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COMPATIBILITY OF BROWN BEAR *Ursus arctos* AND FREE-RANGING SHEEP IN NORWAY

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Abstract

In 1992, the Norwegian Parliament adopted a plan for brown bear Ursus arctos *management. The main goal of the plan was two-fold: (1) ensure viable bear populations within five core areas along the border of neighbouring countries; and (2) limit the damage caused by bear on sheep* Ovis aries *grazing on open rangeland, which has increased over the last few years. In this study we have examined the possibility of attaining both these political aims. Sheep losses in two study areas within bear core areas rose considerably during the period 1981–1993, when the Scandinavian bear population increased by 1·5% a year. We found a significant correlation between the estimated number of bears and the loss of grazing ewes in both areas. No such relationship was found in the control areas (considered to be without bears) adjacent to the study area. We found no relationship between number of ewes lost and number of ewes grazing. Shooting of bears that presumably killed sheep had no effect on the number of ewes lost during the following season, probably because the number of bears killed in Norway was less than the number of bears immigrating from Sweden. Killing more bears is not compatible with the political aims of the management plan. It is difficult to reach all the political goals under the current situation. The loss of sheep will probably continue to increase unless changes are made in sheep husbandry methods in the core areas. Alternatively, sheep must be moved out of the areas set aside for the re-establishment of bears.* © *1997 Elsevier Science Ltd*

Keywords: brown bear, sheep, management, conflict, Norway.

INTRODUCTION

Originally, brown bears *Ursus arctos* were found throughout Norway and Sweden (Collet, 1912; Lönnberg, 1929). Swenson *et al.* (1995) estimated the bear population to be about 3100 in Norway and 1650 in Sweden during the mid-1800s. The bear, like other large carnivores, was in direct conflict with livestock, which led to an intense eradication effort, including national bounties on bears during 1733–1930 in Norway and 1647–1893 in Sweden. In Norway, local bounties were in effect until the bear was totally protected in 1973. Sweden gradually introduced more protective measures from 1893 until 1927. The early abolition of the national bounty and protective measures in Sweden were probably the main reasons that bears survived in small populations there; in Norway, the species was already functionally exterminated by the time the national bounty was abolished (Swenson *et al.*, 1995).

The management of bears in Norway is today based on a management plan adopted by the Norwegian Parliament in 1992 (Miljøverndepartementet, 1992); in this paper the management plan will be referred to as the Large Predator Plan. Estimates of the brown bear population in Norway have varied greatly from 1965 to 1994, from 25–50 bears (Myrberget, 1969) to a minimum of 157–230 bears in 1978–1982, based on reports from the public (Kolstad *et al.*, 1986). A re-evaluation of the population's status using the same methodology, but with more critical criteria, yielded minimum estimates of 96–123 bears during 1983–1986 (Sørensen *et al.*, 1990). Based on censuses of radio-marked bears, Swenson *et al.* (1995) estimated the average number of bears in Norway to be only 14 (excluding the northernmost county of Finnmark). The Directorate of Nature Management assumes today that there are on average about 20–25 bears in Norway, of which about 15 form part of the Scandinavian bear population and 6–11 (in Finnmark County) part of the Russian–Finnish bear population. The estimate of the average numbers of bears in Norway is lower than the total number visiting Norway, because many bears wander between Norway and Sweden (Wabakken & Maartmann, 1994).

The main goal of the Large Predator Plan regarding the brown bear was to ensure a viable population within specific management zones, called bear core areas, located along the national border (Fig. 1). But the most recent estimates indicate that there are at present no

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viable bear populations in Norway (Swenson *et al.*, 1995). The main goal for the Norwegian Parliament must therefore be to *re-establish* reproducing bear populations. The Swedish bear population is increasing, and the female concentration areas in Sweden are near the border and the Norwegian core areas (Swenson *et al.*, 1994, 1995) (Fig. 1). The re-establishment of bears in Norway is therefore dependent on immigration of bears from Sweden, and from Russia and Finland in the far north. For a further discussion see Sagør *et al.* (1995).

