Bioforsk Rapport
Bioforsk Report
Vol. 8 Nr. 176 2013

The virtual fencing system Nofence - trials 2013

Learning ability and sheep welfare

Brunberg, E.I., Bergslid, R. & Sørheim, K.M.
Bioforsk, Organic Food and Farming

www.bioforsk.no

Hovedkontor/Head office
Frederik A. Dahls vei 20
N-1430 Ås
Tel.: (+47) 40 60 41 00
post@bioforsk.no

Bioforsk Organic food and farming
Gunnars veg 6
6630 Tingvoll
Tel.: (+47) 40 60 41 00
Emma.Brunberg@bioforsk.no

Title:
The virtual fencing system Nofence – trials 2013
Author(s):
Brunberg, E.I., Bergslid, R. & Sørheim, K.M.

Date:	*Availability:*	*Project No.:*	*Archive No.:*
20.12.2013	Open	20180/20200	
Report No.:	*ISBN-no:*	*Number of pages:*	*Number of appendices:*
176/2013	978-82-17-01188-0	16	0

Employer:	*Contact person:*
Regionale forskningsfond Midt-Norge, Møre og Romsdal fylkeskommune, Fylkesmannens landbruksavdeling Møre og Romsdal, NoFence AS, Norges forskningsråd	

Keywords:	*Field of work:*
Virtuelt gjerde, sau, dyrevelferd, læring	Husdyrvitenskap
Virtual fence, sheep, animal welfare, learning	Animal Science

Sammendrag:

Nofence er et GPS - basert virtuelt gjerdesystem tenkt brukt på beitedyr. Hvert dyr bærer en klave rundt nakken, og dersom dyret krysser en forhåndsdefinert grense, vil dyret få en advarsel i form av et lydsignal etterfulgt av et elektrisk støt.
Målet med de to forsøkene som oppsummeres i denne rapporten har vært å:

1. Teste Nofence på sau og lam, med fokus på dyrevelferd og innlæring
2. Utvikle og teste en innlæringsprotokoll for Nofence
3. Sammenligne effekten av Nofence med eller uten bruk av et enkelt fysisk gjerde

I forsøk 1 ble tre grupper plassert på hvert sitt beite i fire dager. Hver gruppe besto av tre søyer med lam. Langs den ene siden av beitet var det en Nofence grense. De to første dagene var det plassert et fysisk gjerde utenfor Nofence-grensen. Det fysiske gjerdet ble fjernet på dag tre. På dag 4 ble Nofence-grensen flyttet til motsatt side av beitet. På dag 3, når det fysiske gjerdet ble tatt vekk, fikk sauene flere strømstøt og var utenfor NoFence-grensen nesten 50 % av tiden. I løpet av forsøksperioden var det flere tekniske problemer med Nofence-systemet.

I forsøk 2 var det fire grupper med åtte sauer i hver gruppe. På dag 1 var sauene på beite med en Nofence-grense. På dag 2 var sauene på beite med to Nofence-grenser. På begge dagene var det et fysisk gjerde utenfor Nofence-grensen på formiddagen. De fysiske gjerdene ble fjernet på ettermiddagen. Mange av sauene fikk maksimalt antall strømstøt både dag 1 og dag 2. De fleste av sauene tilbrakte mesteparten av tiden sin utenfor Nofence-grensen om ettermiddagen på dag 2. Også i dette forsøket var det tekniske problemer med Nofence-systemet. Etter to dager ble forsøket avsluttet på grunn av tekniske problemer og innlæringsvansker hos sauene.

Det var flere forhold som gjorde det vanskelig å gjennomføre planlagte utprøvinger. De tekniske problemene med systemet må være løst før det vurderes å gjennomføre nye forsøk på dyr. Resultatene fra disse forsøkene viser at systemet har utfordringer i forhold til læring, blant annet pga. flokkinstinkt og individuelle forskjeller på følsomhet for strøm. Per i dag fungerer ikke Nofence på en akseptabel måte, og det kan være en risiko for redusert dyrevelferd.

Summary:

NoFence is a GPS-based virtual fencing system to be used for grazing animals. Each animal wears a collar and if crossing a predefined border, the animal will get a sound warning followed by an electric shock. The aims with the two experiments reported in this report were to:

1. To test Nofence on sheep with young lambs focusing on animal welfare and learning.
2. To develop and test a learning protocol for Nofence.
3. To compare the function of Nofence when using it with and without a simple physical fence.

In experiment 1, three groups with three ewes and their lambs in each group, were placed on a pasture for four days. At one side of the pasture, there was a Nofence border. The first two days, it was a physical fence outside the border. This fence was removed day 3. On day 4, the Nofence border was moved to the other end of the pasture. On day 3, when the physical fence was absent, the sheep received more shocks and spent almost 50% of the time outside allowed area. There were also many technical problems with Nofence during this trial.

