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Home Range Size and Choice of Management Strategy for Lynx in Scandinavia

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ABSTRACT / Annual and seasonal home ranges were calculated for 47 Eurasian lynx in four Scandinavian study sites (two in Sweden and two in Norway). The observed home ranges were the largest reported for the species, with study site averages ranging from 600 to 1400 km^2 for resident males and from 300 to 800 km^2 for resident females. When home range sizes were compared to the size of protected areas (national parks and nature reserves) in Scandinavia, it was concluded that very few protected areas contained sufficient forest to provide space for more than a few individuals. As a direct consequence of this, most lynx need to be conserved in the multiuse seminatural forest habitats that cover large areas in Scandinavia. This conservation strategy leads to a number of conflicts with some land uses (sheep and semidomestic reindeer herding, and roe deer hunters), but not all (forestry and moose harvest). Accordingly research must be aimed at understanding the ecology of these conflicts, and finding solutions.

Enormous changes in the attitudes that the general public has towards large carnivores have occurred in recent decades (Mech 1995, 1996). Instead of eradication, the goal in most countries now is conservation of viable populations. For example, state bounties were removed from Eurasian lynx (*Lynx lynx*) in Scandinavia in 1912 in Sweden and 1980 in Norway. Both Scandinavian countries now have stated polices of conserving viable lynx populations and allowing hunting where and when populations allow. Similar changes in objective have occurred worldwide, but achieving these new conservation goals is posing unique challenges for the wildlife management agencies of all countries because of the polarized viewpoints that large carnivores generate. Their charisma endears them to a large segment of the public, while the conflicts (especially with livestock) that they generate cause strong negative reactions among other interest groups (Breitenmoser 1998). Finding a way to balance all the conflicting interests (biological and social) requires a clear conceptually framed conservation strategy (Breitenmoser 1998). Because of the diverse ecologies of large carnivores, this strategy must be based on a species-specific foundation of scientific knowledge.

The home range sizes of various animal species have been among the basic pieces of biological data collected by research projects during recent decades. Although home range size is intuitively regarded as being important by scientists and managers (Joshi and others 1995), and there has been much technical development of methods to calculate it (Harris and others 1990, Gallerani Kawson and Rodgers 1997, De Solla and others 1999), a formal conceptual framework into which it can be placed has been generally lacking, apart from some energetic or habitat-related applications (e.g., Tufto and others 1996, Powell and others 1997). The development of landscape ecology theory, and its focus on scale, has begun to provide a conceptual applied-ecological framework into which it can be placed (Wiens 1989). Although the concept of scale involves major theoretical issues of vital importance to wildlife management, the primary issue for management is to define at what absolute spatial scale a given ecological process operates.

KEY WORDS: Lynx; Nature reserves; Seminatural forest; Conservation strategy

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Table 1. Details of four lynx study sites in Scandinavia[a]

Country	Norway		Sweden	
Study site	Hedmark	Nord-Trøndelag	Bergslagen	Sarek
Latittude	61° 30′ N	64° 30′ N	59° 30′ N	67° N
Habitat	BF	BF / LA	BF	BF / LA / HA
Study period[b]	1995–98	1994–95	1996–98	1994–98
Wild prey[c]	Roe deer,* red deer, wild reindeer, mountain hare, capercaille, black grouse	Roe deer,* mountain hare, capercaille, black grouse	Roe deer,* mountain hare, brown hare, capercaille, black grouse	Ptarmigan, mountain hare, capercaille, black grouse
Domestic prey[c]	Sheep	Semidomestic reindeer,* sheep		Semidomestic reindeer*
Radio-collared lynx[c]	39	15	31	51

[a]The main prey species in each study area is marked with an asterisk. BF = boreal forest, LA = low alpine (above the treeline), HA = high alpine.

[b]The study period indicated here describes the period for which radio-tracking data were included in this analysis. Data collection has continued in the Hedmark, Sarek and Bergslagen study sites.

[c]Lynx diet has been studied through analysis of scats, kills and stomach contents. In the areas where at least 2 of these methods has been used, there have been no discrepancies in the relative ranking of prey (Linnell and others 1996b; Sunde and Kvam 1997; Pedersen and others 1999; Sunde and others 2000).

