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Gastrointestinal helminths in sheep (*Ovis aries*) in Iceland; their prevalence, abundance and geographic distribution

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SUMMARY

During the slaughtering period (September–October) the gastrointestinal tracts were collected from one lamb from each of a total of 94 Icelandic sheep farms. The lambs were aged 4–5½ months. The farms were selected to reflect the distribution of farms in the country. The gastrointestinal tract of each lamb was searched for parasitic helminths, the adults of the larger nematode species and the adult males of the smaller nematode species identified by species and counted and the total length of cestodes measured.

The following 11 nematode species were found: *Teladorsagia circumcincta* (incl. *T. c. trifurcata* and *T. c. davtiani*), *Trichostrongylus axei, T. capricola*, *T. vitrinus*, *Nematodirus filicollis*, *N. spathiger*, *Cooperia oncophora* (incl. *C. o. zurnabada*), *Bunostomum trigonocephalum, Chabertia ovina, Oesophagostomum venulosum* and *Trichuris ovis*. The cestode *Moniezia expansa* was also found.

The results from each lamb are presented, together with maps showing the geographical distribution and prevalence of each helminth species. The results are compared with earlier findings. The relationship between the numbers of individuals of some of the morphs, species or genera are examined. Finally a comparison is made of which gastrointestinal helminth species have been found in sheep in the countries bordering the northernmost part of the Atlantic Ocean, and the possible reasons for some of the differences are discussed.

Key words: gastrointestinal helminths, Iceland, *Ovis aries*, sheep.

YFIRLIT

Ormar í meltingarvegi sauðfjár (Ovis aries) *á Íslandi, tíðni þeirra, fjöldi og landfræðileg útbreiðsla*

Í sláturtíðinni (sept.–okt.) var safnað meltingarvegum úr alls 94 lömbum, einu frá hverjum bæ. Aldur lambanna var 4–5½ mánuðir. Bæirnir voru valdir með það í huga að endurspegla dreifingu bændabýla um landið. Í meltingarveginum var leitað að sníkjuormum, fullþroska ormar stærri þráðormategundanna og karldýr smærri þráðormategundanna greind til tegunda og taldir og heildarlengd bandorma mæld.

Alls fundust 11 tegundir þráðorma og 1 bandormstegund. Af tegundum sem lifa í vinstur fundust þráðormarnir *Teladorsagia circumcincta* (*T. c. trifurcata* og *T. c. davtiani* innifaldar) og *Trichostrongylus axei*. Af tegundum sem lifa í mjógörn fundust þráðormarnir *Trichostrongylus capricola*, *T. vitrinus*, *Nematodirus filicollis*, *N. spathiger*, *Cooperia oncophora* (*C. o. zurnabada* innifalin) og *Bunostomum trigonocephalum*. Einnig fannst bandormurinn *Moniezia expansa*. Af tegundum sem lifa í ristli og langa fundust þráðormarnir *Chabertia ovina, Oesophagostomum venulosum* og *Trichuris ovis*.

Niðurstöður úr hverju lambi eru birtar, ásamt kortum af útbreiðslu og tíðni einstakra ormategunda um landið. Niðurstöðurnar eru bornar saman við eldri rannsóknir. Kannað er samhengi milli einstaklingafjölda nokkurra afbrigða, tegunda eða ættkvísla ormategundanna. Að lokum er borið saman hvaða ormategundir hafa fundist í meltingarvegi sauðfjár í löndunum nyrst við Atlantshafið og nokkrar hugsanlegar ástæður mismunandi útbreiðslu ræddar.

INTRODUCTION

The Icelandic sheep is a special breed which belongs to the Northern European short-tailed group of sheep and was imported during the settlement of the country in the 9th to 10th centuries (Aðalsteinsson, 1981), probably mainly from Norway and the British Isles.

There are no reports of sheep importation after the time of the settlement, until 1757. Since then, sheep of other breeds have been imported several times from the neighbouring European countries, but they are believed to have had negligible influence on the breed. Sheep were last imported in 1946.

The number of winter-fed sheep in Iceland is now approx. 490 000, after a historical maximum of 891 000 in 1978 (Farmers Association of Iceland, 2001). The sheep are usually housed from November to May and fed hay and/or silage, as well as limited amounts of concentrates. During the past 15 years feeding with round-bale (and recently also square-bale), high dry-matter silage has become predominant. The sheep usually receive one or two anthelmintic treatments while housed. Lambing takes mainly place in May. During the first few weeks after lambing the sheep are kept near the farmhouses on cultivated pastures, but after that they usually graze either on permanent lowland pastures of considerable area, or common hill pastures of vast area (Figure 1). In September the sheep are rounded up, and the lambs and adult sheep not intended for breeding are slaughtered. The rest of the flock are kept near the farms until they are housed.

For the last five decades Iceland has been divided into an increasing number of quarantine areas to fight infectious sheep diseases. The number of these areas is now approx. 35. Strict restrictions apply to transport of sheep between these areas.

It is clear from the above that helminth species in sheep that are found in the neighbouring countries had, until the middle of the 20th century, the opportunity to be brought to Iceland and to spread throughout the country.

A few studies, based on autopsies of sheep and identification of their helminth species, have been carried out on the prevalence and abundance of gastrointestinal helminths in sheep in Iceland, but these studies have been performed on sheep from limited areas (Einarsson, 1904, 1905; Dungal, 1936; Dungal and Gíslason, 1936) or on single farms and under experimental conditions (Gíslason, 1965, 1968; Richter, 1976, 1977). Information on these helminths from most parts of the country has been limited and circumstantial, and no general overview of the prevalence, abundance and geographical distribution of gastrointestinal helminths of sheep in Iceland has existed.

The objective of this study was to identify the helminth species found in the gastrointestinal tracts of lambs in Iceland in the autumn and to study the prevalence, abundance and geographical distribution of these species in the country.

MATERIALS AND METHODS

During the slaughtering period in 1992 and 1993 (approx. 20 September to 10 October), district veterinarians were asked to collect the gastrointestinal tract from one normal, healthy lamb from each of 4–6 farms from different parts of their districts, and send them

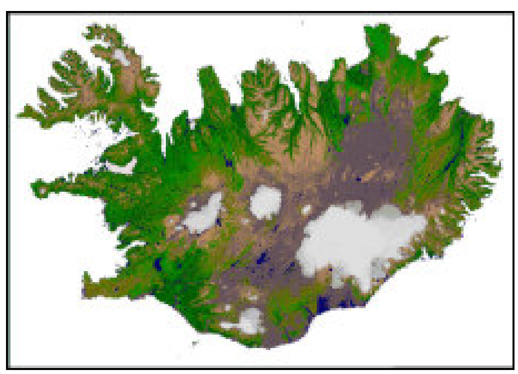

Figure 1. Vegetation photograph of Iceland. (Published by The National Land Survey of Iceland, 1993).