In experiment 2, the sheep were divided into four groups with eight ewes in each group. On day 1, the sheep were on a pasture with one Nofence border and on day 2 with two Nofence borders. In the morning both days, there were physical fences outside the virtual border. These were removed in the afternoon. After two days of trials, this trial was ended due to technical problems and learning difficulties. Many of the sheep received the maximum allowed number of shocks both day 1 and 2 and most of the sheep spent a majority of the time on the wrong side of the border in the afternoon on day 2. There were technical problems also during this experiment.

There were several problems with the trials this year that made it difficult to perform the intended research. The technical problems must be completely solved before anyone aim at possibly perform any more experiments with animals. Moreover, the results this year show that there are challenges regarding learning due to the herd instinct and individual differences in how sensitive the animals are regarding the shocks. The conclusion is therefore that as it is working now, Nofence was not functioning in an acceptable way and there is a risk for reduced animal welfare.

Land/Country:	Norway
Fylke/County:	Møre & Romsdal
Kommune/Municipality:	Tingvoll
Sted/Lokalitet:	Tingvoll

Approved	Project leader
Kristin Sørheim	Emma Brunberg

Contents

1. Introduction

Being able to keep grazing sheep on large rangeland pastures during summertime is an important attribute in Norwegian sheep production, although not without challenges. Fencing these large areas is not feasible, which means that it is difficult to keep the animals out from areas that are not suitable for the animals to be in. Moreover, supervision and hence early detection of disease can be a challenge when the animals are spread over large areas.

Different virtual fencing systems have in common that the creators wish to keep animals either within a predefined area or out from an area not suited for the animals. Most systems use some kind of aversive stimuli (most commonly electricity), with a prior warning signal, to teach the animals to be in the correct area. Not many of the virtual fencing systems are actually in use, but the first system (patented 1971) used on dogs are still in use in countries in which it is allowed. Research targeting virtual fences has usually consisted of small studies including a limited amount of animals and tested out in small groups (i.e. Bishop-Hurley et al., 2007; Brunberg, 2012; Henriksen & Berntsen, 2011; Jouven et al., 2012; Tiedemann et al., 1999).

Nofence is a virtual fencing system developed for Norwegian animal production by Oscar Hovde Berntsen and the company Nofence AS. In the present study, we have focused on sheep. The main parts of the system is a collar with a GPS and two electrodes. The collar gives a sound signal as soon as a sheep crosses the predefined GPS based border and if the sheep continues to walk over the border it will receive a weak electric shock. If the sheep instead turn when hearing the sound signal, the signal will end and no shock will be received. As the system is presently programmed, the animals can receive maximum four shocks per occasion they cross the border and max five shocks/24 hours. Although, the aim with Nofence is that the animals, after a short learning period, should not receive any shocks but simply turn on the sound signal.

If any virtual fencing system is to be used commercially in Norwegian sheep production, each individual within a large group must be able to learn the system simultaneously and in a rather short time. A learning procedure must also be simple to perform for the farmer. The system must of course function the intended way and the animals should not cross the border. Moreover, animal welfare should be of highest priority. There is, and should be, rather strict regulations around the use of aversive stimuli such as electricity. It is well known that electricity can cause stress in animals (i.e. Lee et al., 2008; Schilder & van der Borg, 2004 and Weiss et al., 1981). Therefore, before considering approving Nofence in commercial use, its implications on animal welfare must be thoroughly examined, which were the purpose of these experiments. The trials in 2011 and 2012 are thoroughly described by Henriksen & Berntsen (2011) and Brunberg (2012). In the experiment performed in 2012, it was concluded that the system needs to be tested on sheep with lambs. That the animals learn the system quickly is of highest importance for animal welfare, and it was therefore suggested that a learning procedure must be developed and tested.

There were three aims with the experiments performed 2013:

1. To test Nofence on sheep with young lambs focusing on animal welfare and learning.
2. To develop and test a learning protocol for Nofence.
3. To compare the function of Nofence when using it with and without a simple physical fence.

2. Methods

2.1 Experiment 1

2.1.1 Animals

Nine ewes with their 16 lambs (1-3 lambs/ewe) were divided into groups of three. The sheep were between one and six years old and were either Norwegian Short Tail Landrace (OL; N=5) or Norwegian white (NW; N=4). The composition of each of the three groups are shown in Table 1. Each animal was individually marked with spray colour on the back and the lambs were marked with the same marking as their mothers. I.e. it was possible to distinguish to which ewe each lamb belonged, but it was not possible to distinguish between lambs within a sibling group.

Table 1. Group, breed, age and lambs for the sheep included in experiment 1. NW=Norwegian white, NL= Norwegian Short Tail Landrace.

Group	Sheep	Breed	Age	No of lambs
A	1	NL	5	2
A	2	NW	1	1
A	3	NW	4	2
B	4	NL	6	2
B	5	NW	4	2
B	6	NL	1	1
C	7	NW	4	3
C	8	NL	3	2
C	9	NL	1	1

Before putting a color on all ewes, they were shaved around the neck to make sure the collar electrodes had contact with the skin.

