The Hardangervidda wild reindeer herd: a problematic management history

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Abstract: The unique and internationally important wild reindeer *Rangifer tarandus* herd on the Hardangervidda plateau of southern Norway has shown frequent and extreme fluctuations in harvest numbers for the past 60 years, despite considerable effort to stabilize the herd size at a winter carrying capacity of 9000 – 12 000 animals . In the absence of large mammalian predators, herd size is managed through hunting. Here we attempt to unravel the causes of the management problems related to this population by examining the relative roles of historical, biological and management-related processes. From 1900 - 1950 the population remained mainly low due to a combination of generous harvest quotas, poaching and competition from domestic reindeer. From 1950 - 2012 three extreme harvest peaks of between 4500 - 9500 animals occurred, followed by three equally extreme troughs including two shorter periods of total protection. This extreme harvest fluctuation contrasts with the estimated annual harvest of 2300 - 3000 needed to stabilize the winter herd between 9000 - 12 000 animals. We conclude that this population has been difficult to manage mainly because of 1) a management based on frequently unreliable population data on herd size (especially before 2001), 2) lack of in depth analyses and evaluation of both recruitment and sex and age composition and 3) a low and highly variable harvest success (harvest/quota) due mainly to poor hunter mobility, a disadvantage when reindeer must be harvested from large flocks that constantly move upwind, seeking refuge on small areas with few hunters. More reliable population data to create better harvest models plus increased hunter mobility are necessary to attain a more sustainable herd size, implying an improvement of the current herd survey methodology available to local reindeer boards. Finally, a critical and independent evaluation of the scientific methodology employed to study and manage this herd is needed.

Key words: Hardangervidda; harvest success; hunting; landowners; management; population dynamics; *Rangifer tarandus;* wild reindeer.

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Introduction

In the absence of population controlling predators, wild reindeer (*Rangifer tarandus*) (hereafter reindeer) herds in Norway are managed by hunting to maintain harvestable populations at desired densities. The target population density is set in relation to estimates of food availability, in particular that of grazing-sensitive lichens which are the preferred winter forage (Gaare, 1968; Gaare & Skogland, 1975, 1980; Skog-

land, 1984b, 1989b). This harvest adjustment to the food resource was instigated following severe overgrazing in the wake of an uncontrolled increase in the Snøhetta herd in the early 1960's (Jordhøy, 2001). The extent to which wildlife managers are able to adjust harvest levels to stabilize the population size will largely depend upon the following factors. First, continuous and reliable population estimates which may be hard to obtain, even when considerable resources are invested (Strand *et al.,* 2012). Second, population estimates will not include annual variation in reproduction rates or neonatal survival rates when the surveys are made before the birth pulse. Third, when the desired harvest is based on annual quotas, harvest success (proportion of the quota harvested) will often show considerable variation. These management problems have been pointed out repeatedly in the past (Skogland & Bendiksen, 1984; Skogland, 1989a; Strand *et al.,* 2004), and resources have been allocated in an attempt to meet the requirement for stable and sustainable herd size of the 23 reindeer herds in southern Norway. Implemented management measures following the Snøhetta case have stabilized herd size in many areas, preventing dramatic herd fluctuations and severe overgrazing. An example among the better managed herds would be the Forelhogna population where harvest by sport hunters has proven sufficient to regulate population size (Strand *et al.,* 2012).

The Hardangervidda plateau in southern Norway is home to the largest wild reindeer herd in Europe, a population both unique and internationally important in virtue of its size, relatively intact nomadic behavior and location in Norway's largest national park. It is more than twice the size of the next largest Norwegian herd in Rondane (Bevanger & Jordhøy, 2004) and of considerable economic and recreational value for landowners, hunters and non-hunters alike. Consequently, high-quality management of the population including a stable winter herd size within carrying capacity limits, plus stable and high harvest success would be expected. However, a review of the harvest history of this herd for the past century reveals a pattern of extreme and highly erratic variation in both herd size and annual harvest, *i.e.* a result incompatible with management expectations.

Here we attempt to unravel the causes of the management problems related to this population in the years prior to 2001 by examining the relative roles of historical, biological and management-related processes as drivers of the herd dynamics. Specifically we 1) review the management history of the Hardangervidda reindeer herd as part of the framework for explaining its persistent management problems, 2) use a regression model to help explain the relationships between hunting quotas and the number of reindeer harvested, 3) attempt to model the herd size change from winter 2001 when a reliable herd size estimate was obtained, as a basis for comparison with other estimates of winter herd size employed in the management of this population and 4) discuss how meteorological events, landownership patterns and changes in hunter behavior may be influencing hunter success and thereby the achievement of management goals.

Material and methods

Study area

The Hardangervidda plateau (hereafter Hardangervidda), located in southern Norway (60° 25´N; 9° 15´E) (Østbye *et al.,* 1975), covers approximately 8200 km^2 of alpine habitat, mostly between 1100 and 1300 m a.s.l. Forty-two percent of Hardangervidda (3422 km^2) is located within the Hardangervidda National Park, and most of the area is remote and accessible only by foot. However, during the hunting and gillnetting season, seaplanes and helicopters are allowed to land on specific lakes or sites, and 4-wheel-drive vehicles may be used to transport

fish and game out of the mountains along designated tracts. Otherwise, almost all motorized traffic is forbidden on Hardangervidda. Hunting is allowed within the park.

