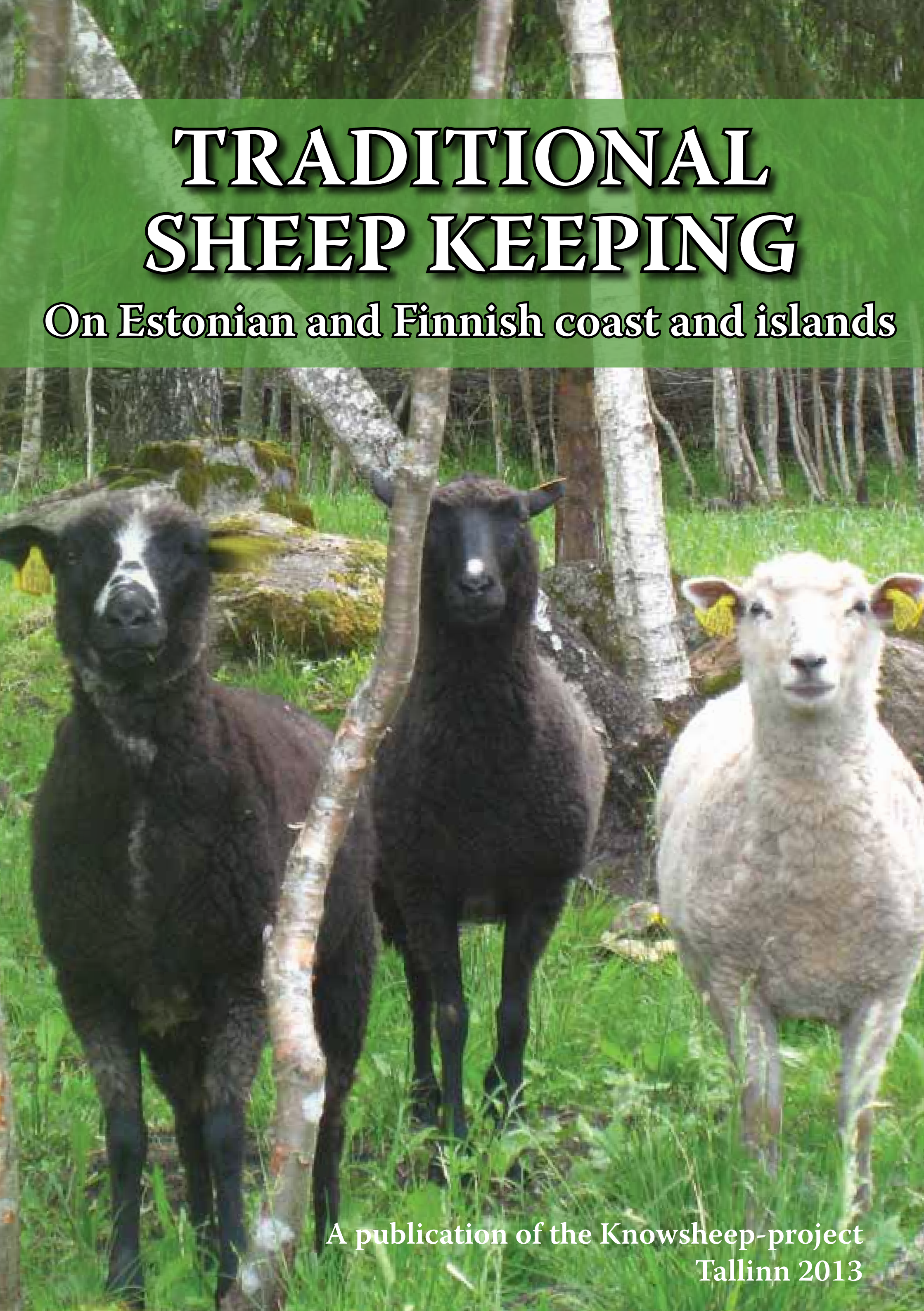
TRADITIONAL SHEEP KEEPING

On Estonian and Finnish coast and islands



A publication of the Knowsheep-project
Tallinn 2013

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
INVESTING IN YOUR FUTURE

CENTRAL BALTIC
INTERREG IV A
PROGRAMME
2007–2013

TRADITIONAL SHEEP KEEPING

On Estonian and Finnish coast and islands

Studies carried out by Interreg IVA KNOWSHEEP

KNOW SHEEP

Tallinn 2013

The Knowsheep-project is financed by European Union, European Regional Development Fund, Central Baltic Interreg IV A Programme 2007-2013, Archipelago and Islands Sub-programme.

Editor: Veiko Kastanje
Technical editor: Svea Aavik
Translator: Luisa Translation Bureau
Printed in Estonia by Rebellis

Front cover photo: Annika Michelson
Back cover photo: Veiko Kastanje

ISBN 978-9949-9504-5-4

CONTENTS

INTRODUCTION

This collection contains articles on the results of research and development activities carried out from 2011–2013 within the scope of the KNOWSHEEP project. The articles discuss ways of feeding sheep, grazing sheep on semi-natural grasslands, the security of sheep pastures, the spread of sheep parasites and the characteristics and uses of wool. There is also an analytical overview of the resources, needs and potential development opportunities of sheep farming on Estonian and Finnish islands and in coastal areas.

KNOWSHEEP is an acronym formed from the name 'Developing a knowledge-based sheep industry on the Baltic Sea islands'; the project was carried out under the Archipelago and Islands Sub-Programme of the European Union's Central Baltic INTERREG IV A Programme. The project lasted for three years.

KNOWSHEEP aimed to popularise sheep farming, raise awareness among sheep farmers and find solutions to known problems in traditional sheep farming on the islands and in the coastal areas of Estonia and Finland.

The project was carried out by researchers from the Estonian Research Institute of Agriculture (now the Estonian Crop Research Institute) in cooperation with specialists from the Institute of Veterinary Medicine and Animal Sciences of the Estonian University of Life Sciences, Turku University (Finland), HAMK University of Applied Sciences (Finland), MTT Agrifood Research (Finland), the non-profit associations Saaremaa Vill and Hiiu Veis ja Lammas, and the town of Pargas (Finland). Many sheep farmers from Estonian and Finnish islands and coastal areas also participated in the project as partners.

The project was structured in five work packages: WP1 – project management and coordination; WP2 – resource analysis and strategic planning; WP3 – research and development; WP4 – establishment of sheep information centres; and WP5 – training and information dissemination. The research and development package comprised five subjects: 1. Feeding sheep; 2. Grazing sheep on semi-natural grasslands; 3. Security of sheep pastures – problems related to wolves and eagles; 4. Study of the spread of sheep parasites on sheep farms on the West-Estonian islands; and 5. Study of the characteristics and uses of wool and related product development.

This book represents one form of output of studying the above research subjects.

As a research and development coordinator and a participant in the research and development activities of the KNOWSHEEP project I hope that this publication will contribute to an overall increase in the awareness of sheep farmers and, ultimately, to traditional sheep farming becoming more popular in Estonia and Finland.

Veiko Kastanje
KNOWSHEEP coordinator,
Estonian Crop Research Institute

SHEEP PARASITES AND THEIR CONTROL

T. Järvis

Institute of Veterinary Medicine and Animal Sciences, Estonian University of Life Sciences, Kreutzwaldi 62, 51014 Tartu, Estonia; e-mail: toivo.jarvis@emu.ee

Abstract. Sheep parasitic diseases affecting feed ingestion, feed digestibility and variety of physiological processes can be manifest in many ways. These include a decrease in the yield and value of animals and their products at slaughter, reduced live-weight gain a.o. It is important to underline that subclinical parasitic diseases can result higher cost to farmers then clinical disease.

There are lot of sheep infecting parasites, including gastrointestinal nematodes, lungworms, tapeworms, liver flukes, unicellular parasites, mites, lice and flies.

Firstly the review on most important sheep parasites and the epidemiology of gastrointestinal nematodes is presented in this paper. Secondly the control of sheep parasites is dealt, including prophylactic measures, anthelmintic drugs, their correct use and measures of control to prevent anthelmintic resistance.

Key words: Sheep parasites, gastrointestinal nematodes, epidemiology, control of parasites, anthelmintic drugs, anthelmintic resistance.

INTRODUCTION

Sheep breeding, besides cattle and pig breeding, is the supplementary branch of animal breeding in Estonia. In addition to sheep meat the wool and skin are important products. Sheep breeding is useful also from the point of environmental protection.

During recent years sheep breeders have begun to expand the main herd and the number of breeders has increased. In turn of the year 2011/2012 the number of sheep in Estonia was 78200. The number of organically kept sheep is increased as well. In the year 2008 their percentage was 42.5% from the total number of sheep in Estonia.

Sheep meat as wool production is arising. Sheep meat, especially valuable dietetic quality lamb meat is very much sought after on the market. Additionally, sheep export has been started in recent years.

The most important infectious diseases of sheep what can lead to high economical losses are considered to be parasitic infections.

Parasitic infections can affect feed ingestion, feed digestibility and variety of physiological processes, which can be manifested in many ways. These include premature death, a change in the value of animals and their products at slaughter, reduced live-weight gain, reduced yield and quality of products, altered feed conversation efficiency a.o. These in turn have effects on herd productivity, on the capacity to maintain and improve a herd, on human nutrition a.o.

In case of moderate infection of parasites and in good feeding and keeping conditions of sheep the course of parasitic diseases is often asymptomatic. Although far less dramatic, the insidious losses to subclinical infections involve large numbers of sheep for prolonged periods of time and result much higher cost to the farmers then clinical disease. Control of subclinical parasitism has the potential to improve ewe body weight by up to 6 kg, to increase the number of foetuses by >12 foetuses per 100 ewes and to increase weight of twin lambs weaned by >2 kg (West et al., 2009).

In contrast to microbial infections, where replication of organisms occurs entirely within host, the important nematode parasites of livestock have an obligatory free-living stage on pasture. Thus pastures provide the link between the free-living and parasitic phases of gastrointestinal parasites of grazing livestock and every nematode parasite present within the host has been separately acquired by the ingestion of an infective larval stage from pasture.

Another important contrast between microbial and metazoan parasite infections is the time required for the completion of the within host phase of the life cycle – a matter of hours for bacteria and viruses, but several weeks for nematodes. A minimum or threshold level of antigenic information must be produced by nematode parasite burdens before immunological reaction and mobilization of host responses affecting nematode survival in the host occurs. As a consequence, microbial infections characteristically induce prompt and aggressive immune reactions by the host, whereas nematodes induce varying forms of immunological tolerance to permit their longer survival. Immunity generally develops slowly, is dependent upon a good nutritional state and is abrogated by any form of stress experienced by the animal. Consequently, parasites are ubiquitous where ever grazing livestock are kept and pose a constant and often high infectious pressure on animals. Parasite infections in grazing livestock are almost always a mixture of species. All have deleterious effects and collectively they lead to chronic illthrift. Due to severe parasitic infection weakness, oedema under the jaw, paleness (anaemia) and abomasitis in sheep was registered (Manninen & Oksanen, 2010). Economic evaluations consistently show that the major losses due to parasites are of animal production, rather than on mortality.

This is a real possibility that humans may be infected with some sheep protozoan parasites (Robertson, 2009).

In recent years, there has been an increasing demand by consumers that agricultural products should be "clean". Impetus for "clean" livestock products has followed adverse publicity surrounding purported agrochemical inducted effects on human health and the development of super-resistant human pathogens, caused by the use of antibiotics in intensive livestock production systems. The threat of adverse effects on the environment from the use of any chemicals in agricultural production has also driven this agenda. This has been accompanied by the rapid increase in popularity of organic farming, especially in European countries Waller, 2006).

IMPORTANT SHEEP PARASITES

There are lot of sheep infecting parasites, including gastrointestinal nematodes (GIN), lungworms, tapeworms, liver flukes, protozoa and ectoparasites (Fig. 1, 2).

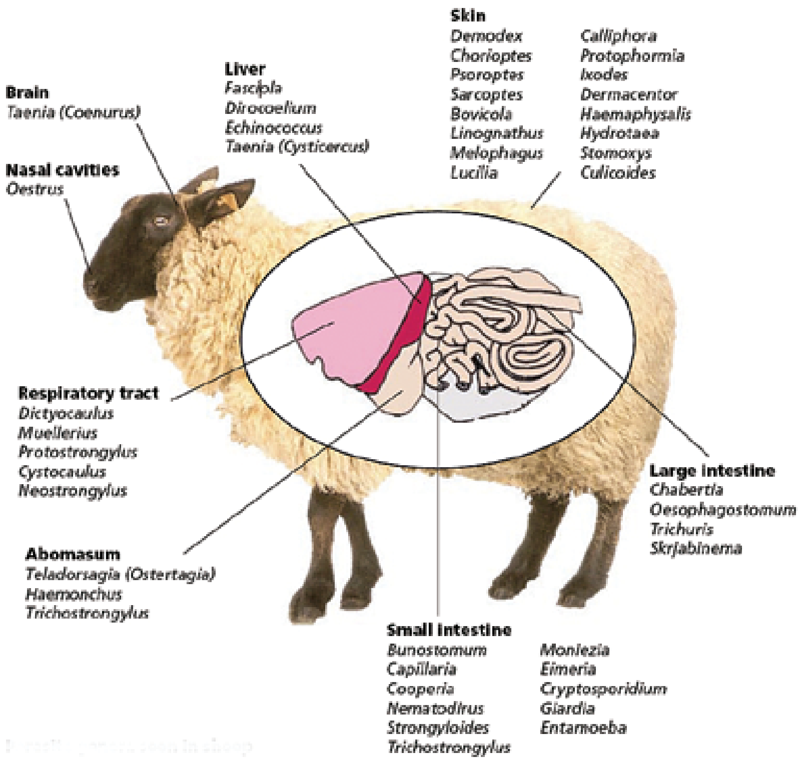


Figure 1. Parasite genera seen in sheep (Taylor, 2009).

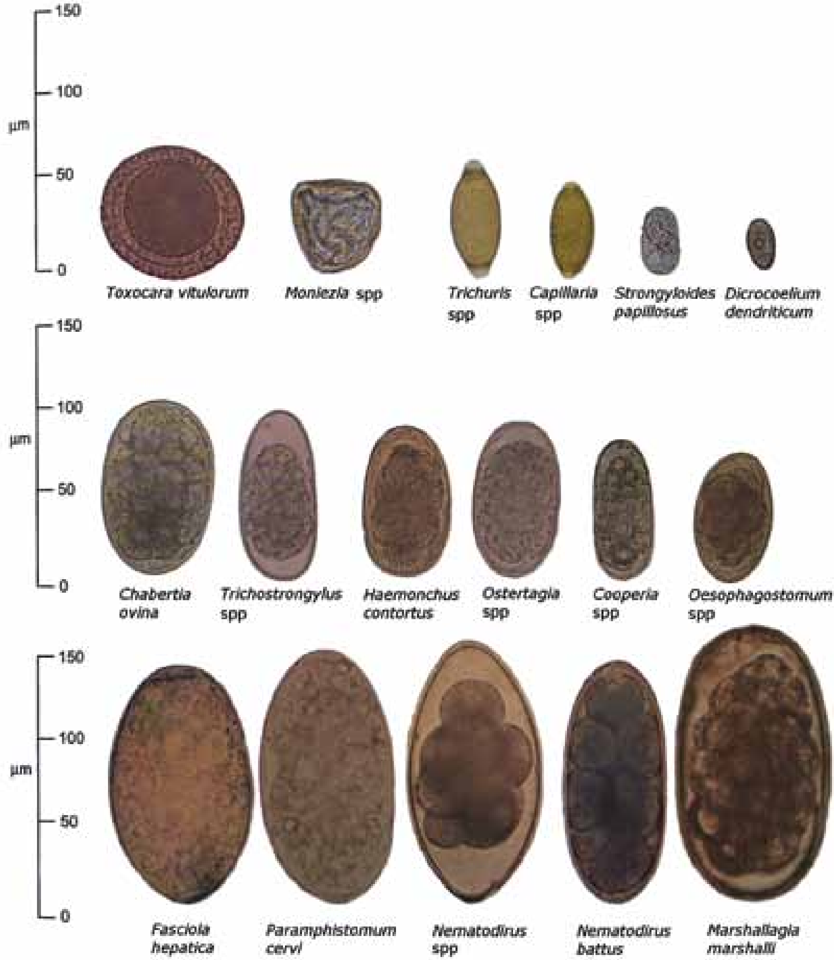


Figure 2. Worm eggs from ruminants (Taylor et al., 2007).

1. Endoparasites

1.1 GIN

By Taylor (2009) there are about 20 species of GIN (mostly strongylides) that could be found commonly in sheep (genera *Ostertogia, Haemonchus* and *Trichostrongylus axei* in abomasum; genera *Trichostrongylus, Nematodirus, Cooperia, Bunostomum, Strongyloides* and *Capillaria* in small intestine; genera *Oesophagostomum, Trichuris* and *Chabertia* in large intestine). Their length is mostly 0.6–3 cm. The pathogenicity varies with species, the numbers of nematodes present as well as host factors as age, nutritional status and body condition. The life cycles of the GIN are very similar, with some minor exceptions (Fig. 3). The life cycle is direct i.e. without intermediate host. Adult female worm in the sheep lay eggs that pass out in the faeces and hatch, each egg releasing one first stage larva (L1). The L1 develops to the L2 and L3. The L3 is the infective stage. L3 migrate on to the herbage where they are ingested by sheep. In the walls of the stomach or intestines they develop into L4, before emerging as adult worms about 14 days later. The prepatent period (between ingestion of L3 and the appearance of eggs in the faeces) is generally between 16–21 days. Adult worms that are not killed by anthelmintics or expelled from the sheep by immune mechanisms survive typically less than three months before dying naturally.

Important variations on the basic life cycle are:

1) for *Nematodirus spp* development to the L3 takes place within the egg. With *N. battus,* hatching and release of the L3 occurs as a result of climatic stimulus. The prepatent period can be as short as 14 days;
2) the L3 of *Strongyloides papillosus* can infect the host by ingestion or by skin penetration. Transmission to lambs may also occur via the milk of the ewe. The prepatent period is about 9 days;
3) infection of the host with *Bunostomum trigonocephalum* occurs by ingestion or through the skin. Following skin penetration the larvae pass to the lungs and then to the small intestine.

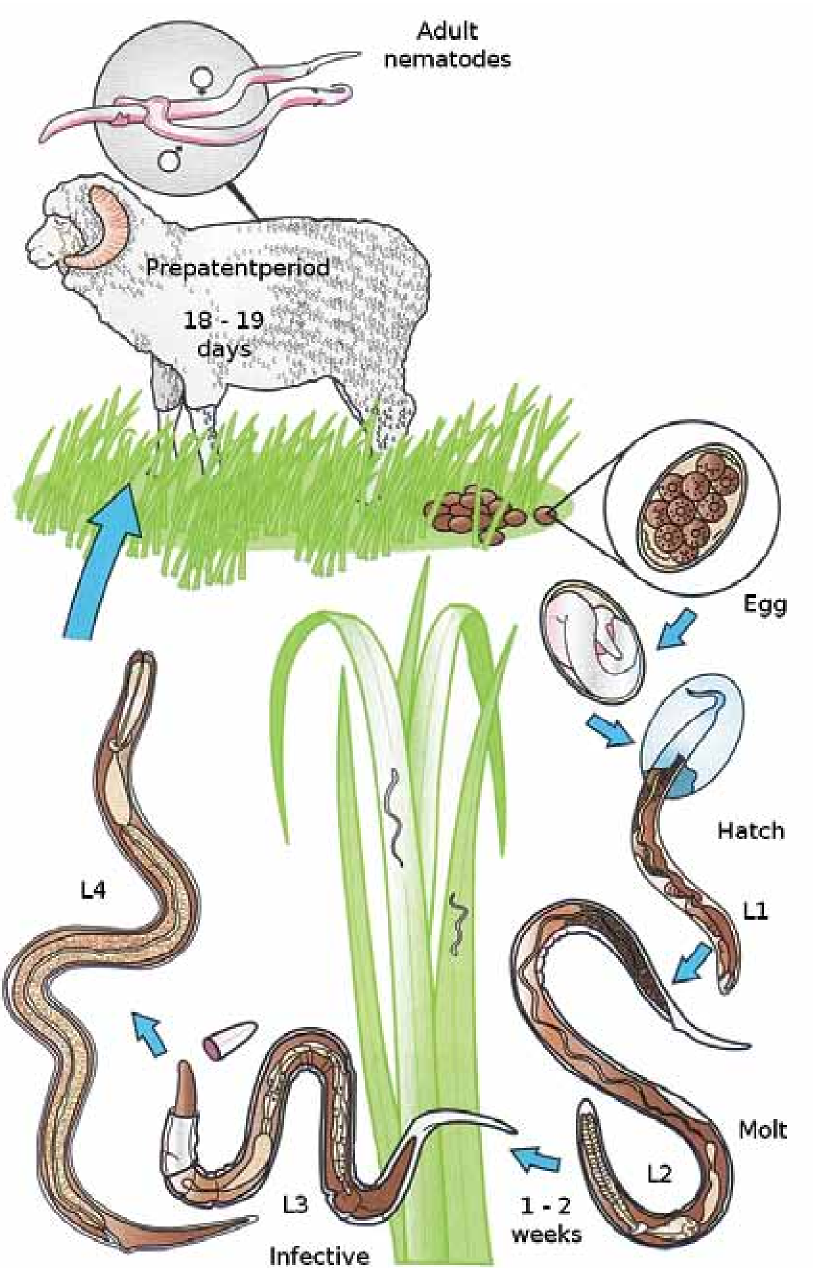


Figure 3. Life history of a typical strongylid nematode *Haemonchus contortus* (Bowman, 2009).

The prepatent period is about 56 days;

4) infection of the sheep with *Trichuris ovis* occurs through ingestion of the L1 in the egg. After ingestion L1 is released, all moults occur within the sheep. The prepatent period is one to three months (Abbot et al., 2009).

The principal clinical sign in sheep infected with GIN is diarrhoea

Figure 4. Acute diarrhoea in sheep (Dalton, 2008).

1.2. Lungworms

Sheep are infected with a number of lungworm species, the most important being *Dictyocaulus filaria* (5–10 cm in length). The females lay eggs in the airways, which are coughed up and swallowed. The eggs hatch and the Ll are passed out in the faeces, where they moult to L3. Infective larvae on the herbage are ingested by sheep. The L3 penetrate the intestinal mucosa and pass to the mesenteric lymph nodes, where they moult. After that the L4 travel via lymph and blood to the lungs and breaks out the capillaries into the alveoli about one week after infection. The final moult occurs in the bronchioles and the young adults then move up the bronchi and mature. The prepatent period is about 4–5 weeks. Longevity can be from 2–3 months up to about 6–9 months.

The distribution and prevalence of little (0.5–3.5 cm) lungworms *(Muellerius capillaris, Cystocaulus ocreatus* and *Neostrongylus linearis* in the lung parenchyma; *Protostrongylus rufescens* in small bronchi) are partly attributable to the presence of the molluscan intermediate hosts. The prepatent period is about 4–9 weeks and the longevity of little lungworms in 5–6 years.

Factors that play a part in ensuring the endemicity of lungworms are first, the ability of L1 to survive for months in faecal pellets and secondly, the persistence of L3 in the mollusc for the lifetime of the mollusc, each of which depends on climatic conditions, especially high rainfall.

1.3. Tapeworms

Adult tapeworm *(Moniezia spp,* from 2–3 to 10 meters long) infections are seen relatively frequently in grazing sheep. The life cycle requires an intermediate host – oribatid pasture mites. Mature proglottids or eggs are passed in the faeces and on pasture where the oncospheres (L1) are ingested by forage mites. The embryos develop in the body cavity of the mite to cysticercoids in 1–4 months and infection of the sheep is by ingestion mites during grazing. The prepatent period is approximately 6 weeks, patent infection persists about 3 months (Handbook ..., 2010).

Larval stages of *Taenia* species may harm the sheep – for example *Taenia multiceps (Coenurus cerebralis),* found in the brain and *T. hydatigena (Cysticercus tenuicollis),* found on liver and in abdominal cavity. Others, such as *Echinococcus granulosus* larva (a hydatid cyst) could be found on the lungs and liver.

1.4. Flukes

The life cycle of the liver fluke *Fasciola hepatica* (2–3 cm long) is complex, involving an intermediate host, the mud snail *Lymnaea truncatula* and several free-living stages. The role of the snail, who prefers muddy, slightly acidic conditions, particularly areas associated with poor drainage, means that the incidence of *F. hepatica* is far greater in the wetter areas and in years when there is high summer rainfall. Adult fluke lay eggs that are passed out onto pasture in the faeces. At suitable temperatures a miracidium (L1) develops within egg, hatches and migrates in thin films of moisture, actively seeking the snail host. Within the snail L1 undergoes two development stages, including multiplication, eventually becoming infective cercariae (about 600), which emerge from the snail, when the temperature and moisture levels are suitable. The cercariae migrate onto wet herbage, encysting as adolescariae, the highly resistant infective stage. Following ingestion, the young flukes migrate to the liver, through which they tunnel, causing considerable tissue damage. The prepatent period is about 10–12 weeks. The whole cycle takes 18–20 weeks (Abbot et al., 2009). The longevity of *F. hepatica* in sheep may be years. Characteristic symptom of chronical fasciolosis is submandibular oedema (Fig. 5).

Figure 5. Submandibular oedema caused by *Fasciola hepatica* (Eckert et al., 2005).

Small lanceolate fluke *Dicrocoelium dendriticum* (length 0.8–1.2 cm). The eggs do not hatch until digested by the first intermediate host, a land snail, in which two generations of sporocysts develop, which then produce cercariae. The slime balls of cercariae are ingested by ants (genus *Formica).* The resulting metacercariae infect the brain, causing the ants to climb to the top of blades of grass, where they are more likely to be eaten by grazing sheep. The metacercariae hatch in the small intestine and the young flukes migrate up the main bile duct and then to smaller ducts in the liver. There is no parenchymal migration. The prepatent period is 10–12 weeks. The total life cycle takes approximately 6 months. The flukes are long-lived (several years).

1.5. Unicellular parasites

Eimeria

There are 11 different species of *Eimeria* in sheep, but not all are highly pathogenic (Skirnisson, 2007). They are microscopic (about 20–30 μm in length) parasites of the intestine. Their complicated life cycle involves asexual reproduction (schizogony) and sexual reproduction (gametogony) in the epithelial cells. Sporulation of the oocysts in the environment, necessary for successful infection, takes few days in ideal weather, but several weeks if the weather is cool. The prepatent period for *E.ovinoidalis* is 12–15 days, for *E.crandallis* 13–20 days, usual sporulation time is 1–3 days. The pathogenic lesions are mainly in the caecum and colon.

Cryptosporidium parvum

This is a microscopic (about 5 μm) zoonotic parasite of the small intestine, i.e. infects ruminants and people and may cause severe gastrointestinal disease in people (Yang et al., 2009). *C.parvum* is a coccidial organism with a similar life cycle to *Eimeria* but it takes only a few days to complete the life cycle (schizogony, gametogony, sporogony) and produce oocysts. The oocysts are already infective in fresh faeces and very resistant to environmental factors. Part of *C.parvum* oocysts releases their sporozoites in intestine, causing auto-infection.

Giardia duodenalis

Giardia is a microscopic (11–19 x 7–10 μm) flagellate parasite of the small intestine. It's zoonotic (infects livestock, dogs, cats, rodents and people). The life cycle is simple and direct. The trophozoite stage divides by binary fission to produce further trophozoites. Trophozoites encyst forming resistant cysts stages that pass out in the faeces of the host, being already infective. Prepatent period is 4–8 days.

2. Ectoparasites

2.1. Mites

Psoroptes ovis causes psoroptic mange ("sheep *scab").* They are non-burrowing mites 0.4–0.8 mm in length. Adult female produces eggs, life cycle takes about 3 weeks. The life expectancy for an adult female is about 16 days (2–6 weeks). *P.ovis* feeds sucking a lipid emulsion of skin cells and lymph. Hypersensitivity causes inflammation, surface exudation, scale and crust formation. Infestation in sheep leads to severe pruritus, wool loss, restlessness, biting and scratching, weight loss, reduced weight gain and in some cases, death (Fig. 6). *P.ovis* is infective also for cattle.

Figure 6. Sheep with psoroptic mange (Taylor et al., 2007).

Chorioptes bovis causes chorioptic mange ("leg and scrotal mange"). They are nonburrowing mites particularly on legs, base of tail and upper rear surface of the udder. The have mouthpart which is adapted for chewing skin debris. The life cycle is typical for mites. Host reactions are usually induced only when numbers increase to thousands of mites per host. Scabs and scales develop. *C.bovis* infects also cattle, horses and goats.

Sarcoptes scabiei var. ovis causes sarcoptic mange ("scabies"). The skin burrowing mites are 0.2–0.5 mm in length and prefer regions without wool. Affected areas are at first erythematous and scurfy. The intense pruritus is present, sheep scratch and rub the head, body and legs against trees, posts and walls. In severe cases the skin becomes thickened, with marked loss of wool and crusts form. The life cycle takes about 3 weeks, the life expectancy is 7–8 weeks.

2.2. Lice

Damalinia (Bovicola) ovis is reddish brown chewing lice up to 3 mm long. He prefers areas close to the skin such as the back, neck and shoulders, but is highly mobile. The whole life cycle takes 2–3 weeks, the life expectancy is about 4 weeks. *D.ovis* chews the outer layers of the hair shafts, dermal scales and blood scabs, causing irritation, resulting in rubbing and scratching, with matting and loss of hair. Lice reduce the quality of wool.

Linagnathus ovillus – "long-nosed louse", "sheep face louse". This is a blue-black sucking louse approximately 2.5 mm long and is found mainly on the face. The egg to adult cycle requires about 20–40 days, the life expectancy is 4–6 weeks. Infestation results in a chronic dermatitis. Because they are blood feeders, anaemia is common, where high population of lice exist.

L.pedalis – "sheep foot louse". It's bluish grey sucking louse up to 2 mm in length and prefers sites which are more lightly wooled areas of the body as legs, belly and feet (Taylor et al., 2007).

2.3. Flies

Melophagus ovinus – "sheep ked". It's hairy, brown, wingless, approximately 5–8 mm long fly. They have piercing blood-sucking mouthparts and strong legs. The mature larvae produced by the female adhere to the wool. These pupate immediately. The 3–4 mm long brown puparia are easily visible on the fleece. This form is very resistant to insecticides. Adult keds emerge in summer, their life expectancy is 4–6 months. The most obvious sign is pruritus and tearing the fleece. The faeces of the keds produce stains in the coat (pinkish-brown) that do not wash readily. Irritation causes discolouration of the hide with raised nodules and reduced weight gain.

Oestrus ovis – sheep nasal bot. It's yellowish brown 10–12 mm long nonparasitic fly. The females infect the sheep by squirting a jet of liquid containing larvae at the nostrils during flight. So the parasitic stage is the larvae which inhabit the nasal passages of the sheep. They grow up to 3 cm in length. The new deposited L1 start to migrate up the nose through the sinuses causing irritation. They attach to the lining of the passages using the oral hooks, which further irritates the sheep. The first moult occurs in the nasal passages and the L2 crawl into the frontal sinuses, where they complete their growth and migrate back to the nostrils, from where they are sneezed out to the ground. Larvae pupate in the ground and then emerge as flies. Time from infection to dropping out is variable, up to 9 months in the areas with temperate climate. The fly survives only 2 weeks in the summer. Sheep show nasal discharge and sneezing and rub their noses on fixed objects. Circling and lack of coordination may develop. As the fly approaches the sheep will bunch, stamp their feet, they are very irritated, feeding is interrupted and animals may fail to weight gain.

EPIDEMIOLOGY OF GIN

The knowledge of the epidemiology of parasite infections at the regional or even local level is a prerequisite for the design of an integrated approach of parasite control combining the most relevant solutions at the farm level.

- The first year grazing lambs are the age group most susceptible to the establishment of pathogenic worm burden.
- Yearlings and adult sheep may act as worm carriers. Their faecal egg output is responsible for spring contamination of pastures.
- Infective larvae may survive the winter and may serve as source of initial infection of lambs in the early period of the grazing season. With dry summers the build-up of pasture infectivity may be delayed until the autumn. Thus the epidemiological importance of the overwintered L3 on the pasture depends on climatic factors (temperature, snow cover, moisture etc.). Global warming can change the epidemiology of GIN.
- Periparturient egg rise (PPER) of the faecal egg output seen in ewes from about two weeks prior to lambing until six weeks post-lambing, promotes spring pasture contamination. The intensive egg discharge by the primary worm populations established in the highly susceptible offspring generation plays a major role in the build-up of the midsummer rise of infective larvae on pasture.
- Rainy and warm weather promotes larval survival and development, dryness and direct sunshine are lethal to eggs and larvae. L3 are more resistant than Ll or L2.
- Overstocking and congregation of animals around watering points of the pasture in drought condition may lead to heavy challenge.
- Although level of larvae on pasture follows a fairly typical seasonal pattern, pastures remain infective throughout the whole grazing season.
- Insufficient nutrition and other parasitic infections (fasciolosis, dictyocaulosis, eimeriosis etc.) as common predisposing factors

may promote outbreak and clinical severity of the disease.

- Towards the end of the grazing season, a proportion of the new GIN infection will not progress to adults in the sheep organism, but will rather remain at the L4 stage and become hypobiotic.
- Lambs will develop immunity to parasites over-time. This period varies with the type of GIN but generally occurs over 4 to 6 months, but varies between breeds and between animals. However, high challenges of GIN on pasture can overwhelm the sheep's immunity and cause disease. Immunity is also greatly affected by nutrition, particularly dietary protein.
- Due to the strong overlap of nematodes infecting sheep and goats, mixed grazing between sheep and goats should be avoided.

CONTROL OF PARASITES

The goal of a parasite control program is to control the level of parasites on the farm to a level which has minimal production costs without allowing the development of anthelmintic resistance (sustainable integrated parasite management).

On a sheep farm, there are two populations of parasites - the parasitic population which resides in the animal, and the free-living parasites which reside on pasture. Most of the time, the larger population is the free-living and is the population not exposed to the anthelmintics (refugia).

1. Prophylactic measures for maintenance a minimal population of GIN on pasture

The occurrence of helminths in sheep is markedly influenced by the farm managing practice (Skirnisson, 2011).

- Rotate pastures with other livestock species (cattle, horses). Typically at intervals from 2 to 6 months. Co-grazing with cattle may help.
- Sheep and goats share same parasites. Never graze sheep and goats together. Adult goats do not develop immunity to parasites

and so will be a serious source of pasture contamination.

- Rest pastures that are heavily contaminated. Select it for plowing, reseeding, haying and/or grazing with another species.
- Do not spread manure onto pasture. Poorly composted manure can be a source of parasites.
- Use low-risk pastures for the most susceptible animals. Graze weaned lambs on newly seeded pasture or hay field.
- Remain the sheep on the pasture after treatment for up to 3–5 days to allow for a mild reinfection. This means that the parasite load in the animal is now a mix of susceptible parasites (from the reinfection) and a few resistant to anthelmintics parasites (left over from deworming). This allows a susceptible refugia to be maintained.
- Use pasture rotation. This strategy relies on movement of sheep to another pasture just before the larvae develop to L3 stage (variable depending on weather, longer in cool weather but shorter in warm weather). On average the worst time period between grazing sessions is 3 weeks - the most likely time that the eggs have hatched and developed to L3.
- Do no graze late gestation or early lactation ewes as the PPER in ewes is an important source of spring season pasture contamination.
- Do not graze lambs with ewes, wean lambs early. If lambs are not grazed until after weaning (50–60 days of age), then exposure to the PPER of ewes can be minimized.
- Rotate weaned lambs ahead of ewes. This way there is less risk from exposure to PPER contaminated pasture.
- Do not overgraze. Overgrazing pasture will increase the infection rate by forcing the sheep to graze close to the soil (long grass is safer than short grass).

2. Anthelmintic drugs for sheep

Anthelmintic drugs are divided into board-spectrum (able to kill a wide variety of parasites) and narrow-spectrum (only able to kill one or two types of parasites).

2.1. Broad-spectrum anthelmintics

Benzimidazoles (BZ) are effective against all nematodes and most of them against adult tapeworms. They are also ovicidal (activity against eggs). Fenhendazole and albendazole are most commonly used for sheep. Albendazole also has activity against adult flukes, but should not be used during breeding or the first trimester of pregnancy.

There is one BZ anthelmintic (triclabendazole), which is narrow spectrum – liver fluke only (Abbot et al., 2009).

Imidazothiazoles (IAT) and tetrahydropyrimidines. This group contains levamisole, pyrantel and morantel. They are not ovicidal. Levamisole is effective against a broad range of adult worms, but less against the immature stages. It is particularly effective against lungworms. Morantel can be used against GIN, but is not effective against immature stages. Pyrantel is rarely used.

Macrocyclic lactones (ML). This group contains the avermectins (ivermectin, doramectin, eprinomectin) and the milbemycins (moxidectin), ML have activity against most nematodes, but not tapeworms or flukes. They also have activity against some arthropod ectoparasites, specifically sucking lice (*Linognathus sp.*) and nose bots (*Oestrus ovis*), as well as keds (*Melophagus ovinus*) and mange (*Psoroptes, Chorioptes, Sarcoptes*). Moxidectin is considered to have significant prolonged activity against strongylides (*Ostertagia, Haemonchus*).

Amino-acetonitrile derivatives (AAD). The first product from this new class of drugs is monepantel. It has excellent activity against resistant strains of GIN as well as immature forms of nematodes, in particular *Haemonchus* (Handbook … , 2010).

Activity against hypobiotic larvae

Albendazole, fenbendazole, oxfendazole, netobimin, levamisole, doramectin, ivermectin and moxidectin are effective against arrested L4 of the abomasal nematodes. The activity of the BZ and IAT is considered relatively poor compared to the ML.

2.2. Narrow-spectrum anthelmintics

The substituted phenols (nitroxynil) and the salicylanilides (closantel, oxyclozanide) are narrow-spectrum anthelmintics. They are affective only against trematodes and blood-sucking nematodes (*Fasciola* and *Haemonchus*). Praziquantel is a quinoline-pyrazine and is active against the sheep tapeworms (*Moniezia sp*).

Activity against ectoparasites
The ML are also effective against sucking lice (*Linognathus sp.*), nasal bots (*Oestrus ovis*) and mange mites (*Psoroptes, Chorioptes, Sarcoptes*) when given by injection. There is little or no activity against biting lice (*Damalinia ovis*) and ticks. While effective against keds, they are not effective against the pupae.

3. Advices for correct use of anthelmintic (AH) drugs

Basic rules by Torres-Acosta & Hoste (2008).

1. In relation of AH products.
    - Read the instructions of the drug carefully. Request advice from the specialist in doubt.
    - Respect instructions about use and storage (dose, route of administration, end of use date).
    - Use only ready-made combinations of drugs.
    - Verify the dosing device before use.
    - Off-licence use of AH drugs must be limited to farms where licenced products have been proven to be ineffective and only under close supervision of a veterinarian.
2. In relation to the animal.
    - Use the correct dose recommended for the sheep.
    - Administer the oral AH in the back of the tongue.
    - Treat when animals have been fasted 12-24 hours.
3. In relation to the herd.
    - Do not treat when refugia is limited or destroyed (clean pasture, dry or winter season).
    - Reduce to a minimum the number of treatments per year.
    - Use parasitological criteria for the use of AH treatments. Fundamental in good parasite control is accurate and correct diagnosis (Taylor, 2010).

- Treat the sheep according to the weight of the largest animal in the group.
- Alternate AH groups on yearly basis.
- Verify efficacy of AH treatment once per year (two weeks after the treatment).
- Use quarantine treatment for the newly introduced animals. Sheep should be yarded at least for 48 hours to ensure that any viable nematode parasite eggs have been voided before they are turned onto pasture (Sargison, 2011a).

Standards, which define organic production systems, specifically state that the prophylactic use of drugs, including of course anthelmintics, is prohibited.

ANTHELMINTIC RESISTANCE (AR)

Resistance is the heritable ability of the parasite to tolerate a normally effective dose of the anthelmintic.

An unsatisfactory response of parasitized animals to treatment is usually the first apparent sign of presence of AH resistant nematodes on a given farm. AR threatens the sustainability of sheep production if it is allowed to reach a high enough level (Sargison, 2011b). On most sheep farms, the first indications of AR are the failure of lambs to reach finished weights by late autumn, scouring and even deaths due to parasitic gastroenteritis, despite preventive anthelmintic treatments (Sargison, 2011a). AR can result in clinically inapparent, suboptimal growth rates for some time before these overt signs of disease are seen.

Before suspecting AR, it is recommended that other possible causes leading to drug inefficacy are investigated (see advices for correct use).

Anthelmintic resistant worms developed as a result of their frequent exposure to the available commercial drugs. With time, the genes of those worms able to survive anthelmintic exposure prevail over those of the susceptible worms, making treatments becoming less efficacious than expected.

1. Management flaws favouring the development of AR

Besides the chemical nature of the drug, life expectancy and fecundity of adult worms, egg deposition etc., the most common management flaws identified as favouring the development of AR on farm are:

- Lack of quarantine of newly introduced animals. If these animals carry resistant worms, they may increase the risk of AR in their new farm.
- Treatment of all animals in the herd. After treatment, a small number of resistant worms will survive and will be able to "seed" pastures with resistant eggs. Thus, in time, animals will acquire only resistant larvae from the paddocks.
- Underdosing.
- Using the same group of anthelmintics for long periods of time.
- Frequent treatment.
- Systematic treatment, which is not related to the local pattern of parasite infection.

The most widely used technique to detect AR on farms is the Faecal Egg Count Reduction Test (FECRT). If one decides to perform a FECRT for certain anthelmintic, he requires a minimum of 30 lambs or young adults (first grazing season) with elevated faecal egg counts. Ten to 15 lambs are randomly assigned to control and treatment groups. Individual faecal samples are obtained per rectum on day 0 (treatment day), lambs are weighed using a scale and treated appropriately. The controls are not treated but are sampled. All the lambs are returned to the same pasture to graze. All the lambs are sampled again later (14 days for BZ and ML, 7 days for IAT). The post-treatment faecal egg counts are compared to the control. Failure of reduce by 95% or greater compared to the control indicates resistance. Confidence intervals (CI) are also calculated and if the lower CI is < 90%, then AR is indicated as well (Handbook ..., 2010).

2. Measures of control to prevent AR

- Test for AR on the farm. The right time to combat drug resistance is before it becomes apparent and widespread.
- When resistance to a certain drug is detected, its use should be discontinued.
- Avoid introducing resistant worms by deworming all new animals before adding them to the existing stock.
- Administer anthelmintics effectively. Give the correct dose in the correct way.
- Use the anthelmintics only when necessary. Faecal egg count monitoring has an important role.
- Rotate anthelmintic groups on an annual basis.
- Adopt strategies to preserve susceptible worms on the farm:
    1) part-flock treatment. Farmers looking to exploit low-contaminated pastures should be encouraged to use highly efficacious treatments and to leave about 10% of the flock untreated;
    2) targeted selective treatments. Obvious indicators are animals in low body condition, reduced growth rates or those with signs of scouring;
    3) delay the "move" after the "dose". The "dose" and "move" approach has been widely used. The rationale behind it is to treat animals before to move them to a "clean" pasture (absence of L3 as result of cultivation, reseeding, severe winter or dry season etc.). Although long recommended, this approach can select heavily for AR as most eggs that will be deposited on the paddocks will be those surviving the anthelmintic treatment, i.e. from resistant populations.
- Integrate dosing with stock management (see prophylactic measures for maintainance a minimal population of GIN in pasture).
- Avoid nutritional stress. Ewes fed a ration that has high levels of undegradable protein are less affected by periparturient

relaxation in immunity (PPRI) and as such produce much lower numbers of worm eggs postlambing. Creep feeding of lambs provides additional nutritive support and may help delay early exposure to larvae on pasture.

- Exploit breed resistance. Local indigenous breeds are able to thrive in their traditional environment and also to tolerate, or resist, worm infections.
- Breeding sheep for worm resistance.
- Use forages with anthelmintic properties. Grazing on bioactive forages has been shown to reduce the negative effects of parasitism in sheep (Abbot et al., 2009).

CONCLUSIONS

Economical losses due to sheep parasites can be significantly reduced combining prophylactic measures with responsible use of anthelmintic drugs.

Farmers understanding on the necessity of knowledge-based parasite control in sheep management and consistent implementation of measures are of great importance.

ACKNOWLEDGEMENTS: This study was supported by the project KNOWSHEEP of the INTERREG IVA PROGRAMME.

REFERENCES

Abbot, K. A., Taylor, M. & Stubbings, L. A. 2009. *Sustainable worm control strategies for sheep.* SCOPS, www.nationalsheep.org.uk,_51.

Bowman, D. D. 2009. *Georgis' Parasitology for Veterinarians*. Saunders, St. Louis, 451.

Dalton, C. 2008. Diarrhoea in sheep.http://www.lifestyleblock.co.nz/lifestyle-file/livestock-a-pets/sheep/item/136-diarrhoea-in-sheep.html

Eckert, J., Friedhoff, K. T., Zahner, H. & Deplazes, P. 2005. *Lehrbuch der Parasitologie für die Tiermedicin.* Enke Verlag, Stuttgart, 575S.

Handbook for control of internal parasites of sheep. 2010. Ontario Veterinary College, University of Guelph, Guelph, 50.

Manninen, S.-M. & Oksanen, A. 2010, Haemonosis in a sheep flock in North Finland. *Acta Vet. Scand.* **52**, Sl, 519.

Robertson, L. J. 2009. *Giardia* and *Cryptosporidium* infections in sheep and goats: a review of the potential for transmission to humans via environmental contamination. *Epidemiol. Infect.* **137**, 913–921.

Sargison, N. D. 2011a. Pharmaceutical control of endoparasitic helminth infections in sheep. *Vet. Clin. Food Anim.* **27**, 139–156.

Sargison, N. 2011b. Responsible use of anthelmintics for nematode control in sheep and cattle. *In Practice* **33**, 318–327.

Skirnisson, K. 2007. *Eimeria* spp. (Coccidia, Protozoa) infections in a flock of sheep in Iceland: Species composition and seasonal abundance. *Icel. Agric. Sci.* **20,** 73–80.

Skirnisson, K. 2011. Association of farming practice and the seasonal occurrence of gastrointestinal helminths in a flock of sheep in Iceland. *Icel. Agric. Sci.* **24**, 43–54.

Taylor, M. 2009. Changing patterns of parasitism in sheep. *In Practice* **31**, 474–483.

Taylor, M. A. 2010. Parasitological examinations in sheep health management. *Small Ruminant Res.* **92**, 120–125.

Taylor, M. A., Coop, R. L., Wall, R. L. 2007. *Vet. Parasitol.* Blackwell Publishing, Ames, 874.

Torres-Acosta. J. F. J. & Hoste, H. 2008. Alternative or improved methods to limit gastro-intestinal parasitism in grazing sheep and goats. *Small Ruminant Res.* **77**, 159–173.

Waller, P. J. 2006. Sustainable nematode parasite control strategies for ruminant livestock by grazing management and biological control. *Anim. Feed Sci. Tech.* **126**, 277–289.

West, D. M., Pomroy, W. E., Kenyon, P. R., Morris, S. T., Smith, S. L. & Burnham, D. L. 2009. Estimating the cost of subclinical parasitism in grazing ewes. *Small Ruminant Res.* **86**, 84–86.

Yang, R., Jacobson, C., Gordon, C. & Ryan, U. 2009. Prevalence and molecular characterisation of *Cryptosporidium* and *Giardia* species in pre-weaned sheep in Australia. *Vet. Parasitol.* **161**, 19–24.

PARASITOLOGICAL SITUATION OF SHEEP FARMS ON THE BALTIC SEA ISLANDS

T. Järvis and E. Mägi

Estonian University of Life Sciences, Institute of Veterinary Medicine and Animal Sciences, Kreutzwaldi 62, 51014 Tartu, Estonia
e-mail: toivo.jarvis@emu.ee

Abstract. Parasites are important production-limiting diseases in livestock farming. Their proper treatment and control requires knowledge of their presence, epidemiology, and diagnostics. We investigated the presence of the gastrointestinal parasites in pooled flock faecal samples from the islands Saaremaa (n=21), Hiiumaa (n=18), and Vormsi (n=7), collected in 2011–2012. The samples were investigated microscopically after quantitative flotation, acid-fast contrast staining for Cryptosporidium oocysts, and direct immunofluorescence for Giardia cysts. Findings included nematodes: Strongylida spp. (94.6%), Strongyloides spp. (70.7%), Trichuris spp. (9.8%); cestodes: Moniezia spp. (22.8%); trematodes: Dicrocoelium spp. (3.3%) and protozoans: Eimeria spp. (94.6%), Giardia spp. (69.6%), Cryptosporidium spp. (60.9%). E. spp. oocysts and Strongylida eggs were shed in levels that may indicate problems in some flocks. The most dominant species of Eimeria was the highly pathogenic E. ovinoidalis (64.4%), but the other clinically important species, E. crandallis did not dominate any samples. Based on the presented findings, it appeared that the flocks had different parasitic problems needing evidence based treatments for sustainable control. An overview on some sheep keeping and health factors on farms is presented.

Key words*:* sheep, parasites, protozoa, nematoda, cestoda, prevalence, infection intensity, the questionnaire

INTRODUCTION

Ovine gastrointestinal (GI) parasites are important pathogens affecting the health of the animals and the income of their farmers (Fitzgerald, 1980; Chartier & Paraud, 2012). Clinical signs of disease, such as diarrhoea, and even mortalities affect mainly young animals (Hansen & Perry, 1994; Chartier & Paraud, 2012). Sub-clinical effects, such as long term weight loss and reduced growth, are probably more important considerations to a modern livestock production aiming for improvement of production through healthier animals (Fitzgerald, 1980; Foreyt, 1990; Taylor, 2009). To achieve such a lasting effect the farmers and veterinarians require knowledge of parasites affecting the sheep, risks affecting the presence of parasites, and methods to detect and treat the infections in a sustainable way (Sargison, 2011; Chartier & Paraud, 2012).

Sheep in the Northern hemisphere are potentially exposed to a wide range of parasites, including gastrointestinal nematodes (GIN), lungworms, tapeworms, liver flukes, unicellular organisms, and ectoparasites (Domke et al., 2012). There are over 20 different species of GIN of sheep, what can cause clinical or subclinical disease with reduced growth rate, body condition and milk production. Protozoan parasites constitute another group of common and important gastrointestinal causes of disease, mainly: *Eimeria*, *Cryptosporidium*, and *Giardia* (Fitzgerald, 1980; Pfister & Flury, 1985; Dittmar et al., 2010; Saratsis, et al., 2011). It has previously been shown that *Eimeria* and *Cryptosporidium* are prevalent in Estonain dairy flocks and cause substantial losses to farmers when uncontrolled (Lassen et al. 2009a; Lassen & Østergaard, 2012). Ovines are likely to be similarly affected in Estonia by the clinial and subclinical infections (Sweeny et al., 2011). The most pathogenic *Eimeria* species is considered to be *E. ovinoidalis* (Catchpole et al., 1976; Chartier & Paraud, 2012), and *E. crandallis* is considered mildly pathogenic in lambs (Catchpole & Gregory, 1985). Other species such as *E. ahsata, E. marsica*, *E. bakuensis, E. granulosa,* and *E. parva* have been reported to show clinical signs in lambs (Mahrt & Sherrick, 1965; Gregory & Catchpole, 1987; Berriatua et al., 1994; Reeg et al., 2005; Skirnisson, 2007).