2.1.2 Experimental setup

Each morning at approximately 10 AM during five consecutive days, each group were moved from the stable to three pastures measuring 20 x 30 meters, fenced with electric fences. They were moved back into the stable again after two hours of observation.

On day 0, the sheep were habituated to the pasture and no actual experimental treatment was applied. On day 1, the electrical fence on one side of the pasture was exchanged for a Nofence border with a physical fence 7 meters outside the border. This step was repeated on day 2. On day 3, the physical fence outside the border was removed. On day 4, the Nofence border was moved to the opposite side of the pasture with a physical fence 7-10 meters outside the border. See figure 1 for a drawing over the pasture.

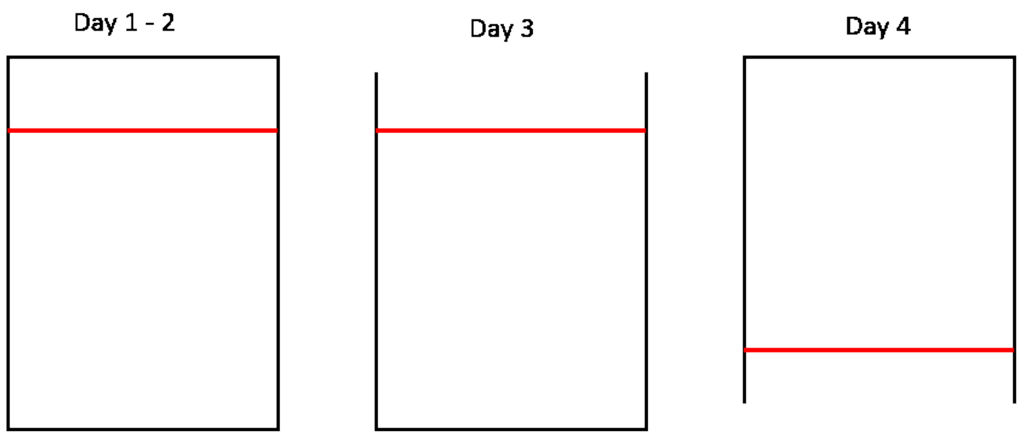

Fig 1. A drawing of the test pasture on day 1-4. Physical fences are represented by black lines, and the Nofence border by the red line. On Day 4, there was an outer security fence 7-10 meters outside the Nofence border.

If the animals ran out from the pasture and out of sight from the observers, we tried to move them back into the pasture once, but if they escaped one more time the trial was ended.

2.1.3 Observations and recordings

The number of shocks were automatically registered by each collar or communicated directly to a web page. Unfortunately, the registration of sound signals were not complete due to technical limitations. Hence, the sound signal data is not completely reliable and cannot be reported here.

One observer was placed by each pasture to supervise and to register the position of each animal (allowed zone or exclusion zone) every second minute during two hours. In three cases, the sheep ran out of sight from the observers. In those cases all the remaining observations were registered as exclusion zone. The observers also continuously recorded if/when the sheep went over the border, reaction to the sound/shock and if anything unexpected happened with the technical equipment.

2.1.4 Data analysis

Any differences in the number of received shocks between the different days were analysed with SAS software (version 9.3, SAS institute, Inc. Cory, NC, USA) using the MIXED procedure and assuming a Poisson distribution. A model using group and sheep nested within group as random effects and day as a fixed effect. Differences regarding the proportion of observations that were spent in the exclusion zone has not yet been statistically analysed.

2.2 Experiment 2

2.2.1 Animals

Thirty-two ewes and their lambs were randomly distributed into four groups with eight ewes in each group. The ewes had between none and three lambs each. The ewes were between one and 6 years old and were either Norwegian Short Tail Landrace (NL; N=18) or

Norwegian white (NW; N=12). We do not have information about age and breed for one of the ewes. Each ewe was individually marked with spray colour on the back of the sheep. One of the lambs in group B was sick day 2, hence this ewe was removed from the experiment. The composition of each of the three groups are shown in Table 2.

Table 2. All participating animals, their breed, age and number of lambs in experiment 2.

Group	Animal	Breed	Age	No of lambs
A	1	NW	3	3
A	2	NW	2	2
A	3	NL	1	1
A	4	NL	5	2
A	5	NL	1	2
A	6	NW	4	3
A	7	NL	1	0
A	8	NL	4	3
B	9	NW	6	3
B	10	NW	3	2
B	11	NL	4	3
B	12	NW	5	3
B	13	NL	2	2
B	14	NL	1	1
B	15	NL	6	3
C	16	NW	4	0
C	17	NW	1	0
C	18	NL	1	0
C	19	NL	1	1
C	20	NL	1	0
C	21	NL	2	2
C	22	NL	2	2
C	23	NL	1	0
D	24	*	*	*
D	25	NL	1	1
D	26	NW	1	0
D	27	NW	2	0
D	28	NL	1	0
D	29	NW	1	0
D	30	NW	1	0
D	31	NL	1	0

2.2.2 Experimental setup

Each group was placed on a pasture measuring 50 x 25 meters, fenced with electric fences. Water and shelter was available on the pastures.

