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Effects of Recreational Cabins, Trails and Their Removal for Restoration of Reindeer Winter Ranges

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Abstract

Conservation efforts have secured the partial recovery of Europe's wild reindeer, although only in 24 separate fragments of their original range, now separated by resorts and roads. Full recovery of the original range will require restoration of migration routes across developed or disturbed areas. We analyzed distribution of around 3500 *Rangifer tarandus tarandus* (reindeer) during winters (1984–2005) in relation to 10 alpine resorts and prior to and following relocation of ski trails and cabins in Norway done to restore use of former habitat.

Reindeer used areas within 15 km of resorts, which is less than expected based on the availability of habitat, most likely as a result of cross-country skiing activity surrounding the resorts, limiting their access to other ranges and historic migration corridors. Reindeer abundance declined and mean distance between reindeer groups and resorts increased with increasing resort size. No apparent habituation to resorts was observed during the 20-year study period. However, when ski trails and an associated tourist cabin were removed to restore access to historic habitat, reindeer moved into the area. No such change in reindeer distribution was observed in the 10 years preceding relocation, or at the other nine resorts where no such experiments were conducted. Regulation of human traffic, relocation of trails, and removal of infrastructure and cabins are apparently effective in restoring access to and use of historic ranges and migration routes. However, restoration of historic migration routes between ranges will likely require the removal of hundreds of recreational cabins in order to become effective.

Key words: disturbance, fragmentation, leisure, recreation, reindeer, resort, restoration, second home, tourism, trail.

Introduction

Humankind has directly altered one-third of the planet, fragmented another third and caused great reductions in biodiversity (UNEP 2001, 2004; Bissonette & Adair 2008). A series of studies have assessed effects of human disturbance sources on wildlife and vegetation (Mainini et al. 1993; Taylor & Knight 2003; Blanc et al. 2006; George & Crooks 2006; Nepal & Way 2007) and subsequent restoration efforts of lost habitat (Rosatte et al. 2007; Zamith & Scarano 2006; Menges 2008).

Restoration of historic ranges and migration routes has, in recent years, been discussed, particularly, in relation to larger mammals like wolves (*Canis lupus*) (Bissonette & Adair 2008), brown bears (*Ursus arctos*) (Nellemann et al. 2007), elk (*Cervus elaphus*) (Larkin et al. 2004; Rosatte et al. 2007), desert bighorn sheep (*Ovis canadensis*) (DeYoung et al. 2000), and species like caribou and reindeer *Rangifer tarandus* spp., where climate change will make small fragmented populations highly vulnerable to extreme weather conditions (Tyler et al. 2007). Although many smaller fragments of these wildlife ranges are now protected, their connectivity remains limited due to growing recreational development across former migration corridors and on the perimeter of parks (Gill & Williams 1994; Gill 2000; De Gruchy et al. 2001; UNEP 2001, 2004; Needham et al. 2004; Kaltenborn et al. 2007).

Demand has increased to restore lost or disrupted habitat outside parks (Pitt & Jordan 1996; Rosatte et al. 2007). Fulfilling conservation strategies while mitigating impacts of growing tourism activity in and around parks is indeed a common challenge for most managers (Nortongriffiths & Southey 1995; Noss et al. 1996; Taylor & Knight 2003; Mullner et al. 2004; McKinney 2005; Nepal & Way 2007.

A number of studies have documented impacts on and redistribution of reindeer and caribou associated with development in Alaska, Canada, Norway, Sweden, and Finland (see Wolfe et al. 2000; National Research Council 2003; Vistnes and Nellemann 2007 for reviews), and most managers now

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attempt to limit development (Bradshaw et al. 1997; Johnson et al. 2005; Lawler et al. 2005). Reindeer and caribou tend to be most sensitive to disturbance during calving (Murphy & Curatolo 1987; Cumming 1992; Maier et al. 1998; Cronin et al. 2000; Vistnes & Nellemann 2001) and most tolerant during insect harassment (Pollard et al. 1996; Skarin 2006), although studies generally depict 45–95% reductions in use within 2.5–5 km of potential disturbance sources, compared to areas away from disturbance (Vistnes & Nellemann 2007).