Estonian sheep have previously been investigated by Kaarma and Mägi (2000), Mägi and Kaarma, (2002), and Mägi and Sahk (2004). The investigations examined the population dynamics of strongylids, *Moniezia* and *Eimeria* in the period 1996–2006. Until now the information on sheep parasites on The Baltic Sea islands has remained unexplored. Few is known on sheep management and parasite control measures on sheep farms.

The main aim of the current study was to investigate the parasitic situation (gastrointestinal parasites) in the sheep flocks on the Estonian biggest islands during two visits in 2011 and 2012 with a focus on identifying the present *Eimeria* species.

MATERIALS AND METHODS

Study population

On the targeted islands, 368 flocks of the 559 registered had 9 animals or more and were included in the study (mean: 46, median: 21). The selected flocks were distributed as: Saaremaa n=267, Vormsi n=7, Hiiumaa n=94. A minimum sample size of 34 animals was calculated to be sufficient to prove absence of detectable parasitic infections with a minimum expected prevalence of 30%. This calculation was based on 79% sensitivity and 93% specificity of the acid-fast staining method (Quilez et al., 1996). A total of 46 flocks were planned for visits based on a balanced representation of the selection criteria: flocks size (9–49 sheep (n=16), 50–150 sheep (n=17), >150 sheep (n=13)), production type (organic (n=27), and non-organic (n=19), and distribution on the islands (Saaremaa (n=21), Hiiumaa (n=18), and Vormsi (n=7). According to logistic possibilities farmers were randomly contacted from the list and asked to participate, and so forth, until the balance of the desired criteria had been fulfilled. Flock sizes of the sampled farms varied between 9–350 animals (mean: 104, median: 82) and represent all types of flocks on the islands.

Sample collection

Selected farms were visited twice (in the spring and autumn) in 2011—2012. Fresh faecal samples were randomly collected into plastic bags on pastures and sheds in the accordance to the number of sheep in the farm (as minimum 20 samples). Samples were kept cool in airtight container until delivery to laboratory within 24—72 hours.

Concentration flotation of parasite eggs

Faecal samples from each flock were mixed in the bag before pooling a 2.15g±0.60 STDV sub-samples into a new plastic bag. After mixing the pooled sample thoroughly a 4g sub-sample taken for analysis. The quantitative flotation was performed accordingly to modified instructions by Roepstorff and Nansen (1998) using an in-house reading chamber (Henriksen & Korsholm, 1984) and sugar-salt flotation medium ($\rho = 1.26$ g/cm^3) as previously described (Lassen et al., 2009a).

The sample was screened as 3 vertical rows (0.06 ml) using x200 magnification (Ceti, Topic T light microscope) and findings recorded and counted as oocysts per gram faeces (OPG) or eggs per gram faeces (EPG). *Eimeria* species were determined at x400 magnification according to descriptions of Levine (1985) of the unsporulated oocysts. The each species was counted and the most frequently occurring species was defined as dominant in the sample.

Semi-quantitative estimation of *Cryptosporidium* oocysts

Approximately 0.1 g of faeces was spread as a thin smear on microscopic slides and air dried before fixing in ethanol and staining according to instructions originally described by Henriksen and Pohlenz (1981). Samples were searched for oocysts at x400 using a light microscope. If oocysts were found averages of three random visual areas were taken as the oocyst count and classified as: low (1–5 oocysts per visual area (OVA) = 10^4–10^5 oocysts per gram (OPG)), medium (6–25 OVA = 10^5–10^6 OPG), and high (>25 OVA = >10^6 OPG).

Direct immunofluorescence test for *Giardia* spp.

As for the concentration flotation of parasite eggs four grams of the flock sample was dissolved in 56 ml tap water, resting for 30 min and then filtered through one layer of gauze into a new plastic cup. Ten ml of the mixed solution was transferred to a 14 ml centrifuge tube and the faecal material spun down (263 RCF, 7 min). The supernatant was removed with a pasteur pipette and the pellet resuspended in 5 ml phosphate buffered saline (Roti-Stock 10x PBS, Carl Roth GmBh, Germany) to an approximately 1/10 dilution. After vortexing 20 µl was transferred to a 8 mm wide well on a teflon coated slide. A negative control (PBS) was added on each slide. The slide was completely dried before fixing the material to the slide for 5 min using ethanol. After drying 25 µl of fluorescent labelled specific antibodies were added (Crypto/Giarda Cel, Cellabs, UK). The slide incubated at 37 ^{0}C for 30 minutes in a humidity chamber. Excess reagent was removed by washing in PBS and air dried for 5 min. Mounting fluid was added to each well and a cover glass added. The entire well was examined for presence of fluorescent *Giardia* cysts at x400 magnification using the FITC filter on a Nikon Eclipse 80i microscope.

Statistics

Differences in occurrences of different parasites in the flocks on different islands were examined using a chi-square analysis, while a *t*-test was used to estimate differences between years. R version 2.15.2 (The R Foundation for Statistical Computing) was used for the analysis. Prevalences and 95% confidence intervals (CI) were calculated using mid-P using OpenEpi (http://www.openepi.com) as were sample sizes.

The questionnaire

The questionnaire of sheep keeping and health was compiled and farmers' answers discussed in each farm on the day of sampling.

RESULTS

Distribution of intestinal parasites

Sheep in all flocks were infected with parasites. The presence of different intestinal parasites is presented in Table 1 and Table 2. Eimeria, Cryptosporidium, Giardia, Strongylida, Strongyloides, Moniezia, and Trichuris were found on all islands whereas Dicrocoelium eggs were only found on Saaremaa. Eimeria and Strongylida were found in almost all flocks but also Cryptosporidium, Giardia and Strongyloides were observed in the majority of the flocks.

Table 1. Prevalences (Mid P exact) of protozoa and cestodes found in sheep flocks on Estonian islands in 2011–2012.

	n	*Eimeria.* n, % [95% CI]	*Giardia* n, % [95% CI]	*Cryptosporidium* n, % [95% CI]	*Moniezia* n, % [95% CI]
All	92	87, 94.6% [83.4;98.0]	64, 69.6% [59.6;78.3]	56, 60.9% [50.6;70.4]	21, 22.8% [15.1;32.2]
Vormsi	14	13, 92.9% [69.5;99.6]	10, 71.4% [44.6;90.2]	12, 85.7% [60.3;97.5]	8, 57.1% [31.2;80.4]
Hiimaa	36	35, 97.2% [87.1;99.9]	24, 66.7% [50.2;80.5]	26, 72.2% [56.1;85.0]	8, 22.2% [10.9; 37.9]
Saare-maa	42	39, 92.9% [81.8;98.2]	30, 71.4% [56.5;83.5]	18, 42.9% [28.6;58.1]	5, 19.1% [9.3; 33.0]

Table 2. Prevalences (Mid P exact) of nematodes and trematodes found in sheep flocks on Estonian islands in 2011–2012.

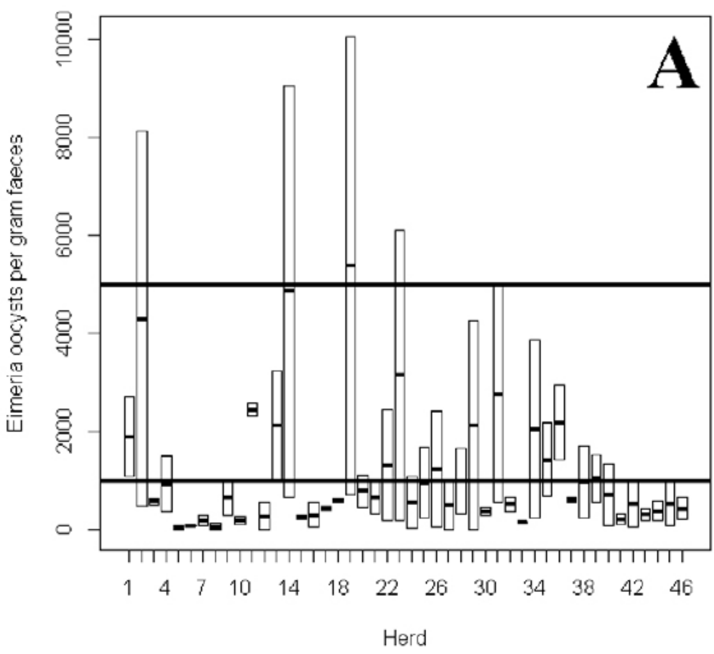
	n	*Strongylida* n, % [95% CI]	*Strongyloides* n, % [95% CI]	*Trichuris* n, % [95% CI]	*Dicrocoelium* n, % [95% CI]
All	92	87, 94.6% [83.4;98.0]	65, 70.7% [60.8;79.3]	9, 9.8% [4.9; 17,2]	3, 3.3% [0.8; 8.6]
Vormsi	14	14, 100.0% [80.7;100.0]	12, 85.7% [60.3;97.5]	4, 28.6% [9.8; 55.5]	0, 0% [0.0; 19.3]
Hiimaa	36	33, 91.7% [79.0;97.8]	25, 69.4% [53.1;82.8]	2, 5.6% [0.9; 17.2]	0, 0% [0.0; 8.0]
Saare-maa	42	40, 95.2% [85.2;99.2]	31, 73.8% [59.0;85.4]	3, 7.1% [1.9; 18.2]	3, 7.1% [1.9; 18.2]

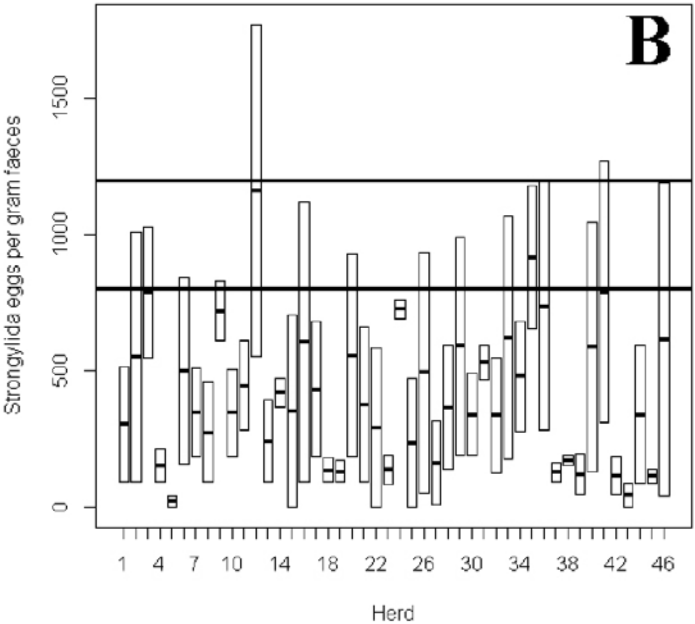
Intensity of parasites in the flocks

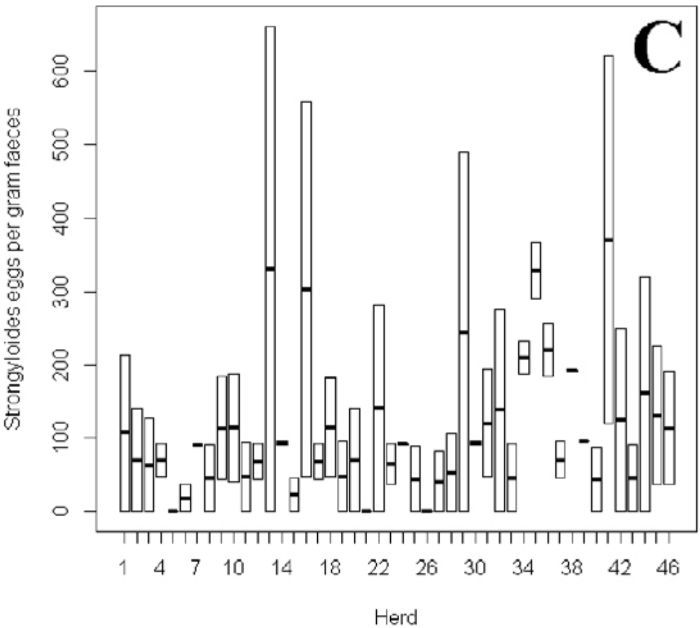
The presence of parasitic oocysts and eggs in the flocks faecal samples ranged 0–10,060 OPG (median: 535, mean: 1,159) for *Eimeria*, 0–1,771 EPG (median: 248, mean: 411) for *Strongylida*, 0–662 EPG (median: 90, mean: 110) for *Strongyloides*, 0–1,378 EPG (median: 0, mean: 76) for *Moniezia*, 0–188 EPG (median: 0, mean: 9) for *Trichuris*, and 0–94 EPG (median: 0, mean: 3) for *Dicrocoelium.* Semi-quantitative scores for *Cryptosporidium* spp. were distributed as, none: 31.1%

(n=39, 29.6–49.4 95% CI), low: 47.8% (n=44, 37.8–58.0 95% CI), medium: 10.9% (n=10, 5.7–18.5 95% CI), and high: 2.2% (n=2, 0.4–7.0 95% CI).

Less cases of *Giardia* spp. was observed in the flocks sampled ($p<0.001$) in 2011 compared to 2012, but the opposite was seen for semi-quantitative intensity scores for *Cryptosporidium* spp. ($p=0.02$). *Moniezia* eggs counts also dropped between the two years ($p=0.03$). A large variation was observed in the OPG's of *Eimeria* between flocks (Fig. 1A), whereas the number of *Strongylida* eggs found in the flocks varied a little (Fig. 1B). *Strongyloides* eggs were found to vary between flocks, but generally at very moderate levels (Fig. 1C). Only few flocks had evidence of *Moniezia* eggs in larger amounts (Fig. 1D).




B
Strongylida eggs per gram faeces
0
500
1000
1500
1
4
7
10
14
18
22
26
30
34
38
42
46
Herd


C
Strongyloides eggs per gram faeces
0
100
200
300
400
500
600
1
4
7
10
14
18
22
26
30
34
38
42
46
Herd

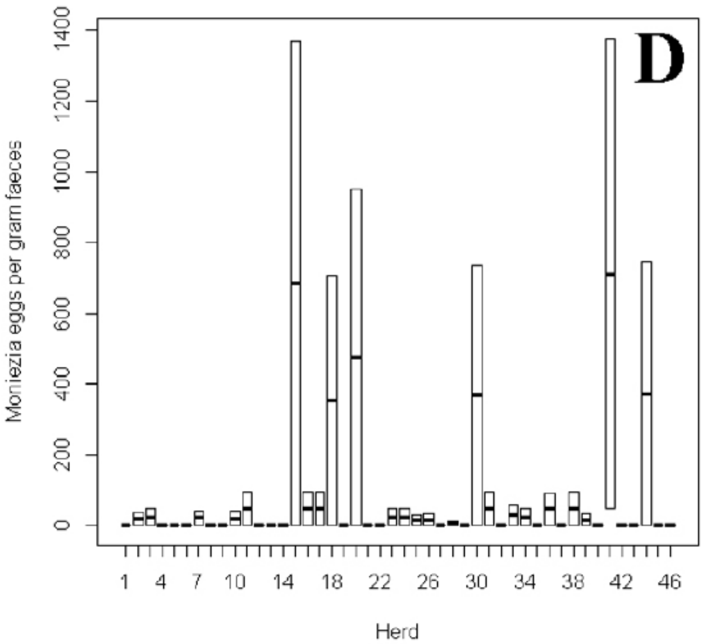


Figure 1. Boxplot of flock averages of oocysts per gram faeces (OPG) *Eimeria* spp. (A), and eggs per gram faeces (EPG) *Strongylida* spp. (B), *Strongyloides* spp. (C), and *Moniezia* spp. (D) found in Estonian sheep from Saaremaa, Hiiumaa and Vormsi between 2011–2012. Vertical bars in figure A and B indicate limits for low to medium (lower bar) and medium to high (upper bar) infection intensities (Hansen & Perry, 1994; Lassen et al. 2009b).

Eimeria species distribution

Eleven ovine species of *Eimeria* were identified in the samples (Table 3). For future reference the unsporulated species are presented in *Eimeria ovinoidalis* was found in almost all samples (93.1%) and dominating 64.4% of the samples (Table 4). *Eimeria crandallis* was found in 14.9% of the samples, but did not dominate in any of them. The 11 identified ovine species were found on all islands with the exception of *E. marsica* that was only found on Saaremaa. Mean oocysts levels were highest in samples where *E. pallida, E. parva, E. bakuensis, E. ovinoidalis*, and *E. granulosa* were dominating. *E. ashata* was only observed dominating in one flock and in low numbers.

Sheep management and parasite control on farms
We did not succeed to get answers for questionnaire questions only from one farm. The farmers answers are presented in Tables 5–6.

Table 3. *Eimeria* species present in Estonian sheep flocks on islands Vormsi, Hiiumaa, and Saaremaa sampled in 2011 and 2012. OPG = oocysts per gram faeces. CI = confidence interval.

Eimeria-positive flocks	Total n=87	Vormsi n=13	Hiiumaa n=35	Saaremaa n=39
	n, % [95% CI]	n, % [95% CI]	n, % [95% CI]	n, % [95% CI]
E. pallida	27, 31.0 [22.0;41.3]	2, 15.4 [2.7;42.2]	12, 34.3 [20.1;51.0]	13, 33.3 [20.0;49.1]
E. parva	33, 37.9 [28.2;48.5]	3, 23.1 [6.2;50.9]	10, 28.6 [15.5;45.1]	20, 51.3 [37.8;66.6]
E. marsica	2, 2.3 [0.4;7.4]	0, 0.0 [0.0;20.6]	0, 0.0 [0.0;8.2]	2, 5.1 [0.9;15.9]
E. ovinoidalis	81, 93.1 [86.2;97.2]	12, 92.3 [67.5;99.6]	34, 97.1 [86.7;99.9]	35, 89.7 [77.1;96.7]
E. weybridgensis	29, 33.3 [24.0;43.7]	9. 69.2 [41.3;89.4]	7, 20.0 [9.2;35.6]	13, 33.3 [20.0;49.1]
E. crandallis	13, 14.9 [8.6;23.6]	1, 7.7 [0.4;32.5]	4, 11.4 [3.8;25.3]	8, 20.5 [10.0;35.3]
E. faurei	25, 28.7 [20.0;38.9]	6, 46.2 [21.3;72.6]	7, 20.0 [9.2;35.6]	12, 30.8 [17.9;46.4]
E. granulosa	23, 26.4 [18.0;36.4]	2, 15.4 [2.7;42.2]	6, 17.1 [7.3;32.3]	15, 38.5 [24.3;54.3]
E. bakuensis	44, 50.6 [40.1;61.0]	7, 53.9 [27.4;78.7]	16, 45.7 [29.9;62.2]	21, 53.9 [38.2;68.9]
E. intricata	4, 4.6 [1.5;10.7]	1, 7.7 [0.4;32.5]	1, 2.9 [0.1;13.3]	2, 5.1 [0.9;15.9]
E. ahsata	20, 23.0 [15.1;32.7]	5, 38.5 [15.7;65.9]	3, 8.6 [2.2;21.6]	12, 30.8 [17.9;46.4]

Table 4. *Eimeria* species dominating in Estonian sheep flocks on islands Vormsi, Hiiumaa, and Saaremaa sampled in 2011 and 2012. OPG = oocysts per gram faeces. NA = No data available. CI = confidence interval.

Eimeria-positive flocks	Frequency n=87	OPG n=87	Range n=87
	n, % [95% CI]	Mean [95% CI]	Min Max
E. pallida	4, 6 [1.5;10.7]	2239 [-182;4659]	192 3861
E. parva	9, 10.4 [5.2;18.1]	1815 [-669;4299]	213 10060
E. marsica	0, 0.0 [0.0;3.4]	0 [0;3]	0 0
E. ovinoidalis	56, 64.4 [53.9;73.9]	991 [657;1324]	45 6107
E. weybridgensis	0, 0.0 [0.0;3.4]	0 [0;3]	0 0
E. crandallis	0, 0.0 [0.0; 3.4]	0 [0;3]	0 0
E. faurei	3, 3.5 [0.9; 9.1]	617 [-299;1532]	284 1013
E. granulosa	6, 6.9 [2.8; 13.8]	481 [81;882]	49 1119
E. bakuensis	8, 9.2 [4.4; 16.7]	1841 [-1114;4796]	94 9044
E. intricata	0, 0.0 [0.0; 3.4]	0 [0;3]	0 0
E. ahsata	1, 1.2% [0.1; 5.5]	94 NA	94 94

Table 5. Questionnaire on sheep keeping.

The variables and categories	Number of farms	Frequency (%)
Farm size: small farm	16	35.6
medium farm	17	37.8
large farm	12	26.7
Farm type: organic farm	27	60
conventional farm	18	40
Keeping: inside during winter	32	71.1
outdoors continuously	13	28.9
Lambing: inside during winter	32	71.1
outdoors	13	28.9
Size of pen per sheep: under $1m^2$	2	6.2
$1–1.5m^2$	19	59.8
over $1.5m^2$	11	34.4
Stable cleaning: frequently	5	11.6
infrequently	33	76.7
not used	3	7.0
Sheep per ha of pasture: under 2	4	8.9
2–3	5	11.1
over 3	36	80.0
Grazing type: permanent pasture	3	6.7
partly permanent pasture	11	24.4
rough grazing	31	68.9
Watering: tap water	11	24.4
natural water bodies	6	13.3
both available	28	62.2
Number of lambs per ewe: under 1.3	11	24.4
1.3–1.5	21	46.7
over 1.5	13	28.9

Table 6. Questionnaire on sheep health.

The variables and categories	Number of farms	Frequency (%)
Lamb mortality: under 6%	17	37.8
6–14%	11	24.4
over 14%	17	37.8
Ewe mortality: under 5%	36	80.0
5–10%	9	20.0
over 10%	0	0.0
Causes of mortality: determined partially	20	50
unknown	20	50
Clinical signs: mainly diarrhoea	36	80
other	3	6.7
none noticed	6	13.3
Prophylactic quarantine: yes	5	11.1
no	40	88.9
Anthelmintic treatment: regular	27	60.0
random (partial)	3	6.7
not performed	15	33.3
Protozoan parasite control: regular	0	0.0
if needed	2	4.4
not performed	43	95.6
Ectoparasite control: regular	0	0.0
if needed	24	53.3
not performed	21	46.7
Parasitological surveys: carried out (partly)	14	31.1
not performed	31	68.9
Importance of sheep parasites: important	34	75.6
of little importance	11	24.4
Knowledge of parasites: seminars mainly	26	57.8
books and internet mainly	10	22.2
other farmers mainly	9	20.0

DISCUSSION

The study set to investigate the parasitological situation in sheep flocks located on the largest Estonian islands: Saaremaa, Hiiumaa, and Vormsi. The samples investigated have to be considered flock means of the parasitic status as the faeces were randomly collected from unknown animals and unknown ages. Infection intensities of some individual animals are thus likely to be higher than represented here as animals that were not shedding parasite eggs will have diluted samples with high OPG's and EPG's. As a consequence, some flocks are likely to be classified as false negatives for some parasites, and the true prevalences are likely higher than presented. This kept in mind, it is clear that evidence proved the presence of many parasites in the sheep at levels that may indicate possible health problems and losses to the farmers. *Eimeria*, *Strongylida, Strongyloides, Giardia* and *Cryptosporidium* appeared to be the dominant parasites in the investigated sheep. *Dicrocoelium* spp. was only observed in flocks from Saaremaa, but it is possible the low number of eggs normally observed by flotation can have been missed in the pooled flock samples from the other investigated islands. Sedimentation techniques would have to be used for adequately estimated the presence of trematodes in the sheep flocks. *Trichuris* spp. seemed to be present, mainly on the island Vormsi, but the evidence did not indicate shedding of eggs in large numbers.

Infection intensities

The average flock EPG's of nematodes not only confirmed the presence but also provided evidence of the general infection intensities. Based on guidelines for sheep by Hansen and Perry (1994) quantitative measurements of mixed nematode infections in young animals can be classified as: 50–800 EPG (light), 801–1200 EPG (moderate), and >1200 EPG (heavy). The handbook highlights the importance of taking into account differences in pathogenicity of the nematodes in different regions of the world when applying these guidelines. Information on the pathogenicity of nematodes relevant to sheep in Estonia such as *Haemonchus, Ostertagia, Trichostrongylus, Nematodirus* a.o., is currently poorly known. In Fig. 1 we demonstrated that most flocks had a light infection intensity of *Strongylida* but with variations that spanned into medium and high infection intensities. These numbers that are a flock averages are likely to contain some individuals shedding eggs at levels that indicate a severe infection, depending on the species of the parasite, season, and age of the animal. As for *Strongyloides* species, the infection intensities were all in the light category. Generally, *Strongyloides* in sheep (exl. 2–6 weeks old lambs) are not considered pathogenic in this region (Atle Domke, personal communication). It thus seems these parasites represent a smaller problem to the farmers, though a few farms indicated large variations in EPG's (Fig. 1C).

Moniezia eggs were generally not shed in large amounts and eggs above a hundred EPG's seemed to be limited to six flocks. Despite a sample prevalence of 22.8% the parasite appeared in different flocks (Fig. 1D) during the two samplings of the experiment. This is suggesting reservoirs of the parasite (infected soil mites) are present on most farms and may develop into health problems if favourable conditions are present for the parasite and the infection goes unnoticed.

Large variation was observed in OPG's of *Eimeria* in flocks (Fig. 1A). Most flocks had either low or medium levels as mean infection intensities. Only one flock consistently had a high excretion of oocysts by the sheep. A few flocks indicated a considerable variation which may be driven by the importance of season, presence of young animals, and management changes. *Cryptosporidium* oocysts were very common in flocks, but rarely suggesting more than a low infection intensity. It is the first time the presence of *Giardia* is described in Estonian sheep and the results indicate *Giardia* is one of the most common parasitic infections. *Eimeria*, *Cryptosporidium*, and *Giardia*, are all important pathogens of young animals and were observed in >60% of the samples. The three different protozoans share the most common clinical sign in young animals: diarrhoea, but the subclinical infections are more common and costly to the production (Fitzgerald, 1980; Foreyt, 1990). *Cryptosporidium* and *Giardia* are zoonotic pathogens but there is evidence that they may not be an important reservoir for human infections (Ryan et al., 2005), and if so *Crypt-*

osporidium may be the more important of the two (Robertson, 2009; Robertson et al., 2010). To confirm this for Estonia subgenotyping of strains are needed. *Cryptosporidium* and *Giardia* are often considered together as they share some transmission routes, particularly in water, but depend on the terrain, use of land, chemical elements, and environmental factors (Duris et al., 2013). The decline of *Giardia* while more flocks had *Cryptosporidium* oocysts in the studied period may be attributed to different transmission routes in sheep flocks. Such factors need identification through carefully planned epidemiological studies. Such studies should take into account that these specific parasites represent underdiagnosed zoonoses, and Estonia has been reporting one of the highest rates of giardiosis per capita in Europe (ECDC, 2011; Estonian Health Board, 2013).

Annual and demographic differences

No apparent difference was noted between flocks, years, islands, and EPG's when it comes to the most common nematode groups, *Strongylida* and *Strongyloides*. Protozoan cysts and oocysts varied in their presence to a larger extent. The variation in the flock can be considered as a change of the general parasitic status inside the flock between the two sampling times. Variation in Fig. 1 can thus be used to show where there may be a more stable situation (low variation) or a situation where individual animals or the flock shed more parasites in their faeces (large variation). Large variation in the number of *Eimeria* oocysts in faeces was observed between flocks (Fig. 1A) indicating large differences in potential problems. *Eimeria* OPG values decreased from 2011 to 2012. Such variations inside a flock may be attributed to annual differences in the climate, such as variations in the weather or management practices. The levels of *Moniezia* spp. eggs decreased from 2011 to 2012, possibly attributed to annual changes in presence of the secondary hosts, orbatid mites, in the pastures (Sinitsin, 1931). However, there is not a direct correlation between the presence of *Moniezia* eggs in faeces and infection intensities (Skirnisson, 2011). In addition, *Moniezia* appears to be a local flock problem, mainly on Vormsi (Table 1), rather than a general one (Fig. 1D).

Differences between islands were observed (data not shown) for

Cryptosporidium spp., *Moniezia* spp. and *Trichuris* spp. but had to be disregarded due to seasonal interference in the sample strategy. In follow up studies samplings would need to be during the same period of time to ensure comparison.

***Eimeria* species**

Eleven species of *Eimeria* were identified. Though the highly pathogenic species, *E. ovinoidalis,* was clearly dominating in the majority of the samples, its mean OPG was not the highest. The highest mean OPG's were dominated by *E. parva*, *E. pallida* and *E. bakuensis* that dominated 4.6%, 10.4%, and 9.2% of the investigated flock samples respectively. *Eimeria pallida* and *E. bakuensis,* that are considered lesser pathogenic species, may play a role in animals shedding high levels of oocysts in some Estonian sheep flocks. Other species that have been described to cause clinical symptoms, including *E. crandallis,* were present in the samples but did not dominate in any flocks. This indicated that this species do not yet appear to have the conditions needed to be a cause of high OPG's and possibly eimeriosis in sheep flocks on Estonian islands. From these observations it appears *E. ovinoidalis* is the predominant *Eimeria* infection in the flocks.

Official reports from the Estonian Veterinary and Food Laboratory between 2000–2010 show that a mean of 30 (median: 29, range 0–91) faecal samples are submitted for parasitological investigations there yearly. This almost negligible number of investigations can be interpreted as a low interest in evidence based parasite control. However, it is important to empathize that diagnostic services available to veterinarians who do wish to submit samples have to be up to date to provide sufficient basis for treatment. The veterinarians must have species specific information and precise egg or oocysts counts from the diagnostic analysis to be able to practice evidence based medicine. In the absence of such services, anti-parasitic treatments may either not happen at all, or be non-evidence based. In the latter, the blind or misunderstood practices of medication may develop more permanent problems such as resistance to parasitic drugs as seen in several countries (Domke et al., 2011; Saddiqi et al., 2012).

The questionnaire

The predominant grazing type used was rough grazing of sheep. Only about quarter of farms used permanent pastures with rough grazing. Sheep in all ages (incl. lambs) were pastured together. It is accepted that separately keeping of young stock from adults reduces the risk of transmission of parasites *via* pasture to lambs. Youngstock is more susceptible to infection and may fall ill clinically. The number of sheep per ha of pasture was a little over three in most farms, what is considered to be a good density of sheep flock. But in some individual farms the density was too high (up to 18 sheep per ha). Water only from natural water bodies was available in about 13% of flocks, but in most farms in addition to that tap water was accessible for sheep. Size of pen for sheep was almost normal (1–1.5 m^2) in most farms, with range from 0.5 to 7.0. Stable cleaning as one of the prophylactic measures against parasite infection was performed once per year (without disinfection) in most farms.

Fecundity of ewes was estimated as normal-good (1.3–1.5 and over 1.5 lambs per ewe) in three-quarters of farms, whereas other farms had fertility problems. The numbers of lambs per ewe ranged from 0.6 to 2.0.

One of the main indicators of the health status of sheep is the mortality, especially lamb mortality. Since the lamb mortality rate up to 10% could be acceptable in flocks, many flocks had serious problems with this (range from 0 to 75%). Nevertheless the main reason of such high mortality was not the poor health status of lambs, but wild carnivores (wolves, lynxes, foxes) and eagles. Other causes of sheep mortality were determined partially or staid unknown in half of cases. These included stillbirths, monsters, parturition lesions, uterine prolapse, flatulence a.o. In these years (2011–2012) sheep mortality was not registered in 5 farms (11.1%). From clinical signs mainly diarrhoea, in few cases fatigue, hair loss and decrease in weight gain were noticed by farmers. The frequent reason of diarrhoea seemed to be consumption of fresh grass at turnout in spring as well as intensive infection with gastrointestinal parasites. Prophylactic quarantine for introduced sheep as one of the measures against parasite distribution was used very rarely and partially (only about in 11% of farms). In these farms the introduced sheep were kept in isolation up to one week without thorough parasitological investigation and treatment.

Although anthelmintic treatment is not the only measure, it remains an important tool for parasite control (Cabaret et al., 2009). In our study anthelmintic treatment was the main measure for parasite control in sheep farms and was regularly (1–2 times per year) carried out in 60% of farms. The drugs were no used in third of farms. During two years of study the percentage of farms without anthelmintic treatment increased (from 11.1% in 2011 to 33.3% in 2012). Since the number of organic farms did not change, probably the main reason of this was our study, during what the farmers have been informed on parasitological situation in the farms. Prior to the study knowledge on internal parasites on a farm was practically missing.

If treatment was attempted, it was generally on flocklevel. Only some farmers used anthelmintic drugs on group of sheep (lambs only). Protozoan parasite control was practically missing in all farms. On the basis of our study results the control of coccidians in sheep flocks is of great importance. Ectoparasite control was carried out in about half of farms, if sheep keds and sucking lice were observed.

Three-quarters of farmers answered that parasites are the important factors influencing sheep health, the others believed that the parasite problem is of little importance. Probably the farmers' standpoint depends on their own experience and knowledge. Farmers' knowledge on sheep parasites was obtained mostly on training courses of sheep breeders, secondly from books, internet and other farmers.

Sheep parasites and their control measures are dealt thoroughly in the article written by Toivo Järvis in the same research book.

CONCLUSIONS

Faecal samples from Estonian sheep flocks on Saaremaa, Hiiumaa, and Vormsi contained *Eimeria*, *Cryptosporidium*, *Giardia*, *Strongylida, Strongyloides, Moniezia*, and to a lesser extent *Trichuris* and *Dicrocoelium*. *Eimeria* and *Strongylida* were widespread, whereas *Moniezia* may present local flock problems.

Cryptosporidium was commonly found in the sheep, but in low numbers. We present the first evidence of *Giardia* being a common parasitic infection in Estonian flocks. *Eimeria ovinoidalis* was the most common and pathogenic species found dominating samples, in the contrast to *E. crandallis*, which did not dominate any samples. Besides of antiparasitic treatment the farmers should introduce also other (prophylactic) measures for effective parasite control in the sheep flocks. Attention should be paid to the control of coccidians.

ACKNOWLEDGEMENTS: We would like to thank Central Baltic INTERREG IV A Programme 2007–2013, project AI 13 (Knowsheep) for funding the study, Ivi Novak for practical assistance, Peep Piirsalu for advices on questionnaire part, Brian Lassen for language editing parts the manuscript and the farmers for participation.

REFERENCES

Berriatua, E., Green, L. E., & Morgan, K. L. 1994. A descriptive epidemiological study of coccidiosis in early lambing housed flocks. *Vet. Parasitol.* **54** (4), 337–351.

Cabaret, J., Benoit, M., Laignel, G. & Nicourt. C. 2009. Current management of farms and internal parasites by conventional and organic meat sheep French farmers and acceptance of targeted selective treatments. *Vet. Parasitol.* **164**, 21– 29.

Catchpole, J. & Gregory, M. W. 1985. Pathogenicity of the coccidium *Eimeria crandallis* in laboratory lambs. *Parasitol.* **9** (1), 45–52.

Catchpole, J., Norton, C. C. & Joyner, L. P. 1976. Experiments with defined multispecific coccidial infections in lambs. *Parasitol.* **72** (2), 137–147.

Chartier, C. & Paraud, C. 2012. Coccidiosis due to *Eimeria* in sheep and goats, a review. *Small Ruminant Res.* **103** (1), 84–92.

Dittmar, K., Mundt, H. C., Grzonka, E., Daugschies, A. & Bangoura, B. 2010. Ovine coccidiosis in housed lambs in Saxony-Anhalt (central Germany). *Berl. Munch. Tierarztl.* **123** (1–2), 49–57.

Domke, A. V., Chartier, C., Gjerde, B., Leine, N., Vatn, S., Osterås, O. & Stuen, S. 2011. Worm control practice against gastro-intestinal parasites in Norweigan sheep and goat flocks. *Acta Vet. Scand.* **53** (1), 29.

Domke, A. V., Chartier, C., Gjerde, B., Leine, N., Vatn, S. & Stuen, S. 2012. Prevalence of gastrointestinal helminths, lungworms and liver fluke in sheep and goats in Norway. *Vet. Parasitol.* (ahead of print)

Duris, J. W., Reif, A. G., Krouse, D. A. & Isaacs, N. M. 2013. Factors related to occurrence and distribution of selected bacterial and protozoan pathogens in Pennsylvania streams. *Water Res.* **47** (1), 300–314.

European Centre for Disease Prevention and Control (ECDC). 2011. *Annual Epidemiological Report 2011. Reporting on 2009 surveillance data and 2010 epidemic intelligence data.* Stockholm, 87–89.

Estonian Health Board. Nakkushaigused Eestis. 2013. http://www.terviseamet.ee/nakkushaigused/nakkushaigustesse-haigestumine.html.

Fitzgerald, P. R. 1980. The economic impact of coccidiosis in domestic animals. *Adv. Vet. Sci. Comp. Med.* **24**, 121–143.

Foreyt, W. J. 1990. Coccidiosis and cryptosporidiosis in sheep and goats. *Vet. Clin. N. Am. – Food A.* **6** (3), 655–670.

Gregory, M. W. & Catchpole, J. 1987. Output of coccidial oocysts (particularly Eimeria crandallis) by naturally-infected lambs: daily and hourly patterns and clinical significance. *Deut. Med. Wochenschr.* **94**, 521–525.

Hansen, J. & Perry, B. D. 1994. *The epidemiology, diagnosis and control of helminth parasites of ruminants.* International Laboratory for Research on Animal Diseases, Nairobi, Kenya, 171 pp.

Henriksen, S. A. & Pohlenz, J. F. L. 1981. Staining of cryptosporidia by a modified Ziehl–Neelsen. *Acta Vet. Scand.* **22**, 594–596.

Henriksen, S. & Korsholm, H. 1984. Parasitologisk undersøgelse af fæcesprøver. Konstruktion og anvendelse af et enkelt opbygget tællekammer. *Dan. Vet. Tidskr.* **67**, 1193–1196.

Kaarma, A. & Mägi, E. 2000. *Moniezia spp*. population dynamics in lambs and its dependance on grazing conditions. *Veterinaarmeditsiin,* Tartu, 52–57 (in Estonian).

Lassen, B., Viltrop, A., Raaperi, K. & Järvis, T. 2009a. *Eimeria* and *Cryptosporidium* in Estonian dairy farms in regard to age, species, and diarrhoea. *Vet. Parasitol.* **166** (3–4), 212–219.

Lassen, B., Viltrop, A. & Järvis, T. 2009b. Flock factors influencing oocyst production of *Eimeria* and *Cryptosporidium* in Estonian dairy cattle. *Parasitol. Res.* **105** (5), 1211–1222.

Lassen, B. & Østergaard, S. 2012. Estimation of the economical effects of *Eimeria* infections in Estonian dairy flocks using a stochastic model. *Prev. Vet. Med.* **106** (3–4), 258–265.

Levine, N. 1985. *Veterinary Protozoology.* The Iowa University State Press, Iowa, 130–232.

Mahrt, J. L. & Sherrick, C. W. 1965. Coccidiosis due to *Eimeria ahsata* in feed lot lambs in Illinois. *J. Am. Vet. Med. Assoc.* **146**, 1415–1416.

Mägi, E. & Kaarma, A. 2002. Population dynamics of sheep digestive tract strongylatoses in Estonian climate conditions. *Nematology*, **4**: *Programme and abstracts of the IVth International Congress of Nematology 8–13 June 2002. Tenbel, Spain*, 313.

Mägi, E. & Sahk, M. 2004. Studies on sheep digestive tract parasites in Estonia. *Ani-*

mals. Health. Food Quality: *Proceedings of the International Scientific Conference 15 October 2004. Jelgava*, 187–191.

Pfister, K. & Flury, B. 1985. Kokzidiose beim Schaf. *Schweiz. Arch. Tierh.* **127**, 433–441.

Quilez, J., Sanchez-Acedo, C., Clavel, A., del Cacho, E. & Lopez-Bernad, F. 1996. Comparison of an acid-fast stain and a monoclonal antibody-based immunofluorescence reagent for the detection of *Cryptosporidium* oocysts in faecal specimens from cattle and pigs. *Vet. Parasitol.* **67** (1–2), 75–81.

Reeg, K. J., Gauly, M., Bauer, C., Mertens, C., Erhardt, G. & Zahner, H. 2005. Coccidial infections in housed lambs: oocyst excretion, antibody levels and genetic influences on the infection. *Vet. Parasitol.* **127** (3–4), 209–219.

Robertson, L. J., Gjerde, B. K. & Furuseth Hansen, E. 2010. The zoonotic potential of *Giardia* and *Cryptosporidium* in Norwegian sheep: a longitudinal investigation of 6 flocks of lambs. *Vet. Parasitol.* **171** (1–2), 140–145.

Robertson, L. J. 2009. *Giardia* and *Cryptosporidium* infections in sheep and goats: a review of the potential for transmission to humans via environmental contamination. *Epidemiol. Infect.* **137** (7), 913–921.

Roepstorff, A. & Nansen, P. 1998. *Epidemiology, diagnosis and control of helminth parasites of swine. FAO Animal Health Manual.* FAO, Rome, Italy, 51–56.

Ryan, U. M., Bath, C., Robertson, I., Read, C., Elliot, A., McInnes, L., Traub, R. & Besier, B. 2005. Sheep may not be an important zoonotic reservoir for *Cryptosporidium* and *Giardia* parasites. *Appl. Environ. Microb.* **71** (9), 4992–4997. Saddiqi, H. A., Jabbar, A., Babar, W., Sarwar, M., Iqbal, Z. & Cabaret, J. 2012. Contrasting views of animal healthcare providers on worm control practices for sheep and goats in an arid environment. *Parasite*, **19** (1), 53–61.

Saratsis, A., Joachim, A., Alexandros, S. & Sotiraki, S. 2011. Lamb coccidiosis dynamics in different dairy production systems. *Vet. Parasitol.* **181** (2–4), 131–138.

Sargison, N. D. 2011. Pharmaceutical control of endoparasitic helminth infections in sheep. *Vet. Clin. N. Am. – Food A.* **27** (1), 139–156.

Sinitsin, D. F. 1931. A Glimpse into the life history of the tapeworm of sheep, *Moniezia expansa*. *J. Parasitol.* **17** (4), 223–227.

Skirnisson, K. 2007. *Eimeria* spp (Coccidia, Protozoa) infections in a flock of sheep in Iceland: Species composition and seasonal abundance. *Icelandic Agr. Sci.* **20**, 73–80.

Skirnisson, K. 2011. Association of farming practice and the seasonal occurrence of gastrointestinal helminths in a flock of sheep in Iceland. *Icelandic Agr. Sci.* **24**, 43–45

Sweeny, J. P., Ryan, U. M., Robertson, I. D. & Jacobson, C. 2011. *Cryptosporidium* and *Giardia* associated with reduced lamb carcase productivity. *Vet. Parasitol.* **182** (2–4), 127–139.

Taylor, M. 2009. Changing patterns of parasitism in sheep. *In Practice*, **31**, 474–483.

WOOL: STRUCTURE AND PROPERTIES

K. Kabun

Estonian Crop Research Institute, J. Aamisepa 1, 48309 Jõgeva, Estonia
e-mail: katrinkabun@gmail.com

WOOL FIBRE STRUCTURE

By definition, wool is the hairs obtained from sheep, goats, camels, llamas, rabbits or other animals by shearing or combing that are suitable for spinning or felting. However, first and foremost, wool is associated with sheep. One can use such phrases as 'camel wool' and 'goat wool', but in this case it is important to specify which animal the wool comes from.

Chemically, wool is a protein fibre and consists mainly of elements such as carbon, oxygen, nitrogen and sulphur. Figure 1 depicts the sophisticated cell structure and hierarchy of elements in wool fibre.

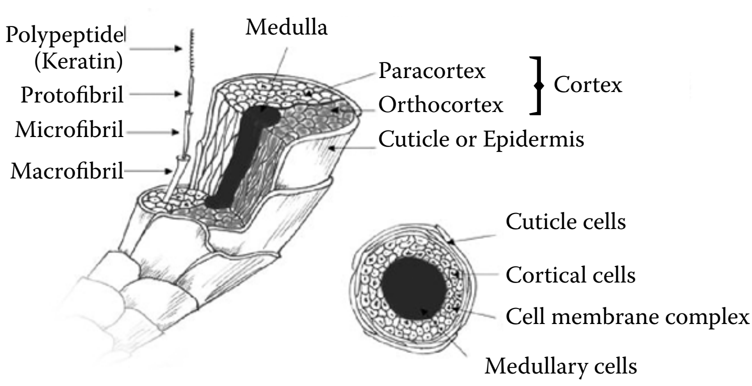


Figure 1. Cross section of wool fibre. Illustrations: Katrin Kabun

The cuticle is the outermost layer of a wool hair. It consists of at least four layers: the epicuticle, two layers of the exocuticle and the endocuticle. Cuticle cells constitute thin, flattened scale cells with serrated edges. The cuticle cells of fine undercoat wool hair are circular, but those of other hairs overlap in a manner comparable to that of roof shingles or fish scales. The cuticle layer protects the wool fibre and determines its lustre and felting properties.

The cortical layer or cortex is located under the cuticle layer. Cortical cells are narrow spindle-shaped fibre cells, which make up the bulk of the fibre volume (90% in undercoat wool hair, 60-70% in overcoat hair and 5–6% in dead wool hair). The cortex is composed of paracortex (40–10%) and otrhocortex cells (60–90%). Their position in relation to each other, helically arranged along the length of the fibre, is what gives the fibre its crimp. Cortical cells, in turn, are made up of even smaller elements – from macro-, micro- and protofibrils up to alpha-keratin molecules (alpha-helix). The cortex layer determines the elasticity, strength and thickness of a wool hair. The colour pigment is also located in the cortex layer. Fine wool hairs mostly consist of the cuticle and cortex layers.

The medulla consists of loosely bound medullary cells, which are partly air-filled polygon-shaped corneous cells. Under a microscope the medulla layer appears as an intermittent or continuous dark band. Not all wool hairs have a medulla layer, which normally occurs in overcoat hairs that have a larger diameter and are less curly, as well as in transitional and dead wool hairs. Due to the presence of air in medullary cells, the medulla reduces the thermal conductivity of wool hairs and increases their hygroscopicity, but also makes them more brittle.

FLEECE, STAPLE AND WOOL TYPES

Fleece is the wool shorn from a sheep in a single entire layer (i.e. not yet separated). Fleece consists of staples or locks of wool that are held close to one another by connecting wool hairs (in homogeneous, strongly interconnected wool) or tufts (in heterogeneous wool where the connection between wool hairs is weaker). The structure and shape of staples (tufts) enables the fleece to be evaluated – including the type and quality of wool (length, density, crimp and lanolin level) and the conditions in which the animal has been kept. A staple, in turn, is formed of individual wool hairs, the bulk of which is made up of undercoat or true wool hairs, transitional wool hairs and overcoat wool hairs.

Undercoat or true wool hairs (Figure 2, 1) are relatively short (up to 12 cm in length), fine (15–25 μm) and curly, located under the overcoat wool and consisting of only the cuticle and cortical layers (no medulla). In fine wool sheep (e.g. Merino), the fleece is formed solely of undercoat wool hairs.

Transitional wool hairs (Figure 2, 2) are coarser (26–65 μm) and longer than undercoat wool hairs, consisting primarily of the cuticle and cortical layers, but also sometimes having an intermittent medulla layer. Such hairs occur mainly in semi-fine and coarse wool sheep fleeces, as well as in the fleeces of aboriginal breeds.

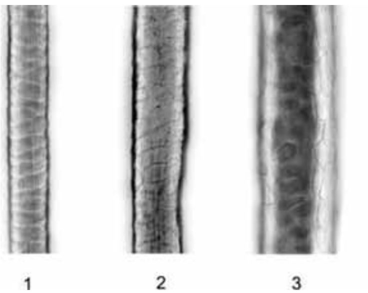


Figure 2. Main wool hair types in fleeces (400-fold magnification).

Overcoat wool hairs (Figure 2, 3) are coarser (35–200 μm), longer (10–35 cm), stronger and straighter (wavy), and consist of the cuticle, cortical and medulla layers. In cultivated breeds these wool hairs are generally finer than and not as varied as transitional wool hairs; in aboriginal native breeds these hairs are coarser. Overcoat hairs are further divided into normal, dry and dead hairs.

Fleeces can also contain awn hairs (short, straight, strong hairs with a medulla that grow on the head, ears and legs; more rarely also in the fleece), kemp hairs (similar to awn hairs, but white and brittle) and dead hairs (coarse, lacklustre, colourless hair with a strong medulla layer).

Figure 3 presents a comparison of wool hair types (with their diameters) as distinguished in six fleeces. 1 & 2 – overcoat hair (52 μm) and undercoat hair (26 μm) in a two-layer fleece; 3 & 4 – overcoat hair

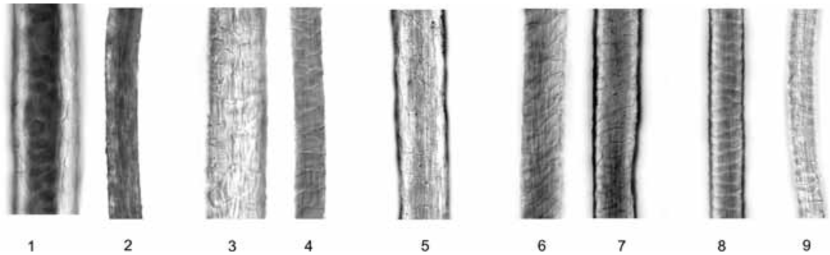


Figure 3. 400-fold magnification of wool hairs in different types of fleeces.

(40 μm) and undercoat hair (23 μm) in a two-layer fleece; 5 – lustrous transitional hair (39 μm); 6 & 7 – undercoat hair (34 μm) and overcoat hair (34 μm) in a transitional hair-type fleece; 8 – lustrous undercoat hair (26 μm) in a fine wool fleece; and 9 – lacklustre undercoat hair (20 μm) in a fine wool fleece.

Depending on the composition of a staple and the dominant wool hair types in it, three main types of fleeces can be distinguished, as set out below.

Archaic type with strong overcoat hairs (Figure 4). This fleece is the closest to the wool of the ancestors of today's sheep. The fleece

Figure 4. Tufts containing overcoat wool hairs on the left; a tuft containing overcoat wool, and separated layers on the right.

consists of two distinct layers. The top layer is made up of strong and coarse hairs that protect the animals from climatic and other physical influences and give the yarn its strength. The lower layer is formed of fine wool hairs, which make the yarn soft and warm.

Strong overcoat wool is suitable for products that need to be hard-

Figure 5. Sheepskin with curly and glossy overcoat wool.

wearing, such as loom-woven coverlets, rya rugs and other textiles, durable knitted socks and needle-netted work gloves. If the overcoat is glossy and curly, it is perfect for a long-lasting fur (see Figure 5), because the wool fibres will preserve their form and will not mat.

