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The near extinction and recovery of brown bears in Scandinavia in relation to the bear management policies of Norway and Sweden

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Records of bountied brown bears *Ursus arctos* in Norway and Sweden were analysed to estimate population size in the mid-1800's, and changes in population size and distribution in relation to the bear management policies of both countries. In the mid-1800's about 65% of the bears in Scandinavia were in Norway (perhaps 3,100 in Norway and 1,650 in Sweden). Both countries tried to eliminate the bear in the 1800's; Sweden was more effective. By the turn of the century, the numbers of bears were low in both countries. The lowest population level in the population remnants that have subsequently survived occurred around 1930 and was estimated at 130 bears. Sweden's policy was changed at the turn of the century to save the bear from extinction. This policy was successful, and the population is now large and expanding. Norway did not change its policy and bears were virtually eliminated by 1920-30. Since 1975, bear observations increased in Norway. This coincided temporally with an abrupt increase in the Swedish bear population, and bears reappeared sooner in areas closer to the remnant Swedish populations. Both conditions support our conclusion that the bear was virtually exterminated in Norway and suggest that bears observed now are primarily immigrants from Sweden, except for far northern Norway, which was recolonised from Russia and Finland. Today, we estimate that the Scandinavian bear population numbers about 700, with about 2% in Norway (on average about 14 in Norway, 650-700 in Sweden). This is a drastic reduction in the estimate of bears in Norway, compared with earlier studies. The trends in bear numbers responded to the policies in effect. The most effective measures used in Scandinavia to conserve bears were those that reduced or eliminated the economic incentive for people to kill them. Our analysis also suggests that population estimates based on reports from observations made by the general public can be greatly inflated.

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Numbers and distribution of the brown bear *Ursus arctos* worldwide have declined by more than 50% since the mid-1800's due to overexploitation by humans, habitat loss, and insularisation of the remaining bears into small populations (Servheen 1990). The decline of brown bears in Scandinavia has been documented separately in Swe-

den (Ekman 1910, Lönnberg 1929) and Norway (Aaseth 1934, 1935, Myrberget 1969). It is well documented that, after a population bottleneck in the early 1900's, the population in Sweden has increased dramatically in both number and range (Swenson et al. 1994a, in press). The situation in Norway has been unclear. Until the mid-

1970's, many thought that the population was close to extinction (Myrberget 1978). In 1978-82 an evaluation of the status of bears based on newspaper accounts and reports from the public yielded minimum estimates of 157-230 bears in Norway in 17 definable populations and a recommendation that the species be considered vulnerable, but not threatened (Kolstad et al. 1986). This study received criticism (Stenseth & Steen 1987, Elgmork 1988, 1992), and a reevaluation of the population's status using a more critical methodology yielded minimum estimates of 102-153 bears during 1983-86 and the conclusion that the bear should be considered endangered in two areas of Norway (Sørensen et al. 1990). In a plan to manage large predators, passed by the Norwegian Parliament, the population was estimated to be about 100 in the early 1990's (Miljøverndepartementet 1991-92).

The management of bears in Norway is an emotional subject, because of the predation by bears on untended livestock, primarily sheep, grazing on open range (Sørensen et al. in press). Bears also receive, generally, negative coverage in newspapers (Frafjord 1988). The situation is less controversial in Sweden, but there is a widespread feeling among hunters that there are enough bears to allow higher quotas than are allowed presently (Swenson & Sandegren in press). As Norway and Sweden share the Scandinavian Peninsula, we have analysed the historical status and trends of the brown bear from a Scandinavian perspective for the first time. We also consider the effects of various bear population management policies that have been implemented in the two countries. Our goal was twofold: 1) to provide a Scandinavian perspective on the historical status and trends of the brown bear and 2) to evaluate which conservation efforts were most effective in Scandinavia. The first will hopefully be of help in both countries in deciding on future management strategies; the second may be useful to managers in other countries that are trying to conserve threatened bear populations.

Methods

This study was based primarily on an analysis of the harvest statistics for bears in Norway and Sweden. In Sweden, bounties were paid until 1893. In Norway national bounties were paid until 1930, but local bounties were allowed until 1972. These statistics are probably better than usual hunting statistics because they are records of official expenditures. The Norwegian data were summarised by county and year for the years 1846-1977 by Statistisk Sentralbyrå (1978). Swedish data were summarised by county and year for 1856-1927 by Lönnberg (1929) and by county and five-year period for 1815-1905, for most counties and periods, by Ekman (1910).

Population size by county was estimated from the recorded annual harvest for at least ten years before 1856. Variance estimates were not available for the Swedish data. For 1856-65, mean harvests with 95% confidence intervals (CI) were obtained for each county in both countries. If the pre-1856 estimate was included within the 95% confidence intervals of the 1856-65 harvest, the population was considered to have been stable during the period. At the present time, the Scandinavian brown bear population apparently can sustain a legal harvest of about 7% per year (Swenson et al. 1994a, b). Therefore, for the counties with stable populations, the mean annual pre-1856 harvest was divided by 0.07 to obtain a population estimate. For declining populations, the annual rate of decline from pre-1856 to 1856-1865 was added to 0.07 and the annual harvest was divided by this sum. This corrected for the declining status of these populations. In some cases, we may have failed to identify a declining population with this method. The result would be an inflated population estimate. However, most populations that were declining rapidly were probably identified.

Bears were considered to be functionally extinct in a county when bears no longer were bountied every year. The year of functional extinction was defined arbitrarily as the end of the last consecutive series of at least 3 years that bears were bountied. Although arbitrary, this is a reasonable estimate of the time when the population was virtually gone in the county considering the very high hunting pressure (Aaseth 1934, 1935, Johnsen 1947) and the large distances over which bears can wander (Björvall et al. 1989, Wabakken et al. 1992), and thus be shot in a county with no established bear population. The »last year a bear was shot« was the last year a bear was bountied followed by a period of at least 20 years with no bears bountied.

The effect of various policy changes on the bear harvest was examined by comparing the harvest five years before the change with five years following it. The year of change was excluded. Such a short period was chosen because the populations usually were declining rapidly.

The perceived trend of the bear population in Sweden was obtained from the annual reports of the Swedish Hunters' Association. Each year since 1963, the hunters in each county reported their perceived status of game populations in their county as increasing since the previous year, stable, declining, or not present in the county. We calculated a simple index for the entire country for each year by giving »increase« a value of +1, »stable« 0, and »decrease« -1. We then obtained an average for the counties reporting bears.

We estimated the Scandinavian bear population size by modifying a recent estimate from Sweden (Swenson et al. 1994a). This estimate was based on the fact that there are four geographically distinct areas in Sweden in which

96% of the female harvest was concentrated. Density estimates of adult females were obtained from a Petersen estimate based on mark-observation data (Bailey 1952) from two of these, and relative densities were estimated from hunter harvest data in all four. The resulting estimates of adult female density were multiplied by size of these female areas to obtain an estimate of adult females. The estimated age and sex structure of the population was used to arrive at a total population estimate. A reevaluation of the distribution of killed females, which now included data from Norway, showed that two of these female concentration areas extend into Norway. We calculated new population estimates in these two areas by using the previous density estimates and the new area siz-

es. In the southernmost area, a new population estimate was available from 1993, using a Petersen estimate based on marked- unmarked ratios of adult females seen in company with radio-marked adult males. A population estimate of adult females was obtained within the home ranges of the radio-marked females that were in estrus in 1993. This was expanded to the entire southernmost area using the proportion of bears (presumably females) observed in the company of marked adult males inside this area during the breeding season (May-June) during 1985-93. The estimated age and sex structure of the population was used to obtain a total population estimate from the estimate of adult females in estrus (see Swenson et al. 1994a for further details of methods).