Growth in outdoor recreational activity is rising (Stewart & Stynes 1994; Vorkinn 2003; Hall & Müller 2004; McIntyre et al. 2006; Kaltenborn et al. 2007). In Norway, the number of recreational cabins and resorts has grown steadily since the early 1980s, from an annual construction of around 1500 to > 5000 new second homes in 2007 (Lie et al. 2006; Kaltenborn et al. 2007) as part of a global trend in the leisure industry (Gallent & Tewdwr-Jones 2000; Hall & Müller 2004; Moss 2006).

Studies have shown that because resorts are commonly associated with a large network of foot or ski trails, the human influence zone of recreational resorts of a few hundred cabins may be compared to that of towns with several thousand inhabitants (Nellemann et al. 2007). In Norway, density of groomed trails vary in the range of 0.1–2 km/km^2, reaching some 25 km out from the actual concentration of cabins for the largest resorts (Vorkinn 2003; Jordhøy 2006). The extent of the trail system is, in general, directly related to the size of the resorts, severely restraining access to former historic ranges and migration corridors (Vistnes et al. 2001; Fairbanks & Tullous 2002; Taylor & Knight 2003; McKinney 2005; Blanc et al. 2006; George & Crooks 2006; Shepherd & Whittington 2006; Nepal & Way 2007).

Availability of suitable habitat is critical when attempting to restore former ranges (Pitt & Jordan 1996; Larkin et al. 2004; Rosatte et al. 2007). Reindeer in southern Norway traditionally select windblown ridges between 800 and 1300 m.a.s.l. in winter at the perimeter of the mountain plateaus for both grazing and migration (Nellemann 1996; Nellemann et al. 2001; Vistnes et al. 2004), but the very same areas have been exposed to recreational development across decades. As the number of cabins and demands for trails are rising, regulation of human traffic, seasonal closing of trails, and removal or relocation of trails are increasingly debated as a means to restore formerly used habitat and lost migration corridors.

Understanding the effects of extent and regulation of resorts and trails on accessibility of reindeer to their ranges, and the effects of removing them, is therefore crucial for future restoration of migration routes and historic ranges. Herein, we investigate the effects on reindeer distribution and movements of large resorts and removal of cabins and trails across a 20-year period.

Methods

Study Area

The study took place in the Rondane region (61°30′N 10°00′E) of south-central Norway, comprising an area of around 3300 km^2 (Fig. 1). The entire northern half of the study area is protected, including the Rondane National Park. Around 60% of the area is located between 1000 and 1500 m, elevations where the largest share of winter ranges of reindeer are found (Nellemann et al. 2001). Annual precipitation ranges from 400 to 700 mm. Snow cover is very extensive (complete except for ridges), typically arriving in the mountains in late September or early October and melting in mid-May to early June. Snow depth varies from a few centimeters on windblown exposed ridges to several meters in low-lying terrain. There are numerous papers on reindeer, habitat selection, and snow conditions from the area (Nellemann 1996; Nellemann et al. 2000; Vistnes et al. 2004; Vistnes & Nellemann 2008).

The area is dominated by lichen heath, rocks, and gravel in the northern and central parts, whereas the southern part has a higher proportion of meadows, grass, and willow communities, though mainly below 1000 m (Nellemann et al. 2000). The entire area is rich in exposed lichen heath. Vegetation on ridges is dominated by lichen species, but some occasional grasses, sedges (*Carex rupestris*, *Kobresia myosuroides*, *Luzula* sp.), rushes (*Juncus trifidus*), mosses (*Racomitrium lanuginosum* and *Polytrichum piliferum*), and shrubs (*Loiseleura procumbens* and *Betula nana*, at lower elevations also *Empetrum nigrum*) are also found. *Arctostaphylos* sp. are common as well. Lichens include *Cladina stellaris*, *Flavocetraria nivalis*, *Alectoria ochroleucha*, and to a lesser extent *Alectoria nigricans*, *Bryocáulon divérgens*, *Flavocetraria cucullata*, *Thamnólia vermiculáris*, and on rocks, *Rhizocarpon geographicum* coll., *Umbilicária* sp., *Hypogymnia* (syn *Parmelia*) *alpicola*. Further down the ridge, *Cladina rangiferina*, *Cl. mitis, Cladonia* sp., *Stereocaulon* sp., and *Cetraria* sp. are also common (for a description of grazing patterns on ridge communities, see Vistnes & Nellemann 2008).