The herd is of mixed wild and domestic origin (Reimers *et al.,* 2012) and is reported to have gone through substantial temporal genetic alterations during the period from early medieval times to the present, in particular during the 19th and 20th centuries when reindeer husbandry was practiced in this mountain region (Enerstvedt, 1993; Røed *et al.,* 2011). The golden eagle (*Aquila chrysaetos*), a known predator on reindeer (Nybakk *et al.,* 1999; Nybakk *et al.,* 2002), occurs regularly here, though larger mammalian carnivores were functionally exterminated from the area in the mid- and late -19th century. Although wolf (*Canis lupus*), brown bear (*Ursus arctos*), lynx (*Lynx lynx*), and wolverine (*Gulo gulo*) are recovering in parts of Norway (Swenson *et al.,* 1995; Wabakken *et al.,* 2001), they are only irregular visitors to Hardangervidda. An exception is the wolverine that occasionally breeds here or in neighboring mountain areas (Persson & Brøseth, 2011).

The management system

Reindeer herds in Norway are currently managed through quota-regulated recreational hunting. The annual quota for each herd is determined through a two-step process. First, a local reindeer board (Villreinutvalget) representing both private landowners and public land managers (the right to hunt belongs to landowners in Norway, both private and public) proposes a hunting quota based on best available information on herd size, sex and age structure, recruitment, and desired population size. This quota must then be approved by a regional reindeer board (Villreinnemnda). The members of the regional reindeer board are appointed by the Directorate for Nature Management (DN) following recommendations from the various municipalities encompassing the reindeer management unit. DN is the leading professional environmental authority in Norway. The regional board acts under instruction of a county governor. Finally, the hunting quota must be approved by DN. (On 1 July, 2013, DN became the *Norwegian Environment Agency*. In this study however, we use the old agency designation, *i.e.* DN.)

This quota is then divided among landowners in proportion to the size of each estate, relative to the size of the entire reindeer management area. Because individual mountain estates in Norway tend to be small, landowners often form estate conglomerates that often comprise many landowners. This increases the mean size of "hunting units" (*i.e.* single estates or conglomerates of estates). The larger a hunting unit is, the greater the probability of there being reindeer there during the hunt. Within the 7994 km^2 Hardangervidda reindeer management area there are presently 145 hunting units (*vald* in Norwegian) (Bevanger & Jordhøy, 2004). At the start of the hunting season, hunters are usually obliged to hunt only within their respective hunting unit boundaries. Hunters often experience that the smaller hunting units in particular are devoid of reindeer. However, in recent years hunter mobility has improved as hunters that have initially been unsuccessful on their own hunting units, towards the end of the hunting season have increasingly been allowed access to other units where reindeer have concentrated. Hunting permits are issued to hunters either as calves, females/yearling males, or adult males. Females and yearling males comprise a pooled group since they are difficult for hunters to distinguish between. Presently, the hunting season is from 20 August to 30 September.

Humans have hunted reindeer on Hardangervidda for seven-eight thousand years (Indrelid, 1985) following the last glaciation and nearly continually for the past century (Fig.1, Table 1). Up until 1954, efforts to manage

Table 1. Summary of events that have had an impact on the size and management of the Hardangervidda wild reindeer herd from 1902 – 2012. The point in time for each event is shown in Fig. 1.

Event no.	Year	Event
1	1902 - 06	Reideer hunting banned throughout Norway; considerable poaching suspected.
2	1930	A new system to determine the hunting quota and its distribution to landowners is implemented. One animal per 20 Km^2 of reindeer habitat could now be shot, i.e. the previous quota of 3 animals per hunter on state land was abolished. Poaching is still prevalent.
3	1954	Impementation of the first aerial winter census of the herd. Poaching still a problem.
4	1957-70	Termination of domestic reindeer herding in Hardangervidda in 1957, followed by a 3-fold increase in herd size by 1965, and a major herd reduction between 1966 and 1970.
5	1969	The first aerial summer census of the herd is conducted.
5	1969	First collection of jawbones from hunter-killed reindeer to determine age composition and relative condition.
6	1971-72	Hunting is banned.
7	1974-79	Implementation of the first five-year management plan that set the winter herd size to 10 000 animals.
8	1979	Implementation of annual calf counts and autumn herd sex and age composition.
9	1981	Establishment of Hardangervidda National Park.
10	1983	Extensive winter sampling of the herd realed poor condition, low reproduction and high calf mortality.
11	1991	Start of NINA`s National Cervid Monitoring Program that for Hardangervidda included annual calf recruitment estimates, sex and age composition counts and collection of mandibles for condition.
12	1990 - 94	Management plan set the winter herd to 9000 animals.
13	1995 - 99	Management plan set the winter herd to 10 000 animals.
14	1999 - 2000	NINA estimates the herd at 12 000 - 14 000 winter animals based on model simultation.
14	1999	First radio-tagging of reindeer.
15	2004	Hunting is banned for one year.

the population based on established scientific methodology were sporadic. Since then, the population has been monitored more regularly to provide estimates of herd size, sex and age structure, recruitment and physical condition.

