

# The effects of highway traffic on wild reindeer

Bjørn Iuell<sup>1</sup> & Olav Strand<sup>2</sup>

<sup>1</sup>Environmental Section, Road Development Department, Directorate of Public Roads, Norwegian Public Roads Administration, Norway, e-mail: bjorn.iuell@vegvesen.no; <sup>2</sup>Norwegian Institute for Nature Research, Tungasletta 2, 7485 Trondheim, Norway, e-mail: olav.strand@nina.no

**Abstract.** In 2002 scientists from the Norwegian Institute of Nature Research (NINA) were engaged by the Norwegian Public Roads Administration (NPRA) in a 5-year study to undertake research on patterns of reindeer habitat use and movements in areas believed to be influenced by the road. The main purpose of the project was to find out to which degree the road and/or the traffic generated by the road constitute a barrier for the wild reindeer, and if it has a repelling effect on the animals.

The project equipped altogether 37 animals with GPS-transmitters providing detailed and accurate data on their habitat use and movements. The GPS units were programmed to register the position of each animal every 3rd hour, and the data were stored in the collar. Since the wild reindeer are living in herds up to some thousand animals, approximately 70-80 % of the total population was covered.

Maps of the distribution of different reindeer food resources (e.g. lichens) were produced by using field surveys and satellite images (LANDSAT 5). The winter grazing areas were found mainly in the eastern parts and along the Hw 7, while the summer areas were located in the south west and around the Hardangerjøkulen glacier.

The major findings of the project were that Hw 7 in fact has a repelling effect on the wild reindeer, as have other areas with human activity, e.g. the major hiking and skiing tracks between the tourist cottages. The GPS-data show that there is a significant reduction of the reindeer use of the areas close to the Hw 7, up to 8 kms from the road. This zone of avoidance also strengthens the barrier effect of the road such that the migration routes to and from the north are more or less cut off. The same effect can be found in the vegetation maps, but the correlation is not as strong as in the GPS-data. When the GPS-data were compared with the distribution of lichen resources, it appeared that animals do not use some of the areas richest in lichens. Hw 7 can be seen as a behavioral barrier, hindering the migration of reindeer between the central and the northern parts of Hardangervidda.

The project has also documented that the movements of the reindeer are heavily influenced by the direction of the wind, and, in wintertime, the snow conditions. During winters with a lot of snow the animals are found in the eastern parts; where there is usually less snow than in the western parts. The wild reindeer's use of the terrain is dependent on the population density and the available food resources. The possibility for the animals to have access to winter grazing grounds in the northern and eastern parts in years with much snow, can be crucial.

**Key words:** Wild reindeer, roads, barrier, fragmentation, disturbance, GPS

## 1. Introduction

More than 60% of Norway's land area is situated above the timber line, which is approximately 1.000 meters above sea level in southern Norway. These alpine and sub-arctic tundra areas in the southern parts of the country are a refuge for the remnant populations of European mountain reindeer (Reimers *et al.* 1980). The Norwegian topography is from nature's side fragmented by long and

deep fjords, with narrow valleys surrounded by high and steep mountains. Norway is still called the green lung of Europe, and the density of roads is only 0.6 km/km<sup>2</sup> compared to the Netherlands at 3.8 km/km<sup>2</sup> (Trocmé *et al.* 2003). The densest developed areas are along the coast, and in the deep valleys.

The major road systems are relatively simple (Fig. 1), and they follow the topographic patterns that naturally fragment the country into a matrix of forested and mountainous habitats. The possible impacts of roads on Norwegian wildlife can be illustrated by their distribution and traffic levels. The total road network, including private roads and forestry roads, constitute a rather close and dense network covering larger parts of the landscape (Fig. 2).