[d]Of these 136 radio-collared lynx, only 47 were adult residents for whom enough data existed suitable for home range analysis.

Our objective here is to present original home range size data on Eurasian lynx from four study sites in Scandinavia and demonstrate how this basic scientific data is vital in shaping a fundamental decision that underlies any conservation or management strategy—setting the correct spatial scale for management. The primary importance of this is evaluating the potential role that protected areas, as opposed to multiuse landscapes, can have in securing viable lynx populations (Green 1994, Fritts and Carbyn 1995, Joshi and others 1995) and then to decide which administrative unit is the most valid to manage lynx populations. We shall then highlight further implications that this management decision, and home range size in general, has for the practical management and conservation of lynx in Scandinavia for the 21st century.

Study Areas and Methods

Between 1994 and 1998, 136 lynx were radio-collared in four study areas (Table 1) in Scandinavia (Andrén and others 1998) using a variety of methods. Darting from helicopters was used virtually exclusively in the Sarek study area, whereas the other three areas used a combination of box traps and foot snares (Nybakk and others 1996), and trained dogs, in addition to implanting transmitters in newborn kittens (Arnemo and others 1999).

The radio-collared lynx were relocated using varying sampling routines. In each study site, efforts were made to locate all animals at least once or twice per month as a minimum sample. Aircraft were used mainly for this regular work to reduce any possible biases due to the animal's location with respect to roads. Additionally more intensive radio-tracking from both the ground (cars or snowmobiles) and the air was carried out during different periods. No home ranges were calculated when less than 14 or 20 locations were available for a seasonal or annual home range, respectively, although in most cases many more locations were available. It is evident that home range areas calculated using such small numbers of locations may underestimate true home range size. However, it was necessary to operate with such a low threshold to include some of the ranges from the Sarek site. The potential error is minimized by the use of aerial tracking and the fact that locations are spread throughout the year so as to reduce autocorrelation. We believe that this simple approach to home range analysis is sufficient for the objectives of this paper, although this limitation should be borne in mind. Based on general experience, and specific trials, the accuracy of locations was considered to be within at least 500 m of the estimated location.

Data from all study sites were analyzed in a standardized manner. The year was divided into two seasons, summer (a snow-free season) and winter (when snow was on the ground). Because of the northern latitude of the Sarek study site, summer was shorter (1 June–30 November) than in the other study sites (1 May–30 November). Each lynx year (for calculation of annual ranges) started on the first day of summer. Annual home ranges were calculated only for cases where we had at least six months of tracking data. Home range data were analyzed using the Ranges V computer program (Kenward and Hodder 1996). Home range areas were calculated using the 100% minimum convex polygon (MCP) and 95% adaptive kernel methods. Standard default options within the Ranges V program were used for the adaptive kernel analysis with the exception of using a 20 × 20 grid for more rapid analysis. All available locations were used in calculation of MCP areas because the method makes no assumptions about independence of locations. In contrast, only one location per day was utilized for adaptive kernel analysis. When more than one location was available, we used the location that was closest to midday. Only resident adult animals (at least 2 years old) were used in this analysis. Consequently, only data from 47 adult lynx were utilized in this analysis (15, 15, 13, and 4 individuals from the Sarek, Bergslagen, Hedmark, and North-Trøndelag study sites respectively). Home ranges from different animals in different years were assumed to be independent for the purposes of this analysis. Systematic estimates of prey density where not available for the four study sites, however, based on a general impression from the field and hunting statistics, it was easy to rank the study areas in terms of ungulate abundance [roe deer (*Capreolus capreolus*) and semidomestic reindeer (*Rangifer tarandus*); Table 1] as Bergslagen > North-Trøndelag ≅ Sarek > Hedmark.

Statistics on the sizes of protected areas were taken from IUCN (1998) and data on the sizes of administrative units in Norway and Sweden were obtained from the respective national Central Statistical Bureaus. Data on human harvests of wild ungulates and carnivore depredation on livestock were also taken from official statistics from the respective wildlife management agencies. Statistical analysis was performed using the SPSS computer package. Because some sample sizes were small, nonparametric analyses were used throughout. Within-site sex-differences were compared using Mann-Whitney U tests, between-site differences in male and female home ranges were compared using Kruskal-Wallis ANOVA, and within individual seasonal variation was compared using the Wilcoxon signed-rank test.

