Causes of diarrhoea in lambs during autumn and early winter in an Icelandic flock of sheep

KARL SKIRNISSON[1]

AND

HAKON HANSSON[2]

[1]*Institute for Experimental Pathology, University of Iceland, Keldur, IS-112 Reykjavík, Iceland*
E-mail: karlsk@hi.is

[2]*Ásvegi 31, 760 Breiðdalsvík, Iceland*
E-mail: hih@eldhorn.is

ABASTRACT

In 2002 intestinal parasites and bacterial infections were studied on the Fossárdalur sheep farm, Eastern Iceland, where for years lambs have suffered from severe diarrhoea in autumn and early winter that sometimes has become fatal. Mainly food changes, but sometimes also *Giardia duodenalis,* were regarded as probable causes for short-term diarrhoea in some lambs soon after their return from upland ranges in September or early October. By the middle of October, after approximately three weeks' grazing on lowland pastures, all examined lambs on the farm suffered from coccidiosis for one or more weeks, with severe diarrhoea and a typical weight loss. Oocysts per gram faeces (opg) values peaked two to three weeks after the onset of the diarrhoea. Lambs were highly susceptible to eimerian infections when they returned to the oocyst-contaminated pastures in autumn. Massive spring coccidiosis is probably more or less avoided because lambs are usually released, still protected against eimerian infections, at approximately two weeks of age to the vast, infection-free summer rangelands. The common *Entamoeba ovis,* and rare *Cryptosporidium* sp., and rare helminth infections were never suspected of contributing to the autumn diarrhoea. *Clostridum* sp., the only pathogenic bacteria detected on the farm, was found in lambs arriving late from upland ranges with severe coccidiosis. It remains uncertain if the bacteria also contributed to their diarrhoea.

Keywords: coccidiosis, diarrhoea, mortality, pathogens, protozoans, sheep

YFIRLIT

Rannsóknir á orsökum skitu í haustlömbum á fjárbúinu í Fossárdal í Berufirði

Innri sníkjudýr og bakteríusýkingar voru rannsakaðar haustið 2002 á fjárbúinu í Fossárdal þar sem mikil skita hefur hrjáð sum lömb að haustlagi um árabil og nokkur lömb drepist hvert haust. Talið er að fóðurbreytingar orsaki sótt sem vart verður við í sumum lömbum fljótlega eftir komu af fjalli í september eða í byrjun október þótt frumdýrið *Giardia duodenalis* eigi þar hugsanlega einnig stundum hlut að máli. Á hinn bóginn er skita sem vart verður við eftir um þriggja vikna beit á láglendi fyrst og fremst rakin til sýkinga af völdum hnísla, *Eimeria* spp. Hníslasóttin varir að minnsta kosti í viku og stundum lengur. Lömbin léttast og tveimur til þremur vikum eftir að sóttin hefst fara hníslar að koma fram í skítnum sem þá er oftast á ný orðinn sparðaður. Lömb á bænum virtust mjög næm fyrir hníslasýkingum þegar þau komu af fjalli. Er það talið vera vegna þess að hníslasótt fær sjaldnast tækifæri til að magnast upp að vorlagi því lömbum er sleppt á fjall það ungum (um tveggja vikna aldur) að þau eru enn með verulega meðfædda vörn gegn hníslasmiti. Fé gengur síðan það dreift í sumarhögum að líkur á hníslasmiti eru litlar fyrr en aftur er komið á láglendi. Algengar haustsýkingar af *Entamoeba ovis* og sjaldgæfar *Cryptosporidium* sp. og bandorms- og þráðormasýkingar eru ekki taldar eiga þátt í haustskitu á bænum. Eina sjúkdómsvaldandi bakterían sem tókst að staðfesta, *Clostridum* sp., fannst í desember í síðheimtungum með bullandi hníslasótt en óvíst er hvort bakterían átti einnig þátt í þeim niðurgangi.

INTRODUCTION

For more than a decade, on the Fossárdalur sheep farm in eastern Iceland (Figure 1) severe diarrhoea has afflicted lambs in autumn and early winter. Some lambs suffer from diarrhoea within a few days after their return from the mountainous summer rangelands to the lowland around the farm, but usually the diarrhoea starts within approximately three weeks. Almost all diarrhoeic lambs recover without treatment, but every autumn one or a few lambs have died. Sometimes the administration of anticoccidials, anthelmintics and even antibiotic drugs, are considered to have reduced mortalities and contributed to quicker recovery. The cause of the diarrhoea has remained unknown, although coccidiosis has been suspected.

Almost 60 years ago coccidians of the genus *Eimeria* were first reported to cause coccidiosis in sheep in Iceland (Vigfússon & Gíslason 1947) and a few studies have already been carried out on total oocyst excretion of eimerians in different seasons in different age classes of sheep in the country (Richter 1974, 1976, 1977, 1979, Richter & Eydal 1985, Richter et al. 1983). Morphological studies on sporulated oocysts have shown that all the 11 species that occur in sheep in Western Europe (Eckert et al. 1995, Rommel 2000) are also present in Iceland (Reginsson & Richter 1997, Skirnisson & Gudmundsdottir, unpublished). Other enteric protozoa occurring in Icelandic sheep include *Giardia duodenalis* Davaine, (syn. *intestinalis, lamblia, bovis, caprae*), first detected in a two-month-old lamb in Iceland in 1991 (Skirnisson, unpublished) and since then frequently found (Richter, unpublished, Skirnisson, unpublished). *Cryptosporidium* sp. has also been commonly reported in lambs in various parts of Iceland in early summer (Skírnisson et al. 1993). Several helminth species also parasitize sheep (Richter 2002).

The aim of this study was to investigate the cause of autumn and early winter diarrhoea in lambs on the farm Fossárdalur. Special emphasis was placed on the enteric parasites occurring in the flock. In addition, the presence of pathogenic bacteria was assessed in the faeces of diarrhoeic lambs. Results of further investigations on parasitic infections in lambs on the farm, including species composition and the seasonal occurrence of *Eimeria* spp. and helminth infections, are in the process of being published elsewhere (Skirnisson & Gudmundsdottir, unpublished, Skirnisson, unpublished).