1. mynd. Gróðurkort af Íslandi. (Útgefandi Landmælingar Íslands, 1993).

to the Institute for Experimental Pathology, Keldur, University of Iceland. All the lambs were aged approx. 4–5½ months.

Having in mind a map of the inhabited areas in Iceland (Figure 2), a total of 94 farms (68 farms in 1992 and 26 farms in 1993), distributed as evenly as possible over the country, were then selected from this material (Figure 3).

All the samples were submitted frozen, and were thawed for collection of helminths 1–16 months later.

The abomasum was cut open and the contents were washed into a bucket, under a strong flow of water. More water was added to give a total volume of five litres. While agitating the bucket, four subsamples of 50 ml (altogether 1/25 of the total material) were taken. The rest was washed through a sieve with a grid aperture of 250 µm, and searched macroscopically for large nematodes. The subsamples were washed gently through a sieve with a grid aperture of 100 µm. Material remaining in the sieve was poured into a Petri dish and examined on a dark background under a binocular stereoscope. All adult, male nematodes, with well-developed spicules, were transferred to a microscope slide, identified by species and counted. In order to estimate the total adult nematode burden of each species, the number of male nematodes of each species found in the subsamples was multiplied by 25 and then again by 2, accounting for the adult female nematodes.

The same method was used on the small intestine, except that the intestine was not cut open, but its content was pressed out and the remaining material washed out with running water. All segments of *Moniezia*-cestodes were collected and their length measured in cm.

The large intestine was cut open and its contents washed through a sieve with a grid aperture of 250 µm. The contents of the sieve were put in small portions into a large tray, water was added, and the contents were macroscopically searched for large nematodes. The nematodes found were transferred to a microscope slide, identified by species and counted.

The nematodes were identified using as a reference the drawings and descriptions from Skryabin (1949–54), Soulsby (1965), Lapage (1968) and Anonymous (1992).

Several specimens of all helminth species found in lambs from eight farms (no. 1, 14, 28, 48, 53, 66, 75 and 84) (Table 1) from different regions of the country (Figure 3), were sent to the Identification Service of the International Institute of Parasitology, 395A Hatfield Road, St. Albans, Herts AL4 0XU, United Kingdom where they were control identified by dr Lynda Gibbons and dr Arlene Jones.

Figure 2. Inhabited areas of Iceland in 1980 (Guðbergsson, 1989).
2. mynd. Búsetukort af Íslandi 1980.

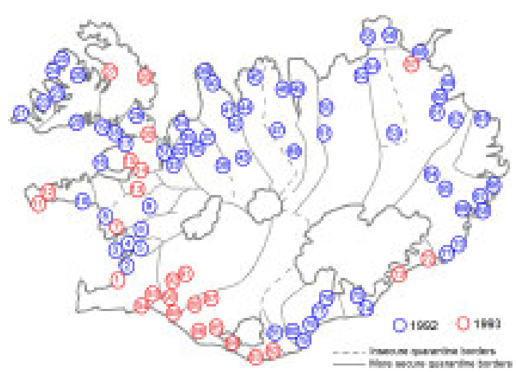

Figure 3. Farms where samples were collected.
3. mynd. Bæir þar sem sýni voru tekin.

Table 1. The numbers of adult gastrointestinal helminths in lambs in Iceland in Sept.–Oct. 1992/1993.
1. tafla. Fjöldi fullþroska orma í meltingarvegi lamba á Íslandi í september–október 1992/1993.

	Abomasum				Small intestine							Large intestine		
	Teladorsagia circumcincta			*Trichostrongylus*			*Nematodirus*		*Cooperia*	*Bunost.*	*Moniezia*	*Chabertia*	*Oesoph.*	*Trichuris*
Lamb no.	*circumcincta*	*trifurcata*	*davtiani*	*axei*	*capricola*	*vitrinus*	*filicollis*	*spathiger*	*oncophora*	*trigonocephalum*	*expansa* (cm)	*ovina*	*venulosum*	*ovis*
1	350	0	0	150	0	0	8250	0	0	0	0	0	0	0
2	850	50	0	0	0	0	350	0	0	0	766	0	0	0
3	50	0	0	100	0	0	3250	150	0	1	0	0	1	1
4	1050	0	150	0	50	0	200	0	0	0	176	17	5	2
5	2300	150	150	0	150	250	2900	0	0	0	425	24	3	2
6	800	0	0	0	200	0	4600	900	0	0	332	1	1	1
7	1700	50	100	150	200	0	2350	0	50	0	713	2	1	0
8	1850	0	50	0	0	0	850	50	0	0	1266	0	0	0
9	1250	50	50	0	0	0	100	50	0	0	20	0	3	0
10	500	0	0	0	100	0	600	700	0	0	646	0	0	0
11	1250	0	0	0	0	0	1850	50	0	0	760	0	0	0
12	2250	50	0	0	200	0	550	0	0	0	0	0	0	0
13	2500	0	50	0	100	0	800	150	0	0	1972	1	1	0
14	2650	0	100	0	1500	650	600	350	0	0	35	3	22	0
15	4450	200	0	0	450	0	100	300	0	0	2201	0	4	0
16	1150	0	50	0	150	0	150	0	0	0	110	1	15	0
17	6700	200	150	0	250	50	150	50	0	0	1	3	10	1
18	350	50	0	0	550	0	0	200	0	0	756	1	2	2
19	1150	0	50	0	150	0	50	50	0	0	0	1	2	1
20	550	0	50	0	0	0	250	0	0	0	0	0	0	1
21	900	50	50	0	450	650	1100	450	0	0	822	3	16	0
22	1850	100	50	0	0	0	0	0	0	0	0	0	0	0
23	1100	100	100	0	0	0	150	100	0	0	211	6	6	7
24	1150	50	0	0	500	0	100	0	0	0	0	0	0	0
25	2200	100	0	0	0	0	0	0	0	0	237	0	0	0
26	2150	0	250	0	0	0	150	50	0	0	741	1	1	0
27	1400	0	200	0	350	0	800	650	0	0	385	0	2	0
28	1300	50	150	0	50	0	0	150	0	0	145	0	0	0
29	250	50	0	0	550	50	50	100	0	0	0	0	0	0
30	4000	50	100	0	850	600	200	600	0	0	0	0	0	0
31	750	0	0	0	0	0	50	850	0	0	40	0	0	0
32	200	0	0	0	250	0	100	300	0	0	0	1	1	0