Table 1. Year of functional extinction, year last recorded bear shot, and population and density estimates in the mid-1800's by county for brown bear in Scandinavia.

County	Year of functional extinction <i>a)</i>	Year last bear shot	Year next bear shot <i>b)</i>	Annual harvest before 1856 <i>c)</i>	Rate of decline <i>d)</i>	Population estimate <i>e)</i>	Density (n/1000 km ²)
SWEDEN							
Norrbottn, Nb <i>f)</i>				21.8		311	3.2
Västerbotten, Vb		-		29.8	0.050	248	4.5
Jämtland, J		-		25.0		357	7.3
Västernorrland, Vn	1878	1894	1927	9.1		130	6.1
Gävleborg, G	1877	1895	1965	15.9	0.025	167	9.0
Kopparberg, K	1897	1897	1927	20.3		290	10.4
Värmland, V1	1878	1898	1993	12.1	0.012	148	8.2
Sweden total						1651	
NORWAY							
Finnmark, F <i>g)</i>	1910	1931	1971	22.6	0.036	213	6.1
Troms, Ts <i>g)</i>	1910						
Nordland, N1	1913			33.7		481	17.1
Nord-Trøndelag, NT	1905			32.2		460	23.2
Sør-Trøndelag, ST	1888	1912	1967	11.3		161	13.0
Møre og Romsdal, MR	1919	1924		19.8		283	35.8
Sogn og Fjordane, SF	1918	1956		13.7		196	28.6
Oppland, O	1913	1924	1945 <i>h)</i>	7.6		109	6.0
Hedmark, Hm	1886	1909	1945	13.1	0.026	136	6.2
Hordaland, H1	1871	1905		2.2		31	4.6
Buskerud, B	1931	1956		12.3		176	17.7
Akershus, Ah	1856	1904		1.0			
Rogaland, R	1871	1908		2.2		31	4.8
Vest-Agder, VA	1882	1910		2.9	0.106	16	2.7
Aust-Agder, AA	1915	1915		22.0		314	47.9
Telemark, Tm	1920	1949 <i>i)</i>		33.5		479	45.2
Vestfold, Vf	1917	1921		3.4	0.122	18	9.6
Østfold, Ø	1859	1859		0.5			
Norway total						3104	

a) The last year bears were killed during three consecutive years (data available from 1845 in Norway and 1856 in Sweden).

b) Following a hiatus of at least 20 years, and thought to be bears dispersing into the area.

c) 1824-36, 1839-43 in Värmland, 1827-36, 1851-55 in the rest of Sweden, 1846-55 in Norway.

d) Mean annual rate of decline to 1856-65 for those counties with significantly greater harvest before 1856 than in 1856-65.

e) Calculated by dividing mean harvest before 1856 by 0.07, or 0.07 plus the annual rate of decline, where appropriate, see the text. Counties with populations that became functionally extinct before 1865 are excluded.

f) Abbreviations are used in Fig. 1 to identify counties.

g) Data from Finnmark and Troms were combined until 1865.

h) One shot in 1945, none since then.

i) Prior to 1949, the last one shot was in 1927.

Results

Population estimate in the mid-1800's

Based on the harvest of bears by county and a sustainable harvest rate of 7%, estimated population sizes of bears were calculated for 7 counties in Sweden and 15 in Norway where functional extinction had not occurred by 1865 (Table 1). Totally, the estimate for Norway was about 3,100 bears, compared to about 1,600-1,700 in Sweden, ie. about 65% of the bears in Scandinavia occurred in Norway.

The estimated numbers per county varied widely, from 16 to 481. For comparison, densities were calculated based on the entire land area of the counties. These densities also varied widely, from 3 bears/1000 km² in Vest-Agder to 48/1000 km² in Aust-Agder, both in Norway (Table 1). These densities were divided into 4 arbitrary groups based on the distribution of the values: low density (2-5 bears/1000 km²), moderate density (6-11), high (13-24) and very high densities (28-48). There was a distinct geographical pattern in bear densities (Fig. 1). Low densities occurred in northern Sweden and the southwestern part of southern Norway. Medium densities occurred in central Scandinavia, on both sides of the border, and in northern Norway. High densities were found in mid-Nor-

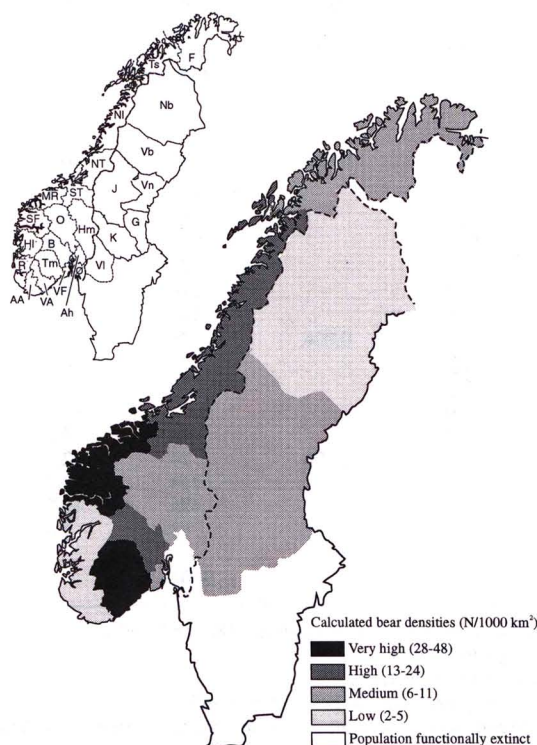


Figure 1. Relative densities of brown bears by county in Scandinavia around 1850, based on harvest statistics (see table 1 for county abbreviations, and the text for details).

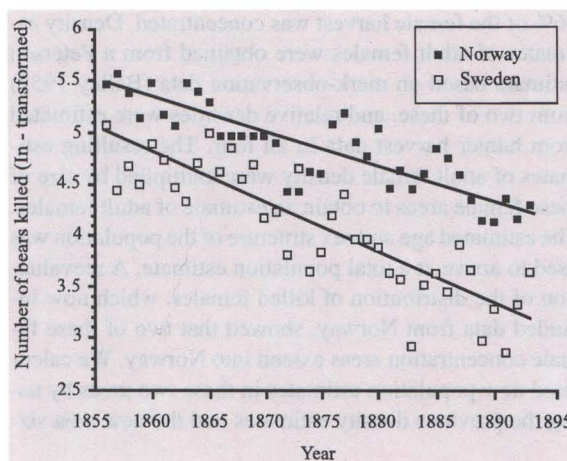


Figure 2. Declines in the number of brown bears killed in Norway ($r = -0.856$, $P < 0.0001$) and Sweden ($r = -0.752$, $P < 0.0001$) during 1856-1893.

way and central parts of south Norway. Very high densities were found in the northwestern and southern parts of south Norway. Estimated densities in the high and very high categories were only found in Norway.

