinium furca</i>	16	-	-	-	-	-	-	13	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-
<i>Entodinium imaii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-	-	-	-
<i>Entodinium lobosopinosum</i>	-	5	3	10	4	-	-	-	9	-	-	17	-	-	-	-	7	34	-	-	-	-	-
<i>Entodinium longinucleatum</i>	-	2	-	10	4	24	-	13	9	-	5	-	31	-	30	6	7	36	32	-	-	-	-
<i>Entodinium minimum</i>	38	2	3	-	-	21	-	-	9	-	5	-	-	-	30	-	7	34	-	-	-	-	-

Note: Please see the full reference list of the article, Booyse, D. & Dehority, B.A., 2011, 'Rumen protozoa in South African sheep with a summary of the worldwide distribution of sheep protozoa', *Onderstepoort Journal of Veterinary Research* 78(1), Art. #307, 7 pages. doi:10.4102/ojvr.v78i1.307, for more information.

TS, this study; USSR, Union of Soviet Socialist Republics (former federal union of 15 constituent republics).
 (1) Fantham 1920; (2) Selim *et al.* 1996; (3) Selim *et al.* 1999; (4) Imai *et al.* 1989; (5) Imai and Ogimoto 1978; (6) Dehority 1978; (7) Wertheim 1935; (8) Göçmen *et al.* 2001; (9) Moriggi 1941; (10) De la Fuente, Skrimsson and Dehority 2006; (11) Dehority and Pursler 1970; (12) Grain 1966; (13) Banerjee 1955; (14) Dogiel 1927; (15) Fantham 1921; (16) Van der Wath and Myburgh 1941; (17) Lubinsky 1957; (18) Dehority 2004; (19) Dehority 1975; (20) Coleman and Hall 1972; (21) Göçmen 2003b; (22) Bush and Kofoid 1948; (23) Imai, Katsuno and Ogimoto 1979; (24) Hsiung 1931; (25) Kofoid and MacLennan 1932; (26) Ogimoto and Imai 1981; (27) Das Gupta 1935; (28) Göçmen 2003a; (29) Dehority and Potter 1974; (30) Ökten, Göçmen and Torun 1997; (31) Eadie 1957; (32) Marinho 1983; (33) Dehority 1974; (34) Göçmen and Gürelli 2009b; (35) Göçmen *et al.* 1999; (36) Göçmen and Gürelli 2009a; (37) Latteur 1969; (38) Fantham 1926.

Table 1 continues on the next page →



TABLE 2 (Continues...): Compilation of the protozoan fauna reported for domestic sheep (*Ovis aries*) from numerous geographical locations around the world. The numbers in each locality refers to the references listed below the table.