Results and discussion

Home Range Sizes in Scandinavia

The results of the home range analysis are summarized in Table 2. Within each area, adult males had larger summer and annual home ranges than adult females; however, winter ranges were not significantly different between the sexes. The home range analysis method used did not influence the significance or direction of the results, although kernel home ranges were generally smaller than MCP estimates, being less influenced by outliers.

There were significant differences between male lynx in the different study sites for summer, winter, and annual home ranges, and for both home range analysis methods (Table 3). Female home ranges also differed in summer and annually between the sites, but were only significantly different in winter using the kernel home range estimators (Table 3). The choice of home range estimator therefore slightly influenced the significance of the results, although the nonsignificant result for the MCP analysis of females in winter was also less than 0.1.

Seasonal differences between an individual's summer and winter range were not found for males with all study sites combined ($Z = -1.01$, $n = 19$, $P = 0.31$; $Z = -1.13$, $n = 19$, $P = 0.26$, for MCP and kernel estimators, respectively). In contrast, individual females used smaller home ranges during summer than winter ($Z = -3.41$, $n = 27$, $P = 0.001$; $Z = -3.50$, $n = 27$, $P < 0.001$, for MCP and kernel estimators, respectively). This is supported by the fact that within-site sexual differences were generally only found during summer (Table 2), with the exception of North-Trøndelag, where no differences between the sexes were evident in the small sample for which data were available. Therefore, it appears that female lynx show much greater seasonal variation in home range size than males.

For both sexes, and for summer, winter, and annual home ranges, it is clear that the Hedmark home ranges were much larger than the ranges from North Trøndelag, Sarek, and Bergslagen. However, there was much variation between individuals within the study sites. For example, adult male summer home ranges varied between 600 and 3000 km^2. Prey availability is often regarded as being one of the central determinants of home range size (Powell and others 1997), and it appears that the home range size ranking of study sites follows the ranking that would be expected from our knowledge of the prey base for these sites. In Hedmark there are no semidomestic reindeer, and the high snowfall characteristic of the area severely limits the density of roe deer, which are the main wild prey in this ecoregion. In contrast, Sarek provided abundant populations of semidomestic reindeer (Pedersen and others 1999), North Trøndelag had both semidomestic reindeer and roe deer (Sunde and Kvam 1997, Sunde and others 2000), while Bergslagen had a medium-to-high density of roe deer.

Table 2. Sizes of winter, summer, and annual home ranges for adult male and female lynx in four Scandinavian study sites, calculated using minimum convex polygon (MCP) and adaptive kernel methods[a]

	Area by MCP (km^2; mean ± SD)	*N*	Area by kernel (km^2; mean ± SD)	*N*
Sarek				
Summer				
Male	380 ± 161**	8	254 ± 84***	8
Female	169 ± 123	20	105 ± 100	20
Winter				
Male	464 ± 183 NS	6	291 ± 129 NS	6
Female	404 ± 287	16	330 ± 329	16
Annual				
Male	709 ± 258*	8	431 ± 83**	8
Female	407 ± 267	21	251 ± 203	21
Hedmark				
Summer				
Male	1127 ± 819***	13	854 ± 621***	13
Female	450 ± 252	16	270 ± 234	16
Winter				
Male	859 ± 453 NS	8	729 ± 467 NS	8
Female	603 ± 232	12	477 ± 189	12
Annual				
Male	1456 ± 918*	7	886 ± 356*	7
Female	832 ± 206	10	535 ± 225	10
Bergslagen				
Summer				
Male	356 ± 187**	13	244 ± 128**	13
Female	145 ± 85	6	85 ± 71	6
Winter				
Male	433 ± 207 NS	6	246 ± 105*	6
Female	319 ± 115	3	114 ± 44	3
Annual				
Male	632 ± 254	4	305 ± 117	4
Female	307	1	97 ±	1
North Trøndelag				
Summer				
Male	1415 ± 1109 NS	3	1299 ± 953 NS	3
Female	363 ± 153	4	466 ± 166	4
Winter				
Male	800 ± 198	2	898 ± 258	2
Female	364	1	758 ± −	1
Annual				
Male	1515 ± 1010 NS	3	1499 ± 944 NS	3
Female	561 ± 70	2	610 ± 85	2

[a]The same individual in different years has been treated as an independent sample. Tests refer to differences between the sexes (Wilcoxon signed rank test; NS = $P > 0.05$,* $P < 0.05$,** $P < 0.01$,*** $P < 0.001$).