Figure 1. The Fossárdalur sheep farm and its surroundings. Sheep are housed and fed hay or silage from late autumn until the end of the lambing season in May. From early June until September ewes and lambs graze on natural rangelands in the surrounding mountains.

MATERIALS AND METHODS

Farming practice

Almost 500 winter-fed ewes are kept on the *Fossárdalur* farm (64°45'13.47 N, 14°31'03.-81W, Figure 1). From late autumn until May sheep are fed with hay or silage twice a day. Mating of ewes and replacement ewe lambs starts in the second half of December. Approximately 143 days later parturition starts in the second week of May and lasts until early June. Replacement ewe lambs usually give birth to one lamb, but the older ewes normally give birth to two lambs. After parturition, ewes and lambs graze for one to two, but rarely up to three weeks, on home pastures before being released on extensive summer rangelands in adjacent mountains. Under favourable spring conditions release of sheep starts as early as the end of May, but usually most sheep are released in the first week, or early in the second week of June. In the latter half of September, sheep are gathered and driven back to the lowland. Slaughter lambs are separated from the ewes and kept in a flock on home pastures until their transport to the slaughterhouse in late September or early October. Slaughter lambs that do not arrive until October graze on home pastures until transported to the slaughterhouse later in the month. If lambs arrive after the last slaughtering date, they are penned in the sheep house and fed during winter.

In September, the farmers select approximately 70 replacement ewe lambs that are weaned from their mothers and kept in a flock grazing on home pastures until the middle of October. At this point they are grouped together in a sheep house and hay feeding starts.

Medical treatment and vaccination practice

Usually slaughter lambs do not receive any medical treatment. Late arriving, winter-fed lambs and replacement ewe lambs routinely receive either of the anthelmintics Fenbendazol (Panacur vet, Fenasól vet) or Ivermectin (Oramec Drench vet) at the onset of housing. All lambs are vaccinated against paratuberculosis (caused by *Mycobacterium avium* subsp. paratuberculosis). In late winter pregnant ewes and replacement ewe lambs routinely receive the Elliot CWD vaccine that protects against *Clostridium perfringens* B (Lamb dysentery) and D (Enterotoxaemia) and *Cl. septicum* (Braxy, Bradsot).

In previous decades, diarrhoeic lambs have frequently received anticoccidials (Vecoxan, Baycox), sulfonamids (Sulfadimidin, Primazol), the anthelmintics Fenbendazol or Ivermectin and sometimes antibiotics (Terramycin, Depomycin) in order to avoid mortality, and possibly accelerate recovery.

The lambs and the study period

In autumn 2002, two different groups of lambs were studied. The first group (A) consisted of 11 lambs, which all got diarrhoea in autumn or early winter. Routine search for intestinal parasites and pathogenic bacteria (including *Salmonella, Campylobacter* and *Clostridium*) was performed on one or more faecal samples from each lamb, altogether 56 samples. Eight of these lambs were slaughter lambs, three of which got watery diarrhoea as early as September, just a few days after arriving on the lowlands, but five got diarrhoea in October, after a longer period on the lowland. The remaining three lambs arrived from the rangelands in November and were immediately placed in a sheep house. Two to three weeks later they had attacks of acute diarrhoea. Intestinal parasitic infections were examined until the end of January, but bacterial examinations were performed during the first diarrhoeic period.

The second group (B) consisted of 10 replacement ewe lambs (REL1-10) randomly selected from the group of 70 lambs. They never received any parasitic or bacteriological treatments, whereas the remaining 60 lambs received the anthelmintic Ivermectin (Oramec Drench vet) when first housed. From 23 September, when the lambs arrived on the lowland, until housing on 18 October, the replacement ewe lambs grazed on an uncultivated lowland area adjacent to the farm. At four-day intervals until November 11 (13 occasions in

50 days) faecal samples were taken from these lambs.

Sampling was carried out by the farmers. Rectal faecal samples were taken wearing disposable gloves and placed in a wide, sterile 80 ml plastic container with a screw cap. Samples were sent overnight to the laboratory at Keldur, where examination usually followed in the next day or two. At the time of sampling the farmers also examined the clinical status of each lamb and weighed it within an accuracy of one kilogram.

Laboratory methods and identification

The consistency of each faecal sample (FC) was classified into the categories: 1 for normal pellets, 2 for soft pellets, 3 for paste, and 4 for liquid faeces. For more accurate description of faecal consistency, the intermediate values 1.5, 2.5 and 3.5, were further estimated.

To obtain quantitative estimates of the total coccidian (*Eimeria* spp.) oocyst excretion, and the number of nematode eggs, samples were examined with a modified McMaster method (Anonymous 1986). After centrifugation of 14 ml of the suspension the supernatant was decanted and refilled with Parasitosol (specific density 1.27g ml^{-1}, Meku®, DK 7171, Denmark) to the same level. Four McMaster chambers were filled and examined at a 125x magnification under a microscope. Thus, the minimum numbers detectable were 50 oocysts per gram faeces (opg) and 50 nematode eggs per gram faeces (epg).

In order to detect cysts of other protozoans (*G. duodenalis, Entamoeba ovis* Swellengrebel, and sometimes (in the case of heavy infections) also *Cryptosporidium* sp.) the 56 faecal samples from the diarrhoeic lambs (Group A) and altogether 54 samples from the replacement ewe lambs (Group B) were routinely examined by light microscopy using the Formalin-Ethylacetate-Concentration Method (Evergreen Industries 2002). Samples from the replacement ewe lambs were collected on 23 September and 1, 9 and 13 October, respectively (40 samples). The 14 remaining samples were collected later in October and November in those cases where diarrhoea was observed.

