

Large-scale segregation of tourists and wild reindeer in three Norwegian national parks: Management implications

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ABSTRACT

The challenge to harmonize nature-based tourism with species conservation is important both from an economic, cultural and ecological perspective. One approach for understanding this interaction is to compare the spatio-temporal overlap between tourism activities and the focal species' space use, with the purpose to identify areas, periods, and conditions in which tourism exerts the highest negative impact. Here, we combine GPS data from 66 wild reindeer with on-site surveys of tourist (n = 13434 respondents at 66 locations) and trail use counters (n = 99 sites) in three Norwegian national parks. Our findings highlight a large-scale segregation during the summer season, as wild reindeer move to areas less prone to disturbance by humans. Based on these findings, we discuss a management model to segregate tourists from wild reindeer in space and/or time during summer with the goal of long-term sustainable coexistence.

1. Introduction

In recent years there has been a major paradigm shift in Norwegian National Park (NPs) policy and management along with the rise of the nature-based tourism industry. A national strategy for tourism and a program for developing local visitor strategies within NPs were presented in 2015 (Norwegian Environment Agency, 2015) with the intention to improve local economies related to tourism both within and adjacent to NPs, but not at the expense of conservation priorities. The goal was to increase the overall number of visitors by promoting a few strategic access points to the NPs while simultaneously advertising other attractions primarily at the fringes of the parks. However, this plan would require harmonization with conservation goals for flora and fauna. Of particular concern is the protection of the last remaining populations of wild mountain reindeer (*Rangifer tarandus tarandus*) in Europe, including 35 000 individuals in winter herds that lived in 50 000 km² mountain areas in southern-Norway (Kjørstad et al., 2017).

During the past decade there has been an increased awareness of the impact from anthropogenic activities on these animals that live in large herds in remote areas above the tree line and are particularly sensitive to human disturbance. High-resolution GPS tracking data on wild reindeer in Norway, in one area continuous GPS collared reindeer since 2001, allowed scientists to quantify the differential and cumulative impact of a large range of infrastructures. A network of infrastructure

such as roads, railways, tourist cottages, and popular hiking trails has the potential to significantly hamper reindeer migrations and space use, and has already led to substantial habitat loss and severe fragmentation and isolation of the populations (Nellemann et al., 2010; Panzacchi et al., 2016; Panzacchi, Van Moorter, Jordhøy, & Strand, 2013a; Panzacchi, Van Moorter, & Strand, 2013b; Panzacchi, Van Moorter, Strand, Loe, & Reimers, 2015). Although more than 60 peer-reviewed papers have been studying disturbance effects of tourist and recreational activities on reindeer in the Nordic countries, very few discuss concrete management implications and suggest measures to promote human-wildlife co-existence (for review see Skogland & Grøvan, 1988; Reimers & Colman, 2006; Vistnes & Nellemann, 2008; Skarin & Åhman, 2014).

A deeper understanding of the mechanisms shaping dynamic interactions between reindeer and humans is needed to guide flexible management strategies aimed at reducing adverse anthropogenic pressures and increasing the potential for human-wildlife coexistence (Kaltenborn, Andersen, & Gundersen, 2014). Hence, there is an urgent need to study human-reindeer interactions, and to investigate the actual potential of NPs to fulfill their multiple goals of species conservation and tourism development. It is important to identify high-conflict areas, where tourism has its greatest adverse impact on wild reindeer, and the conditions promoting human-wildlife coexistence. This would form the basis for developing adequate mitigation and offset measures, such as

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setting restrictions to the number of visitors in critical periods, identifying protection areas such as calving areas or migration corridors, or developing push-pull visitor strategies, which we discuss below (Gundersen, Mehmetoglu, Vistad, & Andersen, 2015).

Most Norwegian NPs are located in remote areas and contain practically no roads or heavy infrastructure (Nature Diversity Act, 2009). By international comparison their location, physical appearance, and level of services usually matches the IUCN (International Union for Conservation of Nature) category for wilderness, rather than the category for national parks (category II; IUCN). The predominant summer use in Norwegian NPs is hiking. Hiking is a legitimate and publicly desirable activity, and the restrictions on other modes of travel in the NPs constitute an important motivational factor for hikers to visit these areas. National park tourists can be classified into a variety of profiles, each characterized by specific motivational factors, needs, and expectations to achieve specific types of experiences (Fredman & Heberlein, 2005; Leask, 2016). The “push and pull framework” is commonly used to investigate visitor behavior in tourism research (Uysal et al., 1994; Baloglu & Uysal, 1996; Kim, Lee, & Klenosky, 2003; Yoon & Uysal, 2005). Push factors are internal and intrinsic to the tourist (Crompton, 1979), based on a perceived need to satisfy disequilibrium by performing a specific journey or action (Dann, 1977). Examples of push factors may include the search and longing for “authenticity”, solitude, tranquility, socialization, or the need for a change of scenery or escape from a mundane environment (Crompton, 1979). Pull factors are characteristics of the destination that may arouse the desire for travel in a potential tourist (Crompton, 1979) and attract tourists to specific destinations (Kim et al., 2003). Pull factors are attributes that make it worthwhile to visit heritage places, unique natural landscapes, to practice specific activities, or to attend specific events (Haukeland, Veisten, & Grue, 2010), and are most often characterized by ease-of-access, facilities, and information (Kim et al., 2003; Tverijonaitea, Ólafsdóttira, & Thorsteinsson, 2018). One of the main principles in sustainable tourism management is that visitation should not exceed an area's lowest tolerance. Both push and pull factors play a role in motivating potential tourists to plan and pursue a specific travel plan. Hence, by using push-pull strategies purposefully, management could succeed in accommodating a wide spectrum of recreational opportunities (i.e. both for those seeking comfort and those seeking wilderness; Vistad & Vorkinn, 2012) while still maintaining sustainable use of the area. For instance, careful use of so-called pull factors in less vulnerable areas of the NPs is essential, in interaction with knowledge about the diversity of push factors that needs to be met through the individual nature experiences in the NPs (Gundersen et al., 2015).

Robust knowledge about the effects of disturbance is a necessary baseline when setting management goals for visitation patterns and volume (Haukeland, Veisten, Grue, & Vistad, 2013; Tyre & Michaels, 2011). Interestingly, a visitor survey conducted among Norwegians showed that ecotourists, i.e. those travelling to relatively undisturbed or uncontaminated natural areas to enjoy nature, represent both the largest and the most environmentally concerned segment of all visitors (Mehmetoglu, 2010). This is supported by a Swedish study showing that environmentally-oriented individuals have different recreational preferences compared to others, and prefer outdoor activities with little or no impact on the environment (Wolf-Watz, Sandell, & Fredman, 2011). These examples suggest that there is a great potential for encouraging tourists to adopt more sustainable behaviors in NPs by using management techniques specifically tailored to their profiles and preferences.