Home Ranges in Scandinavia Versus Elsewhere

These home ranges of Eurasian lynx were far larger than those reported from other study sites in Europe. Annual home range sizes for males in the Swiss Alps ranged from 275 to 450 km^2 and averaged 364 km^2 and 194 km^2 in the Swiss Jura mountains and Poland's Bialowieza Forest, respectively. The equivalent values for females were 96–135 km^2, 216 km^2, and 100 km^2 (Haller and Breitenmnoser 1986, Breitenmoser and others 1993, Jedrzejewski and others 1996). The Scandinavian home ranges were, on average, at least twice, and in the case of Hedmark four times, as large as these home ranges from continental Europe.

In much of the early literature on Eurasian lynx (e.g., Haglund 1966) there was extensive reference made to studies on the congeneric Canadian lynx (*Lynx canadensis*). This comparison has shown itself to be seriously flawed because the two species are quite different in feeding ecology and scale of movements. While Canadian lynx feed mainly on lagomorphs, Eurasian lynx feed mainly on ungulates (Jedrzejewski and others 1993, Mowat and others 1999). Canadian lynx

Table 3. Tests for differences in home range size at four Scandinavian study sites[a]

Summer	Winter	Annual
MCP - Male		
$\chi^2 = 21.7$, $df = 3$, $P < 0.001$	$\chi^2 = 8.8$, $df = 3$, $P = 0.03$	$\chi^2 = 10.3$, $df = 3$, $P = 0.017$
Kernel - Male		
$\chi^2 = 25.7$, $df = 3$, $P < 0.001$	$\chi^2 = 12.5$, $df = 3$, $P = 0.006$	$\chi^2 = 16.1$, $df = 3$, $P = 0.001$
MCP - Female		
$\chi^2 = 20.1$, $df = 3$, $P < 0.001$	$\chi^2 = 6.3$, $df = 3$, $P = 0.097$	$\chi^2 = 13.6$, $df = 3$, $P = 0.004$
Kernel - Female		
$\chi^2 = 17.2$, $df = 3$, $P = 0.001$	$\chi^2 = 12.1$, $df = 3$, $P = 0.007$	$\chi^2 = 14.8$, $df = 3$, $P = 0.002$

[a]A Kruskal-Wallis ANOVA has been used.

home ranges are almost always under 50–100 km^2 (Mowat and others 1999), considerably smaller than those reported here for Eurasian lynx.

This shows the mistakes that can develop when extrapolating data from a related species or even from different populations. These home range sizes for lynx in Scandinavia are also among the largest reported for any felid, equaling or exceeding even those of the much larger Siberian tigers (*Panthera tigris*), snow leopards (*P. oncia*), or cougars (*Puma concolor*) that are often cited as animals with 'vast' home range requirements (Jackson and Ahlborn 1989, Oli 1997, Miquelle and others 1999, Pierce and others 1999). Without the original telemetry data obtained in these recent studies, it would have been impossible to predict the size of lynx home ranges in these Scandinavian sites, especially Hedmark.

Role of Protected Areas in Lynx Conservation in Scandinavia

Protected areas have been a central element in the conservation strategy for several large carnivore species (Mills 1991), most notably the tiger in India (Seidensticker 1997). However, it has long been understood that the large home ranges of large carnivores make it difficult to contain viable populations only within isolated protected areas (Nowell and Jackson 1996). The result often has been a mixed strategy where protected areas provide protection for a core population that ensures a base population level, but where viability is enhanced by allowing additional individuals to occupy the multiuse land around the protected areas (Fritts and Carbyn 1995, Nowell and Jackson 1996). The relative contribution of the protected areas versus the multiuse lands to a conservation strategy depends on the ratio of home range sizes to reserve sizes.