Data sources and statistical analyses

Data on annual hunting quotas and the number of reindeer harvested were retrieved from official Norwegian hunting statistics (Statistics Norway). Data on estimates of herd size, sex and age composition, and management measures were retrieved from various reports provided by DN, the Norwegian Institute for Nature Research (NINA), and the local reindeer board for Hardangervidda (see text to Fig. 2 for references).

We used least squares linear regression models to measure the predictive strength of the hunting quota for the harvest. Means are shown with ± 1 standard deviation.

The extensive data acquired by NINA on recruitment and herd composition over 20 years have apparently not been tested in population models. An accurate herd survey conducted in winter 2001 when the local reindeer board succeeded in obtaining a reliable herd size estimate of 5,200 animals (Lund, 2001) serves as the basis for such a population model test, applying recruitment and herd composition data from Solberg *et al.* (2012), Reimers (2012) and twenty annual NINA reports (1991-2011) published in the journal *Villreinen*. We used their data on recruitment rates (calves per 100 females 1+ yr, plus year-

ling males) recorded in summer from air photographs of reindeer groups encountered and on herd structure in October (calves, females 1+ yr, yearling males, 2-yr-old males and males 3+ yr) in an attempt to compare the herd size increase from winter 2001 in three model scenarios involving different yearling proportions in the estimated herd recruitment rates. Up until 2005 NINA maintained that their recruitment rates estimated calves per 100 females 1+ yr and that they were able to exclude yearling males from their estimates (see Reimers, 2006).

Females in this area normally breed for the first time as yearlings (their second autumn) and give birth as 2-year-olds (Reimers, 1983). As our model comparisons focus on recruitment and estimated number of yearlings year N-1 converted to 2-year-olds year N, and an assumption of similar survival of yearlings from year to year, we do not vary the yearling mortality as a factor in the model. As the Solberg et al. (2012) recruitment rates include both yearling males and yearling females that were calves the preceding year and hence did not reproduce, we recalculated the recruitment rates to estimate calves per 100 females 2+ yr. According to the NINA reports, calves made up approximately 20 % (mean = 19.8 ± 2.3, range = 14.0 – 22.8) of the herd after the hunting season over the 20-year period. The recalculated recruitment rates follow from:

$r = rp/(1 - (y/(f + c)))$ (I)

where r = recalculated recruitment percentage (calves per 100 females 2+ yr), rp = Solberg et al. (2012) recruitment percentage, y = yearling percentage that takes either the value 0 indicating no yearlings, 10 indicating 10 % yearlings and 15 indicating 15 % yearlings in the groups (e.g. scenarios labeled NINA 1 - 3 in Fig. 5), f = percentage females 1 yr+, and c = the percentage calves in the October structure, both in year N – 1.

In order to model the three scenarios, we also needed an estimate of natural mortality following the hunting season. Since no data concerning winter mortality in different wild reindeer herds have previously been obtained, we have used the figure of 5% from domestic herds (Rehbinder, 1975). The herd estimates follow from the model:

$h_2 = (h_1 + ci - ha - m)(yr = N)$ (II)

where h_2 = winter $herd_{(yr = N+1)}$, h_1 = winter $herd_{(yr = N)}$, ci = calf increment $h_1 * f/100 * r/100$, ha = harvest, m = mortality set at 5 % of herd size after the hunting season.

Results

Herd size history 1890 – 1970

There are few written accounts of the reindeer herd between 1890 and 1950. During this period the official reported harvest was low (Fig. 1), though the statistics are believed to be unreliable due to poaching and insufficient reporting. Introduction of the Wildlife Act of 1899 set the hunting season for reindeer to 15 August - 14 September. Hunters on state land were permitted to kill three animals per hunting license, while on private land there was no limit. Overexploitation led to total protection of the herd from 1902 – 1906 (NOU, 1974) (Table 1). The harvest increase from 1907 to a peak in 1916 of about 1000 animals reflects a corresponding herd increase following this 5-year hunting ban (Fig. 1).

Domestic reindeer herding on Hardangervidda was initiated in 1783 (Tveitnes, 1980) and became extensive towards the end of 1800 (Enerstvedt, 1993). The Mountain Pasture Committee (Fjellbeitekomiteen, 1911) estimated the wild reindeer herd on Hardangervidda in 1911 to be 10 000 animals in addition to the 11 000 domestic reindeer present then. From 1916 to 1930 the number of wild reindeer declined to about 2000 - 3000 (NOU, 1974). Lack of resources for game law enforcement invited poaching and conflicts with domestic reindeer herders apparently contributed to keep the herd at a low level.