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Lamb no.	Abomasum: *Teladorsagia circumcincta* *circumcincta*	*Teladorsagia circumcincta* *trifurcata*	*Teladorsagia circumcincta* *davtiani*	*Trichostrongylus* *axei*	*Trichostrongylus* *capricola*	*Trichostrongylus* *vitrinus*	Small intestine: *Nematodirus* *filicollis*	*Nematodirus* *spathiger*	*Cooperia oncophora*	*Bunost. trigonocephalum*	*Moniezia expansa* (cm)	Large intestine: *Chabertia ovina*	*Oesoph. venulosum*	*Trichuris ovis*
33	1000	50	50	0	450	0	150	200	0	0	0	0	0	0
34	650	0	0	0	0	0	550	450	0	0	56	0	0	0
35	2000	0	0	0	350	0	100	200	0	0	664	0	0	0
36	1100	0	0	0	100	0	50	100	0	0	560	0	0	0
37	150	0	50	0	0	0	0	100	0	0	515	0	0	0
38	150	0	0	0	350	0	0	50	0	0	0	5	0	7
39	1750	0	100	0	500	100	450	3150	0	0	20	0	0	2
40	1000	0	0	0	50	0	700	1100	0	0	940	0	0	0
41	300	0	0	0	50	0	0	150	0	0	1238	3	0	1
42	450	50	0	0	0	0	0	50	0	0	0	0	0	0
43	1950	0	50	0	350	0	150	650	0	0	0	2	3	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	1550	50	0	0	100	0	100	0	0	0	1240	2	0	0
46	1300	0	100	0	50	0	750	1400	0	0	752	0	0	0
47	1150	100	0	0	0	0	1000	650	0	0	0	13	0	0
48	2150	0	0	50	150	0	1700	2400	50	0	0	5	0	9
49	1300	0	0	0	350	0	1250	2200	0	0	0	0	0	1
50	250	0	0	0	0	0	0	2250	0	0	574	0	0	0
51	150	0	0	0	50	0	0	100	0	0	614	0	0	0
52	1000	0	0	0	0	0	250	1300	0	0	113	1	1	2
53	1300	0	0	0	0	0	50	700	0	0	2010	0	0	2
54	1700	100	150	0	0	0	50	600	0	0	2081	0	0	0
55	2550	100	0	0	0	0	0	100	0	0	2078	0	0	0
56	1750	100	100	0	1700	0	200	350	0	0	28	0	4	0
57	700	0	0	0	0	0	50	500	0	0	0	0	0	3
58	1250	0	0	0	50	0	0	50	0	0	58	1	1	0
59	1250	0	150	0	0	0	100	100	0	0	1231	0	0	0
60	1350	150	0	0	100	0	150	1200	0	0	394	0	1	0
61	1800	150	100	0	0	0	0	150	0	0	57	2	0	4
62	2900	0	100	0	1000	100	800	4850	0	0	1600	2	0	7
63	1050	0	0	0	0	0	50	0	0	0	0	0	0	2
64	1200	0	0	0	50	0	100	300	0	0	2701	1	0	2
65	300	0	50	0	0	0	150	50	0	0	20	0	0	1
66	6150	0	450	0	150	300	200	0	0	0	0	37	3	1
67	1000	50	50	0	0	0	250	50	0	0	1261	0	0	0

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Lamb no.	Abomasum: *Teladorsagia circumcincta* *circum-cincta*	*tri-furcata*	*davti-ani*	*Trichostrongylus* *axei*	*capri-cola*	*vitrinus*	Small intestine: *Nematodirus* *fili-collis*	*spath-iger*	*Cooperia onco-phora*	*Bunost. trigono-cephalum*	*Moniezia expansa* (cm)	Large intestine: *Chabertia ovina*	*Oesoph. venulosum*	*Trichuris ovis*
68	1650	100	100	0	0	100	0	0	0	0	115	2	0	0
69	2100	50	50	0	0	0	300	0	0	0	154	0	0	0
70	950	0	50	0	0	0	50	0	0	0	0	0	0	1
71	2100	0	0	0	50	0	0	50	0	0	0	0	0	0
72	800	50	0	0	0	0	250	0	0	0	0	0	0	0
73	1500	0	0	0	0	0	1950	0	0	0	1135	2	0	0
74	1650	50	0	0	0	0	2250	0	0	0	16	26	0	0
75	1200	50	100	0	100	0	300	50	0	0	0	12	1	11
76	1650	0	50	0	150	0	200	50	0	0	0	3	0	2
77	3100	0	100	0	0	0	1200	800	0	0	409	6	3	2
78	1500	0	50	50	450	50	2900	450	0	0	0	39	0	0
79	350	0	200	0	0	0	15750	1800	0	0	0	0	0	0
80	2100	50	50	0	300	0	4050	550	0	0	695	6	0	0
81	3750	0	150	0	0	0	6950	0	0	0	1717	22	0	1
82	1800	0	0	0	0	0	0	50	0	0	77	4	0	0
83	1150	100	50	0	0	0	10900	0	0	0	482	2	0	0
84	3300	200	0	0	0	0	3800	0	100	0	2119	15	0	1
85	2800	0	50	0	50	0	1350	600	0	0	5637	2	0	2
86	1800	50	100	700	150	50	200	0	0	1	222	0	0	0
87	400	0	50	0	0	0	0	150	0	0	1494	0	0	0
88	1900	50	100	0	50	0	2250	0	0	0	0	28	0	0
89	2250	0	100	0	50	0	9250	0	0	0	240	16	0	0
90	1650	50	0	0	0	0	7500	350	0	0	13	2	0	0
91	3150	100	100	0	0	0	350	0	0	0	0	0	0	2
92	900	0	100	0	0	0	800	0	0	0	637	5	0	5
93	2450	0	300	0	0	0	1250	0	0	0	552	1	0	1
94	900	50	0	0	0	0	800	0	0	0	1597	0	0	0
Mean	1546.8	34.0	55.3	12.8	152.7	31.4	1219.2	389.9	2.13	0.02	541.2	3.53	1.20	0.96
Lambs found infected	93	39	50	6	48	12	76	63	3	2	64	44	26	33
Min. prevalence, %	98.9	41.5	53.2	6.4	51.1	12.8	80.9	67.0	3.2					
Prevalence, %										2.1	68.1	46.8	27.1	35.1

For the genera *Teladorsagia*, *Trichostrongylus*, *Nematodirus* and *Cooperia* the numbers of nematodes are based on the number of males in 1/25 subsamples and therefore muliplied with 25 for the total number of males and then with 2, accounting for the females. For the genera *Bunostomum*, *Chabertia*, *Oesophagostomum* and *Trichuris* the numbers are the total numbers of the nematodes found. For *Moniezia* the numbers are the total length of the relaxed tapeworm segments found.

Table 2. Regression analyses of helminth numbers.
2. tafla. Aðhvarfsgreining á fjölda sníkjuorma.