Wool with a smooth transition between undercoat and overcoat hairs (Figure 6) is a two-layer wool in which the layers are relatively difficult to distinguish because the coarseness of the overcoat hairs resembles that of the undercoat hairs due to the selections that have been made for hundreds of centuries. Nevertheless, overcoat hairs have retained their characteristic length, they are slightly wavy

Figure 6. Staples of wool with a smooth transition between undercoat and overcoat hairs, and separated undercoat and overcoat hairs.

or curly, and often beautifully shiny. Wool with a smooth transition between undercoat and overcoat hairs makes an ideal handicraft yarn – both woollen yarn and high-quality worsted yarn.

The wool of fine wool sheep is single-layered and consists primarily of uniform fine wool hairs (Fig. 7). Hairs in the fleece can be tightly curled or moderately wavy, and are relatively short in length. Shorter fibres can be used as carded wool, while longer fibres are also suitable for high-quality worsted wool. Fine-wool yarn is soft and therefore suitable for products which come into contact with the skin, but which do not have to be particularly durable, such as scarves, hats and sweaters. Very high-quality fabrics can be produced from fine wool industrially.

Figure 7. Fine wool staples of varying crimp.

The quality of wool is not consistent in a fleece. The best wool (smoother and longer fibres) comes from the shoulder and side areas of a sheep; the worst wool (uneven and shorter fibres) is that shorn from the lower parts of the legs, tail and underbelly. While one of the objectives of wool sheep breeding is to achieve fleeces of consistent quality, native breeds have preserved their intra-breed diversity, and in addition to different colours their fleeces also contain different types of wool. Figure 8 shows the wool types in the fleece of a native sheep: overcoat, transitional and fine wool hairs are all represented.

Figure 8. Different types of wool in the fleece of a sheep.

QUALITY AND PROPERTIES OF WOOL

The quality of wool is evaluated on the basis of the physical (technological) characteristics of the wool hairs. The most important of these are fineness, length, uniformity, strength, crimp, tenacity, resilience, formability, lustre, colour, moisture and hygroscopicity. Other important characteristics include the percent of wool hairs with a medulla, the amount of plant residues in the fleece, the volume of wool (cm^3/g) and the share of soiling in relation to the total length of the staple. These characteristics determine the usability and the suitable processing method of the wool.

Based on the structure, chemical composition and physical characteristics of wool fibres, the properties of wool as a material can be determined.

Wool is a good thermal insulator. The best thermal insulator is air. Wool and woollen fabric contain air at several levels: both in and (due to the natural crimp) between the wool fibres, which makes the garment airier and contributes to thermal insulation.

Wool is also a very good sound dampener. Noise in the air is reduced through the absorption of sound energy. Hard surfaces reflect sound, but wool absorbs sound energy and converts it into another type of energy – usually thermal energy.

Wool is fire-resistant. Wool contains large amounts of nitrogen and sulphur, which are natural fire retardants. As the relative quantity of oxygen is higher in wool fibres than in the surrounding air, the oxygen concentration in the air would have to be increased for wool to burn. The ignition temperature of wool is slightly below 600 °C.

Wool is characterised by high moisture absorption. It can absorb moisture from the environment to up to 35% of its weight, thus participating in the balancing of indoor air humidity. Moisture is transported into the internal structures of the wool fibres, which is why the wool does not feel wet when touched. It is also noteworthy that the absorption of moisture is accompanied by the generation of heat, and therefore moist wool does not even feel cold or wet in outdoor conditions. While absorbing moisture, wool fibres also repel liquids. This property is due to the scaly surface of the wool fibres, which are coated with a wax film. As such, rather than being absorbed into the fabric, liquid forms drops on the surface of the woollen material which are easily wiped off before a permanent stain forms.

Wool also affects indoor air quality, being able to absorb and bind the smells of chemicals, as well as nitrogen, carbon dioxide, sulphur dioxide, formaldehydes and other harmful contaminants that can occur indoors.

Wool is a fully biodegradable material. The few woollen textile remains found in the earth's crust were only preserved thanks to the metal salts in the metal ornaments attached to them.

In conclusion, wool is a unique textile material whose properties have not been fully emulated in spite of the rapid development of modern technology. Being completely biodegradable, wool definitely deserves greater attention and use.

REFERENCES

Nõmmera, E. & Jaama, K. 1943. *Lambavill: villa omadused, sordid ja –kaubandus.* Tallinn, 'Agronoom' cooperative publishing house.

Alexander, P. & Hudson, R. F. 1954. *Wool: its chemistry and physics***.** London, Chapman & Hall Ltd.

Jaama, K.1984 *Lambakasvatuse käsiraamat*. Tallinn, Valgus.

Piirsalu, P. & Zarnez, K. 1997. Vill Eesti lammaste villa peenusest ja teistest villa kvaliteedi näitajatest, *Lammas ja kits 6.*

Piirsalu, P. 1998. Vill ja selle kvaliteeti iseloomustavad omadused. *Lammas ja kits 7.*

Höcker, H. 2002. Fibre morphology: In: Simpson, W., S. & Crawshaw, G.,H. (Eds.) *Wool: Science and technology*. Cambridge: Woodhead Publishing Ltd. 60–79.

Pierlot, T. 2010. Presentation: *Wool's fashion secrets - the natural advantages*. [pdf document]. [5 January 2013].http://www.csiro.au/files/files/pvwn.pdf

Viikna, A. 2004. *Tekstiilikeemia I Ettevalmistusprotsessid*. Tallinn, TUT Press House.

Viikna, A. 2005. *Kiuteadus*. Tallinn, TUT Press House.

EXPERIENCES OF FREE-RANGING ESTONIAN NATIVE SHEEP. CASE: KILTSI MEADOW

A. Michelson

HAMK Biotalous (HAMK University of Applied Sciences)
Mustialantie 105, 31310 Mustiala, Finland
annika.michelson@hamk.fi

Summary. Our traditional rural landscapes are formed by small and hardy native sheep in cooperation with human. Native sheep are well adapted to the harsh northern climate, flora and fauna. The slow growing Estonian native sheep is a good grazer on semi-natural pastures. It keeps the vegetation low, and thus providing a wide range of rare plants, birds and insects with suitable habitat. Estonian native sheep has preserved a tight flock structure and flocking response, which benefit them if they are attacked by predators. By keeping local native sheep you keep up both the animal genetic diversity as well as the local biodiversity in the landscape. The multi-purpose northern native sheep gives man a wide range of products such as wool, fur, meat, bones, horn and a traditional aesthetic and diverse landscape for recreation.

1. BACKGROUND

For centuries human has developed and changed the Nordic agricultural landscape together with native animals. We cultivate in a harsh climate close to the Arctic Circle and our semi-natural pastures and meadows represent a large range of different topography, soil types and management methods. Moreover the pastures are nearly always located in connection to forest. This results in a varied cultural landscape that has been managed in a traditional way for a long time. Plants growing on the semi-natural meadows are adapted to local specific conditions. They have developed unique, local characteristics and gene combinations. Natural genetic variation within one species is the basis for breeding of new plants and development of new species. This has been, and still is, important for development of agriculture with local adaption. Many of our semi-natural pastures have valuable local fodder plants such as herbs, grasses and clover. These plants are important as they cover large areas and have good fodder characteristics. Many of these plants have also an ability to expand if one open up new land for them. No modern seed mix nor any new species can compensate these plant communities when our semi-natural pastures and meadows once already are overgrown. (Svalheim et al., 2005, 3–4,7).

Semi-natural pastures in Estonia and Finland have traditionally been grazed by small hardy local native sheep. It used to be a multi-purpose animal giving meat, wool, skin, bones and horn for people. Native sheep grows slowly compared to modern meat breeds and it is well adapted to gain fodder at traditional semi-natural pastures (Michelson & Jäetma, 2013). There has been a large decrease in the amount of traditionally managed semi-natural pastures as it is economically hard to compete with fast growing meat breeds kept at cultivated pastures as well as with imported cheap wool from abroad.

Estonian native sheep was re-discovered and genetically studied as late as 2006 (Saarma, 2009; Ärmpalu-Idvand, 2009). Estonian native sheep belong, as all other native sheep in North Europe, to the North-European short-tailed sheep family and has not been recognized as a local native breed. Few studies have ever been made about them. The sheep was preserved in small herds in the private farming sector during Soviet Union time. The sheep was kept purely for self-subsidiary reasons, in order to get meat and multi-colored wool for own use. The sheep has been managed in a very traditional way. This sheep has never been bred by any breeding organization, but only undergone natural selection according to farmers subsidiary needs. It is small in size (adult 30–50 kg) and slow growing (1 year to receive slaughter weight). It is healthy and a good mother with high fertility. It has typically double coated wool with a wide range of colors, curl, luster and fineness. Traditionally sheep in North Europe was free-ranging.

2. METHOD

The research was done on one sheep flock in 2011–2013 at Kiltsi Meadow (8 ha size) in the time periods 14.5.2011–22.9.2011; 27.5.2012–16.8.2012 and 25.5.2013–18.7.2013. Kiltsi is located 130 km southeast of Tallinn in Väike-Maarja Municipal, 59°5'N and 26,°10'E. The meadow is located on the edge of Vao ancient valley and Vao stream, a part of Põltsamaa river, flows in the valley. The meadow has different biotopes, some areas are dry, others fresh and some moist as groundwater level rises at parts close to the stream in spring. Sheep has access to dry pine and spruce forest and a moist broadleaved forest. Most part of the meadow is covered with thin soil and all soil is rich in limestone. The prevailing grass at the meadow is *Briza media* with a large amount of orchids *Gymnadenia conopsea*. Other rare plants are *Listera Ovata, Botrychium lunaria* and *Gentiana cruciata* The meadow has been in extensive agricultural use for a long time. In 19th century it was Vao Manor horse pasture and horses were kept grazing at the meadow until 1970ies. An ancient stone construction, "Kiltsi stone boat", is located at the meadow, which indicate that the area has been in use for a long time.

Estonian native sheep were free-ranging on the meadow and they could daily choose where to go and what to graze, see photo 1. The sheep were daily shepherded. The sheep were kept inside night time due to the risk of predators. The sheep went out 7.30–8.30 a.m. and were put indoor for the night 20–22 p.m. Sheep has a grazing rhythm with bouts of grazing and resting. During the resting bouts other work could be carried out on the farm. Shepherding was done either at a distance or by walking together with the flock. Grazing and resting bouts were monitored 27 days during 2011–2013. Observations on plant and plant part preference were carried out on daily basis. 13 days (9 in 2011; 4 in 2012) were monitored with a Global Positioning System Ventus G730 datalogger. Ventus has an incorrect range of 2 meters in an open area. The datalogger was all days on the leader ewe of the flock.

Daily cleaning was done at the camping site and inside the shelter. The amount of droppings was measured in kg (2011, 2012) and estimated in liters (2013). The sheep had salt stone and water inside the animal shelter. There were 18 sheep summer 2011; only 6 in 2012 and 20 in 2013. The amount of sheep decreased during the summer in 2011 and 2013. The amount of adult ewes was 5 in 2011 and 2012, but 7 in 2013. Sheep of different age and sex were kept in the herd.

3. DAILY MAINTENANCE BEHAVIOUR

Sheep has a great plasticity and can adapt to many environments. In the North of Europe the native sheep can stand warm summers as well as very cold winters. The traditional sheep keeping practice in the old days in Finland and Estonia was free-ranging with close herding during the day and enclosure at night. Free-ranging is still carried out to a smaller extent with small herds in Estonia, but it is not anymore used in Finland. Only when sheep are kept on islands they can stay outside also at night (archipelago areas, lake areas of Finland). The enclosure at night was due to a large amount of mosquitos as well as predator risk at night.

Photo 1. Estonian native sheep with blooming *Primula veris* 15.5.2011.

Domestic sheep herds have to develop structures that are different from those of their wild ancestors as man keeps separate both ages and sexes of sheep. Social structures are also frequently changed as man brings in strangers and separate individuals that have close bonds. In free-ranging feeding behaviour and the way in which animals use the environment are given considerable attention. Each pattern of behaviour has a special adaptive function. In this study daily maintenance behaviour and social spacing at pastures are studied in more detail.

Daily maintenance behaviour is considered as basic activities necessary for the maintenance and survival of the sheep (Arnold & Dudzinski, 1978, x-xi). To the daily activities are grazing, browsing and / or feeding on supplements, drinking, walking, ruminating, resting, defaecating and urinating. These all are linked to a daily pattern of changing activities. Time used on grazing and rumination / resting was monitored at Kiltsi meadow. (Arnold & Dudzinski, 1978, xi). The daily activities are influenced by weather conditions and the need to minimize physiological stress due to heat or cold or by internal demands of the individual animal (Arnold & Dudzinski, 1978, 1). Beyond some limits the need to minimize physiological stress is greater than the nutritional needs and the sheep will reduce the time they spend on feeding. (Arnold & Dudzinski, 1978, x).

Sheep are predominantly "grazers" (Lynch et al., 1992), eating grass and other herbage. There are more than 126 plants growing at Kiltsi Meadow. Rutter (2002) writes that sheep do not relish eating leaves of trees or bushes, and will eat grass when given a choice. However, estonian native sheep enjoy eating leaves, photo 2 (Jaama, 1946, 26–27). Native sheep in North Europe has traditionally been kept free-ranging at forest pastures or pastures with access to forest. Winter time a large part of their fodder was traditionally dried leaves. (Wohlonen, 1927, 88–91).

Due to Arnold & Dudzinski (1978, 1) most studies show that major grazing periods begin around sunrise and another before sunset. In between these are the secondary grazing periods. Sheep avoid grazing at night, and this is believed to be an inner anti-predator response (Rutter, 2002, 147; Arnold & Dudzinski, 1978, 1). The timing of these secondary periods is influenced mainly by several climatic factors and by grazing pressure. (Arnold & Dudzinski, 1978, 1).

Photo 2. Estonian native sheep enjoys a lot different kinds of leaves, needles and bark. Photos and illustrations: Annika Michelson

The act of grazing involves the selection of herbage, its prehension, mastication and swallowing. The time spent grazing includes the time spent searching for food, i.e. walking. The animal varies the number of bites it takes and the size of these bites and both are influenced by the structure of the vegetation. Rate of eating will also be varied according to climatic conditions and the status of the animal. Animal age and health influences also on grazing. (Arnold & Dudzinski, 1978, 11–12).

Sheep stomach is divided into 4 separate compartments, the largest of which is called the rumen. This contains a variety of microorganisms that are capable of digesting cellulose. This means that sheep can eat and digest grass and other plant material, for example leaves, needles and bark from trees. Rumination is an important part of the digestive process of sheep. Rumination takes time. Partially digested material travel back from the rumen up to the mouth. Here the material is chewed again, typically for about 1 minute, before it is swallowed again. This additional chewing helps the microbial and protozoal breakdown of the plant cellulose. Sheep spend typically one-third of the day ruminating. (Rutter, 2002, 146). Estonian native sheep was using from 39% to 66 % ruminating and resting daily. More time was used ruminating in May and July than in September, Table 1.

Table 1. Estonian native sheep grazing versus rumination & resting time in percent, 2011–2013 (N25 days).

Month	Grazing	Ruminating & resting
May	41%	59%
June	35%	66%
July	42%	58%
August	49%	51%
September	62%	39%
Average	45,8%	54,6%

During a normal day at the pasture sheep have several bouts of grazing and ruminating. Arnold and Dudzinski (1978) have made some comparative studies concerning sheep grazing time on different sheep breeds. The results are as follows:

- Dorset Horn: 9.8 h
- Border Leicester x Merino: 9.5 h
- Merino: 9.5 h
- Corriedale: 9.1 h

In extreme climates native breeds may be better adapted physiologically. An example is that for sheep in Egypt which are grazed during the day only the local Ossimi sheep grazed in summer 4 hours whereas exotic breeds did so only for 2 hours because of heat stress. (Arnold & Dudzinski, 1978, 15).

The time spent on grazing at Kiltsi Meadow varied from 4,5 h to 6,1 h, see Figure 1. The time spent on ruminating / resting varied from 3,4 h to 8,4 h. The maximum time spent at grazing was 7,3 h in September and at the same day they spent the minimum time resting, only 2,5 h (7.9.2011). The maximum in resting per day was 9,8 h (14.6.2012, 31.7.2012), all very warm days.

Feeding bouts of sheep living in maritime climates (New Zealand, United Kingdom) with cool summers and having large quantities of highly digestible grass and clover, ate in feeding bouts which lasted

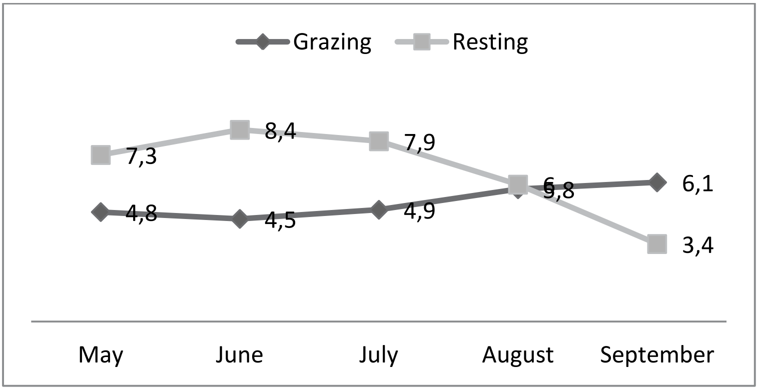


Figure 1. Average length of total time spent on grazing and resting per day in hours at Kiltsi Meadows 2011–2013 (N 27 days).

from 20 to 90 minutes. They had as many as 9 bouts over the 24-hour cycle. Each grazing bout was followed by a resting bout of 45 to 90 minutes when sheep lie down and ruminate or rest. Grazing is often concentrated around the first four hour after dawn and in the last four hours around sunset but can easily start before dawn and extend long into the dark. (Lynch et al., 1992, 12–13).

The amount of time spent on grazing and resting changed during the summer at Kiltsi Meadow. In the beginning of the summer there were shorter grazing bouts, but frequently kept, Figure 2–3. In May

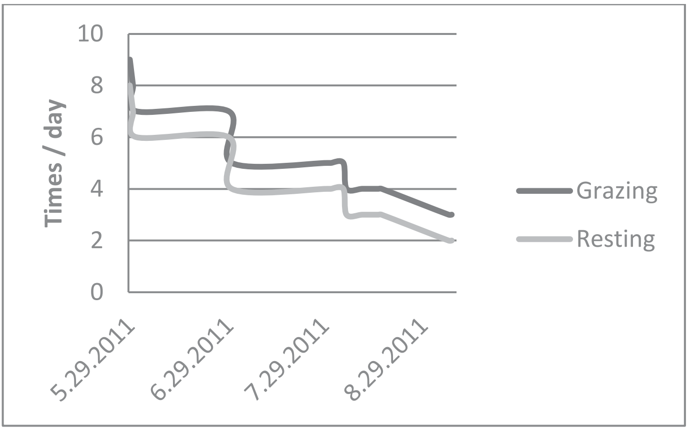


Figure 2. Amount of grazing and resting bouts per day 2011 (N14).

they grazed 9 times and rested 8 times, which is similar to the experience from New Zealand and United Kingdom (Lynch et al., 1992, 12–13). In June and July they kept 5 to 7 grazing bouts. In August the sheep grazed 5 times and rested 4 times and in September they grazed 3 times and rested 2 times (2011). In 2012 there was only one lamb and then the whole flock grazed and rested fewer times. In 2013 it was very warm and sheep grazed fewer times, this happened 31.5.2012, 1.7.2012, 30.7.2012 and 2.6.2013. Grazing routines were annually interrupted due to a lot of mosquitos, often at the beginning of the grazing season (May, June).

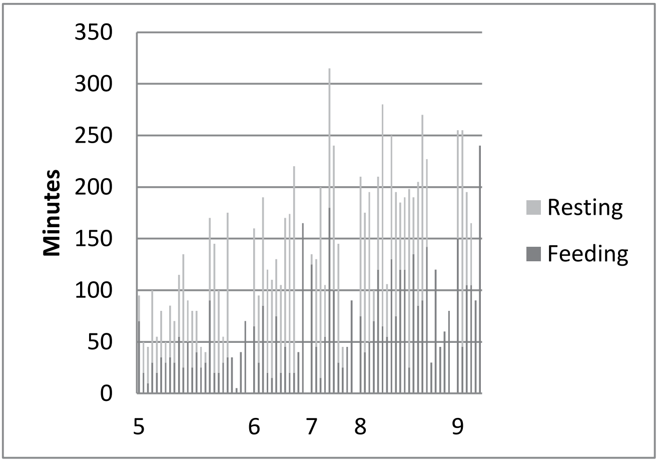


Figure 3. Length of feeding and resting bouts at Kiltsi Meadow 2011 (minutes / day / month).

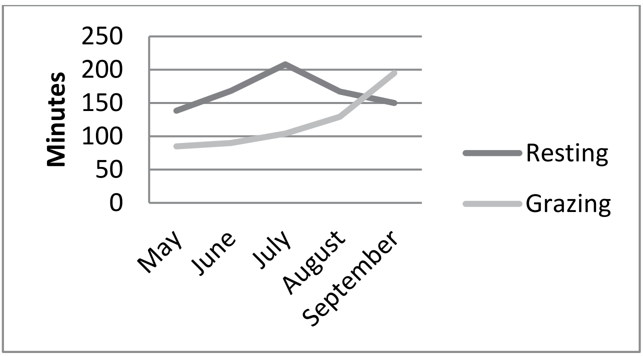


Figure 4. Longest grazing and resting bout in minutes (average N25) 2011–2013.

The grazing and resting bouts varied in time. At Figure 4 you see an average of the longest grazing and resting bouts 2011-2013. The longest time bout spent on grazing grows during the pasture season from 85 minutes in May to 195 minutes in September. This is much longer than experience on grazing bouts in New Zealand and United Kingdom, from 20 to 90 minutes (Lynch et al, 1992, 12–13). It may be that the shorter growing season with a lot of light makes animals more active in grazing. Consequently the resting bout length is decreasing during the season. The longest resting bout had a peak in the middle of the summer when the weather was warmest, Figure 4. At the end of the season there will be more grazing than resting. Estonian native sheep gets restless, walking and idling more during the last part of the grazing period, (before getting stalled in for the winter).

The longest resting peak was usually starting at noon. In average the longest resting peak was 169 minutes (N25). The longest resting was 475 minutes (31.7.2012). That day the sheep were inside resting for the whole day as it was very hot outside. Sheep can predict if it will be a hot day and start graze earlier. (Arnold & Dudzinski, 1978, 5). The shortest mid-day resting peak was 70 minutes (29.5.2011). The longest daily resting peak was usually spent between 12 and 17 p.m.

64 % of the longest daily grazing period took place in the evening or late afternoon (N25), another peak was in the morning. Figure 5 shows a day with the longest grazing peak in the afternoon and the second long-

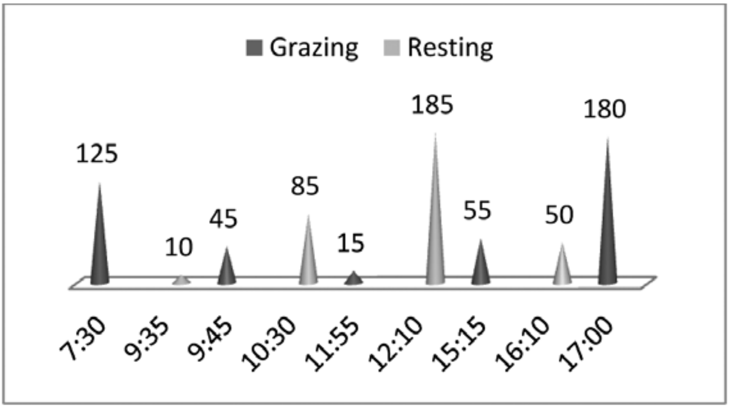


Figure 5. Grazing and resting bouts 31.7.2011 with the feeding peak late afternoon (minutes).

est in the morning. Sheep are sensitive to both temperature and humidity, though insulated by wool. Sheep are also sensitive to the day length as they relate the start of the afternoon grazing to the time of sunset. (Arnold & Dudzinski, 1978, 6). If sheep were let out later than usually in the morning, they grazed more intensively during the day, than if they were let out earlier. During warm days the sheep got leaves to eat inside the shelter and they were let staying out longer in the evening. Arnold & Dudzinski (1978,6) writes that cold conditions appear to have little effect on the diurnal pattern of grazing sheep, but field studies at Kiltsi Meadow show that sheep graze longer periods the colder the weather is.

In 2011 and 2013 the herd was approximately of the same size 18–20 sheep. In 2011 sheep grazed until September, but in 2013 only until middle of July. In both years there seem to be a change in how they use

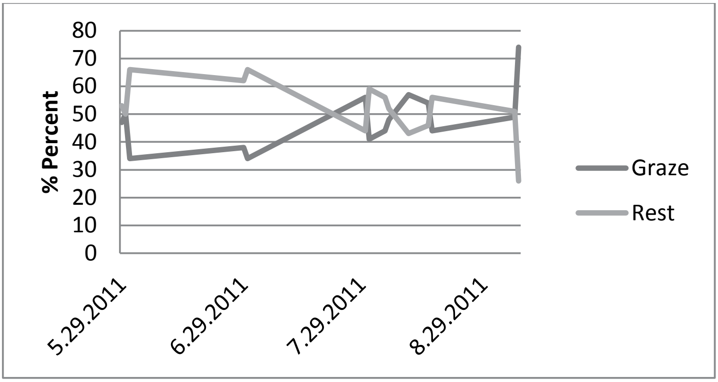


Figure 6. Grazing and resting in 2011, 18 sheep (%) (N14).

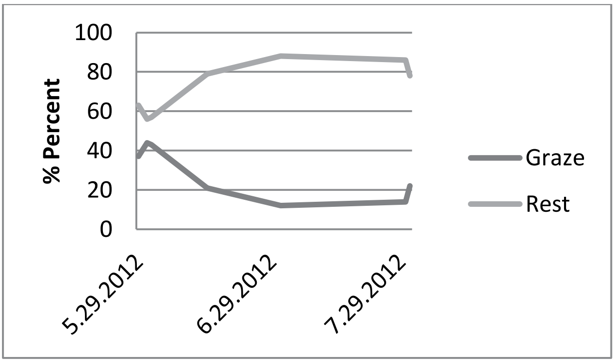


Figure 7. Grazing and resting in 2012, 6 sheep (%), (N5).

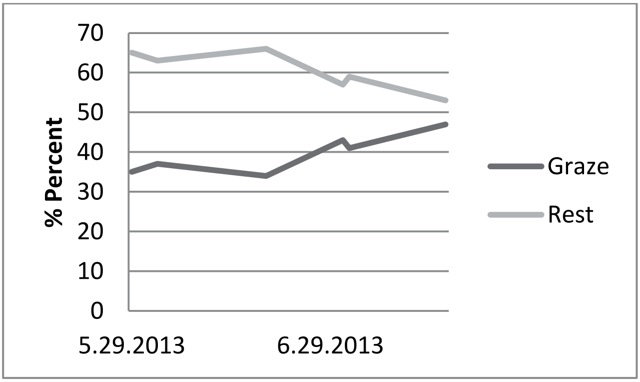


Figure 8. Grazing and resting in 2013, 18– 20 sheep (%), (N6).

time in the end of July, see Figure 6 and 8. The longer grazing time at the end of the season is due lower fodder nutrient content towards the end of the growing season. In the late summer lambs are larger and are also able to graze for a longer time. At the end of July sheep made a change in areas grazed, starting using areas further away from the forest edge. In September 2011 sheep spent more time grazing than resting, see Figure 6. In summer 2012 the herd was small with only one lamb, consequently the adult ewes could graze as much as they wanted and did not have to think about any lambs, see Figure 7.

The time spent grazing reflects the animal's need for food and shelter. The animal will have an increased need for food if it is pregnant or lactating, cold or has experienced a period of poor nutrition. If it is cold it will seek shelter and may adjust its grazing behaviour to do so. (Arnold & Dudzinski, 1978, 16). Grazing time increase with age up to about 3 years and after that grazing time may decline. A decline with age may occur because the teeth become worn (Arnold & Dudzinski, 1978, 16). It was observed that those having a longer grazing period did not start grazing earlier but grazed longer at the end of the grazing bout, while the other members of the flock already had returned to the camping site. Young mother ewes suckling had longer grazing period in the beginning of the grazing period (May–June), as well as young growing lambs (July–August).

In windy weather sheep graze towards the wind but if it starts to rain they change and graze away from it. (Arnold & Dudzinski, 1978, 9). In heavy rain sheep went inside the shelter at Kiltsi Meadow. During rainy weather or after rain the sheep preferred to graze in the forest, where it was dry grass under the trees. With a shortage of food sheep rest less often and have so fewer periods of grazing. (Arnold & Dudzinski, 1978, 9).

A group of animals whose potential grazing time differ may interact socially if grazed together and in this way also modified their grazing time. Such effects can be found among sheep and is called social facilitation. (Arnold & Dudzinski, 1978, 19). Social facilitation was very common among Estonian native sheep at Kiltsi Meadow. In the small free-ranging native sheep herd animals of different sex and age were all together grazing as one united flock. Observations were made that ewes regulated the grazing bout length according to how many small lambs there were in the flock. When the small lambs got tired the leader took the whole flock to rest inside the shelter. A few times it happened that young lambs, old or sick animals lied down at the meadow, while the rest grazed around them. In 2011 the 13 year old leader ewe ended several times her grazing and required all the rest to follow her into the shelter. It could not stand the hot weather nor keep up with the same mowing speed as the rest of the flock. During very warm days (above 25°) the leader did not let the flock members graze more than 15–25 minutes per bout. It did both call and chase flock members back into the shelter. All sheep were black in color 2012 & 2013. Most likely black sheep gets heated more quickly than white sheep. Very seldom a sub-group in the flock wanted to stay longer grazing at the pasture, even if needed. If the main flock went inside for resting, then those with longer grazing needs followed usually the mainstream decision.

When feed is of shorter length on pasture then the animals grazing there will spend more time grazing because they can obtain less per bite (Arnold & Dudzinski, 1978, 20). It was noticed that if sheep were very hungry in the morning (got outside later in the morning) then they decided to graze at areas with bulky food. It was noticed that sheep moved faster when grazing areas with low plant cover compared to areas with higher plant cover. The factors that determine time spent grazing by sheep are poorly understood. (Arnold & Dudzinski, 1978, 22) and more studies are needed.

Chewing the cud is the second most time consuming activity for ruminant animals. The time taken depends on the quantity and quality of food eaten and the amount of "grinding" it requires. Sheep take small bites and the material when swallowed is finer, so they need less chewing during rumination. (Arnold & Dudzinski, 1978, 25). The ruminating and resting time was usually started with scratching themselves against the wooden fence at the camping site next to the night shelter. During evening rest they used often an old pine for scratching themselves. Time used on ruminating was not measured separately from resting time. The sheep was usually lying down when ruminating.

Estonian native sheep at Kiltsi Meadow spent typically idling time with playing or scratching themselves. Adults younger than 2 years old often joined playing with small lambs. Playing was making head clash (with other lambs but also with adults), jumping up on the stone fence, hiding inside the limestone kraal, running and chasing the cat if it entered the pasture. They did also investigate plants, trees, pine, cones and branches. Running of joy was not only done by the lambs, but was several times done by the whole flock at one time. 23.5.2011 lambs started to run around the car in the morning, about 45 minutes after that I had let them out on the pasture. It was a very joyful play for them until I chased them away as one bumped into the car. Not only the small lambs, but also 1–2 year old sheep participated in the run. Towards the end of summer sheep started to idle more, whereas this was done less in beginning of summer. Idling was usually done in the evenings between the grazing bouts. Idling was also done daytime in September on windy days.

During 2011–2013 sheep never lied down outside at the pasture as one flock. They used only the camping site in connection to the night shelter for rumination and resting. At warm days the camping was always inside the shelter. Sheep prefer places with bare soil and did also remove bedding material in order to reach the chilly soil floor inside at warm days. Under very hot days sheep gather into small family groups and shade their heads under each other. Legs are carefully put under the body in order to protect them from mosquitos. Traditional Estonian barns allow maximum air rotation as they are built with two doors, one on each side of the building. It is easy to regulate the temperature

Photo 3. Playing and idling around the limestone kraal.

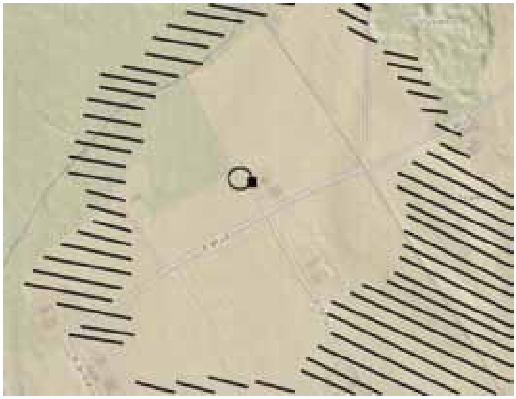
inside the barns during warm days. They are also high ceilings, which gives a good indoor climate.

When resting in the sun, the animal's bodies are at right angles to the sun's rays (Arnold & Dudzinski, 1978, 29).

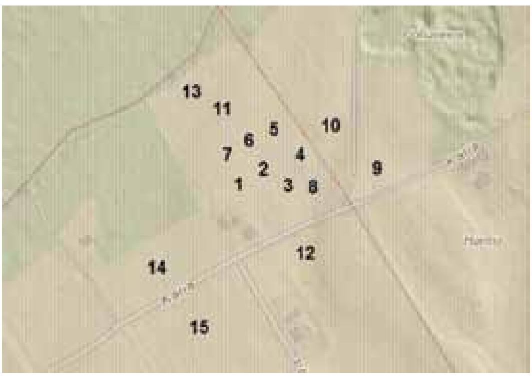
The frequency of drinking depends on temperature, condition of feed and the distribution of water. Sheep at Kiltsi meadow got their water inside the shelter. Often they get enough water with dew from the morning grazing. Days on dry feed increase water drinking as do its frequency with increases in temperature. It is also more frequent in small pastures or where there are several watering points. The more water is available the more drinking will occur. (Arnold & Dudzinski, 1978, 43). Sheep wanted to drink water each time after eating leaves.

4. SOCIAL SPACING AND WALKING

The size of a home range for a sheep flock in free-ranging may have large variations. Bighorns in Canada have from 50–2800 ha whereas Soay home ranges vary from 5 to 16 ha. (Fisher & Matthews, 2001, 215). The home range for free-ranging estonian native sheep at Kiltsi Meadow was ca. 8 ha (observations from 2006 to 2013), see Map 1. Sheep did not use all areas of the meadow. Few studies have been carried out on the reason of variation in use of different areas at pastures (Lynch et al., 1992, 15).



Map 1. Areas not used at Kiltsi Meadow are marked with stripes. The home range is located in the middle as is the shelter (marked with square) and the camping site (marked with a circle).



Map 2. The free-range seasonal grazing order was nearly the same each year (Kiltsi meadow 2011–2013).

The restriction of sheep to a home range is strong. (Arnold & Dudzinski, 1978, 82). The free-ranging estonian native sheep kept their home range area mostly well. Spring 2011 they visited a neighbor's garden at Kalda street and wanted also to spend time at the part of the meadow close to Kalda street.

The sheep grazed the pasture in a very structured way. They started grazing the areas closest to the shelter and grazed for several days one area before they continued to the next closest ungrazed area, see Map 2 and 5. In this way the whole pasture was grazed structurally week by week. The areas further away from the camping site were taken into use later during the grazing season.

There are many factors influencing on dispersion. Undulating country causes flocks to form groups; even light timber does. Sheep will aggregate in large groups or as a whole flock when resting or when drinking and then gradually split up into smaller and smaller groups as they graze away from water or camp site. The grazing formation often begins as a wide arc or front, which then breaks up as the sheep move. (Arnold & Dudzinski, 1978, 73–74). Sheep within groups maintain a certain distance from their nearest neighbor when grazing. This nearest neighbor distance tends to be a characteristic of the breed. Nearest neighbor distance decrease as vegetation quality and homogeneity increase (Rutter, 2002, 151). Estonian native sheep grazed most of the time very close to each other, ca. 1 meter between individuals. From time to time they grazed so close to each other that their sides nearly touched each other. They could also put their muzzles very close to each other (crowding), which also is typically seen when a mother and lamb graze together.

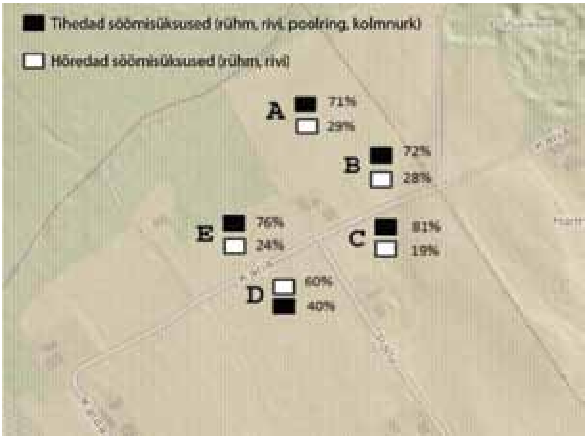
Hundreds of photos of formations formed by Estonian native sheep was taken during the grazing season. 110 grazing situations at the pasture were photographed during 68 days. Photos were taken randomly during the days. There were identified 6 different grazing formations among Estonian native sheep:

1. Close groups
2. Close lines
3. Close triangles
4. Loose groups
5. Loose lines
6. Semicircle

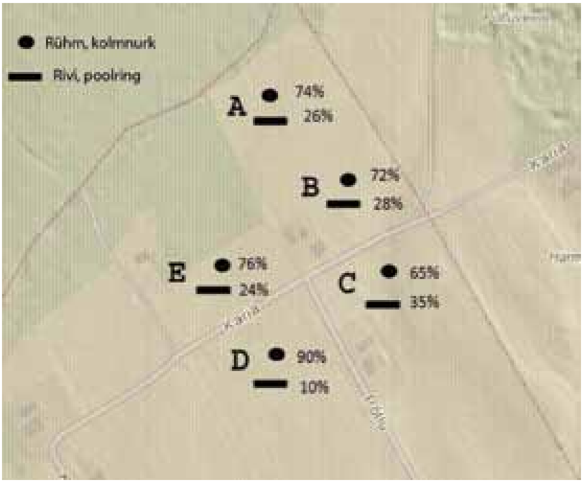
The formations can be seen at Photo 4–5. In 2011 and 2013 the main flock was occasionally divided into one main and one sub-group, but they never stood far from each other.

Photo 4. Semicircle up to the left, triangle down to the left. Loose group up to the right, close group down to the right.

Photo 5. Loose line formation up, close line formation down.



Map 3. Close or loose formation formed while grazing.



Map 4. Group or line formation formed while grazing.

The formations were plotted at a map according to the location where they had formed them. The information was sorted according to five different field locations A-E. The formations were divided in two different groups: close or loose formations, Map 3 and group and line formations, Map 4.

Field C had the highest amount of close formations, 81%, see Map 3. As much as 35% of the formations were line formations, see Map 4. Field C has restricted view to three sides. Topographically the field is rising towards East; there is a small forest with a house and garden to the South, another garden to the North and only open view to southwest. Field C is also surrounded by roads on two sides. The sheep had to be most alert when grazing field C as there was both car traffics and frequently walking people at the road

Field D had the highest amount of loose formations, 60%, see Map 3.

Field D is large, located further from the forest and the sheep have a good view to all sides when grazing at this field. This is most likely the main reason why they formed so much loose formations at field D. 90% of the formations were loose groups, only 10% line formations. Field D was typically used first in the end of July and in August, which is also the period when wolf start to become active.

Distances at Kiltsi Meadow are short and sheep walked to get shadow into the shelter every time they started ruminating and resting. In 2011 and 2012 13 GPS monitoring days were carried out, 9 days in 2011 (August) and 4 days in 2012 (June, July, August). The distance walked and speed used during the daily grazing was measured with a Ventus G730, see photo 6. The datalogger was fastened on the same ewe during all monitoring days.

The distance walked by sheep on rangelands depends on the type of vegetation. Several studies have shown that breeds of sheep differ in the distance walked each day. (Arnold & Dudzinski, 1978, 42). Estonian native sheep walked between 2,1 to 4,3 km daily, see Figure 9. The distance is similar to other recorded sheep travelling distances, see Table 2. The shorter distance walked in June and July may be both as there were fewer sheep in 2012 and that they walk less during warm

Photo 6. Ventus G730 is cheap and easy to use.

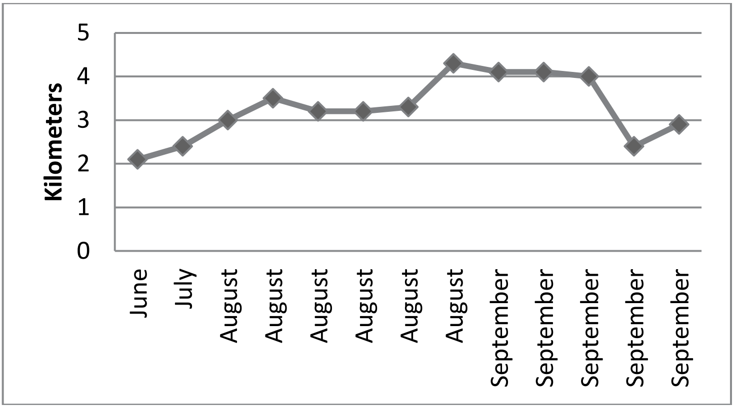


Figure 9. Kilometers walked by Estonian native sheep.

days. Estonian native sheep become a more active walker in the autumn. Even if the sheep spent more time at the pasture it did not mean that they walked more. Figure 10 shows that in September they spent less time at the meadow, but walked more meters per hour.

Table 2. Recorded distanced travelled daily by sheep in different environments (Arnold & Dudzinski, 1978, 41; Michelson, 2013).

Location	Pasture size (ha)	Distance walked (km)
Stratford, Great Britain	0.2	winter 1.5–2.7 summer 0.7–1.6
Aberdeen, Great Britain	0.4	3.3–5.3
Palmerston North, New Zealand	0.4–20	0.4–3.1
Kiltsi Meadow, Estonia	8	2,1–4,3
Groot Fontein, South Africa	125	5.2–8.0
Oregon, USA	1000	1.6
Utah, USA	1134	2.9–5.1
Montana, USA	1620	7.6
Ivanhoe, Australia	2000	3.2–5.5
Deniliquin	1310	8–14
Deniliquin, Australia	910	4.7–6.2

Fisher & Matthews (2001, 215) writes that there often is pattern of daily movement within the home range, such that sheep occupy a similar part of the home range at the same time on several days in a row. In

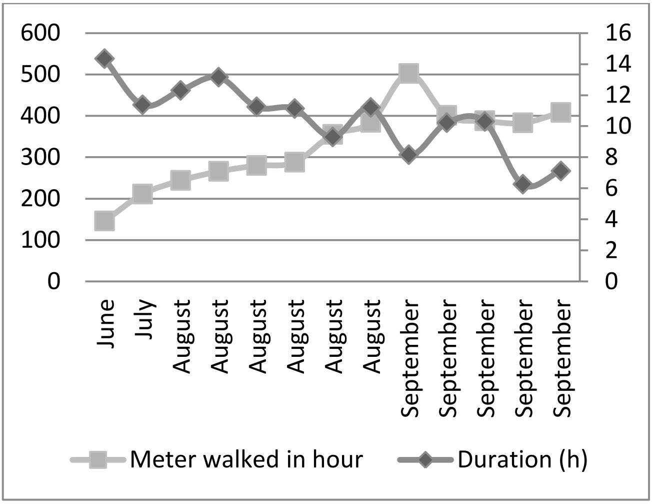
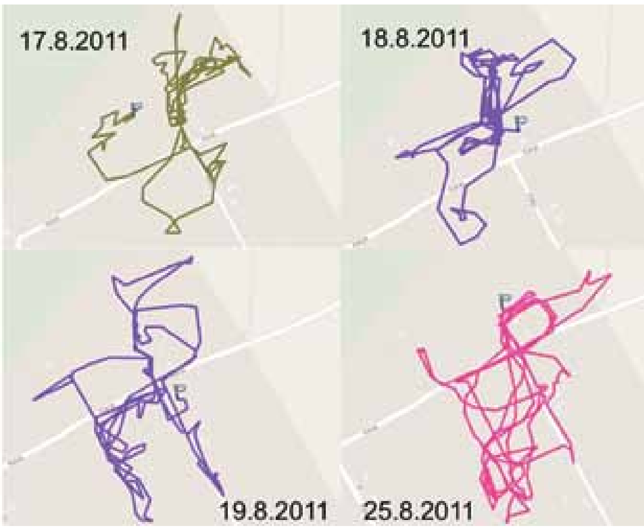
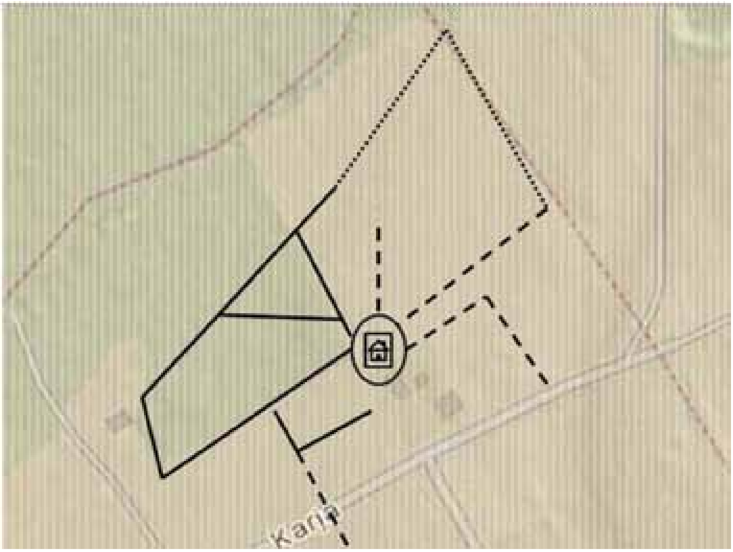


Figure 10. Time spent at the pasture and distance walked per hour (N13).



Map 5. Daily grazing routes similar to each other.

a group of Soay sheep the home range area was restricted during May when the lambs were young, and extended in autumn. At Map 5 four days close to each other were recorded and it can be seen how the pattern slowly changes from day to day, but still they are very similar to each other. Several observations were made on sheep spending 5–7 days on



Map 6. Tracks used by sheep at Kiltsi Meadow.

one locality before changing the pattern. The pattern varied with season.

In large pastures sheep tracks usually move parallel to fence lines for up to 50 m, provided there are no obstructions, and then at some distance from the fence run in various directions. It appears that sheep use the fence lines for orientation. Sheep makes more tracks than cattle. In large pastures sheep may establish straight tracks radiating out into the pasture but often start from the watering points. Sheep also form tracks for general movement between environments and do more "trailing" in large pastures than in small pastures even when feed is abundant. (Arnold & Dudzinski, 1978, 69–70).

Estonian native sheep likes to walk at tracks and roads, as well as following linear objects in the pasture. There are several small gravel roads at Kiltsi Meadow, see Map 6. The black lines are regularly mowed tracks that both human and sheep use. The broken lines are tracks made by sheep. Summer 2013 some artificial mowed tracks were established (dotted lines at Map 6). The start of the artificial track was a path that sheep had been using already from before. However, I continued the path in a new direction in order to steer their grazing. Sheep did also start using these new paths and started grazing areas that they had not grazed that much in former years.

The "following" nature of the sheep often results in them walking in a single row as animals move from one area to another (Lynch et al., 1992, 63). Estonian native sheep can very quickly move from one area to another. They changed normally area by walking as a single file. In the morning they started by walking out in a single file. The maximum daily speed varied from 8–20 km/h. The only speed that was used several times was the maximum speed 20 km/h, which they used on four days. The sheep was usually not disturbed by walking or bicycling human. Estonian native sheep move normally from one grazing area to another by walking, not by trotting. Trotting was usually only used if there was an outer interference in grazing. Trotting was also done when they had to get rid of insects, when they were disturbed by human, a dog or a car approaching at the road.

All members of the sheep flock participated in daily guarding. The main guarding responsibility was on the leader ewe and other adult ewes.

5. ESTONIAN NATIVE SHEEP AND PLANT PREFERENCES

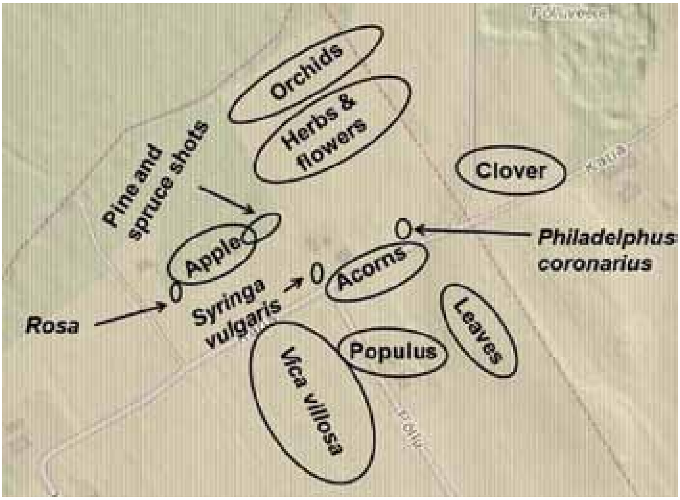
Diet selection is based on sheep making a decision concerning what plant species, individual plants and parts of plants it will eat. Sheep have a relatively narrow muzzle and they are capable of selecting plant parts with high precision. (Lynch et al., 1992, 23–24) North-European short-tailed sheep is a light sheep and it has narrower muzzle compared to heavier meat breeds. Sheep either bite the vegetation off the plant or it is broken as they prip it with their teeth and jerk their heads forwards or backwards. Measurements show that 79% of the head jerks are backwards. Sheep move with its muzzles in a horizontal plane as they graze and select in a vertical plane. Because sheep have smaller mouths and teeth they can take smaller bites and they are so able to be more selective than cattle or horses if they wish. However, sheep are able to vary their methods of harvesting food according to the structure of the vegetation. Within the plant communities two types of preferences are seen: some species are preferred to others and a certain plant parts are found preferable to other parts.

Estonian native sheep had a large variety of species to choose among at Kiltsi Meadow and different plants were grazed in different ways and at different time during the season. Estonian native sheep takes often small bites from certain plants, for example the newest shot at *Vicia villosa,* small bites of *Medicago lupulina or* a single leave from a thorny rose bush. In August they may intake larger amounts of leaves of *Filipendula ulmaria*, and first in September they start grazing leaves of *Dactylis glomerata*. Much time was spent on searching suitable plants and they moved fast across the meadow when grazing.

Not all areas of pasture are visited with equal frequency, especially when food is abundant. Sheep often restrict their grazing to certain favored area and creates in this way heterogeneity in the vegetation. (Arnold & Dudzinski, 1978, 100). At low grazing pressures sheep will utilize only part of the pasture, concentrating their grazing close to water and camping site. As heterogeneity of vegetation and topography increases, so does the variation in use of the environment by grazing animals. (Arnold & Dudzinski, 1978, 86). It has been indicated that the same plant species have different acceptability when grown under different nutrient regimes. Such differences will occur naturally on different types of soil or with different fertilization. (Arnold & Dudzinski, 1978, 90). Topography, soil moisture and weather have been showed important in many studies. The sheep had also some favored spots, where they spent a lot of time grazing, Map 7.