The area contains the main historic winter ranges of the wild reindeer herds, which migrate there from calving and summer ranges (Snøhetta). Previous studies have documented reindeer avoidance of infrastructure, resorts, and trails in the region (Nellemann et al. 2000; Vistnes et al. 2004; Jordhøy 2006). Currently, there is little or no migration between Snøhetta and Rondane wild reindeer herds, which are separated by a highway and a railroad (Vistnes et al. 2004).

Today, the study area holds around 3500 reindeer (the Rondane herd). The herd size has been relatively stable since 1987. Pitfall trapping systems document extensive migration between the ranges from the far west to the east and from north to south within Rondane (Barth 1996). The population is regulated mainly by an annual cull of nearly 1000 reindeer by hunters. The hunting season is from 20 August to 25 September and hunting is permitted within the national park. There are virtually no large predators in the region, except for a few *Gulo gulo* (wolverines) and *Aquila chrysaetos* (golden eagles) (Ministry of the Environment 2003; Sæther et al. 2003).

There are several thousand cabins in the study area, mostly concentrated in resorts at the perimeter of the range. The resorts are used extensively for cross-country skiing in winter, with a network of groomed or marked ski trails extending

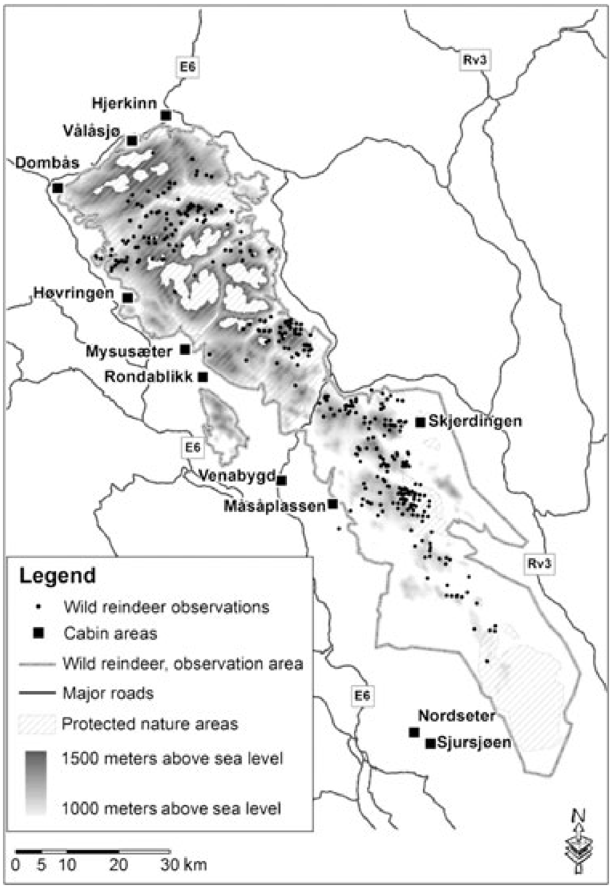

Figure 1. Rondane wild reindeer region: the study area in south-central Norway where reindeer surveys were conducted during March 1984–2005.

far into the range. Recreational snowmobile driving is not allowed in the study area. Nearly 80% of the cabin owners go on day trips, typically within 15 km of the resorts (Vorkinn 2003). In addition to the local networks of cross-country ski trails, several main trails run north–south within the study area, including the so-called Troll ski trail. This trail was one of a few situated in the interior of the range, running between tourist cabins at higher altitudes. Around 1995, the Troll ski trail was moved closer to the nearest resort, 4–5 km west of its original position, and a tourist cabin (Breitjønnbu) was removed and replaced by another one (Jammerdalsbu) by the new trail. This reduced human activity substantially in the central parts of the southern range. The operation gave us the opportunity to test the potential response in reindeer distribution at these sites prior to and following the relocation compared to the other resorts where no such changes in trail or cabin locations had been made.