At 9 AM on day 1, the electrical fence on one side of the pasture was exchanged for a Nofence border with a physical fence 7 meters outside the border and the group were kept there for three hours. After two hours, any sheep that were positioned outside the Nofence border (exclusion zone, outside “allowed area”) were brought back into the allowed area. In the afternoon (after about 30 minutes break in the observations), the outer physical fence was removed and the procedure from the morning repeated. The procedure was repeated at day 2, with the exception that two Nofence borders were used. At 9AM on day 3, the electrical fence on two sides of the pasture was exchanged for two Nofence borders with physical fences 7 meters outside the border. In the afternoon, the outer physical fences were removed as well. According to the experimental setup, the same treatment would be applied on day 3 and 4, but with three and four Nofence borders respectively. On day 5, we planned to move the sheep to a new pasture with four Nofence borders. Half of the groups would have been moved to a pasture without any physical cues outside the borders, and the other half would have a very simple physical fence outside the Nofence border. However, due to the results, the experiment was interrupted after day 2. See figure 2 for a drawing of the pasture and experimental setup.

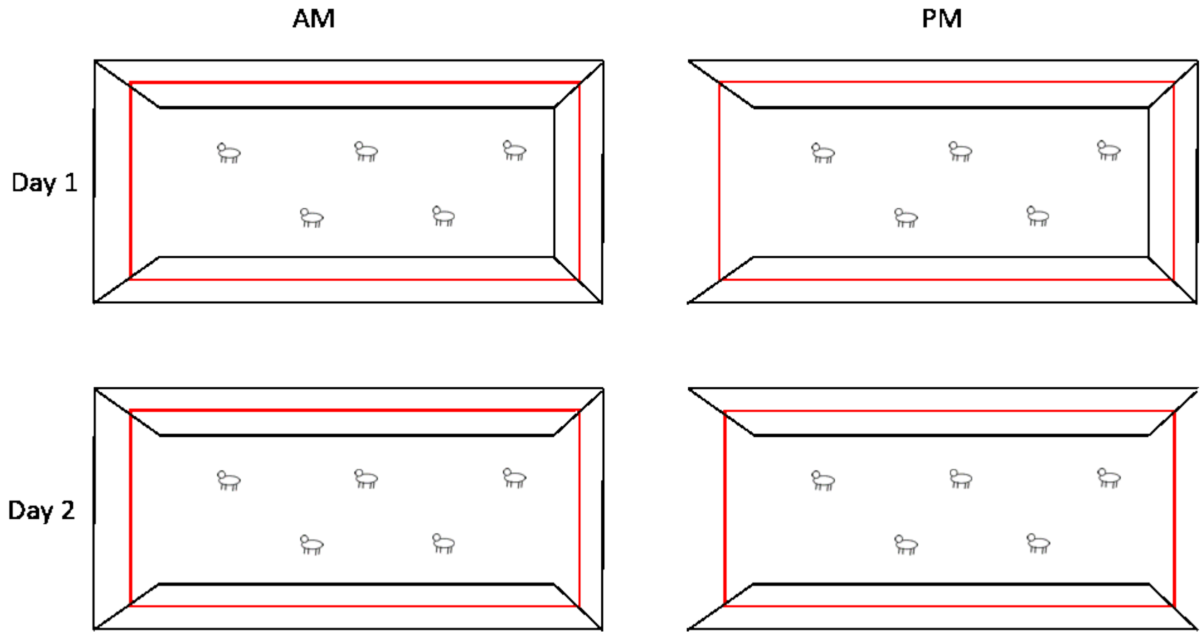

Fig 2. The pasture in experiment 2. The two top drawings represent day 1 (one virtual border) and the two below day 2 (with two Nofence borders). The left column is the morning treatment (with physical fence outside the border) and the right column the afternoon treatment (without physical fences). The black lines represent physical fences that were removed throughout the trial. The red lines indicate the virtual borders.

2.2.3 Observations and recordings

The number of sound signals and shocks were automatically registered by each collar. The position of each animal (allowed zone or exclusion zone) was registered every second minute during three hours in the morning and three hours in the afternoon. After two hours of observation (in the morning as well as in the afternoon) all animals that were in any of the exclusion zones, were brought back into the allowed zone. It was a 30 min pause in the observations after the first three hours. Each time one or several sheep crossed a border it was registered with a video camera. As far as possible, the observers continuously noted if/when a sheep went over the border and its reaction to sound/shock.

2.2.4 Data analysis

The data analysis was performed in the same way as in experiment 1.

