BEHAVIORAL RESPONSES OF FERAL REINDEER (*Rangifer tarandus tarandus*) TO DIRECT APPROACH BY SKIER AND SNOW-KITER: -experimental measurements and piecewise-linear modelling

ATFERDSRESPONSER HOS VILLREIN (*Rangifer tarandus tarandus*) VED DIREKTE PROVOKASJON FRA SKILØPER OG KITER: -eksperimentelle målinger og stykkevis lineær modellering

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#### PREFACE

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Very special thanks to Jakob.

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Marte Synnøve Lilleeng

Eg skal ut i det fri Vera gauken i li Vera bjønnen som vaknar i bjønnehi Vera sol vera regn Vera fuglen under sky Vera alt som denna dagen kan by (Odd Nordstoga 2006)

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### ABSTRACT

The behavioral response in feral reindeer (*Rangifer tarandus tarandus*) towards directly approaching snow-kiters vs. skiers in Norefjell-Reinsjøfjell, Norway, was studied during February and March 2006. All response distances were longer when approached by a snow-kiter than by a skier (all; p < 0.001). Median fright response distance was 370 m vs. 89 m, flight response distance 327 m vs. 53 m and distance escaped by reindeer was 481 m vs. 57 m for snow-kiters and skiers respectively. Encounter distance were significantly larger in snow-kite provocations than in ski provocations (p = 0.001) and had a significant effect on fright and flight response distances (p = 0.000), but not on distance escaped by reindeer (p = 0.370). The effect of provocation method was highly significant also when encounter distance was entered as covariate (p = 0.000).

Piecewise-linear modeling of spatial occurrence of snow-kiters and skiers in a wild reindeer area based on these response distances reinforced the difference in effect of the two sources of disturbance. The predictability of a certain number of skiers on a trail results in *no more* encounters between reindeer and skier. This implies that with a ski trail saturated with skiers, reindeer will loose *no* feeding time. With a high number of snow-kiters the reindeer will loose *all* available time normally spent on feeding during daylight hours. This study is to my knowledge the first to test the effect of disturbance on reindeer mathematically.

Keywords: Fright behaviour, human disturbance, response distances, spatial predictability

# SAMMENDRAG

Eksperimentelle målinger ble gjort av villreinens reaksjon på provokasjon fra en kiter og en skigåer. Studiet ble utført i Norefjell-Reinsjøfjell i Buskerud, Norgei løpet av februar og mars 2006. Provokasjon fra en kiter ga lengre responsdistanser enn en skiløper (alle responser; p < 0.001). Median fryktrespons-distanse var 370 m vs. 89 m, fluktrespons-distanse 327 m vs. 53 m og distansen reinen flyktet var 481 m vs. 57 m, for henholdsvis kiter og skiløper. Distansen mellom skiløper eller kiter og reinen ved start av provokasjon (startdistanse) var signifikant større ved kiteprovokasjoner enn ved skiprovokasjoner (p = 0.001) og hadde en significant effekt for frykt- og fluktresponsdistanser (p = 0.000), men ikke for distanse reinen flyktet (p = 0.370). Effekten av provokasjonsmetode var sterkt signifikant for responsdistansene selv når startdistansen ble tatt med som kovariat (p = 0.000).

Jeg har utviklet en stykkevis lineær modell som støtter resultatene over. Inkorporert i modellen er romlig forutsigbarhet av skiløpere som følger en skiløype, og tilsvarende mangel på dette for kitere som antas å bevege seg utenfor etablerte løyper. Relativt tap av beitetid for reinen som følge av forstyrrelse fra kitere vokste lineært helt til *all* beitetid var tapt. Tilsvarende for skiløpere viste at relativt tap av beitetid etter hvert gikk mot *null*. Dette understreker at forutsigbarhet i rom gjør at reinen kan føre til redusert antall møter mellom mennesker og villrein og er med dette for første gang vist matematisk.

## INTRODUCTION

A nomadic existence is often found in populations or species with scarce or scattered resources. For large animals, nomadic existence requires large areas for movements and migrations. Seasonal variation in resource availability as well as predator avoidance may enhance the boundaries and total amount of area used over time. Thus, the home range of a population is often larger than the most common, core areas used for foraging (Eide *et al.*, 2004). Wild reindeer (*Rangifer tarandus tarandus*) inhabit an arctic/high alpine environment, with a relatively short summer season and slow growing main winter food resource, i.e. lichens. Snow depth and ice conditions during winter control access to forage and thus, greatly influence reindeer survival and condition (Reimers, 1983, Kumpula and Colpaert, 2003).

Reindeer have also evolved through predation. An evolutionary arms race exists between predator and prey, and selection pressure increases the efficiency of the prey's ability to avoid predation (Dawkins and Krebs, 1979, Frid and Dill, 2002). Therefore, both the ability to be unpredictable in terms of spatial location and early detection of predators are important characteristics of wild reindeer. The most important natural predators for wild reindeer in Norway are wolverine (*Gulo gulo*), golden eagles (*Aquila chrysaetos*) and wolves (*Canis lupus*) (Skogland, 1991). Humans have also been hunting reindeer since ancient times (Jordhøy *et al.*, 2005). Co-evolution with predators has resulted in the underlying sensitivity of reindeer towards human disturbance, with fright and flight being the usual behaviour response towards approaching humans on foot or skis (Thomson, 1977). As the numbers of wolverine and wolves in Norway are low (2006; <20 wolves in eastern Norway (Wabakken *et al.*, 2006) and <400 wolverines (Brøseth and Andersen, 2006), humans are presently the most important regulatory factor for reindeer (Jordhøy, 2001).

While the human population is expanding both in numbers and resource use, the total area left untouched by humans decreases daily. In Norway, the amount of area > 4 km from anthropogenic infrastructure has decreased from 48 % of the country's total land area (1900) to 12 % (2003) (MD, 2005). The wild reindeer in Norway previously consisted of four large populations. Today's 25 000 feral and wild reindeer are fragmented and managed in 23 so called "wild reindeer areas" (Andersen and Hustad, 2004) with little or no migration in between. Among these are the only remaining mountain reindeer with wild genetic origins in Europe, which, according to the Bern-convention (1979), Norway has a special responsibility

to preserve. To assure proper management of the remaining wild reindeer, it is important to understand the effects of human induced disturbance.

Reindeer fright behaviour is controlled by numerous parameters such as social status, physiological condition, previous experience with a stimulus, and disturbance source (Pépin *et al.*, 1996, MD, 2005). Living in groups can result in a single disturbance affecting the entire herd (Andersen and Hustad, 2004). This again affects time available for foraging. Reductions in foraging time, possibly in the short term but certainly prolonged loss (Colman *et al.*, 2003), can reduce individual condition and, indirectly, lead to reduction in individual reproduction and survival (Reimers *et al.*, 2003).