Reindeer Surveys and Mapping

Local park and mountain rangers keep track of the main reindeer herds in Rondane throughout the winter. Surveys of reindeer were conducted annually in mid-March (1984–2005) using snowmobiles. Generally, two snowmobiles followed 5-km wide transects running east–west, terrain permitting, and stayed in radio or visual contact to avoid any double counting. The surveys were designed to achieve almost complete counting, which was made possible by the open quality of the terrain and gently rolling landscape. Reindeer are quite easily spotted even at several kilometers distance due to the even snow cover, and numbers observed over the years have been quite stable. Unlike in some of the mountains to the far west in Norway where terrain and surveying is difficult, herds are usually very easily spotted in this area, though quite minor stray groups or individual bulls may be missed as they frequently move into lowland forests. The method has been used for decades and has been the basis of several investigations in the region (Nellemann et al. 2000; Vistnes et al. 2004; Vistnes & Nellemann, 2008). Reindeer groups, sex, and numbers were recorded on 1:50,000 topographical maps, and in more recent years by global positioning systems (GPS). Spotting scopes with 60 × magnification were used to reduce disturbance of the reindeer.

Mapping of resorts and cabin densities was carried out based on the national building database from the State Mapping Agency and interviews with the local municipality authorities. The extent of resorts was delimited in geographic information systems (GIS) using only contiguous 1-km grid squares with more than 5 cabins and a minimum size of 25 cabins to be classified as a resort.

Statistical Analysis

Statistical analyses were performed in Sigmastat (SPSS 1997). Data were first subjected to a Kolmogorov–Smirnov test for normality. The distribution of reindeer was analyzed in relation to altitude, and the distance to nearest resort was calculated for each group using GIS. The distribution of the area in relation to altitude and distance to resorts was also calculated using GIS (ArcInfo). Use versus availability was tested using the chi-square test. If significant differences were found, the Bonferroni z-statistic test was used to determine differences in use versus availability of terrain located between 1000 and 1500 m.a.s.l. at 2-km intervals to resorts (Neu et al. 1974). p Values less than 0.05 were considered statistically significant. Student t tests were used to test differences between mean group distances to nearest resorts prior to versus after 1994 for each resort. In addition, we computed 75% kernels with the Ranges 6 computer package (Anatrack Ltd., Wareham, Dorset, U.K.) and default settings for contours (fitted to locations), smoothing factor ($h = 1$), and grid size (40), to identify potential changes in mean reindeer distribution prior to and after 1994 for the northern, central, and southern parts of the range (where trails and a cabin were moved in the latter). Polynomial regression was used to identify potential relationships between the size of resort and mean distance to the nearest reindeer groups and the cumulative number of reindeer observed within 30 km from each resort (1984–2005). As these zones may overlap for some resorts, we assigned reindeer groups only to the nearest cabin resort. Hence, we were able to test for individual differences among resorts, the effect of removing trails and a cabin, and the possible effects of resort size on reindeer distributions.