A second goal of the Large Predator Plan is to reduce or, alternatively, limit the loss of unguarded free-ranging sheep caused by bears, which is the main management problem with bears in Norway. This conflict has been increasing during recent years (Bratberg & Kjønsberg, 1993; Kvam *et al.*, 1993). Bad relationships and poor cooperation between professional managers and sheep farmers may also contribute to the increasing conflict. The interaction between bears and sheep leads mainly to two problems: economic loss of sheep, and illegal killing of bears (Johnson & Griffel, 1982; Jorgensen, 1983).

Here we examine the compatibility of these goals and attempt to answer the question: 'Is it possible to re-establish reproducing bear populations in Norway and concurrently limit the losses of free-ranging sheep within bear core areas?' The increasing loss of sheep along the border with Sweden may be explained either by higher density-dependent mortality caused by parasites, disease, accidents, etc., in an increasing number of sheep grazing on open rangeland, or by an increasing emigration of bears from Sweden. Two hypotheses were therefore considered: (1) there is a positive relationship between the number of grazing sheep and the number of sheep lost; and (2) there is a positive relationship between the number of bears and the losses of grazing sheep.

The killing of marauding bears is intended to reduce the losses of sheep although it is not always known that the actual marauder is killed. It probably has a short-term effect, but the long-term effect is not clear. We hypothesised that (3) the killing of marauding bears during 1981–1993 reduced the loss of sheep the year after the killing(s).

STUDY AREA AND METHODS

Two study areas, one in central and one in south-eastern Norway, were each divided into two subsites, a bear site and a control site (Fig. 1). Bear sites consisted of municipalities totally or partly within the bear core areas, where the state has paid compensation for more than 25 ewes killed by bears during 1982–1993. The control sites consisted of municipalities totally or partly outside the core areas (presumed to be free of bears), where no compensation was paid for bear damage during 1982–1993. They were close to the bear areas to ensure that other variables that may influence the loss of sheep, such as topography, toxic plants, etc., were as similar as possible in the two groups. The number of sheep was approximately the same in each pair of sites. Municipalities in which 1 to 25 ewes were compensated for during this period were excluded from the study.

The bear site in central Norway is within the northern boreal region. The habitats are dominated by birch forests and sparse low-yielding productive coniferous forests with extensive areas of minerotrophic mires (Dahl *et al.*, 1986). The upper limit follows the climatic timberline. The control site lies partly in the southern boreal region, because of maritime influence, and is dominated by coniferous forests and interspersed with wide areas of grey alder *Alnus incana* forests and mires. Both sites in south-eastern Norway are within the northern and the middle boreal regions, which are also dominated by coniferous forests.

The actual number of sheep grazing was obtained from official records, which included 75–100% of the sheep owners within the study areas. We considered only ewes, because brown bears in Norway prefer ewes (Kvam *et al.*, 1995). The other major predators in the areas, lynx *Lynx lynx* and wolverine *Gulo gulo*, prefer lambs (Directorate for Nature Management, pers. comm.). In our statistical analyses, we used the total loss of ewes, not only those documented as killed by bears.

Our estimates of the number of bears are based on 318 in the central Scandinavian subpopulation (CSS)