	Slope	R	P-value
Teladorsagia circumcincta circumcinta vs *T. c. trifurcata*	9.3	0.40	<0.0001
Teladorsagia circumcincta circumcincta vs *T. c. davtiani*	7.5	0.49	<0.0001
Teladorsagia circumcincta (all three morphs combined) vs *Trichostrongylus capricola* and *T. vitrinus* combined	0.84	0.25	0.0145
Teladorsagia circumcincta (all three morphs combined) vs *Nematodirus filicollis* and *N. spathiger* combined			0.9589
Teladorsagia circumcincta (all three morphs combined) vs *Moniezia expansa*	0.005	0.17	0.0944
Trichostrongylus capricola and *T. vitrinus* combined vs *Nematodirus filicollis* and *N. spathiger* combined			0.7796
Trichostrongylus capricola and *T. vitrinus* combined vs *Moniezia expansa*			0.3109
Nematodirus filicollis and *N. spathiger* combined vs *Moniezia expansa*			0.9731

R= Regression coefficient.

Using the statistical software program StatView, regression analysis was used to test the relationship between parasite numbers of some of the morphs, species and genera. The tests were performed on actually counted numbers.

RESULTS

In all, 12 helminth species (11 species of nematodes and one cestode species) were found (Table 1).

Of helminths normally living in the abomasum, the following nematode species were found: *Teladorsagia circumcincta* (incl. *T. trifurcata* and *T. davtiani*) and *Trichostrongylus axei*.

Of helminths normally living in the small intestine, the following nematode species were found: *Trichostrongylus capricola*, *T. vitrinus*, *Nematodirus filicollis*, *N. spathiger*, *Cooperia oncophora* (incl. *C. zurnabada*) and *Bunostomum trigonocephalum*. The cestode *Moniezia expansa* was also found.

Of helminths normally living in the large intestine, the following nematode species were found: *Chabertia ovina, Oesophagostomum venulosum* and *Trichuris ovis*.

All the gastrointestinal helminth species which had previously been reported from sheep in Iceland, except *Haemonchus contortus*, were found in this study. No new species were found.

Regression analyses were performed, in order to see if there was a relationship between the numbers of some of the *Teladorsagia* morphs, and also between the numbers of some of the helminth genera. The results are shown in Table 2. There was a highly significant relationship between the *Teladorsagia* morphs tested but less significant or not significant between the genera.

DISCUSSION AND CONCLUSIONS

In the past, most parasite species of sheep in NW Europe have probably been introduced to Iceland, and have had the opportunity to spread throughout the country. The climate in Iceland and the sheep management practices, are probably the main factors determining which species became endemic, as well as determining their distribution, prevalence and abundance.

The climate of Iceland is oceanic. However, cimatic conditions vary somewhat in different parts of the country. For instance the northeastern and northern inland areas receive much less precipitation than other parts of the country and the seasonal temperature variation is larger there than elsewhere. Such differences may, of course, have an influence on the geographical distribution, prevalence and abundance of the various helminth species and may also be a factor in the seasonal variation between regions regarding when a certain helminth species reaches a maximum.

The sheep usually receive one or two anthelmintic treatments while housed during the winter. Such anthelmintic treatments have been practised for many decades in Iceland. This practice must certainly have had a considerable effect on the prevalence and abundance of the helminths, especially on those species which do not over-winter or have problems over-wintering as eggs or larvae outside the sheep. Such species must now have lower prevalence than before, or may even have been eradicated.

Although studies on the prevalence and abundance of gastrointestinal helminths in sheep in Iceland, based on autopsies of sheep and identification of their helminth species, have been performed earlier these studies have been performed on sheep from limited areas (Einarsson, 1904, 1905; Dungal, 1936; Dungal and Gíslason, 1936) or on single farms under experimental conditions (Gíslason, 1965, 1968; Richter, 1976, 1977). Furthermore, these studies have mainly been performed on lambs, and during the slaughtering period (Sept./Oct.) or later, except for one study on lambs slaughtered on 11 August (Gíslason, 1968). In the articles reporting on the older studies (Einarsson, 1904, 1905; Dungal, 1936; Dungal and Gíslason, 1936) the research methods were not or incompletely described, but in later studies (Gíslason, 1965; Richter, 1976, 1977; and probably Gíslason, 1968) similar or the same methods were used as in the present study.

Of particular interest for comparison with the present study (see later) are the studies of Dungal and Gíslason in 1933 and 1935 (Dungal, 1936; Dungal and Gíslason, 1936). They searched for worms in the intestinal tract of 102 sheep in October–November 1933 and 115–120 sheep in September–December 1935. The sheep came from “different places in the south-west part of the country”. The ages of the sheep were not specified. Since the research methods used were not described in detail, it makes it in some cases difficult to compare the results of the studies on the numbers of the “small nematodes” (*Teladorsagia*, *Trichostrongylus*, *Nematodirus* and *Cooperia*) with the present study. The “larger nematodes” (*Bunostomum, Chabertia, Oesophagostomum* and *Trichuris*) and the tapeworm (*Moniezia*) are much more easily found and counted and the results therefore more comparable with the present study. Later studies on the prevalence of helminth species (Gíslason, 1965, 1968; Richter, 1976, 1977) have been conducted on single farms and under experimental conditions, and are therefore not discussed in any detail in this context.

The samples in the present study were taken from total of 94 lambs, and the farms were selected so that they would reflect the geographical distribution of farms in the country. But there are additional variables. Circumstances during grazing have no doubt varied considerably. Some of the lambs have grazed on extensive hill pastures and others on more densely grazed lowland pastures. Some have grazed inland and others nearer to the coast. The location of the farms is not always a reliable indicator of where, and on what kind of pasture, the lambs had been grazing. Since information on where the lambs had been grazing could not be obtained, it would be unwise to draw extensive conclusions from the numbers of helminths in individual lambs.

Most of the samples in the present study were collected in the autumn of 1992, while the rest could not be obtained until the autumn of 1993 (Figure 3). Since the climate can vary somewhat between years, this may possibly skew the comparison between different parts of the country. Such a possible distortion is, however, unlikely to be of such magnitude as to be significant in this context.

The samples were collected during the slaughtering period (Sept./Oct.) and only from lambs (aged 4–5½ months). The results thus only show the number of adult helminths in this age group during this time of year. It can be safely assumed that the number of individuals of specific helminth species varies considerably by season and the age of the sheep, and that samples taken from sheep in other seasons and at other ages could show different proportions.

The numbers presented in this study for the "small nematodes" (*Teladorsagia*, *Trichostrongylus*, *Nematodirus* and *Cooperia*) are solely based on the numbers of adult males. The female small nematodes were not identified by species, since this is in many cases more difficult and uncertain. But in order to give an indication of the total adult nematode burden of these species, the numbers of male nematodes are multiplied by 2. It is known, however, that not all nematode species have equal numbers of both genders.

Only subsamples (1/25) were studied in order to find and count the "small nematodes". Therefore some of these species may not have been found in some infected lambs and the observed prevalence values for these nematodes in this study are therefore probably only minimum figures. On the other hand all the "larger nematodes" and tapeworms present in the lambs have presumably been found.