Analyses of visitor spatial behavior and segmentation are commonly used for visitor conflict management, both to identify management zones and to identify recreation opportunity and suitability (Riungu, Peterson, Beeco, & Brown, 2018). Backcountry management plans to reduce socio-ecological impacts, often encourage the dispersal of visitors. However, backcountry visitors tend to be clustered and highly concentrated in entrance areas and along marked trails within the

Nordic NPs (Raadik, Cottrell, Fredman, Ritter, & Newman, 2010; Pietilä & Kangas, 2015; Gundersen et al., 2015). Here we used zoning to regulate problematic activities in sensitive wild reindeer areas, but at same time provide high-quality visitor experiences for a range of tourism and recreation opportunities (i.e. Boyd & Butler, 1996). There are several (mainly US) wildland tourism management models that aid balancing nature-based tourism and conservation of natural resources in protected areas. These models, e.g. ROS – Recreation opportunity spectrum (Clark & Stankey, 1979; Boyd & Butler, 1996), LAC – Limits of acceptable change (Stankey, Cole, Lucas, Peterson, & Frissell, 1985), VIM – Visitor impact management (Graefe, Kuss, & Vaske, 1990), or VERP – Visitor experience and resource protection (National Park Service, 1995) are based on defining conservation and management goals for the area, continuously monitoring the activities therein, and deciding on acceptable levels impacts in the different management zones (Manning, 2010). The ROS and LAC framework have been adapted to a Nordic management context, and similar concepts are commonly used in different natural landscapes (i.e. mountain) since the 1980s (Aasetre & Gundersen, 2012; Pietilä & Kangas, 2015; Raadik et al., 2010). These planning frameworks provides opportunities for activities in certain areas that is supposed to realize people's desired experiences, and theoretically, everyone has access to different zones that respond to various interests and needs. The ambition is to find a balance between landscape use and conservation by directing people to areas with low conflict potential with nature conservation. In this paper we rely upon these management traditions, but also face specific challenges in the Nordic countries where the public access rights apply even within NPs (Pietilä & Kangas, 2015; Raadik et al., 2010; Tverijonaitea et al., 2018; Vistad & Vorkinn, 2012). Several management tactics are therefore controversial or unacceptable, e.g. restricting access to an area and charging access fees.

In conclusion, NP management in wild reindeer ranges is facing a tradeoff between the sustainability of tourism from a socio-economic *versus* a conservation perspective (Kaltenborn et al., 2014). However, the potential for human-reindeer coexistence in NPs could be substantial if humans and reindeer were segregated in time and space (Flemsæter, Gundersen, Rønningen, & Strand, 2018). This could be achieved for example by channeling tourist activities away from core reindeer areas during critical periods or to areas of marginal importance for conservation, while accommodating tourist needs, requirements and preferences. Within a multidisciplinary context, based on large amount of data from both social sciences and ecology, this paper investigates the possibility for large scale spatial segregation between reindeer and tourists during summer, and the possibility to keep the number of tourists at acceptable levels in critical reindeer areas. In this paper we will:

1. Characterize the main profiles of visitors in three large NPs during summer, using questionnaires;
2. Quantify the number of NPs visitors and develop a new methodology to quantify their spatiotemporal patterns (i.e. estimate the daily intensity of use of each hiking trail), by analyzing jointly questionnaires and automatic people counters;
3. Illustrate the macroscopic impact of spatiotemporal dynamics of visitors along trails on wild reindeer area use, using GPS-tracking locations collected in the same areas and periods;
4. Discuss the possibility to develop more sustainable visitor management strategies that minimize the impact of tourism on wild reindeer.

2. Material and methods

2.1. Study areas

The study was conducted in three Norwegian NPs, Dovrefjell-Sunddalsfjella (DSNP; 1693 km²), Rondane-Dovre (RNP; Rondane-963

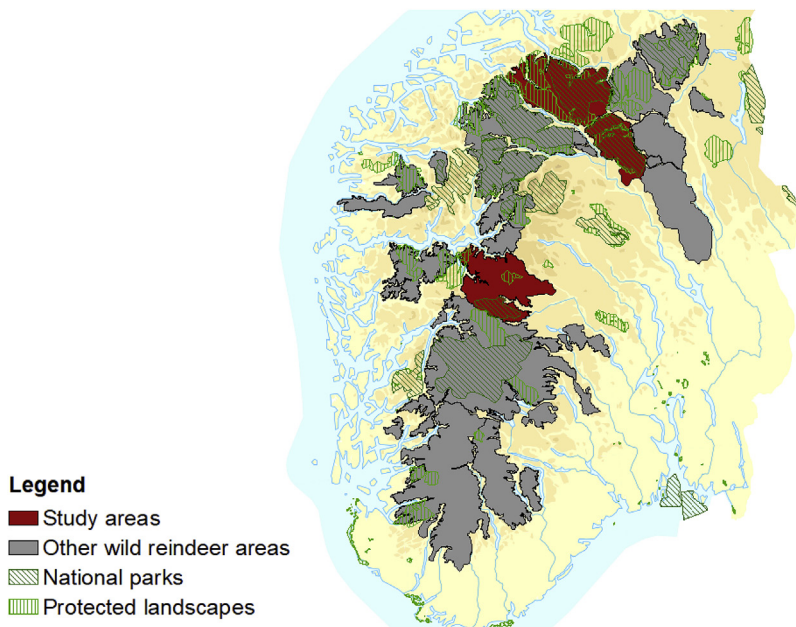


Fig. 1. Wild reindeer management areas, including 23 distinct herds (in grey). The three focal study areas - Rondane-Dovre (RNP – upper right), Dovrefjell-Sunndalsfjella (DSNP, upper-left), and Hallingskarvet (HNP, lower) – are in red. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

km², Dovre-289 km²) and Hallingskarvet (HNP; 450 km²). In 1962, RNP became the first NP in Norway, while DSNP and HNP were established in 1974 and 2006, respectively. One of the main motivations for establishing these NPs was the protection of important habitat for wild reindeer. These NPs comprise significant portions of the three largest wild reindeer management areas in Norway (Fig. 1): DSNP includes part of the 3300 km² Snøhetta area, RNP includes part of the 1200 km² Rondane area, and HNP includes part of the 2000 km² Nordfjella area. The most ancient wild mountain reindeer in Europe inhabit DSNP and RNP, while reindeer in Nordfjella are descendent from semi-domesticated animals (Røed et al., 2014).

In these NPs, a large proportion of the landscape is located above the timberline, and appears as a mosaic of mountain vegetation. The density of trails is much higher within RNP (mean: 1001 ± 523 SD meter/km²) compared to HNP (617 ± 577 m/km²) or DSNP (426 ± 378 m/km²). In RNP there are no areas further than 5 km from trails or roads, while in DSNP and, in particular, in HNP there are several remote areas. On the fringes of the wild reindeer ranges, all areas are characterized by very high density of infrastructure, including gravel roads, private cottages, hotels, marked trails, and large tourist lodges.

2.2. Data on tourist space use

Obtaining accurate visitor counts in remote backcountry settings is challenging, especially over large areas with dispersed use with virtually countless hiking possibilities (Kajala et al., 2007). Space use by tourists was measured during summer (from 15. June to 1. October) in the three study areas using a combination of on-site self-registration checkpoints and automatic people counters.

Self-registration checkpoints consisted of boxes placed in strategic positions in proximity of the main access points of each NP (n = 24 checkpoints in DSNP, n = 14 in RNP, n = 28 in HNP). At each checkpoint visitors filled out a questionnaire (in Norwegian, English and German) and drew their pre- or post-hiking route on a map. Questionnaires were collected in the first year of study (2009 in DSNP and RNP, and 2010 in HNP). Questions were chosen to allow us to create a profile of the visitor, including demographic parameters, preferences for and use of infrastructure, characteristics of their trip, accommodation, and knowledge about the area they were visiting. Each check point was inspected 7 or 8 times during the summer. In total,

3651 questionnaires were completed by respondents older than 15 years in DSNP, 5574 in RNP, and 4209 in HNP. A test for non-response bias was made (Gundersen et al., 2015) in the DSNP area, and the overall results showed some minor biases that were mainly in accordance with similar international non-response studies (e.g. Fredman, Romild, Emmelin, & Yuan, Fredman 2009; Hindsley, Landry, & Gentner, 2011): local inhabitants tended to be underrepresented, while highly educated people interested in recreational activities and nature conservation tended to be overrepresented.

We installed 99 automatic people counters (EcoCounter, with a pyroelectric two-way sensor); 40 in DSNP (in use between 2009 and 2017), 41 in RNP (2009–2017), and 18 in HNP (2010–2017). The accuracy of the automatic counters is subject to both qualitative errors, as they can record movements that do not represent actual visitors, and technical errors, caused by characteristics of the counter or the installation site (Kajala et al., 2007). The accuracy of the counters (i.e. for the number of visitors detected) has been intensively tested, and it has been shown to operate within a 5% margin with proper installation (Andersen, Gundersen, Wold, & Stange, 2012). Regarding qualitative errors we have corrected the number of counts related to installation and operation of the counters and detections of animals (sheep, dogs etc.). Installation of the counter 1 m above the trail body may have missed some children, but small children are always hiking together with adults that have been counted.