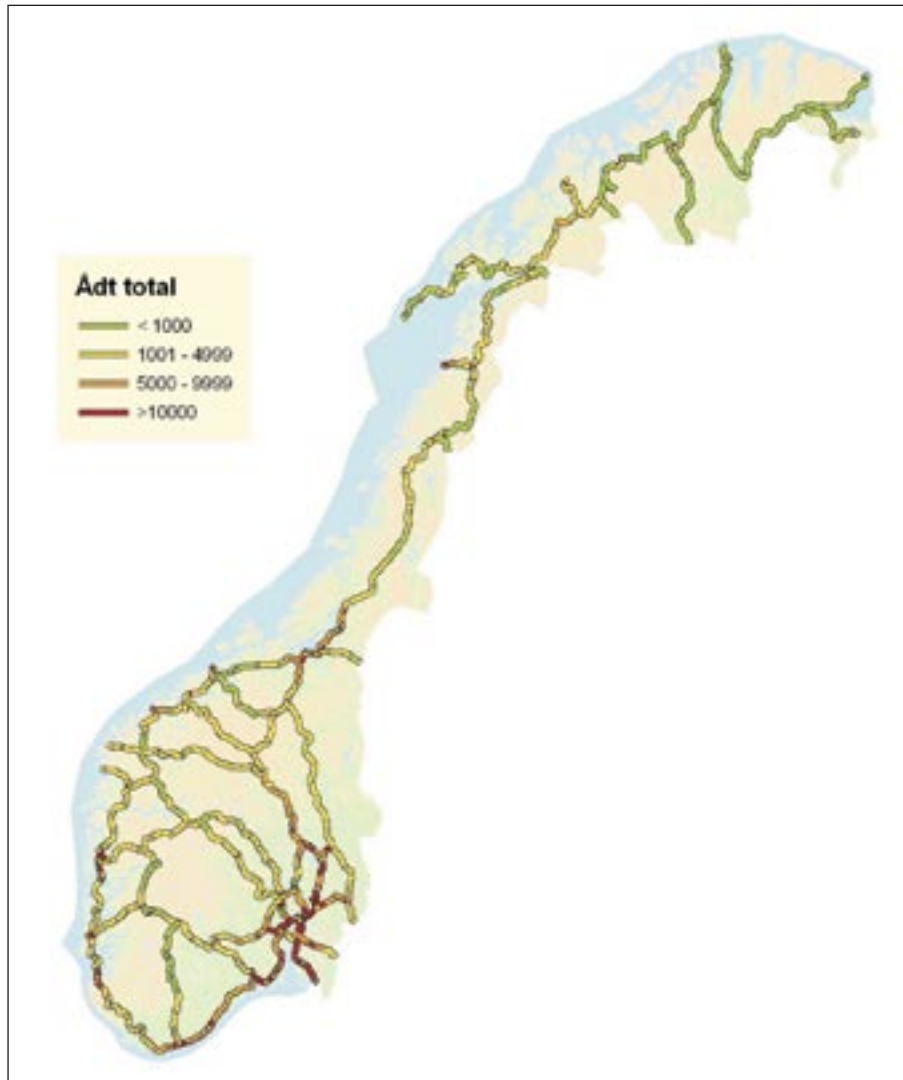


**Fig. 1.** Main roads in Norway  
(Source: Statens vegvesen)



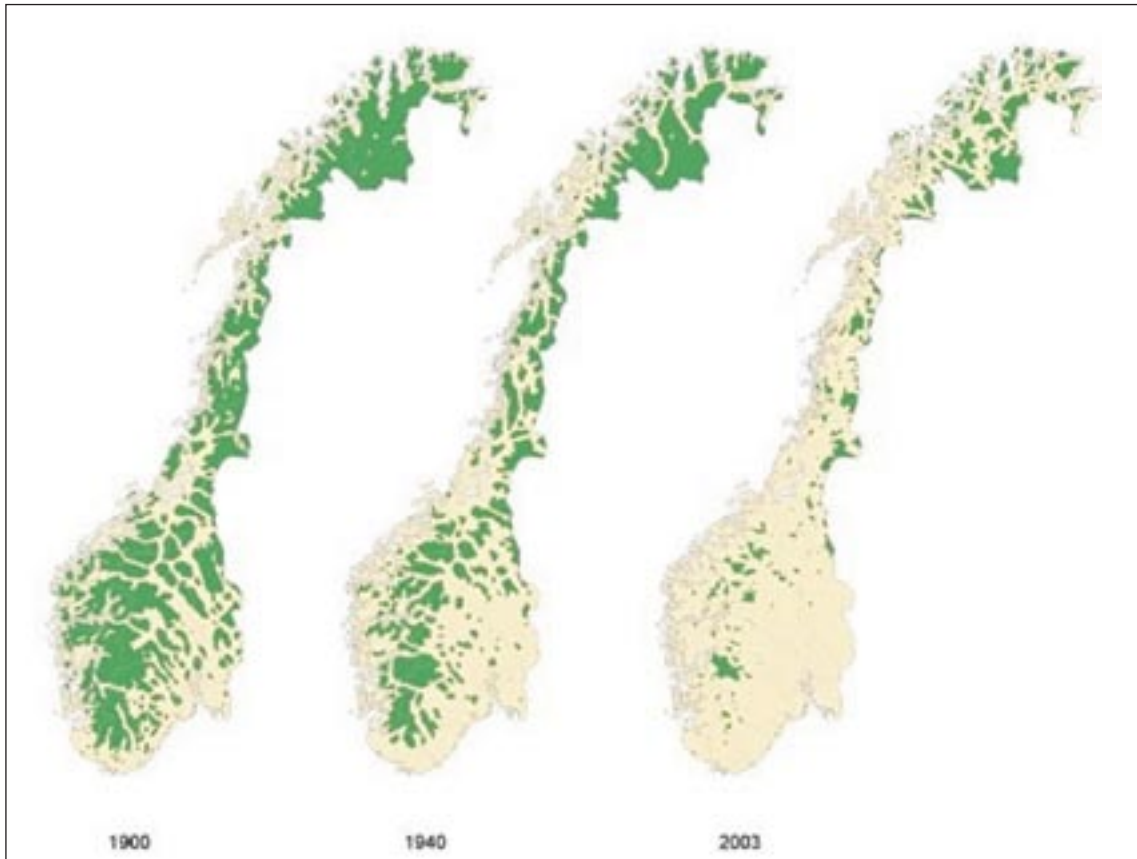
**Fig. 2.** All roads in Norway  
(Source: Statens vegvesen)

The traffic density on Norwegian roads is relatively low compared to most western European countries, and the average daily traffic (ADT) is highest in the south east part of the country and around the major cities (Fig. 3).



**Fig. 3.** Average daily traffic (ADT) on main roads in Norway (2004) (Source: Statens vegvesen)

The transportation network together with the network of power lines, dams and regulated water courses, leaves just a few spots of untouched nature left. This can be illustrated in maps classifying habitats into undisturbed and developed areas. Figure 4 shows that the distribution of ‘wilderness areas’ (areas more than 5 kilometers from larger technical installations, be it roads, railways, power lines, built-up areas or regulated water courses), has become greatly reduced since 1900. In fact more than 95% of the areas classified as ‘wilderness’ in Southern Norway have disappeared during the last century. The remaining wilderness areas are mainly protected areas above the timber line.



**Fig. 4.** Changes in the area of undisturbed land between 1988 and 2003 (Source: Statens kartverk/DN)

### Wild reindeer

When the glaciers withdrew at the end of the last ice-age, some 10.000 years ago, reindeer migrated into these areas from at least two different directions. Some reindeer came from the south and central Europe, and inhabits today the southernmost areas in Norway. A second immigration came from the east, and descendants from this immigration are mainly found in the northern reindeer areas (DN 1995; Andersen & Hustad 2005). There is still a predominant and documented genetic difference between these two groups of reindeer.

Prior to the industrial development wild reindeer moved more or less freely in 2-3 defined areas in southern Norway, the major barriers being the deep valleys between the mountain plateaus. The present distribution of wild reindeer into 23 more or less isolated management units (Fig. 5) is thus a result of both natural factors, and effects of human activity and infrastructure (Reimers *et al.* 1980; Skogland & Mølmen 1980).