A potential challenge for the wellbeing of reindeer has arisen with an increasing amount of snow-kiting, a relative new sport introduced in Norway approximately 10 years ago. Snow-kiting, also called ski-sailing, is the use of kite or sail to move forwards on skis or a snowboard. The maximum speed has been measured to about 100 km/h, while most snowkiters move within the range of 3 to 40 km/h. The kite is connected to the skier with thin, 25-30 metres long nylon lines. Due to the manoeuvrability of the kite, the activity is mostly conducted in open terrain, such as frozen lakes, farmland or alpine areas above the tree line. This sport is not yet fully organized, and the exact number of users is unknown. Snow-kite users can be divided into two subgroups; the first being those using the kite as a means for movement from A to B (hereby referred to as tour-kiting). A tour-kiter covers from 30 to 70 kilometres on a normal day. Central persons in the Norwegian milieu (Geir Norland and Markus Landrø pers. comm.) estimate the potential number of tour-kiters to be very low, as this is a very complex sport demanding skills in orientation, reading the terrain and wind while moving and first-aid. The number of tour-kiters is difficult to estimate, but may be as low as 10-30 people (Geir Norland and Markus Landrø pers. comm.). The other user subgroup is more stationary, using areas in proximity of roads or railway systems. These snowkiters concentrate on doing acrobatic tricks that requires physical strength and coordination. Central persons in this user-group estimate the mean use of area per day by a "stationary" snow-kiter to be approximately 0.5 km<sup>2</sup>. There are about 800 known, active contestants (participating at more than one event per winter) and 4000-5000 contestants participating at snow-kiting events at least once a year (Lilleeng unpubl.) Presently, snow-kiting is probably the fastest growing winter sport in Norway, and both wildlife managers and politicians have shown concern for snow-kiting's potential negative interaction with wild reindeer.

Previous studies have investigated the effects on reindeer from hikers (Colman *et al.*, 2001, Egeland, 2004, Reimers *et al.*, 2006), skiers (Reimers *et al.*, 2003, Egeland, 2004,

Reimers *et al.*, 2006), snow mobile (Tyler, 1991, Reimers *et al.*, 2003), vehicle (Horejsi, 1981) and stationary infrastructure such as tourist resorts (Helle and Särkelä, 1993), hydroelectric reservoirs (Nellemann *et al.*, 2003), and power lines (Flydal, 2002, Vistnes and Nellemann, 2001a, Vistnes and Nellemann, 2001b, Vistnes *et al.*, 2004, Reimers *et al.*, 2007).

In addition to reindeer, a few studies have investigated potential effects of sports like biking, paragliders, and dog-animal interaction on other species (e.g. chamois (*Rupricapra rupricapra*) (Gander and Ingold, 1997, Enggist-Düblin and Ingold, 2003) bison (*Bison bison*), mule deer (*Odocoileus hemionus*) and pronghorn antelope (*Antilocapra americana*) (Taylor and Knight, 2003b), mule deer and birds (Miller *et al.*, 2001)).

However, before now, the effect of snow-kiting on reindeer or other wildlife had not been investigated. Previous studies have proposed that the spatial predictability of a disturbance can reduce the loss of feeding time and/or habitat use (e.g. the effect of snowmobiles in reindeer (Reimers *et al.* 2003, Reimers and Colman, 2006) and hikers in bison, mule deer and pronghorn antelope (Taylor and Knight 2003b). However, they did not explain this mathematically. I developed a mathematical model to evaluate the difference in spatial and temporal disturbance effects from skiers and snow-kiters on reindeer. These two types of disturbance exhibit different human use of the terrain. Most skiers follow prepared trails, while most snow-kiters move around more freely and are potentially much more randomly distributed over reindeer habitat.

The objective of the study was to provide a relative measure of the effect of snowkiting disturbances on wild reindeer behaviour by (1) conducting provocation experiments to estimate reindeers' reaction distances following a direct disturbance by a skier or snow-kiter, (2) comparing these distances measured previously for reindeer with similar reaction distances towards a skier, and (3) assessing differences in temporal and spatial effects following disturbance from skiers and snow-kiters using piecewise-linear modelling.

## MATERIAL AND METHODS

### Study Area

Norefjell-Reinsjøfjell (NR) (60° 25' N; 9° 05' E) is an alpine area at 900-1314 m. a. s. l, located in Buskerud County. The managed wild reindeer area is 314 km<sup>2</sup> and encompasses Krødsherad, Flå, Nes, Sigdal and Nore and Uvdal municipalities. The terrain is mainly composed of small rolling hills, and it contains numerous small and one large lake (Reinsjø). The climate is continental (Hagemoen and Reimers, 2002) and the foraging conditions for reindeer are good. The area has a network of footpaths and ski-trails and is popular for recreation. There are numerous ski trails in the alpine area maintained daily by snowmobiles during winter. Nes municipality, which encompasses much of the study area, has app. 34 000 visitor-days for the winter months of December to March (Linda Sofie Øye, personal communication).

There are no known large mammalian predators presently residing in the area, but there have been sporadic observations of roaming wolverines and wolves. The golden eagle hatches regularly in the area, and the density of golden eagle territories ranges from 0.26-0.71 pairs per 100 km<sup>2</sup> (FMB, 2004). Lynx (*Lynx lynx*) are found in forests surrounding the study area (Reimers and Svela, 2001).

#### Study Population

The feral reindeer population maintains a seasonal migration pattern between the two subareas "Norefjell" and "Reinsjøfjell" (Fig. 1). In April, females migrate to calving areas in the southeast. During winter, the herds are found in the north-western region, Reinsjøfjell (Fig. 1). The winter population is relatively stable, ranging from 500-750 animals (Reimers, 1992, Finstad, 2005). For the winter of 2005, there were app. 570 reindeer, providing a density of 1.82 reindeer/km<sup>2</sup>. The origin of today's population is from semi-domestic animals reverted to a wild condition after herding reindeer in the area was abandoned in 1968. The genetic origin is from reindeer imported from the Swedish forests (Bevanger and Jordhøy, 2004). The population exhibits relatively high body weights compared to other wild or feral reindeer populations in Norway (Reimers, 1997). Yearly quota hunting was first initiated in 1992 when the winter population was 734 animals; the total harvest was then 347 animals (Finstad, 2005). The hunting quota for 2005 was 200 animals with a 90% success rate (SSB, 2006).



**Figure 1** The core area used by feral reindeer in Norefjell-Reinsjøfjell. Migration occurs seasonally; grey area in the northwest is used during winter, while the sub-area to the southeast is used for calving and summer pasture. Based on: Naturbase, the Norwegian Directorate for Nature Management, 2006, <u>www.dirnat.no</u>.

## Data Collection

The study was conducted in February and March 2006; a winter with late snow and good foraging conditions for reindeer. The animals were localized by snow tracking on skis and scanning with binoculars. Infrequently a snowmobile was also used to facilitate searching. I assumed that the use of snowmobiles was not an interrupting factor, the argument being that snowmobiles maintain the ski trails daily throughout winter, The snowmobile drivers claim that the reindeer have become accustomed to their snowmobiles and pay them little or no attention (Helge Holm pers. comm.). This was confirmed while conducting fieldwork; i.e., the reindeer did not show any alert response behaviour by our snowmobile use.

When animals were first localized, the provocation method (skier or snow-kiter) was chosen randomly before deciding the starting position. Reindeer were disturbed by a snow-kiter or a skier in alternating provocations with at least one hour in between. The kites colour, either red or blue, was in strong contrast to the sky. Schnidrig-Petrig and Ingold (2001) found no significant effect of colour in paraglider on reaction among chamois. Reindeer are probably able to see colours, but are unable to distinguish between red and blue (Reimers and Colman, 2006). I therefore assumed no effect of colour of kite in my study. We used both foil and tube kites, with sizes ranging from 10 to 16 km<sup>2</sup>. The lines were 25-30 metres long, but the mean height of the kite in the sky varied between provocations, for example, according to its angle against the wind. The size of the kite used was regulated by wind speed and kite type. Foil kites need less wind, and this leads to the use of smaller foil- than tube kites.