3. Results

3.1 Experiment 1

3.1.1 Number of shocks

In experiment 1, nine ewes with lambs were divided into groups of three and were let out on a pasture with one Nofence border for four days. On day 1 and 2, there was a physical fence 3 m outside the Nofence border. On day 3, the physical fence was removed and on day 4 the Nofence border was moved to the other end of the pasture with a physical fence approximately 10 meters outside the border. On day 3, when the physical fence was removed, all sheep except one received the maximum number of five shocks and the average number of shocks on this day was higher than on day four when the border was located at a new side of the pasture. I.e. the physical fence seems to be important for respecting the border. For detailed data, see the text below and Table 3.

During those four days, the sheep received between six and 20 shocks with an average of 10.9±2.0 (mean±S.E.) The statistical analysis showed that the number of shocks were different between the different days (P=0.02; F=3.93). The pairwise comparisons showed that more shocks were received day 3 (when the physical fence was removed) than day 4 (when the border was moved) (P=0.02), all other comparisons were non significant (P>0.05).

Table 3. Number of received shocks for each individual for the different treatments (Phys: with physical fence outside the border, NoPhys: no physical fence outside the border, move: moved the Nofence border to the other end of the pasture).

Animal	Day 1 (Phys)	Day 2 (Phys)	Day 3 (NoPhys)	Day 4 (Move)
1	2[1]	4	5	0[1]
2	5	5	5	4[1]
3	3	4	0[1]	0[1]
4	5	5	5[1]	5[1]
5	0	1	5[1]	1[1]
6	*	4	*	*
7	1[1]	0[1]	5	2[1]
8	1[1]	0[1]	5[1]	0[1]
9	4[1]	0[1]	5[1]	0[1]
Mean±S.E.	2.63±0.68^{AB}	2.38±0.82^{AB}	4.38±0.63^{A}	1.5±0.71^{B}

[1]These numbers are based on communication from the collar to a net page and on notes from the observations since data stored in the collar log was defect or missing.

3.1.2 Observations outside the Nofence border

That the greatest challenge was when the physical fence was removed is also reflected when considering how large proportion of the time the animals spent in the exclusion zone, e.g. outside the border. On average, the sheep spent half of the observations outside the border on day 3 when the fence was removed, while it was below 10% of the time on the other days. For detailed numbers, see the text below and Table 4.

Table 4. Proportion of the observations in the exclusion zone.

Animal	Day 1 (Phys)	Day 2 (Phys)	Day 3 (NoPhys)	Day 4 (Move)
1	0.02	0.18	0.07	0.00
2	0.15	0.18	0.07	0.00
3	0.02	0.18	0.10	0.00
4	0.07	0.03	0.33	0.70
5	0.00	0.00	0.26	0.07
6	0.00	0.00	0.34	0.07
7	0.00	0.00	1.00	0.00
8	0.00	0.00	1.00	0.00
9	0.00	0.00	1.00	0.00
Mean±S.E.	0.03	0.06	0.46	0.09

During the four days, we registered that one or both lambs in a sibling couple were outside the borders at 205 occasions. At those 205 occasions, their mothers were registered as being inside (i.e. the lambs were outside and the sheep inside) at 95 (53.6%) occasions and outside (i.e. both mother and at least one lamb outside) at 110 (46.3%) occasions.

3.1.3 Other remarks – function of the collars/reaction to shock

At 15 occasions, the observer at pasture A reported that two of the animals got sound signals or shocks when they were well inside the allowed area. At these occasions, the animals were in the opposite end of the pasture seen from the Nofence border. There were Nofence borders approximately 5 m outside the physical fence to make sure that the animals were not affected by this border. Although, it seems like this border was unstable and therefore “moved” inside the allowed area. This was only the case for some of the collars.

At 11 occasions, the observers on all pastures (but mainly pasture A) noted that the animals went outside the border but no sound/correction was given, or was given after they had been grazing outside the borders for some minutes.

At 12 occasions the observers noted that animals got shocks but either without any reaction at all (six occasions) or a very mild reaction (six occasions). These notes regarded four animals (hence almost half of the animals). It should be noted that many of the animals reacted very severe on the shocks, even though the strength of the shock was equal for all animals.

When removing the collars after four days, we saw signs of blisters from the collars (i.e. the skin was slightly red).

3.2 Experiment 2

In experiment 2, four groups with eight ewes in each group were let out on a pasture for two days. In the morning of Day 1 (D1 AM) the pasture had one Nofence border with a physical fence, but the physical fence was taken away in the afternoon (D1 PM). On day 2 there were two Nofence borders opposite to each other with physical fences outside the border in the morning (D2 AM) and without physical fences in the afternoon (D2 PM). The sheep could receive a maximum of five shocks during one day and a majority of the sheep received all five shocks during both days. Since most of the shocks were received already in the morning, less were received in the afternoon. On average, they received an equal number of shocks both day one and two.

That the sheep already received many shocks in the morning is also reflected in how large proportion of the observations they spent outside the border. When they had received all of their shocks, they could also spend more time in the exclusion zone in the afternoon compared with in the morning. On Day 2, all ewes in two of the groups spent a majority of the time in the exclusion zone. Hence, it seems to be a difference between the groups as well. For more detailed information, see the text below, table 5 and Fig. 3.

