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Cumulative Impacts of Tourist Resorts on Wild Reindeer (*Rangifer tarandus tarandus*) during Winter

CHRISTIAN NELLEMANN,[1] PER JORDHØY,[2] OLE-GUNNAR STØEN[3] and OLAV STRAND[2]

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ABSTRACT. Potential avoidance by wild reindeer (*Rangifer tarandus tarandus*) of high-altitude tourist resorts during winter was investigated in and near Rondane National Park in Norway. Distribution of reindeer was mapped using systematic snowmobile surveys during 1991–96 and compared with results from investigations of snow and vegetation characteristics. Maternal reindeer avoided a 10 km zone around the resort. Cows and calves increased in density from 0.6 ± 0.6 reindeer km^{-2} at 5–10 km from the resort to 7.6 ± 2.2 reindeer km^{-2} at 15–25 km from the resort. Bulls and yearlings were more tolerant, constituting nearly 92% of all observed animals 5–10 km from the resort. Nearly all animals avoided the zone within 5 km of the resort. There were no significant differences in distribution of lichen heath, hardness of snow, integrated ram hardness index (IRH) values, or snow depths on ridges with increasing distance from the resort. Available biomass of lichens was ca. 1200 g m^{-2} 0–5 km from the resort and decreased to a low of ca. 250 g m^{-2} at 15–25 km distance, a pattern that probably reflects overgrazing as a result of avoiding the tourist resort. Such avoidance implies reduced forage intake during winter, substantial reduction in available habitat, and lower productivity of the herd. The results suggest that avoidance by wild animals of sources of anthropogenic disturbance may involve long-term impacts, such as reductions in carrying capacity, that are more serious than those expected from direct physiological stress.

Key words: avoidance, development, disturbance, EIA, grazing ecology, lichen, reindeer, *Rangifer*, snow, tourism

RÉSUMÉ. On a étudié le comportement d'évitement des stations touristiques de haute altitude que semble manifester le renne sauvage (*Rangifer tarandus tarandus*) en hiver, dans le parc national Rondane même et dans ses environs, en Norvège. La distribution du renne a été cartographiée à l'aide de relevés systématiques effectués en motoneige entre 1991 et 1996, et comparée avec les résultats d'études des caractéristiques de la neige et de la végétation. Les mères rennes évitaient une zone de 10 km autour de la station. Les femelles et leurs petits augmentaient en densité de 0,6 ± 0,6 renne•km^{-2} entre 5 et 10 km de la station, à 7,6 ± 2,2 renne•km^{-2} entre 15 et 25 km de la station. Les mâles et les jeunes d'un an manifestaient une plus grande tolérance, représentant près de 92 p. cent de tous les animaux observés entre 5 et 10 km de la station. Pratiquement tous les animaux évitaient la zone située dans un rayon de 5 km. On n'a pas trouvé de différences significatives en fonction de l'éloignement de la station, dans la distribution de la bruyère à lichens, la dureté de la neige, les valeurs de l'indice intégré de dureté au bélier ou l'épaisseur nivale sur les crêtes. La biomasse de lichens disponible était d'environ 1200 g•m^{-2} entre 0 et 5 km de la station et diminuait à un minimum d'environ 250 g•m^{-2} à une distance de 15 à 25 km, répartition qui reflète probablement un surpâturage résultant de l'évitement de la station touristique. Ce comportement a pour conséquence une réduction de la consommation de végétation durant l'hiver, une réduction substantielle de l'habitat disponible et une diminution de la productivité du troupeau. Les résultats suggèrent que l'évitement de sources de perturbation anthropogénique par les animaux sauvages peut avoir des répercussions à long terme, comme des baisses de la capacité de charge biogénique, répercussions qui sont plus graves que celles auxquelles on s'attend d'un stress physiologique direct.

Mots clés: évitement, mise en valeur, perturbation, ÉIE, écologie de pâture, lichen, renne, *Rangifer*, neige, tourisme

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INTRODUCTION

Anthropogenic disturbance of wildlife has traditionally been assessed in relation to direct physical destruction or alteration of habitat (Maki, 1992; Reijnen and Foppen, 1994; Catterall et al., 1998) or in relation to direct stress or disturbance, through studies of fright behavior, flight distances, or stress hormone production (Hanson, 1981; Horejsi, 1981; Johnson and Todd, 1981; Fancy, 1983; Curatolo and Murphy, 1986; Murphy and Curatolo, 1987;