From the single plant sheep eat leaf in preference to stem and green material in preference to dry. The material eaten, when compared to the material rejected, is usually higher in nitrogen, phosphate and gross energy. Opinion varies on whether eaten material is higher in sugars and minerals. (Arnold & Dudzinski, 1978, 100).

The role of sight, tough in the lips, taste and smell are all involved in diet selection. Sight is used primarily to orient the grazing animal to other sheep, and to its environment. Sheep do recognize conspicuous food plants by sight, but do not use sight to help them graze selectively (Arnold & Dudzinski, 1978, 102). Sheep has a sensory response developed to give adequate nutrition and they select food to minimize unpleasant and maximize pleasant and may often select plants not for their nutritional advantages but for their flavor. (Arnold & Dudzinski, 1978, 119).



Map 7. Favored grazing areas at Kiltsi Meadow.

Information about sheep feeding preferences was made concerning 76 plants and trees at Kiltsi Meadow. 62 plants were grazed, 14 species were not seen to be grazed, 13 plants they liked a lot. There was a large difference of seasonal preferences or on what parts they eat of the plant. A favorite plant is defined as a plant that the by purpose go and search for. By experience they know where the plants grow and go to graze it. When they are given favorite leaves they start to chew already before they get them. Favorite plants are also those that they run to get, such like acorns in the autumn. The following plants were favorite plants at Kiltsi Meadow: *Betula, Frangula alnus, Gymnadenia conopsea, Malus domestica, Medicago lupulina, Philadelphus coronarius, Plantago major, Quercus robur, Rosa, Salix, Syringa vulgaris, Trifolium repens* and *Vicia villosa.*

The following plants were good daily grazing plants: *Achillea millefolium, Aegopodium podagraria, Convolvulus arvensis, Dactylis glomerata, Festuca ovina, Festuca sp., Filipendula vulgaris, Frangula alnus, Knautia arvensis, Lathyrus pratensis, Pastinaca sativa, Picea abies, Pinus sylvestris, Populus, Primula veris, Taraxacum, Tragopogon pratensis, Trifolium medium* and *Trifolium pretense.* Many smaller grasses are also grazed, for example several *Carex* species which not were identified separately. Also many low growing herbs were not identified.

Observations concerning sheep grazing the following plants were made seldom or never: *Antennaria dioica, Anthemis tinctoria, Briza media, Euphrasia stricta, Filipendula ulmaria, Galium album, Galium boreale, Galium verum, Hypericum perforatum, Leucanthemum vulgare, Origanum vulgare, Prunella vulgaris, Ranunculus acris and Verbascum nigrum.*

Different parts may be grazed at different time. For example early spring they eat *Primula veris* leaves, but stopped as soon as they got stems. *Primula veris* flowers were less eaten, but when the seeds are ready and dry they grazed them. *Taraxacum* species leaves are grazed young and then ready seeds are grazed later during the season. In the beginning of the summer they grazed one week mostly *Villosa vicia*. The sheep took never all plants from a small habitat but left always some plants ungrazed (G*entiana cruciate,* willow leaves). Sheep eat likely blue (*Campanula*) and red colored (*Gymnadenia conopsea)* flowers, whereas yellow flowers (*Primula veris, Asteraceae, Taraxacum, Agrimonia eupatoria, Bunias orientalis, Pilosella officinarum)* often are ignored. Most likely the smell of the flowers determines what to eat and not eat, but more studies are needed. More detailed results from the observation on preferred plants and plant parts can be seen at http://goo.gl/Zs9sLL.

Sheep seems to have an excellent memory of the location of preferred foods. Experience, particularly in early life, may alter the later behaviour of an animal. Sheep reared to 3 years of age without any grazing experience were shown to obtain much less food per hour of grazing than sheep reared on pasture. Preferences amongst a choice of pasture plants can be strongly influenced by experience. (Arnold & Dudzinski, 1978, 113). Age, breed, physiological state and individuality varies the feeding desires. Sheep living close to the sea are used to feed on seaweeds (Lynch et al., 1992, 11; Ärmpalu-Idvand, 2009). It has been found out that lambs at 5 months of age have a diet that is higher in digestibility and in nitrogen content and lower in fiber than of older sheep. (Arnold & Dudzinski, 1978, 114). The diets selected by individuals in a flock vary considerably in both botanical and chemical composition (Arnold & Dudzinski, 1978, 116). Sheep change their diets during the day, this occurs in part because of changes in location of grazing during the day. Diets contain more dry material and less nitrogen when the sheep had been fasted overnight. (Arnold & Dudzinski, 1978, 118).

There seems to be a variety between individual preferences. In 2007 a young ram lamb was the only one to eat spruce bark and spring 2007 an old ewe ate a huge amount of blooms of *Convallaria majalis* and leaves of *Paris quadrifolia*. Lambs at Kiltsi Meadow did in 2011 fancy leaves of a wild rose, adults did not eat them. Plants that were covered with limestone dust along the roads were very taste for some. All fancied to graze at edges of roads and tracks. Annually one autumn favorite is acorns that during the night fall down from the oak on the gravel road. First thing in the morning is to check and eat the acorns dropped during the night, see photo 7. It may be that slightly poisoned plants regulate the level of worms.

5.1. Sheep and orchids

One large group of rare plants on limestone semi-natural meadows is orchids. There are few studies on the important role the senses play in the selection of diet among sheep. This is difficult research because the interactive relationships of taste, smell, the role of prior experience and memory. Flower heads have an attractive smell to sheep (Arnold & Dudzinski, 1978, 103).

Photo 7. Estonian native sheep at Kiltsi meadow loves eating acorns.

One of the main plants for protection at Kiltsi Meadow is the orchid *Gymnadenia conopsea.* The amount of it has been recorded since 2003. Sheep was starting to graze the meadow in 2006. Orchids were eaten by sheep at Kiltsi Meadow especially in 2008, 2011 and 2013.

All these years there were several small lambs in the flock (2008: 8; 2011: 12; 2013: 13) but only one in 2012. During 2011–2013 all enjoyed, but especially sheep under 1 year old, syringa leaves, rose leaves, apple leaves and mock-orange leaves, all plants having a nice smell. The sheep avoid medical herbs like *Achillea millefolium, Verbascum nigrum, Leucanthemum vulgare, Anthemis tinctoria, Hypericum perforatum, Euphrasia officinalis, Carum carvi and Origanum vulgare.* All these medical herbs have a strong taste. It is known that sheep may use touch for recognition of an individual plant or plant part. There is a blind area of some 3 cm directly in front of the nose and it is logical to expect that the selection of a particular plant is based on odour and on touch with ingestion or rejection by taste or / and feel within the mouth. (Lynch et al., 1992, 36). At two occasions I have seen how experienced ewes check if a plant is edible. In 2011 the oldest ewe in the flock noticed one exemplar of *Anthemis tinctoria.* This plant is not common at the meadow. The ewe took the whole flower into her mouth, then it opened the mouth and let it out again - untouched. It did not eat it. It was left without any sign of being inside the mouth of a sheep, all fragile petals were untouched. The same happened 30.6.2013 with *Verbascum nigrum.* There are also few exemplares of these at the meadow. Ewe experienced in grazing took a part of the small flower at the stem in her mouth, let it off , and left the plant growing.

According to Natalia Dudareva (2005, 2013) plant scent develops as following: *"Plants tend to have their scent output at maximal levels only when the flowers are ready for pollination and when its potential pollinators are active as well. During flower development, newly opened and young flowers, which are not ready to function as pollen donors, produce fewer odors and are less attractive to pollinators than are older flowers."*

Estonian native sheep, with a high level of local flora knowledge, is a gourmet fodder grazer. If possible they choose plants with pleasant scent and taste. The fact that it is the smell that is important is emphasized by the observations at Kiltsi meadow concerning time when native sheep decide to eat the orchids. The sheep do not touch the orchids when they still are developing, but first when they start sending a scent. The orchid start opening the small flowers from down and continue up to the top. First when all flowers are ready for pollination it starts sending out an intensive pleasant scent. It takes usually some days in order to get most flowers opened. When the flower reach its maximal level of scent then sheep cannot resist them, but eat the whole flower leaving only the empty stem left. In the period 2006 to 2013 the sheep have followed the same pattern when grazing the orchids, few days after all flowers are at their maximum they eat them.

At Figure 11 is showed the amount of orchids and amount of sheep at Kiltsi meadow. How is it possible that sheep eat the orchids and at the same time their amount is growing? It is well known that sheep eat orchids and the environmental sector have given negative feedback to farmers keeping sheep at meadows with orchids. They have been told to stop grazing the orchid meadows, even if the meadows have been grazed traditionally with sheep for centuries. One orchid plant produce thousands of seeds and in good germinating conditions even a low amount of succeeding plants are enough.

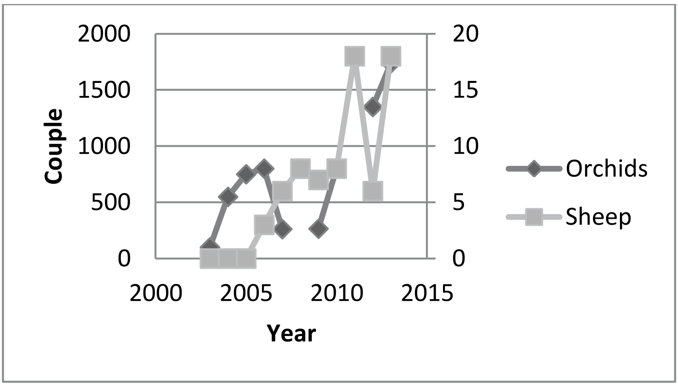


Figure 11. Amount of estonian native sheep and *Gymnadenia conopsea* at Kiltsi Meadow 2002–2013. In 2008 & 2011 no data as sheep eat the orchids. In 2007 & 2009 sheep eat some before monitoring them.

Photo 8. Young *Gymnadenia conopsea* plants at Kiltsi Meadow marked with a blue dot (19.7.2013).

In summer 2013 new seed propagated plants at Kiltsi meadow was studied. Several (7–8) young plants were found around older plants, see photo 8. Sheep provide orchids with a perfect growing habitat by grazing semi-natural meadows. Close to the ground there are often mosses that keep the moisture needed for orchid's germination. As soon as they start to grow they need a lot of light, which there is plenty of in a well grazed semi-natural meadow.

There are different observations concerning sheep grazing orchids and many species of orchids have different colors and smell. More studies are needed concerning both smell and lambs preferences on orchids.

6. HEALTHY SHEEP AT A HEALTHY MEADOW

Small traditional sheep flocks that have been kept at the same farm for many sheep generations have their firm routines in how to use the pasture areas. In several studies is shown that faeces are concentrated at the sheep camping site. (Arnold & Dudzinski, 1978, 95). The camping sites and the paths are those that get most droppings.

Sheep do not drop manure in an unstructured way, but it can be foreseen where it will be dropped. In many semi-natural meadows there grow plants that are sensitive towards additional nutrients. Some plants grow only if the soil has a low content of nutrients. Urination was typically done inside the shelter or just outside the shelter, typically when rising up in the morning. Defaecations were typically done once by each individual during the night and when starting walking to the meadow in the morning. The morning defaecation was done outside the night shelter typically within 0–30 meters from the shelter. Defaecation was also done during the day typically in connection with movements from one part of the meadow to another, on roads & paths and in connection to the camping site.

In Estonia there has been, and still is, among small traditional sheep farmers an old habit to pick up the faeces left by sheep. Cleaning is mostly done on the camping site and areas close to it. Also tracks may be cleaned. This management method has been carried out at Kiltsi meadow in 2006–2013. The camping site, shelter and most common used paths were daily cleaned of faeces. Depending on the size of the flock this job took from 15 minutes daily(ca. 5 liters of droppings of 5–8 sheep) to 30 minutes (10 liters of dropping of 10–18 sheep). 10 sheep (6 adults, 4 lambs) gives in May 7 liter manure daily and in June-August 10 l. It is estimated that 70% of faeces is found in a radius of 50 m from the camping site / shelter and more 20% in a distance of 70 meters from the animal shelter. It is estimated that only 5–10% can be found at other areas of the meadow (no extra fodder given).

The benefit from collecting faeces is large. The camping site will remain clean, as will the shelter be inside. New bedding material was added daily, which results in as much bedding material used summer time as wintertime. There was though a lower amount of insects, which resulted that animals spent likely time inside the shelter as there was both shadow and less insects indoor than outdoor. Daily cleaning gives especially a lower amount of flies (*Brachycera)* and horse-flies (*Tabanidae).*

An environment free of faeces decrease the level of insects, which gives a lower risk of getting worms. As the level of worms is less you need to treat sheep with less pesticide or avoid them totally. Many worm pesticides used for sheep have a negative impact on biodiversity, for example on dung beetles. The larvae of dung beetles play an important role when manure is composted. Many dung beetles are endangered species. If you want to protect dung beetles then you should give worm pesticides to the sheep 1 to 2 weeks before they are let out pasturing semi-natural meadows. (Danielsson et al., 2002, 14–15) Sheep, and human, enjoy staying in an insect free environment and also the wool will be of better quality due to less dirt.

7. EFFECTS OF BEHAVIOUR AND RECOMMENDATIONS

Estonian native sheep is the traditional grazer of semi-natural pastures including alvars and coastal meadows. Estonian native sheep do not suffer from any behavioral problems associated with agricultural intensification. This does not mean that their welfare cannot be compromised and they can still be exposed to different stressful situations. At the pasture they may be exposed to heat and cold and need shelter, they should be sheared twice a year, hoofs should be cut regularly and they should be given enough nutrition. The semi-natural pastures and meadows used by Estonian native sheep are in many aspects similar to the natural habitat of their wild ancestors. It is only at these semi-natural pastures were they can perform their full repertoire of natural behaviour and keep on preserving their valuable characteristics. Their daily pasture activities are shown at Figure 12.

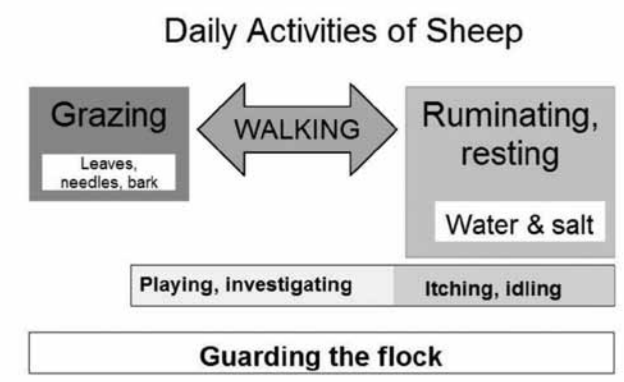


Figure 12. Daily activities of Estonian native sheep at Kiltsi Meadow 2006–2013. The size of the boxes shows an estimated relationship on used time in doing different activities daily. Modified Lynch et al., 1992, 19.

Traditional farm management systems contribute to a rich farmland biodiversity. Estonian native sheep likes to eat leaves, bark and needles as well as plants tasting and smelling good, among others *Gymnadenia conopsea.* Observations at Kiltsi Meadow shows that sheep by grazing semi-natural pastures provide this orchid with good germination conditions, which will increase the amount of orchids in the meadow. Estonian native sheep is an active, fast mowing grazer, that mainly graze in close formations. It graze in a structural well organized way. The effects of transfer of nutrients can have a strong localized effect, with quite different botanical composition on and near camping sites. In small traditional sheep flocks daily cleaning gives good results. One can manipulate the location of paths, water and camping place in order to change sheep behaviour. Trials at Kiltsi Meadow with pre-cut paths showed that the animals started to use them when moving from one grazing area to another.

Observations at Kiltsi Meadow shows that man himself is less effective than sheep itself in creating favorable habitat in semi-natural ecosystems. Free-ranging traditional small sheep flocks utilize more areas and give the best care a habitat with its ecosystem can desire. The aesthetic value of grazing animals is considerable. Semi-natural pastures require a hardy sheep that is active in seeking for food. There is no doubt that many breeds of sheep can adapt, behaviorally, back to the natural state and could be managed in the way to maintain these semi-natural areas. Native sheep will tough always be the most suitable to be used for grazing these areas. Shearing will be needed for native sheep, but you will also get attributes like, hardy, independent, healthy, fleet of foot, vigilant for predator threat and attractive to look at when using native sheep at semi-natural pastures.

REFERENCES

Arnold, G. W. & Dudzinski, M. L. 1978. Ethology of Free-Ranging Domestic Animals. Developments in Animal and Veterinary Sciences 2, Elsevier Scientific Publishing Company, 198 pp.

Danielsson, D.-A., Christensson, D. & Wiktelius, S. 2002. Parasitbekämpining och biologiskt mångfals. Biologiskt mångfald och variation i odlingslandskapet, Jordbruksverket.

Dudareva, N. 2005. Why do flowers have scents? Scientific American. 18th April 2005. Electronic source 16.9.2013 http://www.scientificamerican.com/article.cfm?id=why-do-flowers-have-scent

Dudareva, N., Klempien, A., Muhlemann, J. K. & Kaplan, I. 2013. Biosynthesis, function and metabolic engineering of plant volatile organic compounds. New Phytologist,198:16–32, p.22.

Fisher, A. & Matthews, L. 2001.The Social Behaviour of Sheep in Keeling, L. J. & Gonyou, H. W. (Ed.). Social Behaviour in Farm Animals, CABI Pubishing, 211–245 pp.

Jaama, K. 1946. Lambakasvatus. R. K.Teaduslik kirjandus.

Lynch, J. J.; Hinch, G. N. & Adams, D. B. 1992. The Behaviour of Sheep. Biological Principles and Implications for Production. CAB International and CSIRO Australia.

Michelson, A. & Jäetma, I. 2005–2013. Practical experience from Estonian native sheep keeping at Sae Farm and Mündi Farm. Unpublished materials.

Rutter, M. S. Behaviour of Sheep and Goats in Jensen, Pe (Ed.), 2002. The Ethology of Domestic Animals. An Introductory Text. CABI Publishing, 145–157 pp.

Saarma, U. 2009. Eesti ja Euroopa põlistlammaste lugu kahe teadusuuringu valguses. Eesti Loodus 20, pp.13–17.

Svalheim, E., Asdal Å., Hauge, L., Marum, P. & Ueland, J. 2005.Fôrplanter i gamle enger og beiter. Bevaring av genressurses. Genresurssutvalg for kulturplanter. Planteforsk Landvik, pp. 3–4, 7.

Vohlonen, M. 1927. Nykyaikainen lammastalous. Tieto ja taito 54. Werner Söderström osakeyhtiö.

Ärmpalu-Idvand, A. 2009. Kihnu maalammas on elus ja hea tervise juures. Eesti Loodus. 10, pp.6–12.

LARGE CARNIVORE AND EAGLE DAMAGE PREVENTION MEASURES IN ESTONIAN AND FINNISH BALTIC ISLANDS AND COASTAL AREAS

T. Otstavel

Estonian Crop Research Institute, J. Aamisepa 1, Jõgeva, 48309 Jõgeva County, Estonia; e-mail: teet.otstavel@helsinki.fi

Abstract. This study was a part of the 'KNOWSHEEP' – project. The subproject of 'Livestock guarding dogs (LGDs) for sheep' included the subtheme 'Safety on Pastures'. The objective was to study possibilities of farmers to enhance safety on pastures against large carnivores and eagle predation and benefit from the use of large carnivore prevention measures, especially LGDs. The aim was to describe the themes of local conditions and practices arising at the subproject of islands and coastal areas in Estonia and Finland. Data collection for this study conducted through visits to farms and the (semi-structured) interviews, narratives and interactive seminars. The main conclusions from this narrow but unique area were that damage prevention using LGDs can be highly successful, but needs effort depending on the background variables of the farms, of the individual traits of LGDs and the possibility of farmers to invest their time in training, especially in conditions of no LGD tradition. Concerning threats some differences occured. In Estonia LGDs appeared to be a straight answer towards attacks and damages but in Finland more towards the fear of damages in future and a way to increase the feeling of safety concerning any intruders or transmission of animal diseases. LGDs were described as a tool for eagle damage prevention. The topic remained for future research because of the shortage of observations. For continuation of the positive diminishing trend, further research of local contexts concerning both LGDs and farm conditions will be needed. Wider benefits from the use of LGDs for e.g. agritourism are also one topic to be studied further.

Key words: Large carnivore prevention, LGD, LPD, white-tailed eagle, Estonian, Finnish, Baltic islands, coastal areas.

INTRODUCTION

The research and results of this study are a part of the 'KNOWSHEEP' – project, an Archipelago and Islands Sub-programme of 'The Central Baltic INTERREG IV A Programme 2007–2013'. The subproject 'Livestock Guarding Dogs (LGDs) for sheep' was included in the topic 'Safety on Pastures'. The objective was to research the possibilities of farmers to enhance the safety on pastures against large carnivore and eagle predation and benefit from the use of large carnivore prevention methods, especially using LGDs in Estonian and Finnish coastal areas and islands.

In a wider sense, the 'KNOWSHEEP's aim was to improve the environmental conditions, to increase the attractiveness of the regions, to strengthen the regional identity through better sheep security and welfare (e.g. possibility to continue feeding on semi-natural meadows without serious large carnivore damages and a drop of profitability in sheep farming). The activities of the subproject 'Livestock Guarding Dogs (LGDs) for sheep' were carried out at Saaremaa and Hiiumaa Islands, as well as at Harjumaa and Pärnumaa coastal areas in Estonia, and at Turku Archipelago (Åbo Skärgård) in Finland.

Most of the continental territories of Finland and Estonia were not included in the Central Baltic INTERREG IV A Programme area. At the beginning of the subproject 'Livestock Guarding Dogs (LGDs) for sheep' in 2011 sheep farming was a growing branch of agriculture both in Finland and in Estonia partly also because of the trend of using semi-natural meadows for pasturing. Even geographically so close positioned, differences could be recognized as to pasturing practices and large carnivore predation in Finnish and Estonian project areas. The Finnish project area included Archipelago region divided into thousands of small islands, where sheep are traditionally shipped for the whole grazing period without closer supervision. In Estonia there are just a few islands with a size comparable to continental conditions.

There were permanent lynx (*Lynx lynx*) and white-tailed eagle (*Haliaeëtus albicilla*) populations in the Finnish project area. The closest gray wolf (*Canis lupus*) packs were situated in the neighbour communities of the project area (e.g. Laitila, Loimaa, Mynämäki, Pöytyä) Some random trespassers are not known to cause any recognizable damage in the project area. Finnish project area farmers reported losses due to lynx, white-tailed eagle and a random trespasser brown bear (*Ursus arctos*) (http://www.rktl.fi/riista/suurpedot).

In the Estonian project area there occurred great changes at the beginning of the project period as to wolf population. Brown bear, lynx and wolf populations were spread over most of the Estonian continental area at the beginning of the XXI century with additionally a few lynx litters on Hiiumaa Island. In 2011 the first wolf litters over decades were discovered both at Hiiumaa and Saaremaa Islands with a result of especially severe predation on sheep in Saaremaa starting from 2011 (Estonian Environment Agency, 2013).

Photo 1. In regions where livestock moves to open range pastures or high mountainous areas LGDs have been continuously used for centuries. LGDs success may depend more heavily on the ability and willingness of herders to choose suitable individual dogs, train and use them properly.
Photos: Teet Otstavel

Conservation management of wolf, lynx and bear in Estonia

Since 2007 the compensations for nature damages towards agriculture and domestic animals are paid by the Estonian state. The trained experts of Environmental Board inspect all the reported large carnivore damage cases. Confirmed cases are compensated up to 100% of the market value. Subsidies for prevention measures such as electric fences are paid on up to 50% of proved real costs (European Commission 2013 – Estonia, Männil).

The population size of wolf was around 230 in Estonia in 2010. The goal of population level is according to the current national management plan: 1) to keep the number of annual reproductions between 15–25; 2) to keep the distribution equal over the country in suitable habitats, and 3) to reduce damages on livestock. Wolf population size is controlled by hunting in Estonia. The wolf is included in the list of game species with an open season from 1.11. to 28.02. Population control is more concentrated in agricultural areas thus giving more protection to packs living in the bigger forest habitats. The main conflicts emerged are damages on livestock (mainly sheep; 209 damage cases and depredation costs 95'000 € in 2011) and on wild ungulates (European Commission 2013 – Estonia, Männil; Männil & Kont, 2012).

It is estimated that no significant threats for favourable conservation status of wolf population are foreseen in predictable future in Estonia. However, decreasing acceptance due to damages to livestock and on wild game ungulates can cause higher pressure to increase the hunting quotas and/or increase of illegal killing. Wolves in Estonia are part of the large Baltic population and are found all over the country including the bigger islands. Reproductions occur in all counties (European Commission, 2013; Estonia, Männil).

The main conflict over lynx is with hunters because of the competition for wild ungulates especially during harsh years with low roe deer (*Capreolus capreolus)* density. Lynx depredation on livestock is minor compared to wolf in Estonia (20 damage cases and depredation costs 2'000 € in 2011). Lynx with increasing trend of population of 790 (Autumn 2010) is included in the list of game species in Estonia with an open season from 1.12. to 28.02. There are no significant threats for favourable conservation status of lynx population. Still, reduction of roe deer in Estonia may cause negative attitudes towards the lynx followed by higher pressure to increase the hunting quotas and/or increase of illegal killing. (European Commission, 2013; Estonia, Männil)

Conflicts with bears exist mainly over destruction of beehives while damage to livestock is rare in Estonia (95 damage cases and depredation costs 13'200 € in 2011). Bear is on the list of game species in Estonia with an open season from 1.08. to 31.10. Hunting is only allowed following the objective to reduce damages killing. Environmental Board may issue licenses to shoot nuisance individuals outside the open season. This legal opportunity has not been used during the last 10 years. There are no significant threats for conservation status of bear population in predictable future. However, it may be beneficial to take into account the roles of legal harvest, selective hunting and disturbance in carnivore management work. (European Commission, 2013; Estonia, Männil)

Conservation management of wolf, lynx and bear in Finland

The population size of wolf in Finland was 150–166 in 2012, but according to the estimate from the Finnish Game and Fisheries Research Institute (February 2013), there were only 120–135 wolves in Finland (Jansson, 2013). In the current situation the wolf is listed as an endangered species in Finland, and hunting for population management is not allowed (European Commission 2013; Wolf – Finland, Kojola). All harvest is targeted to remove wolves that cause exceptional damage or move too close to human residences. These removals can be performed year round.

The principal goal of the Finnish compensation system for the large carnivore damages is the full compensation of the damage. Public funding for preventive measures to protect livestock is reserved for electric fences. Attacks on sheep are a minor problem in Finland as compared to Estonia (number of cases/year 2007–2011 range: 650–1001 reindeer, 30–120 sheep, 2–6 other livestock (cattle, horses), 25–35 dogs and depredation costs / year 2007–2011 range: 500'000 – 1'350'000 € (reindeer) 32'688 – 154'302 € (other depredation) (European Commission 2013; Wolf – Finland, Kojola). Wolves kill domestic dogs in hunting situations and some wolves may also repeatedly take dogs from house-yards (Kojola & Kuittinen, 2002). Illegal hunting may explain the recent population decline of wolf (Kojola et al., 2011). Legal harvest instead is strictly regulated. The genetic diversity of Finland's wolves has slightly decreased with decreasing population size. The recent expansion of wolves to South-Western Finland with high human densities has created an active public debate including criticism toward the management policy (Janson, 2013).

The population size of Lynx in 2012 was around 2340–2610 (> 1 year old) in Finland. The compensations for large carnivore damages are paid according to full compensation principle bounded by the annually budgeted money resources. The main conflict over lynx (outside the reindeer husbandry area) is with the hunters over predation on wild ungulates – roe deer and introduced white-tailed deer (*Odocoileus virginianus*) (number of cases/year reindeer husbandry area in 2011: 554 reindeer totalled 827'122€; rest of Finland in 2011: 25 domestic animals totalled 15'600€). Among the most common causes of death in wild lynx, apart from hunting, is however traffic. Illegal killing of lynx occurs, but how commonly or how widely it happens, is not known (European Commission 2013; Lynx – Finland, Holmala & Kojola).

Lynx is not under immediate threat in Finland. Annual growth of the population has been on average 16% (range 2 to 28%) from 1998–2012. For the hunting season 2012–2013 the maximum number of permissible derogations was set to circa 16% of the estimated minimum population, which should lead to a stable lynx population (European Commission 2013; Lynx – Finland, Holmala & Kojola).

The population size of bears in Finland is 1600–1800. The rules concerning the protection of the bear population are written in the hunting law. The potential hunting season for bears is opened on August 20 and lasts until the end of October (European Commission 2013; Bear – Finland, Kojola).

The principal goal in the compensation system is full compensation for the damage. Public funding is provided for electric fences to protect livestock and beehives. The goal for population management is to regulate the population in the regions where bear densities are the highest – the zone of established population – and where bears cause the greatest damage – the area of reindeer (number of cases/year 2007–2011 mean/range: 681 reindeer, 30–100 sheep, 0–5 other livestock, 0–4 dogs, 150–250 beehives, hundreds of packages of silage and some damage in oatfields; 750'000 € for reindeer & 172'700 € for other depredation).

The mean annual legal harvest level has been 8% from 1996 through 2012, assuming population estimates are correct. Poaching occurs but overall poaching is not a considerable threat to bears in Finland. The conflicts occur when bears destroy beehives and silage packed in plastic for cattle, and kill some livestock. If the berry crop is poor, bears can search for food in gardens and backyards. Public attitudes toward bears have improved over the last 10 years (European Commission 2013; Bear – Finland, Kojola).

Large carnivore damage prevention measures

In principle, damage prevention to succeed, either humans or carnivores should alter their behaviour. Guarding animals are a special type in the group of prevention measures as their working ability can be multidimensional. Fencing involves constructing a physical barrier that will keep human resources and carnivores apart. However, a Livestock Fence as such is normally not suitable to fulfil the role of a Carnivore Damage Prevention (CDP) fence as such. The general assessment is that usually electric fences are recommended, but also well built and maintained non-electric fences can be effective. The features of fences are carnivore and farm characteristic dependent (e.g. Reinhardt et al., 2012, Vidrich, 2002). Traditional fixed fences of mesh wire have been found effective against wolves if improved by applying electricity and a height up to 160 cm (Wam 2004a, 2004b). VerCauteren et al. (2012) describes that mesh wire fence is a commonly used method for deer farms raising red-or fallow deer (*Cervus elaphus* and *Dama dama*) in many European countries. Those fences are usually at least 180 cm, and prevent wolves from jumping or climbing over. However, these fences may also need protection against digging. In Spain a mesh wire fence 200 cm in height with barbed wire on top was tested. The fence was dug an additional 50 cm into the ground and proved to be 100% safe against wolves or stray dogs (LIFE – COEX C6, 2008). Mertens et al. (2002) and Cortés (2007) found that electric fences of 150 cm were effective against wolves. In Scandinavia electric fences with five wires or cords at 20, 40, 60, 90 and 120 cm above the ground have proven to be nearly wolf and bear proof (Levin, 2000; Wam et al., 2004).

Recommendations are to keep at least 4000–5000 V on the fence so the animals get not habituated to light electric shocks (Levin, 2000, 2005; Mertens et al., 2002; Vidrih, 2002). In Scandinavia mesh wire sheep fences are improved with a ground wire and an additional electric wire 10– 15 cm above the fence to prevent from climbing of lynx or bears (Levin, 2000, Wam et al., 2004). However, net fences cannot maintain high voltage over long distances like wire fences. In Germany electric sheep nets are the most popular method for fencing in sheep and goats (VerCauteren et al., 2012). The higher and closer the wires are (e.g. < 20 cm apart) for jumpers or the firmer the basements are for the sake of the crawlers, the better (Levin, 2002). Most of the wolves do not jump over fences and several countries do not usually have specific recommendations, except Sweden, where the removal of jumping wolves was attempted (Reinhardt et al., 2012).

Frightening measures are possible options to behavioural modification (Shivik, 2006). Repellents use disruptive stimuli e.g. visual or noise stimuli that affect carnivores' behaviour by frightening. However, the repellents can quickly become familiar and thus accustomed by carnivores.

White-tailed eagle population and damage prevention measures

White-tailed eagle (*Haliaeetus albicilla*) has its strongholds in Norway and Russia (which together hold >55% of the European population (BirdLife International 2013), and important populations in south-west Greenland, Sweden, Poland and Germany. Smaller numbers of breed exist e.g. in Iceland, United Kingdom, Finland, Estonia, Latvia, Lithuania, Belarus, Austria, Czech Republic, Slovakia and Slovenia. In Estonia the legal protection of nests and nest trees, started since 1957; in Finland 1926 (Council of Europe 2002). In Estonia white-tailed eagle is nesting (nearly 200 pairs) on the islands of Saaremaa and Hiiumaa and on the western coast of Estonia, but also on the coast of Lake Peipsi. In Finland white-tailed eagle is nesting mainly in coastal areas, around 200 pairs (http://wwf.fi).

Eagles rarely attack livestock close around buildings. However, fences are no constraint to eagles and any marks may not be able to observe. Sheep may only vanish from the pasture. White-tailed eagle predation is thought to occur because of lack of natural prey. The damaged individuals may have had a high probability of dying soon for other causes (Marquiss et. al., 2003). In Scottish study little evidence was found that white-tailed eagles would take live lambs (Simms et. al., 2010). However local impacts on individual farmers could be significant (Marquiss et. al., 2003; Simms et. al., 2010).

Frightening measures, sheltering, herding or feeding, if there is shortage of suitable prey for eagles, non-lethal prevention measures are possible. Eagles prefer relatively more open than brushy and wooded areas in where to take their prey. Newborn young lambs should be kept indoors or at least not in open areas until they are several weeks old. Herding of livestock can help, but as eagle may also adapt to existing conditions after some time humans may not frighten it any longer.

Frightening measures as sonic devices or scarecrows may not have long lasting effect because the adaptation capabilities of the eagles. LGDs as prevention measure are known but there is not much research on the effects of guard dogs to prevent eagle predation (c.f. e.g. Andelt 1992, Rigg 2001). In smaller pastures and not

Photo 2. A well built and maintained Carnivore Damage Prevention (CDP) fence can protect from ground predators but not from eagles..

Livestock Guarding Dogs (LGDs) as a prevention measure

Using LGDs as a measure of protection can be almost as old as domestication of production animals (e.g. Rigg, 2001, Landry et al., 2005, Gehring et al., 2010). The purpose of having LGDs was to minimize the damage caused by large carnivores to livestock. During the whole period of domestication the large carnivores have caused damages and harm to herdsman. Domesticated animals have always been an easier prey compared to wild ungulates and game. Domesticated animals are slower in motion, they stick together and stay at the same grazing areas, what makes them easy to catch. Livestock guarding breeds are among the oldest dog breeds in Europe (e.g. Topashka-Ancheva et al., 2009 and Savolainen et al., 2002) and the role of the flock guardian may have been one of the first tasks for the domesticated dog. In areas, where large carnivores almost disappeared, the tradition of using working LGDs also weakened (Linnell et al., 1996). In the regions where livestock still moves to open range pastures or high mountainous areas during summer and back down to the valleys during winter, LGDs are continually used as working dogs. This has been done for centuries e.g. in southern Europe as in France, Spain and Italy, where it is common for sheep to graze outside throughout the year. In Asia, Southern-, Middle- and Eastern-Europe benefiting from LGDs constitutes a tradition in the whole context of herding. Differently from these areas the method has been unknown or the knowledge has been lost in Northern Europe, e.g. Germany, Nordic and Baltic countries (Reinhardt et al., 2012). Due to the climate winter shelters have been used in wintertime for domestic animals and herders or enclosed pastures in summertime in those areas.

LGD breeds include e.g. the Akbash Dog, the Anatolian Shepherd Dog, the Caucasian Ovcharka, the Central-Asian Ovcharka, the Estrela Mountain Dog, the Great Pyrenees, the Pyrenean Mastiff, the Kangal Dog, the Komondor, the Kuvasz, the Maremma Sheepdog, the Polish Tatra Sheepdog, the Slovakian Cuvac and local variations, which can be very important locally. E.g. in Spain shepherds crossbred the Mastín mastiff with village dogs to get dogs that are quicker to run after wolves (Gehring et al., 2010). There are differences in opinion on the recognition or even spelling of breed names (Landry, 1999b). The exact list of the breeds regarded as a guarding dog can be different in different parts of the world, but as González et al. (2012) noted, also the mixed breed dogs can be effective in large carnivore damage prevention. However, their success may depend more heavily on the ability and willingness of herders to choose suitable individual dogs and train and use them properly. Below Table 1 presents a list of LGD breeds according to Rigg (2001).

Nowadays many of the known LGD breeds are white as it is preferable that they blend in with sheep and are more easily distinguished from predators. Coppinger and Coppinger (1978) described three aspects of behaviour required for a dog to succeed as a livestock guardian: it must be attentive (pays attention to and follows livestock), trustworthy (does not harm them) and protective (wards off external threats). LGDs are supposed to be alert but react only when a real disturbance occurs (Dawydiak & Sims, 2004). LGDs work by staying with the livestock and driving away intruders, any need for physical conflict rarely occurs (Rigg, 2004). LGD should be kept with, brought up with, socialised with and bonded with the stock it is going to protect (Coppinger, 1992). Often there is a need for more than one LGD to keep up necessary level of protection and to give the opportunity to work as a dog pack with divided duties as a contra force for a wolf pack.

In Europe after the return of large carnivores also interest towards the LGDs increased. During the last 20 years research involving LGDs as a preventive method has been carried out e.g. in Poland: Nowak and Myslajek, 2005; Smietana, 2005; in Portugal: Ribeiro and Petrucci-Fonseca, 2004; Ribeiro and Petrucci-Fonseca, 2005; in Slovakia: Rigg, 2005; in Sweden: Levin 2005. Several results confirmed the effectiveness of LGDs. In Portugal the damages decreased by 72% of those farms where adult LGDs were integrated. In Spain the number of attacks on flocks decreased by 61% per year after the dogs were introduced. LGDs reduced the damages in Mercantour, France by 81% of the fenced pastures, but only by 39% of the unfenced pastures. Livestock guarding dogs are regarded as an effective preventive method, especially in combination with electric fences. The decisive factor for the effectiveness of LGDs seems to be, in addition to the number of LGDs, that LGDs are raised and trained correctly (Reinhardt et al., 2012, Rigg, 2005).

Table 1. LGD breeds (Rigg, 2001).

Country/region of origin	Breed
Afghanistan	Sage Koochi
Bulgaria	Barachesto ovcharsko kuche (Barachesto) Karakachansko kuche (Karakatchan)
Caucasus	Kavkaskaya ovcharka (Caucasian Shepherd Dog, with Georgian, Armenian, Azerbaydjan and Dagestan varieties)
Croatia	Tornjak, Croatian Guard Dog
France	Patou des Pyrénées (Great Pyrenees), Briard, Alpine Shepherd Dog
Greece	Elinikos Pimenikos (Greek Shepherd Dog)
Hungary	Komondor, Kuvasz
Iran	Sage Mazandarani
Italy	Maremmano-Abruzzese (Maremma), Bergamo Shepherd Dog
Kirgizia	Kirgizkaya ovcharka (Kirgizian Shepherd Dog)
Mongolia	Buryato (Mongolian Livestock Guarding Dog)
Morocco	Aidi (Atlas Guard Dog or Chien de l'Atlas)
Nepal and northern India	Bhotia (Himalayan Mastiff)
Poland	Owczarek Podhalañski (Tatra Mountain Dog or Goral)
Portugal	Cão de Castro Laboreiro, Cão da Serra da Estrela, Rafeiro do Alentejo
Romania	Ciobanese romanesc Carpatin (Romanian Shepherd Dog), Ciobanesc romanesc Mioritic (Mioritic Shepherd Dog)
Russia	South Russian Ovtcharka, Stredneaziatskaya Ovcharka (Central Asian Shepherd), Iounjnorousskaia Ovcharka (Central Asian Shepherd)
Slovakia	Slovenský èuvaè (Slovak Chuvatch, Liptok)
Slovenia	Krasky Ovcar (Kras, Karst or Istrian Shepherd)
Spain	Pyrenean or Navarre Mastiff, Mastin Espagnol (Spanish Mastiff), Perro de Pastor Mallorquin
Switzerland	Great Swiss or Swiss Grand Bouvier, Bernese Mountain Dog or Bouvier, St. Bernard (?)
Tadjikistan	Dahmarda (Tadjikian Mastiff)
Tibet	Do-Khy (Tibetan Mastiff), Tibetan Kyi-Apso
Turkey	Akbash, Kangal Kopegi, Sivas Kangal or Karabash (Anatolian Mastiff or Shepherd Dog), Kars Dog, Kurd Steppe Dog
Turkmenistan	Alabay Koyunchi, Chokcha (Turkmenian Shepherd)
Uzbekistan	Torkuz, Sarkangik
Former Yugoslavia, Macedonia	Sharplaninatz (Yugoslavian Shepherd Dog)

In Nordic countries the use of LGDs for protecting sheep has been studied in Norway, Sweden and Finland (e.g. Hansen and Smith, 1999, Levin, 2005, Otstavel et al., 2009). However, Norwegian methods are not directly applicable at Estonian or Finnish conditions as Norwegian sheep, dependently on behaviour typical for local breeds, are widely dispersed on open range. Some countries recommend a minimum number of dogs: Switzerland, France and Germany (Saxony) recommend two dogs per flock, Poland one dog per 80 sheep and the Piedmont region of Italy and Sweden one dog per 100 sheep (Reinhardt et al., 2012).

In the United States LGDs have been introduced as a new method of guarding flocks. Research was initiated during the late 1970`s by several organizations to evaluate the use of guarding dogs to protect livestock from coyotes (*Canis latrans*) and feral dogs. A peak in popularity of LGDs began as lethal methods of predator control became banned (e.g. Green and Woodruff, 1999). In general LGDs were capable of reducing predation on sheep in a variety of management systems. (Linhart et al., 1979; Coppinger et al. 1983; Green and Woodruff 1983a, 1983b; Black and Green, 1985; Dawydiak & Sims, 2004). LGDs have been largely incorporated into western US sheep production operations; for example by 1993, 65 percent of the sheep producers in Colorado were using guard dogs (Andelt et al., 1999; Shivik, 2006).

Recent study made by VerCauteren et al. (2012) concerning the 'Use of livestock protection dogs for reducing predation and transmission of pathogens from wildlife to cattle' in Northern Michigan, USA and the Alps and Jura mountains of Europe showed that no livestock losses were attributed to predators on their Livestock Protection Dogs (LPD) -term sometimes used for LGDs- protected farms in the USA, whereas neighbouring unprotected farms experienced depredations (Gehring et al., 2010b). At European sites VerCauteren et al. (2012) observed a decrease if not a total disappearance of damage by wild boar. Wild boar can be a host for TB, thus the efficacy of LPDs against wild boar is important in reducing both damage and potential for transmission of pathogens to domestic livestock and exclusion through the use of LPDs (Gortazar et al., 2005). Concurrent avoidance by red deer of pastures protected by LPDs was also observed and a decrease in damage to livestock fences by wildlife. LGDs demonstrated the ability to effectively protect livestock when raised with attention to details such as building strong bonds with protected animals, minimizing potential to roam, and providing a suitable level of protection for the level of threat. LGDs found to be selected carefully and containment strategy to address predictable issues with routine predation on a cattle herd by an established pack of wolves in vast remote country may require deployment of several LPDs and of a breed suited for such a challenging situation.

In some situations only LGDs may not be sufficient alone, but may also require an integrated system of techniques to effectively address the issue as fences or lethal control or measures such as confinement of livestock at night. VerCauteren et al. (2012) notes that in the areas, where the use of LGDs for protecting cattle is still relatively uncommon, there is a need for further research and evaluation. LGDs can serve as a valuable, pro-active management tool that could be incorporated into common livestock husbandry practices to help reduce losses to predators and wildlife diseases. However, the public acceptance and understanding both by farmers and public institutions will determine the possibility of LGDs as a valuable tool for local countriside.

In Germany large carnivore (LC) damage prevention methods that may work there were recently evaluated (Reinhardt et al., 2012).

The goal for the project was to build up recommendations for livestock protection measures, prevention- and compensation payment schemes based on experiences in Germany and other European countries. The result was that probably there is no single livestock protection measure providing 100% safety. For German conditions a combination of electric fences and livestock guarding dogs as the most effective method was recommended. Often electric sheep nets are sufficient for reducing predation on sheep or goats as wolves or other carnivores rarely jump over fences. However the combination of electric fences and livestock guarding dogs (LGD) was regarded as the most effective . When using LGDs the authors recommended a constant support for LGD keepers as part of preventive system, especially LGDs; compensation should be coupled to prevention; in confirmed wolf areas the decision on granting compensation payments should be made by focusing on the correct use of preventive methods and not so much on whether the damage was caused by a wolf or a dog. (Reinhardt et al., 2012, p. 70).

In Italy Mattiello et al. (2012) found that there should be deeper and more longitudinal research of characteristics and risk factors of the farm locations, especially the farms with thick vegetation cover and closeness to the high density of wolves. The study was carried out in Val di Cecina, Southern District of Pisa (Tuscany, Italy). In this area, the stable presence of two wolf packs in the Berignone-Tatti and Monterufoli-Caselli Natural Reserves was confirmed. The results concerning the LGDs were somewhat ambivalent. The frequency of chronic damages was higher in farms with guardian dogs than in those without. However, 27% of the farmers declared that there was a reduction of damages events following the introduction of guardian dogs. Guardian dogs were present in 52.1% of the farms.

The commonest breeds were Maremmano, Great Pyrenees and Caucasian shepherds. They were present mainly on large farms (with an average of more than 500 sheep/farm), and the average number of sheep per guardian dog was 119.5 ± 12.0 (min 20, max 325). Possible explanations seemed to be that the conditions for carnivore attacks were favourable on these farms; the flocks were big, vegetation was thick and the average number of sheep per guardian dog was seemingly quite high. Authors called for further investigations to be carried out in order to test the effectiveness of suitable and properly used prevention measures.

More promising results reported from 'The LIFE COEX' project, which was implemented in Portugal, Spain, France, Italy and Croatia (Salvatori & Mertens, 2012). The aim of the project was to minimize problems and tackle socio-economic issues associated to the presence of wolves and bears in areas where they had disappeared for many decades ago. The rural communities had already abandoned some of the traditional practices used for protecting livestock from predator's attacks. The measures were adapted and implemented to local conditions. Achieved results were extremely positive, particularly in the areas where wolves are expanding. As an example, after installation of electric large carnivore prevention fences, for example in Portugal the damage suffered by holdings from wolf attacks decreased by 100%, in

Spain 99% and in Italy58%. In France and Croatia measures were adopted for intersectoral involvement (tourism and agriculture), which have contributed to the development of a participatory approach for wolf management, e.g. ecotourism activities in the French Pyrenees, in Croatia, in Italy and in Portugal were supported.

Satisfaction of the new LGD owners in Italy was very high, with 72–90 % of the holders interviewed declaring to be very satisfied with the dogs. Livestock guarding dogs seemed to require assistance for at least the first two years of pup life. If emphasized of the cost/effectiveness reasons, the farms with considerable damages are probably often the most interested in LGDs. Although the damage suffered can also be importantly emotional. The satisfaction of holding owners where fences were installed was positive in 85.2% of the interviewed sample, declaring that the fences were easy to use and manage, provided security at night and were effective also against other predators next to wolf. However, the correct use of electric fences should be monitored constantly. All the holdings in Portugal and Spain expressed their degree of satisfaction as Very satisfied. Prevention of damage and assisting livestock owners in testing and adopting new measures assessed to have higher probability to be a long-term solution of conflicts between wolf and humans than just compensation of damages suffered (Salvatori & Mertens, 2012).

In Estonia and Finland due to the pasturing season lasting only half of the year, finding the correct balance between dog bonding to the family and livestock should be practised. Traditional approaches emphasize the importance of minimal human interaction with dogs (e.g. Lorenz and Coppinger, 1987; Green and Woodruff, 1999; Hansen and Smith, 1999). Too much human interaction may cause LGDs to be less effective in protecting livestock due to desire to be with humans instead of remaining with sheep or cattle. However, puppies should be familiarized enough so that the farmers could handle LGDs for training, transport, or health care (VerCauteren et al., 2012). The LGD has also to be socialized to people and places outside their own territory (e.g Davydiak & Sims, 2004). In any case, the LGDs are individuals with their unique traits and hence also the selecting and raising an effective LGD is always somewhat unpredictable and different task.

Photo 3. However the most effective is regarded a combination of electric fences and LGDs.

THE AIM OF THE STUDY

The objective of this research was to study the possibilities of farmers to enhance the safety on pastures against large carnivores and white-tailed eagle predation and benefit from the use of large carnivore prevention methods, especially using LGDs at Estonian and Finnish coastal area and islands.

The aim was to explore the large carnivore damage preventive measures used in the conditions of the subproject area of Saaremaa, Hiiumaa, Harjumaa and Pärnumaa in Estonia, and of Turku Archipelago (Åbo Skärgård) in Finland. The special aim was to describe the themes of local conditions and practices arising on subproject farms.

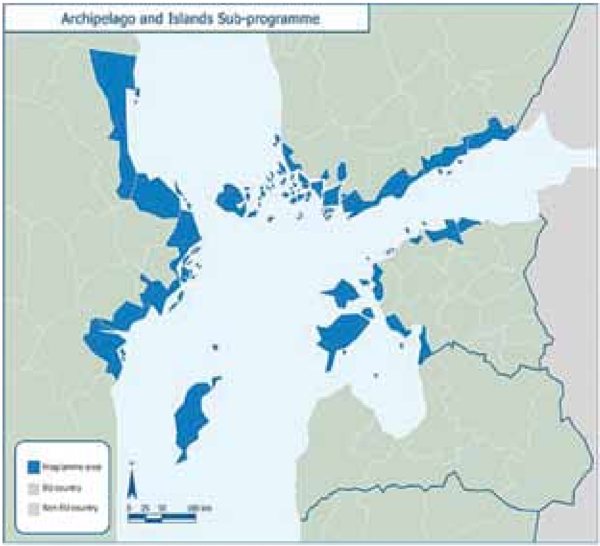
MATERIALS AND METHODS

The research methods included analysis of local knowledge cases from the project farms about the conditions concerning large carnivore and eagle damage prevention measures used on the farms. During the research conducted data collection through visits on the project farms and the (semi-structured) interviews and narratives gathered from the farmers. The perspective was local knowledge driven; starting from participating farms and stakeholders, e.g. three interactive seminars for communication and training the farmers to use LGDs were carried out at Saaremaa, Hiiumaa and Pargas.

The number of the farms included in the project was dependent on the enthusiasm of the farmers who voluntarily agreed to buy LGD puppies on their own cost. As the first step it was tried to find farms having time and being willing to participate in the research. Also farms already using LGDs were searched for in the project area. Two of them (EF1 and EF2) were found in the Estonian project area. Not a single farm in the Finnish project area using LGDs was found in 2011. There were several farms in Finland who had started to use LGDs, some of them already for decades (Otstavel et al., 2009), but they were situated outside the project area which was covering only the South-Western coastal regions (see Map 1).