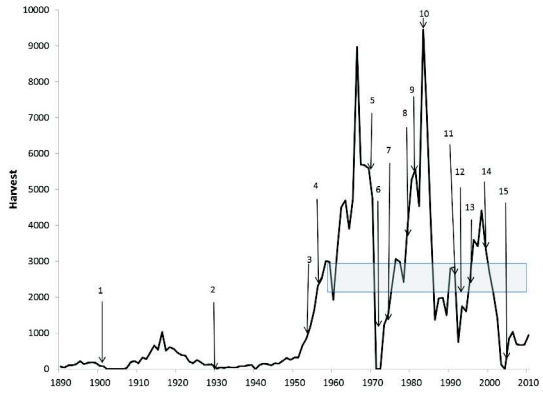

Figure 1. Harvest data for the Norwegian Hardangervidda wild reindeer herd for the period 1890 - 2010 based on official hunting statistics. The vertical arrows indicate when various management measures were implemented (see Table 1 for a detailed description). Shaded rectangular area indicates the harvest range of 2300 - 3000 animals predicted to be necessary for maintaining a carrying capacity winter herd of 9000 - 12 000 (Svein Erik Lund pers. comm.).

In 1930, the quota of three animals per hunter on state land was abolished. Instead, an area-based quota system was established whereby one animal could be shot for each 20 km^2 of reindeer habitat. During the 2nd World War (1940 - 1945) legal hunting was terminated. The combination of small harvest quotas plus incursion from the domestic herd led to a rapid increase in the reindeer herd from 1945 to 1960. Skogland (1989b) estimated the herd to be 12 000 animals during the winter of 1954. This increase was followed by a harvest increase which peaked at 8972 animals in 1966 (Fig. 1).

As a result of problems with the increasing wild reindeer herd and the termination of grazing contracts with land owners, the last remaining domestic reindeer company (Opdal Renkompani) closed down and slaughtered its herd of 1446 animals in 1957 (Enerstvedt, 1993).

From 1954 the wild reindeer herd continued to increase, reaching an all-time high of around 26 000 animals in winter 1965 (Skogland, 1989a, 1990b). Thereafter followed a dramatic harvest increase and herd decline that terminated in a hunting ban in 1971 and 1972 (Figs.1 and 2).

In the 1960's a more scientific-based management was introduced including herd counts, collection of mandibles and carcass weights for analyses of animal condition (Table 1) and hunting quotas specified by sex and age. Based on the estimated supply of winter lichen forage (Gaare & Skogland, 1975, 1980; Skogland, 1980, 1984b) the management objective was set at a winter herd size of 10 000 – 12 000 animals. During the 1969 and 1970 hunting seasons, lower jaw bones were collected for an evaluation of animal condition and herd age structure. This was repeated in 1973 and 1974, and annually from 1991 (Solberg *et al.,* 2012).

Herd size history 1970 – 2011

In 1979 annual composition counts from the ground in October were first implemented recording calves, females 1+ years, yearling males, 2-yr-old males and males 3 +years in all groups encountered (Solberg *et al.,* 2012). From 1987, calf recruitment was recorded from air photographs of reindeer groups encountered during summer. From 1991 these composition counts became a standard part of the National Cervid Monitoring Program financed by DN and implemented by NINA as the institution responsible for monitoring herd size of the Hardangervidda reindeer herd, plus six other wild reindeer herds in southern Norway (Solberg *et al.,* 2012). The purpose was to supply both the local and regional reindeer boards plus the central authorities (*i.e.* DN) with relevant data to assist in management of the herds.

In 1973 DN introduced the two-part reindeer tagging system whereby once the animal was killed, the hunter filled in the date, sex and age of the animal on the part of the tag that should be attached to the carcass during transportation, thus preventing more than one use of the permit. At the same time, the law enforce-

ment system was improved on Hardangervidda primarily through an increased number of game wardens (Dale, 1989). These two management measures facilitated a better control of the harvest, while NINA's October herd composition counts and June/July recruitment program were instigated to provide the biological data considered necessary for sound management of the seven major wild reindeer herds in southern Norway (Solberg *et al.,* 2012). After a hunting ban in 1971-72 the herd increased more rapidly than anticipated, reaching a second all-time high in summer 1983 of about 23 000 animals (Fig. 2). The hunting quota that year was set to 13 766 animals, and during the following two years the winter herd was reduced to 10 000 - 15 000 animals.

Based upon estimates of winter range carrying capacity (Gaare & Skogland, 1975), the first five-year management plan for Hardangervidda (1974 - 1979) recommended a winter herd of 10 000 animals. Later plans have adjusted this figure to range between 9 000-12 000 (Svein Erik Lund, pers. comm.). An aerial summer count in 1979 indicated 21 700 animals (Krafft, 1981). A revised management plan for 1979 – 1984 was set to reduce the winter herd to 12 000 animals by 1985. In the winter of 1983 - 84 the physical status of the winter herd was investigated revealing poor condition and low recruitment (Skogland, 1983, 1990a). In spite of the management goal of 12 000 animals, the summer herd in 1983 was estimated at 23 000 (Skogland, 1989a).