[1] Department of Biology and Nature Conservation, Agricultural University of Norway, Box 5014, 1432 Ås, Norway; present address: Norwegian Institute for Nature Research (NINA), Pressesenteret, Storhove 2624 Lillehammer, Norway; christian. nellemann@ninalil.ninaniku.no
[2] Norwegian Institute for Nature Research, Tungasletta 2, 7005 Trondheim, Norway
[3] Norwegian Polar Institute, 9005 Longyearbyen, Norway

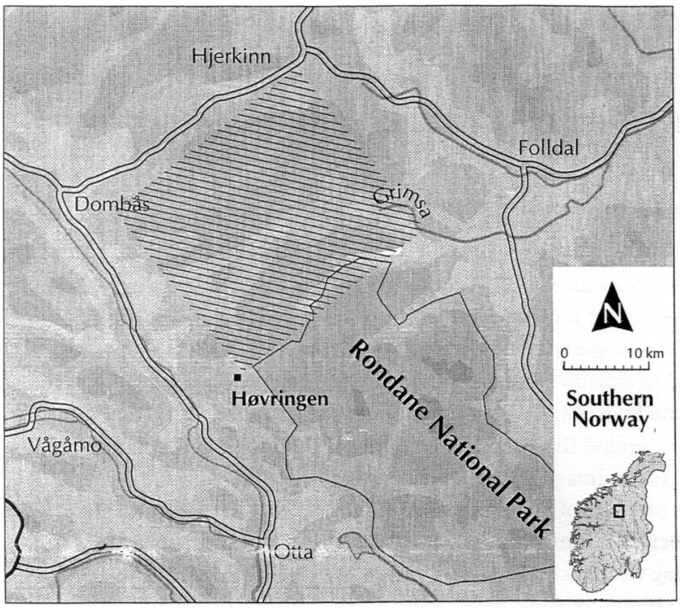

FIG. 1. Location of the study area (shaded) including the northernmost portion of Rondane National Park in south-central Norway, 1996.

Harrington and Veitch, 1991; Dervo and Muniz, 1994; Andersen et al., 1996; Weisenberger et al., 1996; Wasser et al., 1997). In recent years, attention has increasingly been focused on so-called avoidance behavior (Cameron et al., 1979, 1992, 1995; Nellemann, 1997; Nellemann and Cameron, 1998). Wildlife may travel through zones of development, but greatly reduce their use of areas within or near sources of disturbance, thereby reducing optimal foraging or fledging success or increasing risks of predation (Hockin et al., 1992; Reijnen et al., 1995; Cameron and Ver Hoef, 1996; Rodway et al., 1996; Fox and Madsen, 1997; Lord et al., 1997; Verlinden, 1997).

Reindeer (*Rangifer tarandus tarandus*) winter ranges in Norway are increasingly being used for recreational purposes like cross-country skiing. The result is a rapidly growing number of high-altitude cabins and tourist resorts. While such development may be limited in its physical extent, potential avoidance by reindeer may limit the total areas available for foraging, or restrict travel through a landscape fragmented by trails and tourist resorts. Currently very little is known about whether reindeer may reduce their access to important winter foraging areas by avoiding tourist resorts and ski trails. Information on the quality and intensity of use of limited lichen resources near or distant from sources of development is therefore important for evaluating potential long-term effects of disturbance on carrying capacity. In this study, we test the hypothesis that maternal cow-calf groups that are presumably sensitive to disturbance (Nellemann and Cameron, 1998) avoid grazing areas near tourist resorts. We further test the hypothesis that a redistribution of animals away from disturbance sources will affect lichen biomass and composition available for grazing in background areas.

STUDY AREA

The study was conducted in and north of the Rondane National Park in southern Norway during 1991–96. The area consists of rugged terrain (Nellemann and Fry, 1995), dominated by alpine vegetation from 1000 to 1500 m a.s.l. and by barren rock or year-round snow at 1500–2000 m a.s.l. Vegetation consists of some snowbed communities (primarily graminoids of the genera *Carex*, *Agrostis*, and *Deschampsia*, in addition to *Salix herbacea*), but mainly moist and dry shrub heath (primarily prostrate *Salix* sp. and *Betula nana* shrubs, *Cladina* and *Stereocaulon* sp. lichen). Exposed ridges are dominated by *Cetraria nivalis* and gravel. Approximately 1500 wild reindeer have their winter grounds in northern Rondane. Before 1900, the herd migrated northwestward to the Snøhetta region during summer and returned in autumn and winter (Jordhøy et al., 1997), but this migration ceased after construction of a railroad and highway through the main valley that separates the Snøhetta mountain range from the Rondane range. Annual precipitation of approximately 700 mm, with shallow snow at higher altitudes during most of the winter, results in overall high availability of lichen resources for reindeer during winter.