To categorise roughly the intensity of *G. duodenalis* and *E. ovis* infections by the use of the FPC method an estimated abundance (EA) factor was defined for each sample. If less than five cysts were noticed on a single microscope slide examined, this was given the value 1+; slides with 6-30 cysts were rated 2+, and if more than 30 cysts were seen, the estimated abundance factor (EA) was ranked 3+. EA values were used to describe roughly individual and temporal intensity changes of *G. duodenalis* and *E. ovis* infections.

A direct immunofluorescence detection procedure (MeriFluor®) was used to test for *Cryptosporidium* oocysts and *Giardia* cysts. A sample combining material from four sampling dates from October and November was prepared for each lamb in order to increase the detection level of the method.

Photographs were made with a Leica DC 300 digital camera mounted on a Leitz microscope equipped with a Nomarski (DIC) contrast.

RESULTS

Group A. Parasitic and bacterial infections of diarrhoeic lambs

September

Within five to seven days after return to lowland pastures on 23 September, eight out of 400 slaughter lambs (2%) already had watery diarrhoea. Diarrhoea stopped within three or four days in these lambs, and all recovered on their own without any medical treatment. Examination of faecal samples from three of these lambs revealed in all cases, moderate or high *Giardia* infections (EA: 2+, 2+, 3+). Also, moderate *E. ovis* cyst numbers were observed (EA: 2+) in all cases. Low *Eimeria* spp. opg values did not exceed 900, and low nematode epg values ranged from 50 to 150. Bacterial cultivations from faeces represented normal intestinal bacterial flora and no pathogenic species were found.

October

Five lambs arriving on the lowland in October were examined after experiencing diarrhoea. Four of them recovered but one died (see below). Two of the lambs that recovered did not receive any medical treatment, but the other two were each given both the anticoccidial, Vecoxan, and the anthelmintic, Fenbendazol. At the onset of the diarrhoea, *G. duodenalis* was found in three of the four lambs (EA: 1+, 1+, 3+). Eimerian opg values were relatively low in all cases (ranging between 1.200 and 11.400) and moderate *E. ovis* cyst numbers (EA 2+) were usually observed. Nematode epg values were less than 100. Bacterial cultivations from faeces represented normal intestinal bacterial flora and no pathogenic species were found.

Death of a diarrhoeic lamb due to coccidiosis?

During the study, a ram lamb died despite careful nursing and anticoccidial, anthelmintic and antibacterial treatments that, however, masked the possibilities of detecting the parasitic and/or bacterial pathogens involved. It had returned healthy on 5 October from the summer ranges, by then weighing 53 kg. After grazing close to the farm for almost two weeks, waiting for transport to the slaughterhouse, the ram got watery diarrhoea, which prevented it being taken to slaughter. A few days after the onset of the diarrhoea, the lamb stopped feeding and drinking and became so weak that it was unable to stand upright. On the eleventh diarrhoeic day, the dying lamb was fatally anaesthetized. Post mortem examination showed extensive enteritis and pneumonia. Presumably due to heavy coccidiosis, sections from the small intestine showed goblet cell hyperplasia and scattered dilated glandular crypts that were filled with mucus and cell debris. Paracortical lymphoid hyperplasia was observed in lymph nodes. Diffuse swelling and mild vacuolisation in hepatocytes was seen in sections from the liver. Microscopic examination of lung sections revealed acute purulent bronchiolitis with acute alveolar inflammation and scattered foci of plant material. Thus, the malnourished, dehydrated lamb was about to die from aspiration pneumonia.

November, December and January

Three lambs arrived on the lowland during the second week of November. Upon entering the sheep house, they were treated with anthelmintics. However, anticoccidials and antibiotics were deliberately withheld in forthcoming months. Approximately three weeks after being housed, each lamb got watery diarrhoea for one-to-two weeks. After this diarrhoeic phase, faeces became normally formed again on two sampling occasions, but during the second half of December and in January, further diarrhoeic periods were observed (Figure 2). Parasitological examinations during the lambs' first diarrhoeic period in December did not support the hypothesis that *G. duodenalis, E. ovis* or *Cryptosporidium* sp. contributed to the diarrhoea and no helminths eggs were found due to the obviously effective anthelmintic treatment. Comparable infection pattern of ovine eimerian infections were observed in all lambs (Figure 2). However, maximum opg values and the width of the opg peaks somehow varied in the three lambs. The lamb with the highest and widest opg peak (Figure 2C) lost 22% (8 kg) of its live weight, but the weight loss of the remaining two was less severe (10% and 2%, respectively).

Bacteria belonging to the genus *Clostridium* were grown from faecal samples taken at the onset of the diarrhoeic period.

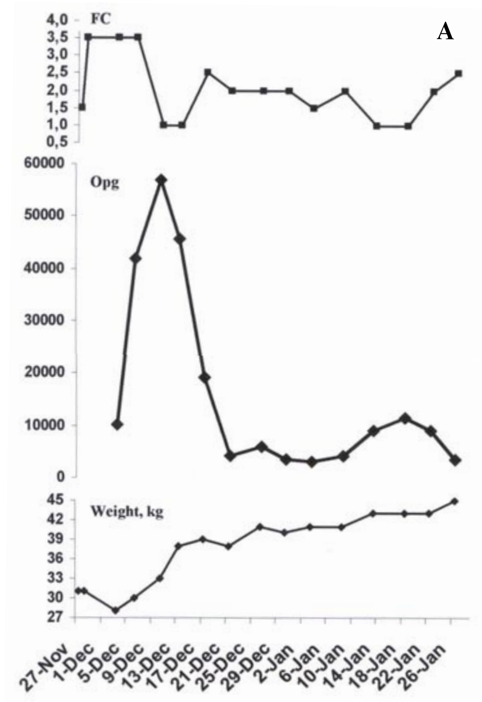
Group B. Parasites of 10 replacement ewe lambs