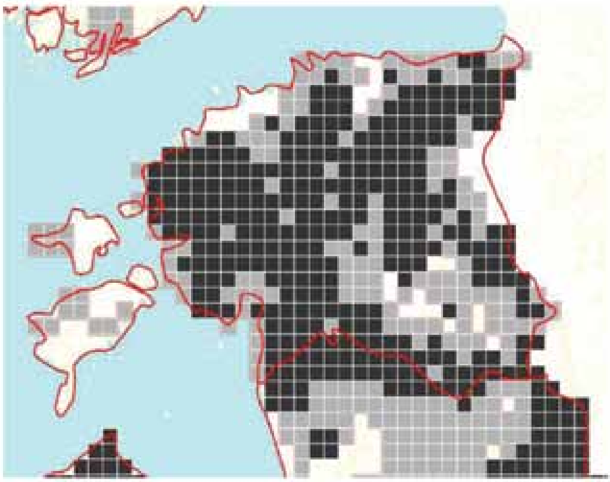
The subproject research activities were carried out on the islands of Saaremaa and Hiiumaa, as well as in Harjumaa and Pärnumaa coastal areas in Estonia, and in Turku Archipelago /Åbo Skärgård in South-Western Finland. Half of the Estonian farms were situated on coastal areas and half on the islands. All farms were located on islands in Finland. Locations were coded with EL(1–4); Estonia and FL(1–5); Finland. EL1 and EL3 located on the coastal areas.

The rates of predation on Finnish subproject farms were quite low compared to Estonian farms (see Table 2.). One reason, that was mentioned by locals, was a high density of European roe deer (*Capreolus capreolus*) as one of the main prey especially for lynx in the Finnish subproject area. In Estonian subproject area especially the wolf was returning to the subproject areas and possibility for predation was higher.

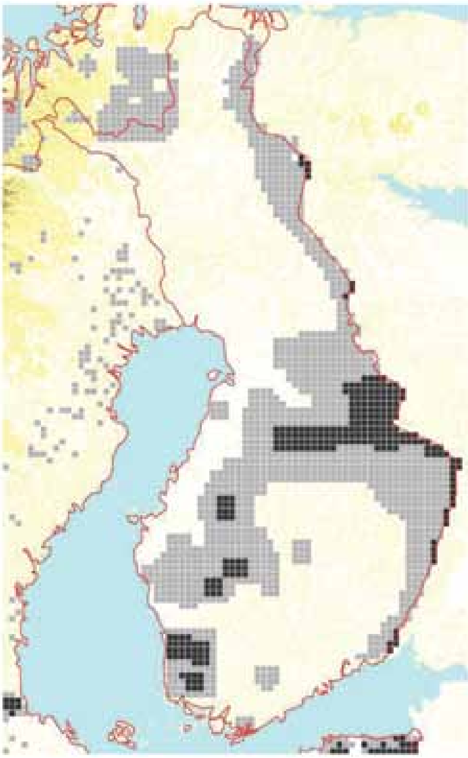


Map 1: The geographical coverage of the Archipelago and Islands Sub-programme area.

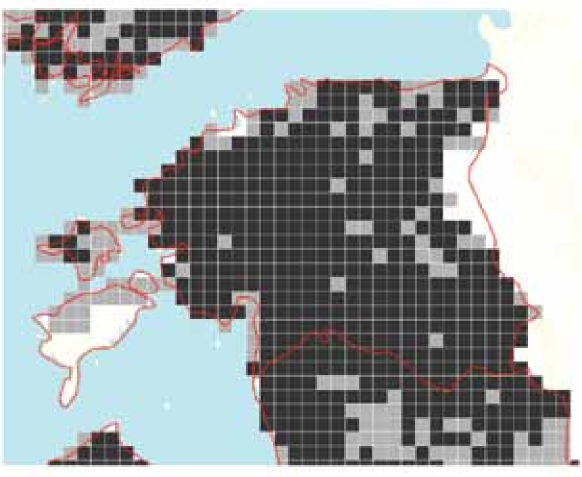
Project area and the density of large carnivores



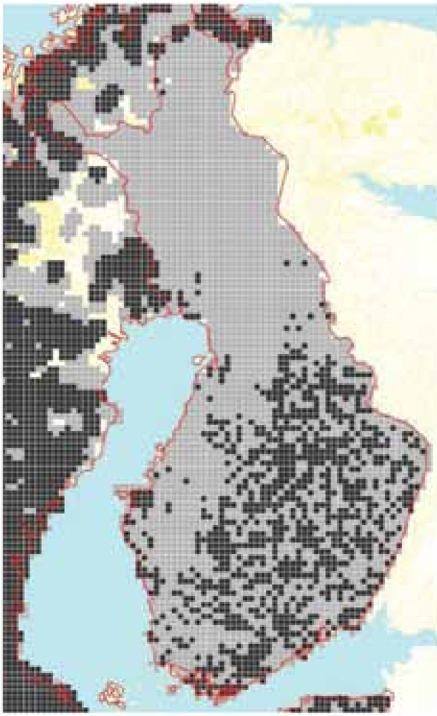
Map 2: Wolf distribution in Estonia 2008–2010. Männil, European Commission 2013. Dark cells: reproduction; grey cells: sporadic occurrence.



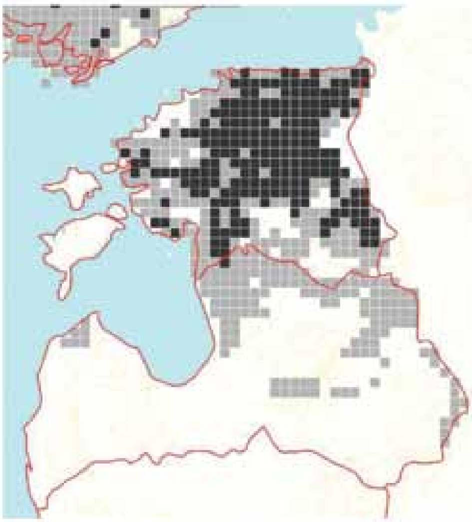
Map 3: Wolf distribution in Finland 2009–2011. Kojola, European Commission, 2013. Dark cells: reproduction; grey cells: sporadic occurrence.



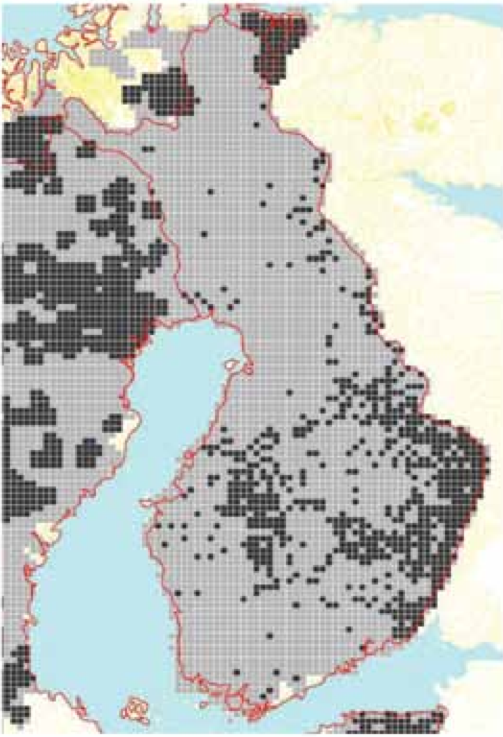
Map 4: Lynx distribution in Estonia 2008–2010. Männil, European Commission 2013. Dark cells: reproduction grey cells; sporadic occurrence.



Map 5: Lynx distribution in Finland 2009–2011. Holmala & Kojola, European Commission 2013. Dark cells: reproduction; grey cells: sporadic occurrence.



Map 6: Bear distribution in Estonia 2007–2010. Männil, European Commission 2013. Dark cells: reproduction; grey cells: sporadic occurrence.



Map 7: Bear distribution in Finland 2009–2012. Kojola, European Commission 2013. Dark cells: reproduction; grey cells: sporadic occurrence.

Farms of Estonian Islands and Coastal Areas

In the Estonian project area there were eight farms, which had time and were willing to participate (EF1-8) and that already had or took a positive consideration to acquiring LGDs.

EF1 can be called one of the pioneers of Estonian LGD pastoral practise. The farm was situated in EL1 with the amount of sheep < 80 in a semi-natural 11 ha pastoral area. They had acquired their Maremmano-Abruzzese LGDs in 2008, one male from Finland and one female from Switzerland. The farm was situated in the area with high density of wolf, brown bear, lynx but also fox (*Vulpes vulpes*) and white-tailed eagle population.

Table 2. Summary of described damage prevention themes

Farm / Year of acquiring LGDs	Number of LGDs	Reason for (not) acquiring LGD	Number of damages	Benefits from LGDs	Difficulties concerning LGDs	Other prevention measures
Estonia:						
EF1/ 2008	1 male, 1 female Maremmano-Abruzzese + 1 male puppy	In a natural park with high density of wolf, brown bear, lynx, fox and white-tailed eagle	0	Prevented attacks, from 2011 no depredation	No	No
EF2/ 2011	2 female Maremmano-Abruzzese, juvenile siblings	Wolf predation at 2010. High wolf, lynx and white-tailed eagle density area	10 sheep killed, 8 injured in 2010; 2 killed lambs by eagle 2012	No damage in areas guarded by LGDs	Same sex conflicts between juvenile siblings	No
EF3/ 2011	2 female ,Tatra Mountain Dog, juvenile siblings	Big damages caused by wolf starting in 2011	50 sheep killed in 2011, 30 sheep killed in 2012, many wounded	Only 1 attack on sheep in 2013; loss of 1 sheep	Same sex conflicts between juvenile siblings, chasing the sheep, ceased	Wolf damage protection fence in building process
EF4/ 2011	1 male Maremmano-Abruzzese juvenile	Lynx and white-tailed eagle area with nearby wolf and brown bear habitats < 10 km.	13 sheep killed by a pack of stray dogs, LGD on a leash	No damage in areas guarded by LGD	Chasing the sheep, ceased	No

Farm / Year of acquiring LGDs	**Number of LGDs**	**Reason for (not) acquiring LGD**	**Number of damages**	**Benefits from LGDs**	**Difficulties concerning LGDs**	**Other prevention measures**
EF5/ 2011	1 female Maremmano-Abruzzese juvenile	Wolf, lynx and brown bear presence territories	No	No damages	No damages or behavioural problems	No
EF6/ 2011	1 male and 1 female Slovak Chuvatch puppies	Suffered from lynx predation in 2011	3 sheep	No large carnivore or eagle damages	Adolescent insecure behaviour, chasing the sheep, ceased	Wolf damage protection fence in building process
EF7/ *2013*	1 male Pyrenean Mountain Dog juvenile	Unconfirmed eagle and fox predation on lambs, possibility of human interference	Possible uncounted sheep damage by humans before LGD	Not possible to evaluate yet	No	No
EF8	0	No damages	0			No
Finland:						
FF1/ 2011	1 male Maremmano-Abruzzese juvenile	High density of lynx, no damage	0	No damage	LGD wandering around, difficulties to stay at the pastures; not uncommon for juvenile	No

FF2/ 2012	1 male, a six year old (adult) Spanish Mastiff	High density of lynx, no damage, lifestyle	0	Not even fox attacks although poultry and ducks loose	No	No
FF3	0	Lynx and white-tailed eagle; few damages	Unknown predation ≤ 2 lambs or sheep			No
FF4	0	Lynx and white-tailed eagle, separate island, few damages	Unknown predation ≤ 2 lambs or sheep			No
FF5	Postponing the acquiring of LGDs	Lynx and white-tailed eagle presence, but no damages	0			No
FF6	Postponing the acquiring of LGDs	Lynx and white-tailed eagle presence, but no damages	0			No
FF7	LGDs possible in the future	White-tailed eagle presence, but no damages	0			No

EF2 with the amount of sheep <90 and goats <10 in the pastoral area < 10 ha located at EL3 suffered from wolf predation in 2010 (ten killed and eight injured). As situated in high wolf, lynx and white-tailed eagle density area including random bears, they decided to acquire LGDs in 2011 (two Maremmano-Abruzzese female siblings from the same litter).

EF3 located at EL4 with the amount of sheep < 450, horses < 7 and Highland Cattle < 20 in the pastoral area < 100 ha. The farm suffered from sudden wolf predation in 2011 (50 sheep killed, additionally many wounded but not counted). The area was earlier known as an island free from large carnivores, except the white-tailed eagle presence. In 2011, there however had developed a wolf pack littering successfully. The farm decided to acquire two Tatra Mountain Dog female siblings for semi-natural pastures in 2011.

EF4 located at EL1 with the amount of sheep < 30 and the pastoral area < 5 ha. The farm was at lynx and white-tailed eagle presence area with nearby wolf and brown bear habitats < 10 km. They decided to acquire a Maremmano-Abruzzese LGD male in 2011.

EF5 located at EL1 with the amount of sheep < 10 and the pastoral area < 5 ha. The farm was situated at wolf, lynx and brown bear presence territories. They decided to acquire a Maremmano-Abruzzese LGD female at 2011.

EF6 located at EL2 with the amount of sheep <250 and < 15 goats and the pastoral area < 25 ha. The farm was an organic farm suffering from lynx predation in 2011 (three killed sheep). EL2 island, differently from EL4 island, was a lynx population area, but similarly to EL4 got the reproductive wolf population in 2011. EF6 acquired two Slovak Chuvatch puppies, a male and a female, in 2011.

EF7 was an organic farm located at EL4 with the amount of sheep <100 and < 10 goats and with the pastoral area < 90 ha. The farm was situated in a high-density white-tailed eagle population area. They had suffered from unconfirmed eagle and fox predation on lambs, but as an exception they reported about yearly losses of adult sheep before Midsummer and Christmas period. Due to distant location of the pastures from human habitat, but still close to operated road, it raised a suspicion of possible human interference, what comes to the final fate of the adult sheep. As a preventive measure, the farm purchased a Pyrenean Mountain Dog in 2013.

EF8 was an organic farm situated in EL4 with the amount of sheep < 200 and with the pastoral area < 10 ha. The farm was situated close to wolf pack territory < 15 km and having continuous presence of fox at the pastures but had not suffered from any predation. They were considering acquiring LGDs, in case there occurs predation on their farm.

Farms at Finnish Islands and Coastal Areas

In Finland seven farms considered (FF1-FF7) a possibility of exploiting LGDs. Finnish farm FF1 was located at FL1 with the amount of sheep < 100 and pastoral area < 20 ha. They had been informed about the high density of lynx on the island. The farm had not suffered from predation but they considered it possible in the future. The pastures of F1 were around the farmyard giving a possibility to use the LGD. FF1 acquired a Maremmano-Abruzzese LGD male juvenile in 2011. Additionally to sheep FF1 raised goats, hens and horses.

FF2 with the amount of sheep < 10 and pastoral area < 2 ha was a small organic farm situated in FL2. The farm was in a lynx population area but had not suffered from predation. FF2 acquired a six year old (adult) male Spanish Mastiff LGD equally to protect livestock as well as a part of traditional lifestyle. FF2 was also keeping horses, hens and ducks.

FF3 with the amount of sheep < 100 and pastoral area < 50 ha was an organic farm situated at FL3 with lynx and white-tailed eagle population. FF3 suffered from unknown predation ≤ 2lambs or sheep yearly, but decided to postpone the purchasing of LGDs because of the big number of separately situated pasture sections in different locations possibly not suitable for LGD supervision. The other reason not to acquire LGDs was that the number of losses stayed yearly low and the farmers accepted them as a 'fee to the nature'.

FF4, with the amount of sheep < 100 and pastoral area < 50 ha was situated in FL2 with lynx and white-tailed eagle population. FF4 suffered, similarly to FF3, from unknown predation ≤ 2 lambs or sheep yearly, but decided to postpone the acquiring of LGDs because of the main summer pasture location on a separate island with an approach dependent on boat transport. The conditions were suitable for the sheep, but not easy for exploitation of LGDs because of the daily need of fodder for the dogs. The separated island conditions did not also support the supervision of LGDs to follow their desirable behaviour and give an opportunity for corrections.

FF5 with the amount of sheep < 20 and pastoral area < 10 ha situated at FL4 was similar to FF6 situated in FL5 with the amount of sheep < 30 and pastoral area < 20 ha. Both of the farms were situated in the areas, where lynx and white-tailed eagle presence had been recognized by local habitats, but neither of them had suffered from any predation, what was the reason for postponing the acquiring of LGDs.

FF7 located at FL4 got their sheep < 20 in 2012. FF7 was noticeable because of the different possibilities of pasturing sheep on very many different archipelago islands with the distance up to 50 km between the islands and with the possibility of territorial varying of pastoral area 0,5 < 300 ha. All the pastures were situated in the white-tailed eagle territories and some of them in the lynx territories, but as the sheep during the first grazing period were pasturing close to human habitation, there was no need for a LGD at that moment. The plan of the farmer about notable increase of the number of sheep could generate the need for LGDs in the future.

RESULTS AND DISCUSSION

There were, naturally, several features what changed during the subproject perid (2011–2013). Farms reported about the increase of the amount of sheep and pastoral areas, what was caused by the upside trend of sheep farming and sheep products consuming. There were also general comments from the local stakeholders about overall positive uprising effect of the 'KNOWSHEEP' – project for the economical activity of the farms. As an example the numbers of changes on farms: sheep increased at EF1 from 80 to 120, at EF6 from 250 to 300, at EF7 from 100 to 106 in Estonia and at FF7 from (0) 20 to 25 in Finland. Pastoral areas increased at EF2 from 7 ha to 10 ha, at EF3 from 100 ha to 130 ha, at EF6 from 25 ha to 32 ha in Estonia and at FF7 from 250 ha to 300 ha in Finland.

On the other hand the eagle and large carnivore population location went through rapid changes causing depredation in such areas, where it was unknown earlier. The most dramatic changes were experienced at Hiiumaa and Saaremaa islands, where the wolf influence had been unknown for decades but due to cold winters and frozen sea enabled the migration of wolves to those islands with the result of severe predation on selected farms.

The numbers of LGDs on farms also changed. There were mainly farms who acquired LGDs during the project period, but also farms, who had to give away some of their LGDs. The most positive change in the amount of LGDs on farms was the birth of new litters. EF2 transferred one of their two female sisters to another farm because of the lack of compatibility and continuous struggle for position. After that both LGDs carried out their duty satisfactorily in two separate farms.

According to the traditional view it should be beneficial, if the LGD puppies are born on the farm in the middle of the stock and are the descendants of working dogs, because differences in temperament between dogs of the same breed may be greater than those between LGDs of different breeds (Dawydiak & Sims, 2004, Rigg, 2001, Lorenz, 1985). In our subproject there were half of the LGDs having working dog parents. It was not apparent that in the group of these farm cases there would have been clear causality for success of LGDs if the parents were working dogs or not.

However, as a result of this subproject there was successful breeding of farm background LGD puppies. Four litters have been born to the subproject farms: three litters for EF1 in 2010 (L1), 2012 (L2) and 2013 (L4) and one litter (L3) for EF6 in 2013. The LGD puppies from L1 and L2 were all sold to farms. Two puppies from L1 and three puppies from L2 were sold from Estonia to Finland. One of those male puppies from L2 is guarding thousands of free grazing geese on a farm in Eastern-Finland, as LGDs are also useful for guarding different types of domestic animals and poultry.

Farms ofn Estonian Islands and Coastal Areas

Estonian participating farm EF1 was aware of the high density of large carnivores, foxes and white-tailed eagles. Wolves where known to have a hide spot with a possible attempt to settle down at < 5 km distance from the farm, but they predated at neighbourhood sheep farm in 2011 at < 3 km into the other direction. To reach the destination the wolves had to circle EF1. Local habitats also informed about the presence of nine different brown bears in the surrounding national park section.

In June 2011 the female LGD got severe wounds in her head and front body, which needed 15 stitches to be treated. The veterinary, on the bases of the nature of the wounds and existing circumstances, concluded that it was high possibility that the wounds had been caused by a lynx. In August 2011 Ravens (*Corvus corax*) attacked a lamb, but due to the interference of LGDs it ended up only with the wounds in the head area. From 2011up to nowadays there has not been any depredation at EF1.

The litters in 2010 (L1), 2012 (L2) and 2013 (L4) born at EF1 among the sheep have a "working background" and were involved together with the older LGDs to real protective activities. The puppies also had a role model from the elder dogs, how to properly treat sheep and were punished by LGD parents for misbehaviour. A male puppy from L2 was kept on the farm EF1 to elevate the level of protection.

At EF2 a wolf attack took place in September 2010. There were ten sheep killed and eight injured. The farmers decided to acquire two LGDs. After that there has not been any depredation except one case in 2012. Until that they had already transferred the other female LGD sibling to another farm, so there was only one left. The predation occurred during the time the LGD was closed into the barn because of the heat. The sheep where attacked by white-tailed eagle with the result of two killed lambs. The LGD was not to be blamed for not being protective, as it did not have a chance to interfere with the situation.

EF3 suffered from severe wolf predation as well as in comparison with the project co-operation farms, but also in the whole Estonian scale. EL4 was known as large carnivore vacant area until 2010, when the first damages caused by wolves were reported (Estonian Environment Agency, 2013). In 2010 there was no predation towards the sheep of EF3, but in 2011 they lost 50 sheep as killed and uncountable amount of more or less wounded sheep, some of them in a need for veterinary care or even emergency slaughter. The reason for high predation rate was a nearby situated wolf den in 2011 and 2012. Most of the attacks happened in spring, as wolves were consuming food for the litter or in the autumn period, when the wolf pack started to move around together with the juveniles. The farmers got the picture, that their sheep were easy targets for training the juveniles. (Estonian Environment Agency, 2013)

EF3 started to put up wolf protection fences and acquired two Tatra Mountain Dog females from the same litter in the age of approximately six months. The idea of acquiring two LGDs was to achieve better protection coverage from the bigger number of LGDs but also to have playmates for each other to avoid playing with lambs.

In 2012 EF3 lost 30 sheep as killed and several suffered from injuries. There had been a progress in building wolf damage protection fences, but they did not surround all the pastoral areas because the building was time and especially finance consuming. The LGDs were from a kennel and did not have any "working background". They had not been raised up together with sheep, so they did not have any experience of guarding sheep. The age of acquiring around six months, as later could be seen, was also an obstacle to get bonded to the sheep.

EF3 had an experience of herding dogs but not an experience of LGDs. LGDs were not strictly located together with sheep, but had possibilities to spend time in pleasant activities with humans outside pastoral areas, which disturbed the bonding to the sheep. LGDs were allowed to have a possibility to chase sheep in the frames of a game and were not forbidden immediately. That caused injures for lambs and sheep and some losses of lambs and sheep, when LGDs were left together with the flock without human supervision. The two LGD females had also leadership and mutual problems to be solved, what shows, as well as on the bases of the example of EF2, that the benefits and disadvantages of acquiring two (female) puppies from the same litter should be considered first and foremost.

During the autumn 2012 more wolf damage protection fences were built at EF3 and it was paid more attention to discipline the LGDs for attentiveness (staying at the pastures together with sheep instead of searching for human company) and trustworthy (not being allowed to chase the sheep).

By 2013 the LGDs at EF3 were more experienced, there was a bigger coverage of wolf damage protection fences on the borders of the pastures and two wolves in 2011 and seven wolves in 2012 were captured on the island (Estonian Environment Agency, 2013). As a result of all these measures there has been this far only one attack on EF3 sheep in 2013, September, which ended up with a loss of one adult sheep. As a contribution to that it can be considered that there is not yet a total coverage of wolf protection fences around all the pastures and the pastures are all too big an area (< 130 ha) for two LGDs to be guarded. It is possible that the presence of LGDs broke off the ongoing wolf attack and diminished the losses. The farmers described a new behaviour of LGDs recognized after the predation had happened. One of the LGDs stayed with the killed sheep, while another went to alert the farmers and returned leading them to the place where the incident had happened. A week later a female adult wolf was captured a few kilometres from the pasture, the predation had taken place. LGDs at EF3 have started to carry out their responsibilities after the application period. The process seems to continue successfully.

EF4 and EF5 where similar by size (< 5 ha) but their location differed in urbanity level, in the nature of pastures but also in the amount of sheep. Both farms were situated at EL1. EF4 had started to raise sheep at 2005 and had < 30 sheep by 2011 located at the edge of the village on a cultural pasture surrounded with an electric fence. EF5 purchased their < 10 sheep in 2011 to a semi-natural pasture in wilderness surrounded by forest. Both of the farms acquired their LGDs in 2011 from the same litter.

EF4 had a male LGD with a high energy level, which caused situations of chasing the sheep; nevertheless the LGD had grown up at a sheep farm. The other reason for chasing the sheep was the behaviour of sheep, which were not used to the LGD, feared it and flocked together to rush to seek the shelter from the LGD to the barn. The LGD managed to irritate the farmers, who had challenges, what comes to LGDs special behaviour patterns. Those situations, instead of training proper behaviour, could end up chaining the LGD, what again raised the energy level of the LGD.

An attack by a pack of stray dogs towards sheep occurred while the LGD was tied up. Furious barking of the LGD on chain, unable to carry out protective measures, caught the farmers' attention. Thus the farmers managed to break off the attack after the pack of stray dogs had managed to chase the sheep into the barn and had injured or killed 13 sheep. After that incident more serious efforts were taken to teach the LGD trustworthy behaviour and to decrease the energy level in harmless ways. The LGD is nowadays, partly as a result of the training (including the farmers) but also due to bigger confidence, brought by aging, trusted to stay together with the sheep as well as kept at the pasture during the night time, while the sheep are in the barn, to lower the energy level. The process seems to continue successfully.

EF5 acquired their LGD in the same time together with sheep from the same farm as EF4. On behalf of the sheep being used to LGD together with the farmers trustful attitude and immediate correcting in cases of misbehaviour helped the young LGD to easily settle as a proper guard. No damages or behavioural problems have been reported from EF5.

EF6 acquired their LGD puppies from the country of origin, but the LGDs did not have a farm background. The pick was made by an experienced local breeder and the idea of acquiring two puppies together with an age difference of one month was to enable to fulfil the need for playing without focusing the playing behaviour at the sheep. As the LGDs were acquired before the winter period, when sheep in Estonia are traditionally kept in a barn, the puppies also were accommodated together with the sheep. During the presence of farmers while feeding and milking the sheep or carrying out other work inside the barn, the LGD juveniles were under supervision, but the rest of the time they started to mishandle the situation.

To avoid letting the juveniles to chase the sheep, what sometimes ended up with wounding the sheep, they were bard into a small pen for the time period, when there was no human supervision. That, as an opposite, caused accumulation of energy for the juveniles. The pen was not firm enough to hold the juvenile LGDs and after liberating themselves they chased goatlings and lambs sometimes with mortal results for some of them. The pen was strengthened to stop the killings, but it did not solve the energy accumulation problem. Neither did it add self-confidence to the LGD juveniles.

The farmers were advised to significantly add the time and possibilities of supervised freedom in the sense of time and space, but it was challenging for them to commit because of the large amount of other farm work waiting to be carried out. In the beginning of grazing period of 2012 the LGDs refused to stay together with sheep at the pastures, which could have been caused by the habit of living in the barn in a small pen with no need for independent choices to be made. Behaviour of the LGDs in the pasture was also very insecure, what could lead to chasing the sheep in the pastures or the trespassers. Deserting the pasture was also common for the juveniles.

On the other hand, differently from the puppies of the same sex from the same litter, these LGDs did not have any medial conflicts. With the help of improving the pasture fences, supervised training and separating the LGDs during the female was bringing up the litter in 2013, both of the LGDs stopped chasing the flock. The male LGD has still problems with staying with the sheep in the pastures but it can be allowed now to move around loosely in the farm territory. The female is staying with the puppies in a one-hectare pasture area with some self-secure sheep and goats. No chasing of the flock has been recognized neither by the females nor by the puppies. This process also seems to continue towards a better direction.

EF7 was one of the farms, which considered acquiring LGDs when contacted in 2011. The practical need leaded to the solution in 2013. As the sheep mainly delivered in the pasture, it was hard to count the losses of newborn lambs to the white-tailed eagles. White-tailed eagles are specialized to patrol on the ground besides the delivering sheep and it was counted 16 white-tailed eagles in the end of the summer 2011 circulating at the same time nearby EF7 (authors fieldwork observations). During the farm visit in September 2013 the juvenile LGD was six months old, attentive, trustworthy and human tolerant at that moment. It was too early to expect protectiveness from this young LGD.

EF8 has survived so far without damages. The farmers had not recognized even the foxes, constantly present at the pasture, causing no newborn lamb depredation. It remains unclear, if there exists some kind of truce between those two species, or are the farmers just tolerant towards foxes. As there has not occurred any wolf predation, even if the pastures are suitable and easy to guard for LGDs, the LGDs are still not on agenda.

Farms of Finnish Islands and Coastal Areas

FF1 got their LGD from the same litter as EF2. Due to the cold winter the juvenile LGD was kept in the human residence instead of the barn. The LGD grew up human tolerant but still in 2013 preferred to stay at the farmyard instead of the pastures. There has not been any predation this far, but the farmers hope that in case there occurs some alert at the pastures surrounding the farmyard, the LGD is capable to react protectively. The other special trait for this LGD was wandering around in nearby enclosures, which is not uncommon for young

Photo 4. The traditional view is, that it should be beneficial, if the LGD puppies are born at farm in the middle of the stock and are the descendants of working dogs.

LGDs. It raises a question, could it benefit the effectiveness of guarding, if the LGD is familiar with the surroundings of the farm and in the same time leaves marks about its presence on a wider area.

FF2 did not face any difficulties with their LGD. FF2 acquired a LGD, who was six years old. It came well along with all the different animals at the farm including other dogs. They reported that not a single fox had approached their farm, although they have poultry and ducks wandering loose at the territory. The other explanation (additionally to the age factor) could be the calm and trustful attitude of the farmers towards the LGD.

FF3-FF7 have not yet made a decision of acquiring LGDs.

It seems to be essential that it is worth to predict the need of flock protection and to acquire the LGDs preventively, as it can take several years until LGDs start to be an effective and protective tool against large carnivore predation as the example of EF2, EF3, EF4, EF6 and EF7 shows to us.

CONCLUSIONS

This study was a part of the 'KNOWSHEEP' – project, an Archipelago and Islands Sub-programme of 'The Central Baltic INTERREG IV A Programme 2007–2013'. The subproject 'Livestock Guarding Dogs (LGDs) for sheep' was included in the topic of 'Safety on Pastures'. In a wider sense, the aim of 'KNOWSHEEP' was to improve the environmental conditions and increase the attractiveness of the regions, better sheep security and economic welfare (e.g. possibility to carry on feeding on semi-natural meadows without serious large carnivore damages and a drop of profitability in sheep farming). The activities of the subproject 'Livestock Guarding Dogs (LGDs) for sheep' were carried out at Saaremaa and Hiiumaa islands, as well as at Harjumaa and Pärnumaa coastal areas in Estonia, and at Turku Archipelago (Åbo Skärgård) in Finland.

The objective was to study the possibilities of the farmers to enhance the safety on pastures against large carnivore and eagle predation and benefit from the use of large carnivore prevention methods, especially using LGDs on Estonian and Finnish coastal areas and islands. The aim was to explore and describe the themes found studying local conditions and practices arising at subproject farms.

The main result was that the large carnivore damage prevention was possible by using LGDs, even highly successful in some cases, but needed some effort depending on the background conditions of the farms and the individual traits of LGDs. It was also essential that the farmers were able to invest their time for LGD-suitable training.

The experiences from the farms also showed, that the background of working LGD ancestors does not guarantee the desirable traits. It was not apparent, that in the group of these farm cases there would have been clear causality for success of LGDs, if the parents were working LGDs or not. Individual behavioural traits, pasture conditions, behaviour of sheep, farmers' experience for training LGDs, density of predators, types and characteristics of carnivores nearby and several other variables influenced the future success of a LGD as an individual. When using the LGDs, it is useful to notice; that sometimes it is an alternative to move a LGD to other conditions and that in these new surroundings LGD can be successful although it was not earlier.

Photo 5. Characteristics of the farm and geographical surroundings have to be taken into account. If pastures are shattered like in archipelago area or split by fences, an extra effort might be needed to end up with a result of satisfactory protection and a confident LGD.

This study focused on local experiences in narrow but interesting and unique archipelago areas. In these conditions with difficulties to build up fences or use frightening measures, LGDs can be highly effective because they are more flexible to use. The results showed that the used number of LGDs should be sufficient in relation to the guarded animals, suitable individuals in relation to context on the farm in question and well trained. It was also found that an ordinary livestock fence naturally did not function like a proper carnivore damage prevention fence. There was no possibility to estimate closer how different kind of frightening measures or different types of fences might be suitable in archipelago conditions because in the group of project farms they were not widely used. LGDs were mentioned by farmers as a tool also for white-tailed eagle damage prevention, and some success was described. However there was still shortage of observations of eagle attacks and the topic remained for future research. For conservation management of white-tailed eagle the damage prevention is an important topic especially in archipelago and coastal areas.

Reinhardt et al. (2012) recommended for German context e.g.: "Most effective appears to be a combination of electric fences and livestock guarding dogs (LGD). However, it will be imperative to provide shepherds not only with dogs but also with expert advice on the raising and training of these dogs. When compensation is not coupled with prevention the incentive to use prevention measures accurately may be weak. Summarised results of this subproject are much in line with the Reinhardt et al. (2012) results and consider training of the new users of LGDs as a necessary action in the areas where no former tradition of LGDs exists.

A notable difference between Estonian and Finnish farms in this subproject was the difference of damages. On Estonian farms LGDs were concrete answers to attacks and damages but in Finland more towards the fear of damages in future and a way to increase general feeling of safety towards any intruders e.g. reducing danger of transmission of animal diseases from unwanted visitors or wildlife to cattle (c.f. VerCauteren et al., 2012).

The results supported the possibility of a much wider use of LGDs, if the costs, and assistance with the measures could be developed towards better suitability to the practical contexts on the farms and integration with other applicable prevention tools. The positive trend of diminishing attacks and damages among the case farms could be found during subproject period. In order to assure post-project positive trend in the subproject area and enhance the sustainable conservation in other parts of the Baltic sea area, further research of damage prevention measures in different contexts and the guidance of their use as well as cooperative and incentive processes will be needed to secure both humans well-being on farms and also economical prospects. Nowadays rural areas need every economic income possible both from e.g. the eco-tourism or hunting and from traditional farming.

Summary of the aspects when using LGDs on the basis of this subproject:

- LGDs can prevent large carnivore damages and may have a function also towards other unwanted visitors.
- Successful working behaviour manages for a LGD sometimes quite easily, but occasionally longer time is needed.

Photo 6 Using LGDs improves the welfare of domestic animals not being killed, large predators not suffering from the conflict with humans and LGDs being able to carry out their natural behaviour.

- Time planned in advance and efforts made for LGD training support LGDs later success.
- Acquiring a working background LGD was not the only answer for success in the frames of this subproject, but the suitability of the individual LGD was also emphatic.
- Rarely merely young LGDs may leave their flocks for chasing game but they may exhibit excessive play behaviour and hence injure sheep. The immediate correction training is then required, and also a relocating of the LGD together with more self-confident sheep (livestock) individuals might help.
- LGDs need to be carefully managed also to avoid problems of LGDs being overly protective towards strangers.
- Characteristics of the farm and geographical surroundings have to be taken into account. If pastures are shattered, like in archipelago area, or split by fences, an extra effort might be needed to end up with a result of satisfactory protection and a confident LGD.
- LGDs may prevent also eagle predation, but this was not witnessed

during the subproject. It has to be taken in consideration the very different features of attacks coming from the air, when planning the protection system and selecting LGDs.

- At agro tourism farms an efficient LGD can be an income generating attraction for visitors and one necessary tool in prevention and controlling risks of animal diseases.
- Financial supporting of preventive measures can help to reduce the predation on livestock. Lower or no predation at all does not only save the lives of livestock but diminishes also the injures, veterinary costs, stress for farmers and animals.
- Effective preventive measures can be cost effective in many senses but sometimes the results are achieved in a longer run.
- Functional preventive measures support animal welfare from the point of view of livestock not hurt and LGDs enable to carry out typical behaviour. Predators profit from better attitudes and less persecution.

REFERENCES

Andelt,T. W. F. 1992. Effectiveness of livestock guarding dogs for reducing predation on domestic sheep. *Wildlife Society Bulletin* 20:55–62.

Bangs, E. & Shivik, J. A. 2001. Wolf conflict with livestock in the north-western United States. *Carnivore Damage Prevention News* 3:2–5.

BirdLife International. 2013. Species factsheet: Haliaeetus albicilla. Downloaded from http://www.birdlife.org on 10/2013.

Bisi, J. & Kurki, S. 2008. *The wolf debate in Finland. Expectations and objectives for the management of the wolf population at regional and national level*. Publications 12, Ruralia Institute, University of Helsinki, Seinäjoki.

Black, H. L. & Green, J. S. 1985. Navajo use of mixed-breed dogs for management of predators. *J. Range Manage*. 38: 11–15, 1985.

Boitani, L., 2000. *Action plan for the conservation of Wolves in Europe (Canis lupus).* No. 113. 1–85. Bern Convention, Strasbourg Cedex, Council of Europe, Nature and Environment.

Bombford, M., & O'Brien, P. H. 1990. Sonic deterrents in animal damage control: a review of device tests and effectiveness. *Wildlife Society Bulletin* 18:411–422.

Coppinger, L. 1992. Sheepdog environments in the Old World. Dog Log. *Livestock Guard Dog Association 2*: 12–14, 1992.

Coppinger, R. & Coppinger, L. 1978. *Livestock guarding dogs*. Hampshire College, Amherst MA., 1978.

Council of Europe. 2002. Convention on the conservation of Europe wildlife and natural habitats. Action Plan for the conservation of White-tailed Sea Eagle (Haliaeetus albicilla). Standing Committee 22nd meeting, Strasbourg, 2–5 December 2002.

Dawydiak, O. & Sims, D. 2004 *Livestock Protection Dogs – Selection, Care and Training*. Second Edition. Alpine Blue Ribbon Books, Loveland Colorado, 2004.

Estonian Environment Agency. 2013. *Status of Game populations in Estonia and proposal for hunting in 2013.* Koostajad: Männil, P., Veeroja, R.

European Commission 2013. *Status, management and distribution of large carnivores – bear, lynx, wolf & wolverine – in Europe. March 2013, Part 2.* (cited Wolf: Männil, P. & Kojola, I.; Lynx: Männil, P., Holmala K. & Kojola, I.; Bear: Männil, P. & Kojola, I.).

Gehring, T. M. Vercauteren, K. C. & Landry, J.-M. 2010. Livestock Protection Dogs in the 21st Century: Is an Ancient Tool Relevant to Modern Conservation Challenges? *BioScience* April 2010 / Vol. 60 No. 4.

González, A.o, Novaro, A., Funes, M., Pailacura, O., Bolgeri, M. J. & Walker, S., 2012. Mixed-breed guarding dogs reduce conflict between goat herders and native carnivores in Patagonia. *Human–Wildlife Interactions* 6(2):327–334, Fall 2012.

Gortazar, C., Ferroglio, E., Höfle, U., Frölich, K. &Vicente, J., 2007. Diseases shared between wildlife and livestock: a European perspective. *Eur. J.Wildl. Res.* 53, 241–256.

Green, J. S. & Woodruff, R. A.. 1990. Livestock guarding dogs: protecting sheep from predators. *US Department of Agriculture Agricultural Information Bulletin* No 588. pp 31.

Green, J. S. & Woodruff, R. A. 1983. The use of three breeds of dog to protect rangeland sheep from predators. *Appl. An. Ethol.* 11: 141–161, 1983.

Hansen, I., Staaland, T. & Ringsø, A. 2002. Patrolling with Livestock Guard Dogs: A Potential Method to Reduce Predation on Sheep. *Acta Agriculturae Scandinavica*: Section A, Animal Science 52 (1): 43–48.

Hansen, J. & Smith, M-E. 1999. Livestock Guarding dogs in Norway part II: different working regimes*. J. Range Manage.* 52 (4): 312–316, 1999.

Jansson, E. 2013. *Past and present genetic diversity and structure of the Finnish wolf population*. Acta Universitatis Ouluensis, A Scientiae Rerum Naturalium 608.

Kaartinen, S. 2011. *Space use and habitat sekection ot the wolf (canis lupus) in human altered environment in Finland*. Acta Universitatis Ouluensis. A Scientiae Rerum Naturalium 570. University of Oulu. 2011.

Karlsson, J. & Sjöström, M. 2011. Subsidized Fencing of Livestock as a Means of Increasing Tolerance for Wolves. *Ecology and Society*, 16.

Kojola, I. & Kuittinen, J. 2002: Wolf attacks on dogs in Finland. *Wildlife Society Bulletin* 30: 498–501.

Kojola, I., Helle, P. & Heikkinen, S. 2011. Recent changes in wolf population in Finland based on various data sets. *Suomen Riista* 57: 55–62 (in Finnish with English summary).

Kojola, I., Ronkainen, S., Hakala, A., Heikkinen, S. & Kokko, S. 2004: Interactions between wolves Canis lupus and dogs C. familiaris in Finland. *Wildlife Biology* 10: 101–105.

Landry, J.-M. 1999. The use of guard dogs in the Swiss Alps: a first analysis. KORA report.

Levin, M., 2000. Electrical fence against large predators. *Carnivore Damage Prevention News* No. 2: 6–7.

Levin, M., 2002. How to prevent Damage from Large Predators with Electric Fences. *Carnivore Damage Prevention News* No. 5: 5–8.

Levin, M., 2005. Livestock Guarding Dogs in Sweden: a Preliminary Report. *Carnivore Damage Prevention News* No. 8: 8–9.

Linhart, S. B., Sterner, R. T., Carrigan, T. C.& Henne, D. R. 1979. Kommondor guard dogs reduce sheep losses to coyotes: a preliminary evaluation*. J. Range Manage.* 35: 238–241, 1979.

Linnell, J. D. C., Smith, M. E., Odden, J., Kaczensky, P. & Swenson, J. E. 1996. Strategies for the reduction of carnivore-livestock conflicts: a review. Carnivores and sheep farming and Norway 4. *NINA Opdragsmelding* 443:1–118.

Linnell, J. D. C., Swenson, J. E. & Andersen, R. 2001. Predators and people: conservation of large carnivores is possible at high human densities if management policy is favourable. *Animal Conservation* (2001) 4, 345–349.

Lorenz, J. R. 1985. Introducing livestock-guarding dogs. Extension Circular 1224/ June. Oregon

Männil, P. & Kont, R. (edit.) 2012. *Action plan for conservation and management of wolf, lynx and brown bear in Estonia in 2012–2021* (in Estonian). Ministry of the Environment.

Männil, P., Veeroja, R. & Tõnisson, J. 2011. *Status of Game populations in Estonia and proposal for hunting in 2011* (in Estonian with English summary and figures). Estonian Environment Information Centre. http://www.keskkonnainfo.ee/failid/ULUKITE_SEIREARUANNE_2011.pdf

Marquiss, M., Madders, M., Irvine, J., & Carss, D. N. 2003. *The impact of Whitetailed Eagles on Sheep Farming on Mull*. Final Report. Centre for Ecology and Hydrology, Banchory.

Mattiello, S., Bresciani, T., Gaggero, S. Russo, C. & Mazzarone, V. 2012. Sheep predation: Characteristics and risk factors. *Small Ruminant Research*, Volume 105, Issues 1–3, June 2012, Pages 315–320.

Meadows, L, & Knowlton, F. F. 2000. Efficacy of guard llamas to reduce canine predation on domestic sheep. *Wildlife Society Bulletin* 28:614–622.

Milner, J. M. & Redpath, S. M. 2013. *Building an evidence base for managing species conflict in Scotland*. Scottish Natural Heritage Commissioned Report No. 611.

Nowak, S. & Mysłajek, R. W. 2004. Livestock guarding dogs in the western part of the polish Carpathians. *Carnivore Damage Prev. News* 1, 13–17.

Otstavel, T.,Vuori, K., Sims, D. E., Valros, A., Vainio, O. &Saloniemi, H. 2009. The First Experience of Livestock Guarding Dogs (LGD)Preventing Large Carnivore Damages in Finland. *Estonian Journal of Ecology*, 58.

Pulliainen, E. 1980: The status, structure and behavior of populations of the wolf (Canis l. lupus L.) along the Fenno-Soviet border. *Annales Zoologici Fennici* 17: 107–112.

Pulliainen, E.: Studies on the wolf (Canis lupus L.) in Finland. *Annales Zoologici Fennici* 2: 215–259, 1965.

Reinhardt, I., Rauerb, G., Kluth, G., Kaczensky, P., Knauer, F. & Wotschikowsky, U. 2012. Livestock protection methods applicable for Germany – a Country newly recolonized by wolves. *Hystrix, the Italian Journal of Mammalogy* ISSN 0394–1914 20th July 2012.

Ribeiro, S. & Petrucci-Fonseca, F., 2004. Recovering the Use of Livestock Guarding Dogs in Portugal: Results of a Long-Term Action. *Carnivore Damage Prevention News* No. 7:2–5.

Ribeiro, S. & Petrucci-Fonseca, F., 2005. The Use of Livestock Guarding Dogs in Portugal. *Carnivore Damage Prevention News* No. 9: 27–33.

Rigg, R. 2001. *Livestock guarding dogs: their current use world wide.* IUCN/SSC Canid Specialist Group Occasional Paper No 1.

Rigg, R. 2004. *The extent of predation on livestock by large carnivores in Slovakia and mitigating carnivore-human conflict using livestock guarding dogs*. MSc. Thesis, University of Aberdeen, 2004

Rigg, R., Fino, S., Wechselberger, M., Gorman, M. L. & Sillero-Zubiri, C. et al. 2011. Mitigating carnivore-livestock conflict in Europe: lessons from Slovakia. *Oryx* 45. 2 (Apr 2011): 272–280.

Salvatori, V. & Mertens, A. D. 2012. Damage prevention methods in Europe: experiences from LIFE nature projects. . *Hystrix, It. J. Mamm*. (2012) 23(1): 73–79.

Savolainen, P., Zhang, Y., Luo, J., Lundeberg, J. & Leitner, T. 2002. Genetic evidence for an East Asian origin of domestic dogs. *Science* 298: 1610–1613, 2002.

Shivik, J. A. 2006. Tools for the Edge: What's New for Conserving Carnivores. *BioScience*. March 2006 / Vol. 56 No. 3.

Shivik, J. A., Treves A. & Callahan, P. 2003. Nonlethal techniques for managing predation: primary and secondary repellents. Conservation Biology 17:1531–1537.

Simms, I. C., Ormston, C. M., Somerwill, K. E., Cairns, C. L., Tobin, F. R., Judge. J. &Tomlinson, A. 2010. A pilot study into sea eagle predation on lambs in the Gairloch Area. Final Report, SNH.

Smietana, W. 2005. Use of Tatra Mountains Shepherd Dogs in the Bieszczady Mountains and Bieszczady Foothills, Poland. *Carnivore Damage Prevention News* No. 8: 10–12.

Stander, P. E. 1990. A suggested management strategy for stock raiding llions in Namibia. *South African Journal of Wildlife Management* 20:37–43.

Topashka-Ancheva, M., Gerasimova, Ts., Dinchev, V. & Dimitrov, K. 2009. Karayological data about the Bulgarian native dog breed "Karakachan dog". *Biotechnol. & Biotechnol.* EQ. 23/2009/SE.

VerCauteren, K. C., Lavelle, M. J., Gehring, T. M.& Landry, J.-M. 2012. Cow dogs: Use of livestock protection dogs for reducing predation and transmission of pathogens from wildlife to cattle. *Applied Animal Behaviour Science* 140 (2012) 128–136

Vidrih, A. 2002. Electric Fencing and Carnivore Damage Prevention. *Carnivore Damage Prevention News* No. 5:10–11.

Wam, H. K., 2004a. Reduced wolf attacks on sheep in Østfold. Norway using electric fencing. Carniv. *Damage Prev. News* 7, 12–13.

Wam, H. K., 2004b. A simple carnivore improvement of existing sheep fencing. *Carniv. Damage Prev. News* 7, 14–15.

KNOWSHEEP-PROJECT ON THE RESOURCES AND DEVELOPMENT NEEDS OF THE SHEEP INDUSTRY IN FINNISH AND ESTONIAN COASTAL AND ISLAND REGIONS

R. Räikkönen[1] and S. Kurppa[2]

[1] MTT Agrifood Research Finland, Latokartanonkaari 9, 00790 Helsinki, Finland; e-mail: raija.raikkonen@mtt.fi
[2] MTT Agrifood Research Finland, Myllytie 1, 31600 Jokioinen, Finland; e-mail: sirpa.kurppa@mtt.fi

Abstract. This article provides an overview of the characteristics of Finnish and Estonian coastal and island areas, the native sheep used in sheep husbandry, entrepreneur resources, the versatility of sheep entrepreneurship and related development needs and opportunities. Based on research results, a strategy and development plan for the region's sheep industry is drawn up for the coming 5–10 years.

Here, where arable land is a limited resource, many have found diversified rural entrepreneurship to be the only viable way of earning a sufficient livelihood. To run a multi-functional business, the entrepreneur needs to master many trades, and to know and follow the practices, recommendations, rules and regulations of each. Variable roles, low profitability and the burden of bureaucracy have left many struggling with stress and a shortage of time. Nowadays, agricultural subsidies are a necessary means to ensure the profitability of sheep husbandry.

Environmental factors have a considerable impact on the abilities and objectives of rural enterprises. From the sustainable development point of view point, the problem lies in the fact that ecological, social and economic aspects are not, in practice, interlinked. In sheep farming, for example, this is demonstrated by the entrepreneurs' inability to receive adequate compensation for their work in the production of public goods (landscaping and other ecosystem services).

Business model innovation and enterprise development, combined with

the present trendiness of sheep and sheep products, have, however, created new demand on the market and opened up opportunities for product innovation. When developing sheep products and services, customer orientation, customer proximity and associated accountability should be given priority; they should also be emphasised in client acquisition and marketing. Stronger networking between enterprises allows for increased volumes and improved cost-effectiveness.

For businesses, the adoption of a strategy-based approach would prove very useful. A sufficiently challenging and clear vision is a must. The roles of the network businesses can be divided to include both company-specific and joint strategic goals. Those involved should, however, agree on who is responsible for the achievement of the objectives. A roadmap is a good way not only of monitoring progress, but in the case of more demanding challenges also of considering additional measures.

Through a strategy process, both administrative changes and research-oriented development challenges can be advanced. Applied research based on the needs of livelihood is likely to provide solutions to the most challenging questions, and also contributes to administrative development. In addition to sheep-related enterprises, networking between the industry, research and administration is more crucial than ever. The development of the industry starts, however, with the entrepreneurs and their businesses.