METHODS

During March 1991–96, systematic snowmobile surveys of reindeer were conducted in the study area on three contiguous transects, each approximately 7.5 km wide and 25 km long, starting from the southeast (1 km NE from the Høvringen cabin resort) and moving ca. 45° to the northwest (Fig. 1). Minor deviations from these trails were necessary because of terrain, but a complete survey was made each year. All groups of reindeer observed were classified according to number, sex, and age (Jordhøy et al., 1996), and their locations were marked using GPS or on 1:50 000 topographical maps of the study area. Strip transects were subdivided into 2.5 km (6.25 km^2) segments, thus obtaining a total of 60 6.25 km^2 quadrats. Twelve quadrats were excluded (lakes and terrain > 30°), giving the final data set of 48 quadrats.

During March 1996, 27 sites, each 20 × 50 m, were randomly selected within lichen heath communities. Centre points from each site were selected randomly from a 100 × 100 m grid covering the entire study area (Nellemann, 1996). Lichen heaths constitute the vegetation type that area reindeer use almost exclusively in winter (Nellemann, 1996). A 1:50 000 scale vegetation map was used to identify general distribution of lichen heaths (Larsson and Rekdal, 1991). Vegetation type was further confirmed in the field by identification of vegetation in snow craters within each site. At each site, five random plots, each 1 × 1 m, were randomly selected and marked.

TABLE 1. Number of individuals, male groups (bulls and yearlings), maternal groups (cows, yearlings and calves) and group size (mean ± s.e.) of reindeer in winter within a 30 km belt from a tourist resort in northern Rondane (Fig. 1), 1991–96.

Year	Total Reindeer	Males	Male groups	Male group size	Females and calves	Calves/100 adult females	Maternal groups	Maternal group size
1991	990	560	3	187 ± 97	430	59	1	430
1992	1609	509	5	102 ± 32	1100	74	1	1100
1993	1208	270	1	270	938	55	5	188 ± 40
1994	1118	286	2	143 ± 101	832	55	4	208 ± 84
1995	1015	117	1	117	898	47	6	150 ± 70
1996	1044	193	1	193	851	50	1	851

Snow depth and hardness were recorded at each plot using a Ramsonde penetrometer. Ram hardness (H_r) was calculated using the following equation:

$$H_r = (P_h \times h_{hd} \times n_{hd})d^{-1} + Q$$

where P_h is the mass of the load (g), h_{hd} is the height of the hammer drop (cm), n_{hd} is the number of hammer drops, d is the penetration into the snow cover (cm), and Q is the total mass of the Ramsonde.

An integrated ram hardness index (IRH) was calculated to derive a better index of forage availability (Tucker et al., 1991; Nellemann, 1996, 1998):

$$\text{IRH} = H_r \times d$$

In July 1997, we revisited all sites to perform vegetation analyses. Vegetation cover of the dominant graminoids, shrubs, and lichen species was recorded by counting the number of 10 × 10 cm cells with > 50% cover out of 100 possible cells on a 1 × 1 m square vegetation frame (Wratten and Fry, 1980; Nellemann and Thomsen, 1994). Thirty-five random plots were clipped, dried, and weighed to establish lichen cover–biomass relationships.

Statistical analysis was performed in Sigmastat (Kuo et al., 1992). Data were subjected to a Kolmogorov-Smirnov test of normality. Densities of reindeer for different distance zones from the tourist resort (0.0–4.9 km, 5.0–9.9 km, 10.0–14.9 km, and > 15.0 km) were compared using Kruskal-Wallis tests and multiple pairwise comparisons with Dunn's tests. Use versus availability of distance zones (< 10 km and > 10 km from the resort, respectively) was assessed using chi-square tests. If those results were significant, the Bonferroni z-statistic was applied to test for differences among classes (Neu et al., 1974). In all cases, p-values < 0.05 were considered statistically significant.

RESULTS

Density of reindeer in winter within the study area varied from year to year in 1991–96 (Table 1), possibly in response to variation in weather conditions and abundance of cross-country skiers. Total number of reindeer varied from 990 in 1991 to 1609 in 1992, with an average density of 3.9 ± 0.3 reindeer km^{-2}. Each year from 1991 to 1996, the reindeer were distributed into an average 5 ± 1 groups. Mean group size was 225 ± 43 reindeer.