Despite the existence of 49,297 km^2 of protected areas (IUCN categories I, II, and IV) in Scandinavia, there are very few single areas that are large enough to contain more than a few lynx with the observed home range sizes (Figure 1). Norway and Sweden have only two national parks each that are large enough to contain a single male lynx with a Hedmark home range size. The suitability of national parks decreases even

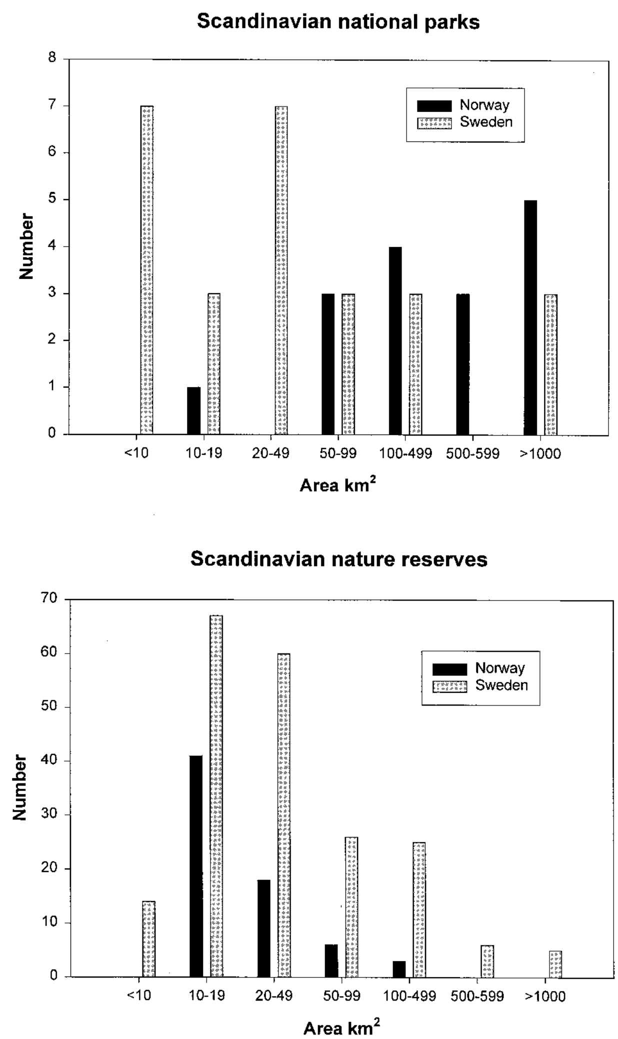

Figure 1. Frequency distribution of the sizes of protected areas in Norway and Sweden.

Table 4. Lynx habitat suitability and conflict in Scandinavian multiuse landscapes[a]

Forest area (% of total)	Hunting bags		Human density	Sheep		Semi-domestic reindeer	
	Roe deer[b]	Moose[c]		Grazed	Killed by lynx[d]	Grazed	Killed by lynx[e]
Norway							
120 000 km^2 (40%)	30,000–60,000	36,000	13/km^2	2.5 million[f]	9268	187,000	4301
Sweden							
290 000 km^2 (59%)	200,000–400,000	94,000	19/km^2	450,000[g]	114	239,000	2563
Factors role							
H	P/C		H	P/C	C	P/C	C

[a]Each factor is marked with either an H as an indicator of habitat suitability, a P for prey, or a C as an indicator of conflict potential.

[b]Range of values from 1990s.

[c]1997 hunting bags.

[d]Official figures for numbers compensated in 1998.

[e]Official figures for numbers compensated in 1995–1996 grazing season.

[f]Mostly free-ranging in summer.