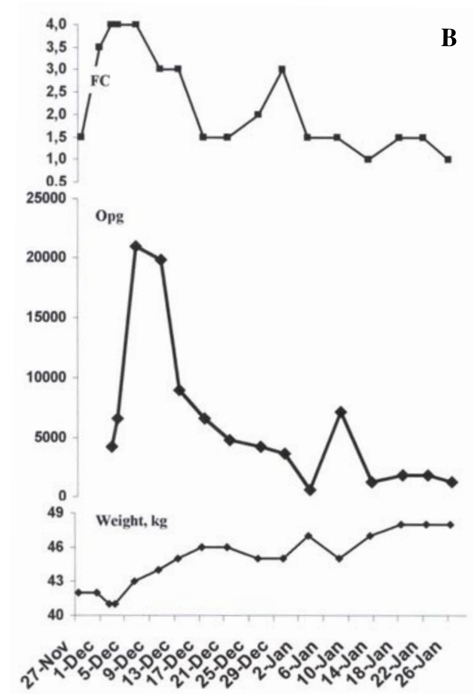
The early diarrhoeic phase

Within five to seven days after return to lowland pastures two out of the 70 replacement ewe lambs (3%) already had watery diarrhoea. Diarrhoea stopped within three or four days and both lambs recovered without any medical treatment.

Giardia duodenalis

All the replacement ewe lambs examined were





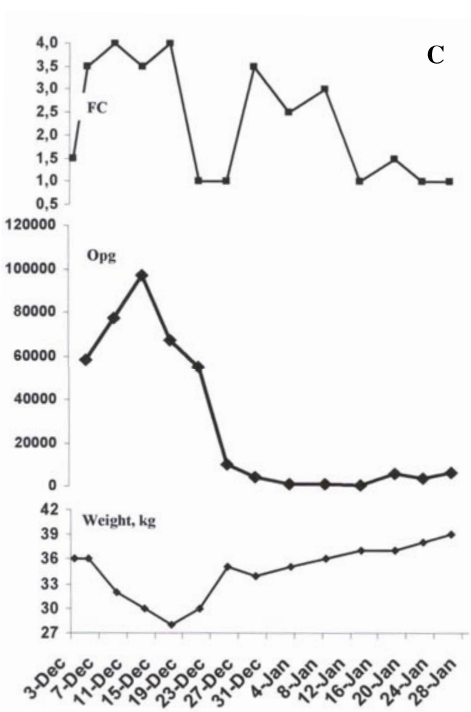


Figure 2. Faecal consistency values (FC), total *Eimeria* spp. oocyst numbers per gram faeces (opg) and life weight changes of three lambs during their housing early winter. The lambs arrived in the second week of November from the mountain ranges.

infected with *G. duodenalis*. After examination of several samples from each lamb, the FPC method had only confirmed cysts in eight of the lambs (cumulative detection level 80%). On the average, cysts were found in 35.2% of examined samples (n=54). The MeriFluor method, however, confirmed the presence of the parasite in all lambs.

Regression analysis showed no significant correlation between faeces consistency (FC) and cyst abundance (EA) in the 19 positive samples (Figure 3).

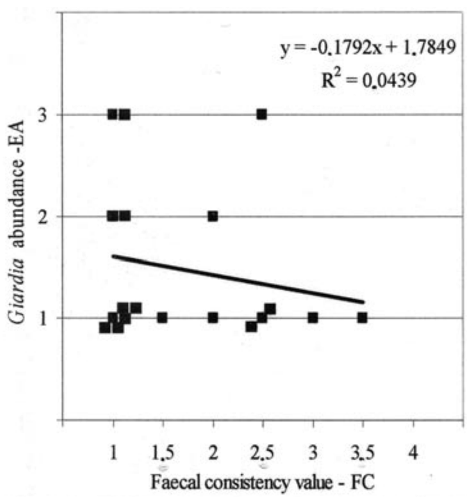


Figure 3. Comparison of estimated *Giardia duodenalis* cyst abundance per sample (EA) and faecal consistency (FC) values (1 normal pellets, 2 soft pellets, 3 paste, 4 liquid faeces) in 19 samples collected during autumn from 8 replacement ewe lambs.

Entamoeba ovis

All replacement ewe lambs were infected with *E. ovis* but clear abundance changes of the amoeba were observed between lambs. The highest average EA value was 2.8 in one lamb, REL 7 (EA 3+ on all sampling dates, except once when EA was 2+); three lambs had values ranging between 2.2 and 2.0; five lambs had EA values ranging between 1.6 and 1.2. The lowest EA value measured was 0.8 in REL9 (1+ on three sampling dates and no cysts could be detected in one sample).

Furthermore, temporal changes were observed. Significantly higher average EA values were reported in lambs as they returned from the summer rangelands on September 23 (2.44, n=9) than in October (1.69, n=30) (t-test, P=0.003).

No significant relation appeared when EA and faecal consistency (FC) values were compared in the 45 positive samples (Figure 4).