On average, the number of shocks were 3.35±0.34 with one border and physical fence (Day 1 AM), 0.71±0.23 with one border without physical fence (Day 1 PM). On Day 2, the average was 3.0±0.39 with two borders and physical fence (Day 2 AM) and 1.65±0.40 with two borders without a physical fence (Day 2 PM). Values for each individual are presented in Table 5 and mean values for all animals in Figure 2. Out of the 28 sheep that wore collars that reported correct to the collar log, 20 (71%) received the maximum number of 5 shocks. On Day 2, this number was 20 out of 26 (77%).

Table 5. All individual sheep that participated in experiment 2 and the number of shocks they received and the proportion observations in the exclusion zone in the four treatments (T1-T4).

Group	Sheep	Number of shocks				Proportion of observations exclusion zone			
		D1 AM	D1 PM	D2 AM	D2 PM	D1 AM	D1 PM	D2 AM	D2 PM
A	1	3	0	2	7	0	0	0	0.28
A	2	2	3	*	*	0	0	0	0.43
A	3	1	4	5	0	0	0	0.20	0.28
A	4	0	0	5	0	0	0	0.03	0.46
A	5	5	0	5	0	0	0.21	0.18	0.44
A	6	*	*	5	0	0	0	0.38	0.43
A	7	5	0	5	0	0	0.26	0.13	0.28
A	8	1	4	*	*	0	0.21	0.15	0.43
B	9	4	1	1	0	0.02	0.95	0.02	0.80
B	10	5	0	*	*	0.36	1	*	*
B	11	5	0	5	0	0.15	1	0.15	0.80
B	12	5	0	*	*	0.07	0.98	0.33	0.89
B	13	5	0	5	0	0.18	1	0.26	0.80
B	14	5	0	5	0	0.39	1	0.39	0.89
B	15	5	0	2	0	0	1	0	0.80
B	16	*	*	*	*	0	0.95	0	0.80
C	17	3	2	0	4	0	0.16	0	1
C	18	4	1	5	1	4	0.21	0.02	0.67
C	19	5	0	5	0	0	0.25	0.13	0.67
C	20	4	1	2	3	0	0.25	0	0.61
C	21	3	2	1	4	0	0.25	0	0.61
C	22	5	0	5	0	0.03	0.25	0.49	0.67
C	23	4	1	5	0	0	0.25	0.52	0.67
C	24	5	0	5	0	0.03	0.25	0.34	0.67
D	25	1	0	1	4	0	0	0	0.31
D	26	*	*	*	*	0.08	0.07	0.08	0.18
D	27	*	*	2	3	0.02	0	0.05	0.02
D	28	0	0	0	4	0	0	0	0.03
D	29	0	1	2	3	0.05	0	0	0.11
D	30	4	0	3	2	0	0	0	0.3

D	31	3	0	1	1	0	0	0	0.02
D	32	2	0	0	4	0	0	0	0.02

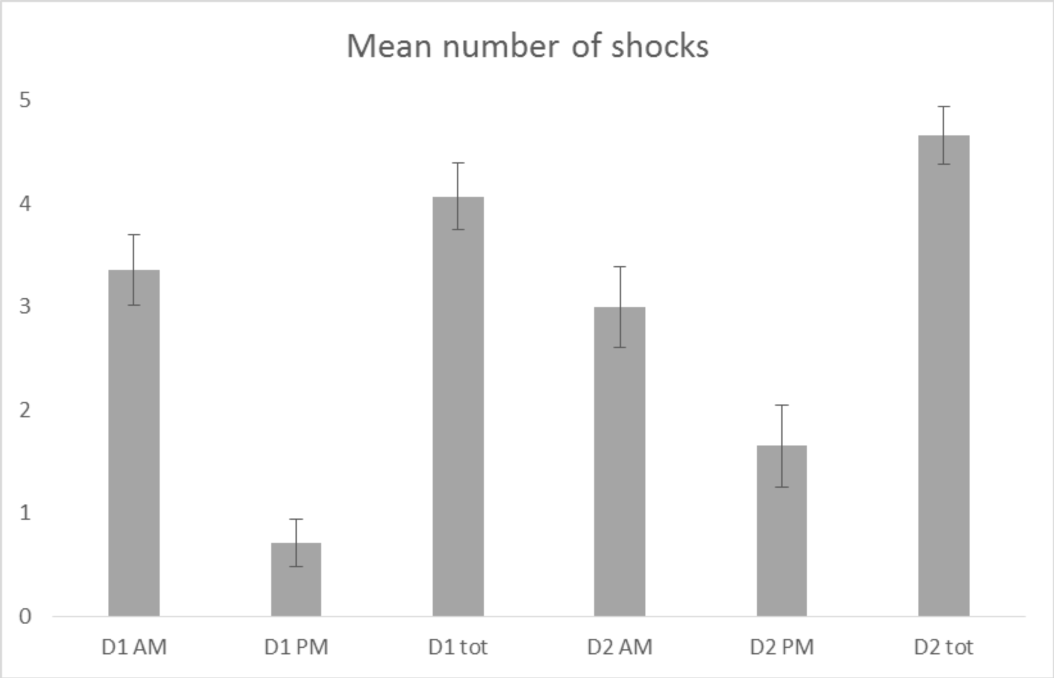

Figure 3. Mean number of received shocks on day 1 (one Nofence border, D1) and day 2 (two Nofence borders, D2), AM (with a physical fence outside the border) and PM (without a physical fence outside the border). The animals could receive a maximum of five shocks/day.