Population declines in Norway and Sweden

The number of brown bears declined rapidly in both Norway and Sweden during the last half of the 1800's, based on the bounty results (Fig. 2). The situation in the two countries can be compared for the period between 1856, when annual kill statistics are first available from Sweden, and 1893, the last year bounties were paid in Sweden. During this period, the number of bounties paid annually (natural-logarithm transformed) declined significantly in both Norway ($r = -0.856$, $df = 37$, $P < 0.0001$) and Sweden ($r = -0.752$, $df = 37$, $P < 0.0001$). The annual rate of decline in Norway, 3.2% (95% confidence intervals = 2.5-3.8%), was less than in Sweden, 4.8% (3.9-5.7%). Presumably, the number of bears also declined significantly more rapidly in Sweden than in Norway during this period. During 1856-93, a total of 2,605 bears was bountied in Sweden, compared with 5,164 in Norway.

Geographical patterns of extinction

Originally, bears were found throughout Scandinavia (Collett 1911-12, Lönnberg 1929). In southernmost Sweden, bears were practically exterminated by the 1700's. In the rest of the southern quarter of Sweden and the southeasternmost county in Norway (Østfold), the last bears were shot before or around the middle of the last century (Lönnberg 1929, Table 1). Using the year of functional extinction as an illustration, the extinction progressed generally from south to north and from the low-

lands towards the mountains (Fig. 3). By 1890 the Scandinavian bear population was divided into two parts, with the population in southern Norway separated from that in central and northern Scandinavia. Bears in Sweden were functionally extinct in all but the three northernmost counties by 1900, and in Norway bears were functionally extinct except for one county in the south (Buskerud) by 1930 (Fig. 3). By 1910-20, bears were mostly restricted to the mountainous western portions of northern Sweden, and several isolated populations in central Scandinavia, only one of which has survived (Fig. 4). The population in Buskerud, south Norway, is now extinct (Elgmork 1994).

The situation in the northernmost county of Norway (Finnmark) is somewhat unclear. Functional extinction appears to have occurred in 1910, but then 51 bears were bountied between 1932 and 1940, and bears were shot each year during 1953-1955 and 1970-1973. Bears were shot in only 12 (26%) of the remaining 47 years from 1910 to 1970.

There is no population estimate for the time when bears were at their lowest level in Scandinavia. Bears declined in Sweden until 1927, when stricter protective measures were introduced (Lönnerberg 1929), and there were some indications of increase after that (Lönnerberg 1935). By 1942, Selander and Fries (1943) estimated 294 bears in Sweden. If we consider 1930 to be the low point for bears in Sweden and assume an annual population growth of 7% (Swenson et al. 1994a, b) to 1942, we obtain 130 bears as an estimate for the population bottleneck in the populations that subsequently survived. There were more than 130 bears in Scandinavia at that time, but the other populations became extinct (Fig. 4).

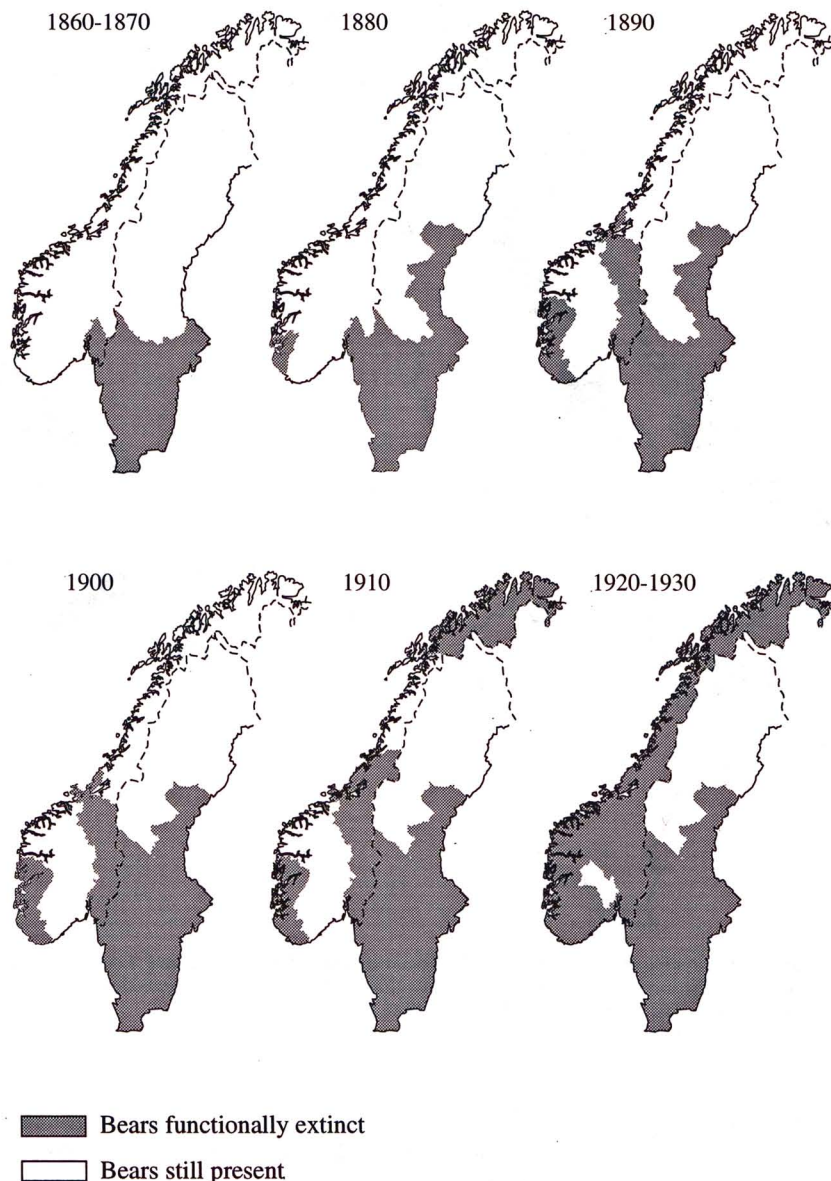


Figure 3. Geographic pattern of brown bear extinction in Scandinavia from 1860 to 1930, based on the year of functional extinction for each county (see the text for definition).

Temporal and geographical pattern of the recent increase

Bears became functionally extinct in all but 3 counties in Scandinavia (Fig. 3 and 4). However, bears apparently returned to several counties after the year of functional extinction, usually after an absence of several decades (Table 1). Bears returned more quickly to the counties of Mid-Norway and to the northernmost county in Norway than to those of south central Scandinavia (Fig. 5).