The people counters, in combination with questionnaires collected at self-registration checkpoints, allowed us to calculate a response rate for the survey. The automatic counters recorded a total of 88780 visitors at the 41 NP entrances, including a self-registration checkpoint in 2009 (DSNP, RNP) and 2010 (HNP) (altogether n = 8345 respondents), indicating an overall response rate of 9.4% for the survey material (8.5% in DSNP, and 10.2% and 11.4% in RNP and HNP respectively, Table 1). However, the response rate is somewhat underestimated because some of the respondent filled out a questionnaire on behalf of a group of people (mostly two or three persons, and very rarely including groups more than 10 members).

2.3. Estimation of Trail Use Index

With several hundred trail segments in the NPs, it was infeasible to install automatic counters at all segments. Hence, the people counters allowed us to obtain a large amount of data on daily use of the trail

Table 1

Key characteristics of the data sampled in the three study areas including on site surveys using self-registration checkpoints and automatic counters. Target population are all visitors to the national parks.

Study areas/ year of sampling	Target population approximately number of visitors	Sampling frame N of self- registration checkpoints	Sample N of questionnaires compiled	N of different individuals (when one answers for a group of people)	Response rate (%, as compared with visitor volume from automatic counters)	N of trail segments travelled by the respondents	N of locations of automatic counters in 2009–2017
DSNP 2009	45000	24	3651	5223	8.5	9116	40
RNP 2009	90000	14	5574	8234	10.2	14530	41
HNP 2010	75000	28	4209	6021	11.4	7087	18

segments, but only along a limited number of trail segments. To obtain a complete overview of the daily hiking patterns along the entire trail network in the study areas we combined the counter data with the fewer, but complete, hiking routes drawn by the survey respondents. Each route was digitized, and all routes were overlaid to calculate the tourist volume along each trail. Each trail was then divided into shorter segments, separated at the intersection with other trails. These trail segments became the basic unit through which we could link survey data with data from automatic counters and thereby obtain a proxy of the daily intensity of use. We called this the Trail Use Index, TUI, and calculated the index value as follows. First, using the route from the drawings we calculated the relative tourist volume of each segment. After, we weighed the relative tourist volume of each segment based on the number of visitors recorded at the automatic counter from the most representative segment in each area. We validated the TUI using data from all other automatic counters, and we found a strong linear relationship between TUI and the number of people counted at these selected segments ($n = 99$ segments, $R^2 = 0.767$). Thus, our estimates of TUI along different trails were quite robust.

2.4. Data on wild reindeer space use

In 2009–2016 a series of ecological research projects have been conducted in the same areas to investigate the effect of anthropogenic disturbance on GPS monitored reindeer. In total, 66 female reindeer (25 in DSNP, 20 in RNP, 21 in HNP) have been equipped with GPS devices with drop-off systems. For each individual we selected 1 GPS location every 3 h during the period June 15th–October 1st, to match the study period for NP visitors. The GPS locations were displayed in maps to illustrate the intensity of use in the area.

Because males were not included in our study, our results refer only to females. Females are more sensitive to summer disturbance due to the potential impact on their offspring and future reproductive output. Male reindeer seem to show different patterns of space use, and often use areas outside of the core reindeer habitat, including areas with higher tourist volume (Strand et al., 2014). Based on previous integrated analyses of reindeer GPS data and tourists in these study areas (Panzacchi et al., 2013a, 2013b, 2015, 2016; Strand et al., 2014; Strand, Flemsæter, Gundersen, & Rønningen, 2013) we identified: 1) *remote areas* with low cumulative density of roads and trails, or areas with low human disturbance, with trails with $TUI < 30$ visitors per day these are highly preferred by reindeer during the tourist season, and are likely to be of key importance for conservation, 2) *intensely used trails*, i.e. trails with $TUI > 30$ visitors per day, that are likely to hamper reindeer movements and affect negatively space use in its proximity, and 3) *potential barriers*, with $TUI > 80$ visitors per day. These studies reported no reindeer crossing of trails with $TUI > 220$ visitors per day.

3. Results

3.1. Visitor profiles

We used the data from the self-registration checkpoints to characterize visitors' profiles in each NP (Table 2). Hiking was the most

common activity in all areas, while other activities such as mountain biking, climbing, kayaking etc. comprised only between 5% and 10% of all visitors. RNP was the most popular destination in terms of visitor numbers, and with the highest proportion of daytrip hikers, most of whom were Norwegian. RNP has a very dense network of marked trails and tourist lodges, and most visitors stayed within proximity to these. DSNP is the park with most foreign and first-time visitors, and HNP had visitors with the highest preferences for recreational infrastructure and tolerance towards meeting other visitors.

3.2. Daily visitor volume

Previous studies showed that the day-to-day use of a trails varies largely with factors such as weather conditions, weekdays vs. weekends, hunting season, etc. (Andersen, Gundersen, Wold, & Stange, 2014). In all three areas we identified three periods characterized by marked differences in TUI during the summer season: low intensity (Jun 15th–Jul 14th), high intensity (Jul 15th–Aug 19th) and hunting season (Aug 20th–Sept 20th) with a somewhat intermediate intensity. The peak in TUI occurred in all areas between the end of July and the beginning of August. During the reindeer hunting period TUI was much lower compared to the high tourist season, and it was highest during the first week. Among the three NPs, TUI was higher in RNP (max: 6038 recordings per day) than in HNP (max: 4035) and DSNP (max: 1810; Fig. 2).

3.3. Visitor volume and reindeer space use

We identified large variations in visitor volume, both between and within the study areas (Fig. 3). While some areas are characterized by a dense network of trails and with high tourist volume, others have fewer trails and lower visitor numbers. Reindeer locations showed similar macroscopic patterns during the eight years and in the three study areas: reindeer were noticeably very concentrated in space during the low and high tourist season, and appeared much more dispersed during the hunting period. It is also noticeable that the reindeer herds used a smaller part of their ranges during summer. Thus, the comparison between visitor and reindeer highlights seasonal, large-scale segregation, and suggests that, whenever available, reindeer attempt to move to areas with the lowest density of trails, or to areas with lowest TUI during the entire tourist season.

The most striking result when comparing the TUI with reindeer GPS locations was the macroscopic barrier effect associated with a few, very popular trails. These trails had a $TUI > 80$ visitors per day (estimated as 8 visitors/hour over a 10-h period). To illustrate the co-existence of tourist and reindeer more in detail, we give examples of area sections that include the trails with the highest rate of TUI within each study area. The core area in RNP had several trails with an extremely high TUI during high tourist season (Fig. 4), and it is easy to identify preferred areas for reindeer. The reindeer completely avoided areas in the mid-sections of RNP that include the dense network of trails with $TUI > 80$ visitors per day. Only one GPS collared reindeer crossed over this trail, in the nighttime, during high tourist season (01:00, August 5th, 2014) in the whole sampling period. A similar situation can be

Table 2

Characterization of visitors' profiles in Rondane (RNP), Dovrefjell-Sunndalsfjella (DSNP) and Hallingskarvet (HNP) national parks.