4. Discussion

The aim with our testing of Nofence have been mainly to evaluate both negative and positive effects on stress and animal welfare. Due to technical failures as well as difficulties for the animals to learn the system, the testing has been delayed and the progress less than wished. Taking the results from last year into account, we chose to focus on three issues this year:

1. To test Nofence on sheep with young lambs
2. To develop and test a learning protocol for Nofence.
3. To compare the function of Nofence when using it with and without a simple physical fence.

4.1 The technology

Just like the trials in 2012, there were several problems with the technology during both experiments this year. In fact, the problems were so substantial so that our conception is that these problems alone makes it unacceptable for practical use in commercial settings. We supervised the animals at all times during the experiments and this was completely necessary due to the unstable technology. The problems were of different kinds, some mainly had consequences for the actual experiment. For example, many of the collars had to be re-activated each morning, this would not have been possible with a larger flock. The communication between the collar and net page did not work satisfactory, which made the data analysis difficult. Other problems would, in another setting, have potentially negative effects on stress and animal welfare. Some of the collars gave neither sound cues nor corrections although the animals were clearly outside the borders, others gave signals/corrections when the sheep were either well inside the allowed area or when it already had received all five shocks. All these technical problems had clear effects on the results and was one of the most important reasons that the experiments were difficult to perform and that no conclusions can be drawn.

Moreover, the physical conformation of the collar needs to be thought through. In our experiments, we shaved the sheep around the neck and it is not known what happens if the wool would grow during the summer. Moreover, we saw signs of blisters that probably would have worsened to an unacceptable level over time.

4.2 Experiment 1

In experiment 1, we repeated the experiment performed in 2012. E.g. the sheep were tested with only one Nofence border at a time, with and without a physical fence. One difference last year was that we then performed a pre-selection during which 27 sheep were tested individually and the quickest learners were selected for the experiment (see Brunberg (2012) for details). The sheep participating this year had their first experience with Nofence when they were let out on the experimental pasture, as opposed to the sheep used in 2012, which all experienced two shocks each during the pre-selection. And, perhaps even more important, it was the quickest learners that were selected, e.g. last year we had nine easy learners and this year we had nine randomly selected animals participating. This had effects on the results. The ewes this year experienced more shocks compared to the sheep 2012 (on average 1.9 shocks/sheep 2012 compared to 10.9 this year).

During the pre-selection 2012, animals that reacted very severely to the shocks (five out of 24) were excluded as were sheep that did not react when they received a shock (three out of 24). This year, the observers noted that four of the sheep did not react at all or showed a very mild reaction to the shocks. This may also be an important factor for the difference between the experiment 2012 and 2013.

Another difference was that the ewes had young lambs this year. How large role these played in the results can only be speculated around, but it did not seem like the lambs were the reason for the sheep going over the border. The lambs were so young that they most of the time kept a short distance from their mothers. Moreover, the mothers did not seem very worried when the lambs crossed the border. As seen in experiment one, the ewes were observed staying within the borders in almost 50% of the cases when one or several lambs were outside. In the cases where both mother and lamb were outside the border we did not register if lamb or ewe went out first, but our opinion is that it almost always were the mothers that went out first (or all sheep went out as one group). If the mother stayed inside, the lambs did as well.

The sheep received more shocks during day 3 when there was no physical fence compared to the last day of the trial, but there were no statistical difference between any of the other days. However, the lack of significance between day 1/2 and day 3 may be due to the low number of animals since the average number of shocks is higher on day 4. On day 3, seven out of the eight sheep with functioning collars received all of their five shocks. This is also reflected in how much time the spent in the so called exclusion zone outside the allowed area. Last year, we concluded that the physical fence outside the border played a clear role for the learning process, this was obvious also this year. Teaching the animals Nofence without a physical fence as a help is in our opinion not an option.

Regarding experiment 1, it should be considered that some of the corrections in one of the groups were received even though the animals were not outside the border due to the technical problems.

4.3 Experiment 2

The second aim was to try out a learning protocol. The goal was to introduce one new Nofence border every day, first with a physical fence and later on without. Although, for animal welfare reasons, the criterion for the animals to being able to continue to the next day was that the majority of the animals in one group should have functioning collars and should have received less than five shocks. This was not fulfilled for any of the groups on day 2, which meant that we interrupted the trials after this day. Hence, the learning protocol used in this experiment was not successful. It would perhaps be more successful to teach the sheep individually and to remove individuals that repeatedly crossed the border, but this is not an option in commercial production. Our criterion when developing the learning protocol was that it should be possible to perform in a group, that the animals should be able to learn the system without too much involvement of the farmer (e.g. not individual learning) and that it should not take too much time. Since we interrupted the trials, we did not have the option to test if Nofence functioned better with a simple physical fence than without.