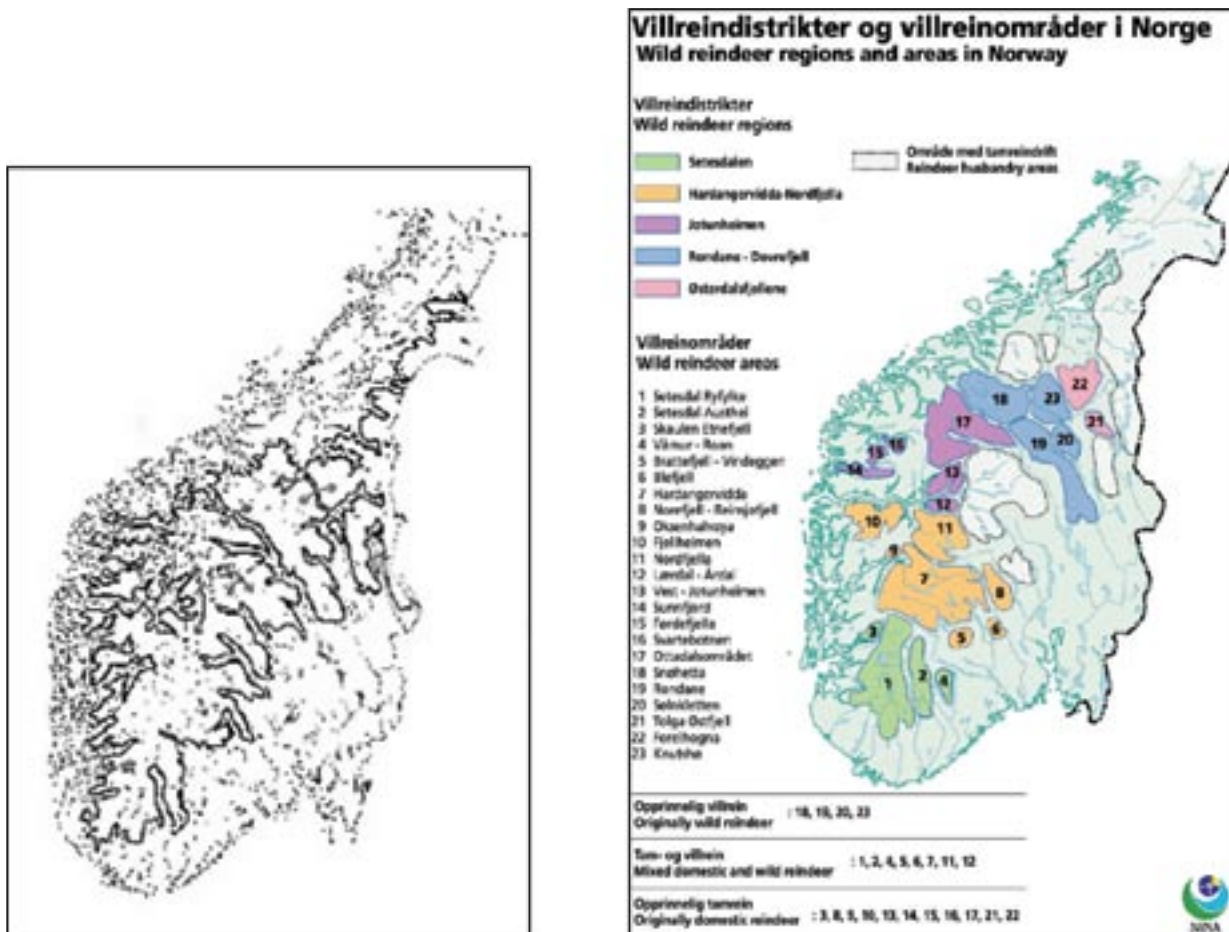


Fig. 5. Wild reindeer areas in South Norway before and now

Today the distribution of wild reindeer is limited to the southern parts of Norway, with approximately 30.000 animals left (Jordhøy *et al.* 1997). The hunting tradition is still strong, and the annual harvest varies between 3.000 and 10.000 animals, depending on the production and population levels. Hunting is strictly regulated by the means of annual population censuses and yearly adjusted hunting quotas.

Norwegian wild reindeer do not migrate over huge distances like caribou or reindeer populations found in large arctic tundra areas, but they do have nomadic and seasonal movements at a smaller scale between winter, summer and calving areas. Reindeer also lives in herds and aggregate in relatively large groups. In evolutionary terms this herding behavior is seen as an adaptation to co-existence with large predators (Skogland 1989). Today large predators are functionally extinct from the Norwegian wild reindeer areas, and hunting is the single most important factor limiting reindeer numbers and preventing populations from overgrazing their habitat (Skogland 1985). As a result of deep snow and limited access to other forage, reindeer in southern Norway utilize lichens as their main winter forage (Kojola, Helle *et al.* 1995; Gaare 1997). Unlike green plants, lichens keep all their biomass above ground (they have no roots), and have slow recovery rates (up to 20 -30 years) following periods with high grazing pressure (Helle & Särkelä 1993; Miller 2000). Management and conservation of wild reindeer is therefore directed both at population management through harvest, aiming to keep populations at reasonable levels in relation to available pastures, and to protect remaining habitats from further developments (DN 1995; Andersen & Hustad 2005).

Wild reindeer are known to be sensitive to disturbance caused by different kinds of human activity (Wolfe *et al.* 2000; Nellemann *et al.* 2003). Even at long distances reindeer responds to skiers, hikers, snow scooters and other vehicles. In the rather flat and open mountain areas reindeer



are known to have a flight distance at several hundred meters, and sometimes escapes disturbances by several kilometres (Reimers *et al.* 2000; Nellemann *et al.* 2001; Vistnes & Nellemann 2001; Reimers *et al.* 2003). Known effects of human disturbances and infrastructure on reindeer behavior and habitat use can be summarized on two different levels. First, at an individual or a direct level, corresponding to changes in behavior or physiological state of single events where animals are disturbed by human activities. Second, effects of disturbances are demonstrated at the population level, where effects are documented through loss of important migration routes and grazing habitats (Wolfe *et al.* 2000). The latter studies are more easily related to management questions (since they are documenting effects at the population or landscape level), but are less interpretable with respect to their underlying mechanisms and effects of single disturbances.