Results

Distribution of Reindeer in Relation to Traffic Patterns and Size of Resorts

On average, 3536 ± 275 (SE) reindeer were recorded annually in the 22 years surveyed. We identified 10 major resorts varying in size from 25 to > 550 cabins. The majority of the reindeer, 95.4%, was observed at altitudes of 1000–1500 m.a.s.l. (mean 1177 ± 6 (SE); SD = ±130). Of 77,801 counted animals, 3.4% were located below 1000 m.a.s.l. and only 1.2% was located above 1500 m.a.s.l. Areas within 14 km from all resorts were used less than expected from availability, while areas > 14 km from resorts were used more than expected (Fig. 2). However, this figure was partly confounded by the fact that small resorts with a few dozen cabins had far less extensive avoidance zones than large resorts. Indeed, size of resorts and the associated human activity most likely proportionally affected reindeer abundance and distribution in the area surrounding the resorts (Fig. 3a & 3b). Mean distance of herds to nearest tourist resort increased with size of resorts (Fig. 3a). The cumulative number of reindeer for the period 1995–2005 (where no changes in trails occurred) declined with growing size of resorts (Fig. 3b).

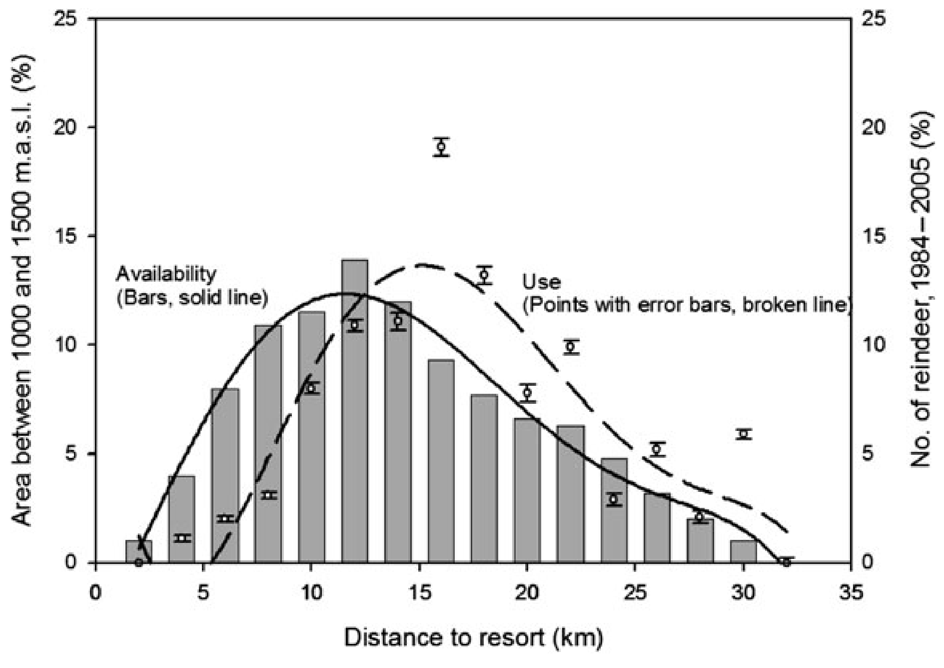

Figure 2. Availability (bars; solid line) and use of area by reindeer between 1000 and 1500 m.a.s.l. (points with error bars, broken line) at 2-km intervals to any resort in the Rondane region, Norway, 1984–2005. Error bars represent 90% Bonferroni confidence intervals.

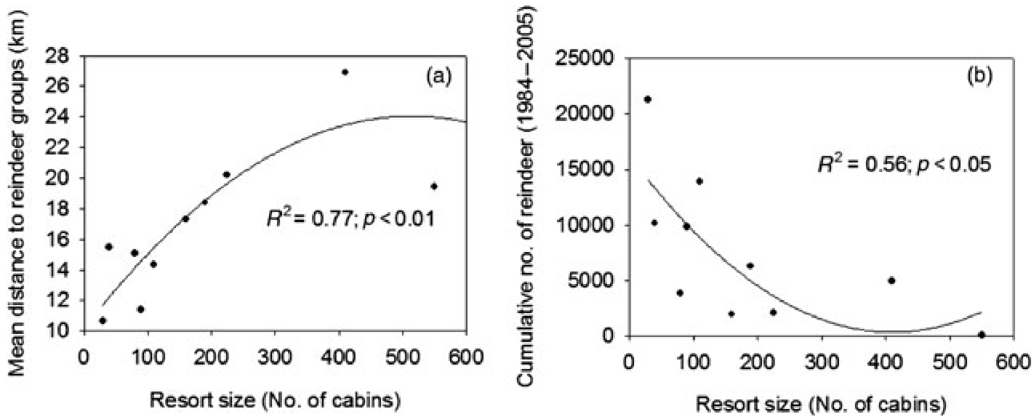

Figure 3. The relationship between size of resorts and (a) mean distance to reindeer groups and (b) cumulative number of reindeer from 1984 to 2005. Each reindeer group was assigned to the closest resort.