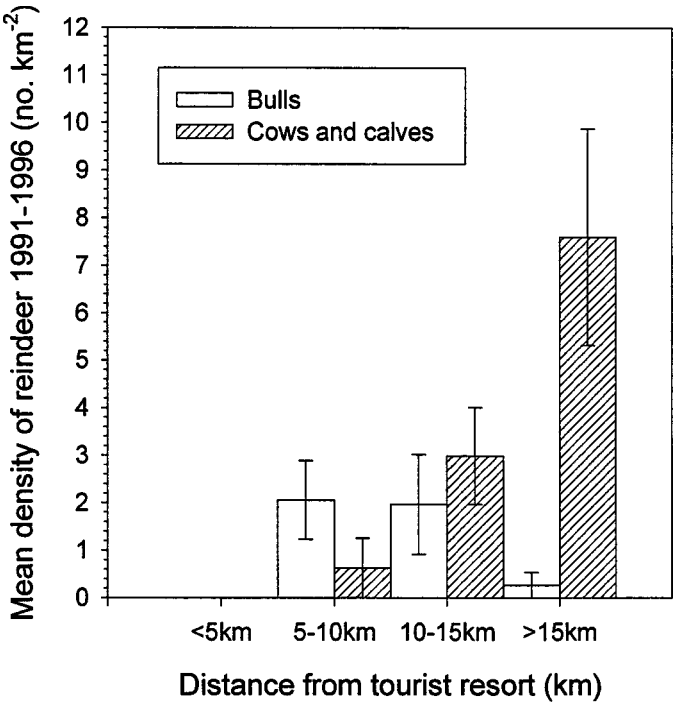

FIG. 2. Mean density of male and female reindeer 1991–96 at different distance zones from a high-altitude tourist resort (Høvringen), Rondane, Norway.

Density of reindeer generally increased with increasing distance from the tourist resort (Fig. 2). No groups of animals were observed within 5 km of surface structures at the tourist resort. Density of females and calves was 0.6 ± 0.6 reindeer km^{-2} at 5–10 km from the resort, increasing by a factor of 12 to 7.6 ± 2.2 reindeer km^{-2} at 15–25 km from the resort. From 1991 to 1996, reindeer used the area 0–10 km from the resort less than expected from its availability in every year except 1994, when a large bull-dominated group was observed 7 km from the resort (Table 2).

Bulls and yearlings, which are generally more tolerant of disturbance (Nellemann and Cameron, 1998), comprised nearly 92% (mean 1991–96) of all animals 5–10 km from structures. Ca. 94% (mean 1991–96) of all females and calves avoided areas within 10 km of the tourist resort; this corresponded to nearly 95% of all maternal groups observed in the period. Only a single maternal group was observed (in 1994) within the 5–10 km zone.

TABLE 2. Bonferroni joint confidence intervals for reindeer use versus availability of 6.25 km^2 quadrats.

Year	Distance zone to tourist resort	Proportion of area	Expected occurrence	Observed occurrence	Proportion observed	95% confidence interval on proportion of occurrence[1]
1991	0.0–9.9 km	0.5	495	50	0.05	[0.03; 0.07]
1991	10.0–25.0 km	0.5	495	940	0.95	[0.93; 0.98]
1992	0.0–9.9 km	0.5	804	319	0.20	[0.17; 0.22]
1992	10.0–25.0 km	0.5	804	1290	0.80	[0.77; 0.83]
1993	0.0–9.9 km	0.5	302	270	0.22	[0.19; 0.25]
1993	10.0–25.0 km	0.5	302	938	0.78	[0.75; 0.81]
1994	0.0–9.9 km	0.5	559	571	0.51	[0.47; 0.55]
1994	10.0–25.0 km	0.5	559	547	0.49	[0.45; 0.53]
1995	0.0–9.9 km	0.5	507	0	0.00	≅ 0
1995	10.0–25.0 km	0.5	507	1015	1.00	≅ 1
1996	0.0–9.9 km	0.5	522	0	0.00	≅ 0
1996	10.0–25.0 km	0.5	522	1044	1.00	≅ 1

[1] Calculations according to Neu et al. (1974).

Among the three distance zones, there were no significant differences in snow depth, Ram-hardness, or integrated Ram hardness (IRH) within lichen heaths (Fig. 3a-c). There were no noticeable differences among the distance categories with regard to distribution of lichen heaths (ca. 54% at 0–5 km, 43% at 5–10 km, and 46% at > 10 km distance). Overall, there was little difference in availability of lichen heath communities corresponding to distance from the resort.