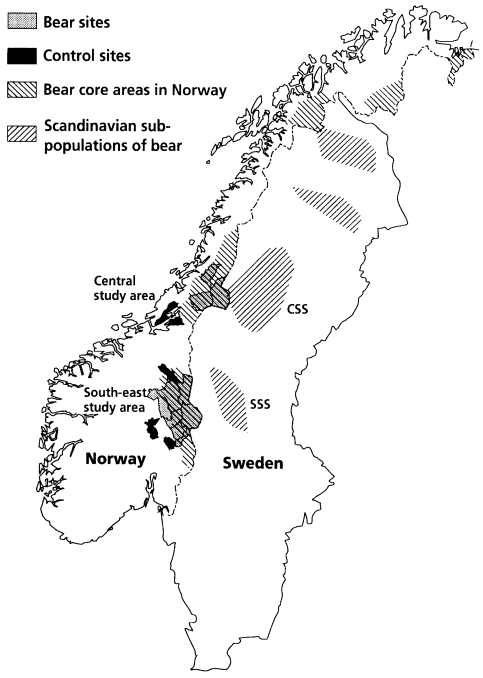

Fig. 1. The administratively-decided core areas for brown bear in Norway, the bear sites and control sites used in this study and the female concentration areas in Sweden; CSS, central Scandinavian subpopulation; SSS, southern Scandinavian subpopulation (from Swenson *et al.*, 1994).

and 151 in the southern Scandinavian subpopulation (SSS) in 1993 (Swenson *et al.*, 1994), respectively, and a 1·5% annual growth rate during the study period (Swenson *et al.*, 1994). Bears in central Norway come from the CSS and those in the south-east from SSS (Fig. 1). These estimates are based on a study of the development of bear populations within a larger area, and there have been no attempts to estimate the number of bears each year within each bear site. The total number of bears within a smaller area may show variation over the year and also between years that do not necessarily reflect the development within the whole population.

The percentage loss of ewes cannot be evaluated in relation to the number of grazing ewes by correlation analysis because of autocorrelation (Eberhardt, 1970). Therefore, we compared the slope of the regression line for the number of ewes lost against the number of ewes grazing in bear areas and control areas, using ANCOVA to test the interaction term. If the number of ewes grazing is the major factor influencing loss of ewes, there would be no difference between bear sites and control sites.

We used partial correlation analyses to examine the effects of (1) the number of ewes grazing, and (2) the number of bears in CSS and SSS, on the number of ewes lost in central Norway and south-eastern Norway, respectively. The percentage loss of ewes was regressed against the number of bears to determine the effect of shooting bears on sheep losses the following year. We used a *t*-test to compare the residuals from this regression line for years immediately after the killing of bears against other years.

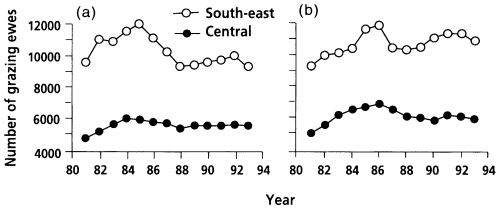

Fig. 2. The numbers of ewes grazing each year (a) in the bear sites and (b) the control sites during 1981–1993.

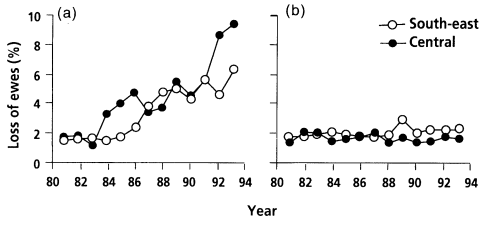

Fig. 3. The percentage loss of ewes each year (a) in the bear sites and (b) the control sites during 1981–1993.

RESULTS

Loss of ewes in relation to the number of ewes grazing

The number of ewes in both bear and control sites in south-eastern Norway increased from 1981 to 1985, followed by declines, more marked in the former sites (Fig. 2). In central Norway, the number of grazing ewes was relatively stable both in the bear sites and control sites during 1981–1993. The percentage loss of ewes increased dramatically in both the bear sites, from 1·8% to 9·3% in the central bear site and from 1·6% to 6·3% in the south-eastern bear site (Fig. 3). In contrast the loss of ewes in the control sites remained low and stable (Fig. 3).

In south-eastern Norway the slope of the regression line of the number of ewes lost against the number of ewes grazing was significantly different between the bear site (slope $\beta = -0{\cdot}73$) and the control site ($\beta = 0{\cdot}46$) (ANCOVA, site × number of ewes interaction, $F_{11,1} = 11{\cdot}99$, $p = 0{\cdot}002$). No significant difference between these two types of sites appeared in central Norway. A significant correlation between the number of ewes grazing and the number of ewes lost was only found in the control site in central Norway (Table 1).