Although kite size potentially influences reindeers' reactions towards a snow-kiter, I assumed difference in kite size not to affect the responses of the animals in my study. The kite was unpacked and rigged out of sight of the reindeer. As the lines of the kites are very long and the study area was mostly terrain with many small hills, reindeer often sighted the kite before they sighted the kiter. Therefore, an observer positioned themselves such that they could observe the entire provocation without being obvious to the reindeer. The observer maintained visibility with the provoker and the reindeer throughout the provocation, and the entire event was recorded by the observer on video. Through radio contact, the observer informed the provoker when to drop markings according to the reindeers reactions. The markings were metal rings, 5 cm in diameter with 30 cm long red textiles attached. They were easily located in the snow and remained at their drop sight despite heavy winds. The reindeers' reactions were measured by back-tracking from a group's centre point to each marker and measuring the distances to each marker to the closest meter with lasers monoculars.

The method used for the snow-kiting provocations was to kite directly towards a group at a constant speed (mean speed was 8.8 km/h). The provocation continued until the kiter reached the centre location of the group's original "pre-disturbed" location (Fig.2). Similar procedure was used when skiing, but the speed of approach was slower (mean speed was 3.1 km/h), i.e. the natural speed of a skier off trail. For additional details on ski provocations methods, see Colman *et al.* (2001). I compared the ski data collected in 2006 with data from the years 2002 – 2005 (same area and methods) (Reimers *et al.* unpubl.).



*Figure 2* The disturbance procedure for a snow-kiter. The distance from 0 to A, B, C and D represents the "encounter", "fright", "flight" distances and "distance moved", respectively.

To compare the effect of disturbance by skier and snow-kiter, I measured three response distances as well as the encounter distance. I use the terms standardized in Taylor and Knight (2003a) with the modifications used by Reimers *et al.* (2003):

- 1) *Encounter Distance (A)*: the distance between the start point and the estimated centre point of the herd at start of the provocation.
- *Fright distance (B)*: distance between the observer and the herd centre point when ≥50 % of the herd exhibited a fright response by grouping together. Two fright responses were possible.
- 3) Flight distance (C): distance between the observer and the herd at the moment of flight. Flight distance was measured at distance where ≥50 % of the herd evidently started moving away from the provoker. Two flight responses were possible.
- 4) *Distance moved (D)*: straight line distance from where reindeer took flight to where they stopped fleeing from the provoker, i.e. when the herd resumed more relaxed behaviour (grazing or lying).

All distances were measured with laser monoculars (Leica Scan 1200). When possible, "distance moved" was also measured with laser monoculars. When this distance was long (>500 m), I used a GPS or added intervals measured with the laser monoculars.

As in Colman *et al.* (2001), additional 11 independent variables were recorded for each provocation, see overview in appendix 2.

When possible, I provoked the same group twice or more the same day to investigate whether the animals became habituated to this repetitive stimulus. The time span between repeated provocation procedures was minimum one hour and maximum one day. Herds were recognized by number of individuals, age and sex structure and eventually numbered neck collars. If the provoker went out of sight because of e.g. hilly terrain and no alert response was observed, the provoker measured a new encounter distance as soon as they were visible again for the animals. On one occasion, this occurred without the new encounter distance being measured and I omitted this observation in my analysis of encounter distances.

### Data and Statistical analysis

The software used for statistical analysis was Minitab® Release 14.1 and Microsoft® Office Excel 2003. For normality tests, Anderson-Darling and Ryan Joiner normality tests was used. My data exhibited a normal distribution, but to compare with the dataset from 2002-2005, I log<sub>e</sub> transformed all data and used parametric tests. I tested for equal variances with the F-test and Levene's test. To investigate differences between provocation methods and significant

effects of independent variables, I used paired t-test and GLM and one-way ANOVA with Tukey's comparisons, assuming equal variance. Effect of all independent variables (appendix 2), provocation methods 1 and 2 pooled, was investigated with one-way ANOVA. I used Pearson correlation to test for correlation between responses with pooled data separated only by provocation method. Chi-square analyses were carried out to test for difference in sample sizes between provocation methods.

#### Model description

The normal response of wild and feral reindeer when encountering humans is to cease their "normal", undisturbed activity, for example grazing or lying, and move away. This results in reduced time and space for feeding. I developed a model to describe the expected effects of provocation from skiers and snow-kiters, measured in expected numbers of encounters and loss of feeding time, for wild reindeer. For mathematical demands for simplicity, the model was based on the following assumptions:

-Most skiers prefer to follow marked and prepared trails, providing a much faster glide with today's modern skis and less energetically costly than skiing off-trail. In the model, I therefore expected all skiers to follow marked trails.

-I expect the movements of snow-kiters to be more random and unevenly distributed in the terrain. As they use the wind as their source of energy to move, they will not gain much in the effect of prepared trails like skiers do, but they may have to move in certain directions in relation to the wind. In the model, I assumed that snow-kiters choose their routes randomly such that one snow-kiter does not show a higher probability of following a track from another snow-kiter or marked ski trails.

The important aspect in the model is the difference in predictability for the two types of provocations in the reindeers' habitat, and I have demonstrated this mathematically.

The model is based on probability of encounters between wild or feral reindeer herds and either skiers or snow-kiters. Encounters will occur when distance between provoker and a reindeer herd are at maximum flight distance. Each provoker will contribute to an area where encounters can possibly occur. The size of this area depends on the mean duration of a disturbance source and velocity of locomotion. The area of influence of one skier ( $I_S$ ) and one snow-kiter ( $I_K$ ), i.e. where an encounter may occur between a reindeer herd and skier and snow-kiter, respectively, is represented by the following equations:

$$I_s = 2r_s v_s \Delta t \tag{eq.2.1}$$

$$I_k = 2r_k v_k \Delta t \tag{eq.2.2}$$

where  $r_s$  and  $r_k$  are the flight reaction distances, measured in kilometres, for ski and snow-kite provocations, respectively.  $v_s$ , and  $v_k$  are mean velocities of the ski and snow-kite provokers, and  $\Delta t$  is any one time interval during a "day" and with a constant duration, measured in hours. The shape of influence area per skier or snow-kiter will look like this:



The area of influence in any one time interval ( $\Delta t$ ) will have an upper limit. For skiers, the maximum area of influence will depend on the length of the ski trail, as we assume that all skiers use this trail, and therefore, encounters with reindeer will only happen in relation to the trail. For snow-kiters, the maximum area of influence will equal the entire alpine range for reindeer above the tree-line. Following the assumptions, no encounters will occur in areas where encounters have already occurred. The size of the area of influence (A) depends on the number of disturbers and is described by the following equations:

$$A^{s}(n) = \begin{cases} 2nr_{s}v_{s}\Delta t, & 0 < n \le \frac{L}{2v_{s}\Delta t} \\ 2r_{s}L - 2nr_{s}v_{s}\Delta t, & \frac{L}{2v_{s}\Delta t} < n \le \frac{L}{v_{s}\Delta t} \\ 0, & n > \frac{L}{v_{s}\Delta t} \end{cases}$$

$$A^{\kappa}(n) = \begin{cases} 2nr_{k}v_{k}\Delta t, & 0 < n \le \frac{F}{4r_{k}v_{k}t_{rk}} \\ F - 2nr_{k}v_{k}\Delta t, & \frac{F}{4r_{k}v_{k}t_{rk}} < n \le \frac{F}{2r_{k}v_{k}t_{r}} \end{cases}$$

$$(eq. 3.1)$$

$$(eq. 3.2)$$

$$n > \frac{F}{2r_{k}v_{k}t_{r}}$$

where L is the length of the ski trail measured in kilometres,  $n_s$  and  $n_k$  are numbers of ski and snow-kite provokers, respectively.  $t_r$  represents the reindeer's reaction time, measured in hours. F is the total area of winter range above the tree-line for the reindeer population, measured in square kilometres.