## **2. Methods and materials**

### **2.1. Study area**

The Hardangervidda is the largest mountain plateau in Northern Europe (app. 8200 km<sup>2</sup>) and can still be found as a rather large green spot in maps with classified wilderness areas in Norway (Fig. 4). Hardangervidda is also the home for the largest population of the remnant European wild reindeer. A larger part of the Hardangervidda is today protected as a National park (3422 km<sup>2</sup>), and is still used for hunting, fishing and other out-door activities.

The Hw 7 is one of several roads between the two major cities Oslo (the capital) and Bergen, on the west coast, and crosses the northern parts of Hardangervidda. The Norwegian Directorate for Nature Management (DN) has suggested closing down the part that crosses Hardangervidda, a stretch of about 40 km, during the winter months. The aim is to restore reindeer habitat use in the northern parts of Hardangervidda. Even if the road has very low traffic in the winter months (300-400 ADT), the proposal has caused a lot of protest and discussion locally. Due to the local protests, the road is still open, except during periods of winter storms. The Norwegian Public Roads Administration (NPRA) therefore had to carry out a survey in 2001, including both the biological issues and the socio-economical effects of such a drastic measure. The survey led to the establishment of a 5-year study of the wild reindeer's use of the area in wintertime, based on the use of GPS-collars attached to reindeer, and mapping of the grazing patterns of the wild reindeer. The project was financed by the NPRA, and was carried out by the Norwegian Institute for Nature Research (NINA), starting in 2002. The project was closed in 2006, and the results presented in this paper is taken from the final report of the project (Strand *et al.* 2005).

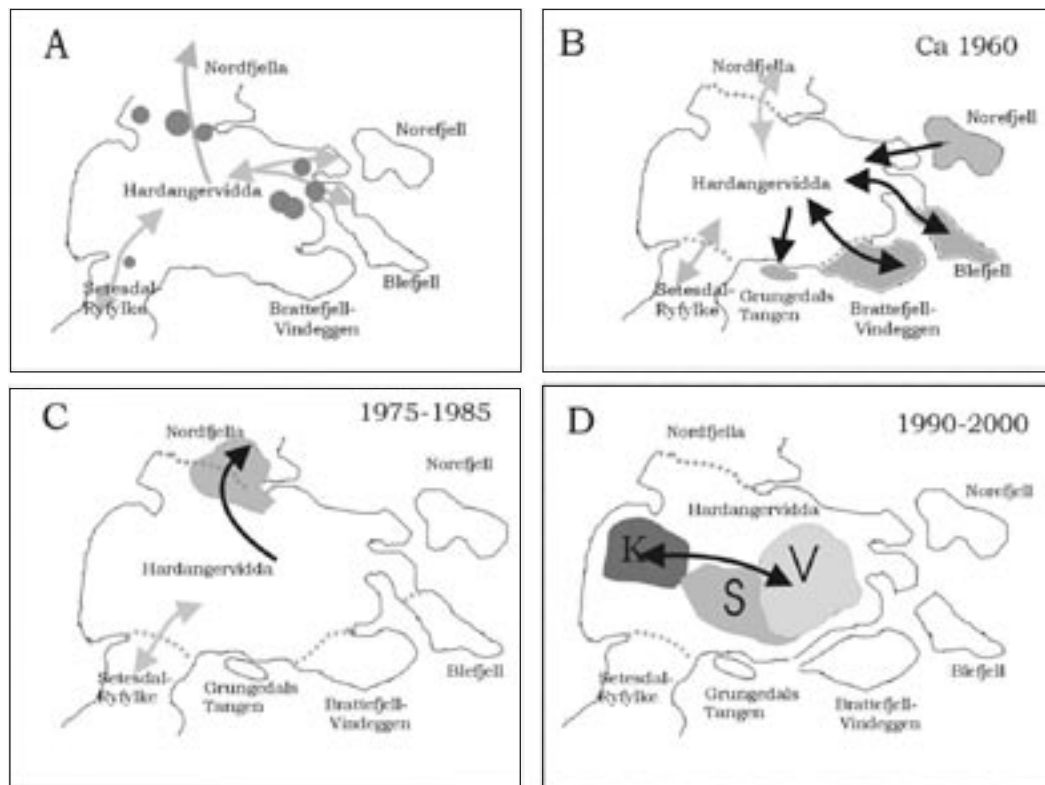
### **2.2. Data collection**

In order to disentangle the effects of human disturbance on the habitat use of wild reindeer at Hardangervidda, the project adopted a two fold approach, focusing on both reindeer habitat use in relation to human disturbances, and the relationship between reindeer grazing and vegetation. In addition to studies based on GPS collared reindeer and the use of habitat maps the project also collected historical data including old pit fall systems and former reindeer migration routes.

Detailed data on reindeer habitat use (from GPS collars) were used together with habitat distribution maps in a GIS based analyses of reindeer habitat selection. The rationality behind these types of studies was to generate models for reindeer habitat selection including standard parameters such as seasonality, elevation, aspect and vegetation cover. Possible effects of human activities (and the road) have been tested as single elements in the models, and their ability to explain the residual variation in the models were used in order to test the hypothesis regarding disturbance effects on reindeer habitat use.