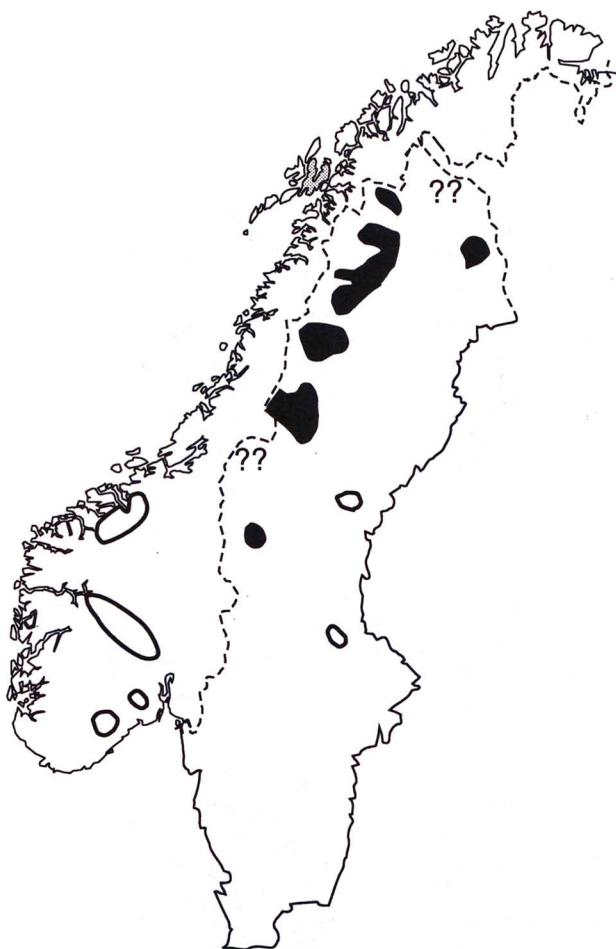


Figure 4. Distribution of the brown bear in Scandinavia during 1910-20, when the distribution was most restricted (from Ekman 1910 and Johnsen 1947). The population marked with open circles subsequently became extinct.

Indices for all of the counties with bear populations in Sweden showed a relatively stable period to 1975, followed by an abrupt increase and then a period of sustained increase (Fig. 6). Although it is difficult to detect annual changes in densities of bears, it is not difficult to detect the colonisation of areas where bears had been exterminated.

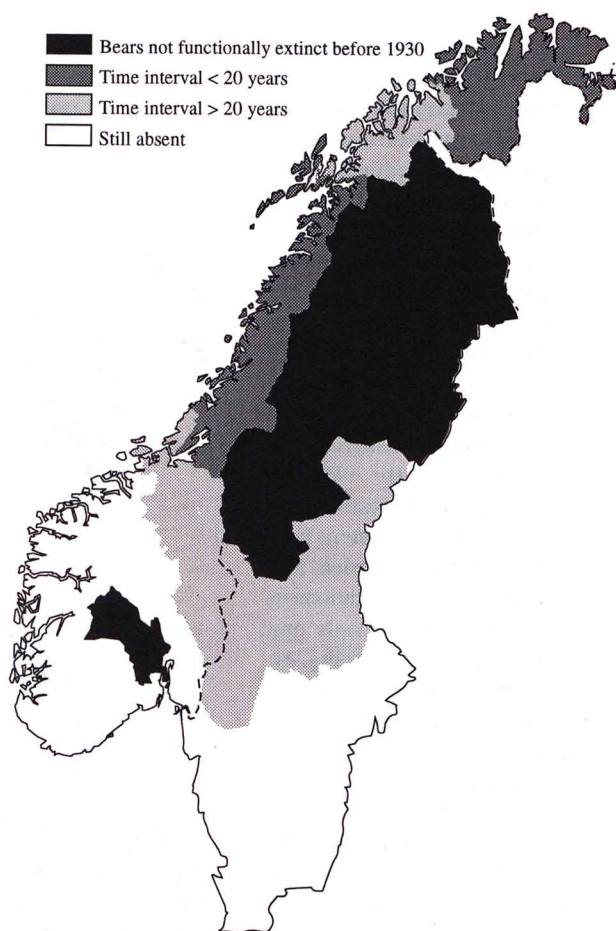


Figure 5. Length of the time brown bears were absent from the harvest statistics for the counties in Scandinavia.

In Norway the bear was considered to be practically exterminated in 1965, with a population of only 25-50 individuals (Myrberget 1969, 1978). However, a large number of observations were reported in 1975 and especially in 1976 (Heggberget & Myrberget 1979, Elgmork 1979). As a result, population estimates for Norway increased dramatically after this period, but then declined to a some-

Table 2. Published estimates of the number of brown bears in Norway, excluding Finnmark.

Time period	Estimated number <i>a)</i>	Comments	Source
1965	15 - 41	Minimum - maximum	Myrberget (1969)
1978	77 - 135	Minimum - maximum	Myrberget (1978)
1978-1982	130 - 194	Absolute minimum - probable minimum	Kolstad et al. (1986)
1983-1986	76 - 119	Absolute minimum - probable minimum	Sørensen et al. (1990)
1994	14	Average number in spring	This study

a) When estimates for all or parts of Troms and Finnmark are given together, we arbitrarily halved the estimate to obtain a number for Finnmark.

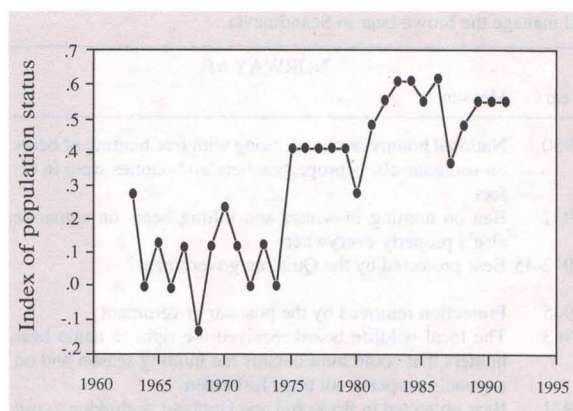


Figure 6. Perceived status of the brown bear in Sweden, 1963-1991, based on annual reports from the county hunters' organisations. »Status« is an average index for the whole country, with 1=increase in all counties, 0=no change, -1=decrease in all counties.

what lower level in the mid-1980's when methods of population estimation were changed somewhat (Table 2).

Present population size

We made a population estimate for Scandinavia (excluding Finnmark, Norway, whose bears are part of the Russian-Finnish bear population). There are four female concentration areas in Sweden (Swenson et al. 1994a). The locations of five females shot in Norway during 1981-1993 indicate that two of these areas extend into Norway (Nn and M, Fig. 7). An estimate for these areas was recalculated, using the density estimates in Swenson et al. (1994a) and the sizes of the expanded areas (Table 3). In 1993, we located 5 radio-marked adult males (≥ 4 years old) twice a week using an airplane during the breeding season (May-June) in female concentration area S and its surroundings. Eight radio-marked breeding females ≥ 3 years old without young were present during this time. Twelve of the 21 female observations with the marked males were marked females, which gave an estimate of 13.5 breeding females (95% CI=10.2-22.2) in an area of 4,100 km², the cumulative home ranges of the marked breeding females. We used the formula of Bailey (1952) for the population estimate and that of Krebs (1989) for the binomial confidence intervals. We estimated 21.2 total females ≥ 3 years old, because adult females are with young during 36% of the spring breeding seasons in this area and do not associate with males (Swenson et al. 1994a). During 1985-93, 54% of 87 aerial observations of bears with marked, adult males during the breeding season were within this area of 4,100 km². Assuming that this distribution was representative of females in this general area gives a total estimate of 39.3 adult females, or 151 bears, based on the sex and age structure presented in Swenson et al. (1994a). Only aerial observations were

Table 3. Brown bear population estimates in Scandinavia based on female concentration areas, excluding Finnmark County, Norway.