Cover of lichens decreased with increasing distance from the resort (Table 3). Cover was significantly higher on the snow-covered lee side of ridges compared to the ridges among all distance categories. *Cladina alpestris*, *Cetraria nivalis*, and *Alectoria ochroleucha* were the most abundant lichens on ridges, and all declined in cover with distance from the resort. *C. alpestris*, which made up most of the lichen cover on lee slopes, also declined in cover with distance from the resort. There were generally fewer changes in lichen cover on the lee side of ridges as distance from the resort increased, reflecting generally deeper and more packed snow. The cover estimates reflected biomass well; at any cover estimate, however, biomass tended to be near 100% greater in the low-use areas 0–5 km from the tourist resort than in intensively used background areas > 10 km away (Fig. 4). Available lichen biomass on ridges (from cover in Table 3 and regressions from Fig. 4) decreased from a cover of ca. 85% at 0–5 km from the resort to ca. 40% at 15–25 km from the resort. This decrease corresponds to a decline in biomass from ca. 1200 g m^{-2} at 0–5 km to ca. 250 g m^{-2} at 15–25 km distance (Fig. 5).

DISCUSSION

Distribution of reindeer during winter 1991–96 shows that, within a seemingly uniform landscape, reindeer avoided areas within 0–5 km from the tourist resort and generally reduced use of areas 5–15 km from the resort. Similar avoidance in relation to tourist resorts has been observed for semidomestic reindeer during winter (Helle and Särkelä, 1993) and spring (Vistnes, 1999).

Maternal groups were the most sensitive to disturbance, locating themselves primarily 15–25 km from the resort, the farthest distance possible in this mountain area. Conversely, bulls and yearlings predominated in the zone 5–10 km from the resort, reflecting their greater tolerance of disturbance (Nellemann and Cameron, 1998). However, even for males, the zone 0–5 km from the resort remained unused. Maternal groups were observed occasionally 5–10 km from the resorts during snowstorms or during early winter, when tourists were generally absent. Avoidance of the 0–5 km zone by both males and females probably reflects an approximate critical tolerance distance to larger concentrations of cabins independent of human activity. Similar sex-dependent sensitivity to disturbance has also been noted in studies of calving caribou relative to oil development, roads, and pipelines in Alaska (Nellemann and Cameron, 1996, 1998). High sensitivity of maternal groups to anthropogenic disturbance during calving may be attributable to an adaptation by maternal females to avoid predation on calves (Bergerud and Page, 1987; Helle et al., 1990; Fancy and Whitten, 1991). However, the avoidance by both sexes here also suggests that hunting by humans, the primary mortality factor for Norwegian reindeer, may have induced increased sensitivity to human activity at a broader scale.

Avoidance of technical structures by reindeer/caribou is generally very high during calving, even when human traffic is low or absent (Cameron et al., 1995; Cameron and Ver Hoef, 1996; Nellemann and Cameron, 1996, 1998; Vistnes, 1999). Our results, like those of Helle and Särkelä (1993), show that avoidance also may be substantial during winter. Avoidance by reindeer/caribou in the range of 4–10 km has been recorded in relation to roads, pipelines,