0,

When encounters occur, reindeer will move away from a disturbance, and the area available for the reindeer will decrease. The size of this area depends on the number of disturbers and will differ for skiers and snow-kiters. I named the area available to reindeer "Settle area", and calculate this in the following equations:

$$S_{s}(n) = \begin{cases} F - n\pi r_{s}^{2}, & 0 < n < \frac{2L}{\pi r_{s}} \\ F - 2r_{s}L, & n \ge \frac{2L}{\pi r_{s}} \end{cases}$$
 (eq.4.1)  
$$S_{k}(n) = \begin{cases} F - n\pi r_{k}^{2}, & 0 < n < \frac{F}{\pi r_{k}^{2}} \\ 0, & n \ge \frac{F}{\pi r_{k}^{2}} \end{cases}$$
 (eq.4.2)

The area where reindeer can run into, and therefore "escape" the disturbance, will be rather large; close to F, when there are few provokers. When the area is visited by skiers, the available settlement area will reach a lower limit, and the animals will never have less than F- $2r_sL$  area to utilize. There is no lower limit when the area is visited by snow-kiters because of the random and potentially wide-spread distribution of this provocation stimulus. With a number of snow-kiters larger than  $F/\pi r_k^2$  there is no longer any Settle area for the reindeer.

The expected numbers of encounters per day for skiers and snow-kiters, respectively, is represented by the following equations:

$$E_{s}(n) = \begin{cases} \frac{D}{F} \cdot 2nr_{s}v_{s}, & 0 < n \le \frac{L}{v_{s}t_{r}} \\ \frac{D}{\Delta tF}(2r_{s}L - 2nr_{s}v_{s}(t_{r} - \Delta t)), & \frac{L}{v_{s}t_{r}} < n \le \frac{L}{v_{s}(t_{r} - \Delta t)} & (eq.5.1) \\ 0, & n > \frac{L}{v_{s}(t_{r} - \Delta t)} \end{cases}$$

$$E_{k}(n) = \begin{cases} \frac{D}{F} \cdot 2nr_{K}v_{K}, & 0 < n \le \frac{F}{2r_{K}v_{K}t_{r}} \\ \frac{D}{t_{r}}, & n > \frac{F}{2r_{K}v_{K}t_{r}} \end{cases}$$
(eq. 5.2)

where D (= "day") is assumed number of hours per day with skiers and/or snow-kiters in the reindeer area. This probability is the basis for the remaining calculations. I have made an assumption that no new encounters may occur during the time the reindeer are reacting from a skier or snow-kiter, i.e.  $t_r$ , (reaction time). This assumption explains why the number of encounters between reindeer and snow-kiters reaches a limit. At this limit, the reindeer will experience new encounters as soon as they stop reacting from the last encounter.

The relative loss of feeding time is found by the following equations:

$$T_{s}(n) = \frac{E_{s}(n) \cdot t_{r}}{D}$$
 (eq.6.1)

$$T_{k}(n) = \frac{E_{k}(n) \cdot t_{r}}{D} \qquad (eq. 6.2)$$

Written out this becomes the following:

$$T_{s}(n) = \begin{cases} \frac{t_{r}}{F} \cdot 2nr_{s}v_{s}, & 0 < n < \frac{L}{v_{s}t_{r}} \\ \frac{t_{r}}{F\Delta t} \cdot (2r_{s}L - 2nr_{s}v_{s}(t_{r} - \Delta t)), & \frac{L}{v_{s}t_{r}} < n < \frac{L}{v_{s}(t_{r} - \Delta t)} & (eq.7.1) \\ 0, & n > \frac{L}{v_{s}(t_{r} - \Delta t)} \\ 0 < n < \frac{F}{2r_{k}v_{k}t_{r}} & 0 < n < \frac{F}{2r_{k}v_{k}t_{r}} \\ 1, & n \ge \frac{F}{2r_{k}v_{k}t_{r}} \end{cases}$$

The relative habitat loss as consequence of encounters between reindeer and skiers will at maximum equal  $2r_sL/F$ . For encounter between reindeer and snow-kiters the relative loss of habitat would finally be 1. After each encounter the reindeer will abandon an circle area equal to  $\pi f_s^2$  and  $\pi f_k^2$ , where  $f_s$  and  $f_k$  is the "total distance fled" as response to ski and kite provocation, respectively. The loss of habitat will then depend on number of encounters and how long these circles are abandoned.

#### Model parameters

I used the area for the winter range of the NR feral reindeer population, which I calculated from digital maps (1:50000, M711, http://www.statkart.no) with the software ArcViewGIS version 3.1. The size of the winter range area was found to be 110 km2. I assumed all of this to be above the tree-line.

I applied the upper quartiles (Q<sub>3</sub>) of the flight reaction distances and total distance moved (measured after disturbance procedure from snow-kiters (2006) and skiers (2006) in the model. Distances were as follows: "Flight" distance; 0.070 km from skiers and 0.308 km from snow-kiters. "Total distance moved" were 0.122 km from skiers and 0.814 km from snow-kiters. To calculate the total length of the prepared ski trails in the area, I used the paths marked in the map "Nesbyen 1:50000" (Statens Kartverk 05-2002, number 2573). In general through years, the length of the marked and regularly maintained ski trails is approximately 59 kilometres.

The model describes a function of the numbers of disturbers, *n*, i.e. number of skiers and snow-kiters, and I varied these numbers to illustrate the different scenarios. I needed to make an assumption of the mean velocity of the two means of locomotion, and set this to be 7 km/h for skiers and 20km/h for snow-kiters. The mean velocities can easily be assessed by placing a GPS on each skier and snow-kiter in future empirical studies. I have defined the number of hours there will be skiers or snow-kiters in the reindeer area per day, named "*day*", to 8 hours. The number of skiers or snow-kiters in the reindeer area was defined to be constant over a day. This implies that there were just as many skiers in the terrain in the first hour of the "*day*" as at midday and in the last hour of the "*day*". I set all skiers to be evenly spread out in the trail. "Reaction time" (= $t_r$ ) is the number of minutes from when animals initiate flight response until they again achieve normal behaviour. Tyler (1991) found a median reaction time at 3 minutes and 13 seconds in Svalbard reindeer (*Rangifer tarandus platyrhynchus*). I do not have empirical data on reaction time, but this should be measured in future experiments. Svalbard reindeer show less nervous behaviour towards disturbance than mountain reindeer, and therefore, I set  $t_r$  to be five minutes, or 5/60 hour.