Keywords: Sheep husbandry, business, rural entrepreneurship, strategy, roadmap, environment, networking

INTRODUCTION

The Baltic coastal and island regions are characterised by numerous meadows, grazing lands and forest pastures. These areas need grazing, clearing and grass cutting to remain open and for many plants, fungi and animal species to survive. Animals thrive on natural pastures, leaving arable land available for other uses. Thanks to the management of traditional biotopes (Photo 1), the beautiful rural scenery and image are preserved (Schulman, 2007). Animals limit the growth of plants and keep them low. This helps to diversify the flora, hampers the growth of reed and keeps the landscape open (Rannap et al., 2004).

Photo 1. Åland sheep grazing in an area of traditional rural biotopes in Rymättylä, Finland. Photo: Raija Räikkönen

Native breeds

Native breeds are breeds modified by the conditions of the local habitat. Many of them have special habitat-related features, such as the ability to adapt to cold, hot or arid climates, or to modest and one-sided diets. The build of the native sheep enables them to move about and live on rough terrain. The breeds have also built up a resistance to various animal diseases. Native breeds and products are associated with values of sustainable development, ecology, ethics and aesthetics (Karja & Lilja, 2007). These green values have already been utilised in the branding of the Eastern Finncattle, *kyyttö* (Finnish Cultural Foundation, 2009). The same idea could be expanded to the productisation of the archipelago sheep industry.

Finnsheep (Photo 2) is the original sheep breed of Finland. The breed is very well known internationally and has been exported to more than 40 countries. Finnsheep is especially appreciated for its fertility, a trait that remains one of the most important objectives of

Photo 2. Finnsheep. Photo: Finnsheep.fi 4 May 2011

breeding (Koivisto, 2009). Thanks to its reproductive abilities, Finnsheep is often used in breeding and crossbreeding programmes. There are fewer than 15,000 Finnsheep ewes left, of which 5,500 are in pure-bred breeding (Finnish Cultural Foundation, 2009). The survival of the breed is supported by active efforts.

Finnsheep is diverse, and used for both meat and wool production. Ewes weigh 65–75 kg and rams 85–105 kg. The most common colours are white, brown and black. The wool is of high quality and favoured particularly for its felting qualities. The breed also produces beautiful skins for various purposes (Finnsheep, 2011).

Finnsheep are efficient natural pasture grazers. They like to eat leaves and shoots from trees and bushes. As landscape conservators, Finnsheep not only sustain biodiversity, but also retain original breed traits (Finnsheep, 2011).

The isolation of the archipelago has helped the Åland sheep retain its natural characteristics. It was classified as a separate breed from the Finnsheep in a study mapping Nordic short-tailed sheep (Sikka, 2011). Ewes weigh 40 kg and rams 60 kg, making them smaller than Finnsheep. Most animals grow horns, which vary in shape and size. The breed comes in different colours: white, grey and black (Photo 3). Lambs are rarely single-coloured and the colour tends to become lighter with age. Åland sheep have many wool types (Sikka, 2011).

The breed is well-adapted to living in archipelagic conditions. It is small in size and moves nimbly across stones and rocks. When graz-

Photo 3. Åland sheep on Sikka Talu sheep farm in Rymättylä, Finland. Photo: Raija Räikkönen

ing, Åland sheep eat a variety of plants, favouring herbs, meadow plants and shrubs (HAMK, 2011).

As a natural breed, the preservation of the Åland sheep is considered an important part of Åland's culture. The breed produces wool, meat and skins. Due to its small size it cannot compete with meat breeds, but the meat can be sold as a delicacy or a luxury product. The skins are valued for their colour and fur qualities. The wool is used as a raw material for traditional handicrafts (Sikka, 2011).

There are only around 600 Estonian native sheep left. The animals are small in size: the ewes weigh 40 kg and the rams around 50 kg. Estonian native sheep have been found at several different locations in Estonia. (Kihnu, Ruhnu, Saaremaa, Hiiumaa, Virumaa, Setumaa, Viljandimaa). (Michelson, 2011). There are countless reasons for choosing one sheep breed over another. All breeds have meat- or wool-related qualities that appeal to producers. Character and other non-productive traits are also valued. Cultural, ecological, moral and social values increasingly contribute to native sheep rearing. The growing awareness of the diversity and genetics of the animals has also inspired producers to commit to the conservation of indigenous breeds (Karja & Lilja, 2007).

In sheep husbandry, the main line of production can entail meat production (lamb rearing), wool production, production and sale of breeding animals, further processing or the provision of landscaping services. Sheep may also be kept as pets or used to attract visitors to animal yards or farms (Tahkokallio, 2011).

Objectives of farms

In a farm economy that is based on family farms, the private side and the business side are firmly integrated. Work, living and leisure all take place on the farm, and the distinction between working time and free time is blurred. The life cycle of the enterprise merges with that of the family. If there is a successor, this has a greater impact on the risk-taking, contribution and objectives of the business than, for example, the entrepreneur's age. Continuity and constancy also contribute to management, planning and strategy selection (Timonen, 2000; Gasson & Errington, 1993).

Farms have different goals. According to Bridge, growth-oriented entrepreneurs seek to maximise their business opportunities. Small comfort zone businesses, on the other hand, generate enough revenue for owners to achieve their desired standard of living. Once this happens, the entrepreneur has no further motivation for business development. Lifestyle entrepreneurs are engaged in the business because that is their way of life (Bridge et al. 2003). For rural lifestyle entrepreneurs, entrepreneurship is one form of livelihood. Other aspects of life – work, daily routines, family and hobbies – are built around it (Lehtonen, 1999).

Many small businesses do not seek growth, but are content with their size. Commonly, the enterprise has been founded to create employment for the owner. A small business start-up is often motivated by a desire to engage in business in a more relaxed, less competitive setting (Haksever, 1996).

Detection of entrepreneurship opportunities

According to Shane and Venkataraman (2000), entrepreneurship starts with the existence and recognition of opportunities. Some are able to detect such opportunities while others are not. This may be explained by differences in the knowledge base, or in one's ability to see and interpret the world from a business perspective. The realisation of potential is linked to both the existence of opportunities and individual characteristics. Of personal traits, those depicting the situation in life, such as past experience and wealth, as well as differentiating traits, values, attitudes and the need for progression, are also important. Opportunities can consist, for example, of the volume of demand, the potential value of the business and industry characteristics. Opportunities can also relate to situations that primarily enhance current production or alter the functioning of the market (Shane & Venkataraman, 2000; Niittykangas, 2003).

The entrepreneurial process model (Figure 1) developed by Scott Shane (2003) illustrates the factors leading to the attainment of entrepreneurship. Individual properties include psychological and demographic factors. Psychological factors concern attitudes, values, needs, skills and perceptual abilities, as well as traits which in the persona of an entrepreneur often manifest themselves as innovativeness, determination and optimism. A typical entrepreneur is also characterised by energy, risk-taking and a desire for achievement. Demographic factors include, for example, age, sex, family, education and income. Environmental factors pertain to industry and the macro environment, i.e. government officials, economy and technology (Shane, 2003).

In addition to individual entrepreneurial traits, entrepreneurship depends on favourable environmental factors and on entrepreneurial opportunities that the person detects and deploys. Such opportunities are created by the properties of the industry, demand and the potential value of the business. The entrepreneur realises the business idea through resource acquisition, organisational planning and business strategy.

Responsibilities and restrictions constrain strategic choices by determining the framework in which the company must operate. Objectives are also shaped by the interests, background, values and goals of those involved in the enterprise (Ansoff & McDonnell, 1989). Due

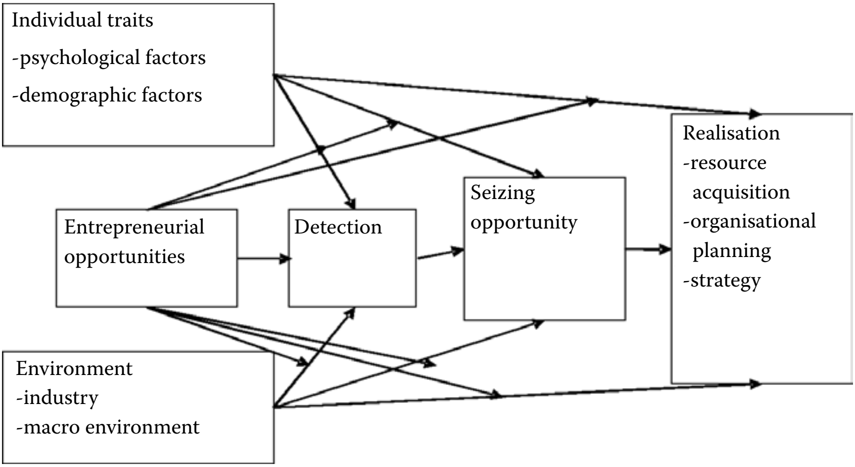


Figure 1. Entrepreneurial process model (Shane, 2003).

to their predominantly small family business background, business-related decisions on farms and in other rural enterprises tend to be based more on owner-entrepreneurship, personal values and motives than on other businesses. Additionally, the common EU agricultural policy sets its own requirements for agricultural entrepreneurs.

Entrepreneur persona

Kuratko and Hodgetts (2001) describe entrepreneurs as independent optimists who believe in their own ability to influence the outcome of the company. They are characterised by an ability to identify and capitalise on opportunities. Entrepreneurs are inventive and optimistic and have original ideas. They are committed to running the business, and show perseverance and resolution. They have a strong desire for achievement and skills in leading people. An entrepreneur is able to solve problems, seek feedback, tolerate ambiguity and take calculated risks. Reliability, tolerance of failure, a high energy level and innovativeness are also typical characteristics. Entrepreneurs understand the relationship between the magnitude of a risk and the amount of profit, and can quite accurately assess the potential of a risk. In the case of growth-oriented entrepreneurs, the company's priority areas are guided by their purposefulness. Achievement of objectives acts as the criterion of performance and determines the success of the business. In the 2000s, the list of entrepreneurial skills was complemented by Kuratko and Hodgetts, who added team-building and a heightened level of self-confidence to it (Kuratko & Hodgetts, 2001). Modern society requires increasingly diverse skills that need to be taken into account in continuous business development. These include, among others, networking, social media, new market channels and the heterogeneity of customer groups.

A certain leader type can be good at one point in the company's development, but as the situation changes, the company may need a different kind of leadership. We all identify possibilities and choose methods of action based on what we have learnt and think is best. Oftentimes, a person is not capable of radical changes in thinking even when the company's situation changes considerably. Management needs four areas of talent for a business to succeed: innovation; analysis-based development; conceptual thinking; and daily leadership (Lehtonen, 1999). If the operations on the farm change or expand, the entrepreneur is faced with added challenges and pressures.

Pyysiäinen and Vesala (2008) underscore three entrepreneurial skills which are essentially about an entrepreneur's ability to identify and utilise general business opportunities in relation to their own economic and social environment. The first is the recognition and dynamic realisation of business opportunities. The second is the utilisation of contacts and networks, through which the entrepreneur can locate new resources and means of implementation. The third is that an entrepreneur must be able to draw up a business strategy and evaluate its functionality (Pyysiäinen & Vesala, 2008).

Farm enterprise values and resources

Farm enterprises seldom emphasise maximised annual income or profit, but rather focus on security, continuity, reduced damage to the environment and capital accumulation. It seems that farm entrepreneurs have two distinct objectives that influence all target-setting: the first is to continue in the present occupation for its intrinsic rewards, such as working with nature, challenges and independence; and the second is to hand over a well-kept farm to the next generation. Family farms have coping mechanisms which do not exist in other companies, and which help in financially difficult times. Such mechanisms include settling for low earned income, accepting outside employment and replacing capital with own work (Timonen, 2000; Gasson & Errington, 1993).

Due to the versatile job description, the owner-manager has a good overall picture of the company. On the other hand, single-person leadership can be risky as no objective information is available. Daily routines may take up too much time, leaving long-term, strategic planning and goal-setting on the sidelines. Personal values, attitudes and preferences wield great influence on small business activities (Laaksonen et al., 2004).

Small business resources such as skills, expertise, time, manpower and funding are limited. Limited resources not only force a company to cope with uncertainty, but also lead to significant risks, as shared risk-taking is not an option (Bridge et al., 2003).

According to Ahlstedt and Laaksonen, small business investments are often dictated by necessity and associated with optimistic earnings expectations. Investment risks are often high (Ahlstedt, 1992; Laaksonen et al., 2004) and increased by uncertainties created by the EU's common agricultural policy.

Enterprise differentiation

Differentiation means standing out from competitors in an area that the customer finds important. The structure of the industry determines how competitors can differentiate themselves from one another. Uniqueness can relate to a product, service, content, intensity or technical feature, or to quality, company procedures or supervisory data. A differentiation strategy seeks to make the gap between the company's incurred costs and the value produced for the customer as wide and permanent as possible (Porter, 1988).

Forsman (1999) says that differentiation is based on unique resources that enable a company to gain a competitive edge on the market. In rural businesses, differentiation tends to focus on existing material resources, or on those gained by training or experience (Forsman, 1999).

Concentration

Through concentration, a company focuses on carefully defined clientele or a segment whose needs are known and can be met. Forsman (1999) believes that a segmentation strategy works well in small businesses, since their resources are limited. In segmentation, the overall market is divided into smaller, coherent entities – segments which are based on different customer needs. Here, the key is knowing how to differentiate products in a way in which large companies have no potential or interest, and thus avoid competition on unit prices (Forsman, 1999).

In concentration strategy, a precisely defined segment forms the company's target group. The company chooses a product or a market segment, or a group of segments, through which it pursues either differentiation or a cost advantage. It confines itself to a specific portion of customers or market needs, deliberately limits competition and focuses on specialised and concentrated skills and resources. In business, results are yielded through the right concentration of resources. With growth and success, a company can start to struggle, and thus lose sight of the source of its success (Kamensky, 2004). On multifunctional farms it can be difficult to distinguish profitable sectors on which to focus.

Diversification

A diversified farm is a farm where other non-agricultural entrepreneurial activities are also practised (Peltola, 2000; Vihtonen & Haverinen, 1995; Rantamäki-Lahtinen, 2009). Rural entrepreneurs have seen diversification either as a necessity brought about by natural or economic circumstances or as a solution to utilise material or immaterial resources more productively by implementing new business ideas (Alsos et al., 2002; Peltola, 2000). Rural areas often have unique resources, such as nature areas, which the entrepreneurs can use in their businesses. Entrepreneurs are skilful, and can better exploit their expertise through diversification. A chance to realise their creativity also adds to motivation (Haines & Davies, 1987).

Diversification by combining separate but closely associated sectors can generate considerable added value. A shared strategy of business units strengthens their competitive advantage. Diversification can tap into material, immaterial or competitor-related opportunities shared by the different areas. The company can make a strategic decision to start providing products or services that complement the existing range or entrust them to an outside provider (Porter, 1988).

The challenges of diversification relate to time management, identifying the core business, business and marketing knowledge, bureaucratic difficulties, lack of industry-specific expertise in advisor organisations and insufficient peer support. Diversification strengthens the enterprise's revenue base and compensates for the seasonality of farming. Even with a heavy workload, compared with traditional farming the mental rewards are greater. Experience of success derives from a certain entrepreneurial freedom, development of a new product or service, self-realisation and the diversity of work (Riusala & Siirilä, 2009).

Networking

Networking is one way of developing a company's business opportunities. Its key benefits include cost-savings in equipment, acquisition, transport and marketing costs. Capital does not need to be dispersed among various activities, and the incorporation of many small producers' products leads to greater volumes and improved delivery reliability. A network opens up possibilities for more diversified product and service entities. Joint marketing generates cost advantages and a centralised 'one stop shop' enhances customer service. A network allows entrepreneurs to focus more on their specific areas of expertise, and makes their work less of a strain. Workloads and peaks become easier to manage. Free time increases and work-related stress decreases. In addition, cooperation encourages the exchange of professional information and learning (Voutilainen et al., 2008).

Hobby farming

Sometimes strong, work-related emotions make professional image, actions and commercialism impossible to match. In the handicraft industry, for example, craftsmen's feelings and the desire to express themselves are important sources of motivation (Rintaniemi, 2002).

Not everyone wants to exploit the possibilities of entrepreneurship, but rather work more freely, in a hobby-like manner.

Marketing of products and services

According to Bridge, small businesses often serve local clients. A close relationship with clients may allow for better adaptability and flexibility (Bridge et al., 2003).

Marketing requires sound expertise in identifying the right channels, targeting and understanding consumer behaviour. The four Ps of marketing emphasise the roles of Product, Price, Place and Promotion when experiencing the value and benefit of a product. Consumers are divided into different groups, each with their own purchase criteria. When designing products, it is worth remembering that only a certain group of consumers will regard, say, low price as an important purchase decision criterion (Deliza & MacFie, 2001).

The contents of communication can have a major impact on the value of a product. Studies indicate that a message customised to consumers' attitudes, beliefs and behaviour has a more profound effect on their awareness and choices than a general message (Brinberg et al., 2000). Informative advertising supports the consumer's intention to change behaviour, while more emotional communication makes us like the product more (Dubé & Cantin, 2000). Brands may play a more significant role than previously thought, and brand-building should hence be given increasing attention (McClure et al., 2004).

Accountability

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). In today's information society, corporate social responsibility is a key success factor. Accountable business has become a permanent worldwide phenomenon. Companies are required to behave in an ethical, moral and open way (Dawkins & Lewis, 2003). Open communication is seen as the basic premise of accountability. Companies in the 21st century are not only expected to report on environmental responsibility, but also on economic and social accountability (Panapanaan et al., 2003).

Consumers, demand and customer-oriented business

Customers' needs are the prime mover behind a business plan. A company must be demand-, customer- and market-oriented. One of the key strategic features is the ability to stand out from the competition. Competitive advantages are factors that clients perceive as values and benefits, and which they then compare with other options. A successful strategy is based on the ability to combine and manage customer needs, competition, organisational knowledge and resources (Kamensky, 2004; Kamensky, 2010).

If the future seems uncertain, scenarios can help in understanding the strategic consequences of uncertainty. Porter says that a ”scenario is an internally consistent view of what the future might turn out to be” (Porter, 1988). Due to the uncertainty of the future, several different versions are drawn up. Scenarios are a helpful tool for predicting the future. Companies that are better at anticipating the changing operational environment have an advantage over their competitors. Scenarios may be constructed at different levels, such as those of industry, the national economy and the global economy. With scenarios, the risks jeopardising the company's operations can be identified early enough and problems avoided (Kamensky, 2010). In their business strategies, farms and rural enterprises should use scenarios or other similar means to prepare them for the future.

Strategy-building

A clearly drawn up strategy improves a company's performance in a rapidly changing business environment, or in cases where its operations come to a halt. It is also a necessary management tool when society lays down requirements which have a significant bearing on company objectives. The main purpose of the compilation and implementation of a strategy is to provide answers to the following two questions: how to choose the right direction of growth from among many uncertain alternatives, and how to redirect people's energy in the chosen direction. In order to be effective, strategic planning requires knowledge of both the company and the operating environment (Ansoff & McDonnell, 1989). In agriculture, the EU's common agricultural policy and related legislation also need to be taken into account when making strategic decisions.

Strategy is like the common thread in company operations. It helps to ensure the future success and profitability of a company. Strategy is about identifying the most important and relevant details from a much larger mass of information, and about an ability to form opinions. It necessitates thinking in an abstract, conceptual way, even if the final strategies must be concrete and pragmatic. Strategy answers the questions 'why' and 'what'. Its content depends on the level and angle of view, which means that the strategies of, for example, managers and employees, can be different. Strategy aims to differentiate among competitors, and requires both the ability and the courage to make informed choices from among different options, but also to refuse many good things. Even in the midst of constant changes one needs to create stability, because strategy is a perpetual process of development. Strategy must always be based on the identification and recognition of facts (Kamensky, 2004).

MATERIALS AND METHODS

As part of the KnowSheep project, MTT Agrifood Research Finland performed a structural survey in the Baltic coastal and island regions in the summer of 2011. The survey included open-ended questions and, for example, a SWOT analysis of the company and its business environment. The research questions tapped into the entrepreneur's background, distribution of sources of income, basic sheep husbandry, landscape management, enterprise resources and the goals and values of the business. It also inquired about the development of operations, cooperation, logistics, marketing and local strengths. The questionnaire was published in the MTT Report 110 (2013).

The questionnaire was translated into the native languages of those living in the project area: Finnish, Swedish and Estonian. The purpose of the survey was to determine the current situation of sheep husbandry, sheep farm resources, skills levels, development needs and objectives. The results formed the basis for the Baltic coastal and island area strategy, and for the development plan provided in the form of a road map for the next 5–10 years.

In Finland, the questionnaire was sent to the Åland Islands and to the archipelago and island municipalities. All farms with more than three sheep were included, amounting to a total of 196 farms. Of these, 63 responded, making the Finnish response rate 32%. The age distribution of the respondents corresponded to that of all sheep entrepreneurs in the area. The results covered all age groups. Of the respondents, 37 were women and 26 were men.

In Estonia, the same questionnaire was sent in an electronic format to 145 sheep husbandry farms. E-mail addresses were obtained from ERIA (the Estonian Research Institute of Agriculture). The farms were located in Saare, Lääne and Hiiu counties. Eight responded that they only reared sheep for their own use, and did not complete the questionnaire. Only 16 farms participated in the survey. It is likely that in Estonia the questionnaire only reached more advanced farms on which sheep husbandry is the main source of income and where the development project itself increased people's motivation to respond. On the islands of Saaremaa and Hiiumaa there are numerous small sheep farms that do not yet have computers. Thus, the questionnaire failed to reach all farms. In Estonia, a significant proportion of sheep are reared for family use only. In addition to the survey, the project included 21 interviews and workshops for both Finnish and Estonian sheep farmers.

RESULTS

In Finland, sheep husbandry is concentrated in the south-west of the country and on the Åland Islands. Most Finnish sheep farmers fall into the 40–65 age group. On average, 40–55-year-old entrepreneurs have the most sheep: around 100 animals. Most Estonian sheep farms are located on Saaremaa and Hiiumaa, where the sheep play an important role in landscape maintenance.

Characteristics of coastal and island region sheep husbandry

At the start of 2010 the Finnish farms responding to the survey had an average of 62 ewes. At the start of 2011 this number had increased slightly to 63, and the entrepreneurs estimated that this trend would continue, reaching 76 by 2015. In Finland, 83% of the survey area sheep are sold to slaughterhouses. Around 6% end up in own use, while the other 11% are sold live as summer sheep or breeding animals or due to discontinued production.

The majority of respondents kept Finnsheep. The next most common breeds were Texel, Åland sheep, Oxford Downs and mixed breeds, all with an equal share. A few farms had Gotlands, Kainuu grey sheep, Rygjas and Dorsets. Almost 50% of the Finnish farms kept only a single breed; 28% had two breeds; and 25% three or more breeds.

The breed had usually been selected based on the farm's line of production. In addition, some breeds had been more to the farmer's liking than others. The highest possible profit was not always the primary objective. Some respondents regarded the sheep as pets, or kept them for personal preferences or cultural reasons. Up to 11% thought that the breed they had was worth preserving. These included Finnish native breeds: Finnsheep, Åland sheep and Kainuu grey sheep. In Finland, the selection of breed depended largely on its meat, wool or skin. In Estonia, sheep have played an important role in post-independence landscaping, re-clearing areas covered by bushes and trees. Hence, in Estonia, suitability for landscaping was deemed the most important criterion for breed selection, followed by meat, wool and skin.

The responding Finnish farms' own pastures averaged 17.6 hectares. Leased pastures amounted to 25 hectares, and some 25.4 hectares were governed by a grazing agreement. The size of the contract area varied greatly from one farm to the next. Sheep are effective traditional landscape maintainers, and can graze on harsh terrain not suitable for farming. Natural pastures are used widely in Finnish and Estonian coastal and island areas. Sheep keep riverbanks open and reeds under control. Natural pasture grazing is one of the defining features of the project area's sheep husbandry.

According to the questionnaire, Finnish farms were 87.6% self-sufficient in roughage and 57.3% in concentrated fodder. The total degree of self-sufficiency was estimated at 77.4%. Self-sufficiency can have a favourable impact on the profitability of farms. Often smaller farms are not able to produce their own feed due to a lack of land, machinery, knowhow or time. To a hobby farmer, buying all feed from outside may prove to be the easiest option.

Coastal and island area sheep are used effectively and comprehensively (Figure 2). Meat is the most important sheep product. Next on the list of reasons for keeping sheep are landscaping, wool and skin. Sheep are also kept as pets, while some farms are acquainting themselves with animal-assisted therapy in the hope of steering their business towards 'Green Care' services. Sheep are small in size and easy to approach, and lambs especially evoke affection. A few farms milk sheep, provide their bones for dog food, or make horn jewellery. Sheep are also leased for shepherding training.

Of the coastal and island region sheep keepers who responded to the KnowSheep project questionnaire, 90% stated that entrepreneurship is small-scale and taxed under the Agriculture and Forestry Income Tax Act. For most, sheep husbandry is simply one part of their farm activities. Especially on farms with only a few sheep, the entrepreneurs often engaged in other businesses, such as further produc-

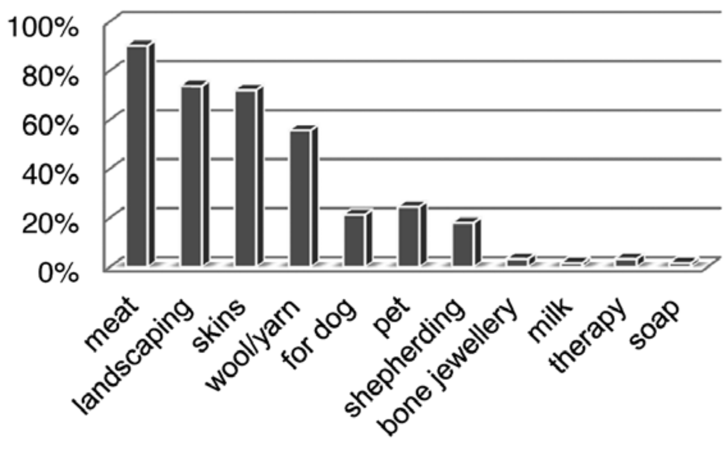


Figure 2. Sheep products utilised by farms (% of respondents).

tion or direct sales. The majority of respondents (over 70%) said that the total revenue generated by sheep rearing is less than €30,000. Only a few achieved a turnover of more than EUR 100,000, the average being EUR 22,000.

Several respondents saw the small scale and diversity of the business as an opportunity. Owner/manager combination is a defining characteristic of rural enterprises. The owners make decisions and implement the plans themselves. The farms are governed by the regulations and limitations of the EU's common agricultural policy, which has increased the recording and reporting of agriculture-related measures. In addition, regulations restrict the freedom of entrepreneurship more than before. The registration obligation has also introduced more paperwork to farmers' job descriptions. Many respondents regarded future uncertainty as a threat, and mentioned the unpredictability of the EU's common agricultural policy.

Investments

In Finland, the rearing of sheep usually takes place in an old cowshed, pigsty or stable. This way, an otherwise idle building can be put to use and the initial investments are small. With the expansion of production, more practical housing is often built. Such housing is designed for multi-purpose use in case the farmer later decides to replace sheep husbandry with something else. Greenhouse structures or old greenhouses can also be converted into sheep barns. Greenhouse sheep barns remain a rarity, but their numbers are increasing. Other buildings used to house sheep include cottages, barns, sheds and open shelters. Sheep can also be kept in old, roofed horizontal silos. In Estonia, most sheep are housed in buildings specially built or modified for the purpose, or in old livestock sheds or greenhouses.

In Finland, 21% of those responding to the MTT questionnaire had invested in a sheep barn in the previous five years, the average investment being EUR 48,700. Amounts invested ranged from a couple of thousand to hundreds of thousands of euros. Sheep keepers are building new sheds and actively renovating old ones. The average entrepreneur had spent EUR 14,900 on mechanising production and

EUR 2,000 on new animals. Over the five-year period, investments in enclosures and new transport equipment totalled EUR 5,100. In Estonia, most investments concerned sheep barns, mechanisation and new animals.

Over the next five-year period, investments related to building and animal stock are expected to continue in Finland, while in Estonia the biggest investments will be made in mechanisation and sheep barns. The quantity of investments is not estimated to change in a significant way. Over the next five years, Finnish sheep entrepreneurs are prepared to invest an average of EUR 40,000 in sheds, EUR 9,700 in mechanisation and EUR 2,000 in the purchase of animals.

Entrepreneurs' goals

Island and coastal region sheep husbandry is to a large extent small-scale entrepreneurship, attended to by one or two family members. Only in some cases had employees been hired from outside. Farms with more than 20 ewes were focused on sheep entrepreneurship, while for those with fewer than 20 ewes it was only one part of the business. Many sheep farms processed wool and skins to make a variety of products.

Of the Finnish respondents, 20% had an action plan, and almost 50% of the farms had set goals for the business. In Estonia, nearly 70% had set goals and close to 60% had drawn up a plan of action. This result indicates that only the more advanced Estonian farms responded to the survey.

Based on the KnowSheep survey, three types of entrepreneurship were identified (Figure 3). The first group consisted of meat-producing, growing farms (Objective 3). The second group included farms that wanted to keep the business 'family-sized' and to maintain the manageability and freedom of entrepreneurship (Objective 2). The third group was formed of those who saw sheep husbandry as a way of life, and to whom it generated necessary additional income or additional income not sufficient to develop the business further. In these cases, the entrepreneurs wanted to live a freer life, kept sheep in addition to their pension or had a job outside the farm (Objective 1).

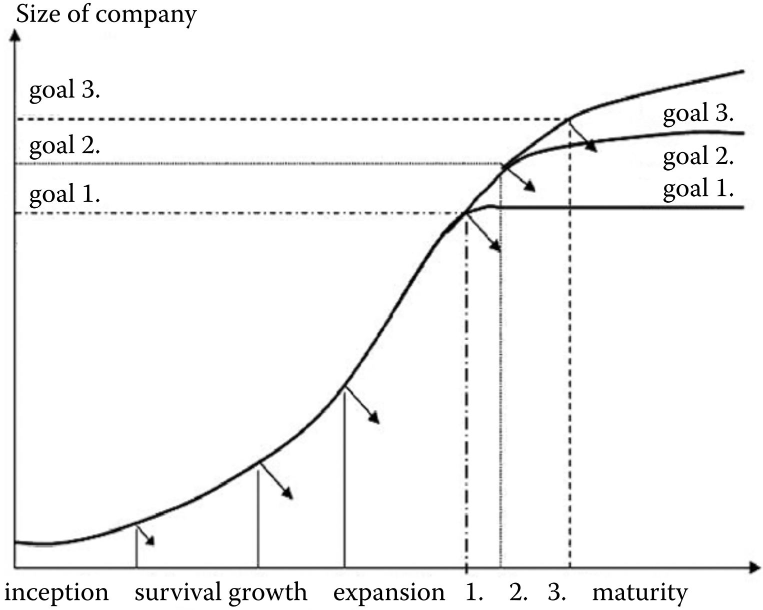


Figure 3. Company growth and rural entrepreneurs' goals. Adapted from Scott-Bruce's (1987) business growth stage model (Niittykangas 2003).

Based on the existing resources, some farms concentrated on sheep husbandry and looked to make their business grow through expansion and lamb meat production. To ease the workload, they had invested in machinery and buildings where the work could be done mechanically. However, many KnowSheep survey respondents felt that the size of the business suited their needs. These farms had found a suitable scale for the business and wanted to continue at the same level. Some farms wanted to keep sheep as a hobby. Lack of time and low profitability were mentioned as the greatest obstacles to the expansion of the business. Often, the lack of a successor did not motivate them to expand, and the farmers settled for the existing scale of production.

Many rural entrepreneurs want to keep their farms in family ownership, and the business is developed with the interests of future successors in mind. If there is no successor, operations are often scaled down according to the entrepreneur's own ability to cope. The rural environment can also provide for a calmer pace of life, which agrees with many keepers. They are content with an income sufficient to cover their daily living expenses. For many senior citizens, sheep provide a way of enriching their lives.

Issues of importance

The objectives of a rural enterprise are heavily influenced by the values of the entrepreneur. Here, unhurriedness, nature and entrepreneurial freedom ranked highest (Figure 4). Although the profitability of the business was important and something to which the entrepreneurs paid attention, company growth and profit maximisation were not the most significant issues.

Especially on multi-functional farms, biodiversity conservation and nature seemed to be close to people's hearts. Although freedom and unhurriedness were regarded as important on all farms regardless of their size, those with fewer sheep felt they had succeeded better at maintaining their entrepreneurial freedom. Multi-functional farms considered customer-specific flexibility very important.

The respondents feel that green values are of great importance. More than 80% felt that practices of sustainable development had brought added value to their business (Figure 5). Two-thirds agreed or completely agreed with the statement that ecology is an important aspect of their products, and that being environmentally friendly is something they can utilise in marketing. Almost 80% paid attention to minimising environmental load, and half will continue to improve the eco-efficiency of their business. The majority of respondents agreed or completely agreed that sheep husbandry is eco-friendly, and that biodiversity conservation is something they find personally important. The special conditions of the coastal and island regions lead to special requirements for the business, because the surrounding diverse nature easily perishes if ignored. Business and products need to be more and more accountable throughout the value chain. The development of local products and services with ecological and ethical value can generate exportable knowledge.

The number of sheep often depends on existing resources. Of all the surveyed entrepreneurs, 90% were of the opinion that the sheep

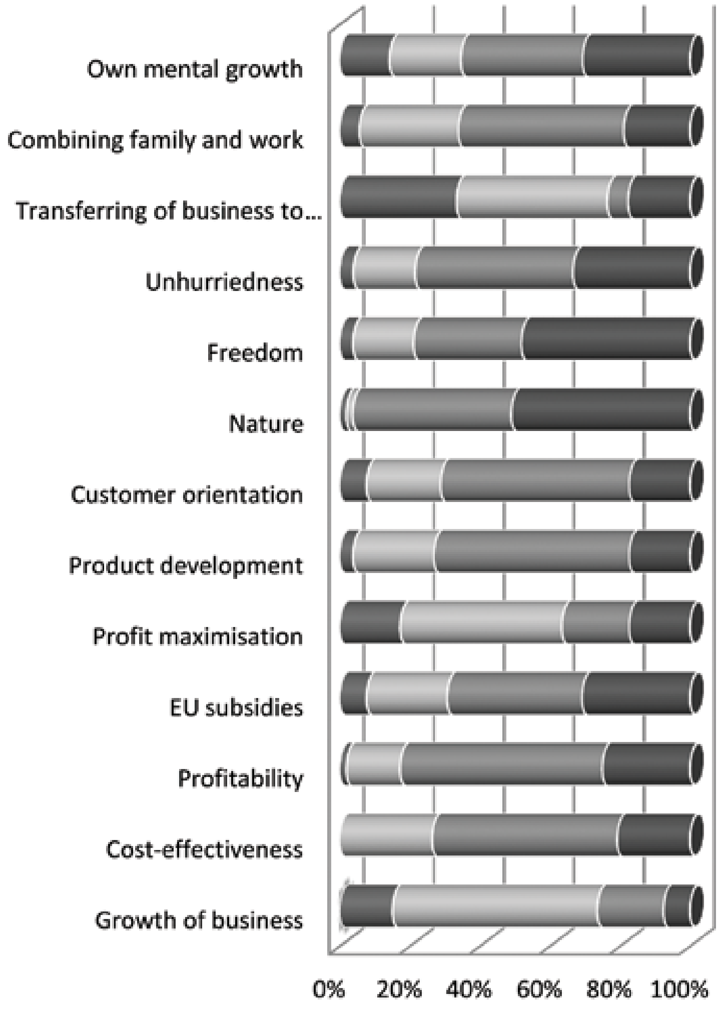


Figure 4. Important aspects of entrepreneurship.

industry's friendly image and green production values were important. Sustainable business practices were emphasised, and sheep husbandry was felt to be eco-friendly. Based on the survey, the ecology and aesthetics of sheep rearing are highly valued among entrepreneurs. They are prepared to act responsibly in their own area, and take responsibility for the welfare of the environment.

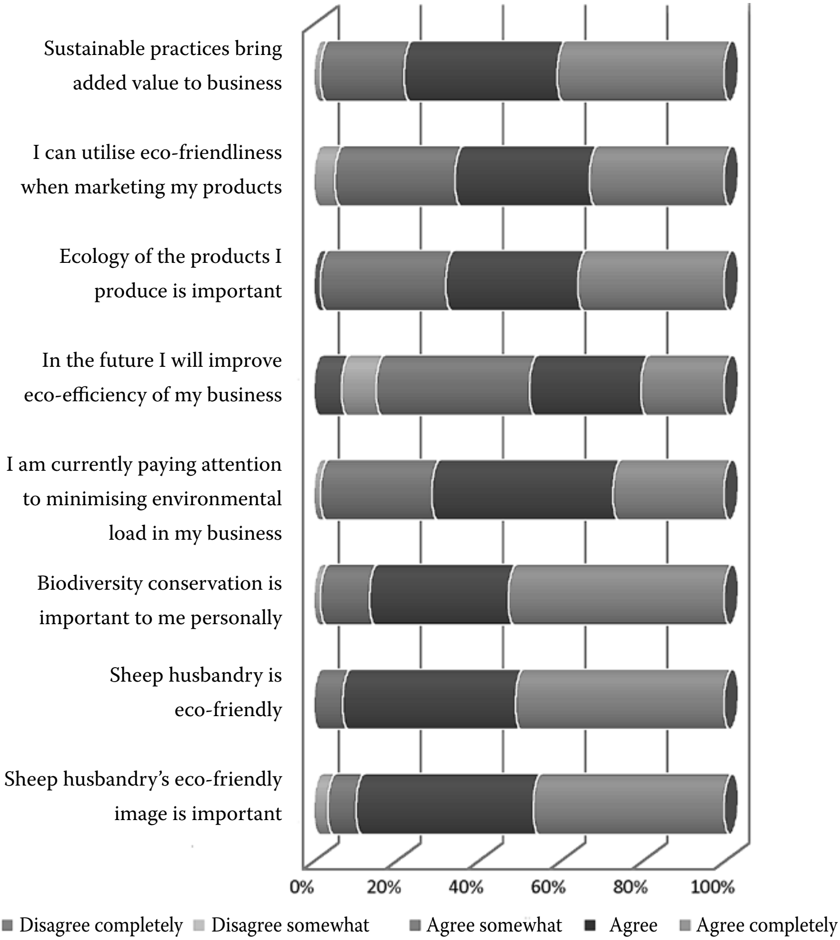


Figure 5. Entrepreneurs' opinions on green values in their production.

The KnowSheep respondents described the entrepreneurs in the region as independent, knowledgeable, versatile and experienced. They were felt to honour traditions and seek profitability in their businesses. Several entrepreneurs mentioned innovativeness, farm development and networking as their strengths. However, many lacked managerial skills, which is partly why further processing had remained a hobby or a very small-scale business.

Training and development needs

Of the responding Finnish and Estonian sheep farmers, around 60% had received entrepreneurship-related training. Professional training included secondary agricultural education programmes, polytechnic courses and university studies in the field of agriculture. Education had provided a firm foundation for running their business. The majority of those surveyed reported that they maintain their skills by reading trade magazines and attending courses. The entrepreneurs had also acquired key skills online, on field trips and through training. Around half of the Estonian respondents and 27% of the Finnish respondents had attended courses on sustainable development or eco-designing. Two-thirds of the Finns and nearly all of the Estonians said they were interested in participating in sustainable development courses, should such courses be held. Sheep entrepreneurs were able to actively use their training in sheep husbandry or other aspects of their business.

The respondents were asked to assess their skills, or intangible resources, in business-related matters. There was very little variation in these skills between the two countries. More than half of those surveyed felt they had no knowledge or very little knowledge of predicting agricultural policy. Many estimated themselves as having moderate skills, very little skill or no skills at all in marketing, sales and product design. The entrepreneurs also found their time management skills lacking. More than half of the entrepreneurs felt they were good or excellent at people management. Both in Finland and Estonia, improvement in sales, marketing, product design and long-term planning were considered particularly important.

SWOT analysis

When assessing the current state of their enterprise and the business environment (Figure 6), the respondents mentioned small production volumes, lack of time and ability to cope as their greatest weaknesses. For most, EU bureaucracy, coping, loss of health and future uncertainty posed the biggest threats. The unprofitability of the sheep industry and animal-related risks were also perceived as threatening. A few entrepreneurs in the region were intimidated by the parcelling out and sale of pastures to summer residents. Sheep entrepreneurs in

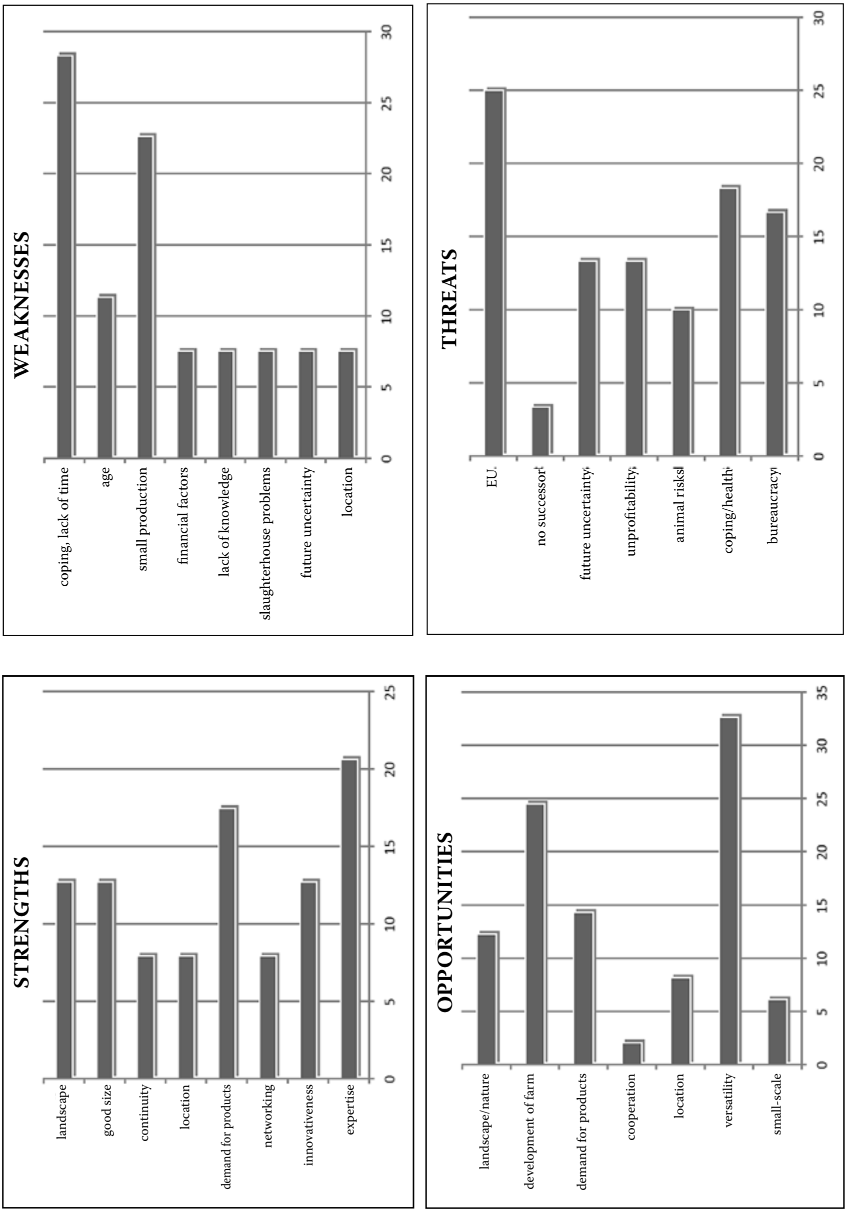


Figure 6. SWOT of sheep industry in Baltic coastal and island regions (% of respondents).

both the Finnish and Estonian coastal and island areas listed expertise, demand for products, innovation and landscaping as their strengths. Many also liked the location of their farm and the size of their company. In regard to opportunities, many entrepreneurs saw potential in diversification and business development.

The key strengths of the surrounding area included unique nature, security, tranquillity and rural landscapes. Markets, events and traditional craft and food culture were perceived as worth preserving. Grazing, fishing and island traditions, as well as the preservation of old rural estates, were also considered important. The entrepreneurs emphasised the significance and impact of nature and landscape on their businesses.

Profitability monitoring

More than 40% of the Finnish respondents monitored company profitability via tax accounting or bookkeeping. Another 17% utilised income statement and balance sheet data, while 23% used bank statements. Only 14% relied on estimates, and 3% did not monitor profitability at all. Multi-functional farms with fewer sheep proved more likely to use estimation than large sheep farms. Of the Estonian respondents, 24% used bookkeeping to track profitability, another 24% utilised income statement and balance sheet data and 36% used bank statements. Only 12% relied on estimates, and 4% did not monitor profitability in any way. Both the Finnish and the Estonian sheep entrepreneurs track the profitability of their operations and thus have a good opportunity to use the accumulated data to lead their businesses in an even more profitable direction.

The majority of respondents assessed the turnover of sheep husbandry to be around EUR 20,000 per year, including sales revenue and possible subsidies. Of the business or entrepreneur's total net income (100%), sheep husbandry made up, on average, around 35% (Figure 7). The respondents expected to see a slight increase in sheep-generated revenue over the next five years. On average, forestry accounted for around 15% of overall income, while the share of other agricultural and horticultural products was more than 40%. Tourism accounted

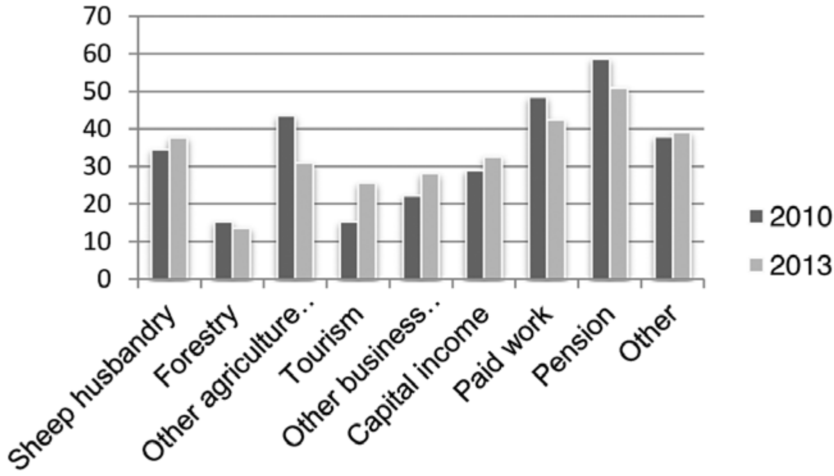


Figure 7. Income distribution in 2010 and estimate for 2013 (%).

for 15% of average income and was expected to rise to over 25% in the future. Other business income, such as further processing and direct sales, was estimated at 20%, but was expected to be close to 30% in the future.

However, the majority of respondents estimated that their income from tourism or other activities was far below EUR 10,000, which reflects the scale and diversity of the businesses. On the other hand, some of the larger multi-functional farms had concentrated heavily on tourism or another line of business. For most, capital income accounted for less than 10% of overall income, and this proportion was expected to show only a slight increase. According to the survey, a few farms had invested significant amounts of capital income in the business. Paid work made up less than 40% of average net income, while the pension share was estimated at around 60%. On this basis, we can conclude that sheep husbandry often continues after retirement. The proportion of other sources of income was less than 40%.

Cooperation and networking

According to the Finnish respondents, cooperation between sheep entrepreneurs was limited to machine service entrepreneurs, financial and tax return specialists, further processing businesses and other sheep production entrepreneurs. Other forms of company cooperation related to slaughtering, further processing, grazing and gratuitous services. Multi-functional farms were keener than others to cooperate with tourism service providers and various village and neighbourhood associations. Big sheep farms, for their part, were more likely to work with lobbying organisations and machine service providers and to make joint acquisitions for supplies of input.

In Estonia, company cooperation existed in further processing, gratuitous services and sales. The respondents reported active cooperation between sheep entrepreneurs, nature conservation organisations and other sheep producers, and some cooperation with further processing companies, restaurants, machine service providers and associations.

Cooperation between sheep production entrepreneurs and their interest groups leaves room for improvement. Although the entrepreneurs are burdened with too much work and a lack of time, they do not tend to outsource any aspects of their work or utilise the expertise of others.

Marketing

Rural entrepreneurs in the coastal and island regions mainly sold their products and services through traditional market channels. Due to limited production capacity, there was little marketing and market cooperation. When production is small-scale, marketing efforts can be targeted at the neighbouring area. As the business expands, more customers are needed, and the company must decide which marketing channels are best-suited to reaching the desired customer segment.

Very few Finnish and Estonian sheep farms have conducted market or business environment surveys. Over 70% of the respondents targeted the local area when marketing their products and services. The average entrepreneur used two marketing channels, of which word-of-mouth and public events were most popular. One fifth of entrepreneurs had a website, and a few used other social networks. Some of the respondents did not market their products or services at all. A frequent customer list was maintained by 40% of the respondents, and a quarter offered loyalty benefits. Of the factors enhancing the competitiveness of their products, quality, cleanliness, ecology, locality, the entrepreneur's reputation and the welfare of the animals ranked highest.

Opportunities and future prospects of coastal and island region sheep husbandry

Returns from selling agricultural products are not sufficient to cover production costs. As such, EU subsidies play a significant role in maintaining the industry. According to the MTT survey, 70% of Finnish rural entrepreneurs regarded EU subsidies as important or very important, while in Estonia the corresponding figure was 100%.

Of the Finnish respondents, 44% agreed or completely agreed with the statement that sheep subsidies govern the operation of the farm, while 19% disagreed completely. In Estonia the corresponding figures were 63% and 6% respectively. Landscape management subsidies were considered particularly necessary, as public goods, freely available to all, are difficult to commercialise as chargeable services.

Based on the survey, the impact of subsidies varied in Finland and Estonia. Environmental aid and environmental special aid played an important role in Finnish sheep rearing, while on a number of farms the investment subsidy and subsidy for the conservation of indigenous breeds had no bearing on production. In Estonia, of sheep production subsidies, aid for ecological production and the subsidy for livestock grazing had the biggest impact on production. Aid concerning insurance, private meat storage, production animal breeding and protection of endangered animals had no significance on the production of the responding farms.

The responding sheep entrepreneurs felt that a lack of time and low profitability were the biggest barriers to the expansion of business (Figure 8). Many were content with their current scale of production. Often, the lack of a successor did not motivate them to expand, and the farmers settled for the existing scale.

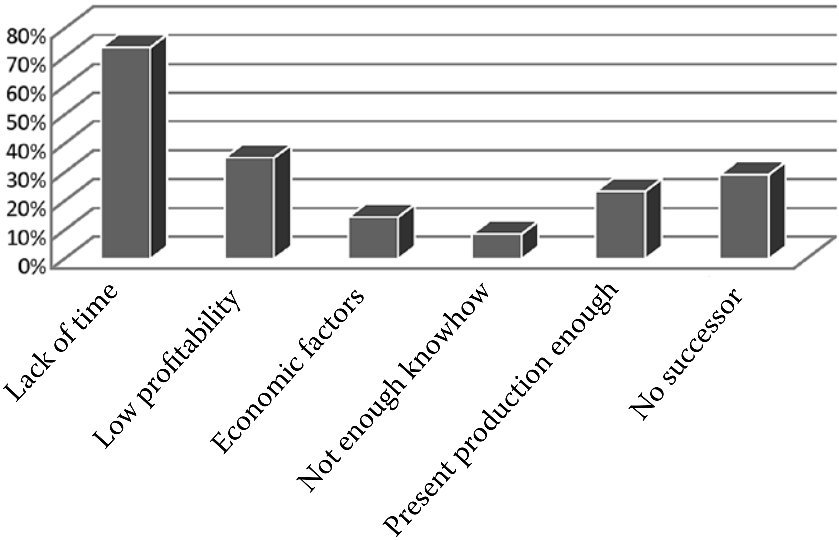


Figure 8. Obstacles to expansion (% of respondents).