It seems like there are three different reasons for a sheep to cross the border:

1. The sheep do not learn the system
2. The sheep do not react on the shocks

3. Sheep that do learn the system and clearly show a reaction on the shocks, but cross the border due to an attraction. For example feed or another sheep outside the border.

All of the above reasons are of course problems when it comes to the function of Nofence and at least two of them are clearly potential animal welfare problems. If a sheep does not learn that they can avoid the corrections by turning when they hear the sound signal, they cannot foresee or control the aversive stimuli. It is known that being able to control an aversive stimuli clearly reduces the stress level, compared to not being able to control it (i.e. Weiss et al. 1981). If the absence of a clear reaction to the shock is a sign that the sheep does not experience the shocks as painful, this cannot be regarded as a welfare problem. On the other hand, if those sheep attracts other group members to cross the border (hence, point three above), it may cause stress and reduced welfare among others. Some of the animals learned quickly how to avoid the shock and actively avoided it. Although, we saw examples when other ewes went over the border and remaining ewes and lambs stood on the allowed side of the border hesitating for several minutes before running over the border, obviously stressed by the situation.

4.4 The future – conclusions and recommendations

The intentions with Nofence are good and if the system would have worked just as intended, we see a potential that could have been positive both for the farmer and for the animals. Although, there are many challenges that to our opinion would lead to potential problems with both the intended function as well as animal welfare.

The described challenges regarding the technology has been one of the reasons that the experiments have been delayed both 2012 and 2013 and that we haven’t been able to try out all the factors that we intended. Before even considering any more experiments in which animals are involved, the technology must be proved stable at all times. Although, even if the problems with the technology are solved, we see a very problematic challenge regarding the learning possibilities of the animals, the individual differences in how they react to the shocks as well as the herd instinct. This makes it impossible to trust that the animals respect the Nofence border and that sheep welfare can be ensured in every situation. Since some of the animals react very severe on the shock, it is not an option to increase the shock. In any case, we strongly advice against using Nofence in critical areas, such as roads or railways.

It still seems like visual cues, such as a physical fence or a certain position of the border in the terrain is important for the animals. Hence, one option would be to test Nofence with a very simple physical fence outside the border. However, this needs to be tested and, as earlier mentioned, before doing more testing on animals more basic studies and documentation on the technology must be performed.

Due to the technical difficulties as well as learning challenges, our trials were delayed and interrupted. Therefore, we cannot say anything certain about animal welfare. Our assessment is mainly based on detailed observations of the sheep. For the animals that really learn the system quick and stayed inside the border at all times, we could not observe any welfare problems. Although, this was rather unusual and the challenges that exist propose that there may be unnecessary stress for the animals and a possibility for reduced animal welfare.

5. References

Bishop-Hurley, G.J., Swain, D.L., Anderson, D.M., Sikka, P., Crossman, C. & Corke, P. 2007. Virtual fencing applications: Implementing and testing an automated cattle control system. Computers and Electronics in Agriculture, 56: 14-22.

Brunberg, E.I. 2012. Sheep welfare in the virtual fencing system NoFence: trials 2011. Bioforsk Report 7, 174.

Henriksen, B.I.F. & Berntsen, O.H. 2011. Utprøving av NoFence elektronisk gjerde i forhold til dyrevelferd – Prototype 1. Bioforsk Rapport, 6, 95.

Jouven, M., Leroy, H., Ickoqicz., A. and Lapeyronie, P. 2012. Can virtual fences be used to control grazing sheep? The Rangeland Journal 34: 111-123.

Lee., C., Fisher, A.D., Reed, M.T. & Henshall, J.M. (2008). The effect of low energy electric shock on cortisol, B-endorphin, heart rate and behaviour of cattle. Appl Anim Beh Sci, 113:32-42.

Schilder, M.B.H & van der Borg, J.A.M. 2004. Training dogs with help of the shock collar: short and long term behavioural effects. Applied Animal Behaviour Science, 85: 319-334.

Tiedemann, A.R., Quigley, T.M., White, L.D., Lauritzen, W.S.& McInnis, M.L. 1999. Electronic (Fenceless) control of livestock. Res. Pap. PNW-RP-510. Portland, OR: U.S. Depertment of Agriculture, Forest Service, Pacificic Northwest Research Station.

Weiss, J.M., Goodman, P.A., Losito, B.G., Corrigan, S., Charry, J.M. & Bailey, W.H. 1981. Behavioral depression produced by an uncontrollable stressor: Relationship to norepinephrine, dopamine, and serotonin levels in various regions of rat brain. Brain Research Reviews, 3: 167-205.