# RESULTS

## Sample size

On one occasion fright response was observed as the snow-kiter got the kite up in the air, but had not got enough wind to move forward towards the herd. As the herd showed direct fright response we could use the encounter and flight reaction distance, but got no true escape distance and therefore omitted this result. Additional to this event, not all provocation experiments were successfully completed. For examples, on several occasions there was too little wind, and once the herd was disturbed by an airplane circling close above it. Overview of all sample sizes is found in appendix 1.

# **Correlation analysis**

There was no significant correlation between the dependent variables for snow-kite provocations, except for the fright and flight distances, which were positively correlated to one another (Table 1). For ski provocations, all dependent variables were positively correlated (Table 2).

**Table 1** Pearson correlation for the dependent variables fright, flight, and distance moved by feral reindeer,Norefjell-Reinsjøfjell, South-central Norway 2006 when disturbed by a snow-kiter.

	Fright distance		Flight distance		
	Pearson	p-value	Pearson	p- value	
	correlation		correlation		
Fright distance					
Flight distance	0.727	0.026			
Distance moved	-0.171	0.660	-0.408	0.213	

**Table 2** Pearson correlation for the dependent variables fright, flight and distance moved by feral reindeer,Norefjell-Reinsjøfjell, South-central Norway 2006 when disturbed by a skier.

	Fright distance		Flight distance				
	Pearson	p-value	Pearson	p- value			
	correlation		correlation				
Fright distance							
Flight distance	0.933	0.000					
Distance moved	0.640	0.034	0.705	0.015			

### Response distances

The median response distance when provoked by a snow-kiter (method 1) were as follows; "fright" 370 m, range 185-882 m, "flight" 327 m, range 127-477 m and "total distance moved" 481 meters, range 175-1154 m. The corresponding distances for provocations by a skier season 2006 (method 2) were; "fright" 89 meters, range 38-320 m, "flight" 53 meters, range 21-200 m, and "total distance moved" 56.5 meters, range 19-200 m. The median response distances for provocations by a skiing person season 2002-2005 (method 3) were; "fright" 138.5 meters, range 40-305 m, "flight" 103 meters, range 18-302 m, and "total distance moved" 263 meters, range 2-1750 m (all; Fig. 3).

#### Encounter distance

There was a significant difference in encounter distance between provocation methods (F = 8.13, df = 2, p = 0.001). Encounter distance for snow-kite provocations was significantly larger than for ski provocations (2; t = 3.542, p = 0.002, and 3; t = 3.767, p=0.001). There was no difference in encounter distance between ski provocations (2 and 3; t = 0.835, p = 0.683).



**Figure 3** Distances measured in meters for the fright and flight initiation distances and distance moved by feral reindeer in Norefjell-Reinsjøfjell, south-central Norway for the three categories of provocation, snow-kiter 2006 (1), skier 2006 (2) and skier 2002-2005 (3). Horizontal lines represent medians, boxes the 95% confidence intervals, asterixes extreme values. Extreme values are defined as observations larger than third quartile plus the product of 1.5 times the interquartile range  $\{Q_3+1.5(Q_3-Q_1)\}$ , or smaller than first quartile minus the product of 1.5 times the interquartile range  $\{Q_1-1.5(Q_3-Q_1)\}$ .

# Effect of provocation method with encounter distance as covariate

"Distance moved" was the only response where encounter distance did not have a significant effect (F = 0.81, df = 1, p = 0.370) (Table 3). For "fright" and "flight" responses, encounter distance had a significant effect (all; p = 0.000). When encounter distance was entered as a covariate, the GLM with provocation method as fixed factor explained 57.23% and 41.36% of the variation for fright and flight, respectively (Table 3). Snow-kite gave significantly longer response distances than ski year 2006 (all; p  $\leq$  0.005, adjusted for encounter distance) (Table 3). There were no significant differences in "fright" distance for ski provocations carried out in year 2006 and the years 2002-2005, but "flight" and "distance moved" were shorter in 2006 compared to 2002-2005 (Table 3). For comparison, "fright" and "flight" distance were shorter in ski provocation in 2002-2005 compared to in snow-kite provocations, whereas "distance moved" did not differ between these means of provocation (Table 3).

comparison (T), and the regression line calculated with "method" as a fixed		Provocation Treatment 95% CI T Adjusted mean 95% cI p-value			2-1 -0.959 (-1.423, -0.496) -4.949 0.000	3-1 -0.687 (-1.059, -0.316) -4.420 0.000	3-2 0.272 (-0.049, -0.593) 2.028 0.112			2-1 -0.950 (-1.503, -0.397) -4.104 0.000	3-1 -0.461 (-0.891, -0.030) -2.559 0.033	3-2 0.489 (0.089, 0.890) 2.919 0.012			2-1 -1.969 (-3.171, -0.767) -3.915 0.001	3-1 -0.522 (-1.496,0.451) -1.282 0.409	
ted with '					6) -4.	6) -4.	3) 2.			7) -4.	0) -2.	) 2.			7) -3.	) -1.	-
sion line calcula		95% CI			(-1.423, -0.490	(-1.059, -0.310	(-0.049, -0.59			(-1.503, -0.397	(-0.891, -0.030	(0.089, 0.890)			(-3.171, -0.76	(-1.496,0.451	
and the regress		Treatment mean			-0.959	-0.687	0.272			-0.950	-0.461	0.489			-1.969	-0.522	
t comparison (T),		Provocation method			2-1	3-1	3-2			2-1	3-1	3-2			2-1	3-1	0
Tukey's		t	3.23	6.73				2.76	4.71				3.07	06.0			
variate.		SE coef	0.340	060.0				0.637	0.109				1.319	0.226			
ice as co		Coef	1.622	0.608				1.756	0.514				4.053	0.203			
er distar		d	0.003	0.000	0.000			0.007	0.000	0.000			0.003	0.370	0.000		
encount		F		45.25	12.97				22.16	8.50				0.81	10.71		
3), with		Df		1	7				1	7				1	7		
12-2005 (		$\mathbb{R}^2$		0.572					0.414					0.240			
ski 2006 (2) and ski 201	ł.	Independent variables	Intercept	log <sub>E</sub> encounter distance	provocation method			Intercept	log <sub>E</sub> encounter distance	provocation method			Intercept	log <sub>E</sub> encounter distance	provocation method		
kite 2006 (1), .	factor. $\alpha = 0.05$	Response variable	log <sub>E</sub> Fright distance					log <sub>E</sub> Flight distance					log <sub>E</sub> Distance				

Table 3 The GLM for fright and flight distances and distance moved by feral reindeer in Norefjell-Reinsjøfjell, south-central Norway for the three categories of provocation,

## Effect of year in flight response for ski provocations 2002-2005

There was a significant effect of year on flight response for ski provocations carried out in the years 2002-2005 (F = 2.96, df = 3, p = 0.039). The flight responses measured in 2003 was significantly larger than flight responses measured in 2002 (t = 2.816, adjusted p-value = 0.032). There were no difference among other years or 2002 and 2003 and other years.