[g]Mostly grazed inside fenced pastures.

more considering that lynx are mainly forest dwellers (Moa and others 1998a,b), because most of the area within national parks is above the treeline (Nilsson and Götmark 1992). [This is also a common problem in other countries (e.g. Fritts and Carbyn 1995).] For example, in Norway only 5% of the area of national parks consists of forest habitats, and no single national park contains more than 150 km^2 of forest. Nature reserves are equally small in size (Figure 1), and the larger ones suffer from the same problem as national parks in containing mainly mountain habitat. The only protected area that shows potential for protecting any significant number of lynx is the complex of neighboring national parks (Sarek, Stora Sjöfjallet, and Padejelanta) and reserves (Sjaunja forest reserve) in northeastern Sweden, which totals 8082 km^2 and is about 50% forest.

We therefore conclude that protected areas have only a very limited role to play in lynx conservation in Scandinavia. It is unlikely that even a few *individuals* have home ranges that are restricted to protected areas, let alone any *populations*. The implication is that lynx conservation must occur in the multiuse landscapes that cover most of Scandinavia. However, large carnivore conservation in multiuse landscapes is always a difficult task and involves a number of issues concerned with habitat suitability and conflicts with other land-uses (Maehr 1990).

Suitability of Multiuse Landscapes in Scandinavia for Lynx Conservation

From a European perspective, Scandinavia is regarded as being a 'wilderness' of relatively undeveloped habitat. While there is in fact very little true wilderness left, most of the landscape is covered by seminatural forest habitats (Table 4). These forests are among the world's most intensively exploited forests (Esseen and others 1992), with most of the landscape having been converted to a mosaic of even-aged stands, and are generally privately owned. Despite extensive modification, these habitats still provide good lynx habitat, with abundant populations of wild lynx prey (Sunde and Kvam 1997), especially roe deer (Table 4). In northern areas where roe deer are rare (Cederlund and Liberg 1995), semidomestic reindeer (*Rangifer tarandus*) are abundant. Human population (Table 4) and road density are among the lowest in Europe, and lynx have shown themselves to be very tolerant of most human activities (Sunde and others 1998). Following removal of state bounties and better regulation of harvest, lynx numbers have rapidly increased to reoccupy, and even exceed, much of their former distribution from the 19th century. There is, therefore, every reason to regard the exploited forests of Scandinavia as very suitable lynx habitat. However, suitability does not imply peaceful coexistence, as lynx populations can cause severe conflict with some land-uses.

Conflicts Between Lynx and Other Land Uses

The three major conflicts involving lynx in Scandinavian multiuse landscapes are with domestic sheep, semidomestic reindeer, and with roe deer hunters; however, the relative extent of each conflict varies between Norway and Sweden.

Domestic sheep occur in both countries (Table 4), although husbandry differs. Norwegian sheep are grazed in forest and mountain habitats each summer with little supervison or attempt to control their movements. In Sweden sheep are grazed mainly on fields or fenced forest pastures. The different forms of husbandry clearly influence the level of depredation (Linnell and others 1996a) (Table 4), and the Norwegian losses are on an unprecedented level when compared to other European studies (Kaczensky 1996). In both countries there are clearly established routines for validating predation as the documented or suspected cause of mortality or loss, so these numbers are likely to be close to the real losses. The large home ranges imply that there are probably very few individual lynx in Norway that do not have sheep within their home ranges, which results in encounter rates with flocks always being high.

Lynx depredation on semidomestic reindeer is an equally large problem in both countries (Table 4). While the fact that lynx kill reindeer is not disputed, there has been much debate about the exact numbers (Bjärvall and others 1990, Kvam and others 1995, Pedersen and others 1999). In recent years the number compensated in Norway has increased largely because of an increased awareness of the true extent of predation. Recent comparative data from Sweden does not exist because they have adopted a new compensation system based on the numbers of lynx present rather than the numbers of reindeer killed.

Roe deer are widely distributed through lynx range in both countries, and where they occur they form the main component of lynx diet (Haglund 1966, Dunker 1988, Linnell and others 1996b, Liberg 1997, Sunde and Kvam 1997, Aanes and others 1998). Studies of lynx kill rates showed surprisingly little variation between study sites (Breitenmoser and Haller 1993, Linnell and others 1996b, Okarma and others 1997, Andersen and others unpublished) despite wide variation in roe deer density. This implies that lynx have the potential to have greater impacts on low-density roe deer populations. However, as yet there is no clear understanding of how lynx predation is affecting roe deer populations. The picture is further complicated by the impacts that snow and red fox (*Vulpes vulpes*) predation have on roe deer (Lindström and others 1994, Liberg 1997, Aanes and others 1998, Holand and others 1998).