The period 1995 - 2000 was characterized by large quotas and a growing uncertainty concerning herd size. In 1999 a capture/recapture study of the herd was initiated using GPS-collared animals tracked by aircraft in order to obtain, among other information, better herd size estimates to improve the minimum count summer surveys (Strand *et al.,* 2003) that previously had tended to be unreliable. Between 1995 and 2003 there were conflicting views

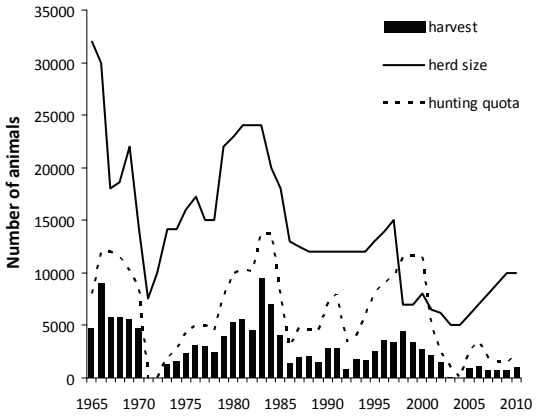

Figure 2. The estimated summer herd size, the hunting quota and harvest of wild reindeer in Hardangervidda, Norway, 1965 – 2011, based on various sources (Tveitnes, 1980; Krafft, 1981; Skogland, 1985b, 1989a, 1990b; Strand *et al.,* 2004; Solberg *et al.,* 2012). The summer herd size estimates are based on cited references that in some cases do not report if the herd is counted in summer or winter, or if the estimate is based on the whole or segments of the herd. Also, estimates of the herd size reported in Skogland (1990b) and Strand *et al.* (2004) for the period 1970 – 1975 differ somewhat.

between the local reindeer board and NINA personnel concerning herd size (Bråtå, 2005). Based on aerial counts conducted in 1991, DN estimated the herd size to be between 13 500 and 16 000 in 1995 (Bråtå, 2005). In 1998 this conflict came to a head due to a population model simulation conducted by NINA (Bråtå, 2005) which indicated an alarmingly large population, with the result that DN issued an additional free calf quota to all licensed reindeer hunters (Bråtå, 2005). Finally, in the winters of 2001 and 2002, the local reindeer board managed to conduct two well-planned and successful aerial counts that placed the herd at 5200 and 4668 animals, respectively (Lund, 2001, 2002). These counts, in stark contrast, showed the herd to be far below the desired level and after a fierce battle conducted through the media (Vaa & Bitustøyl, 2012), hunting was banned in 2004 for one year. The survey method currently employed by the regional reindeer board

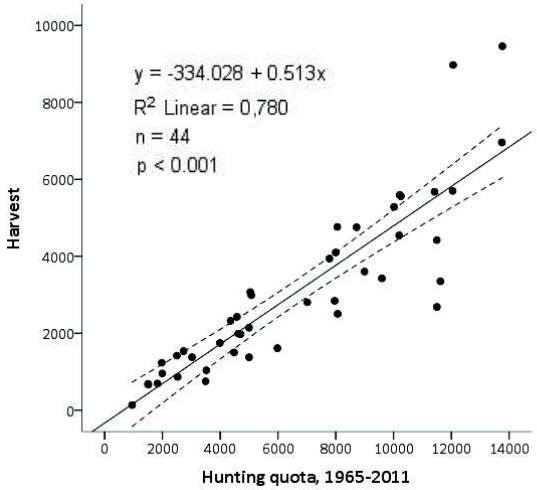

Figure 3. The regression with 95% confidence interval of harvest on hunting quota for 1965 -2011 for the Norwegian Hardangervidda wild reindeer herd, excluding 1971,1972 and 2004 when no hunting occurred.

makes use of 3-5 small fixed-wing aircraft that fly parallel sectors, photographing and GPS-plotting the various herds. This method improvement appears promising for the future management of the herd. Successful management since 2004 has brought the herd up to near the target winter population of 11 000 animals in 2011 (Lund, 2011).

Hunting quotas, harvest and harvest success, 1965 - 2011

The hunting quota for the period 1965 - 2011 explained 78 % of the variation in harvest, with a 1 unit increase of the quota corresponding to a 0.51 unit increase in number shot (Fig. 3). Harvest success, however, was both low and quite variable (mean = 45 % ± 12.9, range 14 – 74, coefficient of variation = 0.29, n = 44).

Herd size vs. recruitment and autumn structure during the years 1979 - 2011

Percent sexually mature females 1 yr+ in the post hunting herd was relatively stable but decreased from 50 – 60 % for the period 1979 – 1992 to 40 - 50 % after 1992 in contrast to recruitment percentages that showed far more variation (Fig. 4).

Herd size estimate from 2001 - 2011

In the following simulation exercise we use the herd size of 5200 animals in 2001. We apply the recruitment and herd structure data from the NINA reports in three scenarios to show that they had the data to predict a reasonably accurate herd size increase in the following years, but apparently did not pursue this opportunity in their summary report (Solberg et al. 2012).