Area a)	Total number of bears			
	Scandinavia	Sweden	Norway b)	% in Sweden b)
Nn	83 c)	82	1	98.8
Ns	131	131	0	100.0
M	318 d)	312	6	98.1
S	151 e)	144	7	95.4
Total	683	669	14	98.0

a) See Fig. 7.

b) Figures are estimates in the spring, use of Norway may be greater in summer and autumn.

c) Based on data in Swenson et al. (1994a), with the female concentration area increased to 14,200 km²; 98.9% in Sweden.

d) As above, new female concentration area of 26,200 km²; 98.1% in Sweden.

e) See the text.

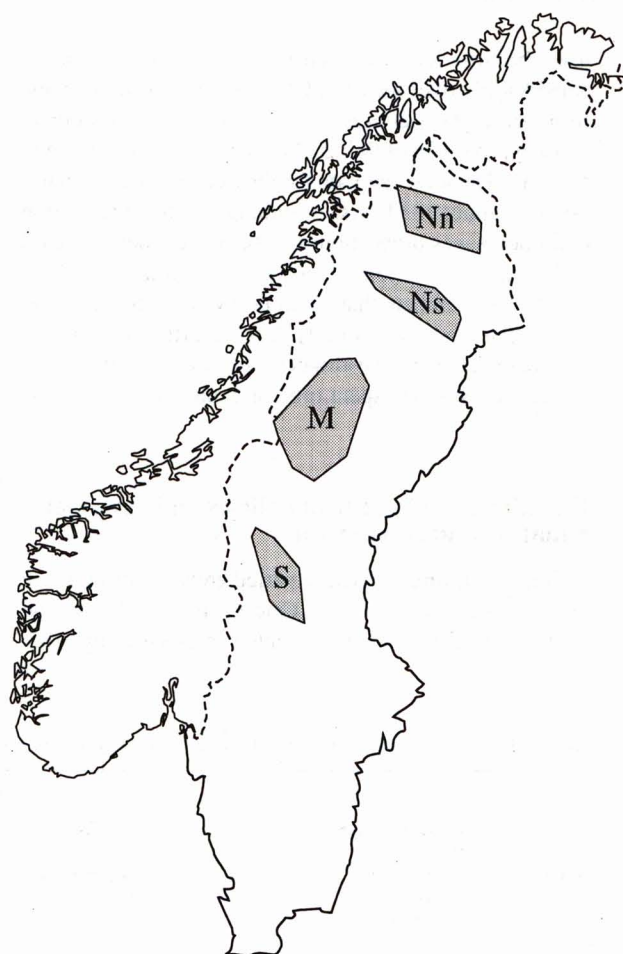


Figure 7. Locations of the four brown bear female concentration areas in Scandinavia, based on locations of hunter-killed bears from 1981-91 in Sweden and 1981-93 in Norway.

Table 4. Year of the implementation of important measures to protect and manage the brown bear in Scandinavia.

SWEDEN <i>a)</i>		NORWAY <i>b)</i>	
Year	Measure	Year	Measure
1891	The local hunting association in Norbotten asked the King's governor to reduce or eliminate bounties	1930	National bounty removed, along with free hunting of bears on someone else's property where no bounties were in effect
1893	All bounties eliminated	1932	Ban on hunting in winter and killing bears on someone else's property everywhere
1905	The Royal Academy of Sciences issues a position statement calling for the protection of bears to avoid extinction	1942-45	Bear protected by the Quisling government
1910	Bears protected in national parks	1945	Protection removed by the postwar government
1912	Ban on killing of bears on someone else's property	1963	The local wildlife board received the right to name bear hunters that could hunt outside the hunting season and on anyone's property; all traps forbidden
1913	Bears protected on Crown land	1971	Bear protected in Buskerud and Oppland, forbidden to use poison
1927	Killed bears become State property	1972	Provisional protection in the whole country
1943	Hunting reintroduced	1973	Final protection in the whole country
1981	Harvest quotas introduced		
1992	Female harvest quotas introduced		

a) Lönnberg (1929)

b) Myrberget (1969), Elgmork (1979)

used, because location intensity from the ground varied considerably over the area. Of the 87 observations made from airplanes mentioned above, four (4.6%) were in Norway, so seven of the 151 bears were assumed to be in Norway. The total estimate for the Scandinavian population was about 683 bears. Assuming that the distribution of all bears was proportional to that of females in area S and to the distribution of female concentration areas M and Nn, we estimate that about 669 were in Sweden and 14 (2%) in Norway (Table 3). It is important to point out that these are average estimates, because many bears, especially in Norway, spent time on both sides of the border.

Effectiveness of political policies on bear extermination and conservation

Policies regarding bears have varied greatly both between the two countries and over time (Table 4). A national bounty for bears was implemented in Norway in 1733.

The bounty increased gradually from 4-8 Crowns before 1845 to 25 Crowns after 1899 (Table 5). In Sweden, a national bounty was implemented in 1647. It was similar to the Norwegian bounty from 1808-64 (12 Crowns), but then increased dramatically in 1864 to 87 Crowns. The new bounty was high, about the value of a cow, and the additional value of the meat and skin was roughly the same (Swenson et al. in press). In addition to the national bounty, local bounties were in effect in both countries. The local bounties were often higher than the national bounty. For example, local bounties in Kopparberg County, Sweden, varied by parish from 0 to 174 Crowns in 1833, when the national bounty was 12 Crowns (Törnebladh et al. 1834). In Norway, county and local bounties varied from 0-1,000 Crowns before 1931 (Aaseth 1934, 1935). In Buskerud County, Norway, the local bounty varied from 0 to 1,500 Crowns when there was no national bounty prior to total protection in 1971 (Elgmork 1979). In 1971, 1,500 Norwegian Crowns equalled USD 210. During 1845-1930, only 2 of 8,274 bears were re-

Table 5. Increases in national bounties for bear in Norway and Sweden, 1845-1899.

Country	Year of increase	National bounty (in Crowns) <i>a)</i>		%
		Before	After	
Norway	1845	8 for adults, 4 for young (2 and 1 riksdaler) <i>b)</i>	12 for all (3 speciedaler)	100
	1863	12 (3 speciedaler)	20 (5 speciedaler)	67
	1899	20	25	25
Sweden	1864	12 (144 skilling banco)	87 (50 riksdaler banco)	625

a) Bounties calculated in Crowns, which were the same value in Norway and Sweden after 1875. No allowance was made for inflation.

b) Values in parentheses are the bounties in the contemporary monetary units.

Table 6. Effect of increase in bounties on number of killed bears in Scandinavia.