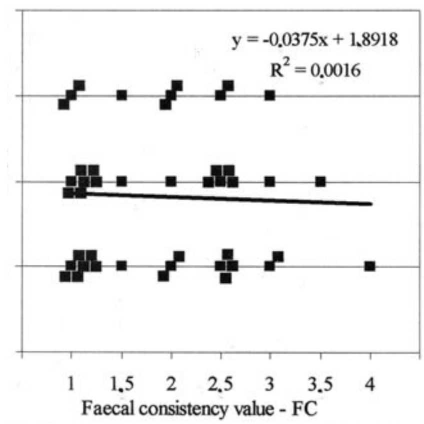


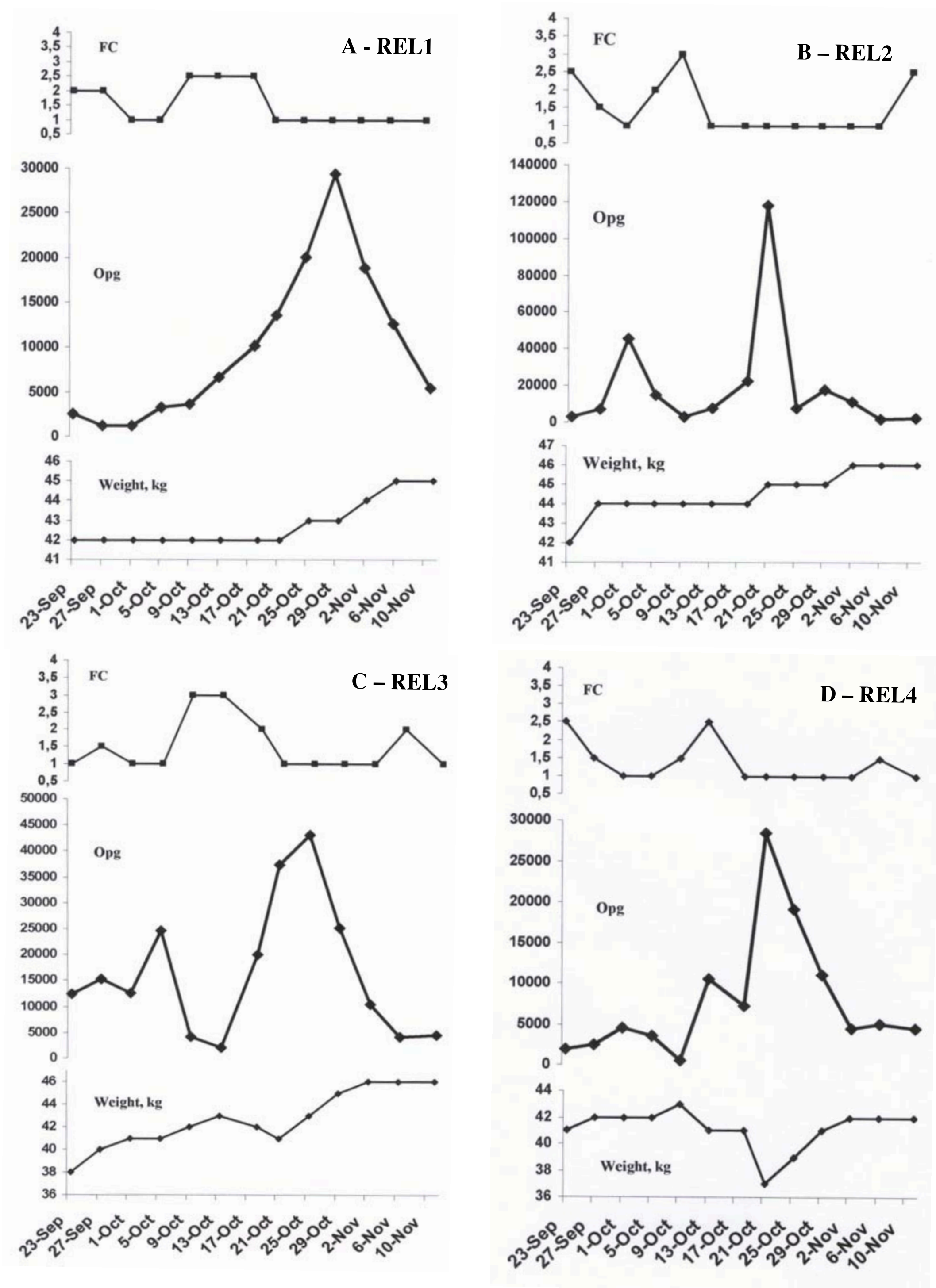
Figure 4. Comparison of estimated *Entamoeba ovis* cyst abundance per sample (EA) and faecal consistency (FC) values (1 normal pellets, 2 soft pellets, 3 paste, 4 liquid faeces) in 45 samples collected during autumn from 10 replacement ewe lambs.

***Cryptosporidium* sp.**

Cryptosporidium sp. oocysts were never observed by the FPC method, but a few oocysts were confirmed in lambs, REL 1 and REL 4, using the MeriFluor method.

***Eimeria* spp.**

Total excretion of eimerian oocysts was low when the lambs returned from the summer rangelands on 23 September. However, through the end of the study period (50 days) one or more similarly shaped opg peaks were observed in all cases (Figure 5). Two main patterns were observed. In all lambs, a prominent opg peak was seen during the second half of October, but also an additional, usually smaller peak, was noticed in three lambs in early October. Peaks were usually narrow and almost symmetrical and did not last for more