In the three scenarios we compare herd size increase with no other change in herd composition than variation in the yearling component in the following manner: no yearlings (NINA 1), 10 % yearlings (NINA 2) and 15 % yearlings (NINA 3) in the recruitment groups (Fig. 5). No yearlings in the recruitment groups, a highly improbable scenario, grossly underestimated herd size increase. A 10 % yearling component in the groups, that accounted for the presence of all or most of the yearling females but no male yearlings, also underestimated the herd size increase. However, increasing the

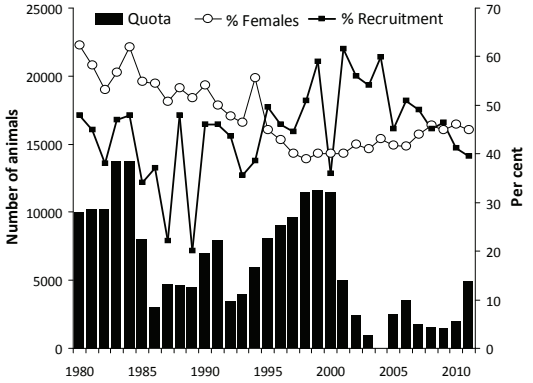

Figure 4. Hunting quotas (number of animals) in year N and estimates of percent recruitment rates (calves per 100 females 1 yr+) and percent females 1 yr+ in the breeding herd in year N - 1. Data for recruitment rate and female proportion of the breeding herd are from Solberg *et al.* (2012) and twenty annual NINA reports (1991-2011) in the journal Villreinen.

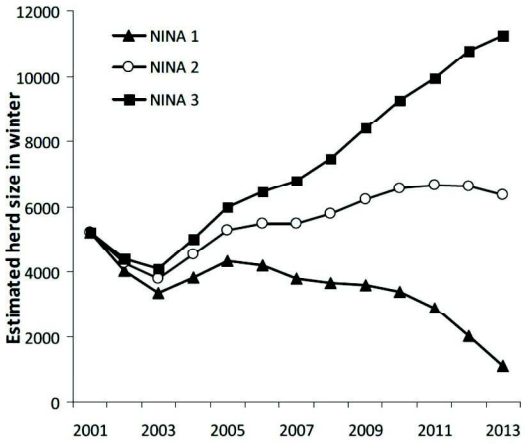

Figure 5. Estimated wild reindeer winter herd size in Hardangervidda 2001 – 2013 based upon the herd size estimated in 2001 (Lund, 2001), harvest data (Statistics Norway), recruitment and female composition data reported in Solberg *et al.* (2012) and NINA reports (see text to Fig. 4). Mortality rates are set to 5 % of the herd after the harvest. The models represent three scenarios where recruitment rates (calves per 100 females 1 yr+) are based upon 1) absence of yearlings, *i.e.* the recruitment rate estimate calves per 100 female 2 yr+ (NINA 1), 10 % yearlings (NINA 2) and 15 % yearlings (NINA 3) in the 1 yr+ female groups (see the Methods section).

yearling component to 15 %, that includes a high percentage of the yearling males, targeted the herd size increase reasonably well (11 261 animals), as a herd size estimate of 10 175 animals was found during a successful air survey in March 2013 (Svein Erik Lund, pers. comm.).

Discussion

To our knowledge, all data collected from Norwegian wild reindeer herds over the past 70 years indicate that population size and composition has primarily been regulated through management processes (*e.g.* quality and quantity of population data and hunting success) rather than natural processes (*e.g.* predation, starvation and recruitment failure). Thus failure to stabilize herd size at the target level is related primarily to poor management, including both the evaluation and interpretation of existing data. None of the other 22 herds in southern Norway with the exception of Snøhetta (Jordhøy, 2001) have encountered management problems even approaching those experienced by the Hardangervidda herd, despite similar ecological conditions and management systems.

Though the annual harvest tracked the quota in a linear fashion reasonably well, hunting success averaged only 45 % and showed large annual variation, particularly at the upper end of the regression when the population exceeded management goals and hunting quotas were therefore large. In reality, however, there is reason to believe that harvest success actually averaged higher, and varied less than that indicated by the regression. This is because the harvest quotas, *i.e.* those issued to hunters (and used in our regression to calculate harvest success), are not always the same as the target quotas, *i.e.* those actually required to maintain the desired size of the winter herd. The harvest quotas are often set considerably higher than the target quotas in an attempt to compensate for previous experience with poor harvest success. As an example, if recent harvest success (*i.e.* harvest/target quota) has only averaged 0.50, then the harvest quota issued to hunters would be doubled in an attempt to attain the target quota. Though we are aware that this happens, the degree of "adjustment" actually implemented by the regional reindeer board, and approved by DN, seems to be based on "rule of thumb" only, and with considerable annual variation. Most likely, the official quota adjustments are greatest when the need to reduce the herd is most crucial, *e.g.* when herd size has far exceeded management goals, and less or nothing when the herd size is below target level. An extreme example of a quota adjustment may be seen in Fig. 2 for the years 1998 - 2000, when the quota far exceeded the estimated herd size. Had the herd size estimate been accurate and the hunt been effective, the herd could poten-

tially have been extirpated in 1998. Obviously the management model contains major flaws.

If the real target quotas had been available and used to calculate the regression instead of the harvest quotas, the R^2 value, and therefore the explanatory value of the regression, would likely have been better. Since they are not available, it has been impossible to calculate true harvest success. However, and most important, despite the fact that actual harvest success has likely been better than the official statistics indicate, the annual harvest has still fluctuated wildly. This would suggest that more of the problem with the management of this herd lies in calculating the correct target quota, and less in attaining it, than previously thought. Calculating the correct target quota seemingly requires more precise information on *e.g.* herd size and recruitment than that previously available. Obviously the present quota system used to regulate the harvest needs to be improved if the Hardangervidda herd is to be more effectively managed in the future.