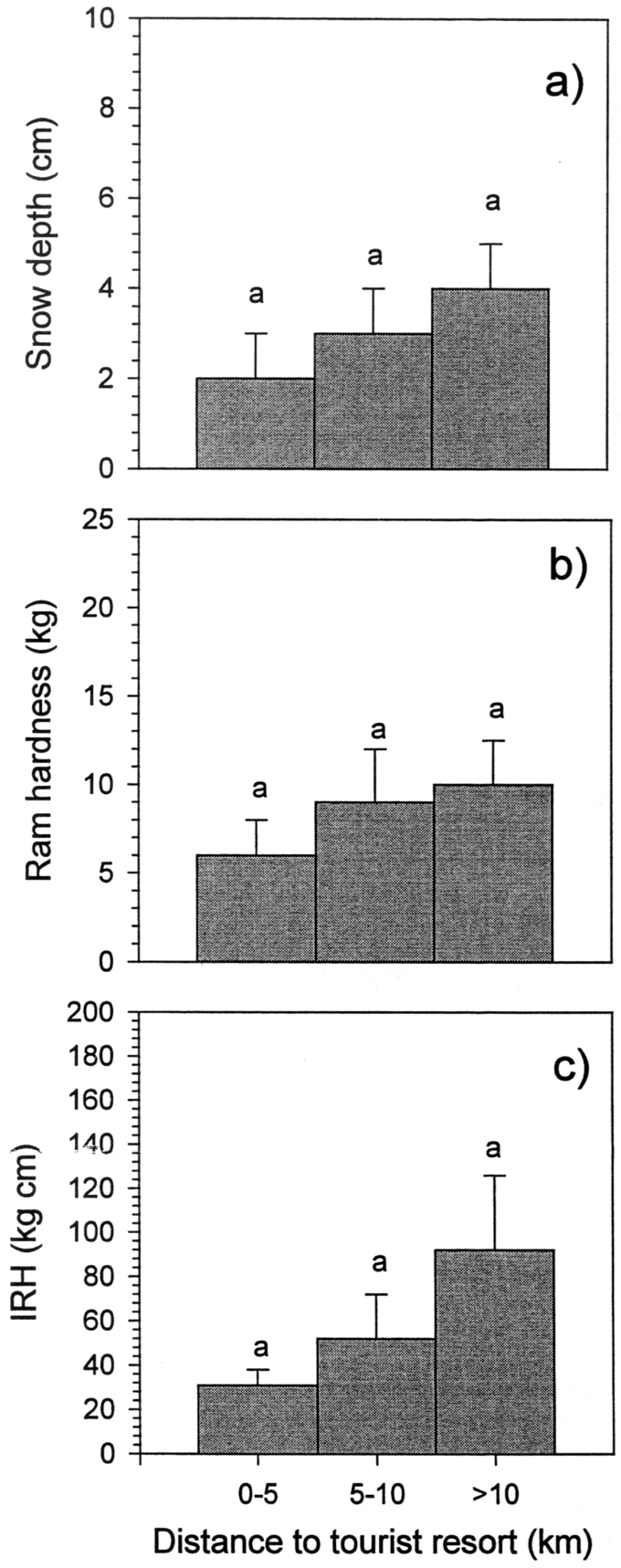

FIG. 3. Snow depth, Ram hardness of snow and Integrated Ram Hardness (IRH) on ridges with lichen heath at different distance zones from a high-altitude tourist resort, Rondane, Norway 1996.

cabin resorts, and power transmission lines during spring and winter (Helle and Särkelä, 1993; Cameron et al., 1995; Cameron and Ver Hoef, 1996; Nellemann and Cameron, 1996, 1998; Vistnes, 1999; this study). Avoidance behaviour is also known from other continents and species, e.g., wildlife in Africa (Verlinden, 1997). However, during warm summer days with heavy insect harassment, caribou can travel through zones with elevated roads, pads, or pipelines to move to insect relief habitat, or to select elevated, more windy sites in an otherwise flat landscape (Pollard et al., 1996). Notably, even during summer, caribou tend to avoid areas with surface development when insect harassment is low and foraging is possible. Indeed, Pollard et al. (1996) found that the number of caribou within the Prudhoe Bay Oilfield during July and August 1990–93 was, on average, 91% lower on days with low insect abundance than on days with high insect abundance (mean 510 ± 187 vs. 5738 ± 1437, respectively, 1990–93, $p < 0.01$, Mann-Whitney test; data from Table 1 in Pollard et al., 1996). These results clearly support the consensus that maternal caribou and reindeer avoid technical structures or humans under most conditions, except when foraging is restricted during periods of heavy insect harassment (Nellemann, 1997).

The twelvefold higher density of female reindeer more than 10 km from the resort most probably resulted from redistribution of reindeer from the area 0–10 km distant from the tourist resort to undisturbed areas beyond 10 km (Cameron and Ver Hoef, 1996; Nellemann and Cameron, 1996; Verlinden, 1997). This possible shift in distribution and range use resulted in substantial underuse of areas near tourist resorts, combined with a potential overuse of limited foraging areas beyond (Nellemann and Cameron, 1996, 1998). As available forage tends to have a scattered distribution during winter, primarily associated with rugged terrain and windblown ridges, density of reindeer easily becomes crucial to carrying capacity (Miller et al., 1975; Reimers, 1977, 1982, 1983; Helle and Säntti, 1982; Skogland, 1983, 1985, 1986; Roby and Thing, 1985; Nellemann, 1996). Hence, substantial underuse of nearly 50% of the study area and resultant overuse of a limited forage resource is a situation comparable to a 100% increase in reindeer density in a nondisturbed area. This is a dramatic management perspective in Norway, where density of reindeer is regulated by hunting primarily in relation to condition of winter ranges. Possible effects are thus overgrazing of limited lichen resources with slow regeneration rates (Scotter, 1966; Gaare and Skogland, 1975; Thompson and McCourt, 1980; Helle, 1984; Thomas and Herviux, 1986; Nieminen and Heiskari, 1989).