Species or form	South Africa	Egypt	Libya	Iceland	Canada	China	Europe	India	Italy	Iran	Japan	Pakistan	Russia	Scotland	Siberia	Turkey	USA	Yugoslavia	Cyprus	Portugal	Alaska	France	USSR	Britain
<i>Entodinium minimum parvicauda</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-
<i>Entodinium monolobum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-
<i>Entodinium nanellum</i>	38	2	3	10	4	-	-	13	9	-	5	-	-	-	-	30	6	7	34	32	-	-	-	-
<i>Entodinium nanum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	31	-	-	-	-	-	-	33	-	-	-
<i>Entodinium oeketae</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-	-	-
<i>Entodinium ogimotai</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-	-	-
<i>Entodinium orbicularis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	-	-	-	-	33	-	-
<i>Entodinium ovinum</i>	-	2	-	-	4	24	-	-	-	-	5	-	-	-	-	30	-	7	34	32	-	-	-	-
<i>Entodinium ovoideum</i>	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Entodinium parvum</i>	TS	2	3	10	4	-	-	-	-	-	5	-	-	-	-	-	-	-	7	34	32	-	-	-
<i>Entodinium protuberans</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	33	-	-
<i>Entodinium quadricuspis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-	-	-
<i>Entodinium rectangulatum</i>	-	-	-	-	-	-	-	-	-	-	-	17	-	-	-	30	6	-	34	32	-	-	-	-
<i>Entodinium rectangulatum lobosopinosum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	34	-	-	-	-	-
<i>Entodinium rostratum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	7	34	-	-	-	-	-
<i>Entodinium semahatae</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-
<i>Entodinium simplex</i>	TS	2	3	-	4	24	-	-	9	-	5	-	-	-	37	30	22	7	34	32	-	-	-	-
<i>Entodinium simulans</i>	-	-	-	-	-	-	-	-	-	-	-	17	-	-	-	-	6	-	34	-	-	-	-	-
<i>Entodinium simulans caudatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	34	32	-	-	-	-
<i>Entodinium simulans dubardi</i>	-	-	-	-	-	-	-	-	-	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-
<i>Entodinium simulans lobosopinosum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	34	-	-	-	-	-
<i>Entodinium triacum dextrum</i>	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	30	-	-	34	-	-	-	-	-
<i>Entodinium williamsi</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	34	-	-	-	-	-
<i>Entodinium williamsi turcicum</i>	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-	-	-	-
<i>Eodinium bilobosum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	14	-	7	-	-	-	-	-	-
<i>Eodinium postovesiculatum</i>	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-
<i>Eodinium rectangulatum</i>	-	-	-	-	-	-	-	-	-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Diplodinium anacanthum</i>	-	2	-	10	-	24	-	-	-	-	5	-	-	-	-	21	-	7	-	-	-	-	-	-
<i>f. monacanthum</i>	-	-	-	10	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>f. diacanthum</i>	-	-	-	10	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>f. triacanthum</i>	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>f. tetracanthum</i>	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>f. pentacanthum</i>	-	-	-	-	-	24	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>f. anisacanthum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Diplodinium costatum</i>	-	-	-	-	-	27	-	-	9	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-
<i>Diplodinium dentatum</i>	38	-	-	10	-	-	-	-	-	-	5	-	-	-	-	-	6	-	-	-	-	-	-	-
<i>Diplodinium flabellum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	-	-	-	-	-	-	-
<i>Diplodinium flabellum aspinatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	-	-	-	-	-	-	-
<i>Diplodinium flabellum monospinatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	-	-	-	-	-	-	-

Note: Please see the full reference list of the article, Booyse, D. & Dehority, B.A., 2011, 'Rumen protozoa in South African sheep with a summary of the worldwide distribution of sheep protozoa', *Onderstepoort Journal of Veterinary Research* 78(1), Art. #307, 7 pages. doi:10.4102/ojvr.v78i1.307, for more information.

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Table 1 continues on the next page →



TABLE 2 (Continues...): Compilation of the protozoan fauna reported for domestic sheep (*Ovis aries*) from numerous geographical locations around the world. The numbers in each locality refers to the references listed below the table.