Parameter (Proportion %)	RNP (n = 5574)	DSNP (n = 3651)	HNP (n = 4209)
Hiking	95.1	90.8	93.7
Daytrip hiking	63.2	46.9	57.1
Foreign visitors	30.1	36.1	20.6
Number of nationalities (Norwegians excluded)	32	32	23
First-time visitors	37.2	46.6	35.1
Hiking only on marked trails	88.6	79.7	83.3
High preferences for recreational infrastructure and tolerance towards other visitors (Low wilderness purism, for definition see Vistad & Vorkinn, 2012)	69.3	59.9	73.3
Children represented in the group	16.0	19.1	21.8
Visitors from local municipalities	3.9	14.2	15.7

described from the western part of HNP during high tourist season (Fig. 5), including the intensively used trail segments from Finse railway station towards Aurlandsdalen (TUI > 80 visitors per day). Here, 4 GPS collared animals crossed over this trail in nighttime (04:00, August 12, 2012), two of them came back the same day and the two others came back three days later. Note the large avoidance effect of areas east of the most used trails in HNP. In DSNP we illustrate a similar situation in the low season (Fig. 6), and the trails from Kongsvold railway stations to the tourist cabin Reinheim make an obvious barrier for the reindeer (TUI > 50–80 visitors per day). During the whole sampling period, here, 2 GPS collared reindeer (probably in a large herd) crossed over this trail at nighttime (03:00, June 3rd, 2015) and back again same day, and 3 GPS collared (probably in a large herd) crossed the trail early in the morning (06:00, July 14, 2009) and back again the same day. The area south of these intensively used trails is not used by reindeer in this tourism period.

3.4. Identification of conflicting trails segments

We identified from the hiking route drawn by the respondents a large amount of marked and unmarked trail segments in the three study areas: RNP has 172 segments with a total length of 1180 km, HNP has 166 segments and 1566 km, and DSNP has 113 segments with a total length of 780 km. RNP has altogether 32 trail meters per km² that became more or less a barrier for the wild reindeer, and the same figure for HNP is 28 trail meters per km² (Fig. 7). DSNP has the lowest density of trails, no trail segments with TUI > 80 visitors per day, and only 30

trail meters per km² reindeer range that may affect their movement negatively (TUI > 30–80 visitors per day).

4. Discussion

4.1. Tourism challenges the wild reindeer spatial needs

Our data show that visitors' use of large-scale simple recreational infrastructure like marked hiking trails, bridges, and tourist cabins have led to habitat fragmentation for the wild reindeer during the summer season. GPS monitored reindeer tended to use areas characterized by low TUI during both the low (Jun 15th –Jul 14th) and high (Jul 15th - Aug 19th) tourist season. The effects from recreational infrastructure and human disturbance on wild reindeer have been reviewed frequently in the past (i.e. [Reimers & Colman, 2006](#); [Vistnes & Nellemann, 2008](#); [Kjørstad et al., 2017](#)). In short, these studies indicate a range of wild reindeer responses, including individual and physiological responses, change in behavior (increased stress, activity, energy consumption, decreased time spent on foraging etc.), and avoidance effects in terms of changes in habitat use. Visitor infrastructure has in many cases been shown to lead to reduced use of habitat, a loss of foraging resources, and changes in old migration routes (less crossings, crossing delays or termination of crossings). Hence, management for reducing wild reindeer disturbance is about visitor management. Improved understanding of the visitors' spatiotemporal use and their characteristics is critical in designing effective and robust management interventions ([Scolozzi, Schirpke, Detassis, Abdullah, & Gretter, 2014](#)).

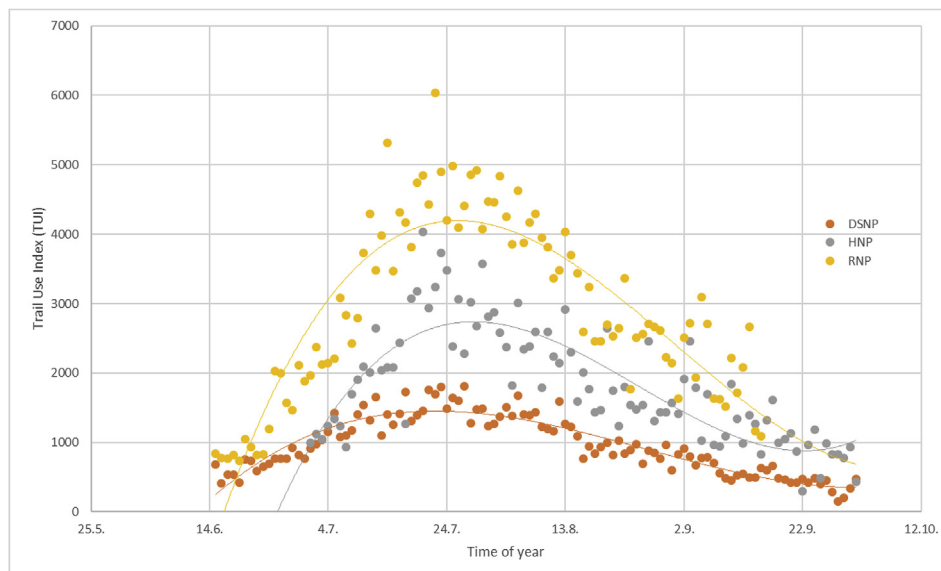


Fig. 2. Daily temporal variation in the Trail Use Index from June 15th to October 1st in Dovrefjell-Sunndalsfjella (DSNP) and Rondane (RNP) in the period of 2009–2016, and Hallingskarvet (HNP) in the period of 2010–2016.