Country	Increase in bounty	Year	Annual kill		t	1-tailed P
			5 years before	5 years after		
Sweden	625%	1864	99.8 ± 10.3 a)	115.2 ± 9.5	1.10	0.15
Norway	67%	1863	191.0 ± 14.9	168.0 ± 15.9	1.05	0.16 b)
»	25%	1899	47.0 ± 3.1	40.6 ± 6.4	0.9	0.20 b)

a) Mean ± SE

b) Decreases in harvest; opposite of the expected direction.

corded to have been shot in Norway without a bounty being paid, compared with 22 of 95 bears (23%) during 1931-71.

Although Sweden introduced bounties about 100 years earlier than Norway and had a much higher bounty than Norway after 1864, Sweden introduced measures to protect the bear earlier and more rapidly than did Norway (Table 4). For example, Norway removed national, but not local, bounties 37 years later than Sweden, and gave the bear complete protection 45 years later than Sweden. All bounties were removed in Norway 78 years later than in Sweden. Sweden initiated an autumn hunting season in 1943 and bears are still hunted under a strict quota system (Table 4).

Changes in the bounties showed similar effects on harvest in both countries. Three comparisons of harvest before and after bounty increases showed no measurable effect (Table 6). However, removal of national bounties (Norway) and all bounties (Sweden) were associated with significant reductions in the harvest (Table 7). Similarly, there was a significant reduction in harvest in Sweden when bears were declared »the Crown's wildlife« (Kronans villebråd), which meant that all dead bears were state property without compensation to the hunter. In both countries, it was still legal to shoot bears in self-defence and to protect livestock throughout this period. Surprisingly, there was no reduction in harvest in Norway after the introduction of total protection (Table 7). Shooting of bears after they were protected was to control livestock losses and was done with the permission of the wildlife

authorities, although a few were killed by hunters who felt threatened by a bear.

The harvest in Norway declined after the elimination of the Swedish bounties in 1893; annual harvest in 1888-92 was 67.8 ± 3.6 (SE), compared with 47.0 ± 3.1 in 1894-98 ($t = 4.371$, $df = 9$, $P = 0.002$). It also declined after Sweden outlawed hunting of bears on Crown land in 1912; annual harvest in 1907-11 was 23.8 ± 3.1 , compared with 10.2 ± 1.3 in 1913-17 ($t = 4.05$, $df = 9$, $P = 0.004$). It remained unchanged when dead bears were declared state property in Sweden in 1927; annual harvest in 1922-26 was 3.2 ± 1.0 , compared with 2.8 ± 0.8 in 1928-32 ($t = 0.318$, $df = 9$, $P = 0.76$).

Discussion

The situation in the mid-1800's

The population of brown bears in Scandinavia was undoubtedly large in the mid-1800's, although it was declining and already extinct in southernmost Sweden. We estimated population sizes of about 3,100 in Norway and 1,650 in Sweden at this time. This is greater than the estimates for Norway of 2,000-3,000 (Elgmork 1979) and <2,000 (Myrberget 1965), based on the same material. We have better demographic data on which to base our estimates and the densities we obtained are comparable with present densities reported from European Russia (Chestin et al. 1992; Schevchenko 1990). However, the actual estimate is less important than the conclusion that

Table 7. Effectiveness of protective measures for bears in Scandinavia.

Country	Protective measure	Year initiated	Annual kill		t	1-tailed P
			5 years before a)	5 years after		
Sweden	Removal of all bounties	1893	25.4 ± 3.7	14.4 ± 3.4	2.20	0.03
»	Protected on Crown land	1913	7.2 ± 1.6	6.8 ± 2.0	0.15	0.44
»	All dead bears became state property	1927	8.2 ± 1.7	0.8 ± 0.4	4.29	0.0014
Norway	Removal of national bounty	1930 }	2.8 ± 0.8	0.6 ± 0.9	2.46	0.015
»	Protected 2 Nov-16 May	1932 }				
»	Full protection	1972	1.6 ± 0.5	1.2 ± 0.5	0.57	0.59

a) Excluding year(s) of action

there were some very high densities of brown bear in some areas in Norway, but not in Sweden (on a county-wide basis) in the mid-1800's. About 65% of the Scandinavian bears occurred in Norway. This is supported by the observation that a harvest of 2,605 bears in Sweden during 1856-93 led to a significantly greater decline in harvest, and presumably population size, than a harvest of 5,164 bears in Norway during the same period.

The subsequent decline

The political goal of both countries prior to the start of this century was to eliminate bears. Even in the medieval regional laws in both countries, citizens were encouraged to kill bears and other predators. According to Zetterberg (1951), a »war of extermination« was conducted in Sweden before and during the 1800's. Discussions about a new tax to finance a revised bounty system in Sweden in the 1830's showed that King Carl XIV Johan and most representatives from the counties viewed bounties as a method to exterminate predators (Danckwardt 1832, 1833) or at least to reduce their numbers (Jeansson 1834). In Norway, extermination was an expressed goal, as illustrated by the »Laws of extermination of predators and protection of other game« enacted in 1845 and 1863, and chapter 3 of the Law concerning hunting and trapping of 1899, which was entitled »On bounties for the extermination of predators and raptors«. The pressure on bears was great, and increased over time with the improvement of firearms and transportation systems (Collett 1911-12, Lönnberg 1929). An illustration of the intensity of persecution comes from Collett (1911-12), who noted that several of the bears killed in Norway in the early 1900's had been wounded previously. Also, Aaseth (1934, 1935) recorded many intensive efforts to eradicate bears in Norway. Besides hunting, bears were killed using leg-hold traps, self-triggering guns and poison (Aaseth 1934, 1935, Olstad 1945, Johnsen 1947). The intense efforts to eradicate the brown bear were apparently very successful, as indicated by the decline in killed bears over time and contraction of the range.

The significantly greater decline in harvest over time in Sweden than Norway during 1856-93 suggests that efforts to reduce bears were more successful in Sweden. This may be a factor of topography. Most of Sweden is gently rolling, in contrast to the extremely rugged terrain in much of Norway. This difference has allowed the development of a better railroad and road network in Sweden and, perhaps more significantly, allowed more efficient tracking of bears to their dens in late autumn in Sweden. Killing bears in their dens was the most common way of hunting them at that time in both countries (Ekman 1910, Olstad 1945). The higher bounty in Sweden than in Norway probably did not contribute to the higher rate of

decline there, because the kill in Sweden did not increase when the bounty was raised.

By the turn of the century, the situation was critical for the brown bear in Scandinavia. In 1905 the Swedish Royal Academy of Sciences issued a statement saying »it is a matter of honour for our country that this interesting animal be protected from complete extermination« (Lönnberg 1929). Ekman (1910) described the gradual retreat of the bear in Sweden and stated that the next step along the present trend, if it is taken, will be the complete extermination of the bear. Similarly, Collett (1911-12) predicted that the brown bear would disappear from Norway's fauna within a relatively short time. We calculated that, at the lowest point for the brown bear population in Scandinavia, around 1930, there were about 130 bears in the areas where bears survived to now. These bears occurred in four geographically separated areas (Swenson et al. 1994a).