Species or form	South Africa	Egypt	Libya	Iceland	Canada	China	Europe	India	Italy	Iran	Japan	Pakistan	Russia	Scotland	Siberia	Turkey	USA	Yugoslavia	Cyprus	Portugal	Alaska	France	USSR	Britain
<i>Diplodinium lobatum</i>	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Diplodinium major</i>	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Diplodinium monolobosum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-
<i>Diplodinium polygonale</i>	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Diplodinium quinquecaudatum</i>	-	-	-	-	-	7	-	-	-	-	-	7	-	14	-	-	-	-	-	-	-	-	-	-
<i>Diplodinium rangiferi</i>	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eudiplodinium bovis</i>	-	-	-	10	-	24	-	-	-	-	5	-	14	-	-	-	-	-	-	-	-	-	-	-
<i>Eudiplodinium dilobum</i>	-	-	-	10	-	24	-	-	-	-	-	-	14	-	-	-	6	-	-	-	-	-	-	-
<i>Eudiplodinium monolobum</i>	-	-	-	-	-	-	-	-	9	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eudiplodinium neglectum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-
<i>Eudiplodinium rostratum</i>	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-
<i>Eudiplodinium maggi</i>	-	-	-	10	-	24	-	-	9	-	5	-	-	-	-	-	35	18	-	-	-	-	-	-
<i>Ostracodinium clipeolum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-
<i>Ostracodinium crassum</i>	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ostracodinium gracile</i>	TS	-	-	10	-	24	-	-	-	-	-	-	-	-	-	35	6	7	-	-	-	-	14	-
<i>Ostracodinium mammosum</i>	-	-	-	-	-	-	-	13	9	-	-	-	-	-	-	-	6	7	-	-	-	-	-	-
<i>Ostracodinium obtusum</i>	-	-	-	10	-	24	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ostracodinium rugoliricatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-
<i>Ostracodinium trivesiculatum</i>	TS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-
<i>Ostracodinium venustum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-
<i>Metadinium affine</i>	-	-	-	10	4	24	-	-	9	-	5	-	-	-	-	35	6	7	-	-	-	-	-	-
<i>Metadinium medium</i>	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-
<i>Metadinium minorum</i>	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	19	-	-	-	-	-	-	-
<i>Metadinium tauricum</i>	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	35	-	7	-	-	33	-	14	-
<i>Enoploplastron triloculatum</i>	TS	-	-	10	4	24	-	-	9	-	23	-	-	31	-	8	-	7	-	-	-	29	-	-
<i>Elytroplastron bubali</i>	-	-	-	10	-	-	-	25	-	-	-	-	-	31	-	-	-	-	-	-	-	-	-	-
<i>Polyplastron longitergum</i>	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Polyplastron multivesiculatum</i>	TS	2	-	-	4	24	-	-	-	-	5	-	-	-	-	35	6	7	-	-	-	-	20	-
<i>Epidinium cattanei</i>	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Epidinium eberleini</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	-	-	-	-	-	-	-
<i>Epidinium ecaudatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
f. <i>ecaudatum</i>	1	-	3	5	-	7	-	-	8	-	9	-	-	-	10	21	22	24	35	-	-	-	-	-
f. <i>caudatum</i>	1	2	3	-	-	-	-	-	8	-	9	-	-	-	-	21	-	-	35	-	-	-	-	-
f. <i>bicaudatum</i>	1	-	-	-	-	24	-	-	-	-	-	-	-	-	8	-	-	28	-	-	-	-	-	-
f. <i>tricaudatum</i>	1	-	-	-	-	-	-	-	9	-	-	-	-	-	-	8	-	-	-	-	33	-	-	-
f. <i>quadricaudatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	22	7	35	-	-	-	-	-
f. <i>parvicaudatum</i>	-	-	-	-	-	-	-	13	-	-	-	-	-	-	-	-	22	7	35	-	-	-	-	-
<i>Epidinium hamatum</i>	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-
<i>Epidinium graini</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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Table 1 continues on the next page →

Species or form	South Africa	Egypt	Libya	Iceland	Canada	China	Europe	India	Italy	Iran	Japan	Pakistan	Russia	Scotland	Siberia	Turkey	USA	Yugoslavia	Cyprus	Portugal	Alaska	France	USSR	Britain
<i>f. graini</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	21	-	-	-	-	-
<i>f. caudaquadriconotum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	-	-	-	-	-
<i>f. caudatricoronatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	-	-	-	-	-
<i>Ophryoscolex bicinctus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	22	7	-	-	-	-	-	-
<i>Ophryoscolex buissoni</i>	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	-	22	-	-	-	-	-	-	-
<i>Ophryoscolex caudatus</i>	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ophryoscolex purkynjei</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>f. bicoronatus</i>	TS	-	-	-	-	24	-	-	9	-	-	-	14	-	-	35	22	-	-	-	-	-	-	-
<i>f. bifidobicinctus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	28	-	-	-	-	-
<i>f. bifidoquadriricinctus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	28	-	-	-	-	-
<i>f. purkynjei</i>	38	2	-	4	-	24	-	-	9	-	-	-	14	-	-	8	22	7	28	-	-	-	-	-
<i>f. quadriconotus</i>	-	-	-	-	-	-	-	-	-	14	-	-	-	-	-	22	28	-	6	-	-	-	-	-
<i>f. tricornotus</i>	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	35	-	-	28	-	-	-	-	-
Total number of protozoa records per locality	30	19	17	29	17	35	3	6	25	2	34	6	10	12	4	45	39	49	47	18	10	1	2	1

Note: Please see the full reference list of the article, Booyse, D. & Dehority, B.A., 2011, 'Rumen protozoa in South African sheep with a summary of the worldwide distribution of sheep protozoa', *Onderstepoort Journal of Veterinary Research* 78(1), Art. #307, 7 pages. doi:10.4102/ojvr.78i1.307, for more information.