In spite of the above-mentioned reservations, this study gives new and extensive information about gastrointestinal helminth species in sheep in the country, and their geographical distribution, prevalence and abundance.

Teladorsagia circumcincta *(comprising the morphs* T. c. circumcincta*,* T. c. trifurcata *and* T. c. davtiani*)*

Einarsson (1905) examined 51 lambs and nine adult sheep in the autumn of 1904, in northern and eastern Iceland. He reported that the most common gastrointestinal nematode species was *Strongylus ostertagi* (probably referring to *Teladorsagia circumcincta*). In the earlier mentioned studies of Dungal and Gíslason (Dungal, 1936; Dungal and Gíslason, 1936) the prevalence of *Ostertagia* (=*Teladorsagia*) *circumcincta* in sheep from several farms in the south-west part of Iceland in the autumns of 1933/1935 were found to be 84%/80%.

In the present study, *Teladorsagia circumcincta* was the most common species. The minimum prevalence was 98.9%, the mean number was 1546.8 and the maximum number 7050 (Table 1, Figure 4). The geographical distribution of *T. circumcincta* in the present study seems to be quite even, and the abundance similar, all over the country.

Gíslason (1968) found that the number of worms of this species in lambs on a farm in West Iceland decreased on the average from about 2800 to about 400 from 11 August until 2 October. Thus it may be inferred that the numbers of adult worms of this species in the lambs in the present study had been considerably higher earlier in the summer.

The higher prevalence in the present study compared with the studies in 1933/1935 might be due to differences in research methods and/or the age of the sheep studied and the time of the year. In the studies in 1933/1935 the investigations were carried out on material collected from the end of September and until December. In fact Dungal and Gíslason (1936) wrote: "From the beginning of the observation on September 26th to the end of October great swarms of Ostertagia were to

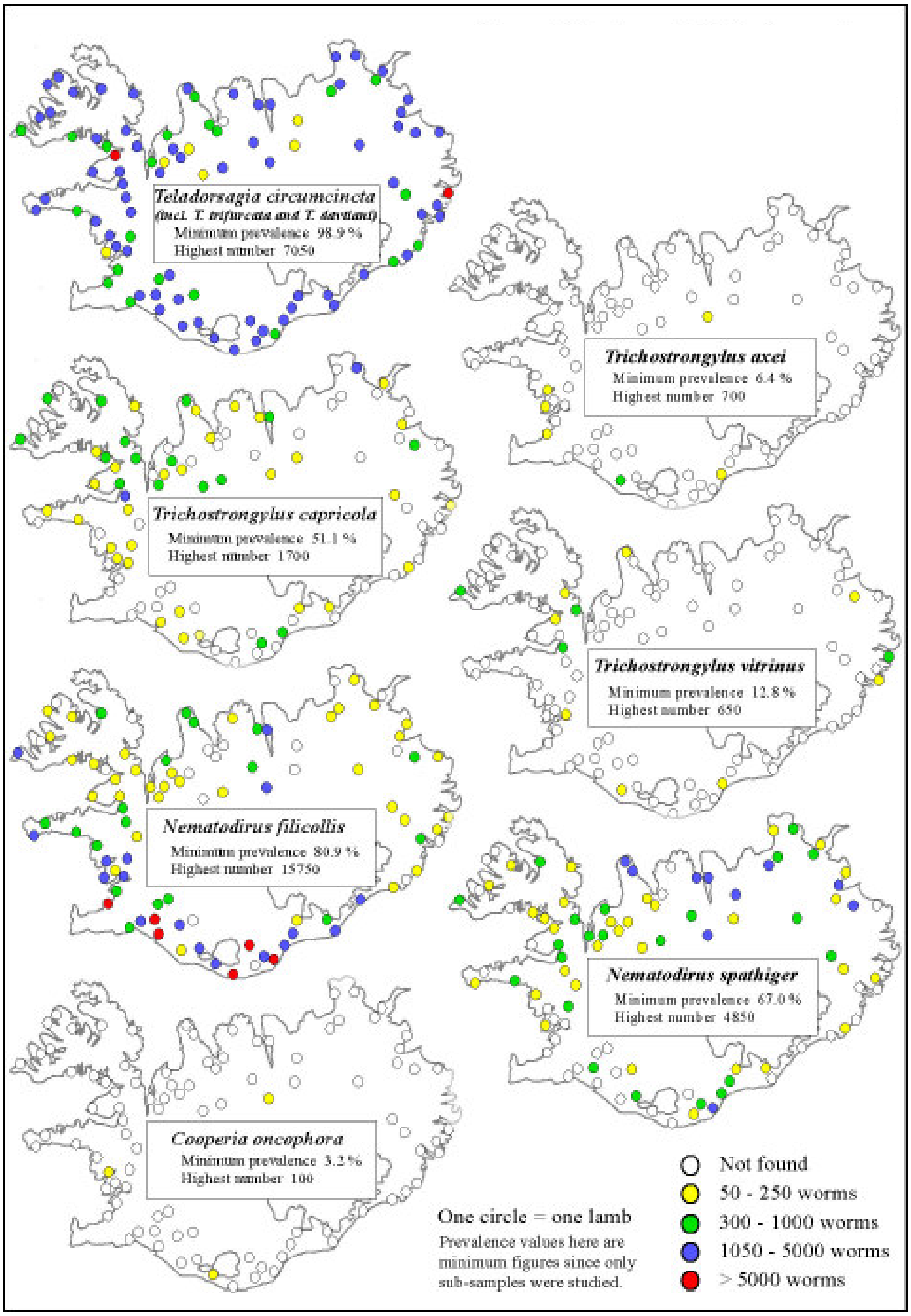

Figure 4. The observed distribution, numbers and minimum prevalence of the adults of the smaller nematode species.

4. mynd. Fundarstaðir, fjöldi og lágmarkstíðni fullþroska orma minni þráðormategundanna.

be found in every sheep. But after that time a considerable decrease was noted and in several cases the worms were entirely absent. In December only very few Ostertagia were found."

The three morphs; *T. circumcincta*, *T. c. trifurcata* and *T. c. davtiani* (Stevenson *et al.*, 1996), were counted separately (Table 1) and the correlation of the numbers of *T. c. trifurcata* on the one hand and *T. c. davtiani* on the other hand with the numbers of the most common morph, *T. c. circumcincta*, were examined. A highly significant positive correlation was observed between the most common morph and the more scarce ones (Table 2). This could indicate that the morphs account respectively for a fairly constant proportion of the population. In this study the proportions of the mean numbers were *T. circumcincta circumcincta* 94.5%, *T. c. trifurcata* 2.1% and *T. c. davtiani* 3.4%. No clear difference could be discerned in the geographical distribution of these morphs (Figure 4).