Table 1. Mean distances to reindeer herds in relation to the 10 tourist resorts surrounding Rondane before and after ski trails and a cabin were moved 4–5 km closer to the Måsåplassen resort.

Resort	*Mean Distance to Reindeer Herd 1984–1994 (km ± SE)*	*Mean Distance to Reindeer Herd 1995–2005 (km ± SE)*	*p (t test)*
Hjerkinn	13.16 ± 0.97	17.06 ± 3.56	0.35; n.s.
Vålåsjøen	15.39 ± 0.89	15.27 ± 0.95	0.92; n.s.
Høvringen	13.13 ± 1.56	10.00 ± 0.74	0.10; n.s.
Mysusæter	20.18 ± 1.28	19.91 ± 1.71	0.92; n.s.
Rondablikk	18.70 ± 0.49	18.07 ± 0.63	0.41; n.s.
Skjerdingen	10.99 ± 0.51	10.98 ± 0.67	0.98; n.s.
Venabygd	16.59 ± 0.21	17.05 ± 0.77	0.71; n.s.
Måsåplassen[a]	18.08 ± 1.73	13.63 ± 0.69	0.02
Nordseter	26.34 ± 0.90	28.33 ± 0.43	0.15; n.s.
Sjusjøen	19.43 ± 0.00[b]	0.00 ± 0.00	—

[a] Måsåplassen was the only resort where ski trails and a tourist cabin were moved closer to the resort around 1995 to reduce disturbance.
[b] Only one small group of bulls—18 animals came within 20 km of this largest resort.
n.s. = not significant.

Effects of Trail Regulation and Habituation on Reindeer Distributions

Mean distance of herds to resorts between 1984–1994 and 1995–2005 did not change significantly for the nine resorts with no change in trail patterns, but decreased significantly for the resort where one trail was relocated and trail density was reduced to reduce disturbance of wild reindeer (Table 1). This pattern was also evident in the degree of overlap between kernels from 1984 to 1994 compared to 1995 to 2005, where the only major new use of areas outside the kernels from 1984 to 1994 took place in the location where trails had been relocated (Fig. 4a & 4b). The kernels of the period 1995–2005 overlapped the 1984–1994 kernels 90%, 89% and 62% in the northern, central and southern areas, respectively. In the northern and central portions of the range, reindeer occupied nearly the same areas in 1995–2005 as in 1984–1994. In the southernmost range, reindeer occupied mainly two areas from 1984 to 1994, while the area between these two including the Breitjønnbu tourist cabin and the Troll ski trail received very little use by reindeer. After the relocation of this cabin and trail 4–5 km west around 1995, reindeer gradually shifted their distribution up to 5 km further west (Table 1; Fig. 4a & 4b), using also the central area between the two former kernels of distribution.

Discussion

The Effect of Elevated Human Traffic on Restoration of Ranges

Reindeer used areas within 15 km from resorts is less than suggested based on the availability of preferred altitudes. This is due to the fact that the largest share (88%) of resort and cabin users go on day trips, most within 10 km from the resorts, a few more than 15 km (Vorkinn 2003). Over 80% of the skiers stay on the groomed trails (Vorkinn 2003). Numerous studies in the last two decades have documented avoidance of infrastructure and human activity by *Rangifer*, during most seasons and in response to a wide range of disturbance sources from ski trails and power lines to heavy oil development and tourist resorts (Cameron et al. 1992; Helle & Särkelä 1993; Smith et al. 2000; Dyer et al. 2001; Nellemann et al. 2001, 2003; Vistnes et al. 2001; Mahoney & Schaefer 2002;