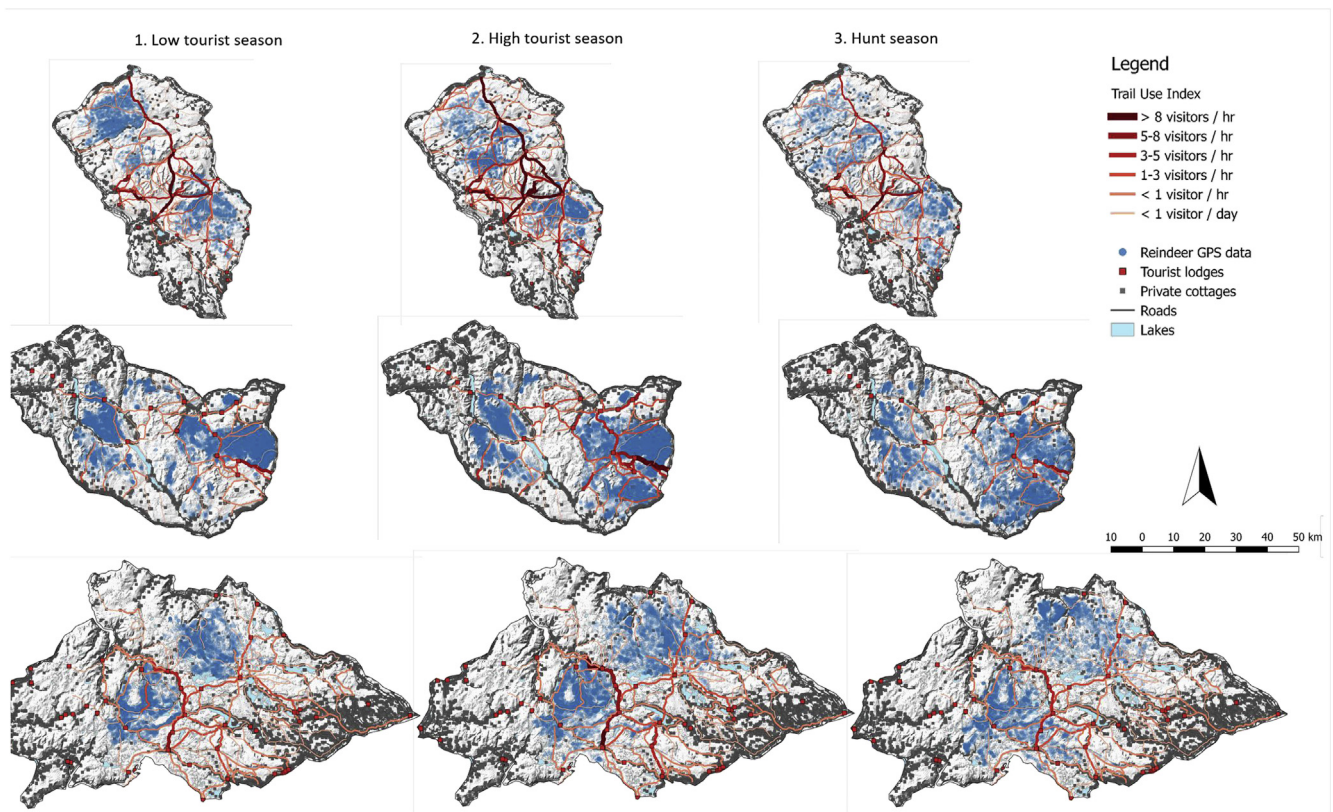


Fig. 3. Trail Use Index (i.e. intensity of use of trails - red lines) and density of reindeer GPS locations (transparent) in three national parks (a–c), in three periods: 1. low tourist season (Jun 15th - Jul 14th); 2. high tourist season (Jul 15th - Aug 19th); hunting season (Aug 20th - Sept 20th), from 2009–10 to 2017. Reindeer GPS locations refer to: 20 reindeer in Rondane-Dovre NP in 2009–2016; 25 reindeer in Dovrefjell-Sunndalsfjella NP in 2007–2016; 21 individuals in Nordfjella wild reindeer range in 2009–2016. The main topographical and hydrological features, and some of the main man-made infrastructures are visualized. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Some marked trails in the study areas have reached visitor levels that challenge the possibilities for reindeer to cross over the trails. In Norwegian NPs the number of tourists is largely determined by the availability and concentration of recreational infrastructure (Haukland et al., 2010), and therefore, areas without such facilities represent low tourist disturbance areas for reindeer. In particular, the western parts of DSNP and HNP host a favorable combination of relatively large areas with low tourist disturbance (since visitors concentrate in the eastern

parts), and preferred reindeer summer habitats (Panzacchi et al., 2015). This allows reindeer to avoid both intense tourist traffic and parasitic insects while using good grazing opportunities. Accordingly, Figs. 5 and 6 show that these areas have been intensely used by GPS monitored wild reindeer during the summer season. On the contrary, Fig. 4 shows that in RNP, areas with low density of trails and low tourist volume seem to be very limited. In addition, practically the entire RNP area is composed of preferred winter habitat, and only sub-optimal summer

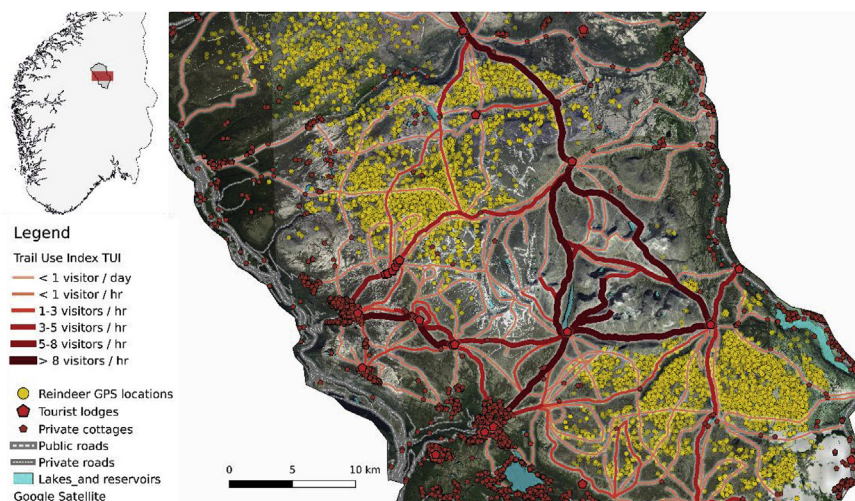


Fig. 4. Trail Use Index and location of 20 GPS monitored reindeer in Rondane-Dovre national park (RNP) area during high tourist season (Jul 15th - Aug 19th) in the period of 2009–2016.

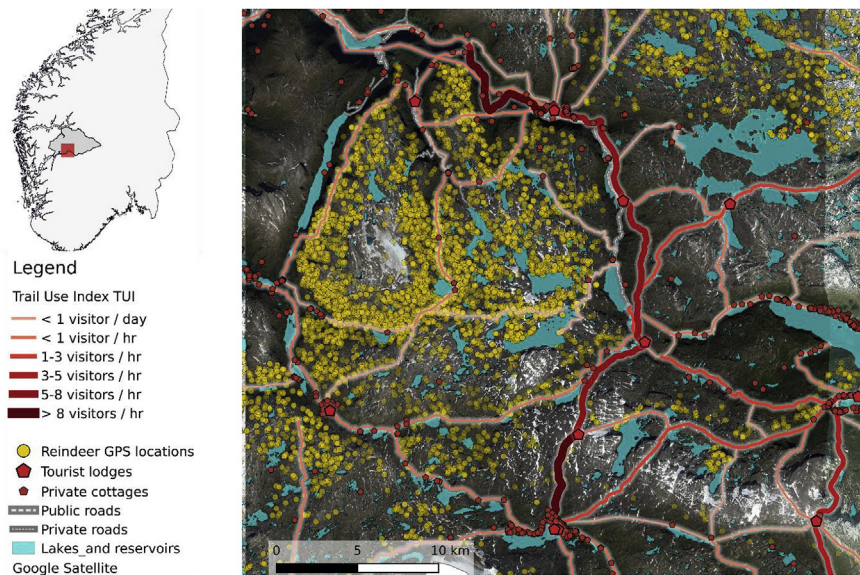


Fig. 5. Trail Use Index and location of 21 GPS monitored reindeer in Hallingskarvet national park (HNP) area during high tourist season (Jul 15th - Aug 19th) in the period of 2009–2016.

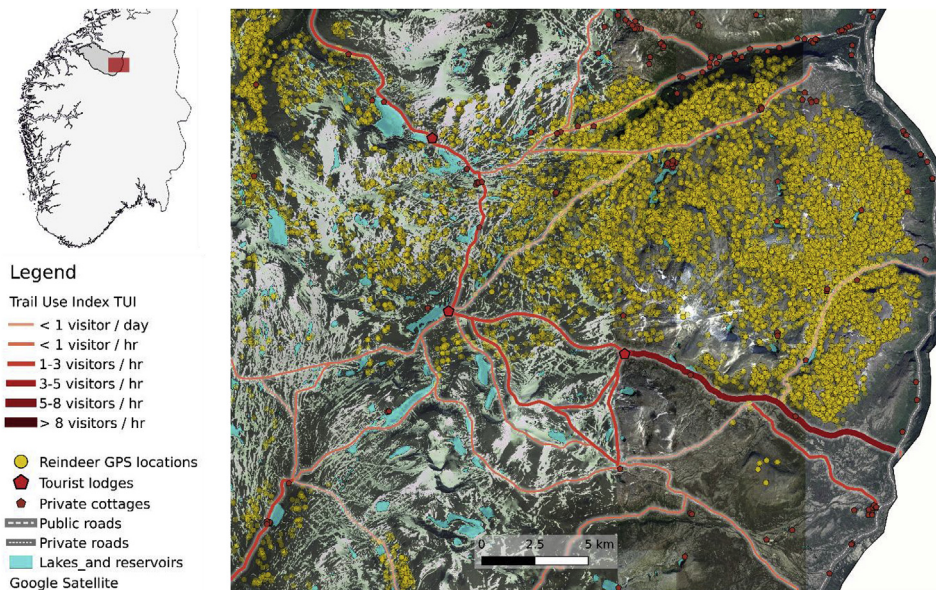


Fig. 6. Trail Use Index and location of 25 GPS monitored reindeer in Dovrefjell-Sunddalsfjella national park (DSNP) area during low tourist season (Jun 15th - Jul 14th) in the period of 2009–2016.