Indeed, our vegetation data indicate that overgrazing may be occurring as a result of redistribution of reindeer away from the tourist resort. Biomass of available lichens per unit area on windblown ridges was five- to sixfold lower in the high-use area more than 10 km from the resort. Differences were substantially smaller on the lee side, although some differences also were observed, primarily

TABLE 3. Cover (%) for major reindeer forage species on slopes and ridges within lichen heath communities at three distance categories (0.0–4.9 km; 5.0–9.9 km; and > 10 km, respectively) to a tourist resort in northern Rondane mountain range, 1996.

Species cover (%)	Distance to tourist resort in km					
	0.0–4.9 (ridge)	5.0–9.9 (ridge)	> 10.0 (ridge)	0.0–4.9 (slope)	5.0–9.9 (slope)	> 10.0 (slope)
Total lichen	86 ± 2a[1]	65 ± 4b	43 ± 5c	88 ± 3b	72 ± 3b	64 ± 8b
Cetraria nivalis	41 ± 3a	40 ± 1a	27 ± 4b	3 ± 1a	4 ± 1a	2 ± 1a
C. islandica	0a	0a	0a	7 ± 1a	14 ± 4a	*19 ± 3b*
Cladina rangiferina	0a	0a	0a	1 ± 1a	1 ± 1a	1 ± 1a
C. mitis	0a	0a	0a	1 ± 1a	1 ± 1a	2 ± 1a
C. alpestris	39 ± 5a	1 ± 1b	2 ± 1b	80 ± 4a	51 ± 7b	35 ± 7c
Alectoria ochroleucha	21 ± 3a	27 ± 5a	10 ± 2b	1 ± 1a	1 ± 1a	1 ± 1a
Total graminoids	0a	1 ± 1a	1 ± 1a	3 ± 1a	9 ± 4ab	10 ± 2b
Juncus trifidus	0a	1 ± 1a	0a	1 ± 1a	3 ± 1a	4 ± 3a
Betula nana	4 ± 1a	13 ± 3b	0a	7 ± 2a	14 ± 5a	3 ± 1a

[1] Different letters a through c indicate significant differences within ridge or slope, respectively (within row only) using Kruskal-Wallis tests with Dunn's tests for multiple comparisons.

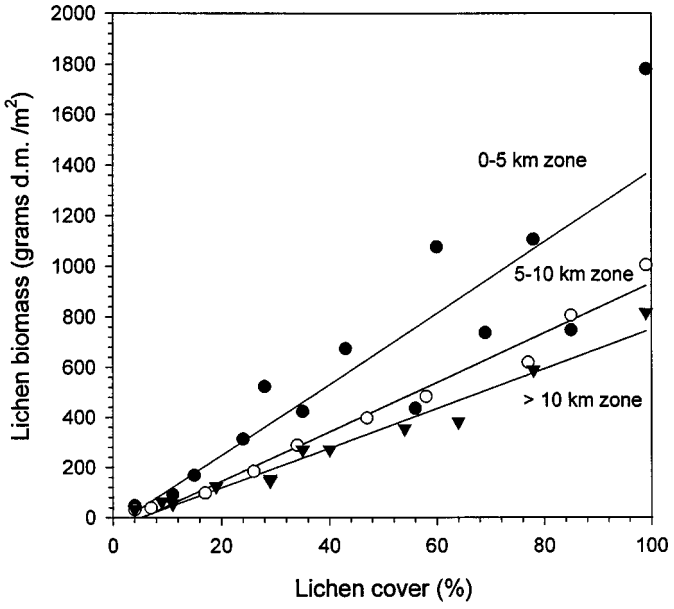

FIG. 4. Cover-biomass relationships for lichens on ridges available for foraging at three distance zones from a high-altitude tourist resort, Rondane, Norway 1996.