A - REL1
FC
Opg
Weight, kg
B – REL2
FC
Opg
Weight, kg
C – REL3
FC
Opg
Weight, kg
D – REL4
FC
Opg
Weight, kg
23-Sep
27-Sep
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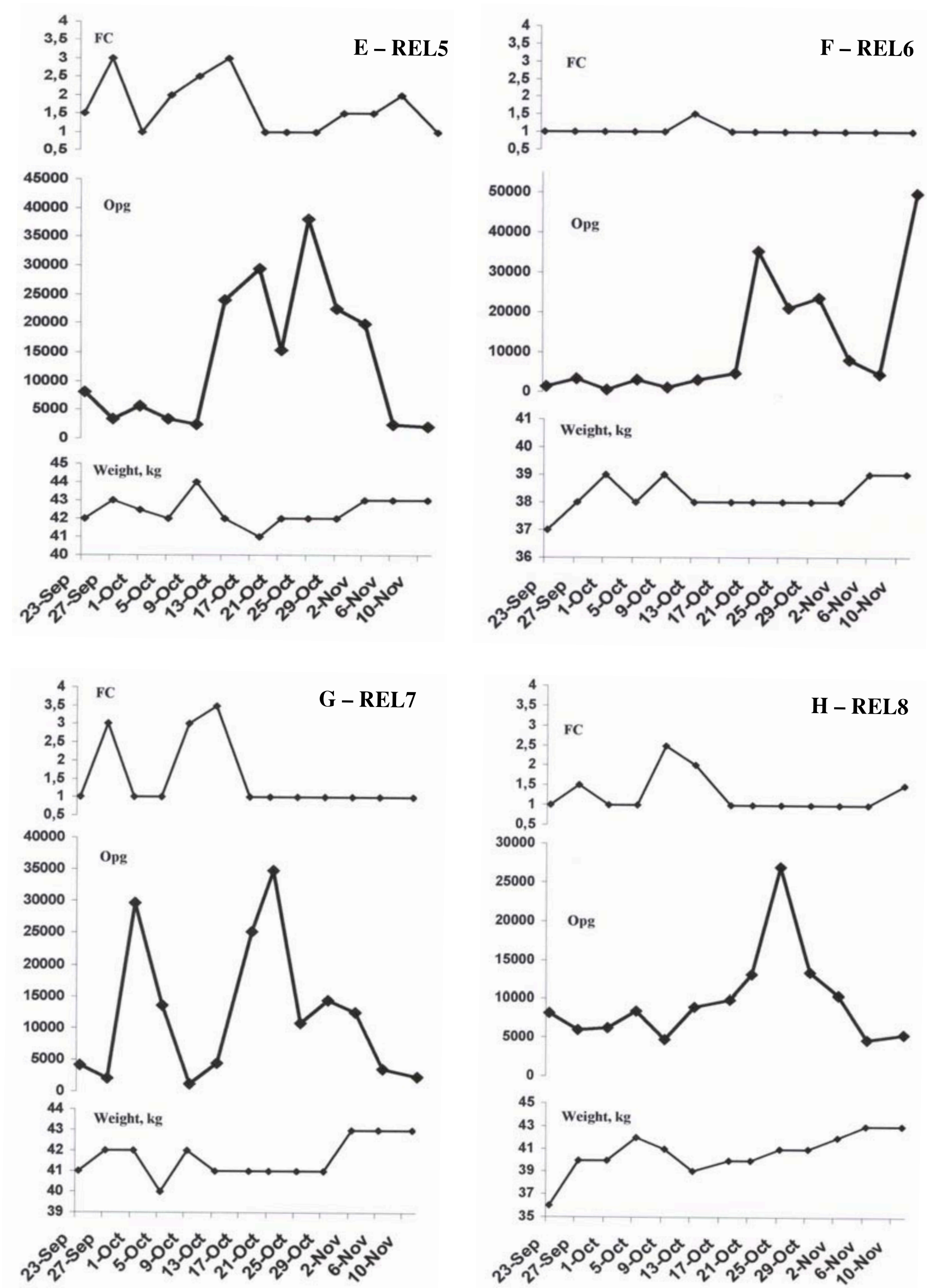
E – REL5
FC
Opg
Weight, kg
F – REL6
FC
Opg
Weight, kg
G – REL7
FC
Opg
Weight, kg
H – REL8
FC
Opg
Weight, kg
23-Sep
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6-Nov
10-Nov

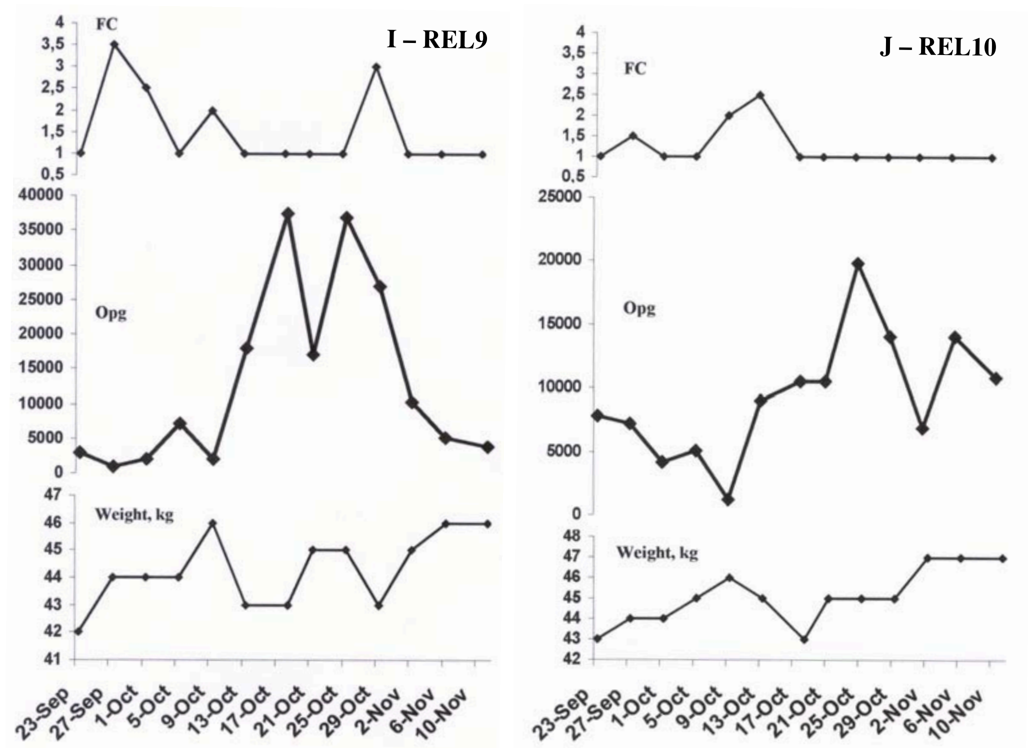

Figure 5. A-J: Faecal consistency values (FC), total Eimeria spp. oocyst numbers per gram faeces (opg) and life weight changes of 10 replacement ewe lambs (REL1-10) on 13 occasions during a 50-day study period in the autumn and early winter of 2002. First sampling was performed when the lambs had been brought from the natural summer rangelands to lowland home pastures. Lambs were penned in sheep houses and indoor feeding started on 18 October.

than a week or two, although in two cases (REL 1 and 9) high oocyst excretion lasted as long as three to four weeks. At the end of the study period, opg values had usually fallen to the same level as observed when lambs came to lowland pastures from the summer rangelands.

Marked live weight changes were observed during autumn (Figure 5). In the first two weeks after returning to the lowland, most of the lambs quickly gained weight of a few kilograms (on average, 2.8 kg, n=10), but then they either started to lose weight for one, two, or in some cases, up to four weeks (eight lambs lost weight) or their weight gain temporarily stopped (in two lambs). Maximum weight loss observed was 6 kg, but on average the lambs lost 2.9 kg.