### 3. Results and discussion

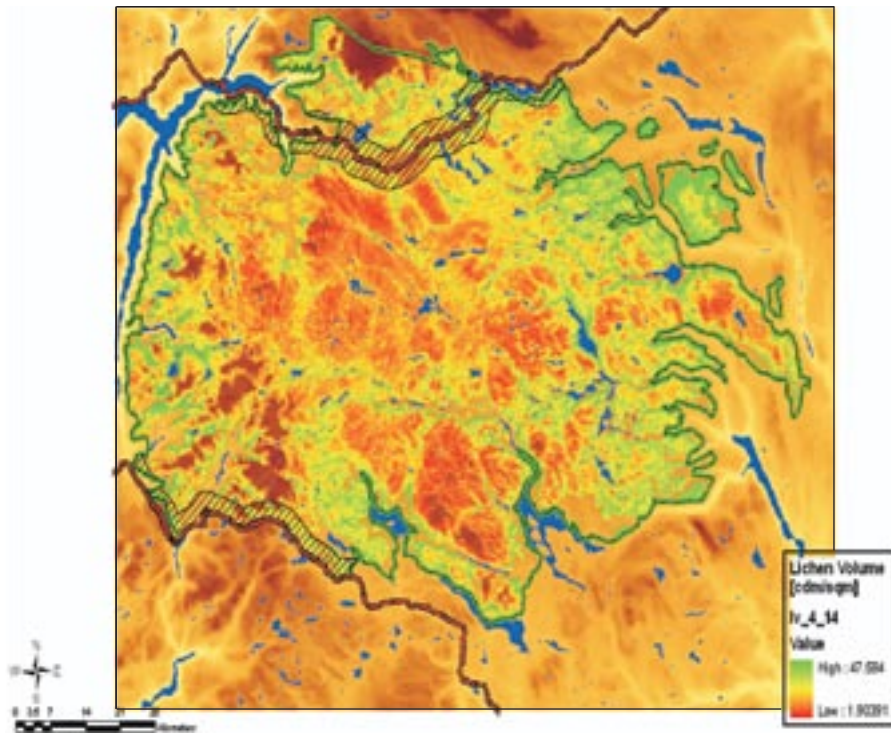
During the last 50 years the density of reindeer at Hardangervidda has fluctuated more than five fold. During periods with high density (in the 1960's and the early 1980's) reindeer has found new and richer grazing areas in the outskirts of Hardangervidda and in neighboring areas (Fig. 6). Available historical data thus indicate that reindeer habitat use is a dynamical process where population density and food competition are important elements. Bearing this and the rather obvious limitations of the historical data in mind, it appears that the functional use of Hardangervidda has changed from a large scale rotation between complementary habitats and calving areas, to a more restricted occupation of central areas. The northern parts of Hardangervidda, including the glacier Hardangerjøkulen, appears to be functionally separated from surrounding areas to the south by Hw 7, and by the Oslo-Bergen railroad to the north.



**Fig. 6.** The past and present use of the Hardangervidda. (K= calving areas, S= summer areas, V= winter areas)

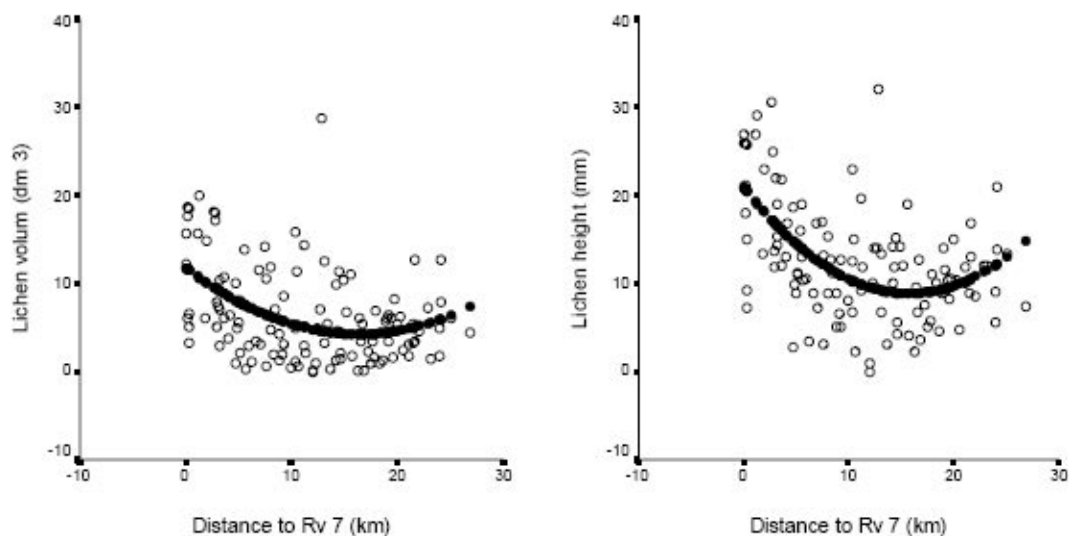
#### 3.1. Mapping of vegetation cover and reindeer pastures

Analyses of remotely sensed data shows that we have been able to map the vegetation cover on Hardangervidda with a reasonable accuracy for our purposes and that ca. 75% of the total satellite image are correctly classified. We had greatest success in classifying lichen heath communities where the classification accuracy is >90%. We had larger difficulties with classification of mires and snow-bed communities, however. Preliminary analyses of the data show relatively large regional differences in vegetation cover and distribution of reindeer summer and winter habitats. Areas with a large proportion of lichen heath communities, which are important to reindeer in winter, are more frequent in central and eastern regions, whereas snow-bed communities and rich summer pastures are more frequently found in southern and western areas (Fig 7). These analyses also confirm that the area north of Hw 7 contains potentially important pastures for reindeer, and that habitats close to the glacier should be regarded as potentially important areas for summer grazing.



**Fig. 7.** Vegetation cover maps describing the spatial distribution of important habitats. Areas with a large proportion of lichen heath communities, which are important to reindeer in winter, are more frequent in central and eastern regions, whereas snow-bed communities (summer grazing) are more frequently found in southern and western areas

Our studies at Hardangervidda have documented rather pronounced and large scale regional differences in lichen biomass, suggesting a substantial increase in reindeer grazing pressure in central and undisturbed areas. Similar results was obtained in areas close to the road, and increasing levels of lichen biomass was observed in areas closer to the road (5-8 km), suggesting that there have been less reindeer grazing in these areas (Fig 8). The reduced biomass of lichens in remote areas further suggest that grazing has suppressed lichen biomass well below optimal levels in these areas, whereas lichens in the outskirts of the area probably has reached their un-grazed maximum biomass.



**Fig. 8.** Measurements of lichen height and volume indicate an increase in reindeer grazing pressure at greater distances (5-8 km) from the road



### 3.2. Using the Global Positioning System (GPS)

To be able to collect more detailed data of the movement of the wild reindeer, we initiated a GPS project, starting with 6 GPS transmitters in 2001, and adding 10 more in 2002 (Fig. 9).