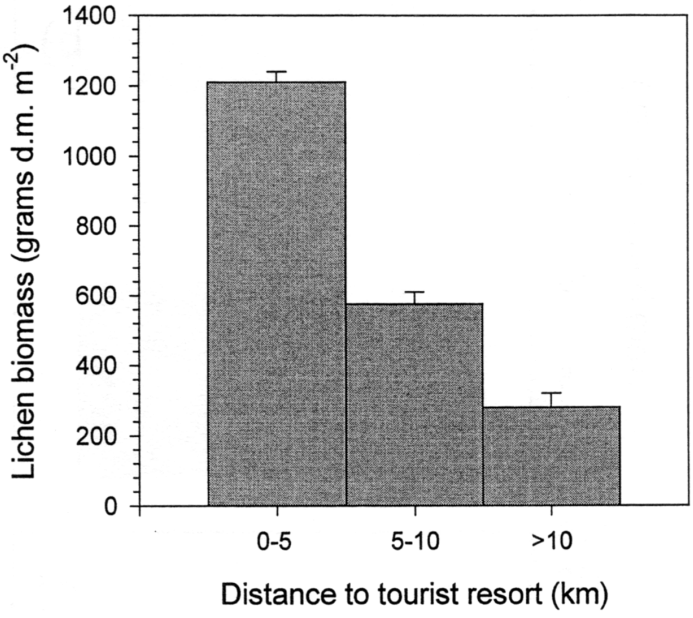

FIG. 5. Estimated lichen biomass on exposed available ridges at three distance zones from a high-altitude tourist resort, Rondane, Norway, 1996.

as a result of grazing in early winter, when the slopes of ridges are more heavily used (Pruitt, 1966; Skogland, 1978; Duquette, 1988; Collins and Smith, 1991; Nellemann, 1996). The ridges themselves, however, characterized by low biomass and shallow snow (Nellemann, 1996), are easily overgrazed in mid- and late winter. Lower biomass, lack of difference in snow depths on exposed ridges, and little difference in distribution of lichen heaths preclude the conclusion that the apparent avoidance could be an artifact of better foraging conditions in areas beyond 10 km from the disturbance. In fact, the opposite is the case with regard to available biomass.

Increasing overgrazing of limited forage resources may result in reduced energy intake for the individual reindeer (White et al., 1975; White, 1983; Nellemann and Cameron, 1996). Lichen are so low in protein, typically < 5%, that intake by reindeer is related primarily to securing a sufficient carbohydrate intake. Reindeer are physiologically well adapted to a low-protein diet through recycling of nitrogen by renal excretion of urea (McEwan and Whitehead, 1970; Hove and Jacobsen, 1975; Hyvärinen et al., 1977; Staaland et al., 1983, 1986). Lichens are important for a sufficient carbohydrate intake during winter, when energy requirements are high. As high lichen intake ratios may increase fecal and body loss of nitrogen (McEwan and Whitehead, 1970; Hove and Jacobsen, 1975), reindeer strategically select for the most easily accessible, though scarce, forage on windblown ridges. Hence, easy access to sufficient quantities of lichen (typically 1–2 kg dry matter daily for adults; Holleman et al., 1979) on exposed ridges is important for sustaining direct daily energy requirements. Overgrazing of ridges, particularly in extreme weather

conditions (Reimers, 1982), has several consequences. It will force reindeer to increase cratering activity (Pruitt, 1966; Bergerud, 1974; LaPerriere and Lent, 1977; Skogland, 1978). It also increases energy expenditure (Thing, 1977; Telfer and Kelsall, 1979; Fancy and White, 1985, 1987), thus reducing body fat and mineral and protein reserves.

Reduced body condition as a result of increased local competition and overgrazing may affect reproductive success (White, 1983). Fat and body reserves are particularly important to pregnant females for the oncoming lactation period in spring (Tyler and Blix, 1990), when metabolic demands are high (Oftedal, 1985; Chan-McLeod et al., 1994). Substantial reductions in energy intake may also affect growth of the foetus and increase the risk of abortion (Russell et al., 1996). Birth weight and maternal body weight are crucial for growth in summer, lactation, and fecundity in autumn (Dauphiné, 1976, Reimers, 1983; White, 1983; Cameron et al., 1993; Gerhart et al., 1997). In addition to a high intensity of hikers in summer, the Rondane mountain ranges are characterized by dry and poor summer ranges, with few meadows or bogs and little snowbed vegetation for grazing. Opportunities for compensatory growth during summer are therefore poor, while migration to alternative summer ranges is restricted by a network of roads and settlements that have fragmented the original migration routes to the west.

Reindeer in Rondane are therefore currently exposed to increasing grazing pressure during winter, poor opportunities for compensatory growth during summer, and increased levels of anthropogenic disturbance throughout all seasons. The combined effect of these factors may explain why calf production has been recorded at a low average of approximately 50 calves/100 adult females in the last 10 years (Jordhøy, unpublished), compared to ca. 90 calves/100 adult females in more favourable ranges. The conclusion remains that the effects of tourist resorts and associated activities clearly exceed the physical footprint of these installations. The cumulative impact of all-season tourism, combined with fragmentation by roads and power lines, may be a serious reduction in the reproductive success of Norwegian reindeer herds and depletion of current winter ranges.

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