Consistency of faeces changed mainly during the first half of the study period. During the latter half, little or no diarrhoea was usually observed (Figure 5). On return to the lowland, faeces were normally formed in six lambs (FC value 1), but the value was 2.0 or 2.5 in the remaining lambs, representing some diarrhoea. Four or eight days later these values had dropped to 1.0 indicating a rapid recovery of the short-term diarrhoea. However, the prominent and widespread FC change started on the fifth or sixth sampling date (on 13 and 17 October) by which time the lambs had been grazing for approximately three weeks on the lowland. Then suddenly all lambs (except REL 6) went through a short but severe diarrhoeic period (Figure 5). After this diarrhoeic phase, by the middle of October, faeces again became normal pellets and did not change, except for some lambs that temporarily showed a short diarrhoea phase at the end of the study period (Figure 5).

As a rule, approximately two weeks after the onset of each diarrhoeic period, opg values peaked.

DISCUSSION

During autumn lambs on the farm went through one or more diarrhoeic phases. The first diarrhoeic phase was observed in lambs as early as during the first week on the lowland. Relatively few lambs on the farm (2-3%) were affected, and all recovered on their own within a few days. Probably, the drastic food change when lambs start grazing on home fields, with different vegetation and higher nutrient value, was the main cause of this diarrhoeic phase. However, *G. duodenalis* might also have contributed to this early diarrhoea, as markedly more cysts were observed in faeces of diarrhoeic lambs (average EC value in four lambs examined was 2.3) than in lambs that were also *Giardia* positive, but had normal pellet faecal consistency at the same time (average EC value 1.0; five lambs). As these lambs recovered within a few days, the pathologic effect was considered to be of negligible importance. Results from October and November (Figure 3), however, strongly suggest that *G. duodenalis* was not a primary cause of diarrhoea in lambs on the farm in autumn.

G. duodenalis is a parasite with a direct life cycle. Hosts become infected by ingestion of cysts in contaminated faeces. Studies abroad have shown that the parasite is able to cause diarrhoea, malabsorption, poor digestion and consequent weight loss in lambs (Ljungström et al. 2001, Olson et al. 1995). Frequently, however, no clinical symptoms are noticed (Rommel 2000) or simultaneous infections with other pathogens, mainly eimerians, hinder an accurate interpretation of results (Taylor et al. 1993). Results obtained abroad have shown that giardiasis usually starts in lambs soon after parturition and then persists for some weeks or even months. In older sheep, intermittent shedding of cysts is frequently noticed and a periparturient rise in cyst excretion is described (Xiao 1994). As a result, increased contamination occurs in the surroundings of newborn lambs. Colostrum from infected ewes does not protect lambs from *Giardia* infections (Xiao 1994). As indicated by the 100% prevalence of infection in the present study, and frequent records from other flocks in the country, *G. duodenalis* seems to be a very common sheep parasite in Iceland but it is still unknown if giardiasis mainly occurs in lambs in spring and early summer as described abroad (Xiao 1994). Prior to 1980, *Giardia* was only sporadically reported from farm animals in the world (Rommel 2000, Xiao 1994). In Iceland the parasite remained undetected in farm animals until parasitologists started to use the sensitive FCP method to search for protozoans in livestock in the early 1990s. Some evidence (Skirnisson et al. 2003) strongly supports the hypothesis that the *Giardia* genotype occurring in Icelandic lambs does not belong to the zoonotic, human pathogenic genotypes A or B (Thompson 2004, Marianne Lebbad, pers. comm.).

To understand our interpretations of coccidiosis in this study, it is necessary to refer to some basic knowledge on ovine eimerian infections. Most of this information has been gathered in Western Europe and it has been compiled and reviewed, for example, by Barutzki et al. (1989), Gregory (1989), Eckert et al. (1995) and Rommel (2000). Firstly, ovine coccidiosis is very common everywhere in the world. The causatives are protozoans of the genus *Eimeria* and the life cycle is direct. Oocysts are shed in faeces and they mature in 1-3 days on the pastures. The prepatent period ranges from 10-33 days. In areas where sheep are housed during winter, oocysts are known to survive on the pastures during months of snow cover and sub-zero temperatures and then become the source of infection in the following year. Also, persistent, sub-clinical infection of ewes acts as a source of infection for lambs (Helle 1969). Clinical signs are bloodstained diarrhoea, dehydration, anorexia, and weight loss. Mortalities are well known. Severity of coccidiosis is strongly related to the oocyst numbers ingested at infection, although a combination of stress factors such as early weaning, overcrowding, cold, travel, poor nutrition or malnutrition, and turning out to pastures can also play a role. Other opportunist pathogens can add further stress (Eckert et al. 1995, Gregory 1989, Rommel 2000).

If lambs grow up and graze on fields where they are born, peak incidence of eimerian infections is usually seen around six weeks of age. After 10 weeks of age usually all lambs in a flock are infected and infection intensity rapidly drops when sheep have reached the age of six months. Finally, it has been shown that repeated ingestion of oocysts leads to continuous immunity against eimerians (Eckert et al. 1995, Gregory 1989, Rommel 2000). More recent data suggest that on some farms, lambs tend to get coccidiosis between 3 and 4 weeks of age (Gregory 1989). Limited studies available from an Icelandic flock have shown similar results. Total eimerian oocyst counts in six newly-born lambs revealed that oocysts were first excreted in a 22 day old lamb, and oocysts had been confirmed in all of them early in their fifth week of life. In two almost five week old lambs, opg values of 350,000 and 625,000, respectively, were noted (Richter 1974). Further studies on Icelandic lambs clearly indicate that lambs that are kept on lowland pastures usually suffer from coccidiosis in early summer and increased oocyst excretion has also been observed during autumn (Richter 1976, 1977, 1979, Richter & Eydal 1985).

Somehow different pattern seems to occur on the Fossárdalur sheep farm. Live weight measures, opg and FC value changes, as well as typical clinical signs, confirm that lambs on the farm got coccidiosis in the third week after their return from their summer rangelands and the start of grazing on eimerian-contaminated home fields. The same pattern was observed among late arriving lambs that came to the lowland in November and were immediately penned in a sheep house. Therefore, lambs apparently not only acquired pathogenic eimerian oocysts when grazing on contaminated fields on lowlands, but also when fed and watered exclusively indoors.