Loss of ewes in relation to the number of bears

There was a significant positive correlation between the number of bears in both CSS and SSS and the number of ewes lost in the respective bear sites, but not in the control sites (Table 1). A regression analysis for bear sites showed that the number of bears in CSS and SSS explained 81% ($\beta = 0{\cdot}90$, $p < 0{\cdot}001$, Fig. 4) and 87% ($\beta = 0{\cdot}93$, $p < 0{\cdot}001$, Fig. 4) of the variation in % loss of ewes, respectively. There were no significant relationships in the control sites.

Killing of marauding bears

Eleven bears, presumably marauders, were killed in the central and five in the south-east study areas during the

Table 1. Partial correlations for the number of ewes lost in the central and south-eastern study area against (a) the number of ewes grazing (statistically controlled for the number of bears), and (b) the number of bears in the respective Swedish populations (statistically controlled for the number of ewes)

Independent variable	Study area	Bear sites		Control sites	
		r partial	*p*	*r* partial	*p*
(a) Ewes grazing	Central	0·19	0·56	0·62	0·03
	South-eastern	–0·66	0·20	0·19	0·56
(b) Bear population	Central	0·89	< 0·001	–0·34	0·27
	South eastern	0·94	< 0·001	0·56	0·06

study period. We found no significant difference between the residual values from the regression line of loss against number of bears for the year after the killing of bears compared with other years in either central Norway ($t = 0{\cdot}65$, d.f. = 11, $p = 0{\cdot}53$, Fig. 5(a)) or in south-east Norway ($t = -1{\cdot}49$, d.f. = 11, $p = 0{\cdot}17$, Fig. 5(b)). Thus, killing bears, at the level that occurred during 1981–1993, apparently had no loss-reducing effect the following year.

DISCUSSION

Relationship between sheep loss and numbers of sheep grazing

Our results did not support hypothesis (1), that there is a consistent positive relationship between the number of sheep grazing and the number of sheep lost. A significant correlation was only found in one of the four study sites (control site in central Norway). This suggests that some local factor was operating at this site.

Relationship between sheep loss and numbers of bears

Our results did support hypothesis (2), that there is a positive relationship between the number of bears and losses of grazing sheep in the two sites. We therefore conclude that the considerable increase in the loss of ewes along the border with Sweden is due to the increased immigration of bears from the increasing population there.

Killing of marauding bears

We reject hypothesis (3), that the killing of marauding bears, at the level observed during 1981–1993, reduces the loss of sheep the year after the bear was killed. We do not know if bears have been killed illegally during this period. If so, our results, but not our conclusion, would change somewhat. The loss of ewes in the bear sites was increasing during the entire study period despite legal and possible illegal killings. Killing bears may briefly prevent or reduce loss of sheep, but this is apparently not a solution of the bear/sheep conflict in the long term, probably because immigration of bears from Sweden is greater than the killing of bears in Norway. An alternative solution to the bear–sheep conflict is to kill all bears that migrate to Norway, but this is not in accordance with the main goal in the Large Predator Plan. In addition, shooting a specific marauding bear can be difficult (Jorgensen, 1983; Wabakken & Maartman, 1994), and it is difficult to distinguish young males from females, which are very important to the re-establishment of a reproducing bear population in Norway (Swenson *et al.*, 1994).