### Group size and group structure

The groups approached were relatively large; the smallest group size was estimated 150 animals. The largest group counted 370 animals (76% of total population). The composition of the group was always mixed, i.e. adult animals from both sexes and with calves.

### Effect of other independent variables

There was a significant quadratic fit for the relationship between flight reaction distances for snow-kite provocations and number of previous provocations (x) done to the same herd (y =  $-15.33 + 180.3x - 22.46x^2$ , df = 1, F = 8.50, p = 0.017, Fig. 4).

The complete results for all other independent variables are found in appendix 3.



**Figure 4** *Quadratic fit line-plot as a function of flight reaction distances (m) and total number of snow-kite provocations done towards the same herd.* 

#### Expected number of encounters

The number of encounters per day show very different outcomes for the source of disturbance. As the number of snow-kiters increase, the number of encounters with reindeer increases linearly until it stabilizes at a constant and high saturation level. The number of encounters reaches a maximum, a saturation threshold, at 96 encounters, which also equals the reaction time (Fig. 5). If the length of these intervals were adjusted, the saturation threshold between reindeer and snow-kiters would always equal the number of intervals in one day. Importantly, with an increasing number of snow-kiters into an area, the number of encounters will reach a threshold when reindeer will have encounters with snow kiters continuously except when running from a disturber. An increase in the number of skiers does not exhibit the same effect; the number of encounters will increase linearly to a certain number of skiers ( $n = \frac{L}{v\Delta t}$ ). At  $n = \frac{L}{v(t_r - \Delta t)}$ , the number of encounters between reindeer and shifts a starte of encounters will be zero (Fig. 5).

skiers will be zero (Fig. 5).



**Figure 5** *Expected numbers of encounters during one day between reindeer and skiers (grey) and snow-kiters (black) as function of numbers of skiers and snow-kiters respectively.* 

At this level, the ski trail becomes "filled up" or saturated with skiers, so that the reindeer will never be at or near the trail or within a distance from trail that is within the flight distance (Fig 6). In other words, the reindeer settle at some distance outside the boundary defined by the maximum reaction distance and any increase in number of skiers (along the prepared trails) has no new effect. The cumulative number of encounters during one day with many skiers will reach a maximum and stabilize at this number. However, it should be noted that at start of a new day, the reindeer are assumed to be randomly distributed (also at or nearby the ski trail).



**Figure 6** Potential area of influence along a prepared ski trail with two densities (A = 8 and B = 4) of skiers through a given area. The dark area is where a skier is in time interval  $\Delta t$  and equals  $I_s = 2r_s v_s t_i$  (eq.2.1). The grey area is where a skier was the last  $t_r$  minutes and equals  $2r_s v_s t_r$ . The white area is where new encounters may occur. Because skiers only use prepared trails, the area for potential encounters with skiers will be limited to the white areas within  $2r_s km$  from the trail. There will be no reindeer in the grey area, as all reindeer that were in that area during the last  $t_r$  minutes would have encountered a skier and taken flight. A trail "saturated" with skiers (A), will result in no encounters between reindeer and skiers. All reindeer will be on one or the other side of the trail, at  $\geq 2r_s km$  distance. For a trail with few skiers (B), encounters between reindeer and skiers can occur in the white areas.

This will result in no encounters, and therefore, no reindeer will be disturbed by skiers after the trail has become saturated. In my model, a saturated ski trail becomes a barrier that reindeer will not cross. However, one can still expect crossings to occur during hours, for example at night or during bad weather, without skiers.

#### The relative loss of feeding time

The expected loss of feeding time is described by similar equations as for the expected number of encounters per day. Reindeer will have an increase in relative loss of feeding time until the number of skiers is  $n < \frac{L}{v_s t_r}$ . Within my defined categories, this equals 101 skiers and the reindeer will at this number of skiers loose approximately 7.5 % of their feeding time. Then the relative loss of feeding time will decrease with number of skiers until n  $= \frac{L}{v_s(t_r - \Delta t)}$ . When n larger than  $\frac{L}{v_s(t_r - \Delta t)}$ , the relative loss of feeding time will return to zero (eq.6.1 and Fig. 7). This is similar to the saturation effect in spatial terms described above.

The relative loss of feeding time for the reindeer following encounters with snowkiters will increase as long as the number of snow-kiters is less than  $\frac{F}{2r_k v_k t_r}$ . At  $n \ge \frac{F}{2r_k v_k t_r}$ , in this case  $n \ge 107$ , the relative loss of feeding time will be 100 % (eq.6.2, Fig. 8).



**Figure 7** The relative loss of feeding time for reindeer after encounters between reindeer and skiers (black) and snow-kiters (grey) as a function of numbers of skiers and snow-kiters, respectively.

I did not model the relative loss of habitat as this would be dependent of how long reindeer stay out of a certain patch after an encounter. The difficult question is how long these circles  $(\pi f_s^2 \text{ and } \pi f_k^2)$  are abandoned. Reindeer would not likely have the same probability of using areas were encounters have just occurred as using other areas. The relative loss of habitat will be linear for low numbers of skiers and snow-kiters in an area, but after some point this dependence will be non-linear and difficult to describe mathematically. What is clear is that after this point, the increase in the relative loss of habitat per snow-kiter will grow asymptotically towards 1 (Fig. 8). Correspondingly, increase in the relative loss of habitat per skiers will grow asymptotically towards  $2r_sL/F$  (Fig. 9).



Number of show-kiters

**Figure 8** Draft of relative loss of habitat for reindeer after encounters between reindeer and snow-kiters as a function of numbers of snow-kiters.



Figure 9 Draft of relative loss of habitat for reindeer after encounters between reindeer and skiers as a function of numbers of snow-kiters.

# DISCUSSION

#### Experimental measurements

There was a clear effect of provocation method. Snow-kite provocations produced longer response distances than ski provocations (method 2 and 3) for all responses (Table 3) except for "distance moved". If one expects reindeer to have predator-specific antipredator responses only, new elements like snow-kiting should result in shorter response distances than skiers. Reindeers' reduced responses towards snowmobiles compared to skiers (Reimers *et al.*, 2003) support this. However, most prey species have also evolved generalized antipredator responses (Frid and Dill, 2002), and velocity and size of threatening element generally induce increase responses in prey (Frid and Dill, 2002, Stankowich and Coss, 2006). The snow-kiter moved faster and appeared larger than the skier. This likely explains the longer response distances towards snow-kiters than skiers found in this study. If only the presence of humans was most relevant, as often concluded in connection with infrastructure development (Reimers and Colman, 2006), there should not have been any difference between responses towards snow-kiters and skiers. In other words, the trigger stimulus fore the reindeers' reaction towards a snow-kiter was most certainly the snow-kite and not the person snow-kiting, while for skiers, it is the person themselves.

Ski provocations from 2002-2005 showed significantly longer flight distances and "distance moved" than my ski provocations in 2006. One possible explanation may be the copresence of snow-kite provocations. The snow-kite provocations may have led to suppression by the reindeer towards the effect of ski provocations. Reindeer may allocate more energy into avoiding the snow-kite by taking flight less frequently and running shorter distance when escaping the ski provoker. As I identified a significant effect of year among the ski response distances from years 2002 and 2003, I also expect the difference between years 2002-2005 and 2006 in ski provocations to posses some natural variation between years. Snow depth, present predation risk and general condition of animals may explain in-between year variation.