Eimeria ovinoidalis McDougald, is by far the most important coccidian species of sheep and can be highly pathogenic, even in field lambs that have been exposed to the organism for some time (Gregory 1989) and hence have had the possibility of developing some resistance. It affects mainly the caecum and colon and causes severe enteritis, which may be haemorrhagic. A very important fact to note is that newborn lambs are protected against *E. ovinoidalis* infections but experiments have shown that susceptibility to this organism rises from zero at birth to a maximum at about 4 weeks (Gregory 1989). In general, little is known about the pathogenicity of the other 10 species reported in sheep, but *Eimeria bakuensis* Musaev, *Eimeria ahsata* Honess, and *Eimeria parva* Kotlán, Móscy & Vajda, are regarded as pathogenic, at least in certain cases (Eckert et al. 1995, Gregory 1989, Rommel 2000). Another part of this study was to determine the eimerian composition in lambs on the farm (Skirnisson & Gudmundsdottir, unpublished). Preliminary results, however, indicate that 71.9% of the oocysts identified in the survey belonged to these pathogenic eimerians (Eckert et al. 1995, Gregory 1989, Rommel 2000). The most pathogenic *E. ovinoidalis* was by far the most common species (relative abundance on the farm was 40.7%) and it was followed by *E. bakuensis* (18.9%), *E. parva* (6.7%) and *E. ahsata* (5.6%). Focusing on *E. ovinoidalis,* this parasite has a prepatent period of 10-15 days before symptoms of coccidiosis become apparent, and then the symptoms last for 7-10 days (Rommel 2000). This timing fits well with the infection pattern described in the lambs in Fossárdalur. Using the same argument, it also seems likely that the lambs that showed a distinct opg peak in early October (REL 2, 3 and 7) had already been grazing in oocyst-contaminated areas in early September. Presumably their mothers had already returned to the lowland before active gathering took place.

If information on the farming practice in Fossárdalur is viewed in the light of the knowledge that lambs progressively start to lose their natural protection against *E. ovinoidalis* at the age of two weeks (Gregory 1989) it must be pointed out that ewes on the farm are usually released with their lambs to summer rangelands when lambs are still so young that they are naturally protected against infections of, at least, the most dangerous *Eimeria* species. And when lambs become progressively susceptible to eimerian infections they have usually reached the summer rangelands where the possibility of infection by coccidians (and helminths) generally are considered to be negligible. This could also explain why the lambs on the farm are so susceptible to coccidian infections when they return to the lowland in autumn. Thus, the farming practice is likely to postpone spring coccidiosis infections until autumn, as lambs seem not to have the opportunity to acquire sufficient immunity against ovine eimerians during spring and early summer.

If samples had been collected at intervals shorter than four days, opg, FC and live weight curves would certainly have become more accurate and, for example, the obviously quite narrow opg peaks would have been better established. Nevertheless, the curves obtained clearly represent certain individual variations. For example, the height and width of curves was quite different. Some lambs lost much more weight than others, and some lambs seemed to recover earlier than others. The reasons for these obvious individual differences are unknown, but it can be speculated that they are related to factors that were not measured, such as the immune status of the lambs and the infection dose of the eimerian species involved in each case.

The results did not indicate that *E. ovis* and/or *Cryptosporidium* sp. were primarily involved in diarrhoea on the farm in autumn. The reason why *E. ovis* infections were significantly more abundant in lambs as they returned from the summer ranges than during the grazing and the housing period is also unknown. According to Levine (1961) *E. ovis* was described in 1914 and frequently reported the following decades from the intestines of sheep throughout the world, usually in high prevalence. In recent decades, however, *E. ovis* has not been included in textbooks on parasites, and the species seems to be considered a commensal in the intestines of sheep. Our results support this theory.

Cryptosporidium sp. apparently occurred rarely in lambs on the farm in autumn. As the parasite is known to infect new-born animals (Rommel 2000), it is possible that the lambs examined were already immune to the parasite. Studies have shown that *Cryptosporidium* sp. is commonly found in spring and early summer in lambs and in other ruminants in all parts of Iceland (Skírnisson et al. 1993, Skirnisson, unpublished).

Helminths were not considered to play any significant role in causing diarrhoea in the lambs during autumn. As shown elsewhere, low epg values were found in the lambs when they returned from the summer rangelands (Skirnisson, unpublished).

Neither *Salmonella* nor *Campylobacter* bacteria were cultivated from faeces of diarrhoeic lambs on the farm. Therefore, these are excluded as possible diarrhoeic causes. The only pathogenic bacteria reported on the farm belonged to the genus *Clostridium.* Probably, the species involved was *Cl. perfringens* (Eggert Gunnarsson, pers. comm.) and it was only found in December in late arriving lambs. In late winter adult sheep on the farm are vaccinated against *Cl. perfringens* B and D as well as *Cl. septicum.* It is unknown if maternal immunity still protects lambs of vaccinated ewes in autumn, but indirect evidence indicates that this might be the case, at least until early autumn (Hansson, unpublished data). It remains open if *Clostridium* also contributed to the diarrhoea in the late arriving lambs definitely suffering from coccidiosis.

One or a few lambs have typically died each year on the farm in the autumn during preceding decades. In the present study, mortalities were unusually low, as only one lamb died. In that case, various medical treatments had masked the possibilities of detecting parasitic and/or bacterial pathogens involved, but as coccidiosis symptoms typically start two weeks after the onset of grazing on the lowland, pathogenic eimerians are assumed to be primarily responsible for its death. In comparable cases of previous years, the co-author and the farmers repeatedly experienced that early treatment with antibacterials, like Terramycin and Depomycin, reduced mortality rates and also, in many cases, accelerated the recovery of seriously diseased lambs. In these cases, antibacterials may have minimized the effect of secondary infections after the coccidiosis phase.

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