T. circumcincta has been reported from reindeer (Sigurðarson, 1993) and goats (Kristmundsson and Richter, 2000) in Iceland.

Trichostrongylus axei, Trichostrongylus capricola, Trichostrongylus vitrinus

Einarsson (1904) reports that he found *Str. retortæformis* (probably referring to *Trichostrongylus capricola* and/or *vitrinus*). It is notable that Dungal and Gíslason (Dungal, 1936; Dungal and Gíslason, 1936) do not mention these species in their studies in 1933 and 1935. This could indicate that differences in research methods and/or that the search for, and identification of, the smallest nematodes in the studies was not emphasized and/or that they were present in very low numbers. In 1964 Gíslason (1965) found all three *Trichostrongylus* species in a grazing experiment on a farm in SW-Iceland and all these species have been found in published autopsy studies since then (Gíslason, 1968; Richter, 1976, 1977).

In the present study the minimum prevalence / mean number / maximum number was: *T. axei* 6.4%/12.8/700, *T. capricola* 51.1%/152.7/1700 and *T. vitrinus* 12.8%/31.4/650 (Table 1, Figure 4). The distribution and abundance of the species seems to be fairly similar all over the country.

In Iceland *T. axei* has also been reported from cattle (Ingólfsson and Gíslason, 1975) and horses (Eydal, 1983; Eydal and Gunnarsson, 1994). *T. capricola* has also been reported from goats (Kristmundsson and Richter, 2000) and cattle (Ingólfsson and Gíslason, 1975). *T. vitrinus* has possibly been found in cattle (Ingólfsson and Gíslason, 1975). All three species have been reported from reindeer in Iceland (Sigurðarson, 1993).

Nematodirus filicollis, Nematodirus spathiger

Einarsson (1904) reports that he found *Str. filicollis* (probably referring to *Nematodirus spathiger* and/or *filicollis*). Dungal and Gíslason (Dungal, 1936; Dungal and Gíslason, 1936) found the prevalence of *Nematodirus filicollis* (*N. spathiger* possibly inclusive) in the south west part of Iceland in 1933/1935 to be 66%/40%, based on studies of 102/119 sheep. They believed that the use of carbontetrachloride as an anthelmintic during the winter, which began at that time, was the cause of the observed change in prevalence. Gíslason (1965) observed both *Nematodirus* species in an experiment on a farm in SW-Iceland in 1964 and both species have been found in the published autopsy studies since then (Gíslason, 1968; Richter, 1976, 1977).

In the present study both *Nematodirus* species were common, and were found in most parts of the country. The minimum prevalence / mean number / maximum number was for *N. filicollis* 80.9%/1219.2/15 750 and for *N. spathiger* 67.0%/389.9/4850 (Table 1, Figure 4). When both species are counted together, the total minimum prevalence is 95.7%.

Earlier studies in Iceland (Richter, 1974) indicate that the eggs of *N. filicollis* and/or *N.*

spathiger reach their maximum in lambs in the autumn. These findings coincide with results of Gíslason (1968) who found in lambs on a farm in West Iceland that the number of *N. filicollis* increased on the average from about 200 to about 6800 and the number of *N. spathiger* from about 40 to about 440 from 11 August to 2 October. One might therefore presume that in the present study samples were collected at the time of year when the number of mature worms of these species is near the maximum.

The lower prevalence in the studies in 1933/1935 compared with the present study might at least to some extent be due to differences in research methods and/or differences in the age of the sheep studied and time of the year, as mentioned for *Teladorsagia circumcincta*.

Even though both *Nematodirus* species are common and found in most parts of the country, their abundance in this study seems to vary between regions of the country. *N. filicollis* is more common in the southwest, while *N. spathiger* is more common in the north (Figure 4). This geographical difference in the observed abundance of these species might reflect some climatic differences between these parts of the country.

Both *Nematodirus* species have been reported from reindeer (Sigurðarson, 1993) and goats (Kristmundsson and Richter, 2000) in Iceland.

Cooperia oncophora (*incl.* C. o. zurnabada)

Pálsson (1962) mentions *Cooperia* sp. in a survey of nematodes in sheep, and Gíslason (1968) maintains that a total of three or four individuals of *C. oncophora* had by then been found in sheep in Iceland. This species has been found in published autopsy studies since then (Richter, 1976, 1977).

In the present study this species was found only in small numbers, and only on three farms. The minimum prevalence was 3.2, the mean number was 2.13, and the maximum number 100 (Table 1, Figure 4). Two specimens, one from southern and one from northern Iceland, were sent to the International Institute of Parasitology in the UK for control identification. The specimen from the south was identified as *C. oncophora* while the one from the north was identified as the variant *C. oncophora* var. *zurnabada*. This is the first record of *C. o. zurnabada* in Iceland.

C. oncophora has been reported from cattle in Iceland (Ingólfsson and Gíslason, 1975). This species is primarily a parasite of cattle which may occasionally transfer to sheep.

Bunostomum trigonocephalum

Dungal and Gíslason (Dungal, 1936; Dungal and Gíslason, 1936) found the prevalence of *B. trigonocephalum* in the south-west part of Iceland in 1933/1935 to be 78%/36%, based on studies of 102/118 sheep. They concluded that the use of carbontetrachloride as an anthelmintic during the winter, which began at that time, was the cause of the observed drop in prevalence between these years. This species has been found in autopsy studies since then (Gíslason, 1965, 1968; Richter, 1976).

In the present study this species was only found on two farms and only one specimen on each (prevalence 2.1% mean number 0.02) (Table 1, Figure 5). *B. trigonocephalum* has probably difficulty in surviving the winter outside the sheep, and hence the generally practiced anthelmintic treatment during the winter for many decades has probably had great impact on the prevalence of this species.

Chabertia ovina

Einarsson (1904) reports that he found *Str. hypostomus* (probably referring to *Chabertia ovina*). Dungal and Gíslason (1936) found the prevalence of *Chabertia ovina* in the south-west part of Iceland in 1935 to be 46%, and the number of worms was over 100 in seven sheep and 10–100 in eight of a total of 119 sheep.

In the present study the prevalence of *C.*

ovina was 46.8%, the mean number 3.53, and the maximum number 39. (Table 1, Figure 5). The prevalence seems to be similar to that of 1935, but the abundance is lower. *C. ovina* was found in most districts, but seems to be somewhat more common in the southern part of Iceland (Figure 5).

C. ovina has been reported from goats in Iceland (Kristmundsson and Richter, 2000).

Oesophagostomum venulosum

Einarsson (1904) reports that he found *Str. dentatus*? (probably referring to *Oesophagostomum venulosum*). Dungal and Gíslason (1936) found the prevalence of *Oesophagostomum venulosum* in the south-west part of Iceland in 1935 to be 37%, and the number of worms was over 10 in only one of a total of 120 sheep.