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TABLE 3: Protozoa recorded in Bighorn (*Ovis canadensis*) and Dall (*Ovis dalli*) sheep. The numbers in each locality refers to the references listed below the table.

Protozoa listed per host	California	Scotland	Siberia	Alaska
Bighorn sheep	-	-	-	-
<i>Entodinium bicarinatum</i>	-	-	3	-
<i>Entodinium bicaudatum</i> †	1	-	-	-
<i>Entodinium chatterjee</i>	1	-	-	-
<i>Entodinium exiguum</i> †	1	-	-	-
<i>Entodinium nanum</i> †	1	3	-	-
<i>Entodinium orbicularis</i> †	1	-	-	-
<i>Entodinium truncatum</i>	1	-	-	-
<i>Enoploplastron trilocricatum</i> †	1	-	-	-
<i>Metadinium tauricum</i> †	1	-	-	-
<i>Polyplastron californiense</i>	1	-	-	-
Dall sheep	-	-	-	-
<i>Entodinium anteroneucleatum</i> †	-	-	-	2
<i>Entodinium bicaudatum</i> †	-	-	-	2
<i>Entodinium constrictum</i> †	-	-	-	2
<i>Entodinium dalli</i>	-	-	-	2
<i>Entodinium nanum</i> †	-	-	-	2
<i>Metadinium tauricum</i> †	-	-	-	2
<i>Polyplastron alaskum</i>	-	-	-	2
<i>Ophryoscolex bicinctus</i> †	-	-	-	2
<i>Ophryoscolex buissoni</i> †	-	-	-	2
<i>Ophryoscolex purkynjei</i> †	-	-	-	-
<i>f. bicoronatus</i> †	-	-	-	2
<i>f. caudatus</i> †***	-	-	-	2
Total number of species and forms	9	1	1	11

†, Protozoa recorded in domestic sheep.

(1) Bush, M. & Kofoid, C.A., 1948, 'Ciliates from the Sierra Nevada bighorn (*Ovis canadensis sierrae* Grinnell)', *University of California Publications in Zoology* 53, 287–261; (2) Dehority, B.A., 1974, 'Rumen ciliate fauna of Alaskan Moose (*Alces Americana*), Musk-Ox (*Ovisbos moschatus*) and Dall Mountain sheep (*Ovis dalli*)', *Journal of Protozoology* 21, 26–32; (3) Latteur, B., 1969, 'Revision systématique de la Famille des *Ophryoscolecidae* Stein, 1858: sous-Famille des *Entodiniinae* Lubinsky, 1957, Genre *Entodinium* Stein, 1958', *Annales de la Societe Royal Zoologique de Belgique* 99, 3–25.

of both *Epidinium* spp. and *Ophryoscolex* spp. have been redefined and are used in Table 2. The total number of protozoa found in each of the localities indicated in Table 2 is summarised and listed at the end of the table.

Table 3 lists species and forms of protozoa observed in wild Bighorn and Dall sheep in the USA. Bighorn sheep are found in the Rocky Mountains from Colorado to Canada, whilst the Dall sheep live further north, reaching into Alaska. Many of the protozoa found in these two species (10 in Bighorn and 11 in Dall sheep) are also present in domestic sheep. Although not reported from domestic sheep, at least two species have been observed in Turkish cattle, namely *Entodinium dalli*, and a second form, *Entodinium dalli rudidorosospinatum* (Göçmen & Öktem 1996). Of particular interest is the presence of two new species of *Polyplastron*, neither of which has been observed elsewhere.

It is possible that as further in-depth studies are conducted, we will find a somewhat uniform distribution of protozoal species around the world.

Conclusion

We identified 10 species of rumen ciliate protozoa that had not been previously observed in rumen contents of South



African sheep. This brings the total of species observed in this country to 30. The collection of protozoal fauna in South African sheep was compared to previous data reported for sheep worldwide and appeared to be somewhat less diverse.

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