Distance moved was not significantly longer for snow-kiters compared to ski provocations from 2002-2005. If the difference in reindeer's response towards snow-kiters and skiers is constant, this result may imply that distance moved from snow-kite provocations will be even larger in some years. Additional explanation may be related to my sample size. With a small sample size, potentially randomly distributed extreme values may be missed, such as those found in the older data. In this context, extreme values may be explained by thresholds. This may be elements in the terrain, such as a lake, forest or other unsuitable areas. Ydenberg and Dill (1986) argues that fleeing distance and probability of flight should increase for prey at patches with reduced resources, as the gain from remaining in site is lower than the risk of predation. This may have lead to longer "distance moved" for some of the ski provocations from the 2002-2005 data. Note that the same arguments may induce shorter response distances if patch quality are perceived high (Frid and Dill, 2002). Furthermore, if the herd was already "on the move" when the provocation sequence occurred, the "distance moved" may also be elongated, as the animals were already heading towards another destination. Thomson (1977) described typical winter movement patterns for wild reindeer; herds remain relatively resident for 1-3 days before moving towards another area and the mean distance moved to be approximately 3 kilometres per 24 hours. Mårell *et al.* (2002) also studied movement patterns in reindeer and found the reindeer to follow terrain features more often than was expected from random walk models. Both these studies indicate why response distances measured over many occurrences will likely provide some outliers.

The encounter distance had a significant effect on fright and flight distances; i.e., larger encounter distances correlated to larger fright and flight distances. This is in accordance with Reimers et al. (2006), suggesting that the exposure time may be important for flight distance. This is also supported by Tyler (1991) and Colman et al. (2001) for Svalbard reindeer. Positive relationship between encounter and response towards anthropogenic disturbances has also been shown for other species, e.g. bison, pronghorn antelope and mule deer (Taylor and Knight, 2003b), black-tailed deer (Stankowich and Coss, 2006). The probability of detecting an object follows the exposing time of the provoker/disturbance. When alert distance is long, the amount of time possible for showing fright and flight behaviour will also increase, and therefore, these distances should logically increase with encounter distance. Taylor and Knight (2003b) argued that encounter distance may stand as the "upper limit at which wildlife could respond", indicating that even longer encounter distances would induce even longer response distances. However, distance moved was not correlated to encounter distance, or to the other response distances except flight distance for ski provocations (Table 1 and 2). This may imply that the distance feral reindeer in NR disperse from a provocation is not affected by a disturber's exposure time. Thus, the animals would not have run further if they had the option. Furthermore, as there are no apparent reasons why a predator approaching at longer distances should have improved hunting success, I would not expect the distance moved to increase with increasing encounter distance.

Encounter distances were significantly longer for snow-kiters than ski provocations. One reason for longer encounter distances in snow-kite provocations compared to skiers might be the height of the kite, often 25-30 metres in the air. At these heights, and especially in hilly terrain, the kite could be visible long before to the snow-kiter. Compared to a skier, the resulting encounter distances would therefore be consistently longer. However, this is a natural part of the overall stimuli from a snow-kiter. The same hilly terrain that can potentially increase the encounter distance for snow-kiters can have the opposite effect for a skier. When a skier momentarily disappears from a herd during a provocation, and if no alert behaviour is recorded when they regain visibility with the herd, the skier measured a new and invariably shorter encounter distance. This never happened during snow-kiting provocations, and thus, is another reason why the overall encounter distance was shorter for skiers versus snow-kiters. My results are therefore in general agreement with Reimers *et al.* (2006), who found significant effects of encounter distance, in addition to group size and season.

As all recorded herds were classified as "large", the effect of group size could not be analysed. Numerous studies show that individual vigilance decreases with increasing group size (Roberts, 1996), while increasing group size is also expected to give reduced frequency of flight (Recarte *et al.*, 1998). This is supported in reindeer as well. Reimers *et al.* (2006) found a decrease in response distances as the number of animals in group increased.

Murphy and Curatolo (1986) found groups with calves to be the most sensitive, showing the largest response distances in their study of in caribou (*Rangifer tarandus granti*). Colman *et al.* (2001) also found females with calves to disperse further than other groups, but group structure had no significant effect on other response distances. However, these two studies were done in summer season, when calves are just a few months old. Reimers *et al.* (2006) did not find an effect of group structure, and this study covered winter, summer and autumn season. All groups in my study were mixed, containing females, calves, and males, and I am uncertain as to how strictly male or female groups would have responded.

Number of previous snow-kite provocations affects flight distance. I found a significant quadratic fit between numbers of snow-kite provocations on the same herd and their flight distances. The flight distance increased for the first provocation, and thereafter decreased. As the sample size was low, further investigation is needed to be able to draw conclusions in terms of habituation or sensitization. Nevertheless, the trend is logical in terms of habituation towards a non-destructive experience towards snow-kiters over a short (3-8 hours) time span. An interesting aspect of this would be to eventually incorporate learned behavior, either habituation ore sensitization and for both snow-kiting and skiers, into my model calculations.

# Piecewise-linear modeling of snow-kiters vs. skiers in reindeer habitat

The model showed a very different outcome for disturbances from snow-kiters versus skiers. With a high number of snow-kiters the reindeer will loose *all* available time normally spent on feeding during daylight hours (Fig. 7). They will also be on the move from snow-kiters all day. This is in contrast to the outcome of many skiers on a ski trail; the ski trail becomes saturated and the expected number of encounters between reindeer and skiers increases to a threshold and then falls to zero. My results are in agreement with previous literature; animal reactions towards human activities are usually less dramatic and may cease altogether (i.e. become habituated) when the disturbance is non-destructive and predictable in time and/or space (Recarte *et al.*, 1998, Hamr, 1988, Bullock *et al.*, 1993, MacArthur *et al.*, 1982, Reimers and Colman, 2006). Importantly, before now, this claim had not been tested, and wheter my model assumptions and parameters are entire correct, the scenarios generated from such an excersise revealed interesting results. The model can of course be modified and adjusted according to other species, other disturbance stimuli, or reactions distances by reindeer in other areas that are either more or less timid towards the defined activities.

Pépin *et al.* (1996) found that area use in Pyrenean chamois increased with distance from a hiking trail, and since this distribution of animals minimized the probability of encounters between humans and chamois, the trail makes the disturbance predictable. If all hikers moved around randomly, the disturbance effect would presumably be larger.

Enggist-Düblin and Ingold (2003) modelled the impact of both hikers and paragliders on chamois and claimed that with modifications, their model may be applied to other species. They argue that "it is not the single disturbance event, but its repeated occurrence that affects the animals the most". I agree with this, but would like to add that the spatial distribution is equally important. Vistnes and Nellemann (2001b) claimed that ski trails produced the most negative effects out of their three linear obstacles studied (power lines, roads and ski trails). However, they claimed that this was due to the vicinity of tourist resorts to ski trails. Therefore, the authors' results state that human presence is more severe than infrastructure itself. In addition, the effect of skiers on the trail and the ski trail itself were not separated. In future studies, potential interactions between co-occurring variables and factors need to be isolated and studied both separately and together to decipher true effects.