There are a number of interacting factors influencing hunting success that may help to explain the failure to maintain the herd at carrying capacity. Of the total Hardangervidda reindeer range, 5560 km^2 (68 %) is in private ownership while 2434 km^2 is publically owned. Presently, this total area is divided into approximately 145 hunting units. On private land, units tend to be smaller than on public land. Whereas hunter mobility is usually limited to each hunter´s designated hunting unit, reindeer can move unconstrained. Reindeer tend to concentrate in large flocks, particularly when hunted, and to move constantly upwind, apparently to better detect predators. During years with a constant wind direction over many days during the hunting season, large flocks will tend to congregate on very limited areas on Hardangervidda. While the few hunters on these limited areas can fill their bags quickly, the large majority of hunters elsewhere have few if any animals to hunt, as long as the wind direction persists. During such years, hunting success on Hardangervidda tends to be low. Thus the combination of reindeer behaviour, the pattern of estate size and distribution, and limited hunter mobility tends to both limit and vary the harvest success on Hardangervidda. In an attempt to alleviate this problem, new management practices were implemented in 1983 whereby 1) smaller estates were merged into larger units, 2) hunters on areas devoid of animals were allowed to hunt on neighbouring areas and 3) the hunting season was sometimes extended by several days during years with low initial harvest success. Though there has been some resistance to these new measures, they appear to have improved both hunter mobility and harvest success (Lund, 2012). A thorough evaluation of these new measures is overdue.

Recent advances in communications technology and hunter behaviour may be influencing harvest success as well. Earlier, reindeer hunting was part of the subsistence basis for people living in areas surrounding Hardangervidda and hunters tended to remain in the mountains until their quotas were filled. With an improving economy and more recreationally motivated hunters, weekend hunting has become more common. However, successful hunting above tree line is highly weather-dependent. Likewise, weekend forays of only 2-3 days are often too short for hunters to effectively reach, hunt, and bring out felled animals. This behavioural change appears to have reduced hunting success. Also, the increasing use of mobile phones to communicate the location of reindeer herds to colleagues tends to concentrate hunters more than before. Hunter concentration, in turn, leads to the formation of tighter reindeer flocks and increased flock running, reducing the chance for safe shooting and therefore lowering hunting success. Furthermore, hunters waiting for mobile phone information on flock location frequently arrive after groups have relocated, as

flock movement increases sharply during the hunting season (Reimers *et al.,* 2013).

Despite substantial support in terms of funding and manpower over the past 40 years, management of the reindeer herd on Hardangervidda has proven difficult, as evidenced by the extreme and rapid fluctuations in herd size and harvest success during this period.

A critical question relates to why the use of the population data from NINA's National Cervid Monitoring Program (Solberg *et al.,* 2006; Strand *et al.,* 2006; Solberg *et al.,* 2012) collected during the past 20 years has failed to maintain the herd at the management target level of 9000 to 12000 winter animals. A primary reason apparently relates to the difficulty in obtaining reliable aerial winter counts on an area as large as Hardangervidda during the few short periods when snow and weather conditions are favourable. Additional reasons include: 1) the apparent inability of minimum counts during June/July to reliably estimate herd size and 2) the apparent poor accuracy of data on recruitment and herd sex and age composition employed to predict the herd status and size. In addition, it is uncertain whether the collected recruitment and herd composition data have, in fact, actually been employed by the responsible managers as tools for modelling herd size. Apparently low recruitment rates in years of stable herd size have not resulted in reduced hunting quotas, just as high recruitment rates have not led to higher quotas.

An obvious weakness relating to the applied management research on reproduction and herd structure carried out during the past 20 years is the lack of a critical and independent evaluation of the methods employed. The method currently in use by NINA (Jordhøy *et al.,* 1996; Jordhøy *et al.,* 2003) for determination of early calf mortality or calf production is counting calves and females 1+ years in June/July from aerial photographs (Skogland, 1984a, 1985a; Andersen *et al.,* 2005). This method is based on the assumption that the number of yearling males is negligible in the post-calving reindeer groups and that the calf/female ratio reflects the annual recruitment, an assumption that has been tested and found to underestimate calf production (Reimers, 2006). The fact that these estimates also include yearling females that were calves the preceding year and hence did not breed, also adds to the estimate error.

However, we circumvented these shortcomings by adjusting the reported recruitment rates in July in three scenarios involving 1) no yearlings present in the groups (NINA 1), 2) 10 % yearlings present (NINA 2) and 3) 15 % yearlings present (NINA 3, which implies the presence of an estimated 50 % of the yearling males). These simulations indicated that NINA 3 with 15 % yearlings present in the breeding group predicts the herd size change reasonably well, while the other two alternatives underestimate herd size increase. This corresponds to an annual recruitment rate of 65 %, a value that is higher than the 60 % recorded in Rondane and lower than the 70 – 80 % (calves per 100 females 2+ year) recorded in June from the ground during the years 2005 – 2007 in Hardangervidda, North Ottadalen and Norefjell-Reinsjøfjell (Reimers, 2012; Eigil Reimers unpublished data). It is not known whether the crude recruitment estimates or the adjusted estimates we applied here have been used to assist in management of the herd.