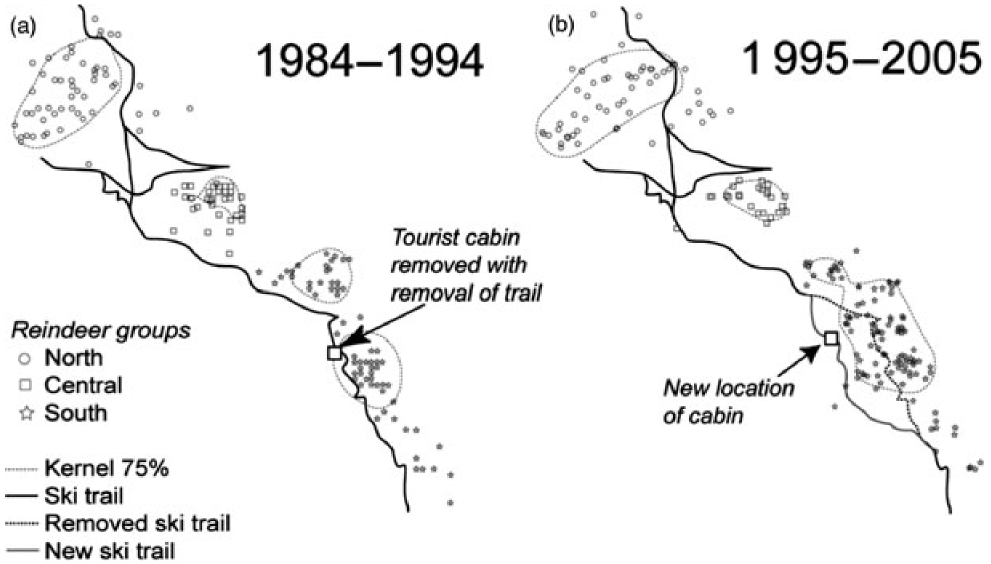

Figure 4. Distribution of reindeer herds (points and 75% kernels) and trails for the periods 1984–1994 and 1995–2005, showing the westward shift in reindeer distribution observed in the southernmost cluster following the relocation of ski trails and a cabin around 1995. The new reindeer distribution from 1995 to 2005 is located where the old trail used to be. Activity was low on the northernmost trail.

Schaefer & Mahoney 2007). Although some studies have not reported any avoidance, these studies mainly addressed local scale behavior or distributional patterns, typically within 3 km from potential disturbance sources (Burson et al. 2000; Yost & Wright 2001; Lawler et al. 2005; Reimers et al. 2006). The likelihood of finding impacts has been shown to be strongly dependent on the spatial and temporal scale of the assessments. Only 7% of short term, local scale studies have been found to report avoidance or other negative impacts, while 83% of long term, regional scale studies observed such impacts (Vistnes & Nellemann 2007). Among these, this study reports some of the widest zones of avoidance, with an average of 15 km. Hence, it will be extremely difficult for reindeer to take former ranges or migration corridors in use unless the tourist activity becomes limited around these points of crossing. Indeed, this is even more pronounced for big resorts.

The Effect of Resort Size

Large resorts cause activity far beyond the physical footprint and may thus explain why it has not been possible to restore reindeer to the full historic range in spite of some undeveloped sections within and between ranges. Resort size was the primary factor explaining the differences in distribution among individual resorts. Indeed, it is likely that reindeer, based on a risk evaluation and on the availability of alternative habitat, respond differently to different types of infrastructure (Dyer et al. 2001; Frid & Dill 2002; Vistnes et al. 2004; Johnson et al. 2005). This study shows that avoidance may be as far reaching as 15–25 km from the largest resorts, but varies with the extent of disturbance sources and the degree of human activity. Other studies have shown that avoidance may progress up to a certain threshold, beyond which *Rangifer* will abandon the use of disturbed areas if alternative habitat is available (Gill et al. 2001; Nellemann et al. 2003; Skarin et al. 2004). Otherwise, reproductive implications may be observed (National Research Council 2003; Nellemann et al. 2003; Cameron et al. 2005). However, more importantly, if reindeer do not habituate, or if the migration corridors are not restored by removing cabins, reindeer will be unable to reoccupy the former ranges.