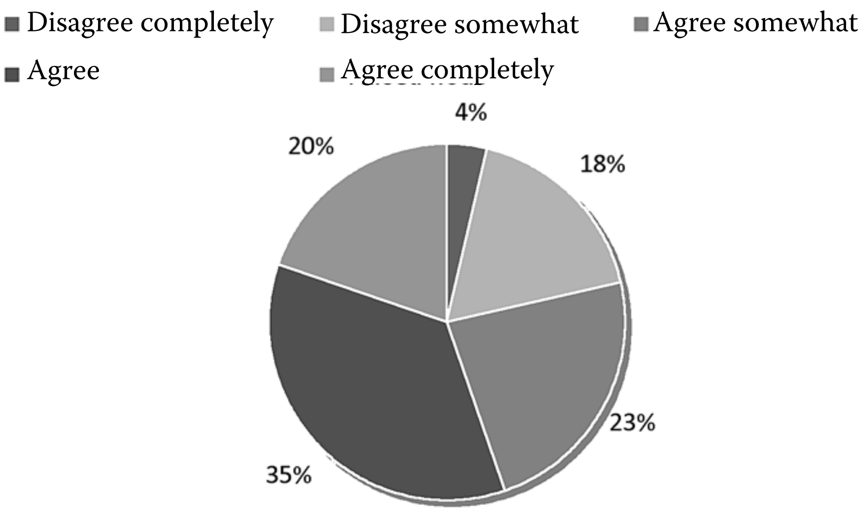


Figure 9. Prospects for sheep production in Finland (% of respondents).

In spite of the heavy workload and unprofitability, 56% of the Finnish respondents agreed or completely agreed with the statement that the future of the sheep industry looks positive. The proportion of those who partly or completely disagreed with this statement was 21% (Figure 9).

Of the Finnish respondents, 33% estimated that they would increase sheep production, 40% that they would maintain their current level, 15% that they would retire, 9% that they would cut down on production and 3% that they planned to discontinue it altogether. In Estonia, 23% of the farms estimate that they would increase production, while 55% said that they would continue at the same level. A few producers are planning to retire, reduce production or stop completely (Figure 10).

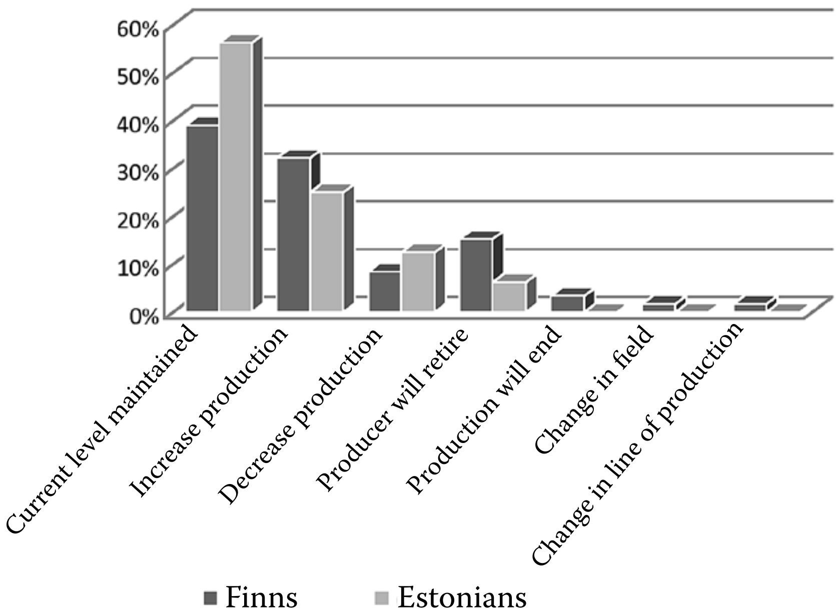


Figure 10. Prospects of development of sheep entrepreneurship in Finland and Estonia over next ten years (% of respondents).

DISCUSSION

In the following section, the results of the survey are compiled into a strategy and development plan for sheep husbandry in the coastal and island regions. The proposals concern the next 5-10 years.

Vision

Finnish and Estonian coastal and island region sheep entrepreneurs offer their customers ecological, locally sourced, high-quality products and memorable services. The customers return to the area to experience meaningful moments in their lives again, counting on high quality and excellent service. Sheep are valuable landscape conservators and help to maintain biodiversity in the Baltic coastal and island areas.

Business idea

Accountability, professionalism and cost-effectiveness are the cornerstones of a versatile sheep industry in Finnish and Estonian coastal and island regions – one that provides high-quality, customer-oriented products and services produced in an ethical and sustainable manner. The products reflect local diversity, culture and characteristics.

Values

Finnish and Estonian coastal and island area sheep husbandry is based on customer orientation, high quality, continuous development, responsibility and interest group loyalty.

Sheep entrepreneurs are skilled and eager to develop themselves. Customer orientation, cost-effectiveness and quality are their cornerstones. Environmental changes and trends are perceived as opportunities for new and innovative business. The archipelago is an active tourist area. Nature is nurtured with the help of sheep and is regarded as a valuable and unique form of public goods which tourists can also enjoy. Natural materials, locality, local food and electronic channels are utilised effectively in marketing. Customers can count on steady quality and availability in individual companies and business networks. In all utility and design/premium articles, as well as in services, the aim is standardisation and high quality.

All actions in Finnish and Estonian coastal and island areas are founded on values of sustainable development, which covers environmental, economic and social responsibility. Entrepreneurs appreciate biodiversity conservation and care for the environment. Profitable, high-quality business and social responsibility include networking, good practice and tending to the welfare of both the animals and the entrepreneurs themselves. Many of the entrepreneurs only barely cope with their workload and need to be supported by, for example, reducing the amount of red tape. Regional solutions are needed to improve the welfare of the animals, as on Saaremaa, for example, sheep grazing on natural pastures are exposed to wolf attacks.

Sheep entrepreneurs are open, honest and reliable partners who develop best practice with their associates and customers. Cooperation is developed with integrity and respect for all parties within the industry and between sectors.

Strategic goals and priority areas for development of the Baltic coastal and island region: proposal for 2014-2020

The objectives of this sheep production strategy relate to the Finnish and Estonian coastal and island areas. They are based on a survey carried out by MTT Agrifood Research Finland, in which the entrepreneurs in the area assessed their values, significant factors and development needs. The successful achievement of these objectives requires each company's commitment to mutual goals by taking into account their individual points of departure.

Objectives of sheep-related business development (Figure 11):

- business development
- accountability
- networking

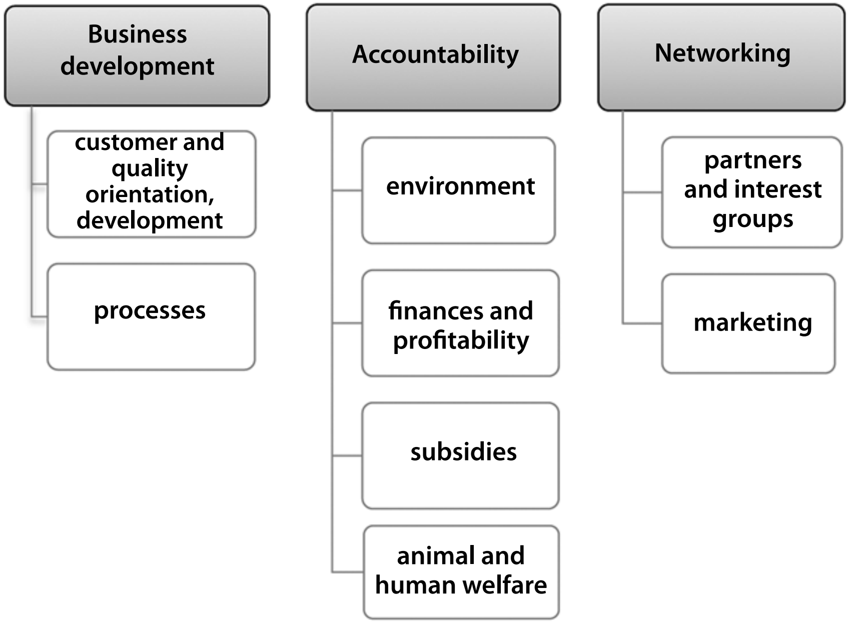


Figure 11. Strategic priorities and development targets for Baltic coastal and island region from 2012–2020

Proposals for action:

- business is built towards customer and quality orientation in a cost-effective manner
- focus on product design (quality improvement and standardisation and service design)
- improved process transparency and reliability (traceability and safety)
- due to the sensitivity of the region's natural environment, action is taken to preserve nature and its diversity and valuable and unique wildlife is managed with the sheep
- a long-term business plan which includes economic, social and environmental responsibility is made on the basis of a sustainable development approach
- business expenditure and revenue streams are analysed for improved profitability

- livelihood is secured in part with subsidies, with landscaping-related subsidies given particular attention due to the specific characteristics of the region
- more attention is paid to human and animal welfare through various means, solutions are sought to decrease entrepreneurs' work-related stress and animal welfare is improved with regional solutions – on Saaremaa, for example, wolf attacks on grazing sheep are addressed
- cooperation with entrepreneurs, developer organisations and authorities is increased and trust is generated via transparency
- networks, effective marketing channels and sales are developed and natural materials, locality, local food and electronic channels are utilised effectively in marketing

Measures proposed in development plan

The proposals for action are presented in table format. The need for them arose from the survey responses, related interviews and workshops organised for Finnish and Estonian sheep farmers.

Business development

Key change factors

Social structures are changing, and with them farms' business models. A tighter economic situation, renewed municipal structures and an aging population open up new opportunities for entrepreneurship and service maintenance. Demand and consumer habits are shifting towards an emphasis on local, high-quality food, cleanliness, aesthetics and health benefits.

Current situation

Consumers are becoming increasingly appreciative of indigenous, safe, local food. Purchase criteria and demand have changed. Consumers are segmented, which opens up possibilities for specialised products. A responsible way of thinking has increased among consumers. Sheep are 'trendy' as an animal and as meat. New sectors, such as welfare and health services (Green Care), have started taking an interest in the animals.

PERSPECTIVE Business development	**GOALS**	**ACTIONS**
Customer orientation, quality and development	Creation of new, in-demand products and business concepts	Studies, analyses, customer feedback, product development, innovation workshops and research
	Increased knowledge and commercialised services and new businesses	Training (sheep rearing and wool processing) and more business
	Added reliability, traceability, safety and aesthetics	Business skills development: product development, quality systems, process diagrams and business plans
	Increased customer-oriented product design	Customer cooperation in development work
Processes	Improved production chains and more cost-effective companies	Enhanced technology
	More standardisation (e.g. natural pasture meat)	Improved quality and homogeneity, more service design and criteria for standardisation

Lamb meat represents a growing market. Competition with imported meat is fierce. Raw materials and the origin of the products are often difficult to trace. In the meat industry, small consignments generate high service prices. Due to seasonal production, local meat is not available in the spring.

Business lacks product design and pricing skills. There is not enough specialisation in meat, milk and wool, and further processing is very limited. Advisors are absent in small-scale processing. There is no regional wool industry. Market value is disregarded. New, low-cost marketing channels like the Internet have emerged.

In Estonia, the sheep industry has long traditions as part of self-sufficient farming. In Finland, sheep husbandry culture is young and fragile, and the commercial sector holds a very strong bargaining position.

Accountability

Key change factors

In a world where the load on the environment has increased and it is one faced with climate change and added uncertainty, aspects of economic, social and environmental responsibility gain value. The regional economy is strengthened, making better use of local resources. Organic issues and welfare are emphasised. Public funding is reduced and privatisation increases. Rural communities need change and entrepreneurship to keep services and rural areas alive.

Current situation

Sheep have an important role to play in the cultural heritage of the islands. They are well-suited to small-scale farming and weaker grazing areas. Grazing animal production is perceived as ethical and ecological. The cultural landscape and wildlife diversity are considered worth cherishing. There are sufficient numbers of meadows in the archipelago, but not enough information on grazing sheep on natural pastures. The 'Slow Food' concept is well-suited to sheep production and multi-functional entrepreneurship.

Sheep husbandry is unprofitable. Producers do not get the required compensation for their work, resulting in diminishing motivation to pursue the trade.

Bureaucracy and the Foodstuffs Act pose challenges for small business owners. Due to the versatile job description and all of the sector-specific provisions and regulations, multi-functional entrepreneurs struggle with a lack of time.

In Estonia, guidance is often found lacking, veterinary services are not readily available and slaughtering and cutting pose problems. Predators cause sheep losses. The use of leather, wool and skins is strongly associated with craft culture.

PERSPECTIVE Accountability	**GOALS**	**ACTIONS**
Environment	Sheep industry burdens the environment and waterways as little as possible	Less energy and water consumption and less waste
		More recycling
		Selecting environmentally friendly forms of energy
	Preservation of diversity and enhanced nature values	Environmental management system for businesses and contributing to environmental values
Economy and profitability	Company focuses on profitable activities	Companies monitor sector-specific flows of income and expenditure
		Attention to adequate subsidies (public goods)

	Increased efficiency (Lean method)	Monitoring of key figures of financial responsibility (GRI): turnover, customer volume, salaries and material procurement
	High-quality products sell for more	Added value elements emphasised in products and services
	Business is goal-oriented	Companies make strategic plans
Animal and human welfare	Healthy and happy animals	Definition of animal welfare criteria
		Implementation of best practice
	On Saaremaa, sheep are not attacked by predators on natural pastures	Regional solutions are sought and livestock guard dogs are trained
	Breeding programme renewed in line with sustainable development	Uniform set of criteria defined
	More efficient utilisation of wool	Criteria for wool characteristics created
	Healthy and happy people	Working hours are planned and occupational safety and training are increased
		More transparent business

		Monitoring of social responsibility indicators (GRI): occupational accidents, sick leave, customer satisfaction and training days
	Moderation of red tape in small businesses	Promotion of reasonable, risk-based laws and regulations

Networking

Key change factors

Rapid network connections and information technology globalise businesses and communication. The gap between 'rural' and 'urban' diminishes. Information transfer and e-business add to regional equality. Current trends intensify, emphasising rural areas' role in future-building and innovation. There is an increased sense of community.

Current situation

There is very little cooperation between interest groups and producers. Structured cooperation does not exist. It is difficult to get lambs to slaughterhouses when needed. Marketing know-how and product marketing are absent. In Estonia, unwillingness to develop small-scale production prevails.

PERSPECTIVE Networking	**GOALS**	**ACTIONS**
Partners and interest groups (business owners, developer organisations, projects, customers and authorities)	Companies develop and production chains become more functional	Cooperation networks are created: aid policy, regulations, development organisations, business networks, production chains and retail
	New products and product families are generated	Operations are made more profitable
	Added trust	More transparent processes
	More industry understanding	More cooperation and networking
	Reasonable legislation for each company size	Promotion of reasonable, risk-based bureaucracy
	Functional cooperation networks	More general registers and statistics
		New, effective marketing channels
Marketing	Functional marketing chains and joint website	Efficient use of the Internet (websites, portals, blogs and Facebook) and creation of a common marketing channel
	Customers are familiar with sheep products	Customers are trained as part of marketing to use meat and natural materials from sheep

	Increased sales	Productisation of products and services and more information/images combined with products (e.g. recipes)

CONCLUSIONS

Wool and skin craftsmanship, grazing-based landscape management and the further processing of meat from sheep taking place in Finnish and Estonian coastal and island areas are representations of versatile rural entrepreneurship. Sheep can offer opportunities as a business or hobby, as a source of income or to generate images. In the coastal and island region, arable land is a limited resource, and for many sheep farmers multi-functional rural entrepreneurship is the only way of securing an adequate livelihood. Multi-functional entrepreneurship requires the knowledge and application of various multi-sectoral regulations.

Variable roles, low profitability and the burden of bureaucracy have left many struggling with stress and a lack of time. The well-being of these rural entrepreneurs should be given more attention. As in many rural areas, small enterprises are important contributors to coastal and island areas. They provide services and keep the region vibrant.

Farm activities are governed by sheep-related subsidies. According to the survey, in both Finland and Estonia agricultural subsidies are a prerequisite for profitable sheep husbandry. National and EU subsidies secure the future of the industry and contribute to food security and food self-sufficiency.

Sheep grazing is a significant part of landscape management, especially in coastal and island areas. The sheep that graze in forests, meadows or on islands do not require intensive production, but care for the landscape while bringing agriculture closer to people and providing an ecological choice for food. Beach-front overgrowth needs to be prevented in advance, because after many years of negligence the task of reversing it becomes almost impossible. Landscaping with livestock requires daily work: the animals' welfare needs to be monitored, they have to be taken to pastures and the grazing areas need to fenced. Some maintenance, such as clearing work, is simply too much for the animals. From the sustainable development view point, the problem lies in the fact that the ecological, social and economic aspects are not, in practice, interlinked. In sheep farming, for example, this is demonstrated by entrepreneurs' inability to receive adequate compensation for their work in the production of public goods (landscaping and other ecosystem services).

Archipelagic conditions pose limitations on companies' operations, which results in the comprehensive and effective utilisation of sheep. Production volumes are small and a sufficiently large market can often be found in the surrounding area. Farms increasing or diversifying their production often face new challenges in both cost control and marketing. With an expanding business and an increasing number of products, new market outlets need to be found to sell the products. Here, joint marketing can prove beneficial through resource sharing and improved visibility. One, shared marketing portal would make product and service information much easier to disseminate. Enhanced networking could also generate more volume and bring cost savings by increasing the efficiency of operations.

Accountability is a trend which needs to be incorporated in a practical and systematic manner. The strengths and uniqueness of the region, and the added value of products and services, could be utilised more in marketing. Modern customers are segmented, and small rural entrepreneurs' product batches can be sufficient for specialised customer groups. Coastal and island regions provide an ideal setting for service provision and its comprehensive development. Many recent trends have boosted rural enterprises' competitiveness: local food, organic food, locality, nature, well-being and sustainable development are all modern-day phenomena.

Modern, profitable businesses need to be founded on customer needs and their understanding, on competitive and organisational expertise and on the ability to combine and manage resources. The same is true of farms and other rural enterprises. Companies must possess superior features which make them stand out from other companies. As small-scale businesses, most farms are flexible and adaptable enough to react swiftly to operating environment changes. When properly combined, a high level of quality, nature, rural culture, local history, entrepreneurial characteristics and innovative business concepts provide excellent opportunities for unique competitive advantages.

Farms live in constant change, which makes it difficult to foresee the future. Entrepreneurs need to stay tuned in to the times. Strategic decisions are influenced by the business environment, entrepreneurs' values, the business sector, existing resources, entrepreneurial and personal characteristics and the goals set by the entrepreneur. Such people can strengthen their businesses through process planning and business strategies.

Creativity, resources and knowledge are valuable assets. Most modern rural entrepreneurs are skilled in a multitude of fields. They utilise their knowledge through strategic choices and are capable and courageous enough to modify them, where necessary.

In both Finland and Estonia around 70% of the respondents said they would increase or continue working in sheep husbandry during the next ten years. For them, the adoption of a strategy-based approach would be very beneficial. Strategic goals can include both company-specific and industry-specific goals. Those involved should, however, agree on who is responsible for the achievement of the said objectives. During the project, measures suggested in the development plan are compiled into a roadmap, which is a good way of monitoring progress, and in the case of more demanding challenges, of considering additional measures.

Through a strategy process, both administrative changes and research-oriented development challenges can be advanced. Applied research based on the needs of livelihood is likely to provide solutions to the most challenging questions, and also contribute to administrative development. In addition to sheep-related enterprises, networking between the industry, research and administration is more crucial than ever. The development of the industry starts, however, with the entrepreneurs and their businesses.

ACKNOWLEDGEMENTS: The KnowSheep project, launched in 2011, seeks to develop diverse sheep husbandry in the Baltic coastal and island areas. In addition to basic sheep rearing, it is related to landscape management and further processing related to meat, wool and skins. The KnowSheep project is being implemented in collaboration with the Estonian Research Institute of Agriculture, the Estonian University of Life Sciences, the Institute of Veterinary Science, the Saaremaa Wool Association, the Hiiumaa Sheep and Cattle Society, HAMK University of Applied Sciences, the University of Turku and the town of Pargas in Finland. We wish to thank our partners for their cooperation and dedication to develop the region and multi-functional sheep husbandry. The project has received funding from the Central Baltic Interreg IV programme, the Regional Council of Southwest Finland and the participating organisations. Thanks to them it has been possible to carry out valuable research and development work in the project area. Warm thanks also to the project steering group, which has actively followed the progress of the project in accordance with the project plan.

Leena Rantamäki-Lahtinen, Senior Researcher, and Arja Seppälä, Researcher, from MTT Agrifood Research Finland, have participated in the project as experts in their respective fields. Lastly, we wish to extend our sincere thanks and appreciation to all experts and participating entrepreneurs for their openness, activeness and cooperation.

REFERENCES

Ahlstedt, L. 1992. *Pienyritykset ja niiden yhteistoimintaverkot.* Teoses: Jahnukainen (toim.). Uudistuva pienyritys. Gummerus Kirjapaino Oy. Jyväskylä. 317–325 s.

Ansoff, H. I. & McDonnell, E. J. 1989. *Strategia 2000.* Oy Rastor Ab/Rastor-Julkaisut. Gummerus Oy. Jyväskylä.

Alsos, G., Ljunggren, E. & Pettersen, L. 2002. *What triggers the start-up of business activities? An empirical investigation within agriculture.* RENT XVI, Entrepreneurship and small business conference proceedings. Vol. 1. Barchelona, Spain: Universitat Autonoma de Barcelona. 465–483 s.

Bridge, S., O'Neill, K. & Cromie, S. 2003. *Understanding Enterprise, Entrepreneurship and Small Business.* New York, Palgrave Macmillan. 520 s.

Brinberg, D., Axelson, M. L. & Price, S. (2000). *Changing food knowledge, food choice, and dietary fiber consumption by using tailored messages.* Appetite 35, 35–43.

Brundtland 1987; World Commission on Environment and Development.

Dawkins, J. & Lewis, S. 2003. CSR in Stakeholder Expectations: And Their Implication for Company Strategy. Journal of Business Ethics 44: 185–193.

Dubé, L., Cantin, I. (2000). *Promoting health or promoting pleasure? A contingency approach to the effect of informational and emotional appeals on food liking and consumption.* Appetite, 35, 251–262.

Deliza, R. & MacFie, H. 2001. *Food, People and Society*. Springer.

Eskola, M. 2013. *Markkinointimahdollisuuksia rannikko- ja saaristoalueen lammastuottajille*. MTT raportti 96: 42 p. http://urn.fi/URN:ISBN:978-952-487-453-3

Finnsheep 2011. *Tuotanto ja ominaisuudet.* http://www.finnsheep.fi/. (06.05.2011)

Forsman, S. 1999. *Erilaistaminen ja hintastrategiat elintarvikealan maaseutuyrityksissä*. Helsinki: MTT julkaisu 93.

Gasson, R. & Errington, A. 1993. *The farm family business.* CAP International. 290 s. Oxon, UK.

Haines, M. & Davies, R. 1987. *Diversifying the farm business.* UK: BSP Professional Books. 304 s. ISBN 0-632-01822-4.

Haksever, C. 1996. *Total Quality Management in the Small Business Environment.* Vol 39, nro 2: 33–40 s.

HAMK, 2011, M*aatiaiseläimet*. http://sites.google.com/site/maatiaiselaeimet/maatiaislammas/aalandsfaaret. (09.05.2011)

Kamensky, M. 2004. *Strateginen johtaminen*. Gummerus Oy, Jyväskylä.

Kamensky, M. 2010. *Strateginen johtaminen menestyksen timantti*. 2. tarkistettu painos. Kariston Kirjapaino Oy. Hämeenlinna.

Karja, M. & Lilja, T. 2007 (toim.). *Alkuperäisrotujen säilyttämisen taloudelliset, sosiaaliset ja kulttuuriset lähtökohdat*, Jokioinen MTT:n Julkaisu 106; https://portal.mtt.fi/portal/page/portal/www/Tietopaketit/Elaingeenivarat/944A907D2A42925BE040A8C0033C4F3A. (06.05.2011)

Kuratko, D. F. & Hodgetts, R. M. 2001. *Entrepreneurship a contemporary approach.* Fift edition. USA: South-Western.

Laaksonen, M., Forsman, S. & Immonen, H. 2004. *Kokonaisvaltaisen suorituskyvyn mittausjärjestelmän rakentaminen elintarvikealan pienyrityksen käyttöön*. MTT:n selvityksiä 64.

Lehtonen, P. (toim.) 1999. *Strateginen yrittäjyys.* Kauppakaari. WSOY. Helsinki.

Luukkonen, T., Kurppa, S. & Räikkönen R. 2012. *Knowsheep- hankkeen kartoituksia lammastuotannosta: Lammastuotantosuunta kartoitus, geneettinen potentiaali ja ympäristö kartoitus.* MTT Raportti 55: 70 p. http://urn.fi/URN:ISBN:978-952-487-390-1.

Michelson, A., 2011. Hämeen ammattikorkeakoulu Mustiala.

Internet: Northern European Short-Tailed Sheep. https://docs.google.com/present/

view?id=0AZnoRYCGipSFZGhxczhjN2dfMjU2NmNzcDRwanpi&hl=fi&pli=1. (05.04.2011)

McClure, S. M., Li, J., Tomlin, D., Cypert, K. S., Montague, K. S., Montague, P. R. (2004). *Neural correlates of behavioral preference for culturally familiar drinks*. Neuron, 44, 379-387.

Niittykangas, H. 2003. *Yrittäjä ja yrityksen toimintaympäristö.* Jyväskylän yliopisto, Taloustieteen tiedekunta. Julkaisu N:o 134/2003. ISBN 951-39-1477-1. Jyväskylä. 294 s.

Panapanaan, V. M., Linnanen, L., Karvonen, M.-M. & Phan, V. T. 2003. *Roadmapping Corporate Social Responsibility in Finnish Companies*. Journal of Business Ethics, No. 44, pp. 133–148.

Peltola, A. 2000. *Viljelijäperheiden monitoimisuus suomalaisilla maatiloilla.* MTTL:n julkaisuja 96. ISBN 951-687-074-0. Vammala: MTTL. 280 s.

Porter, M. E. 1988. *Kilpailuetu. Miten ylivoimainen osaaminen luodaan ja säilytetään.* Weilin & Göös. Espoo.

Pyysiäinen, J. (toim.) & Vesala, K. M. 2008. *Understanding entrepreneurial skills in the farm context*. Frick: Research Institute of Organic Agriculture (FiBL). 485 s.

Rannap, R., Briggs, L., Lotman, K., Lepik, I. & Rannap, V., 2004. Ministry of the Environment of the Republic of Estonia; *Coastal meadow management, Best Practice Guidelines.* http://www.botany.ut.ee/mari.moora/Coastal_Meadow_Preservation_in_Estonia.pdf. (28.04.2011)

Rantamäki-Lahtinen, L. 2009. *The success of the diversified farm – resource-based view.* MTT. https://helda.helsinki.fi/bitstream/handle/10138/20926/thesucce.pdf?sequence=1. (05.08.2011)

Riusala, K. & Sirilä, H. 2009. *Monialayrittäjyys maaseudun mahdollisuutena*. Vaasan yliopisto Levon-instituutti. Vaasa.

Räikkönen, R. & Kurppa, S. 2013. *Monimuotoinen maaseutuyrittäjyys – case KnowSheep.* MTT Raportti 110: 74 p. ISBN 978-952-487-475-5. http://urn.fi/URN:ISBN:978-952-487-475-5.

Schane, S. 2003. *A General Theory of Entrepreneurship.* The Individual – Opportunity Nexus. Great Britain.

Schane, S. & Verkataraman, S. 2000. *The promise of Entrepreneurship as a Field of Recearch.* Academy of Management Review 25(1): 217–226.

Schulman, A. 2007. *Perinnebiotooppien hoitokortti 10 – Tuottoa perinnebiotooppien hoitamisesta.* Paino Erweko Painotuote Oy. http://www.mmm.fi/attachments/mmm/tutkimus/lumottu/5uUFXiSp8/Perinnebiotooppi_hoitokortti.pdf. (22.08.2011)

Sikka, K. 2011. Opinnäytetyö, *Ahvenanmaan pässilinjat*. https://publications.theseus.fi/bitstream/handle/10024/26781/Sikka%20Katja.pdf?sequence=1. (28.04.2011)

Suomen Kulttuurirahasto, 2009. http://www.skr.fi/default.asp?docId=17826. (06.05.2011)

Tahkokallio, N. 2011. *Lammastalouden taloudellinen kehittäminen*; Opinnäytetyö, Laurea Hyvinkää. Saadaval internetis: http://publications.theseus.fi/bitstream/handle/10024/26061/Tahkokallio_Niina.pdf?sequence=1. (09.05.2011)

Timonen, R. 2000. *Yrittävyys, liikkeenjohto ja menestyminen maatilayrityksissä.* Julkaisuja nro 28, Maatalouden liiketaloustiede, Helsingin yliopisto, Taloustieteenlaitos.

Vihtonen, T. & Haverinen, T. 1995. *Monialaisen maatilayrityksen tuloslaskenta.* MTTL:n tiedonantoja 202. Helsinki MTTL. 110 s. ISBN 952-9538-57-X.

Voutilainen, O., Vehmasto, E. & Vihinen, H. 2008. *Verkostoituminen maatilojen monialaistumisen edistämisessä – Liperin ja Mäntyharjun tapaustutkimus.* ISBN 978-952-487-158-7. MTT:n selvityksiä 154. http://www.mtt.fi/mtts/pdf/mtts154.pdf. (22.11.2012)

SHEEP FEEDS AND FEEDING CHARACTERISTICS IN THE BALTIC SEA REGION

Uno Tamm[1] & Laura Kütt[2]

[1] Estonian Crop Research Institute, J. Aamisepa 1, 48309 Jõgeva, Estonia; e-mail: uno.tamm@etki.ee
[2] Estonian Crop Research Institute, J. Aamisepa 1, 48309 Jõgeva, Estonia; e-mail: laura.kytt@etki.ee

Abstract: During the KNOWSHEEP project, the botanical composition and plant communities were observed over three years and pasture grass samples were collected on a total of 14 sheep pastures in Estonia and 17 sheep pastures in Finland. In addition, 18 and 15 soil samples were taken from pastures in Estonia and Finland, respectively. Most of the grasslands used to feed sheep in Estonia were dry boreo-nemoral grasslands rich in white clover (*Trifolium repens*) and grasses. The shares of dry cultivated meadows and ameliorated natural grasslands were the largest among the sheep pastures in Finland. The proportion of toxic and inedible plants was low.

Compared to other pastures, the grass grown on cultivated pastures and upland pastures had the highest nutritive value and it was suitable for sheep in all age groups. Grass collected from wooded and coastal pastures was of a lower value in terms of both protein and energy content. Grass silage with a higher nutritive value was obtained from legume and grass swards. The quality of hay was highly variable, depending on the botanical composition of the sward, the time it was made and the prevailing weather conditions at that time. Hay harvested from upland grasslands and coastal areas was characterised by a higher nutritive value. Where haymaking and ensiling were late, protein and metabolisable energy levels decreased substantially in the harvested grass.

The study revealed that differences in the increase in botanical diversity in grazed areas proved significant in only one study year, which suggests that three years may not be long enough to assess the impact of grazing on the species composition and diversity of plant communities.

Key words: sheep, sheep pasture, grazing, nutritive value, feed, feeding, hay, silage, intake

INTRODUCTION

Species diversity and the need to preserve it on both semi-natural grasslands (Znamenskiy et al., 2006) and arable land (Mills et al., 2007) are increasingly gaining attention. The preservation of species diversity is often associated with moderate disturbance, such as grazing and mowing, which is why extensive grassland management is regarded as one of the main ways of preserving species diversity (Pärtel et al., 2005). This position is also supported by studies which have found that grazing has a favourable impact on many grassland plant species (Pykälä, 2005) and increases the diversity of plant communities (Bullock et al., 2001; Pavlů et al., 2006). Grazing also influences the quality of grass on pastures (Pavlů et al., 2006). It has been established that the crude protein content and digestibility of plants are higher in intensely grazed areas (Pavlů et al., 2006). Moreover, a higher diversity of pasture grasses increases the stability of plant communities (Provenza, 1996).

Sheep usually prefer varied pasture grass to a monoculture pasture feed (Parsons et al., 1994). Adding other plant species and thus also different kinds of secondary metabolites to the pasture grasses grazed can contribute to animals' feed intake and growth (Provenza, 1996). Other benefits of diverse feeding include a balanced diet, increased intake of feeds with different nutritive values and a reduction in the ingestion of toxic feeds, as well as maintaining diversity of microflora in the rumen of animals (Provenza, 1996).

Soil conditions determine the growth of different species and the stability of the grassland. Areas vulnerable to droughts and temporarily waterlogged land parcels require more attention. Almost all grass plant species cultivated in Estonia grow well in mesophile areas. Dry habitats are suitable for lucernes (*Medicago*), fodder galega (*Galega orientalis*), orchard grass (*Dactylis glomerata*), smooth brome (*Bromus inermis*), tall fescue (*Festuca arundinacea*) and red fescue (*Festuca rubra*). Meadow foxtail (*Alopecurus pratensis*), reed canary-grass

(*Phalaris arundinacea*), timothy (*Phleum pratense*) and alsike clover (*Trifolium hybridum*) grow better in humid areas. In mown grasslands account should be taken of the fact that the optimal harvest time of grass plant crops with a similar development speed lasts for 3–5 days and that the selected species and varieties constituting the feed mix should yield a harvest with the maximum nutritive value at the time of mowing. Therefore, mixes used on mown grasslands usually consist of 2–3 species. The harvest time is determined on the basis of the main species. Historically, the earliest mixes were used in crop rotations on arable fields where clover-rich field hay is still used to maintain the fertility of the soil and produce valuable animal feed. Nowadays, the European Union Common Agricultural Policy Implementation Act provides that support for short-term grasslands (swards aged 1–4 years) is twice the support provided for growing older swards. This accelerates the renewal of the grass plants sown and raises the level of cultivation. Grass plants characterised by faster initial development and shorter life are grown on short-term grasslands. The selection of species is based on the habitat conditions and the purpose of use of the grassland. Given that areas characterised by limited utility are often used as grasslands, the effectiveness of grassland management depends on the ability to choose the appropriate species and varieties. Leguminous plants are more demanding of the growth environment. To characterise legumes and grasses and use them as potential forage, their morphological differences in the various stages of development must be analysed, and the impact of different harvest times on the chemical composition and nutritive value of the leaves and stems and on the quantity of dry matter (DM) yield must be evaluated. Nutritious forage in sheep's feeding ration must be characterised by high intake and digestibility and moderate protein content.

MATERIALS AND METHODS

The study of grasslands and sheep feed was conducted within the scope of the KNOWSHEEP project from 2011–2013. Six sheep farmers from Estonia and six from Finland participated in the study. The Estonian sheep farms were located on the island of Saaremaa (one in

Salme municipality and one in Pihtla municipality), in West Estonia (three farms in Ridala municipality) and North Estonia (one sheep farm in Lahemaa, Kuusalu municipality).

The Finnish sheep farms were all located in South-West Finland: the Turku archipelago, around the town of Pargas, and in Kemiö.

In order to describe the botanical composition of sheep pastures, the abundance of plant species (expressed as a percent) was determined in 2 x 2 m sample plots. Plant species were determined on the basis of *Eesti taimede määraja* /Guide to Estonian Plants/ (Krall et al., 2007) and habitat types were determined using *Eesti taimkatte kasvukohatüüpide klassifikatsioon* /Classification of Estonian Vegetation Site Types/ (Paal, 1997). Soil samples were collected from all sheep pastures (where the sheep pastures were located on the same soil massif, samples were taken from one soil massif). Using a soil auger, samples were collected in at least six different places on each pasture. The soil samples were sent to a laboratory where the pH and K, P and organic matter content were determined.

Data were processed using Microsoft Excel 2003. Based on the botanical composition abundance estimates determined for the sheep pastures, the Shannon-Wiener (SW) diversity index was calculated according to the formula

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

where S = number of species, i = number of individuals belonging to the *i*th species and p_i = abundance of a species as a proportion of the abundance of all species in the sample.

The SW diversity indices so obtained for the results of each year observed were compared in Microsoft Excel, using a *t*-test, to identify possible differences in species diversity of sheep pastures between the years. The 'Paired Two Sample for Means' *t*-test was used.

RESULTS AND DISCUSSION

In Estonia, most of the grasslands used to feed sheep by the project partners were dry boreo-nemoral grasslands. Some sheep pastures were also located on coastal meadows (Photo 1), ameliorated natural grasslands and wooded meadows. In Estonia, plant communities were determined, the botanical composition was assessed and pasture grass samples were collected on a total of 14 sheep pastures over the three years. In addition, 18 soil samples were taken from pastures in Estonia.

Despite the similar natural site type, plant communities were relatively dissimilar on boreo-nemoral grasslands and therefore a single plant community type could not be identified on these sheep pastures. Pastures rich in white clover (*Trifolium repens*) and grasses were the most frequent, with a mix of red fescue (*Festuca rubra*) and white clover (*Trifolium repens*) usually prevailing. Pastures with dominant grasses were also frequent, but their share was slightly smaller.

In Finland, plant communities were determined, the botanical composition was assessed and pasture grass samples were collected on a total of 17 sheep pastures. In addition, 15 soil samples were taken from

Photo 1. Coastal grassland in Ridala municipality, Western Estonia. Photos: Veiko Kastanje

pastures in Finland. The shares of dry cultivated meadows and ameliorated natural grasslands were the largest among the sheep pastures used by Finnish sheep farmers. To a lesser extent, coastal meadows and dry boreo-nemoral grasslands were also represented among the sheep pastures. The most common were grasslands rich in grasses and plant communities consisting of meadow foxtail (*Alopecurus pratensis*), smooth-stalked meadow grass (*Poa pratensis*), red fescue (*Festuca rubra*) and meadow fescue (*Festuca pratensis*). Pastures rich in grasses and white clover (*Trifolium repens*) were also represented, to a lesser extent.

Differences, which were associated in particular with the pH of soil, were observed between the soils of the Estonian and Finnish sheep pastures. In Estonia the soil was mostly neutral in all areas (pH 6.8–7.3), primarily due to the gravelly soil and limestone bedrock. In Finland, however, the soil was acidic in all areas (pH 4.1–5.3); this is due to the granite bedrock. Significant variability was observed for other soil parameters in the soils of both the Estonian and Finnish sheep pastures. The analyses also indicated that the soils were usually deficient in phosphorus rather than potassium.

Typical plant communities in grasslands

Dry boreo-nemoral grasslands

The most frequent species were white clover (*Trifolium repens*), common yarrow (*Achillea millefolium*), mouse-ear chickweed (*Cerastium fontanum*), meadow buttercup (*Ranunculus acris*), common dandelion (*Taraxacum officinale*) and grasses – red fescue (*Festuca rubra*), smooth-stalked meadow grass (*Poa pratensis*), meadow fescue (*Festuca pratensis*), orchard grass (*Dactylis glomerata*) and common bent (*Agrostis capillaris*). The most abundant species included white clover (*Trifolium repens*), red fescue (*Festuca rubra*), common yarrow (*Achillea millefolium*) and smooth-stalked meadow grass (*Poa pratensis*). The plant communities on this site type included those of red fescue (*Festuca rubra*) and white clover (*Trifolium repens*); white clover (*Trifolium repens*) and common bent (*Agrostis capillaris*); dropwort (*Filipendula vulgaris*) and blue moor grass (*Sesleria caerulea*); and sheep's fescue (*Festuca ovina*) and white clover (*Trifolium repens*). Dry boreo-nemoral grasslands were also some of the most species-rich sheep pastures.

The phosphorus content of the soil of dry boreo-nemoral grasslands was highly variable from region to region, being either very low (less than 10 mg/kg) or high (145 mg/kg). The potassium content was typically moderate (over 100 mg/kg). The organic matter content was moderate (2.2–3.5%).

Alvars

The most frequent species were brown knapweed (*Centaurea jacea*), meadow buttercup (*Ranunculus Acris*), yellow bedstraw (*Galium verum*), willowleaf yellowhead (*Inula salicina*), quaking grass (*Briza media*), meadow fescue (*Festuca pratensis*), orchard grass (*Dactylis glomerata*) and timothy (*Phleum pratense*).

Vegetation on moist alvars differed somewhat from that on dry alvars. The most abundant species on moist alvars included (in descending order) willowleaf yellowhead (*Inula salicina*), field horsetail (*Equisetum arvense*), common silverweed (*Potentilla anserina*), common sedge (*Carex nigra*), blue sedge (*Carex flacca*) and brown knapweed (*Centaurea jacea*). Plant communities were those of blue moor grass (*Sesleria caerulea*) and blue sedge (*Carex flacca*).

The most abundant species observed on dry alvars were sheep's fescue (*Festuca ovina*), meadow oat-grass (*Helictotrichon pratense*), brown knapweed (*Centaurea jacea*) black medic (*Medicago lupulina*) and red fescue (*Festuca rubra*); plant communities were those of sheep's fescue (*Festuca ovina*), common lady's mantle (*Alchemilla vulgaris*) and white clover (*Trifolium repens*). Alvars were also some of the most species-rich sheep pastures.

The phosphorus and potassium content of the soils was low: 13 mg/kg and 94 mg/kg, respectively. The organic matter content of the soils was high: 5.3%.

Heath meadows

The most frequent and also the most abundant species were common bent (*Agrostis capillaris*), sweet vernal grass (*Anthoxanthum odora-*

tum), white clover (*Trifolium repens*) and smooth-stalked meadow grass (*Poa pratensis*). Plant communities were those of sweet vernal grass (*Anthoxanthum odoratum*) and red fescue (*Festuca rubra*). Soils were acidic (pH 4.2), the phosphorus content was high (85 mg/kg) and the potassium content was very low (less than 40 mg/kg).

Coastal meadows

The most frequent grasses included common reed (*Phragmites australis*), common bent (*Agrostis capillaris*), red fescue (*Festuca rubra*), tufted hair-grass (*Deschampsia cespitosa*) and rough-stalked meadow grass (*Poa trivialis*). The most frequent forbs were autumn hawkbit (*Leontodon autumnalis*), white clover (*Trifolium repens*), common silverweed (*Potentilla anserina*) and common marsh-bedstraw (*Galium palustre*). The most abundant species included common reed (*Phragmites australis*), common bent (*Agrostis capillaris*), white clover (*Trifolium repens*) and red fescue (*Festuca rubra*). There was occasionally also plenty of saltmarsh rush (*Juncus gerardii*), purple moor grass (*Molinia caerulea*), blue moor grass (*Sesleria caerulea*), slender spike-rush (*Eleocharis uniglumis*) and blue sedge (*Carex flacca*). The plant communities of coastal meadows were those of purple moor grass (*Molinia caerulea*) and dragon's teeth (*Tetragonolobus maritimus*); sea milkwort (*Glaux maritima*) and saltmarsh rush (*Juncus gerardii*); and red fescue (*Festuca rubra*) and slender spike-rush (*Eleocharis uniglumis*).

The phosphorus content of soils was low (mostly <6 mg/kg) in coastal meadows. The potassium content was medium to high – on average around 200 mg/kg. The organic matter content of the soils was medium, ranging between 2.3% and 3.2% in most cases.

Wooded pastures

The wooded pastures used as sheep pastures were highly varied and included fresh boreo-nemoral forests, dry boreo-nemoral forests and alvar forests. Therefore, it is difficult to highlight the most abundant and thus the most characteristic species representative of wooded pastures. As for grasses, the most frequent species were common bent (*Agrostis capillaris*), rough-stalked meadow grass (*Poa trivialis*) and red fescue (*Festuca rubra*). The most common forbs included meadow buttercup (*Ranunculus Acris*), common hepatica (*Hepatica nobilis*), water avens (*Geum rivale*), dog-violet (*Viola riviniana*), common dandelion (*Taraxacum officinale*), germander speedwell (*Veronica chamaedrys*), common stitchwort (*Stellaria graminea*), tormentil (*Potentilla erecta*), northern bedstraw (*Galium boreale*), wild strawberry (*Fragaria vesca*) and cow parsley (*Anthriscus sylvestris*).

The phosphorus content of the soil was very low in wooded pastures, at less than 10 mg/kg, and higher in only one case. The potassium content of the soil was highly variable (from a very low level of 49 mg/kg to a high level of 285 mg/kg). The organic matter content of the soil was generally quite high at 3.5%.

Ameliorated natural grasslands

The most common species were common yarrow (*Achillea millefolium*) and common dandelion (*Taraxacum officinale*). Frequent species also included white clover (*Trifolium repens*), cow parsley (*Anthriscus sylvestris*), meadow buttercup (*Ranunculus acris*), tufted vetch (*Vicia cracca*), common stitchwort (*Stellaria graminea*) and grasses – timothy (*Phleum pratense*), orchard grass (*Dactylis glomerata*), red fescue (*Festuca rubra*), common bent (*Agrostis capillaris*) and smooth-stalked meadow grass (*Poa pratensis*). The most abundant species included (in descending order) common yarrow (*Achillea millefolium*), orchard grass (Dactylis glomerata), red fescue (Festuca rubra), meadow foxtail (*Alopecurus pratensis*), white clover (*Trifolium repens*) and timothy (*Phleum pratense*). The most typical plant communities were those of white clover (*Trifolium repens*) and red fescue (*Festuca rubra*); meadow fescue (*Festuca pratensis*) and orchard grass (*Dactylis glomerata*); meadow foxtail (*Alopecurus pratensis*) and smooth-stalked meadow grass (*Poa pratensis*); and white clover (*Trifolium repens*) and common bent (*Agrostis capillaris*).

The phosphorus content of the soil was mostly medium, ranging between 40 and 80 mg/kg, and in only a few cases much lower. The potassium content of the Finnish soils was mostly high – over 200 mg/kg. In the Estonian soils the potassium content was somewhat lower – 95 mg/kg on average. The organic matter content of soil was variable – mostly over 3.5%, but in some cases a little lower.

Cultivated pastures

The species composition of cultivated pastures obviously depends on the mixture of the seeds sown there. The cultivated pastures covered by this study were dominated by grasses. The most common and also the most abundant species included timothy (*Phleum pratense*), orchard grass (*Dactylis glomerata*) and couch grass (*Elymus repens*), as well as common dandelion (*Taraxacum officinale*), white clover (*Trifolium repens*) and creeping thistle (*Cirsium arvense*). Meadow fescue (*Festuca pratensis*) was also rather prevalent. One of the most typical plant communities was that of undergrowth grasses and white clover (*Trifolium repens*). As expected, the species diversity of cultivated pastures was low compared to other site types.

The phosphorus content of the soil varied greatly. There were cultivated pastures where the P content of soil was very low (less than 20 mg/kg) and very high (100 mg/kg). The potassium content of the soil was high, at more than 200 mg/kg; the K content was lower in only a few places. The average organic matter content of the soil was 3%.

The results of the study indicate, as expected, that semi-natural grasslands are more diverse than cultivated grasslands in terms of botanical composition.

Toxic and inedible plants on sheep pastures

There were no plants on pastures which are toxic to sheep, or their share was very small. Although sea arrowgrass (*Triglochin maritimum*) and yellow loosestrife (*Lysimachia vulgaris*), both of which are somewhat toxic to sheep, were occasionally spotted on coastal meadows, their abundance was low. A few poisonous plants were also observed on wooded pastures, such as lily of the valley (*Convallaria majalis*) and false lily of the valley (*Maianthemum bifolium*), but as the abundance of the plants was not high, it is unlikely that these plant species could significantly affect the health of the sheep. In addition, studies have shown that sheep are able to distinguish toxic feed from other feeds and avoid it or choose feeds which are the least toxic (Wang & Provenza, 1997).

No plants poisonous to sheep were found on dry upland grasslands, ameliorated natural grasslands or cultivated pastures, but there were some inedible plants like creeping thistle (*Cirsium arvense*), common silverweed (*Potentilla anserina*), ribwort plantain (*Plantago lanceolata*), germander speedwell (*Veronica chamaedrys*) and heath speedwell (*Veronica officinalis*), the abundance of which was nevertheless very moderate.

Grassland plants that are less valuable as grazing plants can be divided into the following groups:

1. Hazardous grassland weeds – tufted hair-grass (*Deschampsia caespidosa*), winter cress (*Barbarea*) curled dock (*Rumex crispus*), thistle (*Cirsium*) and nettle (*Urtica*)
2. Weeds of limited edibility – plantain (*Plantago*), buttercup (*Ranunculus*), common silverweed (*Potentilla anserina*), common self-heal (*Prunella vulgaris*), speedwell (*Veronica*) and orchard grass (*Dactylis glomerata*)
3. Edible weeds – common dandelion (*Taraxacum officinale*), sedges (*Carex*), knotweed (*Polygonum*) and cow parsley (*Anthriscus sylvestris*)
4. Herbs – lady's mantle (*Alchemilla*), ribwort plantain (*Plantago lanceolata*), chicory (*Cichorium*) and caraway (*Carum*)

In general, sheep farmers need not worry about toxic and inedible plants on pastures, as their share in plant communities is usually marginal and if sheep get the necessary nutrients from sufficient quantities of other grassland plants and are properly fed, eating a couple of poisonous plants will not affect their overall health status (Wang & Provenza, 1996).

Changes in diversity of species during observation period

In the course of the Knowsheep project the botanical composition of the sheep pastures studied were compared using a t-test. The results of the test showed that increases in the diversity of species in grazed areas were significantly different ($p = 0.0007$) in 2011 and 2012. The result obtained may indicate that grazing has a positive effect on the diversity of plant species. Other studies have also found that grazing increases the diversity of plant species on grasslands (Bullock et al., 2001; Pavlů et al., 2006).

However, the t-test in which the botanical diversity of the sheep pastures in 2012 and 2013 was compared indicated that grazing did not have any effect on the vegetation, as there was no statistically significant difference in the number of species in these years ($p = 0.968$).

These different results may be due to a certain variability of vegetation in different years, which suggests that three years may not be long enough to assess the impact of grazing on the botanical composition and diversity of plant communities. An earlier study also concluded that although grazing may result in plant species of a higher feed value being included in plant communities, many species do not exhibit a grazing impact within a three-year grazing experiment (Isselstein et al., 2007). To better understand the impact of grazing on plant communities, it is necessary to carry out longer-term experiments, as the response of vegetation to such disturbance may only develop over a longer period of time (Bullock et al., 2001).