The recruitment figures estimated by NINA varied annually from 22 - 62% (mean = 45% ± 9) during the period 1979 – 2011 (Solberg *et al.,* 2012), a variation thought to realistically reflect birth pulses. Corresponding and even more dramatic calf recruitment variation is reported from Svalbard in the high Arctic (Reimers, 1982; Solberg *et al.,* 2001; Milner *et al.,* 2003; Omsjoe *et al.,* 2009). Here recruitment variation relates predominantly to early calf mortality in June and July following severe

winter weather. At lower latitudes, predation appears to be the most important mortality factor among reindeer and caribou (Nybakk *et al.,* 2002; Valkenburg *et al.,* 2004; Norberg *et al.,* 2006; Pinard *et al.,* 2012). There are reasons to expect both high and stable reindeer calf survival in Norwegian alpine habitats with low predation and a relatively stable winter climate. Preliminary results (Reimers, 2012) and Eigil Reimers (unpublished data) indicate this to be so.

In a self-evaluation, Strand *et al.,* (2006) recommended that the recruitment and herd composition counts for reindeer in the National Cervid Monitoring Program be maintained without major modification. Likewise, in a corresponding self-evaluation of the entire program (Solberg *et al.,* 2006; Solberg *et al.,* 2012) the authors did not emphasize a need for any major change in the program, nor for an external evaluation. Interestingly, in none of these summary reports did NINA apply their recruitment and herd structure data in attempts to model herd development in Hardangervidda, or in any of the six other wild reindeer herds in southern Norway from which they have sampled population data for 20 years.

Conclusions

We conclude that the persistent management problems of the Hardangervidda herd are mainly caused by a mixture of 1) often unreliable or insufficiently evaluated data for key population parameters, including herd size, adult sex and age composition, and recruitment; 2) the apparent anti-predator adaptation of reindeer to flock and constantly move into the wind, a behavior that leads to large concentrations of animals, often on areas with few hunters; 3) a complicated land ownership structure that limits hunter mobility, and therefore their capacity to hunt where reindeer have concentrated; 4) changed hunter behaviour related to *e.g.* communication via mobile phones; 5) existing herd data in most cases not having been exposed to peer-reviewed evaluation, and 6) existing data have apparently not been tested in population models in order to validate their quality. Although it may prove difficult to change hunter habits, land ownership structure or the quota system in order to facilitate better herd management, improving hunter access across hunting units is achievable and should lead to increased harvest success. Likewise, further support for refinement of methodology for successfully estimating herd size conducted by the local reindeer board is necessary, together with the initiation of a long-term wild reindeer study of the key factors influencing reproduction and calf mortality.

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Utviklingen av villreinstammen på Hardangervidda, en problematisk forvaltningshistorie

Abstract in Norwegian/Sammendrag: Jaktuttaket fra den store og internasjonalt viktige sørnorske bestanden av villrein (*Rangifer tarandus*) på Hardangervidda har de siste 60 åra variert kraftig til tross for betydelig innsats for å stabilisere vinterstammen til 9000 – 12 000 dyr, som antas å være områdets langsiktige bæreevne med hensyn på kvalitet og kvantitet av vinterbeiter. I denne artikkelen forsøker vi å belyse de vedvarende forvaltningsutfordringene knyttet til stammen ved en samlet vurdering av de historiske, biologiske og forvaltningsrelaterte prosessene rundt bestandsutviklingen. En kombinasjon av dårlig kvoteregulering, ulovlig jakt og konkurranse med tamreindrift gjorde at stammen i perioden 1900 til 1950 periodevis var liten. Fra 1950 til 2012 har det vært tre perioder med store jaktuttak på mellom 4500 og 9500 dyr etterfulgt av tre perioder med

et lavt jaktuttak inklusive to totalfredninger. Bestandsutviklingen disse årene avviker kraftig fra bestandsmålet og en beregnet optimal årlig avkastning på mellom 2300 og 3000 dyr. Vi identifiserer og diskuterer tre hovedårsaker til forvaltningsproblemene: 1) forvaltningen har ofte tatt utgangspunkt i usikre data om bestandens størrelse (særlig før 2001), 2) manglende modellrelevant analyse av kalvetilvekst og alders- og kjønnsfordeling og 3) en varierende og ofte lav fellingssuksess (felte dyr/tildelt kvote) kombinert med liten jegermobilitet og villreinens vindavhengige trekkatferd som ofte resulterer i konsentrasjon av store flokker på små areal og dermed redusert samlet jaktsuksess. En fellingsmodell som bygger på sikrere bestandsdata og en bedre jegermobilitet er nødvendig for å oppnå en bærekraftig forvaltning av stammen. Det innebærer bl.a. en videreutvikling og styrkning av Villreinutvalgets tellingsbestrebelser og en kritisk og uavhengig evaluering av de vitenskapelige metodene som i dag anvendes for innhenting av bestandsdata for bruk i forvaltningen.