Diverging national policies at the turn of the century: effects on bear numbers

At the turn of the century, the predator policies of Norway and Sweden diverged in spite of the fact that the countries were united in a political union (1814-1905). Swedish policy was changed to try to save the bear by eliminating all bounties in 1893 and gradually introducing more protective measures until 1927 (Table 4). Lönnberg (1929) expressed concern that illegally killed Swedish bears were being bountied in Norway. However, Norwegian harvest declined following the elimination of bounties and protection of bears on state land in Sweden and remained virtually unchanged when Sweden removed the economic value of dead bears. Although smuggling of Swedish bears to Norway for bounty may have occurred, our results suggest that it was not common. However, some bears shot in Sweden could have been sold in Norway without collecting the bounty, because the price of bear skins was so high (Lönnberg 1929).

The varying size of local bounties could have resulted in bears being bountied in a different municipality than where they were shot. Our data are analysed on a county level, meaning that only longer movements, across county boundaries, would affect our results. Travel was difficult and expensive in the last century. The 638-km trip from Stockholm to Malmö, for example, took 3 days by train in 1865 and cost 16.87 Crowns one way, compared with a standard labourer's daily wage of 1.50 Crowns (Lagerqvist & Nathorst-Böös 1985). In addition, passports issued by the local police were required for domestic travel until 1860 (Stoa & Sandberg 1992). Based on Törnebladh et al. (1834), the size of municipal bounties appeared to be inversely related to bear occurrence, and were financed by local taxes. The killing of a

bear was an important event in the rural areas, and bear hunters were often depicted in books about local history and family histories. We do not know if a stranger (recognisable by dialect) could successfully bounty a bear unless local people knew for certain that it had been killed in their municipality. If this occurred regularly, the effect on our results would be an underestimated rate of decline and geographical extent of functional extinction in counties with few bears. Our basic conclusions would not be changed.

Swedish efforts to conserve the bear were successful. An investigation in 1942 concluded that the population had increased to about 300 bears and recommended an autumn hunting season (Selander & Fries 1943). Later national estimates were 350–450 bears in 1966 (Haglund 1968), and 400–600 in 1975–76 (Björvall 1980). In 1991, 620 were estimated to be in Sweden, based on an intensive radio-telemetry study in two areas (Swenson et al. 1994a). The population increased at an annual rate of 1.5% over this 50-year period, and the distribution had increased to one reminiscent of the distribution in the mid-1800's (Swenson et al., in press). In 1943, hunting was allowed in 3 counties in Sweden. By 1993, hunting of bears was allowed in 6 counties, including 3 where bears had been functionally extinct previously.

After the turn of the century, Norway continued its policy of reducing the number of bears. By 1930, when the first partial protection was introduced, we regard bears to have been already functionally extinct in all but one isolated county in southern Norway. Bears had already returned to the northernmost county, Finnmark, probably from Russia and Finland (Wikan 1970). Myrberget (1969) reached a similar conclusion based on a larger data base, which also included newspaper reports, questionnaires to local sheriffs and reports from forestry officials. The Norwegian bear population was estimated to be 25–50 individuals in 1965 (Myrberget 1969). By the early 1970's, when bears were fully protected, the common opinion was that the species was almost extinct in Norway. The remaining bears were restricted to the one small isolated population, and extensions of populations in neighbouring countries (Myrberget 1978, Elgmork 1987). In 1975 and 1976, the foraging conditions for bears were exceptionally poor (Elgmork 1987) and a large number of sightings were reported then and later (Heggberget & Myrberget 1979). Sightings occurred in the western and southern parts of southern Norway where bears were thought to have been extinct (Kvam et al. 1983, Elgmork 1976). It was hypothesised that the bears had been there all the time but were low-density, cryptic populations of shy individuals (Mysterud 1977, Elgmork 1987), and Kolstad et al. (1986) concluded that the population was increasing. However, a re-evaluation of the data from the isolated Vassfaret population in southern Norway sug-

gests that there may have been only one bear present in the early 1970's. No evidence of bears could be found during intensive tracking in 1990 and 1991 and the population is now considered to be extinct (Bækken et al., in press; Elgmork 1994).

Our results suggest that Myrberget's (1969) conclusions were correct; the bear was close to extinction in Norway by 1930–40, and the few bears on the eastern border were immigrants from neighbouring countries, primarily Sweden. We have estimated that Norway contained about 65% of the bears in Scandinavia in 1850. Now the percentage is about 2% on average (Table 3).

It appears that on the same peninsula we have two countries that could have exterminated the bear, but only one did. It is not evident to us why the two countries diverged in their policies towards the bear at the turn of the century. Both countries were poor at this time and were among the three European countries with the largest relative emigration to North America (Andersson & Weibull 1988). Both countries had considerable numbers of domestic animals on open range in the 1800's. For example, wolves and bears were reported to have killed 1,291 domestic animals in Troms County, Norway (25,121 km²) in 1856, of which 1,245 (96%) were sheep and goats (Collett 1911–12). Predatory animals were reported to have killed 1,441 domestic animals in Västerbotten County, Sweden (55,100 km²), in 1827 of which 1,274 (88%) were sheep and goats (Danckwardt 1832). Thus, sheep and goats dominated the large losses in both counties. The reason for the differences between the two countries may lie in differences in the economic situation and structure and patterns of settlement.

The reoccurrence of bears in Norway

Considering that bears were virtually eliminated from Norway by 1930, and that the one isolated population that remained is now extinct, how can we explain the increase in observations noted after 1975? The most likely explanation is that the bears were dispersing from the increasing Swedish population (except from Finnmark which probably is more influenced by the situation in neighbouring Russia and Finland). This would explain the geographical pattern shown in Fig. 5, where bears were shot again after a time interval of less than 20 years in the Norwegian counties close to the remnant Swedish populations (Fig. 4). The interval was greater than 20 years in the counties farther from these Swedish remnant populations. The lack of bear reoccurrence around Buskerud (Fig. 5) supports Elgmork's (1994) conclusion that the population there was not viable. The timing of increased sightings of bears in Norway (Table 2) also corresponds temporally with the perceived increase in the Swedish population (Fig. 6). The increase in number of bears in

Sweden after the mid-1970's appears to be related to the relatively low harvest of bears in the late 1960's through the mid-1980's (Swenson & Sandegren, in press). We now know that many Scandinavian male bears have extremely large home ranges, making long rapid movements, up to 250 km in 9 days, and that dispersing subadult males can move >200 km from their place of birth (Björvall et al. 1989, Wabakken et al. 1992, Swenson et al. 1994b, unpubl. data from our Scandinavian bear project). This means that a male on the Norwegian-Swedish border could reach the counties on the west coast of southern Norway in about a week (Wabakken et al. 1992). Thus, dispersal from the large and increasing Swedish population is sufficient to explain the timing, geographical extent, and distances from Sweden of the recent bear observations in Norway.