ranges (Panzacchi et al., 2015). Hence, in RNP the overall environmental conditions for reindeer seem to be very challenging, and the herds may be forced to avoid interactions with visitors at a more fine-meshed spatiotemporal scale. In particular, the popular hiking routes in the central part of RNP (Fig. 4), with associated tourist facilities and more than 250 visitors per day, prevent reindeer from using an area that could otherwise provide access to important seasonal resources. A study using archaeological data (pitfall traps and bow-stands used for reindeer hunting since pre-historic times), including our three study areas, showed that the avoidance of historic grazing areas and movement corridors has developed through time, since the industrial revolution, parallel to the increase in anthropogenic infrastructures (Panzacchi et al., 2013a). Several of the most important migration corridors were lost during the past centuries due to infrastructure development and disturbance (Panzacchi et al., 2016; Reimers & Colman, 2006; Skogland, 1986), resulting in fragmentation from two or three

large populations units before the industrial development to more than 23 more or less distinct populations today. The fragmentation process is still going on, not only by infrastructure development, but first of all by an increasing tourist visitation in the mountains (Strand et al., 2014). Despite the presence of 74 historical pitfall traps along the hiking route in the main tourist axis in RNP (suggesting historical use of this area), none of the GPS collared reindeer were crossing over the area since 2009. This strongly suggests that the route is not used anymore (Strand et al., 2014). This historical context serves as a macroscopic backdrop to the patterns of fragmentation and isolation we observe within our study areas in present day on a much smaller scale. Although, we did not analyze the spatiotemporal movements of reindeer in relation to tourist activities, one obvious explanation, supported by several previous studies in the same areas (op. cit.), is that the fragmentation is caused by presence of hikers. There is, however, a need for more holistic analyses to investigate the complex relationship between tourist

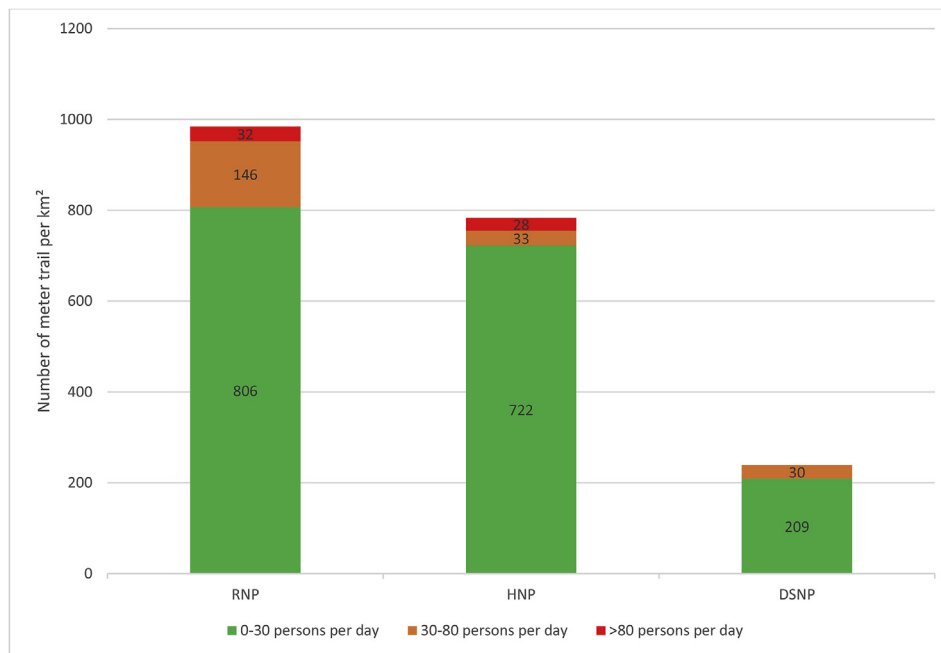


Fig. 7. Trail Use Index in three use intensity classes expressed by meter trail per km² wild reindeer range during high season: Jul 15th - Aug 19th in Rondane national park (RNP), Hallingskarvet national park (HNP) and Dovrefjell-Sunndalsfjella national park (DSNP).

behavior and infrastructure (e.g. trail density, daily TUI at trail segments) and the probability for reindeer trail crossing. These kinds of studies must consider the complexity of biotic (e.g. grazing resources, insect parasites) and abiotic (e.g. topography, waterways) factors that affect the spatial habitat use of reindeer herds.

Paradoxically, and on the contrary to the tourist seasons; during the hunting period (Aug 20th - Sept 20th) reindeer were scattered throughout a much larger area, and there is noticeable overlap with the area used by tourists and hunters. This response is remarkable, also considering that the number of hunters is consistently much lower compared to that of hikers. Previous studies demonstrated that during the hunting season, reindeer almost double their home range size, and, because of their increased movement rate, they get closer to infrastructures and cross trails more frequently, especially during night/early morning (Panzacchi et al., 2013a; Strand et al., 2013, 2014). Hence, during the hunting season reindeer appear to be in a “state of panic”, since almost one third of the population is harvested. Considering that reindeer live in herds often composed of hundreds or thousands of individuals, this implies that each herd is subjected to a high frequency of disturbance from the hunters that amounts to a higher disturbance pressure than that caused by tourism in this period.

4.2. Possibilities to manage visitors

Visitors' reasons for visiting Norwegian national parks can be as diverse as the visitor group itself. Numerous studies have investigated components of visitation behavior, such as individual factors (e.g. personality, preferences, motives, attitudes, lifestyle, socio-demography), social components (crowding, solitude, modern activities), environmental conditions (undisturbed, large areas), and management regime (e.g. restrictions, facilities). In the following we discuss a few key characteristics of the types of visitors that are often grouped together in NP tourism analyses, namely daytrip hikers, foreign and first-time visitors, and visitors that are tied to designated recreational infrastructure (Kajala et al., 2007; Manning, 2010; Mehmetoglu, 2007; Pierce & Manning, 2015; Pietilä & Kangas, 2015; Raadik et al., 2010).

Our results show that hiking is overwhelmingly the dominating activity in the three NPs (more than 90%). It should, however, be noted

that hiking often involves multiple additional activities such as photographing, watching wildlife, and geocaching, and that the hiker group is likely to be very diverse with respect to motivations and perceptions (Fredman & Heberlein, 2005; Haukeland, Grue, & Veisten, 2010). From an international perspective, Norwegian national parks hold (by law) seemingly pristine landscape qualities and few recreational facilities, which are qualitatively similar to designated Wilderness areas in the United States (Holt-Jensen, 1978). A substantial portion of the visitors expects and desires environmental factors like landscape naturalness, social factors such as solitude, and a management regime with low level of recreational facilities and infrastructure (Vistad & Vorkinn, 2012). In this context the legal protection of areas as national parks represents attributes that are important motivational factors for visiting the area because it prevents further recreational and commercial development (e.g. cabins, hotels) and associated infrastructure (e.g. roads, power lines) within the park. Consequently, construction of new tourism infrastructure and development of local attractions should – and may only – be located outside or in the fringe areas of the national park (Gundersen et al., 2015).