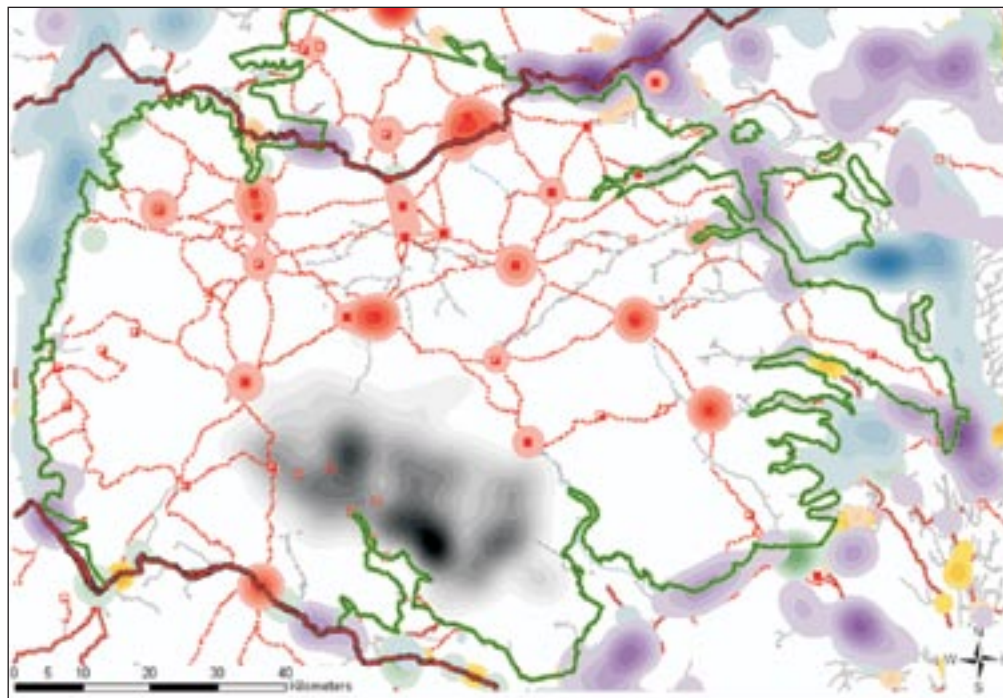


**Fig. 9.** Wild reindeer with GPS-collar. (Photo: Bjørn Iuell)

The GPS collars were programmed to register the location of each animal every 3rd hour. The collar also sent out a VHF signal, so the animal could be tracked. The GPS system used on Hardangervidda also allows remote download of data, and was used to collect a data samples at the start of the project. Due to high field costs we later abandoned this routine, and instead downloaded data when collars were retrieved from hunters or by removing collars by a remotely triggered ‘drop-of’ mechanism mounted on the collar.

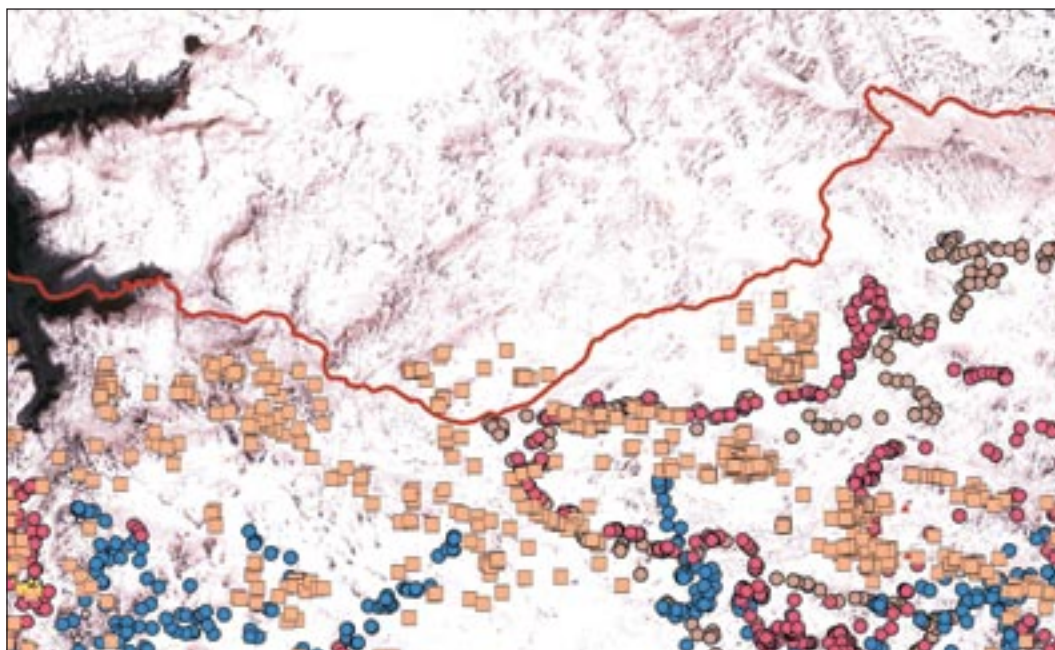
Although we experienced some technical problems with some of the GPS collars most of them were working as scheduled. Late autumn 2004 we discovered that one out of a group of five similar collars had serious malfunctions. It was likely that all five collars had the same problems, and therefore 10 new reindeer were collared to collect the amount of data we needed. At the most we have had more than 20 GPS-collared reindeer females on Hardangervidda. During the project we have been able to collect data from 37 animals and altogether more than 100.000 data points with an average accuracy within 25 m.

Analyzes of the GPS data indicate that the collared animals had a rather uneven distribution, and that the central areas have been extensively used (Fig. 10). This effect seems to be especially strong in summertime (June, July and August) when animals have used less than 20% of the available area. During winter, reindeer seem to be more dispersed, and applications of Resource-Selection Function (RSF) models have confirmed a strong selection for lichen heath communities.