In the present study the prevalence of *O. venulosum* was 27.7%, the mean number 1.20, and the maximum number 22 (Table 1, Figure 5). The prevalence and abundance seems to be similar to what was found in 1935. *O. venulosum* was found in most parts of Iceland, but seems to be somewhat more com-

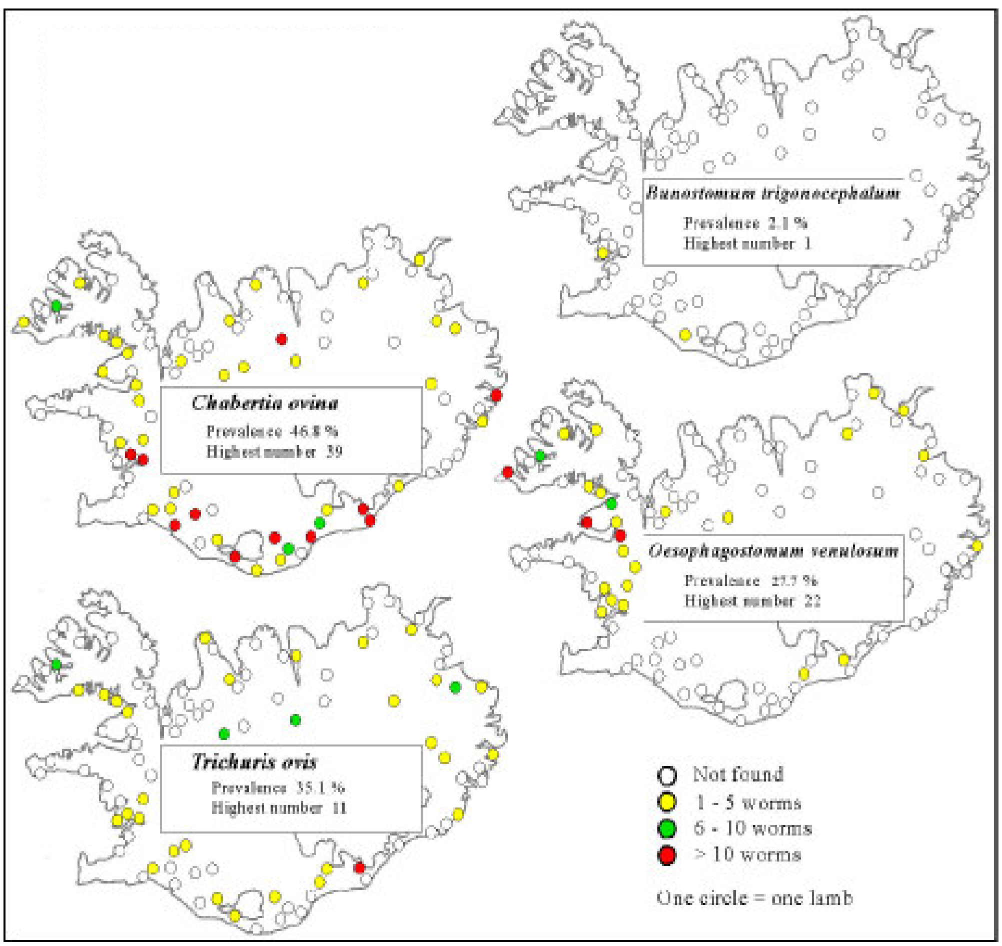

Figure 5. The observed distribution, numbers and prevalence of the adults of the larger nematode species.
5. mynd. Fundarstaðir, fjöldi og tíðni fullþroska orma stærri þráðormategundanna.

mon in the western part of the country (Figure 5).

O. venulosum has been reported from reindeer (Sigurðarson, 1993) and goats (Kristmundsson and Richter, 2000) in Iceland.

Trichuris ovis

Einarsson (1904) reports that he found *Trichocephalus affinis* (probably referring to *Trichuris ovis*). Dungal and Gíslason (1936) found the prevalence of *Trichocephalus dispar* (probably *Trichuris ovis*) in the south-west part of Iceland in 1935 to be 52, and the number of worms was over 100 in one sheep and 10–100 in nine of a total of 120 sheep.

In the present study the prevalence of *Trichuris ovis* was 35.1%, the mean number 0.96, and the maximum number 11 (Table 1, Figure 5). The prevalence and abundance are considerably lower than those found in 1935. *T. ovis* was found in most parts of Iceland, and there was no discernible regional difference in abundance (Figure 5).

T. ovis has been reported from reindeer (Sigurðarson, 1993) and goats (Kristmundsson and Richter, 2000) in Iceland.

Moniezia expansa

Krabbe (1864, 1865) reported that *Taenia* (probably *Moniezia*) *expansa* was very common in sheep in Iceland. Einarsson (1904) found the prevalence of tapeworms to be 20% in 45 lambs and 11% in nine adult sheep during the winter of 1903/1904. Dungal and Gíslason (1936) found the prevalence of *Moniezia expansa* in the south west part of Iceland in the fall and early winter of 1935 to be 38% in approx. 120 sheep.

In the present study the prevalence of *M. expansa* was 68.1%, the mean total length of segments was 5.41 metres and the maximum total length in a lamb 56.4 metres (Table 1, Figure 6). *M. expansa* was found in most districts, and there was no discernible difference by region (Figure 6). The prevalence is much higher than found in the earlier studies. The reason is probably at least partly due to the fact that this tapeworm is short lived, only a few months, and is more common in lambs than older sheep (Soulsby, 1965; Lapage, 1968; Eckert *et al.*, 1992).

M. expansa has been reported from goats (Kristmundsson and Richter, 2000) and *Moniezia* sp. has been reported from cattle (Ingólfsson and Gíslason, 1975) and reindeer (Sigurðarson, 1993) in Iceland.

A positive relationship between the numbers of individuals of the various helminth species which live in the gastrointestinal tract could be expected. The eggs are passed in the

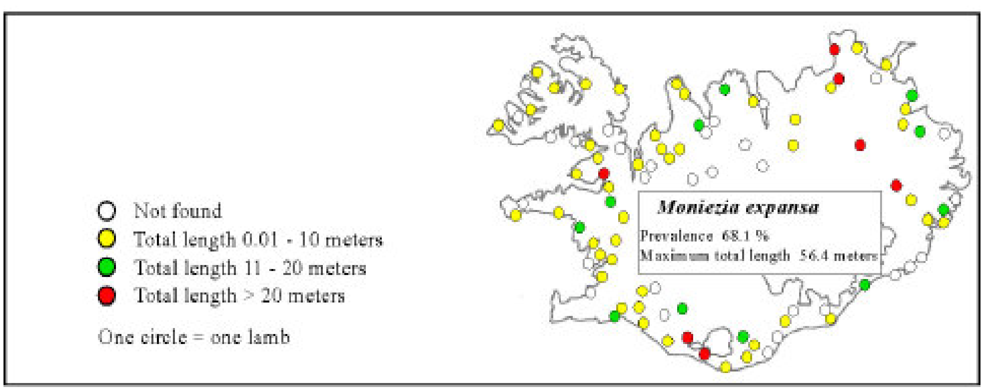

Figure 6. The observed distribution, total length of segments and prevalence of the tapeworm *Moniezia expansa*.
6. mynd. Fundarstaðir, samanlögð lengd liða og tíðni bandormsins Moniezia expansa.

faeces, and infection takes place orally, in the same or a similar way in most of these species. If there is extensive infection by one species in the environment, it is thus likely that the same would apply to other species. However, little or no correlation in parasite numbers could be observed at genera level in the present data (Table 2).