Data from our respondents showed that more than one third of all visitors were first-time visitors (both foreign and domestic; Table 2). First-time visitors are well-studied in international literature (i.e. Xiang, Chia-Kuen, Hyounggon, & Petrick, 2008). However, most of the literature focuses on a specific destination or point of interest, where visitors stay for days and go out-and-back from the point of entry. In Norway the most common mode of visiting national parks is to hike a long loop, which is not as well reported in the literature (Mehmetoglu, 2007). There are reasons to believe that first-time visitors and regular visitors are different in various aspects of their behavior (Xiang et al., 2008), and first-time visitors are generally more diverse (e.g. Cohen, 2003). For example, first-time visitors include both those who planned their visit and those who paid visit during an unplanned stop during a longer round-trip. First-time visitors hence differ significantly with regards to their knowledge about the national park, and may, in general, be easier to guide or direct by management actions. For managers, an important point is understanding how these visitors obtain information about the park. As first-time visitors always need information about specific attractions and hiking alternatives, there is a great potential for

managers to funnel this group of visitors to certain areas (Fredman, Friberg, & Emmelin, 2007; Haukeland et al., 2013). Several NP visitor studies from Norway during the last years have documented that the visitors primarily seek hiking suggestions, maps, special attractions, and difficulty ratings, and that they prefer to find the information on the internet and on signboards at the parking lot (e.g. Selvaag & Wold, 2018; Vistad, Selvaag, & Wold, 2018). These studies also confirm that first-time visitors seek information more frequently than the experienced visitors. Managing these two groups in a way that cause limited impact on the reindeer populations might therefore require different approaches. Earlier studies indicate that regular visitors to a larger extent hike off-trail and to a larger extent intermix with the core reindeer areas (Gundersen et al., 2015). Furthermore, overnight visitors at Iceland have lower tolerance for crowding than day visitors (Cságoly, Sæþórsdóttir, & Ólafsdóttir, 2017), which could be because regular visitors tend to stay longer at a destination (Xiang et al., 2008). A larger part of the day visitors belongs to the urban end of the recreational opportunity spectrum and have stronger preferences for destination settings that provide facilities and services (Pierce & Manning, 2015; Tverijonaitea et al., 2018). Consequently, an increased number of day visitors to an attraction or a specific area often causes a decrease in the number of overnight visitors (Cságoly et al., 2017). Whether this crowding effect pushes regular and overnight visitors further into the park is an interesting hypothesis that should be explored by future studies, as it could have negative consequences for conservation values.

Our data show that visitors are strongly tied to simple recreational infrastructure in the three NPs. There is a trend in the Nordic countries that entrance facilities, marked trails, bridges, lookouts and signs, and tourist cabins have become more important for the visitors (Haukeland et al., 2010; Tverijonaitea et al., 2018; Wall-Reinius & Bäck, 2011). The most used trails are in entrance areas with well-known attractions (heritage places, summits, landmarks) or in areas with larger tourist cabins. Such pull factors are attributes that make it worthwhile to visit the NPs for many visitors and are among the most promising ways to channel visitors towards less vulnerable areas (Flemseter et al., 2018). Furthermore, our results show that large wilderness-like areas in the NPs have a very dispersed use and little to no recreational infrastructure. Off-trail users include adventurers and wilderness seekers, visitors participating in fishing, hunting and berry-picking, and locals, for example with grazing rights in the national parks (Gundersen et al., 2015). To balance the need for visitor satisfaction and nature conservation in national parks it is critical to have knowledge about visitor tolerance/preferences for facilitation and for values like solitude, remoteness and isolation (Scolozzi et al., 2014). Most of the research on NP users have focused on their motivations and perceptions, but have rarely related these factors to their preferences for management (Haukeland et al., 2013; Vistad & Vorkinn, 2012). The core question in the NP areas is: What kinds of visitor impacts are acceptable on wild reindeer populations, and where? The process of defining limits of

acceptable change in Norwegian NPs has up to date solely been based on knowledge on ecological effects and the resilience of ecosystem and species to disturbance (Haukeland et al., 2013), and not on an understanding of users' perceptions, tolerance and preferences of the effects of tourism (Vistad & Vorkinn, 2012).

The socio-ecological interrelations in NPs are complex. They include both human-human and human-nature interactions that may cause challenges and unpredicted outcomes for managers. Managing this complexity requires a spatial zonation approach that caters to the different needs of visitors along the push-factor spectrum. Push motives can be viewed as indicators of destination loyalty (Yoon & Uysal, 2005), which has strong marketing implications. Factors that have been associated with tourists' motivation to visit NPs are an enhanced social status, the desire to escape, relax, socialize, and self-improve, and a search for diversity, knowledge expansion, adventure and unique experiences (Haukeland et al., 2010; Leask, 2016; Mehmetoglu, 2007). At the same time, it is important to consider pull factors as visitors need to know where their goals and preferences can be achieved. Large increases in visitor numbers to Nordic NPs have led to a rapid and largely unplanned expansion of infrastructure and services in the entrance areas. Many of the new services are in the urban end of the recreational opportunity spectrum (Tverijonaitea et al., 2018), and inevitably include levels of infrastructure not previously seen in Nordic NPs nor handled by their laws and statutes. To handle the growth in visitor numbers, their preferences for services, and the subsequent changes in the recreation industry, there is an urgent need for a comprehensive strategy that balances development with conservation values. Spatial zonation within the national parks may be the best solution to maintain conservation values and meet the demands for experiences by tourists. In this effort, an important first step is to propose units with different levels of recreational qualities that satisfy the expectations of the different visitor groups in a way that minimizes conflict with conservation (Cságoly et al., 2017).

4.3. Implications for tourism management

Our study shows that wild reindeer space use is negatively affected by high density of trails in NPs, and by a high intensity of use of each trail. Based on this and comprehensive theories/experiences on wilderness management zoning, especially the ROS and LAC concepts, from different parts of the world (Manning, 2010), we suggest a large-scale spatio-temporal zoning regime to minimize the adverse effects of recreation on wild reindeer (Table 3). Some areas are characterized by low number of marked and unmarked trails with low visitor volumes and tend to be more intensely used by reindeer during summer. The proportion of visitors classified as "high wilderness purists", with preferences for solitude and minor facilities, use more frequently these areas (Vistad & Vorkinn, 2012). We name these areas **Wilderness areas**. Second, in a large part of the wild reindeer range there may be a higher

Table 3
Principal strategies for categorizing visitors and management characteristics of the three zones defined in the study.

Attributes/Area zone	Wilderness	Backcountry hiking	Entrance
Reindeer – tourist interaction	Refuge-wilderness	Intermixed	Avoidance - Developed
Typical recreational motivation	Wilderness/solitude experience Subsistence harvesting Herding	Nature experience Doing different activities	Attractions Social
Trail density	Very low	Low-High	High
Visitor volume	Very low	Low-High	High
Visitor strategy	Push (-Pull) factors	Pull (-Push) factors	Pull factors
Management concept	Non-development Restoration	Manipulation Negotiations	Developing
Management actions	Remove infrastructure that have impact on wild reindeer (marked trails, bridges, cabins, power lines etc.)	Remove or move infrastructure that have impact on wild reindeer (marked trails, bridges, cabins, power lines etc.)	Construct new infrastructure and facilities to attract people to less vulnerable areas

potential for co-existence with visitors (mostly hikers). We have named these areas **Backcountry hiking areas**. The third zone includes mostly fringe areas that wild reindeer avoid to a large extent during summer, due to a very high concentration of infrastructure and anthropogenic disturbance. These areas typically host a high proportion of visitors classified as “low wilderness purists”, which are often first-time national or foreign visitors doing daytrips or short walks (Gundersen et al., 2015; Vistad & Vorkinn, 2012). We have named these areas **Entrance areas**, including tourist destinations and attractions. Both DSNP and HNP have very large wilderness areas that seem to function as refuge areas for wild reindeer during peak tourist seasons, while in RNP the tourists and wild reindeer overlap to a higher degree. We discuss these differences and their implications for wild reindeer conservation, and management possibilities considering the visitors’ recreational preferences.