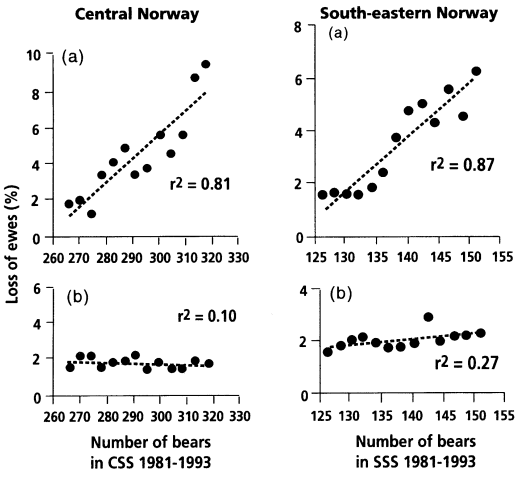

Fig. 4. Relationship between percentage loss of ewes and the number of bears (a) in the bear sites and (b) the control sites.

Loss-reducing practices

As there have been no empirical studies in Norway it is impossible to document the effectiveness of practices to reduce losses of sheep. In fact, there has been a considerable increase in the loss of ewes, leading to increasing conflict between management authorities and sheep farmers. The major problem with tending sheep in Norway is that the sheep range too widely. There is also no definition of what losses are acceptable, but such a definition is clearly needed.

Coexistence of bears and sheep?

To return to our original question, 'Is it possible to re-establish reproducing bear populations in Norway and concurrently limit the losses of unguarded free-

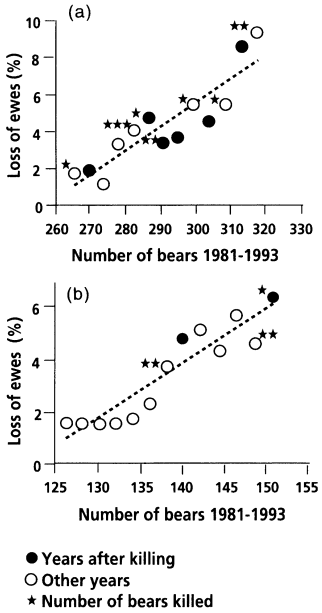

Fig. 5. The percentage loss of ewes in the bear sites in relation to the number of bears in (a) CSS and (b) SSS, and whether or not bears were killed the previous year.

ranging sheep within bear core areas?', we are afraid the answer is a qualified 'no'. The increasing immigration of bears into Norway from Sweden will increase bear/sheep interactions, which our results show increases sheep losses. Bear predation on sheep appears to be learned (Johnson & Griffel, 1982; Jorgensen, 1983; Knight & Judd, 1983), and since bears and sheep prefer the same habitat in some periods of the year, encounters between bears and sheep are increased during these periods (Jorgensen, 1983; Wabakken & Maartmann, 1994). Wabakken and Maartmann (1994) found that resident male bears spent much time during the breeding season in Sweden, where there was a much higher density of females, but were mainly in Norway in July and August, where almost all grazing sheep were. However, Jorgensen (1983) found that radio-collared bears did not leave their established home ranges, either to approach or avoid the sheep.

We predict that an increasing bear population in Norway will lead to an increasing loss of sheep using the current methods of sheep husbandry. New areas, which so far have experienced only small losses of sheep, may experience large losses in the future. Increased bear/sheep interactions also lead to an increased killing of bears (Johnson & Griffel, 1982; Knight & Judd, 1983), which in Norway is a threat to the re-establishment of the bear under current conditions. Without changes in the method of farming sheep, both of the main goals in the Large Predator Plan will be very difficult to accomplish. In Norway, virtually all of the 2·2 million sheep that graze in the mountains and forests do so untended. This is a major change from the previous century, when bears and other large carnivores were more common and sheep were managed more closely (Nedkvitne *et al.*, 1995). It is important to point out that the bear management core areas in Norway have been established where the densities of grazing sheep are lowest (Miljøverndepartementet, 1992). Nevertheless, it is apparent that losses due to bears are considerable in these core areas. The most likely solution to the bear/sheep conflict is to separate bears and sheep to a greater extent both temporally and spatially. If it is not possible to change the method of raising sheep to give them better protection from bears, moving sheep out of the core areas could be necessary to allow the re-establishment of reproducing brown bear populations in Norway.