Given the popularity of roe deer hunting and the economic value of the meat and hunting licenses, there is a potential indirect conflict between hunters and lynx if lynx predation leads to declines in roe deer harvests. This potential conflict cannot be mitigated except through controlling lynx population density and has to be accepted as an intrinsic cost associated with lynx conservation. The conflict with domestic sheep husbandry can be mitigated through changes in sheep husbandry during summer (Linnell and others 1996a), although these will result in extra costs for the industry (Krogstad and others 2000) that will have to be covered through increased subsidy. Lynx predation on reindeer is a far harder conflict to reduce because of the wide-ranging nature of reindeer herding and the fact that the animals are vulnerable to predation throughout the year. The effect of more intensive herding and improving individual condition are still being evaluated (Kvam and others 1998). The picture is further complicated by the dietary dependence of lynx on reindeer in northern areas where roe deer are absent (Pedersen and others 1999). In this situation, some form of compensation payment or extra subsidy will always be necessary.

There are, however, many other forms of land use with which lynx do not come into conflict. The intensive forestry industries of both Scandinavian countries pose virtually no threats to lynx, as the environmental constraints imposed on their activities are generated by threats to species that are far more vulnerable to habitat change than lynx (Esseen and others 1992, Linnell and others 2000). Moose (*Alces alces*) hunting is also a major industry in Scandinavian forests (Table 4) and can provide a source of income equal to timber cutting for some landowners (Cederlund and Bergström 1996). In other words, lynx conservation in multiuse lands is associated with real economic costs (Boman 1995) resulting from conflicts with some, but not all, land uses. The extent of these conflicts should not be underestimated as they directly affect public acceptance of lynx and other large carnivores (Kaltenborn and others 1999), and lynx conservation will depend on public acceptance. This is evident in the different management objectives of the Norwegian and Swedish authorities. Norway has the objective of maintaining its present lynx population of 500 lynx, whereas Sweden intends to maintain a population of at least 1000 lynx. Although there are several other socioeconomic differences between Norway and Sweden, these different objectives for lynx and large carnivores in general are at least in part due to the major differences in the level of conflict with sheep husbandry (Swenson and others 1995, Landa and others 2000).

Harvesting Lynx Populations

Lynx are currently harvested in both Scandinavian countries, motivated by a combination of a desire to control lynx numbers and/or distribution (as a result of conflicts), and because of an appreciation of the challenge of lynx hunting among recreational hunters. Although large carnivore harvest is often controversial (Koch 1994, Rabinowitz 1995, Jackson and Nowell 1996), total protection is not a valid or desirable option in Scandinavia. Presently harvest is regulated by quotas set by national or regional authorities. However, for lynx harvests to be compatible with lynx conservation, there are a number of prerequisites that must be fulfilled. These include a good understanding of lynx population dynamics and effective monitoring of the population. Because there are no potential unharvested source populations within protected areas, all individuals are potentially vulnerable to harvest. This greatly increases the required precision in management routines that ensure that the populations are not overharvested (Litvaitis and others 1996).

The large home ranges reported for Scandinavian lynx have direct bearing on monitoring and management. The variation that we have documented in home range size within Scandinavia, and when compared to Swiss and Polish studies, shows the importance of using space-use data from the correct population. If data from European studies had been used it would have led to severe overestimation of population size (Østergren and Segerstrøm 1998).

The most obvious use for home range size data in management comes when setting management units that are based on the correct scale. A variety of administrative units (national, county, municipality, hunting area, landowner) are involved with wildlife management in Scandinavia. The amount of control that each level in the hierarchy has varies with the species in question. The home range data presented here indicate that most municipalities are unlikely to contain more than a few individual lynx within their borders and are therefore unsuitable as management units (Figure 2). The smallest administrative unit that is likely to have any biological relevance is the county level, although even here the smaller counties may need to coordinate their management actions.