In *Entrance areas*, characterized by practically no overlap between space use of wild reindeer and tourists, “pull strategies” could be a suitable tool to attract and channel tourists towards non-problematic areas. Such management strategies would fit well with a dominating trend in tourist behavior, the preference and demand for designated infrastructures, attractions and basic facilities (e.g. Haukeland et al., 2010; Veisten, Haukeland, Baardsen, Degnes-Ødemark, & Grue, 2014; Wall-Reinius & Bäck, 2011). Mountain tourism destinations provide a wide range of local qualities and attractions that can act as “pull factors” for potential tourists (e.g. scenic viewpoints, heritage sites, peculiar landscape characteristics), all regarded as important attractions in Norwegian NPs (Haukeland et al., 2010; Mehmetoglu & Normann, 2013). A strategy focusing on “pull” factors would also be in line with the new visitation policy and management of Norwegian NPs (Norwegian Environment Agency, 2015). A comprehensive approach to attract and manage visitors in mountain areas is about to be developed, including plans for the construction of tourist infrastructures at the main entrances of NPs, and branding and marketing strategies for the NPs (Norwegian Environment Agency, 2015), for example through strategic infrastructure planning such as visitor centers, viewpoints, natural and cultural heritage sites, information boards, marked trails, campsites and bridges (Haukeland et al., 2010). Infrastructure development is expected to attract and concentrate visitors in specific areas by providing service facilities, while other areas are expected to be safeguarded as valuable wild reindeer habitats. However, pull factors interact intimately with individual push factors, e.g. since tourist infrastructures and development impact negatively on the experience of those who are seeking “wilderness” or “authentic” experiences in nature, and/or prefer solitude (Fredman, Wall-Reinius, & Grundén, 2012; Raadik et al., 2010; Vistad & Vorkinn, 2012). Hence, it is also important to provide and brand wilderness areas for such visitors in fringe areas outside refuge areas for wild reindeer. A future development of *Entrance areas* may to a larger extent also include possibilities for the visitors to reach semi-wilderness areas close by, to avoid that regular visitors experience crowding and thus, seek new and more vulnerable areas further into the mountain.

In *Backcountry hiking areas* the management is very much about trail management, since most of the visitation is tied to marked trails. Trail restrictions and manipulation of trail-related infrastructure would affect visitor categories highly connected to these kinds of infrastructure, like cabin-to-cabin tourists, foreign visitors, females, and first-time visitors (Gundersen et al., 2015). On the other side, different types of area restrictions in space and time will hit or provoke visitors dominated by local users, those doing subsistence and recreational harvesting (hunters, fishers, berry-pickers), local farmers tending their livestock, and wilderness seekers. The implementation of area regulations is highly controversial in Norway, since the *Outdoor Recreation Act (1957)* grants open access to non-motorized activities and free roaming in all uncultivated land for hikers, skiers etc. The *Nature Diversity Act (2009)* explicitly states that this right applies generally, including NPs. But there is still a possibility to introduce regulation of activities such as

hiking, biking etc. in certain zones or in certain periods, if a conservation goal listed in the local protection regulations is threatened, even in a NP. Currently however, very few such regulations are in action, in any Norwegian NP (Gundersen et al., 2015). In the present Norwegian NP management system, such regulations cannot be based on a tradeoff between visitor preferences and conservation goals but be based on scientific findings concerning the vulnerability and protection needs of the actual species.

In *Wilderness areas*, where management strategies should aim at reducing disturbance of reindeer, we suggest managing trails to keep visitor volumes below the threshold of 30 visitors per day during the tourist seasons. However, we cannot look at this strategy in isolation. If total visitor numbers remained constant it would merely shift the distribution of the excess people (i.e. those that exceed the 30-visitors-per-day quota) to other parts of the park and increase TUI at those trail segments. To address these issues, further research is needed on how to channel people to new areas voluntarily in a manner that is not at odds with reindeer conservation priorities where tourist volume is less than 30 visitors per day, management authorities could start monitoring the trails and, if needed, consider different measures to keep the volume below the suggested threshold. Several push measures are possible, depending on the local situation, including providing information to the visitors about the wild reindeer and their spatial needs of resources, branding/marketing alternative routes for the tourists, remove signs and marks along the trails, or manipulate the entrance including removing or decrease the car parking area. If such measures are insufficient for attracting wild reindeer to use the area, the authorities should consider removing the trails from the refuge area. Wild reindeer occur in many NPs and other protected areas in southern Norway, and a sustainable long-term management strategy should aim at avoiding further development of recreational infrastructure and other facilities that might stimulate increased visitation of the area.

Our study is based on an extensive data set on tourists and reindeer and highlights several macroscopic management issues that require immediate attention. Given the importance of landscape connectivity for population viability, and the amount of economic interest involved, this study also highlights the urgent need to perform further in-depth analyses on reindeer-human interactions in a spatiotemporal framework. The analysis would benefit from local knowledge, and should focus on the year-round, cumulative impact of all infrastructure and sources of human disturbance. Recent work has laid the basis for zonation by identifying the impact radius of a range of infrastructure and sources of disturbance (e.g. Panzacchi et al., 2013a; Panzacchi et al., 2013b; Panzacchi et al., 2015; Panzacchi et al., 2016), and major research efforts are currently aiming at identifying functional areas for reindeer.

Critics of ROS, LAC and similar concepts argue that these are expert-based, rational planning frameworks that emphasize the setting (site, facility design), at the expense of who the visitors are and what they seek (e.g. Pietilä & Kangas, 2015; Raadik et al., 2010). This criticism might be even more relevant in the Norwegian NP management system where the term “differentiated management” only means regulation of visitors based on scientific knowledge about vulnerable species and key habitats for vulnerable species (Gundersen et al., 2015). In the present Norwegian management system, the possibility for regulating hikers and visitors in vulnerable reindeer areas within NPs, has hardly ever been implemented. The reason is probably the deeply grounded tradition and respect for the public right of access to the outdoors, that goes back many hundred years.

5. Conclusion

Based on the macroscopic evidence of tourist-reindeer interactions, a large range of previous studies, and ongoing investigations on reindeer-tourist interactions at finer spatiotemporal scales, we recommend management authorities to adopt push-pull strategies to attempt

harmonizing the apparently contrasting goals of increased sustainable tourism and reindeer conservation in mountain areas. We identified three management zones where we suggest specific management strategies. *Wilderness areas* are crucial for wild reindeer through the peak tourist season in July and August, before the hunting season. In these areas management authorities are highly recommended to avoid construction of new facilities and infrastructure in the future, and even by re-wilding the area by removing trails and other infrastructures hampering reindeer space use in some places. In this context, Fig. 3 shows several trail segments that need to be considered removed or include some level of travel restrictions. In *Backcountry hiking areas*, where tourist and wild reindeer space use overlap to a higher degree, both push and pull strategies could be used to improve the conditions for wild reindeer. This would include moving a few problematic trails to areas of lesser importance for reindeer, thereby “pulling” people towards areas of lesser conflict. In the third category, *Entrance areas* outside of protected or core reindeer areas, there could be more possibilities for land management to develop recreational infrastructures. Such measures are expected to reduce pressure in backcountry hiking and wilderness areas and keep visitors in the fringe areas that wild reindeer already avoid. This may both reduce tourist pressure in more vulnerable areas, and increase the visitor volume in Entrance areas, thus promoting local economies. Because “wilderness and solitude seekers” will find these areas less attractive, it is also important to identify smaller wilderness areas close to the entrances. Future studies should identify the mechanisms driving the spatiotemporal dynamics of tourists-reindeer interactions. Such information would make us better equipped to accommodate the requirements from both tourists and wild reindeer.

Author contributions

Vegard Gundersen: Project leader social science, study design, main writer social science, co-writer ecology.

Odd Inge Vistad: Co-writer social science.

Manuela Panzacchi: Data analyses, maps, co-writer ecology.

Olav Strand: Project leader GPS reindeer, co-writer ecology.

Bram Van Moorter: Data analyses, maps, co-writer ecology.

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< au id="au4" > **Olav Strand**: Mountain ecology, population ecology, grazing ecology, predation, conservation biology, mammals, wild reindeer, polar fox.



< au id="au5" > **Bram Van Moorter**: Spatial ecology, animal space use and movement, ecological connectivity, psychology, modelling of socio-ecological systems, agent-based modelling, modelling adaptive management.