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REFERENCES

Bratberg, T. M. and Kjønsberg, K. (1993) Tap av sau på beite. Hedmark fylke 1971–1992. *Fylkesmannen i Hedmark, Landbruksavdelingen*, Hamar, Norway.

Collet, R. (1912) *Norges hvirveldyr. Bind 1, pattedyr*. Aschehough, Kristiania (Oslo).

Dahl, E., Elven, E., Moen, A. and Skogen, A. (1986) *Vegetasjonsregionkart over Norge 1:1500 000. Nasjonalatlas for Norge*. Statens kartverk, Oslo.

Eberhardt, L. L. (1970) Correlation, regression and density dependence. *Ecology* **51**, 306–310.

Johnson, S. J. and Griffel, D. E. (1982) Sheep losses on grizzly bear range. *Journal of Wildlife Management*. **46**, 786–790.

Jorgensen, C. J. (1983) Bear–sheep interactions, Tharghee National Forest. *International Conference of Bear Research and Management*. **5**, 191–200.

Knight, R. R. and Judd, S. L. (1983) Grizzly bears that kill livestock. *International Conference of Bear Research and Management*. **5**, 186–191.

Kolstad, M., Mysterud, I., Kvam, T., Sørensen, O. J. and Wikan, S. (1986) Status of the brown bear in Norway: distribution and population 1978–82. *Biological Conservation*. **38**, 79–99.

Kvam, T., Eggen T., Knutsen, K. and Sørensen, O. J. (1995) Årsrapport fra Rovdyrprosjektene i Nord-Trøndelag 1994. *Norwegian Institute for Nature Research, Trondheim, Oppdragsmelding*, No. 364.

Kvam, T., Eggen, T., Knutsen, K., Overskaug, K., Solstad, T. and Sørensen, O. J. (1993) Årsrapport fra Rovdyrprosjektene i Nord-Trøndelag 1992. *Norwegian Institute for Nature Research, Trondheim, Oppdragsmelding*, No. 194.

Lönnberg, E. (1929) *Björnen i Sverige* 1856–1928. Almqvist and Wiksells boktryckeri, Uppsala and Stockholm.

Miljøverndepartementet (1992) Om forvaltning av bjørn, jerv, ulv og gaupe (Rovviltmeldingen) *Stortingsmelding*, No. 27.

Myrberget, S. (1969) Den norske bestanden av bjørn (*Ursus arctos* L.). *Meddelelser fra Statens Viltundersøkelser*. **2**, 1–21.

Nedkvitne, J. J., Garmo, T. H. and Staaland, H. (1995) *Beitedyr i kulturlandskap*. Landbruksforlaget, Oslo.

Sagør, J. T., Swenson, J. E. and Røskaft, E. (1995) Bjørn og sauehold: Er det mulig å nå Rovviltmeldingens målsettinger? *Norwegian Institute for Nature Research, Trondheim, Fagrapport*, No. 014.

Swenson, J. E., Sandgren, F., Wabakken, P., Bjärvall, A., Söderberg, A. and Franzen, R. (1994) Bjørnens historiske og nåværende status og forvaltning i Skandinavia. *Norwegian Institute for Nature Research, Trondheim, Forskningsrapport*, No. 53.

Swenson, J. E., Wabakken, P., Sandgren, F., Bjärvall, A., Franzen, R. and Söderberg, A. (1995) The near extinction and recovery of brown bears in Scandinavia in relation to the bear management policies of Norway and Sweden. *Wildlife Biology*. **1**, 11–25.

Sørensen, O. J., Overskaug, K. and Kvam, T. (1990) Status of the brown bear in Norway 1983–1986. *International Conference of Bear Research and Management*. **8**, 17–23.

Wabakken, P. and Maartmann, E. (1994) Sluttrapport for bjørn-sau prosjektet i Hedmark 1990–93. *Norwegian Institute for Nature Research, Trondheim*, Forskningsrapport, No. 58.