Different seasonal grazing may also have different effects on vegetation and its diversity. Heavy grazing during midsummer can have a negative impact on species diversity (Bullock et al., 2001). An excessive grazing load on plants and thereby also on the soil (its nutrient and water content) means that plants will not be able to regenerate quickly enough and that both the growth of plants and species richness may decrease. Also, different grazing loads affect species in different ways. Some plant species can show a positive response to intensive grazing, while others respond negatively (Bullock et al., 2001). Too much grazing is likely to eventually affect the abundance of all species, which was also indicated in a study where the impact of rotational grazing and intensive grazing on plant diversity were compared (Pavlů et al., 2003). In that study, it was found that the abundance of species of plants increases as a result of rotational grazing, while continuous grazing leads to a decrease in the number of plant species.

With a view to maintaining botanical diversity, it is important to avoid excessive grazing loads. In Estonia, suitable grazing loads are 8–10 ewes (with lambs) per hectare on cultivated pastures and 1–3 ewes (with lambs) per hectare on semi-natural pastures (Piirsalu, 2012). On heavily grazed pastures, weeds may start dominating in the plant community (Bullock et al., 2001) and their nutritive value and intake may fall short of those of the pasture plants usually preferred by the animals.

Nutritive value of forages

Changes in nutritive value during the vegetation period are most affected by the development stage of plants. The nutritive value of grass plants decreases with an increase in the mass of grass. The digestible nutrient content and the economic productivity of forage decline in later stages of development. The digestibility of forage is affected by its fibre concentration and the ratio of fibre components; as the cell membrane substance grows, the plant undergoes chemical and structural changes. The cellulose, hemicellulose and lignin content of cell walls increases; the first two are partly digestible by the anaerobic microorganisms of the rumen, but lignin is indigestible. In later stages of development, the lignin content of the stem is high in clover and especially in lucerne. As the cell walls age, the composition of lignin changes from guaiacol-type to syringol-type lignin, which forms cross-links with cellulose and hemicellulose, preventing their digestion.

Weather effects on nutritive value of forage

While the quality of forage is most affected by the time the grass plants are used, the environment – temperature and precipitation – constitutes an important factor that has an impact on plants of the same age. The digestibility of leaves and stems decreases in line with an increase in temperature; the development of herbage is particularly fast in spring-summer as a result of abrupt warming. The results of experimental work in Saku show that spring-time humidity and temperature conditions that differ from the multi-year average have a stronger impact on the growth dynamics of plants than the condition of the soil (fertilisation). Low spring-time temperatures, along with moisture deficiency, slow the development and growth of plants and lead to a higher ratio of leaves/stems. The sum of effective temperatures (>5 °C) accumulating from the beginning of the vegetation period is closely related to the growth and nutritive value of grass plants (Fig. 1). The result is positively correlated with the DM yield of legumes and grasses in the first cut ($r=0.71$ and $r=0.93$, respectively; $P<0.001$), and negatively correlated with the digestibility of DM ($r=-0.75$, $P<0.001$). A rise in the sum of effective temperatures by 10 degrees resulted in a decrease in the multi-year average digestibility of the growing season's

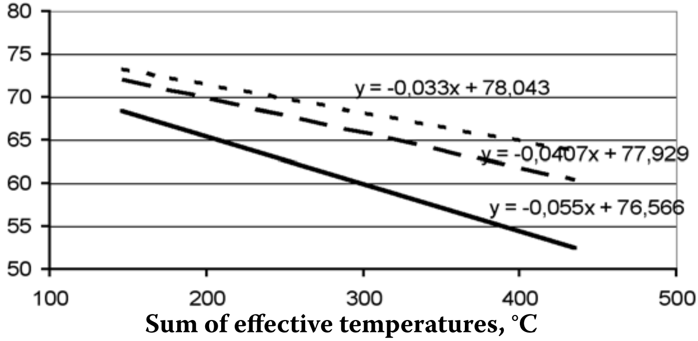


Figure 1. Correlation between digestibility of grass and sum of effective temperatures (— grasses; – – – lucerne; …… red clover) (Tamm & Tamm, 2007).

first cut by 0.33% for early red clover (*Trifolium pratense*), 0.41% for lucerne (Medicago) and 0.55% for grasses.

The amount of heat required for plants to mature to the stage optimal for cutting accumulates in May for grasses and in May and the first half of June for leguminous plants.

It is economically important to find the optimal relation between the increase in DM yield and the decrease in the nutritive value of the forage. The goal is to obtain the highest total yield of digestible nutrients whose nutritive value meets the requirements of the criterion of good forage. The forage in Table 1 which meets requirements is harvested in different development stages, depending on the species.

Table 1. Nutritive requirements in evaluating forages (Tamm, 2005: Nutritive value of forage).

Indicators	Evaluation		
	Good	Satisfactory	Poor
Protein,%	> 15	12-15	< 12
NDF % legumes	< 41	42-50	> 50
NDF % grasses	< 55	56-60	> 60
ADF % legumes	< 31	32-37	> 37
ADF % grasses	< 32	33-40	> 40
Digestibility %	> 65	55-65	< 55
ME MJ/kg	> 9.5	8-9.5	< 8

The optimal time for harvesting timothy is at the end of the stem elongation stage; in the case of a cold and dry spring, the optimal harvest time is postponed to the beginning of the ear emergence stage. Meadow fescue and ryegrass can be cut later than timothy (at the beginning of the ear emergence stage). The development of perennial ryegrass is slower and the nutritive value of the species remains at a high level in the middle of the ear emergence stage.

The digestibility of lucerne DM remains compliant with the requirements of the criterion of good forage at the beginning of flowering, while the digestibility of clover corresponds to the reference value during full flowering (Table 2).

Table 2. Digestible DM (DDM) yield (t/ha) and digestibility (D, %) of legumes and grasses.

Species	Stem elongation stage		Beginning of ear emergence /budding stage		Ear emergence/ flowering stage	
	DDM	D%	DDM	D%	DDM	D%
Timothy	2.50	65	3.22	64	4.02	62
Meadow fescue	1.88	67	3.01	65	3.79	64
Perennial ryegrass	2.44	69	3.19	67	4.10	66
Lucerne	3.02	68	3.31	66	4.47	64
Red clover	2.44	70	2.75	67	3.75	66

Chemical composition of legumes and grasses

Protein

A problem in feeding forage-based rations to sheep is that the feed protein and energy are hydrolysed in the rumen at different speeds. The plants' own proteolytic enzymes contribute to the very rapid hydrolysis of protein in the rumen. The activity of plant enzymes in protein hydrolysis is one of the reasons why protein in fresh grass is hydrolysed 10 times faster compared to dry hay. Forage protein is readily degradable in the rumen and there is not enough energy to fully utilise it in the digestion process. Table 3 shows the crude protein content of legumes and grasses, and the dynamics of its decrease. Legumes are richer in protein than grasses. Perennial ryegrass has a somewhat higher protein content and the dynamics of its decrease are slower compared to other grasses; timothy, by contrast, is rich in protein only before the end of the stem elongation stage. The decrease in the protein concentration of legumes in relation to plant development takes place much more slowly.

In addition to the protein content of forage, the solubility of protein in rumen fluid and degradability by rumen micro-organisms should also be taken into account. The amino acids and ammonia released during the fermentation process are used by microflora for the synthesis of microbial protein whose digestibility is up to 70% (Oll, 1994). The degradation of insoluble protein is 2–4 times slower compared to soluble protein. The effectiveness of the utilisation of legume protein is lower compared to grasses.

Table 3. Average protein content g kg^{-1} DM (2006–2008).

Species	Development stage		
	Stem elongation stage	Beginning of ear emergence /budding stage	Ear emergence/ flowering stage
Timothy	179	148	116
Meadow fescue	180	154	124
Perennial ryegrass	205	161	133
Lucerne	230	201	163
Red clover	212	183	145

The high degradability of protein in the rumen causes a decline in the utilisation of nitrogen (N), particularly in lucerne silage. In red clover (*Trifolium pratense*) the degradability of N is reduced by a ferment called polyphenol oxidase (PPO). Clover leaves contain more PPO than other parts of the plant. Feeds with high PPO activity reduce protein and lipid losses in the rumen.

Fibres and digestibility

Grasses and legumes differ in terms of neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) content.

Grasses typically have higher NDF and ADF content than leguminous forage crops (Table 4).

Table 4. Changes in ADF and NDF content of grass plants (g kg^{-1} DM) during development cycle.

Species	Stem elongation stage		Beginning of ear emergence /budding stage		Ear emergence/ flowering stage	
	ADF	NDF	ADF	NDF	ADF	NDF
Timothy	306	516	342	570	357	599
Meadow fescue	283	511	306	538	348	586
Perennial ryegrass	238	451	283	506	312	541
Lucerne	263	343	293	407	327	450
Red clover	237	337	267	380	297	412

NDF is composed of cellulose, hemicellulose and lignin. The digestibility of the NDF fraction is determined by the concentration and proportions of cellulose, hemicellulose and lignin. Since the soluble material of cells is well digested by ruminants, the quantity and quality of NDF determine the digestibility of the forage as a whole. The proportions of the compounds in the NDF fraction are different in forages and change substantially even within an individual forage over the development cycle of the grass plants. The availability of energy from forage is limited by the fibre concentration in the fodder, because fibre is slowly and incompletely digested. Grass fibre is more digestible than that of legumes, but that of legumes is digested at a faster rate. Ruminants digest 40–50% of legume fibre and 60-70% of grass fibre (Smith et al., 1972).

The hemicellulose content of grasses is 2.5–1.6 times higher than that of leguminous plants, but the difference decreases as the plants mature (Sullivan, 1966). While the NDF content of legumes is lower than that of grasses, the base figure for lignin is higher in legumes than in grasses. Legumes are typically more easily digested than grasses – not because legume fibre is easier to digest, but because legumes contain less fibre than grasses. Intake and digestibility depend on the level of mastication of the forage, the speed of passage through the fore-stomachs and the rate of NDF digestibility in the rumen. The level of mastication and the speed of passage through the fore-stomachs are higher in the case of legumes. Compared to grasses, legumes have a higher share of non-degradable NDF, but the speed of their NDF degradation is higher.

The proportion of leaves in the biomass exceeding 50% in earlier stages of development ensures a high nutritive value of forage, as stems are characterised by high NDF content and low TP content in more mature stages of development (Table 5). The ratio of leaves to stems is lower in the flowering stage than in earlier stages of development. This is due, on the one hand, to DM biomass accumulation in the stems, and on the other hand to the falling off of lower leaves as the herbage grows together. The ratio of leaves to stems is an additional factor to be observed in assessing the nutritive value of grass plants.

Table 5. NDF and TP content in g kg-1 DM of stems/stalks.

Species	Stem elongation stage		Beginning of ear emergence /budding stage		Ear emergence/flowering stage	
	NDF	TP	NDF	TP	NDF	TP
Timothy	541	121	660	101	688	85
Meadow fescue	537	128	624	114	661	97
Perennial ryegrass	529	122	612	106	620	93
Lucerne	469	161	542	128	625	87
Red clover	403	141	498	115	545	82

Timothy that has reached the ear emergence stage makes for a fibre-rich forage. The fibre content of the stems of meadow fescue, and especially perennial ryegrass, is lower. At the end of the stem elongation stage, the lignin concentration in NDF was 2.9 times higher in the stems of legumes than in the stems of grasses. Compared to the stem elongation stage, the lignin content grew by 56% in the stems of grasses by the middle of the ear emergence stage, and by 72% in the stems of legumes by the middle of the flowering stage. It should be noted that the base figures for legumes were higher than those for grasses.

Lignin as an indigestible component directly reduces the intake and digestibility of forage (Jung, 1989). The negative impact of tissue lignification on nutritive value derives from the decrease in metabolisable energy concentration and the reduction in the intake of forage dry matter.

Minerals in grass plants

Laboratories are mostly limited to determining the content of calcium (Ca), phosphorus (P), potassium (K) and magnesium (Mg) in forages. The most dynamic of these is K, which is involved in the metabolic processes of the plant and is the main intracellular cation. K enhances the absorption of nitrogen compounds in plants, and protein-rich plant parts (young leaves and buds) are, therefore, also richer in K. An increasing concentration of soluble K reduces the absorption of Ca and Mg in plants. The data obtained from the analysis conducted during the project indicate a correlation between the content of K and Ca (lucerne $r=0.36$, clover $r=0.37$, grasses $r=0.70$, $P<0.05$), and between the content of K and Mg (lucerne $r= 0.36$, clover $r=0.53$, grasses $r=0.51$). Due to the antagonism of the elements, a high K content may inhibit the entry of Mg into plants, and eating grass with a low Mg content may be a cause of grass tetany in animals. This disease can also occur in the case of a silage-rich ration.

K concentrations of forage above 15 g/kg cover ruminants' need for K. Any excess amounts of K are readily excreted in urine. K intensifies the lignification of plant cell walls, as it activates the synthesis of carbohydrates and thereby the formation of lignin.

Phosphorus (P) is an indispensable element in proteins, nucleic acids, hormones, enzymes and other important plant growth regulators. The P content of forages varies to a large extent (1.7–4.3 g kg^{1}). According to the trial data, the P content was higher in early mowing. The P content in the dry matter of grasses – timothy (*Phleum pratense*), meadow fescue (*Festuca pratensis*) and perennial ryegrass (*Lolium perenne*) – was 3.3–3.4 g kg^{-1} in the first cut and 2.7–2.9 g kg-1 in a later cut. Legumes were a little richer in P (3.0–3.7 g kg^{-1}). Leaves contained more P than stems (4.1 and 2.9 g kg^{-1}, respectively).

Calcium (Ca) is necessary for the growth and development of plants, because it is involved in the metabolism of carbohydrates and proteins. Ca content varies substantially in different plant species. Clover and lucerne were richer in Ca than grasses. Among the vegetative parts of plants, the leaves had the highest content of Ca and crude ash. Adult animals assimilate up to 50% of the calcium derived from feed. The Ca:P ratio (1,5–2:1) in the ration needs to be observed in feeding animals. Too high a ratio (3–5:1) may impair the assimilation of P and Mg. In clover and lucernes the ratio is high (4–5:1) and can be improved by adding grasses to crop mixes. The Ca:P ratio is lower in grasses (1.2:1 in the first cut; 1.4:1 in the second and third cuts).

Magnesium (Mg) forms part of the composition of chlorophyll, protoplasm and substances required for the growth of plants. Mg is in positive correlation with Ca and protein. Plants are richer in Mg in early development stages than in later cuts. The data also indicated that Mg content is higher in legumes than in grasses. According to the trial data, the Mg content of clover was 3.0 in the early harvest and 2.6 g kg^{-1} in the late cut, and the Mg content of grasses was 1.5 and 1.2 g kg^{-1}, respectively. The Mg content of plants is lower in growing seasons characterised by heavy precipitation, as Mg is leached from the soil. K has negative effects on the absorption of Mg, whereas Ca can increase the absorption of Mg. The uptake of Mg can be reduced by a low level of carbohydrates and high protein concentration. Growing mixed crops of legumes and grasses enables the content of mineral elements in forages to be optimised.

Mixed crop forages

Legumes differ from grasses in terms of chemical composition and nutritive value characteristics. In mixed crops, species complement one another. Mixed crops of legumes and grasses have the following advantages compared to pure-sown crops:

1. mixed crops are generally more productive than pure crops of the same species;
2. protein content is higher in mixed crops than in pure-sown crops of grasses;
3. appropriate proportions of legumes and grasses in mixed crops improve the digestibility and intake of forage; and
4. mixed crops extend the optimal time during which to harvest the forage.

Rhizobia (bacteria inhabiting the roots of leguminous plants and living in symbiosis with the plants) fix atmospheric nitrogen (N_2), which can be used by both the leguminous host plants and – through the soil – the grasses included in mixed crops. This makes it possible to reduce the use of inorganic nitrogen fertilisers in agriculture. On the other hand, the high protein content of pure legume crops and its high rumen degradability creates problems in feeding, but the crude protein content of mixed crops is normally close to the optimum. The ensiling of legumes involves problems with fermentation and N emissions which can be alleviated by using mixed crops.

Mixes of red clover (*Trifolium pratense*) and grasses

Compared to pure-sown clover crops, mixes with grasses provide higher total harvests. In mixed forages the concentration of water-soluble carbohydrates and metabolisable energy are higher, and such forages are characterised by higher digestibility than pure red clover. Ca and Mg content are lower in mixes than in pure-sown red clover crops.

Red clover tolerates cover crops well, but failures of undersown crops have frequently been observed in the case of large grain harvests resulting from heavy fertilisation. Therefore, red clover is sown without a cover crop, with the harvest of the seeding year being used for animal feed. In this case, it is advisable to grow early varieties of red clover.

Early red clover develops as a summer variety and provides blooming stems as early as the seeding year. If sown without a cover crop, the first shoots of red clover start to appear a month after germination, and if the first harvest is cut in the bud formation stage, another harvest can be cut at the end of September.

In mixed field hay crops, red clover is mixed with timothy to improve the lodging resistance of the stand, to avoid spaces from becoming overgrown with weeds and to prolong the life of the crops. The choice of grass species for sowing without a cover crop is diverse (annual, biennial or perennial).

In early development stages, early red clover has low dry matter content and a high nutritive value. As the share of grasses in the harvest of red clover increases, the dry matter and fibre content grows, the protein content decreases and the protein balance in the rumen becomes more favourable. When choosing the species of grasses in the mix, their development speed, nutritive value and impact on the harvest need to be taken into account.

According to trial data, the grasses used in the mix reduced the metabolisable energy and content of metabolisable protein of the forage, but the resulting forage still exceeded the minimum requirement for good forage. The impact of grasses on the nutritive value of the dry matter was greater in the first cut than in the second. Compared to pure-sown red clover, the metabolisable energy content was reduced by the addition of smooth brome (*Bromus inermis*) by 0.6–0.8 MJ and by the addition of Italian ryegrass (*Lolium multiflorum*) and timothy (*Phleum pratense*) by 0.2–0.4 MJ; and the metabolisable protein content was reduced in the mix with smooth brome by 0.2–0.7% and in the mix with Italian ryegrass and timothy by 0.1–0.4%. During the first cut, the smooth brome was in the ear emergence stage and its impact on the nutritive value of the mixed crop was negative. During the second cut it was producing abundant vegetative long shoots. Due to late development, the timothy was at the beginning of the ear emergence stage during the first cut and in the stem elongation stage during the second. The impact of the timothy on the harvest of the second cut was low due to the modest aftermath growth of the species.

Mixes of lucerne with grasses

Lucerne (*Medicago*) is more drought-tolerant and develops faster than red clover (*Trifolium pratense*). If sown with grasses, the protein content of the forage's dry matter increases ($r=0.63$, $P<0.01$) and the NDF content decreases ($r=-0.55$, $P<0.01$). Mixed crops exceeded the harvests of pure-sown lucerne by 11.7% in the case of hybrid lucerne (*Medicago x varia*) varieties and by 12.3% in the case of common lucerne (*Medicago sativa*). The four-year average harvest of common lucerne exceeded that of hybrid lucerne by 11%, because the harvest of the third cut of hybrid lucerne is very low.

The first and second cuts of the trial mix of common lucerne (*Medicago sativa*) 'FSG408DP' and perennial ryegrass (*Lolium perenne*) 'Raidi' produced a protein content of 149–159 g kg^{-1} DM and an NDF content of 450–478 g kg^{-1} DM. Pure-sown perennial ryegrass 'Raidi', however, produced the following results: protein 125-144 g kg^{-1} DM and NDF 492–512 g kg^{-1} DM.

The metabolisable energy content of dry matter was 9.9-10.2 MJ kg^{-1} in the first cut. A change in the seed rate of timothy is not likely to have any impact on the metabolisable energy content of dry matter

($r=0.3$, $P<0.05$). During the second cut the plants were at a later stage of development and therefore the nutritive value of dry matter was lower (9.3–9.6 MJ ME kg^{-1}). The nutritive value of the third cut was higher compared to the previous two cuts: ME 10.5–10.6 MJ kg^{-1} for lucerne and as much as 10.9–11.1 MJ kg^{-1} DM for hybrid lucerne.

The three-year average protein content of mixed crops was optimal in the first and second cuts (157–195 g kg^{-1} DM) and high in the third cut (219 g kg^{-1} DM in the mix of common lucerne and hybrid ryegrass). The protein content correlated credibly with the share of lucerne in the mixed crop ($r=0.73$, $P<0.05$). The protein content of pure-sown lucerne was 207–233 g kg^{-1} DM in the first, second and third cuts. During the first cut the plants were at the end of the budding stage or at the beginning of the flowering stage, depending on the temperature and precipitation in spring-summer.

The NDF level of mixed crops was higher, but the digestibility of DM and the energy content of the forage were lower compared to pure-sown lucerne (Table 6).

Table 6. Nutritive value of DM in pure-sown lucerne and mixed crops of lucerne and grasses.

Crop	NDF g/kg	Digestibility,%	ME MJ/kg
Pure-sown lucerne FSG 408 DP	382	66	10.3
Same, mixed crop	424	65	10.1
Pure-sown lucerne 'Karlu'	365	66	10.4
Same, mixed crop	445	63	9.8

Over the three trial years, the DM digestibility in the first and second cuts of mixed crops composed of lucerne and hybrid ryegrass (Lolium hybridum) and lucerne and meadow fescue (Festuca pratensis) was comparable to the digestibility of pure-sown lucerne (630-660 g kg^{-1} and 635–680 g kg^{-1} DM for mixes and pure-sown lucerne, respectively).

Instead of classic timothy, leafier grasses characterised by an average speed of development are better suited for inclusion in the seed mixes of legumes/grasses. Hybrid ryegrass, perennial ryegrass, tall fescue and meadow fescue grow more evenly in mixes with legumes and ensure the good nutritive value of forage throughout the growing season.

Yield and nutritive value of mixes of bird's-foot trefoil with grasses

Bird's-foot trefoil (*Lotus corniculatus*) is limited in prevalence in Estonia, but remains significant as forage. Bird's-foot trefoil contains tannin. The chemical composition of tannins creates a defence system in plants against fungi, mould and bacteria. The tannins of legumes can have both positive and negative effects on the nutritive value of forages. High concentrations of tannins suppress feed intake and digestibility in animals, because high tannin concentration is associated with high lignin content and low TP and digestibility. Low to moderate concentrations of tannins have a positive effect on the protein metabolism of forage and prevent bloats and parasitic worms in animals. Tannins and soluble protein form a compound which is insoluble in the rumen (pH 5.8–6.8) but soluble in the abomasum, where the pH conditions are extreme (pH 2.5–3.5), and in the small intestine (pH 7.5–8.5).

The tannin content of forage can reduce the degradability of protein in the rumen and increase the absorption of protein in the small intestine. Bird's-foot trefoil 'Norcen' is characterised by a moderate tannin concentration (23 g CE kg^{-1} DM); the tannin concentration is higher in spring and summer, and its levels are higher in leaves and flowers than in stems. Tannin correlates positively with the concentration of non-degradable protein.

One of the tasks of the study carried out in Saku was to identify the impact of grasses (timothy, meadow fescue and perennial ryegrass), red clover (tetraploid 'Varte') and lucerne (common lucerne FSG 408DP) in mixed crops with bird's-foot trefoil. The results based on three cuts showed that the competitiveness of bird's-foot trefoil is low in mixed crops. When sown with red clover and lucerne, bird's-foot trefoil formed the under-storey and accounted for 2–6% in the first cut. From the second cut it was only represented by individual plants in the mixes.

Bird's-foot trefoil was more persistent with grasses. There was a positive correlation between the proportion of bird's-foot trefoil in the first cut and the TP% in the first cut ($P<0.05$, $r=0.93$); as the proportion of bird's-foot trefoil increased, TP grew, while NDF and ADF values decreased ($P<0.05$ NDF $r=0.90$ and ADF $r= 0.64$). The dry matter yield of pure-sown bird's-foot trefoil was 7.3 t ha^{-1} in the first year, 4.6 t ha^{-1} in the second year and 9.9 t ha^{-1} in the third year. In the mix with grasses the yield increased to 11 tonnes i.e. by 21–46%. In all trial years the highest yields were obtained when growing bird's-foot trefoil with timothy.

Assessments of nutritive value indicated that the greatest changes in the chemical composition occurred in the first cut of the bird's-foot trefoil mixed with grasses; on average, the NDF level was 23% lower and the ADF level was 6% lower in mixed crops compared to pure-sown grasses. The protein content in the dry matter of pure-sown bird's-foot trefoil was 180–210 g kg^{-1}, but 60–140 g kg^{-1} when mixed with grasses.

The threshold value of metabolisable energy was set at 9.5 MJ kg^{1} and a greater value was obtained in all cuts of pure-sown bird's-foot trefoil and in the second and third cuts of mixed crops.

The first cut of mixed crops could not be harvested earlier in the case of the 'Norcen' variety because of the late start in its growth in spring and its slow development. Earlier varieties of bird's-foot trefoil should be included in mixes, adding grasses of high nutritive value. According to the trial data, perennial ryegrass ('Raidi' variety) was the most effective addition to the mix. Bird's-foot trefoil is suitable for mixing with grasses in ecological areas that are less favourable for white clover (drier soils with lower soil fertility).

In conclusion, the moderate presence of grasses in mixes with legumes increases the nutritive value of the forage and generally improves the DM yield. Legume/grass mixes mature later, because legumes need more heat for growth and development compared to grasses. While a moderate share (30–50%) of grasses in mixes reduces the protein content and digestibility of the forage, the forage obtained still meets the good forage criterion if harvested at the optimal time. The concentration of leaves is usually higher in mixes, because the lower leaves of legumes fall off or dry at a slower rate. Assessment of the species composition of mixed crops is important in determining the optimal cutting time.

If harvesting is late, the faster development of grasses will lead to a substantial reduction in protein and metabolisable energy levels.

Legumes increase the P content in mixed crops, while grasses reduce the Ca content, which has an indirect positive effect on the health and production of animals.

Photo 2: A pasture is the best place to feed sheep in summer.

Sheep feeds

Pasture grass

The pasture chosen for grazing must be suitable for sheep in terms of the concentration of nutritional factors corresponding to the age group of the sheep. Compared to grasses on cultivated pastures whose palatability accounts for 70–80%, the palatability of grasses growing on natural pastures is much lower i.e. 50–60% (Jaama, 1984). Good-quality pasture grass is usually sufficient for feeding sheep (Photo 2) if the necessary minerals and clean water are readily available to them (Umberger, 2009).

The nutritive value of pasture grass is mainly determined by the botanical and morphological composition of the vegetation, the environment in which the grass is growing and the age of the plants (Lambert & Litherland, 2000).

Red fescue (*Festuca rubra*), meadow fescue (*Festuca pratensis)*, ryegrass (*Lolium*), meadow foxtail (*Alopecurus pratensis*), white clover (*Trifolium repens*) and alsike clover (*Trifolium hybridum*) are considered the best sheep pasture plants (Jaama, 1984). Sheep also enjoy eating a number of other forbs (Clark & Harris, 1985). The nutritive value of legumes is generally considered to be higher than that of grasses (Ulyatt et al., 1976; Lambert & Litherland, 2000). Macronutrients (such as energy and protein) are the key factors that affect sheep's selection of feed, and feeds rich in rapidly fermentable energy are therefore preferred by sheep (Wang & Provenza, 1996).

In the United States it has been found that grasslands where the share of clover or other legumes exceeds 50% should be avoided during the breeding season of sheep, because legumes may contain oestrogenic compounds, which reduce conception rates (Umberger, 2009). Also, it has been ascertained that although sheep otherwise prefer to eat clover, on pastures with a very high share of white clover (Trifolium repens) they will start to show a preference for other plants (Clark & Harris, 1985).

Other legume species may also prove useful for sheep due to the content of other substances, such as tannins, which are typically found in bird's-foot trefoil (Lotus) varieties (Grebrehiwot et al., 2002). Plants with a higher tannin content help to reduce internal parasites in sheep (Villalba et al., 2010; Barry & McNabb, 1999). It has also been found that medium concentrations of tannins (30-40 g/kg DM) in bird's-foot trefoil (Lotus corniculatus) increase wool growth and milk secretion in sheep (Barry & McNabb, 1999). Moreover, tannins found in plants can help prevent gases/bloats in sheep (Waghorn et al., 1990). However, too high a content of tannins in plants is not good for sheep, because tannins bind proteins in the rumen, thereby reducing their decomposition and dissolution by rumen microbes (Waghorn et al., 1990).

In addition to the botanical composition of plants, the intake of pasture grass is also affected by the age and height of the grass. With age, the soluble and rapidly degradable fraction of the plant cell (proteins and monosaccharides) decreases, while the share of the cell wall, which is not readily soluble, increases (Seoane et al., 1982; Baumont et al., 2000), and so the digestibility (Jung & Allen, 1995) and nutritive value of the feed decline (Christen et al., 1990). As plants grow older, their NDF content increases and the digestibility of NDF decreases (Bernes et al., 2007) due to the lignification process in plant leaves and stems (Stone, 1994). As a result, the feed stays in the rumen for a longer period of time and keeps it full longer (Baumont et al., 2000); feed intake is therefore reduced. This process occurs to an even greater extent in the case of plant stems (Lambert & Litherland, 2000).

Therefore, old feed with a high cell wall concentration cannot meet the energy needs of sheep, because sheep are unable to eat sufficient quantities of such feed to obtain the necessary amount of energy (Jung & Allen, 1995).

In most cases, sheep prefer short (5–15 cm high), fresh, leafy forbs to more mature stemmed grasses (Umberger, 2009), because plant leaves have a higher nutrient content than stems (Lambert & Litherland, 2000). Compared to stems, the protein content of leaves decreases more slowly as the plant matures (Stone, 1994), which may be one of the reasons why sheep prefer leaves over stems. With age, the proportion of stems increases compared to leaves and hence intake declines (Seoane et al., 1982).

Data on the nutritive value of grass samples collected on the pastures belonging to the project partners are set out in Table 7. Grass grown on a cultivated pasture and on upland pastures had the highest nutritive value and was suitable for sheep in all age groups. Grass collected from wooded and coastal pastures was of a lower value in terms of both protein and energy content.

On wooded pastures, brush clearing and tree thinning had only recently been carried out, and the herb layer was in the early stage of formation. Sheep were used to reduce the brush layer on wooded pastures. From a rational feeding point of view, it is possible to use free ewes and ewes in early pregnancy for this purpose. Lactating ewes and weaned lambs need much higher nutrient concentrations. By the beginning of the mating period, ewes should be well-fed and thus the period of their grazing on wooded pastures is limited.

Table 7. Nutritive value of pasture grass DM.

Indicator	Cultivated pasture	Upland pasture	Wooded pasture	Coastal pasture
Protein, %	17.9	16.1	13.9	12.8
MP, g	92	88	82	77
DDM, %	67	66	63	62
DMI, %	2.7	2.6	2.3	2.2
Phosphorus, g	3.2	2.5	2.6	2.7
ME MJ/kg	10.7	9.8	9.2	9.6

The share of legumes was low in the vegetation of coastal pastures and thus the protein content of the feed was low. The nutritive value was also reduced by the abundance of common reed (*Phragmites australis*). The community of sea milkwort (*Glaux maritima*) and saltmarsh rush (*Juncus gerardii*) had the highest nutritive value, but it only grew on a narrow strip of coastal land.

Grass silage

Studies conducted by Finnish researchers have concluded that since silage has a greater nutritive value than hay, it is well suited to replacing the forage of pregnant and lactating ewes. It was also found that sheep grew better when fed with silage than when fed with hay (Sormunen-Cristian & Jauhianen, 2001).

In a study conducted in Sweden it was found that when sheep were given only silage the meat obtained was of a higher quality than that of sheep fed with hay (Bernes et al., 2011). However, it should be borne in mind that silage alone may not be enough for lactating ewes. A Swedish study concluded that feeding with just silage is insufficient for ewes with more than one lamb (Bernes & Stengärde, 2011). Even if the silage is of very good quality, it is not sufficient for the optimal growth of sheep (Bernes et al., 2011), and therefore sheep should also be given concentrated feed.

One way to improve the intake of low-quality silage is to increase the microbial activity in the rumen of sheep. To this end, feeds that are high in energy and thereby increase microbial protein synthesis and short-chain fatty acid production could be added to silage (Vranić et al., 2007).

Therefore, the presence of legumes in silage is also important. One study has found that red clover and lucerne silage helped to better meet the nutritional requirements of ewes in late stages of pregnancy compared to silage made of grasses (Speijersa et al., 2005). In addition, it has been found that the protein in legume silage is easier to digest than the protein in timothy silage (Laforest et al., 1986). However, care should be taken to avoid giving red clover-rich pasture grass and silage to sheep before the start of the mating season and during the mating season, because a high intake of clover can significantly reduce the number of lambs born (Thomson, 1975).

The time of mowing also affects the quality of silage. Silage made from grass cut in earlier periods is of a higher nutritive value than silage made from grass harvested later (Castle et al., 1980). One study found that sheep's intake of silage with a higher dry matter content exceeded that of silage with low dry matter content, but this could also be due to the fact that the silage with high dry matter content contained a greater degree of water-soluble sugars and hemicellulose (Beaulieu et al., 1993).

The results of determining the nutritive value of grass silage on the sheep farms belonging to the project partners are presented in Table 8 based on the botanical composition of the silage. In terms of land parcels, short-term grassland (red clover silage) included in the rotation of crops and permanent grasslands used for more than five years were used to prepare silage. Semi-natural habitats were inappropriate for the production of silage due to the small harvest, the abundance of stones and the uneven landscape.

Table 8. Nutritive value of grass silage DM.

Indicator	Grass silage	Red clover silage	Galega silage	Lucerne silage
Protein, %	9.9	13.3	14.5	14.6
MP, g	77	83	84	85
DDM, %	60	62	62	63
DMI, %	1.8	2.1	2.1	2.1
Phosphorus, g	2.2	2.8	2.8	3.0
ME MJ/kg	9.4	9.7	9.6	9.7

The data show that grass silage with a higher nutritive value was obtained from legume and grass swards. The relatively low protein content was due to late harvesting. Although the Institute advised of the optimal time for making silage, grass silage was still usually produced 1-2 weeks later. The reason for this was that the farmers outsourced the preparation of silage rolls from other farms. Service providers, however, first made the silage necessary for their own farms and only thereafter undertook this outsourced work.

Hay as winter feed for sheep

Hay has traditionally been the main feed for sheep in the winter period in Estonia. Despite the often low nutrient content of dry hay and the greater time and energy resources needed for its mastication and digestion, ruminants still prefer it to other feeds. If the fibre content of hay is too high, hay intake drops because the fermentation ability of sheep rumen is lower compared to that of cows (Cannas, 2002). High cell wall content causes the feed to remain in the rumen longer, and thus the intake of hay is reduced in line with the decline in the quality of hay (Welch & Smith, 1969). When harvesting hay for sheep, one should bear in mind that prolonged exposure of hay to the sun causes a loss of carotenoids and vitamin A activity (Coleman & Henry, 2002). Also, rain can leach water-soluble nutrients from mown hay (Cole-

Photo 3. A project partner has found an effective way of reducing the amount of roughage wasted when feeding sheep – Merike Liivlaid from Soobasauna farm and Uno Tamm, a senior researcher at the Estonian Crop Research Institute, study a home-made round feeding rack.

man & Henry, 2002). Furthermore, drying reduces the digestibility of nitrogen contained in grass (75% for fresh grass; 71% for dried grass) (Beever et al., 1971).

Data on the laboratory analyses of the hay collected from the sheep farms are set out in Table 9. Permanent grasslands (old cultivated meadows) and semi-natural communities of natural grasslands (coastal and upland grasslands) were used for haymaking. Hay-baling technology was used on all farms.

The quality of hay was highly variable, depending on the botanical composition of the sward, the time it was made and the prevailing weather conditions at that time. Hay was mostly harvested during the first ten days of July. Permanent grasslands and natural areas yielded both good and poor-quality hay. Hay harvested from upland grasslands and coastal areas was characterised by a higher nutritive value. This hay was fine-stemmed and also contained a moderate proportion of legumes – clover (*Trifolium*), vetch(*Vicia*) and black medic (Medicago lupulina). The nutritive value of the hay harvested on permanent grasslands was lower due to the presence of orchard grass (Dactylis glomerata) and meadow foxtail (Alopecurus pratensis) in the swards.

To avoid proper hay being rendered unfit for consumption by the sheep themselves, it is advisable to place it in a feeding rack where sheep can comfortably get it in sufficient quantities, yet not pull large amounts of it down onto the ground (Photo 3).

Table 9. Nutritive value of hay DM.

Indicator	Hay from permanent grasslands		Hay from natural grasslands	
	Good	Poor	Good	Poor
Protein, %	11.5	5.2	12.7	7.5
MP, g	78	56	81	64
DDM, %	60	54	62	61
DMI, %	2.0	1.7	2.1	1.8
Phosphorus, g	2.2	1.6	3.0	2.8
ME MJ/kg	8.5	7.6	9.0	8.8

Piirsalu (2012) notes that, in terms of the nutritive value of hay, good hay is that whose ME content in DM exceeds 9.5 MJ; hay with an ME content of 8.5 MJ can be regarded as average, while hay with an ME content of 7.5 MJ is to be regarded as poor.

If haymaking fails or the hay is of poor nutritive value, the sheep can also be fed oat or barley straw. Data from analyses suggest that the protein content of oat straw is 8.0% and that its ME level is 7.8 MJ.

ACKNOWLEDGEMENTS: The studies underpinning this article were financed by the KNOWSHEEP project ('Developing a knowledge-based sheep industry on the Baltic Sea islands'), which was carried out under the Archipelago and Islands Sub-Programme of the European Union's Central Baltic INTERREG IV A Programme. The silage monitoring data collected during the project 'Dynamics of quantitative changes in forage', funded by the Estonian Ministry of Agriculture, were also used in the article.

The authors are grateful to all of the sheep farmers and colleagues involved in the project.

REFERENCES

Baumont, R., Prache, S., Meuret, M. & Morand-Fehr, P. 2000. How forage characteristics influence behavior and intake in small ruminants: a review. *Livestock Production Science* **64**, 15–28.

Barry, T. N. & McNabb, W. C. 1999. The implications of condensed tannins on the nutritive value of temperate forages fed to ruminants. *British Journal of Nutrition* **81**, 263–272.

Beaulieu, R., Seoane, J. R., Savoie, P., Tremblay, D., Tremblay, G. F. & Thériault, R. 1993. Effects of dry-matter content on the nutritive value of individually wrapped round-bale timothy silage fed to sheep. *Canadian Journal of Animal Science* **73**, 343–354.

Beever, D. E., Thomson, D. J., Pfeffer, E. & Armstrong, D. G. 1971. The effect of drying and ensiling grass on its digestion in sheep. Sites of energy and carbohydrate digestion. *British Journal of Nutrition* **26**, 123–134.

Bernes, G., Hetta, M. & Martinsson, K. 2007. Effect of maturity in timothy on silage quality and lamb performance. *Options Méditerranéennes*, Series A, No. 74.

Bernes, G. & Stengärde, L. 2011. Sheep fed only silage or silage supplemented with concentrates. 1. Effects on ewe performance and blood metabolites. *Small Ruminant Research* **102**, 108–113.

Bernes, G., Turner, T. & Pickova, J. 2011. Sheep fed only silage or silage supplemented with concentrates 2. Effects on lamb performance and fatty acid profile of ewe milk and lamb meat. *Small Ruminant Research* **102**, 114–124.

Bullock, J. M., Franklin, J., Stevenson, M. J., Silvertown, J., Coulson, S. J., Gregory, S. J. & Tofts, R. 2001. A plant trait analysis of responses to grazing in a long-term experiment.

Journal of Applied Ecology **38**, 253–267.

Cannas, A. 2002. Feeding of lactating ewes. In Pulina, G. (ed.): *Dairy Sheep Feeding and Nutrition.* Avenue Media, Bologna, Italy, s. 79–103.

Castle, M. E., Retter, W. C. & Watson, J. N. 1980. Silage and milk production: a comparison between three grass silages of different digestibilities. *Grass and Forage Science* 53: 219–225.

Christen, A. M., Seoane, J. R. & Leroux, G. D. 1990. The nutritive value for sheep of quackgrass and timothy hays harvested at two stages of growth. *Journal of Animal Science* **68**, 3350–3359.

Clark, D. A. & Harris, P. S. 1985. Composition of the diet of sheep grazing swards of differing white clover content and spatial distribution. *New Zealand Journal of Agricultural Research* **28**, 233–240.

Coleman, S. W. & Henry, D. A. 2002. Nutritive Value of Herbage. In Freer, M. & Dove, H. (eds.): *Sheep Nutrition.* CABI, Wallingford, UK. S. 4–10.

Grebrehiwot, L., Beuselinck, P. & Roberts, C. 2002. Seasonal variations in condensed tannin concentration of three Lotus species. *Agron. Journal* **94**, 1059–1065.

Isselstein, J., Griffith, B. A., Pradel, P. & Venerus, S. 2007. Effects of livestock breed and grazing intensity on biodiversity and production in grazing systems: 1. Nutritive value of herbage and livestock performance. *Grass Forage Science* **62**, 145–158.

Jaama, K. 1984. Lambakasvataja käsiraamat. Tallinn, Valgus.

Jung, H. G. 1989. Forage lignins and their effects on fiber digestibility. *Agron. Journal.* **81**:39–46.

Jung, H. G. & Allen, M. S. 1995. Characteristics of plant cell walls affecting intake and digestibility of forages by ruminants. *Journal of Animal Science* **73**, 2774–2790.

Krall, H., Kukk, T., Kull, T., Kuusk, V., Leht, M., Oja, T., Reier, Ü., Sepp, S., Zingel, H. & Tuulik, T. 2007. Eesti taimede määraja. Eesti Loodusfoto, Tartu.

Laforest, J. P., Seoane, J. R., Dupuis, G., Phillip, L. & Flipot, P. M. 1986. Estimation of the nutritive value of silages. *Canadian Journal of Animal Science* **66**, 117–127.

Lambert, M. G. & Litherland, A. J. 2000. A practitioner's guide to pasture quality. *Proceedings of the New Zealand Grassland Association* **62**, 111–115.

Mills, J., Rook, A. J., Dumont, B., Isselstein, J., Scimone, M. & Wallis De Vries, M. F.

2007. Effect of livestock breed and grazing intensity on grazing systems: 5. Management and policy implications. *Grass Forage Science* **62**, 429–436.

Oll, Ü. 1994. Söötmisõpetus. Tallinn, Valgus, 303 s.

Paal, J. 1997. Eesti taimkatte kasvukohatüüpide klassifikatsioon. Keskkonnaministeeriumi ja ÜRO Keskkonnaprogramm, Tallinn.

Parsons, A. J., Newman, J. A., Penning, P. D., Harvey, A. & Orr, R. J. 1994. Diet preference of sheep: effects of recent diet, physiological state and species abundance. *Journal of Animal Ecology* **63**, 465–478.

Pavlů, V., Hejcman, M., Pavlů, L. & Gaisler, J. 2003. Effect of rotational and continuous grazing on vegetation of an upland grassland in the Jizerské hory Mts, Czech republic.

Folia Geobotanica **38**, 21–34.

Pavlů, V., Hejcman, M., Pavlů, L., Gaisler, J. & Nežerková, P. 2006. Effect of continuous grazing on forage quality, quantity and animal performance. *Agriculture, Ecosystems and Environment* **113**, 349–355.

Piirsalu, P. 2012. Lambakasvatus I. Tartumaa Põllumeeste Liit, (Põltsamaa: Vali Press), Tartu 155–156 s.

Provenza, F. D. 1996. Acquired aversions as the basis for varied diets of ruminants foraging on rangelands. *Journal of Animal Science* **74**, 2010–2020.

Pärtel, M., Sammul, M. & Bruun, H. H. 2005. Biodiversity in temperate European grasslands: origin and conservation. In: Lillak, R., Viiralt, R., Linke, A. & Geherman, V. (eds.) *Integrating efficient grassland farming and biodiversity. Grassland Science in Europe 10.,* s. 1–14. Estonian Grassland Society, Tartu.

Pykälä, J. 2005. Plant species responses to cattle grazing in mesic semi-natural grassland. *Agriculture, Ecosystems and Environment* **108**, 109–117.

Seoane, J. R., Côté, M. & Visser, S. A. 1982. The relationship between voluntary intake and the physical properties of forages. *Canadian Journal of Animal Science* **62**, 473–480.

Smith, L. W., Goering H. K. & Gordon C. H. 1972. Relationships of forage compositions with Rates of Cell Wall Digestion and Indidestibility of Cell Walls *J Dairy sci* **55**:1140–1147.

Sormunen-Cristian, R. & Jauhianen, L. 2001. Comparison of hay and silage for pregnant and lactating Finnish Landrace ewes. *Small Ruminant Research* **39**, 47–57.

Speijersa, M. H. M., Frasera, M. D., Haresigna, W., Theobalda, V. J. & Moorby, J. M. 2005. Effects of ensiled forage legumes on performance of twin-bearing ewes and their progeny. *Animal Science* **81**, 271–282.

Stone, B. A. 1994. Prospects for improving the nutritive value of temperate, perennial pasture grasses. *New Zealand Journal of Agricultural Research* **37**, 349–363.

Sullivan, J. T. 1966 Studies of the hemicelluloses of Forage plants, *J Anim Sci,.* **25**:83–86.

Tamm, U. 2005. Rohusööda toiteväärtus. Saku, 86 s.

Tamm, U. 2006. Lutsernikasvatus. Saku, 71 s.

Tamm, U. & Tamm, S. 2007 Efektiivsete temperatuuride mõju rohusööda toiteväärtusele. *Agronoomia 2007*, s. 91–94.

Thomson, D. J. 1975. The effect of feeding red clover conserved by drying or ensiling on reproduction in the ewe. *Journal of British Grassland Society* **30**, 149–152.

Ulyatt, M. J., Lancashire, J. A. & Jones, W. T. 1976. The nutritive value of legumes. *Proceedings of the New Zealand Grassland Association* **38** (I), 107–l 18.

Umberger, S. H. 2009. Feeding Sheep. *Virginia Cooperative Extension Publication*. Virginia State University, Virginia, USA, s. 410–853.

Villalba, J. J., Provenza, F. D., Hall, J. O. & Lisonbee, L. D. 2010. Selection of tannins by sheep in response to gastro-intestinal nematode infection. *Journal of Animal Science* **88**, 2189–2198.

Vranić, M., Knežević, M., Bošnjak, K., Leto, J. & Perćulija, G. 2007. Feeding value of low quality grass silage supplemented with maize silage for sheep. *Agricultural and Food Science* **16**, 17–24.

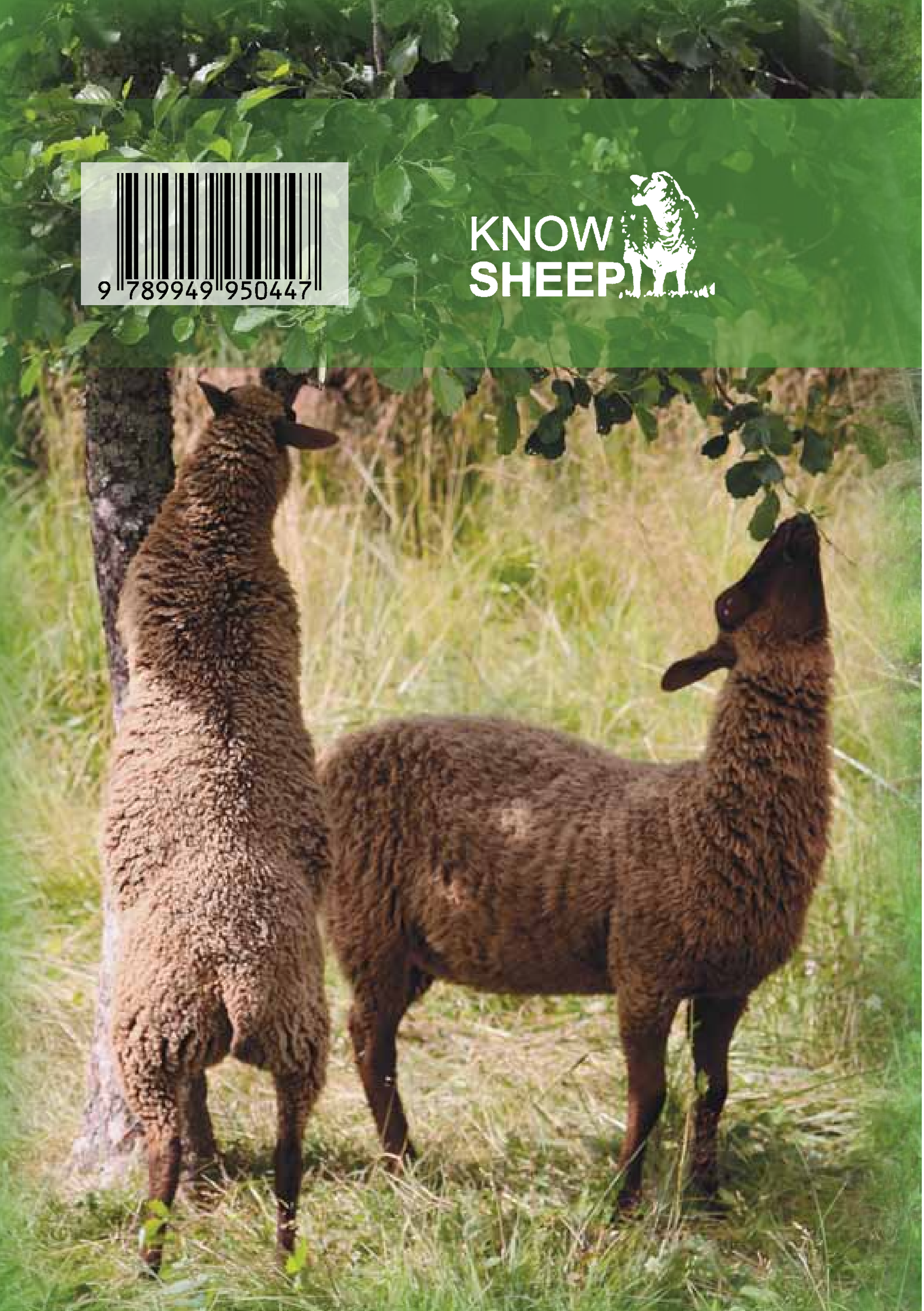
Waghorn, G. C., Jones, W. T., Shelton, I. D. & McNabb, W. C. 1990. Condensed tannins and the nutritive value of herbage. *Proceedings of the New Zealand Grassland Association* **51**, 171–176.

Wang, J. & Provenza, F. D. 1996. Food deprivation affects preference of sheep for foods varying in nutrients and a toxin. *Journal of Chemical Ecology* **22**, 2011–2021.

Wang, J. & Provenza, F. D. 1997. Dynamics of preference by sheep offered foods varying in flavors, nutrients, and a toxin. *Journal of Chemical Ecology* **23**, 275–288.

Welch, J. G. & Smith, A. M. 1969. Influence of forage quality on rumination time in sheep. *Journal of Animal Science* **28**, 813–818.

Znamenskiy, S., Helm, A. & Pärtel, M. 2006. Threatened alvar grasslands in NW Russia and their relationship to alvars in Estonia. *Biodiversity and Conservation* **15**, 1797–1809.


9 789949 950447
KNOW
SHEEP