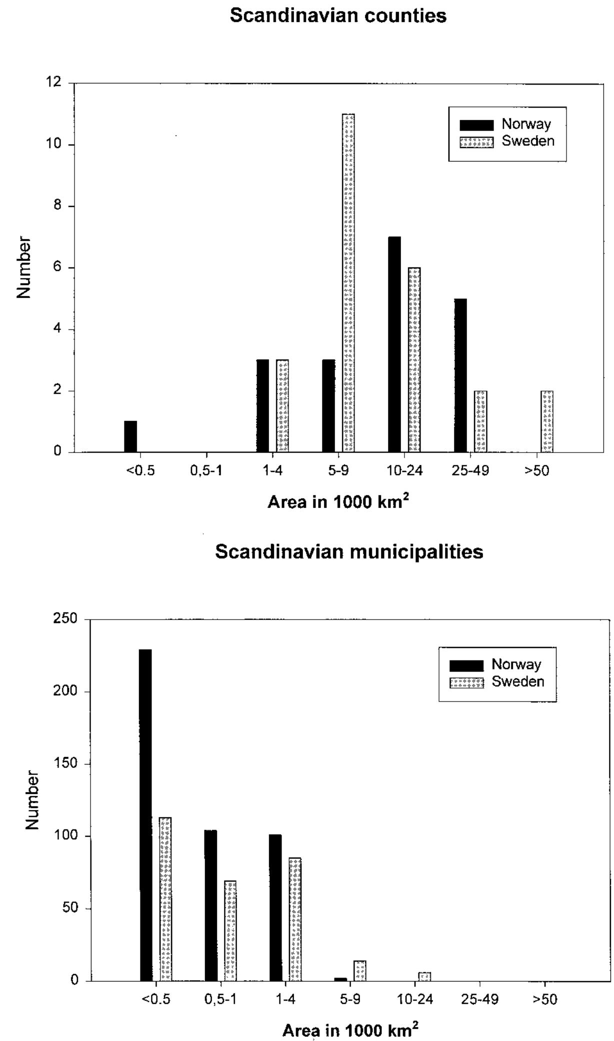

Figure 2. Frequency distribution of the sizes of administrative units in Norway and Sweden.

Research Needs for Coexistence

In order for lynx conservation to succeed in Scandinavia's multiuse landscapes, there is a clear need for further research into several aspects of lynx ecology. These include the following priority topics;

1. Mortality rates due to human causes. When lynx occupy multiuse landscapes, it is highly likely that human-caused mortality will dominate from causes such as legal and illegal harvest and traffic kills. Accurate quanification will be needed for an effective understanding of population dynamics.
2. Reproductive rates. When lynx are being harvested, an accurate quantification of reproductive rates will be needed to calculate appropriate harvest rates.
3. Monitoring. Effective monitoring will be required to ensure that harvest is compatible with stated management objectives, and ensure fair compensation is paid for livestock losses.
4. Livestock depredation. A better understanding of the ecology of livestock depredation (e.g., Pedersen and others 1999) and the extent to which it is due to problem individuals (Linnell and others 1999) will assist in planning mitigation measures and developing fair compensation levels.
5. Impact on roe deer. The potential impact of lynx on roe deer will have both social and economic consequences. These will in turn affect public acceptance for lynx.
6. Dispersal. The dispersal behavior of lynx will affect the potential for managers to achieve geographically-differentiated management, allowing different objectives to be achieved in different regions.

Conclusions

The important conclusion presented here is that Eurasian lynx in Scandinavia have huge home ranges. Although this may seem somewhat trivial from a biological point of view, it has consequences for the development of the whole management/conservation/research strategy for lynx in Scandinavia. The inability of protected areas to serve as a reservoir for unexploited populations, or even as a buffer for individuals against overharvest, greatly increases the precision required from monitoring and population dynamics studies that are used to set hunting quotas. The fact that conservation must occur in multiuse landscapes requires much research effort into the ecology of conflicts and the development of mitigation measures. It is hoped that clearly identifying this conceptual framework at an early stage will encourage the effectively targeted research required for the lynx conservation potential of Scandinavian multiuse landscapes to become a reality.

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