**Fig. 10.** Plots of the GPS-registrations of wild reindeer during mid-summer (June-August) show that the animals use a relatively limited part of the Hardangervidda. Dark color indicates high density of registrations. Green line: The boundary of the Hardangervidda reindeer area. Dark red line: Hw 7 in the north and E 134 in the south. Light red lines: main hiking tracks between mountain cottages (red circles, size of circle indicates number of beds). Blue and violet signature indicates areas of respectively all-year residences and holiday houses/tourist resorts.

Detailed studies of the GPS plots close to Hw 7 show a pattern of movement than can be described as the result of fear or avoidance (Fig. 11).

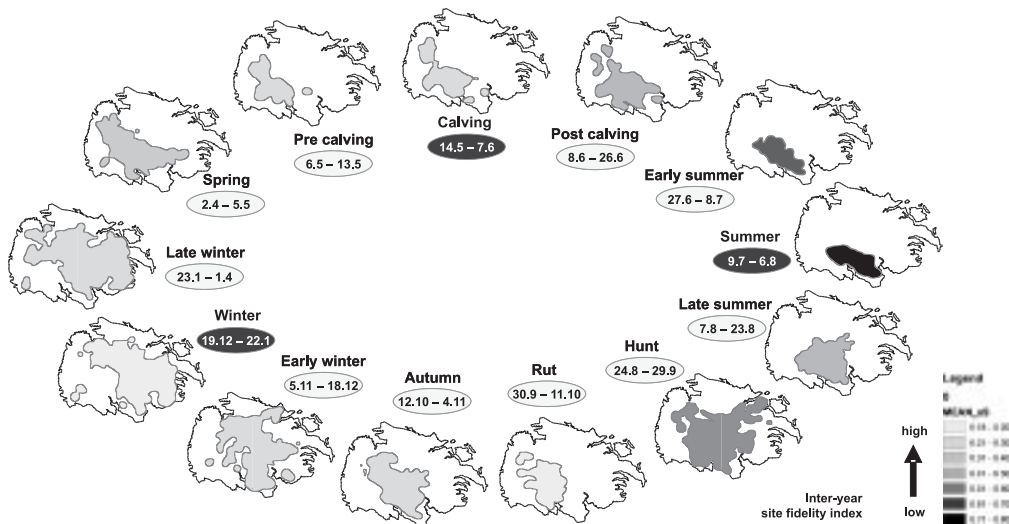


**Fig. 11.** Movements of wild reindeer according to GPS-registration of 4 different animals close to Hw7 (red line)

## 4. Conclusions

Maps of the distribution of different reindeer food resources (e.g. lichens) were produced by using field surveys and satellite images (LANDSAT 5). These estimates uncover significant gradients with respect to vegetation distribution and quality within the research area. For instance, winter pastures dominate in the eastern parts, while there is less winter vegetation in the southwest and larger areas of summer pastures. With regard to areas close to Hw7 in particular, mapping reveals that the areas around the Hardangerjøkulen glacier are particularly rich in snow beds, and therefore represents an important summer pasture resource. Along and south of Hw7, larger areas of winter pastures are located. Areas with possible impact from Hw7 therefore also include pastures important for the reindeer during the winter. The areas north of Hw7 are primarily summer pasture, however, it should be stressed that these areas also serve a function as travel routes for the reindeer, and ‘relief’ pastures during years where the snow conditions makes it difficult to find food.

The area use pattern found through the GPS-registrations, reveals that it is possible to subdivide the use of Hardangervidda into 12 different ‘seasons’, with differences in migration pattern and habitat use (Fig. 12). In interpreting these results, the calving, summer and winter seasons are particularly focused on. Analyses of the data indicate that predation and/or insect harassment, vegetation distribution, snow cover and access to pastures are all important factors in understanding the semi-nomadic use of the living areas of the wild reindeer.



**Fig. 12.** The wild reindeer’s use of Hardangervidda subdivided into 12 different ‘seasons’, with differences in migration pattern and habitat use. The darker the colour, the more is the same area used from year to year

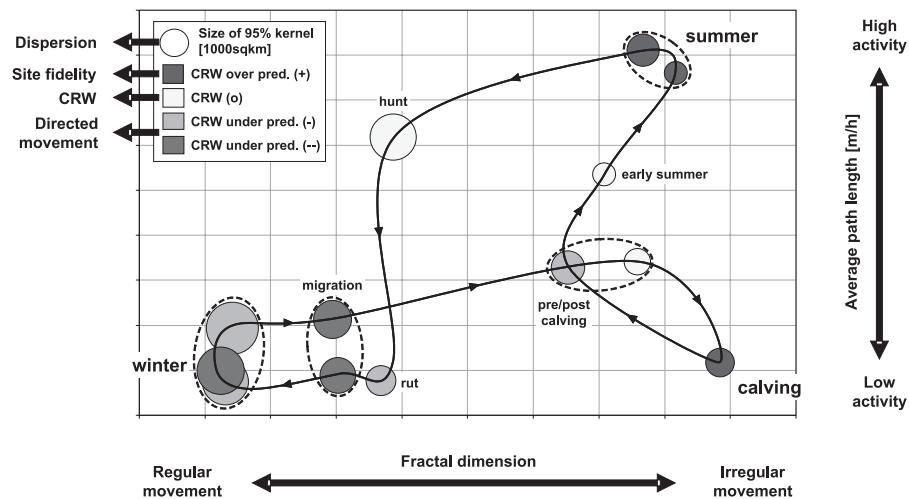
During the summer the reindeer herds at Hardangervidda use a rather small part of the mountain plateau, and the data from this project indicate that the animals are using the same area over several years.

The use of the *calving grounds* is more variable between years; during the last few years calving has taken place in the southern and central areas while earlier it mainly took place in the western and north-western parts of the plateau.