Habituation

In this study, we were unable to detect any indication of reindeer habituation to human activity for the 20-year period addressed. On the other hand, we did not detect any increase in avoidance zones as a response to the increased construction of second homes during the past 20 years. Although minor shifts in distribution occurred in different winters with varying snow conditions, reindeer consistently selected for undisturbed areas and maintained a rather constant and significant distance from tourist resorts to the north, east, south, and west throughout the entire study. In interior areas, ski trails are scarce. A few are, however, groomed, and these are likely to influence reindeer use locally, as could be seen through the response in reindeer when relocating one such trail. Changes in trail systems and regulation in traffic may therefore have positive effects on wild reindeer habitat use, especially in late winter and around the Easter holidays when human activity is high in the region. Hence, it is essential that regulation of traffic is done with particular reference to the time when reindeer are likely to migrate, such as in spring and autumn, if use of the full range is to be restored.

Restoration Implications

Our results indicate that the degree of disturbance and subsequent loss of habitat can be mitigated, controlled, or even reduced through regulation of human activities or through the removal or relocation of disturbance sources. Therefore, experimental removal or introduction of trails may result in immediate changes in wildlife distributions. This has also been found for other species, such as *Canis lupus* (wolves) and *Antilocapra americana* (pronghorn antelopes) (Fairbanks & Tullous 2002; Shepherd & Whittington 2006). In Norway, an alpine road in the Dovrefjell–Sunndalsfjella National Park has been removed to restore wild reindeer habitat (Jordhøy 2006), and is likely important for the future restoration of the historic main east–west migration route. Indeed, the Snøhetta West herd northwest of this area has been cut off in a nonwintering area with very deep snow due to development in their historic migration route. In 2006, nearly half of this population was killed in an avalanche as they were searching for food on a steep slope. With climate change, the restoration of former migration corridors (Vistnes et al. 2004) will probably gain increasing significance (Tyler et al. 2007). The far-reaching effects of trails around major cabins or resorts suggest that some infrastructure or cabins must be removed if reindeer are to be restored to the full extent of their habitat again, and if reindeer are once again to migrate.

Implications for Conservation

- Development of resorts and associated trail systems should be avoided near any existing winter ranges or existing or historic migration corridors. This includes avoiding any development, even small, in the mountain passes between ranges, also for ranges with herds that are now temporarily managed separately.
- Increasing the number of cabins or number of users even of an already established resort may increase impacts on wild reindeer and further reduce the ability of reindeer to cross that particular area, and, hence, limit any effect of restoration in the areas beyond.
- Human activity along the trail systems and around resorts is the primary disturbing factor for wildlife and regulation is important during all seasons, including summer, winter, and migration time in spring and autumn, not just calving, which has previously received most of the attention.
- Hunting, parking, extensive camping, and any development should be restricted several kilometres from roads in the narrow historic migration corridors across mountain passes to avoid increased reluctance of reindeer to approach such areas. Use of tunnels to direct train and road traffic underground in these passes, and removal of the scattered cabins in such passes should become a long-term goal.
- Mitigation of impacts from resorts or trail systems in protected areas can be effectively done by regulation of human traffic, but use of migration corridors must likely include removal of cabins as well.
- Lost ranges may be restored by removing or relocating critical cabins and trails.
- Reindeer respond rapidly to reduction in perceived human threat and reestablish use of habitat once human traffic is reduced or removed, thus providing great opportunity for restoring reindeer migrations across the full former range.
- Restoration of migration corridors between the current fragments of the original range will make the reindeer far less vulnerable to extreme weather and climate change and is probably the most important factor for long-term restoration.

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