Comparison with sheep helminths in the neighbouring countries

Sheep have been present in the British Isles and Norway since pre-historic times.

Sheep were brought to the Faroe Islands, probably from the British Isles and Norway, during the settlement of the islands, which took place in the 8th and 9th centuries, or even earlier. Later there were some imports from Iceland, the British Isles and possibly other countries, and the last import was in 1961 (Hanusson, 2001).

Sheep were brought to Iceland during the settlement of the country in the 9th to 10th centuries, probably from Norway and the British Isles. After that there are no reports of importation of sheep until 1757. From that time until 1946, sheep were imported several times from neighbouring European countries.

Sheep were brought to Greenland from Iceland during the Norse settlement in the 10th and 11th centuries, but sheep farming died out in the 15th century. Sheep were occasionally brought to Greenland in the 18th and 19th centuries, but again sheep farming was abandoned. The present-day sheep stocks in Greenland are mainly descended from 175 sheep which were transported from N-Iceland to Greenland in 1915, with the admixture of some stock descended from 11 sheep brought from the Faroes in 1906 and eight from Denmark (the Faroes?) in 1908. Rams were imported from Iceland in 1921 and 1934, and the last import was of rams from Norway, probably in 1957 (Kristiansen, 1998; Sigurdsson, 1938; Stefán Scheving Thorsteinsson, Agricultural Research Institute, Iceland, pers. comm. 2002).

The imports of sheep, together with the climate and/or sheep management practices, are probably the main factors determining which gastrointestinal helminth species became endemic in the countries bordering the North Atlantic. Thus it is interesting to compare which species have been reported from sheep in these countries. Table 3 shows a list of the gastrointestinal helminth species reported from sheep in Greenland, Iceland, the Faroe Islands, Norway and the United Kingdom. On this list several items are noteworthy. A few examples will be mentioned here.

Haemonchus contortus. In the early part of the 20th century, some general publications mention this species as being present in Icelandic sheep. However, this species was not found in post mortem studies on sheep at the beginning of the century (Einarsson, 1904, 1905) and Dungal and Gíslason (1936) maintain that *H. contortus* has never been found in Iceland. In 1966 the finding of two "small and slim" *H. contortus* from a sheep in south Iceland was reported (Gíslason, 1968). Since then this species has never been found. The species must thus be either very rare, or not present in Iceland. If it is not present, it has probably not been able to establish itself due to the climatic conditions, or has been eradicated by the anthelmintic treatments practised during the winter.

Nematodirus helvetianus, primarily a parasite in cattle, has been reported from sheep in Greenland, Norway and the United Kingdom, but neither in the Faroe Islands nor in Iceland and *Nematodirus abnormalis* has been reported from sheep in Greenland but not in the other countries (Table 3). Speculative explanations could be that *N. helvetianus* was introduced to Greenland with cattle and *N. abnormalis* with wild caribou (Rose, 1990).

Also worth noting in Table 3 is that *Trichostrongylus capricola* has been reported from sheep in Greenland, Iceland and Norway but not in the Faroe Islands or the United Kingdom. Also that *T. colubriformis* has been reported from sheep in Norway and the United

Table 3. Gastrointestinal helminth species reported from sheep in Greenland, Iceland, the Faroe Islands, Norway and the United Kingdom[a].
3. tafla. Sníkjuormategundir sem skýrt hefur verið frá að hafi fundist í meltingarvegi sauðfjár á Grænlandi, Íslandi, í Færeyjum, Noregi og á Bretlandi.

	G	I	F	N	UK
Abomasum					
Haemonchus contortus		(+)		+	+
Marshallagia marshalli				+	
Ostertagia ostertagi				+	+
O. leptospicularis					+
Skrjabinagia kolchida					+
Teladorsagia circumcincta					
(incl. *T. trifurcata* and *T. davtiani*)	+	+	+	+	+
Trichostrongylus axei		+	+	+	+
Small intestine					
Ascaris suum					+
Bunostomum trigonocephalum		+		+	+
Capillaria bovis					+
Capillaria sp.				+	
Cooperia curticei				+	+
C. mcmasteri				+	
C. oncophora		+		+	+
C. punctata					+
Moniezia benedeni				+	+
M. expansa		+	+	+	+
Moniezia sp.	+				
Nematodirus abnormalis	+				
N. battus			+	+	+
N. filicollis		+	+	+	+
N. helvetianus	+			+	+
N. spathiger	+	+		+	+
Strongyloides papillosus				+	+
Trichostrongylus capricola	+	+		+	
T. colubriformis				+	+
T. vitrinus		+	+	+	+
Large intestine					
Chabertia ovina		+	+	+	+
Oesophagostomum venulosum		+	+	+	+
Skrjabinema ovis				+	
Trichuris ovis	+	+	+	+	+
T. skrjabini					+

a) References: Greenland (G): Rose, 1990. Iceland (I): The present article. Faroe Islands (F): Hanusson, 2001. Norway (N): Helle, 1969, 1971, pers. comm. 1993; Björn Gjerde, Norwegian College of Veterinary Medicine, Oslo, pers. comm. 2002. United Kingdom (UK): Scofield, 1983; Arlene Jones and Eileen Harris, Natural History Museum, London, pers. comm. 2002.

Kingdom, but not in the Faroe Islands, Iceland or Greenland.

Finally it should be pointed out that at least seven species of gastrointestinal helminths of sheep found in Iceland, i.e. *Trichostrongylus axei*, *Bunostomum trigonocephalum*, *Cooperia oncophora*, *Nematodirus filicollis*, *Trichostrongylus vitrinus*, *Chabertia ovina* and *Oesophagostomum venulosum*, have not been found in sheep in Greenland (Table 3), even though the sheep stock there, approx. 21 000 winter-fed sheep in 1990 (Rose, 1990), originates mainly from sheep brought from Iceland (see earlier). This may be attributable to various factors in the case of the different species: that the relevant species was not present in Iceland when the sheep were introduced into Greenland, that the species was not present in the specific animals imported, that it did not establish itself or find suitable conditions in Greenland, that it has been eradicated subsequently from Greenland's sheep population, or that it has not yet been found in sheep in Greenland.

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