The animals use the winter pastures more extensively, and they are using a significantly larger area compared to the summer situation. Possibly due to local snow cover and food access, the use of the winter pastures has a significant, inter-annual variation as well. During year one of the project the snow cover was quite insignificant in the western and northern parts, and during the period 2001-2003, these areas were frequently in use by the animals. During the last years of the project the snow cover was more ‘normal’, i.e. more snow in the west compared to the east, and the animals

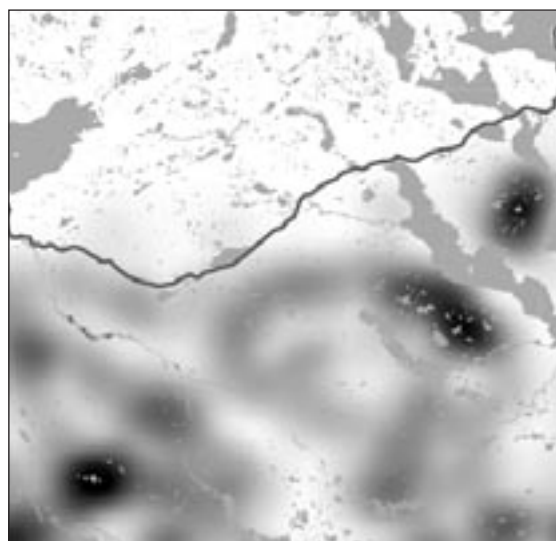
did to a greater extent use the eastern parts. GPS-registrations and snow cover maps indicate that the snow depth is an important factor in explaining how the reindeer use their winter habitat. It is quite evident that the animals, even at a low population density (5 000-6 000 animals), expand their pasture areas during periods with difficult snow conditions.

The GPS-data show that most of the reindeer population is using a rather small area in the central south of Hardangervidda during mid-summer, but also that even if they are not moving very far, their activity is high (Fig. 13). In the winter months the situation is quite the opposite; the activity is lower than in the summer, but the animals are still moving over long distances.



**Fig. 13.** Illustration of the activity levels and the movements of the wild reindeer throughout the 'reindeer-year' at Hardangervidda

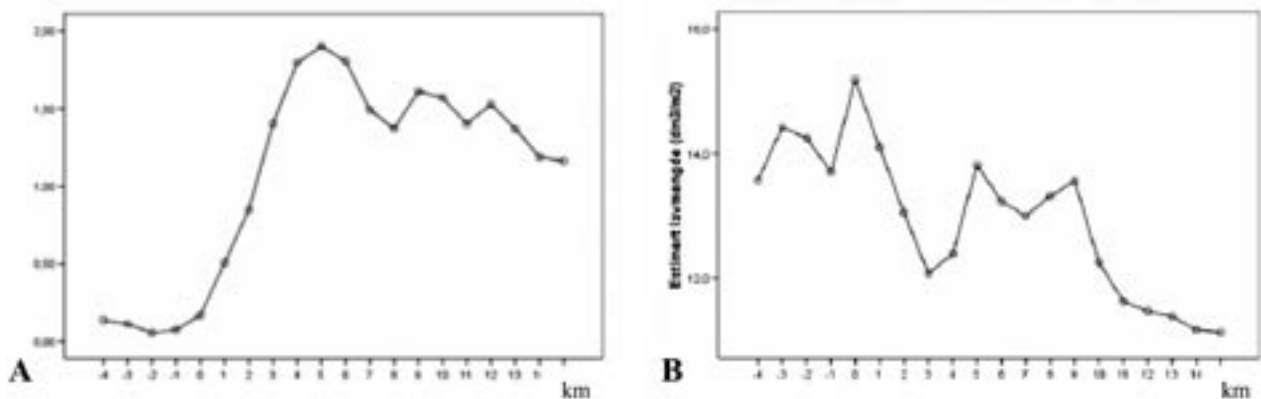
The major findings of the project were that Hw 7 in fact has a repelling effect on the wild reindeer, as have other areas with human activity, e.g. the major hiking and skiing tracks between the tourist cottages. The GPS-data show that there is a significant reduction of the reindeer use of the areas close to the Hw 7, up to 8 km from the road (Figs. 14 and 15A). This zone of avoidance also strengthens the barrier effect of the road, leaving the migration routes to and from the north more or less cut off.



**Fig. 14.** Plots of the GPS-registrations of wild reindeer in the vicinity of Hw 7 (thick line). Dark color indicates high density of registrations



The same effect can be found by analysing the vegetation maps (Fig. 15B), but the correlation is not as strong as in the GPS-data. When the GPS-data were compared with the distribution of lichen resources, it appeared that animals do not use areas richest in lichens.



**Fig. 15.** A – Density of reindeer (GPS-registrations) and the distance to Hw 7 (km); B – Amount of lichens ( $\text{dm}^3/\text{m}^2$ ) and the distance to Hw 7 (km).

Hw 7 can be seen as a behavioral barrier, hindering the migration of reindeer between the central and the northern parts of Hardangervidda. However, it is possible to see considerable local variation in this pattern. Among other things, topography seems to be important both for reindeer use of the area and lichen biomass on the ground. This is particularly evident for two areas where the animals approach the road much more closely compared to other areas. Archaeological remains of large trapping systems suggest that these areas coincide with migration routes traditionally used by this nomadic species. The GPS data from the project indicate that these routes are still of potential importance for migrating purposes.

Habitat-use analyses indicate that it is particularly during the winter period that the highway constitutes a problem for the wild reindeer. During this 5 year project reindeer with GPS-radio collars have been observed to cross Hw7 at only two occasions. One herd crossed the Hw7 early 2003, just to return a few days later. In recent years, summer use of areas proximate to Hw7 (and the areas close to the Hardangerjøkulen glacier) has been limited to summer pasturing by bucks.

The wild reindeer's use of the terrain is dependent on the population density and the available food resources. The possibility for the animals to have access to winter grazing grounds in the northern and eastern parts in years with much snow, can be crucial. During the period when this project took place, the reindeer population was relatively small (5.000 – 6.000 animals), but still the animals have used areas in the periphery. The management goal for the reindeer population at Hardangervidda is set to 10.000 – 12.000 animals. And as the population density increases, the winter grazing areas at the outskirts of the mountain plateau will become more and more important. How the reindeer then will react on barriers like Hw 7 is hard to predict, and further research is therefore needed.

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