The situation in Finnmark northern Norway, is similar to that of the rest of the country (Wikan 1970). It appears that bears were functionally extinct in 1910, but returned by the early 1930's to the easternmost part of the country next to the Finnish border, which became the Russian border after World War II (Aaseth 1934, 1935, Myrberget 1969). On the Russian side of the border, densities of bears are estimated at about 5/1000 km² (Chestin 1992). Pulliainen (1990) reported relatively low densities of bears in northern Finland and documented net immigration of bears into northern Finland, adjacent to Finnmark from Russia during 1977-85.

An evaluation of previous population estimates in Norway

We estimated the size of the bear population in Norway (excluding Finnmark) to be about 14 on average (Table 2). The estimate of only 1 bear on average on the Norwegian side of the »Nn« area seems to be somewhat low based on the documented occurrences of bears there (Bergström et al. 1993), but this is an area with few bears. As the bears in Norway are at the periphery of the Scandinavian population, numbers there should vary within and between years because many of these bears have home ranges that straddle the border. In Hedmark, there appears to be more bears on the Norwegian side of the border in summer-autumn than in spring, perhaps in response to the availability of sheep in Norway (Wabakken & Maartmann 1994). The same trend has been observed in Nord-Trøndelag, Norway (O.J. Sørensen & T. Kvam, pers. comm.). Thus, our estimate of the average number of bears in Norway may be lower than the number usually present in summer and autumn. Furthermore, variations in size of the emigrating cohort, food availability, and weather, will affect movements into Norway.

The minimum population estimates for Norway during 1978-86 are much higher than our estimate of 14 bears on

average in spring (Table 2). We can best compare the various population estimates in Hedmark County, southeastern Norway. Kolstad et al. (1986) estimated a minimum of 29-35 bears in 1978-82, based on »mostly diverse, chance accounts from local communities, received indirectly through the daily press or given directly to research workers« (Kolstad et al. 1986). Sørensen et al. (1990), using the same method but a more rigorous examination of the reports, estimated 13-18 bears in 1983-86. Elgmork (1992, in press) compared the number of bear observations per moose-hunter day in an area he assumed contained one bear (Vassfaret in Buskerud) with corresponding data from Hedmark, and estimated 12 bears were present in 1976-78. Our project estimated averages of 2.9, 5.1, and 6.5 bears in spring 1991, 1992, and 1993, respectively, based on a Petersen estimator using intensively radio-tracked bears and tracks on the snow reported by the public and corrected for the time they spent in Sweden (Swenson et al. 1994b). Our estimate of seven bears (Table 3) was based on a Petersen estimator using sightings of females with marked males during the breeding season, and was independent of the 1991-93 estimates. The mean of the 1991-93 estimates (4.8 bears) and our estimate of bears were based on Petersen estimators with marked animals, and yielded values that were 15% and 22% of that reported by Kolstad et al. (1986). Likewise, Elgmork (1994) considered his earlier estimates of 15 and seven bears in the Vassfaret area of Norway, based mainly on unconfirmed observations, to be too optimistic. He now feels that 1-2 was a more correct estimate. This means that Myrberget's (1969) estimate of 15-41 bears in Norway south of Finnmark is probably overestimated by at least 100%, because he reported 8-20 bears in the Vassfaret area. In addition, Sørensen et al. (in press) now regard their estimates of bears in Norway made during the 1970's and 1980's to be overestimated. Elgmork et al. (1976) found that 32% of reports of bear sign from the public in Norway were false and another 16% were impossible to evaluate. This indicates that population estimates of bears based on reports from the public can give highly inflated results.

Is it reasonable that the number of bears in Norway has increased only slowly even though bears have been protected for 20 years, while the population in Sweden has increased by 1.5% per year (Swenson et al. 1994a) in spite of being hunted? We have calculated that the Scandinavian bear population can sustain a 7% annual mortality due to legal hunting and that hunting mortality has averaged 5.5% annually in Sweden during the past 50 years (Swenson et al. 1994a, b). In Norway south of Finnmark 1.2 bears have been killed per year after protection was enacted in 1973. Most of these kills were approved by the authorities to remove bears killing livestock, but a few were killed in self-defense by hunters who felt threatened.

This kill is 8.6% of the estimated spring population of 14. Thus, man-caused mortality appears to have been higher in Norway, perhaps high enough to prevent numbers from increasing as fast as in Sweden in spite of emigration from Sweden.

Implications for conservation

Our results have several management implications. First, Swedish policy protected the bears in time to save them. We estimate that the minimum population size was about 130 bears in four separate areas, or a mean of about 35 per area. This should be an encouragement to countries that are trying to save small bear populations, although we should point out that about six other isolated populations became extinct. Norway apparently protected the bear after it was essentially extinct. Secondly, the conservation measures that reduced or eliminated the economic advantages of killing a bear had the greatest effect (Table 7). This is a disquieting result because trafficking in bear parts has placed a considerable economic value on dead bears (Servheen 1990). Thirdly, the population estimates from Norway based primarily on reported observations from the public seemed to greatly overestimate the true population size. This overestimation allowed management authorities to remove a seemingly insignificant number of problem bears. Based on our estimates, this small harvest was more than a sustainable harvest and perhaps was great enough to keep the population from increasing at the same rate as it did in Sweden, even considering the bear immigration from Sweden. This illustrates the value of an accurate population estimate, and reiterates the results of Knight & Eberhardt (1985) that small brown bear populations can be very sensitive to removal of only a few individuals.

The future of the brown bear in Scandinavia

There appears to be ample suitable bear habitat in Scandinavia. The growth of the Swedish portion of the population to almost 700 from ca 130 in 1930 shows that there is still suitable habitat for bears. This is certainly also the case for Norway. The formerly higher bear densities in Norway suggest that Norway contained better bear habitat, on average, than Sweden. However, the high concentration of leisure cabins in parts of Norway and high densities of forest roads over most of both countries may have reduced habitat quality somewhat (Elgmork 1978). A comparison of Figs. 1 and 4 indicates that the best bear habitats in Scandinavia are now devoid of bears, at least viable populations of bears. All evidence points to overhunting as the major reason for the decline of bears in Scandinavia and harvest rate still is a major factor influencing population trend (Swenson & Sandegren, in press).

Although the Scandinavian bear population appears to be secure at this time, the number of bears in Norway is small and they may have been overharvested since they received protection.

The problem for the management of bears in Norway at the present time is sheep that are let out to graze untended on open range in mountainous and forested areas. In the 1980's there were about 2.2 million sheep grazing on open range (Miljøverndepartementet 1991-92). The number of sheep that were documented by biologists to have been killed by bears and for which the State paid compensation has increased from under 200 per year in 1974 (Kvam et al. 1990) to about 1000 in 1990 (Miljøverndepartementet 1991-92). This increase suggests an increasing bear population, although annual variation is great. The figure in 1990 was still only 0.04% of the total number of sheep on the range in Norway (Miljøverndepartementet 1991-92). In comparison, very few sheep graze on open range in Sweden, and only 64 sheep were documented to have been killed by bears in the fiscal year 1992-93 (R. Franzén, unpubl. data). The Norwegian Parliament has adopted a plan to favour bears in management decisions in five »core areas« along the national border and to allow reproducing females to establish themselves there (Miljøverndepartementet 1991-92). The present Swedish policy is to allow the population to continue to increase (Frisén & Eriksson 1992).

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