Regarding the assumptions made for the parameters in my model, I used 5 minutes reaction time for both encounters with skiers and snow-kiters. Reaction time will likely differ between the sources of disturbance. A difference may have some biological relevance, but I assume this would not exceed the difference in effect of probability of encounter, and therefore, not produce a significant change in the results from relative loss of feeding time.

To be able to do precise calculations, the assumed span of time reindeer will abandon an area after encounter must be thoroughly monitored and discussed. If a second encounter occurs from a different angle than the first, what is the probability of reindeer escaping back to the position previous to the first encounter? A strong selection pressure on traits for detecting predators should be more relevant for survival than traits for associating predation risk with geography. For instance, the reindeer does not stay in the calving sites, chosen for its low predation risk, all year (Ferguson and Elkie, 2004). The spatial/geographical memory in reindeer should be subject for further investigation.

It follows logically from the model that the length and amount of ski trails in an area will affect the impact of skiers for reindeer. If the trails in this case were longer, the number of skiers were saturation level is reached would be higher. The potential relative loss of feeding time will increase with ski trail length, but a prolonged yet empty ski trail will not provide a negative effect on reindeer. In the model, I assumed all skiers to use prepared ski trails. This will not apply to all skiers, as some prefer not using such trails. But as long as most skiers follow trails, my model realistically describes the general difference in possible impact from snow-kiters and skiers on reindeer feeding time.

#### Future research

According to wild reindeer management, all disturbances towards reindeer besides hunting are to be minimized. As the aim of this study was to highlight possible differences in reindeer's response towards snow-kiters and skiers, I held the sample size at a minimum to avoid unnecessary disturbance towards the reindeer while attempting to allow for enough provocations needed to identify potential statistical significant differences. The sample size was also regulated by a number of other factors; a restricted field season, poor weather in the field, few independent herds of reindeer, and the snow-kite procedure being challenging to perform. These factors will presumably be the same for snow-kiters in general, and may regulate how much influence snow-kiting eventually invokes upon reindeer.

Optimally, I aimed to conduct the experiment in an area with reindeer possessing a more wild genetic origin in addition to NR but this was practically impossible due to oppositions from local stakeholders and regional management authorities in the other areas.

The NR-population seems to be habituated to skiers as the response distances measured in this area are significantly shorter than in other areas (Eftestøl 1998, Bjørn Dahle pers. comm.).

This study should be repeated in the future in order to eliminate year as a possible variable affecting the measured distances. It would be interesting to compare the response distances with other wild reindeer areas, preferably where the reindeer population has a different genetic origin and different behaviour repertoire towards human activities. Additional research should be investigating the long-term effect of snow-kiting on reindeer condition, reproduction and possible habituation.

#### Management implications

Maintaining energy balance is especially important for reindeer in winter. Therefore, the "flight distance" and "distance moved" are perhaps the most important reaction variables for management considerations. In this study I used the direct disturbance, and as Taylor and Knight (2003a) also argue, tangential approach is more likely to be the dominant form of disturbance. Therefore, my study is a 'worst-case scenario'. As the kite was often sighted by the reindeer before the kiter themselves were able to detect the reindeer, implementation of buffer zones will probably not be successful in the case with snow-kiters. This is because they are much more likely, than for example skiers, to disturb reindeer without knowing it. Possible management solutions would be allowing snow-kiting in all areas except for some defined vulnerable sites, e.g. core areas for reindeer during winter. This could also be reversed by the management authorities recommending certain areas for snow-kiting. This should then be mountainous areas with no wild reindeer, but with all elements necessary for snow-kiting. As my results showed stronger negative effect of snow-kiters versus skiers, and as no long-term studies have yet been conducted, I recommend that the management authorities consider certain restrictions to snow-kiting in wild reindeer areas.

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# APPENDIX

Response	Method	Ν	Mean	SE mean	St Dev	Median
Fright	1	9	418	68.6	205.8	370
	2	11	122.4	28.7	95.1	89
	3	64	149.5	8.46	67.6	139
Flight	1	11	244.2	30.4	100.9	237
	2	11	74.6	16.5	54.7	53
	3	65	122.9	8.45	67.9	103
Distance moved	1	9	537.2	94.3	283	481
	2	12	74.1	16.2	56.2	263
	3	65	400.2	47.9	386.3	

**Appendix 1** Observed mean and median response distance in feral reindeer in Norefjell-Reinsjøfjell, southcentral Norway for the three categories of disturbance, kite 2006 (1), ski 2006 (2) and ski 2002-2005 (3).

#### Appendix 2

The 11 independent variables recorded for each provocation (as in Colman et al. (2001) :

- a. Weather conditions (clear sky, cloudy, partly cloudy or foggy)
- b. Temperature
- c. Wind direction (whether the disturber had the wind *from* behind, side, front or no wind)
- d. Wind speed
- e. Topography (level or hilly)
- f. Position of the provocateur in terrain in relation to the reindeer (above, level or below the animals)
- g. Size of group (<20, 20-75 or >75 individuals)
- h. Age and sex structure of group (adult males, adult females with calves or mixed sex and age)
- i. Activity pattern of group prior to disturbance procedure (lying, grazing, moving or mixed)
- j. Disturbance method (kiter or skier)
- k. Length of disturbance procedure in minutes

Independent variable	Response	Df	F	$\mathbf{R}^2$	р	
No. of disturbances this day	log <sub>E</sub> Fright distance	4	0.19	0.049	0.938	
	log <sub>E</sub> Flight distance	4	0.36	0.078	0.834	
	$log_E$ Distance moved	4	0.63	0.136	0.648	
No. of disturbances previous days	log <sub>E</sub> Fright distance	4	0.80	0.177	0.541	
	$\log_{E}$ Flight distance	4	0.60	0.125	0.664	
	$log_E$ Distance moved	4	0.89	0.182	0.494	
Temperature	log <sub>E</sub> Fright distance	4	0.34	0.084	0.845	
	$\log_{E}$ Flight distance	4	0.37	0.081	0.824	
	$log_E$ Distance moved	4	0.58	0.127	0.679	
Weather	log <sub>E</sub> Fright distance	2	0.37	0.041	0.699	
	$\log_{E}$ Flight distance	2	0.68	0.067	0.520	
	$log_E$ Distance moved	2	0.19	0.020	0.832	
Direction of disturbance in relation to wind	$log_E$ Fright distance	3	4.50	0.457	0.018	*
	$\log_{E}$ Flight distance	3	2.53	0.297	0.089	
	$\log_E \text{Distance moved}$	3	1.43	0.202	0.268	
Direction of disturbance in relation to sun	log <sub>E</sub> Fright distance	2	3.34	0.295	0.061	
	$\log_{E}$ Flight distance	2	3.34	0.271	0.058	
	$log_E$ Distance moved	2	0.87	0.093	0.438	
Direction of disturbance in relation to terrain	$log_E$ Fright distance	2	1.30	0.133	0.298	
	$\log_{E}$ Flight distance	2	3.49	0.269	0.051	
	$\log_E \text{Distance moved}$	2	0.45	0.047	0.647	

**Appendix 3** Results from one-way ANOVA of the fright and flight initiation distances and distance moved by feral reindeer in Norefjell-Reinsjøfjell, south-central Norway.  $Log_E$  of response distances, snow-kite and ski disturbances 2006 pooled. Asterix were independent variable had significant effect.  $\alpha$ =0.05.